

FOREST: a PGF/TikZ-based package for drawing linguistic trees

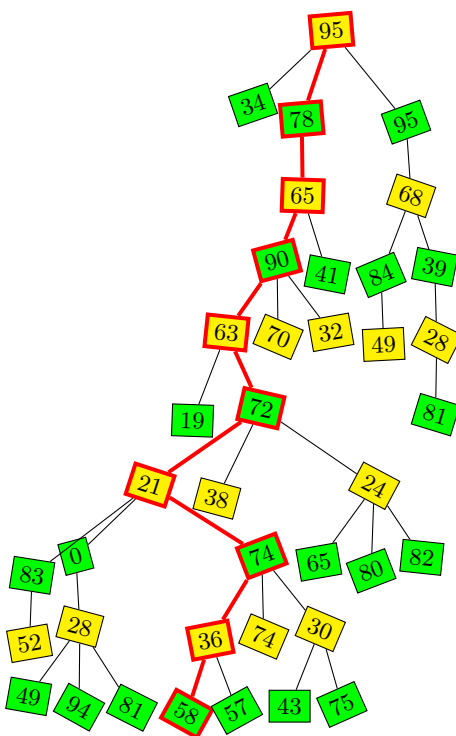
v1.04

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Abstract

FOREST is a PGF/TikZ-based package for drawing linguistic (and other kinds of) trees. Its main features are (i) a packing algorithm which can produce very compact trees; (ii) a user-friendly interface consisting of the familiar bracket encoding of trees plus the key-value interface to option-setting; (iii) many tree-formatting options, with control over option values of individual nodes and mechanisms for their manipulation; (iv) the possibility to decorate the tree using the full power of PGF/TikZ; (v) an externalization mechanism sensitive to code-changes.



```
\pgfmathsetseed{14285}
\begin{forest}
  random tree/.style n args={3}{% #1=max levels, #2=max children, #3=max content
    content/.pgfmath={random(0,#3)},
    if={#1>0}{repeat={random(0,#2)}{append={[,random tree={#1-1}{#2}{#3}]}}{}}},
  for deepest/.style={before drawing tree={
    alias=deepest,
    where={y(<y("deepest"))}{alias=deepest}{},
    for name={deepest}{#1}},
    colorone/.style={fill=yellow,for children=colortwo}, colortwo/.style={fill=green,for children=colorone},
    important/.style={draw=red,line width=1.5pt,edge={red,line width=1.5pt,draw}},
    before typesetting nodes={colorone, for tree={draw,s sep=2pt,rotate={int(30*rand)},l+={5*rand}}},
    for deepest={for ancestors'={important,typeset node}}
    [,random tree={9}{3}{100}]
  }
\end{forest}
```

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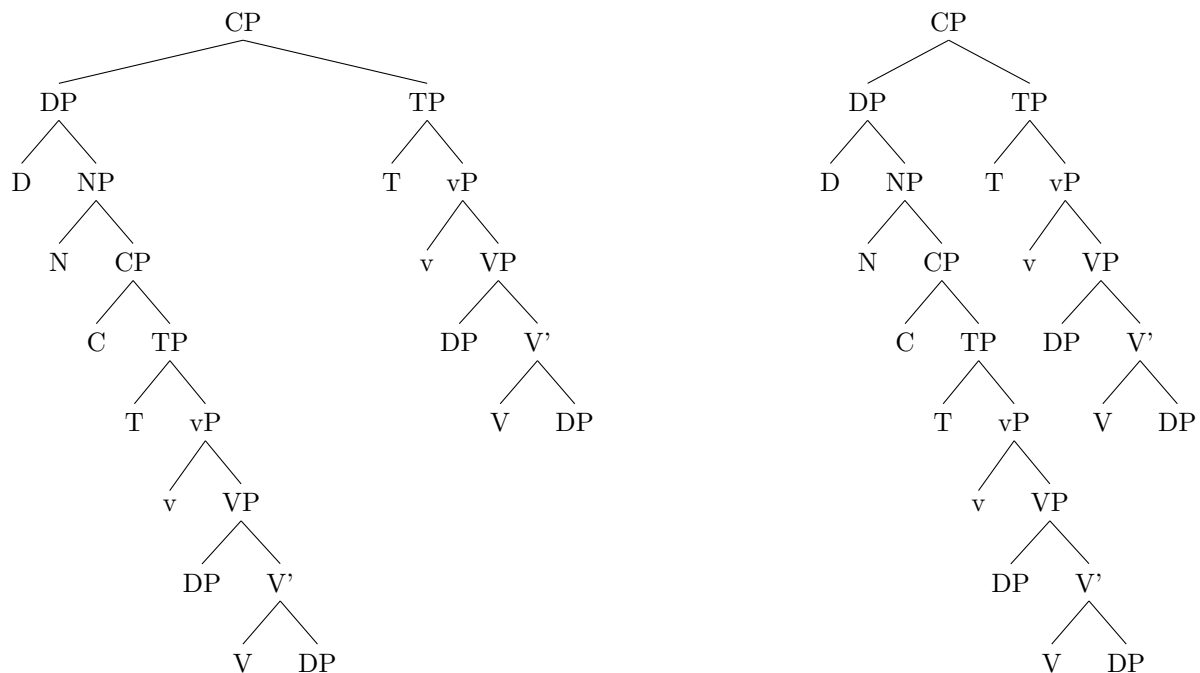
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Part I

User's Guide

1 Introduction

Over several years, I had been a grateful user of various packages for typesetting linguistic trees. My main experience was with `qtree` and `synttree`, but as far as I can tell, all of the tools on the market had the same problem: sometimes, the trees were just too wide. They looked something like the tree on the left, while I wanted something like the tree on the right.



Luckily, it was possible to tweak some parameters by hand to get a narrower tree, but as I quite dislike constant manual adjustments, I eventually started to develop FOREST. It started out as `xyforest`, but lost the `xy` prefix as I became increasingly fond of `PGF/TikZ`, which offered not only a drawing package but also a ‘programming paradigm.’ It is due to the awesome power of the supplementary facilities of `PGF/TikZ` that FOREST is now, I believe, the most flexible tree typesetting package for \LaTeX you can get.

After all the advertising, a disclaimer. Although the present version is definitely usable (and has been already used), the package and its documentation are still under development: comments, criticism, suggestions and code are all very welcome!

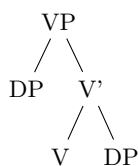
FOREST is [available](#) at [CTAN](#), and I have also started a [style repository](#) at [GitHub](#).

2 Tutorial

This short tutorial progresses from basic through useful to obscure ...

2.1 Basic usage

A tree is input by enclosing its specification in a `forest` environment. The tree is encoded by *the bracket syntax*: every node is enclosed in square brackets; the children of a node are given within its brackets, after its content.



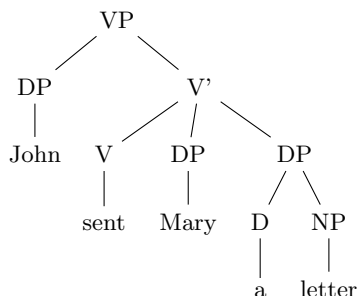
```

\begin{forest}
[VP
[DP]
[V'
[V]
[DP]
]
]
\end{forest}

```

(2)

Binary trees are nice, but not the only thing this package can draw. Note that by default, the children are vertically centered with respect to their parent, i.e. the parent is vertically aligned with the midpoint between the first and the last child.



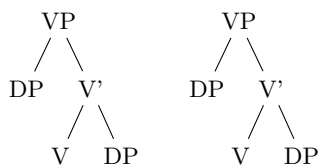
```

\begin{forest}
[VP
[DP[John]]
[V'
[V[sent]]
[DP[Mary]]
[DP[D[a]] [NP[letter]]]
]
]
\end{forest}

```

(3)

Spaces around brackets are ignored — format your code as you desire!



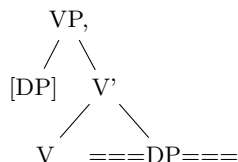
```

\begin{forest}
[VP[DP][V'[V][DP]]]
\end{forest}
\quad
\begin{forest}[VP
[DP][V'[V][DP]]
]\end{forest}

```

(4)

If you need a square bracket as part of a node's content, use braces. The same is true for the other characters which have a special meaning in the FOREST package: comma , and equality sign =.



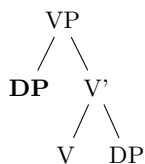
```

\begin{forest}
[V{P,}]
[{{[DP]}}]
[V'
[V]
[{{===DP===}}]]
]\end{forest}

```

(5)

Macros in a node specification will be expanded when the node is drawn — you can freely use formatting commands inside nodes!



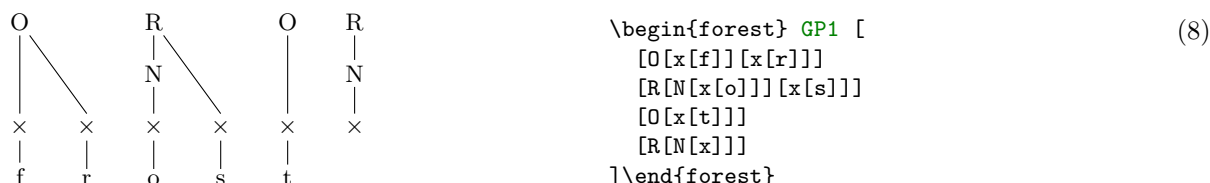
```

\begin{forest}
[VP
[{{\textbf{DP}}}]
[V'
[V]
[DP]]]
]\end{forest}

```

(6)

All the examples given above produced top-down trees with centered children. The other sections of this manual explain how various properties of a tree can be changed, making it possible to typeset radically different-looking trees. However, you don't have to learn everything about this package to profit from its power. Using styles, you can draw predefined types of trees with ease. For example, a phonologist can use the [GP1](#) style from §4 to easily typeset (Government Phonology) phonological representations. The style is applied simply by writing its name before the first (opening) bracket of the tree.



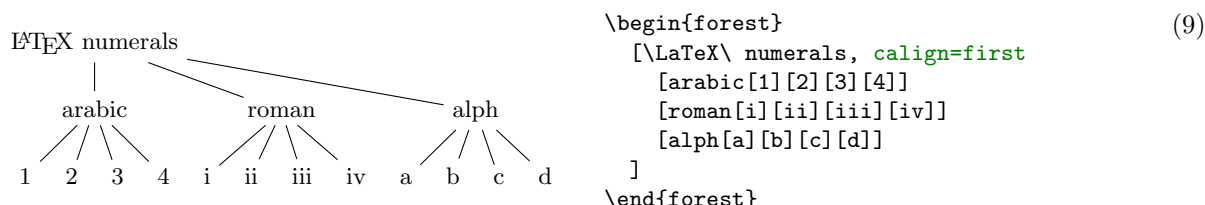
Of course, someone needs to develop the style — you, me, your local T_EXnician ... Fortunately, designing styles is not very difficult once you know your FOREST options. If you write one, please contribute!

I have started a [style repository](#) at GitHub. Hopefully, it will grow ... Check it out, download the styles ... and contribute them!

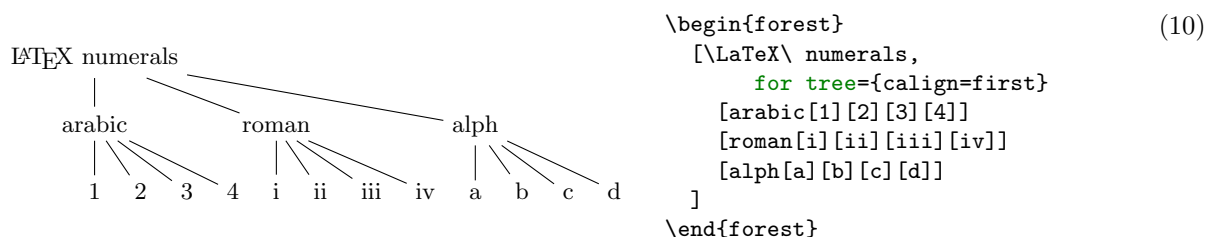
2.2 Options

A node can be given various options, which control various properties of the node and the tree. For example, at the end of section 2.1, we have seen that the **GP1** style vertically aligns the parent with the first child. This is achieved by setting option **calign** (for *child-alignment*) to **first** (child).

Let's try. Options are given inside the brackets, following the content, but separated from it by a comma. (If multiple options are given, they are also separated by commas.) A single option assignment takes the form $\langle option\ name \rangle = \langle option\ value \rangle$. (There are also options which do not require a value or have a default value: these are given simply as $\langle option\ name \rangle$.)



The experiment has succeeded only partially. The root node's children are aligned as desired (so **calign=first** applied to the root node), but the value of the **calign** option didn't get automatically assigned to the root's children! *An option given at some node applies only to that node.* In FOREST, the options are passed to the node's relatives via special options, called *propagators*. (We'll call the options that actually change some property of the node *node options*.) What we need above is the **for tree** propagator. Observe:



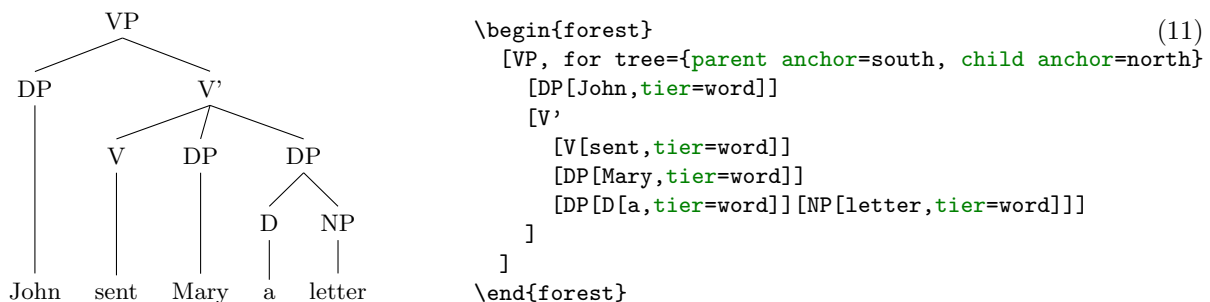
The value of propagator **for tree** is the option string that we want to process. This option string is propagated to all the nodes in the subtree¹ rooted in the current node (i.e. the node where **for tree** was given), including the node itself. (Propagator **for descendants** is just like **for tree**, only that it excludes the node itself. There are many other **for** ... propagators; for the complete list, see sections 3.3.6 and 3.5.1.)

Some other useful options are **parent anchor**, **child anchor** and **tier**. The **parent anchor** and **child anchor** options tell where the parent's and child's endpoint of the edge between them should be, respectively: usually, the value is either empty (meaning a smartly determined border point [see 2, §16.11]; this is the default) or a compass direction [see 2, §16.5.1]. (Note: the **parent anchor** determines where the edge from the child will arrive to this node, not where the node's edge to its parent will start!)

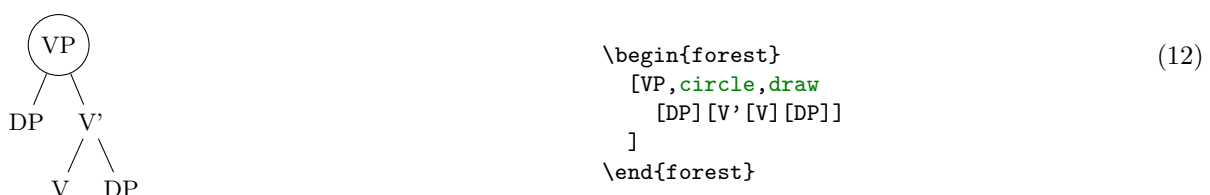
Option **tier** is what makes the skeletal points \times in example (8) align horizontally although they occur at different levels in the logical structure of the tree. Using option **tier** is very simple: just set

¹It might be more precise to call this option **for subtree** ... but this name at least saves some typing.

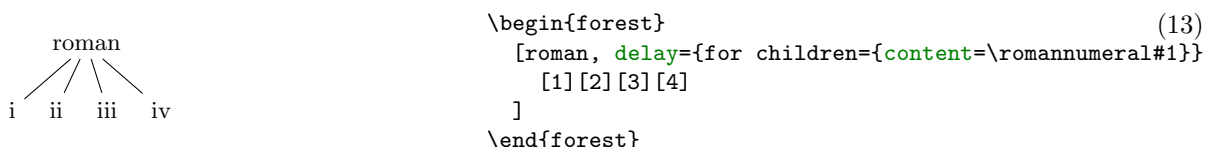
`tier=`*tier name* at all the nodes that you want to align horizontally. Any tier name will do, as long as the tier names of different tiers are different ... (Yes, you can have multiple tiers!)



Before discussing the variety of FOREST's options, it is worth mentioning that FOREST's node accepts all options [2, see §16] that TikZ's node does — mostly, it just passes them on to TikZ. For example, you can easily encircle a node like this:²



Let's have another look at example (8). You will note that the skeletal positions were input by typing `xs`, while the result looks like this: \times (input as `\times` in math mode). Obviously, the content of the node can be changed. Even more, it can be manipulated: added to, doubled, boldened, emphasized, etc. We will demonstrate this by making example (10) a bit fancier: we'll write the input in the arabic numbers and have L^AT_EX convert it to the other formats. We'll start with the easiest case of roman numerals: to get them, we can use the (plain) T_EX command `\romannumeral`. To change the content of the node, we use option `content`. When specifying its new value, we can use `#1` to insert the current content.³



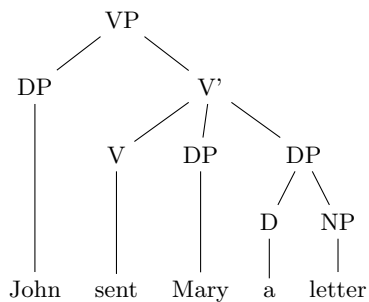
This example introduces another option: `delay`. Without it, the example wouldn't work: we would get arabic numerals. This is so because of the order in which the options are processed. The processing proceeds through the tree in a depth-first, parent-first fashion (first the parent is processed, and then its children, recursively). The option string of a node is processed linearly, in the order they were given. (Option `content` is specified implicitly and is always the first.) If a propagator is encountered, the options given as its value are propagated *immediately*. The net effect is that if the above example contained simply `roman,for children={content=...}`, the `content` option given there would be processed *before* the implicit content options given to the children (i.e. numbers 1, 2, 3 and 4). Thus, there would be nothing for the `\romannumeral` to change — it would actually crash; more generally, the content assigned in such a way would get overridden by the implicit content. Option `delay` is true to its name. It delays the processing of its option string argument until the whole tree was processed. In other words, it introduces cyclical option processing. Whatever is delayed in one cycle, gets processed in the next one. The number of cycles is not limited — you can nest `delays` as deep as you need.

Unlike `for` ... options we have met before, option `delay` is not a spatial, but a temporal propagator. Several other temporal propagators options exist, see §3.3.7.

²If option `draw` was not given, the shape of the node would still be circular, but the edge would not be drawn. For details, see [2, §16].

³This mechanism is called *wrapping*. `content` is the only option where wrapping works implicitly (simply because I assume that wrapping will be almost exclusively used with this option). To wrap values of other options, use handler `.wrap value`; see §3.4.

We are now ready to learn about simple conditionals. Every node option has the corresponding `if` ... and `where` ... keys. `if <option>=<value><true options><false options>` checks whether the value of `<option>` equals `<value>`. If so, `<true options>` are processed, otherwise `<false options>`. The `where` ... keys are the same, but do this for the every node in the subtree; informally speaking, `where = for tree + if`. To see this in action, consider the rewrite of the `tier` example (11) from above. We don't set the tiers manually, but rather put the terminal nodes (option `n children` is a read-only option containing the number of children) on tier `word`.⁴



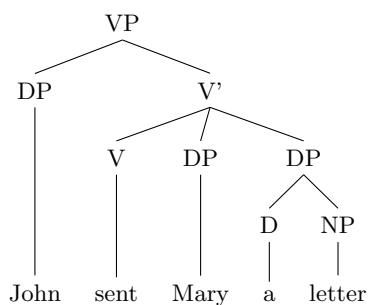
```

\begin{forest}
  where n children=0{tier=word}{}
  [VP
    [DP[John]]
    [V'
      [V[sent]]
      [DP[Mary]]
      [DP[D[a]] [NP[letter]]]
    ]
  ]
\end{forest}

```

(14)

Finally, let's talk about styles. Styles are simply collections of options. (They are not actually defined in the `FOREST` package, but rather inherited from `pgfkeys`.) If you often want to have non-default parent/child anchors, say south/north as in example (11), you would save some typing by defining a style. Styles are defined using PGF's handler `.style`. (In the example below, style `ns edges` is first defined and then used.)



```

\begin{forest}
  sn edges/.style={for tree={
    parent anchor=south, child anchor=north}},
  sn edges
  [VP,
    [DP[John,tier=word]]
    [V'
      [V[sent,tier=word]]
      [DP[Mary,tier=word]]
      [DP[D[a,tier=word]] [NP[letter,tier=word]]]]
  ]
\end{forest}

```

(15)

If you want to use a style in more than one tree, you have to define it outside the `forest` environment. Use macro `\forestset` to do this.

```

\forestset{
  sn edges/.style={for tree={parent anchor=south, child anchor=north}},
  background tree/.style={for tree={
    text opacity=0.2,draw opacity=0.2,edge={draw opacity=0.2}}}
}

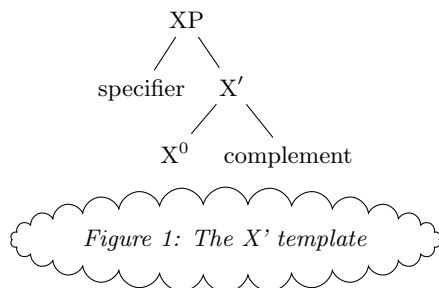
```

You might have noticed that the last two examples contain options (actually, keys) even before the first opening bracket, contradicting what was said at the beginning of this section. This is mainly just syntactic sugar (it can separate the design and the content): such preamble keys behave as if they were given in the root node, the only difference (which often does not matter) being that they get processed before all other root node options, even the implicit content.

2.3 Decorating the tree

The tree can be decorated (think movement arrows) with arbitrary TikZ code.

⁴We could omit the braces around 0 because it is a single character. If we were hunting for nodes with 42 children, we'd have to write `where n children={42}`....



```

\begin{forest}
  [XP
    [specifier
      [X'$
        [X$~0$]
        [complement]
      ]
    ]
  ]
  \node at (current bounding box.south)
    [below=1ex,draw,cloud,aspect=6,cloud puffs=30]
    {\emph{Figure 1: The X' template}};
\end{forest}

```

However, decorating the tree would make little sense if one could not refer to the nodes. The simplest way to do so is to give them a TikZ name using the `name` option, and then use this name in TikZ code as any other (TikZ) node name.

```

\begin{forest}
  [CP
    [DP,name=spec CP]
    [\dots
      [,phantom]
      [VP
        [DP]
        [V'
          [V]
          [DP,name=object]]]]]
    \draw[->,dotted] (object) to[out=south west,in=south] (spec CP);
\end{forest}

```

It gets better than this, however! In the previous examples, we put the TikZ code after the tree specification, i.e. after the closing bracket of the root node. In fact, you can put TikZ code after *any* closing bracket, and FOREST will know what the current node is. (Putting the code after a node's bracket is actually just a special way to provide a value for option `tikz` of that node.) To refer to the current node, simply use an empty node name. This works both with and without anchors [see 2, §16.11]: below, `(.south east)` and `()`.

```

\begin{forest}
  [CP
    [DP,name=spec CP]
    [\dots
      [,phantom]
      [VP
        [DP]
        [V'
          [V]
          [DP,draw] {
            \draw[->,dotted] () to[out=south west,in=south] (spec CP);
            \draw[<-,red] (.south east)--++(0em,-4ex)--++(-2em,0pt)
              node[anchor=east,align=center]{This guy\\has moved!};
          }
        ]
      ]
    ]
  ]
\end{forest}

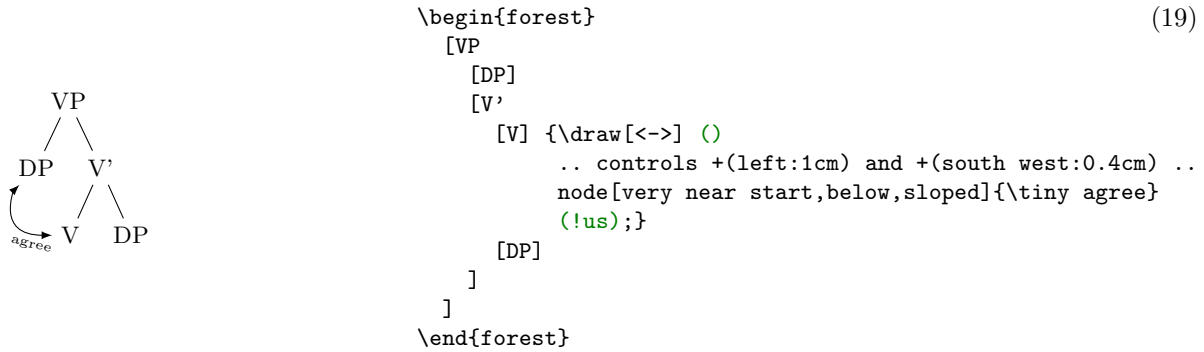
```

Important: the TikZ code should usually be enclosed in braces to hide it from the bracket parser. You don't want all the bracketed code (e.g. `[->,dotted]`) to become tree nodes, right? (Well, they probably wouldn't anyway, because TeX would spit out a thousand errors.)

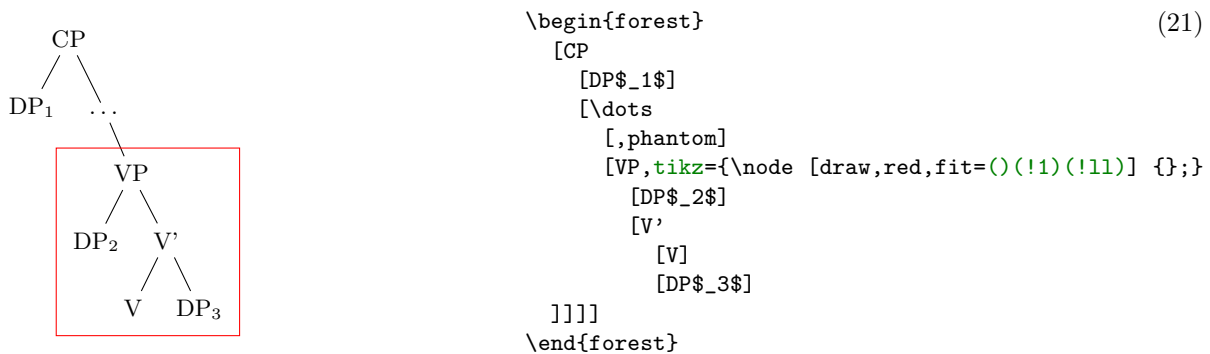
Finally, the most powerful tool in the node reference toolbox: *relative nodes*. It is possible to refer to other nodes which stand in some (most often geometrical) relation to the current node. To do this, follow the node's name with a `!` and a *node walk* specification.

A node walk is a concise⁵ way of expressing node relations. It is simply a string of steps, which are represented by single characters, where: **u** stands for the parent node (up); **p** for the previous sibling; **n** for the next sibling; **s** for *the* sibling (useful only in binary trees); **1, 2, ... 9** for first, second, ... ninth child; **l**, for the last child, etc. For the complete specification, see section 3.5.1.

To see the node walk in action, consider the following examples. In the first example, the agree arrow connects the V node, specified simply as `()`, since the TikZ code follows `[V]`, and the DP node, which is described as “a sister of V’s parent”: `!us = up + sibling`.



The second example uses TikZ’s fitting library to compute the smallest rectangle containing node VP, its first child (DP₂) and its last grandchild (DP₃). The example also illustrates that the TikZ code can be specified via the “normal” option syntax, i.e. as a value to option `tikz`.⁶

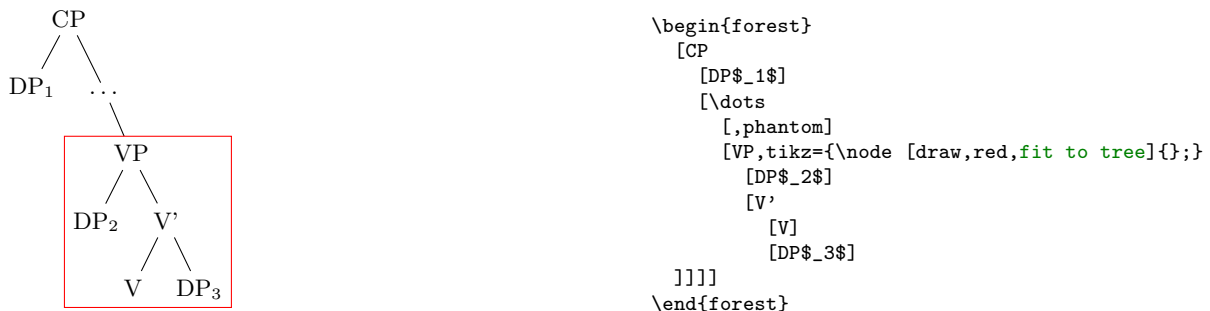


2.4 Node positioning

FOREST positions the nodes by a recursive bottom-up algorithm which, for every non-terminal node, computes the positions of the node’s children relative to their parent. By default, all the children will be aligned horizontally some distance down from their parent: the “normal” tree grows down. More generally, however, the direction of growth can change from node to node; this is controlled by option `grow=<direction>`.⁷ The system thus computes and stores the positions of children using a coordinate

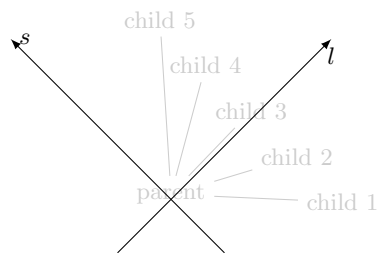
⁵Actually, FOREST distinguishes two kinds of steps in node walks: long and short steps. This section introduces only short steps. See §3.5.1.

⁶Actually, there’s a simpler way to do this: use `fit to tree`!



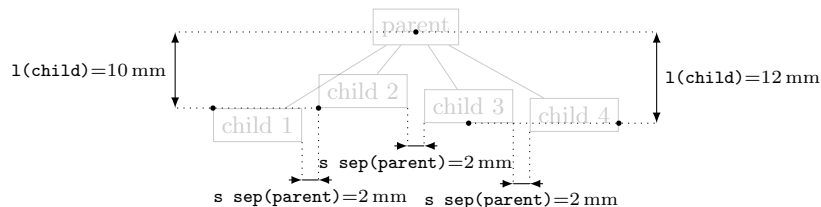
⁷The direction can be specified either in degrees (following the standard mathematical convention that 0 degrees is to the right, and that degrees increase counter-clockwise) or by the compass directions: `east`, `north`, `east`, `north`, etc.

system dependent on the parent, called an *ls-coordinate system*: the origin is the parent's anchor; l-axis is in the direction of growth in the parent; s-axis is orthogonal to the l-axis (positive side in the counter-clockwise direction from l-axis); l stands for *level*, s for *sibling*. The example shows the ls-coordinate system for a node with `grow=45`.



```
\begin{forest} background tree
  [parent, grow=45
    [child 1][child 2][child 3][child 4][child 5]
  ]
  \draw[,>](-135:1cm)--(45:3cm) node[below]{$l$};
  \draw[,>](-45:1cm)--(135:3cm) node[right]{$s$};
\end{forest}
```

The l-coordinate of children is (almost) completely under your control, i.e. you set what is often called the level distance by yourself. Simply set option `l` to change the distance of a node from its parent. More precisely, `l`, and the related option `s`, control the distance between the (node) anchors of a node and its parent. The anchor of a node can be changed using option `anchor`: by default, nodes are anchored at their base; see [2, §16.5.1].) In the example below, positions of the anchors are shown by dots: observe that anchors of nodes with the same `l` are aligned and that the distances between the anchors of the children and the parent are as specified in the code.⁸



⁸Here are the definitions of the macros for measuring distances. Args: the x or y distance between points #2 and #3 is measured; #4 is where the distance line starts (given as an absolute coordinate or an offset to #2); #5 are node options; the optional arg #1 is the format of label. (Lengths are printed using package `printlen`.)

```
\newcommand\measurexdistance[5][#####]{\measurexorydistance{#2}{#3}{#4}{#5}{x}{-}{(5pt,0)}{#1}}
\newcommand\measureydistance[5][#####]{\measurexorydistance{#2}{#3}{#4}{#5}{y}{|}{(0,5pt)}{#1}}
\tikzset{dimension/.style={<->,>=latex,thin,every rectangle node/.style={midway,font=\scriptsize}},
  guideline/.style=dotted}
\newdimen\absmd
\def\measurexorydistance#1#2#3#4#5#6#7#8{%
  \path #1 #3 #6 coordinate(md1) #1; \draw[guideline] #1 -- (md1);
  \path (md1) #6 coordinate(md2) #2; \draw[guideline] #2 -- (md2);
  \path let \p1=($(md1)-(md2)$), \n1={abs(#51)} in \pgfextra{\xdef\md{#51}\global\absmd=\n1\relax};
  \def\distancelabelwrapper##1{#8}%
  \ifdim\absmd>5mm
    \draw[dimension] (md1)--(md2) node[#4]{\distancelabelwrapper{\uselengthunit{mm}\rndprintlength\absmd}};
  \else
    \ifdim\md>0pt
      \draw[dimension,<-] (md1)-->#7; \draw[dimension,<-] let \p1=($(0,0)-#7$) in (md2)-->(\p1);
    \else
      \draw[dimension,<-] let \p1=($(0,0)-#7$) in (md1)-->(\p1); \draw[dimension,<-] (md2)-->#7;
    \fi
    \draw[dimension,-] (md1)--(md2) node[#4]{\distancelabelwrapper{\uselengthunit{mm}\rndprintlength\absmd}};
  \fi}
```

```

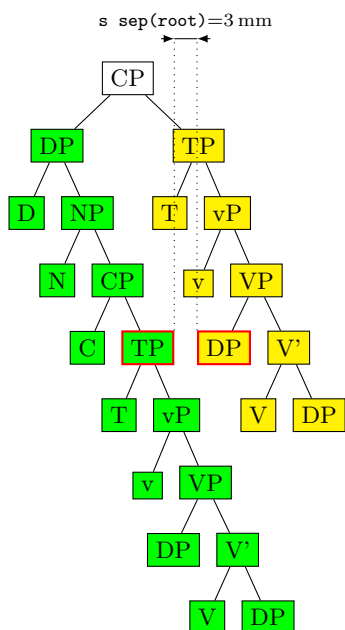
\begin{forest} background tree,
  for tree={draw,tikz={\fill[] (.anchor) circle[radius=1pt];}}
  [parent
    [child 1, l=10mm, anchor=north west]
    [child 2, l=10mm, anchor=south west]
    [child 3, l=12mm, anchor=south]
    [child 4, l=12mm, anchor=base east]
  ]
  \measureydistance[\texttt{l(child)}=#1]{(!2.anchor)}{(!.anchor)}{(!1.anchor)+(-5mm,0)}{left}
  \measureydistance[\texttt{l(child)}=#1]{(!3.anchor)}{(!.anchor)}{(!4.anchor)+(5mm,0)}{right}
  \measurexdistance[\texttt{s sep(parent)}=#1]{(!1.south east)}{(!2.south west)}{+(0,-5mm)}{below}
  \measurexdistance[\texttt{s sep(parent)}=#1]{(!2.south east)}{(!3.south west)}{+(0,-5mm)}{below}
  \measurexdistance[\texttt{s sep(parent)}=#1]{(!3.south east)}{(!4.south west)}{+(0,-8mm)}{below}
\end{forest}

```

(24)

Positioning the children in the s-dimension is the job and *raison d'être* of the package. As a first approximation: the children are positioned so that the distance between them is at least the value of option `s sep` (s-separation), which defaults to double PGF's `inner xsep` (and this is 0.3333em by default). As you can see from the example above, s-separation is the distance between the borders of the nodes, not their anchors!

A fuller story is that `s sep` does not control the s-distance between two siblings, but rather the distance between the subtrees rooted in the siblings. When the green and the yellow child of the white node are s-positioned in the example below, the horizontal distance between the green and the yellow subtree is computed. It can be seen with the naked eye that the closest nodes of the subtrees are the TP and the DP with a red border. Thus, the children of the root CP (top green DP and top yellow TP) are positioned so that the horizontal distance between the red-bordered TP and DP equals `s sep`.



```

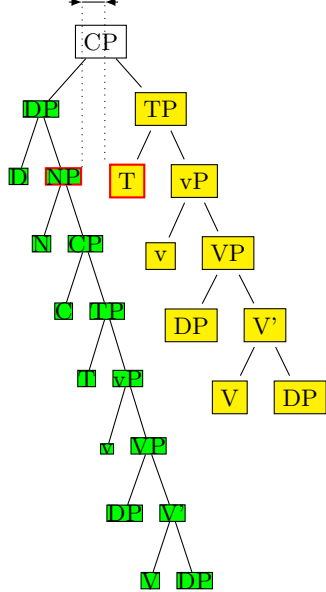
\begin{forest}
  important/.style={name=#1,draw={red,thick}}
  [CP, s sep=3mm, for tree=draw
    [DP, for tree={fill=green}
      [D] [NP[N] [CP[C] [TP,important=left
        [T] [vP[v] [VP[DP] [V' [V] [DP]]]]]]]]
      [TP,for tree={fill=yellow}
        [T] [vP[v] [VP[DP,important=right] [V' [V] [DP]]]]]]
    ]
  \measurexdistance[\texttt{s sep(root)}=#1]
    {(left.north east)}{(right.north west)}{(!.north)+(0,3mm)}{above}
\end{forest}

```

(25)

Note that FOREST computes the same distances between nodes regardless of whether the nodes are filled or not, or whether their border is drawn or not. Filling the node or drawing its border does not change its size. You can change the size by adjusting TikZ's `inner sep` and `outer sep` [2, §16.2.2], as shown below:

s sep(root)=3 mm



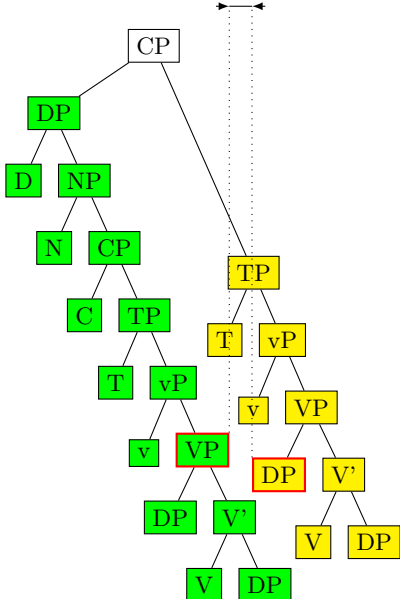
```
\begin{forest}
important/.style={name=#1,draw={red,thick}}
[CP, s sep=3mm, for tree=draw
  [DP, for tree={fill=green,inner sep=0}
    [D] [NP,important=left[N] [CP[C] [TP[T] [vP[v]
      [VP[DP] [V' [V] [DP]]]]]]]]
    [TP,for tree={fill=yellow,outer sep=2pt}
      [T,important=right] [vP[v] [VP[DP] [V' [V] [DP]]]]]]
  ]
\measurexdistance[\texttt{s sep(root)}=#1]
  {(left.north east)}{(right.north west)}{(.north)+(0,3mm)}{above}
\end{forest}
```

(26)

(This looks ugly!) Observe that having increased `outer sep` makes the edges stop touching borders of the nodes. By (PGF's) default, the `outer sep` is exactly half of the border line width, so that the edges start and finish precisely at the border.

Let's play a bit and change the 1 of the root of the yellow subtree. Below, we set the vertical distance of the yellow TP to its parent to 3cm: and the yellow submarine sinks diagonally ... Now, the closest nodes are the higher yellow DP and the green VP.

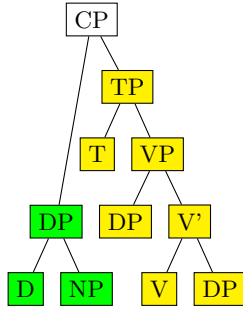
s sep(root)=3 mm



```
\begin{forest}
important/.style={name=#1,draw={red,thick}}
[CP, s sep=3mm, for tree=draw
  [DP, for tree={fill=green}
    [D] [NP[N] [CP[C] [TP
      [T] [vP[v] [VP,important=left[DP] [V' [V] [DP]]]]]]]]
    [TP,for tree={fill=yellow}, l=3cm
      [T] [vP[v] [VP[DP,important=right] [V' [V] [DP]]]]]]
  ]
\measurexdistance[\texttt{s sep(root)}=#1]
  {(left.north east)}{(right.north west)}{(.north)+(0,3mm)}{above}
\end{forest}
```

(27)

Note that the yellow and green nodes are not vertically aligned anymore. The positioning algorithm has no problem with that. But you, as a user, might have, so here's a neat trick. (This only works in the "normal" circumstances, which are easier to see than describe.)

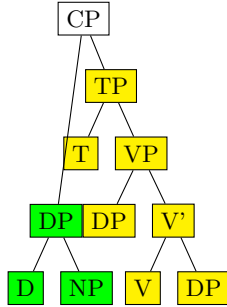


```
\begin{forest}
  [CP, for tree=draw
    [DP, for tree={fill=green},l*=3
      [D] [NP]]
    [TP,for tree={fill=yellow}
      [T] [VP [DP] [V' [V] [DP]]]]
  ]
\end{forest}
```

(28)

We have changed DP's `l`'s value via "augmented assignment" known from many programming languages: above, we have used `l*=3` to triple 's value; we could have also said `l+=5mm` or `l-=5mm` to increase or decrease its value by 5mm, respectively. This mechanism works for every numeric and dimensional option in FOREST.

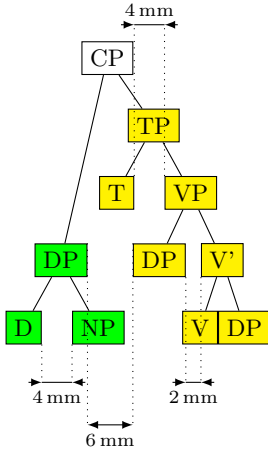
Let's now play with option `s sep`.



```
\begin{forest}
  [CP, for tree=draw, s sep=0
    [DP, for tree={fill=green},l*=3
      [D] [NP]]
    [TP,for tree={fill=yellow}
      [T] [VP [DP] [V' [V] [DP]]]]
  ]
\end{forest}
```

(29)

Surprised? You shouldn't be. The value of `s sep` at a given node controls the s-distance *between the subtrees rooted in the children of that node!* It has no influence over the internal geometry of these subtrees. In the above example, we have set `s sep=0` only for the root node, so the green and the yellow subtree are touching, although internally, their nodes are not. Let's play a bit more. In the following example, we set the `s sep` to: 0 at the last branching level (level 3; the root is level 0), to 2mm at level 2, to 4mm at level 1 and to 6mm at level 0.



```
\begin{forest}
  for tree={s sep=(3-level)*2mm}
  [CP, for tree=draw
    [DP, for tree={fill=green},l*=3
      [D] [NP]]
    [TP,for tree={fill=yellow}
      [T] [VP [DP] [V' [V] [DP]]]]
  ]
  \measurexdistance{(!11.south east)}{(!12.south west)}{+(0,-5mm)}{below}
  \path(md2)-|coordinate(md){(!221.south east)};
  \measurexdistance{(!221.south east)}{(!222.south west)}{(md)}{below}
  \measurexdistance{(!21.north east)}{(!22.north west)}{+(0,2cm)}{above}
  \measurexdistance{(!1.north east)}{(!221.north west)}{+(0,-2.4cm)}{below}
\end{forest}
```

(30)

As we go up the tree, the nodes "spread." At the lowest level, V and DP are touching. In the third level, the `s sep` of level 2 applies, so DP and V' are 2mm apart. At the second level we have two pairs of nodes, D and NP, and T and TP: they are 4mm apart. Finally, at level 1, the `s sep` of level 0 applies, so the green and yellow DP are 6mm apart. (Note that D and NP are at level 2, not 4! Level is a matter of structure, not geometry.)

As you have probably noticed, this example also demonstrated that we can compute the value of an option using an (arbitrarily complex) formula. This is thanks to PGF's module `pgfmath`. FOREST provides an interface to `pgfmath` by defining `pgfmath` functions for every node option, and some other

The final separation parameter is `1 sep`. It determines the minimal separation of a node from its descendants. If the value of `1` is too small, then *all* the children (and thus their subtrees) are pushed away from the parent (by increasing their `1s`), so that the distance between the node's and each child's subtree boundary is at least `1 sep`. The initial `1` can be too small for two reasons: either some child is too high, or the parent is too deep. The first problem is easier to see: we force the situation using a bottom-aligned multiline node. (Multiline nodes can be easily created using `\` as a line-separator. However, you must first specify the horizontal alignment using option `align` (see §3.3.1). Bottom vertical alignment is achieved by setting `base=bottom`; the default, unlike in *TikZ*, is `base=top`).

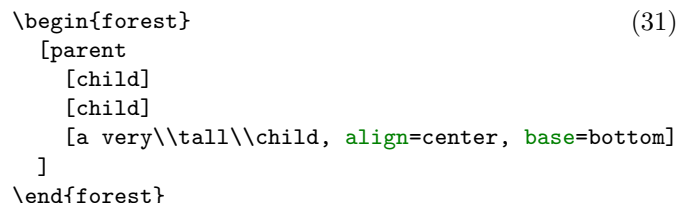
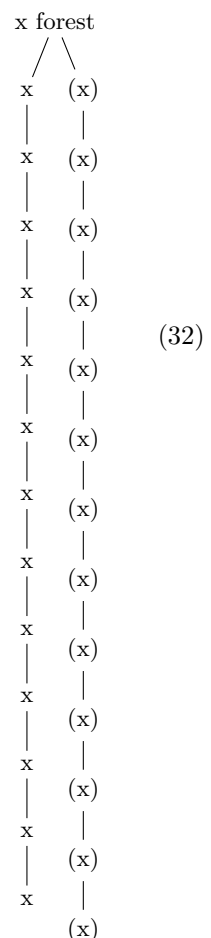


Figure 1 illustrates three syntactic tree structures for the phrase "the cat sat on the mat". The trees are labeled "l+=5mm", "default", and "l-=5mm".

- l+=5mm:** The root node is *AdjP*. It branches into *AdvP* and *Adj'*. *AdvP* branches into "the" and "cat". *Adj'* branches into "sat" and *PP*. *PP* branches into "on" and *NP*. *NP* branches into "the" and "mat".
- default:** The root node is *AdjP*. It branches into *AdvP* and *Adj'*. *AdvP* branches into "the" and "cat". *Adj'* branches into "sat" and *PP*. *PP* branches into "on" and *NP*. *NP* branches into "the" and "mat".
- l-=5mm:** The root node is *AdjP*. It branches into *AdvP* and *Adj'*. *AdvP* branches into "the" and "cat". *Adj'* branches into "sat" and *PP*. *PP* branches into "on" and *NP*. *NP* branches into "the" and "mat".

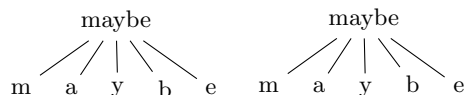


15

2.4.1 The defaults, or the hairy details of vertical alignment

In this section we discuss the default values of options controlling the l-alignment of the nodes. The defaults are set with top-down trees in mind, so l-alignment is actually vertical alignment. There are two desired effects of the defaults. First, the spacing between the nodes of a tree should adjust to the current font size. Second, the nodes of a given level should be vertically aligned (at the base), if possible.

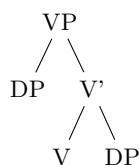
Let us start with the base alignment: `TikZ`'s default is to anchor the nodes at their center, while `FOREST`, given the usual content of nodes in linguistic representations, rather anchors them at the base [2, §16.5.1]. The difference is particularly clear for a “phonological” representation:



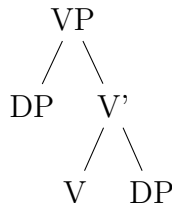
```
\begin{forest} for tree={anchor=center} (33)
  [maybe[m] [a] [y] [b] [e]]
\end{forest}\quad
\begin{forest}
  [maybe[m] [a] [y] [b] [e]]
\end{forest}
```

The following example shows that the vertical distance between nodes depends on the current font size.

A small tree



and a large tree

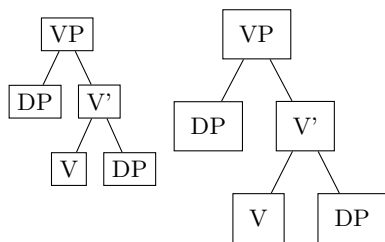


```
\hbox{\small A small tree (34)
\begin{forest} baseline
  [VP[DP] [V' [V] [DP]]]
\end{forest}
\normalsize and
\large
a large tree
\begin{forest} baseline
  [VP[DP] [V' [V] [DP]]]
\end{forest}}
```

Furthermore, the distance between nodes also depends on the value of `PGF`'s `inner sep` (which also depends on the font size by default: it equals 0.3333 em).

$$l \text{ sep} = \text{height}(\text{strut}) + \text{inner ysep}$$

The default value of `s sep` depends on `inner xsep`: more precisely, it equals double `inner xsep`).

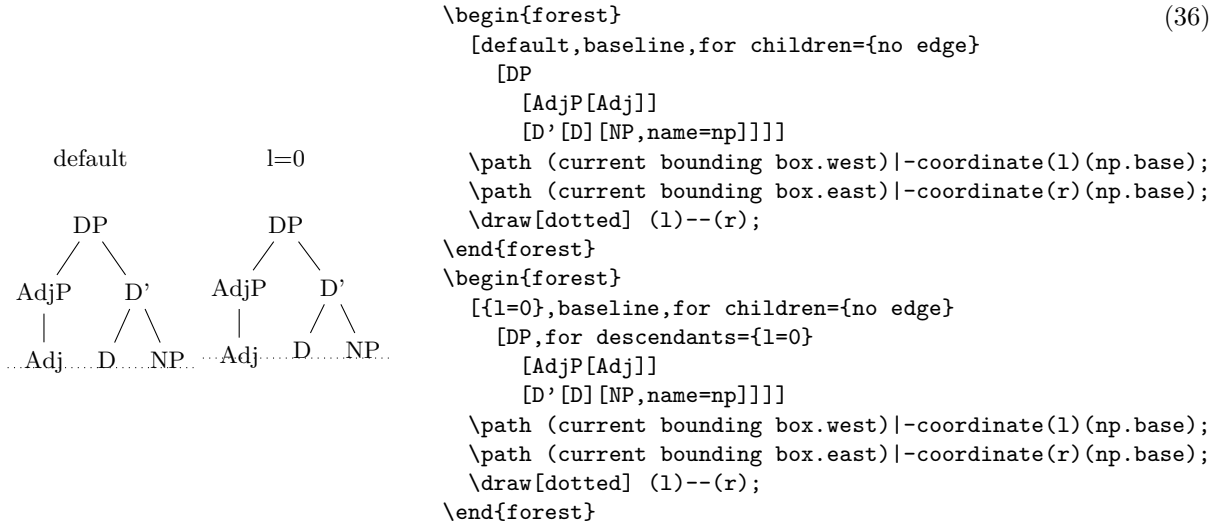


```
\begin{forest} baseline,for tree=draw (35)
  [VP[DP] [V' [V] [DP]]]
\end{forest}
\pgfkeys{/pgf/inner sep=0.6666em}
\begin{forest} baseline,for tree=draw
  [VP[DP] [V' [V] [DP]]]
\end{forest}
```

Now a hairy detail: the formula for the default `l`.

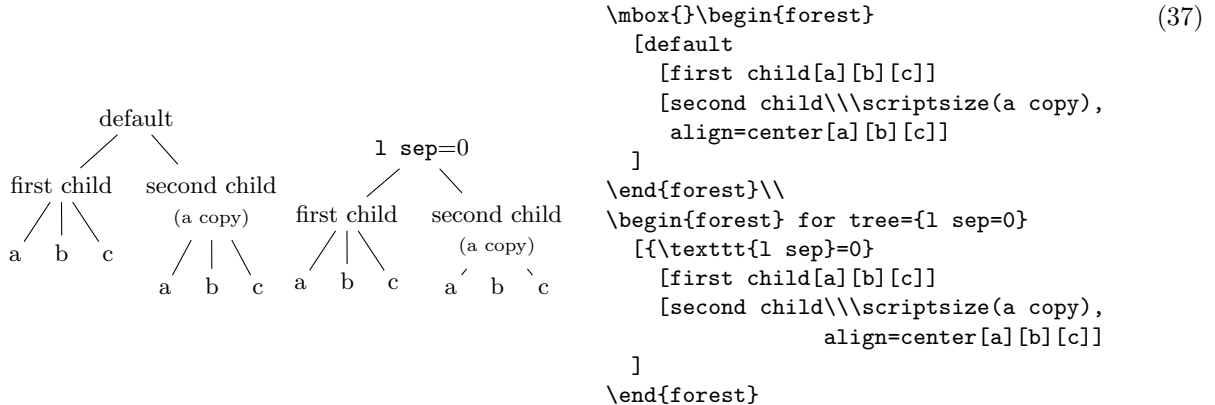
$$l = l \text{ sep} + 2 \cdot \text{outer ysep} + \text{total height}('dj')$$

To understand what this is all about we must first explain why it is necessary to set the default `l` at all? Wouldn't it be enough to simply set `l sep` (leaving `l` at 0)? The problem is that not all letters have the same height and depth. A tree where the vertical position of the nodes would be controlled solely by (a constant) `l sep` could result in a ragged tree (although the height of the child–parent edges would be constant).



The vertical misalignment of Adj in the right tree is a consequence of the fact that letter j is the only letter with non-zero depth in the tree. Since only `l sep` (which is constant throughout the tree) controls the vertical positioning, Adj, child of AdjP, is pushed lower than the other nodes on level 2. If the content of the nodes is variable enough (various heights and depths), the cumulative effect can be quite strong, see the right tree of example (32).

Setting only a default `l sep` thus does not work well enough in general. The same is true for the reverse possibility, setting a default `l` (and leaving `l sep` at 0). In the example below, the depth of the multiline node (anchored at the top line) is such that the child–parent edges are just too short if the level distance is kept constant. Sometimes, misalignment is much preferred ...



