

The *robotarm* package

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Abstract

With the *robotarm* package, you can draw configurable planar robot arms with ease, using TikZ. 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`).

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1 Macros

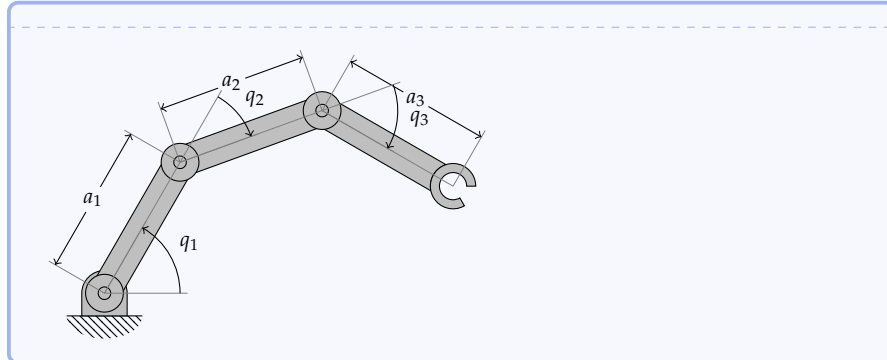
1.1 `robotArm`

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

This is the main macro of the *robotarm* package. It is meant to be used in the `tikzpicture` environment¹, from the TikZ [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}
```

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



$\langle num \rangle$ 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 $\langle key\text{-value list} \rangle$ values can consist of the keys listed below.

geometry= $\langle key\text{-value list} \rangle$

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 $\langle key\text{-value list} \rangle$ can be one or more of the following.

a= $\langle value \rangle$ (initially 2)

a $\langle num \rangle$ = $\langle value \rangle$ (initially the value of **a**)

The **a** key sets the default length for all links that are drawn in the $\backslash\text{robotArm}^{\text{P.1}}$ command. For every link, this can be overruled by the dynamically created keys **a** $\langle num \rangle$, e.g. to set only the length of link 3 to 3, use **a3**=3.

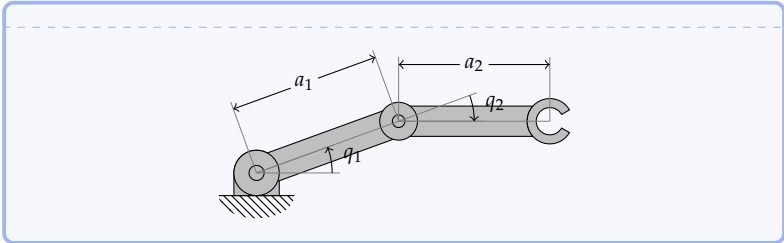
```
\robotArm[config={q1=20,q2=-20,q3=-20},
  geometry={a=3,a3=1}]{3}
```

r= $\langle value \rangle$ (initially 0.25)

r $\langle num \rangle$ = $\langle value \rangle$ (initially the value of **r**)

The **r** key sets the default joint radius for all links drawn in the $\backslash\text{robotArm}^{\text{P.1}}$ command. For every link this can be overruled by the dynamically created keys **r** $\langle num \rangle$.

```
\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

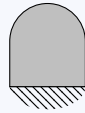
```

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.

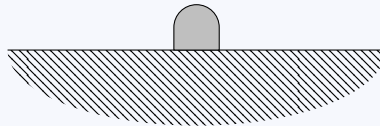
```
\robotArmBaseLink[width=1, height=0.6]
```



`/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.

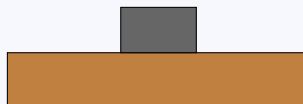
```
\robotArmBaseLink[world width=5, world height=1]
```



`/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);  
  }]  
]
```



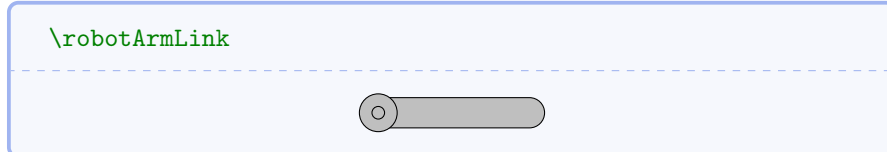
To access the values of the keys listed above you can use the following macros in your redefinition:

