The *robotarm* package

Marcus J.W. Snippe
maxsnippe[at]gmail.nl

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Abstract

With the *robotarm* package, you can draw configurable planar robot arms with ease, using Ti*k*Z. It defines the macro (`\robotArm`) and a lot of ways to configure it. Additionally, you can use or redefine the macros used to draw the base link (`\robotArmBaseLink` → P. 3), a single link (`\robotArmLink` → P. 5), or the end effector (`\robotArmEndEffector` → P. 6).

Contents

1 Macros

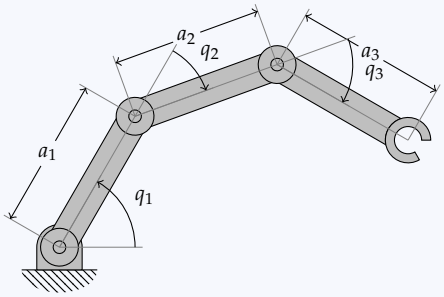
1.1 robotArm

`\robotArm[`⟨*key-value list*⟩`]{`⟨*num*⟩`}`

This is the main macro of the *robotarm* package. It is meant to be used in the `tikzpicture` environment[1], from the Ti*k*Z [1] package, and installs some styles for additional drawing, e.g. `/tikz/in link` → P. 8.

```
\begin{tikzpicture}
  \robotArm[config={q1=60,q2=-40,q3=-50}]{3}
\end{tikzpicture}
```

[1] The first example still includes the `tikzpicture` environment, but for following examples,it will be omitted in the example code.



⟨*num*⟩ defines the number of links that will be drawn. For an N link robot arm, the N^{th} link will be the end effector link.
The ⟨*key-value list*⟩ values can consist of the keys listed below.

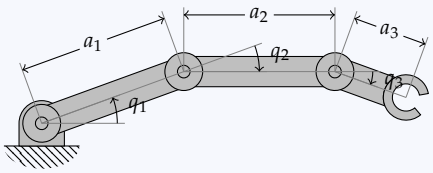
`geometry`=⟨*key-value list*⟩

The `geometry` key can be used to set geometrical configuration options of the robot arm, e.g. link length and link width. The keys in ⟨*key-value list*⟩ can be one or more of the following.

`a`=⟨*value*⟩ (initially 2)
`a`⟨***num***⟩=⟨*value*⟩ (initially the value of `a`)

The `a` key sets the default length for all links that are drawn in the `\robotArm` → P. 1 command. For every link, this can be overruled by the dynamically created keys `a`⟨*num*⟩, e.g. to set only the length of link 3 to 3, use `a3=3`.

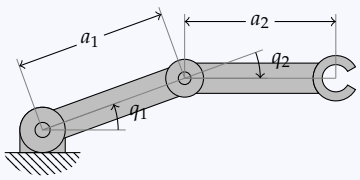
```
\robotArm[config={q1=20,q2=-20,q3=-20},
  geometry={a=3,a3=1}]{3}
```



`r`=⟨*value*⟩ (initially `0.25`)
`r`⟨***num***⟩=⟨*value*⟩ (initially the value of `r`)

The `r` key sets the default joint radius for all links drawn in the `\robotArm` → P. 1 command. For every link this can be overruled by the dynamically created keys `r`⟨*num*⟩.

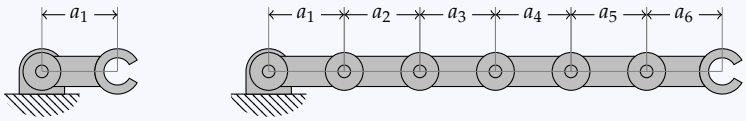
```
\robotArm[config={q1=20,q2=-20},
  geometry={r=0.5,r1=0.3}]{2}
```



`w`=⟨*value*⟩ (initially `0.4`)
`w`⟨***num***⟩=⟨*value*⟩ (initially the value of `w`)