Thus, the idea is to make `l` and `l sep` work as a team: `l` prevents misalignments, if possible, while `l sep` determines the minimal vertical distance between levels. Each of the two options deals with a certain kind of a “deviant” node, i.e. a node which is too high or too deep, or a node which is not high or deep enough, so we need to postulate what a *standard* node is, and synchronize them so that their effect on standard nodes is the same.

By default, FOREST sets the standard node to be a node containing letters d and j. Linguistic representations consist mainly of letters, and in the T_EX’s default Computer Modern font, d is the highest letter (not character!), and j the deepest, so this decision guarantees that trees containing only letters will look nice. If the tree contains many parentheses, like the right tree of example (32), the default will of course fail and the standard node needs to be modified. But for many applications, including nodes with indices, the default works.

The standard node can be changed using macro `\forestStandardNode`; see 3.7.

2.5 Advanced option setting

We have already seen that the value of options can be manipulated: in (13) we have converted numeric content from arabic into roman numerals using the *wrapping* mechanism `content=\romannumeral#1`; in (28), we have tripled the value of 1 by saying `1*=3`. In this section, we will learn about the mechanisms for setting and referring to option values offered by FOREST.

One other way to access an option value is using macro `\forestoption`. The macro takes a single argument: an option name. (For details, see §3.3.) In the following example, the node’s child sequence number is appended to the existing content. (This is therefore also an example of wrapping.)

$$\begin{array}{cccccc}
 c_1 & o_2 & u_3 & n_4 & t_5 \\
 \end{array}$$

```

\begin{forest}
  [,phantom,delay={for descendants={
    content=#1$_{\forestoption{n}}$}]
  [c] [o] [u] [n] [t]]
\end{forest}

```

(38)

However, only options of the current node can be accessed using `\forestoption`. To access option values of other nodes, FOREST’s extensions to the PGF’s mathematical library `pgfmath`, documented in [2, part VI], must be used. To see `pgfmath` in action, first take a look at the crazy tree on the title page, and observe how the nodes are rotated: the value given to (TikZ) option `rotate` is a full-fledged `pgfmath` expression yielding an integer in the range from -30 to 30 . Similarly, `l+` adds a random float in the $[-5, 5]$ range to the current value of `l`.

Example (30) demonstrated that information about the node, like the node’s level, can be accessed within `pgfmath` expressions. All options are accessible in this way, i.e. every option has a corresponding `pgfmath` function. For example, we could rotate the node based on its content:

```

\begin{forest}
  delay={for tree={rotate=content}}
  [30[-10[5] [0]] [-90[180]] [90[-60] [90]]]
\end{forest}

```

(39)

All numeric, dimensional and boolean options of FOREST automatically pass the given value through `pgfmath`. If you need pass the value through `pgfmath` for a string option, use the `.pgfmath` handler. The following example sets the node’s content to its child sequence number (the root has child sequence number 0).

```

\begin{forest}
  delay={for tree={content/.pgfmath=int(n)}}
  [[[] [] []] [[] []]]
\end{forest}

```

(40)

As mentioned above, using `pgfmath` it is possible to access options of non-current nodes. This is achieved by providing the option function with a *relative node name* (see §3.5) argument.⁹ In the next example, we rotate the node based on the content of its parent.

```

\begin{forest}
  delay={for descendants={rotate=content("!u")}}
  [30[-10[5] [0]] [-90[180]] [90[-60] [90]]]
\end{forest}

```

(41)

⁹The form without parentheses `option_name` that we have been using until now to refer to an option of the current node is just a short-hand notation for `option_name()` — note that in some contexts, like preceding `+` or `-`, the short form does not work! (The same seems to be true for all `pgfmath` functions with “optional” arguments.)

Note that the argument of the option function is surrounded by double quotation marks: this is to prevent evaluation of the relative node name as a `pgfmath` function — which it is not.

Handlers `.wrap pgfmath arg` and `.wrap n pgfmath args` (for $n = 2, \dots, 8$) combine the wrapping mechanism with the `pgfmath` evaluation. The idea is to compute (most often, just access option values) arguments using `pgfmath` and then wrap them with the given macro. Below, this is used to include the number of parent's children in the index.

```
\begin{forest} [,phantom,delay={for descendants={
                                content/.wrap 3 pgfmath args=
                                {#1$_{#2/#3}$}{content}{n}{n_children("!u")}}]
  c1/5  o2/5  u3/5  n4/5  t5/5
  [c][o][u][n][t]]
\end{forest}
```

Note the underscore `_` character in `n_children`: in `pgfmath` function names, spaces, apostrophes and other non-alphanumeric characters from option names are all replaced by underscores.

As another example, let's make the numerals example (9) a bit fancier. The numeral type is read off the parent's content and used to construct the appropriate control sequence (`\@arabic`, `\@roman` and `\@alph`). (Also, the numbers are not specified in content anymore: we simply read the sequence number `n`. And, to save some horizontal space for the code, each child of the root is pushed further down.)

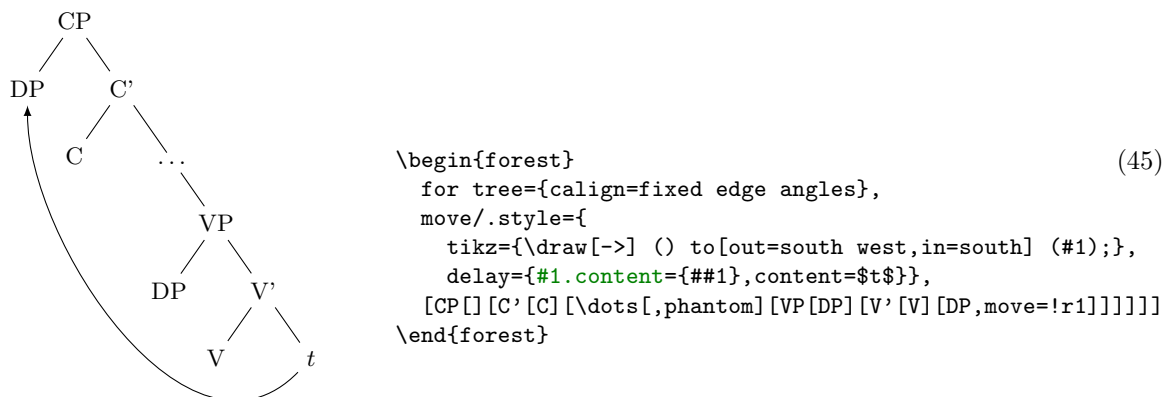
```
\begin{forest}
  delay={where level={2}{content/.wrap 2 pgfmath args=
    {\csname @#1\endcsname{#2}}{content("!u")}{n}}},
  for children={l*=n},
  [\LaTeX numerals,
   [arabic[] [] [] []]
   [roman[] [] [] []]
   [alph[] [] [] []]
  ]
\end{forest}
```

The final way to use `pgfmath` expressions in FOREST: `if` clauses. In section 2.2, we have seen that every option has a corresponding `if ...` (and `where ...`) option. However, these are just a matter of convenience. The full power resides in the general `if` option, which takes three arguments: `if=<condition><true options><>false options>`, where `<condition>` can be any `pgfmath` expression (non-zero means true, zero means false). (Once again, option `where` is an abbreviation for `for tree={if=...}`.) In the following example, `if` option is used to orient the arrows from the smaller number to the greater, and to color the odd and even numbers differently.

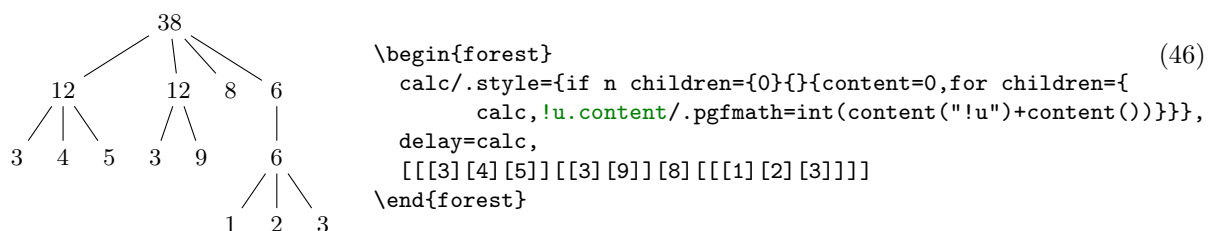
```
\pgfmathsetseed{314159}
\begin{forest}
  before typesetting nodes={
    for descendants={
      if={content()>content("!u")}{edge=->}{
        if={content()<content("!u")}{edge=<-}{}},
      edge label/.wrap pgfmath arg=
        {node[midway,above,sloped,font=\scriptsize]{+#1}}
        {int(abs(content()-content("!u")))}
    },
    for tree={circle,if={mod(content(),2)==0}
      {fill=yellow}{fill=green}}
  }
  [,random tree={3}{3}{100}]
\end{forest}
```

This exhausts the ways of using `pgfmath` in forest. We continue by introducing *relative node setting*: write `<relative node name>.<option>=<value>` to set the value of `<option>` of the specified relative node. Important: computation (`pgfmath` or `wrap`) of the value is done in the context of the original node. The following example defines style move which not only draws an arrow from the source to the target, but also moves the content of the source to the target (leaving a trace). Note the difference between `#1` and

##1: **#1** is the argument of the style `move`, i.e. the given node walk, while **##1** is the original option value (in this case, `content`).



In the following example, the content of the branching nodes is computed by `FOREST`: a branching node is a sum of its children. Besides the use of the relative node setting, this example notably uses a recursive style: for each child of the node, style `calc` first applies itself to the child and then adds the result to the node; obviously, recursion is made to stop at terminal nodes.



2.6 Externalization

`FOREST` can be quite slow, due to the slowness of both `PGF/TikZ` and its own computations. However, using *externalization*, the amount of time spent in `FOREST` in everyday life can be reduced dramatically. The idea is to typeset the trees only once, saving them in separate PDFs, and then, on the subsequent compilations of the document, simply include these PDFs instead of doing the lengthy tree-typesetting all over again.

`FOREST`'s externalization mechanism is built on top of `TikZ`'s `external` library. It enhances it by automatically detecting the code and context changes: the tree is recompiled if and only if either the code in the `forest` environment or the context (arbitrary parameters; by default, the parameters of the standard node) changes.

To use `FOREST`'s externalization facilities, say:¹⁰

```

\usepackage[external]{forest}
\tikzexternalize

```

If your `forest` environment contains some macro, you will probably want the externalized tree to be recompiled when the definition of the macro changes. To achieve this, use `\forestset{external/depends on macro=\macro}`. The effect is local to the \TeX group.

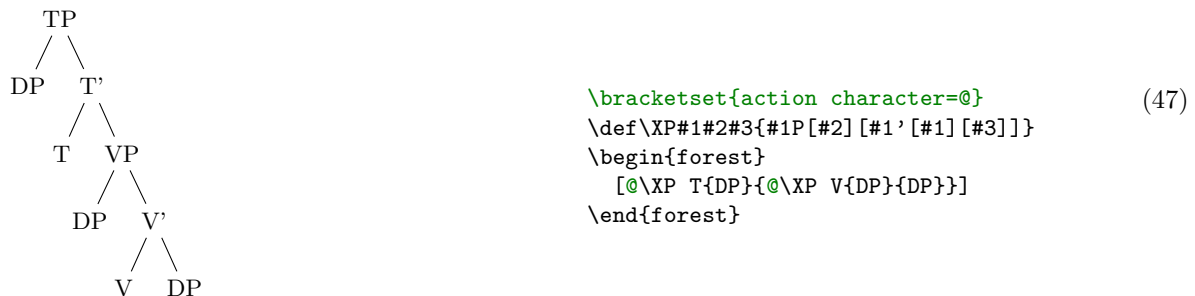
`TikZ`'s externalization library promises a `\label` inside the externalized graphics to work out-of-box, while `\ref` inside the externalized graphics should work only if the externalization is run manually or by `make` [2, §32.4.1]. A bit surprisingly perhaps, the situation is roughly reversed in `FOREST`. `\ref` inside the externalized graphics will work out-of-box. `\label` inside the externalized graphics will not work at

¹⁰When you switch on the externalization for a document containing many `forest` environments, the first compilation can take quite a while, much more than the compilation without externalization. (For example, more than ten minutes for the document you are reading!) Subsequent compilations, however, will be very fast.

all. Sorry. (The reason is that FOREST prepares the node content in advance, before merging it in the whole tree, which is when *TikZ*'s externalization is used.)

2.7 Expansion control in the bracket parser

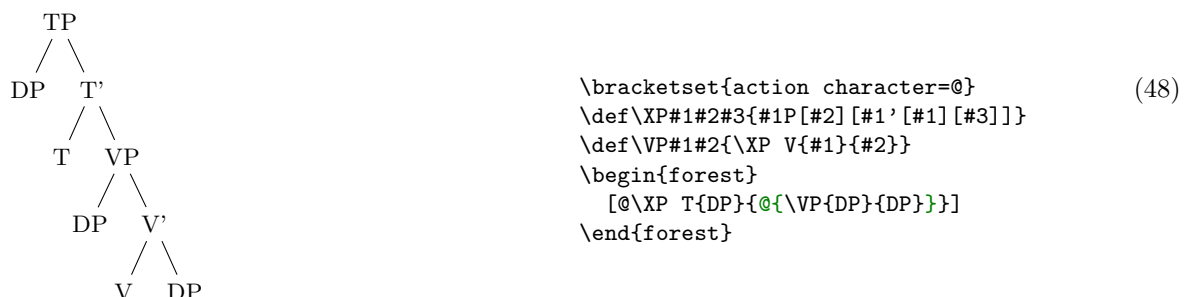
By default, macros in the bracket encoding of a tree are not expanded until nodes are being drawn — this way, node specification can contain formatting instructions, as illustrated in section 2.1. However, sometimes it is useful to expand macros while parsing the bracket representation, for example to define tree templates such as the X-bar template, familiar to generative grammarians:¹¹



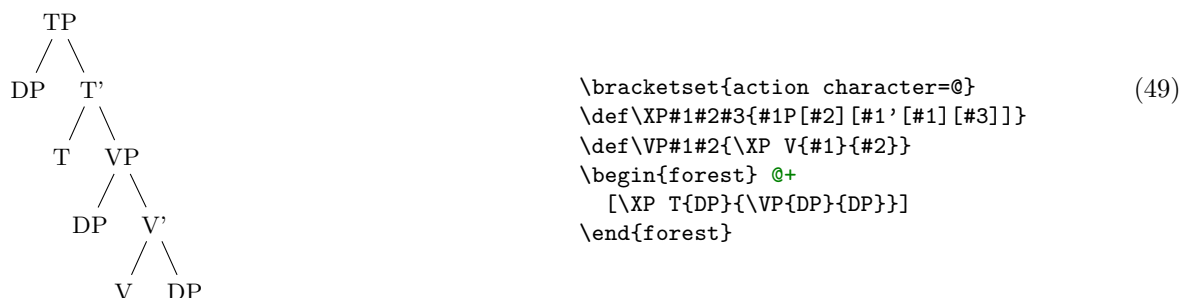
In the above example, the `\XP` macro is preceded by the *action character* `@`: as the result, the token following the action character was expanded before the parsing proceeded.

The action character is not hard coded into FOREST. Actually, there is no action character by default. (There's enough special characters in FOREST already, anyway, and the situations where controlling the expansion is preferable to using the `pgfkeys` interface are not numerous.) It is defined at the top of the example by processing key `action character` in the `/bracket` path; the definition is local to the `TEX` group.

Let us continue with the description of the expansion control facilities of the bracket parser. The expandable token following the action character is expanded only once. Thus, if one defined macro `\VP` in terms of the general `\XP` and tried to use it in the same fashion as `\XP` above, he would fail. The correct way is to follow the action character by a braced expression: the braced expression is fully expanded before bracket-parsing is resumed.



In some applications, the need for macro expansion might be much more common than the need to embed formatting instructions. Therefore, the bracket parser provides commands `@+` and `@-`: `@+` switches to full expansion mode — all tokens are fully expanded before parsing them; `@-` switches back to the default mode, where nothing is automatically expanded.



¹¹Honestly, dynamic node creation might be a better way to do this; see §3.3.8.

All the action commands discussed above were dealing only with T_EX’s macro expansion. There is one final action command, `@@`, which yields control to the user code and expects it to call `\bracketResume` to resume parsing. This is useful to e.g. implement automatic node enumeration:

$ \begin{array}{cccccc} \times_1 & \times_2 & \times_3 & \times_4 & \times_5 & \times_6 \\ & & & & & \\ f & o & r & e & s & t \end{array} $	<pre> \bracketset{action character=@} \newcount\xcount \def\x#1{@@\advance\xcount1 \edef\xtemp{[$\noexpand\times_{\the\xcount}\\$[\#1]]}% \expandafter\bracketResume\xtemp } \begin{forest} phantom, delay={where level=1{content={\strut #1}}{}} @+ [\x{f}\x{o}\x{r}\x{e}\x{s}\x{t}] \end{forest}$</pre> <div style="text-align: right;">(50)</div>
---	--

This example is fairly complex, so let’s discuss how it works. `@+` switches to the full expansion mode, so that macro `\x` can be easily run. The real magic hides in this macro. In order to be able to advance the node counter `\xcount`, the macro takes control from FOREST by the `@@` command. Since we’re already in control, we can use `\edef` to define the node content. Finally, the `\xtemp` macro containing the node specification is expanded with the resume command stucked in front of the expansion.

3 Reference

3.1 Environments

environment `\begin{forest}` $\langle tree \rangle$ `\end{forest}`

`\Forest` $[*]{\langle tree \rangle}$

The environment and the starless version of the macro introduce a group; the starred macro does not, so the created nodes can be used afterwards. (Note that this will leave a lot of temporary macros lying around. This shouldn’t be a problem, however, since all of them reside in the `\forest` namespace.)

3.2 The bracket representation

A bracket representation of a tree is a token list with the following syntax:

$$\begin{aligned}
 \langle tree \rangle &= [\langle preamble \rangle] \langle node \rangle \\
 \langle node \rangle &= [[\langle content \rangle] [, \langle keylist \rangle]] \langle afterthought \rangle \\
 \langle preamble \rangle &= \langle keylist \rangle \\
 \langle keylist \rangle &= \langle key-value \rangle [, \langle keylist \rangle] \\
 \langle key-value \rangle &= \langle key \rangle | \langle key \rangle = \langle value \rangle \\
 \langle children \rangle &= \langle node \rangle [\langle children \rangle]
 \end{aligned}$$

The actual input might be different, though, since expansion may have occurred during the input reading. Expansion control sequences of FOREST’s bracket parser are shown below.

$\langle action\ character \rangle -$	no-expansion mode (default): nothing is expanded
$\langle action\ character \rangle +$	expansion mode: everything is fully expanded
$\langle action\ character \rangle \langle token \rangle$	expand $\langle token \rangle$
$\langle action\ character \rangle \langle T_{E}X-group \rangle$	fully expand $\langle T_{E}X-group \rangle$
$\langle action\ character \rangle \langle action\ character \rangle$	yield control; upon finishing its job, user’s code should call <code>\bracketResume</code>

Customization To customize the bracket parser, call `\bracketset{keylist}`, where the keys can be the following.

```
opening bracket= $\langle character \rangle$  [
closing bracket= $\langle character \rangle$  ]
action character= $\langle character \rangle$  none
```

By redefining the following two keys, the bracket parser can be used outside FOREST.

new node= $\langle preamble \rangle \langle node\ specification \rangle \langle csname \rangle$. Required semantics: create a new node given the preamble (in the case of a new root node) and the node specification and store the new node’s id into $\langle csname \rangle$.

set afterthought= $\langle afterthought \rangle \langle node\ id \rangle$. Required semantics: store the afterthought in the node with given id.

3.3 Options and keys

The position and outlook of nodes is controlled by *options*. Many options can be set for a node. *Each node’s options are set independently of other nodes*: in particular, setting an option of a node does *not* set this option for the node’s descendants.

Options are set using PGF’s key management utility `pgfkeys` [2, §55]. In the bracket representation of a tree (see §3.2), each node can be given a $\langle keylist \rangle$. After parsing the representation of the tree, the keylists of the nodes are processed (recursively, in a depth-first, parent-first fashion). The preamble is processed first, in the context of the root node.¹²

The node whose keylist is being processed is the *current node*. During the processing of the keylist, the current node can temporarily change. This mainly happens when propagators (§3.3.6) are being processed.

Options can be set in various ways, depending on the option type (the types are listed below). The most straightforward way is to use the key with the same name as the option:

$\langle option \rangle = \langle value \rangle$ Sets the value of $\langle option \rangle$ of the current node to $\langle value \rangle$.

Notes: (i) Obviously, this does not work for read-only options. (ii) Some option types override this behaviour.

It is also possible to set a non-current option:

$\langle relative\ node\ name \rangle . \langle option \rangle = \langle value \rangle$ Sets the value of $\langle option \rangle$ of the node specified by $\langle relative\ node\ name \rangle$ to $\langle value \rangle$.

Notes: (i) $\langle value \rangle$ is evaluated in the context of the current node. (ii) In general, the resolution of $\langle relative\ node\ name \rangle$ depends on the current node; see §3.5. (iii) $\langle option \rangle$ can also be an “augmented operator” (see below) or an additional option-setting key defined for a specific option.

The option values can be not only set, but also read.

- Using macros `\forestoption{option}` and `\foresteoption{option}`, options of the current node can be accessed in T_EX code. (“T_EX code” includes $\langle value \rangle$ expressions!).

In the context of `\edef` or PGF’s handler `.expanded` [2, §55.4.6], `\forestoption` expands precisely to the token list of the option value, while `\foresteoption` allows the option value to be expanded as well.

- Using `pgfmath` functions defined by FOREST, options of both current and non-current nodes can be accessed. For details, see §3.6.

¹²The value of a key (if it is given) is interpreted as one or more arguments to the key command. If there is only one argument, the situation is simple: the whole value is the argument. When the key takes more than one argument, each argument should be enclosed in braces, unless, as usual in T_EX, the argument is a single token. (The pairs of braces can be separated by whitespace.) An argument should also be enclosed in braces if it contains a special character: a comma `,`, an equal sign `=` or a bracket `[]`.

We continue with listing of all keys defined for every option. The set of defined keys and their meanings depends on the option type. Option types and the type-specific keys can be found in the list below. Common to all types are two simple conditionals, `if <option>` and `where <option>`, which are defined for every `<option>`; for details, see §3.3.6.

type `<toks>` contains T_EX's `<balanced text>` [1, 275].

A toks `<option>` additionally defines the following keys:

`<option>+=<toks>` appends the given `<toks>` to the current value of the option.

`<option>-=<toks>` prepends the given `<toks>` to the current value of the option.

`if in <option>=<toks><true keylist><false keylist>` checks if `<toks>` occurs in the option value; if it does, `<true keylist>` are executed, otherwise `<false keylist>`.

`where in <option>=<toks><true keylist><false keylist>` is a style equivalent to `for tree={if in <option>=<toks><true keylist><false keylist>}`: for every node in the subtree rooted in the current node, `if in <option>` is executed in the context of that node.

type `<autowrapped toks>` is a subtype of `<toks>` and contains T_EX's `<balanced text>` [1, 275].

`<option>=<toks>` of an autowrapped `<option>` is equivalent to `<option>/.wrap value=<toks>` of a normal `<toks>` option.

Keyvals `<option>+=<toks>` and `<option>-=<toks>` are equivalent to `<option>+/.wrap value=<toks>` and `<option>-/.wrap value=<toks>`, respectively. The normal toks behaviour can be accessed via keys `<option>'`, `<option>+'` and `<option>-'`.

type `<keylist>` is a subtype of `<toks>` and contains a comma-separated list of `<key>[=<value>]` pairs.

Augmented operators `<option>+` and `<option>-` automatically insert a comma before/after the appended/prepended material.

`<option>=<keylist>` of a keylist option is equivalent to `<option>+=<keylist>`. In other words, keylists behave additively by default. The rationale is that one usually wants to add keys to a keylist. The usual, non-additive behaviour can be accessed by `<option>'=<keylist>`.

type `<dimen>` contains a dimension.

The value given to a dimension option is automatically evaluated by pgfm_{ath}. In other words:

`<option>=<pgfmath>` is an implicit `<option>/.pgfmath=<pgfmath>`.

For a `<dimen>` option `<option>`, the following additional keys (“augmented assignments”) are defined:

- `<option>+=<value>` is equivalent to `<option>=<option>()+<value>`
- `<option>-=<value>` is equivalent to `<option>=<option>()-<value>`
- `<option>*=<value>` is equivalent to `<option>=<option>()*<value>`
- `<option>:=<value>` is equivalent to `<option>=<option>()/<value>`

The evaluation of `<pgfmath>` can be quite slow. There are two tricks to speed things up if the `<pgfmath>` expression is simple, i.e. just a T_EX `<dimen>`:

1. pgfm_{ath} evaluation of simple values can be sped up by prepending `+` to the value [2, §62.1];
2. use the key `<option>'=<value>` to invoke a normal T_EX assignment.

The two above-mentioned speed-up tricks work for the augmented assignments as well. The keys for the second, T_EX-only trick are: `<option>'+`, `<option>'-`, `<option>'*` and `<option>:'` — note that for the latter two, the value should be an integer.

type `<count>` contains an integer.

The additional keys and their behaviour are the same as for the `<dimen>` options.

type *boolean* contains 0 (false) or 1 (true).

In the general case, the value given to a *boolean* option is automatically parsed by `pgfmath` (just as for *count* and *dimen*): if the computed value is non-zero, 1 is stored; otherwise, 0 is stored. Note that `pgfmath` recognizes constants `true` and `false`, so it is possible to write *option*=`true` and *option*=`false`.

If key *option* is given no argument, `pgfmath` evaluation does not apply and a true value is set. To quickly set a false value, use key `not option` (with no arguments).

The following subsections are a complete reference to the part of the user interface residing in the `pgfkeys`’ path `/forest`. In plain language, they list all the options known to `FOREST`. More precisely, however, not only options are listed, but also other keys, such as propagators, conditionals, etc.

Before listing the keys, it is worth mentioning that users can also define their own keys. The easiest way to do this is by using *styles*. Styles are a feature of the `pgfkeys` package. They are named keylists, whose usage ranges from mere abbreviations through templates to devices implementing recursion. To define a style, use PGF’s handler `.style` [2, §55.4.4]: *style name*/.`style`=*keylist*.

Using the following keys, users can also declare their own options. The new options will behave exactly like the predefined ones.

`declare toks=<option name><default value>` Declares a *toks* option.

`declare autowrapped toks=<option name><default value>` Declares an *autowrapped toks* option.

`declare keylist=<option name><default value>` Declares a *keylist* option.

`declare dimen=<option name><default value>` Declares a *dimen* option.

`declare count=<option name><default value>` Declares a *count* option.

`declare boolean=<option name><default value>` Declares a *boolean* option.

The style definitions and option declarations given among the other keys in the bracket specification are local to the current tree. To define globally accessible styles and options (well, definitions are always local to the current \TeX group), use macro `\forestset` outside the `forest` environment:¹³

`\forestset{<keylist>}`

Execute *keylist* with the default path set to `/forest`.

→ Usually, no current node is set when this macro is called. Thus, executing node options in this place will *fail*. However, if you have some nodes lying around, you can use propagator `for name=<node name>` to set the node with the given name as current.

3.3.1 Node appearance

The following options apply at stage `typesetting nodes`. Changing them afterwards has no effect in the normal course of events.

option `align=left, aspect=align | center, aspect=align | right, aspect=align | <toks: tabular header> {}`

Creates a left/center/right-aligned multiline node, or a tabular node. In the `content` option, the lines of the node should be separated by `\\` and the columns (if any) by `&`, as usual.

The vertical alignment of the multiline/tabular node can be specified by option `base`.

special value	actual value
<code>left</code>	<code>@{}l@{}</code>
<code>center</code>	<code>@{}c@{}</code>
<code>right</code>	<code>@{}r@{}</code>

top base
right aligned

left aligned
bottom base

```
\begin{forest} 1 sep+=2ex
[special value&actual value\\hline
\rkeyname{left, aspect=align}&||\texttt{@\{\\}l@{\}}\\
\rkeyname{center, aspect=align}&||\texttt{@\{\\}c@{\}}\\
\rkeyname{right, aspect=align}&||\texttt{@\{\\}r@{\}}\\
, align=ll, draw
[top base\\right aligned, align=right, base=top]
[left aligned\\bottom base, align=left, base=bottom]
]
\end{forest}
```

¹³`\forestset{<keylist>}` is equivalent to `\pgfkeys{/forest, <keylist>}`.

Internally, setting this option has two effects:

1. The option value (a `tabular` environment header specification) is set. The special values `left`, `center` and `right` invoke styles setting the actual header to the value shown in the above example.

→ If you know that the `align` was set with a special value, you can easily check the value using `if in align`.

2. Option `content format` is set to the following value:

```
\noexpand\begin{tabular}[\forestoption{base}]{\forestoption{align}}%
\forestoption{content}%
\noexpand\end{tabular}%
```

As you can see, it is this value that determines that options `base`, `align` and `content` specify the vertical alignment, header and content of the table.

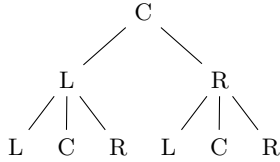
option `base`= \langle *toks: vertical alignment* \rangle `t`

This option controls the vertical alignment of multiline (and in general, `tabular`) nodes created with `align`. Its value becomes the optional argument to the `tabular` environment. Thus, sensible values are `t` (the top line of the table will be the baseline) and `b` (the bottom line of the table will be the baseline). Note that this will only have effect if the node is anchored on a baseline, like in the default case of `anchor=base`.

For readability, you can use `top` and `bottom` instead of `t` and `b`. (`top` and `bottom` are still stored as `t` and `b`.)

option `content`= \langle *autowrapped toks* \rangle The content of the node. `{}`

Normally, the value of option `content` is given implicitly by virtue of the special (initial) position of content in the bracket representation (see §3.2). However, the option also be set explicitly, as any other option.



```
\begin{forest}
  delay={for tree={
    if n=1{content=L}
      {if n'=1{content=R}
        {content=C}}}}
  [[[] [] []][[] [] []]]
\end{forest}
```

(52)

Note that the execution of the `content` option should usually be delayed: otherwise, the implicitly given content (in the example below, the empty string) will override the explicitly given content.



```
\begin{forest}
  for tree={
    if n=1{content=L}
      {if n'=1{content=R}
        {content=C}}}}
  [[[] [] []][[] [] []]]
\end{forest}
```

(53)

option `content format`= \langle *toks* \rangle `\forestoption{content}`

When typesetting the node under the default conditions (see option `node format`), the value of this option is passed to the TikZ `node` operation as its \langle *text* \rangle argument [2, §16.2]. The default value of the option simply puts the content in the node.

This is a fairly low level option, but sometimes you might still want to change its value. If you do so, take care of what is expanded when. For details, read the documentation of option `node format` and macros `\forestoption` and `\foresteoption`; for an example, see option `align`.

style **math content** The content of the node will be typeset in a math environment.

This style is just an abbreviation for `content format={\ensuremath{\forestoption{content}}}`.

option **node format**= $\langle toks \rangle$ \noexpand\node
[\forestoption{node options},anchor=\forestoption{anchor}]
(\forestoption{name}){\forestoption{content format}};

The node is typeset by executing the expansion of this option's value in a `tikzpicture` environment.

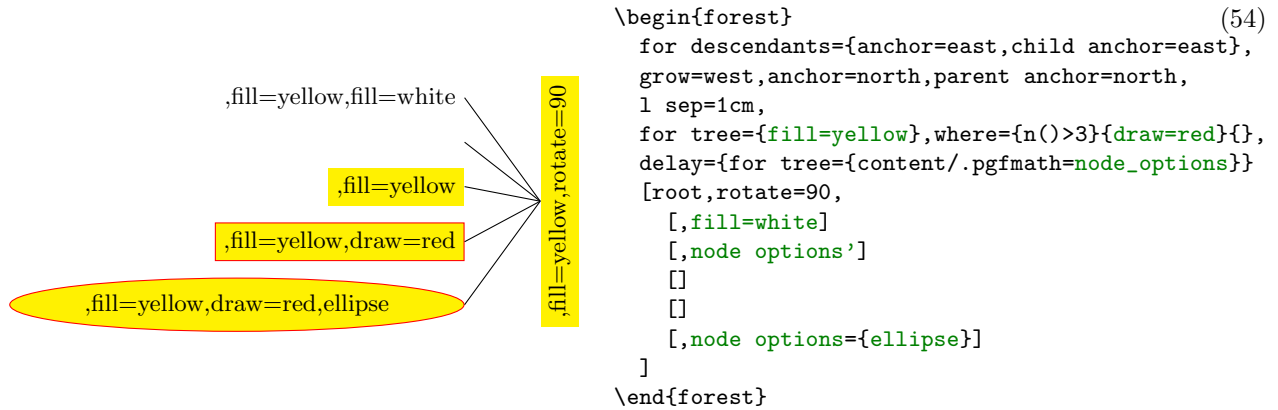
Important: the value of this option is first expanded using `\edef` and only then executed. Note that in its default value, `content format` is fully expanded using `\forestoption`: this is necessary for complex content formats, such as `tabular` environments.

This is a low level option. Ideally, there should be no need to change its value. If you do, note that the TikZ node you create should be named using the value of option `name`; otherwise, parent-child edges can't be drawn, see option `edge path`.

option **node options**= $\langle keylist \rangle$ {}

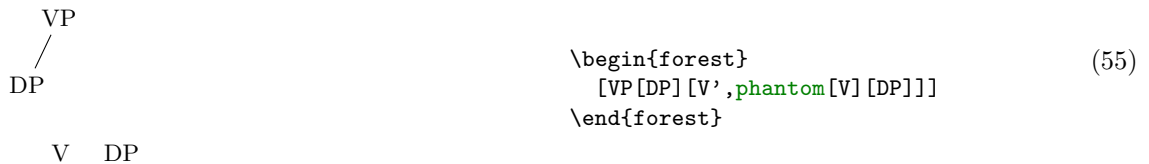
When the node is being typeset under the default conditions (see option `node format`), the content of this option is passed to TikZ as options to the TikZ `node` operation [2, §16].

This option is rarely manipulated manually: almost all options unknown to FOREST are automatically appended to `node options`. Exceptions are (i) `label` and `pin`, which require special attention in order to work; and (ii) `anchor`, which is saved in order to retain the information about the selected anchor.



option **phantom**= $\langle boolean \rangle$ false

A phantom node and its surrounding edges are taken into account when packing, but not drawn. (This option applies in stage `draw tree`.)



3.3.2 Node position

Most of the following options apply at stage `pack`. Changing them afterwards has no effect in the normal course of events. (Options `l`, `s`, `x`, `y` and `anchor` are exceptions; see their documentation for details).

option **anchor**=*<toks: TikZ anchor name>*

base

This is essentially a TikZ option [see 2, §16.5.1] — it is passed to TikZ as a node option when the node is typeset (this option thus applies in stage **typeset nodes**) — but it is also saved by FOREST.

The effect of this option is only observable when a node has a sibling: the anchors of all siblings are s-aligned (if their **ls** have not been modified after packing).

In the TikZ code, you can refer to the node’s anchor using the generic anchor **anchor**.

option **calign**=*child|child edge|midpoint|edge midpoint|fixed angles|fixed edge angles* center first|last|center.

The packing algorithm positions the children so that they don’t overlap, effectively computing the minimal distances between the node anchors of the children. This option (**calign** stands for child alignment) specifies how the children are positioned with respect to the parent (while respecting the above-mentioned minimal distances).

The child alignment methods refer to the primary and the secondary child, and to the primary and the secondary angle. These are set using the keys described just after **calign**.

calign=child s-aligns the node anchors of the parent and the primary child.

calign=child edge s-aligns the parent anchor of the parent and the child anchor of the primary child.

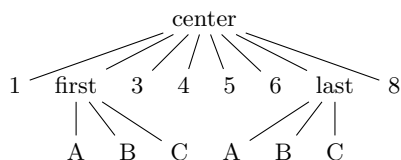
calign=first is an abbreviation for **calign=child**, **calign child=1**.

calign=last is an abbreviation for **calign=child**, **calign child=-1**.

calign=midpoint s-aligns the parent’s node anchor and the midpoint between the primary and the secondary child’s node anchor.

calign=edge midpoint s-aligns the parent’s parent anchor and the midpoint between the primary and the secondary child’s child anchor.

calign=center is an abbreviation for **calign=midpoint**, **calign primary child=1**, **calign secondary child=-1**.



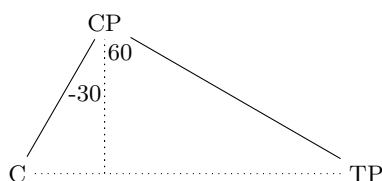
```
\begin{forest}
[center,calign=center[1]
[first,calign=first[A][B][C]][3][4][5][6]
[last,calign=last[A][B][C]][8]]
\end{forest}
```

calign=fixed angles: The angle between the direction of growth at the current node (specified by option **grow**) and the line through the node anchors of the parent and the primary/secondary child will equal the primary/secondary angle.

To achieve this, the block of children might be spread or further distanced from the parent.

calign=fixed edge angles: The angle between the direction of growth at the current node (specified by option **grow**) and the line through the parent’s parent anchor and the primary/secondary child’s child anchor will equal the primary/secondary angle.

To achieve this, the block of children might be spread or further distanced from the parent.



```
\begin{forest}
calign=fixed edge angles,
calign primary angle=-30,calign secondary angle=60,
for tree={l=2cm}
[CP[C][TP]]
\draw[dotted] (!1) -| coordinate(p) () (!2) -| ();
\path ()--(p) node[pos=0.4,left,inner sep=1pt]{-30};
\path ()--(p) node[pos=0.1,right,inner sep=1pt]{60};
\end{forest}
```

`calign child=<count>` is an abbreviation for `calign primary child=<count>`.

option `calign primary child=<count>` Sets the primary child. (See `calign`.) 1
 <count> is the child's sequence number. Negative numbers start counting at the last child.

option `calign secondary child=<count>` Sets the secondary child. (See `calign`.) -1
 <count> is the child's sequence number. Negative numbers start counting at the last child.

`calign angle=<count>` is an abbreviation for `calign primary angle=-<count>`, `calign secondary angle=<count>`.

option `calign primary angle=<count>` Sets the primary angle. (See `calign`.) -35

option `calign secondary angle=<count>` Sets the secondary angle. (See `calign`.) 35

`calign with current` s-aligns the node anchors of the current node and its parent. This key is an abbreviation for:

for parent/.wrap pgfmath arg={calign=child,calign primary child=##1}{n}.

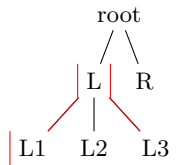
`calign with current edge` s-aligns the child anchor of the current node and the parent anchor of its parent. This key is an abbreviation for:

for parent/.wrap pgfmath arg={calign=child edge,calign primary child=##1}{n}.

option `fit=tight|rectangle|band` tight

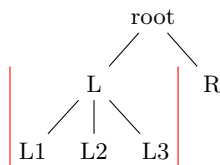
This option sets the type of the (s-)boundary that will be computed for the subtree rooted in the node, thereby determining how it will be packed into the subtree rooted in the node's parent. There are three choices:¹⁴

- `fit=tight`: an exact boundary of the node's subtree is computed, resulting in a compactly packed tree. Below, the boundary of subtree L is drawn.



```
(59)
\begin{forest}
  delay={for tree={name/.pgfmath=content}}
  [root
    [L,fit=tight, % default
      show boundary
      [L1] [L2] [L3]]
    [R]]
\end{forest}
```

- `fit=rectangle`: puts the node's subtree in a rectangle and effectively packs this rectangle; the resulting tree will usually be wider.

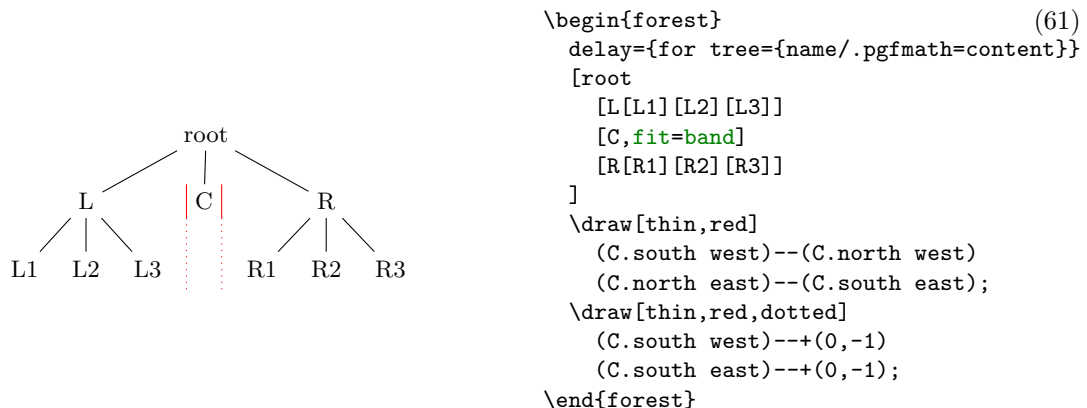


```
(60)
\begin{forest}
  delay={for tree={name/.pgfmath=content}}
  [root
    [L,fit=rectangle,
      show boundary
      [L1] [L2] [L3]]
    [R]]
\end{forest}
```

¹⁴Below is the definition of style `show boundary`. The use path trick is adjusted from [TeX Stackexchange question Calling a previously named path in tikz](#).

```
\makeatletter\tikzset{use path/.code={\tikz@addmode{\pgfsyssoftpath@setcurrentpath#1}
\appto\tikz@preactions{\let\tikz@actions@path#1}}\makeatother
\forestset{show boundary/.style={
  before drawing tree={get min s tree boundary=\minboundary, get max s tree boundary=\maxboundary},
  tikz+={\draw[red,use path=\minboundary]; \draw[red,use path=\maxboundary];}}
```

- **fit=band**: puts the node's subtree in a rectangle of “infinite depth”: the space under the node and its descendants will be kept clear.



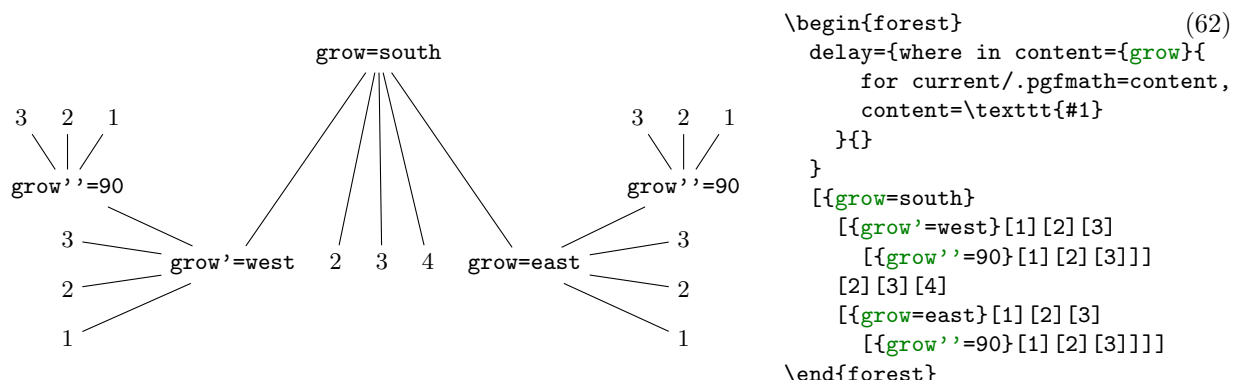
option **grow**= $\langle count \rangle$ The direction of the tree's growth at the node.

270

The growth direction is understood as in TikZ's tree library [2, §18.5.2] when using the default growth method: the (node anchor's of the) children of the node are placed on a line orthogonal to the current direction of growth. (The final result might be different, however, if **l** is changed after packing or if some child undergoes tier alignment.)

This option is essentially numeric (**pgfmath** function **grow** will always return an integer), but there are some twists. The growth direction can be specified either numerically or as a compass direction (**east**, **north east**, ...). Furthermore, like in TikZ, setting the growth direction using key **grow** additionally sets the value of option **reversed** to **false**, while setting it with **grow'** sets it to **true**; to change the growth direction without influencing **reversed**, use key **grow''**.

Between stages **pack** and **compute xy**, the value of **grow** should not be changed.



option **ignore**= $\langle boolean \rangle$

false

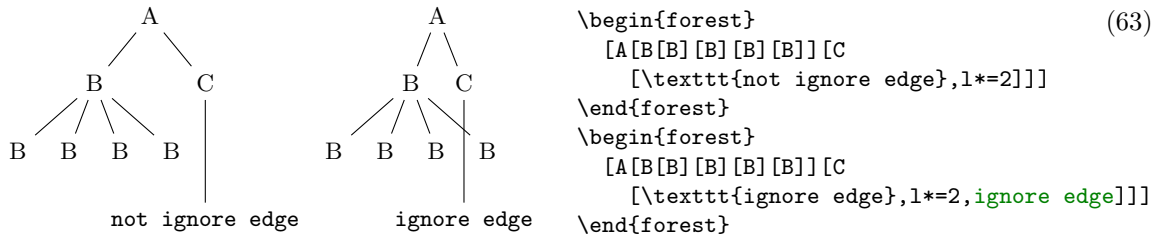
If this option is set, the packing mechanism ignores the node, i.e. it pretends that the node has no boundary. Note: this only applies to the node, not to the tree.

Maybe someone will even find this option useful for some reason ...

option **ignore edge**= $\langle boolean \rangle$

false

If this option is set, the packing mechanism ignores the edge from the node to the parent, i.e. nodes and other edges can overlap it. (See §5 for some problematic situations.)



option **l**= $\langle dimen \rangle$ The l-position of the node, in the parent's ls-coordinate system. (The origin of a node's ls-coordinate system is at its (node) anchor. The l-axis points in the direction of the tree growth at the node, which is given by option **grow**. The s-axis is orthogonal to the l-axis; the positive side is in the counter-clockwise direction from l axis.)

The initial value of l is set from the standard node. By default, it equals:

$$l \text{ sep} + 2 \cdot \text{outer ysep} + \text{total height}(\text{standard node})$$

The value of l can be changed at any point, with different effects.

- The value of l at the beginning of stage **pack** determines the minimal l-distance between the anchors of the node and its parent. Thus, changing l before packing will influence this process. (During packing, l can be increased due to parent's l sep, tier alignment, or **calign** method **fixed (edge) angles**.)
- Changing l after packing but before stage **compute xy** will result in a manual adjustment of the computed position. (The augmented operators can be useful here.)
- Changing l after the absolute positions have been computed has no effect in the normal course of events.

option **l sep**= $\langle dimen \rangle$ The minimal l-distance between the node and its descendants.

This option determines the l-distance between the *boundaries* of the node and its descendants, not node anchors. The final effect is that there will be a l sep wide band, in the l-dimension, between the node and all its descendants.

The initial value of l sep is set from the standard node and equals

$$\text{height}(\text{strut}) + \text{inner ysep}$$

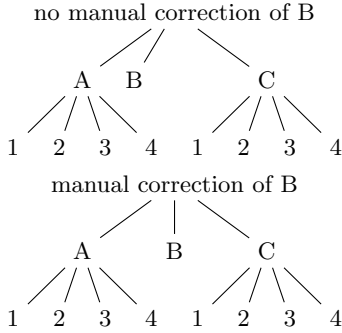
Note that despite the similar name, the semantics of l sep and s sep are quite different.

option **reversed**= $\langle boolean \rangle$ false

If **false**, the children are positioned around the node in the counter-clockwise direction; if **true**, in the clockwise direction. See also **grow**.

option **s**= $\langle dimen \rangle$ The s-position of the node, in the parent's ls-coordinate system. (The origin of a node's ls-coordinate system is at its (node) anchor. The l-axis points in the direction of the tree growth at the node, which is given by option **grow**. The s-axis is orthogonal to the l-axis; the positive side is in the counter-clockwise direction from l axis.)

The value of s is computed by the packing mechanism. Any value given before packing is overridden. In short, it only makes sense to (inspect and) change this option after stage **pack**, which can be useful for manual corrections, like below. (B is closer to A than C because packing proceeds from the first to the last child — the position of B would be the same if there was no C.) Changing the value of s after stage **compute xy** has no effect.



```

\begin{minipage}{.5\linewidth}
\begin{forest}
  [no manual correction of B
    [A[1][2][3][4]]
    [B]
    [C[1][2][3][4]]
  ]
\end{forest}

\begin{forest}
  [manual correction of B
    [A[1][2][3][4]]
    [B,before computing xy={s=(s("!p")+s("!n"))/2}]
    [C[1][2][3][4]]
  ]
\end{forest}
\end{minipage}

```

option **s sep**= $\langle \text{dimen} \rangle$

The subtrees rooted in the node’s children will be kept at least **s sep** apart in the s-dimension. Note that **s sep** is about the minimal distance between node *boundaries*, not node anchors.

The initial value of **s sep** is set from the standard node and equals $2 \cdot \text{inner xsep}$.

Note that despite the similar name, the semantics of **s sep** and **l sep** are quite different.

option **tier**= $\langle \text{toks} \rangle$ { }

Setting this option to something non-empty “puts a node on a tier.” All the nodes on the same tier are aligned in the l-dimension.

Tier alignment across changes in growth direction is impossible. In the case of incompatible options, FOREST will yield an error.

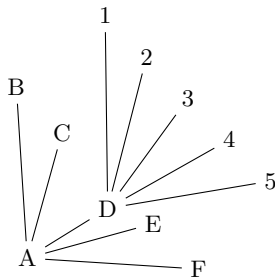
Tier alignment also does not work well with **calign=fixed (edge) angles**, because these child alignment methods may change the l-position of the children. When this might happen, FOREST will yield a warning.

option **x**= $\langle \text{dimen} \rangle$

option **y**= $\langle \text{dimen} \rangle$

x and **y** are the coordinates of the node in the “normal” (paper) coordinate system, relative to the root of the tree that is being drawn. So, essentially, they are absolute coordinates.

The values of **x** and **y** are computed in stage **compute xy**. It only makes sense to inspect and change them (for manual adjustments) afterwards (normally, in the **before drawing tree** hook, see §3.3.7.)



```

\begin{forest}
  for tree={grow'=45,l=1.5cm}
  [A[B][C][D,before drawing tree={y-=4mm}[1][2][3][4][5]][E][F]]
\end{forest}

```

3.3.3 Edges

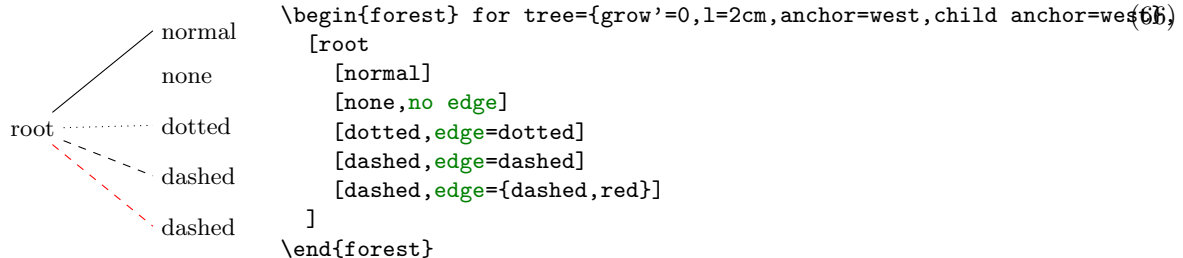
These options determine the shape and position of the edge from a node to its parent. They apply at stage **draw tree**.

option **child anchor**=*(toks)* See **parent anchor**. {}

option **edge**=*(keylist)* draw

When **edge path** has its default value, the value of this option is passed as options to the TikZ **\path** expression used to draw the edge between the node and its parent.

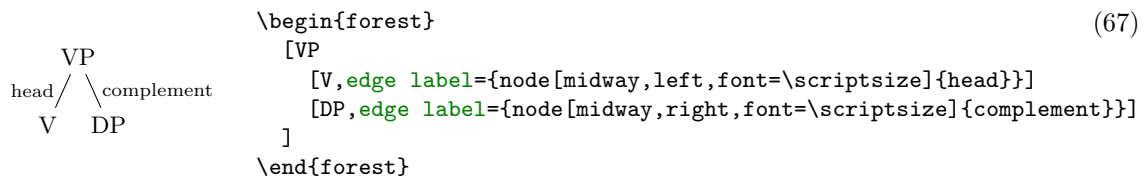
Also see key **no edge**.



option **edge label**=*(toks: TikZ code)* {}

When **edge path** has its default value, the value of this option is used at the end of the edge path specification to typeset a node (or nodes) along the edge.

The packing mechanism is not sensitive to edge labels.



option **edge path**=*(toks: TikZ code)* \noexpand\path[\forestoption{edge}]
(!u.parent anchor)--(.child anchor)\forestoption{edge label};

This option contains the code that draws the edge from the node to its parent. By default, it creates a path consisting of a single line segment between the node's **child anchor** and its parent's **parent anchor**. Options given by **edge** are passed to the path; by default, the path is simply drawn. Contents of **edge label** are used to potentially place a node (or nodes) along the edge.

When setting this option, the values of options **edge** and **edge label** can be used in the edge path specification to include the values of options **edge** and **edge node**. Furthermore, two generic anchors, **parent anchor** and **child anchor**, are defined, to facilitate access to options **parent anchor** and **child anchor** from the TikZ code.

The node positioning algorithm is sensitive to edges, i.e. it will avoid a node overlapping an edge or two edges overlapping. However, the positioning algorithm always behaves as if the **edge path** had the default value — *changing the edge path does not influence the packing!* Sorry. (Parent-child edges can be ignored, however: see option **ignore edge**.)

option **parent anchor**=*(toks: TikZ anchor)* (Information also applies to option **child anchor**.) {}

FOREST defines generic anchors **parent anchor** and **child anchor** (which work only for FOREST and not also TikZ nodes, of course) to facilitate reference to the desired endpoints of child-parent edges. Whenever one of these anchors is invoked, it looks up the value of the **parent anchor** or **child anchor** of the node named in the coordinate specification, and forwards the request to the (TikZ) anchor given as the value.

