ctz-euclide

Typst Port

Euclidean Geometry for Typst

A comprehensive geometry package built on CeTZ
Version 0.1.0

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1. Introduction

`ctz-euclide` is a geometry package for Typst, a port of the LaTeX package `tkz-euclide`. Built on top of CeTZ (a powerful drawing library), it provides high-level constructions for Euclidean geometry.

1.1. Features

- **Point Registry**: Define points once, reference them by name throughout your figure
- **Geometric Constructions**: Perpendiculars, parallels, bisectors, mediators
- **Intersections**: Line–line, line–circle, circle–circle with multiple solution handling
- **Triangle Centers**: Centroid, circumcenter, incenter, orthocenter, and 10+ specialized centers
- **Special Triangles**: Medial, orthic, intouch triangles
- **Transformations**: Rotation, reflection, translation, homothety, projection
- **Drawing & Styling**: Points, labels, angles, segments with tick marks
- **Grid & Axes**: Coordinate systems with customizable appearance
- **Clipping**: Mathematical line clipping for clean bounded figures

1.2. Installation

Import the package in your Typst document:

```
#import "@preview/cetz:0.4.2" as cetz
#import "@preview/ctz-euclide:0.1.0" as ctz-lib

#let ctz = ctz-lib.create-api(cetz)
```

All figures must begin with:

```
#cetz.canvas({
  import cetz.draw: *
  (ctz.init)()

  // Your geometry code here
})
```

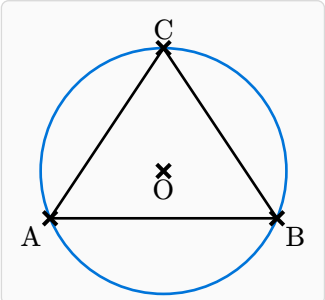
The `(ctz.init)()` call initializes the point registry and coordinate resolver.

1.3. Basic Usage

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  // Define points
  (ctz.pts)(A: (0, 0), B: (4, 0), C: (2, 3))

  // Draw triangle
  line("A", "B", "C", "A", stroke: black)

  // Find circumcenter and draw circumcircle
  (ctz.circumcenter)("O", "A", "B", "C")
  circle("O", "A", stroke: blue)

  // Draw and label points
  (ctz.points)("A", "B", "C", "O")
  (ctz.labels)("A", "B", "C", "O",
    A: "below left", B: "below right",
    C: "above", O: "below")
})
```

Figure



2. Core Concepts

2.1. The Point Registry

The point registry is the heart of `ctz-euclide`. Once you define a point with a name, that name can be used directly in CeTZ drawing commands.

```
(ctz.pts)(A: (0, 0), B: (3, 4))  // Register points A and B
line("A", "B")                    // Use them directly in CeTZ
```

Under the hood, `(ctz.init)()` installs a coordinate resolver that translates `"A"` to the stored coordinates. Both `"A"` and `"tkz:A"` resolve to the same point.

2.2. Figure Scaling

Control the size of your figures using CeTZ's `length` parameter:

```
#cetz.canvas(length: 0.8cm, { ... })
```

This scales everything proportionally, including stroke widths. Typical values:

- `0.6cm` – small inline figures
- `0.8cm` – standard examples
- `1.0cm` – large detailed figures

2.3. Coordinate Systems

Points can be defined in multiple ways:

```
// Explicit coordinates
(ctz.pts)(A: (2, 3))

// Using existing CeTZ coordinates
(ctz.pts)(B: (rel: (1, 1), to: "A"))

// Mixed: numbers and existing points
(ctz.pts)(C: (4, 0), D: "A", E: (3, 2))
```

3. Point Definitions

3.1. Basic Points — `pts`

Define one or more points at specific coordinates:

```
(ctz.pts)(A: (0, 0), B: (4, 0), C: (2, 3))
```

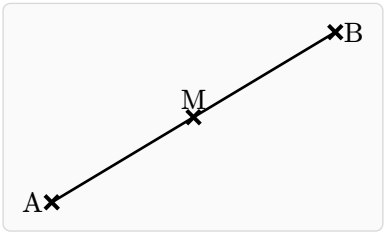
3.2. Midpoint — `midpoint`

Find the midpoint of a segment:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 3))
  (ctz.midpoint)("M", "A", "B")

  line("A", "B", stroke: black)
  (ctz.points)("A", "B", "M")
  (ctz.labels)("A", "B", "M",
    A: "left", B: "right", M: "above")
})
```

