The triangletools package

Vu Van Dung

May 3, 2020

Contents

1 Introduction **1**

2 Loading the package **2**

3 User interface **2**
3.1 Accessing the keys . . . 2
3.2 Triangle centers . . . 2
3.3 Other utilities . . . 5
3.3.1 Line tools . . . 5
3.3.2 The barycentric coordinate system . . . 7
3.3.3 Distance-finding utility . . . 8
3.4 Customization . . . 8

4 Implementation **8**
4.1 The main package file . . . 8
4.2 Errors and warnings . . . 9
4.3 The backend layer . . . 10
4.3.1 The line tools utility . . . 10
4.3.2 The barycentric coordinate system utility . . . 12
4.3.3 Distance-finding utility . . . 14
4.4 Construction of triangle centers . . . 15
4.4.1 X_1 – The incenter . . . 16
4.4.2 X_2 – The centroid . . . 17
4.4.3 X_3 – The circumcenter . . . 17
4.4.4 X_4 – The orthocenter . . . 18
4.4.5 X_5 – The nine-point center . . . 18
4.4.6 X_6 – The symmedian point . . . 19
4.4.7 X_7 – The Gergonne point . . . 19
4.4.8 X_8 – The Nagel point . . . 20
4.4.9 X_9 – The *mittenpunkt* . . . 20
4.4.10 X_{10} – The Spieker point . . . 20
4.5 The frontend layer . . . 21

Index **23**

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 3.3) 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.

```
\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* Ti*k*Z coordinate. That is, in the following example,

```
\begin{tikzpicture}
  \draw (0,0) -- (3,0) coordinate (a);
\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` Ti*k*Z library.

3.1 Accessing the keys

`/tikz/trt` `/tikz/trt={`⟨*keys*⟩`}`

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.

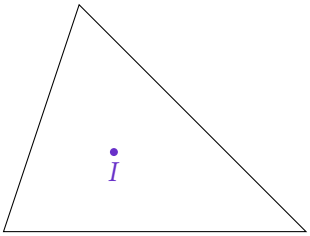
3.2 Triangle centers

`incenter` `/tikz/triangletools/incenter=(`⟨*coor 1*⟩`)(`⟨*coor 2*⟩`)(`⟨*coor 3*⟩`)`

`\trt_sp_incenter:nnnn` `\trt_sp_incenter:nnnn {`⟨*coor 1*⟩`}{`⟨*coor 2*⟩`}{`⟨*coor 3*⟩`}{`⟨*name*⟩`}`

Find the incenter X_1 of the triangle joining Ti*k*Z coordinates ⟨*coor 1*⟩, ⟨*coor 2*⟩ and ⟨*coor 3*⟩. The incenter is saved to Ti*k*Z coordinate ⟨*name*⟩.

If you use the key (why do you use the function anyway), ⟨*name*⟩ is set to `trt output` by default. You can change that using `output name`, see Section 3.4.



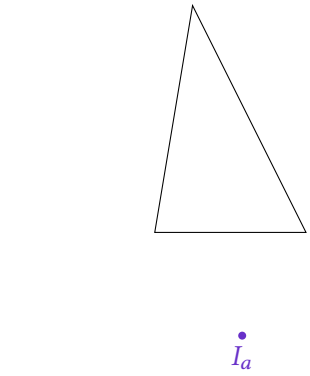

```
\begin {tikzpicture}
  \draw (1,3) coordinate (a) --
        (0,0) coordinate (b) --
        (4,0) coordinate (c) -- cycle;
  \fill[maincolor,trt={incenter=(a)(b)(c)}] (trt output)
    circle[radius=1.5pt] node[below] {$I$};
\end{tikzpicture}
```

---

excenter
\trt_sp_excenter:nnnn

/tikz/triangletools/excenter=(⟨*coor 1*⟩)(⟨*coor 2*⟩)(⟨*coor 3*⟩)
\trt_sp_excenter:nnnn {⟨*coor 1*⟩}{⟨*coor 2*⟩}{⟨*coor 3*⟩}{⟨*name*⟩}

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



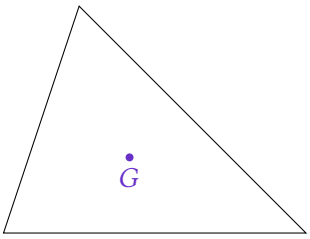

```
\begin {tikzpicture}
  \draw (.5,3) coordinate (a) --
        (0 ,0) coordinate (b) --
        (2 ,0) coordinate (c) -- cycle;
  \fill[maincolor,trt={excenter=(a)(b)(c)}] (trt output)
    circle[radius=1.5pt] node[below] {$I_a$};
\end{tikzpicture}
```

---

centroid
\trt_sp_centroid:nnnn

/tikz/triangletools/centroid=(⟨*coor 1*⟩)(⟨*coor 2*⟩)(⟨*coor 3*⟩)
\trt_sp_centroid:nnnn {⟨*coor 1*⟩}{⟨*coor 2*⟩}{⟨*coor 3*⟩}{⟨*name*⟩}

Find the centroid X_2 of the triangle.



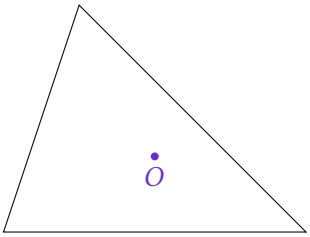

```
\begin {tikzpicture}
  \draw (1,3) coordinate (a) --
        (0,0) coordinate (b) --
        (4,0) coordinate (c) -- cycle;
  \fill[maincolor,trt={centroid=(a)(b)(c)}] (trt output)
    circle[radius=1.5pt] node[below] {$G$};
\end{tikzpicture}
```

---

circumcenter
\trt_sp_circumcenter:nnnn

/tikz/triangletools/circumcenter=(⟨*coor 1*⟩)(⟨*coor 2*⟩)(⟨*coor 3*⟩)
\trt_sp_circumcenter:nnnn {⟨*coor 1*⟩}{⟨*coor 2*⟩}{⟨*coor 3*⟩}{⟨*name*⟩}

Find the circumcenter X_3 of the triangle.



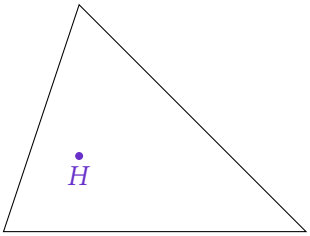

```
\begin {tikzpicture}
  \draw (1,3) coordinate (a) --
        (0,0) coordinate (b) --
        (4,0) coordinate (c) -- cycle;
  \fill[maincolor,trt={circumcenter=(a)(b)(c)}] (trt output)
    circle[radius=1.5pt] node[below] {$O$};
\end{tikzpicture}
```

---

orthocenter
\trt_sp_orthocenter:nnnn

/tikz/triangletools/orthocenter=(⟨*coor 1*⟩)(⟨*coor 2*⟩)(⟨*coor 3*⟩)
\trt_sp_orthocenter:nnnn {⟨*coor 1*⟩}{⟨*coor 2*⟩}{⟨*coor 3*⟩}{⟨*name*⟩}

Find the orthocenter X_4 of the triangle.



