

# The triangletools package

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# 1 Introduction

This package aims to help you construct special points in a triangle directly in a short and easy way. Using this package, you can construct most important points listed in Clark Kimberling's Encyclopedia of Triangle Centers (ETC). Currently, all points numbered from  $X_1$  and  $X_{10}$ , as well as the excenter, are supported; however with other utilities in this package (see Section 3.4) and a bit of knowledge in geometry and expl3 programming, you can construct even more.

## 2 Loading the package

This package can be loaded as usual.

```
1 \usepackage{triangletools}
```

It will load TikZ and expl3 automatically.

## 3 User interface

The user interface of this package, including that of the utilities, is provided as pgf keys under the tree `/tikz/triangletools`.

Note that, in the following sections, a *coordinate* means a *named* TikZ coordinate. That is, in the following example,

```
1 \begin{tikzpicture}
2   \draw (0,0) -- (3,0) coordinate (a);
3 \end{tikzpicture}
```

`a` is a named coordinate, while `0,0` or `3,0` are *not* named coordinates. The current implementation of this package only allows named coordinates in the user interface. It is like the `angles` TikZ library.

### 3.1 Accessing the keys

---

`/tikz/trt` `/tikz/trt={\langle keys \rangle}`

It executes *keys* with the key path set to `/tikz/triangletools`, which is the main key tree of this package.

This key is used to access all other keys in the user interface.

### 3.2 Circles associated with triangle centers

---

`\trtradius`

---

Some points, for example the incenter and the circumcenter, are associated with some special circles. If the requested point is associated with a circle, this macro stores the radius of that circle, in points (pt).

This macro is assigned *globally* every time a point is requested. Therefore, it stores the radius related to the last point that has a circle. So beware that while it always gives you some values once you have drawn such points, that value might not be what you want. It is recommended to use this macro *immediately after* the execution of triangle center keys.

In Section 3.3, if a point has a `\trtradius` associated to it, the circle will be drawn in the code example. Currently  $X_1$ , the excenter,  $X_3$ ,  $X_5$  and  $X_{10}$  can change the value of `\trtradius`.

If the macro is used before any center with a circle is constructed, an error message will be issued.

### 3.3 Triangle centers

---

`incenter`

---

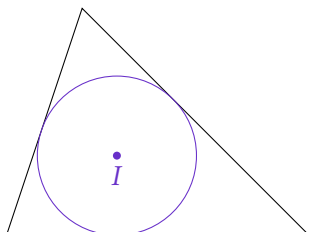
`\trt_sp_incenter:nnnn`

---

```
/tikz/triangletools/incenter=(\langle coor 1 \rangle)(\langle coor 2 \rangle)(\langle coor 3 \rangle)
\trt_sp_incenter:nnnn {\langle coor 1 \rangle}{\langle coor 2 \rangle}{\langle coor 3 \rangle}{\langle name \rangle}
```

Find the incenter  $X_1$  of the triangle joining TikZ coordinates  $\langle coor 1 \rangle$ ,  $\langle coor 2 \rangle$  and  $\langle coor 3 \rangle$ . The incenter is saved to TikZ coordinate  $\langle name \rangle$ .

If you use the key (why do you use the function anyway),  $\langle name \rangle$  is set to `trt output` by default. You can change that using output name, see Section 3.5.



```
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3     (0,0) coordinate (b) --
4     (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={incenter=(a)(b)(c)}] (trt output)
6     circle[radius=1.5pt] node[below] {$I$};
7   \draw[maincolor] (trt output) circle (\trtradius);
8 \end{tikzpicture}
```

---

`excenter`

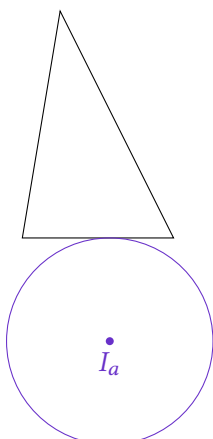
---

`\trt_sp_excenter:nnnn`

---

```
/tikz/triangletools/excenter=(\langle coor 1 \rangle)(\langle coor 2 \rangle)(\langle coor 3 \rangle)
\trt_sp_excenter:nnnn {\langle coor 1 \rangle}{\langle coor 2 \rangle}{\langle coor 3 \rangle}{\langle name \rangle}
```

Find the excenter of the triangle. The returned point will be on the internal angular bisector at  $\langle coor 1 \rangle$ . Note that the order matters: `excenter=(a)(b)(c)` is *different* from `excenter=(b)(a)(c)`.

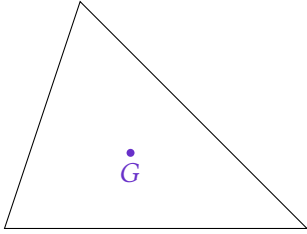


```
1 \begin{tikzpicture}
2   \draw (.5,3) coordinate (a) --
3     (0 ,0) coordinate (b) --
4     (2 ,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={excenter=(a)(b)(c)}] (trt output)
6     circle[radius=1.5pt] node[below] {$I_a$};
7   \draw[maincolor] (trt output) circle (\trtradius);
8 \end{tikzpicture}
```

---

centroid  
 $\backslash\mathrm{trt\_sp\_centroid:nnnn}$

---



$\backslash\mathrm{tikz/triangletools/centroid}=(\langle\mathrm{coor\ 1}\rangle)(\langle\mathrm{coor\ 2}\rangle)(\langle\mathrm{coor\ 3}\rangle)$   
 $\backslash\mathrm{trt\_sp\_centroid:nnnn}\ \{\langle\mathrm{coor\ 1}\rangle\}\{\langle\mathrm{coor\ 2}\rangle\}\{\langle\mathrm{coor\ 3}\rangle\}\{\langle\mathrm{name}\rangle\}$

Find the centroid  $X_2$  of the triangle.

```

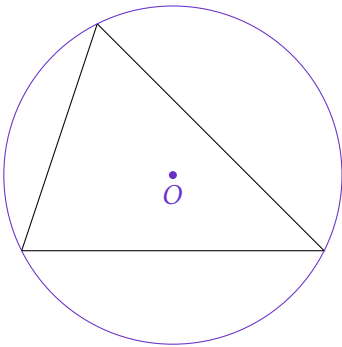
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={centroid=(a)(b)(c)}] (trt output)
6     circle[radius=1.5pt] node[below] {$G$};
7 \end{tikzpicture}

```

---

circumcenter  
 $\backslash\mathrm{trt\_sp\_circumcenter:nnnn}$

---



$\backslash\mathrm{tikz/triangletools/circumcenter}=(\langle\mathrm{coor\ 1}\rangle)(\langle\mathrm{coor\ 2}\rangle)(\langle\mathrm{coor\ 3}\rangle)$   
 $\backslash\mathrm{trt\_sp\_circumcenter:nnnn}\ \{\langle\mathrm{coor\ 1}\rangle\}\{\langle\mathrm{coor\ 2}\rangle\}\{\langle\mathrm{coor\ 3}\rangle\}\{\langle\mathrm{name}\rangle\}$

Find the circumcenter  $X_3$  of the triangle.

```

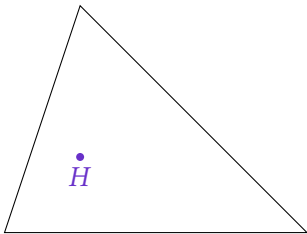
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={circumcenter=(a)(b)(c)}] (trt output)
6     circle[radius=1.5pt] node[below] {$O$};
7   \draw[maincolor] (trt output) circle (\trtradius);
8 \end{tikzpicture}

```

---

orthocenter  
 $\backslash\mathrm{trt\_sp\_orthocenter:nnnn}$

---



$\backslash\mathrm{tikz/triangletools/orthocenter}=(\langle\mathrm{coor\ 1}\rangle)(\langle\mathrm{coor\ 2}\rangle)(\langle\mathrm{coor\ 3}\rangle)$   
 $\backslash\mathrm{trt\_sp\_orthocenter:nnnn}\ \{\langle\mathrm{coor\ 1}\rangle\}\{\langle\mathrm{coor\ 2}\rangle\}\{\langle\mathrm{coor\ 3}\rangle\}\{\langle\mathrm{name}\rangle\}$

Find the orthocenter  $X_4$  of the triangle.

```

1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={orthocenter=(a)(b)(c)}] (trt output)
6     circle[radius=1.5pt] node[below] {$H$};
7 \end{tikzpicture}

```

---

triangle\_center

---

$\backslash\mathrm{tikz/triangletools/triangle\ center}=(\langle\mathrm{coor\ 1}\rangle)(\langle\mathrm{coor\ 2}\rangle)(\langle\mathrm{coor\ 3}\rangle)(\langle\mathrm{index}\rangle)$

Find the point  $X_{\langle\mathrm{index}\rangle}$  of the triangle. Currently  $\langle\mathrm{index}\rangle$  can be any integer between and including 1 and 10.