Figure



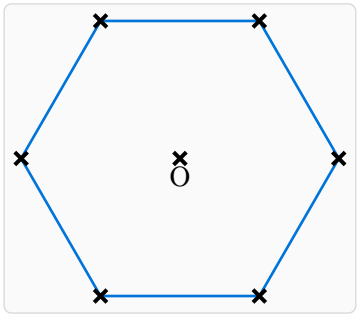
3.3. Regular Polygons — `regular-polygon`

Generate vertices of a regular n-gon:

Code

```
#cetz.canvas(length: 0.7cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(O: (0, 0), A: (3, 0))
  (ctz.regular-polygon)(("A", "B", "C", "D", "E",
"F"), "O", "A")

  line("A", "B", "C", "D", "E", "F", "A", stroke:
blue)
  (ctz.points)("A", "B", "C", "D", "E", "F", "O")
  (ctz.labels)("O", O: "below")
})
```

Figure



3.4. Linear Combination — `linear`

Define a point along a line: $P = A + k(B - A)$

```
(ctz.linear)("P", "A", "B", 0.3)  // P is 30% from A to B
(ctz.linear)("Q", "A", "B", 1.5)  // Q extends beyond B
```

4. Line Constructions

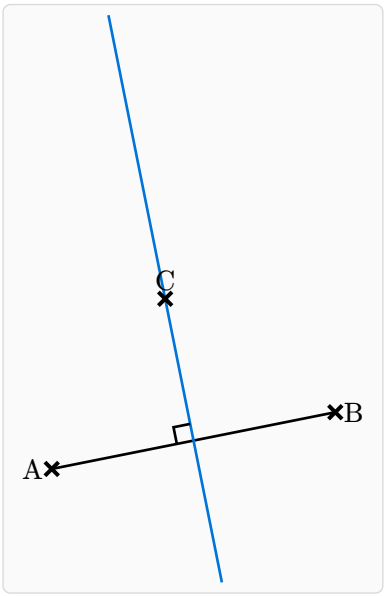
4.1. Perpendicular — `perp`

Construct a perpendicular line through a point:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 1), C: (2, 3))
  (ctz.perp)("P1", "P2", ("A", "B"), "C")
  (ctz.project)("H", "C", "A", "B")

  line("A", "B", stroke: black)
  line("P1", "P2", stroke: blue)
  (ctz.mark-right-angle)("A", "H", "C", size: 0.3)

  (ctz.points)("A", "B", "C")
  (ctz.labels)("A", "B", "C",
    A: "left", B: "right", C: "above")
})
```

Figure



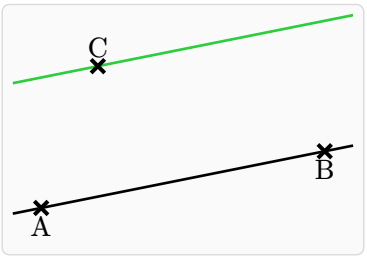
4.2. Parallel — `para`

Construct a parallel line through a point:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 1), C: (1, 2.5))
  (ctz.para)("P1", "P2", ("A", "B"), "C")

  (ctz.set-clip)(-0.5, -0.5, 5.5, 3.5)
  (ctz.line)("A", "B", add: (2, 2), stroke: black)
  (ctz.line)("P1", "P2", add: (2, 2), stroke: green)

  (ctz.points)("A", "B", "C")
  (ctz.labels)("A", "B", "C",
    A: "below", B: "below", C: "above")
})
```

Figure



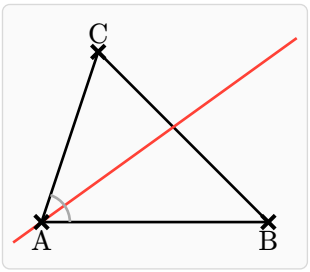
4.3. Angle Bisector — `bisect`

Construct the bisector of an angle:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (4, 0), C: (1, 3))
  (ctz.bisect)("D1", "D2", "C", "A", "B")

  (ctz.set-clip)(-0.5, -0.5, 4.5, 3.5)
  line("A", "B", "C", "A", stroke: black)
  (ctz.seg)("D1", "D2", stroke: red)