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

1.3 robotArmLink

`\robotArmLink[⟨key-value list⟩]`

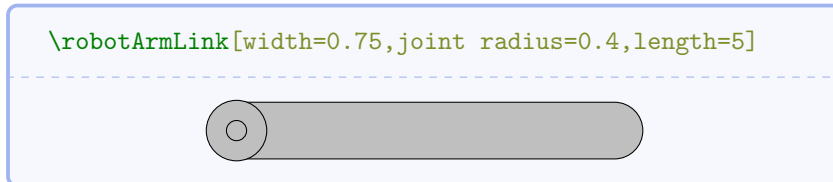
This command is used in `\robotArm→P.1` to draw the links in a foreach loop. It can also be used to draw your own link(s). The default link looks as follows:



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

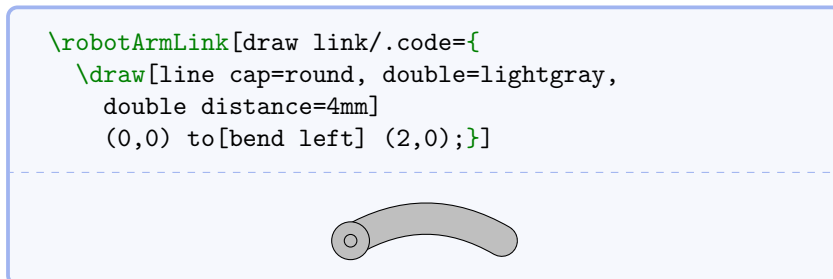
```
/robotarm/link/width=⟨value⟩ (initially 0.4)  
/robotarm/link/length=⟨value⟩ (initially 2.0)  
/robotarm/link/joint radius=⟨value⟩ (initially 0.25)
```

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

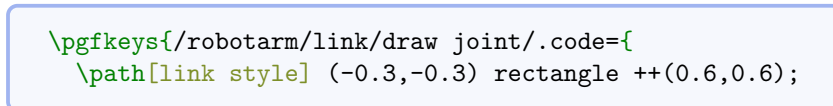


```
/robotarm/link/draw link (code executing key)  
/robotarm/link/draw joint (code executing key)
```

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



Of course you can also do this globally so it applies to all links².

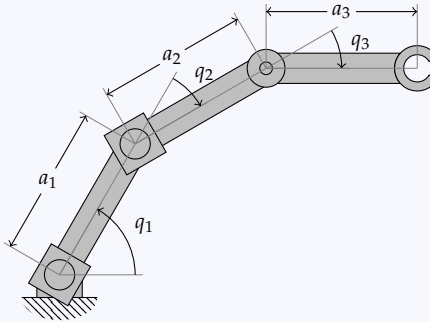


²For the end effector to change too, you have to redefine `/robotarm/end effector/draw joint→P.7` too.

```

\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@joinradius`.

1.4 robotArmEndEffector

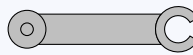
`\robotArmEndEffector` [*key-value list*]

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.

<code>/robotarm/end effector/width=<i>value</i></code>	(initially 0.4)
<code>/robotarm/end effector/length=<i>value</i></code>	(initially 2.0)
<code>/robotarm/end effector/joint radius=<i>value</i></code>	(initially 0.25)
<code>/robotarm/end effector/gripper radius=<i>value</i></code>	(initially 0.3)
<code>/robotarm/end effector/gripper opening angle=<i>angle</i></code>	(initially 60)

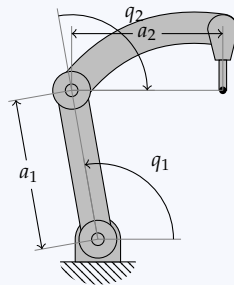
The geometrical properties of the final link and the end effector, which defaults to a gripper, can be tuned with these keys. Due to some trigonometric functions in the drawing code of `/robotarm/end effector/draw`

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@joinradius,
- \RA@endeff@gripperradius, and
- \RA@endeff@gripperopeningangle.

2 TikZ styles

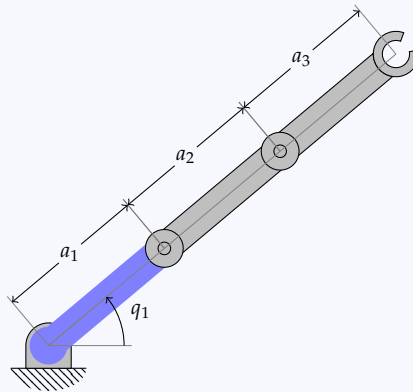
```
/tikz/in link=<number> (style)  
/tikz/in base link (style)  
/tikz/in world (style)  
/tikz/in end effector (style)
```

Only installed after calling $\backslash\text{robotArm}^{\text{P.1}}$ 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 $\text{/robotarm/styles/link}^{\text{P.3}}$. Only works one way. To change link styles used in $\backslash\text{robotArm}^{\text{P.1}}$, change the appropriate $\text{/robotarm/styles/link}^{\text{P.3}}$.

