PGF/TikZ - Graphics for LaTeX

A tutorial

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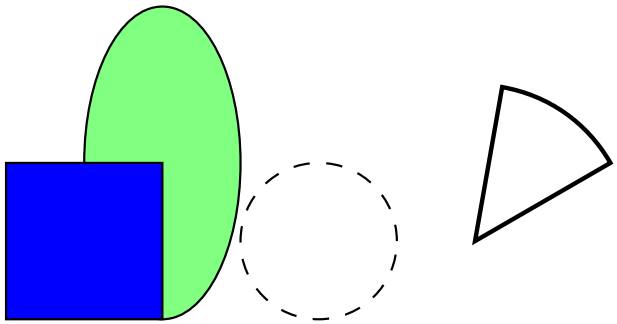
PGF and TikZ

- According to its author, Till Tantau (Lübeck), PGF/TikZ stands for *"Portable Graphics Format"* and *"TikZ ist kein Zeichenprogramm"*.
- PGF: internal engine; TikZ: frontend
- nicely integrated into LaTeX and Beamer
- works for PostScript output (`dvips`) as well as for PDF generation (`pdflatex, dvipdfmx`)
- DVI previewer are not always able to show the graphics correctly. Look at the PS or PDF output!
- TikZ is cool for 2D pictures. For 3D graphics I prefer other tools, e.g. Asymptote.

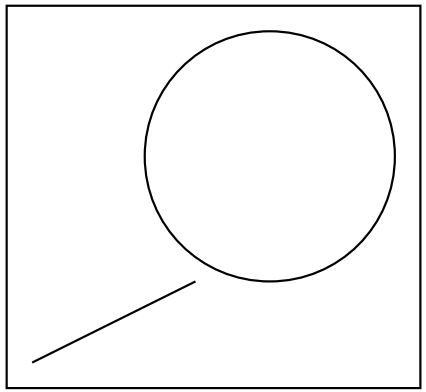
```
\usepackage{tikz}
\usetikzlibrary{arrows,shapes,trees,..} % loads some tikz extensions
```

- Use `\tikz ... ;` for simple inline commands:
  The code `\tikz \draw (0pt,0pt) -- (20pt,6pt);` yields  and
  `\tikz \fill[orange] (0,0) circle (1ex);` provides  .
- Use `\begin{tikzpicture}...\end{tikzpicture}` for larger pictures:



```
\begin{tikzpicture}
  \draw[style=dashed] (2,.5) circle (0.5);
  \draw[fill=green!50] (1,1)
      ellipse (.5 and 1);
  \draw[fill=blue] (0,0) rectangle (1,1);
  \draw[style=thick]
     (3,.5) -- +(30:1) arc(30:80:1) -- cycle;
\end{tikzpicture}
```

- Coordinate system starts at lower left corner of canvas
- Canvas is made large enough to hold the picture
- Tip: make boundary of canvas visible,
  if necessary, move the picture box around using
  `\hspace*{..}, \vspace*{..}`
- Unit of length: `1cm`, other units are possible
- Tip: don't use units, use the `scale` option
  of `tikzpicture`

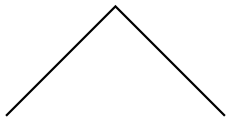


```
\usetikzlibrary{backgrounds}
...
\vspace*{-2.3cm}\hspace{8cm}%
\begin{tikzpicture}[ scale=.8, show background rectangle]
  \draw (2,2) circle (1);
  \draw (1 mm, 10 pt) -- (4 em, 1);
\end{tikzpicture}
```

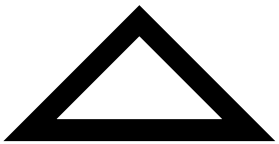
(A solution in the spirit of LaTeX would be the use of a multicolumn environment or of minipages. But sometimes the `\hspace/vspace` hack is faster and more flexible.)