  (ctz.angle)("A", "C", "B", radius: 0.5, stroke:
gray)
  (ctz.points)("A", "B", "C")
  (ctz.labels)("A", "B", "C",
    A: "below", B: "below", C: "above")
})
```

Figure



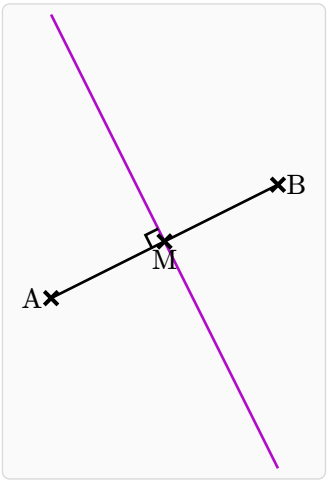
4.4. Perpendicular Bisector — `mediator`

Construct the perpendicular bisector of a segment:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (1, 1), B: (5, 3))
  (ctz.mediator)("M1", "M2", "A", "B")
  (ctz.midpoint)("M", "A", "B")

  line("A", "B", stroke: black)
  line("M1", "M2", stroke: purple)
  (ctz.mark-right-angle)("M1", "M", "A", size: 0.25)

  (ctz.points)("A", "B", "M")
  (ctz.labels)("A", "B", "M",
    A: "left", B: "right", M: "below")
})
```

Figure



5. Intersections

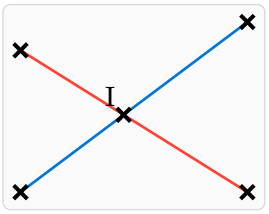
5.1. Line–Line — `ll`

Find the intersection of two lines:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (4, 3),
            C: (4, 0), D: (0, 2.5))
  (ctz.ll)("I", ("A", "B"), ("C", "D"))

  line("A", "B", stroke: blue)
  line("C", "D", stroke: red)

  (ctz.points)("A", "B", "C", "D", "I")
  (ctz.labels)("I", I: "above left")
})
```

Figure



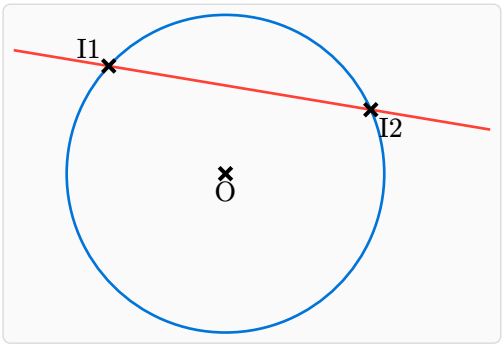
5.2. Line–Circle — `lc`

Find intersections of a line with a circle:

Code

```
#cetz.canvas(length: 0.7cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(O: (0, 0), R: (3, 0),
            A: (-2, 2), B: (4, 1))
  (ctz.lc)(("I1", "I2"), ("A", "B"),
    (center: "O", through: "R"))

  circle("O", "R", stroke: blue)
  (ctz.set-clip)(-4, -4, 5, 4)
  (ctz.line)("A", "B", add: (2, 2), stroke: red)

  (ctz.points)("O", "I1", "I2")
  (ctz.labels)("O", "I1", "I2",
    O: "below", I1: "above left", I2: "below right")
})
```

Figure



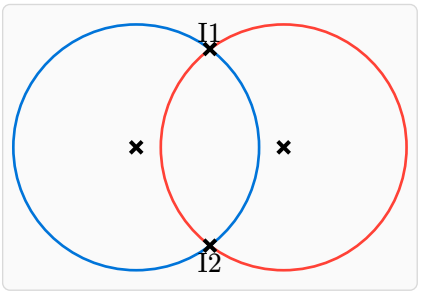
5.3. Circle–Circle — `cc`

Find intersections of two circles:

Code

```
#cetz.canvas(length: 0.65cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(O1: (0, 0), O2: (3, 0),
            R1: (2.5, 0), R2: (5.5, 0))
  (ctz.cc)(("I1", "I2"),
    (center: "O1", through: "R1"),
    (center: "O2", through: "R2"))

  circle("O1", "R1", stroke: blue)
  circle("O2", "R2", stroke: red)

  (ctz.points)("O1", "O2", "I1", "I2")
  (ctz.labels)("I1", "I2",
    I1: "above", I2: "below")
})
```

Figure



6. Triangle Centers

6.1. Basic Centers

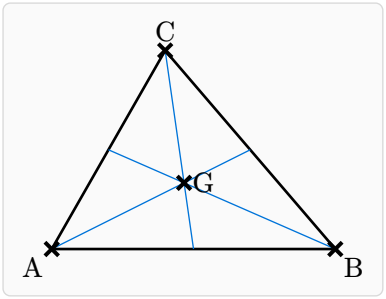
6.1.1. Centroid — `centroid`

The intersection of medians (center of mass):

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0), C: (2, 3.5))
  (ctz.centroid)("G", "A", "B", "C")

  // Draw medians
  (ctz.midpoint)("Ma", "B", "C")
  (ctz.midpoint)("Mb", "A", "C")
  (ctz.midpoint)("Mc", "A", "B")

  line("A", "B", "C", "A", stroke: black)
  line("A", "Ma", stroke: blue + 0.5pt)
  line("B", "Mb", stroke: blue + 0.5pt)
  line("C", "Mc", stroke: blue + 0.5pt)

  (ctz.points)("A", "B", "C", "G")
  (ctz.labels)("A", "B", "C", "G",
    A: "below left", B: "below right",
    C: "above", G: "right")
})
```