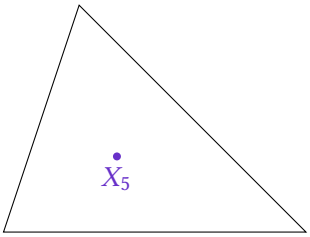

```
\begin {tikzpicture}
  \draw (1,3) coordinate (a) --
        (0,0) coordinate (b) --
        (4,0) coordinate (c) -- cycle;
  \fill[maincolor,trt={orthocenter=(a)(b)(c)}] (trt output)
    circle[radius=1.5pt] node[below] {$H$};
\end{tikzpicture}
```

`triangle_center` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(⟨index⟩)`

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

`\trt_sp_ninepointcenter:nnnn` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(5)`
`\trt_sp_ninepointcenter:nnnn {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨name⟩}`

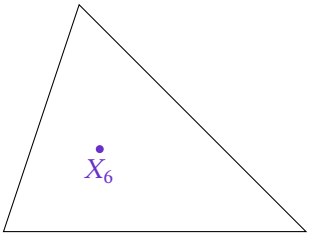
Find the nine-point center X_5 of the triangle.




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

`\trt_sp_symmedian:nnnn` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(6)`
`\trt_sp_symmedian:nnnn {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨name⟩}`

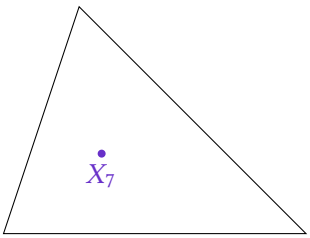
Find the symmedian point X_6 (*aka.* the Lemoine point or Grebe point) of the triangle.




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

`\trt_sp_gergonne:nnnn` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(7)`
`\trt_sp_gergonne:nnnn {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨name⟩}`

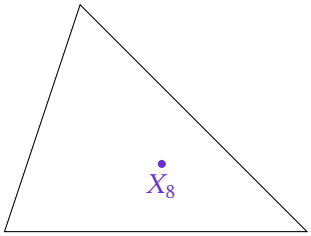
Find the Gergonne point X_7 of the triangle.




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

`\trt_sp_nagel:nnnn` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(8)`
`\trt_sp_nagel:nnnn {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨name⟩}`

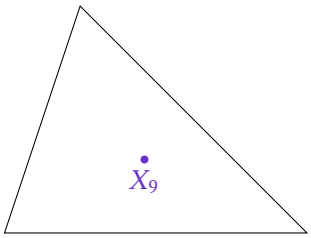
Find the Nagel point X_8 of the triangle.




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

`\trt_sp_mittenpunkt:nnnn` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(9)`
`\trt_sp_mittenpunkt:nnnn {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨name⟩}`

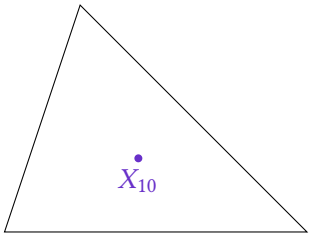
Find the *mittenpunkt* X_9 of the triangle.




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

`\trt_sp_spieker:nnnn` `/tikz/trangletools/triangle center=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)(10)`
`\trt_sp_spieker:nnnn {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨name⟩}`

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




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

3.3 Other utilities

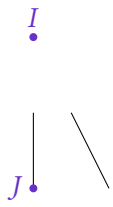
3.3.1 Line tools

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

`intersection` `/tikz/trangletools/intersection=(⟨coor 1⟩)(⟨coor 2⟩)--(⟨coor 3⟩)(⟨coor 4⟩)`

There are two lines, the first joins ⟨*coor 1*⟩ and ⟨*coor 2*⟩, and the other joins ⟨*coor 3*⟩ and ⟨*coor 4*⟩. This finds the intersection of these lines.

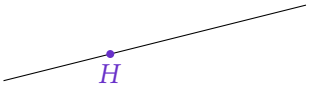
If the two lines are parallel, `trt output` is set to `(0,0)`, and the package will report a warning.




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

foot_of_perpendicular `/tikz/triangletools/foot of perpendicular=(⟨coor 1⟩)--(⟨coor 2⟩)(⟨coor 3⟩)`

Find the foot of perpendicular of point ⟨*coor 1*⟩ to the line joining ⟨*coor 2*⟩ and ⟨*coor 3*⟩.

- 

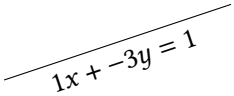

```
\begin {tikzpicture}
  \draw (0,0) coordinate (b) -- (4,1) coordinate (c);
  \fill (1,2) circle (1.5pt) coordinate (a);
  \fill[maincolor,trt={foot of perpendicular=(a)--(b)(c)}] (trt output)
    circle (1.5pt) node[below] {$H$};
\end{tikzpicture}
```

You can do much more using these expl3 functions.

\trt_lt_get_line_equation:nnNNN `\trt_lt_get_line_equation:nnNNN{⟨coor 1⟩}{⟨coor 2⟩}⟨a⟩⟨b⟩⟨c⟩`

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

Note that for any pair of points ⟨*coor 1*⟩ and ⟨*coor 2*⟩, there are infinitely many solutions for ⟨*a*⟩, ⟨*b*⟩ and ⟨*c*⟩. 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.




```
\begin {tikzpicture}
  \coordinate (a) at (1,0);
  \coordinate (b) at (4,1);
  \ExplSyntaxOn
  \fp_new:N \l_foo_tmpa_fp
  \fp_new:N \l_foo_tmpb_fp
  \fp_new:N \l_foo_tmpc_fp
  \trt_lt_get_line_equation:nnNNN {a} {b}
    \l_foo_tmpa_fp \l_foo_tmpb_fp \l_foo_tmpc_fp
  \fp_new:N \c_foo_cm_fp
  \fp_set:Nn \c_foo_cm_fp {28.45275590551181}
  \def \resultequation {
    $\fp_eval:n {round (\l_foo_tmpa_fp / \c_foo_cm_fp)}x +
     \fp_eval:n {round (\l_foo_tmpb_fp / \c_foo_cm_fp)}y
    =\fp_eval:n {round (\l_foo_tmpc_fp / (\c_foo_cm_fp * \c_foo_cm_fp))}$
  }
  \ExplSyntaxOff
  \draw (a) -- (b) node[midway,sloped,below] {\resultequation};
\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 ⟨*x*⟩ and ⟨*y*⟩.

All arguments are floating points variables, ⟨*x*⟩ and ⟨*y*⟩ needs to be local variables.

\trt_lt_get_intersection_coordinate:nnnnNN `\trt_lt_get_intersection_coordinate:nnnnNN {⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}{⟨coor 4⟩}⟨x⟩⟨y⟩`

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

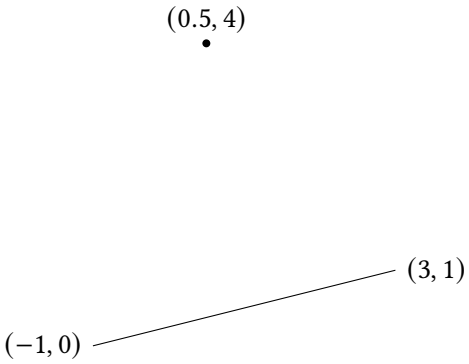
A warning will be raised if the lines are parallel, in that case ⟨*x*⟩ and ⟨*y*⟩ are set to zero.

This is the base of `intersection`.

