UNIVERSITÄT ZU LÜBECK
INSTITUTE FOR
THEORETICAL COMPUTER SCIENCE

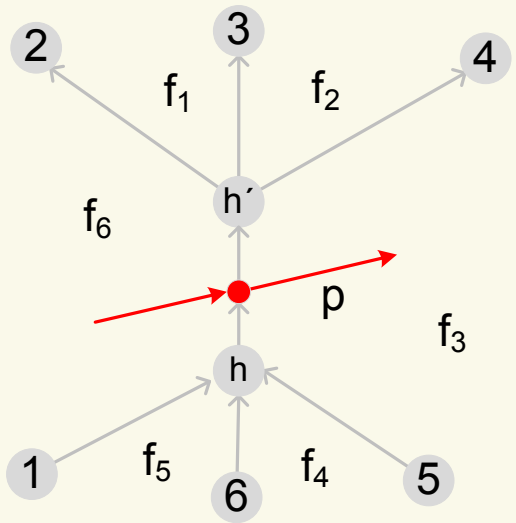
Graph Drawing in Ti*k*Z

Till Tantau

Graph Drawing Conference 2012

IM FOCUS DAS LEBEN

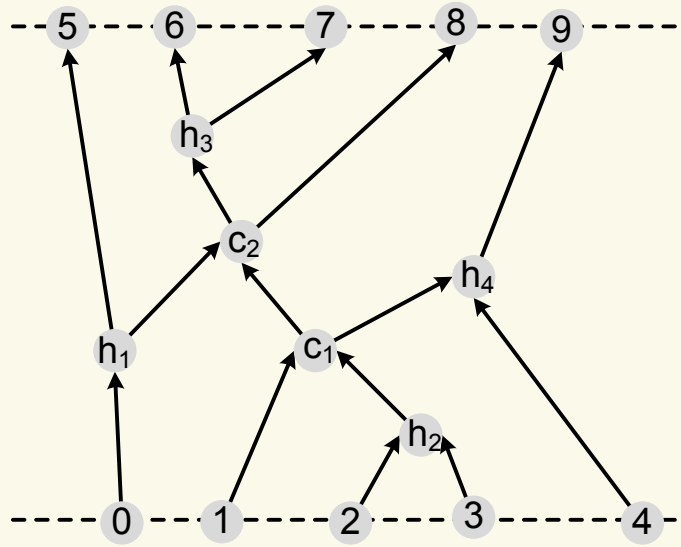
The Problem: Integrating Graph Drawings Into Documents



(b) A realization of p.

al arc can reduce the crossings

aints, are restricted to the

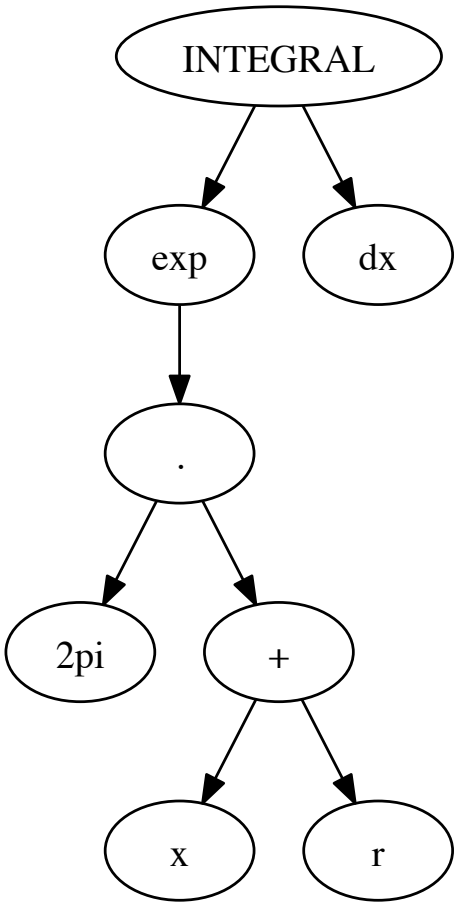


(a)

