

Graph visualization with Graphviz

DRAWING SET

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Using drawing tools to manually create graphs and diagrams can be a slow and convoluted process. The Graphviz toolbox offers a faster way. Based on a short text with the information for the graph, Graphviz quickly generates a neat drawing. **BY TIM SCHÜRMANN**

Graphviz is a useful toolbox to have on hand if you need an automated approach to generating graphs (see the “Terminology” box). Computer users fumble through generating graphs, starting with E/R diagrams for visualizing database schemas to hierarchical tree structures that represent an organization’s shareholdings or a chain of command. Normally, the information is located in square boxes that must be positioned carefully, without overlapping with other boxes, before drawing any connecting arrows. This is the kind of challenge in which Graphviz excels – users simply specify the relationships between the elements, and the tool automatically outputs an attractive drawing. Don’t look for a neat graphical editor in which you can specify the relations. Instead, Graphviz reads a text-based description of the graph in a special markup language. (LaTeX uses a

similar approach, although the two systems have nothing in common apart from this.)

Graphviz has been included with all popular Linux distributions for years now. Installing the package is simple – just point and click in your favorite package manager. You can also download the latest source code version from the Graphviz homepage [1] and follow standard procedure to build and install:

```
configure; make; make install
```

Whichever way you choose to go, you should have a collection of tools on your disk when you are done.

Don’t Forget to Write

Before you can put the Graphviz tools through their paces, you need a description of the graph you want to create. To create a description, you need to write a

text file in the dot language, which is simple to learn. For example, Listing 1 implements a simple, directed graph.

The description starts by defining a directed graph called *G* with three nodes: *father*, *son*, and *daughter*. In contrast to many other programming languages, there is no need to explicitly declare the nodes. You can just go ahead and use them. The arrows specify which nodes the edges connect. Loops are permitted. The following would point to itself:

```
father -> father
```

An optional semicolon terminates each line. As you can see from the parentheses, the syntax is modelled on that of the C programming language. C is also the

Listing 1: example1.dot

```
01 digraph G {
02  /* The father has a son and
03   a daughter: */
03  father -> son;
04  father -> daughter;
05 }
```

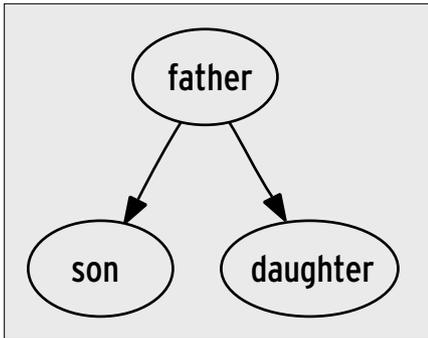


Figure 1: The description in Listing 1 creates this directed graph.

source for comment tagging, which uses `/*` to open and `*/` to close a comment.

On the Dot

To convert this description to a drawing, you now need to run the dot tool. Confusingly, the tool uses the same name as the markup language. The following command creates a PNG file (Figure 1):

```
dot -Tpng example1.dot >
-o example1.png
```

In addition to this, dot supports PostScript (`-Tps` parameter), JPG, Gif, Fig, SVG, and a number of other more or less exotic formats. Direct PDF output is not supported right now, but you can use the Ghostscript `ps2pdf` tool as a workaround. Don't forget to specify the `-o`

Terminology

A graph uses lines to connect multiple boxes. The boxes are referred to as nodes, and the lines as edges. An example of a graph might be a map of a freeway, where cities are nodes and the roads themselves are edges. A graph in which the links are represented by arrows is referred to as a directed graph (or digraph). Without the arrows, this would be an undirected graph. You could think of directed edges as one-way streets.

There is a mathematically sound – and thus, slightly cryptic – way of expressing this. A (directed) graph:

$$G = (V, E)$$

comprises a set of nodes, and a set of edges (E), where the letter contains pairs of (directed) nodes of the form:

$$e = (x, y)$$

along with a filename. If you do, the tool will send the output directly to the console. The same thing applies to the `-T` parameter; without the parameter, dot will simply output the text description of the drawing.

Red Alert

If the description does not contain instructions to the contrary, dot will create oval nodes labeled with their names.