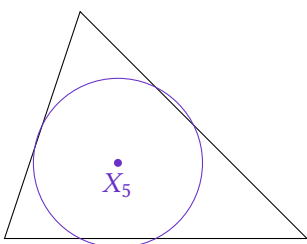
---

$\backslash\mathrm{trt\_sp\_ninepointcenter:nnnn}$

---

$\backslash\mathrm{tikz/triangletools/triangle\ center}=(\langle\mathrm{coor\ 1}\rangle)(\langle\mathrm{coor\ 2}\rangle)(\langle\mathrm{coor\ 3}\rangle)(5)$   
 $\backslash\mathrm{trt\_sp\_ninepointcenter:nnnn}\ \{\langle\mathrm{coor\ 1}\rangle\}\{\langle\mathrm{coor\ 2}\rangle\}\{\langle\mathrm{coor\ 3}\rangle\}\{\langle\mathrm{name}\rangle\}$

Find the nine-point center  $X_5$  of the triangle.



```

1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={triangle center=(a)(b)(c)(5)}] (trt output)
6     circle[radius=1.5pt] node[below] {$X_5$};
7   \draw[maincolor] (trt output) circle (\trtradius);
8 \end{tikzpicture}

```

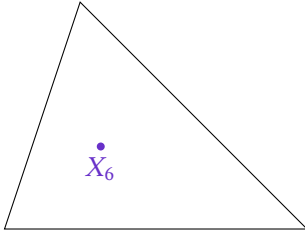
---

---

`\trt_sp_symmedian:nnnn`

`/tikz/triangletools/triangle center=(\langle coor 1\rangle)(\langle coor 2\rangle)(\langle coor 3\rangle)(6)`  
`\trt_sp_symmedian:nnnn {\langle coor 1\rangle}{\langle coor 2\rangle}{\langle coor 3\rangle}{\langle name\rangle}`

Find the symmedian point  $X_6$  (aka. the Lemoine point or Grebe point) of the triangle.



```
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={triangle center=(a)(b)(c)(6)}] (trt output)
6     circle[radius=1.5pt] node[below] {$X_6$};
7 \end{tikzpicture}
```

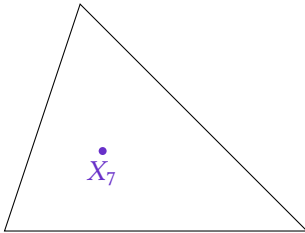
---

---

`\trt_sp_gergonne:nnnn`

`/tikz/triangletools/triangle center=(\langle coor 1\rangle)(\langle coor 2\rangle)(\langle coor 3\rangle)(7)`  
`\trt_sp_gergonne:nnnn {\langle coor 1\rangle}{\langle coor 2\rangle}{\langle coor 3\rangle}{\langle name\rangle}`

Find the Gergonne point  $X_7$  of the triangle.



```
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={triangle center=(a)(b)(c)(7)}] (trt output)
6     circle[radius=1.5pt] node[below] {$X_7$};
7 \end{tikzpicture}
```

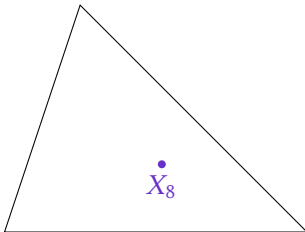
---

---

`\trt_sp_nagel:nnnn`

`/tikz/triangletools/triangle center=(\langle coor 1\rangle)(\langle coor 2\rangle)(\langle coor 3\rangle)(8)`  
`\trt_sp_nagel:nnnn {\langle coor 1\rangle}{\langle coor 2\rangle}{\langle coor 3\rangle}{\langle name\rangle}`

Find the Nagel point  $X_8$  of the triangle.



```
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={triangle center=(a)(b)(c)(8)}] (trt output)
6     circle[radius=1.5pt] node[below] {$X_8$};
7 \end{tikzpicture}
```

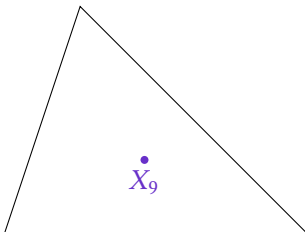
---

---

`\trt_sp_mittenpunkt:nnnn`

`/tikz/triangletools/triangle center=(\langle coor 1\rangle)(\langle coor 2\rangle)(\langle coor 3\rangle)(9)`  
`\trt_sp_mittenpunkt:nnnn {\langle coor 1\rangle}{\langle coor 2\rangle}{\langle coor 3\rangle}{\langle name\rangle}`

Find the *mittenpunkt*  $X_9$  of the triangle.



```
1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={triangle center=(a)(b)(c)(9)}] (trt output)
6     circle[radius=1.5pt] node[below] {$X_9$};
7 \end{tikzpicture}
```

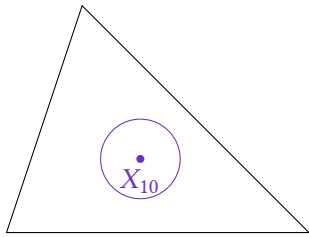
---

---

`\trt_sp_spieker:nnnn`

`/tikz/triangletools/triangle center=(\langle coor 1\rangle)(\langle coor 2\rangle)(\langle coor 3\rangle)(10)`  
`\trt_sp_spieker:nnnn {\langle coor 1\rangle}{\langle coor 2\rangle}{\langle coor 3\rangle}{\langle name\rangle}`

Find the Spieker center  $X_{10}$  of the triangle.



```

1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3     (0,0) coordinate (b) --
4     (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={triangle center=(a)(b)(c)(10)}] (trt output)
6     circle[radius=1.5pt] node[below] {$X_{10}$};
7   \draw[maincolor] (trt output) circle (\trradius);
8 \end{tikzpicture}

```

### 3.4 Other utilities

#### 3.4.1 Line tools

The line tools utility can help you play with some (very basic) operations related to lines.

---

intersection

---

/tikz/triangletools/intersection=( $\langle coor 1 \rangle$ )( $\langle coor 2 \rangle$ )--( $\langle coor 3 \rangle$ )( $\langle coor 4 \rangle$ )

There are two lines, the first joins  $\langle coor 1 \rangle$  and  $\langle coor 2 \rangle$ , and the other joins  $\langle coor 3 \rangle$  and  $\langle coor 4 \rangle$ . This finds the intersection of these lines.

If the two lines are parallel, trt output is set to (0,0), and the package will report a warning.



```

1 \begin{tikzpicture}
2   \draw (0,0) coordinate (a) -- (0,1) coordinate (b);
3   \draw (1,0) coordinate (c) -- (.5,1) coordinate (d);
4   \coordinate (e) at (1,1);
5   \fill[maincolor,trt={intersection=(a)(b)--(c)(d)}] (trt output)
6     circle (1.5pt) node[above] {$I$};
7   \fill[maincolor,trt={intersection=(a)(b)--(c)(e)}] (trt output)
8     circle (1.5pt) node[left] {$J$};
9 \end{tikzpicture}

```

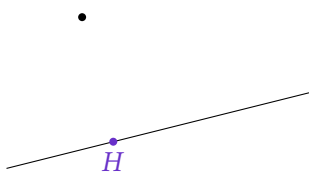
---

foot\_of\_perpendicular

---

/tikz/triangletools/foot of perpendicular=( $\langle coor 1 \rangle$ )--( $\langle coor 2 \rangle$ )( $\langle coor 3 \rangle$ )

Find the foot of perpendicular of point  $\langle coor 1 \rangle$  to the line joining  $\langle coor 2 \rangle$  and  $\langle coor 3 \rangle$ .



```

1 \begin{tikzpicture}
2   \draw (0,0) coordinate (b) -- (4,1) coordinate (c);
3   \fill (1,2) circle (1.5pt) coordinate (a);
4   \fill[maincolor,trt={foot of perpendicular=(a)--(b)(c)}] (trt output)
5     circle (1.5pt) node[below] {$H$};
6 \end{tikzpicture}

```

You can do much more using these expl3 functions.

---

\trt\_lt\_get\_line\_equation:nnNNN

---

\trt\_lt\_get\_line\_equation:nnNNN{ $\langle coor 1 \rangle$ }{ $\langle coor 2 \rangle$ }{ $\langle a \rangle$ }{ $\langle b \rangle$ }{ $\langle c \rangle$ }

Find the equation of the line joining  $\langle coor 1 \rangle$  and  $\langle coor 2 \rangle$ , in the form of  $ax + by = c$ . The l3fp local variables  $\langle a \rangle$ ,  $\langle b \rangle$  and  $\langle c \rangle$  will be set accordingly.

Note that for any pair of points  $\langle coor 1 \rangle$  and  $\langle coor 2 \rangle$ , there are infinitely many solutions for  $\langle a \rangle$ ,  $\langle b \rangle$  and  $\langle c \rangle$ . This function will produce one of such solution. While the solution is likely to be the simplest of all possible ones, this is not guaranteed.

$$1x + -3y = 1$$

Actual values:

$a = 0.9999995650601154$

$b = -2.999998695180348$

$c = 0.99999913012042$

```

1 \begin{tikzpicture}
2   \coordinate (a) at (1,0);
3   \coordinate (b) at (4,1);
4   \ExplSyntaxOn
5   \fp_new:N \l_foo_tmpa_fp
6   \fp_new:N \l_foo_tmpb_fp
7   \fp_new:N \l_foo_tmpc_fp
8   \trt_lt_get_line_equation:nnNNN {a} {b}
9     \l_foo_tmpa_fp \l_foo_tmpb_fp \l_foo_tmpc_fp
10  \def \resultequation {
11    $\fp_eval:n {round (\l_foo_tmpa_fp / 1cm)}x +
12    \fp_eval:n {round (\l_foo_tmpb_fp / 1cm)}y
13    =\fp_eval:n {round (\l_foo_tmpc_fp / (1cm * 1cm))}$
14  }
15  \ExplSyntaxOff
16  \draw (a) -- (b) node[midway,sloped,below] {\resultequation};
17  \ExplSyntaxOn
18  \path (1,-1) node[below,align=left] {
19    Actual ~ values:\\
20    $a = \fp_eval:n {\l_foo_tmpa_fp / 1cm}$\\
21    $b = \fp_eval:n {\l_foo_tmpb_fp / 1cm}$\\
22    $c = \fp_eval:n {\l_foo_tmpc_fp / (1cm * 1cm)}$
23  };
24  \ExplSyntaxOff
25 \end{tikzpicture}

```

---

`\trt_lt_get_intersection_line:NNNNNNNN`

---

`\trt_lt_get_intersection_line:NNNNNNNN{a1}{b1}{c1}{a2}{b2}{c2}{x}{y}`

This function finds the intersection of lines  $a_1x + b_1y = c_1$  and  $a_2x + b_2y = c_2$ , afterwards store the dimensions of the intersection in variables  $\langle x \rangle$  and  $\langle y \rangle$ .

All arguments are floating points variables,  $\langle x \rangle$  and  $\langle y \rangle$  needs to be local variables.

---

`\trt_lt_get_intersection_coordinate:nnnnNN`

---

`\trt_lt_get_intersection_coordinate:nnnnNN`  
`{\langle coor 1 \rangle}{\langle coor 2 \rangle}{\langle coor 3 \rangle}{\langle coor 4 \rangle}{\langle x \rangle}{\langle y \rangle}`

This function is a wrapper of `\trt_lt_get_intersection_line:NNNNNNNN`. It finds the intersection of the line joining  $\langle coor 1 \rangle$ ,  $\langle coor 2 \rangle$  and the line joining  $\langle coor 3 \rangle$ ,  $\langle coor 4 \rangle$ . The dimensions of the returned point is stored in  $\langle x \rangle$  and  $\langle y \rangle$ , which are local l3fp variables.

A warning will be raised if the lines are parallel, in that case  $\langle x \rangle$  and  $\langle y \rangle$  are set to zero.