Paths

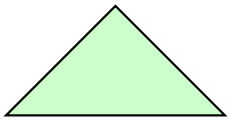
- Basic elements are paths and nodes.
- A path is a series of straight and curved line segments.
- Paths can be drawn, filled or used for clipping of subsequent drawings:



```
\path[draw] (1,1) -- (2,2) -- (3,1);
```

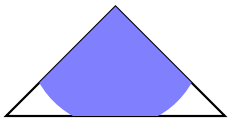


```
\path[draw,line width=4pt] (1,1) -- (2,2)--(3,1)--cycle;
```



```
\path[draw, fill=green!20] (1,1)--(2,2)--(3,1)--cycle;
```

```
\path[fill=green] (1,1) -- (2,2) -- (3,1) -- cycle;
```

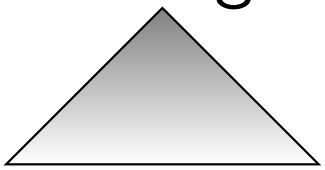


```
\path[clip, draw] (1,1)--(2,2)--(3,1)--cycle;
\path[fill=blue!50] (2, 1.7) circle (.8);
```

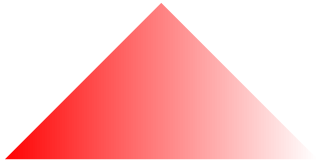
- Abbreviations:

```
\draw = \path[draw], \fill = \path[fill], \clip = \path[clip]
 \filldraw = \path[fill,draw], \shade = \path[shade], ...
```

Shading

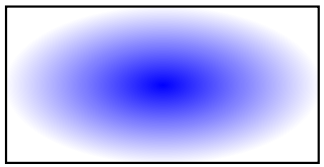


```
\path[shade,draw] (1,1) -- (2,2)--(3,1)--cycle;
```

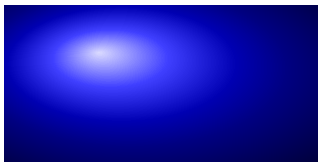


```
\shade[left color=red] (1,1)--(2,2)--(3,1)--cycle;
```

```
\shade[top color=red, bottom color=green]
          (0,0) rectangle (2,1);
```



```
\shade[draw,shading=radial, inner color=blue]
          (0,0) rectangle (2,1);
```

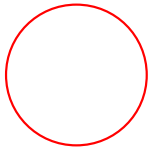


```
\shade[shading=ball, ball color=blue]
          (0,0) rectangle (2,1);
```

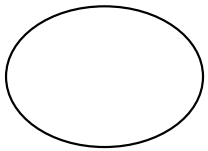
```
\shade[shading=ball, ball color=blue]  (0,0) circle (.3);
\shade[shading=ball, ball color=white] (1,0) circle (.3);
\shade[shading=ball, ball color=black] (2,0) circle (.3);
```

Simple shapes

```
\draw (0, 0) rectangle (2, 1);
```

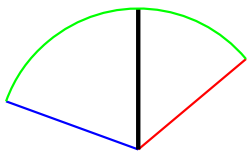


```
\draw[color=red] (0, 0) circle (.5);
```



```
\draw (0, 0) ellipse (.7 and 0.5);
```

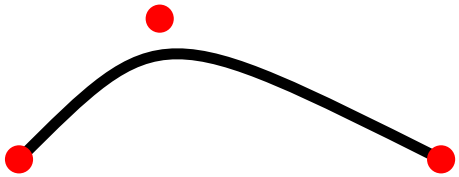
Polar coordinates:



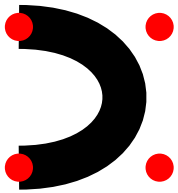
```
\draw[color=red] (0,0) -- (40:1);
\draw[color=blue] (0,0) -- (160:1);
\draw[thick] (0,0) -- (90:1);
\draw[color=green] (40:1) arc (40:160:1);
```

Curved lines

- Specify 1 or 2 “control points” between two points of the path.
- Curve starts in the direction of the first control point, then gradually changes direction to the second control point, then to the target point (cubic Bézier interpolation)



