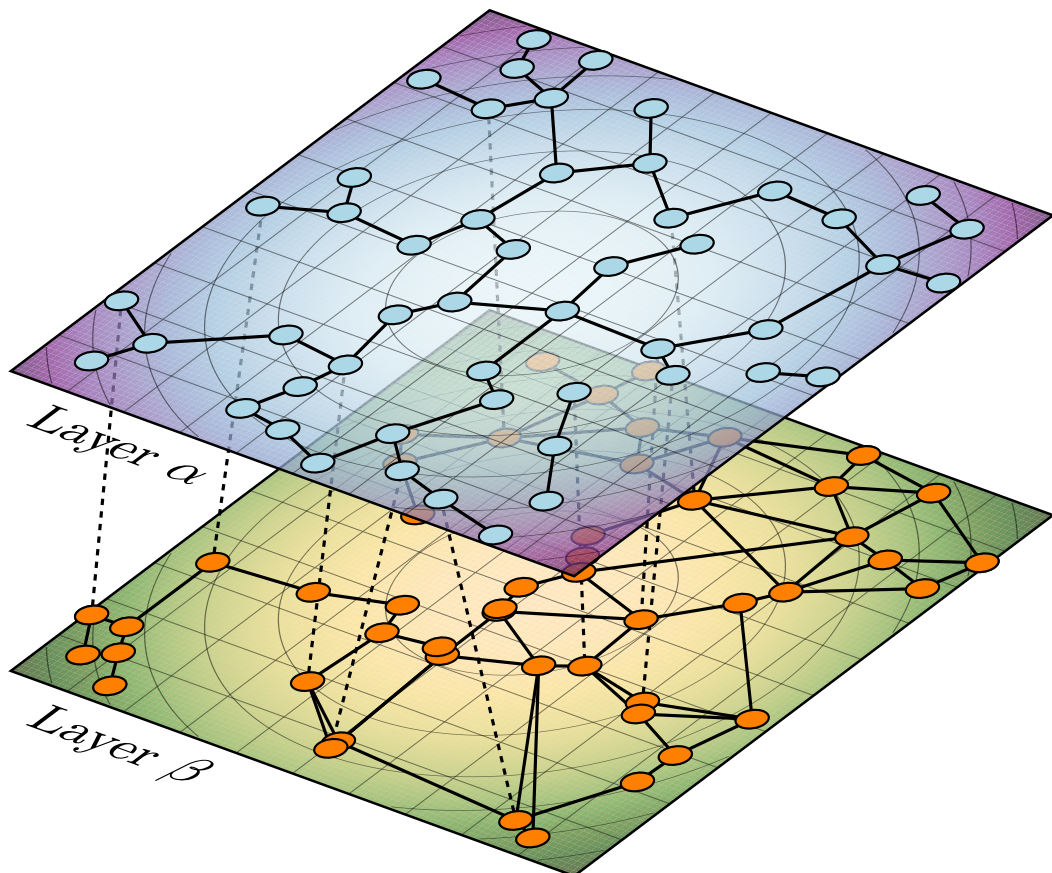


JÜRGEN HACKL

TIKZ-NETWORK MANUAL



VERSION 0.4

The tikz-network package is still under development. Hence, changes in the commands and functionality cannot be excluded.

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VERSION 0.4

<https://github.com/hackl/tikz-network>

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1 Introduction

In recent years, complex network theory becomes more and more popular within the scientific community. Besides a solid mathematical base on which these theories are built on, a visual representation of the networks allow communicating complex relationships to a broad audience.

Nowadays, a variety of great visualization tools are available, which helps to structure, filter, manipulate and of course to visualize the networks. However, they come with some limitations, including the need for specific software tools, difficulties to embed the outputs properly in a \LaTeX file (e.g. font type, font size, additional equations and math symbols needed, ...) and challenges in the post-processing of the graphs, without rerunning the software tools again.

In order to overcome this issues, the package `tikz-network` was created. Some of the features are:

- \LaTeX is a standard for scientific publications and widely used
- beside \LaTeX no other software is needed
- no programming skills are needed
- simple to use but allows 100% control over the output
- easy for post-processing (e.g. adding drawings, texts, equations, ...)
- same fonts, font sizes, mathematical symbols, ... as in the document
- no quality loss of the output due to the pdf format
- networks are easy to adapt or modify for lectures or small examples
- able to visualize larger networks
- three-dimensional visualization of (multilayer) networks
- compatible with other visualization tools

1.1 How to read this manual?

The aim of this manual is to describe the use of the `tikz-network` library for visualizing networks. To ensure an easy use of the elements and to keep the clarity, this manual is structured as follows:

- In Chapter 2 the elements to create simple networks (by hand) in a plane are explained. Thereby, the use of the commands `\Vertex` and `\Edge` are shown.
- How to create complex networks from external files¹ are explained in Chapter 3. The main commands, therefore are `\Vertices` and `\Edges` which are using the same options as in the simple case.
- In Chapter 4, the visualization of multilayer networks is explained. Additional visualization tools such as `\Plane` and `Layer` are introduced.
- The default settings used and how they can be modified is explained in Chapter 5.
- Information about troubleshooting and support is given in Chapter 6
- Since this is the alpha version (0.1) of the package, features which will be probably added and commands which have to be fixed are listed in Appendix B.

¹ e.g. `igraph` or `networkx`

1.1.1 A few explanations

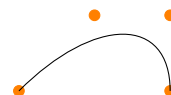
The images in this manual are created with the `tikz-network` library or `TikZ`. The code used for this is specified for each image.

```
\begin{tikzpicture}
  \filldraw (-.2,.2) circle (2pt) (.2,.2) circle (2pt);
  \draw (0,0) circle (5mm) (-.3,-.1) .. controls (0,-.3) ..
    (.3,-.1);
\end{tikzpicture}
```



Special additions which are needed for a better understanding are shown in orange but are not in the sample code available.

```
\begin{tikzpicture}
  \draw (0,0) .. controls (1,1) and (2,1) .. (2,0);
\end{tikzpicture}
```



1.1.2 Inputs

The commands in the `tikz-network` library (e.g. `\Vertex`, `\Edge`) always start with capital letters and DO NOT need a semicolon «;» at the end. Boolean arguments start also with capital letters (e.g. `<NoLabel>`). Arguments which need an user input, use are written in small letters (e.g. `<color>`).

Basically, one can distinguish between the mandatory argument `{ }` and the optional argument `[]`. The first values must be entered compulsory. By contrast, nothing has to be entered for the optional input. Additional features (e.g. `<size>`) can be activated when entering optional parameters.

When entering size values the base unit is always predefined in $[cm]^2$, except for line widths which are dedined in $[pt]$. Percentage values % are always specified as decimal values; for example, $100\% = 1.0$ and 10% corresponds to 0.1 .

² The default unit can be changed with `\SetDefaultUnit`; see Section 5.1

1.1.3 Additional help

Is the manual not enough, occur some ambiguities or some TikZ commands are unclear, please have a look in the “TikZ and PGF Manual” from Till Tantau³.

Should you have any further questions, please do not hesitate to contact me.

³ <http://mirror.switch.ch/ftp/mirror/tex/graphics/pgf/base/doc/pgfmanual.pdf>

1.2 Installation

Actually, we can hardly speak of an installation since only the necessary package `tikz-network` must be loaded in the preamble of your document.

The current release of the package is available via CTAN⁴. A release candidate for the next version of `tikz-network` is available on github⁵

⁴ **TODO!** upload the package to CTAN, and add here the link

⁵ <https://github.com/hackl/>

Is the package installed or the style file is stored in the folder of the main file, so the library can be imported, as the following example shows:

```
% -----
% header
\documentclass{scrreprt}

% -----
% packages
\usepackage{tikz-network}
```

1.3 Additional necessary packages

To use all commands and options of TikZ, possibly some packages need to be reloaded. These missing files (or their names) appear in the error log when you convert the file. However, for the package described in this manual, it is sufficient to use the library and the TikZ standard commands.

2 Simple Networks

2.1 Vertex

One essential command is `\Vertex`, which allow placing vertices in the document and modify their appearance.

```
\Vertex[⟨local options⟩]{Name}
```

In order to be able to place a vertex, a non-empty *Name* argument is required. This argument defines the vertex's reference name, which must be unique. Mathematical symbols are not allowed as name as well as no blank spaces. The *Name* should not be confused with the *⟨label⟩*, that is used for display; for example one may want to display A_1 while the name will be $A1$.

For a `\Vertex` the following options are available:

Option	Default	Type	Definition
<code>x</code>	<code>o</code>	measure	x-coordinate
<code>y</code>	<code>o</code>	measure	y-coordinate
<code>size</code>	<code>{}</code>	measure	diameter of the circle
<code>color</code>	<code>{}</code>	color	fill color of vertex
<code>opacity</code>	<code>{}</code>	number	opacity of the fill color
<code>shape</code>	<code>{}</code>	string	shape of the vertex
<code>label</code>	<code>{}</code>	string	label
<code>fontsize</code>	<code>{}</code>	string	font size of the label
<code>fontcolor</code>	<code>{}</code>	color	font color of the label
<code>fontscale</code>	<code>{}</code>	number	scale of the label
<code>position</code>	<code>center</code>	value ^a	label position
<code>distance</code>	<code>o</code>	measure	label distance from the center
<code>style</code>	<code>{}</code>	string	additional TikZ styles
<code>layer</code>	<code>{}</code>	number	assigned layer of the vertex
<code>NoLabel</code>	<code>false</code>	Boolean	delete the label
<code>IdAsLabel</code>	<code>false</code>	Boolean	uses the <i>Name</i> as label
<code>Math</code>	<code>false</code>	Boolean	displays the label in math mode
<code>RGB</code>	<code>false</code>	Boolean	allow RGB colors
<code>Pseudo</code>	<code>false</code>	Boolean	create a pseudo vertex

^a either measure or string

Table 2.1: Local options for the `\Vertex` command.