This is the base of intersection.

```

1 \begin{tikzpicture}
2   \draw (0,0) coordinate (a) -- (0,1) coordinate (b);
3   \draw (1,0) coordinate (c) -- (.5,1) coordinate (d);
4   \ExplSyntaxOn
5   \fp_new:N \l_foo_tmpa_fp
6   \fp_new:N \l_foo_tmpb_fp
7   \trt_lt_get_intersection_coordinate:nnnnNN {a} {b} {c} {d}
8     \l_foo_tmpa_fp \l_foo_tmpb_fp
9   \coordinate (i) at (\fp_to_dim:N \l_foo_tmpa_fp,
10     \fp_to_dim:N \l_foo_tmpb_fp);
11  \ExplSyntaxOff
12  \fill[maincolor] (i) circle (1.5pt);
13 \end{tikzpicture}

```

---

`\trt_lt_get_perpendicular_equation:nnNNNNNN`

---

`\trt_lt_get_perpendicular_equation:nnNNNNNN{\langle coor 1 \rangle}{a1}{b1}{c1}{a2}{b2}{c2}`

This function finds the line of equation  $a_2x + b_2y = c_2$  that passes coordinate  $\langle coor 1 \rangle$  and is perpendicular to  $a_1x + b_1y = c_1$ .

(0.5, 4)



(3, 1)

(-1, 0)

Equation of perpendicular line:

$$4x + 1y = 6$$

Actual values:

$$a = 3.999998260240463$$

$$b = 0.9999995650601154$$

$$c = 5.999993708152788$$

```
1 \begin{tikzpicture}
2   \draw (-1,0) coordinate (b) node[left] {$(-1,0)$} --
3     (3,1) coordinate (c) node[right] {$ (3,1)$};
4   \fill (0.5,4) circle (1.5pt) coordinate (a) node[above] {$ (0.5,4)$};
5   \ExplSyntaxOn
6   \fp_new:N \l_foo_tmpa_fp
7   \fp_new:N \l_foo_tmpb_fp
8   \fp_new:N \l_foo_tmpe_fp
9   \fp_new:N \l_foo_tmpe_fp
10  \fp_new:N \l_foo_tmpe_fp
11  \fp_new:N \l_foo_tmpe_fp
12  \trt_lt_get_line_equation:nnNNN {b} {c}
13    \l_foo_tmpa_fp \l_foo_tmpe_fp \l_foo_tmpe_fp
14  \trt_lt_get_perpendicular_equation:nnNNNN {a}
15    \l_foo_tmpa_fp \l_foo_tmpe_fp \l_foo_tmpe_fp
16    \l_foo_tmpe_fp \l_foo_tmpe_fp \l_foo_tmpe_fp
17  \def \resultequation {
18    $\fp_eval:n {round (\l_foo_tmpe_fp / 1cm)}x +
19    \fp_eval:n {round (\l_foo_tmpe_fp / 1cm)}y
20    =\fp_eval:n {round (\l_foo_tmpe_fp / (1cm * 1cm))}$
21  }
22  \ExplSyntaxOff
23  \path (1,0) node[below=3mm,align=center]
24    {Equation of perpendicular line:\\\resultequation};
25  \ExplSyntaxOn
26  \path (1,-1.5) node[below,align=left] {
27    Actual ~ values:\\
28    $a = \fp_eval:n {\l_foo_tmpe_fp / 1cm}$\\
29    $b = \fp_eval:n {\l_foo_tmpe_fp / 1cm}$\\
30    $c = \fp_eval:n {\l_foo_tmpe_fp / (1cm * 1cm)}$
31  };
32  \ExplSyntaxOff
33 \end{tikzpicture}
```

---

`\trt_lt_get_perpendicular_coordinate:nnnNN`

---

`\trt_lt_get_perpendicular_coordinate:nnnNN{<coor 1>}{<coor 2>}{<coor 3>}{<x>}{<y>}`

Find the dimensions of the foot of perpendicular from  $\langle coor\ 1 \rangle$  to the line joining  $\langle coor\ 2 \rangle$  and  $\langle coor\ 3 \rangle$ . Afterwards store the dimensions found in  $\langle x \rangle$  and  $\langle y \rangle$ .

This is the base of foot of perpendicular.

### 3.4.2 The barycentric coordinate system

---

`initialize_barycentric`

---

`/tikz/triangletools/initialize barycentric=(\langle coor 1 \rangle)(\langle coor 2 \rangle)(\langle coor 3 \rangle)`

Use the three coordinates as “anchors” of the barycentric coordinate system.

---

`bc3`

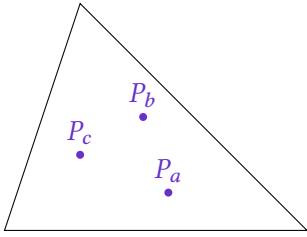
---

`(bc3 cs: \langle l1 \rangle, \langle l2 \rangle, \langle l3 \rangle)`

Using the barycentric coordinate system. Note that the system needs to be initialized in advance using `initialize barycentric`, and an error message will be reported if you do otherwise.

The sum of  $\langle l1 \rangle$ ,  $\langle l2 \rangle$  and  $\langle l3 \rangle$  is not necessarily 1 – the package will take care of that internally.





```

1 \begin{tikzpicture}
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={initialize barycentric=(a)(b)(c)}] (bc3 cs:1,2,3)
6     circle[radius=1.5pt] node[above] {$P_a$};
7   \fill[maincolor,trt={initialize barycentric=(b)(c)(a)}] (bc3 cs:1,2,3)
8     circle[radius=1.5pt] node[above] {$P_b$};
9   \fill[maincolor,trt={initialize barycentric=(c)(a)(b)}] (bc3 cs:1,2,3)
10    circle[radius=1.5pt] node[above] {$P_c$};
11 \end{tikzpicture}

```

### 3.4.3 Distance-finding utility

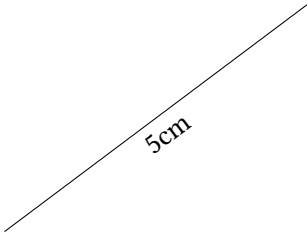
---

`\trt_distance:nnN`

---

`\trt_distance:nnN {<coord 1>} {<coord 2>} <fp var>`

Find distance between `<coord 1>` and `<coord 2>`, and store that value to `<fp var>`.



```

1 \begin{tikzpicture}
2   \path (0,0) coordinate (a) (4,3) coordinate (b);
3   \ExplSyntaxOn
4   \fp_new:N \l_foo_tmpa_fp
5   \trt_distance:nnN {a} {b} \l_foo_tmpa_fp
6   \draw (a) -- (b) node[midway,sloped,below]
7     { \fp_eval:n {round(\l_foo_tmpa_fp / 1cm)} cm };
8   \ExplSyntaxOff
9 \end{tikzpicture}

```

---

`\trt_distance_triangle:nnnNNN`

---

`\trt_distance_triangle:nnnNNN{<coord 1>}{<coord 2>}{<coord 3>}<a><b><c>`

`\trt_distance:nnN` is needed to find the side lengths in a triangle (these side lengths are very helpful in many areas, for instance in this package to find special points based on the barycentric system). However, using it three times in a row is not quite elegant; this function is defined to automate that process.

`<a>` is set to the distance between `<coord 2>` and `<coord 3>`, similar things happen for `<b>` and `<c>`.

### 3.5 Customization

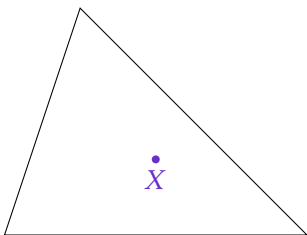
---

`output_name`

---

`/tikz/triangletools/output name=<name>`

This key can be used to change the name of the returned coordinates. The initial value of this key is `trt_output`.



```

1 \begin{tikzpicture}[trt={output name=hello world}]
2   \draw (1,3) coordinate (a) --
3         (0,0) coordinate (b) --
4         (4,0) coordinate (c) -- cycle;
5   \fill[maincolor,trt={circumcenter=(a)(b)(c)}] (hello world)
6     circle[radius=1.5pt] node[below] {$X$};
7 \end{tikzpicture}

```

## 4 Implementation

1 `<@@=trt>`

## 4.1 The main package file

```
2 <*triangletools>
3 \RequirePackage{tikz}
4 \RequirePackage{expl3}
5 \ProvidesExplPackage {triangletools} {2020/04/30} {0.1}
6 {TikZ support for triangular geometry}
```

`\trt@tmp@i` We will use these dimensions many times to extract the dimensions of a TikZ coordinate.  
`\trt@tmp@ii`

```
7 \newdimen\trt@tmp@i
8 \newdimen\trt@tmp@ii
```

*(End definition for `\trt@tmp@i` and `\trt@tmp@ii`. These functions are documented on page ??.)*

Let's load the necessary subpackage files.

```
9 \input {trtmessages.code.tex}
10 \input {trtlinetools.code.tex}
11 \input {trtbarycentric.code.tex}
12 \input {trtdistance.code.tex}
13 \input {trtspecialpoints.code.tex}
14 \input {trtfrontend.code.tex}
15 </triangletools>
```

## 4.2 Errors and warnings

```
16 <*messages>
17 \ProvidesExplFile {trtmessages.code.tex} {2020/04/30} {0.1}
18 {The ~ triangletools ~ package: ~ Messages}
```

We also need to declare some helpful messages that we will use later on.