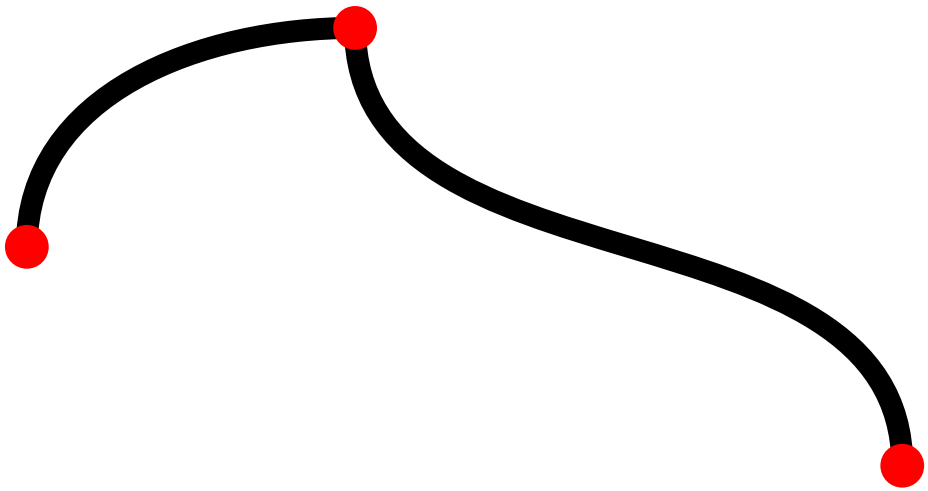
```
\draw[line width=2pt] (0, 0) .. controls(1,1) .. (3, 0);
```



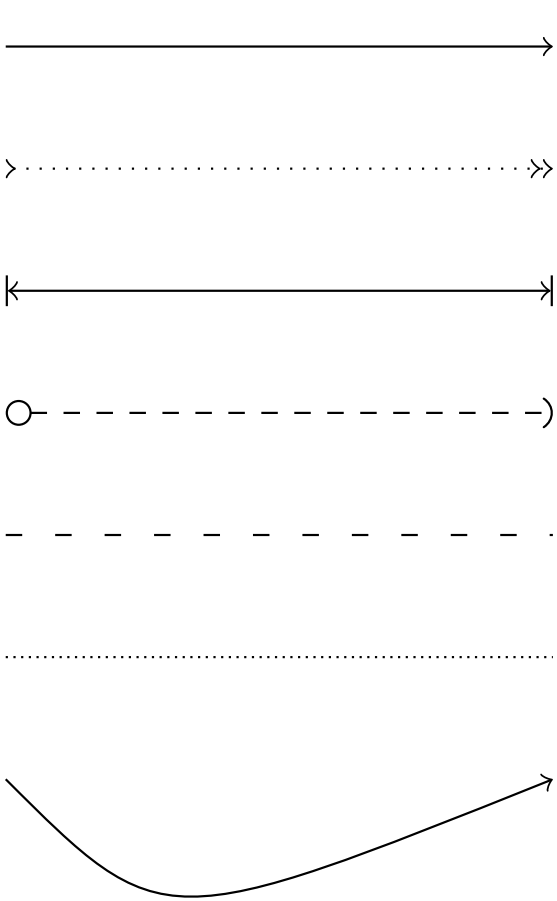
```
\draw[line width=8pt] (0, 0) ..
                      controls(1, 0) and  (1, 1)
                           .. (0, 1);
```

- Another way is to specify directions at start and target:

```
\begin{tikzpicture}[scale=.7]
  \draw[line width=4pt] (0,0) to [out=90, in=180] (3,2)
                              to [out=-90, in=90] (8,-2);
```



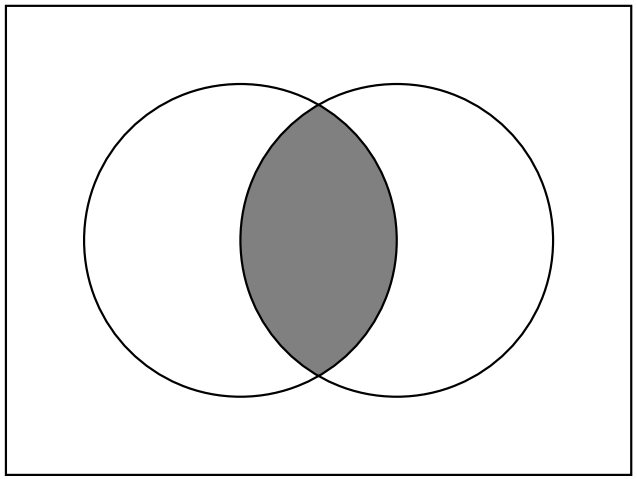
Arrows, dash patterns



```
\draw[->]                (0,0) -- (1,0);
\draw[dotted, >->>]      (0,0) -- (1,0);
\draw[|<->|]             (0,0) -- (1,0);
\draw[dashed, o-)]       (0,0) -- (1,0);
\draw[loosely dashed]    (0,0) -- (1,0);
\draw[densely dotted]    (0,0) -- (1,0);
\draw[->] (0,0) .. controls (.2,-.2) .. (1, 0);
```