Figure



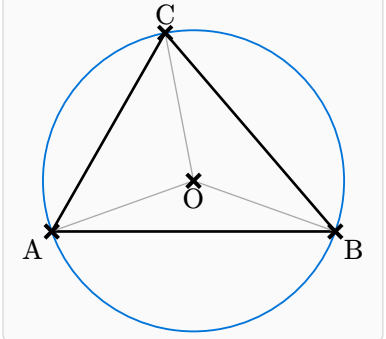
6.1.2. Circumcenter — `circumcenter`

Center of the circumscribed circle:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0), C: (2, 3.5))
  (ctz.circumcenter)("O", "A", "B", "C")

  line("A", "B", "C", "A", stroke: black)
  circle("O", "A", stroke: blue + 0.7pt)

  line("O", "A", stroke: gray + 0.5pt)
  line("O", "B", stroke: gray + 0.5pt)
  line("O", "C", stroke: gray + 0.5pt)

  (ctz.points)("A", "B", "C", "O")
  (ctz.labels)("A", "B", "C", "O",
    A: "below left", B: "below right",
    C: "above", O: "below")
})
```

Figure



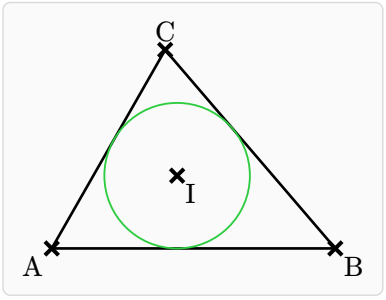
6.1.3. Incenter — `incenter`

Center of the inscribed circle:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0), C: (2, 3.5))
  (ctz.incenter)("I", "A", "B", "C")

  line("A", "B", "C", "A", stroke: black)
  (ctz.incircle)("A", "B", "C", stroke: green +
0.7pt)

  // Angle bisectors
  (ctz.bisect)("Ba1", "Ba2", "I", "B", "C")
  (ctz.bisect)("Bb1", "Bb2", "I", "A", "C")
  (ctz.bisect)("Bc1", "Bc2", "I", "A", "B")

  (ctz.points)("A", "B", "C", "I")
  (ctz.labels)("A", "B", "C", "I",
    A: "below left", B: "below right",
    C: "above", I: "below right")
})
```

Figure



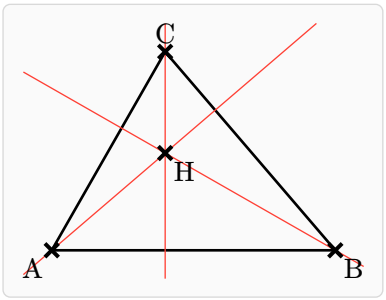
6.1.4. Orthocenter — `orthocenter`

Intersection of altitudes:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0), C: (2, 3.5))
  (ctz.orthocenter)("H", "A", "B", "C")

  // Altitudes (extended as lines)
  (ctz.perp)("Ha1", "Ha2", ("B", "C"), "A")
  (ctz.perp)("Hb1", "Hb2", ("A", "C"), "B")
  (ctz.perp)("Hc1", "Hc2", ("A", "B"), "C")

  (ctz.set-clip)(-0.5, -0.5, 5.5, 4)
  line("A", "B", "C", "A", stroke: black)
  (ctz.line)("A", "Ha1", add: (2, 2), stroke: red +
0.5pt)
  (ctz.line)("B", "Hb1", add: (2, 2), stroke: red +
0.5pt)
  (ctz.line)("C", "Hc1", add: (2, 2), stroke: red +
0.5pt)