The order how the options are entered does not matter. Changes to the default Vertex layout can be made with `\SetVertexStyle`¹

¹ see Section 5.2

```
\Vertex[⟨x⟩=measure,⟨y⟩=measure]{Name}
```

The location of the vertices are determined by Cartesian coordinates in $\langle x \rangle$ and $\langle y \rangle$. The coordinates are optional. If no coordinates are determined the vertex will be placed at the origin $(0,0)$. The

entered *measures* are in default units (cm). Changing the unites (locally) can be done by adding the unit to the *measure*². Changes to the default setting can be made with `\SetDefaultUnit`³.

```
\begin{tikzpicture}
  \Vertex{A}
  \Vertex[x=1,y=1]{B}
  \Vertex[x=2]{C}
\end{tikzpicture}
```

```
\Vertex[⟨size⟩=measure]{Name}
```

The diameter of the vertex can be changed with the option `⟨size⟩`. Per default a vertex has 0.6 cm in diameter. Also, here the default units are cm and have not to be added to the *measure*.

```
\begin{tikzpicture}
  \Vertex[size=.3]{A}
  \Vertex[x=1,size=.7]{B}
  \Vertex[x=2.3,size=1]{C}
\end{tikzpicture}
```

```
\Vertex[⟨color⟩=color]{Name}
```

To change the fill color of each vertex individually, the option `⟨color⟩` has to be used. Without the option `⟨RGB⟩` set, the default TikZ and L^AT_EX colors can be applied.

```
\begin{tikzpicture}
  \Vertex[color = blue]{A}
  \Vertex[x=1,color=red]{B}
  \Vertex[x=2,color=green!70!blue]{C}
\end{tikzpicture}
```

```
\Vertex[⟨opacity⟩=number]{Name}
```

With the option `⟨opacity⟩` the opacity of the vertex fill color can be modified. The range of the *number* lies between 0 and 1. Where 0 represents a fully transparent fill and 1 a solid fill.

```
\begin{tikzpicture}
  \Vertex[opacity = 1]{A}
  \Vertex[x=1,opacity = .7]{B}
  \Vertex[x=2,opacity = .2]{C}
\end{tikzpicture}
```

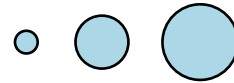
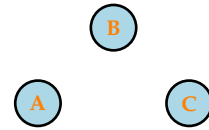
```
\Vertex[⟨shape⟩=string]{Name}
```

With the option `⟨shape⟩` the shape of the vertex can be modified. Thereby the shapes implemented in TikZ can be used, including: *circle*, *rectangle*, *diamond*, *trapezium*, *semicircle*, *isosceles triangle*, ...

```
\begin{tikzpicture}
  \Vertex[shape = rectangle]{A}
  \Vertex[x=1,shape = diamond]{B}
  \Vertex[x=2,shape = isosceles triangle]{C}
\end{tikzpicture}
```

² e.g. `x=1 in`

³ see Section 5.1



```
\Vertex[⟨label⟩=string]{Name}
```

In `tikz-network` there are several ways to define the labels of the vertices and edges. The common way is via the option `⟨label⟩`. Here, any *string* argument can be used, including blank spaces. The environment `$` can be used to display mathematical expressions.

```
\begin{tikzpicture}
  \Vertex[label=foo]{A}
  \Vertex[x=1,label=bar]{B}
  \Vertex[x=2,label=$u_1$]{C}
\end{tikzpicture}
```



```
\Vertex[⟨label⟩=string,⟨fontsize⟩=string]{Name}
```

The font size of the `⟨label⟩` can be modified with the option `⟨fontsize⟩`. Here common \LaTeX font size commands⁴ can be used to change the size of the label.

⁴e.g. `\tiny`, `\scriptsize`,
`\footnotesize`, `\small`, ...

```
\begin{tikzpicture}
  \Vertex[label=foo,fontsize=\normalsize]{A}
  \Vertex[x=1,label=bar,fontsize=\tiny]{B}
  \Vertex[x=2,label=$u_1$,fontsize=\large]{C}
\end{tikzpicture}
```



```
\Vertex[⟨label⟩=string,⟨fontcolor⟩=color]{Name}
```

The color of the `⟨label⟩` can be changed with the option `⟨fontcolor⟩`. Currently, only the default TikZ and \LaTeX colors are supported⁵.

⁵ **TODO!** Add RGB option!

```
\begin{tikzpicture}
  \Vertex[label=foo,fontcolor=blue]{A}
  \Vertex[x=1,label=bar,fontcolor=magenta]{B}
  \Vertex[x=2,label=$u_1$,fontcolor=red]{C}
\end{tikzpicture}
```



```
\Vertex[⟨label⟩=string,⟨fontscale⟩=number]{Name}
```

Contrary to the option `⟨fontsize⟩`, the option `⟨fontscale⟩` does not change the font size itself but scales the current font size up or down. The *number* defines the scale, where numbers between 0 and 1 down scale the font and numbers greater than 1 up scale the label. For example 0.5 reduces the size of the font to 50% of its original size, while 1.2 scales the font to 120%.

```
\begin{tikzpicture}
  \Vertex[label=foo,fontscale=0.5]{A}
  \Vertex[x=1,label=bar,fontscale=1]{B}
  \Vertex[x=2,label=$u_1$,fontscale=2]{C}
\end{tikzpicture}
```



```
\Vertex[⟨label⟩=string,⟨position⟩=value,⟨distance⟩=number]{Name}
```

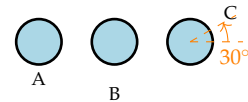
Per default the `⟨position⟩` of the `⟨label⟩` is in the center of the vertex. Classical TikZ commands⁶ can be used to change the `⟨position⟩`

⁶ e.g. *above*, *below*, *left*, *right*, *above left*, *above right*, ...

of the $\langle label \rangle$. Instead, using such command, the position can be determined via an angle, by entering a *number* between -360 and 360 . The origin (0°) is the y axis. A positive *number* change the $\langle position \rangle$ counter clockwise, while a negative *number* make changes clockwise.

With the option, $\langle distance \rangle$ the distance between the vertex and the label can be changed.

```
\begin{tikzpicture}
  \Vertex[label=A,position=below]{A}
  \Vertex[x=1,label=B,position=below,distance=2mm]{B}
  \Vertex[x=2,label=C,position=30,distance=1mm]{C}
\end{tikzpicture}
```



```
\Vertex[ $\langle style \rangle = \{string\}$ ]{Name}
```

Any other TikZ style option or command can be entered via the option $\langle style \rangle$. Most of these commands can be found in the “TikZ and PGF Manual”. Contain the commands additional options (e.g. $\langle shading \rangle = ball$), then the argument for the $\langle style \rangle$ has to be between $\{ \}$ brackets.

```
\begin{tikzpicture}
  \Vertex[style={color=green}]{A}
  \Vertex[x=1,style=dashed]{B}
  \Vertex[x=2,style={shading=ball}]{C}
\end{tikzpicture}
```



```
\Vertex[ $\langle IdAsLabel \rangle$ ]{Name}
```

```
\Vertex[ $\langle NoLabel \rangle$ ,  $\langle label \rangle = string$ ]{Name}
```

$\langle IdAsLabel \rangle$ is a Boolean option which assigns the *Name* of the vertex as label. On the contrary, $\langle NoLabel \rangle$ suppress all labels.

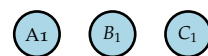
```
\begin{tikzpicture}
  \Vertex[IdAsLabel]{A}
  \Vertex[x=1,label=B,NoLabel]{B}
  \Vertex[x=2,IdAsLabel,NoLabel]{C}
\end{tikzpicture}
```



```
\Vertex[ $\langle Math \rangle$ ,  $\langle label \rangle = string$ ]{Name}
```

The option $\langle Math \rangle$ allows transforming labels into mathematical expressions without using the $\$ \$$ environment. In combination with $\langle IdAsLabel \rangle$ allows this option also mathematical expressions by the definition of the vertex *Name*.

```
\begin{tikzpicture}
  \Vertex[IdAsLabel]{A1}
  \Vertex[x=1,label=B_1,Math]{B}
  \Vertex[x=2,Math,IdAsLabel]{C_1}
\end{tikzpicture}
```



```
\Vertex[ $\langle RGB \rangle$ ,  $\langle color \rangle = RGB\ values$ ]{Name}
```

In order to display RGB colors for the vertex fill color, the option $\langle RGB \rangle$ has to be entered. In combination with this option, the $\langle color \rangle$ has to be a list with the *RGB values*, separated by «,» and within $\{ \}$.⁷

```
\begin{tikzpicture}
  \Vertex[RGB,color={127,201,127}]{A}
  \Vertex[x=1,RGB,color={190,174,212}]{B}
  \Vertex[x=2,RGB,color={253,192,134}]{C}
\end{tikzpicture}
```

```
\Vertex[ $\langle Pseudo \rangle$ ]{ $\langle Name \rangle$ }
```

The option $\langle Pseudo \rangle$ creates a pseudo vertex, where only the vertex name and the vertex coordinate will be drawn. Edges etc, can still be assigned to this vertex.

```
\begin{tikzpicture}
  \Vertex{A}
  \Vertex[x=2,Pseudo]{B}
\end{tikzpicture}
```

```
\Vertex[ $\langle layer \rangle = number$ ]{ $\langle Name \rangle$ }
```

With the option $\langle layer \rangle$ the vertex can be assigned to a specific layer. More about this option and the use of layers is explained in Chapter 4.