In `trtlinetools.code.tex`, when we find the intersection of two lines, a warning will be shown if the lines are parallel. The warning is based on intersection-not-found.

```
19 \msg_new:nnnn {triangletools} {intersection-not-found}
20 {
21   Intersection ~ not ~ found.
22 }
23 {
24   You ~ told ~ me ~ to ~ find ~ the ~ intersection ~ of ~ the ~ line ~
25   joining ~ #1 ~ and ~ #2 ~ and ~ the ~ line ~ joining ~ #3 ~ and ~ #4, ~
26   however ~ these ~ lines ~ are ~ parallel ~ so ~ I ~ can't ~ find ~ any ~
27   intersection. ~ The ~ return ~ point ~ is ~ set ~ to ~ the ~ origin ~
28   (0, ~ 0).
29 }
```

When the barycentric coordinate system, implemented in `trtbarycentric.code.tex`, is used, it should already be initialized, *i.e.* we should already know what are the three “anchor” coordinates of the system. If the coordinate system is not yet initialized, this error will be shown.

```
30 \msg_new:nnnn {triangletools} {uninitialized}
31 {
32   Barycentric ~ coordinate ~ system ~ not ~ initialized.
33 }
34 {
35   You ~ have ~ not ~ initialized ~ the ~ three ~ anchor ~ points ~ for ~
36   the ~ coordinate ~ system. ~ Please ~ initialize ~ the ~ points ~
37   before ~ using ~ the ~ 'bc3' ~ coordinate ~ system.
38 }
```

We do let the user to find triangle center  $X_i$  for any  $i$ . However this package obviously can't implement all points in ETC (in fact, I will implement only some most

important points). An error will be raised if the user tries to use an unimplemented point.

```

39 \msg_new:nnnn {triangletools} {center-not-found}
40 {
41   Triangle ~ center ~ not ~ found.
42 }
43 {
44   I ~ can't ~ find ~ the ~ requested ~ triangle ~ center, ~ because ~
45   point ~ X(#1) ~ is ~ not ~ yet ~ implemented ~ in ~ the ~ triangletools ~
46   package. ~ Try ~ to ~ construct ~ it ~ yourself.
47 }

```

We need to guard against using `\trradius` before the macro stores something.

```

48 \msg_new:nnnn {triangletools} {no-radius-found}
49 {
50   No ~ circles ~ can ~ be ~ constructed.
51 }
52 {
53   I ~ can't ~ construct ~ the ~ requested ~ circle, ~ because ~ you ~ have ~
54   not ~ request ~ me ~ to ~ construct ~ any ~ triangle ~ centers ~ that ~
55   are ~ associated ~ to ~ a ~ circle. ~ I ~ will ~ set ~
56   \protect\trradius\space to ~ zero ~ now.
57 }
58 </messages>

```

## 4.3 The backend layer

### 4.3.1 The line tools utility

```

59 <*linetools>
60 \ProvidesExplFile {trtlinetools.code.tex} {2020/04/30} {0.1}
61 {The ~ triangletools ~ package: ~ Utilities ~ for ~ lines}

```

In `trtlinetools.code.tex`, we will implement the necessary functions to handle lines in a mathematical way.

Firstly, let's declare some internal variables that we will use later.

```

\__trt_lt_pointi_x_fp
\__trt_lt_pointi_y_fp
\__trt_lt_pointii_x_fp
\__trt_lt_pointii_y_fp
62 \fp_new:N \__trt_lt_pointi_x_fp
63 \fp_new:N \__trt_lt_pointi_y_fp
64 \fp_new:N \__trt_lt_pointii_x_fp
65 \fp_new:N \__trt_lt_pointii_y_fp

```

These variables are used to store coordinates of the two vertices of a segment.

*(End definition for `\__trt_lt_pointi_x_fp` and others.)*

```

\__trt_lt_linei_a_fp
\__trt_lt_linei_b_fp
\__trt_lt_linei_c_fp
\__trt_lt_lineii_a_fp
\__trt_lt_lineii_b_fp
\__trt_lt_lineii_c_fp
66 \fp_new:N \__trt_lt_linei_a_fp
67 \fp_new:N \__trt_lt_linei_b_fp
68 \fp_new:N \__trt_lt_linei_c_fp
69 \fp_new:N \__trt_lt_lineii_a_fp
70 \fp_new:N \__trt_lt_lineii_b_fp
71 \fp_new:N \__trt_lt_lineii_c_fp

```

We will store the line equation under the format of  $ax + by = c$ , because this is the most generic format. These six variables will do that job.

*(End definition for `\__trt_lt_linei_a_fp` and others.)*

```

\__trt_lt_tmp_fp
\__trt_lt_tmpa_fp
\__trt_lt_tmpb_fp
72 \fp_new:N \__trt_lt_tmp_fp
73 \fp_new:N \__trt_lt_tmpa_fp
74 \fp_new:N \__trt_lt_tmpb_fp

```

Some additional temporary variables.

(End definition for `\l__trt_lt_tmp_fp`, `\l__trt_lt_tmpa_fp`, and `\l__trt_lt_tmpb_fp`.)

`\trt_lt_get_line_equation:nnNNN` Find the equation of the line passing #1 and #2, and store the values of  $a$ ,  $b$ ,  $c$  found to #3, #4 and #5, which are floating point variables, respectively.

```

75 \cs_new:Npn \trt_lt_get_line_equation:nnNNN #1 #2 #3 #4 #5
76 {
77   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
78   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
79   \fp_set:Nn \l__trt_i_pointi_x_fp {\trt@tmp@i}
80   \fp_set:Nn \l__trt_i_pointi_y_fp {\trt@tmp@ii}
81   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
82   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
83   \fp_set:Nn \l__trt_i_pointii_x_fp {\trt@tmp@i}
84   \fp_set:Nn \l__trt_i_pointii_y_fp {\trt@tmp@ii}

```

There is a simple hack here. We have  $ax_1 + by_1 = c = ax_2 + by_2$ , which is equivalent to  $a(x_1 - x_2) = b(y_2 - y_1)$ . Therefore  $a = y_2 - y_1$  and  $b = x_1 - x_2$  can be used.

```

85   \fp_set:Nn #3
86   {
87     \l__trt_i_pointii_y_fp - \l__trt_i_pointi_y_fp
88   }
89   \fp_set:Nn #4
90   {
91     \l__trt_i_pointi_x_fp - \l__trt_i_pointii_x_fp
92   }
93   \fp_set:Nn #5
94   {
95     #3 * \l__trt_i_pointi_x_fp + #4 * \l__trt_i_pointi_y_fp
96   }
97 }

```

(End definition for `\trt_lt_get_line_equation:nnNNN`. This function is documented on page 6.)

`\trt_lt_get_intersection_line:NNNNNNNN` Find the intersection of two lines with given equation, after that store the intersection coordinate to floating point variables #7 and #8.

```

98 \cs_new:Npn \trt_lt_get_intersection_line:NNNNNNNN #1 #2 #3 #4 #5 #6 #7 #8
99 {
100   \fp_set:Nn \l__trt_lt_tmp_fp { #1 * #5 - #4 * #2 }

```

If `\l__trt_lt_tmp_fp` is zero, the two lines are parallel. In that case, we will issue a warning, and set the intersection coordinate to (0, 0). Otherwise, continue computing as usual.

```

101   \fp_compare:nNnTF {\l__trt_lt_tmp_fp} = {0}
102   {
103     \msg_warning:nnnnnn {triangletools} {intersection-not-found}
104     {(#1)} {(#2)} {(#3)} {(#4)}
105     \fp_set:Nn #7 {0}
106     \fp_set:Nn #8 {0}
107   }
108   {
109     \fp_set:Nn #7 { ( #5 * #3 - #2 * #6 ) / \l__trt_lt_tmp_fp }
110     \fp_set:Nn #8 { ( #1 * #6 - #4 * #3 ) / \l__trt_lt_tmp_fp }
111   }
112 }

```

(End definition for `\trt_lt_get_intersection_line:NNNNNNNN`. This function is documented on page 7.)

`\trt_lt_get_intersection_coordinate:nnnnNN` Let's generalize `\trt_lt_get_intersection_line:NNNNNNNN`. The following function finds the intersection of two lines between #1, #2 and #3, #4, and store the coordinates

to #5 and #6. We still use floating point variables here, as they might be useful in the future.

```

113 \cs_new:Npn \trt_lt_get_intersection_coordinate:nnnnNN #1 #2 #3 #4 #5 #6
114 {
115   \trt_lt_get_line_equation:nnNNN {#1} {#2}
116   \l__trt_lt_line_i_a_fp \l__trt_lt_line_i_b_fp \l__trt_lt_line_i_c_fp
117   \trt_lt_get_line_equation:nnNNN {#3} {#4}
118   \l__trt_lt_line_ii_a_fp \l__trt_lt_line_ii_b_fp \l__trt_lt_line_ii_c_fp
119   \trt_lt_get_intersection_line:NNNNNNNN
120   \l__trt_lt_line_i_a_fp \l__trt_lt_line_i_b_fp \l__trt_lt_line_i_c_fp
121   \l__trt_lt_line_ii_a_fp \l__trt_lt_line_ii_b_fp \l__trt_lt_line_ii_c_fp
122   #5 #6
123 }

```

(End definition for `\trt_lt_get_intersection_coordinate:nnnnNN`. This function is documented on page 7.)

`\__trt_lt_return_intersection:nnnnn`

Now, let's TikZify the above function! Note that I use `overlay` because I don't want to affect the bounding box. The user can use the returned coordinate to change the bounding box in whatever way he wants to.

```

124 \cs_new:Npn \__trt_lt_return_intersection:nnnnn #1 #2 #3 #4 #5
125 {
126   \trt_lt_get_intersection_coordinate:nnnnNN {#1} {#2} {#3} {#4}
127   \l__trt_lt_tmpa_fp \l__trt_lt_tmpb_fp
128   \coordinate[overlay] (#5) at
129     (\fp_to_dim:N \l__trt_lt_tmpa_fp, \fp_to_dim:N \l__trt_lt_tmpb_fp);
130 }

```

(End definition for `\__trt_lt_return_intersection:nnnnn`.)

Next, let's make some implementation regarding perpendicularity.

`\trt_lt_get_perpendicular_equation:nnNNNNN`

This function finds the equation of the line passing point and being perpendicular to a line having a given equation. The task is not quite complicated: note that lines  $ax + by = c$  and  $ay - bx = d$  are perpendicular.

```

131 \cs_new:Npn \trt_lt_get_perpendicular_equation:nnNNNNN #1 #2 #3 #4 #5 #6 #7
132 {
133   \fp_set:Nn #5 { -#3 }
134   \fp_set:Nn #6 { #2 }
135   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
136   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
137   \fp_set:Nn \l__trt_lt_tmpa_fp {\trt@tmp@i}
138   \fp_set:Nn \l__trt_lt_tmpb_fp {\trt@tmp@ii}
139   \fp_set:Nn #7 { #5 * \l__trt_lt_tmpa_fp + #6 * \l__trt_lt_tmpb_fp }
140 }

```

(End definition for `\trt_lt_get_perpendicular_equation:nnNNNNN`. This function is documented on page 7.)