  (ctz.points)("A", "B", "C", "H")
  (ctz.labels)("A", "B", "C", "H",
    A: "below left", B: "below right",
    C: "above", H: "below right")
})
```

Figure



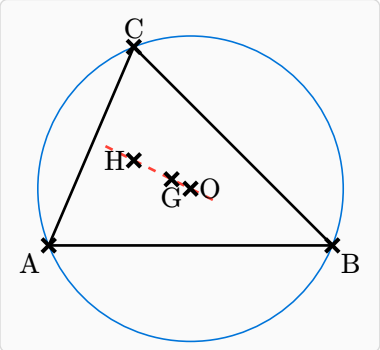
6.2. The Euler Line

In any non-equilateral triangle, the orthocenter H, centroid G, and circumcenter O are collinear. This line is called the **Euler line**, and remarkably, G divides HO in the ratio $2:1$.

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0), C: (1.5, 3.5))

  (ctz.orthocenter)("H", "A", "B", "C")
  (ctz.centroid)("G", "A", "B", "C")
  (ctz.circumcenter)("O", "A", "B", "C")

  (ctz.set-clip)(-0.5, -0.5, 5.5, 4)
  line("A", "B", "C", "A", stroke: black)
  (ctz.line-add)("H", "O", add: 0.5, stroke: (paint:
red, dash: "dashed"))
  circle("O", "A", stroke: blue + 0.6pt)

  (ctz.points)("A", "B", "C", "H", "G", "O")
  (ctz.labels)("A", "B", "C", "H", "G", "O",
    A: "below left", B: "below right", C: "above",
    H: "left", G: "below", O: "right")
})
```

Figure



6.3. Advanced Centers

`ctz-euclide` supports 10+ specialized triangle centers:

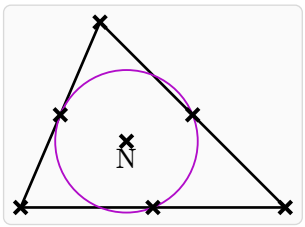
- `lemoine` — Symmedian point (Lemoine point)
- `nagel` — Nagel point
- `gergonne` — Gergonne point
- `spieker` — Spieker center (incenter of medial triangle)
- `euler` — Nine-point circle center
- `feuerbach` — Feuerbach point
- `mittenpunkt` — Mittenpunkt
- `excenter` — Excenter (specify vertex: `"a"`, `"b"`, or `"c"`)

Example with Euler (nine-point) circle:

Code

```
#cetz.canvas(length: 0.7cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0), C: (1.5, 3.5))
  (ctz.euler)("N", "A", "B", "C")

  line("A", "B", "C", "A", stroke: black)

  // Nine-point circle passes through
  // midpoints of sides
  (ctz.midpoint)("Ma", "B", "C")
  (ctz.midpoint)("Mb", "A", "C")
  (ctz.midpoint)("Mc", "A", "B")

  circle("N", "Ma", stroke: purple + 0.7pt)

  (ctz.points)("A", "B", "C", "N", "Ma", "Mb", "Mc")
  (ctz.labels)("N", N: "below")
})
```

Figure



7. Transformations

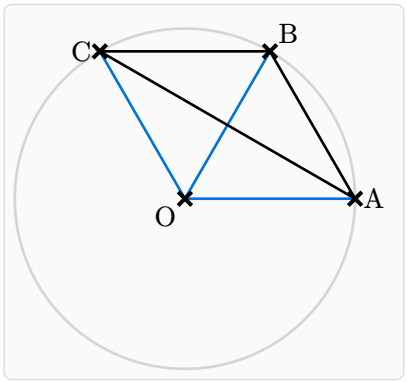
7.1. Rotation — `rotate`

Rotate a point around a center:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(O: (2, 2), A: (5, 2))
  (ctz.rotate)("B", "A", "O", 60)
  (ctz.rotate)("C", "A", "O", 120)

  circle("O", radius: 3, stroke: gray.lighten(50%))
  line("O", "A", stroke: blue)
  line("O", "B", stroke: blue)
  line("O", "C", stroke: blue)
  line("A", "B", "C", "A", stroke: black)

  (ctz.points)("O", "A", "B", "C")
  (ctz.labels)("O", "A", "B", "C",
    O: "below left", A: "right",
    B: "above right", C: "left")
})
```

Figure



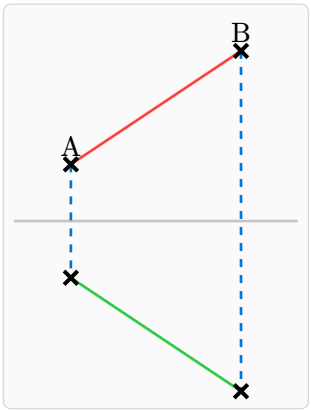
7.2. Reflection — `reflect`

Reflect a point across a line:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (1, 1), B: (4, 3),
            L1: (0, 0), L2: (5, 0))
  (ctz.reflect)("Ap", "A", "L1", "L2")
  (ctz.reflect)("Bp", "B", "L1", "L2")

  line("L1", "L2", stroke: gray.lighten(30%))
  line("A", "Ap", stroke: (paint: blue, dash:
"dashed"))
  line("B", "Bp", stroke: (paint: blue, dash:
"dashed"))
  line("A", "B", stroke: red)
  line("Ap", "Bp", stroke: green)

  (ctz.points)("A", "B", "Ap", "Bp")
  (ctz.labels)("A", "B",
    A: "above", B: "above")
})
```