```
\begin {tikzpicture}
  \draw (0,0) coordinate (a) -- (0,1) coordinate (b);
  \draw (1,0) coordinate (c) -- (.5,1) coordinate (d);
  \ExplSyntaxOn
  \fp_new:N \l_foo_tmpa_fp
  \fp_new:N \l_foo_tmpb_fp
  \trt_lt_get_intersection_coordinate:nnnnNN {a} {b} {c} {d}
    \l_foo_tmpa_fp \l_foo_tmpb_fp
  \coordinate (i) at (\fp_to_dim:N \l_foo_tmpa_fp,
                      \fp_to_dim:N \l_foo_tmpb_fp);
  \ExplSyntaxOff
  \fill[maincolor] (i) circle (1.5pt);
\end{tikzpicture}
```

`\trt_lt_get_perpendicular_equation:nNNNNNN` `\trt_lt_get_perpendicular_equation:nNNNNNN {⟨coor 1⟩}⟨a1⟩⟨b1⟩⟨c1⟩⟨a2⟩⟨b2⟩⟨c2⟩`

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




```
\begin {tikzpicture}
  \draw (-1,0) coordinate (b) node[left] {$(-1,0)$} --
        (3,1)  coordinate (c) node[right] {$(3,1)$};
  \fill (0.5,4) circle (1.5pt) coordinate (a) node[above] {$(0.5,4)$};
  \ExplSyntaxOn
  \fp_new:N \l_foo_tmpa_fp
  \fp_new:N \l_foo_tmpb_fp
  \fp_new:N \l_foo_tmpc_fp
  \fp_new:N \l_foo_tmpd_fp
  \fp_new:N \l_foo_tmpe_fp
  \fp_new:N \l_foo_tmpf_fp
  \trt_lt_get_line_equation:nnNNN {b} {c}
    \l_foo_tmpa_fp \l_foo_tmpb_fp \l_foo_tmpc_fp
  \trt_lt_get_perpendicular_equation:nNNNNNN {a}
    \l_foo_tmpa_fp \l_foo_tmpb_fp \l_foo_tmpc_fp
    \l_foo_tmpd_fp \l_foo_tmpe_fp \l_foo_tmpf_fp
  \fp_new:N \c_foo_cm_fp
  \fp_set:Nn \c_foo_cm_fp {28.45275590551181}
  \def \resultequation {
    $\fp_eval:n {round (\l_foo_tmpd_fp / \c_foo_cm_fp)}x +
     \fp_eval:n {round (\l_foo_tmpe_fp / \c_foo_cm_fp)}y
    =\fp_eval:n {round (\l_foo_tmpf_fp / (\c_foo_cm_fp * \c_foo_cm_fp))}$
  }
  \ExplSyntaxOff
  \path (1,0) node[below=3mm,align=center]
    {Equation of perpendicular line:\\\resultequation};
\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 ⟨*coor 1*⟩ to the line joining ⟨*coor 2*⟩ and ⟨*coor 3*⟩. Afterwards store the dimensions found in ⟨x⟩ and ⟨y⟩.

This is the base of `foot of perpendicular`.

3.3.2 The barycentric coordinate system

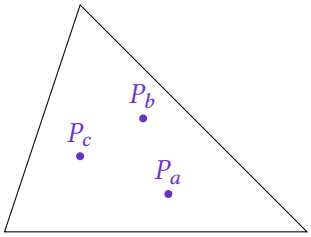
`initialize_barycentric` `/tikz/triangletools/initialize barycentric=(⟨coor 1⟩)(⟨coor 2⟩)(⟨coor 3⟩)`

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

bc3 `(bc3 cs:⟨l1⟩,⟨l2⟩,⟨l3⟩)`

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 ⟨*l1*⟩, ⟨*l2*⟩ and ⟨*l3*⟩ is not necessarily 1 – the package will take care of that internally.

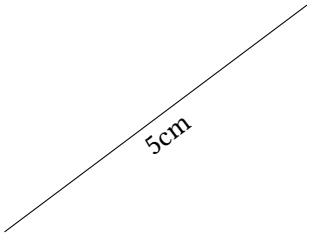



```
\begin {tikzpicture}
  \draw (1,3) coordinate (a) --
        (0,0) coordinate (b) --
        (4,0) coordinate (c) -- cycle;
  \fill[maincolor,trt={initialize barycentric=(a)(b)(c)}] (bc3 cs:1,2,3)
    circle[radius=1.5pt] node[above] {$P_a$};
  \fill[maincolor,trt={initialize barycentric=(b)(c)(a)}]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

3.3.3 Distance-finding utility

\trt_distance:nnN `\trt_distance:nnN {⟨coor 1⟩} {⟨coor 2⟩} ⟨fp var⟩`

Find distance between ⟨*coor 1*⟩ and ⟨*coor 2*⟩, and store that value to ⟨*fp var*⟩.




```
\begin {tikzpicture}
  \path (0,0) coordinate (a) (4,3) coordinate (b);
  \ExplSyntaxOn
  \fp_new:N \l_foo_tmpa_fp
  \trt_distance:nnN {a} {b} \l_foo_tmpa_fp
  \fp_new:N \c_foo_cm_fp
  \fp_set:Nn \c_foo_cm_fp {28.45275590551181}
  \draw (a) -- (b) node[midway,sloped,below]
    { \fp_eval:n {round(\l_foo_tmpa_fp / \c_foo_cm_fp)} cm };
  \ExplSyntaxOff
\end{tikzpicture}
```

\trt_distance_triangle:nnnNNN `\trt_distance_triangle:nnnNNN{⟨coor 1⟩}{⟨coor 2⟩}{⟨coor 3⟩}⟨a⟩⟨b⟩⟨c⟩`

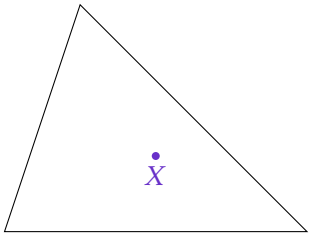
`\trt_distance:nnN` is needed to find the side lengths in a triangle (these side lengths are very helpful in many areas, for instance in this package to find special points based on the barycentric system). However, using it three times in a row is not quite elegant; this function is defined to automate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

⟨*a*⟩ is set to the distance between ⟨*coor 2*⟩ and ⟨*coor 3*⟩, similar things happen for ⟨*b*⟩ and ⟨*c*⟩.

3.4 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`.




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

4 Implementation

⟨@@=trt⟩

4.1 The main package file

⟨*triangletools⟩

```
\RequirePackage{tikz}
\RequirePackage{xparse}
\ProvidesExplPackage {triangletools} {2020/04/30} {0.1}
  {TikZ support for triangular geometry}
```

\trt@tmp@i
\trt@tmp@ii

We will use these dimensions many times to extract the dimensions of a Ti*k*Z coordinate.

```
\newdimen\trt@tmp@i
\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.

```
\input {trtmessages.code.tex}
\input {trtlinetools.code.tex}
\input {trtbarycentric.code.tex}
\input {trtdistance.code.tex}
\input {trtspecialpoints.code.tex}
\input {trtfrontend.code.tex}
```

⟨/triangletools⟩

4.2 Errors and warnings

⟨*messages⟩

```
\ProvidesExplFile {trtmessages.code.tex} {2020/04/30} {0.1}
  {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`.

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

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.

```
\msg_new:nnnn {triangletools} {uninitialized}
  {
    Barycentric ~ coordinate ~ system ~ not ~ initialized.
  }
  {
    You ~ have ~ not ~ initialized ~ the ~ three ~ anchor ~ points ~ for ~
    the ~ coordinate ~ system. ~ Please ~ initialize ~ the ~ points ~
    before ~ using ~ the ~ ‘bc3’ ~ coordinate ~ system.
  }
```

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.

```
\msg_new:nnnn {triangletools} {center-not-found}
  {
    Triangle ~ center ~ not ~ found.
  }
  {
    I ~ can’t ~ find ~ the ~ requested ~ triangle ~ center, ~ because ~
    point ~ X(#1) ~ is ~ not ~ yet ~ implemented ~ in ~ the ~ triangletools ~
    package. ~ Try ~ to ~ construct ~ it ~ yourself.
  }
```

⟨/messages⟩

4.3 The backend layer

4.3.1 The line tools utility

⟨*linetools⟩

```
\ProvidesExplFile {trtlinetools.code.tex} {2020/04/30} {0.1}
  {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.