The indented use of the two anchors is chiefly in **edge path** specification, but they can be used in any TikZ code.



```

\begin{forest}
  for tree={parent anchor=south,child anchor=north}
  [VP[V] [DP]]
  \path[fill=red] (.parent anchor) circle[radius=2pt]
  (!1.child anchor) circle[radius=2pt]
  (!2.child anchor) circle[radius=2pt];
\end{forest}

```

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The empty value (which is the default) is interpreted as in TikZ: as an edge to the appropriate border point.

no edge Clears the edge options (`edge'={}`) and sets **ignore edge**.

triangle Makes the edge to parent a triangular roof. Works only for south-growing trees. Works by changing the value of **edge path**.

3.3.4 Readonly

The values of these options provide various information about the tree and its nodes.

option **id**= $\langle count \rangle$) The internal id of the node.

option **level**= $\langle count \rangle$ The hierarchical level of the node. The root is on level 0.

option **max x**= $\langle dimen \rangle$

option **max y**= $\langle dimen \rangle$

option **min x**= $\langle dimen \rangle$

option **min y**= $\langle dimen \rangle$ Measures of the node, in the shape's coordinate system [see 2, §16.2,§48,§75] shifted so that the node anchor is at the origin.

In **pgfmath** expressions, these options are accessible as **max_x**, **max_y**, **min_x** and **min_y**.

option **n**= $\langle count \rangle$ The child's sequence number in the list of its parent's children.

The enumeration starts with 1. For the root node, **n** equals 0.

option **n'**= $\langle count \rangle$ Like **n**, but starts counting at the last child.

In **pgfmath** expressions, this option is accessible as **n_**.

option **n children**= $\langle count \rangle$ The number of children of the node.

In **pgfmath** expressions, this option is accessible as **n_children**.

3.3.5 Miscellaneous

afterthought= $\langle toks \rangle$ Provides the afterthought explicitly.

This key is normally not used by the end-user, but rather called by the bracket parser. By default, this key is a style defined by **afterthought/.style={tikz+=#{1}}**: afterthoughts are interpreted as (cumulative) TikZ code. If you'd like to use afterthoughts for some other purpose, redefine the key — this will take effect even if you do it in the tree preamble.

alias= $\langle toks \rangle$ Sets the alias for the node's name.

Unlike **name**, **alias** is *not* an option: you cannot e.g. query it's value via a **pgfmath** expression.

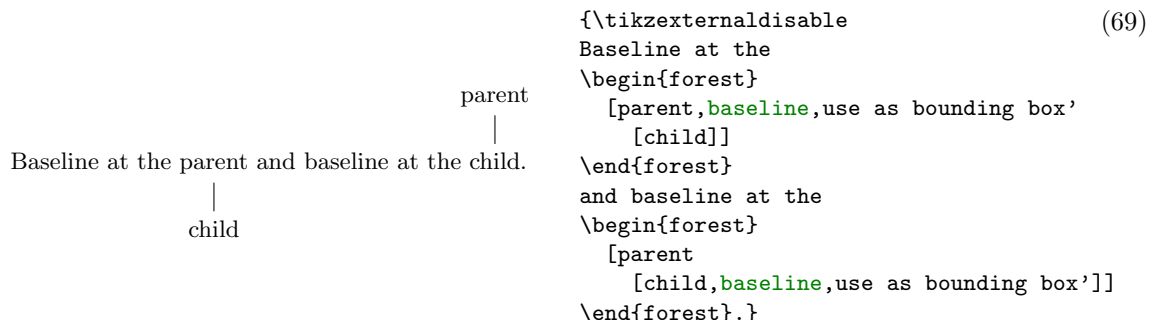
Aliases can be used as the $\langle forest\ node\ name \rangle$ part of a relative node name and as the argument to the **name** step of a node walk. The latter includes the usage as the argument of the **for name** propagator.

Technically speaking, FOREST alias is *not* a TikZ alias! However, you can still use it as a “node name” in TikZ coordinates, since FOREST hacks TikZ's implicit node coordinate system to accept relative node names; see §3.5.2.

baseline The node’s anchor becomes the baseline of the whole tree [cf. 2, §69.3.1].

In plain language, when the tree is inserted in your (normal \TeX) text, it will be vertically aligned to the anchor of the current node.

Behind the scenes, this style sets the alias of the current node to `forest@baseline@node`.



```

begin draw/.code=<toks:  $\text{\TeX}$  code>                                \begin{tikzpicture}
end draw/.code=<toks:  $\text{\TeX}$  code>                                \end{tikzpicture}
```

The code produced by `draw tree` is put in the environment specified by `begin draw` and `end draw`. Thus, it is this environment, normally a `tikzpicture`, that does the actual drawing.

A common use of these keys might be to enclose the `tikzpicture` environment in a `center` environment, thereby automatically centering all trees; or, to provide the TikZ code to execute at the beginning and/or end of the picture.

Note that `begin draw` and `end draw` are *not* node options: they are `\pgfkeys`’ code-storing keys [2, §55.4.3–4].

```

begin forest/.code=<toks:  $\text{\TeX}$  code>                                {}
end forest/.code=<toks:  $\text{\TeX}$  code>                                {}
```

The code stored in these (`\pgfkeys`) keys is executed at the beginning and end of the `forest` environment / `\Forest` macro.

Using these keys is only effective *outside* the `forest` environment, and the effect lasts until the end of the current \TeX group.

For example, executing `\forestset{begin forest/.code=\small}` will typeset all trees (and only trees) in the small font size.

fit to tree Fits the TikZ node to the current node’s subtree.

This key should be used like `/tikz/fit` of the TikZ’s fitting library [see 2, §34]: as an option to TikZ’s `node` operation, the obvious restriction being that `fit to tree` must be used in the context of some `FOREST` node. For an example, see footnote 6.

This key works by calling `/tikz/fit` and providing it with the the coordinates of the subtree’s boundary.

```

get min s tree boundary=<cs>
get max s tree boundary=<cs>
```

Puts the boundary computed during the packing process into the given `<cs>`. The boundary is in the form of PGF path. The `min` and `max` versions give the two sides of the node. For an example, see how the boundaries in the discussion of `fit` were drawn.

label=<toks: TikZ node> The current node is labelled by a TikZ node.

The label is specified as a TikZ option `label` [2, §16.10]. Technically, the value of this option is passed to TikZ’s as a late option [2, §16.14]. (This is so because `FOREST` must first typeset the nodes separately to measure them (stage `typeset nodes`); the preconstructed nodes are inserted in the big picture later, at stage `draw tree`.) Another option with the same technicality is `pin`.

option **name**= $\langle toks \rangle$ Sets the name of the node.

node@ $\langle id \rangle$

The expansion of $\langle toks \rangle$ becomes the $\langle forest\ node\ name \rangle$ of the node. Node names must be unique. The TikZ node created from the FOREST node will get the name specified by this option.

node walk= $\langle node\ walk \rangle$ This key is the most general way to use a $\langle node\ walk \rangle$.

Before starting the $\langle node\ walk \rangle$, key **node walk/before walk** is processed. Then, the $\langle step \rangle$ s composing the $\langle node\ walk \rangle$ are processed: making a step (normally) changes the current node. After every step, key **node walk/every step** is processed. After the walk, key **node walk/after walk** is processed.

node walk/before walk, **node walk/every step** and **node walk/after walk** are processed with **/forest** as the default path: thus, FOREST's options and keys described in §3.3 can be used normally inside their definitions.

- Node walks can be tail-recursive, i.e. you can call another node walk from **node walk/after walk** — embedding another node walk in **node walk/before walk** or **node walk/every step** will probably fail, because the three node walk styles are not saved and restored (a node walk doesn't create a TEX group).
- **every step** and **after walk** can be redefined even during the walk. Obviously, redefining **before walk** during the walk has no effect (in the current walk).

pin= $\langle toks: TikZ\ node \rangle$ The current node gets a pin, see [2, §16.10].

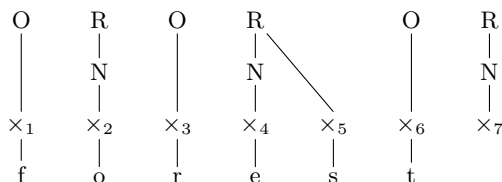
The technical details are the same as for **label**.

use as bounding box The current node's box is used as a bounding box for the whole tree.

use as bounding box' Like **use as bounding box**, but subtracts the (current) inner and outer sep from the node's box. For an example, see **baseline**.

TeX= $\langle toks: TEX\ code \rangle$ The given code is executed immediately.

This can be used for e.g. enumerating nodes:



```

\newcount\xcount
\begin{forest} GP1,
  delay={TeX={\xcount=0}},
  where tier={x}{TeX={\advance\xcount1}},
  content/.expanded={##1$_{\the\xcount}$}}{}}
[
  [O[x[f]]]
  [R[N[x[o]]]]
  [O[x[r]]]
  [R[N[x[e]]] [x[s]]]
  [O[x[t]]]
  [R[N[x]]]
]
\end{forest}

```

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TeX'= $\langle toks: TEX\ code \rangle$ This key is a combination of keys **TeX** and **TeX''**: the given code is both executed and externalized.

TeX''= $\langle toks: TEX\ code \rangle$ The given code is externalized, i.e. it will be executed when the externalized images are loaded.

The image-loading and **TeX'()** produced code are intertwined.

option **tikz**= $\langle toks: TikZ\ code \rangle$ “Decorations.”

{}

The code given as the value of this option will be included in the **tikzpicture** environment used to draw the tree. The code given to various nodes is appended in a depth-first, parent-first fashion. The code is included after all nodes of the tree have been drawn, so it can refer to any node of the tree. Furthermore, relative node names can be used to refer to nodes of the tree, see §3.5.

By default, bracket parser's afterthoughts feed the value of this option. See **afterthought**.

3.3.6 Propagators

Propagators pass the given $\langle keylist \rangle$ to other node(s), delay their processing, or cause them to be processed only under certain conditions.

A propagator can never fail — i.e. if you use `for next` on the last child of some node, no error will arise: the $\langle keylist \rangle$ will simply not be passed to any node. (The generic node walk propagator `for` is an exception. While it will not fail if the final node of the walk does not exist (is null), its node walk can fail when trying to walk away from the null node.)

Spatial propagators pass the given $\langle keylist \rangle$ to other node(s) in the tree. (`for` and `for <step>` always pass the $\langle keylist \rangle$ to a single node.)

propagator **for**= $\langle node\ walk \rangle \langle keylist \rangle$ Processes $\langle keylist \rangle$ in the context of the final node in the $\langle node\ walk \rangle$ starting at the current node.

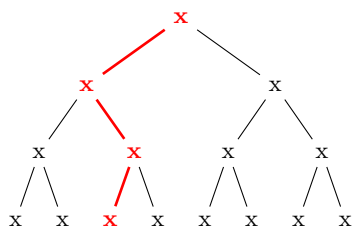
key prefix **for** $\langle step \rangle = \langle keylist \rangle$ Walks a single-step node-walk $\langle step \rangle$ from the current node and passes the given $\langle keylist \rangle$ to the final (i.e. second) node.

$\langle step \rangle$ must be a long node walk step; see §3.5.1. `for <step>=⟨keylist⟩` is equivalent to `for=⟨step⟩keylist`.

Examples: `for parent={1 sep+=3mm}`, `for n=2{circle,draw}`.

propagator **for ancestors**= $\langle keylist \rangle$

propagator **for ancestors'**= $\langle keylist \rangle$ Passes the $\langle keylist \rangle$ to itself, too.



```
\pgfkeys{/forest,
  inptr/.style={%
    red,delay={content={\textbf{##1}}},
    edge={draw,line width=1pt,red}},
  ptr/.style={for ancestors'=inptr}
}
\begin{forest}
  [x
    [x[x[x][x]] [x[x,ptr][x]]]
    [x[x[x][x]] [x[x][x]]]]
\end{forest}
```

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propagator **for all next**= $\langle keylist \rangle$ Passes the $\langle keylist \rangle$ to all the following siblings.

propagator **for all previous**= $\langle keylist \rangle$ Passes the $\langle keylist \rangle$ to all the preceding siblings.

propagator **for children**= $\langle keylist \rangle$

propagator **for descendants**= $\langle keylist \rangle$

propagator **for tree**= $\langle keylist \rangle$

Passes the key to the current node and its the descendants.

This key should really be named `for subtree` ...

Conditionals For all conditionals, both the true and the false keylist are obligatory! Either keylist can be empty, however — but don't omit the braces!

propagator **if**= $\langle pgfmath\ condition \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$

If $\langle pgfmath\ condition \rangle$ evaluates to **true** (non-zero), $\langle true\ keylist \rangle$ is processed (in the context of the current node); otherwise, $\langle false\ keylist \rangle$ is processed.

For a detailed description of `pgfmath` expressions, see [2, part VI]. (In short: write the usual mathematical expressions.)

key prefix **if** $\langle option \rangle = \langle value \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$

A simple conditional is defined for every $\langle option \rangle$: if $\langle value \rangle$ equals the value of the option at the current node, $\langle true\ keylist \rangle$ is executed; otherwise, $\langle false\ keylist \rangle$.

propagator **where** $\langle value \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$

Executes conditional **if** for every node in the current subtree.

key prefix **where** $\langle option \rangle = \langle value \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$

Executes simple conditional **if** $\langle option \rangle$ for every node in the current subtree.

key prefix **if in** $\langle option \rangle = \langle toks \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$

Checks if $\langle toks \rangle$ occurs in the option value; if it does, $\langle true\ keylist \rangle$ are executed, otherwise $\langle false\ keylist \rangle$.

This conditional is defined only for $\langle toks \rangle$ options, see §3.3.

key prefix **where in** $\langle toks\ option \rangle = \langle toks \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$

A style equivalent to **for tree=if in** $\langle option \rangle = \langle toks \rangle \langle true\ keylist \rangle \langle false\ keylist \rangle$: for every node in the subtree rooted in the current node, **if in** $\langle option \rangle$ is executed in the context of that node.

This conditional is defined only for $\langle toks \rangle$ options, see §3.3.

Temporal propagators There are two kinds of temporal propagators. The **before ...** propagators defer the processing of the given keys to a hook just before some stage in the computation. The **delay** propagator is “internal” to the current hook (the first hook, the given options, is implicit): the keys in a hook are processed cyclically, and **delay** delays the processing of the given options until the next cycle. All these keys can be nested without limit. For details, see §3.3.7.

propagator **delay** $\langle keylist \rangle$ Defers the processing of the $\langle keylist \rangle$ until the next cycle.

propagator **delay n** $\langle integer \rangle \langle keylist \rangle$ Defers the processing of the $\langle keylist \rangle$ for n cycles. n may be 0, and it may be given as a **pgfmath** expression.

propagator **if have delayed** $\langle true\ keylist \rangle \langle false\ keylist \rangle$ If any options were delayed in the current cycle (more precisely, up to the point of the execution of this key), process $\langle true\ keylist \rangle$, otherwise process $\langle false\ keylist \rangle$. (**delay n** will trigger “true” for the intermediate cycles.)

propagator **before typesetting nodes** $\langle keylist \rangle$ Defers the processing of the $\langle keylist \rangle$ to until just before the nodes are typeset.

propagator **before packing** $\langle keylist \rangle$ Defers the processing of the $\langle keylist \rangle$ to until just before the nodes are packed.

propagator **before computing xy** $\langle keylist \rangle$ Defers the processing of the $\langle keylist \rangle$ to until just before the absolute positions of the nodes are computed.

propagator **before drawing tree** $\langle keylist \rangle$ Defers the processing of the $\langle keylist \rangle$ to until just before the tree is drawn.

Other propagators

repeat $\langle number \rangle \langle keylist \rangle$ The $\langle keylist \rangle$ is processed $\langle number \rangle$ times.

The $\langle number \rangle$ expression is evaluated using **pgfmath**. Propagator **repeat** also works in node walks.

3.3.7 Stages

FOREST does its job in several steps. The normal course of events is the following:

1. The bracket representation of the tree is parsed and stored in a data structure.
2. The given options are processed, including the options in the preamble, which are processed first (in the context of the root node).
3. Each node is typeset in its own `tikzpicture` environment, saved in a box and its measures are taken.
4. The nodes of the tree are *packed*, i.e. the relative positions of the nodes are computed so that the nodes don't overlap. That's difficult. The result: option `s` is set for all nodes. (Sometimes, the value of `l` is adjusted as well.)
5. Absolute positions, or rather, positions of the nodes relative to the root node are computed. That's easy. The result: options `x` and `y` are set.
6. The TikZ code that will draw the tree is produced. (The nodes are drawn by using the boxes typeset in step 3.)

Steps 1 and 2 collect user input and are thus “fixed”. However, the other steps, which do the actual work, are under user's control.

First, hooks exist which make it possible (and easy) to change node's properties between the processing stages. For a simple example, see example (65): the manual adjustment of `y` can only be done after the absolute positions have been computed, so the processing of this option is deferred by `before drawing tree`. For a more realistic example, see the definition of style `GP1`: before packing, `outer xsep` is set to a high (user determined) value to keep the `x`s uniformly spaced; before drawing the tree, the `outer xsep` is set to 0pt to make the arrows look better.

Second, the execution of the processing stages 3–6 is *completely* under user's control. To facilitate adjusting the processing flow, the approach is twofold. The outer level: FOREST initiates the processing by executing style `stages`, which by default executes the processing stages 3–6, preceding the execution of each stage by processing the options embedded in temporal propagators `before ...` (see §3.3.6). The inner level: each processing step is the sole resident of a stage-style, which makes it easy to adjust the workings of a single step. What follows is the default content of style `stages`, including the default content of the individual stage-styles.

```

style stages

    process keylist=before typesetting nodes
style typeset nodes stage                                {for root'=typeset nodes}
    process keylist=before packing
style pack stage                                          {for root'=pack}
    process keylist=before computing xy
style compute xy stage                                    {for root'=compute xy}
    process keylist=before drawing tree
style draw tree stage                                    {for root'=draw tree}

```

Both style `stages` and the individual stage-styles may be freely modified by the user. Obviously, a style must be redefined before it is processed, so it is safest to do so either outside the `forest` environment (using macro `\forestset`) or in the preamble (in a non-deferred fashion).

Here's the list of keys used either in the default processing or useful in an alternative processing flow.

stage **typeset nodes** Typesets each node of the current node's subtree in its own `tikzpicture` environment. The result is saved in a box and its measures are taken.

stage **typeset nodes'** Like `typeset nodes`, but the node box's content is not overwritten if the box already exists.

typeset node Typesets the *current* node, saving the result in the node box.

This key can be useful also in the default **stages**. If, for example, the node’s content is changed and the node retypeset just before drawing the tree, the node will be positioned as if it contained the “old” content, but have the new content: this is how the constant distance between `\x`s is implemented in the **GP1** style.

stage **pack** The nodes of the tree are *packed*, i.e. the relative positions of the nodes are computed so that the nodes don’t overlap. The result: option **s** is set for all nodes; sometimes (in tier alignment and for some values of **calign**), the value of some nodes’ **l** is adjusted as well.

pack’ “Non-recursive” packing: packs the children of the current node only. (Experimental, use with care, especially when combining with tier alignment.)

stage **compute xy** Computes the positions of the nodes relative to the (formal) root node. The results are stored into options **x** and **y**.

stage **draw tree** Produces the TikZ code that will draw the tree. First, the nodes are drawn (using the boxes typeset in step 3), followed by edges and custom code (see option **tikz**).

stage **draw tree’** Like **draw tree**, but the node boxes are included in the picture using `\copy`, not `\box`, thereby preserving them.

draw tree box=[$\langle T_{\text{EX}} \text{ box} \rangle$] The picture drawn by the subsequent invocations of **draw tree** and **draw tree’** is put into $\langle T_{\text{EX}} \text{ box} \rangle$. If the argument is omitted, the subsequent pictures are typeset normally (the default).

process keylist= $\langle \text{keylist option name} \rangle$ Processes the keylist saved in option $\langle \text{keylist option name} \rangle$ for all the nodes in the *whole* tree.

This key is not sensitive to the current node: it processes the keylists for the whole tree. The calls of this key should *not* be nested.

Keylist-processing proceeds in cycles. In a given cycle, the value of option $\langle \text{keylist option name} \rangle$ is processed for every node, in a recursive (parent-first, depth-first) fashion. During a cycle, keys may be *delayed* using key **delay**. (Keys of the dynamically created nodes are automatically delayed.) Keys delayed in a cycle are processed in the next cycle. The number of cycles is unlimited. When no keys are delayed in a cycle, the processing of a hook is finished.

3.3.8 Dynamic tree

The following keys can be used to change the geometry of the tree by creating new nodes and integrating them into the tree, moving and copying nodes around the tree, and removing nodes from the tree.

The node that will be (re)integrated into the tree can be specified in the following ways:

$\langle \text{empty} \rangle$: uses the last (non-integrated, i.e. created/removed/replaced) node.

$\langle \text{node} \rangle$: a new node is created using the given bracket representation (the node may contain children, i.e. a tree may be specified), and used as the argument to the key.

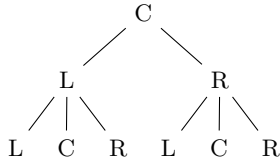
The bracket representation must be enclosed in brackets, which will usually be enclosed in braces to prevent them being parsed while parsing the “host tree.”

$\langle \text{relative node name} \rangle$: the node $\langle \text{relative node name} \rangle$ resolves to will be used.

Here is the list of dynamic tree keys:

dynamic tree **append**= $\langle \text{empty} \rangle \mid [\langle \text{node} \rangle] \mid \langle \text{relative node name} \rangle$

The specified node becomes the new final child of the current node. If the specified node had a parent, it is first removed from its old position.



```

\begin{forest}
  before typesetting nodes={for tree={
    if n=1{content=L}
      {if n'=1{content=R}
        {content=C}}}}
    [,repeat=2{append=[
      ,repeat=3{append={[]}}
    ]}}]
\end{forest}

```

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dynamic tree **create**=[$\langle node \rangle$]

Create a new node. The new node becomes the last node.

dynamic tree **insert after**= $\langle empty \rangle$ | [$\langle node \rangle$] | $\langle relative node name \rangle$

The specified node becomes the new following sibling of the current node. If the specified node had a parent, it is first removed from its old position.

dynamic tree **insert before**= $\langle empty \rangle$ | [$\langle node \rangle$] | $\langle relative node name \rangle$

The specified node becomes the new previous sibling of the current node. If the specified node had a parent, it is first removed from its old position.

dynamic tree **prepend**= $\langle empty \rangle$ | [$\langle node \rangle$] | $\langle relative node name \rangle$

The specified node becomes the new first child of the current node. If the specified node had a parent, it is first removed from its old position.

dynamic tree **remove**

The current node is removed from the tree and becomes the last node.

The node itself is not deleted: it is just not integrated in the tree anymore. Removing the root node has no effect.

dynamic tree **replace by**= $\langle empty \rangle$ | [$\langle node \rangle$] | $\langle relative node name \rangle$

The current node is replaced by the specified node. The current node becomes the last node.

If the specified node is a new node containing a dynamic tree key, it can refer to the replaced node by the $\langle empty \rangle$ specification. This works even if multiple replacements are made.

If **replace by** is used on the root node, the “replacement” becomes the root node (**set root** is used).

dynamic tree **set root**

The current node becomes the new *formal* root of the tree.

Note: If the current node has a parent, it is *not* removed from it. The node becomes the root only in the sense that the default implementation of stage-processing will consider it a root, and thus typeset/pack/draw the (sub)tree rooted in this root. The processing of keys such as **for parent** and **for root** is not affected: **for root** finds the real, geometric root of the current node. To access the formal root, use node walk step **root'**, or the corresponding propagator **for root'**.

If given an existing node, most of the above keys *move* this node (and its subtree, of course). Below are the versions of these operations which rather *copy* the node: either the whole subtree (') or just the node itself ('').

dynamic tree **append'**, **insert after'**, **insert before'**, **prepend'**, **replace by'**

Same as versions without ' (also the same arguments), but it is the copy of the specified node and its subtree that is integrated in the new place.

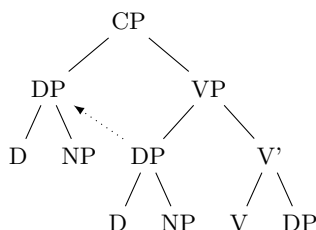
dynamic tree **append''**, **insert after''**, **insert before''**, **prepend''**, **replace by''**

Same as versions without '' (also the same arguments), but it is the copy of the specified node (without its subtree) that is integrated in the new place.

dynamic tree **copy name template**= $\langle empty \rangle$ | $\langle macro\ definition \rangle$ $\langle empty \rangle$

Defines a template for constructing the **name** of the copy from the name of the original. $\langle macro\ definition \rangle$ should be either empty (then, the **name** is constructed from the **id**, as usual), or an expandable macro taking one argument (the name of the original).

→ You might want to **delay** the processing of the copying operations, giving the original nodes the chance to process their keys first!



```
\begin{forest}
  copy name template={copy of #1}
  [CP,delay={prepend'=subject}
    [VP,DP,name=subject[D][NP]] [V' [V] [DP]]]]
  \draw[->,dotted] (subject)--(copy of subject);
\end{forest}
```

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A dynamic tree operation is made in two steps:

- If the argument is given by a $\langle node \rangle$ argument, the new node is created immediately, i.e. while the dynamic tree key is being processed. Any options of the new node are implicitly **delayed**.
- The requested changes in the tree structure are actually made between the cycles of keylist processing.

→ Such a two-stage approach is employed because changing the tree structure during the dynamic tree key processing would lead to an unmanageable order of keylist processing.

→ A consequence of this approach is that nested dynamic tree keys take several cycles to complete. Therefore, be careful when using **delay** and dynamic tree keys simultaneously: in such a case, it is often safer to use **before typesetting nodes** instead of **delay**, see example (72).

→ Further examples: title page (in style `random tree`), (80).

3.4 Handlers

handler **.pgfmath**= $\langle pgfmath\ expression \rangle$

The result is the evaluation of $\langle pgfmath\ expression \rangle$ in the context of the current node.

handler **.wrap value**= $\langle macro\ definition \rangle$

The result is the (single) expansion of the given $\langle macro\ definition \rangle$. The defined macro takes one parameter. The current value of the handled option will be passed as that parameter.

handler **.wrap n pgfmath args**= $\langle macro\ definition \rangle \langle arg\ 1 \rangle \dots \langle arg\ n \rangle$

The result is the (single) expansion of the given $\langle macro\ definition \rangle$. The defined macro takes n parameters, where $n \in \{2, \dots, 8\}$. Expressions $\langle arg\ 1 \rangle$ to $\langle arg\ n \rangle$ are evaluated using **pgfmath** and passed as arguments to the defined macro.

handler **.wrap pgfmath arg**= $\langle macro\ definition \rangle \langle arg \rangle$

Like **.wrap n pgfmath args** for $n = 1$.

3.5 Relative node names

$\langle relative\ node\ name \rangle = [\langle forest\ node\ name \rangle][!\langle node\ walk \rangle]$

$\langle relative\ node\ name \rangle$ refers to the FOREST node at the end of the $\langle node\ walk \rangle$ starting at node named $\langle forest\ node\ name \rangle$. If $\langle forest\ node\ name \rangle$ is omitted, the walk starts at the current node. If $\langle node\ walk \rangle$ is omitted, the “walk” ends at the start node. (Thus, an empty $\langle relative\ node\ name \rangle$ refers to the current node.)

Relative node names can be used in the following contexts:

- FOREST’s `pgfmath` option functions (§3.6) take a relative node name as their argument, e.g. `content("!u")` and `content("!parent")` refer to the content of the parent node.
- An option of a non-current node can be set by $\langle \textit{relative node name} \rangle . \langle \textit{option name} \rangle = \langle \textit{value} \rangle$, see §3.3.
- The `forest` coordinate system, both explicit and implicit; see §3.5.2.

3.5.1 Node walk

A $\langle \textit{node walk} \rangle$ is a sequence of $\langle \textit{step} \rangle$ s describing a path through the tree. The primary use of node walks is in relative node names. However, they can also be used in a “standalone” way, using key `node walk`; see §3.3.5.

Steps are keys in the `/forest/node walk` path. (FOREST always sets this path as default when a node walk is to be used, so step keynames can be used.) Formally, a $\langle \textit{node walk} \rangle$ is thus a keylist, and steps must be separated by commas. There is a twist, however. Some steps also have *short* names, which consist of a single character. The comma between two adjacent short steps can be omitted. Examples:

- `parent, parent, n=2` or `uu2`: the grandparent’s second child (of the current node)
- `first leaf, uu`: the grandparent of the first leaf (of the current node)

The list of long steps:

- $\langle \textit{step} \rangle$ `current` an “empty” step: the current node remains the same¹⁵
- $\langle \textit{step} \rangle$ `first` the primary child
- $\langle \textit{step} \rangle$ `first leaf` the first leaf (terminal node)
- $\langle \textit{step} \rangle$ `group=` $\langle \textit{node walk} \rangle$ treat the given $\langle \textit{node walk} \rangle$ as a single step
- $\langle \textit{step} \rangle$ `last` the last child
- $\langle \textit{step} \rangle$ `last leaf` the last leaf
- $\langle \textit{step} \rangle$ `id=` $\langle \textit{id} \rangle$ the node with the given id
- $\langle \textit{step} \rangle$ `linear next` the next node, in the processing order
- $\langle \textit{step} \rangle$ `linear previous` the previous node, in the processing order
- $\langle \textit{step} \rangle$ `n=n` the *n*th child; counting starts at 1 (not 0)
- $\langle \textit{step} \rangle$ `n’=n` the *n*th child, starting the count from the last child
- $\langle \textit{step} \rangle$ `name` the node with the given name
- $\langle \textit{step} \rangle$ `next` the next sibling
- $\langle \textit{step} \rangle$ `next leaf` the next leaf
(the current node need not be a leaf)
- $\langle \textit{step} \rangle$ `next on tier` the next node on the same tier as the current node
- $\langle \textit{step} \rangle$ `node walk=` $\langle \textit{node walk} \rangle$ embed the given $\langle \textit{node walk} \rangle$
(the `node walk/before walk` and `node walk/after walk` are processed)
- $\langle \textit{step} \rangle$ `parent` the parent
- $\langle \textit{step} \rangle$ `previous` the previous sibling

¹⁵While it might at first sight seem stupid to have an empty step, this is not the case. For example, using propagator `for current` derived from this step, one can process a $\langle \textit{keylist} \rangle$ constructed using `.wrap (n) pgfmath arg(s)` or `.wrap value`.

- $\langle step \rangle$ **previous leaf** the previous leaf
 (the current node need not be a leaf)
- $\langle step \rangle$ **previous on tier** the next node on the same tier as the current node
- repeat**= $n\langle node walk \rangle$ repeat the given $\langle node walk \rangle$ n times
 (each step in every repetition counts as a step)
- $\langle step \rangle$ **root** the root node
- $\langle step \rangle$ **root'** the formal root node (see **set root** in §3.3.8)
- $\langle step \rangle$ **sibling** the sibling
 (don't use if the parent doesn't have exactly two children ...)
- $\langle step \rangle$ **to tier**= $\langle tier \rangle$ the first ancestor of the current node on the given $\langle tier \rangle$
- $\langle step \rangle$ **trip**= $\langle node walk \rangle$ after walking the embedded $\langle node walk \rangle$, return to the current node; the return does not count as a step

For each long $\langle step \rangle$ except **node walk**, **group**, **trip** and **repeat**, propagator **for** $\langle step \rangle$ is also defined. Each such propagator takes a $\langle keylist \rangle$ argument. If the step takes an argument, then so does its propagator; this argument precedes the $\langle keylist \rangle$. See also §3.3.6.

Short steps are single-character keys in the **/forest/node walk** path. They are defined as styles resolving to long steps, e.g. **1/.style={n=1}**. The list of predefined short steps follows.

$\langle short step \rangle$ **1, 2, 3, 4, 5, 6, 7, 8, 9** the first, ..., ninth child

$\langle short step \rangle$ **l** the last child

$\langle short step \rangle$ **u** the parent (up)

$\langle short step \rangle$ **p** the previous sibling

$\langle short step \rangle$ **n** the next sibling

$\langle short step \rangle$ **s** the sibling

$\langle short step \rangle$ **P** the previous leaf

$\langle short step \rangle$ **N** the next leaf

$\langle short step \rangle$ **F** the first leaf

$\langle short step \rangle$ **L** the last leaf

$\langle short step \rangle$ **>** the next node on the current tier

$\langle short step \rangle$ **<** the previous node on the current tier

$\langle short step \rangle$ **c** the current node

$\langle short step \rangle$ **r** the root node

→ You can define your own short steps, or even redefine predefined short steps!

3.5.2 The forest coordinate system

Unless package options `tikzcshack` is set to `false`, TikZ's implicit node coordinate system [2, §13.2.3] is hacked to accept relative node names.¹⁶

The explicit `forest` coordinate system is called simply `forest` and used like this: `(forest cs:⟨forest cs spec⟩)`; see [2, §13.2.5]. `⟨forest cs spec⟩` is a keylist; the following keys are accepted.

`forest cs name=⟨node name⟩` The node with the given name became the current node. The resulting point is its (node) anchor.

`forest cs id=⟨node id⟩` The node with the given name became the current node. The resulting point is its (node) anchor.

`forest cs go=⟨node walk⟩` Walk the given node walk, starting at the current node. The node at the end of the walk becomes the current node. The resulting point is its (node) anchor.

`forest cs anchor=⟨anchor⟩` The resulting point is the given anchor of the current node.

`forest cs l=⟨dimen⟩`

`forest cs s=⟨dimen⟩` Specify the `l` and `s` coordinate of the resulting point.

The coordinate system is the node's ls-coordinate system: its origin is at its (node) anchor; the l-axis points in the direction of the tree growth at the node, which is given by option `grow`; the s-axis is orthogonal to the l-axis; the positive side is in the counter-clockwise direction from l axis.

The resulting point is computed only after both `l` and `s` were given.

Any other key is interpreted as a `⟨relative node name⟩[.⟨anchor⟩]`.

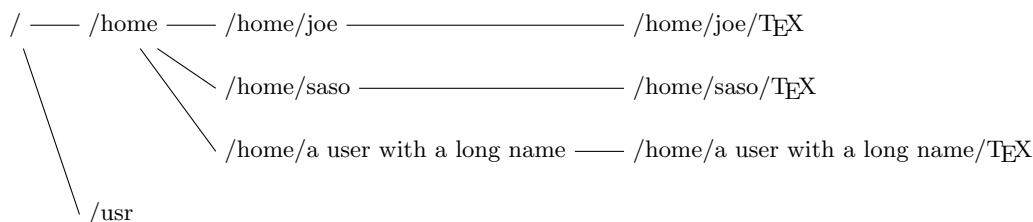
3.6 New pgfmath functions

For every option, FOREST defines a pgfmath function with the same name, with the proviso that all non-alphanumeric characters in the option name are replaced by an underscore `_` in the pgfmath function name.

Pgfmath functions corresponding to options take one argument, a `⟨relative node name⟩` (see §3.5) expression, making it possible to refer to option values of non-current nodes. The `⟨relative node name⟩` expression must be enclosed in double quotes in order to prevent pgfmath evaluation: for example, to refer to the content of the parent, write `content("!u")`. To refer to the option of the current node, use empty parentheses: `content()`.¹⁷

Three string functions are also added to pgfmath: `strequal` tests the equality of its two arguments; `instr` tests if the first string is a substring of the second one; `strcat` joins an arbitrary number of strings.

Some random notes on pgfmath: (i) `&&`, `||` and `!` are boolean “and”, “or” and “not”, respectively. (ii) The equality operator (for numbers and dimensions) is `==`, *not* `=`. And some examples:



¹⁶Actually, the hack can be switched on and off on the fly, using `\ifforesttikzcshack`.

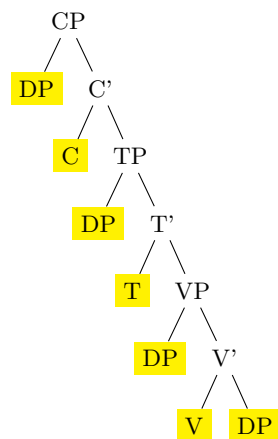
¹⁷In most cases, the parentheses are optional, so `content` is ok. A known case where this doesn't work is preceding an operator: `l+1cm` will fail.

```

\begin{forest}
  for tree={grow'=0,calign=first,l=0,l sep=2em,child anchor=west,anchor=base
    west,fit=band,tier/.pgfmath=level()},
  fullpath/.style={if n=0{}{content/.wrap 2
    pgfmath args={##1/##2}{content("!u")}{content()}}},
  delay={for tree=fullpath,content=/},
  before typesetting nodes={for tree={content=\strut#1}}
[
  [home
    [joe
      [\TeX]]
    [saso
      [\TeX]]
    [a user with a long name
      [\TeX]]]
  [usr]]
\end{forest}

```

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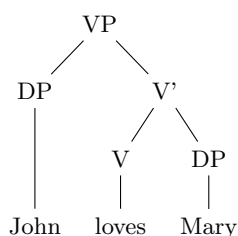


```

\begin{forest}
  delay={for tree={if=
    {\instr("!P",content) && n_children==0}
    {fill=yellow}
    {}
  }}
  [CP[DP][C'[C][TP[DP][T'[T][VP[DP][V'[V][DP]]]]]]]
\end{forest}

```

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```

\begin{forest}
  where n children=0{tier=word,
    if={\instr("!P",content("!u"))}{no edge,
      tikz={\draw (!.north west)--
        (!.north east)--(!u.south)--cycle;
      }}{}
  }{,
    [VP[DP[John]] [V'[V[loves]] [DP[Mary]]]]
  }
\end{forest}

```

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3.7 Standard node

`\forestStandardNode` $\langle node \rangle \langle environment fingerprint \rangle \langle calibration procedure \rangle \langle exported options \rangle$

This macro defines the current *standard node*. The standard node declares some options as *exported*. When a new node is created, the values of the exported options are initialized from the standard node. At the beginning of every `forest` environment, it is checked whether the *environment fingerprint* of the standard node has changed. If it did, the standard node is *calibrated*, adjusting the values of exported options. The *raison d'être* for such a system is given in §2.4.1.

In $\langle node \rangle$, the standard node's content and possibly other options are specified, using the usual bracket representation. The $\langle node \rangle$, however, *must not contain children*. The default: [dj].

The $\langle environment fingerprint \rangle$ must be an expandable macro definition. It's expansion should change whenever the calibration is necessary.

`<calibration procedure>` is a keylist (processed in the `/forest` path) which calculates the values of exported options.

`<exported options>` is a comma-separated list of exported options.

This is how the default standard node is created:

```
\forestStandardNode[dj]
  {%
    \forestOve{\csname forest@id@of@standard node\endcsname}{content},%
    \the\ht\strutbox,\the\pgflinewidth,%
    \pgfkeysvalueof{/pgf/inner ysep},\pgfkeysvalueof{/pgf/outer ysep},%
    \pgfkeysvalueof{/pgf/inner xsep},\pgfkeysvalueof{/pgf/outer xsep}%
  }
  {
    l sep={\the\ht\strutbox+\pgfkeysvalueof{/pgf/inner ysep}},
    l={l_sep()+abs(max_y()-min_y()+2*\pgfkeysvalueof{/pgf/outer ysep})},
    s sep={2*\pgfkeysvalueof{/pgf/inner xsep}}
  }
  {l sep,l,s sep}
```

3.8 Externalization

Externalized tree pictures are compiled only once. The result of the compilation is saved into a separate `.pdf` file and reused on subsequent compilations of the document. If the code of the tree (or the context, see below) is changed, the tree is automatically recompiled.

Externalization is enabled by:

```
\usepackage[external]{forest}
\tikzexternalize
```

Both lines are necessary. TikZ's externalization library is automatically loaded if necessary.

external/optimize Parallels `/tikz/external/optimize`: if `true` (the default), the processing of non-current trees is skipped during the embedded compilation.

external/context If the expansion of the macro stored in this option changes, the tree is recompiled.

external/depends on macro=`<cs>` Adds the definition of macro `<cs>` to `external/context`. Thus, if the definition of `<cs>` is changed, the tree will be recompiled.

FOREST respects or is compatible with several (not all) keys and commands of TikZ's externalization library. In particular, the following keys and commands might be useful; see [2, §32].

- `/tikz/external/remake next`
- `/tikz/external/prefix`
- `/tikz/external/system call`
- `\tikzexternalize`
- `\tikzexternalenable`
- `\tikzexternaldisable`

FOREST does not disturb the externalization of non-FOREST pictures. (At least it shouldn't ...)

The main auxiliary file for externalization has suffix `.for`. The externalized pictures have suffices `-forest-n` (their prefix can be set by `/tikz/external/prefix`, e.g. to a subdirectory). Information on all trees that were ever externalized in the document (even if they were changed or deleted) is kept. If you need a "clean" `.for` file, delete it and recompile. Deleting `-forest-n.pdf` will result in recompilation of a specific tree.

Using `draw tree` and `draw tree'` multiple times is compatible with externalization, as is drawing the tree in the box (see `draw tree box`). If you are trying to externalize a `forest` environment which utilizes `TeX` to produce a visible effect, you will probably need to use `TeX'` and/or `TeX''`.

3.9 Package options

<i>package option</i> external =true false	false
Enable/disable externalization, see §3.8.	
<i>package option</i> tikzcs hack=true false	true
Enable/disable the hack into TikZ's implicate coordinate syntax hacked, see §3.5.	
<i>package option</i> tikzinstallkeys =true false	true
Install certain keys into the /tikz path. Currently: fit to tree .	

4 Gallery

4.1 Styles

GP1 For Government Phonology (v1) representations. Here, the big trick is to evenly space \times s by having a large enough **outer xsep** (adjustable), and then, before drawing (timing control option **before drawing tree**), setting **outer xsep** back to 0pt. The last step is important, otherwise the arrows between \times s won't draw!


```

\newbox\standardnodestrutbox
\setbox\standardnodestrutbox=\hbox to 0pt{\phantom{\forestOve{standard node}{content}}}}
\def\standardnodestrut{\copy\standardnodestrutbox}
\forestset{
  GP1/.style 2 args={
    for n={1}{baseline},
    s sep=0pt, l sep=0pt,
    for descendants={
      l sep=0pt, l={#1},
      anchor=base,calign=first,child anchor=north,
      inner xsep=1pt,inner ysep=2pt,outer sep=0pt,s sep=0pt,
    },
    delay={
      if content={}{\phantom}{for children={no edge}},
      for tree={
        if content={O}{tier=OR}{},
        if content={R}{tier=OR}{},
        if content={N}{tier=N}{},
        if content={x}{
          tier=x,content={${\times}$},outer xsep={#2},
          for tree={calign=center},
          for descendants={content format={\standardnodestrut\forestoption{content}}},
          before drawing tree={outer xsep=0pt,delay={typeset node}},
          s sep=4pt
        }{},
      },
    },
    before drawing tree={where content={}{parent anchor=center,child anchor=center}{}},
  },
  GP1/.default={5ex}{8.0pt},
  associate/.style={%
    tikz+={\draw[densely dotted](!)--(!#1);}},
  spread/.style={
    before drawing tree={tikz+={\draw[dotted](!)--(!#1);}},
  },
  govern/.style={
    before drawing tree={tikz+={\draw[->](!)--(!#1);}},
  },
  p-govern/.style={
    before drawing tree={tikz+={\draw[->](.north) to[out=150,in=30] (!#1.north);}},
  },
  no p-govern/.style={
    before drawing tree={tikz+={\draw[->,loosely dashed](.north) to[out=150,in=30] (!#1.north);}},
  },
  encircle/.style={before drawing tree={circle,draw,inner sep=0pt}},
  fen/.style={pin={[font=\footnotesize,inner sep=1pt,pin edge=<-]10:\textsc{Fen}}},
  el/.style={content=\textsc{\textbf{##1}}},
  head/.style={content=\textsc{\textbf{\underline{##1}}}}
}

```

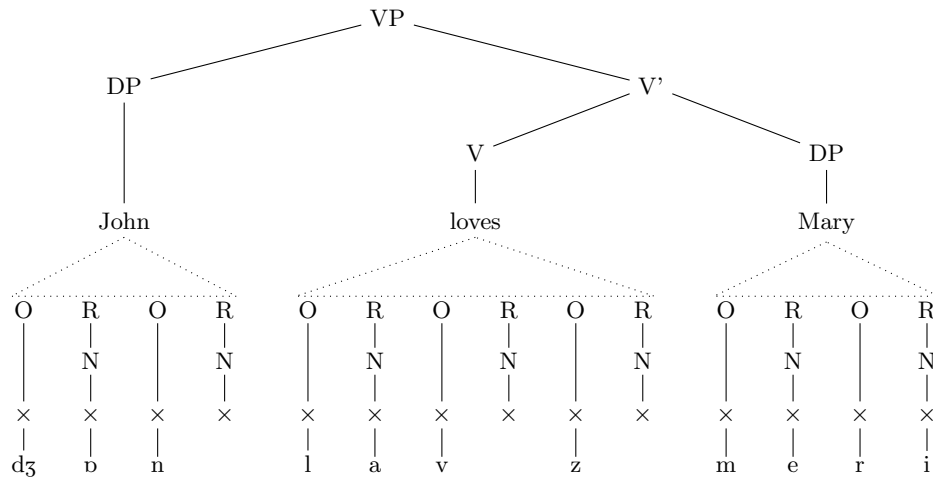
An example of an “embedded” GP1 style:

(77)

```

\begin{forest}
  myGP1/.style={
    GP1,
    delay={where tier={x}{
      for children={content=\textipa{##1}}{}}{
      tikz={\draw[dotted](.south)--
        (!1.north west)--(!1.north east)--cycle;},
      for children={l+=5mm,no edge}
    }
  }
  [VP[DP[John,tier=word,myGP1
    [O[x[dZ]]]
    [R[N[x[6]]]]
    [O[x[n]]]
    [R[N[x]]]
  ]] [V' [V[loves,tier=word,myGP1
    [O[x[l]]]
    [R[N[x[a]]]]
    [O[x[v]]]
    [R[N[x]]]
    [O[x[z]]]
    [R[N[x]]]
  ]] [DP[Mary,tier=word,myGP1
    [O[x[m]]]
    [R[N[x[e]]]]
    [O[x[r]]]
    [R[N[x[i]]]]
  ]]]
\end{forest}%

```



And an example of annotations.

[ei]

[mars]

```

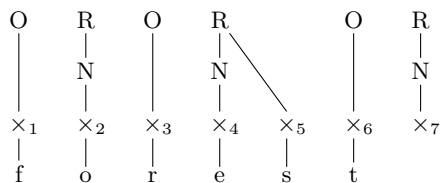
\begin{forest}[,phantom,s sep=1cm
  [{[ei]}, GP1
    [R[N[x[A,el[I,head,associate=N]]][x]]]
  ]
  [{[mars]}, GP1
    [O[x[m]]]
    [R[N[x[a]]][x,encircle,densely dotted[r]]]
    [O[x,encircle,govern=<[s]]]
    [R, fen[N[x]]]
  ]
]\end{forest}

```

(78)

rlap and llap The FOREST versions of TeX’s `\rlap` and `\llap`: the “content” added by these styles will influence neither the packing algorithm nor the anchor positions.

```
\forestset{
  llap/.style={tikz+={
    \edef\forest@temp{\noexpand\node[\forestoption{node options},
      anchor=base east,at=(.base east)]}
    \forest@temp{#1\phantom{\forestoption{content format}}};
  }},
  rlap/.style={tikz+={
    \edef\forest@temp{\noexpand\node[\forestoption{node options},
      anchor=base west,at=(.base west)]}
    \forest@temp{\phantom{\forestoption{content format}}#1};
  }}
}
\newcount\xcount
\begin{forest} GP1,
  delay={
    TeX={\xcount=0},
    where tier={x}{TeX={\advance\xcount1},rlap/.expanded={$_{\the\xcount}$}}{}
  }
  [
    [O[x[f]]]
    [R[N[x[o]]]]
    [O[x[r]]]
    [R[N[x[e]]][x[s]]]
    [O[x[t]]]
    [R[N[x]]]
  ]
\end{forest}
```



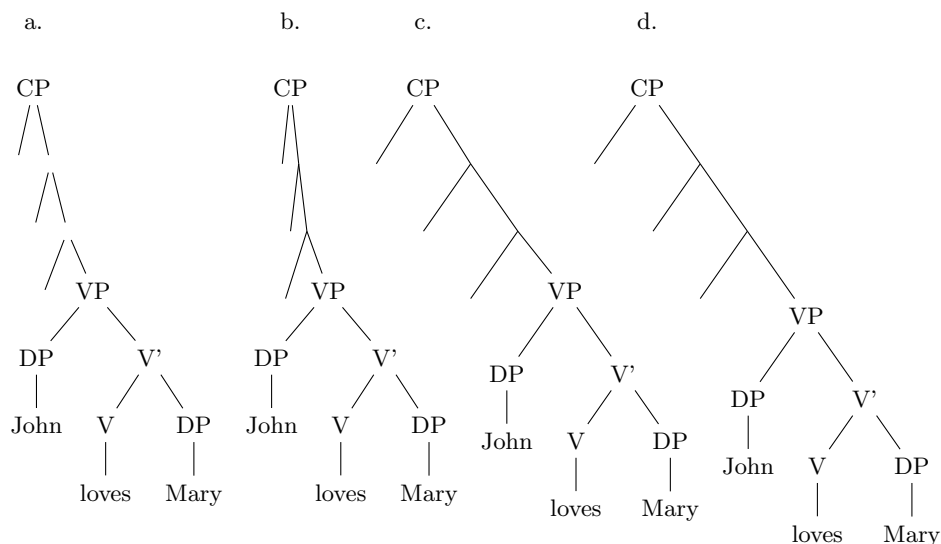
xlist This style makes it easy to put “separate” trees in a picture and enumerate them. For an example, see the `nice empty nodes` style.

```
\makeatletter
\forestset{
  xlist/.style={
    phantom,
    for children={no edge,replace by={[,append,
      delay={content/.wrap pgfmath arg={\@alph{##1}.}{n()+#1}}
    ]}}
  },
  xlist/.default=0
}
\makeatother
```

nice empty nodes We often need empty nodes: tree (a) shows how they look like by default: ugly. First, we don’t want the gaps: we change the shape of empty nodes to coordinate. We get tree (b). Second, the empty nodes seem too close to the other (especially empty) nodes (this is a result of a small default `s sep`). We could use a greater `s sep`, but a better solution seems to be to use `calign=node angle`. The result is shown in (c).

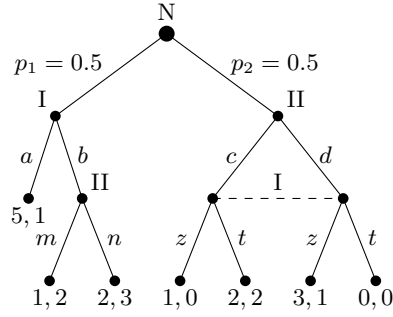
However, at the transitions from empty to non-empty nodes, tree (d) above seems to zigzag (although the base points of the spine nodes are perfectly in line), and the edge to the empty node left to VP seems too long (it reaches to the level of VP's base, while we'd prefer it to stop at the same level as the edge to VP itself). The first problem is solved by substituting `node angle` for `edge angle`; the second one, by anchoring siblings of empty nodes at north.

