Quantum Cube Model LaTeX Package (v0.2.1)

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Introduction

The **Quantum Cube Model (QCM)** package provides commands that make it easy to create diagrams representing the quantum cube model for up to 3 qubits. The package simplifies drawing complex quantum state diagrams inspired by Prof. B. Just's framework.

The key difference to version v0.1.0 of this package is, the new version exposes the tikz picture canves to the user. This allows for far more refined diagramms, and flexability.

Requirements

To use this package include `\usepackage{quantumcubemodel}` in your documents preamble. This package depends on the following LaTeX packages:

```
\RequirePackage{kvoptions}
\RequirePackage{braket}
\RequirePackage{xcolor}
\RequirePackage{tikz}
\usetikzlibrary{3d, calc, arrows.meta}
```

License

References

Bettina Just. *Quantum Computing Compact: Spooky Action at a Distance and Teleportation Easy to Understand*. Berlin, Heidelberg: Springer, 2022. ISBN: 978-3-662-65007-3 978-3-662-65008-0. DOI: 10.1007/978-3-662-65008-0. URL: https://link.springer.com/10.1007/978-3-662-65008-0 (visited on 05/26/2025)

Changelog

- v0.2.1:
  - Add support for standalone coefficients (amplitudes and phases)
  - Add support for Unitary gates with no specific arrow tip style (wireframes)
  - Fix PauliZ transformation diagram on three qubit systems
- v0.2.0:
  - Provide qcmx environment that exposes tikz canvas.
  - Give an option to set the main color.
  - Provide commands for easier amplitude configuration.
  - Provide options to change qubit axis.
  - Enable the use of multiple qcm diagramms in one tikz canvas.

Package options

To change the appearence of your diagramms you can set the main color as follows:

```
\documentclass[preview, border=40px]{standalone}
\usepackage[maincolor=orange]{../quantumcubemodel}

\begin{document}
\begin{qcmx}
    \qcmxO{0.71}
    \qcmxI{0.71}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

Provided commands

All commands are prefixed with **qcmx**.

There are other commands that start with **QCMXINTERNAL** these are for internal purposes only, the use of those is not recomended.

```
\begin{qcmx}
  % Everything happens in this environment
\end{qcmx}
```

In this environment you can call one of the following commands to render a qcm diagram for one, two or three qubit diagramms respectively:

- `\qcmxRenderQ`
- `\qcmxRenderQQ`
- `\qcmxRenderQQQ`

You can draw individual coefficients with:

- `\qcmxRenderCoef`

Initially all amplitudes are set to 0, you can change them with the commands of the following pattern:

`\qcmxO{}` or `\qcmxI{}` for one qubit amplitued at $|0\rangle$ (O) or $|1\rangle$ (I).

`\qcmxOO{}`, `\qcmxOI{}`, `\qcmxIO{}` and `\qcmxII{}` for systems with two qubits.

`\qcmxOOO{}` up to `\qcmxIII{}` for systems with three qubits...

You have to set the amplitudes befor calling the corresponding render command.

Each of theses commands gives you an optional parameter to set a phase (in degrees from 0 to 360) for the coefficient, for the state $-|+\rangle$ this results in:

```
\begin{qcmx}
  \qcmxO[180]{0.71}
  \qcmxI[180]{0.71}
  \qcmxRenderQ
\end{qcmx}
```

If you want to include more than one qcm diagram in one figure, you can define \def\qcmxOffsetX{5} to render the next one 5 units to the left. There are Offsets for X, Y and Z where the direction follows the tikz orientations. To reset the amplitudes and phases back to 0, you can use the corresponding reset command:

- \qcmxClearQ
- \qcmxClearQQ
- \qcmxClearQQQ

Use \def\qcmxOrientationQ{y} to set the orientation of a one qubit system to the y-axis. This needs to be defined befor using the render command. The commands for mutli qubit systems follow the scheme of Q, QQ and QQQ like the render commands. Possible values for orientations are:

- in Systems with one qubit: x, y, z (default: x)
- in Systems with two qubits: xy, xz, yz (default: xy)
- in Systems with three qubits: xyz (default: xyz)

For the transformations there are specialized render commands for the Pauli-Gates X, Y, Z as well as the Hadamard transformation. In multi qubit systems additionaly there a renderers for CNot and CCNot (Toffolie). These follow a scheme like thie: \qcmxRender[OperationName][QubitCount]{qubits} where [OperationName] can be i.e. Hadamard, the [QubitCount] can be QQ.

To render the Hadamard transformation on the x qubit in a system with two qubits this results in:

```
\qcmxRenderHadamardQQ{x}
```

Keep in mind that the \qcmxOrientationQQ setting will be used to determine that the other qubit is y.