```
\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
```



```

12 \newif\ifRA@robotarm@drawannotations
13
14 \pgfkeys{
15   /robotarm/base link/.cd,
16   width/.code={\pgfmathsetmacro\RA@baselink@width{#1}},
17   width=0.6,
18   height/.code={\pgfmathsetmacro\RA@baselink@height{#1}},
19   height=0.3,
20   world width/.code={\pgfmathsetmacro\RA@baselink@worldwidth{#1}},
21   world width=1.0,
22   world height/.code={\pgfmathsetmacro\RA@baselink@worldheight{#1}},
23   world height=0.3,
24   draw base link/.code={%
25     \path[link style]
26       (-1/2*\RA@baselink@width,0)
27       arc (180:0:1/2*\RA@baselink@width)
28       -- ++ (0, -\RA@baselink@height)
29       -- ++ (-\RA@baselink@width, 0)
30       -- cycle;
31   },
32   draw world/.code={%
33     \path[world style]
34       (-1/2*\RA@baselink@worldwidth,-\RA@baselink@height)
35       arc (180:360:{1/2*\RA@baselink@worldwidth}
36         and {\RA@baselink@worldheight}) -- cycle;
37     \path[draw, world style]
38       (-1/2*\RA@baselink@worldwidth,-\RA@baselink@height)
39       -- ++(\RA@baselink@worldwidth,0);
40   },
41   /robotarm/link/.cd,
42   width/.code={\pgfmathsetmacro\RA@link@width{#1}},
43   width=0.4,
44   length/.code={\pgfmathsetmacro\RA@link@length{#1}},
45   length=2.0,
46   joint radius/.code={\pgfmathsetmacro\RA@link@joinradius{#1}},
47   joint radius=0.25,
48   draw link/.code={%
49     \path[link style]
50       (0,1/2*\RA@link@width)
51       -- ++ ( \RA@link@length, 0)
52       arc (90:-90:1/2*\RA@link@width)
53       -- ++ (-\RA@link@length, 0)
54       arc (270:90:1/2*\RA@link@width)
55       -- cycle;
56   },
57   draw joint/.code={%
58     \path[link style]
59       (0,0) circle (\RA@link@joinradius);
60     \path[link style]
61       (0,0) circle (1/3*\RA@link@joinradius);

```