```
\forestset{
  nice empty nodes/.style={
    for tree={calign=fixed edge angles},
    delay={where content={}{shape=coordinate,for parent={for children={anchor=north}}{}}
  }}
\begin{forest}
  [,xlist
    [CP,
      [ [ [ [ [VP[DP[John]] [V' [V[loves]] [DP[Mary]]]]]]]]
    [CP, delay={where content={}{shape=coordinate}{}}
      [ [ [ [ [VP[DP[John]] [V' [V[loves]] [DP[Mary]]]]]]]]
    [CP, for tree={calign=fixed angles},
      delay={where content={}{shape=coordinate}{}}
      [ [ [ [ [VP[DP[John]] [V' [V[loves]] [DP[Mary]]]]]]]]
    [CP, nice empty nodes
      [ [ [ [ [VP[DP[John]] [V' [V[loves]] [DP[Mary]]]]]]]]
  ]
\end{forest}
```



4.2 Examples

The following example was inspired by a question on [TeX Stackexchange: How to change the level distance in tikz-qtree for one level only?](#). The question is about `tikz-qtree`: how to adjust the level distance for the first level only, in order to avoid first-level labels crossing the parent-child edge. While this example solves the problem (by manually shifting the offending labels; see `elo` below), it does more: the preamble is setup so that inputting the tree is very easy.



(82)

```

\def\getfirst#1;#2\endget{#1}
\def\getsecond#1;#2\endget{#2}
\forestset{declare toks={elo}{}} % edge label options
\begin{forest}
  anchors/.style={anchor=#1,child anchor=#1,parent anchor=#1},
  for tree={
    s sep=0.5em,l=8ex,
    if n children=0{anchors=north}{
      if n=1{anchors=south east}{anchors=south west}},
    content format={\$ \forestoption{content} \$}
  },
  anchors=south, outer sep=2pt,
  nomath/.style={content format=\forestoption{content}},
  dot/.style={tikz+={\fill (.child anchor) circle[radius=#1]}},
  dot/.default=2pt,
  dot=3pt,for descendants=dot,
  decision edge label/.style n args=3{
    edge label/.expanded={node[midway,auto=#1,anchor=#2,\forestoption{elo}]{\strut$#3$}}
  },
  decision/.style={if n=1
    {decision edge label={left}{east}{#1}}
    {decision edge label={right}{west}{#1}}
  },
  delay={for descendants={
    decision/.expanded/.wrap pgfmath arg={\getsecond#1\endget}{content},
    content/.expanded/.wrap pgfmath arg={\getfirst#1\endget}{content},
  }},
  [N,nomath
    [I;{p_1=0.5},nomath,elo={yshift=4pt}
      [{5,1};a]
      [II;b,nomath
        [{1,2};m]
        [{2,3};n]
      ]
    ]
    [II;{p_2=0.5},nomath,elo={yshift=4pt}
      [;c
        [{1,0};z]
        [{2,2};t]
      ]
      [;d
        [{3,1};z]
        [{0,0};t]
      ]
    ] {\draw[dashed](!1.anchor)--(!2.anchor) node[pos=0.5,above]{I};}
  ]
\end{forest}

```

5 Known bugs

If you find a bug (there are bound to be some ...), please contact me at saso.zivanovic@guest.arnes.si.

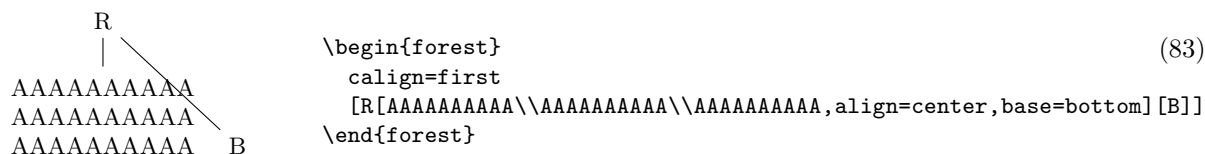
System requirements This package requires L^AT_EX and e_T_EX. If you use something else: sorry.

The requirement for L^AT_EX might be dropped in the future, when I get some time and energy for a code-cleanup (read: to remedy the consequences of my bad programming practices and general disorganization).

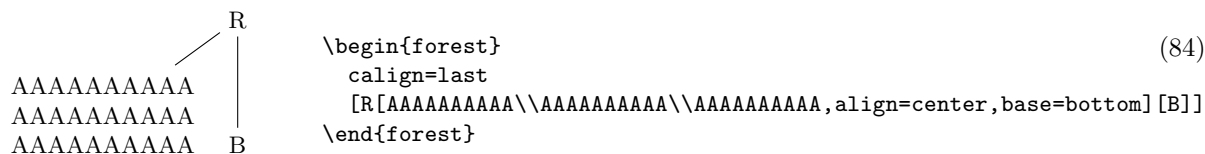
The requirement for e_T_EX will probably stay. If nothing else, FOREST is heavy on boxes: every node requires its own ... and consequently, I have freely used e_T_EX constructs in the code ...

pgf internals FOREST relies on some details of PGF implementation, like the name of the “not yet positioned” nodes. Thus, a new bug might appear with the development of PGF. If you notice one, please let me know.

Edges cutting through sibling nodes In the following example, the R–B edge crosses the AAA node, although `ignore edge` is set to the default `false`.

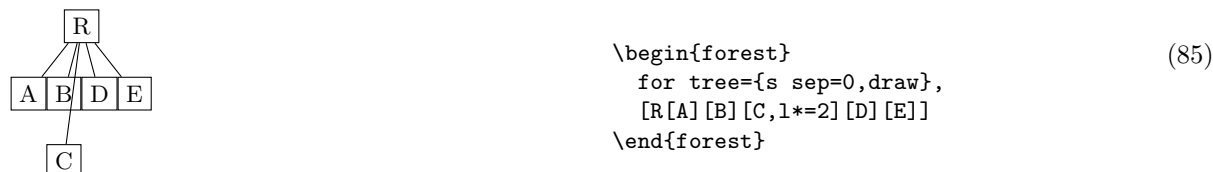


This happens because s-distances between the adjacent children are computed before child alignment (which is obviously the correct order in the general case), but child alignment non-linearly influences the edges. Observe that the with a different value of `calign`, the problem does not arise.



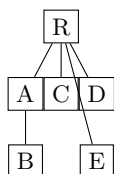
While it would be possible to fix the situation after child alignment (at least for some child alignment methods), I have decided against that, since the distances between siblings would soon become too large. If the AAA node in the example above was large enough, B could easily be pushed off the paper. The bottomline is, please use manual adjustment to fix such situations.

Orphans If the `l` coordinates of adjacent children are too different (as a result of manual adjustment or tier alignment), the packing algorithm might have nothing to say about the desired distance between them: in this sense, node C below is an “orphan.”



To prevent orphans from ending up just anywhere, I have decided to vertically align them with their preceding sibling — although I’m not certain that’s really the best solution. In other words, you can rely that the sequence of s-coordinates of siblings is non-decreasing.

The decision also influences a similar situation, illustrated below. The packing algorithm puts node E immediately next to B (i.e. under C): however, the monotonicity-retaining mechanism then vertically aligns it with its preceding sibling, D.



```

\begin{forest}
  for tree={s sep=0,draw},
  [R[A[B,tier=bottom]] [C] [D] [E,tier=bottom]]
\end{forest}

```

(86)

Obviously, both examples also create the situation of an edge crossing some sibling node(s). Again, I don't think anything sensible can be done about this, in general.

6 Changelog

v1.04 (2013/10/17)

- Fixed an [externalization bug](#).

v1.03 (2013/01/28)

- Bugfix: options of dynamically created nodes didn't get processed.
- Bugfix: the bracket parser was losing spaces before opening braces.
- Bugfix: a family of utility macros dealing with affixing token lists was not expanding content correctly.
- Added style [math content](#).
- Replace key `tikz preamble` with more general [begin draw](#) and [end draw](#).
- Add keys [begin forest](#) and [end forest](#).

v1.02 (2013/01/20)

- Reworked style [stages](#): it's easier to modify the processing flow now.
- Individual stages must now be explicitly called in the context of some (usually root) node.
- Added [delay n](#) and [if have delayed](#).
- Added (experimental) [pack'](#).
- Added reference to the [style repository](#).

v1.01 (2012/11/14)

- Compatibility with the `standalone` package: temporarily disable the effect of `standalone's` package option `tikz` while typesetting nodes.
- Require at least the [2010/08/21] (v2.0) release of package `etoolbox`.
- Require version [2010/10/13] (v2.10, rcs-revision 1.76) of PGF/TikZ. Future compatibility: adjust to the change of the “not yet positioned” node name (2.10 @ → 2.10-csv PGFINTERNAL).
- Add this changelog.

v1.0 (2012/10/31) First public version

Acknowledgements Many thanks to the people who have reported bugs! In the chronological order: Markus Pöchtrager, Timothy Dozat, Ignasi Furio.¹⁸

¹⁸If you're in the list but don't want to be, my apologies and please let me know about it!

Part II

Implementation

A disclaimer: the code could've been much cleaner and better-documented ...
Identification.

```

1 \ProvidesPackage{forest}[2013/10/17 v1.04 Drawing (linguistic) trees]
2
3 \RequirePackage{tikz}[2010/10/13]
4 \usetikzlibrary{shapes}
5 \usetikzlibrary{fit}
6 \usetikzlibrary{calc}
7 \usepgflibrary{intersections}
8
9 \RequirePackage{pgfplots}
10 \RequirePackage{etoolbox}[2010/08/21]
11 \RequirePackage{environ}
12
13 %\usepackage[trace]{trace-pgfkeys}
    /forest is the root of the key hierarchy.
14 \pgfkeys{/forest/.is family}
15 \def\forestset#1{\pgfkeys{/forest}{#1}}
```

7 Patches

These patches apply to pgf/tikz 2.10.

Serious: forest cannot load if this is not patched; disable /handlers/.wrap n pgfmath for n=6,7,8 if you cannot patch.

```

16 \long\def\forest@original@pgfkeysdefnargs@#1#2#3#4{%
17   \ifcase#2\relax
18   \pgfkeyssetvalue{#1/.@args}{}%
19   \or
20   \pgfkeyssetvalue{#1/.@args}{##1}%
21   \or
22   \pgfkeyssetvalue{#1/.@args}{##1##2}%
23   \or
24   \pgfkeyssetvalue{#1/.@args}{##1##2##3}%
25   \or
26   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4}%
27   \or
28   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5}%
29   \or
30   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6}%
31   \or
32   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6}%
33   \or
34   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6##7}%
35   \or
36   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6##7##8}%
37   \or
38   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6##7##8##9}%
39   \else
40   \pgfkeys@error{\string\pgfkeysdefnargs: expected <= 9 arguments, got #2}%
41   \fi
42   \pgfkeysgetvalue{#1/.@args}\pgfkeys@tempargs
43   \def\pgfkeys@temp{\expandafter#4\cname pgfk@#1/.@body\endcsname}%
44   \expandafter\pgfkeys@temp\pgfkeys@tempargs{#3}%
45   % eliminate the \pgfeov at the end such that TeX gobbles spaces
```



```

46 % by using
47 % \pgfkeysdef{#1}{\pgfkeysvalueof{#1/.@@body}##1}
48 % (with expansion of '1'):
49 \edef\pgfkeys@tempargs{\noexpand\pgfkeysvalueof{#1/.@@body}}%
50 \def\pgfkeys@temp{\pgfkeysdef{#1}}%
51 \expandafter\pgfkeys@temp\expandafter{\pgfkeys@tempargs##1}%
52 \pgfkeyssetvalue{#1/.@body}{#3}%
53 }
54
55 \long\def\forest@patched@pgfkeysdefnargs@#1#2#3#4{%
56   \ifcase#2\relax
57   \pgfkeyssetvalue{#1/.@args}{}%
58   \or
59   \pgfkeyssetvalue{#1/.@args}{##1}%
60   \or
61   \pgfkeyssetvalue{#1/.@args}{##1##2}%
62   \or
63   \pgfkeyssetvalue{#1/.@args}{##1##2##3}%
64   \or
65   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4}%
66   \or
67   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5}%
68   \or
69   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6}%
70   %%%% removed:
71   %%%% \or
72   %%%% \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6}%
73   \or
74   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6##7}%
75   \or
76   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6##7##8}%
77   \or
78   \pgfkeyssetvalue{#1/.@args}{##1##2##3##4##5##6##7##8##9}%
79   \else
80   \pgfkeys@error{\string\pgfkeysdefnargs: expected <= 9 arguments, got #2}%
81   \fi
82   \pgfkeysgetvalue{#1/.@args}\pgfkeys@tempargs
83   \def\pgfkeys@temp{\expandafter#4\csname pgfk@#1/.@@body\endcsname}%
84   \expandafter\pgfkeys@temp\pgfkeys@tempargs{#3}%
85   % eliminate the \pgfeov at the end such that TeX gobbles spaces
86   % by using
87   % \pgfkeysdef{#1}{\pgfkeysvalueof{#1/.@@body}##1}
88   % (with expansion of '1'):
89   \edef\pgfkeys@tempargs{\noexpand\pgfkeysvalueof{#1/.@@body}}%
90   \def\pgfkeys@temp{\pgfkeysdef{#1}}%
91   \expandafter\pgfkeys@temp\expandafter{\pgfkeys@tempargs##1}%
92   \pgfkeyssetvalue{#1/.@body}{#3}%
93 }
94 \ifx\pgfkeysdefnargs@\forest@original@pgfkeysdefnargs@
95   \let\pgfkeysdefnargs@\forest@patched@pgfkeysdefnargs@
96 \fi

```

Minor: a leaking space in the very first line.

```

97 \def\forest@original@pgfpointintersectionoflines#1#2#3#4{%
98   {
99     %
100    % Compute orthogonal vector to #1--#2
101    %
102    \pgf@process{#2}%
103    \pgf@xa=\pgf@x%
104    \pgf@ya=\pgf@y%

```

```

105 \pgf@process{#1}%
106 \advance\pgf@xa by-\pgf@x%
107 \advance\pgf@ya by-\pgf@y%
108 \pgf@ya=-\pgf@ya%
109 % Normalise a bit
110 \c@pgf@counta=\pgf@xa%
111 \ifnum\c@pgf@counta<0\relax%
112 \c@pgf@counta=-\c@pgf@counta\relax%
113 \fi%
114 \c@pgf@countb=\pgf@ya%
115 \ifnum\c@pgf@countb<0\relax%
116 \c@pgf@countb=-\c@pgf@countb\relax%
117 \fi%
118 \advance\c@pgf@counta by\c@pgf@countb\relax%
119 \divide\c@pgf@counta by 65536\relax%
120 \ifnum\c@pgf@counta>0\relax%
121 \divide\pgf@xa by\c@pgf@counta\relax%
122 \divide\pgf@ya by\c@pgf@counta\relax%
123 \fi%
124 %
125 % Compute projection
126 %
127 \pgf@xc=\pgf@sys@tonumber{\pgf@ya}\pgf@x%
128 \advance\pgf@xc by\pgf@sys@tonumber{\pgf@xa}\pgf@y%
129 %
130 % The orthogonal vector is (\pgf@ya,\pgf@xa)
131 %
132 %
133 % Compute orthogonal vector to #3--#4
134 %
135 \pgf@process{#4}%
136 \pgf@xb=\pgf@x%
137 \pgf@yb=\pgf@y%
138 \pgf@process{#3}%
139 \advance\pgf@xb by-\pgf@x%
140 \advance\pgf@yb by-\pgf@y%
141 \pgf@yb=-\pgf@yb%
142 % Normalise a bit
143 \c@pgf@counta=\pgf@xb%
144 \ifnum\c@pgf@counta<0\relax%
145 \c@pgf@counta=-\c@pgf@counta\relax%
146 \fi%
147 \c@pgf@countb=\pgf@yb%
148 \ifnum\c@pgf@countb<0\relax%
149 \c@pgf@countb=-\c@pgf@countb\relax%
150 \fi%
151 \advance\c@pgf@counta by\c@pgf@countb\relax%
152 \divide\c@pgf@counta by 65536\relax%
153 \ifnum\c@pgf@counta>0\relax%
154 \divide\pgf@xb by\c@pgf@counta\relax%
155 \divide\pgf@yb by\c@pgf@counta\relax%
156 \fi%
157 %
158 % Compute projection
159 %
160 \pgf@yc=\pgf@sys@tonumber{\pgf@yb}\pgf@x%
161 \advance\pgf@yc by\pgf@sys@tonumber{\pgf@xb}\pgf@y%
162 %
163 % The orthogonal vector is (\pgf@yb,\pgf@xb)
164 %
165 % Setup transformation matrix (this is just to use the matrix

```

```

166 % inversion)
167 %
168 \pgfsettransform{\pgf@sys@tonumber\pgf@ya}{\pgf@sys@tonumber\pgf@yb}{\pgf@sys@tonumber\pgf@xa}{\pgf@sys@
169 \pgftransforminvert%
170 \pgf@process{\pgfpointtransformed{\pgfpoint{\pgf@xc}{\pgf@yc}}}%
171 }%
172 }
173 \def\forest@patched@pgfpointintersectionoflines#1#2#3#4{%
174 {% added the percent sign in this line
175 %
176 % Compute orthogonal vector to #1--#2
177 %
178 \pgf@process{#2}%
179 \pgf@xa=\pgf@x%
180 \pgf@ya=\pgf@y%
181 \pgf@process{#1}%
182 \advance\pgf@xa by-\pgf@x%
183 \advance\pgf@ya by-\pgf@y%
184 \pgf@ya=-\pgf@ya%
185 % Normalise a bit
186 \c@pgf@counta=\pgf@xa%
187 \ifnum\c@pgf@counta<0\relax%
188 \c@pgf@counta=-\c@pgf@counta\relax%
189 \fi%
190 \c@pgf@countb=\pgf@ya%
191 \ifnum\c@pgf@countb<0\relax%
192 \c@pgf@countb=-\c@pgf@countb\relax%
193 \fi%
194 \advance\c@pgf@counta by\c@pgf@countb\relax%
195 \divide\c@pgf@counta by 65536\relax%
196 \ifnum\c@pgf@counta>0\relax%
197 \divide\pgf@xa by\c@pgf@counta\relax%
198 \divide\pgf@ya by\c@pgf@counta\relax%
199 \fi%
200 %
201 % Compute projection
202 %
203 \pgf@xc=\pgf@sys@tonumber{\pgf@ya}\pgf@x%
204 \advance\pgf@xc by\pgf@sys@tonumber{\pgf@xa}\pgf@y%
205 %
206 % The orthogonal vector is (\pgf@ya,\pgf@xa)
207 %
208 %
209 % Compute orthogonal vector to #3--#4
210 %
211 \pgf@process{#4}%
212 \pgf@xb=\pgf@x%
213 \pgf@yb=\pgf@y%
214 \pgf@process{#3}%
215 \advance\pgf@xb by-\pgf@x%
216 \advance\pgf@yb by-\pgf@y%
217 \pgf@yb=-\pgf@yb%
218 % Normalise a bit
219 \c@pgf@counta=\pgf@xb%
220 \ifnum\c@pgf@counta<0\relax%
221 \c@pgf@counta=-\c@pgf@counta\relax%
222 \fi%
223 \c@pgf@countb=\pgf@yb%
224 \ifnum\c@pgf@countb<0\relax%
225 \c@pgf@countb=-\c@pgf@countb\relax%
226 \fi%

```

```

227 \advance\c@pgf@counta by\c@pgf@countb\relax%
228 \divide\c@pgf@counta by 65536\relax%
229 \ifnum\c@pgf@counta>0\relax%
230 \divide\pgf@xb by\c@pgf@counta\relax%
231 \divide\pgf@yb by\c@pgf@counta\relax%
232 \fi%
233 %
234 % Compute projection
235 %
236 \pgf@yc=\pgf@sys@tonumber{\pgf@yb}\pgf@x%
237 \advance\pgf@yc by\pgf@sys@tonumber{\pgf@xb}\pgf@y%
238 %
239 % The orthogonal vector is (\pgf@yb,\pgf@xb)
240 %
241 % Setup transformation matrix (this is just to use the matrix
242 % inversion)
243 %
244 \pgfsettransform{\pgf@sys@tonumber\pgf@ya}{\pgf@sys@tonumber\pgf@yb}{\pgf@sys@tonumber\pgf@xa}{\pgf@sys@tonumber\pgf@yb}{\pgf@sys@tonumber\pgf@xc}{\pgf@sys@tonumber\pgf@yc}%
245 \pgftransforminvert%
246 \pgf@process{\pgfpointtransformed{\pgfpoint{\pgf@xc}{\pgf@yc}}}%
247 }%
248 }
249
250 \ifx\pgfpointintersectionoflines\forest@original\pgfpointintersectionoflines
251 \let\pgfpointintersectionoflines\forest@patched\pgfpointintersectionoflines
252 \fi
253
254 % hah: hacking forest --- it depends on some details of PGF implementation
255 \def\forest@pgf@notyetpositioned{not yet positionedPGFINTERNAL}%
256 \expandafter\ifstrequal\expandafter{\pgfversion}{2.10}{%
257 \def\forest@pgf@notyetpositioned{not yet positioned@}%
258 }{}

```

8 Utilities

Escaping \ifs.

```

259 \long\def\@escapeif#1#2\fi{\fi#1}
260 \long\def\@escapeifif#1#2\fi#3\fi{\fi{\fi#1}
    A factory for creating \...loop... macros.
261 \def\newloop#1{%
262 \count@=\escapechar
263 \escapechar=-1
264 \expandafter\newloop@parse@loopname\string#1\newloop@end
265 \escapechar=\count@
266 }%
267 {\lccode'7='1 \lccode'8='o \lccode'9='p
268 \lowercase{\gdef\newloop@parse@loopname#17889#2\newloop@end{%
269 \edef\newloop@marshal{%
270 \noexpand\csdef{#1loop#2}####1\expandafter\noexpand\csname #1repeat#2\endcsname{%
271 \noexpand\csdef{#1iterate#2}{####1\relax\noexpand\expandafter\expandafter\noexpand\csname#1iterate#2\endcsname
272 \expandafter\noexpand\csname#1iterate#2\endcsname
273 \let\expandafter\noexpand\csname#1iterate#2\endcsname\relax
274 }%
275 }%
276 \newloop@marshal
277 }%
278 }%
279 }%

```

Additional loops (for embedding).

```
280 \newloop\forest@loop
281 \newloop\forest@loopa
282 \newloop\forest@loopb
283 \newloop\forest@loopc
284 \newloop\forest@sort@loop
285 \newloop\forest@sort@loopA
```

New counters, dimens, ifs.

```
286 \newdimen\forest@temp@dimen
287 \newcount\forest@temp@count
288 \newcount\forest@n
289 \newif\ifforest@temp
290 \newcount\forest@temp@global@count
```

Appending and prepending to token lists.

```
291 \def\apptotoks#1#2{\expandafter#1\expandafter{\the#1#2}}
292 \long\def\lapptotoks#1#2{\expandafter#1\expandafter{\the#1#2}}
293 \def\eapptotoks#1#2{\edef\pot@temp{#2}\expandafter\expandafter\expandafter#1\expandafter\expandafter\expandafter\expandafter
294 \def\pretotoks#1#2{\toks@={#2}\expandafter\expandafter\expandafter#1\expandafter\expandafter\expandafter\expandafter{\exp
295 \def\epretotoks#1#2{\edef\pot@temp{#2}\expandafter\expandafter\expandafter#1\expandafter\expandafter\expandafter\expandafter
296 \def\gapptotoks#1#2{\expandafter\global\expandafter#1\expandafter{\the#1#2}}
297 \def\xapptotoks#1#2{\edef\pot@temp{#2}\expandafter\expandafter\expandafter\global\expandafter\expandafter\expandafter\exp
298 \def\gpretotoks#1#2{\toks@={#2}\expandafter\expandafter\expandafter\global\expandafter\expandafter\expandafter\expandafter
299 \def\xpretotoks#1#2{\edef\pot@temp{#2}\expandafter\expandafter\expandafter\global\expandafter\expandafter\expandafter\exp
```

Expanding number arguments.

```
300 \def\expandnumberarg#1#2{\expandafter#1\expandafter{\number#2}}
301 \def\expandtwonumberargs#1#2#3{%
302   \expandafter\expandtwonumberargs@\expandafter#1\expandafter{\number#3}{#2}}
303 \def\expandtwonumberargs@#1#2#3{%
304   \expandafter#1\expandafter{\number#3}{#2}}
305 \def\expandthreenumberargs#1#2#3#4{%
306   \expandafter\expandthreenumberargs@\expandafter#1\expandafter{\number#4}{#2}{#3}}
307 \def\expandthreenumberargs@#1#2#3#4{%
308   \expandafter\expandthreenumberargs@@\expandafter#1\expandafter{\number#4}{#2}{#3}}
309 \def\expandthreenumberargs@@#1#2#3#4{%
310   \expandafter#1\expandafter{\number#4}{#2}{#3}}
```

A macro converting all non-letters in a string to `_`. #1 = string, #2 = receiving macro. Used for declaring pgfmath functions.

```
311 \def\forest@convert@others@to@underscores#1#2{%
312   \def\forest@cotu@result{}%
313   \forest@cotu#1\forest@end
314   \let#2\forest@cotu@result
315 }
316 \def\forest@cotu{%
317   \futurelet\forest@cotu@nextchar\forest@cotu@checkforspace
318 }
319 \def\forest@cotu@checkforspace{%
320   \expandafter\ifx\space\forest@cotu@nextchar
321     \let\forest@cotu@next\forest@cotu@havespace
322   \else
323     \let\forest@cotu@next\forest@cotu@nospace
324   \fi
325   \forest@cotu@next
326 }
327 \def\forest@cotu@havespace#1{%
328   \appto\forest@cotu@result{_}%
329   \forest@cotu#1%
330 }
331 \def\forest@cotu@nospace{%
```

```

332 \ifx\forest@cotu@nextchar\forest@end
333 \escapeif\@gobble
334 \else
335 \escapeif\forest@cotu@nospaceB
336 \fi
337 }
338 \def\forest@cotu@nospaceB{%
339 \ifcat\forest@cotu@nextchar a%
340 \let\forest@cotu@next\forest@cotu@have@alphanum
341 \else
342 \ifcat\forest@cotu@nextchar 0%
343 \let\forest@cotu@next\forest@cotu@have@alphanum
344 \else
345 \let\forest@cotu@next\forest@cotu@haveother
346 \fi
347 \fi
348 \forest@cotu@next
349 }
350 \def\forest@cotu@have@alphanum#1{%
351 \appto\forest@cotu@result{#1}%
352 \forest@cotu
353 }
354 \def\forest@cotu@haveother#1{%
355 \appto\forest@cotu@result{#1}%
356 \forest@cotu
357 }

```

Additional list macros.

```

358 \def\forest@listedel#1#2{% #1 = list, #2 = item
359 \edef\forest@marshal{\noexpand\forest@listdel\noexpand#1{#2}}%
360 \forest@marshal
361 }
362 \def\forest@listcsdel#1#2{%
363 \expandafter\forest@listdel\csname #1\endcsname{#2}%
364 }
365 \def\forest@listcsedel#1#2{%
366 \expandafter\forest@listedel\csname #1\endcsname{#2}%
367 }
368 \edef\forest@restorelistsepcatcode{\noexpand\catcode'\the\catcode'\relax}%
369 \catcode'\|=3
370 \gdef\forest@listdel#1#2{%
371 \def\forest@listedel@A##1|#2|##2\forest@END{%
372 \forest@listedel@B##1|##2\forest@END%|
373 }%
374 \def\forest@listedel@B|##1\forest@END{%|
375 \def#1{##1}%
376 }%
377 \expandafter\forest@listedel@A\expandafter|#1\forest@END%|
378 }
379 \forest@restorelistsepcatcode

```

Strip (the first level of) braces from all the tokens in the argument.

```

380 \def\forest@strip@braces#1{%
381 \forest@strip@braces@A#1\forest@strip@braces@preend\forest@strip@braces@end
382 }
383 \def\forest@strip@braces@A#1#2\forest@strip@braces@end{%
384 #1\ifx\forest@strip@braces@preend#2\else\escapeif{\forest@strip@braces@A#2\forest@strip@braces@end}\fi
385 }

```

8.1 Sorting

Macro `\forest@sort` is the user interface to sorting.

The user should prepare the data in an arbitrarily encoded array,¹⁹ and provide the sorting macro (given in #1) and the array let macro (given in #2): these are the only ways in which sorting algorithms access the data. Both user-given macros should take two parameters, which expand to array indices. The comparison macro should compare the given array items and call `\forest@sort@cmp@gt`, `\forest@sort@cmp@lt` or `\forest@sort@cmp@eq` to signal that the first item is greater than, less than, or equal to the second item. The let macro should “copy” the contents of the second item onto the first item.

The sorting direction is be given in #3: it can one of `\forest@sort@ascending` and `\forest@sort@descending`. #4 and #5 must expand to the lower and upper (both inclusive) indices of the array to be sorted.

`\forest@sort` is just a wrapper for the central sorting macro `\forest@@sort`, storing the comparison macro, the array let macro and the direction. The central sorting macro and the algorithm-specific macros take only two arguments: the array bounds.

```
386 \def\forest@sort#1#2#3#4#5{%
387   \let\forest@sort@cmp#1\relax
388   \let\forest@sort@let#2\relax
389   \let\forest@sort@direction#3\relax
390   \forest@@sort{#4}{#5}%
391 }
```

The central sorting macro. Here it is decided which sorting algorithm will be used: for arrays at least `\forest@quicksort@minarraylength` long, quicksort is used; otherwise, insertion sort.

```
392 \def\forest@quicksort@minarraylength{10000}
393 \def\forest@@sort#1#2{%
394   \ifnum#1<#2\relax\@escapeif{%
395     \forest@sort@m=#2
396     \advance\forest@sort@m -#1
397     \ifnum\forest@sort@m>\forest@quicksort@minarraylength\relax\@escapeif{%
398       \forest@quicksort{#1}{#2}%
399     }\else\@escapeif{%
400       \forest@insertionsort{#1}{#2}%
401     }\fi
402   }\fi
403 }
```

Various counters and macros needed by the sorting algorithms.

```
404 \newcount\forest@sort@m\newcount\forest@sort@k\newcount\forest@sort@p
405 \def\forest@sort@ascending{>}
406 \def\forest@sort@descending{<}
407 \def\forest@sort@cmp{%
408   \PackageError{sort}{You must define forest@sort@cmp function before calling
409     sort}{The macro must take two arguments, indices of the array
410     elements to be compared, and return '=' if the elements are equal
411     and '>'/'<' if the first is greater /less than the second element.}%
412 }
413 \def\forest@sort@cmp@gt{\def\forest@sort@cmp@result{>}}
414 \def\forest@sort@cmp@lt{\def\forest@sort@cmp@result{<}}
415 \def\forest@sort@cmp@eq{\def\forest@sort@cmp@result{=}}
416 \def\forest@sort@let{%
417   \PackageError{sort}{You must define forest@sort@let function before calling
418     sort}{The macro must take two arguments, indices of the array:
419     element 2 must be copied onto element 1.}%
420 }
```

Quick sort macro (adapted from [laansort](#)).

```
421 \def\forest@quicksort#1#2{%
```

¹⁹In forest, arrays are encoded as families of macros. An array-macro name consists of the (optional, but recommended) prefix, the index, and the (optional) suffix (e.g. `\forest@42x`). Prefix establishes the “namespace”, while using more than one suffix simulates an array of named tuples. The length of the array is stored in macro `\<prefix>n`.

Compute the index of the middle element (`\forest@sort@m`).

```

422 \forest@sort@m=#2
423 \advance\forest@sort@m -#1
424 \ifodd\forest@sort@m\relax\advance\forest@sort@m1 \fi
425 \divide\forest@sort@m 2
426 \advance\forest@sort@m #1

```

The pivot element is the median of the first, the middle and the last element.

```

427 \forest@sort@cmp{#1}{#2}%
428 \if\forest@sort@cmp@result=%
429   \forest@sort@p=#1
430 \else
431   \if\forest@sort@cmp@result>%
432     \forest@sort@p=#1\relax
433   \else
434     \forest@sort@p=#2\relax
435   \fi
436 \forest@sort@cmp{\the\forest@sort@p}{\the\forest@sort@m}%
437 \if\forest@sort@cmp@result<%
438   \else
439     \forest@sort@p=\the\forest@sort@m
440   \fi
441 \fi

```

Exchange the pivot and the first element.

```

442 \forest@sort@xch{#1}{\the\forest@sort@p}%

```

Counter `\forest@sort@m` will hold the final location of the pivot element.

```

443 \forest@sort@m=#1\relax

```

Loop through the list.

```

444 \forest@sort@k=#1\relax
445 \forest@sort@loop
446 \ifnum\forest@sort@k<#2\relax
447   \advance\forest@sort@k 1

```

Compare the pivot and the current element.

```

448 \forest@sort@cmp{#1}{\the\forest@sort@k}%

```

If the current element is smaller (ascending) or greater (descending) than the pivot element, move it into the first part of the list, and adjust the final location of the pivot.

```

449 \ifx\forest@sort@direction\forest@sort@cmp@result
450   \advance\forest@sort@m 1
451   \forest@sort@xch{\the\forest@sort@m}{\the\forest@sort@k}
452 \fi
453 \forest@sort@repeat

```

Move the pivot element into its final position.

```

454 \forest@sort@xch{#1}{\the\forest@sort@m}%

```

Recursively call sort on the two parts of the list: elements before the pivot are smaller (ascending order) / greater (descending order) than the pivot; elements after the pivot are greater (ascending order) / smaller (descending order) than the pivot.

```

455 \forest@sort@k=\forest@sort@m
456 \advance\forest@sort@k -1
457 \advance\forest@sort@m 1
458 \edef\forest@sort@marshal{%
459   \noexpand\forest@sort@{#1}{\the\forest@sort@k}%
460   \noexpand\forest@sort@{\the\forest@sort@m}{#2}%
461 }%
462 \forest@sort@marshal
463 }

```

```

464 % We defines the item-exchange macro in terms of the (user-provided)

```



```

465 % array let macro.
466 % \begin{macrocode}
467 \def\forest@sort@exch#1#2{%
468 \forest@sort@let{aux}{#1}%
469 \forest@sort@let{#1}{#2}%
470 \forest@sort@let{#2}{aux}%
471 }

Insertion sort.
472 \def\forest@insertionsort#1#2{%
473 \forest@sort@m=#1
474 \edef\forest@insertionsort@low{#1}%
475 \forest@sort@loopA
476 \ifnum\forest@sort@m<#2
477 \advance\forest@sort@m 1
478 \forest@insertionsort@Qbody
479 \forest@sort@repeatA
480 }
481 \newif\ifforest@insertionsort@loop
482 \def\forest@insertionsort@Qbody{%
483 \forest@sort@let{aux}{\the\forest@sort@m}%
484 \forest@sort@k\forest@sort@m
485 \advance\forest@sort@k -1
486 \forest@insertionsort@looptrue
487 \forest@sort@loop
488 \ifforest@insertionsort@loop
489 \forest@insertionsort@Qbody
490 \forest@sort@repeat
491 \advance\forest@sort@k 1
492 \forest@sort@let{\the\forest@sort@k}{aux}%
493 }
494 \def\forest@insertionsort@Qbody{%
495 \forest@sort@cmp{\the\forest@sort@k}{aux}%
496 \ifx\forest@sort@direction\forest@sort@cmp@result\relax
497 \forest@sort@p=\forest@sort@k
498 \advance\forest@sort@p 1
499 \forest@sort@let{\the\forest@sort@p}{\the\forest@sort@k}%
500 \advance\forest@sort@k -1
501 \ifnum\forest@sort@k<\forest@insertionsort@low\relax
502 \forest@insertionsort@loopfalse
503 \fi
504 \else
505 \forest@insertionsort@loopfalse
506 \fi
507 }

```

Below, several helpers for writing comparison macros are provided. They take two (pairs of) control sequence names and compare their contents.

Compare numbers.

```

508 \def\forest@sort@cmpnumcs#1#2{%
509 \ifnum\csname#1\endcsname>\csname#2\endcsname\relax
510 \forest@sort@cmp@gt
511 \else
512 \ifnum\csname#1\endcsname<\csname#2\endcsname\relax
513 \forest@sort@cmp@lt
514 \else
515 \forest@sort@cmp@eq
516 \fi
517 \fi
518 }

```

Compare dimensions.

```

519 \def\forest@sort@cmpdimcs#1#2{%
520   \ifdim\csname#1\endcsname>\csname#2\endcsname\relax
521     \forest@sort@cmp@gt
522   \else
523     \ifdim\csname#1\endcsname<\csname#2\endcsname\relax
524       \forest@sort@cmp@lt
525     \else
526       \forest@sort@cmp@eq
527     \fi
528   \fi
529 }

```

Compare points (pairs of dimension) (#1,#2) and (#3,#4).

```

530 \def\forest@sort@cmptwodimcs#1#2#3#4{%
531   \ifdim\csname#1\endcsname>\csname#3\endcsname\relax
532     \forest@sort@cmp@gt
533   \else
534     \ifdim\csname#1\endcsname<\csname#3\endcsname\relax
535       \forest@sort@cmp@lt
536     \else
537       \ifdim\csname#2\endcsname>\csname#4\endcsname\relax
538         \forest@sort@cmp@gt
539       \else
540         \ifdim\csname#2\endcsname<\csname#4\endcsname\relax
541           \forest@sort@cmp@lt
542         \else
543           \forest@sort@cmp@eq
544         \fi
545       \fi
546     \fi
547   \fi
548 }

```

The following macro reverses an array. The arguments: #1 is the array let macro; #2 is the start index (inclusive), and #3 is the end index (exclusive).

```

549 \def\forest@reversearray#1#2#3{%
550   \let\forest@sort@let#1%
551   \c@pgf@countc=#2
552   \c@pgf@countd=#3
553   \advance\c@pgf@countd -1
554   \forest@loopa
555   \ifnum\c@pgf@countc<\c@pgf@countd\relax
556     \forest@sort@exch{\the\c@pgf@countc}{\the\c@pgf@countd}%
557     \advance\c@pgf@countc 1
558     \advance\c@pgf@countd -1
559   \forest@repeata
560 }

```

9 The bracket representation parser

9.1 The user interface macros

Settings.

```

561 \def\bracketset#1{\pgfqkeys{/bracket}{#1}}%
562 \bracketset{%
563   /bracket/.is family,
564   /handlers/.let/.style={\pgfkeyscurrentpath/.code={\let#1##1}},
565   opening bracket/.let=\bracket@openingBracket,
566   closing bracket/.let=\bracket@closingBracket,
567   action character/.let=\bracket@actionCharacter,

```

```

568 opening bracket=[,
569 closing bracket=],
570 action character,
571 new node/.code n args={3}{% #1=preamble, #2=node spec, #3=cs receiving the id
572   \forest@node@new#3%
573   \forest@set{#3}{given options}{content'=#2}%
574   \ifblank{#1}{}{%
575     \forest@preto{#3}{given options}{#1,}%
576   }%
577 },
578 set afterthought/.code 2 args={% #1=node id, #2=afterthought
579   \ifblank{#2}{}{\forest@appto{#1}{given options}{,afterthought={#2}}}%
580 }
581 }

```

`\bracketParse` is the macro that should be called to parse a balanced bracket representation. It takes five parameters: `#1` is the code that will be run after parsing the bracket; `#2` is a control sequence that will receive the id of the root of the created tree structure. (The bracket representation should follow (after optional spaces), but is not a formal parameter of the macro.)

```

582 \newtoks\bracket@content
583 \newtoks\bracket@afterthought
584 \def\bracketParse#1#2={%
585   \def\bracketEndParsingHook{#1}%
586   \def\bracket@saveRootNodeTo{#2}%

```

Content and afterthought will be appended to these macros. (The `\bracket@afterthought` toks register is abused for storing the preamble as well — that’s ok, the preamble comes before any afterthoughts.)

```

587 \bracket@content={}%
588 \bracket@afterthought={}%

```

The parser can be in three states: in content (0), in afterthought (1), or starting (2). While in the content/afterthought state, the parser appends all non-control tokens to the content/afterthought macro.

```

589 \let\bracket@state\bracket@state@starting
590 \bracket@ignoreSPACEtrue

```

By default, don’t expand anything.

```

591 \bracket@expandtokensfalse

```

We initialize several control sequences that are used to store some nodes while parsing.

```

592 \def\bracket@parentNode{0}%
593 \def\bracket@rootNode{0}%
594 \def\bracket@newNode{0}%
595 \def\bracket@afterthoughtNode{0}%

```

Finally, we start the parser.

```

596 \bracket@Parse
597 }

```

The other macro that an end user (actually a power user) can use, is actually just a synonym for `\bracket@Parse`. It should be used to resume parsing when the action code has finished its work.

```

598 \def\bracketResume{\bracket@Parse}%

```

9.2 Parsing

We first check if the next token is a space. Spaces need special treatment because they are eaten by both the `\romannumeral` trick and `TEX`s (undelimited) argument parsing algorithm. If a space is found, remember that, eat it up, and restart the parsing.

```

599 \def\bracket@Parse{%
600   \futurelet\bracket@next@token\bracket@Parse@checkForSpace
601 }
602 \def\bracket@Parse@checkForSpace{%
603   \expandafter\ifx\space\bracket@next@token\@escapeif{%

```

```

604 \ifbracket@ignorespaces\else
605 \bracket@haveSpace>true
606 \fi
607 \expandafter\bracket@Parse\romannumeral-‘0%
608 }\else\@escapeif{%
609 \bracket@Parse@maybeexpand
610 }\fi
611 }

```

We either fully expand the next token (using a popular T_EXnical trick ...) or don't expand it at all, depending on the state of `\ifbracket@expandtokens`.

```

612 \newif\ifbracket@expandtokens
613 \def\bracket@Parse@maybeexpand{%
614 \ifbracket@expandtokens\@escapeif{%
615 \expandafter\bracket@Parse@peekAhead\romannumeral-‘0%
616 }\else\@escapeif{%
617 \bracket@Parse@peekAhead
618 }\fi
619 }

```

We then look ahead to see what's coming.

```

620 \def\bracket@Parse@peekAhead{%
621 \futurelet\bracket@next@token\bracket@Parse@checkForTeXGroup
622 }

```

If the next token is a begin-group token, we append the whole group to the content or afterthought macro, depending on the state.

```

623 \def\bracket@Parse@checkForTeXGroup{%
624 \ifx\bracket@next@token\bgroup%
625 \@escapeif{\bracket@Parse@appendGroup}%
626 \else
627 \@escapeif{\bracket@Parse@token}%
628 \fi
629 }

```

This is easy: if a control token is found, run the appropriate macro; otherwise, append the token to the content or afterthought macro, depending on the state.

```

630 \long\def\bracket@Parse@token#1{%
631 \ifx#1\bracket@openingBracket
632 \@escapeif{\bracket@Parse@openingBracketFound}%
633 \else
634 \@escapeif{%
635 \ifx#1\bracket@closingBracket
636 \@escapeif{\bracket@Parse@closingBracketFound}%
637 \else
638 \@escapeif{%
639 \ifx#1\bracket@actionCharacter
640 \@escapeif{\futurelet\bracket@next@token\bracket@Parse@actionCharacterFound}%
641 \else
642 \@escapeif{\bracket@Parse@appendToken#1}%
643 \fi
644 }%
645 \fi
646 }%
647 \fi
648 }

```

Append the token or group to the content or afterthought macro. If a space was found previously, append it as well.

```

649 \newif\ifbracket@haveSpace
650 \newif\ifbracket@ignorespaces
651 \def\bracket@Parse@appendSpace{%

```

```

652 \ifbracket@haveSpace
653   \ifcase\bracket@state\relax
654     \eapptotoks\bracket@content\space
655   \or
656     \eapptotoks\bracket@afterthought\space
657   \or
658     \eapptotoks\bracket@afterthought\space
659   \fi
660   \bracket@haveSpacefalse
661 \fi
662 }
663 \long\def\bracket@Parse@appendToken#1{%
664   \bracket@Parse@appendSpace
665   \ifcase\bracket@state\relax
666     \lapptotoks\bracket@content{#1}%
667   \or
668     \lapptotoks\bracket@afterthought{#1}%
669   \or
670     \lapptotoks\bracket@afterthought{#1}%
671   \fi
672   \bracket@ignorespacesfalse
673   \bracket@Parse
674 }
675 \def\bracket@Parse@appendGroup#1{%
676   \bracket@Parse@appendSpace
677   \ifcase\bracket@state\relax
678     \apptotoks\bracket@content{{#1}}%
679   \or
680     \apptotoks\bracket@afterthought{{#1}}%
681   \or
682     \apptotoks\bracket@afterthought{{#1}}%
683   \fi
684   \bracket@ignorespacesfalse
685   \bracket@Parse
686 }

```

Declare states.

```

687 \def\bracket@state@inContent{0}
688 \def\bracket@state@inAfterthought{1}
689 \def\bracket@state@starting{2}

```

Welcome to the jungle. In the following two macros, new nodes are created, content and afterthought are sent to them, parents and states are changed. . . . Altogether, we distinguish six cases, as shown below: in the schemas, we have just crossed the symbol after the dots. (In all cases, we reset the `\if` for spaces.)

```

690 \def\bracket@Parse@openingBracketFound{%
691   \bracket@haveSpacefalse
692   \ifcase\bracket@state\relax% in content [ ... [

```

[...[: we have just finished gathering the content and are about to begin gathering the content of another node. We create a new node (and put the content (...) into it). Then, if there is a parent node, we append the new node to the list of its children. Next, since we have just crossed an opening bracket, we declare the newly created node to be the parent of the coming node. The state does not change. Finally, we continue parsing.

```

693     \@escapeif{%
694       \bracket@createNode
695       \ifnum\bracket@parentNode=0 \else
696         \forest@node@Append{\bracket@parentNode}{\bracket@newNode}%
697       \fi
698       \let\bracket@parentNode\bracket@newNode
699       \bracket@Parse
700     }%
701   \or % in afterthought   ] ... [

```

]...[: we have just finished gathering the afterthought and are about to begin gathering the content of another node. We add the afterthought (...) to the “afterthought node” and change into the content state. The parent does not change. Finally, we continue parsing.

```

702   \@escapeif{%
703     \bracket@addAfterthought
704     \let\bracket@state\bracket@state@inContent
705     \bracket@Parse
706   }%
707   \else % starting

```

{start}...[: we have just started. Nothing to do yet (we couldn’t have collected any content yet), just get into the content state and continue parsing.

```

708   \@escapeif{%
709     \let\bracket@state\bracket@state@inContent
710     \bracket@Parse
711   }%
712   \fi
713 }

```

```

714 \def\bracket@Parse@closingBracketFound{%
715   \bracket@haveSpacefalse
716   \ifcase\bracket@state\relax % in content [ ... ]

```

[...]: we have just finished gathering the content of a node and are about to begin gathering its afterthought. We create a new node (and put the content (...) into it). If there is no parent node, we’re done with parsing. Otherwise, we set the newly created node to be the “afterthought node”, i.e. the node that will receive the next afterthought, change into the afterthought mode, and continue parsing.

```

717   \@escapeif{%
718     \bracket@createNode
719     \ifnum\bracket@parentNode=0
720       \@escapeif\bracket@endParsingHook
721     \else
722       \@escapeif{%
723         \let\bracket@afterthoughtNode\bracket@newNode
724         \let\bracket@state\bracket@state@inAfterthought
725         \forest@node@Append{\bracket@parentNode}{\bracket@newNode}%
726         \bracket@Parse
727       }%
728     \fi
729   }%
730   \or % in afterthought ] ... ]

```

]...]: we have finished gathering an afterthought of some node and will begin gathering the afterthought of its parent. We first add the afterthought to the afterthought node and set the current parent to be the next afterthought node. We change the parent to the current parent’s parent and check if that node is null. If it is, we’re done with parsing (ignore the trailing spaces), otherwise we continue.

```

731   \@escapeif{%
732     \bracket@addAfterthought
733     \let\bracket@afterthoughtNode\bracket@parentNode
734     \edef\bracket@parentNode{\forestOve{\bracket@parentNode}{@parent}}%
735     \ifnum\bracket@parentNode=0
736       \expandafter\bracket@endParsingHook
737     \else
738       \expandafter\bracket@Parse
739     \fi
740   }%
741   \else % starting

```

{start}...]: something’s obviously wrong with the input here...

```

742   \PackageError{forest}{You’re attempting to start a bracket representation
743     with a closing bracket}{}%
744   \fi
745 }

```

The action character code. What happens is determined by the next token.

```
746 \def\bracket@Parse@actionCharacterFound{%
```

If a braced expression follows, its contents will be fully expanded.

```
747 \ifx\bracket@next@token\bgroup\@escapeif{%
748 \bracket@Parse@action@expandgroup
749 }\else\@escapeif{%
750 \bracket@Parse@action@notagroup
751 }\fi
752 }
753 \def\bracket@Parse@action@expandgroup#1{%
754 \edef\bracket@Parse@action@expandgroup@macro{#1}%
755 \expandafter\bracket@Parse\bracket@Parse@action@expandgroup@macro
756 }
757 \let\bracket@action@fullyexpandCharacter+
758 \let\bracket@action@dontexpandCharacter-
759 \let\bracket@action@executeCharacter!
760 \def\bracket@Parse@action@notagroup#1{%
```

If + follows, tokens will be fully expanded from this point on.

```
761 \ifx#1\bracket@action@fullyexpandCharacter\@escapeif{%
762 \bracket@expandtokenstrue\bracket@Parse
763 }\else\@escapeif{%
```

If - follows, tokens will not be expanded from this point on. (This is the default behaviour.)

```
764 \ifx#1\bracket@action@dontexpandCharacter\@escapeif{%
765 \bracket@expandtokensfalse\bracket@Parse
766 }\else\@escapeif{%
```

Inhibit expansion of the next token.

```
767 \ifx#10\@escapeif{%
768 \bracket@Parse@appendToken
769 }\else\@escapeif{%
```

If another action characted follows, we yield the control. The user is expected to resume the parser manually, using `\bracketResume`.

```
770 \ifx#1\bracket@actionCharacter
771 \else\@escapeif{%
```

Anything else will be expanded once.

```
772 \expandafter\bracket@Parse#1%
773 }\fi
774 }\fi
775 }\fi
776 }\fi
777 }
```

9.3 The tree-structure interface

This macro creates a new node and sets its content (and preamble, if it's a root node). Bracket user must define a 3-arg key `/bracket/new node=<preamble><node specification><node cs>`. User's key must define `<node cs>` to be a macro holding the node's id.

```
778 \def\bracket@createNode{%
779 \ifnum\bracket@rootNode=0
780 % root node
781 \bracketset{new node/.expanded=%
782 {\the\bracket@afterthought}%
783 {\the\bracket@content}%
784 \noexpand\bracket@newNode
785 }%
786 \bracket@afterthought={}%
787 \let\bracket@rootNode\bracket@newNode
```

```

788 \expandafter\let\bracket@saveRootNodeTo\bracket@newNode
789 \else
790 % other nodes
791 \bracketset{new node/.expanded=%
792   {}%
793   {\the\bracket@content}}%
794 \noexpand\bracket@newNode
795 }%
796 \fi
797 \bracket@content={}%
798 }

```

This macro sets the afterthought. Bracket user must define a 2-arg key `/bracket/set afterthought=<node id><afterthought>`.

```

799 \def\bracket@addAfterthought{%
800   \bracketset{%
801     set afterthought/.expanded={\bracket@afterthoughtNode}{\the\bracket@afterthought}}%
802   }%
803   \bracket@afterthought={}%
804 }

```

10 Nodes

Nodes have numeric ids. The node option values of node n are saved in the `\pgfkeys` tree in path `/forest/@node/ n` .

10.1 Option setting and retrieval

Macros for retrieving/setting node options of the current node.

```

805 % full expansion expands precisely to the value
806 \def\forestov#1{\expandafter\expandafter\expandafter\expandonce
807   \pgfkeysvalueof{/forest/@node/\forest@cn/#1}}
808 % full expansion expands all the way
809 \def\forestove#1{\pgfkeysvalueof{/forest/@node/\forest@cn/#1}}
810 % full expansion expands to the cs holding the value
811 \def\forestom#1{\expandafter\expandonce\expandafter{\pgfkeysvalueof{/forest/@node/\forest@cn/#1}}\def\forest
812 \def\forestogget#1#2{\pgfkeysgetvalue{/forest/@node/\forest@cn/#1}{#2}}
813 \def\forestolet#1#2{\pgfkeyslet{/forest/@node/\forest@cn/#1}{#2}}
814 \def\forestoset#1#2{\pgfkeyssetvalue{/forest/@node/\forest@cn/#1}{#2}}
815 \def\forestoeset#1#2{%
816   \edef\forest@option@temp{%
817     \noexpand\pgfkeyssetvalue{/forest/@node/\forest@cn/#1}{#2}}%
818   }\forest@option@temp
819 }
820 \def\forestooppto#1#2{%
821   \forestoeset{#1}{\forestov{#1}\unexpanded{#2}}%
822 }
823 \def\forestoiifdefined#1#2#3{%
824   \pgfkeysifdefined{/forest/@node/\forest@cn/#1}{#2}{#3}%
825 }

```

User macros for retrieving node options of the current node.

```

826 \let\forestoption\forestov
827 \let\foresteooption\forestove

```

Macros for retrieving node options of a node given by its id.

```

828 \def\forestov#1#2{\expandafter\expandafter\expandafter\expandonce
829   \pgfkeysvalueof{/forest/@node/#1/#2}}
830 \def\forestove#1#2{\pgfkeysvalueof{/forest/@node/#1/#2}}
831 % full expansion expands to the cs holding the value

```



```

832 \def\forestOm#1#2{\expandafter\expandonce\expandafter{\pgfkeysvalueof{/forest/@node/#1/#2}}}
833 \def\forestOget#1#2#3{\pgfkeysgetvalue{/forest/@node/#1/#2}{#3}}
834 \def\forestOget#1#2#3{\pgfkeysgetvalue{/forest/@node/#1/#2}{#3}}
835 \def\forestOlet#1#2#3{\pgfkeyslet{/forest/@node/#1/#2}{#3}}
836 \def\forestOset#1#2#3{\pgfkeyssetvalue{/forest/@node/#1/#2}{#3}}
837 \def\forestOset#1#2#3{%
838   \edef\forestoption@temp{%
839     \noexpand\pgfkeyssetvalue{/forest/@node/#1/#2}{#3}%
840   }\forestoption@temp
841 }
842 \def\forestOappto#1#2#3{%
843   \forestOset{#1}{#2}{\forestOv{#1}{#2}\unexpanded{#3}}%
844 }
845 \def\forestOeappto#1#2#3{%
846   \forestOset{#1}{#2}{\forestOv{#1}{#2}#3}%
847 }
848 \def\forestOpreto#1#2#3{%
849   \forestOset{#1}{#2}{\unexpanded{#3}\forestOv{#1}{#2}}%
850 }
851 \def\forestOepreto#1#2#3{%
852   \forestOset{#1}{#2}{#3\forestOv{#1}{#2}}%
853 }
854 \def\forestOifdefined#1#2#3#4{%
855   \pgfkeysifdefined{/forest/@node/#1/#2}{#3}{#4}%
856 }
857 \def\forestOlet0#1#2#3#4{% option #2 of node #1 <-- option #4 of node #3
858   \forestOget{#3}{#4}\forestoption@temp
859   \forestOlet{#1}{#2}\forestoption@temp}
860 \def\forestOleto#1#2#3{%
861   \foresttoget{#3}\forestoption@temp
862   \forestOlet{#1}{#2}\forestoption@temp}
863 \def\forestOleto#1#2#3{%
864   \forestOget{#2}{#3}\forestoption@temp
865   \forestolet{#1}\forestoption@temp}
866 \def\forestOleto#1#2{%
867   \foresttoget{#2}\forestoption@temp
868   \forestolet{#1}\forestoption@temp}

```

Node initialization. Node option declarations append to \forest@node@init.