Clipping and scope

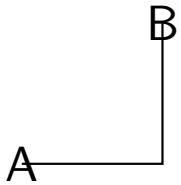
- After a `\clip` command, all subsequent drawings are clipped, only the parts inside the clipping region are drawn.
- Use the `scope` environment to restrict the effect of clipping:



```
\begin{tikzpicture}
   \draw (-2, 1.5) rectangle (2, -1.5);
   \begin{scope}
     \clip (-0.5, 0) circle (1);
     \clip ( 0.5, 0) circle (1);
     \fill[color=gray] (-2,1.5)
                       rectangle (2,-1.5);
   \end{scope}
   \draw (-0.5, 0) circle (1);
   \draw ( 0.5, 0) circle (1);
\end{tikzpicture}
```

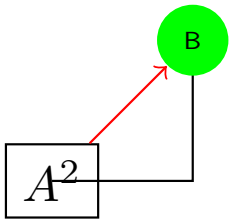
Nodes

- Nodes are added to paths after the path is drawn:




```
\path[draw] (0, 0) node {A} -- (1,0) -- (1,1) node {B};
```

- Nodes can get a name for later references. Nodes have many options.



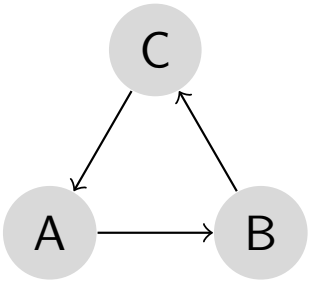

```
\path[draw] (0, 0) node[draw] (nodeA)  {$A^2$} -- (1,0)
    -- (1,1) node[ellipse,fill=green](nodeB) {\tiny B};
\draw[red,->] (nodeA) -- (nodeB);
```

- It is often better to define named nodes first and connect them later, since then the paths are clipped around the notes. For this,

```
\path (x,y) node[Options] (node name) {TeX content of node}
```

can be written as

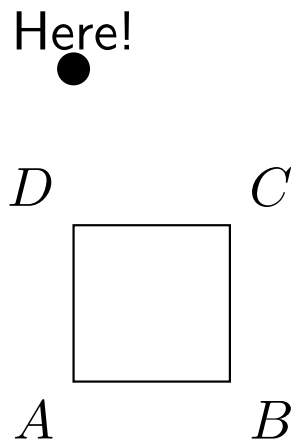
```
\node[Options] (node name) at (x,y) {TeX content of node}
```




```
\begin{tikzpicture}[scale=.9, transform shape]
  \tikzstyle{every node} = [circle, fill=gray!30]
  \node (a) at (0, 0) {A};
  \node (b) at +(0: 1.5) {B};
  \node (c) at +(60: 1.5) {C};
  \foreach \from/\to in {a/b, b/c, c/a}
      \draw [->] (\from) -- (\to);
\end{tikzpicture}
```

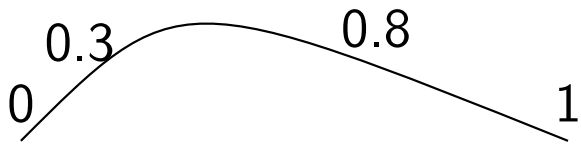
Note: `scale` and other transformations are normally not applied to nodes. If you want that, add the option `transform shape`.