`\l__trt_lt_pointi_x_fp` `\l__trt_lt_pointi_y_fp` `\l__trt_lt_pointii_x_fp` `\l__trt_lt_pointii_y_fp`

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

```
\fp_new:N \l__trt_lt_pointi_x_fp
\fp_new:N \l__trt_lt_pointi_y_fp
\fp_new:N \l__trt_lt_pointii_x_fp
\fp_new:N \l__trt_lt_pointii_y_fp
```

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

`\l__trt_lt_linei_a_fp` `\l__trt_lt_linei_b_fp` `\l__trt_lt_linei_c_fp` `\l__trt_lt_lineii_a_fp` `\l__trt_lt_lineii_b_fp` `\l__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.

```
\fp_new:N \l__trt_lt_linei_a_fp
\fp_new:N \l__trt_lt_linei_b_fp
\fp_new:N \l__trt_lt_linei_c_fp
\fp_new:N \l__trt_lt_lineii_a_fp
\fp_new:N \l__trt_lt_lineii_b_fp
\fp_new:N \l__trt_lt_lineii_c_fp
```

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

`\l__trt_lt_tmp_fp` `\l__trt_lt_tmpa_fp` `\l__trt_lt_tmpb_fp`

Some additional temporary variables.

```
\fp_new:N \l__trt_lt_tmp_fp
```

```
\fp_new:N \l__trt_lt_tmpa_fp
\fp_new:N \l__trt_lt_tmpb_fp
```

(*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.

```
\cs_new:Npn \trt_lt_get_line_equation:nnNNN #1 #2 #3 #4 #5
  {
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
    \fp_set:Nn \l__trt_i_pointi_x_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_i_pointi_y_fp {\trt@tmp@ii}
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
    \fp_set:Nn \l__trt_i_pointii_x_fp {\trt@tmp@i}
    \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.

```
    \fp_set:Nn #3
      {
        \l__trt_i_pointii_y_fp - \l__trt_i_pointi_y_fp
      }
    \fp_set:Nn #4
      {
        \l__trt_i_pointi_x_fp - \l__trt_i_pointii_x_fp
      }
    \fp_set:Nn #5
      {
        #3 * \l__trt_i_pointi_x_fp + #4 * \l__trt_i_pointi_y_fp
      }
  }
```

(*End definition for* `\trt_lt_get_line_equation:nnNNN`. *This function is documented on page 5.*)

`\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`.

```
\cs_new:Npn \trt_lt_get_intersection_line:NNNNNNNN #1 #2 #3 #4 #5 #6 #7 #8
  {
    \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.

```
    \fp_compare:nNnTF {\l__trt_lt_tmp_fp} = {0}
      {
        \msg_warning:nnnnnn {triangletools} {intersection-not-found}
          {(#1)} {(#2)} {(#3)} {(#4)}
        \fp_set:Nn #7 {0}
        \fp_set:Nn #8 {0}
      }
      {
        \fp_set:Nn #7 { ( #5 * #3 - #2 * #6 ) / \l__trt_lt_tmp_fp }
        \fp_set:Nn #8 { ( #1 * #6 - #4 * #3 ) / \l__trt_lt_tmp_fp }
      }
  }
```

(*End definition for* `\trt_lt_get_intersection_line:NNNNNNNN`. *This function is documented on page 6.*)

\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.

```
\cs_new:Npn \trt_lt_get_intersection_coordinate:nnnnNN #1 #2 #3 #4 #5 #6
  {
    \trt_lt_get_line_equation:nnNNN {#1} {#2}
      \l__trt_lt_linei_a_fp \l__trt_lt_linei_b_fp \l__trt_lt_linei_c_fp
    \trt_lt_get_line_equation:nnNNN {#3} {#4}
      \l__trt_lt_lineii_a_fp \l__trt_lt_lineii_b_fp \l__trt_lt_lineii_c_fp
    \trt_lt_get_intersection_line:NNNNNNNN
      \l__trt_lt_linei_a_fp \l__trt_lt_linei_b_fp \l__trt_lt_linei_c_fp
      \l__trt_lt_lineii_a_fp \l__trt_lt_lineii_b_fp \l__trt_lt_lineii_c_fp
      #5 #6
  }
```

(*End definition for* `\trt_lt_get_intersection_coordinate:nnnnNN`. *This function is documented on page* 6.)

__trt_lt_return_intersection:nnnnn

Now, let's Ti*k*Zify 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.

```
\cs_new:Npn \__trt_lt_return_intersection:nnnnn #1 #2 #3 #4 #5
  {
    \trt_lt_get_intersection_coordinate:nnnnNN {#1} {#2} {#3} {#4}
      \l__trt_lt_tmpa_fp \l__trt_lt_tmpb_fp
    \coordinate[overlay] (#5) at
      (\fp_to_dim:N \l__trt_lt_tmpa_fp, \fp_to_dim:N \l__trt_lt_tmpb_fp);
  }
```

(*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.

```
\cs_new:Npn \trt_lt_get_perpendicular_equation:nNNNNNN #1 #2 #3 #4 #5 #6 #7
  {
    \fp_set:Nn #5 { -#3 }
    \fp_set:Nn #6 { #2 }
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
    \fp_set:Nn \l__trt_lt_tmpa_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_lt_tmpb_fp {\trt@tmp@ii}
    \fp_set:Nn #7 { #5 * \l__trt_lt_tmpa_fp + #6 * \l__trt_lt_tmpb_fp }
  }
```

(*End definition for* `\trt_lt_get_perpendicular_equation:nNNNNNN`. *This function is documented on page* 6.)

\trt_lt_get_perpendicular_coordinate:nnnNN

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

```
\cs_new:Npn \trt_lt_get_perpendicular_coordinate:nnnNN #1 #2 #3 #4 #5
  {
    \trt_lt_get_line_equation:nnNNN {#2} {#3}
      \l__trt_lt_linei_a_fp \l__trt_lt_linei_b_fp \l__trt_lt_linei_c_fp

    \trt_lt_get_perpendicular_equation:nNNNNNN {#1}
      \l__trt_lt_linei_a_fp \l__trt_lt_linei_b_fp \l__trt_lt_linei_c_fp
      \l__trt_lt_lineii_a_fp \l__trt_lt_lineii_b_fp \l__trt_lt_lineii_c_fp
```

```
    \trt_lt_get_intersection_line:NNNNNNNN
      \l__trt_lt_linei_a_fp \l__trt_lt_linei_b_fp \l__trt_lt_linei_c_fp
      \l__trt_lt_lineii_a_fp \l__trt_lt_lineii_b_fp \l__trt_lt_lineii_c_fp
      #4 #5
  }
```

(*End definition for* `\trt_lt_get_perpendicular_coordinate:nnnNN`. *This function is documented on page* 7.)

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

```
\cs_new:Npn \__trt_lt_return_perpendicular_coordinate:nnnn #1 #2 #3 #4
  {
    \trt_lt_get_perpendicular_coordinate:nnnNN {#1} {#2} {#3}
      \l__trt_lt_tmpa_fp \l__trt_lt_tmpb_fp
    \coordinate[overlay] (#4) at
      (\fp_to_dim:N \l__trt_lt_tmpa_fp, \fp_to_dim:N \l__trt_lt_tmpb_fp);
  }
⟨/linetools⟩
```

(*End definition for* `\__trt_lt_return_perpendicular_coordinate:nnnn`.)