⁷ e.g. the RGB code for white: $\{255,255,255\}$



2.2 Edge

The second essential command is an `\Edge`, which allow connecting two vertices.

```
\Edge[⟨local options⟩](Vertex i)(Vertex j)
```

Edges can be generated between one or two vertices. In the first case, a self-loop will be generated. As mandatory arguments the *Names* of the vertices which should be connected must be entered between `()` brackets. In case of a directed edge, the order is important. An edge is created from *Vertex i* (origin) to *Vertex j* (destination).

For an `\Edge` the following options are available:

Option	Default	Type	Definition
<code>lw</code>	<code>{}</code>	measure	line width of the edge
<code>color</code>	<code>{}</code>	color	edge color
<code>opacity</code>	<code>{}</code>	number	opacity of the edge
<code>bend</code>	<code>0</code>	number	angle out/in of the vertex
<code>label</code>	<code>{}</code>	string	label
<code>fontsize</code>	<code>{}</code>	string	font size of the label
<code>fontcolor</code>	<code>{}</code>	color	font color of the label
<code>fontscale</code>	<code>{}</code>	number	scale of the label
<code>position</code>	<code>{}</code>	string	label position
<code>distance</code>	<code>0.5</code>	number	label distance from vertex i
<code>style</code>	<code>{}</code>	string	additional TikZ styles
<code>path</code>	<code>{}</code>	list	path over several vertices
<code>loopsize</code>	<code>1cm</code>	measure	size parameter of the self-loop
<code>loopposition</code>	<code>0</code>	number	orientation of the self-loop
<code>loopshape</code>	<code>90</code>	number	loop angle out/in of the vertex
<code>Direct</code>	<code>false</code>	Boolean	allow directed edges
<code>Math</code>	<code>false</code>	Boolean	displays the label in math mode
<code>RGB</code>	<code>false</code>	Boolean	allow RGB colors
<code>NotInBG</code>	<code>false</code>	Boolean	edge is not in the background layer

Table 2.2: Local options for the `\Edge` command.

The options `⟨loopsize⟩`, `⟨loopposition⟩`, and `⟨loopshape⟩` are only for self-loops available.

```
\Edge(Vertex i)(Vertex j)
```

An edge is created between *Vertex i* and *Vertex j*.

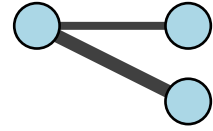
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge(A)(B)
\end{tikzpicture}
```



```
\Edge[⟨lw⟩=measure](Vertex i)(Vertex j)
```

The line width of an edge can be modified with the option `⟨lw⟩`. Here, the unit of the *measure* has to be specified. The default value is 1.5 pt.

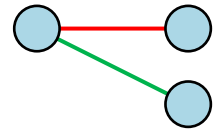
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[lw=3pt](A)(B)
  \Edge[lw=5pt](A)(C)
\end{tikzpicture}
```



```
\Edge[⟨color⟩=color](Vertex i)(Vertex j)
```

To change the line color of each edge individually, the option $\langle color \rangle$ has to be used. Without the option $\langle RGB \rangle$ set, the default TikZ and \LaTeX colors can be applied.

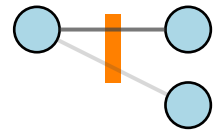
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[color=red](A)(B)
  \Edge[color=green!70!blue](A)(C)
\end{tikzpicture}
```



```
\Edge[⟨opacity⟩=number](Vertex i)(Vertex j)
```

With the option $\langle opacity \rangle$ the opacity of the edge line can be modified. The range of the *number* lies between 0 and 1. Where 0 represents a fully transparent fill and 1 a solid fill.

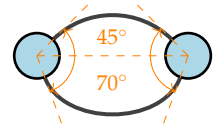
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[opacity=.7](A)(B)
  \Edge[opacity=.2](A)(C)
\end{tikzpicture}
```



```
\Edge[⟨bend⟩=number](Vertex i)(Vertex j)
```

The shape of the edge can be modified with the $\langle bend \rangle$ option. If nothing is specified a straight edge, between the vertices, is drawn. The *number* defines the angle in which the edge is diverging from its straight connection. A positive *number* bend the edge counter clockwise, while a negative *number* make changes clockwise.

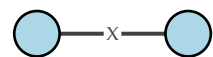
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge[bend=45](A)(B)
  \Edge[bend=-70](A)(B)
\end{tikzpicture}
```



```
\Edge[⟨label⟩=string](Vertex i)(Vertex j)
```

An edge is labeled with the option $\langle label \rangle$. For the label any *string* argument can be used, including blank spaces. The environment $\$ \$$ can be used to display mathematical expressions.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge[label=X](A)(B)
\end{tikzpicture}
```



```
\Edge[⟨label⟩=string,⟨fontsize⟩=string](Vertex i)(Vertex j)
```

The font size of the $\langle label \rangle$ can be modified with the option $\langle fontsize \rangle$. Here common \LaTeX font size commands⁸ can be used to change the size of the label.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[label=X,fontsize=\large](A)(B)
  \Edge[label=Y,fontsize=\tiny](A)(C)
\end{tikzpicture}
```

```
\Edge[⟨label⟩=string,⟨fontcolor⟩=color](Vertex i)(Vertex j)
```

The color of the $\langle label \rangle$ can be changed with the option $\langle fontcolor \rangle$. Currently, only the default TikZ and \LaTeX colors are supported⁹.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[label=X,fontcolor=blue](A)(B)
  \Edge[label=Y,fontcolor=red](A)(C)
\end{tikzpicture}
```

```
\Edge[⟨label⟩=string,⟨fontscale⟩=color](Vertex i)(Vertex j)
```

Contrary to the option $\langle fontsize \rangle$, the option $\langle fontscale \rangle$ does not change the font size itself but scales the current font size up or down. The *number* defines the scale, where numbers between 0 and 1 down scale the font and numbers greater than 1 up scale the label. For example 0.5 reduces the size of the font to 50% of its original size, while 1.2 scales the font to 120%.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[label=X,fontscale=.5](A)(B)
  \Edge[label=Y,fontscale=2](A)(C)
\end{tikzpicture}
```

```
\Edge[⟨label⟩=string,⟨position⟩=string](Vertex i)(Vertex j)
```

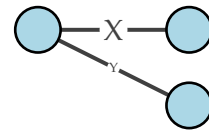
Per default the $\langle label \rangle$ is positioned in between both vertices in the center of the line. Classical TikZ commands¹⁰ can be used to change the $\langle position \rangle$ of the $\langle label \rangle$.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[label=X,position=above](A)(B)
  \Edge[label=Y,position={below left=2mm}](A)(C)
\end{tikzpicture}
```

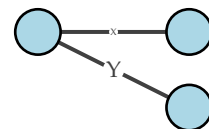
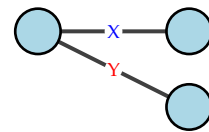
```
\Edge[⟨label⟩=string,⟨distance⟩=number](Vertex i)(Vertex j)
```

The label position between the vertices can be modified with the $\langle distance \rangle$ option. Per default the $\langle label \rangle$ is centered between both vertices. The position is expressed as the percentage of the length between the vertices, e.g. of $\langle distance \rangle=0.7$, the label is placed at 70% of the edge length away of *Vertex i*.

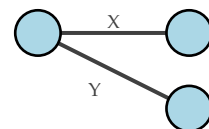
⁸ e.g. `\tiny`, `\scriptsize`, `\footnotesize`, `\small`, ...



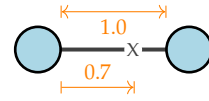
⁹ **TODO!** Add RGB option!



¹⁰ e.g. *above*, *below*, *left*, *right*, *above left*, *above right*, ...




```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge[label=X,distance=.7](A)(B)
\end{tikzpicture}
```



```
\Edge[<style>=string](Vertex i)(Vertex j)
```

Any other TikZ style option or command can be entered via the option $\langle style \rangle$. Most of these commands can be found in the “TikZ and PGF Manual”. Contain the commands additional options (e.g. $\langle shading \rangle = ball$), then the argument for the $\langle style \rangle$ has to be between $\{ \}$ brackets.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge[style={dashed}](A)(B)
\end{tikzpicture}
```

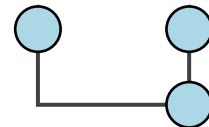


```
\Edge[<path>=list](Vertex i)(Vertex j)
```

In order to draw a finite sequence of edges which connect a sequence of vertices and/or coordinates, the option $\langle path \rangle$ can be used¹¹. The argument for this option has to be a list element indicated by $\{ \}$ brackets, containing the *Names* of the intermediated vertices. New coordinates, i.e. there is no vertex located, can be insert with $\langle x \rangle, \langle y \rangle$. Arguments of the list, have to be separated by commas \langle , \rangle .

¹¹ **TODO!** currently labels and bend edges are not supported!

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[path={A,{0,-1},C,B}](A)(B)
\end{tikzpicture}
```



```
\Edge(Vertex i)(Vertex i)
```

Self-loops are created by using the same vertex as origin and destination. Beside the options explained above, there are three self-loop specific options: $\langle loopsize \rangle$, $\langle loopposition \rangle$, and $\langle loopshape \rangle$.

```
\begin{tikzpicture}
  \Vertex{A}
  \Edge(A)(A)
\end{tikzpicture}
```



```
\Edge[<loopsize>=measure](Vertex i)(Vertex i)
```

With the option $\langle loopsize \rangle$ the length of the edge can be modified. The *measure* value has to be insert together with its units. Per default the $\langle loopsize \rangle$ is 1 cm.