The `w` key sets the default link width for all links drawn in the `\robotArm` P. 1 command. For every link this can be overruled by the dynamically created keys `w`⟨*num*⟩.

```
\tikzset{/robotarm/geometry={a=1}}
\robotArm{1}
\begin{scope}[xshift=3cm]
  \robotArm{6}
\end{scope}
```



`/robotarm/styles/link` (default `draw,fill=lightgray`)

1.2 robotArmBaseLink

`\robotArmBaseLink`[⟨*key-value list*⟩]

This command is used in `\robotArm` P. 1 to draw the base link. It can also be used to draw your own base link. The default base link looks as follows:

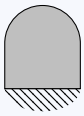
```
\robotArmBaseLink
```

The ⟨*key-value list*⟩ can consist of the keys listed below.

`/robotarm/base link/height`=⟨*value*⟩ (initially `0.6`)
`/robotarm/base link/width`=⟨*value*⟩ (initially `0.3`)

The width and height of the base link can be specified with these keys. The height is measured from the center of the half-circle at the top, to the base.

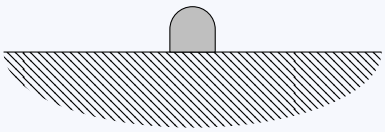
```
\robotArmBaseLink[width=1, height=0.6]
```



/robotarm/base link/world width=⟨*value*⟩ (initially 1.0)
/robotarm/base link/world height=⟨*value*⟩ (initially 0.3)

The width and height of the 'world' drawn below the base link can be specified with these keys.

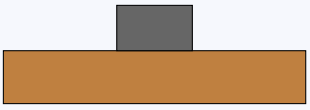
```
\robotArmBaseLink[world width=5, world height=1]
```



/robotarm/base link/draw base link (code executing key)
/robotarm/base link/draw world (code executing key)

These keys are used to draw the 'world' and the base link. If the configuration options above are insufficient, you can redefine these keys, as shown in the not-so-creative example below.

```
\robotArmBaseLink[
  draw world/.code={
    \filldraw[fill=brown] (-2,-1) rectangle (2, -0.3);
  },
  draw base link/.code={
    \filldraw[fill=black!60] (-0.5, -0.3) rectangle
      (0.5, 0.3);
  }]
```



To access the values of the keys listed above you can use the following macros in your redefinition:

- \RA@baselink@width,
- \RA@baselink@height,
- \RA@baselink@worldwidth, and
- \RA@baselink@worldheight.

1.3 robotArmLink

`\robotArmLink[`⟨*key-value list*⟩`]`

This command is used in `\robotArm` → P. 1 to draw the links in a `foreach` loop. It can also be used to draw your own link(s). The default link looks as follows:

```
\robotArmLink
```

The ⟨*key-value list*⟩ can consist of the keys listed below.

`/robotarm/link/width`=⟨*value*⟩ (initially `0.4`)
`/robotarm/link/length`=⟨*value*⟩ (initially `2.0`)
`/robotarm/link/joint radius`=⟨*value*⟩ (initially `0.25`)

The geometrical properties of the links can be configured with these keys.

```
\robotArmLink[width=0.75,joint radius=0.4,length=5]
```

`/robotarm/link/draw link` (code executing key)
`/robotarm/link/draw joint` (code executing key)

Same as for the base link, the actual drawing is done by calling these keys. These can also be redefined to change the drawing.

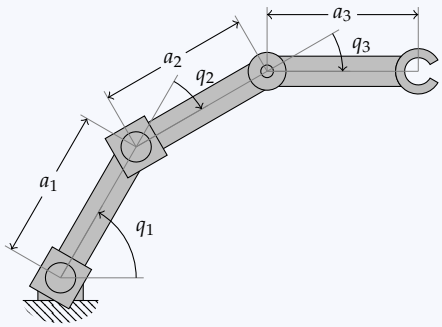
```
\robotArmLink[draw link/.code={
  \draw[line cap=round, double=lightgray,
    double distance=4mm]
    (0,0) to[bend left] (2,0);}]
```

Of course you can also do this globally so it applies to all links[2].

```
\pgfkeys{/robotarm/link/draw joint/.code={
  \path[link style] (-0.3,-0.3) rectangle ++(0.6,0.6);
```

[2] For the end effector to change too, you have to redefine `/robotarm/end effector/draw joint` → P. 7 too.

```
  \path[link style] (0,0) circle (0.2);}}
\robotArm[geometry={a=1.5},
          config={q1=60,q2=-30,q3=-30}]{3}
```



To access the values of the keys listed above you can use the following macros in your redefinition:

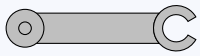
- `\RA@link@width`,
- `\RA@link@length`, and
- `\RA@link@jointradius`.