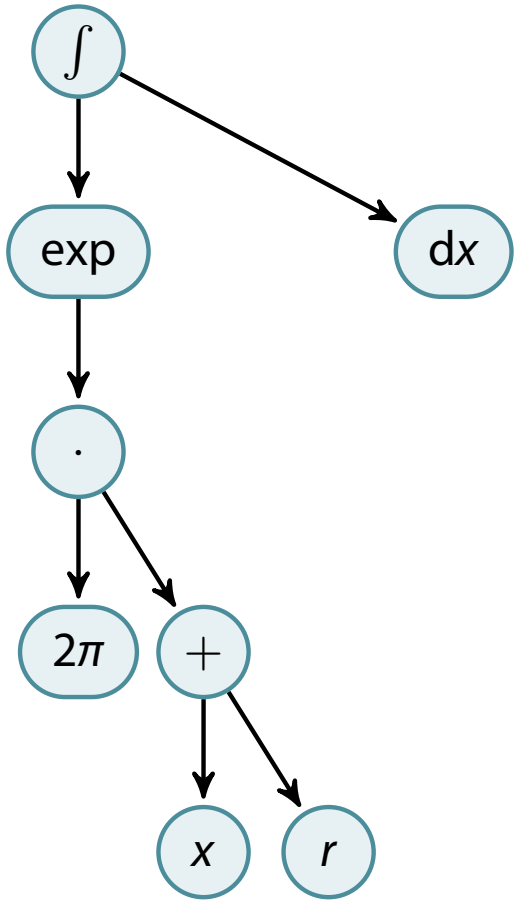
3. Steps towards a final layout: (a)
PR $\mathcal{R}$, (b) fine-layering of the subgra