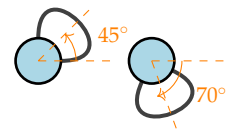
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=1.3]{B}
  \Edge[loopsize=.5cm](A)(A)
  \Edge[loopsize=1.5cm](B)(B)
\end{tikzpicture}
```



```
\Edge[⟨loopposition⟩=number](Vertex i)(Vertex i)
```

The position of the self-loop is defined via the rotation angle around the vertex. The origin (0°) is the y axis. A positive *number* change the $\langle loopposition \rangle$ counter clockwise, while a negative *number* make changes clockwise.

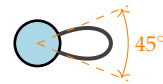
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=1.5]{B}
  \Edge[loopposition=45](A)(A)
  \Edge[loopposition=-70](B)(B)
\end{tikzpicture}
```



```
\Edge[⟨loopshape⟩=number](Vertex i)(Vertex i)
```

The shape of the self-loop is defined by the enclosing angle. The shape can be changed by decreasing or increasing the argument value of the $\langle loopshape \rangle$ option.

```
\begin{tikzpicture}
  \Vertex{A}
  \Edge[loopshape=45](A)(A)
\end{tikzpicture}
```



```
\Edge[⟨Direct⟩](Vertex i)(Vertex j)
```

Directed edges are created by enabling the option $\langle Direct \rangle$. The arrow is drawn from *Vertex i* to *Vertex j*.

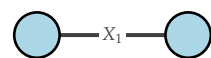
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge[Direct](A)(B)
\end{tikzpicture}
```



```
\Edge[Math, label=⟨string⟩](Vertex i)(Vertex j)
```

The option $\langle Math \rangle$ allows transforming labels into mathematical expressions without using the $\$$ environment.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B}
  \Edge[Math, label=X_1](A)(B)
\end{tikzpicture}
```



```
\Edge[RGB, color=⟨RGB value⟩](Vertex i)(Vertex j)
```

In order to display RGB colors for the line color of the edge, the option $\langle RGB \rangle$ has to be entered. In combination with this option, the $\langle color \rangle$ has to be a list with the *RGB values*, separated by «,» and within $\{ \}$.¹²

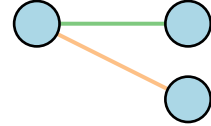
```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=2,y=-1]{C}
  \Edge[RGB,color={127,201,127}](A)(B)
  \Edge[RGB,color={253,192,134}](A)(C)
\end{tikzpicture}
```

$\backslash\text{Edge}[\langle\text{NotInBG}\rangle]\{\text{filename}\}$

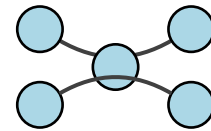
Per default, the edge is drawn on the background layer of the *tikzpicture*. I.e. objects which are created after the edges appear also on top of them. To turn this off, the option $\langle\text{NotInBG}\rangle$ has to be enabled. Changes to the default setting can be made with $\backslash\text{EdgesNotInBG}$ or $\backslash\text{EdgesInBG}$ ¹³.

```
\begin{tikzpicture}
  \Vertex{A} \Vertex[x=2]{B} \Vertex[x=1,y=-.5]{C}
  \Vertex[y=-1]{D} \Vertex[x=2,y=-1]{E}
  \Edge[bend=-30](A)(B)
  \Edge[bend=30,NotInBG](D)(E)
\end{tikzpicture}
```

¹² e.g. the RGB code for white: $\{255,255,255\}$



¹³ See Section 5.3



2.3 Text

While TikZ offers multiple ways to label objects and create text elements, a simplified command `\Text` is implemented, which allow placing and modifying text to the networks.

```
\Text[local options]{string}
```

In order to be able to create a text, a non-empty *string* argument is required. This argument is the actual text added to the figure. Mathematical symbols are entered in the same way as in a normal L^AT_EX document, i.e. between \$ \$.

For a `\Text` the following options are available:

Option	Default	Type	Definition
<code>x</code>	<code>o</code>	measure	x-coordinate
<code>y</code>	<code>o</code>	measure	y-coordinate
<code>fontsize</code>	<code>{}</code>	fontsize	font size of the text
<code>color</code>	<code>{}</code>	color	color of the text
<code>opacity</code>	<code>{}</code>	number	opacity of the text
<code>position</code>	<code>center</code>	string	position of the text to the origin
<code>distance</code>	<code>0cm</code>	measure	distance from the origin
<code>rotation</code>	<code>o</code>	number	rotation of the text
<code>anchor</code>	<code>{}</code>	string	anchor of the text
<code>width</code>	<code>{}</code>	number	width of the text box
<code>style</code>	<code>{}</code>	string	additional TikZ styles
<code>layer</code>	<code>{}</code>	number	assigned layer of the text
RGB	<code>false</code>	Boolean	allow RGB colors

Table 2.3: Local options for the `\Text` command.

The order how the options are entered does not matter. Changes to the default Text layout can be made with `\SetTextStyle`¹⁴

```
\Text[x=measure, y=measure]{string}
```

The location of the text is determined by Cartesian coordinates in $\langle x \rangle$ and $\langle y \rangle$. The coordinates are optional. If no coordinates are determined the text will be placed at the origin (0, 0). The entered *measures* are in default units (cm). Changing the unites (locally) can be done by adding the unit to the *measure*¹⁵. Changes to the default setting can be made with `\SetDefaultUnit`¹⁶.

¹⁴ see Section 5.4

¹⁵ e.g. `x=1in`

¹⁶ see Section 5.1

```
\begin{tikzpicture}
  \Text{A}
  \Text[x=1,y=1]{B}
  \Text[x=2]{C}
\end{tikzpicture}
```

B
A C

```
\Text[fontsize=font size]{string}
```

The font size of the text can be changed with the option $\langle fontsize \rangle$. Per default the font size of the text is defined as `\normalsize`.

```
\begin{tikzpicture}
  \Text[fontsize=\small]{A}
  \Text[x=1,fontsize=\LARGE]{B}
  \Text[x=2,fontsize=\Huge]{C}
\end{tikzpicture}
```

A B C

```
\Text[⟨color⟩=color]{string}
```

To change the text color individually, the option $\langle color \rangle$ has to be used. Without the option $\langle RGB \rangle$ set, the default TikZ and L^AT_EX colors can be applied.

```
\begin{tikzpicture}
  \Text[color = blue]{A}
  \Text[x=1,color=red]{B}
  \Text[x=2,color=green!70!blue]{C}
\end{tikzpicture}
```



```
\Text[⟨opacity⟩=number]{string}
```

With the option $\langle opacity \rangle$ the opacity of the text can be modified. The range of the *number* lies between 0 and 1. Where 0 represents a fully transparent text and 1 a solid text.

```
\begin{tikzpicture}
  \Text[opacity = 1]{A}
  \Text[x=1,opacity = .7]{B}
  \Text[x=2,opacity = .2]{C}
\end{tikzpicture}
```



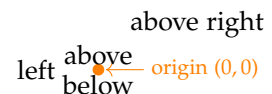
```
\Text[⟨position⟩=string,⟨distance⟩=measure]{string}
```

Per default the $\langle position \rangle$ of the text is in the *center* of the origin. Classical TikZ commands¹⁷ can be used to change the $\langle position \rangle$ of the text.

With the option, $\langle distance \rangle$ the distance between the text and the origin can be changed.

```
\begin{tikzpicture}
  \Text[position=above]{above}
  \Text[position=below]{below}
  \Text[position=left,distance=5mm]{left}
  \Text[position=above right,distance=5mm]{above right}
\end{tikzpicture}
```

¹⁷ e.g. *above, below, left, right, above left, above right,...*



```
\Text[⟨rotation⟩=number]{string}
```

With the $\langle rotation \rangle$, the text can be rotated by entering a *number* between -360 and 360 . The origin (0°) is the *y* axis. A positive *number* change the $\langle position \rangle$ counter clockwise, while a negative *number* make changes clockwise.

```
\begin{tikzpicture}
  \Text[rotation=30]{A}
  \Text[x=1,rotation=45]{B}
  \Text[x=2,rotation=75]{C}
\end{tikzpicture}
```



```
\Text[⟨anchor⟩=string]{string}
```

With the option $\langle anchor \rangle$ the alignment of the text can be changed. Per default the text will be aligned centered. Classical TikZ commands¹⁸ can be used to change the alignment of the text.

```
\begin{tikzpicture}
  \Text[anchor=north east]{NE}
  \Text[x=1,anchor = south]{S}
  \Text[x=2,anchor =south west]{SW}
\end{tikzpicture}
```

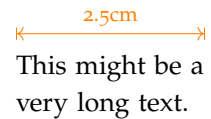
¹⁸ e.g. *north, east, south, west, north east, north west,...*



```
\Text[⟨width⟩=measure]{string}
```

With the option $\langle width \rangle$ enabled, the text will break after the entered *measure*.

```
\begin{tikzpicture}
  \Text[width=2.5cm]{This might be a very long text.}
\end{tikzpicture}
```



```
\Text[⟨style⟩={string}]{string}
```

Any other TikZ style option or command can be entered via the option $\langle style \rangle$. Most of these commands can be found in the “TikZ and PGF Manual”. Contain the commands additional options (e.g. $\langle fill \rangle = red$), then the argument for the $\langle style \rangle$ has to be between $\{ \}$ brackets.

```
\begin{tikzpicture}
  \Text[style={draw,rectangle}]{A}
  \Text[x=1,style={fill=red}]{B}
  \Text[x=2,style={fill=blue,circle,opacity=.3}]{C}
\end{tikzpicture}
```



```
\Text[⟨RGB⟩,⟨color⟩=RGB values]{string}
```

In order to display RGB colors for the text color, the option $\langle RGB \rangle$ has to be entered. In combination with this option, the $\langle color \rangle$ has to be a list with the *RGB values*, separated by \langle , \rangle and within $\{ \}$.¹⁹

¹⁹ e.g. the RGB code for white: $\{255, 255, 255\}$

```
\begin{tikzpicture}
  \Text[RGB,color={127,201,127}]{A}
  \Text[x=1,RGB,color={190,174,212}]{B}
  \Text[x=2,RGB,color={253,192,134}]{C}
\end{tikzpicture}
```



```
\layer[⟨layer⟩=number]{string}
```

With the option $\langle layer \rangle$ the text can be assigned to a specific layer. More about this option and the use of layers is explained in Chapter 4.