```

62   },
63 /robotarm/end effector/.cd,
64   width/.code={\pgfmathsetmacro\RA@endeff@width{#1}},
65   width=0.4,
66   length/.code={\pgfmathsetmacro\RA@endeff@length{#1}},
67   length=2,
68   joint radius/.code={\pgfmathsetmacro\RA@endeff@jointradius{#1}},
69   joint radius=0.25,
70   gripper radius/.code={\pgfmathsetmacro\RA@endeff@gripperradius{#1}},
71   gripper radius=0.3,
72   gripper opening angle/.code={%
73     \pgfmathsetmacro\RA@endeff@gripperopeningangle{#1}},
74   gripper opening angle=60,
75   draw joint/.code={%
76     \path[link style]
77       (0,0) circle (\RA@endeff@jointradius);
78     \path[link style]
79       (0,0) circle (1/3*\RA@endeff@jointradius);
80   },
81   draw link/.code={%
82     \pgfmathsetmacro{\link@startangle}{%
83       180-asin(1/2*\RA@endeff@width/\RA@endeff@gripperradius)}
84     \pgfmathsetmacro{\link@endangle}{%
85       180+asin(1/2*\RA@endeff@width/\RA@endeff@gripperradius)}
86
87     \path[link style]
88       (\RA@endeff@length, 0)
89       ++ (\link@startangle:\RA@endeff@gripperradius)
90       arc (\link@startangle:\link@endangle:\RA@endeff@gripperradius)
91       -- (0,0|-0,-1/2*\RA@endeff@width)
92       arc (-90:90:1/2*\RA@endeff@width)
93       -- cycle;
94   },
95   draw end effector/.code={
96     \draw[link style]
97       (\RA@endeff@length, 0)
98       ++ (-1/2*\RA@endeff@gripperopeningangle:%
99         \RA@endeff@gripperradius)
100      arc [start angle=-1/2*\RA@endeff@gripperopeningangle,
101          delta angle=-360+\RA@endeff@gripperopeningangle,
102          radius=\RA@endeff@gripperradius]
103      -- ++(180+1/2*\RA@endeff@gripperopeningangle:%
104          0.4*\RA@endeff@gripperradius)
105      arc [start angle=1/2*\RA@endeff@gripperopeningangle,
106          delta angle=360-\RA@endeff@gripperopeningangle,
107          radius=0.6*\RA@endeff@gripperradius]
108      -- ++(-1/2*\RA@endeff@gripperopeningangle:%
109          0.4*\RA@endeff@gripperradius)
110      -- cycle;
111   },

```

```

112 /robotarm/.cd,
113   draw annotations/.is if=RA@robotarm@drawannotations,
114   draw annotations=true,
115   every annotation/.style={},
116   every length annotation/.style={},
117   every length annotation arrow/.style={draw,->},
118   every length annotation node/.style={circle,inner sep=0.5pt},
119   every length annotation help line/.style={draw,help lines},
120   every angle annotation/.style={},
121   every angle annotation arrow/.style={draw,->},
122   every angle annotation node/.style={},
123   every angle annotation help line/.style={draw,help lines},
124   base link/.code=\pgfkeys{/robotarm/base link/.cd,#1},
125   link/.code=\pgfkeys{/robotarm/link/.cd,#1},
126   end effector/.code=\pgfkeys{/robotarm/end effector/.cd,#1},
127   geometry/.code=\pgfkeys{/robotarm/geometry/.cd,#1},
128   config/.code=\pgfkeys{/robotarm/config/.cd,#1},
129   spacing/.code=\pgfkeys{/robotarm/annotations/spacing/.cd,#1},
130   labels/.code=\pgfkeys{/robotarm/annotations/labels/.cd,#1},
131   styles/.code=\pgfkeys{/robotarm/styles/.cd,#1},
132 /robotarm/geometry/.cd,
133   a0/.initial=0,
134   a/.initial=2,
135   r/.initial=0.25,
136   w/.initial=0.4,
137 /robotarm/config/q/.initial=0,
138 /robotarm/frames/.cd,
139   in link 0/.style={},
140   in end effector/.style={
141     /robotarm/frames/in link \RA@robotarm@numlinks,
142     shift={%
143       (\pgfkeysvalueof{/robotarm/geometry/a\RA@robotarm@numlinks},0)},
144   },
145   in world/.style={
146     shift={(0,-\RA@baselink@height)}
147   },
148 /robotarm/styles/.cd,
149   world/.style={pattern=north west lines},
150   link/.style={
151     draw,
152     fill=lightgray,
153   },
154   link 0/.style={/robotarm/styles/link},
155 /robotarm/annotations/.cd,
156   spacing/.cd,
157     a/.initial=3,
158     q/.initial=1/2,
159 /robotarm/annotations/.cd,
160   labels/.cd,
161     a/.initial=a,

```

```

162     q/.initial=q,
163 }
164 \tikzset{
165   link style/.style={/robotarm/styles/link},
166   world style/.style={/robotarm/styles/world},
167 }

\robotarmset
168 \newcommand\robotarmset[1]{%
169   \pgfkeys{/robotarm/.cd,#1}%
170 }

\robotArmLink
171 \newcommand\robotArmLink[1][]{
172   \begingroup
173     \pgfkeys{/robotarm/link/.cd,#1}
174
175     \pgfkeys{/robotarm/link/draw link}
176     \pgfkeys{/robotarm/link/draw joint}
177   \endgroup
178 }