`\trt_lt_get_perpendicular_coordinate:nnnNN`

The base implemented, let's find the foot of perpendicular from a point to a segment.

```

141 \cs_new:Npn \trt_lt_get_perpendicular_coordinate:nnnNN #1 #2 #3 #4 #5
142 {
143   \trt_lt_get_line_equation:nnNNN {#2} {#3}
144   \l__trt_lt_line_i_a_fp \l__trt_lt_line_i_b_fp \l__trt_lt_line_i_c_fp
145
146   \trt_lt_get_perpendicular_equation:nnNNNNN {#1}
147   \l__trt_lt_line_i_a_fp \l__trt_lt_line_i_b_fp \l__trt_lt_line_i_c_fp
148   \l__trt_lt_line_ii_a_fp \l__trt_lt_line_ii_b_fp \l__trt_lt_line_ii_c_fp
149
150   \trt_lt_get_intersection_line:NNNNNNNN
151   \l__trt_lt_line_i_a_fp \l__trt_lt_line_i_b_fp \l__trt_lt_line_i_c_fp

```

```

152     \l__trt_lt_lineii_a_fp \l__trt_lt_lineii_b_fp \l__trt_lt_lineii_c_fp
153     #4 #5
154 }

```

(End definition for `\trt_lt_get_perpendicular_coordinate:nnnNN`. This function is documented on page 8.)

`\trt_lt_return_perpendicular_coordinate:nnnn`

This is just a wrapper of `\trt_lt_get_perpendicular_coordinate:nnnNN`.

```

155 \cs_new:Npn \l__trt_lt_return_perpendicular_coordinate:nnnn #1 #2 #3 #4
156 {
157     \trt_lt_get_perpendicular_coordinate:nnnNN {#1} {#2} {#3}
158     \l__trt_lt_tmpa_fp \l__trt_lt_tmpb_fp
159     \coordinate[overlay] (#4) at
160     (\fp_to_dim:N \l__trt_lt_tmpa_fp, \fp_to_dim:N \l__trt_lt_tmpb_fp);
161 }
162 </linetools>

```

(End definition for `\l__trt_lt_return_perpendicular_coordinate:nnnn`.)

### 4.3.2 The barycentric coordinate system utility

```

163 <*barycentric>
164 \ProvidesExplFile {trtbarycentric.code.tex} {2020/04/30} {0.1}
165 {
166     The ~ triangletools ~ package:~ Utilities ~ for ~ the ~ barycentric ~
167     coordinate ~ system.
168 }

```

In `trtbarycentric.code.tex`, we will implement the three-point barycentric coordinate system, which is essential in constructing many special points in a triangle.

```

\l__trt_bc_anchor_ix_fp
\l__trt_bc_anchor_iy_fp
\l__trt_bc_anchor_iix_fp
\l__trt_bc_anchor_iiy_fp
\l__trt_bc_anchor_iiix_fp
\l__trt_bc_anchor_iiiy_fp

```

We use six variables to store the ‘anchors’ of the barycentric coordinate system.

```

169 \fp_new:N \l__trt_bc_anchor_ix_fp
170 \fp_new:N \l__trt_bc_anchor_iy_fp
171 \fp_new:N \l__trt_bc_anchor_iix_fp
172 \fp_new:N \l__trt_bc_anchor_iiy_fp
173 \fp_new:N \l__trt_bc_anchor_iiix_fp
174 \fp_new:N \l__trt_bc_anchor_iiiy_fp

```

(End definition for `\l__trt_bc_anchor_ix_fp` and others.)

```

\l__trt_bc_lambda_i_fp
\l__trt_bc_lambda_ii_fp
\l__trt_bc_lambda_iii_fp

```

We use these variables to store the user input coordinate. Note that our system is a three-point one, hence exactly three number is required.

Why lambda  $\lambda$ ? Well, I don’t know. Wikipedia uses that, so I do the same.

```

175 \fp_new:N \l__trt_bc_lambda_i_fp
176 \fp_new:N \l__trt_bc_lambda_ii_fp
177 \fp_new:N \l__trt_bc_lambda_iii_fp

```

(End definition for `\l__trt_bc_lambda_i_fp`, `\l__trt_bc_lambda_ii_fp`, and `\l__trt_bc_lambda_iii_fp`.)

`\l__trt_bc_initialized_bool`

We need to guard against using the system before initializing. This boolean variable does that job: if it is set to false (default), do nothing.

```

178 \bool_new:N \l__trt_bc_initialized_bool

```

(End definition for `\l__trt_bc_initialized_bool`.)

`\l__trt_bc_tmp_fp`

A temporary variable.

```

179 \fp_new:N \l__trt_bc_tmp_fp

```

(End definition for \l\_\_trt\_bc\_tmp\_fp.)

\\_\_trt\_bc\_initialize:nnn Initialize the barycentric coordinate system. This is the only place where \l\_\_trt\_bc\_initialized\_bool can be set to true, so this function must be executed before everything else in this file.

```
180 \cs_new:Npn \__trt_bc_initialize:nnn #1 #2 #3
181 {
182   \bool_set_true:N \__trt_bc_initialized_bool
183   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
184   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
185   \fp_set:Nn \__trt_bc_anchor_ix_fp {\trt@tmp@i}
186   \fp_set:Nn \__trt_bc_anchor_iy_fp {\trt@tmp@ii}
187   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
188   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
189   \fp_set:Nn \__trt_bc_anchor_iix_fp {\trt@tmp@i}
190   \fp_set:Nn \__trt_bc_anchor_iiy_fp {\trt@tmp@ii}
191   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#3}{center}}
192   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#3}{center}}
193   \fp_set:Nn \__trt_bc_anchor_iiix_fp {\trt@tmp@i}
194   \fp_set:Nn \__trt_bc_anchor_iiiy_fp {\trt@tmp@ii}
195 }
```

(End definition for \\_\_trt\_bc\_initialize:nnn.)

**bc3** The bc3 coordinate system implementation. We will guard against using it when \\_\_trt\_bc\_initialize:nnn is not yet executed – in that case, uninitialized error will be raised.

We will receive arguments of bc3 as #1,#2,#3, so a simple parser is needed. All interesting things will be done with that parser.

```
196 \tikzdeclarecoordinatesystem {bc3}
197 {
198   \bool_if:NTF \__trt_bc_initialized_bool
199   {
200     \__trt_bc_parse:w #1 \q_stop
201   }
202   {
203     \msg_error:nn {triangletools} {uninitialized}
204   }
205 }
```

(End definition for bc3. This function is documented on page 8.)

\\_\_trt\_bc\_parse:w This is the parser we use for bc3.

The conversion from  $\lambda_i$  to the Cartesian format is pretty simple, we have  $x = \lambda_1 x_1 + \lambda_2 x_2 + \lambda_3 x_3$  and the formula for  $y$  is similar. However, first we have to change the value of  $\lambda_i$  so that  $\lambda_1 + \lambda_2 + \lambda_3 = 1$ .

```
206 \cs_new:Npn \__trt_bc_parse:w #1,#2,#3 \q_stop
207 {
208   \fp_set:Nn \__trt_bc_tmp_fp { (#1) + (#2) + (#3) }
209   \fp_set:Nn \__trt_bc_lambda_i_fp { (#1) / (\__trt_bc_tmp_fp) }
210   \fp_set:Nn \__trt_bc_lambda_ii_fp { (#2) / (\__trt_bc_tmp_fp) }
211   \fp_set:Nn \__trt_bc_lambda_iii_fp { (#3) / (\__trt_bc_tmp_fp) }
212   \fp_set:Nn \__trt_tmp_a_fp
213   {
214     \__trt_bc_anchor_ix_fp * \__trt_bc_lambda_i_fp +
215     \__trt_bc_anchor_iix_fp * \__trt_bc_lambda_ii_fp +
216     \__trt_bc_anchor_iiix_fp * \__trt_bc_lambda_iii_fp
217   }
218   \fp_set:Nn \__trt_tmp_b_fp
```

```

219     {
220       \l__trt_bc_anchor_iy_fp * \l__trt_bc_lambda_i_fp +
221       \l__trt_bc_anchor_iiy_fp * \l__trt_bc_lambda_ii_fp +
222       \l__trt_bc_anchor_iiiy_fp * \l__trt_bc_lambda_iiiy_fp
223     }

```

Floating point variables are not  $\TeX$  dimensions, hence `\fp_to_dim:N` is used.

```

224     \pgf@x = \fp_to_dim:N \l__trt_tmp_a_fp
225     \pgf@y = \fp_to_dim:N \l__trt_tmp_b_fp
226   }
227 </barycentric>

```

(End definition for `\__trt_bc_parse:w`.)

### 4.3.3 Distance-finding utility

```

228 <*distance>
229 \ProvidesExplFile {trtdistance.code.tex} {2020/04/30} {0.1}
230 {The ~ triangletools ~ package: ~ Utilities ~ for ~ 2d ~ distance}

```

This file implements functions to find the distance between (2d) TikZ coordinates.

These variables are used to store the coordinates of the points between which we are finding the distance.

```

\l__trt_d_pointi_x_fp
\l__trt_d_pointi_y_fp
\l__trt_d_pointii_x_fp
\l__trt_d_pointii_y_fp
231 \fp_new:N \l__trt_d_pointi_x_fp
232 \fp_new:N \l__trt_d_pointii_x_fp
233 \fp_new:N \l__trt_d_pointi_y_fp
234 \fp_new:N \l__trt_d_pointii_y_fp

```

(End definition for `\l__trt_d_pointi_x_fp` and others.)

`\trt_distance:nnN` Find the distance between TikZ coordinates #1 and #2.

```

235 \cs_new:Npn \trt_distance:nnN #1 #2 #3
236 {
237   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
238   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
239   \fp_set:Nn \l__trt_d_pointi_x_fp {\trt@tmp@i}
240   \fp_set:Nn \l__trt_d_pointi_y_fp {\trt@tmp@ii}
241   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
242   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
243   \fp_set:Nn \l__trt_d_pointii_x_fp {\trt@tmp@i}
244   \fp_set:Nn \l__trt_d_pointii_y_fp {\trt@tmp@ii}
245   \fp_set:Nn #3
246   {
247     sqrt((
248       (\l__trt_d_pointi_x_fp - \l__trt_d_pointii_x_fp) *
249       (\l__trt_d_pointi_x_fp - \l__trt_d_pointii_x_fp)
250     ) + (
251       (\l__trt_d_pointi_y_fp - \l__trt_d_pointii_y_fp) *
252       (\l__trt_d_pointi_y_fp - \l__trt_d_pointii_y_fp)
253     ))
254   }
255 }

```

(End definition for `\trt_distance:nnN`. This function is documented on page 9.)