Figure



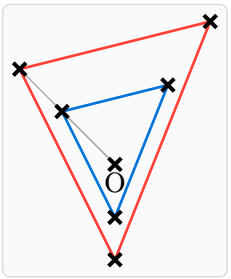
7.3. Homothety (Scaling) — `scale`

Scale a point from a center:

Code

```
#cetz.canvas(length: 0.7cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(O: (2, 2),
            A: (1, 3), B: (3, 3.5), C: (2, 1))
  (ctz.scale)("Ap", "A", "O", 1.8)
  (ctz.scale)("Bp", "B", "O", 1.8)
  (ctz.scale)("Cp", "C", "O", 1.8)

  line("A", "B", "C", "A", stroke: blue)
  line("Ap", "Bp", "Cp", "Ap", stroke: red)

  line("O", "A", stroke: gray + 0.5pt)
  line("O", "Ap", stroke: gray + 0.5pt)

  (ctz.points)("O", "A", "B", "C", "Ap", "Bp", "Cp")
  (ctz.labels)("O", O: "below")
})
```

Figure



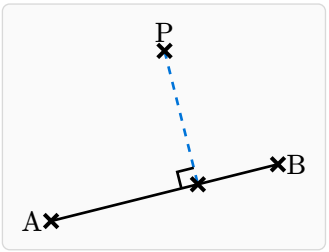
7.4. Projection — `project`

Project a point onto a line:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (1, 1), B: (5, 2),
            P: (3, 4))
  (ctz.project)("Pp", "P", "A", "B")

  line("A", "B", stroke: black)
  line("P", "Pp", stroke: (paint: blue, dash:
"dashed"))
  (ctz.mark-right-angle)("P", "Pp", "A", size: 0.3)

  (ctz.points)("A", "B", "P", "Pp")
  (ctz.labels)("A", "B", "P",
    A: "left", B: "right", P: "above")
})
```

Figure



8. Drawing & Styling

8.1. Points — `points`

Draw point markers:

```
(ctz.points)("A", "B", "C")
```

8.2. Labels — `labels`

Add labels with automatic positioning:

```
(ctz.labels)("A", "B", "C",
  A: "below left",
  B: "below right",
  C: "above")
```

Position keywords: `"above"`, `"below"`, `"left"`, `"right"`, and combinations like `"above left"`.

For fine control, use offset tuples:

```
(ctz.labels)("A",
  A: (pos: "below", offset: (0.1, -0.2)))
```

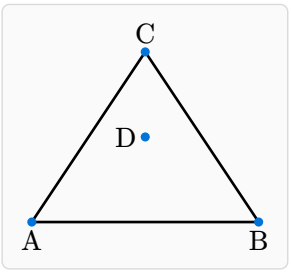
8.3. Global Styling — `style`

Set default appearance for all elements:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  // Set global point style
  (ctz.style)(point: (
    shape: "circle",
    size: 0.08,
    fill: blue,
    stroke: none
  ))

  (ctz.pts)(A: (0, 0), B: (4, 0),
            C: (2, 3), D: (2, 1.5))
  (ctz.polygon)("A", "B", "C", stroke: black)

  (ctz.points)("A", "B", "C", "D")
  (ctz.labels)("A", "B", "C", "D",
    A: "below", B: "below",
    C: "above", D: "left")
})
```

Figure



Point shapes: `"cross"`, `"dot"`, `"circle"`, `"plus"`, `"square"`, `"diamond"`, `"triangle"`.