```
\def\qcmxOrientationQQ{xz}
\qcmxRenderHadamardQQ{x}
```

Results in a different diagram.

The same is true for measurements, the only exceptions are CNot and CCNot, where ther is no single qubit (or two qubit for CCNot) version.

- \qcmxRenderHadamardQ one of [x,y,z]
- \qcmxRenderHadamardQQ one of [x,y,z]
- \qcmxRenderHadamardQQQ one of [x,y,z]
- \qcmxRenderPauliXQ one of [x,y,z]
- \qcmxRenderPauliXQQ one of [x,y,z]
- \qcmxRenderPauliXQQQ one of [x,y,z]
- \qcmxRenderPauliYQ one of [x,y,z]
- \qcmxRenderPauliYQQ one of [x,y,z]
- \qcmxRenderPauliYQQQ one of [x,y,z]
- \qcmxRenderPauliZQ one of [x,y,z]
- \qcmxRenderPauliZQQ one of [x,y,z]
- \qcmxRenderPauliZQQQ one of [x,y,z]
- \qcmxRenderCNotQQ one of [xy,yx,xz,zx,yz,zy]
- \qcmxRenderCNotQQQ one of [xy,yx,xz,zx,yz,zy]
- \qcmxRenderCCNotQQQ one of [xyz,yxz,xzy,zxy,yzx,zyx]
- \qcmxRenderMeasureQ one of [x,y,z]
- \qcmxRenderMeasureQQ one of [x,y,z,xy,xz,yz]
- \qcmxRenderMeasureQQQ one of [x,y,z,xy,xz,yz,xyz]

One qubit states

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\textbf{One qubit in state $\ket{0}$}
\begin{qcmx}
    \qcmxO{1}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

One qubit in state $|0\rangle$


```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\textbf{One qubit in state $\ket{1}$}
\begin{qcmx}
    \qcmxI{1}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

One qubit in state $|1\rangle$


```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\textbf{One qubit in state $\ket{+}$}
\begin{qcmx}
    \qcmxO{0.71}
    \qcmxI{0.71}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

One qubit in state $|+\rangle$

Amplitudes & Phases

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\textbf{One qubit in a statewith arbitrary amplitudes}
\begin{qcmx}
    \qcmxO{0.85}
    \qcmxI{0.53}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

One qubit in a statewith arbitrary amplitudes

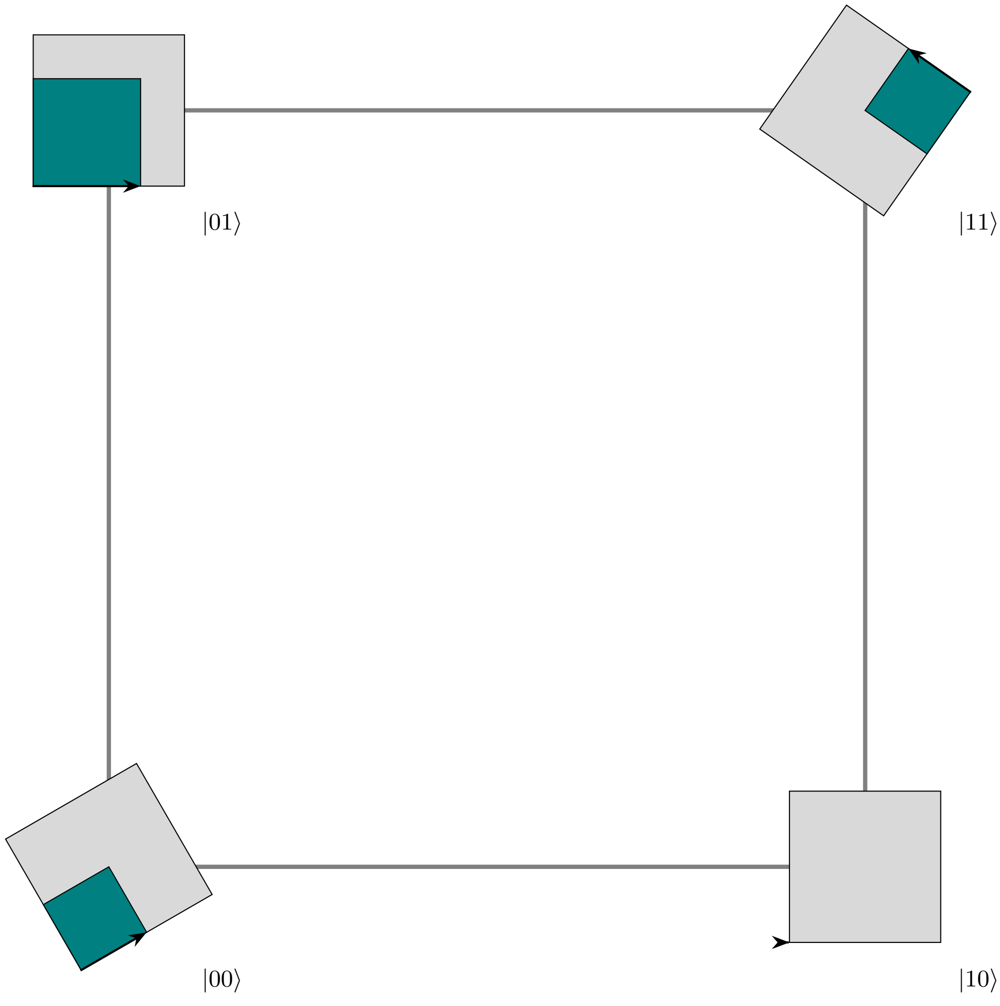

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\textbf{One qubit in a state with complex phases}
\begin{qcmx}
    \qcmxO[30]{0.85}
    \qcmxI[145]{0.53}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

One qubit in a state with complex phases

Two qubit state

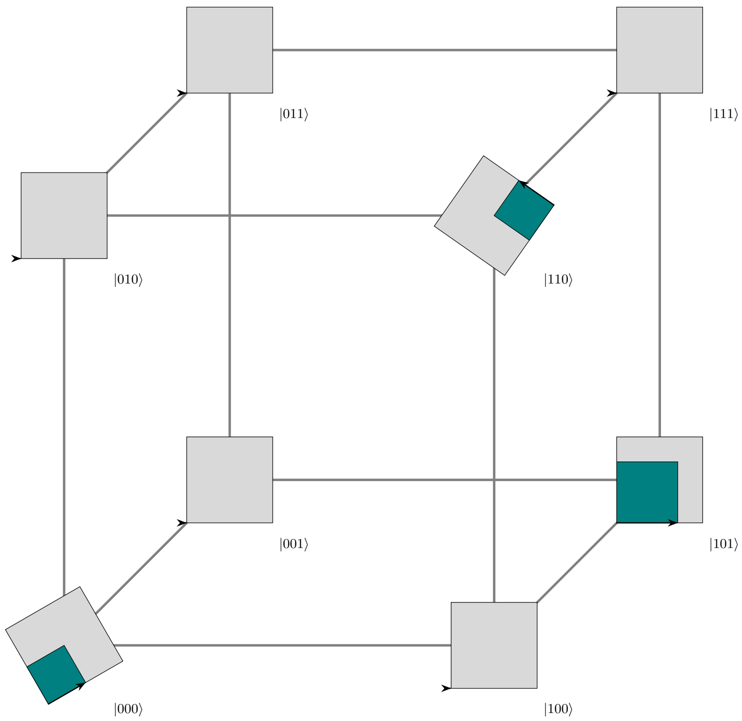
```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\textbf{Two qubits in a state with arbitrary amplitudes and phases}
\begin{qcmx}
    \qcmxOO[30]{0.5}
    \qcmxOI{0.71}
%   \qcmxIO{0} % can be left out, since this is the default value
    \qcmxII[145]{0.5}
    \qcmxRenderQQ
\end{qcmx}
\end{document}
```

Two qubits in a state with arbitrary amplitudes and phases



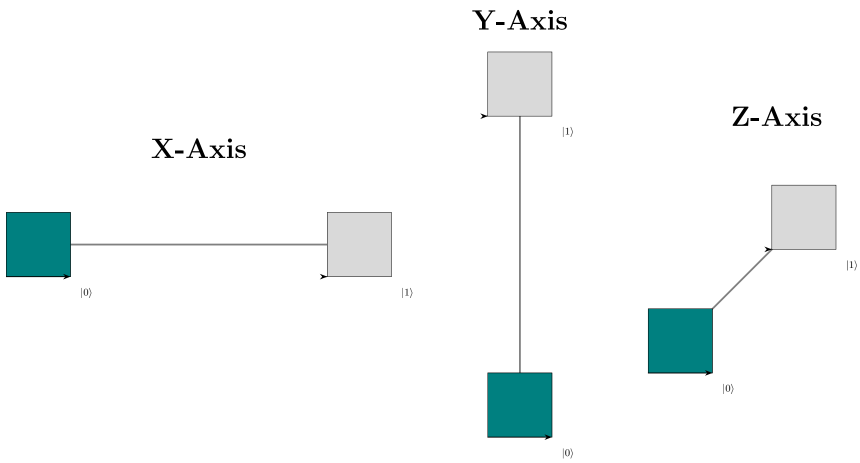
Three qubit state

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \qcmxOOO[30]{0.5}
%   \qcmxOOI{0} % can be left out, since this is the default value
%   \qcmxOIO{0}
%   \qcmxOII{0}
%   \qcmxIOO{0}
    \qcmxIOI{0.71}
    \qcmxIIO[145]{0.5}
%   \qcmxIII{0} % can be left out, since this is the default value
    \qcmxRenderQQQ
\end{qcmx}
\end{document}
```