Let's change this in our example by adding the father's first and second names, using filled, red rectangles. The dot language has a number of attributes that will help us implement the changes. To modify a specific attribute, such as the color or the label, you just assign a different value to the attribute in question:

```
color = red
label = "John Smith"
```

You need to comma-separate the attributes and append them to the node name in square brackets. In the father's case, the syntax is as follows:

```
father [shape = box,
style = filled,
color = red, label =
"John Smith"];
```

The next thing is to insert this line somewhere between the curly braces in the graph. The recommended approach is to define the nodes' appearance first, before going on to define the edges.

If this has worked for the nodes, you can rightly expect it to work for the edges. Just like nodes, users can color edges, change their line styles, or add labels. Again, all you need to do is to append pairs of values in square brackets to the edge in question, as in the following example:

```
father -> daughter [
[style = bold, label =
"first-born", color = blue];
```

The family tree is shown in Listing 2, and the results after running dot against the description are shown in Figure 2.

One for All

Changing the shape of all the nodes in a large graph might sound like a lot of work. The dot markup language uses

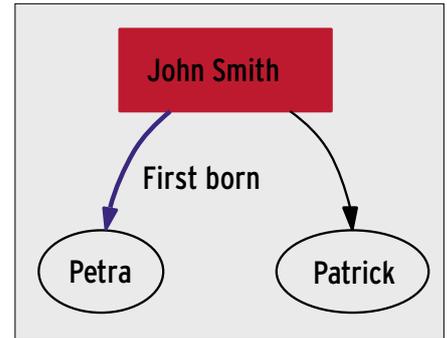


Figure 2: Just a couple of Graphviz instructions are all it takes to color the father node red.

two keywords – `node` and `edge` – to facilitate the task. Changing the attributes of the keywords applies the changes to all elements in the graph. For example, the following:

```
digraph G {
  node [shape = box];
  ...
}
```

assigns a square frame to the nodes – unless the individual node contains attribute instructions to the contrary. The `edge` instruction does the same thing for the edges.

Divisible

Subgraphs are also very useful. You can use them to group nodes that belong together. Listing 3 gives you an example.

In this case, we have introduced a subgraph that contains the daughter and the son. To tell dot to highlight the cluster in the output, you need to start the name with the `cluster` prefix. The other attributes belong to the subgraph; in this case, they define the color and the label. Figure 3 shows the results.

Listing 2: example2.dot

```
01 digraph G {
02   father [shape = box, style =
filled, color = red, label
="John Smith"];
03   daughter [label = "Petra"];
04   son [label = "Patrick"];
05   father -> son;
06   father -> daughter [style =
bold, label = "first-born",
color = blue];
07 }
```

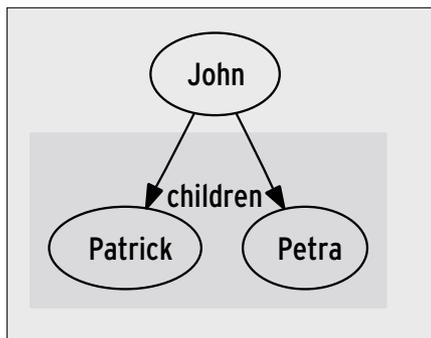


Figure 3: The description in Listing 3 highlights the subgraph with the children.

Classes

Thus far, nodes have just been assigned simple labels. However, the UML class diagram I referred to previously needs nodes with multiple subdivisions.

To do this task in dot, you will first need to switch the frame to a special mode – *record*:

```
node [shape = record]
```

From this point on in the code, dot will do something special with the label for this node, adding vertical lines to subdivide the node into multiple sections:

```
employee [label = >
"{Employee|+ salary : >
int\\|+ name : string\\ | >
+ work() : void\\}" ]
```

The `\|` tags left justify the text, and the curly braces insert vertical bars. This

Listing 3: example3.dot

```
01 digraph G {
02   subgraph cluster_children {
03     style = filled;
04     color = lightgrey;
05     label = "Children";
06
07     daughter [label = "Petra"];
08     son [label = "Patrick"];
09   }
10
11   father [label = "John
12     Smith"];
13   father -> daughter;
14   father -> son;
15 }
```