The Problem: Integrating Graph Drawings Into Documents

GraphViz yields

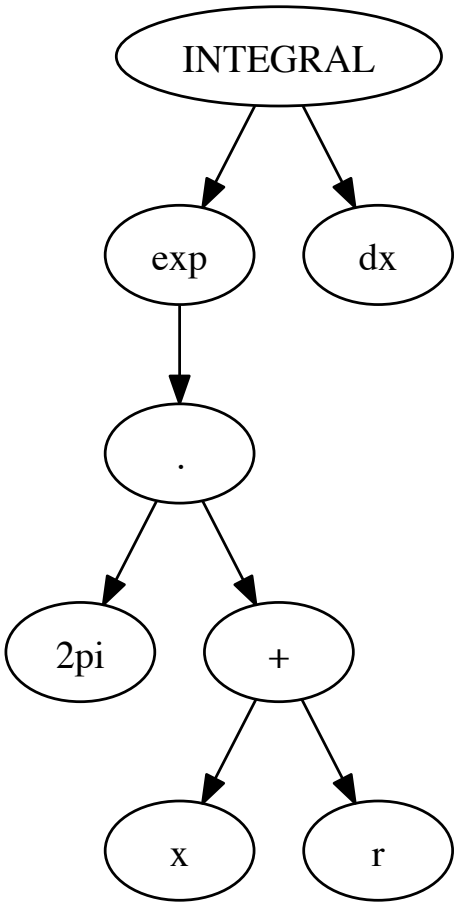


TEX yields

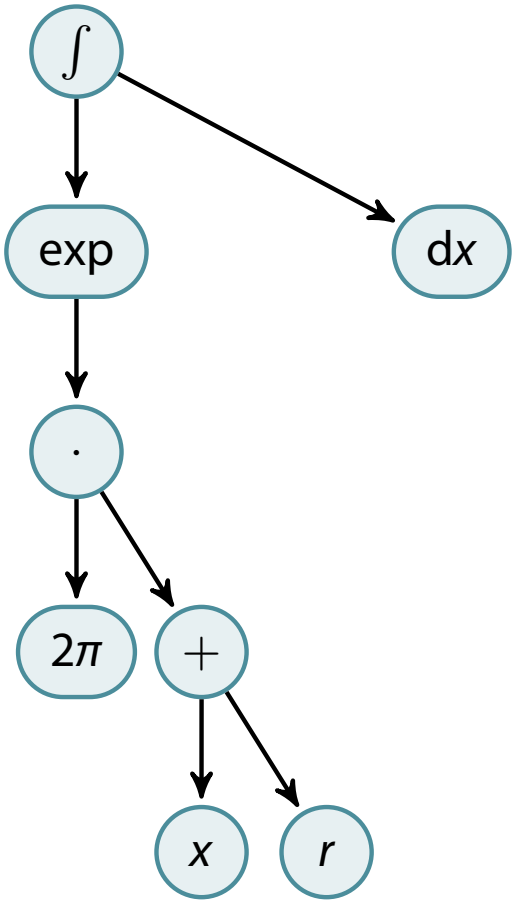


The Problem: Integrating Graph Drawings Into Documents

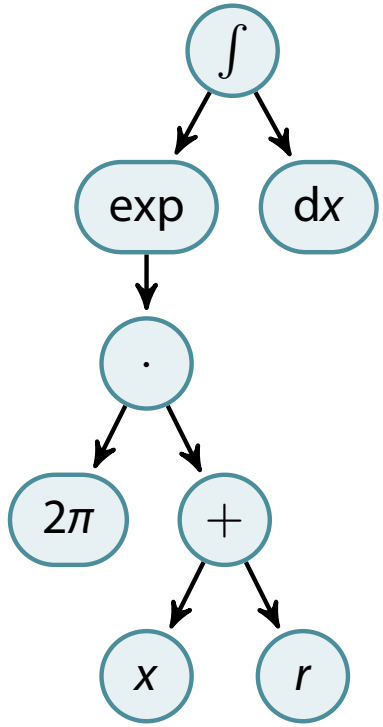
GraphViz yields



TEX yields



What we actually want:



A Solution: Graph Drawing in Ti*k*Z

- Take an *existing document description language* (TEX) with an *embedded graphics description language* (Ti*k*Z).
- Add options and syntactic extensions for *specifying graphs easily*.
- Run graph drawing algorithms *as part of the document processing*.

Advantages

+ Styling of nodes and edges matches main document.
+ Graph drawing algorithms know size of nodes and labels precisely.
+ No external programs needed.
+ Algorithm designers can concentrate on algorithmic aspects.

Talk Outline

How Do I Use It?

How Does It Work?

How Do I Implementing An Algorithm?

TikZ in a Nutshell: The Idea

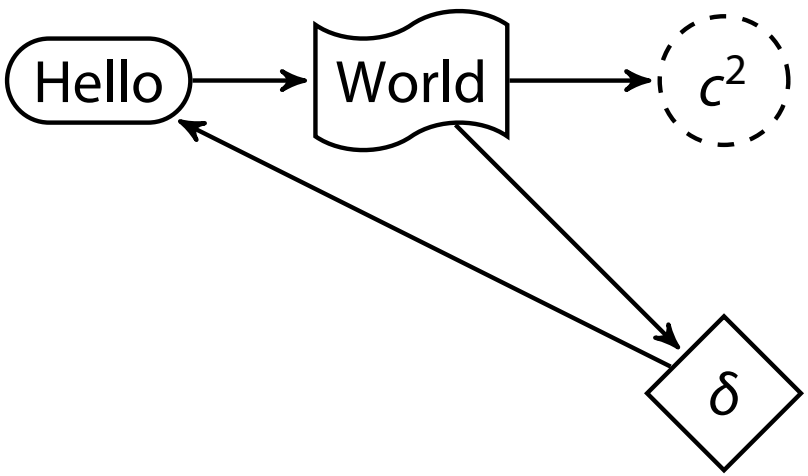
```
\usepackage{tikz}
...
A circle like \tikz {
  \fill[red] (0,0) circle[radius=.5ex];
} is round.
```

A circle like ● is round.