4.3.2 The barycentric coordinate system utility

```
⟨*barycentric⟩
\ProvidesExplFile {trtbarycentric.code.tex} {2020/04/30} {0.1}
  {
    The ~ triangletools ~ package: ~ Utilities ~ for ~ the ~ barycentric ~
    coordinate ~ system.
  }
```

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.

```
\fp_new:N \l__trt_bc_anchor_ix_fp
\fp_new:N \l__trt_bc_anchor_iy_fp
\fp_new:N \l__trt_bc_anchor_iix_fp
\fp_new:N \l__trt_bc_anchor_iiy_fp
\fp_new:N \l__trt_bc_anchor_iiix_fp
\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 λ? Well, I don't know. Wikipedia uses that, so I do the same.

```
\fp_new:N \l__trt_bc_lambda_i_fp
\fp_new:N \l__trt_bc_lambda_ii_fp
\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.

```
\bool_new:N \l__trt_bc_initialized_bool
```

(*End definition for* `\l__trt_bc_initialized_bool`.)

\l__trt_bc_tmp_fp A temporary variable.

```
\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.

```
\cs_new:Npn \__trt_bc_initialize:nnn #1 #2 #3
  {
    \bool_set_true:N \l__trt_bc_initialized_bool
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
    \fp_set:Nn \l__trt_bc_anchor_ix_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_bc_anchor_iy_fp {\trt@tmp@ii}
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
    \fp_set:Nn \l__trt_bc_anchor_iix_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_bc_anchor_iiy_fp {\trt@tmp@ii}
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#3}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#3}{center}}
    \fp_set:Nn \l__trt_bc_anchor_iiix_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_bc_anchor_iiiy_fp {\trt@tmp@ii}
  }
```

(*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.

```
\tikzdeclarecoordinatesystem {bc3}
  {
    \bool_if:NTF \l__trt_bc_initialized_bool
      {
        \__trt_bc_parse:w #1 \q_stop
      }
      {
        \msg_error:nn {triangletools} {uninitialized}
      }
  }
```

(*End definition for* `bc3`. *This function is documented on page 7.*)

__trt_bc_parse:w This is the parser we use for `bc3`.

The conversion from λ_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 λ_i so that $\lambda_1 + \lambda_2 + \lambda_3 = 1$.

```
\cs_new:Npn \__trt_bc_parse:w #1,#2,#3 \q_stop
  {
    \fp_set:Nn \l__trt_bc_tmp_fp { (#1) + (#2) + (#3) }
    \fp_set:Nn \l__trt_bc_lambda_i_fp { (#1) / (\l__trt_bc_tmp_fp) }
    \fp_set:Nn \l__trt_bc_lambda_ii_fp { (#2) / (\l__trt_bc_tmp_fp) }
    \fp_set:Nn \l__trt_bc_lambda_iii_fp { (#3) / (\l__trt_bc_tmp_fp) }
    \fp_set:Nn \l__trt_tmp_a_fp
      {
        \l__trt_bc_anchor_ix_fp * \l__trt_bc_lambda_i_fp +
```

```
      \l__trt_bc_anchor_iix_fp * \l__trt_bc_lambda_ii_fp +
      \l__trt_bc_anchor_iiix_fp * \l__trt_bc_lambda_iii_fp
    }
  \fp_set:Nn \l__trt_tmp_b_fp
    {
      \l__trt_bc_anchor_iy_fp * \l__trt_bc_lambda_i_fp +
      \l__trt_bc_anchor_iiy_fp * \l__trt_bc_lambda_ii_fp +
      \l__trt_bc_anchor_iiiy_fp * \l__trt_bc_lambda_iii_fp
    }
```

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

```
  \pgf@x = \fp_to_dim:N \l__trt_tmp_a_fp
  \pgf@y = \fp_to_dim:N \l__trt_tmp_b_fp
}
```
⟨/barycentric⟩

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

4.3.3 Distance-finding utility

⟨*distance⟩

```
\ProvidesExplFile {trtdistance.code.tex} {2020/04/30} {0.1}
  {The ~ triangletools ~ package: ~ Utilities ~ for ~ 2d ~ distance}
```

This file implements functions to find the distance between (2d) Ti*k*Z coordinates.

`\l__trt_d_pointi_x_fp` `\l__trt_d_pointi_y_fp` `\l__trt_d_pointii_x_fp` `\l__trt_d_pointii_y_fp`

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

```
\fp_new:N \l__trt_d_pointi_x_fp
\fp_new:N \l__trt_d_pointii_x_fp
\fp_new:N \l__trt_d_pointi_y_fp
\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 Ti*k*Z coordinates `#1` and `#2`.

```
\cs_new:Npn \trt_distance:nnN #1 #2 #3
  {
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
    \fp_set:Nn \l__trt_d_pointi_x_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_d_pointi_y_fp {\trt@tmp@ii}
    \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
    \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
    \fp_set:Nn \l__trt_d_pointii_x_fp {\trt@tmp@i}
    \fp_set:Nn \l__trt_d_pointii_y_fp {\trt@tmp@ii}
    \fp_set:Nn #3
      {
        sqrt((
          (\l__trt_d_pointi_x_fp - \l__trt_d_pointii_x_fp) *
          (\l__trt_d_pointi_x_fp - \l__trt_d_pointii_x_fp)
        ) + (
          (\l__trt_d_pointi_y_fp - \l__trt_d_pointii_y_fp) *
          (\l__trt_d_pointi_y_fp - \l__trt_d_pointii_y_fp)
        ))
      }
  }
```

(*End definition for* `\trt_distance:nnN`. *This function is documented on page* 8.)

`\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.

```
\cs_new:Npn \trt_distance_triangle:nnnNNN #1 #2 #3 #4 #5 #6
  {
    \trt_distance:nnN {#2} {#3} #4
    \trt_distance:nnN {#3} {#1} #5
    \trt_distance:nnN {#1} {#2} #6
  }
⟨/distance⟩
```

(*End definition for* `\trt_distance_triangle:nnnNNN`. *This function is documented on page 8.*)

4.4 Construction of triangle centers

```
⟨*specialpoints⟩
\ProvidesExplFile {trtspecialpoints.code.tex} {2020/04/30} {0.1}
  {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` `\l__trt_sp_b_fp` `\l__trt_sp_c_fp`

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

```
\fp_new:N \l__trt_sp_a_fp
\fp_new:N \l__trt_sp_b_fp
\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` `\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`

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

```
\fp_new:N \l__trt_sp_coordinatei_x_fp
\fp_new:N \l__trt_sp_coordinatei_y_fp
\fp_new:N \l__trt_sp_coordinateii_x_fp
\fp_new:N \l__trt_sp_coordinateii_y_fp
\fp_new:N \l__trt_sp_coordinateiii_x_fp
\fp_new:N \l__trt_sp_coordinateiii_y_fp
\fp_new:N \l__trt_sp_linei_a_fp
\fp_new:N \l__trt_sp_linei_b_fp
\fp_new:N \l__trt_sp_linei_c_fp
\fp_new:N \l__trt_sp_lineii_a_fp
\fp_new:N \l__trt_sp_lineii_b_fp
\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` `\l__trt_sp_tmpb_fp` `\l__trt_sp_tmpc_fp`

Some additional temporary variables.

```
\fp_new:N \l__trt_sp_tmpa_fp
\fp_new:N \l__trt_sp_tmpb_fp
\fp_new:N \l__trt_sp_tmpc_fp
```

(*End definition for* `\l__trt_sp_tmpa_fp`, `\l__trt_sp_tmpb_fp`, *and* `\l__trt_sp_tmpc_fp`.)

4.4.1 X_1 – The incenter

Each center will have a function taking four arguments. The first three arguments are the Ti*k*Z coordinates of the triangle vertices; the last argument is the name of the return Ti*k*Z 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).