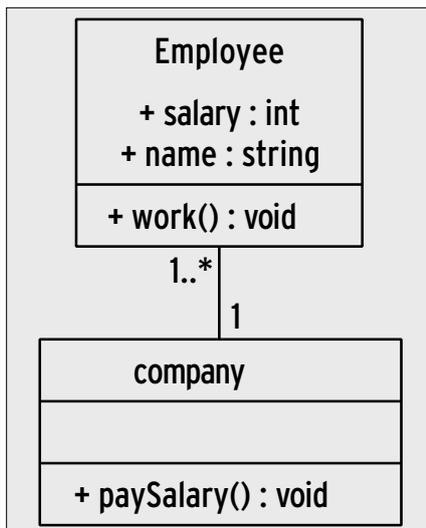


Figure 4: A small UML diagram defined in Listing 4.

gives us a more or less perfect representation of the UML class; all we need now are labels on the edges. In UML, the cardinalities can be positioned at both ends of an edge. To do this, you can use the *headlabel* and *taillabel* attributes:

```
edge [headlabel = "1", >
taillabel = "1..*" ]
```

For an example of a small UML diagram description, see Listing 4. Figure 4 shows the resulting diagram.

Slots

A *record* can do more than this, however. Users can use the divisions in the node to control the links to multiple subsequent nodes. Listing 5 and Figure 5 show you how this works. The angled

Alternatives

The Graphviz programs expect a short description of the graph, which they then automatically convert into a drawing. This leaves users with few options for influencing the kind of results they get. If you appreciate the benefits a description language can give you, but would prefer to have more granular control over the position and shape of the individual elements in the graph, you might prefer one of Graphviz's competitors. Asymptote [2] and GLE [3], in particular, are worth noting. Both can be accessed from within LaTeX. XML-based languages, such as the popular SVG [4], follow a similar approach; however, there is very little in this line of software available right now.

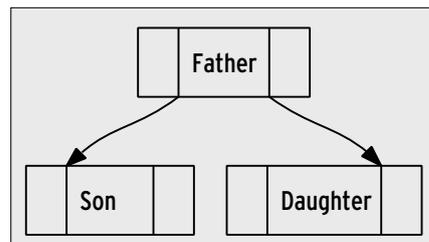


Figure 5: The slots in Listing 5 support the kind of nodes you need to visualize, like hash functions or arrays.

brackets mark special points, known as slots, from which the arrows in the diagram emanate or terminate.

Undirected

Directed graphs are dot's speciality; if you need undirected graphs, you could use another tool from the collection – *neato*. Again, the tool expects dot descriptions; however, it only supports the *graph* keyword, rather than *digraph*. Directed edges are converted to undirected edges using `--`. Listing 6 shows an example. Figures 6a and 6b show the diagrams created by dot and *neato*.

The Tools dot and *neato* use different drawing algorithms. While dot organizes nodes hierarchically, *neato* replaces edges with virtual springs and uses simulated gravity to calculate the correct distance between the nodes, thus creating a symmetric layout. The *twopi* and *circo* tools are also worthy of attention.

Listing 4: UML Diagram

```
01 digraph G {
02   node [shape = record] /*
03     vertical lines in the label
04     are drawn as lines */
05   edge [arrowhead = "none",
06     headlabel = "1", taillabel =
07     "1..*" ]
08
09   /* curly braces mean: drawn
10     a horizontal line, and not a
11     vertical bar (rotate the box
12     through 90 degrees) */
13
14   employee [label =
15     "{Employee|+ salary : int\\|+
16     name : string\\ | + work() :
17     void\\}" ]
18
19   corporation [label =
20     "{Corporation| | + paysalary()
21     : void\\}" ] employee ->
22     corporation
23 }
```

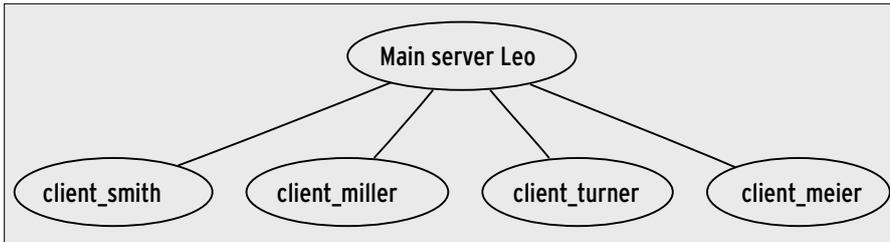


Figure 6a: The undirected graph from Listing 6, rendered by dot.