3 Complex Networks

While in Chapter 2 the building blocks of the networks are introduced, here the main strength of the `tikz-network` package is explained. This includes creating networks based on data, obtained from other sources (e.g. Python, R, GIS). The idea is that the layout will be done by this external sources and `tikz-network` is used make some changes and to recreate the networks in L^AT_EX.

3.1 Vertices

The `\Vertices` command is the extension of the `\Vertex` command. Instead of a single vertex, a set of vertices will be drawn. This set of vertices is defined in an external file but can be modified with `\Vertices`.

```
\Vertices[global options]{filename}
```

The vertices have to be stored in a clear text file¹, preferentially in a `.csv` format. The first row should contain the headings, which are equal to the options defined in Table 2.1. Option are separated by a comma «,». Each new row is corresponds to a new vertex.

```
id, x, y ,size,color ,opacity,label,IdAsLabel,NoLabel
A, 0, 0, .4 ,green , .9 , a , false , false
B, 1, .7, .6 , , .5 , b , false , false
C, 2, 1, .8 ,orange, .3 , c , false , true
D, 2, 0, .5 ,red , .7 , d , true , false
E, .2,1.5, .5 ,gray , , e , false , false
```

Only the `<id>` value is mandatory for a vertex and corresponds to the `Name` argument of a single `\Vertex`. Therefore, the same rules and naming conventions apply as for the `Name` argument: no mathematical expressions, no blank spaces, and the `<id>` must be unique! All other options are optional. No specific order of the options must be maintained. If no value is entered for an option, the default value will be chosen². The `filename` should not contain blank spaces or special characters. The vertices are drawn by the command `\Vertex` with the `filename` plus file format (e.g. `.csv`). If the vertices file is not in the same directory as the main L^AT_EX file, also the path has to be specified.

¹ e.g. `.txt`, `.tex`, `.csv`, `.dat`, ...

File: `vertices.csv`

² **TODO!** This is NOT valid for Boolean options, here values for all vertices have to be entered.

```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
\end{tikzpicture}
```

Predefined `\Vertex` options can be overruled by the *global options* of the `\Vertices` command; I.e. these options apply for all vertices in the file. For the `\Vertices` the following options are available:

Option	Default	Type	Definition
<code>size</code>	<code>{}</code>	measure	diameter of the circles
<code>color</code>	<code>{}</code>	color	fillcolor of vertices
<code>opacity</code>	<code>{}</code>	number	opacity of the fill color
<code>style</code>	<code>{}</code>	string	additional TikZ styles
<code>layer</code>	<code>{}</code>	number	assigned layer of the vertices
<code>NoLabel</code>	false	Boolean	delete the labels
<code>IdAsLabel</code>	false	Boolean	uses the <i>Names</i> as labels
<code>Math</code>	false	Boolean	displays the labels in math mode
<code>RGB</code>	false	Boolean	allow RGB colors
<code>Pseudo</code>	false	Boolean	create a pseudo vertices

The use of these options are similar to the options for a single `\Vertex` defined in Section 2.1.

```
\Vertices[size=measure]{filename}
```

The diameter of the vertices can be changed with the option *size*. Per default a vertex has 0.6 cm in diameter. Also, here the default units are cm and have not to be added to the *measure*.

```
\begin{tikzpicture}
  \Vertices[size=.6]{data/vertices.csv}
\end{tikzpicture}
```

```
\Vertices[color=color]{filename}
```

To change the fill color for all vertices, the option *color* has to be used. Without the option *RGB* set, the default TikZ and L^AT_EX colors can be applied.

```
\begin{tikzpicture}
  \Vertices[color=green!70!blue]{data/vertices.csv}
\end{tikzpicture}
```

```
\Vertices[opacity=number]{filename}
```

With the option *opacity* the opacity of all vertices fills colors can be modified. The range of the *number* lies between 0 and 1. Where 0 represents a fully transparent fill and 1 a solid fill.

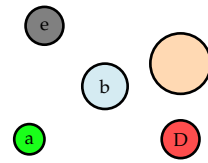
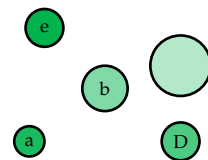
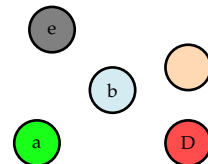


Table 3.1: Global options for the `\Vertices` command.




```
\begin{tikzpicture}
  \Vertices[opacity=.3]{data/vertices.csv}
\end{tikzpicture}
```

```
\Vertices[ $\langle style \rangle$ =string]{filename}
```

Any other TikZ style option or command can be entered via the option $\langle style \rangle$. Most of these commands can be found in the “TikZ and PGF Manual”. Contain the commands additional options (e.g. $\langle shading \rangle$ =ball), then the argument for the $\langle style \rangle$ has to be between $\{ \}$ brackets.

```
\begin{tikzpicture}
  \Vertices[style={shading=ball,blue}]{data/vertices.csv}
\end{tikzpicture}
```

```
\Vertices[ $\langle IdAsLabel \rangle$ ]{filename}
```

```
\Vertices[ $\langle NoLabel \rangle$ ]{filename}
```

$\langle IdAsLabel \rangle$ is a Boolean option which assigns the $\langle id \rangle$ of the single vertices as labels. On the contrary, $\langle NoLabel \rangle$ suppress all labels.

```
\begin{tikzpicture}
  \Vertices[IdAsLabel]{data/vertices.csv}
\end{tikzpicture}
```

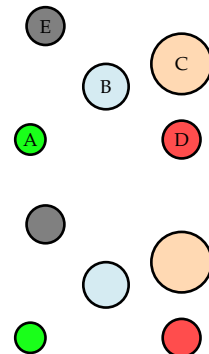
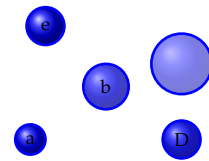
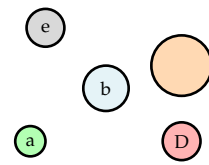
```
\begin{tikzpicture}
  \Vertices[NoLabel]{data/vertices.csv}
\end{tikzpicture}
```

```
\Vertices[ $\langle RGB \rangle$ ]{filename}
```

In order to display RGB colors for the vertex fill colors, the option $\langle RGB \rangle$ has to be entered. Additionally, the RGB values have to be specified in the file where the vertices are stored. Each value has its own column with the caption $\langle R \rangle$, $\langle G \rangle$, and $\langle B \rangle$.

```
id, x, y, size, color, opacity, label, R, G, B
A, 0, 0, .4, green, .9, a, 255, 0, 0
B, 1, .7, .6, , .5, b, 0, 255, 0
C, 2, 1, .8, orange, .3, c, 0, 0, 255
D, 2, 0, .5, red, .7, d, 10, 120, 255
E, .2, 1.5, .5, gray, , e, 76, 55, 255
```

The “normal” color definition can also be part of the vertex definition. If the option $\langle RGB \rangle$ is not set, then the colors under $\langle color \rangle$ are applied.



File: vertices_RGB.csv

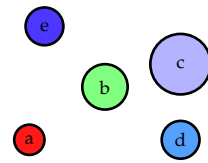
```
\begin{tikzpicture}
  \Vertices[RGB]{data/vertices_RGB.csv}
\end{tikzpicture}
```

```
\Vertices[Pseudo]{filename}
```

The option *Pseudo* creates a pseudo vertices, where only the names and the coordinates of the vertices will be drawn. Edges etc, can still be assigned to these vertices.

```
\Vertices[layer=number]{filename}
```

With the option *layer*, only the vertices on the selected layer are plotted. More about this option and the use of layers is explained in Chapter 4.



3.2 Edges

The `\Edges` command is the extension of the `\Edge` command. Instead of a single edge, a set of edges will be drawn. This set of edges is defined in an external file but can be modified with `\Edges`.

```
\Edges[⟨global options⟩]{filename}
```

Like the vertices, the edges have to be stored in a clear text file³, preferentially in a `.csv` format. The first row should contain the headings, which are equal to the options defined in Table 2.2. Option are separated by a comma «,». Each new row is corresponds to a new edge.

```
u,v,label,lw,color ,opacity,bend, R , G , B ,Direct
A,B, ab ,.5,red , 1 , 30, 0,120,255,false
B,C, bc ,.7,blue , 1 , -60, 76, 55,255,false
B,D, bd ,.5,blue , .5 , -60, 76, 55,255,false
A,E, ae , 1,green , 1 , 75,255, 0, 0,true
C,E, ce , 2,orange, 1 , 0,150,150,150,false
A,A, aa ,.3,black , .5 , 75,255, 0 ,0,false
```

The mandatory values are the $\langle u \rangle$ and $\langle v \rangle$ argument, which corresponds to the *Vertex i* and *Vertex j* arguments of a single `\Edge`. Edges can only create if a vertex exists with the same *Name*. All other options are optional. No specific order of the options must be maintained. If no value is entered for an option, the default value will be chosen⁴. The *filename* should not contain blank spaces or special characters. The edges are drawn by the command `\Edges` with the *filename* plus file format (e.g. `.csv`). If the edges file is not in the same directory as the main \LaTeX file, also the path has to be specified. In order to draw edges, first, the vertices have to be generated. Only then, edges can be assigned.