- TikZ is a *package of TEX-macros* for specifying graphics.
- The macros *transform highlevel descriptions* of graphics into lowlevel *PDF-, PostScript-, or SVG-*primitives during a TEX run.

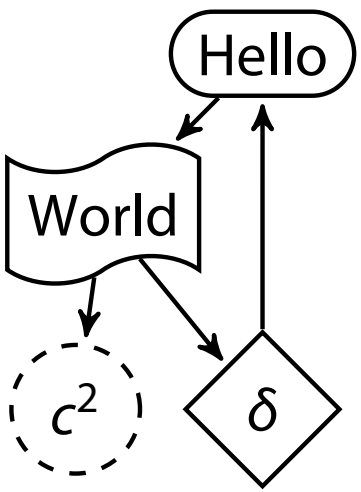
TikZ in a Nutshell: Nodes and Edges

```
\tikz {
  \node (a) at (0,2) [rounded rectangle] {Hello};
  \node (b) at (2,2) [tape]              {World};
  \node (c) at (4,2) [circle, dashed]    {$ c^2 $};
  \node (d) at (4,0) [diamond]           {$ \delta $};
  \draw (a) edge[->] (b)    (b) edge[->] (c)
        (b) edge[->] (d)    (d) edge[->] (a);
}
```



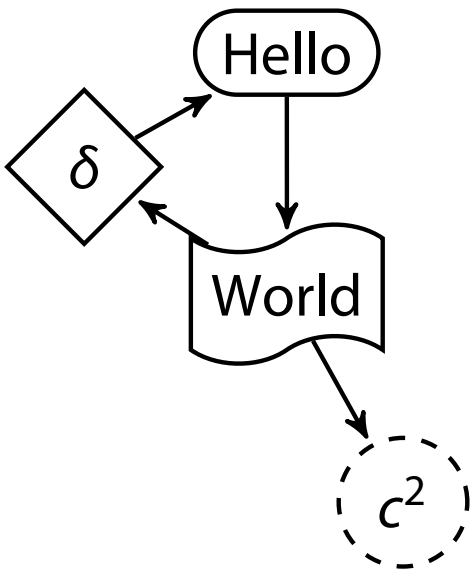
Using the Graph Drawing System = Adding an Option

```
\usetikzlibrary{graphdrawing.layered}
...
\tikz [layered layout] {
  \node (a) at (0,1) [rounded rectangle] {Hello};
  \node (b) at (2,1) [tape]              {World};
  \node (c) at (4,1) [circle, dashed]    {$ c^2 $};
  \node (d) at (4,0) [diamond]           {$ \delta $};
  \draw (a) edge[->] (b)    (b) edge[->] (c)
        (b) edge[->] (d)    (d) edge[->] (a);
}
```



Using the Graph Drawing System = Adding an Option

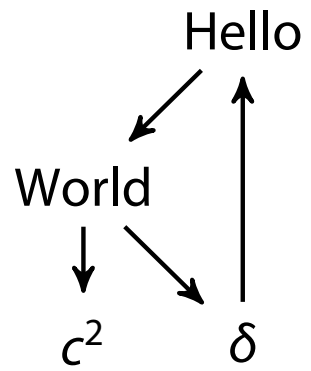
```
\usetikzlibrary{graphdrawing.force}
...
\tikz [spring layout, node distance=1.25cm] {
  \node (a)           [rounded rectangle] {Hello};
  \node (b)           [tape]              {World};
  \node (c)           [circle, dashed]    {$ c^2 $};
  \node (d)           [diamond]           {$ \delta $};
  \draw (a) edge[->] (b)    (b) edge[->] (c)
        (b) edge[->] (d)    (d) edge[->] (a);
}
```