```

869 \def\forest@node@init{%
870   \forestoset{@parent}{0}%
871   \forestoset{@previous}{0}% previous sibling
872   \forestoset{@next}{0}%      next sibling
873   \forestoset{@first}{0}%    primary child
874   \forestoset{@last}{0}%     last child
875 }
876 \def\forest@node@init#1{%
877   \pgfkeysgetvalue{/forest/#1}\forest@node@init@temp
878   \forestolet{#1}\forest@node@init@temp
879 }
880 \newcount\forest@node@maxid
881 \def\forest@node@new#1{% #1 = cs receiving the new node id
882   \advance\forest@node@maxid1
883   \forest@fornode{\the\forest@node@maxid}{%
884     \forest@node@init
885     \forest@node@setname{node@\forest@cn}%
886     \forest@initializefromstandardnode
887     \edef#1{\forest@cn}%
888   }%
889 }
890 \let\forest@node@init@orig\forest@node@init

```

```

891 \def\forest@node@copy#1#2{% #1=from node id, cs receiving the new node id
892   \advance\forest@node@maxid1
893   \def\forest@node@copy#1{\forest@node@copy{#1}{#1}{#1}}%
894   \forest@node@copy{\the\forest@node@maxid}{%
895     \forest@node@init
896     \forest@node@setname{\forest@copy@name@template{\forest@node@copy{#1}{name}}}%
897     \edef#2{\forest@cn}%
898   }%
899   \let\forest@node@copy\forest@node@copy@orig
900 }
901 \forestset{
902   copy name template/.code={\def\forest@copy@name@template##1{#1}},
903   copy name template/.default={node@\the\forest@node@maxid},
904   copy name template
905 }
906 \def\forest@tree@copy#1#2{% #1=from node id, #2=cs receiving the new node id
907   \forest@node@copy{#1}\forest@node@copy@temp@id
908   \forest@node@copy{\forest@node@copy@temp@id}{%
909     \expandafter\forest@tree@copy\expandafter{\forest@node@copy@temp@id}{#1}%
910     \edef#2{\forest@cn}%
911   }%
912 }
913 \def\forest@tree@copy@#1#2{%
914   \forest@node@foreachchild{#2}{%
915     \expandafter\forest@tree@copy\expandafter{\forest@cn}\forest@node@copy@temp@childid
916     \forest@node@append{#1}{\forest@node@copy@temp@childid}%
917   }%
918 }

```

Macro `\forest@cn` holds the current node id (a number). Node 0 is a special “null” node which is used to signal the absence of a node.

```

919 \def\forest@cn{0}
920 \forest@node@init

```

10.2 Tree structure

Node insertion/removal.

For the lowercase variants, `\forest@cn` is the parent/removed node. For the uppercase variants, `#1` is the parent/removed node. For efficiency, the public macros all expand the arguments before calling the internal macros.

```

921 \def\forest@node@append#1{\expandtwonumberargs\forest@node@append{\forest@cn}{#1}}
922 \def\forest@node@prepend#1{\expandtwonumberargs\forest@node@insertafter{\forest@cn}{#1}{0}}
923 \def\forest@node@insertafter#1#2{%
924   \expandthreenumberargs\forest@node@insertafter{\forest@cn}{#1}{#2}}
925 \def\forest@node@insertbefore#1#2{%
926   \expandthreenumberargs\forest@node@insertafter{\forest@cn}{#1}{\forest@node@copy{#2}{@previous}}%
927 }
928 \def\forest@node@remove{\expandnumberarg\forest@node@remove{\forest@cn}}
929 \def\forest@node@append#1#2{\expandtwonumberargs\forest@node@append{#1}{#2}}
930 \def\forest@node@prepend#1#2{\expandtwonumberargs\forest@node@insertafter{#1}{#2}{0}}
931 \def\forest@node@insertafter#1#2#3{% #2 is inserted after #3
932   \expandthreenumberargs\forest@node@insertafter{#1}{#2}{#3}%
933 }
934 \def\forest@node@insertbefore#1#2#3{% #2 is inserted before #3
935   \expandthreenumberargs\forest@node@insertafter{#1}{#2}{\forest@node@copy{#3}{@previous}}%
936 }
937 \def\forest@node@remove#1{\expandnumberarg\forest@node@remove{#1}}
938 \def\forest@node@insertafter#1#2#3{%
939   \ifnum\forest@node@copy{#2}{@parent}=0
940   \else

```

```

941 \PackageError{forest}{Insertafter(#1,#2,#3):
942 node #2 already has a parent (\forestOve{#2}{@parent})}{}%
943 \fi
944 \ifnum#3=0
945 \else
946 \ifnum#1=\forestOve{#3}{@parent}
947 \else
948 \PackageError{forest}{Insertafter(#1,#2,#3): node #1 is not the parent of the
949 intended sibling #3 (with parent \forestOve{#3}{@parent})}{}%
950 \fi
951 \fi
952 \forestOset{#2}{@parent}{#1}%
953 \forestOset{#2}{@previous}{#3}%
954 \ifnum#3=0
955 \forestOget{#1}{@first}\forest@node@temp
956 \forestOset{#1}{@first}{#2}%
957 \else
958 \forestOget{#3}{@next}\forest@node@temp
959 \forestOset{#3}{@next}{#2}%
960 \fi
961 \forestOset{#2}{@next}{\forest@node@temp}%
962 \ifnum\forest@node@temp=0
963 \forestOset{#1}{@last}{#2}%
964 \else
965 \forestOset{\forest@node@temp}{@previous}{#2}%
966 \fi
967 }
968 \def\forest@node@Append@#1#2{%
969 \ifnum\forestOve{#2}{@parent}=0
970 \else
971 \PackageError{forest}{Append(#1,#2):
972 node #2 already has a parent (\forestOve{#2}{@parent})}{}%
973 \fi
974 \forestOset{#2}{@parent}{#1}%
975 \forestOget{#1}{@last}\forest@node@temp
976 \forestOset{#1}{@last}{#2}%
977 \forestOset{#2}{@previous}{\forest@node@temp}%
978 \ifnum\forest@node@temp=0
979 \forestOset{#1}{@first}{#2}%
980 \else
981 \forestOset{\forest@node@temp}{@next}{#2}%
982 \fi
983 }
984 \def\forest@node@Remove@#1{%
985 \forestOget{#1}{@parent}\forest@node@temp@parent
986 \ifnum\forest@node@temp@parent=0
987 \else
988 \forestOget{#1}{@previous}\forest@node@temp@previous
989 \forestOget{#1}{@next}\forest@node@temp@next
990 \ifnum\forest@node@temp@previous=0
991 \forestOset{\forest@node@temp@parent}{@first}{\forest@node@temp@next}%
992 \else
993 \forestOset{\forest@node@temp@previous}{@next}{\forest@node@temp@next}%
994 \fi
995 \ifnum\forest@node@temp@next=0
996 \forestOset{\forest@node@temp@parent}{@last}{\forest@node@temp@previous}%
997 \else
998 \forestOset{\forest@node@temp@next}{@previous}{\forest@node@temp@previous}%
999 \fi
1000 \forestOset{#1}{@parent}{0}%
1001 \forestOset{#1}{@previous}{0}%

```

```

1002 \forestOset{#1}{@next}{0}%
1003 \fi
1004 }

Looping methods.

1005 \def\forest@forthis#1{%
1006 \edef\forest@node@marshal{\unexpanded{#1}\def\noexpand\forest@cn}%
1007 \expandafter\forest@node@marshal\expandafter{\forest@cn}%
1008 }
1009 \def\forest@fornode#1#2{%
1010 \edef\forest@node@marshal{\edef\noexpand\forest@cn{#1}\unexpanded{#2}\def\noexpand\forest@cn}%
1011 \expandafter\forest@node@marshal\expandafter{\forest@cn}%
1012 }
1013 \def\forest@fornode@ifexists#1#2{%
1014 \edef\forest@node@temp{#1}%
1015 \ifnum\forest@node@temp=0
1016 \else
1017 \escapeif{\expandonumberarg\forest@fornode{\forest@node@temp}{#2}}%
1018 \fi
1019 }
1020 \def\forest@node@foreachchild#1{\forest@node@Foreachchild{\forest@cn}{#1}}
1021 \def\forest@node@Foreachchild#1#2{%
1022 \forest@fornode{\forestOve{#1}{@first}}{\forest@node@@forselfandfollowingsiblings{#2}}%
1023 }
1024 \def\forest@node@@forselfandfollowingsiblings#1{%
1025 \ifnum\forest@cn=0
1026 \else
1027 \forest@forthis{#1}%
1028 \escapeif{%
1029 \edef\forest@cn{\forestove{@next}}%
1030 \forest@node@@forselfandfollowingsiblings{#1}%
1031 }%
1032 \fi
1033 }
1034 \def\forest@node@foreach#1{\forest@node@Foreach{\forest@cn}{#1}}
1035 \def\forest@node@Foreach#1#2{%
1036 \forest@fornode{#1}{\forest@node@@foreach{#2}}%
1037 }
1038 \def\forest@node@@foreach#1{%
1039 \forest@forthis{#1}%
1040 \ifnum\forestove{@first}=0
1041 \else\escapeif{%
1042 \edef\forest@cn{\forestove{@first}}%
1043 \forest@node@@forselfandfollowingsiblings{\forest@node@@foreach{#1}}%
1044 }%
1045 \fi
1046 }
1047 \def\forest@node@foreachdescendant#1{\forest@node@Foreachdescendant{\forest@cn}{#1}}
1048 \def\forest@node@Foreachdescendant#1#2{%
1049 \forest@node@Foreachchild{#1}{%
1050 \forest@node@foreach{#2}%
1051 }%
1052 }

Compute n, n', n children and level.

1053 \def\forest@node@Compute@numeric@ts@info#1{%
1054 \forest@node@Foreach{#1}{\forest@node@@compute@numeric@ts@info}%
1055 \ifnum\forestOve{#1}{@parent}=0
1056 \else
1057 \fornode{#1}{\forest@node@@compute@numeric@ts@info@nbar}%
1058 \fi
1059 \forest@node@Foreachdescendant{#1}{\forest@node@@compute@numeric@ts@info@nbar}%

```

```

1060 }
1061 \def\forest@node@@compute@numeric@ts@info{%
1062   \forestset{n children}{0}%
1063   %
1064   \edef\forest@node@temp{\forestove{@previous}}%
1065   \ifnum\forest@node@temp=0
1066     \forestset{n}{1}%
1067   \else
1068     \forestoeset{n}{\number\numexpr\forestOve{\forest@node@temp}{n}+1}%
1069   \fi
1070   %
1071   \edef\forest@node@temp{\forestove{@parent}}%
1072   \ifnum\forest@node@temp=0
1073     \forestset{n}{0}%
1074     \forestset{n'}{0}%
1075     \forestset{level}{0}%
1076   \else
1077     \forestOset{\forest@node@temp}{n children}{%
1078       \number\numexpr\forestOve{\forest@node@temp}{n children}+1%
1079     }%
1080     \forestoeset{level}{%
1081       \number\numexpr\forestOve{\forest@node@temp}{level}+1%
1082     }%
1083   \fi
1084 }
1085 \def\forest@node@@compute@numeric@ts@info@nbar{%
1086   \forestoeset{n'}{\number\numexpr\forestOve{\forestove{@parent}}{n children}-\forestove{n}+1}%
1087 }
1088 \def\forest@node@compute@numeric@ts@info#1{%
1089   \expandnumberarg\forest@node@Compute@numeric@ts@info@{\forest@cn}%
1090 }
1091 \def\forest@node@Compute@numeric@ts@info#1{%
1092   \expandnumberarg\forest@node@Compute@numeric@ts@info@{#1}%
1093 }

```

Tree structure queries.

```

1094 \def\forest@node@rootid{%
1095   \expandnumberarg\forest@node@Rootid{\forest@cn}%
1096 }
1097 \def\forest@node@Rootid#1{% #1=node
1098   \ifnum\forestOve{#1}{@parent}=0
1099     #1%
1100   \else
1101     \@escapeif{\expandnumberarg\forest@node@Rootid{\forestOve{#1}{@parent}}}%
1102   \fi
1103 }
1104 \def\forest@node@nthchildid#1{% #1=n
1105   \ifnum#1<1
1106     0%
1107   \else
1108     \expandnumberarg\forest@node@nthchildid@{\number\forestove{@first}}{#1}%
1109   \fi
1110 }
1111 \def\forest@node@nthchildid@#1#2{%
1112   \ifnum#1=0
1113     0%
1114   \else
1115     \ifnum#2>1
1116       \@escapeifif{\expandtwonumberargs
1117         \forest@node@nthchildid@{\forestOve{#1}{@next}}{\numexpr#2-1}}%
1118     \else

```

```

1119      #1%
1120      \fi
1121      \fi
1122 }
1123 \def\forest@node@nbarthchildid#1{% #1=n
1124   \expandnumberarg\forest@node@nbarthchildid@{\number\forestove{@last}}{#1}%
1125 }
1126 \def\forest@node@nbarthchildid@#1#2{%
1127   \ifnum#1=0
1128     0%
1129   \else
1130     \ifnum#2>1
1131       \@escapeiff{\expandtwonumberargs
1132         \forest@node@nbarthchildid@{\forestove{#1}{@previous}}{\numexpr#2-1}}%
1133     \else
1134       #1%
1135     \fi
1136   \fi
1137 }
1138 \def\forest@node@nornbarthchildid#1{%
1139   \ifnum#1>0
1140     \forest@node@nthchildid{#1}%
1141   \else
1142     \ifnum#1<0
1143       \forest@node@nbarthchildid{-#1}%
1144     \else
1145       \forest@node@nornbarthchildid@error
1146     \fi
1147   \fi
1148 }
1149 \def\forest@node@nornbarthchildid@error{%
1150   \PackageError{forest}{In \string\forest@node@nornbarthchildid, n should !=0}{}%
1151 }
1152 \def\forest@node@previousleafid{%
1153   \expandnumberarg\forest@node@Previousleafid{\forest@cn}%
1154 }
1155 \def\forest@node@Previousleafid#1{%
1156   \ifnum\forestove{#1}{@previous}=0
1157     \@escapeif{\expandnumberarg\forest@node@previousleafid@Goup{#1}}%
1158   \else
1159     \expandnumberarg\forest@node@previousleafid@Gdown{\forestove{#1}{@previous}}%
1160   \fi
1161 }
1162 \def\forest@node@previousleafid@Goup#1{%
1163   \ifnum\forestove{#1}{@parent}=0
1164     \PackageError{forest}{get previous leaf: this is the first leaf}{}%
1165   \else
1166     \@escapeif{\expandnumberarg\forest@node@Previousleafid{\forestove{#1}{@parent}}}%
1167   \fi
1168 }
1169 \def\forest@node@previousleafid@Gdown#1{%
1170   \ifnum\forestove{#1}{@last}=0
1171     #1%
1172   \else
1173     \@escapeif{\expandnumberarg\forest@node@previousleafid@Gdown{\forestove{#1}{@last}}}%
1174   \fi
1175 }
1176 \def\forest@node@nextleafid{%
1177   \expandnumberarg\forest@node@Nextleafid{\forest@cn}%
1178 }
1179 \def\forest@node@Nextleafid#1{%

```

```

1180 \ifnum\forestOve{#1}{@next}=0
1181 \escapeif{\expandnumberarg\forest@node@nextleafid@Goup{#1}}%
1182 \else
1183 \expandnumberarg\forest@node@nextleafid@Gdown{\forestOve{#1}{@next}}%
1184 \fi
1185 }
1186 \def\forest@node@nextleafid@Goup#1{%
1187 \ifnum\forestOve{#1}{@parent}=0
1188 \PackageError{forest}{get next leaf: this is the last leaf}{}%
1189 \else
1190 \escapeif{\expandnumberarg\forest@node@Nextleafid{\forestOve{#1}{@parent}}}%
1191 \fi
1192 }
1193 \def\forest@node@nextleafid@Gdown#1{%
1194 \ifnum\forestOve{#1}{@first}=0
1195 #1%
1196 \else
1197 \escapeif{\expandnumberarg\forest@node@nextleafid@Gdown{\forestOve{#1}{@first}}}%
1198 \fi
1199 }
1200 \def\forest@node@linearnextid{%
1201 \ifnum\forestove{@first}=0
1202 \expandafter\forest@node@linearnextnotdescendantid
1203 \else
1204 \forestove{@first}%
1205 \fi
1206 }
1207 \def\forest@node@linearnextnotdescendantid{%
1208 \expandnumberarg\forest@node@Linearnextnotdescendantid{\forest@cn}%
1209 }
1210 \def\forest@node@Linearnextnotdescendantid#1{%
1211 \ifnum\forestOve{#1}{@next}=0
1212 \escapeif{\expandnumberarg\forest@node@Linearnextnotdescendantid{\forestOve{#1}{@parent}}}%
1213 \else
1214 \forestOve{#1}{@next}%
1215 \fi
1216 }
1217 \def\forest@node@linearpreviousid{%
1218 \ifnum\forestove{@previous}=0
1219 \forestove{@parent}%
1220 \else
1221 \forest@node@previousleafid
1222 \fi
1223 }
1224 \def\forest@ifancestorof#1{% is the current node an ancestor of #1? Yes: #2, no: #3
1225 \expandnumberarg\forest@ifancestorof{\forestOve{#1}{@parent}}%
1226 }
1227 \def\forest@ifancestorof@#1#2#3{%
1228 \ifnum#1=0
1229 \def\forest@ifancestorof@next{\@secondoftwo}%
1230 \else
1231 \ifnum\forest@cn=#1
1232 \def\forest@ifancestorof@next{\@firstoftwo}%
1233 \else
1234 \def\forest@ifancestorof@next{\expandnumberarg\forest@ifancestorof{\forestOve{#1}{@parent}}}%
1235 \fi
1236 \fi
1237 \forest@ifancestorof@next{#2}{#3}%
1238 }

```

10.3 Node walk

```

1239 \newloop\forest@nodewalk@loop
1240 \forestset{
1241   @handlers@save@currentpath/.code={%
1242     \edef\pgfkeyscurrentkey{\pgfkeyscurrentpath}%
1243     \let\forest@currentkey\pgfkeyscurrentkey
1244     \pgfkeys@split@path
1245     \edef\forest@currentpath{\pgfkeyscurrentpath}%
1246     \let\forest@currentname\pgfkeyscurrentname
1247   },
1248   /handlers/.step 0 args/.style={
1249     /forest/@handlers@save@currentpath,
1250     \forest@currentkey/.code={#1\forestset{node walk/every step}},
1251     /forest/for \forest@currentname/.style/.expanded={%
1252       for={\forest@currentname}{####1}%
1253     }
1254   },
1255   /handlers/.step 1 arg/.style={%
1256     /forest/@handlers@save@currentpath,
1257     \forest@currentkey/.code={#1\forestset{node walk/every step}},
1258     /forest/for \forest@currentname/.style 2 args/.expanded={%
1259       for={\forest@currentname=####1}{####2}%
1260     }
1261   },
1262   node walk/.code={%
1263     \forestset{%
1264       node walk/before walk,%
1265       node walk/.cd,
1266       #1,%
1267       /forest/.cd,
1268       node walk/after walk
1269     }%
1270   },
1271   for/.code 2 args={%
1272     \forest@forthis{%
1273       \pgfkeysalso{%
1274         node walk/before walk/.style={},%
1275         node walk/every step/.style={},%
1276         node walk/after walk/.style={/forest,if id=0{}{#2}},%
1277         %node walk/after walk/.style={#2},%
1278         node walk={#1}%
1279       }%
1280     }%
1281   },
1282   node walk/.cd,
1283   before walk/.code={},
1284   every step/.code={},
1285   after walk/.code={},
1286   current/.step 0 args={},
1287   current/.default=1,
1288   next/.step 0 args={\edef\forest@cn{\forestove{@next}}},
1289   next/.default=1,
1290   previous/.step 0 args={\edef\forest@cn{\forestove{@previous}}},
1291   previous/.default=1,
1292   parent/.step 0 args={\edef\forest@cn{\forestove{@parent}}},
1293   parent/.default=1,
1294   first/.step 0 args={\edef\forest@cn{\forestove{@first}}},
1295   first/.default=1,
1296   last/.step 0 args={\edef\forest@cn{\forestove{@last}}},
1297   last/.default=1,

```



```

1298 n/.step 1 arg={%
1299   \def\forest@nodewalk@temp{#1}%
1300   \ifx\forest@nodewalk@temp\pgfkeysnovalue@text
1301     \edef\forest@cn{\forest@node@nthchildid{#1}}%
1302   \else
1303     \edef\forest@cn{\forest@node@nthchildid{#1}}%
1304   \fi
1305 },
1306 n'/.step 1 arg={\edef\forest@cn{\forest@node@nbarthchildid{#1}}},
1307 sibling/.step 0 args={%
1308   \edef\forest@cn{%
1309     \ifnum\forest@previous=0
1310       \forest@node@nextleafid}%
1311   \else
1312     \forest@node@previousleafid}%
1313   \fi
1314 }%,
1315 },
1316 previous leaf/.step 0 args={\edef\forest@cn{\forest@node@previousleafid}},
1317 previous leaf/.default=1,
1318 next leaf/.step 0 args={\edef\forest@cn{\forest@node@nextleafid}},
1319 next leaf/.default=1,
1320 linear next/.step 0 args={\edef\forest@cn{\forest@node@linearnextid}},
1321 linear previous/.step 0 args={\edef\forest@cn{\forest@node@linearpreviousid}},
1322 first leaf/.step 0 args={%
1323   \forest@nodewalk@loop
1324   \edef\forest@cn{\forest@node@firstid}%
1325   \unless\ifnum\forest@previous=0
1326     \forest@nodewalk@repeat
1327   },
1328 last leaf/.step 0 args={%
1329   \forest@nodewalk@loop
1330   \edef\forest@cn{\forest@node@lastid}%
1331   \unless\ifnum\forest@previous=0
1332     \forest@nodewalk@repeat
1333   },
1334 to tier/.step 1 arg={%
1335   \def\forest@nodewalk@giventier{#1}%
1336   \forest@nodewalk@loop
1337   \forest@node@toget{tier}\forest@node@toget{tier}
1338   \unless\ifx\forest@nodewalk@tier\forest@nodewalk@giventier
1339     \forest@node@toget{parent}\forest@node@toget{parent}
1340   \forest@nodewalk@repeat
1341   },
1342 next on tier/.step 0 args={\forest@node@nextontier},
1343 next on tier/.default=1,
1344 previous on tier/.step 0 args={\forest@node@previousontier},
1345 previous on tier/.default=1,
1346 name/.step 1 arg={\edef\forest@cn{\forest@node@nametoid{#1}}},
1347 root/.step 0 args={\edef\forest@cn{\forest@node@rootid}},
1348 root'/.step 0 args={\edef\forest@cn{\forest@node@rootid}},
1349 id/.step 1 arg={\edef\forest@cn{#1}},
1350 % maybe it's not wise to have short-step sequences and names potentially clashing
1351 % .unknown/.code={%
1352 %   \forest@node@ifnamedefined{\pgfkeyscurrentname}%
1353 %     {\pgfkeysalso{name=\pgfkeyscurrentname}}%
1354 %     {\expandafter\forest@nodewalk@shortsteps\pgfkeyscurrentname\forest@nodewalk@endshortsteps}%
1355 % },
1356 .unknown/.code={%
1357   \expandafter\forest@nodewalk@shortsteps\pgfkeyscurrentname\forest@nodewalk@endshortsteps
1358 },

```

```

1359 node walk/.style={/forest/node walk={#1}},
1360 trip/.code={\forest@forthis{\pgfkeysalso{#1}}},
1361 group/.code={\forest@go{#1}\forestset{node walk/every step}},
1362 % repeat is taken later from /forest/repeat
1363 p/.style={previous=1},
1364 %n/.style={next=1}, % defined in "long" n
1365 u/.style={parent=1},
1366 s/.style={sibling},
1367 c/.style={current=1},
1368 r/.style={root},
1369 P/.style={previous leaf=1},
1370 N/.style={next leaf=1},
1371 F/.style={first leaf=1},
1372 L/.style={last leaf=1},
1373 >/.style={next on tier=1},
1374 </.style={previous on tier=1},
1375 1/.style={n=1},
1376 2/.style={n=2},
1377 3/.style={n=3},
1378 4/.style={n=4},
1379 5/.style={n=5},
1380 6/.style={n=6},
1381 7/.style={n=7},
1382 8/.style={n=8},
1383 9/.style={n=9},
1384 l/.style={last=1},
1385 %{...} is short for group={...}
1386 }
1387 \def\forest@nodewalk@nextontier{%
1388   \foresttoget{tier}\forest@nodewalk@giventier
1389   \edef\forest@cn{\forest@node@linearnextnotdescendantid}%
1390   \forest@nodewalk@loop
1391     \foresttoget{tier}\forest@nodewalk@tier
1392   \unless\ifx\forest@nodewalk@tier\forest@nodewalk@giventier
1393     \edef\forest@cn{\forest@node@linearnextid}%
1394   \forest@nodewalk@repeat
1395 }
1396 \def\forest@nodewalk@previousontier{%
1397   \foresttoget{tier}\forest@nodewalk@giventier
1398   \forest@nodewalk@loop
1399     \edef\forest@cn{\forest@node@linearpreviousid}%
1400   \foresttoget{tier}\forest@nodewalk@tier
1401   \unless\ifx\forest@nodewalk@tier\forest@nodewalk@giventier
1402   \forest@nodewalk@repeat
1403 }
1404 \def\forest@nodewalk@shortsteps{%
1405   \futurelet\forest@nodewalk@nexttoken\forest@nodewalk@shortsteps@
1406 }
1407 \def\forest@nodewalk@shortsteps@#1{%
1408   \ifx\forest@nodewalk@nexttoken\forest@nodewalk@endshortsteps
1409   \else
1410     \ifx\forest@nodewalk@nexttoken\bgroup
1411       \pgfkeysalso{group=#1}%
1412       \@escapeifif\forest@nodewalk@shortsteps
1413     \else
1414       \pgfkeysalso{#1}%
1415       \@escapeifif\forest@nodewalk@shortsteps
1416     \fi
1417   \fi
1418 }
1419 \def\forest@go#1{%

```

```

1420 {%
1421   \forestset{%
1422     node walk/before walk/.code={},%
1423     node walk/every step/.code={},%
1424     node walk/after walk/.code={},%
1425     node walk={#1}%
1426   }%
1427   \expandafter
1428 }%
1429 \expandafter\def\expandafter\forest@cn\expandafter{\forest@cn}%
1430 }

```

10.4 Node options

10.4.1 Option-declaration mechanism

Common code for declaring options.

```

1431 \def\forest@declarehandler#1#2#3{%#1=handler for specific type,#2=option name,#3=default value
1432   \pgfkeyssetvalue{/forest/#2}{#3}%
1433   \appto\forest@node@init{\forest@init{#2}}%
1434   \forest@convert@others@to@underscores{#2}\forest@pgfmathoptionname
1435   \edef\forest@marshal{%
1436     \noexpand#1{/forest/#2}{/forest}{#2}{\forest@pgfmathoptionname}%
1437   }\forest@marshal
1438 }
1439 \def\forest@def@with@pgfeov#1#2{% \pgfeov mustn't occur in the arg of the .code handler!!!
1440   \long\def#1##1\pgfeov{#2}%
1441 }

```

Option-declaration handlers.

```

1442 \newtoks\forest@temp@toks
1443 \def\forest@declare@toks@handler#1#2#3#4{%
1444   \forest@declare@toks@handler@A{#1}{#2}{#3}{#4}{}%
1445 }
1446 \def\forest@declare@keylist@handler#1#2#3#4{%
1447   \forest@declare@toks@handler@A{#1}{#2}{#3}{#4}{,}%
1448   \pgfkeysgetvalue{#1/.@cmd}\forest@temp
1449   \pgfkeyslet{#1'/.@cmd}\forest@temp
1450   \pgfkeyssetvalue{#1'/option@name}{#3}%
1451   \pgfkeysgetvalue{#1+/.@cmd}\forest@temp
1452   \pgfkeyslet{#1+/.@cmd}\forest@temp
1453 }
1454 \def\forest@declare@toks@handler@A#1#2#3#4#5{% #1=key,#2=path,#3=name,#4=pgfmathname,#5=infix
1455   \pgfkeysalso{%
1456     #1/.code={\forest@set{\forest@setter@node}{#3}{##1}},
1457     #1+/.code={\forest@appto{\forest@setter@node}{#3}{##1}},
1458     #1-/.code={\forest@preto{\forest@setter@node}{#3}{##1}},
1459     #2/if #3/.code n args={3}{%
1460       \forest@toget{#3}\forest@temp@option@value
1461       \edef\forest@temp@compared@value{\unexpanded{##1}}%
1462       \ifx\forest@temp@option@value\forest@temp@compared@value
1463         \pgfkeysalso{##2}%
1464       \else
1465         \pgfkeysalso{##3}%
1466       \fi
1467     },
1468     #2/if in #3/.code n args={3}{%
1469       \forest@toget{#3}\forest@temp@option@value
1470       \edef\forest@temp@compared@value{\unexpanded{##1}}%
1471       \expandafter\expandafter\expandafter\pgfutil@in@\expandafter\expandafter\expandafter{\expandafter\forest@temp@option@value}
1472       \ifpgfutil@in@
1473         \pgfkeysalso{##2}%

```

```

1474     \else
1475     \pgfkeysalso{##3}%
1476     \fi
1477 },
1478 #2/where #3/.style n args={3}{for tree={#2/if #3={##1}{##2}{##3}}},
1479 #2/where in #3/.style n args={3}{for tree={#2/if in #3={##1}{##2}{##3}}}%
1480 }%
1481 \pgfkeyssetvalue{#1/option@name}{#3}%
1482 \pgfkeyssetvalue{#1+/option@name}{#3}%
1483 \pgfmathdeclarefunction{#4}{1}{\forest@pgfmathhelper@attribute@toks{##1}{#3}}%
1484 }
1485 \def\forest@declareautowrappedtoks@handler#1#2#3#4{% #1=key,#2=path,#3=name,#4=pgfmathname,#5=infix
1486 \forest@declaretoks@handler{#1}{#2}{#3}{#4}%
1487 \pgfkeysgetvalue{#1/.@cmd}\forest@temp
1488 \pgfkeyslet{#1'/.@cmd}\forest@temp
1489 \pgfkeysalso{#1/.style={#1'/.wrap value={##1}}}%
1490 \pgfkeyssetvalue{#1'/option@name}{#3}%
1491 \pgfkeysgetvalue{#1+/.@cmd}\forest@temp
1492 \pgfkeyslet{#1+/.@cmd}\forest@temp
1493 \pgfkeysalso{#1+/.style={#1+/.wrap value={##1}}}%
1494 \pgfkeyssetvalue{#1+/option@name}{#3}%
1495 \pgfkeysgetvalue{#1-/.@cmd}\forest@temp
1496 \pgfkeyslet{#1-/.@cmd}\forest@temp
1497 \pgfkeysalso{#1-/.style={#1-/.wrap value={##1}}}%
1498 \pgfkeyssetvalue{#1-/option@name}{#3}%
1499 }
1500 \def\forest@declarereadonlydimen@handler#1#2#3#4{% #1=key,#2=path,#3=name,#4=pgfmathname
1501 \pgfkeysalso{%
1502 #2/if #3/.code n args={3}{%
1503 \forest@toget{#3}\forest@temp@option@value
1504 \ifdim\forest@temp@option@value=##1\relax
1505 \pgfkeysalso{##2}%
1506 \else
1507 \pgfkeysalso{##3}%
1508 \fi
1509 },
1510 #2/where #3/.style n args={3}{for tree={#2/if #3={##1}{##2}{##3}}},
1511 }%
1512 \pgfmathdeclarefunction{#4}{1}{\forest@pgfmathhelper@attribute@dimen{##1}{#3}}%
1513 }
1514 \def\forest@declaredimen@handler#1#2#3#4{% #1=key,#2=path,#3=name,#4=pgfmathname
1515 \forest@declarereadonlydimen@handler{#1}{#2}{#3}{#4}%
1516 \pgfkeysalso{%
1517 #1/.code={%
1518 \pgfmathsetlengthmacro\forest@temp{##1}%
1519 \forest@0let{\forest@setter@node}{#3}\forest@temp
1520 },
1521 #1+/.code={%
1522 \pgfmathsetlengthmacro\forest@temp{##1}%
1523 \pgfutil@tempdima=\forest@temp{#3}
1524 \advance\pgfutil@tempdima\forest@temp\relax
1525 \forest@0set{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1526 },
1527 #1-/.code={%
1528 \pgfmathsetlengthmacro\forest@temp{##1}%
1529 \pgfutil@tempdima=\forest@temp{#3}
1530 \advance\pgfutil@tempdima-\forest@temp\relax
1531 \forest@0set{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1532 },
1533 #1*/.style={%
1534 #1={#4()*{##1}}%

```

```

1535 },
1536 #1:/ .style={%
1537   #1={#4()/(#1)}%
1538 },
1539 #1'/.code={%
1540   \pgfutil@tempdima=#1\relax
1541   \forestOeset{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1542 },
1543 #1'+/.code={%
1544   \pgfutil@tempdima=\forestove{#3}\relax
1545   \advance\pgfutil@tempdima##1\relax
1546   \forestOeset{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1547 },
1548 #1'-/.code={%
1549   \pgfutil@tempdima=\forestove{#3}\relax
1550   \advance\pgfutil@tempdima-##1\relax
1551   \forestOeset{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1552 },
1553 #1'*/.style={%
1554   \pgfutil@tempdima=\forestove{#3}\relax
1555   \multiply\pgfutil@tempdima##1\relax
1556   \forestOeset{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1557 },
1558 #1':/.style={%
1559   \pgfutil@tempdima=\forestove{#3}\relax
1560   \divide\pgfutil@tempdima##1\relax
1561   \forestOeset{\forest@setter@node}{#3}{\the\pgfutil@tempdima}%
1562 },
1563 }%
1564 \pgfkeyssetvalue{#1/option@name}{#3}%
1565 \pgfkeyssetvalue{#1+/option@name}{#3}%
1566 \pgfkeyssetvalue{#1-/option@name}{#3}%
1567 \pgfkeyssetvalue{#1*/option@name}{#3}%
1568 \pgfkeyssetvalue{#1:/option@name}{#3}%
1569 \pgfkeyssetvalue{#1'/option@name}{#3}%
1570 \pgfkeyssetvalue{#1'+/option@name}{#3}%
1571 \pgfkeyssetvalue{#1'-/option@name}{#3}%
1572 \pgfkeyssetvalue{#1'*/option@name}{#3}%
1573 \pgfkeyssetvalue{#1':/option@name}{#3}%
1574 }
1575 \def\forest@declarereadonlycount@handler#1#2#3#4{% #1=key,#2=path,#3=name,#4=pgfmathname
1576   \pgfkeysalso{
1577     #2/if #3/.code n args={3}{%
1578       \forestoget{#3}\forest@temp@option@value
1579       \ifnum\forest@temp@option@value=##1\relax
1580         \pgfkeysalso{##2}%
1581       \else
1582         \pgfkeysalso{##3}%
1583       \fi
1584     },
1585     #2/where #3/.style n args={3}{for tree={#2/if #3={##1}{##2}{##3}}},
1586   }%
1587   \pgfmathdeclarefunction{#4}{1}{\forest@pgfmathhelper@attribute@count{##1}{#3}}%
1588 }
1589 \def\forest@declarecount@handler#1#2#3#4{% #1=key,#2=path,#3=name,#4=pgfmathname
1590   \forest@declarereadonlycount@handler{#1}{#2}{#3}{#4}%
1591   \pgfkeysalso{
1592     #1/.code={%
1593       \pgfmathtruncatemacro\forest@temp{##1}%
1594       \forestOlet{\forest@setter@node}{#3}\forest@temp
1595     },

```

```

1596 #1+/.code={%
1597   \pgfmathsetlengthmacro\forest@temp{##1}%
1598   \c@pgf@counta=\forestove{#3}\relax
1599   \advance\c@pgf@counta\forest@temp\relax
1600   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1601 },
1602 #1-/.code={%
1603   \pgfmathsetlengthmacro\forest@temp{##1}%
1604   \c@pgf@counta=\forestove{#3}\relax
1605   \advance\c@pgf@counta-\forest@temp\relax
1606   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1607 },
1608 #1*/.code={%
1609   \pgfmathsetlengthmacro\forest@temp{##1}%
1610   \c@pgf@counta=\forestove{#3}\relax
1611   \multiply\c@pgf@counta\forest@temp\relax
1612   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1613 },
1614 #1:/.code={%
1615   \pgfmathsetlengthmacro\forest@temp{##1}%
1616   \c@pgf@counta=\forestove{#3}\relax
1617   \divide\c@pgf@counta\forest@temp\relax
1618   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1619 },
1620 #1'/.code={%
1621   \c@pgf@counta=##1\relax
1622   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1623 },
1624 #1'+/.code={%
1625   \c@pgf@counta=\forestove{#3}\relax
1626   \advance\c@pgf@counta##1\relax
1627   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1628 },
1629 #1'-/.code={%
1630   \c@pgf@counta=\forestove{#3}\relax
1631   \advance\c@pgf@counta-##1\relax
1632   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1633 },
1634 #1'*/.style={%
1635   \c@pgf@counta=\forestove{#3}\relax
1636   \multiply\c@pgf@counta##1\relax
1637   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1638 },
1639 #1':/.style={%
1640   \c@pgf@counta=\forestove{#3}\relax
1641   \divide\c@pgf@counta##1\relax
1642   \forestOreset{\forest@setter@node}{#3}{\the\c@pgf@counta}%
1643 },
1644 }%
1645 \pgfkeyssetvalue{#1/option@name}{#3}%
1646 \pgfkeyssetvalue{#1+/option@name}{#3}%
1647 \pgfkeyssetvalue{#1-/option@name}{#3}%
1648 \pgfkeyssetvalue{#1*/option@name}{#3}%
1649 \pgfkeyssetvalue{#1:/option@name}{#3}%
1650 \pgfkeyssetvalue{#1'/option@name}{#3}%
1651 \pgfkeyssetvalue{#1'+/option@name}{#3}%
1652 \pgfkeyssetvalue{#1'-/option@name}{#3}%
1653 \pgfkeyssetvalue{#1'* /option@name}{#3}%
1654 \pgfkeyssetvalue{#1':/option@name}{#3}%
1655 }
1656 \def\forest@declareboolean@handler#1#2#3#4{% #1=key,#2=path,#3=name,#4=pgfmathname

```

```

1657 \pgfkeysalso{%
1658   #1/.code={%
1659     \ifstrequal{##1}{1}{%
1660       \forest0set{\forest@setter@node}{#3}{1}%
1661     }{%
1662       \pgfmathifthenelse{##1}{1}{0}%
1663       \forest0let{\forest@setter@node}{#3}\pgfmathresult
1664     }%
1665   },
1666   #1/.default=1,
1667   #2/not #3/.code={\forest0set{\forest@setter@node}{#3}{0}},
1668   #2/if #3/.code 2 args={%
1669     \forest0get{#3}\forest@temp@option@value
1670     \ifnum\forest@temp@option@value=1
1671       \pgfkeysalso{##1}%
1672     \else
1673       \pgfkeysalso{##2}%
1674     \fi
1675   },
1676   #2/where #3/.style 2 args={for tree={#2/if #3={##1}{##2}}}
1677 }%
1678 \pgfkeyssetvalue{#1/option@name}{#3}%
1679 \pgfmathdeclarefunction{#4}{1}{\forest@pgfmathhelper@attribute@count{##1}{#3}}%
1680 }
1681 \pgfkeys{/forest,
1682   declare toks/.code 2 args={%
1683     \forest@declarehandler\forest@declaretoks@handler{#1}{#2}%
1684   },
1685   declare autowrapped toks/.code 2 args={%
1686     \forest@declarehandler\forest@declareautowrappedtoks@handler{#1}{#2}%
1687   },
1688   declare keylist/.code 2 args={%
1689     \forest@declarehandler\forest@declarekeylist@handler{#1}{#2}%
1690   },
1691   declare readonly dimen/.code={%
1692     \forest@declarehandler\forest@declarereadonlydimen@handler{#1}{}%
1693   },
1694   declare dimen/.code 2 args={%
1695     \forest@declarehandler\forest@declaredimen@handler{#1}{#2}%
1696   },
1697   declare readonly count/.code={%
1698     \forest@declarehandler\forest@declarereadonlycount@handler{#1}{}%
1699   },
1700   declare count/.code 2 args={%
1701     \forest@declarehandler\forest@declarecount@handler{#1}{#2}%
1702   },
1703   declare boolean/.code 2 args={%
1704     \forest@declarehandler\forest@declareboolean@handler{#1}{#2}%
1705   },
1706   /handlers/.pgfmath/.code={%
1707     \pgfmathparse{#1}%
1708     \pgfkeysalso{\pgfkeyscurrentpath/.expand once=\pgfmathresult}%
1709   },
1710   /handlers/.wrap value/.code={%
1711     \edef\forest@handlers@wrap@currentpath{\pgfkeyscurrentpath}%
1712     \pgfkeysgetvalue{\forest@handlers@wrap@currentpath/option@name}\forest@currentoptionname
1713     \expandafter\forest0get\expandafter{\forest@currentoptionname}\forest@option@value
1714     \forest@def@with@pgfeov\forest@wrap@code{#1}%
1715     \expandafter\edef\expandafter\forest@wrapped@value\expandafter{\expandafter\expandonce\expandafter{\exp
1716     \pgfkeysalso{\forest@handlers@wrap@currentpath/.expand once=\forest@wrapped@value}%
1717   },

```

```

1718 /handlers/.wrap pgfmth arg/.code 2 args={%
1719   \pgfmthparse{#2}\let\forest@wrap@arg@i\pgfmthresult
1720   \edef\forest@wrap@args{{\expandonce\forest@wrap@arg@i}}%
1721   \def\forest@wrap@code##1{#1}%
1722   \expandafter\expandafter\expandafter\forest@temp@toks\expandafter\expandafter\expandafter{\expandafter\fo
1723   \pgfkeysalso{\pgfkeyscurrentpath/.expand once=\the\forest@temp@toks}%
1724 },
1725 /handlers/.wrap 2 pgfmth args/.code n args={3}{%
1726   \pgfmthparse{#2}\let\forest@wrap@arg@i\pgfmthresult
1727   \pgfmthparse{#3}\let\forest@wrap@arg@ii\pgfmthresult
1728   \edef\forest@wrap@args{{\expandonce\forest@wrap@arg@i}{\expandonce\forest@wrap@arg@ii}}%
1729   \def\forest@wrap@code##1##2{#1}%
1730   \expandafter\expandafter\expandafter\def\expandafter\expandafter\expandafter\forest@wrapped\expandafter\fo
1731   \pgfkeysalso{\pgfkeyscurrentpath/.expand once=\forest@wrapped}%
1732 },
1733 /handlers/.wrap 3 pgfmth args/.code n args={4}{%
1734   \forest@wrap@n@pgfmth@args{#2}{#3}{#4}{-}{-}{-}{-}{3}%
1735   \forest@wrap@n@pgfmth@do{#1}{3}},
1736 /handlers/.wrap 4 pgfmth args/.code n args={5}{%
1737   \forest@wrap@n@pgfmth@args{#2}{#3}{#4}{#5}{-}{-}{-}{-}{4}%
1738   \forest@wrap@n@pgfmth@do{#1}{4}},
1739 /handlers/.wrap 5 pgfmth args/.code n args={6}{%
1740   \forest@wrap@n@pgfmth@args{#2}{#3}{#4}{#5}{#6}{-}{-}{-}{5}%
1741   \forest@wrap@n@pgfmth@do{#1}{5}},
1742 /handlers/.wrap 6 pgfmth args/.code n args={7}{%
1743   \forest@wrap@n@pgfmth@args{#2}{#3}{#4}{#5}{#6}{#7}{-}{-}{6}%
1744   \forest@wrap@n@pgfmth@do{#1}{6}},
1745 /handlers/.wrap 7 pgfmth args/.code n args={8}{%
1746   \forest@wrap@n@pgfmth@args{#2}{#3}{#4}{#5}{#6}{#7}{#8}{-}{7}%
1747   \forest@wrap@n@pgfmth@do{#1}{7}},
1748 /handlers/.wrap 8 pgfmth args/.code n args={9}{%
1749   \forest@wrap@n@pgfmth@args{#2}{#3}{#4}{#5}{#6}{#7}{#8}{#9}{8}%
1750   \forest@wrap@n@pgfmth@do{#1}{8}},
1751 }
1752 \def\forest@wrap@n@pgfmth@args#1#2#3#4#5#6#7#8#9{%
1753   \pgfmthparse{#1}\let\forest@wrap@arg@i\pgfmthresult
1754   \ifnum#9>1 \pgfmthparse{#2}\let\forest@wrap@arg@ii\pgfmthresult\fi
1755   \ifnum#9>2 \pgfmthparse{#3}\let\forest@wrap@arg@iii\pgfmthresult\fi
1756   \ifnum#9>3 \pgfmthparse{#4}\let\forest@wrap@arg@iv\pgfmthresult\fi
1757   \ifnum#9>4 \pgfmthparse{#5}\let\forest@wrap@arg@v\pgfmthresult\fi
1758   \ifnum#9>5 \pgfmthparse{#6}\let\forest@wrap@arg@vi\pgfmthresult\fi
1759   \ifnum#9>6 \pgfmthparse{#7}\let\forest@wrap@arg@vii\pgfmthresult\fi
1760   \ifnum#9>7 \pgfmthparse{#8}\let\forest@wrap@arg@viii\pgfmthresult\fi
1761   \edef\forest@wrap@args{%
1762     {\expandonce\forest@wrap@arg@i}
1763     \ifnum#9>1 {\expandonce\forest@wrap@arg@ii}\fi
1764     \ifnum#9>2 {\expandonce\forest@wrap@arg@iii}\fi
1765     \ifnum#9>3 {\expandonce\forest@wrap@arg@iv}\fi
1766     \ifnum#9>4 {\expandonce\forest@wrap@arg@v}\fi
1767     \ifnum#9>5 {\expandonce\forest@wrap@arg@vi}\fi
1768     \ifnum#9>6 {\expandonce\forest@wrap@arg@vii}\fi
1769     \ifnum#9>7 {\expandonce\forest@wrap@arg@viii}\fi
1770   }%
1771 }
1772 \def\forest@wrap@n@pgfmth@do#1#2{%
1773   \ifcase#2\relax
1774   \or\def\forest@wrap@code##1{#1}%
1775   \or\def\forest@wrap@code##1##2{#1}%
1776   \or\def\forest@wrap@code##1##2##3{#1}%
1777   \or\def\forest@wrap@code##1##2##3##4{#1}%
1778   \or\def\forest@wrap@code##1##2##3##4##5{#1}%

```



```

1779 \or\def\forest@wrap@code##1##2##3##4##5##6{#1}%
1780 \or\def\forest@wrap@code##1##2##3##4##5##6##7{#1}%
1781 \or\def\forest@wrap@code##1##2##3##4##5##6##7##8{#1}%
1782 \fi
1783 \expandafter\expandafter\expandafter\def\expandafter\expandafter\expandafter\forest@wrapped\expandafter\exp
1784 \pgfkeysalso{\pgfkeyscurrentpath/.expand once=\forest@wrapped}%
1785 }

```

10.4.2 Declaring options

```

1786 \def\forest@node@setname#1{%
1787   \forestoeset{name}{#1}%
1788   \csedef{forest@id@of@#1}{\forest@cn}%
1789 }
1790 \def\forest@node@Nametoid#1{% #1 = name
1791   \csname forest@id@of@#1\endcsname
1792 }
1793 \def\forest@node@ifnamedefined#1{% #1 = name, #2=true,#3=false
1794   \ifcsname forest@id@of@#1\endcsname
1795     \expandafter\@firstoftwo
1796   \else
1797     \expandafter\@secondoftwo
1798   \fi
1799 }
1800 \def\forest@node@setalias#1{%
1801   \csedef{forest@id@of@#1}{\forest@cn}%
1802 }
1803 \def\forest@node@Setalias#1#2{%
1804   \csedef{forest@id@of@#2}{#1}%
1805 }
1806 \forestset{
1807   TeX/.code={#1},
1808   TeX'/.code={\appto\forest@externalize@loadimages{#1}#1},
1809   TeX''/.code={\appto\forest@externalize@loadimages{#1}},
1810   declare toks={name}{},
1811   name/.code={% override the default setter
1812     \forest@node@setname{#1}%
1813   },
1814   alias/.code={\forest@node@setalias{#1}},
1815   begin draw/.code={\begin{tikzpicture}},
1816   end draw/.code={\end{tikzpicture}},
1817   begin forest/.code={},
1818   end forest/.code={},
1819   declare autowrapped toks={content}{},
1820   declare count={grow}{270},
1821   TeX={% a hack for grow-reversed connection, and compass-based grow specification
1822     \pgfkeysgetvalue{/forest/grow/.@cmd}\forest@temp
1823     \pgfkeyslet{/forest/grow@@/.@cmd}\forest@temp
1824   },
1825   grow/.style={grow@={#1},reversed=0},
1826   grow'/.style={grow@={#1},reversed=1},
1827   grow''/.style={grow@={#1}},
1828   grow@/.is choice,
1829   grow@/east/.style={/forest/grow@@=0},
1830   grow@/north east/.style={/forest/grow@@=45},
1831   grow@/north/.style={/forest/grow@@=90},
1832   grow@/north west/.style={/forest/grow@@=135},
1833   grow@/west/.style={/forest/grow@@=180},
1834   grow@/south west/.style={/forest/grow@@=225},
1835   grow@/south/.style={/forest/grow@@=270},
1836   grow@/south east/.style={/forest/grow@@=315},

```

```

1837 grow@/.unknown/.code={\let\forest@temp@grow\pgfkeyscurrentname
1838 \pgfkeysalso{/forest/grow@@/.expand once=\forest@temp@grow}},
1839 declare boolean={reversed}{0},
1840 declare toks={parent anchor}{},
1841 declare toks={child anchor}{},
1842 declare toks={anchor}{base},
1843 declare toks={calign}{midpoint},
1844 TeX={%
1845 \pgfkeysgetvalue{/forest/calign/.@cmd}\forest@temp
1846 \pgfkeyslet{/forest/calign'/.@cmd}\forest@temp
1847 },
1848 calign/.is choice,
1849 calign/child/.style={calign'=child},
1850 calign/first/.style={calign'=child,calign primary child=1},
1851 calign/last/.style={calign'=child,calign primary child=-1},
1852 calign with current/.style={for parent/.wrap pgfmath arg={calign=child,calign primary child=##1}{n}},
1853 calign with current edge/.style={for parent/.wrap pgfmath arg={calign=child edge,calign primary child=##1}{n}},
1854 calign/child edge/.style={calign'=child edge},
1855 calign/midpoint/.style={calign'=midpoint},
1856 calign/center/.style={calign'=midpoint,calign primary child=1,calign secondary child=-1},
1857 calign/edge midpoint/.style={calign'=edge midpoint},
1858 calign/fixed angles/.style={calign'=fixed angles},
1859 calign/fixed edge angles/.style={calign'=fixed edge angles},
1860 calign/.unknown/.code={\PackageError{forest}{unknown calign '\pgfkeyscurrentname'}{}}},
1861 declare count={calign primary child}{1},
1862 declare count={calign secondary child}{-1},
1863 declare count={calign primary angle}{-35},
1864 declare count={calign secondary angle}{35},
1865 calign child/.style={calign primary child={#1}},
1866 calign angle/.style={calign primary angle={-#1},calign secondary angle={#1}},
1867 declare toks={tier}{},
1868 declare toks={fit}{tight},
1869 declare boolean={ignore}{0},
1870 declare boolean={ignore edge}{0},
1871 no edge/.style={edge'={},ignore edge},
1872 declare keylist={edge}{draw},
1873 declare toks={edge path}{%
1874 \noexpand\path[\forestoption{edge}]%
1875 (\forestOve{\forestove{@parent}}{name}.parent anchor)--(\forestove{name}.child anchor)\forestoption{edge
1876 triangle/.style={edge path={%
1877 \noexpand\path[\forestoption{edge}]%
1878 (\forestove{name}.north east)--(\forestOve{\forestove{@parent}}{name}.south)--(\forestove{name}.north w
1879 declare toks={edge label}{},
1880 declare boolean={phantom}{0},
1881 baseline/.style={alias={forest@baseline@node}},
1882 declare readonly count={n},
1883 declare readonly count={n'},
1884 declare readonly count={n children},
1885 declare readonly count={level},
1886 declare dimen=x{},
1887 declare dimen=y{},
1888 declare dimen={s}{0pt},
1889 declare dimen={l}{6ex}, % just in case: should be set by the calibration
1890 declare dimen={s sep}{0.6666em},
1891 declare dimen={l sep}{1ex}, % just in case: calibration!
1892 declare keylist={node options}{},
1893 declare toks={tikz}{},
1894 afterthought/.style={tikz+=#{#1}},
1895 label/.style={tikz={\path[late options={%
1896 name=\forestoption{name},label={#1}}];}},
1897 pin/.style={tikz={\path[late options={%

```

```

1898     name=\forestoption{name},pin={#1}}];}},
1899 declare toks={content format}{\forestoption{content}},
1900 math content/.style={content format={\ensuremath{\forestoption{content}}}},
1901 declare toks={node format}{%
1902   \noexpand\node
1903   [\forestoption{node options},anchor=\forestoption{anchor}]%
1904   (\forestoption{name})%
1905   {\forestoption{content format}};%
1906 },
1907 tabular@environment/.style={content format={%
1908   \noexpand\begin{tabular}[\forestoption{base}]{\forestoption{align}}%
1909   \forestoption{content}%
1910   \noexpand\end{tabular}%
1911 }},
1912 declare toks={align}{},
1913 TeX={\pgfkeysgetvalue{/forest/align/.@cmd}\forest@temp
1914   \pgfkeyslet{/forest/align'/.@cmd}\forest@temp},
1915 align/.is choice,
1916 align/.unknown/.code={%
1917   \edef\forest@marshal{%
1918     \noexpand\pgfkeysalso{%
1919       align'={\pgfkeyscurrentname},%
1920       tabular@environment
1921     }%
1922   }\forest@marshal
1923 },
1924 align/center/.style={align'={@{}c@{}}},tabular@environment},
1925 align/left/.style={align'={@{}l@{}}},tabular@environment},
1926 align/right/.style={align'={@{}r@{}}},tabular@environment},
1927 declare toks={base}{t},
1928 TeX={\pgfkeysgetvalue{/forest/base/.@cmd}\forest@temp
1929   \pgfkeyslet{/forest/base'/.@cmd}\forest@temp},
1930 base/.is choice,
1931 base/top/.style={base'=t},
1932 base/bottom/.style={base'=b},
1933 base/.unknown/.style={base'/.expand once=\pgfkeyscurrentname},
1934 .unknown/.code={%
1935   \expandafter\pgfutil@in@\expandafter.\expandafter{\pgfkeyscurrentname}%
1936   \ifpgfutil@in@
1937     \expandafter\forest@relatednode@option@setter\pgfkeyscurrentname=#1\forest@END
1938   \else
1939     \edef\forest@marshal{%
1940       \noexpand\pgfkeysalso{node options={\pgfkeyscurrentname=\unexpanded{#1}}}%
1941     }\forest@marshal
1942   \fi
1943 },
1944 get node boundary/.code={%
1945   \foresttoget{boundary}\forest@node@boundary
1946   \def#1{%
1947     \forest@extendpath#1\forest@node@boundary{\pgfpoint{\forestove{x}}{\forestove{y}}}%
1948   },
1949 % get min l tree boundary/.code={%
1950 %   \forest@get@tree@boundary{negative}{\the\numexpr\forestove{grow}-90\relax}#1},
1951 % get max l tree boundary/.code={%
1952 %   \forest@get@tree@boundary{positive}{\the\numexpr\forestove{grow}-90\relax}#1},
1953 get min s tree boundary/.code={%
1954   \forest@get@tree@boundary{negative}{\forestove{grow}}#1},
1955 get max s tree boundary/.code={%
1956   \forest@get@tree@boundary{positive}{\forestove{grow}}#1},
1957 fit to tree/.code={%
1958   \pgfkeysalso{%

```

```

1959     /forest/get min s tree boundary=\forest@temp@negative@boundary,
1960     /forest/get max s tree boundary=\forest@temp@positive@boundary
1961 }%
1962 \edef\forest@temp@boundary{\expandonce{\forest@temp@negative@boundary}\expandonce{\forest@temp@positive@b
1963 \forest@path@getboundingrectangle@xy\forest@temp@boundary
1964 \pgfkeysalso{inner sep=0,fit/.expanded={(\the\pgf@xa,\the\pgf@ya)(\the\pgf@xb,\the\pgf@yb)}}}%
1965 },
1966 use as bounding box/.style={%
1967     before drawing tree={
1968         tikz+/.expanded={%
1969             \noexpand\pgfresetboundingbox
1970             \noexpand\useasboundingbox
1971             ($(.anchor)+(\forestoption{min x},\forestoption{min y}))$)
1972             rectangle
1973             ($(.anchor)+(\forestoption{max x},\forestoption{max y}))$)
1974         };
1975     }
1976 }
1977 },
1978 use as bounding box'/.style={%
1979     before drawing tree={
1980         tikz+/.expanded={%
1981             \noexpand\pgfresetboundingbox
1982             \noexpand\useasboundingbox
1983             ($(.anchor)+(\forestoption{min x}+\pgfkeysvalueof{/pgf/outer xsep}/2+\pgfkeysvalueof{/pgf/inner xsep}
1984             rectangle
1985             ($(.anchor)+(\forestoption{max x}-\pgfkeysvalueof{/pgf/outer xsep}/2-\pgfkeysvalueof{/pgf/inner xsep}
1986         );
1987     }
1988 }
1989 },
1990 }%
1991 \def\forest@get@tree@boundary#1#2#3{%#1=pos/neg,#2=grow,#3=receiving cs
1992 \def#3{}}%
1993 \forest@node@getedge{#1}{#2}\forest@temp@boundary
1994 \forest@extendpath#3\forest@temp@boundary{\pgfpoint{\forestove{x}}{\forestove{y}}}%
1995 }
1996 \def\forest@setter@node{\forest@cn}%
1997 \def\forest@relatednode@option@setter#1.#2=#3\forest@END{%
1998 \forest@forthis{%
1999     \forest@nameandgo{#1}%
2000     \let\forest@setter@node\forest@cn
2001 }%
2002 \pgfkeysalso{#2={#3}}%
2003 \def\forest@setter@node{\forest@cn}%
2004 }%

```

10.4.3 Option propagation

The propagators targeting single nodes are automatically defined by node walk steps definitions.