Orientation and Positioning of qubits

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \node at (5, 3, 0) {\Huge \textbf{X-Axis}};
    \def\qcmxOrientationQ{x} % this is the default
    \qcmxO{1}
    \qcmxRenderQ

    \node at (15, 7, 0) {\Huge \textbf{Y-Axis}};
    \def\qcmxOffsetX{15} %<--- this moves the Y-Axis qubit to the right
    \def\qcmxOffsetY{-5} % and a bit down, relative to the origin (0, 0, 0)

    \def\qcmxOrientationQ{y} %<--- this sets the orientation to the y axis
    \qcmxRenderQ

    \node at (23,4, 0) {\Huge \textbf{Z-Axis}};
    \def\qcmxOffsetX{20}
    \def\qcmxOffsetY{-3}

    \def\qcmxOrientationQ{z}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```



The same works for:

```
\def\qcmxOrientationQQ{xy}
```

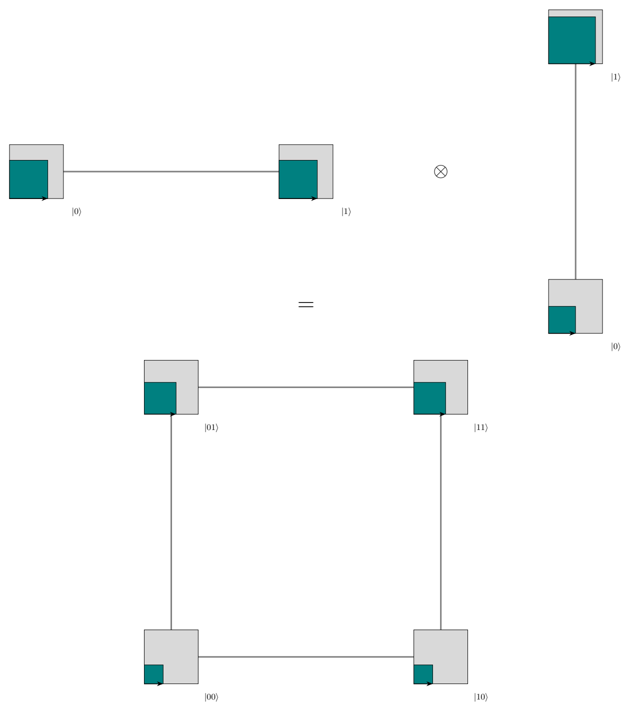
Possible values are xy, xz, yz to set the plane accordingly.