A Concise Syntax for Graphs

- A concise syntax for graphs is important when *humans specify graphs* "by hand."
- The chosen syntax *mixes the philosophies* of DOT and Ti*k*Z.

```
\tikz \graph [layered layout] {
  Hello -> World -> "$c^2$";
  World -> "$\delta$" -> Hello;
};
```

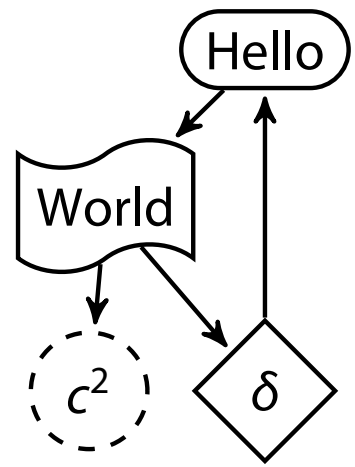


Key Features of TikZ's Syntax for Graphs

- *Node options follow nodes in square brackets.*
- Edge options follow edges in square brackets.
- Additonal edge kinds.
- Natural specification of trees.

```
\tikz \graph [layered layout] {
      Hello   [rounded rectangle]
  ->  World   [tape]
  ->  "$c^2$" [circle, dashed];

  World -> "$\delta$"[diamond]
  ->  Hello;
};
```



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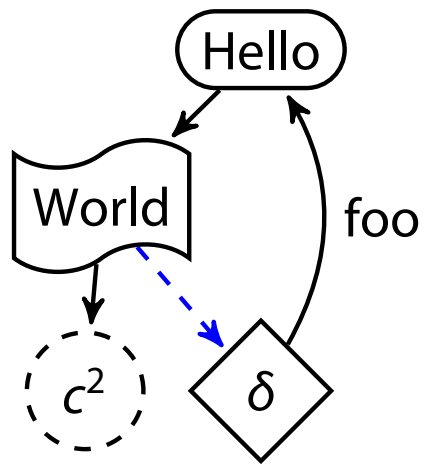
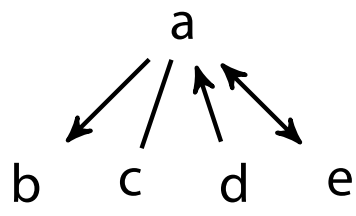
```
\tikz \graph [layered layout] {
      Hello    [rounded rectangle]
  ->  World    [tape]
  ->  "$c^2$"  [circle, dashed];

  World
  ->[dashed, blue] "$\delta$"[diamond]
  ->[bend right, "foo"'] Hello;
};
```



Key Features of TikZ's Syntax for Graphs

- Node options follow nodes in square brackets.
- Edge options follow edges in square brackets.
- *Additonal edge kinds.*
- Natural specification of trees.

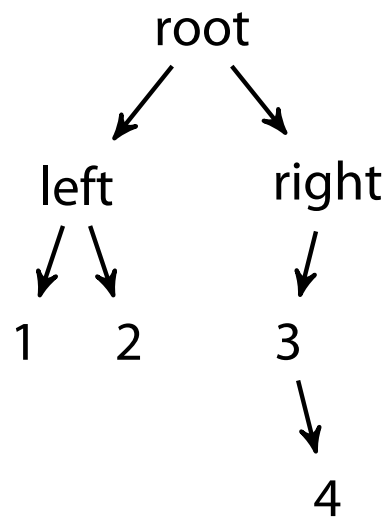
```
\tikz \graph [tree layout] {
  a -> b -- c <- d <-> e;
};
```



Key Features of TikZ's Syntax for Graphs

- Node options follow nodes in square brackets.
- Edge options follow edges in square brackets.
- Additonal edge kinds.
- *Natural specification of trees.*

```
\tikz \graph [binary tree layout] {
  root -> {
    left -> {
      1,
      2
    },
    right -> {
      3 -> { , 4 }
    }
  }
};
```



Talk Outline

How Do I Use It?