```

2005 \forestset{
2006     for tree/.code={\forest@node@foreach{\pgfkeysalso{#1}}},
2007     if/.code n args={3}{%
2008         \pgfmathparse{#1}%
2009         \ifnum\pgfmathresult=0 \pgfkeysalso{#3}\else\pgfkeysalso{#2}\fi
2010     },
2011     where/.style n args={3}{for tree={if={#1}{#2}{#3}}},
2012     for descendants/.code={\forest@node@foreachdescendant{\pgfkeysalso{#1}}},
2013     for all next/.style={for next={#1,for all next={#1}}},
2014     for all previous/.style={for previous={#1,for all previous={#1}}},
2015     for siblings/.style={for all previous={#1,for all next={#1}},

```

```

2016 for ancestors/.style={for parent={#1,for ancestors={#1}}},
2017 for ancestors'/.style={#1,for ancestors={#1}},
2018 for children/.code={\forest@node@foreachchild{\pgfkeysalso{#1}}},
2019 for c-commanded={for sibling={for tree={#1}}},
2020 for c-commanders={for sibling={#1},for parent={for c-commanders={#1}}}
2021 }

```

A bit of complication to allow for nested repeats without \TeX groups.

```

2022 \newcount\forest@repeat@key@depth
2023 \forestset{%
2024   repeat/.code 2 args={%
2025     \advance\forest@repeat@key@depth1
2026     \pgfmathparse{int(#1)}%
2027     \csedef{forest@repeat@key@the\forest@repeat@key@depth}{\pgfmathresult}%
2028     \expandafter\newloop\csname forest@repeat@key@loop@the\forest@repeat@key@depth\endcsname
2029     \def\forest@marshal{%
2030       \csname forest@repeat@key@loop@the\forest@repeat@key@depth\endcsname
2031       \forest@temp@count=\csname forest@repeat@key@the\forest@repeat@key@depth\endcsname\relax
2032       \ifnum\forest@temp@count>0
2033         \advance\forest@temp@count-1
2034         \csedef{forest@repeat@key@the\forest@repeat@key@depth}{\the\forest@temp@count}%
2035         \pgfkeysalso{#2}%
2036       }%
2037       \expandafter\forest@marshal\csname forest@repeat@key@repeat@the\forest@repeat@key@depth\endcsname
2038       \advance\forest@repeat@key@depth-1
2039     },
2040   }
2041   \pgfkeysgetvalue{/forest/repeat/.@cmd}\forest@temp
2042   \pgfkeyslet{/forest/node walk/repeat/.@cmd}\forest@temp
2043 %

```

10.4.4 pgfmath extensions

```

2044 \pgfmathdeclarefunction{strequal}{2}{%
2045   \ifstrequal{#1}{#2}{\def\pgfmathresult{1}}{\def\pgfmathresult{0}}%
2046 }
2047 \pgfmathdeclarefunction{instr}{2}{%
2048   \pgfutil@in@{#1}{#2}%
2049   \ifpgfutil@in@\def\pgfmathresult{1}\else\def\pgfmathresult{0}\fi
2050 }
2051 \pgfmathdeclarefunction{strcat}{...}{%
2052   \edef\pgfmathresult{\forest@strip@braces{#1}}%
2053 }
2054 \def\forest@pgfmathhelper@attribute@toks#1#2{%
2055   \forest@forthis{%
2056     \forest@nameandgo{#1}%
2057     \forest@toget{#2}\pgfmathresult
2058   }%
2059 }
2060 \def\forest@pgfmathhelper@attribute@dimen#1#2{%
2061   \forest@forthis{%
2062     \forest@nameandgo{#1}%
2063     \forest@toget{#2}\forest@temp
2064     \pgfmathparse{+\forest@temp}%
2065   }%
2066 }
2067 \def\forest@pgfmathhelper@attribute@count#1#2{%
2068   \forest@forthis{%
2069     \forest@nameandgo{#1}%
2070     \forest@toget{#2}\forest@temp
2071     \pgfmathtruncatemacro\pgfmathresult{\forest@temp}%

```

```

2072 }%
2073 }
2074 \pgfmathdeclarefunction{id}{1}{%
2075   \forest@forthis{%
2076     \forest@nameandgo{#1}%
2077     \let\pgfmathresult\forest@cn
2078   }%
2079 }
2080 \forestset{%
2081   if id/.code n args={3}{%
2082     \ifnum#1=\forest@cn\relax
2083       \pgfkeysalso{#2}%
2084     \else
2085       \pgfkeysalso{#3}%
2086     \fi
2087   },
2088   where id/.style n args={3}{for tree={if id={#1}{#2}{#3}}}
2089 }

```

10.5 Dynamic tree

```

2090 \def\forest@last@node{0}
2091 \def\forest@nodehandleby@name@nodewalk@or@bracket#1{%
2092   \ifx\pgfkeysnovalue#1%
2093     \edef\forest@last@node{\forest@node@Nametoid{forest@last@node}}%
2094   \else
2095     \forest@nodehandleby@nnb@checkfirst#1\forest@END
2096   \fi
2097 }
2098 \def\forest@nodehandleby@nnb@checkfirst#1#2\forest@END{%
2099   \ifx[#1%
2100     \forest@create@node{#1#2}%
2101   \else
2102     \forest@forthis{%
2103       \forest@nameandgo{#1#2}%
2104       \let\forest@last@node\forest@cn
2105     }%
2106   \fi
2107 }
2108 \def\forest@create@node#1{% #1=bracket representation
2109   \bracketParse{\forest@create@collectafterthought}%
2110   \forest@last@node=#1\forest@end@create@node
2111 }
2112 \def\forest@create@collectafterthought#1\forest@end@create@node{%
2113   \forest@let0{\forest@last@node}{delay}{\forest@last@node}{given options}%
2114   \forest@set{\forest@last@node}{given options}{}%
2115   \forest@eappto{\forest@last@node}{delay}{,\unexpanded{#1}}%
2116 }
2117 \def\forest@create@collectafterthought#1\forest@end@create@node{%
2118   \forest@node@Foreach{\forest@last@node}{%
2119     \forest@tolet0{delay}{given options}%
2120     \forest@set{given options}{}%
2121   }%
2122   \forest@eappto{\forest@last@node}{delay}{,\unexpanded{#1}}%
2123 }
2124 \def\forest@remove@node#1{%
2125   \forest@node@Remove{#1}%
2126 }
2127 \def\forest@append@node#1#2{%
2128   \forest@node@Remove{#2}%
2129   \forest@node@Append{#1}{#2}%

```

```

2130 }
2131 \def\forest@prepend@node#1#2{%
2132   \forest@node@Remove{#2}%
2133   \forest@node@Prepend{#1}{#2}%
2134 }
2135 \def\forest@insertafter@node#1#2{%
2136   \forest@node@Remove{#2}%
2137   \forest@node@Insertafter{\forest@ve{#1}{@parent}}{#2}{#1}%
2138 }
2139 \def\forest@insertbefore@node#1#2{%
2140   \forest@node@Remove{#2}%
2141   \forest@node@Insertbefore{\forest@ve{#1}{@parent}}{#2}{#1}%
2142 }
2143 \def\forest@appto@do@ynamics#1#2{%
2144   \forest@nodehandleby@name@nodewalk@or@bracket{#2}%
2145   \ifcase\forest@dynamics@copyhow\relax\or
2146     \forest@tree@copy{\forest@last@node}\forest@last@node
2147   \or
2148     \forest@node@copy{\forest@last@node}\forest@last@node
2149   \fi
2150   \forest@node@ifnamedefined{\forest@last@node}{%
2151     \forest@preto{\forest@last@node}{delay}
2152     {for id={\forest@node@Nametoid{\forest@last@node}}{alias=\forest@last@node},}%
2153   }{%
2154     \forest@havedelayedoptionstrue
2155     \edef\forest@marshal{%
2156       \noexpand\apptotoks\noexpand\forest@do@ynamics{%
2157         \noexpand#1{\forest@cn}{\forest@last@node}}%
2158     }\forest@marshal
2159 }
2160 \forestset{%
2161   create/.code={\forest@create@node{#1}},
2162   append/.code={\def\forest@dynamics@copyhow{0}\forest@appto@do@ynamics\forest@append@node{#1}},
2163   prepend/.code={\def\forest@dynamics@copyhow{0}\forest@appto@do@ynamics\forest@prepend@node{#1}},
2164   insert after/.code={\def\forest@dynamics@copyhow{0}\forest@appto@do@ynamics\forest@insertafter@node{#1}},
2165   insert before/.code={\def\forest@dynamics@copyhow{0}\forest@appto@do@ynamics\forest@insertbefore@node{#1}},
2166   append'/.code={\def\forest@dynamics@copyhow{1}\forest@appto@do@ynamics\forest@append@node{#1}},
2167   prepend'/.code={\def\forest@dynamics@copyhow{1}\forest@appto@do@ynamics\forest@prepend@node{#1}},
2168   insert after'/.code={\def\forest@dynamics@copyhow{1}\forest@appto@do@ynamics\forest@insertafter@node{#1}},
2169   insert before'/.code={\def\forest@dynamics@copyhow{1}\forest@appto@do@ynamics\forest@insertbefore@node{#1}},
2170   append''/.code={\def\forest@dynamics@copyhow{2}\forest@appto@do@ynamics\forest@append@node{#1}},
2171   prepend''/.code={\def\forest@dynamics@copyhow{2}\forest@appto@do@ynamics\forest@prepend@node{#1}},
2172   insert after''/.code={\def\forest@dynamics@copyhow{2}\forest@appto@do@ynamics\forest@insertafter@node{#1}},
2173   insert before''/.code={\def\forest@dynamics@copyhow{2}\forest@appto@do@ynamics\forest@insertbefore@node{#1}},
2174   remove/.code={%
2175     \pgfkeysalso{alias=\forest@last@node}%
2176     \expandafter\apptotoks\expandafter\forest@do@ynamics\expandafter{%
2177       \expandafter\forest@remove@node\expandafter{\forest@cn}}%
2178   },
2179   set root/.code={%
2180     \forest@nodehandleby@name@nodewalk@or@bracket{#1}%
2181     \edef\forest@marshal{%
2182       \noexpand\apptotoks\noexpand\forest@do@ynamics{%
2183         \def\noexpand\forest@root{\forest@last@node}%
2184       }%
2185     }\forest@marshal
2186   },
2187   replace by/.code={\forest@replaceby@code{#1}{insert after}},
2188   replace by'/.code={\forest@replaceby@code{#1}{insert after'}},
2189   replace by''/.code={\forest@replaceby@code{#1}{insert after''}},
2190 }

```

```

2191 \def\forest@replaceby@code#1#2{%#1=node spec,#2=insert after['']['']}
2192 \ifnum\forest@ve{\parent}=0
2193   \pgfkeysalso{set root={#1}}%
2194 \else
2195   \pgfkeysalso{alias=forest@last@node,#2={#1}}%
2196   \eapptotoks\forest@do@ynamics{%
2197     \noexpand\ifnum\noexpand\forest@ve{\forest@cn}{\parent}=\forest@ve{\parent}
2198     \noexpand\forest@remove@node{\forest@cn}%
2199     \noexpand\fi
2200   }%
2201 \fi
2202 }

```

11 Stages

```

2203 \forestset{
2204   stages/.style={
2205     process keylist=before typesetting nodes,
2206     typeset nodes stage,
2207     process keylist=before packing,
2208     pack stage,
2209     process keylist=before computing xy,
2210     compute xy stage,
2211     process keylist=before drawing tree,
2212     draw tree stage,
2213   },
2214   typeset nodes stage/.style={for root'=typeset nodes},
2215   pack stage/.style={for root'=pack},
2216   compute xy stage/.style={for root'=compute xy},
2217   draw tree stage/.style={for root'=draw tree},
2218   process keylist/.code={\forest@process@hook@keylist{#1}},
2219   declare keylist={given options}{},
2220   declare keylist={before typesetting nodes}{},
2221   declare keylist={before packing}{},
2222   declare keylist={before computing xy}{},
2223   declare keylist={before drawing tree}{},
2224   declare keylist={delay}{},
2225   delay/.append code={\forest@havedelayedoptionstrue},
2226   delay n/.style 2 args={if={#1==0}{#2}{delay@n={#1}{#2}}},
2227   delay@n/.style 2 args={
2228     if={#1==1}{delay={#2}}{delay={delay@n/.wrap pgfmath arg={{##1}{#2}}{#1-1}}}
2229   },
2230   if have delayed/.code 2 args={%
2231     \ifforest@havedelayedoptions\pgfkeysalso{#1}\else\pgfkeysalso{#2}\fi
2232   },
2233   typeset nodes/.code={%
2234     \forest@drawtree@preservenodeboxes@false
2235     \forest@node@foreach{\forest@node@typeset}},
2236   typeset nodes'/.code={%
2237     \forest@drawtree@preservenodeboxes@true
2238     \forest@node@foreach{\forest@node@typeset}},
2239   typeset node/.code={%
2240     \forest@drawtree@preservenodeboxes@false
2241     \forest@node@typeset
2242   },
2243   pack/.code={\forest@pack},
2244   pack'/.code={\forest@pack@onlythisnode},
2245   compute xy/.code={\forest@node@computeabsolute positions},
2246   draw tree box/.store in=\forest@drawtreebox,
2247   draw tree box,
2248   draw tree/.code={%

```



```

2249 \forest@drawtree@preservenodeboxes@false
2250 \forest@node@drawtree
2251 },
2252 draw tree'/.code={%
2253 \forest@drawtree@preservenodeboxes@true
2254 \forest@node@drawtree
2255 },
2256 }
2257 \newtoks\forest@do@ dynamics
2258 \newif\ifforest@havedelayedoptions
2259 \def\forest@process@hook@keylist#1{%
2260 \forest@loopa
2261 \forest@havedelayedoptionsfalse
2262 \forest@do@ dynamics={}%
2263 \forest@for node{\forest@root}{\forest@process@hook@keylist@{#1}}%
2264 \expandafter\ifstreempty\expandafter{\the\forest@do@ dynamics}{}%
2265 \the\forest@do@ dynamics
2266 \forest@node@Compute@numeric@ts@info{\forest@root}%
2267 \forest@havedelayedoptionstrue
2268 }%
2269 \ifforest@havedelayedoptions
2270 \forest@node@Foreach{\forest@root}{%
2271 \forest@toget{delay}\forest@temp@delayed
2272 \forest@tolet{#1}\forest@temp@delayed
2273 \forest@set{delay}{}%
2274 }%
2275 \forest@repeata
2276 }
2277 \def\forest@process@hook@keylist@#1{%
2278 \forest@node@foreach{%
2279 \forest@toget{#1}\forest@temp@keys
2280 \ifdefined\forest@temp@keys}{}%
2281 \forest@set{#1}{}%
2282 \expandafter\forest@set\expandafter{\forest@temp@keys}%
2283 }%
2284 }%
2285 }

```

11.1 Typesetting nodes

```

2286 \def\forest@node@typeset{%
2287 \let\forest@next\forest@node@typeset@
2288 \forest@ifdefined{box}{%
2289 \ifforest@drawtree@preservenodeboxes@
2290 \let\forest@next\relax
2291 \fi
2292 }{%
2293 \locbox\forest@temp@box
2294 \forest@tolet{box}\forest@temp@box
2295 }%
2296 \def\forest@node@typeset@restore{%
2297 \ifdefined\ifsa@tikz\forest@standalone@hack\fi
2298 \forest@next
2299 \forest@node@typeset@restore
2300 }
2301 \def\forest@standalone@hack{%
2302 \ifsa@tikz
2303 \let\forest@standalone@tikzpicture\tikzpicture
2304 \let\forest@standalone@endtikzpicture\endtikzpicture
2305 \let\tikzpicture\sa@orig@tikzpicture
2306 \let\endtikzpicture\sa@orig@endtikzpicture

```

```

2307 \def\forest@node@typeset@restore{%
2308 \let\tikzpicture\forest@standalone@tikzpicture
2309 \let\endtikzpicture\forest@standalone@endtikzpicture
2310 }%
2311 \fi
2312 }
2313 \newbox\forest@box
2314 \def\forest@node@typeset@{%
2315 \forest@get{name}\forest@nodename
2316 \edef\forest@temp@nodeformat{\forest@v{node format}}%
2317 \gdef\forest@smuggle{%
2318 \setbox0=\hbox{%
2319 \begin{tikzpicture}%
2320 \pgfpositionnodelater{\forest@positionnodelater@save}%
2321 \forest@temp@nodeformat
2322 \pgfinterruptpath
2323 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{\forest@computenodeboundary}%
2324 \endpgfinterruptpath
2325 %\forest@compute@node@boundary\forest@temp
2326 %\xappto\forest@smuggle{\noexpand\forest@set{boundary}{\expandafter\forest@temp}}%
2327 \if\relax\forest@v{parent anchor}\relax
2328 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{center}%
2329 \else
2330 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{\forest@v{parent anchor}}%
2331 \fi
2332 \xappto\forest@smuggle{%
2333 \noexpand\forest@set{parent@anchor}{%
2334 \noexpand\noexpand\noexpand\pgf@x=\the\pgf@x\relax
2335 \noexpand\noexpand\noexpand\pgf@y=\the\pgf@y\relax}}%
2336 \if\relax\forest@v{child anchor}\relax
2337 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{center}%
2338 \else
2339 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{\forest@v{child anchor}}%
2340 \fi
2341 \xappto\forest@smuggle{%
2342 \noexpand\forest@set{child@anchor}{%
2343 \noexpand\noexpand\noexpand\pgf@x=\the\pgf@x\relax
2344 \noexpand\noexpand\noexpand\pgf@y=\the\pgf@y\relax}}%
2345 \if\relax\forest@v{anchor}\relax
2346 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{center}%
2347 \else
2348 \pgfpointanchor{\forest@pgf@notyetpositioned\forest@nodename}{\forest@v{anchor}}%
2349 \fi
2350 \xappto\forest@smuggle{%
2351 \noexpand\forest@set{@anchor}{%
2352 \noexpand\noexpand\noexpand\pgf@x=\the\pgf@x\relax
2353 \noexpand\noexpand\noexpand\pgf@y=\the\pgf@y\relax}}%
2354 \end{tikzpicture}%
2355 }%
2356 \setbox\forest@v{box}=\box\forest@box % smuggle the box
2357 \forest@let{boundary}\forest@global@boundary
2358 \forest@smuggle % ... and the rest
2359 }
2360 \forestset{
2361 declare readonly dimen={min x},
2362 declare readonly dimen={min y},
2363 declare readonly dimen={max x},
2364 declare readonly dimen={max y},
2365 }
2366 \def\forest@patch@enormouscoordinateboxbounds@plus#1{%
2367 \expandafter\ifstrequal\expandafter{#1}{16000.0pt}{\def#1{0.0pt}}}%

```

```

2368 }
2369 \def\forest@patch@enormouscoordinateboxbounds@minus#1{%
2370   \expandafter\ifstrequal\expandafter{#1}{-16000.0pt}{\def#1{0.0pt}}{}}%
2371 }
2372 \def\forest@positionnodelater@save{%
2373   \global\setbox\forest@box=\box\pgfpositionnodelaterbox
2374   \xappto\forest@smuggle{\noexpand\forestoset{later@name}{\pgfpositionnodelatername}}%
2375   % a bug in pgf? ---well, here's a patch
2376   \forest@patch@enormouscoordinateboxbounds@plus\pgfpositionnodelaterminx
2377   \forest@patch@enormouscoordinateboxbounds@plus\pgfpositionnodelaterminy
2378   \forest@patch@enormouscoordinateboxbounds@minus\pgfpositionnodelatermaxx
2379   \forest@patch@enormouscoordinateboxbounds@minus\pgfpositionnodelatermaxy
2380   % end of patch
2381   \xappto\forest@smuggle{\noexpand\forestoset{min x}{\pgfpositionnodelaterminx}}%
2382   \xappto\forest@smuggle{\noexpand\forestoset{min y}{\pgfpositionnodelaterminy}}%
2383   \xappto\forest@smuggle{\noexpand\forestoset{max x}{\pgfpositionnodelatermaxx}}%
2384   \xappto\forest@smuggle{\noexpand\forestoset{max y}{\pgfpositionnodelatermaxy}}%
2385 }
2386 \def\forest@node@forest@positionnodelater@restore{%
2387   \ifforest@drawtree@preservenodeboxes@
2388     \let\forest@boxorcopy\copy
2389   \else
2390     \let\forest@boxorcopy\box
2391   \fi
2392   \forestoget{box}\forest@temp
2393   \setbox\pgfpositionnodelaterbox=\forest@boxorcopy\forest@temp
2394   \edef\pgfpositionnodelatername{\forestove{later@name}}%
2395   \edef\pgfpositionnodelaterminx{\forestove{min x}}%
2396   \edef\pgfpositionnodelaterminy{\forestove{min y}}%
2397   \edef\pgfpositionnodelatermaxx{\forestove{max x}}%
2398   \edef\pgfpositionnodelatermaxy{\forestove{max y}}%
2399 }

```

11.2 Packing

Method `pack` should be called to calculate the positions of descendant nodes; the positions are stored in attributes `l` and `s` of these nodes, in a level/sibling coordinate system with origin at the parent's anchor.

```

2400 \def\forest@pack{%
2401   \forest@pack@computetiers
2402   \forest@pack@computegrowthuniformity
2403   \forest@@pack
2404 }
2405 \def\forest@@pack{%
2406   \ifnum\forestove{n children}>0
2407     \ifnum\forestove{uniform growth}>0
2408       \forest@pack@level@uniform
2409       \forest@pack@aligntiers@ofsubtree
2410       \forest@pack@sibling@uniform@recursive
2411     \else
2412       \forest@node@foreachchild{\forest@@pack}%
2413       \forest@pack@level@nonuniform
2414       \forest@pack@aligntiers
2415       \forest@pack@sibling@uniform@applyreversed
2416     \fi
2417   \fi
2418 }
2419 \def\forest@pack@onlythisnode{%
2420   \ifnum\forestove{n children}>0
2421     \forest@pack@computetiers
2422     \forest@pack@level@nonuniform
2423     \forest@pack@aligntiers

```

```

2424 \forest@pack@sibling@uniform@applyreversed
2425 \fi
2426 }

```

Compute growth uniformity for the subtree. A tree grows uniformly if all its branching nodes have the same grow.

```

2427 \def\forest@pack@computegrowthuniformity{%
2428 \forest@node@foreachchild{\forest@pack@computegrowthuniformity}%
2429 \edef\forest@pack@cgu@uniformity{%
2430 \ifnum\forestove{n children}=0
2431 2\else 1\fi
2432 }%
2433 \forestoget{grow}\forest@pack@cgu@parentgrow
2434 \forest@node@foreachchild{%
2435 \ifnum\forestove{uniform growth}=0
2436 \def\forest@pack@cgu@uniformity{0}%
2437 \else
2438 \ifnum\forestove{uniform growth}=1
2439 \ifnum\forestove{grow}=\forest@pack@cgu@parentgrow\relax\else
2440 \def\forest@pack@cgu@uniformity{0}%
2441 \fi
2442 \fi
2443 \fi
2444 }%
2445 \forestolet{uniform growth}\forest@pack@cgu@uniformity
2446 }

```

Pack children in the level dimension in a uniform tree.

```

2447 \def\forest@pack@level@uniform{%
2448 \let\forest@plu@minchildl\relax
2449 \forestoget{grow}\forest@plu@grow
2450 \forest@node@foreachchild{%
2451 \forest@node@getboundingrectangle@ls{\forest@plu@grow}%
2452 \advance\pgf@xa\forestove{l}\relax
2453 \ifx\forest@plu@minchildl\relax
2454 \edef\forest@plu@minchildl{\the\pgf@xa}%
2455 \else
2456 \ifdim\pgf@xa<\forest@plu@minchildl\relax
2457 \edef\forest@plu@minchildl{\the\pgf@xa}%
2458 \fi
2459 \fi
2460 }%
2461 \forest@node@getboundingrectangle@ls{\forest@plu@grow}%
2462 \pgfutil@tempdima=\pgf@xb\relax
2463 \advance\pgfutil@tempdima -\forest@plu@minchildl\relax
2464 \advance\pgfutil@tempdima \forestove{l sep}\relax
2465 \ifdim\pgfutil@tempdima>0pt
2466 \forest@node@foreachchild{%
2467 \forestoeset{l}{\the\dimexpr\forestove{l}+\the\pgfutil@tempdima}%
2468 }%
2469 \fi
2470 \forest@node@foreachchild{%
2471 \ifnum\forestove{n children}>0
2472 \forest@pack@level@uniform
2473 \fi
2474 }%
2475 }

```

Pack children in the level dimension in a non-uniform tree. (Expects the children to be fully packed.)

```

2476 \def\forest@pack@level@nonuniform{%
2477 \let\forest@plu@minchildl\relax
2478 \forestoget{grow}\forest@plu@grow

```

```

2479 \forest@node@foreachchild{%
2480   \forest@node@getedge{negative}{\forest@plu@grow}{\forest@plnu@negativechildedge}%
2481   \forest@node@getedge{positive}{\forest@plu@grow}{\forest@plnu@positivechildedge}%
2482   \def\forest@plnu@childedge{\forest@plnu@negativechildedge\forest@plnu@positivechildedge}%
2483   \forest@path@getboundingrectangle@ls\forest@plnu@childedge{\forest@plu@grow}%
2484   \advance\pgf@xa\forestove{1}\relax
2485   \ifx\forest@plu@minchildl\relax
2486     \edef\forest@plu@minchildl{\the\pgf@xa}%
2487   \else
2488     \ifdim\pgf@xa<\forest@plu@minchildl\relax
2489       \edef\forest@plu@minchildl{\the\pgf@xa}%
2490     \fi
2491   \fi
2492 }%
2493 \forest@node@getboundingrectangle@ls{\forest@plu@grow}%
2494 \pgfutil@tempdima=\pgf@xb\relax
2495 \advance\pgfutil@tempdima -\forest@plu@minchildl\relax
2496 \advance\pgfutil@tempdima \forestove{1 sep}\relax
2497 \ifdim\pgfutil@tempdima>0pt
2498   \forest@node@foreachchild{%
2499     \forestoeset{1}{\the\dimexpr\the\pgfutil@tempdima+\forestove{1}}%
2500   }%
2501 \fi
2502 }

```

Align tiers.

```

2503 \def\forest@pack@aligntiers{%
2504   \forestoget{grow}\forest@temp@parentgrow
2505   \forestoget{@tiers}\forest@temp@tiers
2506   \forlistloop\forest@pack@aligntier@\forest@temp@tiers
2507 }
2508 \def\forest@pack@aligntiers@ofsubtree{%
2509   \forest@node@foreach{\forest@pack@aligntiers}%
2510 }
2511 \def\forest@pack@aligntiers@computeabs1{%
2512   \forestoleto{abs@1}{1}%
2513   \forest@node@foreachdescendant{\forest@pack@aligntiers@computeabs1}%
2514 }
2515 \def\forest@pack@aligntiers@computeabs1@{%
2516   \forestoeset{abs@1}{\the\dimexpr\forestove{1}+\forestove{\forestove{@parent}}{abs@1}}%
2517 }
2518 \def\forest@pack@aligntier@#1{%
2519   \forest@pack@aligntiers@computeabs1
2520   \pgfutil@tempdima=-\maxdimen\relax
2521   \def\forest@temp@currenttier{#1}%
2522   \forest@node@foreach{%
2523     \forestoget{tier}\forest@temp@tier
2524     \ifx\forest@temp@currenttier\forest@temp@tier
2525       \ifdim\pgfutil@tempdima<\forestove{abs@1}\relax
2526         \pgfutil@tempdima=\forestove{abs@1}\relax
2527     \fi
2528   \fi
2529 }%
2530 \ifdim\pgfutil@tempdima=-\maxdimen\relax\else
2531   \forest@node@foreach{%
2532     \forestoget{tier}\forest@temp@tier
2533     \ifx\forest@temp@currenttier\forest@temp@tier
2534       \forestoeset{1}{\the\dimexpr\pgfutil@tempdima-\forestove{abs@1}+\forestove{1}}%
2535     \fi
2536   }%
2537 \fi

```

2538 }

Pack children in the sibling dimension in a uniform tree: recursion.

```
2539 \def\forest@pack@sibling@uniform@recursive{%
2540 \forest@node@foreachchild{\forest@pack@sibling@uniform@recursive}%
2541 \forest@pack@sibling@uniform@applyreversed
2542 }
```

Pack children in the sibling dimension in a uniform tree: applyreversed.

```
2543 \def\forest@pack@sibling@uniform@applyreversed{%
2544 \ifnum\forest@ve{n children}>1
2545 \ifnum\forest@ve{reversed}=0
2546 \pack@sibling@uniform@main{first}{last}{next}{previous}%
2547 \else
2548 \pack@sibling@uniform@main{last}{first}{previous}{next}%
2549 \fi
2550 \fi
2551 }
```

Pack children in the sibling dimension in a uniform tree: the main routine.

```
2552 \def\pack@sibling@uniform@main#1#2#3#4{%
```

Loop through the children. At each iteration, we compute the distance between the negative edge of the current child and the positive edge of the block of the previous children, and then set the `s` attribute of the current child accordingly.

We start the loop with the second (to last) child, having initialized the positive edge of the previous children to the positive edge of the first child.

```
2553 \forest@get{#1}\forest@child
2554 \edef\forest@temp{%
2555 \noexpand\forest@for@node{\forest@ve{#1}}{%
2556 \noexpand\forest@node@getedge
2557 {positive}
2558 {\forest@ve{grow}}
2559 \noexpand\forest@temp@edge
2560 }%
2561 }\forest@temp
2562 \forest@pack@pgfpoint@child@position\forest@child
2563 \let\forest@previous@positive@edge\pgfutil@empty
2564 \forest@extendpath\forest@previous@positive@edge\forest@temp@edge}%
2565 \forest@get{\forest@child}{#3}\forest@child
```

Loop until the current child is the null node.

```
2566 \edef\forest@previous@child@s{0pt}%
2567 \forest@loopb
2568 \unless\ifnum\forest@child=0
```

Get the negative edge of the child.

```
2569 \edef\forest@temp{%
2570 \noexpand\forest@for@node{\forest@child}{%
2571 \noexpand\forest@node@getedge
2572 {negative}
2573 {\forest@ve{grow}}
2574 \noexpand\forest@temp@edge
2575 }%
2576 }\forest@temp
```

Set `\pgf@x` and `\pgf@y` to the position of the child (in the coordinate system of this node).

```
2577 \forest@pack@pgfpoint@child@position\forest@child
```

Translate the edge of the child by the child's position.

```
2578 \let\forest@child@negative@edge\pgfutil@empty
2579 \forest@extendpath\forest@child@negative@edge\forest@temp@edge}%
```

Setup the grow line: the angle is given by this node's `grow` attribute.

```
2580 \forest@setupgrowline{\forestove{grow}}%
```

Get the distance (wrt the grow line) between the positive edge of the previous children and the negative edge of the current child. (The distance can be negative!)

```
2581 \forest@distance@between@edge@paths\forest@previous@positive@edge\forest@child@negative@edge\forest@csdis
```

If the distance is `\relax`, the projections of the edges onto the grow line don't overlap: do nothing.

Otherwise, shift the current child so that its distance to the block of previous children is `s sep`.

```
2582 \ifx\forest@csdistance\relax
```

```
2583   %\forest@reset{\forest@child}{s}{\forest@previous@child@s}%
```

```
2584 \else
```

```
2585   \advance\pgfutil@tempdimb-\forest@csdistance\relax
```

```
2586   \advance\pgfutil@tempdimb\forestove{s sep}\relax
```

```
2587   \forest@reset{\forest@child}{s}{\the\dimexpr\forestove{s}-\forest@csdistance+\forestove{s sep}}%
```

```
2588 \fi
```

Retain monotonicity (is this ok?). (This problem arises when the adjacent children's l are too far apart.)

```
2589 \ifdim\forest@l\forest@child{s}<\forest@previous@child@s\relax
```

```
2590   \forest@reset{\forest@child}{s}{\forest@previous@child@s}%
```

```
2591 \fi
```

Prepare for the next iteration: add the current child's positive edge to the positive edge of the previous children, and set up the next current child.

```
2592 \forest@get{\forest@child}{s}\forest@child@s
```

```
2593 \edef\forest@previous@child@s{\forest@child@s}%
```

```
2594 \edef\forest@temp{%
```

```
2595   \noexpand\forest@for@node{\forest@child}{%
```

```
2596     \noexpand\forest@node@getedge
```

```
2597       {positive}
```

```
2598       {\forestove{grow}}}
```

```
2599   \noexpand\forest@temp@edge
```

```
2600   }%
```

```
2601 }\forest@temp
```

```
2602 \forest@pack@pgfpoint@child@position\forest@child
```

```
2603 \forest@extendpath\forest@previous@positive@edge\forest@temp@edge{}
```

```
2604 \forest@getpositivetightedgeofpath\forest@previous@positive@edge\forest@previous@positive@edge
```

```
2605 \forest@get{\forest@child}{@#3}\forest@child
```

```
2606 \forest@repeatb
```

Shift the position of all children to achieve the desired alignment of the parent and its children.

```
2607 \csname forest@calign@\forestove{calign}\endcsname
```

```
2608 }
```

Get the position of child #1 in the current node, in node's l-s coordinate system.

```
2609 \def\forest@pack@pgfpoint@child@position#1{%
```

```
2610   {%
```

```
2611     \pgftransformreset
```

```
2612     \pgftransformrotate{\forestove{grow}}%
```

```
2613     \forest@for@node{#1}{%
```

```
2614       \pgfpointtransformed{\pgfpoint{\forestove{1}}{\forestove{s}}}%
```

```
2615     }%
```

```
2616   }%
```

```
2617 }
```

Get the position of the node in the grow (#1)-rotated coordinate system.

```
2618 \def\forest@pack@pgfpoint@positioningrow#1{%
```

```
2619   {%
```

```
2620     \pgftransformreset
```

```
2621     \pgftransformrotate{#1}%
```

```
2622     \pgfpointtransformed{\pgfpoint{\forestove{1}}{\forestove{s}}}%
```

```
2623   }%
```

```
2624 }
```

Child alignment.

```

2625 \def\forest@calign@s@shift#1{%
2626   \pgfutil@tempdima=#1\relax
2627   \forest@node@foreachchild{%
2628     \forestoeset{s}{\the\dimexpr\forestove{s}+\pgfutil@tempdima}%
2629   }%
2630 }
2631 \def\forest@calign@child{%
2632   \forest@calign@s@shift{-\forestOve{\forest@node@nornbarthchildid{\forestove{calign primary child}}}{s}}%
2633 }
2634 \csdef{forest@calign@child edge}{%
2635   {%
2636     \edef\forest@temp@child{\forest@node@nornbarthchildid{\forestove{calign primary child}}}%
2637     \pgftransformreset
2638     \pgftransformrotate{\forestove{grow}}%
2639     \pgfpointransformed{\pgfqpoint{\forestOve{\forest@temp@child}{1}}{\forestOve{\forest@temp@child}{s}}}%
2640     \pgf@xa=\pgf@x\relax\pgf@ya=\pgf@y\relax
2641     \forestOve{\forest@temp@child}{child@anchor}%
2642     \advance\pgf@xa\pgf@x\relax\advance\pgf@ya\pgf@y\relax
2643     \forestove{parent@anchor}%
2644     \advance\pgf@xa-\pgf@x\relax\advance\pgf@ya-\pgf@y\relax
2645     \edef\forest@marshal{%
2646       \noexpand\pgftransformreset
2647       \noexpand\pgftransformrotate{-\forestove{grow}}%
2648       \noexpand\pgfpointransformed{\noexpand\pgfqpoint{\the\pgf@xa}{\the\pgf@ya}}%
2649     }\forest@marshal
2650   }%
2651   \forest@calign@s@shift{\the\dimexpr-\the\pgf@y}%
2652 }
2653 \csdef{forest@calign@midpoint}{%
2654   \forest@calign@s@shift{\the\dimexpr Opt -%
2655     (\forestOve{\forest@node@nornbarthchildid{\forestove{calign primary child}}}{s}%
2656     +\forestOve{\forest@node@nornbarthchildid{\forestove{calign secondary child}}}{s}%
2657     )/2\relax
2658   }%
2659 }
2660 \csdef{forest@calign@edge midpoint}{%
2661   {%
2662     \edef\forest@temp@firstchild{\forest@node@nornbarthchildid{\forestove{calign primary child}}}%
2663     \edef\forest@temp@secondchild{\forest@node@nornbarthchildid{\forestove{calign secondary child}}}%
2664     \pgftransformreset
2665     \pgftransformrotate{\forestove{grow}}%
2666     \pgfpointransformed{\pgfqpoint{\forestOve{\forest@temp@firstchild}{1}}{\forestOve{\forest@temp@firstchild}{s}}}%
2667     \pgf@xa=\pgf@x\relax\pgf@ya=\pgf@y\relax
2668     \forestOve{\forest@temp@firstchild}{child@anchor}%
2669     \advance\pgf@xa\pgf@x\relax\advance\pgf@ya\pgf@y\relax
2670     \edef\forest@marshal{%
2671       \noexpand\pgfpointransformed{\noexpand\pgfqpoint{\forestOve{\forest@temp@secondchild}{1}}{\forestOve{\forest@temp@secondchild}{s}}}%
2672     }\forest@marshal
2673     \advance\pgf@xa\pgf@x\relax\advance\pgf@ya\pgf@y\relax
2674     \forestOve{\forest@temp@secondchild}{child@anchor}%
2675     \advance\pgf@xa\pgf@x\relax\advance\pgf@ya\pgf@y\relax
2676     \divide\pgf@xa2 \divide\pgf@ya2
2677     \edef\forest@marshal{%
2678       \noexpand\pgftransformreset
2679       \noexpand\pgftransformrotate{-\forestove{grow}}%
2680       \noexpand\pgfpointransformed{\noexpand\pgfqpoint{\the\pgf@xa}{\the\pgf@ya}}%
2681     }\forest@marshal
2682   }%
2683   \forest@calign@s@shift{\the\dimexpr-\the\pgf@y}%

```


2684 }

Aligns the children to the center of the angles given by the options `calign first angle` and `calign second angle` and spreads them additionally if needed to fill the whole space determined by the option. The version `fixed angles` calculates the angles between node anchors; the version `fixes edge angles` calculates the angles between the node edges.

```

2685 \csdef{forest@calign@fixed angles}{%
2686   \edef\forest@ca@first@child{\forest@node@nornbarthchildid{\forestove{calign primary child}}}%
2687   \edef\forest@ca@second@child{\forest@node@nornbarthchildid{\forestove{calign secondary child}}}%
2688   \ifnum\forestove{reversed}=1
2689     \let\forest@temp\forest@ca@first@child
2690     \let\forest@ca@first@child\forest@ca@second@child
2691     \let\forest@ca@second@child\forest@temp
2692   \fi
2693   \forestOget{\forest@ca@first@child}{l}\forest@ca@first@l
2694   \forestOget{\forest@ca@second@child}{l}\forest@ca@second@l
2695   \pgfmathsetlengthmacro\forest@ca@desired@s@distance{%
2696     tan(\forestove{calign secondary angle})*\forest@ca@second@l
2697     -tan(\forestove{calign primary angle})*\forest@ca@first@l
2698   }%
2699   \forestOget{\forest@ca@first@child}{s}\forest@ca@first@s
2700   \forestOget{\forest@ca@second@child}{s}\forest@ca@second@s
2701   \pgfmathsetlengthmacro\forest@ca@actual@s@distance{%
2702     \forest@ca@second@s-\forest@ca@first@s}%
2703   \ifdim\forest@ca@desired@s@distance>\forest@ca@actual@s@distance\relax
2704     \ifdim\forest@ca@actual@s@distance=0pt
2705       \pgfmathsetlength\pgfutil@tempdima{tan(\forestove{calign primary angle})*\forest@ca@second@l}%
2706       \pgfmathsetlength\pgfutil@tempdimb{\forest@ca@desired@s@distance/(\forestove{n children}-1)}%
2707       \forest@node@foreachchild{%
2708         \forestoeset{s}{\the\pgfutil@tempdima}%
2709         \advance\pgfutil@tempdima\pgfutil@tempdimb
2710       }%
2711       \def\forest@calign@anchor{0pt}%
2712     \else
2713       \pgfmathsetmacro\forest@ca@ratio{%
2714         \forest@ca@desired@s@distance/\forest@ca@actual@s@distance}%
2715       \forest@node@foreachchild{%
2716         \pgfmathsetlengthmacro\forest@temp{\forest@ca@ratio*\forestove{s}}%
2717         \forestolet{s}\forest@temp
2718       }%
2719       \pgfmathsetlengthmacro\forest@calign@anchor{%
2720         -tan(\forestove{calign primary angle})*\forest@ca@first@l}%
2721     \fi
2722   \else
2723     \ifdim\forest@ca@desired@s@distance<\forest@ca@actual@s@distance\relax
2724       \pgfmathsetlengthmacro\forest@ca@ratio{%
2725         \forest@ca@actual@s@distance/\forest@ca@desired@s@distance}%
2726       \forest@node@foreachchild{%
2727         \pgfmathsetlengthmacro\forest@temp{\forest@ca@ratio*\forestove{l}}%
2728         \forestolet{l}\forest@temp
2729       }%
2730       \forestOget{\forest@ca@first@child}{l}\forest@ca@first@l
2731       \pgfmathsetlengthmacro\forest@calign@anchor{%
2732         -tan(\forestove{calign primary angle})*\forest@ca@first@l}%
2733     \fi
2734   \fi
2735   \forest@calign@s@shift{-\forest@calign@anchor}%
2736 }
2737 \csdef{forest@calign@fixed edge angles}{%
2738   \edef\forest@ca@first@child{\forest@node@nornbarthchildid{\forestove{calign primary child}}}%
2739   \edef\forest@ca@second@child{\forest@node@nornbarthchildid{\forestove{calign secondary child}}}%

```

```

2740 \ifnum\forestove{reversed}=1
2741   \let\forest@temp\forest@ca@first@child
2742   \let\forest@ca@first@child\forest@ca@second@child
2743   \let\forest@ca@second@child\forest@temp
2744 \fi
2745 \forestOget{\forest@ca@first@child}{l}\forest@ca@first@l
2746 \forestOget{\forest@ca@second@child}{l}\forest@ca@second@l
2747 \forestOget{parent@anchor}\forest@ca@parent@anchor
2748 \forest@ca@parent@anchor
2749 \edef\forest@ca@parent@anchor@s{\the\pgf@x}%
2750 \edef\forest@ca@parent@anchor@l{\the\pgf@y}%
2751 \forestOget{\forest@ca@first@child}{child@anchor}\forest@ca@first@child@anchor
2752 \forest@ca@first@child@anchor
2753 \edef\forest@ca@first@child@anchor@s{\the\pgf@x}%
2754 \edef\forest@ca@first@child@anchor@l{\the\pgf@y}%
2755 \forestOget{\forest@ca@second@child}{child@anchor}\forest@ca@second@child@anchor
2756 \forest@ca@second@child@anchor
2757 \edef\forest@ca@second@child@anchor@s{\the\pgf@x}%
2758 \edef\forest@ca@second@child@anchor@l{\the\pgf@y}%
2759 \pgfmathsetlengthmacro\forest@ca@desired@second@edge@s{tan(\forestove{calign secondary angle})*%
2760   (\forest@ca@second@l-\forest@ca@second@child@anchor@l+\forest@ca@parent@anchor@l)}%
2761 \pgfmathsetlengthmacro\forest@ca@desired@first@edge@s{tan(\forestove{calign primary angle})*%
2762   (\forest@ca@first@l-\forest@ca@first@child@anchor@l+\forest@ca@parent@anchor@l)}%
2763 \pgfmathsetlengthmacro\forest@ca@desired@s@distance{\forest@ca@desired@second@edge@s-\forest@ca@desired@first@edge@s}%
2764 \forestOget{\forest@ca@first@child}{s}\forest@ca@first@s
2765 \forestOget{\forest@ca@second@child}{s}\forest@ca@second@s
2766 \pgfmathsetlengthmacro\forest@ca@actual@s@distance{%
2767   \forest@ca@second@s+\forest@ca@second@child@anchor@s
2768   -\forest@ca@first@s-\forest@ca@first@child@anchor@s}%
2769 \ifdim\forest@ca@desired@s@distance>\forest@ca@actual@s@distance\relax
2770   \ifdim\forest@ca@actual@s@distance=Opt
2771     \forestOget{n children}\forest@temp@n@children
2772     \forest@node@foreachchild{%
2773       \forestOget{child@anchor}\forest@temp@child@anchor
2774       \forest@temp@child@anchor
2775       \edef\forest@temp@child@anchor@s{\the\pgf@x}%
2776       \pgfmathsetlengthmacro\forest@temp{%
2777         \forest@ca@desired@first@edge@s+(\forestove{n}-1)*\forest@ca@desired@s@distance/(\forest@temp@n@children)}%
2778       \forestOlet{s}\forest@temp
2779     }%
2780     \def\forest@calign@anchor{Opt}%
2781   \else
2782     \pgfmathsetmacro\forest@ca@ratio{%
2783       \forest@ca@desired@s@distance/\forest@ca@actual@s@distance}%
2784     \forest@node@foreachchild{%
2785       \forestOget{child@anchor}\forest@temp@child@anchor
2786       \forest@temp@child@anchor
2787       \edef\forest@temp@child@anchor@s{\the\pgf@x}%
2788       \pgfmathsetlengthmacro\forest@temp{%
2789         \forest@ca@ratio*(%
2790           \forestove{s}-\forest@ca@first@s
2791           +\forest@temp@child@anchor@s-\forest@ca@first@child@anchor@s)%
2792         +\forest@ca@first@s
2793         +\forest@ca@first@child@anchor@s-\forest@temp@child@anchor@s}%
2794       \forestOlet{s}\forest@temp
2795     }%
2796     \pgfmathsetlengthmacro\forest@calign@anchor{%
2797       -tan(\forestove{calign primary angle})*(\forest@ca@first@l-\forest@ca@first@child@anchor@l+\forest@ca@parent@anchor@l)%
2798       +\forest@ca@first@child@anchor@s-\forest@ca@parent@anchor@s
2799     }%
2800 \fi

```

```

2801 \else
2802 \ifdim\forest@ca@desired@s@distance<\forest@ca@actual@s@distance\relax
2803 \pgfmithsetlengthmacro\forest@ca@ratio{%
2804 \forest@ca@actual@s@distance/\forest@ca@desired@s@distance}%
2805 \forest@node@foreachchild{%
2806 \forest@toget{child@anchor}\forest@temp@child@anchor
2807 \forest@temp@child@anchor
2808 \edef\forest@temp@child@anchor@l{\the\pgf@y}%
2809 \pgfmithsetlengthmacro\forest@temp{%
2810 \forest@ca@ratio*(%
2811 \forest@ve{1}+\forest@ca@parent@anchor@l-\forest@temp@child@anchor@l)
2812 -\forest@ca@parent@anchor@l+\forest@temp@child@anchor@l}%
2813 \forest@tolet{1}\forest@temp
2814 }%
2815 \forest@toget{\forest@ca@first@child}{1}\forest@ca@first@l
2816 \pgfmithsetlengthmacro\forest@calign@anchor{%
2817 -tan(\forest@ve{calign primary angle})*(\forest@ca@first@l+\forest@ca@parent@anchor@l-\forest@temp@ch
2818 +\forest@ca@first@child@anchor@s-\forest@ca@parent@anchor@s
2819 }%
2820 \fi
2821 \fi
2822 \forest@calign@s@shift{-\forest@calign@anchor}%
2823 }

```

Get edge: #1 = positive/negative, #2 = grow (in degrees), #3 = the control sequence receiving the resulting path. The edge is taken from the cache (attribute #1@edge@#2) if possible; otherwise, both positive and negative edge are computed and stored in the cache.

```

2824 \def\forest@node@getedge#1#2#3{%
2825 \forest@toget{#1@edge@#2}#3%
2826 \ifx#3\relax
2827 \forest@node@foreachchild{%
2828 \forest@node@getedge{#1}{#2}{\forest@temp@edge}%
2829 }%
2830 \forest@forthis{\forest@node@getedges{#2}}%
2831 \forest@toget{#1@edge@#2}#3%
2832 \fi
2833 }

```

Get edges. #1 = grow (in degrees). The result is stored in attributes `negative@edge@#1` and `positive@edge@#1`. This method expects that the children's edges are already cached.

```

2834 \def\forest@node@getedges#1{%

```

Run the computation in a \TeX group.

```

2835 %{}%

```

Setup the grow line.

```

2836 \forest@setupgrowline{#1}%

```

Get the edge of the node itself.

```

2837 \ifnum\forest@ve{ignore}=0
2838 \forest@toget{boundary}\forest@node@boundary
2839 \else
2840 \def\forest@node@boundary{}%
2841 \fi
2842 \csname forest@getboth\forest@ve{fit}edgesofpath\endcsname
2843 \forest@node@boundary\forest@negative@node@edge\forest@positive@node@edge
2844 \forest@tolet[negative@edge@#1]\forest@negative@node@edge
2845 \forest@tolet[positive@edge@#1]\forest@positive@node@edge

```

Add the edges of the children.