`\trt_distance_triangle:nnnNNN` We mainly need the above function to find the side length in a triangle. Let's create a function that do so automatically.

```

256 \cs_new:Npn \trt_distance_triangle:nnnNNN #1 #2 #3 #4 #5 #6
257 {
258   \trt_distance:nnN {#2} {#3} #4

```



```

259 \trt_distance:nnN {#3} {#1} #5
260 \trt_distance:nnN {#1} {#2} #6
261 }
262 </distance>

```

(End definition for `\trt_distance_triangle:nnnNNN`. This function is documented on page 9.)

## 4.4 Construction of triangle centers

```

263 <*specialpoints>
264 \ProvidesExplFile {trtspecialpoints.code.tex} {2020/04/30} {0.1}
265 {The ~ triangletools ~ package: ~ Triangle ~ center ~ construction}

```

This file will use the utility implemented in the above sections to find some most important triangle centers described in the ETC.

`\l__trt_sp_a_fp` We will need the side length of the triangle for some centers.

```

\l__trt_sp_b_fp
\l__trt_sp_c_fp
266 \fp_new:N \l__trt_sp_a_fp
267 \fp_new:N \l__trt_sp_b_fp
268 \fp_new:N \l__trt_sp_c_fp

```

(End definition for `\l__trt_sp_a_fp`, `\l__trt_sp_b_fp`, and `\l__trt_sp_c_fp`.)

`\l__trt_sp_coordinatei_x_fp` These variables may also be helpful for triangle centers for which a simple formula doesn't exist, e.g. the circumcenter.

```

\l__trt_sp_coordinatei_y_fp
\l__trt_sp_coordinateii_x_fp
\l__trt_sp_coordinateii_y_fp
\l__trt_sp_coordinateiii_x_fp
\l__trt_sp_coordinateiii_y_fp
\l__trt_sp_linei_a_fp
\l__trt_sp_linei_b_fp
\l__trt_sp_linei_c_fp
\l__trt_sp_lineii_a_fp
\l__trt_sp_lineii_b_fp
\l__trt_sp_lineii_c_fp
269 \fp_new:N \l__trt_sp_coordinatei_x_fp
270 \fp_new:N \l__trt_sp_coordinatei_y_fp
271 \fp_new:N \l__trt_sp_coordinateii_x_fp
272 \fp_new:N \l__trt_sp_coordinateii_y_fp
273 \fp_new:N \l__trt_sp_coordinateiii_x_fp
274 \fp_new:N \l__trt_sp_coordinateiii_y_fp
275 \fp_new:N \l__trt_sp_linei_a_fp
276 \fp_new:N \l__trt_sp_linei_b_fp
277 \fp_new:N \l__trt_sp_linei_c_fp
278 \fp_new:N \l__trt_sp_lineii_a_fp
279 \fp_new:N \l__trt_sp_lineii_b_fp
280 \fp_new:N \l__trt_sp_lineii_c_fp

```

(End definition for `\l__trt_sp_coordinatei_x_fp` and others.)

`\l__trt_sp_tmpa_fp` Some additional temporary variables.

```

\l__trt_sp_tmppb_fp
\l__trt_sp_tmppc_fp
281 \fp_new:N \l__trt_sp_tmpa_fp
282 \fp_new:N \l__trt_sp_tmppb_fp
283 \fp_new:N \l__trt_sp_tmppc_fp

```

(End definition for `\l__trt_sp_tmpa_fp`, `\l__trt_sp_tmppb_fp`, and `\l__trt_sp_tmppc_fp`.)

### 4.4.1 $X_1$ – The incenter

Each center will have a function taking four arguments. The first three arguments are the TikZ coordinates of the triangle vertices; the last argument is the name of the return TikZ coordinate.

To prevent conflict between these sister functions when they are used together, I put each of them inside a  $\TeX$  group.

`\trt_sp_incenter:nnnn` Return the incenter. It is based on the barycentric coordinate of the incenter,  $(a, b, c)$ .

```

284 \cs_new:Npn \trt_sp_incenter:nnnn #1 #2 #3 #4
285 {

```

```

286 \group_begin:
287 \__trt_bc_initialize:nnn {#1} {#2} {#3}
288 \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
289 \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
290 \path[overlay] (bc3 ~ cs \c_colon_str
291 \fp_eval:n {\l__trt_sp_a_fp},
292 \fp_eval:n {\l__trt_sp_b_fp},
293 \fp_eval:n {\l__trt_sp_c_fp}) coordinate (#4);
294 \group_end:
295 }

```

(End definition for `\trt_sp_incenter:nnnn`. This function is documented on page 3.)

`\trt_sp_excenter:nnnn` Return the excenter of the triangle, with respect to vertex #1. This center is just a derivation of the incenter; also it is not unique, so it is not assigned a number. Barycentric coordinate of the excenter is  $(-a, b, c)$ , where  $a$  is the length of the side joining #2 and #3.

Note that this is the only function in this series in which argument order is important.

```

296 \cs_new:Npn \trt_sp_excenter:nnnn #1 #2 #3 #4
297 {
298 \group_begin:
299 \__trt_bc_initialize:nnn {#1} {#2} {#3}
300 \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
301 \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
302 \path[overlay] (bc3 ~ cs \c_colon_str
303 \fp_eval:n {- \l__trt_sp_a_fp},
304 \fp_eval:n {\l__trt_sp_b_fp},
305 \fp_eval:n {\l__trt_sp_c_fp}) coordinate (#4);
306 \group_end:
307 }

```

(End definition for `\trt_sp_excenter:nnnn`. This function is documented on page 3.)

#### 4.4.2 $X_2$ – The centroid

`\trt_sp_centroid:nnnn` This is perhaps the simplest of all. Barycentric coordinate:  $(1, 1, 1)$ .

```

308 \cs_new:Npn \trt_sp_centroid:nnnn #1 #2 #3 #4
309 {
310 \group_begin:
311 \__trt_bc_initialize:nnn {#1} {#2} {#3}
312 \path[overlay] (bc3 ~ cs \c_colon_str 1, 1, 1) coordinate (#4);
313 \group_end:
314 }

```

(End definition for `\trt_sp_centroid:nnnn`. This function is documented on page 3.)

#### 4.4.3 $X_3$ – The circumcenter

`\trt_sp_circumcenter:nnnn` This is opposite to  $X_2$ : perhaps this is the most complex of all. The barycentric coordinate formula is not simple enough for me, so I construct this point purely manually: find the intersection of the perpendicular bisectors.

```

315 \cs_new:Npn \trt_sp_circumcenter:nnnn #1 #2 #3 #4
316 {
317 \group_begin:

```

Firstly, let's store the coordinate of the vertices.

```

318 \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}

```

```

319 \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
320 \fp_set:Nn \l__trt_sp_coordinatei_x_fp {\trt@tmp@i}
321 \fp_set:Nn \l__trt_sp_coordinatei_y_fp {\trt@tmp@ii}
322 \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
323 \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
324 \fp_set:Nn \l__trt_sp_coordinateii_x_fp {\trt@tmp@i}
325 \fp_set:Nn \l__trt_sp_coordinateii_y_fp {\trt@tmp@ii}
326 \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#3}{center}}
327 \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#3}{center}}
328 \fp_set:Nn \l__trt_sp_coordinateiii_x_fp {\trt@tmp@i}
329 \fp_set:Nn \l__trt_sp_coordinateiii_y_fp {\trt@tmp@ii}

```

Now, let's change point #2 to the midpoint between #1 and #2, and do the same for #3.

```

330 \fp_set:Nn \l__trt_sp_coordinateii_x_fp
331 {
332   (\l__trt_sp_coordinatei_x_fp + \l__trt_sp_coordinateii_x_fp) / 2
333 }
334 \fp_set:Nn \l__trt_sp_coordinateii_y_fp
335 {
336   (\l__trt_sp_coordinatei_y_fp + \l__trt_sp_coordinateii_y_fp) / 2
337 }
338 \coordinate[overlay] (trt@tmp@ii) at (
339   \fp_to_dim:N \l__trt_sp_coordinateii_x_fp,
340   \fp_to_dim:N \l__trt_sp_coordinateii_y_fp);
341 \fp_set:Nn \l__trt_sp_coordinateiii_x_fp
342 {
343   (\l__trt_sp_coordinatei_x_fp + \l__trt_sp_coordinateiii_x_fp) / 2
344 }
345 \fp_set:Nn \l__trt_sp_coordinateiii_y_fp
346 {
347   (\l__trt_sp_coordinatei_y_fp + \l__trt_sp_coordinateiii_y_fp) / 2
348 }
349 \coordinate[overlay] (trt@tmp@iii) at (
350   \fp_to_dim:N \l__trt_sp_coordinateiii_x_fp,
351   \fp_to_dim:N \l__trt_sp_coordinateiii_y_fp);

```

All we have to do now is to find the equations of the bisectors and their intersection.

```

352 \trt_lt_get_line_equation:nnNNN {#1} {#2}
353   \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
354 \trt_lt_get_perpendicular_equation:nNNNNNN {trt@tmp@ii}
355   \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
356   \l__trt_sp_linei_a_fp \l__trt_sp_linei_b_fp \l__trt_sp_linei_c_fp
357 \trt_lt_get_line_equation:nnNNN {#1} {#3}
358   \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
359 \trt_lt_get_perpendicular_equation:nNNNNNN {trt@tmp@iii}
360   \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
361   \l__trt_sp_lineii_a_fp \l__trt_sp_lineii_b_fp \l__trt_sp_lineii_c_fp
362 \trt_lt_get_intersection_line:NNNNNNNN
363   \l__trt_sp_linei_a_fp \l__trt_sp_linei_b_fp \l__trt_sp_linei_c_fp
364   \l__trt_sp_lineii_a_fp \l__trt_sp_lineii_b_fp \l__trt_sp_lineii_c_fp
365   \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp
366 \coordinate[overlay] (#4) at (
367   \fp_to_dim:N \l__trt_sp_tmpa_fp, \fp_to_dim:N \l__trt_sp_tmpb_fp);
368 \group_end:
369 }

```

Quite surprisingly, the function is still very fast after all this. On my machine it never exceeds 10ms in execution time.

(End definition for `\trt_sp_circumcenter:nnnn`. This function is documented on page 3.)