How Does It Work?

How Do I Implementing An Algorithm?

LuaTEX in a Nutshell

TEX is great, . . .

- but implementing advanced algorithms *is next to impossible.*

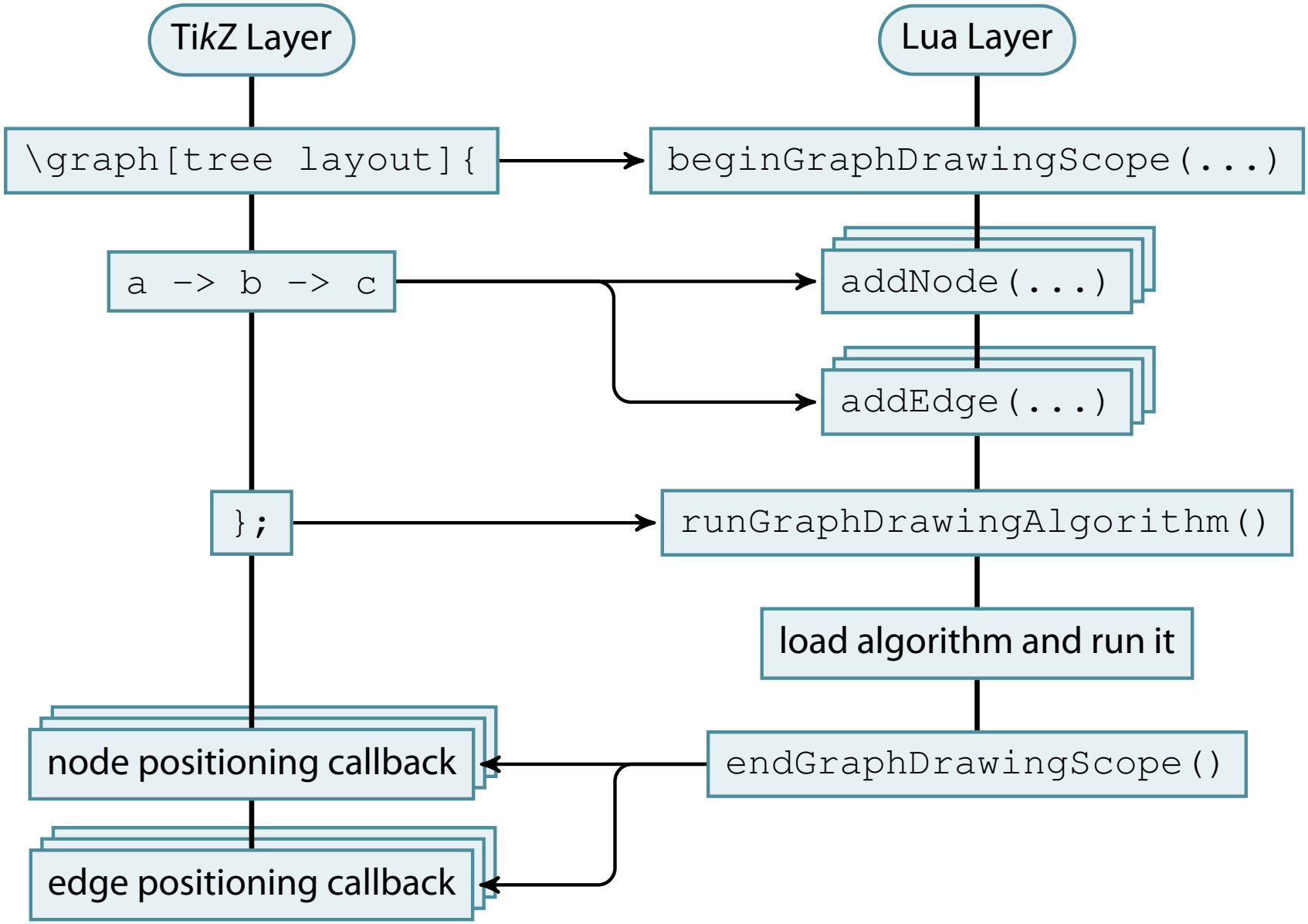
Lua is a small, simple, elegant language, . . .