```
\cs_new:Npn \trt_sp_incenter:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n {\l__trt_sp_a_fp},
        \fp_eval:n {\l__trt_sp_b_fp},
        \fp_eval:n {\l__trt_sp_c_fp}) coordinate (#4);
    \group_end:
  }
```

(*End definition for* `\trt_sp_incenter:nnnn`. *This function is documented on page* 2.)

\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.

```
\cs_new:Npn \trt_sp_excenter:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n {- \l__trt_sp_a_fp},
        \fp_eval:n {\l__trt_sp_b_fp},
        \fp_eval:n {\l__trt_sp_c_fp}) coordinate (#4);
    \group_end:
  }
```

(*End definition for* `\trt_sp_excenter:nnnn`. *This function is documented on page* 2.)

4.4.2 X_2 – The centroid

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

```
\cs_new:Npn \trt_sp_centroid:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \path[overlay] (bc3 ~ cs \c_colon_str 1, 1, 1) coordinate (#4);
    \group_end:
  }
```

(*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.

```
\cs_new:Npn \trt_sp_circumcenter:nnnn #1 #2 #3 #4
  {
    \group_begin:
```

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

```
      \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#1}{center}}
      \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#1}{center}}
      \fp_set:Nn \l__trt_sp_coordinatei_x_fp {\trt@tmp@i}
      \fp_set:Nn \l__trt_sp_coordinatei_y_fp {\trt@tmp@ii}
      \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#2}{center}}
      \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#2}{center}}
      \fp_set:Nn \l__trt_sp_coordinateii_x_fp {\trt@tmp@i}
      \fp_set:Nn \l__trt_sp_coordinateii_y_fp {\trt@tmp@ii}
      \pgfextractx {\trt@tmp@i} {\pgfpointanchor{#3}{center}}
      \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{#3}{center}}
      \fp_set:Nn \l__trt_sp_coordinateiii_x_fp {\trt@tmp@i}
      \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.

```
      \fp_set:Nn \l__trt_sp_coordinateii_x_fp
        {
          (\l__trt_sp_coordinatei_x_fp + \l__trt_sp_coordinateii_x_fp) / 2
        }
      \fp_set:Nn \l__trt_sp_coordinateii_y_fp
        {
          (\l__trt_sp_coordinatei_y_fp + \l__trt_sp_coordinateii_y_fp) / 2
        }
      \coordinate[overlay] (trt@tmp@ii) at (
        \fp_to_dim:N \l__trt_sp_coordinateii_x_fp,
        \fp_to_dim:N \l__trt_sp_coordinateii_y_fp);
      \fp_set:Nn \l__trt_sp_coordinateiii_x_fp
        {
          (\l__trt_sp_coordinatei_x_fp + \l__trt_sp_coordinateiii_x_fp) / 2
        }
      \fp_set:Nn \l__trt_sp_coordinateiii_y_fp
        {
          (\l__trt_sp_coordinatei_y_fp + \l__trt_sp_coordinateiii_y_fp) / 2
        }
      \coordinate[overlay] (trt@tmp@iii) at (
        \fp_to_dim:N \l__trt_sp_coordinateiii_x_fp,
        \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.

```
      \trt_lt_get_line_equation:nnNNN {#1} {#2}
        \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
      \trt_lt_get_perpendicular_equation:nNNNNNN {trt@tmp@ii}
        \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
        \l__trt_sp_linei_a_fp \l__trt_sp_linei_b_fp \l__trt_sp_linei_c_fp
      \trt_lt_get_line_equation:nnNNN {#1} {#3}
        \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
      \trt_lt_get_perpendicular_equation:nNNNNNN {trt@tmp@iii}
        \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp \l__trt_sp_tmpc_fp
        \l__trt_sp_lineii_a_fp \l__trt_sp_lineii_b_fp \l__trt_sp_lineii_c_fp
      \trt_lt_get_intersection_line:NNNNNNNN
        \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
        \l__trt_sp_tmpa_fp \l__trt_sp_tmpb_fp
      \coordinate[overlay] (#4) at (
        \fp_to_dim:N \l__trt_sp_tmpa_fp, \fp_to_dim:N \l__trt_sp_tmpb_fp);
    \group_end:
  }
```

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.

```
\cs_new:Npn \trt_sp_orthocenter:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_lt_return_perpendicular_coordinate:nnnn {#1} {#2} {#3} {trt@tmp@i}
      \__trt_lt_return_perpendicular_coordinate:nnnn {#2} {#1} {#3} {trt@tmp@ii}
      \__trt_lt_return_intersection:nnnnn
        {#1} {trt@tmp@i} {#2} {trt@tmp@ii} {#4}
    \group_end:
  }
```

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

4.4.5 X_5 – The nine-point center

\trt_sp_ninepointcenter:nnnn

Return the center of the nine-point circle.

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

X_5 is 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.

```
      \trt_sp_circumcenter:nnnn {#1} {#2} {#3} {trt@tmp@iii}
      \trt_sp_orthocenter:nnnn {#1} {#2} {#3} {trt@tmp@iv}
      \pgfextractx {\trt@tmp@i} {\pgfpointanchor{trt@tmp@iii}{center}}
      \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{trt@tmp@iii}{center}}
      \fp_set:Nn \l__trt_sp_tmpa_fp {\trt@tmp@i}
      \fp_set:Nn \l__trt_sp_tmpb_fp {\trt@tmp@ii}
      \pgfextractx {\trt@tmp@i} {\pgfpointanchor{trt@tmp@iv}{center}}
      \pgfextracty {\trt@tmp@ii} {\pgfpointanchor{trt@tmp@iv}{center}}
      \fp_set:Nn \l__trt_sp_tmpa_fp { (\trt@tmp@i + \l__trt_sp_tmpa_fp) / 2 }
      \fp_set:Nn \l__trt_sp_tmpb_fp { (\trt@tmp@ii + \l__trt_sp_tmpb_fp) / 2 }
      \coordinate[overlay] (#4) at (\fp_to_dim:N \l__trt_sp_tmpa_fp,
        \fp_to_dim:N \l__trt_sp_tmpb_fp);
    \group_end:
  }
```

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

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).

```
\cs_new:Npn \trt_sp_symmedian:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n {\l__trt_sp_a_fp * \l__trt_sp_a_fp},
        \fp_eval:n {\l__trt_sp_b_fp * \l__trt_sp_b_fp},
```

```
        \fp_eval:n {\l__trt_sp_c_fp * \l__trt_sp_c_fp}) coordinate (#4);
    \group_end:
  }
```

(*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 $(\frac{1}{b+c-a}, \frac{1}{c+a-b}, \frac{1}{a+b-c})$.

```
\cs_new:Npn \trt_sp_gergonne:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n { 1/(\l__trt_sp_b_fp + \l__trt_sp_c_fp - \l__trt_sp_a_fp) },
        \fp_eval:n { 1/(\l__trt_sp_c_fp + \l__trt_sp_a_fp - \l__trt_sp_b_fp) },
        \fp_eval:n { 1/(\l__trt_sp_a_fp + \l__trt_sp_b_fp - \l__trt_sp_c_fp) }
      ) coordinate (#4);
    \group_end:
  }
```

(*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 $(b+c-a, c+a-b, a+b-c)$.