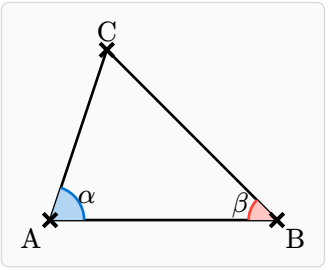
8.4. Angle Marking — `angle`

Mark and label angles:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (4, 0), C: (1, 3))
  line("A", "B", "C", "A", stroke: black)

  (ctz.angle)("A", "B", "C",
    label: $alpha$,
    radius: 0.6,
    fill: blue.lighten(70%),
    stroke: blue)

  (ctz.angle)("B", "C", "A",
    label: $beta$,
    radius: 0.5,
    fill: red.lighten(70%),
    stroke: red)

  (ctz.points)("A", "B", "C")
  (ctz.labels)("A", "B", "C",
    A: "below left", B: "below right", C: "above")
})
```

Figure



8.4.1. Angle Label Positioning

The angle label is automatically placed along the **angle bisector** (the line that divides the angle in half). You can fine-tune the label position using:

- `radius`: Distance from vertex to the arc
- `label-radius`: Distance from vertex to the label (default: `radius + 0.2`)
- `label-offset`: A tuple `(along, perp)` for fine positioning:
  - `along`: Moves label along the bisector (positive = farther from vertex, negative = closer)
  - `perp`: Moves label perpendicular to bisector (positive = counterclockwise, negative = clockwise)

The offset is relative to the bisector's coordinate system, not the canvas axes.

Example with offset:

```
(ctz.angle)("A", "B", "C",
  label: $alpha$,
  radius: 0.6,
  label-radius: 0.9,      // Label at distance 0.9 from vertex
  label-offset: (0.1, 0.15),  // Shift slightly outward and counterclockwise
  fill: blue.lighten(70%))
```

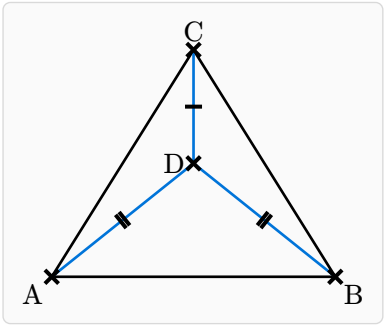
8.5. Segment Marks — `mark-segment`

Mark equal segments with tick marks:

Code

```
#cetz.canvas(length: 0.75cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (5, 0),
            C: (2.5, 4), D: (2.5, 2))
  line("A", "B", "C", "A", stroke: black)
  line("C", "D", stroke: blue)
  line("D", "A", stroke: blue)
  line("D", "B", stroke: blue)

  (ctz.mark-segment)("C", "D", mark: 1)
  (ctz.mark-segment)("D", "A", mark: 2)
  (ctz.mark-segment)("D", "B", mark: 2)

  (ctz.points)("A", "B", "C", "D")
  (ctz.labels)("A", "B", "C", "D",
    A: "below left", B: "below right",
    C: "above", D: "left")
})
```

Figure



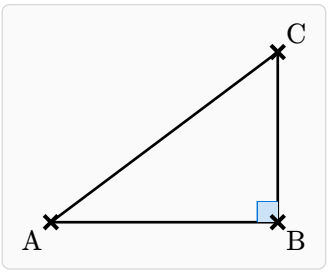
8.6. Right Angle Marks — `mark-right-angle`

Mark 90° angles:

Code

```
#cetz.canvas(length: 0.8cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 0), B: (4, 0), C: (4, 3))
  line("A", "B", "C", "A", stroke: black)

  (ctz.mark-right-angle)("A", "B", "C",
    size: 0.35,
    color: blue,
    fill: blue.lighten(80%))

  (ctz.points)("A", "B", "C")
  (ctz.labels)("A", "B", "C",
    A: "below left", B: "below right", C: "above
right")
})
```

Figure



9. Grid & Axes

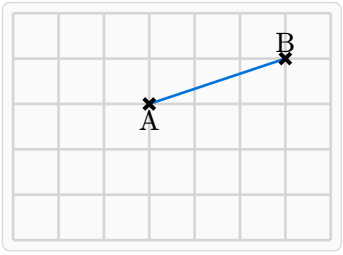
9.1. Basic Grid — `grid`

Draw a coordinate grid:

Code

```
#cetz.canvas(length: 0.6cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.grid)(xmin: -2, xmax: 5,
             ymin: -1, ymax: 4,
             stroke: gray.lighten(50%))

  (ctz.pts)(A: (1, 2), B: (4, 3))
  line("A", "B", stroke: blue + 1pt)

  (ctz.points)("A", "B")
  (ctz.labels)("A", "B",
    A: "below", B: "above")
})
```

Figure



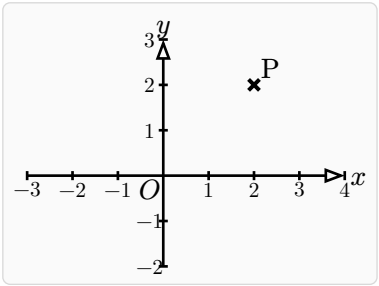
9.2. Axes — `axes`

Draw X and Y axes with labels:

Code