1.4 robotArmEndEffector

`\robotArmEndEffector[`⟨*key-value list*⟩`]`

This command is used in `\robotArm` → P. 1 to draw the final link with the end effector attached. You can also use it outside that command to draw your own end effector.

```
\robotArmEndEffector
```



The ⟨*key-value list*⟩ can consist of the keys listed below.

`/robotarm/end effector/width`=⟨*value*⟩ (initially `0.4`)
`/robotarm/end effector/length`=⟨*value*⟩ (initially `2.0`)
`/robotarm/end effector/joint radius`=⟨*value*⟩ (initially `0.25`)
`/robotarm/end effector/gripper radius`=⟨*value*⟩ (initially `0.3`)
`/robotarm/end effector/gripper opening angle`=⟨*angle*⟩ (initially `60`)

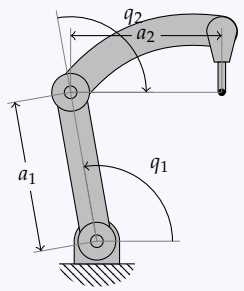
The geometrical properties of the final link and the end effector, which defaults to a gripper, can be tuned with these keys. Due to some trigonometric functions in the drawing code of `/robotarm/end effector/draw`

end effector→P.7, /robotarm/end effector/gripper radius should not be smaller than half of /robotarm/end effector/width.

/robotarm/end effector/draw link (code executing key)
/robotarm/end effector/draw joint (code executing key)
/robotarm/end effector/draw end effector (code executing key)

Again the actual drawing is done by calling these keys. And these can also be redefined to change how the end effector will look, as shown in the example below.

```
\robotArm[
  config={q1=100,q2=-100},
  end effector/.cd,
  draw link/.code={
    \draw[line cap=round, double=lightgray,
          double distance=4mm]
      (0,0) to[bend left]  (2, 0.8);},
  draw end effector/.code={
    \path[link style]
      (1.8, 0.8) arc (180:0:0.2) -- (2.1, 0.4)
      -- (1.9, 0.4) --  cycle;
    \path[link style]
      (2.05,0.4) rectangle (1.95,0.0);
    \fill (2,0) circle (0.05);}]{2}
```



To access the values of the keys listed above you can use the following macros in your redefinition:

- \RA@endeff@width,
- \RA@endeff@length,
- \RA@endeff@jointradius,
- \RA@endeff@gripperradius, and
- \RA@endeff@gripperopeningangle.

2 TikZ styles

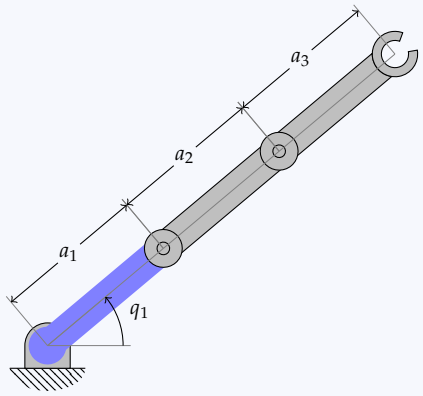
/tikz/in link=⟨*number*⟩ (style)
/tikz/in base link (style)
/tikz/in world (style)
/tikz/in end effector (style)

Only installed after calling \robotArm → P. 1 at least once (last called macro defines these styles, but within scope can be made unique).