- Nodes on a path can have a placement option



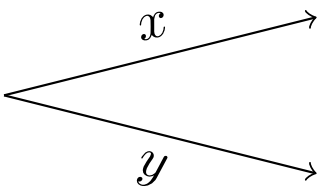

```
\begin{tikzpicture}
  \fill (0,2) circle (3pt) node[above] {Here!};
  \draw (0,0) node[below left] {$A$} --
        (1,0) node[below right] {$B$} --
        (1,1) node[above right] {$C$} --
        (0,1) node[above left]  {$D$} -- cycle;
\end{tikzpicture}
```

- Notes along a path can be positioned by `pos=0...1`. Here `pos=0` is the start and `pos=1` the end of the path:




```
\begin{tikzpicture}
  \draw (0,0) .. controls (1,1) .. (3.5, 0)
       node[pos=0,above] {0}
       node[pos=.3, left] {0.3}
       node[pos=0.8,above]{0.8}
       node[pos=1,above]{1};
\end{tikzpicture}
```

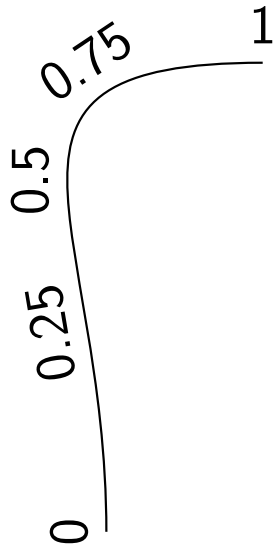
Some more examples




```
\begin{tikzpicture}

  \draw[->] (0,0) -- (2,0.5) node[pos=.5,sloped,above] {$x$};
  \draw[->] (0,0) -- (2,-.5) node[pos=.5,sloped,below] {$y$};

\end{tikzpicture}
```

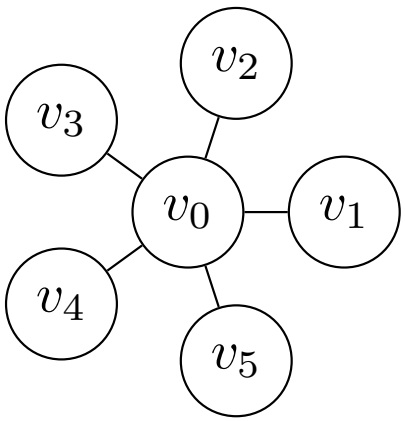



```
\begin{tikzpicture}

  \tikzstyle{every node} = [sloped,above, %
                            allow upside down]
  \draw (0,0).. controls +(up:2cm) and +(left:2cm) ..(1,3)
  \foreach \p in {0,0.25,...,1} {node[pos=\p]{\p}};

\end{tikzpicture}
```

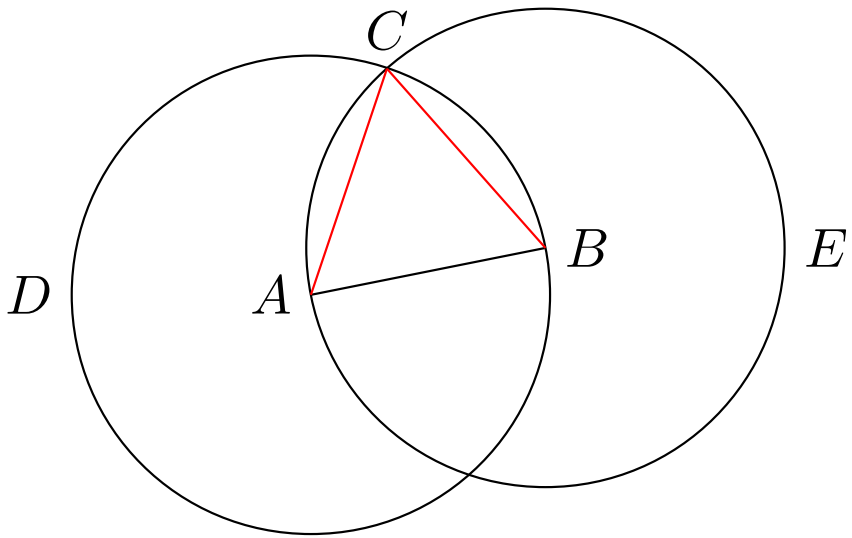
- Simple computations are possible inside TikZ




```
\begin{tikzpicture}
  \tikzstyle{every node}=[draw,shape=circle];
  \node (v0) at (0:0) {$v_0$};
  \node (v1) at (   0:1) {$v_1$};
  \node (v2) at (  72:1) {$v_2$};
  \node (v3) at (2*72:1) {$v_3$};
  \node (v4) at (3*72:1) {$v_4$};
  \node (v5) at (4*72:1) {$v_5$};
  \draw (v0) -- (v1)
        (v0) -- (v2)
        (v0) -- (v3)
        (v0) -- (v4)
        (v0) -- (v5);
\end{tikzpicture}
```