And for future use: \def\qcmxOrientationQQQ{xyz} is reserved, but there are no other valid values except xyz for now.

As you can see, the qcmx environment exposes a 3d Tikz canvas, there for you are free to use commands like \node at... to add descriptive markings.

Two qubit state from two one qubit state

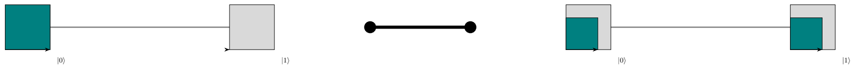
```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \qcmxO{0.71}
    \qcmxI{0.71}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (15,0,0) {\huge$\otimes$};

    \qcmxO{0.5}
    \qcmxI{0.87}
    \def\qcmxOffsetX{20}
    \def\qcmxOffsetY{-5}
    \def\qcmxOrientationQ{y}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (10,-5,0) {\Huge$=$};

    \qcmxOO{0.35}
    \qcmxOI{0.59}
    \qcmxIO{0.35}
    \qcmxII{0.59}
    \def\qcmxOffsetX{5}
    \def\qcmxOffsetY{-18}
    \qcmxRenderQQ
\end{qcmx}
\end{document}
```



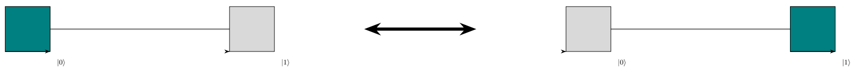
Transformation diagramms

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \node at (10, 0, 0) {\Huge \textbf{Hadamard transformation on one qubit}};
    \def\qcmxOffsetX{0}
    \def\qcmxOffsetY{-3}
    \qcmxO{1}
    \qcmxRenderQ
    \qcmxClearQ

    \def\qcmxOffsetX{15}
    \qcmxRenderHadamardQ{x}

    \qcmxO{0.71}
    \qcmxI{0.71}
    \def\qcmxOffsetX{25}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (10,-10, 0) {\Huge \textbf{Pauli-X transformation on one qubit}};
    \def\qcmxOffsetX{0}
    \def\qcmxOffsetY{-13}
    \qcmxO{1}
    \qcmxRenderQ
    \qcmxClearQ

    \def\qcmxOffsetX{15}
    \qcmxRenderPauliXQ{x}

    \qcmxI{1}
    \def\qcmxOffsetX{25}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (10,-20, 0) {\Huge \textbf{Pauli-Y and Z transformation on one qubit}};
    \def\qcmxOffsetX{0}
    \def\qcmxOffsetY{-24}
    \qcmxO{0.71}
    \qcmxI{0.71}
    \qcmxRenderQ
    \qcmxClearQ

    \def\qcmxOffsetX{15}
    \def\qcmxOffsetY{-23}
    \qcmxRenderPauliYQ{x}
    \def\qcmxOffsetY{-25}
    \qcmxRenderPauliZQ{x}

    \def\qcmxOffsetY{-24}
    \qcmxO[90]{0.71}
    \qcmxI[90]{0.71}
    \def\qcmxOffsetX{25}
    \qcmxRenderQ
\end{qcmx}
\end{document}
```

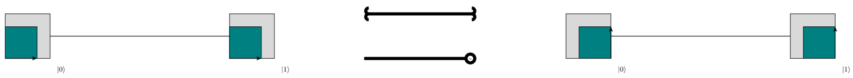
Hadamard transformation on one qubit



Pauli-X transformation on one qubit

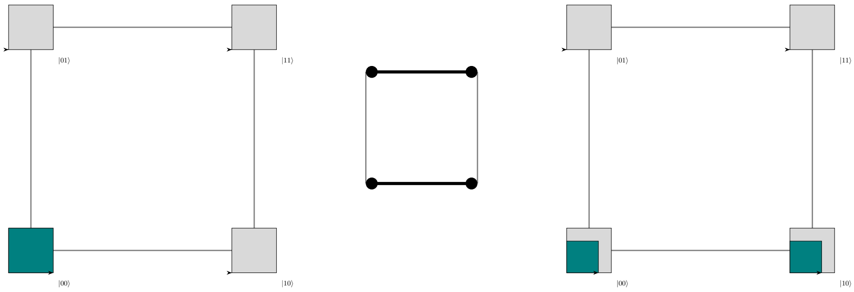


Pauli-Y and Z transformation on one qubit

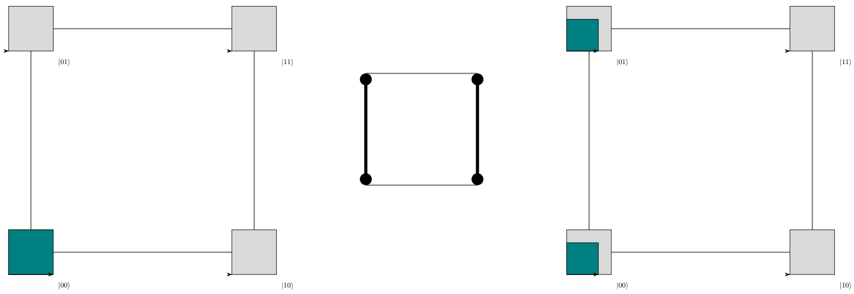