They arrange nodes in a circular pattern; for more details on the algorithms that do this, refer to the Graphviz documentation [5].

Pipe Filters

With a little help from pipes and filters, the dot command-line tool can also be used for scripting or integrated with other Linux programs. To do so, you first need to prepare the graph description in a text buffer, then pass it into dot, and finally pick up the results. A shell script might do it this way, for example:

```
echo "digraph G {father->son;
father->daughter;}" |
dot -Tpng >example7.png
```

In this example, the output from dots is simply redirected to a file, but of course, this could be another (shell) script for additional processing.

The graphical editor, *dotty*, works in the same way. It is not particularly convenient, but it does let you click and point to create graphs.

Listing 5: Complex Links

```
01 digraph G
02 {
03   node [shape = record];
04   /* The "Ports" are shown in
square brackets */
05   father [ label = "<left> |
<center> Father | <right>"];
06   son [ label = "<left> |
<center> Son | <right>"];
07   daughter [ label = "<left> |
<center> Daughter | <right>"];
08
09   "father":center -> "son":
left;
10   "father":center ->
"daughter":right;
11 }
```

If these features do not give you the options you need, you can always create a C program to access the functions in the Graphviz library. The library has convenient functions for parsing text-based files in dot format and dropping the results into a data structure designed explicitly for this purpose.

You can also manipulate graphs in memory and output the results. The program shown in Listing 7 gives you a brief example. It parses a text file with dot commands, draws a graph with a little help from the dot algorithm, and outputs the results. In fact, dot itself is built in a similar fashion.

There are some more sample programs in the *dot.demo* directory that comes with the source code package. The Graphviz homepage has a comprehensive API reference. If you use the API for your own development work, note that

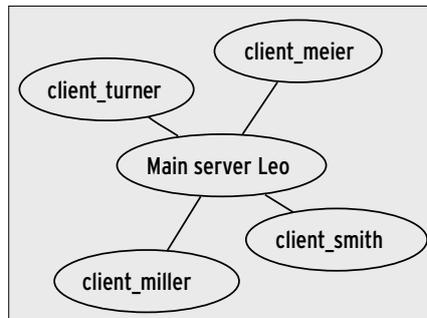


Figure 6b: The undirected graph from Listing 6, rendered by neato.

Listing 6: Undirected Graph

```
01 graph G {
02   server [label = "Main server
Leo"];
03
04   server -- client_smith
05   server -- client_miller;
06   server -- client_turner;
07   server -- client_meier;
08 }
```

the libraries are licensed under the Common Public License.

Conclusions

Once you have come to terms with the graph description language, dot, you will appreciate the tools in the Graphviz package. It is hard to find a faster way to create graphs. Thanks to pipes and filters, dot and company are easy to integrate with other sequences and shell scripts. Plus, if the package is not to your liking, you can check out the "Alternatives" box for similar tools. ■

Listing 7: Graphviz C API

```
01 #include <gvc.h>
02
03 int main()
04 {
05   GVC_t *context;
06   graph_t *graph;
07   FILE *fp;
08
09   context = gvContext();
10   fp = fopen("example.dot",
"r");
11   graph = agread(fp); /* Parse
graph */
12   gvLayout(context, graph,
"dot"); /*Create layout with
dot algorithm */
13   gvRender(context, graph,
"png", stdout); /* Output
graph in PNG format */
14   /*Clean up */
15   gvFreeLayout(context,
graph);
16   agclose(graph);
17   gvFreeContext(context);
18 }
```

INFO

- [1] Graphviz homepage: <http://www.graphviz.org>
- [2] Asymptote homepage: <http://asymptote.sourceforge.net>
- [3] GLE homepage: <http://www.gle-graphics.org>
- [4] SVG format specifications: <http://www.w3.org/Graphics/SVG/>
- [5] Information on the algorithms used by Graphviz: <http://www.graphviz.org/Documentation.php>