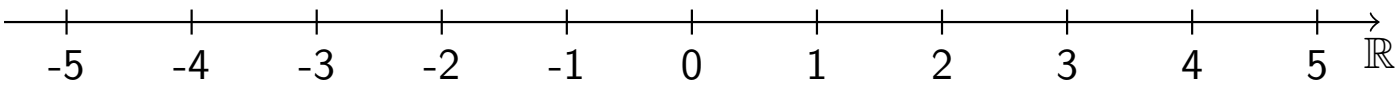
```
\usetikzlibrary{calc,through}

\begin{tikzpicture}[scale=1.2]
   \coordinate [label=left:$A$] (A) at (0,0);
   \coordinate [label=right:$B$] (B) at (1.25,0.25);
   \draw (A) -- (B);
   \node (D) [draw,circle through=(B),label=left:$D$] at (A) {};
   \node (E) [draw,circle through=(A),label=right:$E$] at (B) {};
   \coordinate[label=above:$C$] (C) at (intersection 2 of D and E);
   \draw [red] (A) -- (C);
   \draw [red] (B) -- (C);
\end{tikzpicture}
```



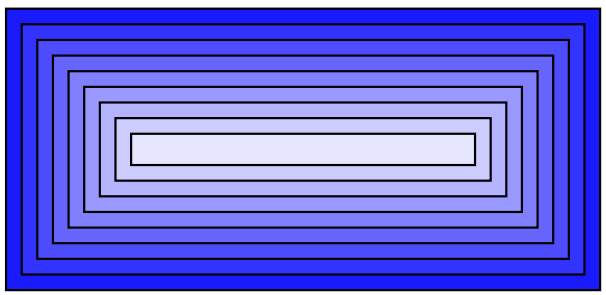
Loops

```
\draw[->] (-5.5,0) -- (5.5,0) node [below] {$\mathbb{R}$};
\foreach \x in {-5,...,5}
    \draw (\x, 0.1) -- (\x, -0.1) node [below] {\x};
```



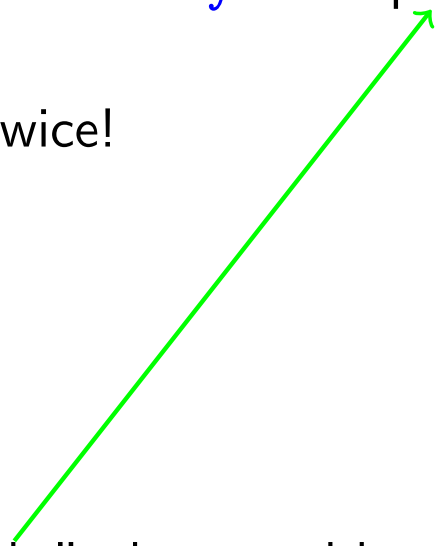

```
\foreach \x in {1,3,...,10}
  \shade[ball color=red!\x 0!green] (\x,0) circle (3mm);
```

```
\foreach \x in {9,...,1}
  \draw[fill=blue!\x0] (-0.1*\x  - 1,  -0.1*\x )
            rectangle  (0.1*\x + 1, 0.1*\x );
```



Referencing nodes outside the current picture

- Add `\tikzstyle{every picture}+=[remember picture]` to your global options
- Add the option `overlay` to all paths that reference nodes outside the current picture
- Run pdflatex twice!