```
\cs_new:Npn \trt_sp_nagel:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n { \l__trt_sp_b_fp + \l__trt_sp_c_fp - \l__trt_sp_a_fp },
        \fp_eval:n { \l__trt_sp_c_fp + \l__trt_sp_a_fp - \l__trt_sp_b_fp },
        \fp_eval:n { \l__trt_sp_a_fp + \l__trt_sp_b_fp - \l__trt_sp_c_fp }
      ) coordinate (#4);
    \group_end:
  }
```

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

4.4.9 X_9 – The *mittenpunkt*

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

```
\cs_new:Npn \trt_sp_mittenpunkt:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n
          {
```

```
            \l__trt_sp_a_fp * (
              \l__trt_sp_b_fp + \l__trt_sp_c_fp - \l__trt_sp_a_fp
            )
          },
        \fp_eval:n
          {
            \l__trt_sp_b_fp * (
              \l__trt_sp_c_fp + \l__trt_sp_a_fp - \l__trt_sp_b_fp
            )
          },
        \fp_eval:n
          {
            \l__trt_sp_c_fp * (
              \l__trt_sp_a_fp + \l__trt_sp_b_fp - \l__trt_sp_c_fp
            )
          }
      ) coordinate (#4);
    \group_end:
  }
```

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

4.4.10 X_{10} – The Spieker point

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

```
\cs_new:Npn \trt_sp_spieker:nnnn #1 #2 #3 #4
  {
    \group_begin:
      \__trt_bc_initialize:nnn {#1} {#2} {#3}
      \trt_distance_triangle:nnnNNN {#1} {#2} {#3}
        \l__trt_sp_a_fp \l__trt_sp_b_fp \l__trt_sp_c_fp
      \path[overlay] (bc3 ~ cs \c_colon_str
        \fp_eval:n { \l__trt_sp_b_fp + \l__trt_sp_c_fp },
        \fp_eval:n { \l__trt_sp_c_fp + \l__trt_sp_a_fp },
        \fp_eval:n { \l__trt_sp_a_fp + \l__trt_sp_b_fp }
      ) coordinate (#4);
    \group_end:
  }
⟨/specialpoints⟩
```

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

4.5 The frontend layer

```
⟨*frontend⟩
\ProvidesExplFile {trtfrontend.code.tex} {2020/04/30} {0.1}
  {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`.

```
\tl_new:N \l__trt_fr_output_name_tl
\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.

```
\int_new:N \l__trt_fr_center_number_int
```

(*End definition for* `\l__trt_fr_center_number_int`.)

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

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

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

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

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

(*End definition for* `output name`. *This function is documented on page* 8.)

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

`foot_of_perpendicular`

```
  intersection/.code ~ args={(#1)(#2)--(#3)(#4)}{
    \__trt_lt_return_intersection:nnnnn {#1} {#2} {#3} {#4}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
  foot ~ of ~ perpendicular/.code ~ args={(#1)--(#2)(#3)}{
    \__trt_lt_return_perpendicular_coordinate:nnnn {#1} {#2} {#3}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
```

(*End definition for* `intersection` *and* `foot of perpendicular`. *These functions are documented on page* 5.)

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

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

(*End definition for* `initialize barycentric`. *This function is documented on page* 7.)

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

`excenter`

`centroid`

`circumcenter`

`orthocenter`

```
  incenter/.code ~ args={(#1)(#2)(#3)}{
    \trt_sp_incenter:nnnn {#1} {#2} {#3}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
  excenter/.code ~ args={(#1)(#2)(#3)}{
    \trt_sp_excenter:nnnn {#1} {#2} {#3}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
  centroid/.code ~ args={(#1)(#2)(#3)}{
    \trt_sp_centroid:nnnn {#1} {#2} {#3}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
  circumcenter/.code ~ args={(#1)(#2)(#3)}{
    \trt_sp_circumcenter:nnnn {#1} {#2} {#3}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
  orthocenter/.code ~ args={(#1)(#2)(#3)}{
    \trt_sp_orthocenter:nnnn {#1} {#2} {#3}
      {\tl_use:N \l__trt_fr_output_name_tl}
  },
```

(*End definition for* `incenter` *and others. These functions are documented on page 2.*)

`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.