/tikz/link style (default /robotarm/styles/link)

Always installed, forwards to /robotarm/styles/link → P. 3. Only works one way. To change link styles used in \robotArm → P. 1, change the appropriate /robotarm/styles/link → P. 3.

```
\tikzset{link style/.style={draw=none, fill=red!50}}
\robotArm[config={q1=40},styles={
  link 1/.style={fill=blue!50}}]{3}
```



3 Implementation

```
1 ⟨*robotarm-package⟩
2 \NeedsTeXFormat{LaTeX2e}
3 \ProvidesPackage{robotarm}
4   [2022/03/08 v0.1 Tikz commands to draw planar robot arms]
5
6 \RequirePackage{tikz}
7
8 \usetikzlibrary{patterns}
9
10 \makeatletter
11
```

```
\newif\ifRA@robotarm@drawannotations

\pgfkeys{
  /robotarm/base link/.cd,
    width/.code={\pgfmathsetmacro\RA@baselink@width{#1}},
    width=0.6,
    height/.code={\pgfmathsetmacro\RA@baselink@height{#1}},
    height=0.3,
    world width/.code={\pgfmathsetmacro\RA@baselink@worldwidth{#1}},
    world width=1.0,
    world height/.code={\pgfmathsetmacro\RA@baselink@worldheight{#1}},
    world height=0.3,
    draw base link/.code={%
      \path[link style]
        (-1/2*\RA@baselink@width,0)
        arc (180:0:1/2*\RA@baselink@width)
        -- ++ (0, -\RA@baselink@height)
        -- ++ (-\RA@baselink@width, 0)
        -- cycle;
    },
    draw world/.code={%
      \path[world style]
        (-1/2*\RA@baselink@worldwidth,-\RA@baselink@height)
        arc (180:360:{1/2*\RA@baselink@worldwidth}
          and {\RA@baselink@worldheight}) -- cycle;
      \path[draw, world style]
        (-1/2*\RA@baselink@worldwidth,-\RA@baselink@height)
        -- ++(\RA@baselink@worldwidth,0);
    },
  /robotarm/link/.cd,
    width/.code={\pgfmathsetmacro\RA@link@width{#1}},
    width=0.4,
    length/.code={\pgfmathsetmacro\RA@link@length{#1}},
    length=2.0,
    joint radius/.code={\pgfmathsetmacro\RA@link@jointradius{#1}},
    joint radius=0.25,
    draw link/.code={%
      \path[link style]
        (0,1/2*\RA@link@width)
        -- ++ ( \RA@link@length, 0)
        arc (90:-90:1/2*\RA@link@width)
        -- ++ (-\RA@link@length, 0)
        arc (270:90:1/2*\RA@link@width)
        -- cycle;
    },
    draw joint/.code={%
      \path[link style]
        (0,0) circle (\RA@link@jointradius);
      \path[link style]
        (0,0) circle (1/3*\RA@link@jointradius);
```

```
  },
/robotarm/end effector/.cd,
  width/.code={\pgfmathsetmacro\RA@endeff@width{#1}},
  width=0.4,
  length/.code={\pgfmathsetmacro\RA@endeff@length{#1}},
  length=2,
  joint radius/.code={\pgfmathsetmacro\RA@endeff@jointradius{#1}},
  joint radius=0.25,
  gripper radius/.code={\pgfmathsetmacro\RA@endeff@gripperradius{#1}},
  gripper radius=0.3,
  gripper opening angle/.code={%
    \pgfmathsetmacro\RA@endeff@gripperopeningangle{#1}},
  gripper opening angle=60,
  draw joint/.code={%
    \path[link style]
      (0,0) circle (\RA@endeff@jointradius);
    \path[link style]
      (0,0) circle (1/3*\RA@endeff@jointradius);
  },
  draw link/.code={%
    \pgfmathsetmacro{\link@startangle}{%