- The word "paths" above and here is really a node:
  `...to all\tikz[baseline,inner sep=0] \node[anchor=base] (n1) {paths}; that reference ...`
- And finally, we draw the arrow:
  `\tikz[overlay]\draw[thick,green,->]  (n2) -- (n1);`

Integration with Beamer

$$y = a\,x + b$$

- slope
- y-intercept

```
\[
  y = \tikz[baseline]{\node[fill=blue!50,anchor=base] (t1){$a$};} x +
    \tikz[baseline]{\node[fill=red!50,anchor=base ] (t2){$b$};}
\]
\begin{itemize}
  \item[]<2-> \tikz\node [fill=blue!50,draw,circle] (n1) {}; slope
  \item[]<3-> \tikz\node [fill=red!50,draw,circle] (n2) {}; y-intercept
\end{itemize}
\begin{tikzpicture}[overlay]
  \path<4->[blue,->] (n1.north) edge [out= 60, in= 135] (t1.north west);
  \path<5>[red,->] (n2.south) edge [out=-70, in=-110] (t2.south);
\end{tikzpicture}
```

Integration with Beamer

$$y = a\,x + b$$

- slope
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```
\[
  y = \tikz[baseline]{\node[fill=blue!50,anchor=base] (t1){$a$};} x +
    \tikz[baseline]{\node[fill=red!50,anchor=base ] (t2){$b$};}
\]
\begin{itemize}
  \item[]<2-> \tikz\node [fill=blue!50,draw,circle] (n1) {}; slope
  \item[]<3-> \tikz\node [fill=red!50,draw,circle] (n2) {}; y-intercept
\end{itemize}
\begin{tikzpicture}[overlay]
  \path<4->[blue,->] (n1.north) edge [out= 60, in= 135] (t1.north west);
  \path<5>[red,->] (n2.south) edge [out=-70, in=-110] (t2.south);
\end{tikzpicture}
```

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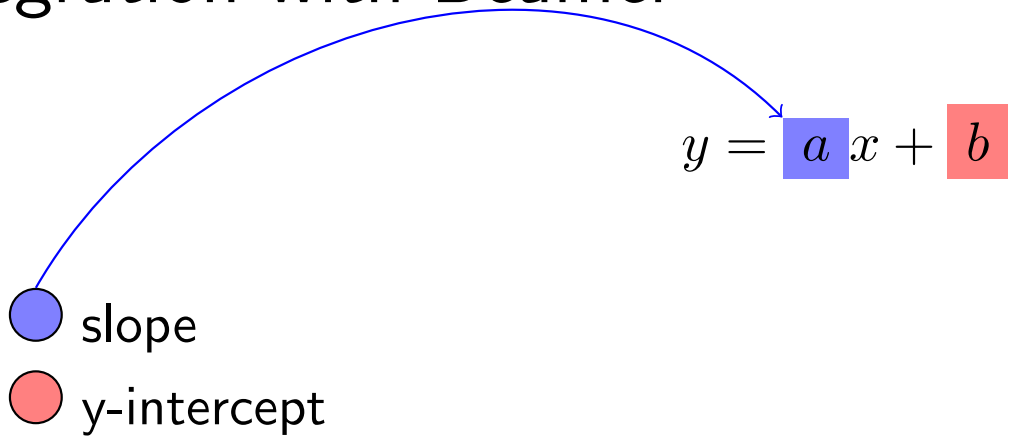
```
\[
  y = \tikz[baseline]{\node[fill=blue!50,anchor=base] (t1){$a$};} x +
    \tikz[baseline]{\node[fill=red!50,anchor=base ] (t2){$b$};}
\]
\begin{itemize}
  \item[]<2-> \tikz\node [fill=blue!50,draw,circle] (n1) {}; slope
  \item[]<3-> \tikz\node [fill=red!50,draw,circle] (n2) {}; y-intercept
\end{itemize}
\begin{tikzpicture}[overlay]
  \path<4->[blue,->] (n1.north) edge [out= 60, in= 135] (t1.north west);
  \path<5>[red,->] (n2.south) edge [out=-70, in=-110] (t2.south);
\end{tikzpicture}
```

Integration with Beamer