#### 4.4.4 $X_4$ – The orthocenter

`\trt_sp_orthocenter:nnnn` Return the orthocenter of the triangle. This point is also constructed manually instead of using a proved formula. However, the utilities help making the construction look very simple.

```

370 \cs_new:Npn \trt_sp_orthocenter:nnnn #1 #2 #3 #4
371 {
372   \group_begin:
373     \__trt_lt_return_perpendicular_coordinate:nnnn {#1} {#2} {#3} {trt@tmp@i}
374     \__trt_lt_return_perpendicular_coordinate:nnnn {#2} {#1} {#3} {trt@tmp@ii}
375     \__trt_lt_return_intersection:nnnnn
376       {#1} {trt@tmp@i} {#2} {trt@tmp@ii} {#4}
377   \group_end:
378 }
```

(End definition for `\trt_sp_orthocenter:nnnn`. This function is documented on page 4.)

#### 4.4.5 $X_5$ – The nine-point center

`\trt_sp_ninepointcenter:nnnn` Return the center of the nine-point circle.

```

379 \cs_new:Npn \trt_sp_ninepointcenter:nnnn #1 #2 #3 #4
380 {
381   \group_begin:
```

$X_5$  is the midpoint of  $X_3$  and  $X_4$ . Therefore, for simplicity,  $X_3$  and  $X_4$  are constructed first. This causes some run-time overhead, however the overall execution time is still below 15ms, which is, in my opinion, still good.

Note that we already used `trt@tmp@i` and `trt@tmp@ii` coordinates in the construction of  $X_3$  and  $X_4$ , so to prevent conflict, `trt@tmp@iii` and `trt@tmp@iv` are used.

```

382   \trt_sp_circumcenter:nnnn {#1} {#2} {#3} {trt@tmp@iii}
383   \trt_sp_orthocenter:nnnn {#1} {#2} {#3} {trt@tmp@iv}
384   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{trt@tmp@iii}{center}}
385   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{trt@tmp@iii}{center}}
386   \fp_set:Nn \__trt_sp_tmpa_fp {\trt@tmp@i}
387   \fp_set:Nn \__trt_sp_tmpb_fp {\trt@tmp@ii}
388   \pgfextractx {\trt@tmp@i} {\pgfpointanchor{trt@tmp@iv}{center}}
389   \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{trt@tmp@iv}{center}}
390   \fp_set:Nn \__trt_sp_tmpa_fp { (\trt@tmp@i + \__trt_sp_tmpa_fp) / 2 }
391   \fp_set:Nn \__trt_sp_tmpb_fp { (\trt@tmp@ii + \__trt_sp_tmpb_fp) / 2 }
392   \coordinate[overlay] (#4) at (\fp_to_dim:N \__trt_sp_tmpa_fp,
393     \fp_to_dim:N \__trt_sp_tmpb_fp);
394   \group_end:
395 }
```

(End definition for `\trt_sp_ninepointcenter:nnnn`. This function is documented on page 4.)

#### 4.4.6 $X_6$ – The symmedian point

`\trt_sp_symmedian:nnnn` Return the symmedian point (*aka.* the Lemoine point or Grebe point). The barycentric coordinate of the point is  $(a^2, b^2, c^2)$ .

```

396 \cs_new:Npn \trt_sp_symmedian:nnnn #1 #2 #3 #4
397 {
398   \group_begin:
399     \__trt_bc_initialize:nnn {#1} {#2} {#3}
400     \trt_distance_triangle:nnNNN {#1} {#2} {#3}
401     \__trt_sp_a_fp \__trt_sp_b_fp \__trt_sp_c_fp
402     \path[overlay] (bc3 ~ cs \c_colon_str
403       \fp_eval:n {\__trt_sp_a_fp * \__trt_sp_a_fp},
404       \fp_eval:n {\__trt_sp_b_fp * \__trt_sp_b_fp},
```

```

405         \fp_eval:n {\l__trt_sp_c_fp * \l__trt_sp_c_fp} coordinate (#4);
406     \group_end:
407 }

```

(End definition for `\trt_sp_symmedian:nnnn`. This function is documented on page 4.)

#### 4.4.7 $X_7$ – The Gergonne point

`\trt_sp_gergonne:nnnn` Return the Gergonne point of the triangle. The barycentric coordinate of the point is  $(\frac{1}{b+c-a}, \frac{1}{c+a-b}, \frac{1}{a+b-c})$ .

```

408 \cs_new:Npn \trt_sp_gergonne:nnnn #1 #2 #3 #4
409 {
410     \group_begin:
411     \__trt_bc_initialize:nnn {#1} {#2} {#3}
412     \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
413     \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
414     \path[overlay] (bc3 ~ cs \c_colon_str
415         \fp_eval:n { 1/(\l__trt_sp_b_fp + \l__trt_sp_c_fp - \l__trt_sp_a_fp) },
416         \fp_eval:n { 1/(\l__trt_sp_c_fp + \l__trt_sp_a_fp - \l__trt_sp_b_fp) },
417         \fp_eval:n { 1/(\l__trt_sp_a_fp + \l__trt_sp_b_fp - \l__trt_sp_c_fp) }
418     ) coordinate (#4);
419     \group_end:
420 }

```

(End definition for `\trt_sp_gergonne:nnnn`. This function is documented on page 4.)

#### 4.4.8 $X_8$ – The Nagel point

`\trt_sp_nagel:nnnn` Return the Nagel point. The barycentric coordinate of the point is  $(b + c - a, c + a - b, a + b - c)$ .

```

421 \cs_new:Npn \trt_sp_nagel:nnnn #1 #2 #3 #4
422 {
423     \group_begin:
424     \__trt_bc_initialize:nnn {#1} {#2} {#3}
425     \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
426     \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
427     \path[overlay] (bc3 ~ cs \c_colon_str
428         \fp_eval:n { \l__trt_sp_b_fp + \l__trt_sp_c_fp - \l__trt_sp_a_fp },
429         \fp_eval:n { \l__trt_sp_c_fp + \l__trt_sp_a_fp - \l__trt_sp_b_fp },
430         \fp_eval:n { \l__trt_sp_a_fp + \l__trt_sp_b_fp - \l__trt_sp_c_fp }
431     ) coordinate (#4);
432     \group_end:
433 }

```

(End definition for `\trt_sp_nagel:nnnn`. This function is documented on page 5.)

#### 4.4.9 $X_9$ – The *mittenpunkt*

`\trt_sp_mittenpunkt:nnnn` Return the *mittenpunkt* of the triangle – its barycentric coordinate is  $(a \times (b + c - a), b \times (c + a - b), c \times (a + b - c))$ .

```

434 \cs_new:Npn \trt_sp_mittenpunkt:nnnn #1 #2 #3 #4
435 {
436     \group_begin:
437     \__trt_bc_initialize:nnn {#1} {#2} {#3}
438     \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
439     \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
440     \path[overlay] (bc3 ~ cs \c_colon_str
441         \fp_eval:n
442         {

```

```

443         \l__trt_sp_a_fp * (
444             \l__trt_sp_b_fp + \l__trt_sp_c_fp - \l__trt_sp_a_fp
445         )
446     },
447     \fp_eval:n
448     {
449         \l__trt_sp_b_fp * (
450             \l__trt_sp_c_fp + \l__trt_sp_a_fp - \l__trt_sp_b_fp
451         )
452     },
453     \fp_eval:n
454     {
455         \l__trt_sp_c_fp * (
456             \l__trt_sp_a_fp + \l__trt_sp_b_fp - \l__trt_sp_c_fp
457         )
458     }
459 ) coordinate (#4);
460 \group_end:
461 }

```

(End definition for `\trt_sp_mittenpunkt:nnnn`. This function is documented on page 5.)

#### 4.4.10 $X_{10}$ – The Spieker point

`\trt_sp_spieker:nnnn` Return the Spieker point. The barycentric coordinate of the point is  $(b+c, c+a, a+b)$ .

```

462 \cs_new:Npn \trt_sp_spieker:nnnn #1 #2 #3 #4
463 {
464     \group_begin:
465     \__trt_bc_initialize:nnn {#1} {#2} {#3}
466     \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
467     \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
468     \path[overlay] (bc3 ~ cs \c_colon_str
469         \fp_eval:n { \l__trt_sp_b_fp + \l__trt_sp_c_fp },
470         \fp_eval:n { \l__trt_sp_c_fp + \l__trt_sp_a_fp },
471         \fp_eval:n { \l__trt_sp_a_fp + \l__trt_sp_b_fp }
472     ) coordinate (#4);
473     \group_end:
474 }
475 </specialpoints>

```

(End definition for `\trt_sp_spieker:nnnn`. This function is documented on page 5.)

### 4.5 The frontend layer

```

476 <frontend>
477 \ProvidesExplFile {trtfrontend.code.tex} {2020/04/30} {0.1}
478 {The ~ triangletools ~ package: ~ The ~ front-end ~ layer}

```

The user interface of the package, which consists solely of pgf keys, will be implemented in this file.

`\l__trt_fr_output_name_tl` Store the name of the output coordinate. Default to `trt_output`.

```

479 \tl_new:N \l__trt_fr_output_name_tl
480 \tl_set:Nn \l__trt_fr_output_name_tl {trt ~ output}

```

(End definition for `\l__trt_fr_output_name_tl`.)

`\l__trt_fr_center_number_int` We only provide specific key for  $X_1, X_2, X_3$  and  $X_4$ . All other points can be referenced using a single generic key. We need to store the index of that point so that we can choose the right function for the point.

```

481 \int_new:N \l__trt_fr_center_number_int

```

(End definition for `\l__trt_fr_center_number_int`.)

`\trradius` This macro will store the radius if a circle is associated. Of course firstly we need a floating point variable specified for that purpose.

`\l__trt_fr_radius_fp`

```
482 \fp_new:N \l__trt_fr_radius_fp
483 \cs_gset_nopar:Npn \trradius
484 {
485   \msg_error:nn {triangletools} {no-radius-found} 0pt
486 }
```

(End definition for `\trradius` and `\l__trt_fr_radius_fp`. This function is documented on page 2.)

`/tikz/trt` Now it's time for the keys. They will be stored under `/tikz/triangletools` and can be accessed at `trt={⟨keys⟩}`.

```
487 \tikzset {
488   triangletools/.is ~ family,
489   trt/.code={\pgfkeys{/tikz/triangletools/.cd,#1}},
490   triangletools/.cd,
```

(End definition for `/tikz/trt`. This function is documented on page 2.)

`output_name` Change the output name of all returned coordinates.

```
491 output ~ name/.code={
492   \tl_set:Nn \l__trt_fr_output_name_tl {#1}
493 },
```

(End definition for `output name`. This function is documented on page 9.)