```latex
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \node at (18, 13, 0) {\Huge \textbf{Hadamard on first of two qubits in xy plane}};
    \qcmxOO{1}
    \qcmxRenderQQ
    \qcmxClearQQ

    \def\qcmxOffsetX{15}
    \def\qcmxOffsetY{3}
    \qcmxRenderHadamardQQ{x}

    \def\qcmxOffsetX{25}
    \def\qcmxOffsetY{0}
    \qcmxOO{0.71}
    \qcmxIO{0.71}
    \qcmxRenderQQ
    \qcmxClearQQ

    \node at (18, -7, 0) {\Huge \textbf{Hadamard on second of two qubits in xy plane}};
    \def\qcmxOffsetX{0}
    \def\qcmxOffsetY{-20}
    \qcmxOO{1}
    \qcmxRenderQQ
    \qcmxClearQQ

    \def\qcmxOffsetX{15}
    \def\qcmxOffsetY{-17}
    \qcmxRenderHadamardQQ{y}


    \def\qcmxOffsetX{25}
    \def\qcmxOffsetY{-20}
    \qcmxOO{0.71}
    \qcmxOI{0.71}
    \qcmxRenderQQ
    \qcmxClearQQ

    \node at (18, -27, 0) {\Huge \textbf{Hadamard on first of two qubits in yz plane}};
    \def\qcmxOrientationQQ{yz}
    \def\qcmxOffsetX{5}
    \def\qcmxOffsetY{-45}
    \qcmxOO{1}
    \qcmxRenderQQ
    \qcmxClearQQ

    \def\qcmxOffsetX{17}
    \def\qcmxOffsetY{-40}
    \qcmxRenderHadamardQQ{y}

    \def\qcmxOffsetX{27}
    \def\qcmxOffsetY{-45}
    \qcmxOO{0.71}
    \qcmxIO{0.71}
    \qcmxRenderQQ
\end{qcmx}
\end{document}
```

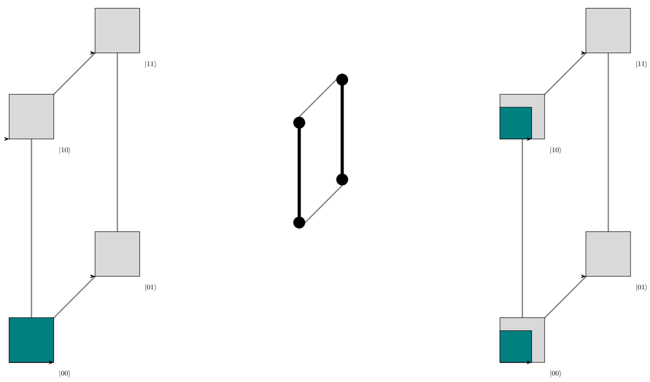
Hadamard on first of two qubits in xy plane



Hadamard on second of two qubits in xy plane



Hadamard on first of two qubits in yz plane

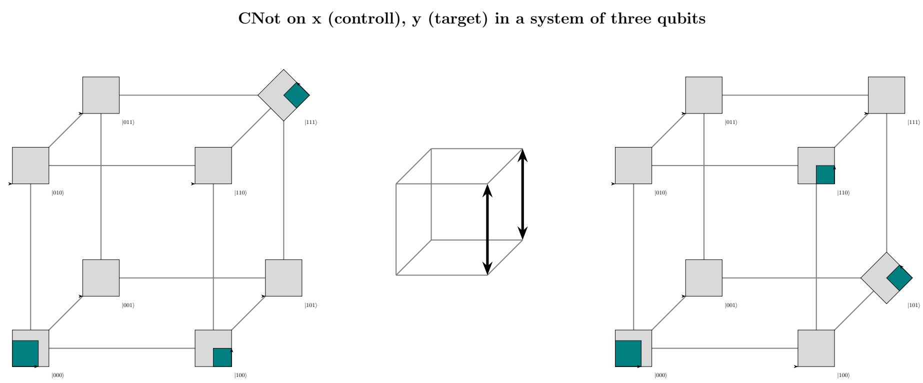


As you can see the orientation of the Hadamard Transform is set by two parts, first the value of \qcmxOrientationQQ is used to determine the plane, then the argument of \qcmxRenderHadamardQQ is used to select the qubit that is transformed.

The same is true for the pauli gates (x, y, z) as well as the three dimensional cube, even though \qcmxOrientationQQQ can only be xyz for now.

Multi qubit transformations

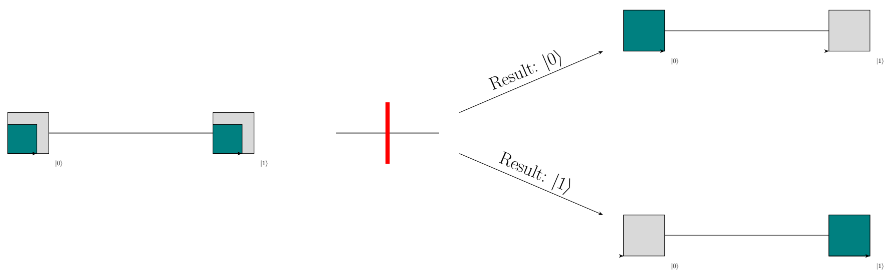
```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \node at (24, 18, 0) {\Huge \textbf{
        CNot on x (controll), y (target) in a system of three qubits
    }};
    \qcmxOOO{0.71}
    \qcmxIOO[90]{0.5}
    \qcmxIII[135]{0.5}
    \qcmxRenderQQQ
    \qcmxClearQQQ