```
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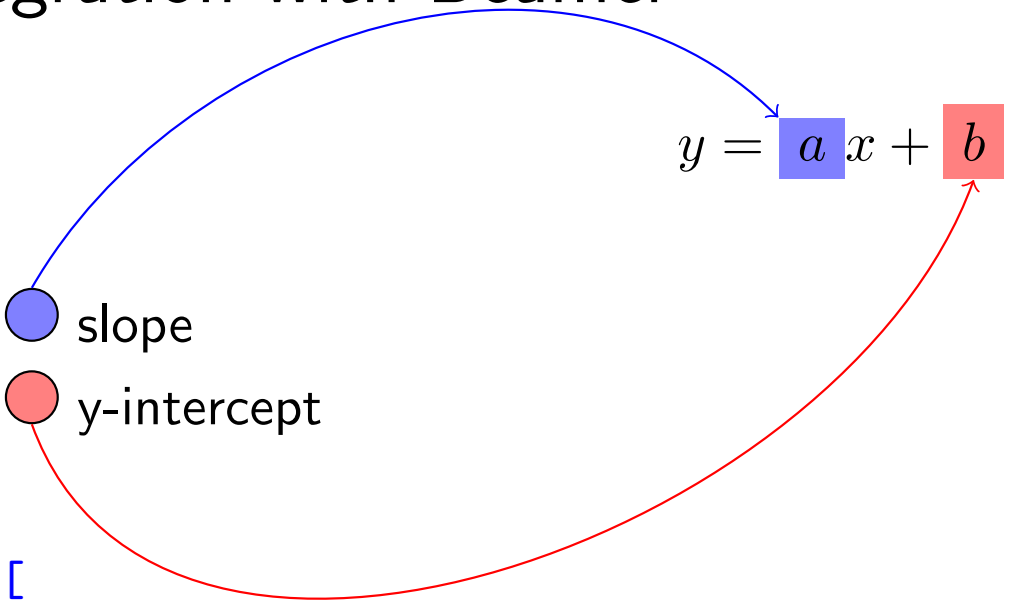
Integration with Beamer

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  \path<5>[red,->] (n2.south) edge [out=-70, in=-110] (t2.south);
\end{tikzpicture}
```
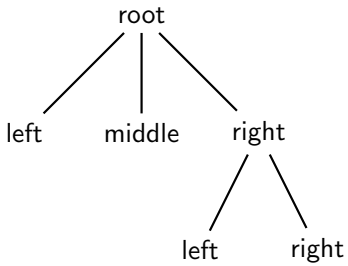
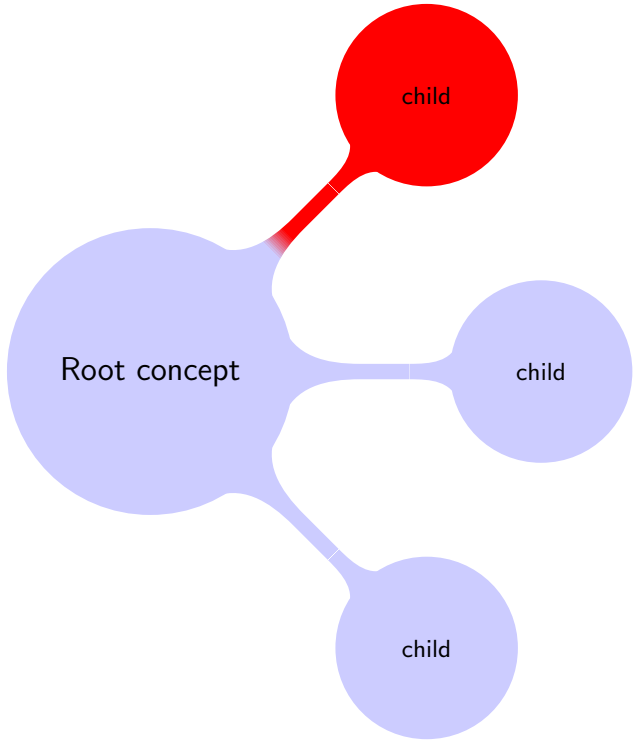

Some Libraries

- Shapes

- Trees



- Mind maps



- Automata drawing, calendar, decorations, matrix, shadows, function and data plots ...

References

- A great source of examples, tutorials etc is
  http://www.texample.net/tikz/
- Some examples were taken from
  http://altermundus.fr/pages/downloads/remember_beamer.pdf,
  http://www.statistiker-wg.de/pgf/tutorials.htm
  and
  http://www.tug.org/pracjourn/2007-1/mertz/
- and of course from the PGF/TikZ Manual.