```

2846 \get@edges@merge[negative]{#1}%
2847 \get@edges@merge[positive]{#1}%
2848 %}%

```

2849 }

Merge the #1 (=negative or positive) edge of the node with #1 edges of the children. #2 = grow angle.

2850 \def\get@edges@merge#1#2{%

2851 \ifnum\forestove{n children}>0

2852 \forestoget{#1@edge@#2}\forest@node@edge

Remember the node's parent anchor and add it to the path (for breaking).

2853 \forestove{parent@anchor}%

2854 \edef\forest@getedge@pa@l{\the\pgf@x}%

2855 \edef\forest@getedge@pa@s{\the\pgf@y}%

2856 \eappto\forest@node@edge{\noexpand\pgfsyssoftpath@movetotoken{\forest@getedge@pa@l}{\forest@getedge@pa@s}}

Switch to this node's (l,s) coordinate system (origin at the node's anchor).

2857 \pgftransformreset

2858 \pgftransformrotate{\forestove{grow}}%

Get the child's (cached) edge, translate it by the child's position, and add it to the path holding all edges. Also add the edge from parent to the child to the path. This gets complicated when the child and/or parent anchor is empty, i.e. automatic border: we can get self-intersecting paths. So we store all the parent-child edges to a safe place first, compute all the possible breaking points (i.e. all the points in node@edge path), and break the parent-child edges on these points.

2859 \def\forest@all@edges{%

2860 \forest@node@foreachchild{%

2861 \forestoget{#1@edge@#2}\forest@temp@edge

2862 \pgfpointtransformed{\pgfpoint{\forestove{l}}{\forestove{s}}}%

2863 \forest@extendpath\forest@node@edge\forest@temp@edge}%

2864 \ifnum\forestove{ignore edge}=0

2865 \pgfpointadd

2866 {\pgfpointtransformed{\pgfpoint{\forestove{l}}{\forestove{s}}}}%

2867 {\forestove{child@anchor}}%

2868 \pgfgetlastxy{\forest@getedge@ca@l}{\forest@getedge@ca@s}%

2869 \eappto\forest@all@edges{%

2870 \noexpand\pgfsyssoftpath@movetotoken{\forest@getedge@pa@l}{\forest@getedge@pa@s}%

2871 \noexpand\pgfsyssoftpath@linetotoken{\forest@getedge@ca@l}{\forest@getedge@ca@s}%

2872 }%

2873 % this deals with potential overlap of the edges:

2874 \eappto\forest@node@edge{\noexpand\pgfsyssoftpath@movetotoken{\forest@getedge@ca@l}{\forest@getedge@ca@s}}

2875 \fi

2876 }%

2877 \ifdefempty{\forest@all@edges}{}{%

2878 \pgfintersectionofpaths{\pgfsetpath\forest@all@edges}{\pgfsetpath\forest@node@edge}%

2879 \def\forest@edgenode@intersections{%

2880 \forest@merge@intersectionloop

2881 \eappto\forest@node@edge{\expandonce{\forest@all@edges}\expandonce{\forest@edgenode@intersections}}%

2882 }%

Process the path into an edge and store the edge.

2883 \csname forest@get#1\forestove{fit}edgeofpath\endcsname\forest@node@edge\forest@node@edge

2884 \forestolet{#1@edge@#2}\forest@node@edge

2885 \fi

2886 }

2887 \newloop\forest@merge@loop

2888 \def\forest@merge@intersectionloop{%

2889 \c@pgf@counta=0

2890 \forest@merge@loop

2891 \ifnum\c@pgf@counta<\pgfintersectionofsolutions\relax

2892 \advance\c@pgf@counta1

2893 \pgfpointintersectionsolution{\the\c@pgf@counta}%

2894 \eappto\forest@edgenode@intersections{\noexpand\pgfsyssoftpath@movetotoken

2895 {\the\pgf@x}{\the\pgf@y}}%

```

2896 \forest@merge@repeat
2897 }

```

Get the bounding rectangle of the node (without descendants). #1 = grow.

```

2898 \def\forest@node@getboundingrectangle@ls#1{%
2899 \forestoget{boundary}\forest@node@boundary
2900 \forest@path@getboundingrectangle@ls\forest@node@boundary{#1}%
2901 }

```

Applies the current coordinate transformation to the points in the path #1. Returns via the current path (so that the coordinate transformation can be set up as local).

```

2902 \def\forest@pgfpathtransformed#1{%
2903 \forest@save@pgfsyssoftpath@tokendef
2904 \let\pgfsyssoftpath@movetotoken\forest@pgfpathtransformed@moveto
2905 \let\pgfsyssoftpath@linetotoken\forest@pgfpathtransformed@lineto
2906 \pgfsyssoftpath@setcurrentpath\pgfutil@empty
2907 #1%
2908 \forest@restore@pgfsyssoftpath@tokendef
2909 }
2910 \def\forest@pgfpathtransformed@moveto#1#2{%
2911 \forest@pgfpathtransformed@op\pgfsyssoftpath@moveto{#1}{#2}%
2912 }
2913 \def\forest@pgfpathtransformed@lineto#1#2{%
2914 \forest@pgfpathtransformed@op\pgfsyssoftpath@lineto{#1}{#2}%
2915 }
2916 \def\forest@pgfpathtransformed@op#1#2#3{%
2917 \pgfpointransformed{\pgfqpoint{#2}{#3}}%
2918 \edef\forest@temp{%
2919 \noexpand#1{\the\pgf@x}{\the\pgf@y}%
2920 }%
2921 \forest@temp
2922 }

```

11.2.1 Tiers

Compute tiers to be aligned at a node. The result is saved in attribute @tiers.

```

2923 \def\forest@pack@computetiers{%
2924 {%
2925 \forest@pack@tiers@getalltiersinsubtree
2926 \forest@pack@tiers@computetierhierarchy
2927 \forest@pack@tiers@findcontainers
2928 \forest@pack@tiers@raisecontainers
2929 \forest@pack@tiers@computeprocessingorder
2930 \gdef\forest@smuggle{%
2931 \forest@pack@tiers@write
2932 }%
2933 \forest@node@foreach{\forestoset{@tiers}}{}}%
2934 \forest@smuggle
2935 }

```

Puts all tiers contained in the subtree into attribute tiers.

```

2936 \def\forest@pack@tiers@getalltiersinsubtree{%
2937 \ifnum\forestove{n children}>0
2938 \forest@node@foreachchild{\forest@pack@tiers@getalltiersinsubtree}%
2939 \fi
2940 \forestoget{tier}\forest@temp@mytier
2941 \def\forest@temp@mytiers{%
2942 \ifdefempty\forest@temp@mytier{}{%
2943 \listadd\forest@temp@mytiers\forest@temp@mytier
2944 }%
2945 \ifnum\forestove{n children}>0
2946 \forest@node@foreachchild{%

```

```

2947     \foresttoget{tiers}\forest@temp@tiers
2948     \forlistloop\forest@pack@tiers@forhandlerA\forest@temp@tiers
2949   }%
2950 \fi
2951 \forestolet{tiers}\forest@temp@mytiers
2952 }
2953 \def\forest@pack@tiers@forhandlerA#1{%
2954   \ifinlist{#1}\forest@temp@mytiers{}{%
2955     \listead\forest@temp@mytiers{#1}%
2956   }%
2957 }

```

Compute a set of higher and lower tiers for each tier. Tier A is higher than tier B iff a node on tier A is an ancestor of a node on tier B.

```

2958 \def\forest@pack@tiers@computetierhierarchy{%
2959   \def\forest@tiers@ancestors{}%
2960   \foresttoget{tiers}\forest@temp@mytiers
2961   \forlistloop\forest@pack@tiers@cth@init\forest@temp@mytiers
2962   \forest@pack@tiers@computetierhierarchy@
2963 }
2964 \def\forest@pack@tiers@cth@init#1{%
2965   \csdef{forest@tiers@higher@#1}{}%
2966   \csdef{forest@tiers@lower@#1}{}%
2967 }
2968 \def\forest@pack@tiers@computetierhierarchy@{%
2969   \foresttoget{tier}\forest@temp@mytier
2970   \ifdefempty\forest@temp@mytier{}{%
2971     \forlistloop\forest@pack@tiers@forhandlerB\forest@tiers@ancestors
2972     \listead\forest@tiers@ancestors\forest@temp@mytier
2973   }%
2974   \forest@node@foreachchild{%
2975     \forest@pack@tiers@computetierhierarchy@
2976   }%
2977   \foresttoget{tier}\forest@temp@mytier
2978   \ifdefempty\forest@temp@mytier{}{%
2979     \forest@listedel\forest@tiers@ancestors\forest@temp@mytier
2980   }%
2981 }
2982 \def\forest@pack@tiers@forhandlerB#1{%
2983   \def\forest@temp@tier{#1}%
2984   \ifx\forest@temp@tier\forest@temp@mytier
2985     \PackageError{forest}{Circular tier hierarchy (tier \forest@temp@mytier)}{ }%
2986   \fi
2987   \ifinlistcs{#1}{forest@tiers@higher@\forest@temp@mytier}{ }{%
2988     \listcsadd{forest@tiers@higher@\forest@temp@mytier}{#1}%
2989   \xifinlistcs\forest@temp@mytier{forest@tiers@lower@#1}{ }{%
2990     \listcseadd{forest@tiers@lower@#1}{\forest@temp@mytier}%
2991 }
2992 \def\forest@pack@tiers@findcontainers{%
2993   \foresttoget{tiers}\forest@temp@tiers
2994   \forlistloop\forest@pack@tiers@findcontainer\forest@temp@tiers
2995 }
2996 \def\forest@pack@tiers@findcontainer#1{%
2997   \def\forest@temp@tier{#1}%
2998   \foresttoget{tier}\forest@temp@mytier
2999   \ifx\forest@temp@tier\forest@temp@mytier
3000     \csdef{forest@tiers@container@#1}{\forest@cn}%
3001   \else\@escapeif{%
3002     \forest@pack@tiers@findcontainerA{#1}%
3003   }\fi%
3004 }

```

```

3005 \def\forest@pack@tiers@findcontainerA#1{%
3006   \c@pgf@counta=0
3007   \forest@node@foreachchild{%
3008     \forest@toget{tiers}\forest@temp@tiers
3009     \ifinlist{#1}\forest@temp@tiers{%
3010       \advance\c@pgf@counta 1
3011       \let\forest@temp@child\forest@cn
3012     }{%}%
3013   }%
3014   \ifnum\c@pgf@counta>1
3015     \csedef\forest@tiers@container@#1{\forest@cn}%
3016   \else\@escapeif{% surely =1
3017     \forest@fornode{\forest@temp@child}{%
3018       \forest@pack@tiers@findcontainer{#1}%
3019     }%
3020   }\fi
3021 }
3022 \def\forest@pack@tiers@raisecontainers{%
3023   \forest@toget{tiers}\forest@temp@mytiers
3024   \forlistloop\forest@pack@tiers@rc@forhandlerA\forest@temp@mytiers
3025 }
3026 \def\forest@pack@tiers@rc@forhandlerA#1{%
3027   \edef\forest@tiers@temptier{#1}%
3028   \letcs\forest@tiers@containernodeoftier{forest@tiers@container@#1}%
3029   \letcs\forest@temp@lowertiers{forest@tiers@lower@#1}%
3030   \forlistloop\forest@pack@tiers@rc@forhandlerB\forest@temp@lowertiers
3031 }
3032 \def\forest@pack@tiers@rc@forhandlerB#1{%
3033   \letcs\forest@tiers@containernodeoflowertier{forest@tiers@container@#1}%
3034   \forest@toget{\forest@tiers@containernodeoflowertier}{content}\lowercontent
3035   \forest@toget{\forest@tiers@containernodeoftier}{content}\uppercontent
3036   \forest@fornode{\forest@tiers@containernodeoflowertier}{%
3037     \forest@ifancestorof
3038       {\forest@tiers@containernodeoftier}
3039       {\csletcs{forest@tiers@container@forest@tiers@temptier}{forest@tiers@container@#1}}%
3040     }%
3041   }%
3042 }
3043 \def\forest@pack@tiers@computeprocessingorder{%
3044   \def\forest@tiers@processingorder{%
3045     \forest@toget{tiers}\forest@tiers@cpo@tierstodo
3046     \forest@loopa
3047     \ifdefempty\forest@tiers@cpo@tierstodo{\forest@tempfalse}{\forest@temptrue}%
3048     \ifforest@temp
3049       \def\forest@tiers@cpo@tiersremaining{%
3050         \def\forest@tiers@cpo@tiersindependent{%
3051           \forlistloop\forest@pack@tiers@cpo@forhandlerA\forest@tiers@cpo@tierstodo
3052           \ifdefempty\forest@tiers@cpo@tiersindependent{%
3053             \PackageError{forest}{Circular tiers!}{}}{}%
3054           \forlistloop\forest@pack@tiers@cpo@forhandlerB\forest@tiers@cpo@tiersremaining
3055           \let\forest@tiers@cpo@tierstodo\forest@tiers@cpo@tiersremaining
3056         \forest@repeata
3057       }
3058     \def\forest@pack@tiers@cpo@forhandlerA#1{%
3059       \ifcempty{forest@tiers@higher@#1}{%
3060         \listadd\forest@tiers@cpo@tiersindependent{#1}%
3061         \listadd\forest@tiers@processingorder{#1}%
3062       }{%
3063         \listadd\forest@tiers@cpo@tiersremaining{#1}%
3064       }%
3065     }

```

```

3066 \def\forest@pack@tiers@cpo@forhandlerB#1{%
3067   \def\forest@pack@tiers@cpo@aremainingtier{#1}%
3068   \forlistloop\forest@pack@tiers@cpo@forhandlerC\forest@tiers@cpo@tiersindependent
3069 }
3070 \def\forest@pack@tiers@cpo@forhandlerC#1{%
3071   \ifinlistcs{#1}{\forest@tiers@higher@\forest@pack@tiers@cpo@aremainingtier}{%
3072     \forest@listcsdel{\forest@tiers@higher@\forest@pack@tiers@cpo@aremainingtier}{#1}%
3073   }{}%
3074 }
3075 \def\forest@pack@tiers@write{%
3076   \forlistloop\forest@pack@tiers@write@forhandler\forest@tiers@processingorder
3077 }
3078 \def\forest@pack@tiers@write@forhandler#1{%
3079   \forest@fornode{\csname forest@tiers@container@#1\endcsname}{%
3080     \forest@pack@tiers@check{#1}%
3081   }%
3082   \xappto\forest@smuggle{%
3083     \noexpand\listadd
3084     \forest@om{\csname forest@tiers@container@#1\endcsname}{@tiers}%
3085     {#1}%
3086   }%
3087 }
3088 % checks if the tier is compatible with growth changes and calign=node/edge angle
3089 \def\forest@pack@tiers@check#1{%
3090   \def\forest@temp@currenttier{#1}%
3091   \forest@node@foreachdescendant{%
3092     \ifnum\forestove{grow}=\forestOve{\forestove{@parent}}{grow}
3093     \else
3094       \forest@pack@tiers@check@grow
3095     \fi
3096     \ifnum\forestove{n children}>1
3097       \foresttoget{calign}\forest@temp
3098       \ifx\forest@temp\forest@pack@tiers@check@nodeangle
3099         \forest@pack@tiers@check@calign
3100       \fi
3101       \ifx\forest@temp\forest@pack@tiers@check@edgeangle
3102         \forest@pack@tiers@check@calign
3103       \fi
3104     \fi
3105   }%
3106 }
3107 \def\forest@pack@tiers@check@nodeangle{node angle}%
3108 \def\forest@pack@tiers@check@edgeangle{edge angle}%
3109 \def\forest@pack@tiers@check@grow{%
3110   \foresttoget{content}\forest@temp@content
3111   \let\forest@temp@currentnode\forest@cn
3112   \forest@node@foreachdescendant{%
3113     \foresttoget{tier}\forest@temp
3114     \ifx\forest@temp@currenttier\forest@temp
3115       \forest@pack@tiers@check@grow@error
3116     \fi
3117   }%
3118 }
3119 \def\forest@pack@tiers@check@grow@error{%
3120   \PackageError{forest}{Tree growth direction changes in node \forest@temp@currentnode\space
3121     (content: \forest@temp@content), while tier '\forest@temp' is specified for nodes both
3122     out- and inside the subtree rooted in node \forest@temp@currentnode. This will not work.}{}%
3123 }
3124 \def\forest@pack@tiers@check@calign{%
3125   \forest@node@foreachchild{%
3126     \foresttoget{tier}\forest@temp

```



```

3127 \ifx\forest@temp@currenttier\forest@temp
3128 \forest@pack@tiers@check@calign@warning
3129 \fi
3130 }%
3131 }
3132 \def\forest@pack@tiers@check@calign@warning{%
3133 \PackageWarning{forest}{Potential option conflict: node \forestove{@parent} (content:
3134 '\forestOve{\forestove{@parent}}{content}') was given 'calign=\forestove{calign}', while its
3135 child \forest@cn\space (content: '\forestove{content}') was given 'tier=\forestove{tier}'.
3136 The parent's 'calign' will only work if the child was the lowest node on its tier before the
3137 alignment.}{}}
3138 }

```

11.2.2 Node boundary

Compute the node boundary: it will be put in the pgf's current path. The computation is done within a generic anchor so that the shape's saved anchors and macros are available.

```

3139 \pgfdeclaregenericanchor{forestcomputenodeboundary}{%
3140 \letcs\forest@temp@boundary@macro\forest@compute@node@boundary@#1}%
3141 \ifcsname forest@compute@node@boundary@#1\endcsname
3142 \csname forest@compute@node@boundary@#1\endcsname
3143 \else
3144 \forest@compute@node@boundary@rectangle
3145 \fi
3146 \pgfsyssoftpath@getcurrentpath\forest@temp
3147 \global\let\forest@global@boundary\forest@temp
3148 }
3149 \def\forest@mt#1{%
3150 \expandafter\pgfpointanchor\expandafter{\pgfreferencednodename}{#1}%
3151 \pgfsyssoftpath@moveto{\the\pgf@x}{\the\pgf@y}%
3152 }%
3153 \def\forest@lt#1{%
3154 \expandafter\pgfpointanchor\expandafter{\pgfreferencednodename}{#1}%
3155 \pgfsyssoftpath@lineto{\the\pgf@x}{\the\pgf@y}%
3156 }%
3157 \def\forest@compute@node@boundary@coordinate{%
3158 \forest@mt{center}}%
3159 }
3160 \def\forest@compute@node@boundary@circle{%
3161 \forest@mt{east}}%
3162 \forest@lt{north east}%
3163 \forest@lt{north}%
3164 \forest@lt{north west}%
3165 \forest@lt{west}%
3166 \forest@lt{south west}%
3167 \forest@lt{south}%
3168 \forest@lt{south east}%
3169 \forest@lt{east}%
3170 }
3171 \def\forest@compute@node@boundary@rectangle{%
3172 \forest@mt{south west}}%
3173 \forest@lt{south east}%
3174 \forest@lt{north east}%
3175 \forest@lt{north west}%
3176 \forest@lt{south west}%
3177 }
3178 \def\forest@compute@node@boundary@diamond{%
3179 \forest@mt{east}}%
3180 \forest@lt{north}%
3181 \forest@lt{west}%

```

```

3182 \forest@lt{south}%
3183 \forest@lt{east}%
3184 }
3185 \let\forest@compute@node@boundary@ellipse\forest@compute@node@boundary@circle
3186 \def\forest@compute@node@boundary@trapezium{%
3187 \forest@mt{top right corner}%
3188 \forest@lt{top left corner}%
3189 \forest@lt{bottom left corner}%
3190 \forest@lt{bottom right corner}%
3191 \forest@lt{top right corner}%
3192 }
3193 \def\forest@compute@node@boundary@semicircle{%
3194 \forest@mt{arc start}%
3195 \forest@lt{north}%
3196 \forest@lt{east}%
3197 \forest@lt{north east}%
3198 \forest@lt{apex}%
3199 \forest@lt{north west}%
3200 \forest@lt{west}%
3201 \forest@lt{arc end}%
3202 \forest@lt{arc start}%
3203 }
3204 \newloop\forest@computenodeboundary@loop
3205 \csdef{forest@compute@node@boundary@regular polygon}{%
3206 \forest@mt{corner 1}%
3207 \c@pgf@counta=\sides\relax
3208 \forest@computenodeboundary@loop
3209 \ifnum\c@pgf@counta>0
3210 \forest@lt{corner \the\c@pgf@counta}%
3211 \advance\c@pgf@counta-1
3212 \forest@computenodeboundary@repeat
3213 }%
3214 \def\forest@compute@node@boundary@star{%
3215 \forest@mt{outer point 1}%
3216 \c@pgf@counta=\totalstarpoints\relax
3217 \divide\c@pgf@counta2
3218 \forest@computenodeboundary@loop
3219 \ifnum\c@pgf@counta>0
3220 \forest@lt{inner point \the\c@pgf@counta}%
3221 \forest@lt{outer point \the\c@pgf@counta}%
3222 \advance\c@pgf@counta-1
3223 \forest@computenodeboundary@repeat
3224 }%
3225 \csdef{forest@compute@node@boundary@isosceles triangle}{%
3226 \forest@mt{apex}%
3227 \forest@lt{left corner}%
3228 \forest@lt{right corner}%
3229 \forest@lt{apex}%
3230 }
3231 \def\forest@compute@node@boundary@kite{%
3232 \forest@mt{upper vertex}%
3233 \forest@lt{left vertex}%
3234 \forest@lt{lower vertex}%
3235 \forest@lt{right vertex}%
3236 \forest@lt{upper vertex}%
3237 }
3238 \def\forest@compute@node@boundary@dart{%
3239 \forest@mt{tip}%
3240 \forest@lt{left tail}%
3241 \forest@lt{tail center}%
3242 \forest@lt{right tail}%

```

```

3243 \forest@lt{tip}%
3244 }
3245 \csdef{forest@compute@node@boundary@circular sector}{%
3246 \forest@mt{sector center}%
3247 \forest@lt{arc start}%
3248 \forest@lt{arc center}%
3249 \forest@lt{arc end}%
3250 \forest@lt{sector center}%
3251 }
3252 \def\forest@compute@node@boundary@cylinder{%
3253 \forest@mt{top}%
3254 \forest@lt{after top}%
3255 \forest@lt{before bottom}%
3256 \forest@lt{bottom}%
3257 \forest@lt{after bottom}%
3258 \forest@lt{before top}%
3259 \forest@lt{top}%
3260 }
3261 \cslet{forest@compute@node@boundary@forbidden sign}\forest@compute@node@boundary@circle
3262 \cslet{forest@compute@node@boundary@magnifying glass}\forest@compute@node@boundary@circle
3263 \def\forest@compute@node@boundary@cloud{%
3264 \getradii
3265 \forest@mt{puff 1}%
3266 \c@pgf@counta=\puffs\relax
3267 \forest@computenodeboundary@loop
3268 \ifnum\c@pgf@counta>0
3269 \forest@lt{puff \the\c@pgf@counta}%
3270 \advance\c@pgf@counta-1
3271 \forest@computenodeboundary@repeat
3272 }
3273 \def\forest@compute@node@boundary@starburst{
3274 \calculatestarburstpoints
3275 \forest@mt{outer point 1}%
3276 \c@pgf@counta=\totalpoints\relax
3277 \divide\c@pgf@counta2
3278 \forest@computenodeboundary@loop
3279 \ifnum\c@pgf@counta>0
3280 \forest@lt{inner point \the\c@pgf@counta}%
3281 \forest@lt{outer point \the\c@pgf@counta}%
3282 \advance\c@pgf@counta-1
3283 \forest@computenodeboundary@repeat
3284 }%
3285 \def\forest@compute@node@boundary@signal{%
3286 \forest@mt{east}%
3287 \forest@lt{south east}%
3288 \forest@lt{south west}%
3289 \forest@lt{west}%
3290 \forest@lt{north west}%
3291 \forest@lt{north east}%
3292 \forest@lt{east}%
3293 }
3294 \def\forest@compute@node@boundary@tape{%
3295 \forest@mt{north east}%
3296 \forest@lt{60}%
3297 \forest@lt{north}%
3298 \forest@lt{120}%
3299 \forest@lt{north west}%
3300 \forest@lt{south west}%
3301 \forest@lt{240}%
3302 \forest@lt{south}%
3303 \forest@lt{310}%

```

```

3304 \forest@lt{south east}%
3305 \forest@lt{north east}%
3306 }
3307 \csdef{forest@compute@node@boundary@single arrow}{%
3308 \forest@mt{tip}%
3309 \forest@lt{after tip}%
3310 \forest@lt{after head}%
3311 \forest@lt{before tail}%
3312 \forest@lt{after tail}%
3313 \forest@lt{before head}%
3314 \forest@lt{before tip}%
3315 \forest@lt{tip}%
3316 }
3317 \csdef{forest@compute@node@boundary@double arrow}{%
3318 \forest@mt{tip 1}%
3319 \forest@lt{after tip 1}%
3320 \forest@lt{after head 1}%
3321 \forest@lt{before head 2}%
3322 \forest@lt{before tip 2}%
3323 \forest@mt{tip 2}%
3324 \forest@lt{after tip 2}%
3325 \forest@lt{after head 2}%
3326 \forest@lt{before head 1}%
3327 \forest@lt{before tip 1}%
3328 \forest@lt{tip 1}%
3329 }
3330 \csdef{forest@compute@node@boundary@arrow box}{%
3331 \forest@mt{before north arrow}%
3332 \forest@lt{before north arrow head}%
3333 \forest@lt{before north arrow tip}%
3334 \forest@lt{north arrow tip}%
3335 \forest@lt{after north arrow tip}%
3336 \forest@lt{after north arrow head}%
3337 \forest@lt{after north arrow}%
3338 \forest@lt{north east}%
3339 \forest@lt{before east arrow}%
3340 \forest@lt{before east arrow head}%
3341 \forest@lt{before east arrow tip}%
3342 \forest@lt{east arrow tip}%
3343 \forest@lt{after east arrow tip}%
3344 \forest@lt{after east arrow head}%
3345 \forest@lt{after east arrow}%
3346 \forest@lt{south east}%
3347 \forest@lt{before south arrow}%
3348 \forest@lt{before south arrow head}%
3349 \forest@lt{before south arrow tip}%
3350 \forest@lt{south arrow tip}%
3351 \forest@lt{after south arrow tip}%
3352 \forest@lt{after south arrow head}%
3353 \forest@lt{after south arrow}%
3354 \forest@lt{south west}%
3355 \forest@lt{before west arrow}%
3356 \forest@lt{before west arrow head}%
3357 \forest@lt{before west arrow tip}%
3358 \forest@lt{west arrow tip}%
3359 \forest@lt{after west arrow tip}%
3360 \forest@lt{after west arrow head}%
3361 \forest@lt{after west arrow}%
3362 \forest@lt{north west}%
3363 \forest@lt{before north arrow}%
3364 }

```

```

3365 \cslet{forest@compute@node@boundary@circle split}\forest@compute@node@boundary@circle
3366 \cslet{forest@compute@node@boundary@circle solidus}\forest@compute@node@boundary@circle
3367 \cslet{forest@compute@node@boundary@ellipse split}\forest@compute@node@boundary@ellipse
3368 \cslet{forest@compute@node@boundary@rectangle split}\forest@compute@node@boundary@rectangle
3369 \def\forest@compute@node@boundary@@callout{%
3370   \beforecalloutpointer
3371   \pgfsyssoftpath@moveto{\the\pgf@x}{\the\pgf@y}%
3372   \calloutpointeranchor
3373   \pgfsyssoftpath@lineto{\the\pgf@x}{\the\pgf@y}%
3374   \aftercalloutpointer
3375   \pgfsyssoftpath@lineto{\the\pgf@x}{\the\pgf@y}%
3376 }
3377 \csdef{forest@compute@node@boundary@rectangle callout}{%
3378   \forest@compute@node@boundary@rectangle
3379   \rectanglecalloutpoints
3380   \forest@compute@node@boundary@@callout
3381 }
3382 \csdef{forest@compute@node@boundary@ellipse callout}{%
3383   \forest@compute@node@boundary@ellipse
3384   \ellipsecalloutpoints
3385   \forest@compute@node@boundary@@callout
3386 }
3387 \csdef{forest@compute@node@boundary@cloud callout}{%
3388   \forest@compute@node@boundary@cloud
3389   % at least a first approx...
3390   \forest@mt{center}%
3391   \forest@lt{pointer}%
3392 }%
3393 \csdef{forest@compute@node@boundary@cross out}{%
3394   \forest@mt{south east}%
3395   \forest@lt{north west}%
3396   \forest@mt{south west}%
3397   \forest@lt{north east}%
3398 }%
3399 \csdef{forest@compute@node@boundary@strike out}{%
3400   \forest@mt{north east}%
3401   \forest@lt{south west}%
3402 }%
3403 \cslet{forest@compute@node@boundary@rounded rectangle}\forest@compute@node@boundary@rectangle
3404 \csdef{forest@compute@node@boundary@chamfered rectangle}{%
3405   \forest@mt{before south west}%
3406   \forest@mt{after south west}%
3407   \forest@lt{before south east}%
3408   \forest@lt{after south east}%
3409   \forest@lt{before north east}%
3410   \forest@lt{after north east}%
3411   \forest@lt{before north west}%
3412   \forest@lt{after north west}%
3413   \forest@lt{before south west}%
3414 }%

```

11.3 Compute absolute positions

Computes absolute positions of descendants relative to this node. Stores the results in attributes `x` and `y`.

```

3415 \def\forest@node@computeabsolutepositions{%
3416   \forestset{x}{0pt}%
3417   \forestset{y}{0pt}%
3418   \edef\forest@marshal{%
3419     \noexpand\forest@node@foreachchild{%

```

```

3420     \noexpand\forest@node@computeabsolutepositions@{0pt}{0pt}{\forestove{grow}}%
3421   }%
3422 } \forest@marshal
3423 }
3424 \def\forest@node@computeabsolutepositions@#1#2#3{%
3425   \pgfpointadd{\pgfpoint{#1}{#2}}{%
3426     \pgfpointadd{\pgfpolar{#3}{\forestove{1}}}{\pgfpolar{90 + #3}{\forestove{s}}}%
3427   \pgfgetlastxy\forest@temp@x\forest@temp@y
3428   \forestolet{x}\forest@temp@x
3429   \forestolet{y}\forest@temp@y
3430   \edef\forest@marshal{%
3431     \noexpand\forest@node@foreachchild{%
3432       \noexpand\forest@node@computeabsolutepositions@{\forest@temp@x}{\forest@temp@y}{\forestove{grow}}%
3433     }%
3434   } \forest@marshal
3435 }

```

11.4 Drawing the tree

```

3436 \newif\ifforest@drawtree@preservenodeboxes@
3437 \def\forest@node@drawtree{%
3438   \expandafter\ifstrequal\expandafter{\forest@drawtreebox}{\pgfkeysnovalue}{%
3439     \let\forest@drawtree@beginbox\relax
3440     \let\forest@drawtree@endbox\relax
3441   }{%
3442     \edef\forest@drawtree@beginbox{\global\setbox\forest@drawtreebox=\hbox\bgroup}%
3443     \let\forest@drawtree@endbox\egroup
3444   }%
3445   \ifforest@external@
3446     \ifforest@externalize@tree@
3447     \forest@temptrue
3448   \else
3449     \tikzifexternalizing{%
3450       \ifforest@was@tikzexternalwasenable
3451         \forest@temptrue
3452         \pgfkeys{/tikz/external/optimize=false}%
3453         \let\forest@drawtree@beginbox\relax
3454         \let\forest@drawtree@endbox\relax
3455       \else
3456         \forest@tempfalse
3457       \fi
3458     }{%
3459       \forest@tempfalse
3460     }%
3461   \fi
3462   \ifforest@temp
3463     \advance\forest@externalize@inner@n 1
3464     \edef\forest@externalize@filename{%
3465       \tikzexternalrealjob-forest-\forest@externalize@outer@n
3466       \ifnum\forest@externalize@inner@n=0 \else.\the\forest@externalize@inner@n\fi}%
3467     \expandafter\tikzsetnextfilename\expandafter{\forest@externalize@filename}%
3468     \tikzexternalenable
3469     \pgfkeysalso{/tikz/external/remake next,/tikz/external/export next}%
3470   \fi
3471   \ifforest@externalize@tree@
3472     \typeout{forest: Invoking a recursive call to generate the external picture
3473       ' \forest@externalize@filename ' for the following context+code:
3474       '\expandafter\detokenize\expandafter{\forest@externalize@id}'}%
3475   \fi
3476 \fi

```

```

3477 %
3478 \ifforesttikzcsack
3479   \let\forest@original@tikz@parse@node\tikz@parse@node
3480   \let\tikz@parse@node\forest@tikz@parse@node
3481 \fi
3482 \pgfkeysgetvalue{/forest/begin draw/.@cmd}\forest@temp@begindraw
3483 \pgfkeysgetvalue{/forest/end draw/.@cmd}\forest@temp@enddraw
3484 \edef\forest@marshal{%
3485   \noexpand\forest@drawtree@beginbox
3486   \expandonce{\forest@temp@begindraw\pgfkeysnovalue\pgfeov}%
3487   \noexpand\forest@node@drawtree@
3488   \expandonce{\forest@temp@enddraw\pgfkeysnovalue\pgfeov}%
3489   \noexpand\forest@drawtree@endbox
3490 }\forest@marshal
3491 \ifforesttikzcsack
3492   \let\tikz@parse@node\forest@original@tikz@parse@node
3493 \fi
3494 %
3495 \ifforest@external@
3496   \ifforest@externalize@tree@
3497     \tikzexternaldisable
3498     \eappto\forest@externalize@checkimages{%
3499       \noexpand\forest@includeexternal@check{\forest@externalize@filename}%
3500     }%
3501     \expandafter\ifstrequal\expandafter{\forest@drawtreebox}{\pgfkeysnovalue}{%
3502       \eappto\forest@externalize@loadimages{%
3503         \noexpand\forest@includeexternal{\forest@externalize@filename}%
3504       }%
3505     }{%
3506       \eappto\forest@externalize@loadimages{%
3507         \noexpand\forest@includeexternal@box\forest@drawtreebox{\forest@externalize@filename}%
3508       }%
3509     }%
3510   \fi
3511 \fi
3512 }
3513 \def\forest@node@drawtree@{%
3514   \forest@node@foreach{\forest@draw@node}%
3515   \forest@node@ifnamedefined{forest@baseline@node}{%
3516     \edef\forest@temp{%
3517       \noexpand\pgfsetbaselinepointlater{%
3518         \noexpand\pgfpointanchor
3519         {\forest@ve{\forest@node@Nametoid{forest@baseline@node}}{name}}
3520         {\forest@ve{\forest@node@Nametoid{forest@baseline@node}}{anchor}}
3521       }%
3522     }\forest@temp
3523   }{}%
3524   \forest@node@foreachdescendant{\forest@draw@edge}%
3525   \forest@node@foreach{\forest@draw@tikz}%
3526 }
3527 \def\forest@draw@node{%
3528   \ifnum\forest@ve{phantom}=0
3529     \forest@node@forest@position@node@later@restore
3530     \ifforest@drawtree@preservenodeboxes@
3531       \pgfnodealias{forest@temp}{\forest@ve{later@name}}%
3532     \fi
3533     \pgfpositionnodenow{\pgfpoint{\forest@ve{x}}{\forest@ve{y}}}%
3534     \ifforest@drawtree@preservenodeboxes@
3535       \pgfnodealias{\forest@ve{later@name}}{\forest@temp}%
3536     \fi
3537   \fi

```

```

3538 }
3539 \def\forest@draw@edge{%
3540   \ifnum\forest@ve{\phantom}=0
3541     \ifnum\forest@ve{\forest@ve{\parent}}{\phantom}=0
3542       \edef\forest@temp{\forest@ve{edge path}}%
3543       \forest@temp
3544       \fi
3545     \fi
3546 }
3547 \def\forest@draw@tikz{%
3548   \forest@ve{tikz}%
3549 }

A hack into TikZ's coordinate parser: implements relative node names!
3550 \def\forest@tikz@parse@node#1(#2){%
3551   \pgfutil@in@.#2}%
3552   \ifpgfutil@in@
3553     \expandafter\forest@tikz@parse@node@checkiftikzname@withdot
3554   \else%
3555     \expandafter\forest@tikz@parse@node@checkiftikzname@withoutdot
3556   \fi%
3557   #1(#2)\forest@end
3558 }
3559 \def\forest@tikz@parse@node@checkiftikzname@withdot#1(#2.#3)\forest@end{%
3560   \forest@tikz@parse@node@checkiftikzname#1{#2}{.#3}}
3561 \def\forest@tikz@parse@node@checkiftikzname@withoutdot#1(#2)\forest@end{%
3562   \forest@tikz@parse@node@checkiftikzname#1{#2}{}}
3563 \def\forest@tikz@parse@node@checkiftikzname#1#2#3{%
3564   \expandafter\ifx\csname pgf@sh@ns@#2\endcsname\relax
3565     \forest@forthis{%
3566       \forest@nameandgo{#2}%
3567       \edef\forest@temp@relativenodename{\forest@ve{name}}%
3568     }%
3569   \else
3570     \def\forest@temp@relativenodename{#2}%
3571   \fi
3572   \expandafter\forest@original@tikz@parse@node\expandafter#1\expandafter(\forest@temp@relativenodename#3)%
3573 }
3574 \def\forest@nameandgo#1{%
3575   \pgfutil@in@!{#1}%
3576   \ifpgfutil@in@
3577     \forest@nameandgo@(#1)%
3578   \else
3579     \ifstrempy{#1}{-}{\edef\forest@cn{\forest@node@Nametoid{#1}}}%
3580   \fi
3581 }
3582 \def\forest@nameandgo@(#1!#2){%
3583   \ifstrempy{#1}{-}{\edef\forest@cn{\forest@node@Nametoid{#1}}}%
3584   \forest@go{#2}%
3585 }

```

parent/child anchor are generic anchors which forward to the real one. There's a hack in there to deal with link pointing to the "border" anchor.

```

3586 \pgfdeclaregenericanchor{parent anchor}{%
3587   \forest@generic@parent@child@anchor{parent }{#1}}
3588 \pgfdeclaregenericanchor{child anchor}{%
3589   \forest@generic@parent@child@anchor{child }{#1}}
3590 \pgfdeclaregenericanchor{anchor}{%
3591   \forest@generic@parent@child@anchor{}{#1}}
3592 \def\forest@generic@parent@child@anchor#1#2{%
3593   \forest@get{\forest@node@Nametoid{\pgfreferencednodename}}{#1anchor}\forest@temp@parent@anchor
3594   \ifdefempty\forest@temp@parent@anchor{%

```



```

3595 \pgf@sh@reanchor{#2}{center}%
3596 \xdef\forest@hack@tikzshapeborder{%
3597 \noexpand\tikz@shapebordertrue
3598 \def\noexpand\tikz@shapeborder@name{\pgfreferencednodename}%
3599 }\aftergroup\forest@hack@tikzshapeborder
3600 }{%
3601 \pgf@sh@reanchor{#2}{\forest@temp@parent@anchor}%
3602 }%
3603 }

```

12 Geometry

A α *grow line* is a line through the origin at angle α . The following macro sets up the grow line, which can then be used by other code (the change is local to the \TeX group). More precisely, two normalized vectors are set up: one (x_g, y_g) on the grow line, and one (x_s, y_s) orthogonal to it—to get (x_s, y_s) , rotate (x_g, y_g) 90° counter-clockwise.

```

3604 \newdimen\forest@xg
3605 \newdimen\forest@yg
3606 \newdimen\forest@xs
3607 \newdimen\forest@ys
3608 \def\forest@setupgrowline#1{%
3609 \edef\forest@grow{#1}%
3610 \pgfpointpolar\forest@grow{1pt}%
3611 \forest@xg=\pgf@x
3612 \forest@yg=\pgf@y
3613 \forest@xs=-\pgf@y
3614 \forest@ys=\pgf@x
3615 }

```

12.1 Projections

The following macro belongs to the `\pgfpoint...` family: it projects point `#1` on the grow line. (The result is returned via `\pgf@x` and `\pgf@y`.) The implementation is based on code from `tikzlibrarycalc`, but optimized for projecting on grow lines, and split to optimize serial usage in `\forest@projectpath`.

```

3616 \def\forest@pgfpointprojectiontogrowline#1{%
3617 \pgf@process{#1}%

```

Calculate the scalar product of (x, y) and (x_g, y_g) : that's the distance of (x, y) to the grow line.

```

3618 \pgfutil@tempdima=\pgf@sys@tonumber{\pgf@x}\forest@xg%
3619 \advance\pgfutil@tempdima by\pgf@sys@tonumber{\pgf@y}\forest@yg%

```

The projection is (x_g, y_g) scaled by the distance.

```

3620 \global\pgf@x=\pgf@sys@tonumber{\pgfutil@tempdima}\forest@xg%
3621 \global\pgf@y=\pgf@sys@tonumber{\pgfutil@tempdima}\forest@yg%
3622 }

```

The following macro calculates the distance of point `#2` to the grow line and stores the result in \TeX -dimension `#1`. The distance is the scalar product of the point vector and the normalized vector orthogonal to the grow line.

```

3623 \def\forest@distancetogrowline#1#2{%
3624 \pgf@process{#2}%
3625 #1=\pgf@sys@tonumber{\pgf@x}\forest@xs\relax
3626 \advance#1 by\pgf@sys@tonumber{\pgf@y}\forest@ys\relax
3627 }

```

Note that the distance to the grow line is positive for points on one of its sides and negative for points on the other side. (It is positive on the side which (x_s, y_s) points to.) We thus say that the grow line partitions the plane into a *positive* and a *negative* side.

The following macro projects all segment edges (“points”) of a simple²⁰ path `#1` onto the grow line. The result is an array of tuples $(\text{xo}, \text{yo}, \text{xp}, \text{yp})$, where `xo` and `yo` stand for the original point, and `xp`

²⁰A path is *simple* if it consists of only move-to and line-to operations.

and `yp` stand for its *projection*. The prefix of the array is given by `#2`. If the array already exists, the new items are appended to it. The array is not sorted: the order of original points in the array is their order in the path. The computation does not destroy the current path. All result-macros have local scope.

The macro is just a wrapper for `\forest@projectpath@process`.

```

3628 \let\forest@pp@n\relax
3629 \def\forest@projectpath@togrowline#1#2{%
3630   \edef\forest@pp@prefix{#2}%
3631   \forest@save@pgfsyssoftpath@tokendefs
3632   \let\pgfsyssoftpath@movetotoken\forest@projectpath@processpoint
3633   \let\pgfsyssoftpath@linetotoken\forest@projectpath@processpoint
3634   \c@pgf@counta=0
3635   #1%
3636   \csedef{#2n}{\the\c@pgf@counta}%
3637   \forest@restore@pgfsyssoftpath@tokendefs
3638 }

```

For each point, remember the point and its projection to grow line.

```

3639 \def\forest@projectpath@processpoint#1#2{%
3640   \pgfqpoint{#1}{#2}%
3641   \expandafter\edef\csname\forest@pp@prefix\the\c@pgf@counta xo\endcsname{\the\pgf@x}%
3642   \expandafter\edef\csname\forest@pp@prefix\the\c@pgf@counta yo\endcsname{\the\pgf@y}%
3643   \forest@pgfpointprojectiontogrowline{}%
3644   \expandafter\edef\csname\forest@pp@prefix\the\c@pgf@counta xp\endcsname{\the\pgf@x}%
3645   \expandafter\edef\csname\forest@pp@prefix\the\c@pgf@counta yp\endcsname{\the\pgf@y}%
3646   \advance\c@pgf@counta 1\relax
3647 }

```

Sort the array (prefix `#1`) produced by `\forest@projectpath@togrowline` by `(xp,yp)`, in the ascending order.

```

3648 \def\forest@sortprojections#1{%
3649   % todo: optimize in cases when we know that the array is actually a
3650   % merger of sorted arrays; when does this happen? in
3651   % distance_between_paths, and when merging the edges of the parent
3652   % and its children in a uniform growth tree
3653   \edef\forest@ppi@inputprefix{#1}%
3654   \c@pgf@counta=\csname#1n\endcsname\relax
3655   \advance\c@pgf@counta -1
3656   \forest@sort\forest@ppiraw@cmp\forest@ppiraw@let\forest@sort@ascending{0}{\the\c@pgf@counta}%
3657 }

```

The following macro processes the data gathered by (possibly more than one invocation of) `\forest@projectpath@togrowline` into array with prefix `#1`. The resulting data is the following.

- Array of projections (prefix `#2`)
 - its items are tuples `(x,y)` (the array is sorted by `x` and `y`), and
 - an inner array of original points (prefix `#2N@`, where `N` is the index of the item in array `#2`. The items of `#2N@` are `x`, `y` and `d`: `x` and `y` are the coordinates of the original point; `d` is its distance to the grow line. The inner array is not sorted.
- A dictionary `#2`: keys are the coordinates `(x,y)` of the original points; a value is the index of the original point's projection in array `#2`.²¹

```

3658 \def\forest@processprojectioninfo#1#2{%
3659   \edef\forest@ppi@inputprefix{#1}%

```

²¹At first sight, this information could be cached “at the source”: by `\forest@pgfpointprojectiontogrowline`. However, due to imprecise intersecting (in `breakpath`), we cheat and merge very adjacent projection points, expecting that the points to project to the merged projection point. All this depends on the given path, so a generic cache is not feasible.

Loop (counter \c@pgf@counta) through the sorted array of raw data.

```

3660 \c@pgf@counta=0
3661 \c@pgf@countb=-1
3662 \loop
3663 \ifnum\c@pgf@counta<\csname#1n\endcsname\relax

```

Check if the projection tuple in the current raw item equals the current projection.

```

3664 \letcs\forest@xo{#1\the\c@pgf@counta xo}%
3665 \letcs\forest@yo{#1\the\c@pgf@counta yo}%
3666 \letcs\forest@xp{#1\the\c@pgf@counta xp}%
3667 \letcs\forest@yp{#1\the\c@pgf@counta yp}%
3668 \ifnum\c@pgf@countb<0
3669 \forest@equaltotolerancefalse
3670 \else
3671 \forest@equaltotolerance
3672 {\pgfqpoint\forest@xp\forest@yp}%
3673 {\pgfqpoint
3674 {\csname#2\the\c@pgf@countb x\endcsname}%
3675 {\csname#2\the\c@pgf@countb y\endcsname}%
3676 }%
3677 \fi
3678 \ifforest@equaltotolerance\else

```

It not, we will append a new item to the outer result array.

```

3679 \advance\c@pgf@countb 1
3680 \cslet{#2\the\c@pgf@countb x}\forest@xp
3681 \cslet{#2\the\c@pgf@countb y}\forest@yp
3682 \csdef{#2\the\c@pgf@countb @n}{0}%
3683 \fi

```

If the projection is actually a projection of one a point in our path:

```

3684 % todo: this is ugly!
3685 \ifdefined\forest@xo\ifx\forest@xo\relax\else
3686 \ifdefined\forest@yo\ifx\forest@yo\relax\else

```

Append the point of the current raw item to the inner array of points projecting to the current projection.

```

3687 \forest@append@point@to@inner@array
3688 \forest@xo\forest@yo
3689 {#2\the\c@pgf@countb @}%

```

Put a new item in the dictionary: key = the original point, value = the projection index.

```

3690 \csedef{#2(\forest@xo,\forest@yo)}{\the\c@pgf@countb}%
3691 \fi\fi
3692 \fi\fi

```

Clean-up the raw array item.

```

3693 \cslet{#1\the\c@pgf@counta xo}\relax
3694 \cslet{#1\the\c@pgf@counta yo}\relax
3695 \cslet{#1\the\c@pgf@counta xp}\relax
3696 \cslet{#1\the\c@pgf@counta yp}\relax
3697 \advance\c@pgf@counta 1
3698 \repeat

```

Clean up the raw array length.

```

3699 \cslet{#1n}\relax

```

Store the length of the outer result array.

```

3700 \advance\c@pgf@countb 1
3701 \csedef{#2n}{\the\c@pgf@countb}%
3702 }

```

Item-exchange macro for quicksorting the raw projection data. (#1 is copied into #2.)

```

3703 \def\forest@ppiraw@let#1#2{%
3704 \csletcs{\forest@ppi@inputprefix#1xo}{\forest@ppi@inputprefix#2xo}%

```

```

3705 \csletcs{\forest@ppi@inputprefix#1yo}{\forest@ppi@inputprefix#2yo}%
3706 \csletcs{\forest@ppi@inputprefix#1xp}{\forest@ppi@inputprefix#2xp}%
3707 \csletcs{\forest@ppi@inputprefix#1yp}{\forest@ppi@inputprefix#2yp}%
3708 }

```

Item comparison macro for quicksorting the raw projection data.

```

3709 \def\forest@ppiraw@cmp#1#2{%
3710   \forest@sort@cmptwodimcs
3711     {\forest@ppi@inputprefix#1xp}{\forest@ppi@inputprefix#1yp}%
3712     {\forest@ppi@inputprefix#2xp}{\forest@ppi@inputprefix#2yp}%
3713 }

```

Append the point (#1,#2) to the (inner) array of points (prefix #3).

```

3714 \def\forest@append@point@to@inner@array#1#2#3{%
3715   \c@pgf@countc=\csname#3n\endcsname\relax
3716   \csedef{#3\the\c@pgf@countc x}{#1}%
3717   \csedef{#3\the\c@pgf@countc y}{#2}%
3718   \forest@distancetogrowline\pgfutil@tempdima{\pgfqpoint#1#2}%
3719   \csedef{#3\the\c@pgf@countc d}{\the\pgfutil@tempdima}%
3720   \advance\c@pgf@countc 1
3721   \csedef{#3n}{\the\c@pgf@countc}%
3722 }

```

12.2 Break path

The following macro computes from the given path (#1) a “broken” path (#3) that contains the same points of the plane, but has potentially more segments, so that, for every point from a given set of points on the grow line, a line through this point perpendicular to the grow line intersects the broken path only at its edge segments (i.e. not between them).

The macro works only for *simple* paths, i.e. paths built using only move-to and line-to operations. Furthermore, `\forest@processprojectioninfo` must be called before calling `\forest@breakpath`: we expect information with prefix #2. The macro updates the information compiled by `\forest@processprojectioninfo` with information about points added by path-breaking.

```

3723 \def\forest@breakpath#1#2#3{%

```

Store the current path in a macro and empty it, then process the stored path. The processing creates a new current path.

```

3724   \edef\forest@bp@prefix{#2}%
3725   \forest@save@pgfsyssoftpath@tokendefs
3726   \let\pgfsyssoftpath@movetotoken\forest@breakpath@processfirstpoint
3727   \let\pgfsyssoftpath@linetotoken\forest@breakpath@processfirstpoint
3728   %\pgfusepath{}% empty the current path. ok?
3729   #1%
3730   \forest@restore@pgfsyssoftpath@tokendefs
3731   \pgfsyssoftpath@getcurrentpath#3%
3732 }

```

The original and the broken path start in the same way. (This code implicitly “repairs” a path that starts illegally, with a line-to operation.)

```

3733 \def\forest@breakpath@processfirstpoint#1#2{%
3734   \forest@breakpath@processmoveto{#1}{#2}%
3735   \let\pgfsyssoftpath@movetotoken\forest@breakpath@processmoveto
3736   \let\pgfsyssoftpath@linetotoken\forest@breakpath@processlineto
3737 }

```

When a move-to operation is encountered, it is simply copied to the broken path, starting a new subpath. Then we remember the last point, its projection’s index (the point dictionary is used here) and the actual projection point.

```

3738 \def\forest@breakpath@processmoveto#1#2{%
3739   \pgfsyssoftpath@moveto{#1}{#2}%
3740   \def\forest@previous@x{#1}%

```

```

3741 \def\forest@previous@y{#2}%
3742 \expandafter\let\expandafter\forest@previous@i
3743 \csname\forest@bp@prefix(#1,#2)\endcsname
3744 \expandafter\let\expandafter\forest@previous@px
3745 \csname\forest@bp@prefix\forest@previous@i x\endcsname
3746 \expandafter\let\expandafter\forest@previous@py
3747 \csname\forest@bp@prefix\forest@previous@i y\endcsname
3748 }

```

This is the heart of the path-breaking procedure.

```

3749 \def\forest@breakpath@processlineto#1#2{%

```

Usually, the broken path will continue with a line-to operation (to the current point (#1,#2)).

```

3750 \let\forest@breakpath@op\pgfsyssoftpath@lineto

```

Get the index of the current point's projection and the projection itself. (The point dictionary is used here.)

```

3751 \expandafter\let\expandafter\forest@i
3752 \csname\forest@bp@prefix(#1,#2)\endcsname
3753 \expandafter\let\expandafter\forest@px
3754 \csname\forest@bp@prefix\forest@i x\endcsname
3755 \expandafter\let\expandafter\forest@py
3756 \csname\forest@bp@prefix\forest@i y\endcsname

```

Test whether the projections of the previous and the current point are the same.

```

3757 \forest@equaltotolerance
3758 {\pgfqpoint{\forest@previous@px}{\forest@previous@py}}%
3759 {\pgfqpoint{\forest@px}{\forest@py}}%
3760 \ifforest@equaltotolerance

```

If so, we are dealing with a segment, perpendicular to the grow line. This segment must be removed, so we change the operation to move-to.

```

3761 \let\forest@breakpath@op\pgfsyssoftpath@moveto
3762 \else

```

Figure out the “direction” of the segment: in the order of the array of projections, or in the reversed order? Setup the loop step and the test condition.

```

3763 \forest@temp@count=\forest@previous@i\relax
3764 \ifnum\forest@previous@i<\forest@i\relax
3765 \def\forest@breakpath@step{1}%
3766 \def\forest@breakpath@test{\forest@temp@count<\forest@i\relax}%
3767 \else
3768 \def\forest@breakpath@step{-1}%
3769 \def\forest@breakpath@test{\forest@temp@count>\forest@i\relax}%
3770 \fi

```

Loop through all the projections between (in the (possibly reversed) array order) the projections of the previous and the current point (both exclusive).

```

3771 \loop
3772 \advance\forest@temp@count\forest@breakpath@step\relax
3773 \expandafter\ifnum\forest@breakpath@test

```

Intersect the current segment with the line through the current (in the loop!) projection perpendicular to the grow line. (There *will* be an intersection.)

```

3774 \pgfpointintersectionoflines
3775 {\pgfqpoint
3776 {\csname\forest@bp@prefix\the\forest@temp@count x\endcsname}%
3777 {\csname\forest@bp@prefix\the\forest@temp@count y\endcsname}%
3778 }%
3779 {\pgfpointadd
3780 {\pgfqpoint
3781 {\csname\forest@bp@prefix\the\forest@temp@count x\endcsname}%
3782 {\csname\forest@bp@prefix\the\forest@temp@count y\endcsname}%

```

```

3783     }%
3784     {\pgfqpoint{\forest@xs}{\forest@ys}}%
3785     }%
3786     {\pgfqpoint{\forest@previous@x}{\forest@previous@y}}%
3787     {\pgfqpoint{#1}{#2}}%
    Break the segment at the intersection.
3788     \pgfgetlastxy\forest@last@x\forest@last@y
3789     \pgfsyssoftpath@lineto\forest@last@x\forest@last@y
    Append the breaking point to the inner array for the projection.
3790     \forest@append@point@to@inner@array
3791     \forest@last@x\forest@last@y
3792     {\forest@bp@prefix\the\forest@temp@count @}%
    Cache the projection of the new segment edge.
3793     \csedef{\forest@bp@prefix(\the\pgf@x,\the\pgf@y)}{\the\forest@temp@count}%
3794     \repeat
3795     \fi
    Add the current point.
3796     \forest@breakpath@op{#1}{#2}%
    Setup new “previous” info: the segment edge, its projection’s index, and the projection.
3797     \def\forest@previous@x{#1}%
3798     \def\forest@previous@y{#2}%
3799     \let\forest@previous@i\forest@i
3800     \let\forest@previous@px\forest@px
3801     \let\forest@previous@py\forest@py
3802 }

```

12.3 Get tight edge of path

This is one of the central algorithms of the package. Given a simple path and a grow line, this method computes its (negative and positive) “tight edge”, which we (informally) define as follows.

Imagine an infinitely long light source parallel to the grow line, on the grow line’s negative/positive side.²² Furthermore imagine that the path is opaque. Then the negative/positive tight edge of the path is the part of the path that is illuminated.

This macro takes three arguments: `#1` is the path; `#2` and `#3` are macros which will receive the negative and the positive edge, respectively. The edges are returned in the `softpath` format. Grow line should be set before calling this macro.

Enclose the computation in a $\text{T}_{\text{E}}\text{X}$ group. This is actually quite crucial: if there was no enclosure, the temporary data (the segment dictionary, to be precise) computed by the prior invocations of the macro could corrupt the computation in the current invocation.