      180-asin(1/2*\RA@endeff@width/\RA@endeff@gripperradius)}
    \pgfmathsetmacro{\link@endangle}{%
      180+asin(1/2*\RA@endeff@width/\RA@endeff@gripperradius)}

    \path[link style]
      (\RA@endeff@length, 0)
      ++ (\link@startangle:\RA@endeff@gripperradius)
      arc (\link@startangle:\link@endangle:\RA@endeff@gripperradius)
      -- (0,0|-0,-1/2*\RA@endeff@width)
      arc (-90:90:1/2*\RA@endeff@width)
      -- cycle;
  },
  draw end effector/.code={
    \draw[link style]
      (\RA@endeff@length, 0)
      ++ (-1/2*\RA@endeff@gripperopeningangle:%
          \RA@endeff@gripperradius)
      arc [start angle=-1/2*\RA@endeff@gripperopeningangle,
           delta angle=-360+\RA@endeff@gripperopeningangle,
           radius=\RA@endeff@gripperradius]
      -- ++(180+1/2*\RA@endeff@gripperopeningangle:%
            0.4*\RA@endeff@gripperradius)
      arc [start angle=1/2*\RA@endeff@gripperopeningangle,
           delta angle=360-\RA@endeff@gripperopeningangle,
           radius=0.6*\RA@endeff@gripperradius]
      -- ++(-1/2*\RA@endeff@gripperopeningangle:%
            0.4*\RA@endeff@gripperradius)
      -- cycle;
  },
```

```
/robotarm/.cd,
  draw annotations/.is if=RA@robotarm@drawannotations,
  draw annotations=true,
  every annotation/.style={},
  every length annotation/.style={},
  every length annotation arrow/.style={draw,->},
  every length annotation node/.style={circle,inner sep=0.5pt},
  every length annotation help line/.style={draw,help lines},
  every angle annotation/.style={},
  every angle annotation arrow/.style={draw,->},
  every angle annotation node/.style={},
  every angle annotation help line/.style={draw,help lines},
  base link/.code=\pgfkeys{/robotarm/base link/.cd,#1},
  link/.code=\pgfkeys{/robotarm/link/.cd,#1},
  end effector/.code=\pgfkeys{/robotarm/end effector/.cd,#1},
  geometry/.code=\pgfkeys{/robotarm/geometry/.cd,#1},
  config/.code=\pgfkeys{/robotarm/config/.cd,#1},
  spacing/.code=\pgfkeys{/robotarm/annotations/spacing/.cd,#1},
  labels/.code=\pgfkeys{/robotarm/annotations/labels/.cd,#1},
  styles/.code=\pgfkeys{/robotarm/styles/.cd,#1},
/robotarm/geometry/.cd,
  a0/.initial=0,
  a/.initial=2,
  r/.initial=0.25,
  w/.initial=0.4,
/robotarm/config/q/.initial=0,
/robotarm/frames/.cd,
  in link 0/.style={},
  in end effector/.style={
    /robotarm/frames/in link \RA@robotarm@numlinks,
    shift={%
      (\pgfkeysvalueof{/robotarm/geometry/a\RA@robotarm@numlinks},0)},
  },
  in world/.style={
    shift={(0,-\RA@baselink@height)}
  },
/robotarm/styles/.cd,
  world/.style={pattern=north west lines},
  link/.style={
    draw,
    fill=lightgray,
  },
  link 0/.style={/robotarm/styles/link},
/robotarm/annotations/.cd,
  spacing/.cd,
    a/.initial=3,
    q/.initial=1/2,
/robotarm/annotations/.cd,
  labels/.cd,
    a/.initial=a,
```

```
      q/.initial=q,
}
\tikzset{
  link style/.style={/robotarm/styles/link},
  world style/.style={/robotarm/styles/world},
}
```