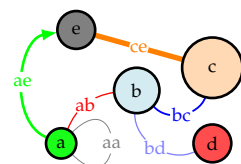
```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges{data/edges.csv}
\end{tikzpicture}
```

Predefined `\Edge` options can be overruled by the $\langle global options \rangle$ of the `\Edges` command; I.e. these options apply for all edges in the file. For the `\Edges` the following options are available:

³ e.g. `.txt`, `.tex`, `.csv`, `.dat`, ...

File: `edges.csv`

⁴ **TODO!** This is NOT valid for Boolean options, here values for all vertices have to be entered.



Option	Default	Type	Definition
lw	{}	measure	line width of the edge
color	{}	color	edge color
opacity	{}	number	opacity of the edge
style	{}	string	additional TikZ styles
vertices	{}	file	vertices were the edges are assigned to
layer	{}	number	edges in specific layers
Direct	false	Boolean	allow directed edges
Math	false	Boolean	displays the labels in math mode
NoLabel	false	Boolean	delete the labels
RGB	false	Boolean	allow RGB colors
NotInBG	false	Boolean	edges are not in the background layer

Table 3.2: Global options for the `\Edges` command.

The use of these options are similar to the options for a single `\Edge` defined in Section 2.2.

```
\Edges[⟨lw⟩=measure]{filename}
```

The line width of the edges can be modified with the option `⟨lw⟩`. Here, the unit of the *measure* can be specified, otherwise, it is in pt.

```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[lw=2.5]{data/edges.csv}
\end{tikzpicture}
```

```
\Edges[⟨color⟩=color]{filename}
```

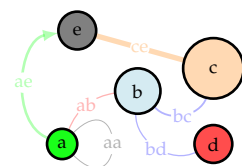
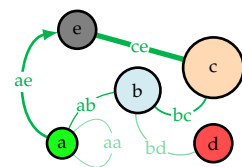
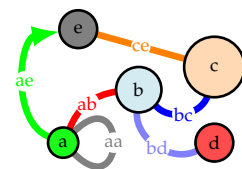
To change the line color of all edges, the option `⟨color⟩` has to be used. Without the option `⟨RGB⟩` set, the default TikZ and L^AT_EX colors can be applied.

```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[color=green!70!blue]{data/edges.csv}
\end{tikzpicture}
```

```
\Edges[⟨opacity⟩=number]{filename}
```

With the option `⟨opacity⟩` the opacity of all edge lines can be modified. The range of the *number* lies between 0 and 1. Where 0 represents a fully transparent fill and 1 a solid fill.

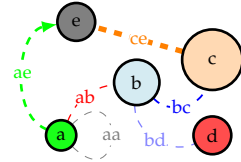
```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[opacity=0.3]{data/edges.csv}
\end{tikzpicture}
```



`\Edges[$\langle style \rangle$ =string]{filename}`

Any other TikZ style option or command can be entered via the option $\langle style \rangle$. Most of these commands can be found in the “TikZ and PGF Manual”.

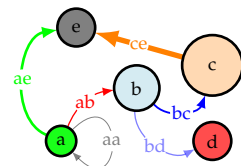
```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[style={dashed}]{data/edges.csv}
\end{tikzpicture}
```



`\Edges[$\langle Direct \rangle$]{filename}`

Directed edges are created by enabling the option $\langle Direct \rangle$. The arrow is drawn from $\langle u \rangle$ to $\langle v \rangle$.

```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[Direct]{data/edges.csv}
\end{tikzpicture}
```



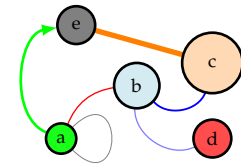
`\Edges[Math]{filename}`

The option $\langle Math \rangle$ allows transforming labels into mathematical expressions without using the $\$$ environment.

`\Edges[$\langle NoLabel \rangle$]{filename}`

The option $\langle NoLabel \rangle$ suppress all edge labels.

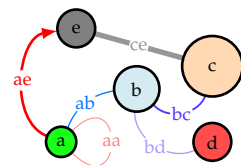
```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[NoLabel]{data/edges.csv}
\end{tikzpicture}
```



`\Edges[$\langle RGB \rangle$]{filename}`

In order to display RGB colors for the edge line colors, the option $\langle RGB \rangle$ has to be entered. Additionally, the RGB values have to be specified in the file where the vertices are stored. Each value has its own column with the caption $\langle R \rangle$, $\langle G \rangle$, and $\langle B \rangle$. The “normal” color definition can also be part of the vertex definition. If the option $\langle RGB \rangle$ is not set, then the colors under $\langle color \rangle$ are applied.

```
\begin{tikzpicture}
  \Vertices{data/vertices.csv}
  \Edges[RGB]{data/edges.csv}
\end{tikzpicture}
```



`\Edges[$\langle NotInBG \rangle$]{filename}`

Per default, the edges are drawn on the background layer of the *tikzpicture*. I.e. objects which are created after the edges appear also on top of them. To turn this off, the option $\langle NotInBG \rangle$ has to be enabled.

```
\Edges[⟨vertices⟩=filename]{filename}
```

Edges can be assigned to a specific set of `\Vertices` with the option `⟨vertices⟩`. Thereby the argument `filename` is the same as used for the `\Vertices` command. This option might be necessary if multiple `\Vertices` are created and edges are assigned at the end.

```
\Edges[⟨layer⟩={layer  $\alpha$ , layer  $\beta$ }] {filename}
```

With the option `⟨layer⟩` only the edges between layer α and β are plotted. The argument is a tuple of both layers indicated by `{ , }`. More about this option and the use of layers is explained in [Chapter 4](#).

4 Multilayer Networks

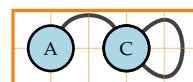
One of the main purposes of the `tikz-network` package is the illustration of multilayer network structures. Thereby, all the previous commands can be used. A multilayer network is represented as a three-dimensional object, where each layer is located at a different z plane. In order to enable this functionality, the option `<multilayer>` has to be used at the beginning of the `tikzpicture`.

4.1 Simple Networks

```
\Vertex[<layer>=number]{Name}
```

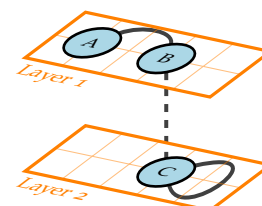
With the option `<layer>` the vertex can be assigned to a specific layer. Layers are defined by numbers (e.g. 1, 2, 3, ...). Working with the `<multilayer>` option, each `\Vertex` has to be assigned to a specific layer. For the edge assignment no additional information is needed.

```
\begin{tikzpicture}[multilayer]
  \Vertex[x=0.5,IdAsLabel,layer=1]{A}
  \Vertex[x=1.5,IdAsLabel,layer=1]{B}
  \Vertex[x=1.5,IdAsLabel,layer=2]{C}
  \Edge[bend=60](A)(B)
  \Edge[style=dashed](B)(C)
  \Edge(C)(C)
\end{tikzpicture}
```



Enabling the option `<multilayer>`, returns the network in a two-dimensional plane, like the networks discussed before. Setting the argument `<multilayer>=3d`, the network is rendered in a three-dimensional representation. Per default, the layer with the lowest number is on the top. This and the spacing between the layers can be changed with the command `\SetLayerDistance`.

```
\begin{tikzpicture}[multilayer=3d]
  \Vertex[x=0.5,IdAsLabel,layer=1]{A}
  \Vertex[x=1.5,IdAsLabel,layer=1]{B}
  \Vertex[x=1.5,IdAsLabel,layer=2]{C}
  \Edge[bend=60](A)(B)
  \Edge[style=dashed](B)(C)
  \Edge(C)(C)
\end{tikzpicture}
```



4.2 Complex Networks

Similar as in Chapter 3 introduced, layers can be assigned to the vertices by adding a column $\langle layer \rangle$ to the file where the vertices are stored.

```
id, x, y, size, color, opacity, label, layer
A, 0, 0, .4, green, .9, a, 1
B, 1, .7, .6, , .5, b, 1
C, 2, 1, .8, orange, .3, c, 1
D, 2, 0, .5, red, .7, d, 2
E, .2, 1.5, .5, gray, , e, 1
F, .1, .5, .7, blue, .3, f, 2
G, 2, 1, .4, cyan, .7, g, 2
H, 1, 1, .4, yellow, .7, h, 2
```

File: ml_vertices.csv

```
u,v, label, lw, color, opacity, bend, Direct
A,B, ab, .5, red, 1, 30, false
B,C, bc, .7, blue, 1, -60, false
A,E, ae, 1, green, 1, 45, true
C,E, ce, 2, orange, 1, 0, false
A,A, aa, .3, black, .5, 75, false
C,G, cg, 1, blue, .5, 0, false
E,H, eh, 1, gray, .5, 0, false
F,A, fa, .7, red, .7, 0, true
D,F, df, .7, cyan, 1, 30, true
F,H, fh, .7, purple, 1, 60, false
D,G, dg, .7, blue, .7, 60, false
```

File: ml_edges.csv

With the commands `\Vertices` and `\Edges`, the network can be created automatically. Again the `\Vertices` vertices should be performed first and then the command `\Edges`.