    \def\qcmxOffsetX{20}
    \def\qcmxOffsetY{4}
    \qcmxRenderCNotQQQ{xy} % x is the controll, y is the target

    \def\qcmxOffsetX{33}
    \def\qcmxOffsetY{0}
    \qcmxOOO{0.71}
    \qcmxIIO[90]{0.5}
    \qcmxIOI[135]{0.5}
    \qcmxRenderQQQ
\end{qcmx}
\end{document}
```



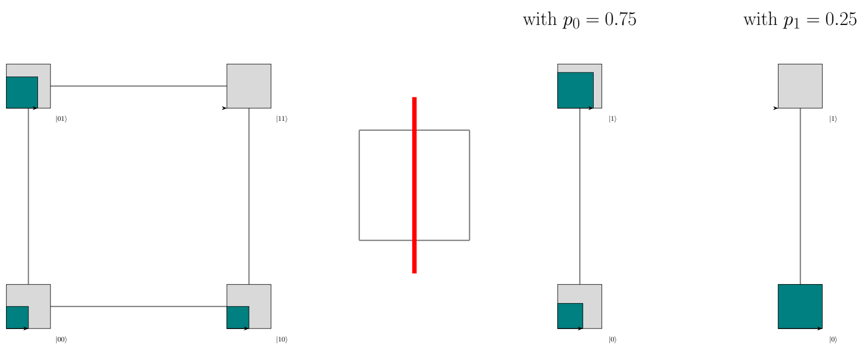
Additionaly there is the CCNot (Toffolie) gate, that can be rendered with the \qcmxRenderCCNotQQQ. Obviously CNot and CCNot are only available in systems with at least two (or three) qubits respectively.

Measurement of Qubits

```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \qcmxO{0.71}
    \qcmxI{0.71}
    \qcmxRenderQ
    \qcmxClearQ

    \def\qcmxOffsetX{15}
    \qcmxRenderMeasureQ{x}

    \draw[black, ->, thick, >=Stealth] (21,1,0) -- (28,4,0)
        node[midway, above, sloped] {\Huge Result: $\ket{0}$};

    \draw[black, ->, thick, >=Stealth] (21,-1,0) -- (28,-4,0)
        node[midway, above, sloped] {\Huge Result: $\ket{1}$};

    \def\qcmxOffsetX{30}
    \def\qcmxOffsetY{5}
    \qcmxO{1}
    \qcmxRenderQ
    \qcmxClearQ

    \def\qcmxOffsetX{30}
    \def\qcmxOffsetY{-5}
    \qcmxI{1}
    \qcmxRenderQ
    \qcmxClearQ
\end{qcmx}
\end{document}
```



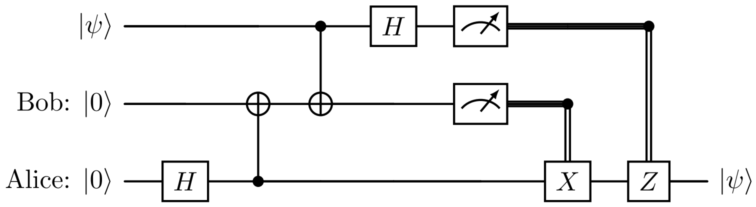
```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \qcmxOO{0.5}
    \qcmxOI{0.71}
    \qcmxIO{0.5}
    \qcmxRenderQQ
    \qcmxClearQQ

    \def\qcmxOffsetX{15}
    \def\qcmxOffsetY{3}
    \qcmxRenderMeasureQQ{x}

    \def\qcmxOffsetX{25}
    \def\qcmxOffsetY{0}
    \def\qcmxOrientationQ{y}

    \node at (25, 13, 0) {\Huge with $p_0 = 0.75$};
    \qcmxO{0.57}
    \qcmxI{0.81}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (35, 13, 0) {\Huge with $p_1 = 0.25$};
    \def\qcmxOffsetX{35}
    \qcmxO{1}
    \qcmxRenderQ