\robotarmset

```
\newcommand\robotarmset[1]{%
  \pgfkeys{/robotarm/.cd,#1}%
}
```

\robotArmLink

```
\newcommand\robotArmLink[1][]{
  \begingroup
    \pgfkeys{/robotarm/link/.cd,#1}

    \pgfkeys{/robotarm/link/draw link}
    \pgfkeys{/robotarm/link/draw joint}
  \endgroup
}
```

\robotArmEndEffector

```
\newcommand\robotArmEndEffector[1][]{
  \begingroup
    \pgfkeys{/robotarm/end effector/.cd,#1}

    \pgfkeys{/robotarm/end effector/draw link}
    \pgfkeys{/robotarm/end effector/draw joint}
    \pgfkeys{/robotarm/end effector/draw end effector}

  \endgroup
}
```

\robotArmBaseLink

```
\newcommand\robotArmBaseLink[1][]{
  \begingroup
    \pgfkeys{/robotarm/base link/.cd,#1}

    \pgfkeys{/robotarm/base link/draw world}
    \pgfkeys{/robotarm/base link/draw base link}
  \endgroup
}
```

\robotArm

```
\newcommand\robotArm[2][]{
  \pgfmathtruncatemacro\RA@robotarm@numlinks{#2}
  \def\@tmpkeys{}
```

```
\foreach \@link [remember=\@link as \@prevlink (initially 0)] in %
  {1,...,\RA@robotarm@numlinks}{
  \xdef\@tmpkeys{\@tmpkeys%
    /robotarm/geometry/a\@link/.initial=%
      \pgfkeysvalueof{/robotarm/geometry/a},%
    /robotarm/geometry/r\@link/.initial=%
      \pgfkeysvalueof{/robotarm/geometry/r},%
    /robotarm/geometry/w\@link/.initial=%
      \pgfkeysvalueof{/robotarm/geometry/w},%
    /robotarm/config/q\@link/.initial=%
      \pgfkeysvalueof{/robotarm/config/q},%
    /robotarm/styles/link \@link/.style={/robotarm/styles/link},%
    /robotarm/annotations/labels/a\@link/.initial={%
      $\pgfkeysvalueof{/robotarm/annotations/labels/a}_{\@link}$},%
    /robotarm/annotations/labels/q\@link/.initial={%
      $\pgfkeysvalueof{/robotarm/annotations/labels/q}_{\@link}$},%
    /robotarm/annotations/spacing/a\@link/.initial={%
      \pgfkeysvalueof{/robotarm/annotations/spacing/a}},%
    /robotarm/annotations/spacing/q\@link/.initial={%
      \pgfkeysvalueof{/robotarm/annotations/spacing/q}},%
  }
}
\expandafter\pgfkeys\expandafter{\@tmpkeys}
\pgfkeys{/robotarm/.cd,#1}
\def\@tmpkeys{}
\foreach \@link [remember=\@link as \@prevlink (initially 0)] in %
  {1,...,\RA@robotarm@numlinks}{
  \xdef\@tmpkeys{\@tmpkeys%
    /robotarm/frames/in link \@link/.style={%
      /robotarm/frames/in link \@prevlink,
      /tikz/shift={%
        (\pgfkeysvalueof{/robotarm/geometry/a\@prevlink},0)},
      /tikz/rotate={\pgfkeysvalueof{/robotarm/config/q\@link}},
    },
  }
}
\expandafter\pgfkeys\expandafter{\@tmpkeys}

\begin{scope}[/robotarm/frames/in link 0,
              link style/.style={/robotarm/styles/link 0}]
  \robotArmBaseLink
\end{scope}

\foreach\link@num in {1,...,\RA@robotarm@numlinks}{
  \begin{scope}[/robotarm/frames/in link \link@num,
                link style/.style={/robotarm/styles/link \link@num}]

    \ifnum\link@num<\RA@robotarm@numlinks
      \robotArmLink[
        joint radius=\pgfkeysvalueof{/robotarm/geometry/r\link@num},
```

```
        length=\pgfkeysvalueof{/robotarm/geometry/a\link@num},
        width=\pgfkeysvalueof{/robotarm/geometry/w\link@num},
      ]
    \else
      \robotArmEndEffector[
        joint radius=\pgfkeysvalueof{/robotarm/geometry/r\link@num},
        length=\pgfkeysvalueof{/robotarm/geometry/a\link@num},
        width=\pgfkeysvalueof{/robotarm/geometry/w\link@num},
      ]
    \fi
  \end{scope}
}
\foreach\link@num in {1,...,\RA@robotarm@numlinks}{
  \begin{scope}[/robotarm/frames/in link \link@num]
    \pgfmathsetmacro\link@length{\pgfkeysvalueof{%
      /robotarm/geometry/a\link@num}}
    \pgfmathsetmacro\link@angle{\pgfkeysvalueof{%
      /robotarm/config/q\link@num}}

    \ifRA@robotarm@drawannotations
      \pgfmathsetmacro\link@lengthannotspacing{%
        \pgfkeysvalueof{/robotarm/annotations/spacing/a\link@num}*
          \pgfkeysvalueof{/robotarm/geometry/r\link@num}}
      \pgfmathsetmacro\link@angleannotspacing{%
        \pgfkeysvalueof{/robotarm/annotations/spacing/q\link@num}*
          \link@length}

      % Length annotation help lines
      \path[/robotarm/every annotation,
            /robotarm/every length annotation,
            /robotarm/every length annotation help line]
        (0,0) -- (\link@length,0);
      \path[/robotarm/every annotation,
            /robotarm/every length annotation,
            /robotarm/every length annotation help line]
        (0,0) -- ++ (0,{\link@lengthannotspacing +
          0.1*sign(\link@lengthannotspacing)});
      \path[/robotarm/every annotation,
            /robotarm/every length annotation,
            /robotarm/every length annotation help line]
        (\link@length,0) -- ++ (0,{\link@lengthannotspacing +
          0.1*sign(\link@lengthannotspacing)});
```