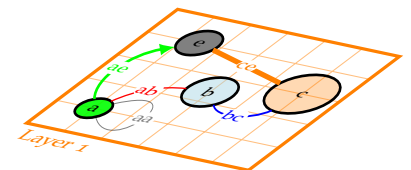
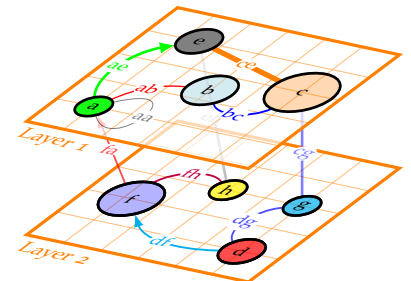
```
\begin{tikzpicture}[multilayer=3d]
  \Vertices{data/ml_vertices.csv}
  \Edges{data/ml_edges.csv}
\end{tikzpicture}
```

```
\Vertices[ $\langle layer \rangle = number$ ]{filename}
```

```
\Edges[ $\langle layer \rangle = \{layer \alpha, layer \beta\}$ ]{filename}
```

With the `\Vertices` option $\langle layer \rangle$ only the vertices on the selected layer are plotted. While, with the `\Edges` option $\langle layer \rangle$, the edges between layer α and β are plotted. The argument is a tuple of both layers indicated by $\{ , \}$.

```
\begin{tikzpicture}[multilayer=3d]
  \Vertices[layer=1]{data/ml_vertices.csv}
  \Edges[layer={1,1}]{data/ml_edges.csv}
\end{tikzpicture}
```



Plotting edges without defining first the vertices can be done with the `\Edges` option $\langle vertices \rangle$. This allows modifying specific sets of Edges.

```
\begin{tikzpicture}[multilayer=3d]
  \Edges[vertices=data/ml_vertices.csv,
        layer={1,2},style=dashed]{data/ml_edges.csv}
\end{tikzpicture}
```

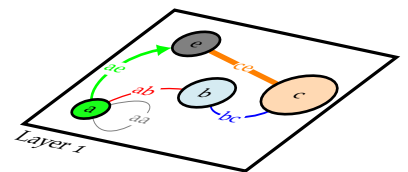


4.3 Layers and Layouts

Besides adding vertices and edges to specific layers, every other TikZ object can be drawn on such a layer using the `Layer` environment. With the option $\langle layer \rangle = layer \alpha$, the position of the canvas can be assigned to the specific layer.

```
\begin{Layer}[\langle layer \rangle = layer \alpha]
\end{Layer}
```

```
\begin{tikzpicture}[multilayer=3d]
  \begin{Layer}[layer=1]
    \draw[very thick] (-.5,-.5) rectangle (2.5,2);
    \node at (-.5,-.5)[below right]{Layer 1};
  \end{Layer}
  \Vertices[layer=1]{data/ml_vertices.csv}
  \Edges[layer={1,1}]{data/ml_edges.csv}
\end{tikzpicture}
```



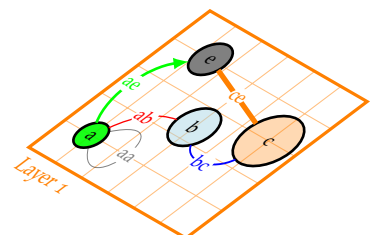
```
\SetLayerDistance{measure}
```

With the command `\SetLayerDistance` the distance between the layers and their orientation can be modified. Per default the distance is set to -2DefaultUnit (here cm). A negative number implies that layers with a higher number will be stacked below layers with a smaller number.

```
\SetCoordinates[\langle xAngle \rangle = number, \langle yAngle \rangle = number, \langle zAngle \rangle = number,
\langle xLength \rangle = number, \langle yLength \rangle = number, \langle zLength \rangle = number]
```

The perspective of the three-dimensional plot can be modified by changing the orientation of the coordinate system, which is done with the command `\SetCoordinates`. Here the angle and the length of each axis can be modified. Angles are defined as a *number* in the range between -360 and 360 . Per default, the lengths of the axes are defined by the identity matrix, i.e. no distortion. If the length ratio is changed x , y , and/or z values are distorted. The `\SetCoordinates` command has to be entered before the $\langle multilayer \rangle$ option is called!

```
\SetCoordinates[xAngle=-30,yLength=1.2,xLength=.8]
\begin{tikzpicture}[multilayer=3d]
  \Vertices[layer=1]{data/ml_vertices.csv}
  \Edges[layer={1,1}]{data/ml_edges.csv}
\end{tikzpicture}
```



4.4 Plane

To support the illustration of multilayer networks, the background of the layer can be simply visualized with the command `\Plane`, which allow to draw boundaries, grids and include images to the layer.

`\Plane[options]`

No obligatory arguments are needed. For a `\Plane` the following options are available:

Option	Default	Type	Definition
<code>x</code>	0	measure	x-coordinate of the origin
<code>y</code>	0	measure	y-coordinate of the origin
<code>width</code>	5 cm	measure	width of the plane
<code>height</code>	5 cm	measure	height of the plane
<code>color</code>	vertexfill	color	fill color of the plane
<code>opacity</code>	0.3	number	opacity of the fill color
<code>grid</code>	{}	measure	spacing of the grid
<code>image</code>	{}	file	path to the image file
<code>style</code>	{}	string	additional TikZ styles
<code>layer</code>	1	number	layer where the plane is located
<code>RGB</code>	false	Boolean	allow RGB colors
<code>NoFill</code>	false	Boolean	disable fill color
<code>NoBorder</code>	false	Boolean	disable border line
<code>ImageAndFill</code>	false	Boolean	allow image and fill color
<code>InBG</code>	false	Boolean	plane is in the background layer

^a either measure or string

Table 4.1: Options for the `\Plane` command.

`\Plane[x=measure, y=measure, width=measure, height=measure]`

A `\Plane` is a rectangle with origin $(\langle x \rangle, \langle y \rangle)$, a given $\langle width \rangle$ and $\langle height \rangle$. The origin is defined in the left lower corner and per default $(0, 0)$. The plane is default 5 cm (width) by 5 cm (height). This default options can be changed with `\SetPlaneWidth` and `\SetPlaneHeight`¹

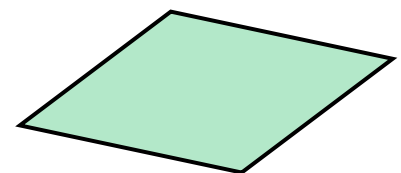
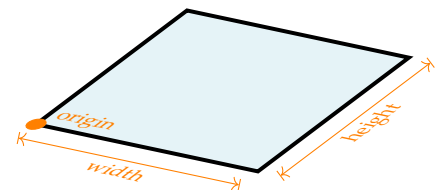
```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5]
\end{tikzpicture}
```

`\Plane[color=color]`

To change the fill color of each plane individually, the option $\langle color \rangle$ has to be used. Without the option $\langle RGB \rangle$ set, the default TikZ and L^AT_EX colors can be applied. Per default the default vertex color is used.

```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,color=green!70!blue]
\end{tikzpicture}
```

¹ See Section 5.5.



`\Plane[opacity]=number]`

With the option *opacity* the opacity of the plane fill color can be modified. The range of the *number* lies between 0 and 1. Where 0 represents a fully transparent fill and 1 a solid fill. Per default the opacity is set to 0.3.

```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,opacity=.7]
\end{tikzpicture}
```

`\Plane[grid]=measure]`

With the option *grid* a grid will be drawn on top of the plane. The argument of this option defines the spacing between the grid lines. The entered *measures* are in default units (cm). Changing the unites (locally) can be done by adding the unit to the *measure*². Changes to the default setting can be made with `\SetDefaultUnit`³.

```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,grid=5mm]
\end{tikzpicture}
```

`\Plane[image]=file]`

An image can be assigned to a plane with the option *image*. The argument is the file name and the folder where the image is stored. The width and height of the figure is scaled to the size of the plane. Without the option *ImageAndFill* the image overwrite the color options.

```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,image=data/plane.png]
\end{tikzpicture}
```

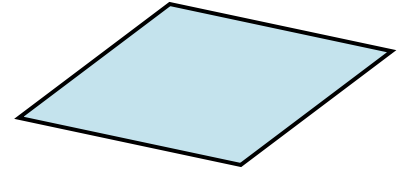
`\Plane[style]=string]`

Any other TikZ style option or command can be entered via the option *style*. Most of these commands can be found in the "TikZ and PGF Manual". Contain the commands additional options (e.g. *inner color*=color), then the argument for the *style* has to be between { } brackets.

```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,style={dashed,inner
    color=white,outer color=red!80}]
\end{tikzpicture}
```

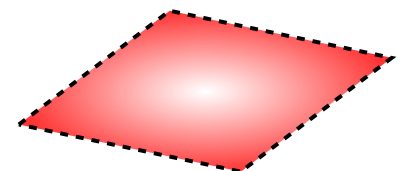
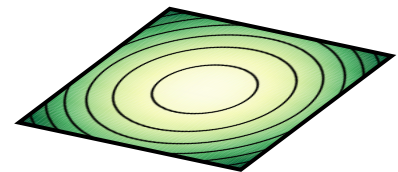
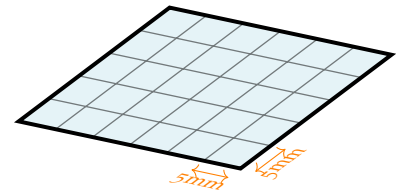
`\Plane[layer]=number]`

With the option *layer*=layer α , the position of the plane can be assigned to a specific layer. Per default the plane is drawn on layer 1.