\robotArmEndEffector
179 \newcommand\robotArmEndEffector[1][]{
180   \begingroup
181     \pgfkeys{/robotarm/end effector/.cd,#1}
182
183     \pgfkeys{/robotarm/end effector/draw link}
184     \pgfkeys{/robotarm/end effector/draw joint}
185     \pgfkeys{/robotarm/end effector/draw end effector}
186
187   \endgroup
188 }

\robotArmBaseLink
189 \newcommand\robotArmBaseLink[1][]{
190   \begingroup
191     \pgfkeys{/robotarm/base link/.cd,#1}
192
193     \pgfkeys{/robotarm/base link/draw world}
194     \pgfkeys{/robotarm/base link/draw base link}
195   \endgroup
196 }

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

```

```

200 \foreach \@link [remember=\@link as \@prevlink (initially 0)] in %
201 {1,...,\RA@robotarm@numlinks}{
202   \xdef\@tmpkeys{\@tmpkeys%
203     /robotarm/geometry/a\@link/.initial=%
204     \pgfkeysvalueof{/robotarm/geometry/a},%
205     /robotarm/geometry/r\@link/.initial=%
206     \pgfkeysvalueof{/robotarm/geometry/r},%
207     /robotarm/geometry/w\@link/.initial=%
208     \pgfkeysvalueof{/robotarm/geometry/w},%
209     /robotarm/config/q\@link/.initial=%
210     \pgfkeysvalueof{/robotarm/config/q},%
211     /robotarm/styles/link \@link/.style={/robotarm/styles/link},%
212     /robotarm/annotations/labels/a\@link/.initial={%
213     $\pgfkeysvalueof{/robotarm/annotations/labels/a}_{\@link}$},%
214     /robotarm/annotations/labels/q\@link/.initial={%
215     $\pgfkeysvalueof{/robotarm/annotations/labels/q}_{\@link}$},%
216     /robotarm/annotations/spacing/a\@link/.initial={%
217     \pgfkeysvalueof{/robotarm/annotations/spacing/a}},%
218     /robotarm/annotations/spacing/q\@link/.initial={%
219     \pgfkeysvalueof{/robotarm/annotations/spacing/q}},%
220   }
221 }
222 \expandafter\pgfkeys\expandafter{\@tmpkeys}
223 \pgfkeys{/robotarm/.cd,#1}
224 \def\@tmpkeys{
225 \foreach \@link [remember=\@link as \@prevlink (initially 0)] in %
226 {1,...,\RA@robotarm@numlinks}{
227   \xdef\@tmpkeys{\@tmpkeys%
228     /robotarm/frames/in link \@link/.style={%
229     /robotarm/frames/in link \@prevlink,
230     /tikz/shift={%
231     (\pgfkeysvalueof{/robotarm/geometry/a\@prevlink},0)},
232     /tikz/rotate={\pgfkeysvalueof{/robotarm/config/q\@link}},
233   },
234   }
235 }
236 \expandafter\pgfkeys\expandafter{\@tmpkeys}
237
238 \begin{scope}[/robotarm/frames/in link 0,
239   link style/.style={/robotarm/styles/link 0}]
240   \robotArmBaseLink
241 \end{scope}
242
243 \foreach\link@num in {1,...,\RA@robotarm@numlinks}{
244   \begin{scope}[/robotarm/frames/in link \link@num,
245     link style/.style={/robotarm/styles/link \link@num}]
246
247     \ifnum\link@num<\RA@robotarm@numlinks
248       \robotArmLink[
249         joint radius=\pgfkeysvalueof{/robotarm/geometry/r\link@num},

```