Length annotation node

```
      \path (0,\link@lengthannotspacing)
        -- coordinate[pos=0.5] (coor) ++ (\link@length,0);
      \node[/robotarm/every annotation,
            /robotarm/every length annotation,
            /robotarm/every length annotation node]
        at (coor) (tag)
```

```
          {\pgfkeysvalueof{/robotarm/annotations/labels/a\link@num}};
```

Length annotation arrows

```
        \path[/robotarm/every annotation,
              /robotarm/every length annotation,
              /robotarm/every length annotation arrow]
          (tag) -- (0,\link@lengthannotspacing);
        \path[/robotarm/every annotation,
              /robotarm/every length annotation,
              /robotarm/every length annotation arrow]
          (tag) -- (\link@length,\link@lengthannotspacing);

        \pgfmathsetmacro\angleannotationcase{%
          ifthenelse(\link@angle==0.0, 0, 1)}
        \ifnum\angleannotationcase>0
          % Angle annotation help lines
          \path[/robotarm/every annotation,
                /robotarm/every angle annotation,
                /robotarm/every angle annotation help line]
            (0,0) -- ++(-\link@angle:{\link@angleannotspacing+0.1});
          \path[/robotarm/every annotation,
                /robotarm/every angle annotation,
                /robotarm/every angle annotation help line]
            (0,0) -- ++(0:{\link@angleannotspacing+0.1});

          % Angle annotation arrow
          \path[/robotarm/every annotation,
                /robotarm/every angle annotation,
                /robotarm/every angle annotation arrow]
            (0,0) ++ (-\link@angle:\link@angleannotspacing)
            arc (-\link@angle:0:\link@angleannotspacing);

          % Angle annotation node
          \node[/robotarm/every annotation,
                /robotarm/every angle annotation,
                /robotarm/every angle annotation node]
            at (-\link@angle/2:\link@angleannotspacing+0.3)
            {\pgfkeysvalueof{/robotarm/annotations/labels/q\link@num}};
        \fi
      \fi
    \end{scope}
  }
```

Install Ti*k*Z styles for coordinate transformations.

```
  \tikzset{
    in link/.style={/robotarm/frames/in link #1},
    in base link/.style={/robotarm/frames/in link 0},
    in end effector/.style={/robotarm/frames/in end effector},
    in world/.style={/robotarm/frames/in world},
  }
}
```

```
\makeatother
⟨/robotarm-package⟩
```

Bibliography

[1] Till Tantau. *The TikZ and PGF Packages. Manual for version 3.1.8b*. Mar. 19, 2021. URL: https://mirrors.ctan.org/graphics/pgf/base/doc/pgfmanual.pdf.

Index

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Change History

v0.1
General: Initial version for publishing 1