- . . . that has been *integrated* into modern versions of TEX:

```
$\sum_{n=1}^{100} n =
\directlua{
  local sum = 0
  for i=1,100 do
    sum = sum + i
  end
  tex.print(sum)
}$
```

$\sum_{n=1}^{100} n = 5050$

How a Graph is Drawn



Talk Outline

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"Graph Drawing" can be seen as. . .

- starting with a *graph*, . . .
- . . . applying a *series of transformations* to it. . .
- . . . and ending with a *drawn graph*.

Graph drawing in Ti*k*Z follows this philosophy:

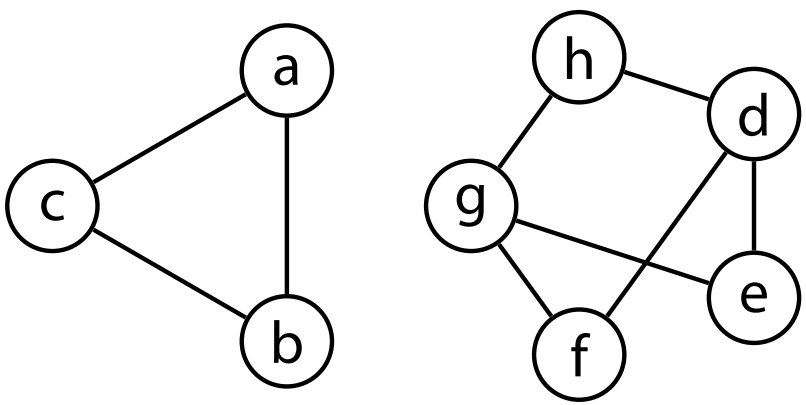
- Algorithms *declare* what kind of graphs they expect
- and also the properties of the graphs they *produce*.

Implementing a New Graph Drawing Algorithm

```
-- File VerySimpleDemo.lua
local VerySimpleDemo = pgf.gd.new_algorithm_class {
  works_only_on_connected_graphs = true,
}

function VerySimpleDemo:run()
  local graph = self.ugraph -- The graph model
  local radius = graph.options['/graph drawing/radius']
  local alpha = (2*math.pi) / #graph.vertices

  -- Iterate over all vertices:
  for i,vertex in ipairs(graph.vertices) do
    vertex.pos.x = math.cos(i*alpha) * radius
    vertex.pos.y = math.sin(i*alpha) * radius
  end
end

return VerySimpleDemo -- This return is a quirk of Lua
```

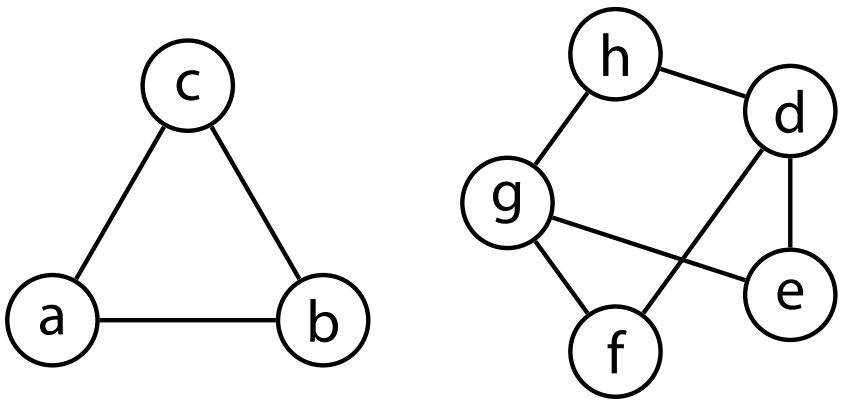
Using the Graph Drawing Algorithm

```
\tikz \graph [ layout=VerySimpleDemo, radius=1cm] {
  a -- b -- c -- a;
  d -- e;
  f -- g -- h -- d -- f;
  e -- g;
};
```