² e.g. x=5 mm

³ see Section 5.1



```
\begin{tikzpicture}[multilayer=3d]
  \SetLayerDistance{-1.5}
  \Plane[x=-.5,y=-.5,width=3,height=2.5,color=green,layer=2]
  \Plane[x=-.5,y=-.5,width=3,height=2.5]
\end{tikzpicture}
```

`\Plane[$\langle RGB \rangle$, $\langle color \rangle$ =RGB values]`

In order to display RGB colors for the plane fill color, the option $\langle RGB \rangle$ has to be entered. In combination with this option, the $\langle color \rangle$ has to be a list with the *RGB values*, separated by «,» and within `{ }`.⁴

```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,RGB,color={0,0,0}]
\end{tikzpicture}
```

`\Plane[$\langle NoFill \rangle$]`

`\Plane[$\langle NoBorder \rangle$]`

$\langle NoFill \rangle$ is a Boolean option which disables the fill color of the plane and $\langle NoBorder \rangle$ is a Boolean option which suppress the border line of the plane.

```
\begin{tikzpicture}[multilayer=3d]
  \SetLayerDistance{-1.5}
  \Plane[x=-.5,y=-.5,width=3,height=2.5,layer=2,NoFill]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,NoBorder]
\end{tikzpicture}
```

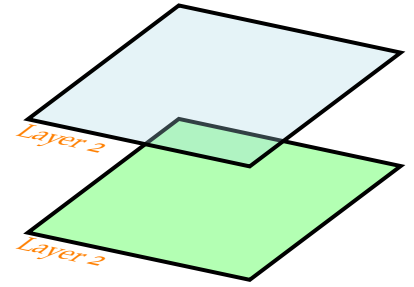
`\Plane[$\langle ImageAndFill \rangle$]`

With the option $\langle ImageAndFill \rangle$ both, image and fill color can be drawn on a plane. The option $\langle opacity \rangle$ is applied to both objects.

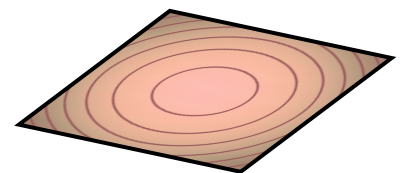
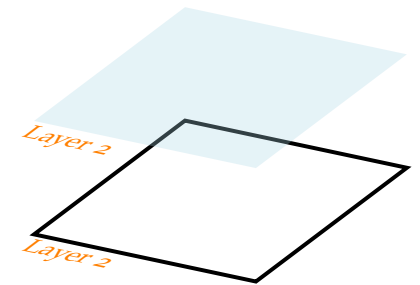
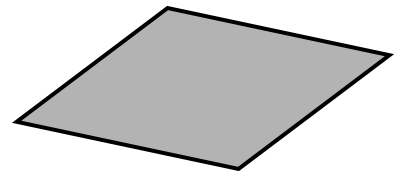
```
\begin{tikzpicture}[multilayer=3d]
  \Plane[x=-.5,y=-.5,width=3,height=2.5,image=data/plane.png,
    color=red,opacity=.4,ImageAndFill]
\end{tikzpicture}
```

`\Plane[$\langle InBG \rangle$]`

A plane is drawn on the current layer of the *tikzpicture*. I.e. objects which are created after the plane appear on top of it and objects created before below of it. With the option $\langle InBG \rangle$ enabled, the plane is drawn on the background layer of the *tikzpicture*.



⁴ e.g. the RGB code for white: `{255,255,255}`



5 Default Settings

In order to customize the look of the networks, each layout setting used can be modified and adapted. There are three categories: General settings, vertex style, and edge style.

5.1 General Settings

With the general settings mainly the sizes, distances and measures of the networks can be modified.

```
\SetDefaultUnit{unit}
```

The command `\SetDefaultUnit` allows to change the units used for drawing the network¹, including diameters of the vertices, x and y coordinates or the distance between the layers. The default unit is cm.

¹ Except the line width, which are defined in pt.

```
\SetDistanceScale{number}
```

With the command `\SetDistanceScale`, the distance between the vertices can be scaled. Per default 1 cm entered corresponds to 1 cm drawn, i.e. `\SetDistanceScale{1}`. Decreasing or increasing the scale changes the drawing distances between the vertices.

```
\SetLayerDistance{measure}
```

With the command `\SetLayerDistance` the distance between the layers and their orientation can be modified. Per default, the distance is set to -2 . A negative number implies that layers with a higher number will be stacked below layers with a smaller number.

```
\SetCoordinates[⟨xAngle⟩=number,⟨yAngle⟩=number,⟨zAngle⟩=number,  
⟨xLength⟩=number,⟨yLength⟩=number,⟨zLength⟩=number]
```

The perspective of the three-dimensional plot can be modified by changing the orientation of the coordinate system, which is done with the command `\SetCoordinates`. Here the angle and the length of each axis can be modified. Angles are defined as a *number* in the range between -360 and 360 . Per default, the length of the axes are defined by the identity matrix, i.e. no distortion. If the length ratio is changed x , y , and/or z values are distorted. The `\SetCoordinates` command has to be entered before the `⟨multilayer⟩` option is called!

5.2 Vertex Style

The appearance of the vertices can be modified with the command `\SetVertexStyle`. This command will change the default settings of the vertices in the network.

```
\SetVertexStyle[document options]
```

The following options are available:

Option	Default	Type	Definition
Shape	circle	text	shape of the vertex
InnerSep	2pt	measure	separation space which will be added inside the shape
OuterSep	opt	measure	separation space outside the background path
MinSize	0.6\DefaultUnit	measure	diameter (size) of the vertex
FillColor	vertexfill	color	color of the vertex
FillOpacity	1	number	opacity of the vertex
LineWidth	1pt	measure	line width of the vertex boundary
LineColor	black	color	line color of the vertex boundary
LineOpacity	1	number	line opacity of the vertex boundary
TextFont	\scriptsize	fontsize	font size of the vertex label
TextColor	black	color	color of the vertex label
TextOpacity	1	number	opacity of the vertex label
TextRotation	0	number	initial rotation of the vertex

Table 5.1: Document style options for the vertices.

5.3 Edge Style

The appearance of the edges can be modified with the command `\SetEdgeStyle`. This command will change the default settings of the edges in the network.

```
\SetEdgeStyle[document options]
```

The following options are available:

Option	Default	Type	Definition
LineWidth	1.5pt	measure	width of the edge
Color	black!75	color	color of the edge
Opacity	1	number	opacity of the edge
Arrow	-latex	text	arrow shape of the directed edge
TextFont	\scriptsize	fontsize	font size of the edge label
TextOpacity	1	number	opacity of the edge label
TextFillColor	white	color	fill color of the edge label
TextFillOpacity	1	number	fill opacity of the edge label
InnerSep	opt	measure	separation space which will be added inside the shape
OuterSep	1pt	measure	separation space outside the background path
TextRotation	0	number	initial rotation of the edge label

Table 5.2: Document style options for the edges.

```
\EdgesNotInBG
```

```
\EdgesInBG
```

Per default edges are drawn on the background layer, with the command `\EdgesNotInBG` this can be disabled, while the command `\EdgesInBG` restores the default setting.

5.4 Text Style

The appearance of the text can be modified with the command `\SetTextStyle`. This command will change the default settings of the text.

```
\SetTextStyle[document options]
```

The following options are available:

Option	Default	Type	Definition
TextFont	<code>\normalsize</code>	fontsize	font size of the text
TextOpacity	1	number	opacity of the text
TextColor	black	color	color of the text
TextOpacity	1	number	opacity of the text
InnerSep	2pt	measure	separation space which will be added inside the shape
OuterSep	opt	measure	separation space outside the background path
TextRotation	0	number	initial rotation of the text

Table 5.3: Document style options for the planes.

5.5 Plane Style

The appearance of the planes can be modified with the command `\SetPlaneStyle`. This command will change the default settings of the planes.

```
\SetPlaneStyle[document options]
```

The following options are available:

Option	Default	Type	Definition
LineWidth	1.5pt	measure	width of the border line
LineColor	black	color	color of the border line
LineOpacity	1	number	opacity of the border line
FillColor	vertexfill	color	fill color of the plane
FillOpacity	0.3	number	fill opacity of the plane
GridLineWidth	0.5pt	measure	width of the grid lines
GridColor	black	color	color of the grid lines
GridOpacity	0.5	number	opacity of the grid lines

Table 5.4: Document style options for the planes.

```
\SetPlaneWidth{measure}
```

```
\SetPlaneHeight{measure}
```

With the commands `\SetPlaneWidth` and `\SetPlaneHeight` the default size of the planes can be modified.

6 Troubleshooting and Support

6.1 *tikz-network* Website

The website for the `tikz-network` packages is located at <https://github.com/hackl/tikz-network>. There, you'll find the actual version of the source code, a bug tracker, and the documentation.

6.2 *Getting Help*

If you've encountered a problem with one of the `tikz-network` commands, have a question, or would like to report a bug, please send an email to me or visit our website.

To help me troubleshoot the problem more quickly, please try to compile your document using the `debug` class option and send the generated `.log` file to the mailing list with a brief description of the problem.

6.3 *Errors, Warnings, and Informational Messages*

The following is a list of all of the errors, warnings, and other messages generated by the `tikz-network` classes and a brief description of their meanings.

Error: ! TeX capacity exceeded, sorry [main memory size=5000000].

The considered network is too large and `pdflatex` runs out of memory. This problem can be solved by using `lualatex` or `xetex` instead.

6.4 *Package Dependencies*

The following is a list of packages that the `tikz-network` package relies upon. Packages marked with an asterisk are optional.

- `etex` – `arrows`
- `xifthen` – `positioning`
- `xkeyval` – `3d`
- `datatool` – `fit`
- `tikz` – `calc`
- `tikz` – `backgrounds`

A ToDo

A.1 Code to fix

- change default entries for Boolean options in the vertices file.

A.2 Documentation

- add indices to the manual.
- extended tutorial/example to the document.
- clean-up and document the .sty file.
- upload the package to CTAN, if it is appropriated tested.

A.3 Features

- add a spherical coordinate system

A.4 Add-ons

- add igraph to tikz-network compiler (e.g. plot function)
- add networkx to tikz-network compiler (e.g. plot function)
- add QGIS to tikz-network compiler

B Add-ons

B.1 Python networks to TikZ with network2tikz

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