\end{qcmx}
\end{document}
```

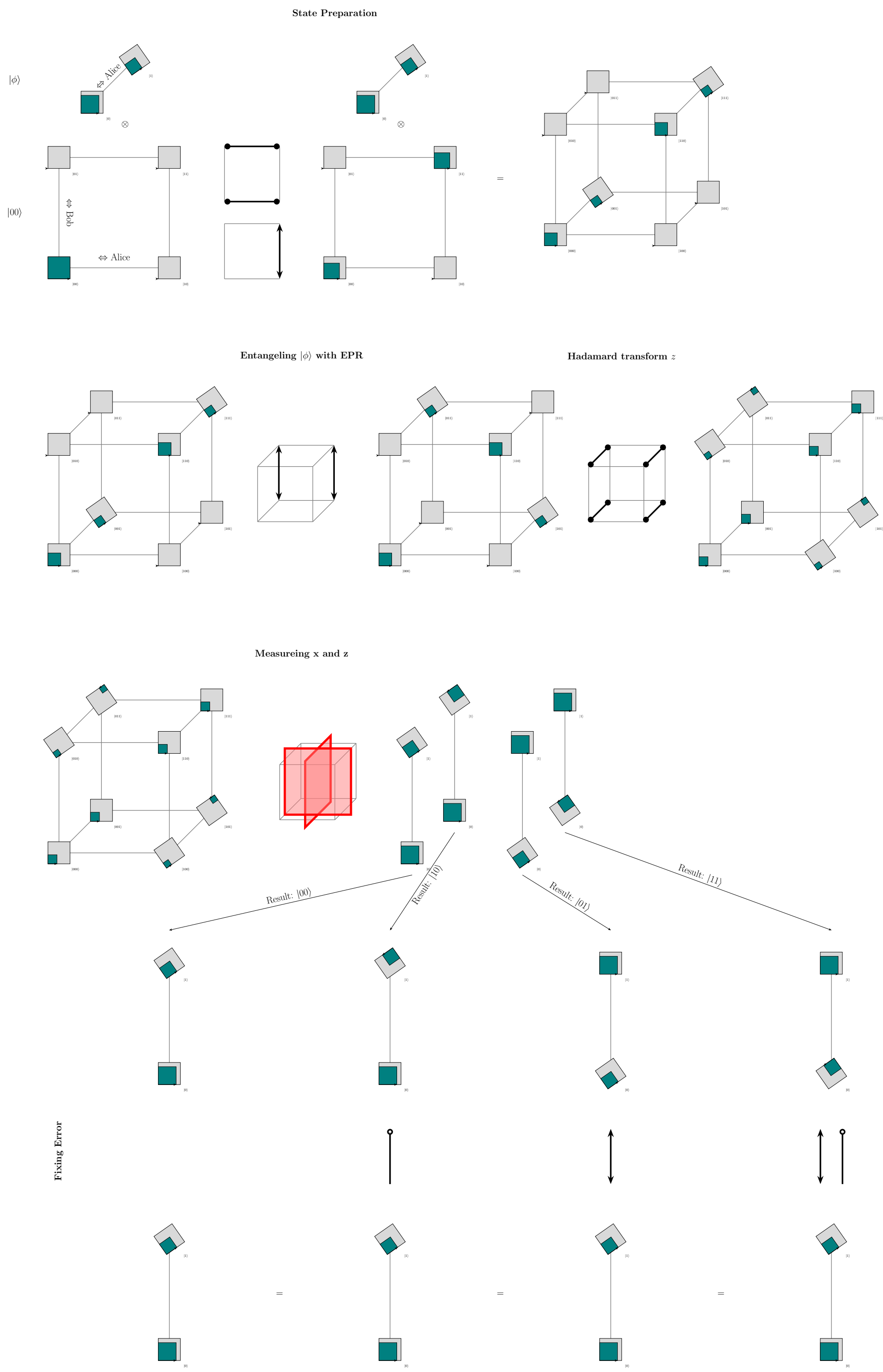


For systems with only partial measurements the \qcmxOrientationQQ and \qcmxOrientationQQQ values are used to determin the unmeasured qubits.

Additionaly it is possible to measure more than one qubit at the same time. For \qcmxRenderMeasureQQ it is possible to choose from x, y, z, xy, xz, yz. While for \qcmxRenderMeasureQQQ xyz is also available.

Example: Teleportation Algorithm





```
\documentclass[preview, border=40px]{standalone}
\usepackage{../quantumcubemodel}
\begin{document}
\begin{qcmx}
    \node at (25,8,0) {\Huge \textbf{State Preparation}};

    \node at (-4,2,0) {\Huge$\ket{\phi}$};
    \node at (-4,-10,0) {\Huge$\ket{00}$};

    \node[rotate=45] at (5,3,1.5) {\Huge $\Leftrightarrow$ Alice};

    \def\qcmxOrientationQ{z}
    \def\qcmxOffsetX{3}
    \def\qcmxOffsetY{0}
    \qcmxO{0.81}
    \qcmxI[35]{0.57}
    \qcmxRenderQ
    \qcmxClearQ
    \node at (6,-2,0) {\Huge$\otimes$};

    \node at (5,-14,0) {\Huge $\Leftrightarrow$ Alice};
    \node[rotate=-90] at (1,-10,0) {\Huge $\Leftrightarrow$ Bob};
    \def\qcmxOffsetX{0}
    \def\qcmxOffsetY{-15}
    \qcmxOO{1}
    \qcmxRenderQQ
    \qcmxClearQQ

    \def\qcmxOffsetX{15}
    \def\qcmxOffsetY{-9}
    \qcmxRenderHadamardQQ{x}
    \def\qcmxOffsetY{-16}
    \qcmxRenderCNotQQ{xy}

    \def\qcmxOffsetX{28}
    \def\qcmxOffsetY{0}
    \qcmxO{0.81}
    \qcmxI[35]{0.57}
    \qcmxRenderQ
    \qcmxClearQ
    \node at (31,-2,0) {\Huge$\otimes$};

    \def\qcmxOffsetX{25}
    \def\qcmxOffsetY{-15}
    \qcmxOO{0.71}
    \qcmxII{0.71}
    \qcmxRenderQQ
    \qcmxClearQQ

    \node at (40,-7,0) {\Huge$=$};
    \def\qcmxOffsetX{45}
    \def\qcmxOffsetY{-12}
    \qcmxOOO{0.58}
    \qcmxOOI[35]{0.4}
    \qcmxIIO{0.58}
    \qcmxIII[35]{0.4}
    \qcmxRenderQQQ
    \qcmxClearQQQ
```

```
\def\qcmxOffsetX{0}
\def\qcmxOffsetY{-41}
\qcmxOOO{0.58}
\qcmxOOI[35]{0.4}
\qcmxIIO{0.58}
\qcmxIII[35]{0.4}
\qcmxRenderQQQ
\qcmxClearQQQ

\node at (22,-23,0) {\Huge \textbf{Entangeling $\ket{\phi}$ with EPR}};
\def\qcmxOffsetX{18}
\def\qcmxOffsetY{-38}
\qcmxRenderCNotQQQ{zy}