```
  triangle ~ center/.code ~ args={(#1)(#2)(#3)(#4)}{
    \int_case:nnF {#4}
      {
        {1} {
          \trt_sp_incenter:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {2} {
          \trt_sp_centroid:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {3} {
          \trt_sp_circumcenter:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {4} {
          \trt_sp_orthocenter:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {5} {
          \trt_sp_ninepointcenter:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {6} {
          \trt_sp_symmedian:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {7} {
          \trt_sp_gergonne:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {8} {
          \trt_sp_nagel:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {9} {
          \trt_sp_mittenpunkt:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
        {10} {
          \trt_sp_spieker:nnnn {#1} {#2} {#3}
            {\tl_use:N \l__trt_fr_output_name_tl}
        }
      }
      {
        \msg_error:nnn {triangletools} {center-not-found} {#4}
      }
  }
}
⟨/frontend⟩
```

(*End definition for* `triangle center`*. This function is documented on page 3.*)

Index

The italic numbers denote the pages where the corresponding entry is described, numbers underlined point to the definition, all others indicate the places where it is

used.

Symbols

/tikz/trt 2, 472

B

bc3 . . . . . 7, 186
bool commands:
\bool_if:NTF 188
\bool_new:N 168
\bool_set_true:N 172

C

centroid 3, 490
circumcenter 3, 490
\coordinate . . 118, 149, 328, 339, 356, 382
cs commands:
\cs_new:Npn 65, 88, 103, 114, 121, 131, 145, 170, 196, 225, 246, 274, 286, 298, 305, 360, 369, 386, 398, 411, 424, 452

E

excenter 2, 490

F

foot_of_perpendicular 5, 479
fp commands:
\fp_compare:nNnTF 91
\fp_eval:n 281, 282, 283, 293, 294, 295, 393, 394, 395, 405, 406, 407, 418, 419, 420, 431, 437, 443, 459, 460, 461
\fp_new:N . 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 159, 160, 161, 162, 163, 164, 165, 166, 167, 169, 221, 222, 223, 224, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273
\fp_set:Nn 69, 70, 73, 74, 75, 79, 83, 90, 95, 96, 99, 100, 123, 124, 127, 128, 129, 175, 176, 179, 180, 183, 184, 198, 199, 200, 201, 202, 208, 229, 230, 233, 234, 235, 310, 311, 314, 315, 318, 319, 320, 324, 331, 335, 376, 377, 380, 381
\fp_to_dim:N . . . 14, 119, 150, 214, 215, 329, 330, 340, 341, 357, 382, 383

G

group commands:
\group_begin: 276, 288, 300, 307, 362, 371, 388, 400, 413, 426, 454
\group_end: 284, 296, 303, 358, 367, 384, 396, 409, 422, 450, 463

I

incenter 2, 490
initialize_barycentric 7, 487
\input 9, 10, 11, 12, 13, 14
int commands:
\int_case:nnTF 511
\int_new:N 471
intersection 5, 479

M

msg commands:
\msg_error:nn 193
\msg_error:nnn 555
\msg_new:nnnn 19, 30, 39
\msg_warning:nnnnnn 93

N

\newdimen 7, 8

O

orthocenter 3, 490
output_name 8, 476

P

\path 280, 292, 302, 392, 404, 417, 430, 458
\pgfextractx . . . 67, 71, 125, 173, 177, 181, 227, 231, 308, 312, 316, 374, 378
\pgfextracty . . . 68, 72, 126, 174, 178, 182, 228, 232, 309, 313, 317, 375, 379
\pgfkeys 474
\pgfpointanchor 67, 68, 71, 72, 125, 126, 173, 174, 177, 178, 181, 182, 227, 228, 231, 232, 308, 309, 312, 313, 316, 317, 374, 375, 378, 379
\ProvidesExplFile 17, 50, 154, 219, 254, 467
\ProvidesExplPackage 5

Q

quark commands:
\q_stop 190, 196

R

\RequirePackage 3, 4

S

str commands:
\c_colon_str 280, 292, 302, 392, 404, 417, 430, 458

T

TeX and LaTeX 2ε commands:
\pgf@x 214
\pgf@y 215
\trt@tmp@i 7, 67, 69, 71, 73, 125, 127, 173, 175, 177, 179, 181, 183, 227, 229, 231, 233, 308, 310, 312, 314, 316, 318, 374, 376, 378, 380
\trt@tmp@ii 7, 68, 70, 72, 74, 126, 128, 174, 176, 178, 180, 182, 184, 228, 230, 232, 234, 309, 311, 313, 315, 317, 319, 375, 377, 379, 381
\tikzdeclarecoordinatesystem 186
\tikzset 472
tl commands:
\tl_new:N 469
\tl_set:Nn 470, 477
\tl_use:N 481, 485, 492, 496, 500, 504, 508, 515, 519, 523, 527, 531, 535, 539, 543, 547, 551
triangle_center 3, 510
trt commands:
\trt_distance:nnN 8, 8, 225, 248, 249, 250

\trt_distance_triangle:nnnNNN 8, 246, 278, 290, 390, 402, 415, 428, 456
\trt_lt_get_intersection_-coordinate:nnnnNN ... 6, 103, 116
\trt_lt_get_intersection_-line:NNNNNNNN 6, 6, 11, 88, 109, 140, 352
\trt_lt_get_line_equation:nnNNN 5, 65, 105, 107, 133, 342, 347
\trt_lt_get_perpendicular_-coordinate:nnnNN .. 7, 12, 131, 147
\trt_lt_get_perpendicular_-equation:nNNNNNN 6, 121, 136, 344, 349
\trt_sp_centroid:nnnn 3, 298, 499, 518
\trt_sp_circumcenter:nnnn 3, 305, 372, 503, 522
\trt_sp_excenter:nnnn ... 2, 286, 495
\trt_sp_gergonne:nnnn ... 4, 398, 538
\trt_sp_incenter:nnnn 2, 274, 491, 514
\trt_sp_mittenpunkt:nnnn . 4, 424, 546
\trt_sp_nagel:nnnn 4, 411, 542
\trt_sp_ninepointcenter:nnnn ... 3, 369, 530
\trt_sp_orthocenter:nnnn 3, 360, 373, 507, 526
\trt_sp_spieker:nnnn 5, 452, 550
\trt_sp_symmedian:nnnn .. 4, 386, 534

trt internal commands:

\l__trt_bc_anchor_iiix_fp 159, 183, 206
\l__trt_bc_anchor_iiiy_fp 159, 184, 212
\l__trt_bc_anchor_iix_fp 159, 179, 205
\l__trt_bc_anchor_iiy_fp 159, 180, 211
\l__trt_bc_anchor_ix_fp 159, 175, 204
\l__trt_bc_anchor_iy_fp 159, 176, 210
__trt_bc_initialize:nnn 14, 170, 277, 289, 301, 389, 401, 414, 427, 455, 488
\l__trt_bc_initialized_bool ... 13, 168, 172, 188
\l__trt_bc_lambda_i_fp 165, 199, 204, 210
\l__trt_bc_lambda_ii_fp 165, 200, 205, 211
\l__trt_bc_lambda_iii_fp 165, 201, 206, 212
__trt_bc_parse:w 190, 196
\l__trt_bc_tmp_fp 169, 198, 199, 200, 201
\l__trt_d_pointi_x_fp 221, 229, 238, 239
\l__trt_d_pointi_y_fp 221, 230, 241, 242
\l__trt_d_pointii_x_fp 221, 233, 238, 239
\l__trt_d_pointii_y_fp 221, 234, 241, 242
\l__trt_fr_center_number_int ... 471
\l__trt_fr_output_name_tl 469, 477, 481, 485, 492, 496, 500, 504, 508, 515, 519, 523, 527, 531, 535, 539, 543, 547, 551
\l__trt_i_pointi_x_fp 69, 81, 85
\l__trt_i_pointi_y_fp 70, 77, 85
\l__trt_i_pointii_x_fp 73, 81
\l__trt_i_pointii_y_fp 74, 77
\l__trt_lt_linei_a_fp 56, 106, 110, 134, 137, 141
\l__trt_lt_linei_b_fp 56, 106, 110, 134, 137, 141
\l__trt_lt_linei_c_fp 56, 106, 110, 134, 137, 141
\l__trt_lt_lineii_a_fp 56, 108, 111, 138, 142
\l__trt_lt_lineii_b_fp 56, 108, 111, 138, 142
\l__trt_lt_lineii_c_fp 56, 108, 111, 138, 142
\l__trt_lt_pointi_x_fp 52
\l__trt_lt_pointi_y_fp 52
\l__trt_lt_pointii_x_fp 52
\l__trt_lt_pointii_y_fp 52
__trt_lt_return_intersection:nnnnn 114, 365, 480
__trt_lt_return_perpendicular_-coordinate:nnnn 145, 363, 364, 484
\l__trt_lt_tmp_fp 11, 62, 90, 91, 99, 100
\l__trt_lt_tmpa_fp 62, 117, 119, 127, 129, 148, 150
\l__trt_lt_tmpb_fp 62, 117, 119, 128, 129, 148, 150
\l__trt_sp_a_fp 256, 279, 281, 291, 293, 391, 393, 403, 405, 406, 407, 416, 418, 419, 420, 429, 433, 434, 440, 446, 457, 460, 461
\l__trt_sp_b_fp 256, 279, 282, 291, 294, 391, 394, 403, 405, 406, 407, 416, 418, 419, 420, 429, 434, 439, 440, 446, 457, 459, 461
\l__trt_sp_c_fp 256, 279, 283, 291, 295, 391, 395, 403, 405, 406, 407, 416, 418, 419, 420, 429, 434, 440, 445, 446, 457, 459, 460
\l__trt_sp_coordinatei_x_fp ... 259, 310, 322, 333
\l__trt_sp_coordinatei_y_fp ... 259, 311, 326, 337
\l__trt_sp_coordinateii_x_fp ... 259, 314, 320, 322, 329
\l__trt_sp_coordinateii_y_fp ... 259, 315, 324, 326, 330
\l__trt_sp_coordinateiii_x_fp .. 259, 318, 331, 333, 340
\l__trt_sp_coordinateiii_y_fp .. 259, 319, 335, 337, 341
\l__trt_sp_linei_a_fp .. 259, 346, 353
\l__trt_sp_linei_b_fp .. 259, 346, 353
\l__trt_sp_linei_c_fp .. 259, 346, 353
\l__trt_sp_lineii_a_fp . 259, 351, 354
\l__trt_sp_lineii_b_fp . 259, 351, 354
\l__trt_sp_lineii_c_fp . 259, 351, 354
\l__trt_sp_tmpa_fp 271, 343, 345, 348, 350, 355, 357, 376, 380, 382
\l__trt_sp_tmpb_fp 271, 343, 345, 348, 350, 355, 357, 377, 381, 383

\l__trt_sp_tmpc_fp 271, 343, 345, 348, 350
\l__trt_tmp_a_fp 202, 214
\l__trt_tmp_b_fp 208, 215