```

3803 \def\forest@getnegativetightedgeofpath#1#2{%
3804   \forest@get@onetightedgeofpath#1\forest@sort@ascending#2}
3805 \def\forest@getpositivetightedgeofpath#1#2{%
3806   \forest@get@onetightedgeofpath#1\forest@sort@descending#2}
3807 \def\forest@get@onetightedgeofpath#1#2#3{%
3808   {%
3809     \forest@get@one@tightedgeofpath#1#2\forest@gep@edge
3810     \global\let\forest@gep@global@edge\forest@gep@edge
3811   }%
3812   \let#3\forest@gep@global@edge
3813 }
3814 \def\forest@get@one@tightedgeofpath#1#2#3{%

```

Project the path to the grow line and compile some useful information.

```

3815   \forest@projectpathtogrowline#1{\forest@pp@}%
3816   \forest@sortprojections{\forest@pp@}%
3817   \forest@processprojectioninfo{\forest@pp@}{\forest@pi@}%

```

²²For the definition of negative/positive side, see `forest@distancetogrowline` in §12.1

Break the path.

```
3818 \forest@breakpath#1{forest@pi@}\forest@brokenpath
```

Compile some more useful information.

```
3819 \forest@sort@inner@arrays{forest@pi@}#2%
```

```
3820 \forest@pathtodict\forest@brokenpath{forest@pi@}%
```

The auxiliary data is set up: do the work!

```
3821 \forest@gettightedgeofpath@getedge
```

```
3822 \pgfsyssoftpath@getcurrentpath\forest@edge
```

Where possible, merge line segments of the path into a single line segment. This is an important optimization, since the edges of the subtrees are computed recursively. Not simplifying the edge could result in a wild growth of the length of the edge (in the sense of the number of segments).

```
3823 \forest@simplifypath\forest@edge#3%
```

```
3824 }
```

Get both negative (stored in #2) and positive (stored in #3) edge of the path #1.

```
3825 \def\forest@getbothtightedgesofpath#1#2#3{%
```

```
3826 {%
```

```
3827 \forest@get@one@tightedgeofpath#1\forest@sort@ascending\forest@gep@firstedge
```

Reverse the order of items in the inner arrays.

```
3828 \c@pgf@counta=0
```

```
3829 \loop
```

```
3830 \ifnum\c@pgf@counta<\forest@pi@n\relax
```

```
3831 \forest@ppi@deflet{forest@pi@the\c@pgf@counta @}%
```

```
3832 \forest@reversearray\forest@ppi@let
```

```
3833 {0}%
```

```
3834 {\csname forest@pi@the\c@pgf@counta @n\endcsname}%
```

```
3835 \advance\c@pgf@counta 1
```

```
3836 \repeat
```

Calling \forest@gettightedgeofpath@getedge now will result in the positive edge.

```
3837 \forest@gettightedgeofpath@getedge
```

```
3838 \pgfsyssoftpath@getcurrentpath\forest@edge
```

```
3839 \forest@simplifypath\forest@edge\forest@gep@secondedge
```

Smuggle the results out of the enclosing TeX group.

```
3840 \global\let\forest@gep@global@firstedge\forest@gep@firstedge
```

```
3841 \global\let\forest@gep@global@secondedge\forest@gep@secondedge
```

```
3842 }%
```

```
3843 \let#2\forest@gep@global@firstedge
```

```
3844 \let#3\forest@gep@global@secondedge
```

```
3845 }
```

Sort the inner arrays of original points wrt the distance to the grow line. #2 = \forest@sort@ascending/\forest@sort@loopa is used here because quicksort uses \loop.)

```
3846 \def\forest@sort@inner@arrays#1#2{%
```

```
3847 \c@pgf@counta=0
```

```
3848 \forest@loopa
```

```
3849 \ifnum\c@pgf@counta<\csname#1n\endcsname
```

```
3850 \c@pgf@countb=\csname#1the\c@pgf@counta @n\endcsname\relax
```

```
3851 \ifnum\c@pgf@countb>1
```

```
3852 \advance\c@pgf@countb -1
```

```
3853 \forest@ppi@deflet{#1the\c@pgf@counta @}%
```

```
3854 \forest@ppi@defcmp{#1the\c@pgf@counta @}%
```

```
3855 \forest@sort\forest@ppi@cmp\forest@ppi@let#2{0}{the\c@pgf@countb}%
```

```
3856 \fi
```

```
3857 \advance\c@pgf@counta 1
```

```
3858 \forest@repeata
```

```
3859 }
```

A macro that will define the item exchange macro for quicksorting the inner arrays of original points.
It takes one argument: the prefix of the inner array.

```
3860 \def\forest@ppi@deflet#1{%
3861   \edef\forest@ppi@let##1##2{%
3862     \noexpand\csletcs{#1##1x}{#1##2x}%
3863     \noexpand\csletcs{#1##1y}{#1##2y}%
3864     \noexpand\csletcs{#1##1d}{#1##2d}%
3865   }%
3866 }
```

A macro that will define the item-compare macro for quicksorting the embedded arrays of original points.
It takes one argument: the prefix of the inner array.

```
3867 \def\forest@ppi@defcmp#1{%
3868   \edef\forest@ppi@cmp##1##2{%
3869     \noexpand\forest@sort@cmpdimcs{#1##1d}{#1##2d}%
3870   }%
3871 }
```

Put path segments into a “segment dictionary”: for each segment of the path from (x_1, y_1) to (x_2, y_2)
let $\text{\forest@}(x_1, y_1) \text{--}(x_2, y_2)$ be \forest@inpath (which can be anything but \relax).

```
3872 \let\forest@inpath\advance
```

This macro is just a wrapper to process the path.

```
3873 \def\forest@pathtodict#1#2{%
3874   \edef\forest@pathtodict@prefix{#2}%
3875   \forest@save@pgfsyssoftpath@tokendefs
3876   \let\pgfsyssoftpath@movetotoken\forest@pathtodict@movetooop
3877   \let\pgfsyssoftpath@linetotoken\forest@pathtodict@linetooop
3878   \def\forest@pathtodict@subpathstart{ }%
3879   #1%
3880   \forest@restore@pgfsyssoftpath@tokendefs
3881 }
```

When a move-to operation is encountered:

```
3882 \def\forest@pathtodict@movetooop#1#2{%
```

If a subpath had just started, it was a degenerate one (a point). No need to store that (i.e. no code would use this information). So, just remember that a new subpath has started.

```
3883   \def\forest@pathtodict@subpathstart{(#1,#2)-}%
3884 }
```

When a line-to operation is encountered:

```
3885 \def\forest@pathtodict@linetooop#1#2{%
```

If the subpath has just started, its start is also the start of the current segment.

```
3886 \if\relax\forest@pathtodict@subpathstart\relax\else
3887   \let\forest@pathtodict@from\forest@pathtodict@subpathstart
3888 \fi
```

Mark the segment as existing.

```
3889   \expandafter\let\csname\forest@pathtodict@prefix\forest@pathtodict@from-(#1,#2)\endcsname\forest@inpath
```

Set the start of the next segment to the current point, and mark that we are in the middle of a subpath.

```
3890   \def\forest@pathtodict@from{(#1,#2)-}%
3891   \def\forest@pathtodict@subpathstart{ }%
3892 }
```

In this macro, the edge is actually computed.

```
3893 \def\forest@gettightedgeofpath@getedge{%
```

Clear the path and the last projection.

```
3894   \pgfsyssoftpath@setcurrentpath\pgfutil@empty
3895   \let\forest@last@x\relax
3896   \let\forest@last@y\relax
```


Loop through the (ordered) array of projections. (Since we will be dealing with the current and the next projection in each iteration of the loop, we loop the counter from the first to the second-to-last projection.)

```

3897 \c@pgf@counta=0
3898 \forest@temp@count=\forest@pi@n\relax
3899 \advance\forest@temp@count -1
3900 \edef\forest@nminusone{\the\forest@temp@count}%
3901 \forest@loopa
3902 \ifnum\c@pgf@counta<\forest@nminusone\relax
3903   \forest@gettightedgeofpath@getedge@loopa
3904 \forest@repeata

```

A special case: the edge ends with a degenerate subpath (a point).

```

3905 \ifnum\forest@nminusone<\forest@n\relax\else
3906   \ifnum\csname forest@pi@\forest@nminusone @n\endcsname>0
3907     \forest@gettightedgeofpath@maybemoveto{\forest@nminusone}{0}%
3908   \fi
3909 \fi
3910 }

```

The body of a loop containing an embedded loop must be put in a separate macro because it contains the `\if...` of the embedded `\loop...` without the matching `\fi`: `\fi` is “hiding” in the embedded `\loop`, which has not been expanded yet.

```

3911 \def\forest@gettightedgeofpath@getedge@loopa{%
3912   \ifnum\csname forest@pi@\the\c@pgf@counta @n\endcsname>0

```

Degenerate case: a subpath of the edge is a point.

```

3913   \forest@gettightedgeofpath@maybemoveto{\the\c@pgf@counta}{0}%

```

Loop through points projecting to the current projection. The preparations above guarantee that the points are ordered (either in the ascending or the descending order) with respect to their distance to the grow line.

```

3914   \c@pgf@countb=0
3915   \forest@loopb
3916   \ifnum\c@pgf@countb<\csname forest@pi@\the\c@pgf@counta @n\endcsname\relax
3917     \forest@gettightedgeofpath@getedge@loopb
3918   \forest@repeatb
3919   \fi
3920   \advance\c@pgf@counta 1
3921 }

```

Loop through points projecting to the next projection. Again, the points are ordered.

```

3922 \def\forest@gettightedgeofpath@getedge@loopb{%
3923   \c@pgf@countc=0
3924   \advance\c@pgf@counta 1
3925   \edef\forest@aplusone{\the\c@pgf@counta}%
3926   \advance\c@pgf@counta -1
3927   \forest@loopc
3928   \ifnum\c@pgf@countc<\csname forest@pi@\forest@aplusone @n\endcsname\relax

```

Test whether [the current point]–[the next point] or [the next point]–[the current point] is a segment in the (broken) path. The first segment found is the one with the minimal/maximal distance (depending on the sort order of arrays of points projecting to the same projection) to the grow line.

Note that for this to work in all cases, the original path should have been broken on its self-intersections. However, a careful reader will probably remember that `\forest@breakpath` does *not* break the path at its self-intersections. This is omitted for performance reasons. Given the intended use of the algorithm (calculating edges of subtrees), self-intersecting paths cannot arise anyway, if only the node boundaries are non-self-intersecting. So, a warning: if you develop a new shape and write a macro computing its boundary, make sure that the computed boundary path is non-self-intersecting!

```

3929   \forest@tempfalse
3930   \expandafter\ifx\csname forest@pi@(%
3931     \csname forest@pi@\the\c@pgf@counta @\the\c@pgf@countb x\endcsname,%

```

```

3932         \csname forest@pi@\the\c@pgf@counta @\the\c@pgf@countb y\endcsname)--(
3933         \csname forest@pi@\forest@aplusone @\the\c@pgf@countc x\endcsname,%
3934         \csname forest@pi@\forest@aplusone @\the\c@pgf@countc y\endcsname)%
3935         \endcsname\forest@inpath
3936         \forest@temptrue
3937     \else
3938         \expandafter\ifx\csname forest@pi@(%
3939         \csname forest@pi@\forest@aplusone @\the\c@pgf@countc x\endcsname,%
3940         \csname forest@pi@\forest@aplusone @\the\c@pgf@countc y\endcsname)--(
3941         \csname forest@pi@\the\c@pgf@counta @\the\c@pgf@countb x\endcsname,%
3942         \csname forest@pi@\the\c@pgf@counta @\the\c@pgf@countb y\endcsname)%
3943         \endcsname\forest@inpath
3944         \forest@temptrue
3945     \fi
3946 \fi
3947 \ifforest@temp

```

We have found the segment with the minimal/maximal distance to the grow line. So let's add it to the edge path.

First, deal with the start point of the edge: check if the current point is the last point. If that is the case (this happens if the current point was the end point of the last segment added to the edge), nothing needs to be done; otherwise (this happens if the current point will start a new subpath of the edge), move to the current point, and update the last-point macros.

```

3948         \forest@gettightedgeofpath@maybemoveto{\the\c@pgf@counta}{\the\c@pgf@countb}%

```

Second, create a line to the end point.

```

3949         \edef\forest@last@x{%
3950         \csname forest@pi@\forest@aplusone @\the\c@pgf@countc x\endcsname}%
3951         \edef\forest@last@y{%
3952         \csname forest@pi@\forest@aplusone @\the\c@pgf@countc y\endcsname}%
3953         \pgfsyssoftpath@lineto\forest@last@x\forest@last@y

```

Finally, “break” out of the `\forest@loopc` and `\forest@loopb`.

```

3954         \c@pgf@countc=\csname forest@pi@\forest@aplusone @n\endcsname
3955         \c@pgf@countb=\csname forest@pi@\the\c@pgf@counta @n\endcsname
3956     \fi
3957     \advance\c@pgf@countc 1
3958     \forest@repeatc
3959     \advance\c@pgf@countb 1
3960 }

```

`\forest@#1@` is an (ordered) array of points projecting to projection with index #1. Check if #2th point of that array equals the last point added to the edge: if not, add it.

```

3961 \def\forest@gettightedgeofpath@maybemoveto#1#2{%
3962     \forest@temptrue
3963     \ifx\forest@last@x\relax\else
3964         \ifdim\forest@last@x=\csname forest@pi@#1@#2x\endcsname\relax
3965         \ifdim\forest@last@y=\csname forest@pi@#1@#2y\endcsname\relax
3966             \forest@tempfalse
3967         \fi
3968     \fi
3969 \fi
3970 \ifforest@temp
3971     \edef\forest@last@x{\csname forest@pi@#1@#2x\endcsname}%
3972     \edef\forest@last@y{\csname forest@pi@#1@#2y\endcsname}%
3973     \pgfsyssoftpath@moveto\forest@last@x\forest@last@y
3974 \fi
3975 }

```

Simplify the resulting path by “unbreaking” segments where possible. (The macro itself is just a wrapper for path processing macros below.)

```

3976 \def\forest@simplifypath#1#2{%

```

```

3977 \pgfsyssoftpath@setcurrentpath\pgfutil@empty
3978 \forest@save@pgfsyssoftpath@tokendefs
3979 \let\pgfsyssoftpath@movetotoken\forest@simplifypath@moveto
3980 \let\pgfsyssoftpath@linetotoken\forest@simplifypath@lineto
3981 \let\forest@last@x\relax
3982 \let\forest@last@y\relax
3983 \let\forest@last@atan\relax
3984 #1%
3985 \ifx\forest@last@x\relax\else
3986   \ifx\forest@last@atan\relax\else
3987     \pgfsyssoftpath@lineto\forest@last@x\forest@last@y
3988   \fi
3989 \fi
3990 \forest@restore@pgfsyssoftpath@tokendefs
3991 \pgfsyssoftpath@getcurrentpath#2%
3992 }

```

When a move-to is encountered, we flush whatever segment we were building, make the move, remember the last position, and set the slope to unknown.

```

3993 \def\forest@simplifypath@moveto#1#2{%
3994   \ifx\forest@last@x\relax\else
3995     \pgfsyssoftpath@lineto\forest@last@x\forest@last@y
3996   \fi
3997   \pgfsyssoftpath@moveto{#1}{#2}%
3998   \def\forest@last@x{#1}%
3999   \def\forest@last@y{#2}%
4000   \let\forest@last@atan\relax
4001 }

```

How much may the segment slopes differ that we can still merge them? (Ignore `pt`, these are degrees.) Also, how good is this number?

```

4002 \def\forest@getedgeofpath@precision{1pt}

```

When a line-to is encountered...

```

4003 \def\forest@simplifypath@lineto#1#2{%
4004   \ifx\forest@last@x\relax

```

If we're not in the middle of a merger, we need to nothing but start it.

```

4005     \def\forest@last@x{#1}%
4006     \def\forest@last@y{#2}%
4007     \let\forest@last@atan\relax
4008   \else

```

Otherwise, we calculate the slope of the current segment (i.e. the segment between the last and the current point), ...

```

4009     \pgfpointdiff{\pgfpoint{#1}{#2}}{\pgfpoint{\forest@last@x}{\forest@last@y}}%
4010     \ifdim\pgf@x<\pgfintersectiontolerance
4011       \ifdim-\pgf@x<\pgfintersectiontolerance
4012         \pgf@x=0pt
4013       \fi
4014     \fi
4015     \csname pgfmataatan2\endcsname{\pgf@x}{\pgf@y}%
4016     \let\forest@current@atan\pgfmathresult
4017     \ifx\forest@last@atan\relax

```

If this is the first segment in the current merger, simply remember the slope and the last point.

```

4018       \def\forest@last@x{#1}%
4019       \def\forest@last@y{#2}%
4020       \let\forest@last@atan\forest@current@atan
4021     \else

```

Otherwise, compare the first and the current slope.

```

4022       \pgfutil@tempdima=\forest@current@atan pt

```

```

4023 \advance\pgfutil@tempdima -\forest@last@atan pt
4024 \ifdim\pgfutil@tempdima<0pt\relax
4025 \multiply\pgfutil@tempdima -1
4026 \fi
4027 \ifdim\pgfutil@tempdima<\forest@getedgeofpath@precision\relax
4028 \else

```

If the slopes differ too much, flush the path up to the previous segment, and set up a new first slope.

```

4029 \pgfsyssoftpath@lineto\forest@last@x\forest@last@y
4030 \let\forest@last@atan\forest@current@atan
4031 \fi

```

In any event, update the last point.

```

4032 \def\forest@last@x{#1}%
4033 \def\forest@last@y{#2}%
4034 \fi
4035 \fi
4036 }

```

12.4 Get rectangle/band edge

```

4037 \def\forest@getnegativerectangleedgeofpath#1#2{%
4038 \forest@getnegativerectangleorbandededgeofpath{#1}{#2}{\the\pgf@xb}}
4039 \def\forest@getpositiverectangleedgeofpath#1#2{%
4040 \forest@getpositiverectangleorbandededgeofpath{#1}{#2}{\the\pgf@xb}}
4041 \def\forest@getbothrectangleedgesofpath#1#2#3{%
4042 \forest@getbothrectangleorbandedgesofpath{#1}{#2}{#3}{\the\pgf@xb}}
4043 \def\forest@bandlength{5000pt} % something large (ca. 180cm), but still manageable for TeX without producing
4044 \def\forest@getnegativebandededgeofpath#1#2{%
4045 \forest@getnegativerectangleorbandededgeofpath{#1}{#2}{\forest@bandlength}}
4046 \def\forest@getpositivebandededgeofpath#1#2{%
4047 \forest@getpositiverectangleorbandededgeofpath{#1}{#2}{\forest@bandlength}}
4048 \def\forest@getbothbandedgesofpath#1#2#3{%
4049 \forest@getbothrectangleorbandedgesofpath{#1}{#2}{#3}{\forest@bandlength}}
4050 \def\forest@getnegativerectangleorbandededgeofpath#1#2#3{%
4051 \forest@path@getboundingrectangle@ls#1{\forest@grow}%
4052 \edef\forest@gre@path{%
4053 \noexpand\pgfsyssoftpath@movetotoken{\the\pgf@xa}{\the\pgf@ya}%
4054 \noexpand\pgfsyssoftpath@linetotoken{#3}{\the\pgf@ya}%
4055 }%
4056 {%
4057 \pgftransformreset
4058 \pgftransformrotate{\forest@grow}%
4059 \forest@pgfpathtransformed\forest@gre@path
4060 }%
4061 \pgfsyssoftpath@getcurrentpath#2%
4062 }
4063 \def\forest@getpositiverectangleorbandededgeofpath#1#2#3{%
4064 \forest@path@getboundingrectangle@ls#1{\forest@grow}%
4065 \edef\forest@gre@path{%
4066 \noexpand\pgfsyssoftpath@movetotoken{\the\pgf@xa}{\the\pgf@yb}%
4067 \noexpand\pgfsyssoftpath@linetotoken{#3}{\the\pgf@yb}%
4068 }%
4069 {%
4070 \pgftransformreset
4071 \pgftransformrotate{\forest@grow}%
4072 \forest@pgfpathtransformed\forest@gre@path
4073 }%
4074 \pgfsyssoftpath@getcurrentpath#2%
4075 }
4076 \def\forest@getbothrectangleorbandedgesofpath#1#2#3#4{%

```

```

4077 \forest@path@getboundingrectangle@ls#1{\forest@grow}%
4078 \edef\forest@gre@negpath{%
4079   \noexpand\pgfsyssoftpath@movetotoken{\the\pgf@xa}{\the\pgf@ya}%
4080   \noexpand\pgfsyssoftpath@linetotoken{#4}{\the\pgf@ya}%
4081 }%
4082 \edef\forest@gre@pospath{%
4083   \noexpand\pgfsyssoftpath@movetotoken{\the\pgf@xa}{\the\pgf@yb}%
4084   \noexpand\pgfsyssoftpath@linetotoken{#4}{\the\pgf@yb}%
4085 }%
4086 {%
4087   \pgftransformreset
4088   \pgftransformrotate{\forest@grow}%
4089   \forest@pgfpathtransformed\forest@gre@negpath
4090 }%
4091 \pgfsyssoftpath@getcurrentpath#2%
4092 {%
4093   \pgftransformreset
4094   \pgftransformrotate{\forest@grow}%
4095   \forest@pgfpathtransformed\forest@gre@pospath
4096 }%
4097 \pgfsyssoftpath@getcurrentpath#3%
4098 }

```

12.5 Distance between paths

Another crucial part of the package.

```

4099 \def\forest@distance@between@edge@paths#1#2#3{%
4100   % #1, #2 = (edge) paths
4101   %
4102   % project paths
4103   \forest@projectpathtogrowline#1{\forest@p1@}%
4104   \forest@projectpathtogrowline#2{\forest@p2@}%
4105   % merge projections (the lists are sorted already, because edge
4106   % paths are |sorted|)
4107   \forest@dbep@mergeprojections
4108   {forest@p1@}{forest@p2@}%
4109   {forest@P1@}{forest@P2@}%
4110   % process projections
4111   \forest@processprojectioninfo{forest@P1@}{forest@PI1@}%
4112   \forest@processprojectioninfo{forest@P2@}{forest@PI2@}%
4113   % break paths
4114   \forest@breakpath#1{\forest@PI1@}\forest@broken@one
4115   \forest@breakpath#2{\forest@PI2@}\forest@broken@two
4116   % sort inner arrays ---optimize: it's enough to find max and min
4117   \forest@sort@inner@arrays{forest@PI1@}\forest@sort@descending
4118   \forest@sort@inner@arrays{forest@PI2@}\forest@sort@ascending
4119   % compute the distance
4120   \let\forest@distance\relax
4121   \c@pgf@countc=0
4122   \loop
4123   \ifnum\c@pgf@countc<\csname forest@PI1@n\endcsname\relax
4124     \ifnum\csname forest@PI1@the\c@pgf@countc @n\endcsname=0 \else
4125       \ifnum\csname forest@PI2@the\c@pgf@countc @n\endcsname=0 \else
4126         \pgfutil@tempdima=\csname forest@PI2@the\c@pgf@countc @0d\endcsname\relax
4127         \advance\pgfutil@tempdima -\csname forest@PI1@the\c@pgf@countc @0d\endcsname\relax
4128         \ifx\forest@distance\relax
4129           \edef\forest@distance{\the\pgfutil@tempdima}%
4130         \else
4131           \ifdim\pgfutil@tempdima<\forest@distance\relax
4132             \edef\forest@distance{\the\pgfutil@tempdima}%
4133           \fi

```

```

4134     \fi
4135     \fi
4136     \fi
4137     \advance\c@pgf@countc 1
4138     \repeat
4139     \let#3\forest@distance
4140 }
4141 % merge projections: we need two projection arrays, both containing
4142 % projection points from both paths, but each with the original
4143 % points from only one path
4144 \def\forest@dbep@mergeprojections#1#2#3#4{%
4145 % TODO: optimize: v bistvu ni treba sortirat, ker je edge path e sortiran
4146 \forest@sortprojections{#1}%
4147 \forest@sortprojections{#2}%
4148 \c@pgf@counta=0
4149 \c@pgf@countb=0
4150 \c@pgf@countc=0
4151 \edef\forest@input@prefix@one{#1}%
4152 \edef\forest@input@prefix@two{#2}%
4153 \edef\forest@output@prefix@one{#3}%
4154 \edef\forest@output@prefix@two{#4}%
4155 \forest@dbep@mp@iterate
4156 \csedef{#3n}{\the\c@pgf@countc}%
4157 \csedef{#4n}{\the\c@pgf@countc}%
4158 }
4159 \def\forest@dbep@mp@iterate{%
4160 \let\forest@dbep@mp@next\forest@dbep@mp@iterate
4161 \ifnum\c@pgf@counta<\csname\forest@input@prefix@one n\endcsname\relax
4162 \ifnum\c@pgf@countb<\csname\forest@input@prefix@two n\endcsname\relax
4163 \let\forest@dbep@mp@next\forest@dbep@mp@do
4164 \else
4165 \let\forest@dbep@mp@next\forest@dbep@mp@iteratefirst
4166 \fi
4167 \else
4168 \ifnum\c@pgf@countb<\csname\forest@input@prefix@two n\endcsname\relax
4169 \let\forest@dbep@mp@next\forest@dbep@mp@iteratesecond
4170 \else
4171 \let\forest@dbep@mp@next\relax
4172 \fi
4173 \fi
4174 \forest@dbep@mp@next
4175 }
4176 \def\forest@dbep@mp@do{%
4177 \forest@sort@cmptwodimcs%
4178 {\forest@input@prefix@one\the\c@pgf@counta xp}%
4179 {\forest@input@prefix@one\the\c@pgf@counta yp}%
4180 {\forest@input@prefix@two\the\c@pgf@countb xp}%
4181 {\forest@input@prefix@two\the\c@pgf@countb yp}%
4182 \if\forest@sort@cmp@result=%
4183 \forest@dbep@mp@store@p\forest@input@prefix@one\c@pgf@counta
4184 \forest@dbep@mp@store@o\forest@input@prefix@one
4185 \c@pgf@counta\forest@output@prefix@one
4186 \forest@dbep@mp@store@o\forest@input@prefix@two
4187 \c@pgf@countb\forest@output@prefix@two
4188 \advance\c@pgf@counta 1
4189 \advance\c@pgf@countb 1
4190 \else
4191 \if\forest@sort@cmp@result>%
4192 \forest@dbep@mp@store@p\forest@input@prefix@two\c@pgf@countb
4193 \forest@dbep@mp@store@o\forest@input@prefix@two
4194 \c@pgf@countb\forest@output@prefix@two

```

```

4195     \advance\c@pgf@countb 1
4196     \else%<
4197     \forest@dbep@mp@@store@p\forest@input@prefix@one\c@pgf@counta
4198     \forest@dbep@mp@@store@o\forest@input@prefix@one
4199     \c@pgf@counta\forest@output@prefix@one
4200     \advance\c@pgf@counta 1
4201     \fi
4202 \fi
4203 \advance\c@pgf@countc 1
4204 \forest@dbep@mp@iterate
4205 }
4206 \def\forest@dbep@mp@@store@p#1#2{%
4207     \csletcs
4208     {\forest@output@prefix@one\the\c@pgf@countc xp}%
4209     {#1\the#2xp}%
4210     \csletcs
4211     {\forest@output@prefix@one\the\c@pgf@countc yp}%
4212     {#1\the#2yp}%
4213     \csletcs
4214     {\forest@output@prefix@two\the\c@pgf@countc xp}%
4215     {#1\the#2xp}%
4216     \csletcs
4217     {\forest@output@prefix@two\the\c@pgf@countc yp}%
4218     {#1\the#2yp}%
4219 }
4220 \def\forest@dbep@mp@@store@o#1#2#3{%
4221     \csletcs{#3\the\c@pgf@countc xo}{#1\the#2xo}%
4222     \csletcs{#3\the\c@pgf@countc yo}{#1\the#2yo}%
4223 }
4224 \def\forest@dbep@mp@iteratefirst{%
4225     \forest@dbep@mp@iterateone\forest@input@prefix@one\c@pgf@counta\forest@output@prefix@one
4226 }
4227 \def\forest@dbep@mp@iteratesecond{%
4228     \forest@dbep@mp@iterateone\forest@input@prefix@two\c@pgf@countb\forest@output@prefix@two
4229 }
4230 \def\forest@dbep@mp@iterateone#1#2#3{%
4231     \loop
4232     \ifnum#2<\csname#1n\endcsname\relax
4233     \forest@dbep@mp@@store@p#1#2%
4234     \forest@dbep@mp@@store@o#1#2#3%
4235     \advance\c@pgf@countc 1
4236     \advance#21
4237     \repeat
4238 }

```

12.6 Utilities

Equality test: points are considered equal if they differ less than `\pgfintersectiontolerance` in each coordinate.

```

4239 \newif\ifforest@equaltotolerance
4240 \def\forest@equaltotolerance#1#2{%
4241     \pgfpointdiff{#1}{#2}%
4242     \ifdim\pgf@x<0pt \multiply\pgf@x -1 \fi
4243     \ifdim\pgf@y<0pt \multiply\pgf@y -1 \fi
4244     \global\forest@equaltotolerancefalse
4245     \ifdim\pgf@x<\pgfintersectiontolerance\relax
4246     \ifdim\pgf@y<\pgfintersectiontolerance\relax
4247     \global\forest@equaltolerancetrue
4248     \fi
4249 \fi

```

```

4250 }}
      Save/restore pgfs \pgfsyssoftpath@...token definitions.
4251 \def\forest@save@pgfsyssoftpath@tokendefs{%
4252   \let\forest@origmovetotoken\pgfsyssoftpath@movetotoken
4253   \let\forest@origlinetotoken\pgfsyssoftpath@linetotoken
4254   \let\forest@origcurvetosupportatoken\pgfsyssoftpath@curvetosupportatoken
4255   \let\forest@origcurvetosupportbtoken\pgfsyssoftpath@curvetosupportbtoken
4256   \let\forest@origcurvetotoken\pgfsyssoftpath@curvetotoken
4257   \let\forest@origrectcornertoken\pgfsyssoftpath@rectcornertoken
4258   \let\forest@origrectsizetoken\pgfsyssoftpath@rectsizetoken
4259   \let\forest@origclosepathtoken\pgfsyssoftpath@closepathtoken
4260   \let\pgfsyssoftpath@movetotoken\forest@badtoken
4261   \let\pgfsyssoftpath@linetotoken\forest@badtoken
4262   \let\pgfsyssoftpath@curvetosupportatoken\forest@badtoken
4263   \let\pgfsyssoftpath@curvetosupportbtoken\forest@badtoken
4264   \let\pgfsyssoftpath@curvetotoken\forest@badtoken
4265   \let\pgfsyssoftpath@rectcornertoken\forest@badtoken
4266   \let\pgfsyssoftpath@rectsizetoken\forest@badtoken
4267   \let\pgfsyssoftpath@closepathtoken\forest@badtoken
4268 }
4269 \def\forest@badtoken{%
4270   \PackageError{forest}{This token should not be in this path}{}%
4271 }
4272 \def\forest@restore@pgfsyssoftpath@tokendefs{%
4273   \let\pgfsyssoftpath@movetotoken\forest@origmovetotoken
4274   \let\pgfsyssoftpath@linetotoken\forest@origlinetotoken
4275   \let\pgfsyssoftpath@curvetosupportatoken\forest@origcurvetosupportatoken
4276   \let\pgfsyssoftpath@curvetosupportbtoken\forest@origcurvetosupportbtoken
4277   \let\pgfsyssoftpath@curvetotoken\forest@origcurvetotoken
4278   \let\pgfsyssoftpath@rectcornertoken\forest@origrectcornertoken
4279   \let\pgfsyssoftpath@rectsizetoken\forest@origrectsizetoken
4280   \let\pgfsyssoftpath@closepathtoken\forest@origclosepathtoken
4281 }
      Extend path #1 with path #2 translated by point #3.
4282 \def\forest@extendpath#1#2#3{%
4283   \pgf@process{#3}%
4284   \pgfsyssoftpath@setcurrentpath#1%
4285   \forest@save@pgfsyssoftpath@tokendefs
4286   \let\pgfsyssoftpath@movetotoken\forest@extendpath@moveto
4287   \let\pgfsyssoftpath@linetotoken\forest@extendpath@lineto
4288   #2%
4289   \forest@restore@pgfsyssoftpath@tokendefs
4290   \pgfsyssoftpath@getcurrentpath#1%
4291 }
4292 \def\forest@extendpath@moveto#1#2{%
4293   \forest@extendpath@do{#1}{#2}\pgfsyssoftpath@moveto
4294 }
4295 \def\forest@extendpath@lineto#1#2{%
4296   \forest@extendpath@do{#1}{#2}\pgfsyssoftpath@lineto
4297 }
4298 \def\forest@extendpath@do#1#2#3{%
4299   {%
4300     \advance\pgf@x #1
4301     \advance\pgf@y #2
4302     #3{\the\pgf@x}{\the\pgf@y}%
4303   }%
4304 }

```

Get bounding rectangle of the path. #1 = the path, #2 = grow. Returns ($\pgf@xa=\min x/l$, $\pgf@ya=\max y/s$, $\pgf@xb=\min x/l$, $\pgf@yb=\max y/s$). (If path #1 is empty, the result is undefined.)


```

4305 \def\forest@path@getboundingrectangle@ls#1#2{%
4306   {%
4307     \pgftransformreset
4308     \pgftransformrotate{-(#2)}%
4309     \forest@pgfpathtransformed#1%
4310   }%
4311   \pgfsyssoftpath@getcurrentpath\forest@gbr@rotatedpath
4312   \forest@path@getboundingrectangle@xy\forest@gbr@rotatedpath
4313 }
4314 \def\forest@path@getboundingrectangle@xy#1{%
4315   \forest@save@pgfsyssoftpath@tokendefs
4316   \let\pgfsyssoftpath@movetotoken\forest@gbr@firstpoint
4317   \let\pgfsyssoftpath@linetotoken\forest@gbr@firstpoint
4318   #1%
4319   \forest@restore@pgfsyssoftpath@tokendefs
4320 }
4321 \def\forest@gbr@firstpoint#1#2{%
4322   \pgf@xa=#1 \pgf@xb=#1 \pgf@ya=#2 \pgf@yb=#2
4323   \let\pgfsyssoftpath@movetotoken\forest@gbr@point
4324   \let\pgfsyssoftpath@linetotoken\forest@gbr@point
4325 }
4326 \def\forest@gbr@point#1#2{%
4327   \ifdim#1<\pgf@xa\relax\pgf@xa=#1 \fi
4328   \ifdim#1>\pgf@xb\relax\pgf@xb=#1 \fi
4329   \ifdim#2<\pgf@ya\relax\pgf@ya=#2 \fi
4330   \ifdim#2>\pgf@yb\relax\pgf@yb=#2 \fi
4331 }

```

13 The outer UI

13.1 Package options

```

4332 \newif\ifforesttikzcshack
4333 \foresttikzcshacktrue
4334 \newif\ifforest@install@keys@to@tikz@path@
4335 \forest@install@keys@to@tikz@path@true
4336 \forestset{package@options/.cd,
4337   external/.is if=forest@external@,
4338   tikzcshack/.is if=foresttikzcshack,
4339   tikzinstallkeys/.is if=forest@install@keys@to@tikz@path@,
4340 }

```

13.2 Externalization

```

4341 \pgfkeys{/forest/external/.cd,
4342   copy command/.initial={cp "\source" "\target"},
4343   optimize/.is if=forest@external@optimize@,
4344   context/.initial={%
4345     \forestOve{\csname forest@id@of@standard node\endcsname}{environment@formula}},
4346   depends on macro/.style={context/.append/.expanded={%
4347     \expandafter\detokenize\expandafter{#1}}},
4348 }
4349 \def\forest@external@copy#1#2{%
4350   \pgfkeysgetvalue{/forest/external/copy command}\forest@copy@command
4351   \ifx\forest@copy@command\pgfkeysnovalue\else
4352     \IfFileExists{#1}{%
4353       {%
4354         \def\source{#1}%
4355         \def\target{#2}%
4356         \immediate\write18{\forest@copy@command}%
4357       }%

```

```

4358   }{}%
4359   \fi
4360 }
4361 \newif\ifforest@external@
4362 \newif\ifforest@external@optimize@
4363 \forest@external@optimize@true
4364 \ProcessPgfpPackageOptions{/forest/package@options}
4365 \ifforest@install@keys@to@tikz@path@
4366   \tikzset{fit to tree/.style={/forest/fit to tree}}
4367 \fi
4368 \ifforest@external@
4369   \ifdefined\tikzexternal@tikz@replacement\else
4370     \usetikzlibrary{external}%
4371   \fi
4372   \pgfkeys{%
4373     /tikz/external/failed ref warnings for={},
4374     /pgf/images/aux in dpth=false,
4375   }%
4376   \tikzifexternalizing{}{%
4377     \forest@external@copy{\jobname.aux}{\jobname.aux.copy}%
4378   }%
4379   \AtBeginDocument{%
4380     \tikzifexternalizing{%
4381       \IfFileExists{\tikzexternalrealjob.aux.copy}{%
4382         \makeatletter
4383         \input \tikzexternalrealjob.aux.copy
4384         \makeatother
4385       }{}%
4386     }{%
4387       \newwrite\forest@auxout
4388       \immediate\openout\forest@auxout=\tikzexternalrealjob.for.tmp
4389     }%
4390     \IfFileExists{\tikzexternalrealjob.for}{%
4391       {%
4392         \makehashother\makeatletter
4393         \input \tikzexternalrealjob.for
4394       }%
4395     }{}%
4396   }%
4397   \AtEndDocument{%
4398     \tikzifexternalizing{}{%
4399       \immediate\closeout\forest@auxout
4400       \forest@external@copy{\jobname.for.tmp}{\jobname.for}%
4401     }%
4402   }%
4403 \fi

```

13.3 The forest environment

There are three ways to invoke FOREST: the environment and the starless and the starred version of the macro. The latter creates no group.

Most of the code in this section deals with externalization.

```

4404 \newenvironment{forest}{\pgfkeysalso{/forest/begin forest}\Collect@Body\forest@env}{%
4405 \long\def\Forest{\pgfkeysalso{/forest/begin forest}\@ifnextchar*{\forest@nogroup}{\forest@group}}
4406 \def\forest@group#1{\forest@env{#1}}
4407 \def\forest@nogroup*#1{\forest@env{#1}}
4408 \newif\ifforest@externalize@tree@
4409 \newif\ifforest@was@tikzexternalwasenable
4410 \long\def\forest@env#1{%
4411   \let\forest@external@next\forest@begin
4412   \forest@was@tikzexternalwasenablefalse

```

```

4413 \ifdefined\tikzexternal@tikz@replacement
4414 \ifx\tikz\tikzexternal@tikz@replacement
4415 \forest@was@tikzexternalwasenabletrue
4416 \tikzexternaldisable
4417 \fi
4418 \fi
4419 \forest@externalize@tree@false
4420 \ifforest@external@
4421 \ifforest@was@tikzexternalwasenable
4422 \tikzifexternalizing{%
4423 \let\forest@external@next\forest@begin@externalizing
4424 }{%
4425 \let\forest@external@next\forest@begin@externalize
4426 }%
4427 \fi
4428 \fi
4429 \forest@standardnode@calibrate
4430 \forest@external@next{#1}%
4431 }

```

We're externalizing, i.e. this code gets executed in the embedded call.

```

4432 \long\def\forest@begin@externalizing#1{%
4433 \forest@external@setup{#1}%
4434 \let\forest@external@next\forest@begin
4435 \forest@externalize@inner@n=-1
4436 \ifforest@external@optimize@\forest@externalizing@maybeoptimize\fi
4437 \forest@external@next{#1}%
4438 \tikzexternalenable
4439 }
4440 \def\forest@externalizing@maybeoptimize{%
4441 \edef\forest@temp{\tikzexternalrealjob-forest-\forest@externalize@outer@n}%
4442 \edef\forest@marshal{%
4443 \noexpand\pgfutil@in@
4444 {\expandafter\detokenize\expandafter{\forest@temp}.}
4445 {\expandafter\detokenize\expandafter{\pgfactualjobname}.}%
4446 }\forest@marshal
4447 \ifpgfutil@in@
4448 \else
4449 \let\forest@external@next@gobble
4450 \fi
4451 }

```

Externalization is enabled, we're in the outer process, deciding if the picture is up-to-date.

```

4452 \long\def\forest@begin@externalize#1{%
4453 \forest@external@setup{#1}%
4454 \iftikzexternal@file@isuptodate
4455 \setbox0=\hbox{%
4456 \csname forest@externalcheck@\forest@externalize@outer@n\endcsname
4457 }%
4458 \fi
4459 \iftikzexternal@file@isuptodate
4460 \csname forest@externalload@\forest@externalize@outer@n\endcsname
4461 \else
4462 \forest@externalize@tree@true
4463 \forest@externalize@inner@n=-1
4464 \forest@begin{#1}%
4465 \ifcsdef{forest@externalize@@\forest@externalize@id}{}%
4466 \immediate\write\forest@auxout{%
4467 \noexpand\forest@external
4468 {\forest@externalize@outer@n}%
4469 {\expandafter\detokenize\expandafter{\forest@externalize@id}}%

```

```

4470      {\expandonce\forest@externalize@checkimages}%
4471      {\expandonce\forest@externalize@loadimages}%
4472    }%
4473  }%
4474  \fi
4475  \tikzexternalenable
4476 }
4477 \def\forest@includeexternal@check#1{%
4478   \tikzsetnextfilename{#1}%
4479   \tikzexternal@externalizefig@systemcall@uptodatecheck
4480 }
4481 \def\makehashother{\catcode'\#=12}%
4482 \long\def\forest@external@setup#1{%
4483   % set up \forest@externalize@id and \forest@externalize@outer@n
4484   % we need to deal with #s correctly (\write doubles them)
4485   \setbox0=\hbox{\makehashother\makeatletter
4486     \scantokens{\forest@temp@toks{#1}}\expandafter
4487   }%
4488   \expandafter\forest@temp@toks\expandafter{\the\forest@temp@toks}%
4489   \edef\forest@temp{\pgfkeysvalueof{/forest/external/context}}%
4490   \edef\forest@externalize@id{%
4491     \expandafter\detokenize\expandafter{\forest@temp}%
4492     @@%
4493     \expandafter\detokenize\expandafter{\the\forest@temp@toks}%
4494   }%
4495   \letcs\forest@externalize@outer@n{forest@externalize@@\forest@externalize@id}%
4496   \ifdefined\forest@externalize@outer@n
4497     \global\tikzexternal@file@isuptodate>true
4498   \else
4499     \global\advance\forest@externalize@max@outer@n 1
4500     \edef\forest@externalize@outer@n{\the\forest@externalize@max@outer@n}%
4501     \global\tikzexternal@file@isuptodate>false
4502   \fi
4503   \def\forest@externalize@loadimages{}%
4504   \def\forest@externalize@checkimages{}%
4505 }
4506 \newcount\forest@externalize@max@outer@n
4507 \global\forest@externalize@max@outer@n=0
4508 \newcount\forest@externalize@inner@n

```

The .for file is a string of calls of this macro.

```

4509 \long\def\forest@external#1#2#3#4{% #1=n,#2=context+source code,#3=update check code, #4=load code
4510   \ifnum\forest@externalize@max@outer@n<#1
4511     \global\forest@externalize@max@outer@n=#1
4512   \fi
4513   \global\csdef{forest@externalize@@\detokenize{#2}}{#1}%
4514   \global\csdef{forest@externalcheck@#1}{#3}%
4515   \global\csdef{forest@externalload@#1}{#4}%
4516   \tikzifexternalizing{}{%
4517     \immediate\write\forest@auxout{%
4518       \noexpand\forest@external{#1}%
4519       {\expandafter\detokenize\expandafter{#2}}%
4520       {\unexpanded{#3}}%
4521       {\unexpanded{#4}}%
4522     }%
4523   }%
4524 }

```

These two macros include the external picture.

```

4525 \def\forest@includeexternal#1{%
4526   \edef\forest@temp{\pgfkeysvalueof{/forest/external/context}}%
4527   \typeout{forest: Including external picture '#1' for forest context+code:

```

```

4528     '\expandafter\detokenize\expandafter{\forest@externalize@id}'}%
4529   {%
4530     %\def\pgf@declaredraftimage##1##2{\def\pgf@image{\hbox{}}}%
4531     \tikzsetnextfilename{#1}%
4532     \tikzexternalenable
4533     \tikz{}%
4534   }%
4535 }
4536 \def\forest@includeexternal@box#1#2{%
4537   \global\setbox#1=\hbox{\forest@includeexternal{#2}}%
4538 }

```

This code runs the bracket parser and stage processing.

```

4539 \long\def\forest@begin#1{%
4540   \iffalse{\fi\forest@parsebracket#1}%
4541 }
4542 \def\forest@parsebracket{%
4543   \bracketParse{\forest@get@root@afterthought}\forest@root=%
4544 }
4545 \def\forest@get@root@afterthought{%
4546   \expandafter\forest@get@root@afterthought@\expandafter{\iffalse}\fi
4547 }
4548 \long\def\forest@get@root@afterthought@#1{%
4549   \ifblank{#1}{}{%
4550     \forest@oappto{\forest@root}{given options}{,afterthought={\unexpanded{#1}}}%
4551   }%
4552   \forest@do
4553 }
4554 \def\forest@do{%
4555   \forest@node@Compute@numeric@ts@info{\forest@root}%
4556   \forestset{process keylist=given options}%
4557   \forestset{stages}%
4558   \pgfkeysalso{/forest/end forest}%
4559   \ifforest@was@tikzexternalwasenable
4560     \tikzexternalenable
4561   \fi
4562 }

```

13.4 Standard node

The standard node should be calibrated when entering the forest env: The standard node init does *not* initialize options from a(nother) standard node!

```

4563 \def\forest@standardnode@new{%
4564   \advance\forest@node@maxid1
4565   \forest@fornode{\the\forest@node@maxid}{%
4566     \forest@node@init
4567     \forest@node@setname{standard node}%
4568   }%
4569 }
4570 \def\forest@standardnode@calibrate{%
4571   \forest@fornode{\forest@node@Nametoid{standard node}}{%
4572     \edef\forest@environment{\forestove{environment@formula}}%
4573     \forest@toget{previous@environment}\forest@previous@environment
4574     \ifx\forest@environment\forest@previous@environment
4575       \forest@tolet{previous@environment}\forest@environment
4576       \forest@node@typeset
4577       \forest@toget{calibration@procedure}\forest@temp
4578       \expandafter\forestset\expandafter{\forest@temp}%
4579     \fi
4580   }%
4581 }

```

Usage: `\forestStandardNode[#1]{#2}{#3}{#4}`. #1 = standard node specification — specify it as any other node content (but without children, of course). #2 = the environment fingerprint: list the values of parameters that influence the standard node’s height and depth; the standard will be adjusted whenever any of these parameters changes. #3 = the calibration procedure: a list of usual forest options which should calculating the values of exported options. #4 = a comma-separated list of exported options: every newly created node receives the initial values of exported options from the standard node. (The standard node definition is local to the \TeX group.)

```

4582 \def\forestStandardNode[#1]#2#3#4{%
4583   \let\forest@standardnode@restoretikzexternal\relax
4584   \ifdefined\tikzexternaldisable
4585     \ifx\tikz\tikzexternal\tikz@replacement
4586       \tikzexternaldisable
4587       \let\forest@standardnode@restoretikzexternal\tikzexternalenable
4588     \fi
4589   \fi
4590   \forest@standardnode@new
4591   \forest@for node{\forest@node@Nametoid{standard node}}{%
4592     \forestset{content=#1}%
4593     \forestset{environment@formula}{#2}%
4594     \edef\forest@temp{\unexpanded{#3}}%
4595     \forestset{calibration@procedure}\forest@temp
4596     \def\forest@calibration@initializing@code{%
4597       \pgfkeys{/forest/initializing@code}{#4}%
4598       \forestset{initializing@code}\forest@calibration@initializing@code
4599     \forest@standardnode@restoretikzexternal
4600   }
4601 }
4602 \forestset{initializing@code/.unknown/.code={%
4603   \eappto\forest@calibration@initializing@code{%
4604     \noexpand\forestOget{\forest@node@Nametoid{standard node}}{\pgfkeyscurrentname}\noexpand\forest@temp
4605     \noexpand\forestset{\pgfkeyscurrentname}\noexpand\forest@temp
4606   }%
4607 }
4608 }

```

This macro is called from a new (non-standard) node’s init.

```

4609 \def\forest@initializefromstandardnode{%
4610   \forestOve{\forest@node@Nametoid{standard node}}{initializing@code}%
4611 }

```

Define the default standard node. Standard content: `dj` — in Computer Modern font, `d` is the highest and `j` the deepest letter (not character!). Environment fingerprint: the height of the strut and the values of inner and outer seps. Calibration procedure: (i) `l sep` equals the height of the strut plus the value of `inner ysep`, implementing both font-size and inner sep dependency; (ii) The effect of `l` on the standard node should be the same as the effect of `l sep`, thus, we derive `l` from `l sep` by adding to the latter the total height of the standard node (plus the double outer sep, one for the parent and one for the child). (iii) `s sep` is straightforward: a double inner xsep. Exported options: options, calculated in the calibration. (Tricks: to change the default anchor, set it in #1 and export it; to set a non-forest node option (such as `draw` or `blue`) as default, set it in #1 and export the (internal) option `node options`.)

```

4612 \forestStandardNode[dj]
4613 {%
4614   \forestOve{\forest@node@Nametoid{standard node}}{content},%
4615   \the\ht\strutbox,\the\pgflinewidth,%
4616   \pgfkeysvalueof{/pgf/inner ysep},\pgfkeysvalueof{/pgf/outer ysep},%
4617   \pgfkeysvalueof{/pgf/inner xsep},\pgfkeysvalueof{/pgf/outer xsep}%
4618 }
4619 {
4620   l sep={\the\ht\strutbox+\pgfkeysvalueof{/pgf/inner ysep}},
4621   l={l sep()+abs(max_y()-min_y())+2*\pgfkeysvalueof{/pgf/outer ysep}},
4622   s sep={2*\pgfkeysvalueof{/pgf/inner xsep}}

```

```

4623 }
4624 {l sep,l,s sep}

```

13.5 ls coordinate system

```

4625 \pgfqkeys{/forest/@cs}{%
4626   name/.code={%
4627     \edef\forest@cn{\forest@node@Nametoid{#1}}%
4628     \forest@forestcs@resetxy},
4629   id/.code={%
4630     \edef\forest@cn{#1}%
4631     \forest@forestcs@resetxy},
4632   go/.code={%
4633     \forest@go{#1}%
4634     \forest@forestcs@resetxy},
4635   anchor/.code={\forest@forestcs@anchor{#1}},
4636   l/.code={%
4637     \pgfmathsetlengthmacro\forest@forestcs@l{#1}%
4638     \forest@forestcs@ls
4639   },
4640   s/.code={%
4641     \pgfmathsetlengthmacro\forest@forestcs@s{#1}%
4642     \forest@forestcs@ls
4643   },
4644   .unknown/.code={%
4645     \expandafter\pgfutil@in@\expandafter.\expandafter{\pgfkeyscurrentname}%
4646     \ifpgfutil@in@
4647       \expandafter\forest@forestcs@namegoanchor\pgfkeyscurrentname\forest@end
4648     \else
4649       \expandafter\forest@nameandgo\expandafter{\pgfkeyscurrentname}%
4650       \forest@forestcs@resetxy
4651     \fi
4652   }
4653 }
4654 \def\forest@forestcs@resetxy{%
4655   \ifnum\forest@cn=0
4656   \else
4657     \global\pgf@x\forestove{x}%
4658     \global\pgf@y\forestove{y}%
4659   \fi
4660 }
4661 \def\forest@forestcs@ls{%
4662   \ifdefined\forest@forestcs@l
4663     \ifdefined\forest@forestcs@s
4664       {%
4665         \pgftransformreset
4666         \pgftransformrotate{\forestove{grow}}%
4667         \pgfpointransformed{\pgfpoint{\forest@forestcs@l}{\forest@forestcs@s}}%
4668       }%
4669     \global\advance\pgf@x\forestove{x}%
4670     \global\advance\pgf@y\forestove{y}%
4671   \fi
4672   \fi
4673 }
4674 \def\forest@forestcs@anchor#1{%
4675   \edef\forest@marshal{%
4676     \noexpand\forest@original@tikz@parse@node\relax
4677     (\forestove{name})\ifx\relax#1\relax\else.\fi#1)%
4678   }\forest@marshal
4679 }

```

```

4680 \def\forest@forestcs@namegoanchor#1.#2\forest@end{%
4681   \forest@nameandgo{#1}%
4682   \forest@forestcs@anchor{#2}%
4683 }
4684 \tikzdeclarecoordinatesystem{forest}{%
4685   \forest@forthis{%
4686     \forest@forestcs@resetxy
4687     \ifdefined\forest@forestcs@l\undef\forest@forestcs@l\fi
4688     \ifdefined\forest@forestcs@s\undef\forest@forestcs@s\fi
4689     \pgfqkeys{/forest/@cs}{#1}%
4690   }%
4691 }

```

References

- [1] Donald E. Knuth. *The TeXbook*. Addison-Wesley, 1996.
- [2] Till Tantau. *TikZ & PGF, Manual for Version 2.10*, 2007.

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