\def\qcmxOffsetX{30}
\def\qcmxOffsetY{-41}
\qcmxOOO{0.58}
\qcmxOII[35]{0.4}
\qcmxIIO{0.58}
\qcmxIOI[35]{0.4}
\qcmxRenderQQQ
\qcmxClearQQQ

\node at (51,-23,0) {\Huge \textbf{Hadamard transform $z$}};
\def\qcmxOffsetX{48}
\def\qcmxOffsetY{-38}
\qcmxRenderHadamardQQQ{z}

\def\qcmxOffsetX{59}
\def\qcmxOffsetY{-41}
\qcmxOOO{0.41}
\qcmxOOI{0.41}
\qcmxOIO[35]{0.28}
\qcmxOII[180+35]{0.28}
\qcmxIOO[35]{0.28}
\qcmxIOI[180+35]{0.28}
\qcmxIIO{0.41}
\qcmxIII{0.41}
\qcmxRenderQQQ
\qcmxClearQQQ


\node at (22,-50,0) {\Huge \textbf{Measureing x and z}};
\def\qcmxOffsetX{0}
\def\qcmxOffsetY{-68}
\qcmxOOO{0.41}
\qcmxOOI{0.41}
\qcmxOIO[35]{0.28}
\qcmxOII[180+35]{0.28}
\qcmxIOO[35]{0.28}
\qcmxIOI[180+35]{0.28}
\qcmxIIO{0.41}
\qcmxIII{0.41}
\qcmxRenderQQQ
\qcmxClearQQQ
```

```
\def\qcmxOffsetX{20}
\def\qcmxOffsetY{-65}
\qcmxRenderMeasureQQQ{xz}

\def\qcmxOffsetX{32}
\def\qcmxOffsetY{-68}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}
\qcmxO{0.81}
\qcmxI[35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{42}
\def\qcmxOffsetY{-68}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}

\qcmxI{0.81}
\qcmxO[35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{32}
\def\qcmxOffsetY{-68}
\def\qcmxOffsetZ{-10}
\def\qcmxOrientationQ{y}

\qcmxO{0.81}
\qcmxI[180+35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{42}
\def\qcmxOffsetY{-68}
\def\qcmxOffsetZ{-10}
\def\qcmxOrientationQ{y}

\qcmxI{0.81}
\qcmxO[180+35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\draw[black, ->, thick, >=Stealth] (32,-70,0) -- (10,-75,0)
    node[midway, above, sloped] {\Huge Result: $\ket{00}$};

\draw[black, ->, thick, >=Stealth] (32,-70,-10) -- (30,-75,0)
    node[midway, below, sloped] {\Huge Result: $\ket{10}$};

\draw[black, ->, thick, >=Stealth] (42,-70,0) -- (50,-75,0)
    node[midway, above, sloped] {\Huge Result: $\ket{01}$};

\draw[black, ->, thick, >=Stealth] (42,-70,-10) -- (70,-75,0)
    node[midway, above, sloped] {\Huge Result: $\ket{11}$};

\node[rotate=90] at (0,-95,0) {\Huge \textbf{Fixing Error}};
```

```
\def\qcmxOffsetX{10}
\def\qcmxOffsetY{-88}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}
\qcmxO{0.81}
\qcmxI[35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{30}
\def\qcmxOffsetY{-88}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}
\qcmxO{0.81}
\qcmxI[180+35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{30}
\def\qcmxOffsetY{-98}
\qcmxRenderPauliZQ{y}

\def\qcmxOffsetX{50}
\def\qcmxOffsetY{-88}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}
\qcmxI{0.81}
\qcmxO[35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{50}
\def\qcmxOffsetY{-98}
\qcmxRenderPauliXQ{y}

\def\qcmxOffsetX{70}
\def\qcmxOffsetY{-88}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}
\qcmxI{0.81}
\qcmxO[180+35]{0.57}
\qcmxRenderQ
\qcmxClearQ

\def\qcmxOffsetX{69}
\def\qcmxOffsetY{-98}
\qcmxRenderPauliXQ{y}
\def\qcmxOffsetX{71}
\def\qcmxOffsetY{-98}
\qcmxRenderPauliZQ{y}


\def\qcmxOffsetX{10}
\def\qcmxOffsetY{-113}
\def\qcmxOffsetZ{0}
\def\qcmxOrientationQ{y}
\qcmxO{0.81}
\qcmxI[35]{0.57}
```

```
    \qcmxRenderQ
    \qcmxClearQ

    \node at (20,-108,0) {\Huge$=$};

    \def\qcmxOffsetX{30}
    \def\qcmxOffsetY{-113}
    \def\qcmxOffsetZ{0}
    \def\qcmxOrientationQ{y}
    \qcmxO{0.81}
    \qcmxI[35]{0.57}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (40,-108,0) {\Huge$=$};

    \def\qcmxOffsetX{50}
    \def\qcmxOffsetY{-113}
    \def\qcmxOffsetZ{0}
    \def\qcmxOrientationQ{y}
    \qcmxO{0.81}
    \qcmxI[35]{0.57}
    \qcmxRenderQ
    \qcmxClearQ

    \node at (60,-108,0) {\Huge$=$};

    \def\qcmxOffsetX{70}
    \def\qcmxOffsetY{-113}
    \def\qcmxOffsetZ{0}
    \def\qcmxOrientationQ{y}
    \qcmxO{0.81}
    \qcmxI[35]{0.57}
    \qcmxRenderQ
    \qcmxClearQ
\end{qcmx}
\end{document}
```