`intersection` The front-end of the line tools utility.  
`foot_of_perpendicular`

```
494 intersection/.code ~ args={(#1)(#2)--(#3)(#4)}{
495   \__trt_lt_return_intersection:nnnn {#1} {#2} {#3} {#4}
496   {\tl_use:N \l__trt_fr_output_name_tl}
497 },
498 foot ~ of ~ perpendicular/.code ~ args={(#1)--(#2)(#3)}{
499   \__trt_lt_return_perpendicular_coordinate:nnnn {#1} {#2} {#3}
500   {\tl_use:N \l__trt_fr_output_name_tl}
501 },
```

(End definition for `intersection` and `foot of perpendicular`. These functions are documented on page 6.)

`initialize_barycentric` The front-end of the barycentric coordinate system.

```
502 initialize ~ barycentric/.code ~ args={(#1)(#2)(#3)}{
503   \__trt_bc_initialize:nnn {#1} {#2} {#3}
504 },
```

(End definition for `initialize barycentric`. This function is documented on page 8.)

`incenter` The front-end of the triangle centers  $X_1$  to  $X_4$  and the excenter.  
`excenter`  
`centroid`  
`circumcenter`  
`orthocenter`

```
505 incenter/.code ~ args={(#1)(#2)(#3)}{
506   \trt_sp_incenter:nnnn {#1} {#2} {#3} {trt@tmp@center}
507   \pgfkeysalso{foot ~ of ~ perpendicular=(trt@tmp@center)--(#1)(#2)}
508   \trt_distance:nnN {\tl_use:N \l__trt_fr_output_name_tl} {trt@tmp@center}
509   \l__trt_fr_radius_fp
510   \cs_gset_nopar:Npx \trradius { \fp_to_dim:N \l__trt_fr_radius_fp }
511   \coordinate (\tl_use:N \l__trt_fr_output_name_tl) at (trt@tmp@center);
512 },
513 excenter/.code ~ args={(#1)(#2)(#3)}{
```

```

514 \trt_sp_excenter:nnnn {#1} {#2} {#3} {trt@tmp@center}
515 \pgfkeysalso{foot ~ of ~ perpendicular=(trt@tmp@center)--(#2)(#3)}
516 \trt_distance:nnN {\tl_use:N \l__trt_fr_output_name_tl} {trt@tmp@center}
517 \l__trt_fr_radius_fp
518 \cs_gset_nopar:Npx \trradius { \fp_to_dim:N \l__trt_fr_radius_fp }
519 \coordinate (\tl_use:N \l__trt_fr_output_name_tl) at (trt@tmp@center);
520 },
521 centroid/.code ~ args={(#1)(#2)(#3)}{
522 \trt_sp_centroid:nnnn {#1} {#2} {#3}
523 {\tl_use:N \l__trt_fr_output_name_tl}
524 },
525 circumcenter/.code ~ args={(#1)(#2)(#3)}{
526 \trt_sp_circumcenter:nnnn {#1} {#2} {#3}
527 {\tl_use:N \l__trt_fr_output_name_tl}
528 \trt_distance:nnN {\tl_use:N \l__trt_fr_output_name_tl} {#1}
529 \l__trt_fr_radius_fp
530 \cs_gset_nopar:Npx \trradius { \fp_to_dim:N \l__trt_fr_radius_fp }
531 },
532 orthocenter/.code ~ args={(#1)(#2)(#3)}{
533 \trt_sp_orthocenter:nnnn {#1} {#2} {#3}
534 {\tl_use:N \l__trt_fr_output_name_tl}
535 },

```

(End definition for *incenter* and others. These functions are documented on page 3.)

**triangle\_center** This key is used to access all centers. I don't give any centers from  $X_5$  a key – this key is necessary to construct them.

```

536 triangle ~ center/.code ~ args={(#1)(#2)(#3)(#4)}{
537 \int_case:nnF {#4}
538 {
539 {1} {
540 \pgfkeysalso{incenter=(#1)(#2)(#3)}
541 }
542 {2} {
543 \pgfkeysalso{centroid=(#1)(#2)(#3)}
544 }
545 {3} {
546 \pgfkeysalso{circumcenter=(#1)(#2)(#3)}
547 }
548 {4} {
549 \pgfkeysalso{orthocenter=(#1)(#2)(#3)}
550 }
551 {5} {
552 \trt_sp_ninepointcenter:nnnn {#1} {#2} {#3}
553 {\tl_use:N \l__trt_fr_output_name_tl}
554 \group_begin:
555 \l__trt_bc_initialize:nnn {#1} {#2} {#3}
556 \coordinate (trt@tmp@mid) at (bc3 ~ cs \c_colon_str 1,1,0);
557 \group_end:
558 \trt_distance:nnN {\tl_use:N \l__trt_fr_output_name_tl} {trt@tmp@mid}
559 \l__trt_fr_radius_fp
560 \cs_gset_nopar:Npx \trradius { \fp_to_dim:N \l__trt_fr_radius_fp }
561 }
562 {6} {
563 \trt_sp_symmedian:nnnn {#1} {#2} {#3}
564 {\tl_use:N \l__trt_fr_output_name_tl}
565 }
566 {7} {
567 \trt_sp_gergonne:nnnn {#1} {#2} {#3}
568 {\tl_use:N \l__trt_fr_output_name_tl}
569 }
570 {8} {
571 \trt_sp_nagel:nnnn {#1} {#2} {#3}

```



```

572         {\tl_use:N \l__trt_fr_output_name_tl}
573     }
574     {9} {
575         \trt_sp_mittenpunkt:nnnn {#1} {#2} {#3}
576         {\tl_use:N \l__trt_fr_output_name_tl}
577     }
578     {10} {
579         \trt_sp_spieker:nnnn {#1} {#2} {#3} {trt@tmp@center}
580         \group_begin:
581             \__trt_bc_initialize:nnn {#1} {#2} {#3}
582             \coordinate (trt@tmp@midi) at (bc3 ~ cs \c_colon_str 1,1,0);
583             \coordinate (trt@tmp@midii) at (bc3 ~ cs \c_colon_str 0,1,1);
584         \group_end:
585         \pgfkeysalso{
586             foot-of~perpendicular=(trt@tmp@center)--(trt@tmp@midi)(trt@tmp@midii)
587         }
588         \trt_distance:nnN {\tl_use:N \l__trt_fr_output_name_tl} {trt@tmp@center}
589         \l__trt_fr_radius_fp
590         \cs_gset_nopar:Npx \trradius { \fp_to_dim:N \l__trt_fr_radius_fp }
591         \coordinate (\tl_use:N \l__trt_fr_output_name_tl) at (trt@tmp@center);
592     }
593 }
594 {
595     \msg_error:nnn {triangletools} {center-not-found} {#4}
596 }
597 }
598 }
599 </frontend>

```

(End definition for *triangle center*. This function is documented on page 4.)

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..... <a href="#">66</a> , <a href="#">116</a> , <a href="#">120</a> , <a href="#">144</a> , <a href="#">147</a> , <a href="#">151</a>	..... <a href="#">269</a> , <a href="#">328</a> , <a href="#">341</a> , <a href="#">343</a> , <a href="#">350</a>
\l__trt_lt_linei_b_fp .....	\l__trt_sp_coordinateiii_y_fp ..
..... <a href="#">66</a> , <a href="#">116</a> , <a href="#">120</a> , <a href="#">144</a> , <a href="#">147</a> , <a href="#">151</a>	..... <a href="#">269</a> , <a href="#">329</a> , <a href="#">345</a> , <a href="#">347</a> , <a href="#">351</a>
\l__trt_lt_lineii_a_fp .....	\l__trt_sp_linei_a_fp .. <a href="#">269</a> , <a href="#">356</a> , <a href="#">363</a>
..... <a href="#">66</a> , <a href="#">118</a> , <a href="#">121</a> , <a href="#">148</a> , <a href="#">152</a>	\l__trt_sp_linei_b_fp .. <a href="#">269</a> , <a href="#">356</a> , <a href="#">363</a>
\l__trt_lt_lineii_b_fp .....	\l__trt_sp_linei_c_fp .. <a href="#">269</a> , <a href="#">356</a> , <a href="#">363</a>
..... <a href="#">66</a> , <a href="#">118</a> , <a href="#">121</a> , <a href="#">148</a> , <a href="#">152</a>	\l__trt_sp_lineii_a_fp .. <a href="#">269</a> , <a href="#">361</a> , <a href="#">364</a>
\l__trt_lt_lineii_c_fp .....	\l__trt_sp_lineii_b_fp .. <a href="#">269</a> , <a href="#">361</a> , <a href="#">364</a>
..... <a href="#">66</a> , <a href="#">118</a> , <a href="#">121</a> , <a href="#">148</a> , <a href="#">152</a>	\l__trt_sp_lineii_c_fp .. <a href="#">269</a> , <a href="#">361</a> , <a href="#">364</a>
\l__trt_lt_pointi_x_fp .....	\l__trt_sp_tmppa_fp .... <a href="#">281</a> , <a href="#">353</a> ,
<a href="#">62</a>	<a href="#">355</a> , <a href="#">358</a> , <a href="#">360</a> , <a href="#">365</a> , <a href="#">367</a> , <a href="#">386</a> , <a href="#">390</a> , <a href="#">392</a>
\l__trt_lt_pointi_y_fp .....	\l__trt_sp_tmppb_fp .... <a href="#">281</a> , <a href="#">353</a> ,
<a href="#">62</a>	<a href="#">355</a> , <a href="#">358</a> , <a href="#">360</a> , <a href="#">365</a> , <a href="#">367</a> , <a href="#">387</a> , <a href="#">391</a> , <a href="#">393</a>
\l__trt_lt_pointii_x_fp .....	\l__trt_sp_tmppc_fp .....
<a href="#">62</a>	..... <a href="#">281</a> , <a href="#">353</a> , <a href="#">355</a> , <a href="#">358</a> , <a href="#">360</a>
\l__trt_lt_pointii_y_fp .....	\l__trt_tmp_a_fp .....
<a href="#">62</a>	<a href="#">212</a> , <a href="#">224</a>
\__trt_lt_return_intersection:nnnnn	\l__trt_tmp_b_fp .....
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	\trradius .....
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	<a href="#">11</a> , <a href="#">56</a> , <a href="#">482</a> , <a href="#">510</a> , <a href="#">518</a> , <a href="#">530</a> , <a href="#">560</a> , <a href="#">590</a>