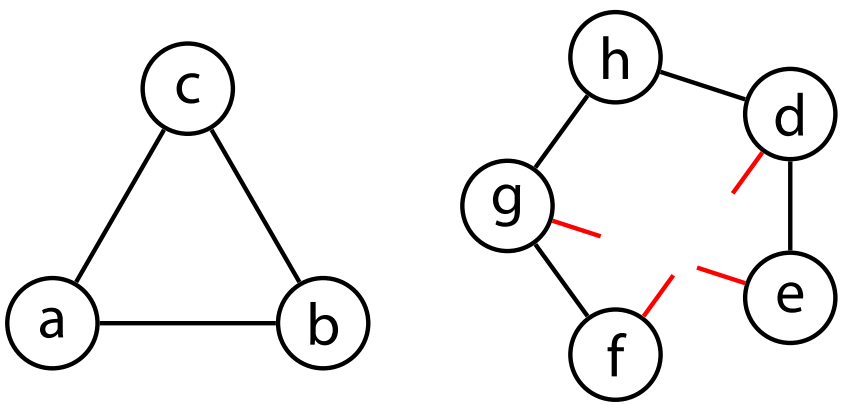
Using the Graph Drawing Algorithm

```
\tikz \graph [ layout=VerySimpleDemo, radius=1cm] {
  a --[orient=right] b -- c -- a;
  d -- e;
  f -- g -- h -- d -- f;
  e -- g;
};
```



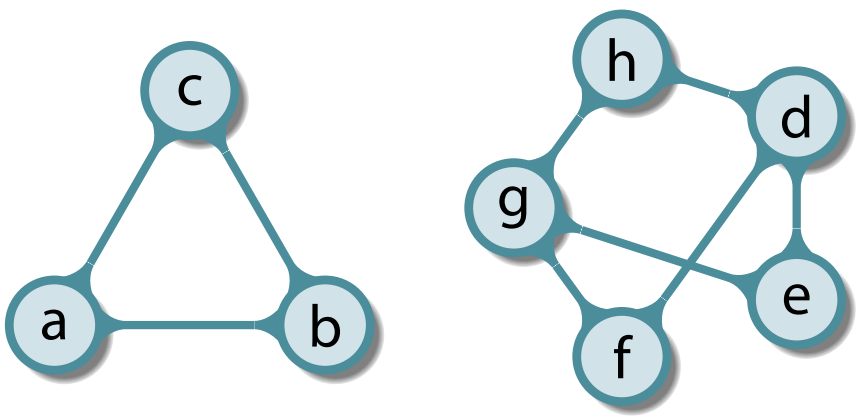
Using the Graph Drawing Algorithm

```
\tikz \graph [ layout=VerySimpleDemo, radius=1cm]
  a --[orient=right] b -- c -- a;
  d -- e;
  f -- g -- h -- d --[stub,red] f;
  e --[stub, red] g;
};
```



Using the Graph Drawing Algorithm

```
\tikz \graph [ layout=VerySimpleDemo, radius=1cm,
               nodes={circle, fill=..., ...},
               edges={circle connection bar, ...}] {
  a --[orient=right] b -- c -- a;
  d -- e;
  f -- g -- h -- d -- f;
  e -- g;
};
```



Conclusion

Graph drawing in Ti*k*Z is aimed at

- *users* who want to draw graphs with up to $\approx$ 100 nodes inside TEX documents and
- *researchers* who want to *implement new algorithms.*

Already implemented algorithms:

- Reingold–Tilford tree drawing.
- Layered Sugiyama method.
- Multi-level force-based algorithms.

Available as part of (the development version of) Ti*k*Z.