```

250     length=\pgfkeysvalueof{/robotarm/geometry/a\link@num},
251     width=\pgfkeysvalueof{/robotarm/geometry/w\link@num},
252   ]
253   \else
254     \robotArmEndEffector[
255       joint radius=\pgfkeysvalueof{/robotarm/geometry/r\link@num},
256       length=\pgfkeysvalueof{/robotarm/geometry/a\link@num},
257       width=\pgfkeysvalueof{/robotarm/geometry/w\link@num},
258     ]
259   \fi
260 \end{scope}
261 }
262 \foreach\link@num in {1,...,\RA@robotarm@numlinks}{
263   \begin{scope}[/robotarm/frames/in link \link@num]
264     \pgfmathsetmacro\link@length{\pgfkeysvalueof{/
265       /robotarm/geometry/a\link@num}}
266     \pgfmathsetmacro\link@angle{\pgfkeysvalueof{/
267       /robotarm/config/q\link@num}}
268
269     \ifRA@robotarm@drawannotations
270       \pgfmathsetmacro\link@lengthannotspacing{%
271         \pgfkeysvalueof{/robotarm/annotations/spacing/a\link@num}*
272         \pgfkeysvalueof{/robotarm/geometry/r\link@num}}
273       \pgfmathsetmacro\link@angleannotspacing{%
274         \pgfkeysvalueof{/robotarm/annotations/spacing/q\link@num}*
275         \link@length}
276
277       % Length annotation help lines
278       \path[/robotarm/every annotation,
279         /robotarm/every length annotation,
280         /robotarm/every length annotation help line]
281         (0,0) -- (\link@length,0);
282       \path[/robotarm/every annotation,
283         /robotarm/every length annotation,
284         /robotarm/every length annotation help line]
285         (0,0) -- ++ (0,{\link@lengthannotspacing +
286           0.1*sign(\link@lengthannotspacing)});
287       \path[/robotarm/every annotation,
288         /robotarm/every length annotation,
289         /robotarm/every length annotation help line]
290         (\link@length,0) -- ++ (0,{\link@lengthannotspacing +
291           0.1*sign(\link@lengthannotspacing)});
292
293       Length annotation node
294       \path (0,\link@lengthannotspacing)
295         -- coordinate[pos=0.5] (coor) ++ (\link@length,0);
296       \node[/robotarm/every annotation,
297         /robotarm/every length annotation,
298         /robotarm/every length annotation node]
299         at (coor) (tag)

```

```

298         {\pgfkeysvalueof{/robotarm/annotations/labels/a\link@num}};
Length annotation arrows
299     \path[/robotarm/every annotation,
300           /robotarm/every length annotation,
301           /robotarm/every length annotation arrow]
302     (tag) -- (0,\link@lengthannotspacing);
303     \path[/robotarm/every annotation,
304           /robotarm/every length annotation,
305           /robotarm/every length annotation arrow]
306     (tag) -- (\link@length,\link@lengthannotspacing);
307
308     \pgfmathsetmacro\angleannotationcase{%
309     ifthenelse(\link@angle==0.0, 0, 1)}
310     \ifnum\angleannotationcase>0
311     % Angle annotation help lines
312     \path[/robotarm/every annotation,
313           /robotarm/every angle annotation,
314           /robotarm/every angle annotation help line]
315     (0,0) -- ++(-\link@angle:\link@angleannotspacing+0.1);
316     \path[/robotarm/every annotation,
317           /robotarm/every angle annotation,
318           /robotarm/every angle annotation help line]
319     (0,0) -- ++(0:\link@angleannotspacing+0.1);
320
321     % Angle annotation arrow
322     \path[/robotarm/every annotation,
323           /robotarm/every angle annotation,
324           /robotarm/every angle annotation arrow]
325     (0,0) ++ (-\link@angle:\link@angleannotspacing)
326     arc (-\link@angle:0:\link@angleannotspacing);
327
328     % Angle annotation node
329     \node[/robotarm/every annotation,
330           /robotarm/every angle annotation,
331           /robotarm/every angle annotation node]
332     at (-\link@angle/2:\link@angleannotspacing+0.3)
333     {\pgfkeysvalueof{/robotarm/annotations/labels/q\link@num}};
334     \fi
335     \fi
336     \end{scope}
337 }

Install TikZ styles for coordinate transformations.
338 \tikzset{
339   in link/.style={/robotarm/frames/in link #1},
340   in base link/.style={/robotarm/frames/in link 0},
341   in end effector/.style={/robotarm/frames/in end effector},
342   in world/.style={/robotarm/frames/in world},
343 }
344 }

```

```
345 \makeatother
346 \end{document}
```


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>.

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Change History

v0.1
General: Initial version for

publishing 1