```
#cetz.canvas(length: 0.6cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.axes)(xmin: -3, xmax: 4,
             ymin: -2, ymax: 3,
             x-label: $x$,
             y-label: $y$,
             origin-label: $0$)

  (ctz.pts)(P: (2, 2))
  (ctz.points)("P")
  (ctz.labels)("P", P: "above right")
})
```

Figure



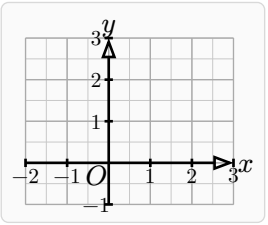
9.3. Grid with Subdivisions

Add finer sub-grid lines:

Code

```
#cetz.canvas(length: 0.55cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.grid)(xmin: -2, xmax: 3,
             ymin: -1, ymax: 3,
             sub: true,
             sub-xstep: 0.5,
             sub-ystep: 0.5,
             sub-stroke: luma(200) + 0.25pt,
             stroke: gray + 0.5pt)

  (ctz.axes)(xmin: -2, xmax: 3,
             ymin: -1, ymax: 3,
             labels: true,
             ticks: true)
})
```

Figure



10. Clipping

When drawing extended lines (like altitudes or angle bisectors that go beyond triangle sides), you may want to clip them to a viewing region. `ctz-euclide` provides mathematical line clipping using the Cohen-Sutherland algorithm.

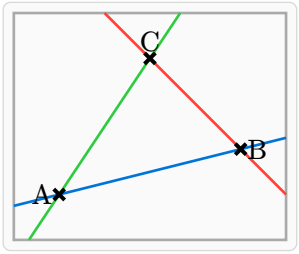
10.1. Global Clipping (Recommended)

Set a clip region once, then all `line` commands automatically clip:

Code

```
#cetz.canvas(length: 0.6cm, {
  import cetz.draw: *
  (ctz.init)()

  (ctz.pts)(A: (0, 1), B: (4, 2), C: (2, 4))

  // Set global clip region
  (ctz.set-clip)(-1, 0, 5, 5)
  (ctz.show-clip)(stroke: gray)

  // These lines auto-clip to bounds
  (ctz.line)("A", "B", add: (5, 5), stroke: blue)
  (ctz.line)("B", "C", add: (5, 5), stroke: red)
  (ctz.line)("C", "A", add: (5, 5), stroke: green)

  (ctz.points)("A", "B", "C")
  (ctz.labels)("A", "B", "C",
    A: "left", B: "right", C: "above")
})
```

Figure



API:

- `(ctz.set-clip)(xmin, ymin, xmax, ymax)` — Set global clip region
- `(ctz.show-clip)(stroke: ...)` — Draw the clip boundary
- `(ctz.line)(a, b, add: (n, m), stroke: ...)` — Extended line (auto-clips)
- `(ctz.seg)(a, b, stroke: ...)` — Simple segment (auto-clips)
- `(ctz.clear-clip)()` — Remove clipping

10.2. Manual Clipping

For per-line control, specify bounds directly:

```
(ctz.clipped-line-add)("A", "B", xmin, ymin, xmax, ymax,
  add: (10, 10), stroke: blue)
```

11. API Reference

11.1. Initialization

`(ctz.init)()` Initialize the point registry and coordinate resolver. **Required** at the start of every figure.

11.2. Point Definitions

`(ctz.pts)(...)` Define points with named arguments: `(ctz.pts)(A: (0, 0), B: (3, 4))`

`(ctz.midpoint)(name, a, b)` Midpoint of segment AB

`(ctz.linear)(name, a, b, k)` Point P = A + k(B - A)

`(ctz.barycentric)(name, a, b, c, wa, wb, wc)` Barycentric combination

`(ctz.regular-polygon)(names, center, first)` Regular polygon vertices

`(ctz.point-on-circle)(name, center, radius, angle)` Point on circle at angle (degrees)

`(ctz.equilateral)(name, a, b)` Third vertex of equilateral triangle

`(ctz.square)(c, d, a, b)` Complete a square given two vertices

`(ctz.golden)(name, a, b)` Golden ratio point on AB

11.3. Line Constructions

`(ctz.perp)(p1, p2, (a, b), through)` Perpendicular to line AB through point

`(ctz.para)(p1, p2, (a, b), through)` Parallel to line AB through point

`(ctz.bisect)(p1, p2, a, vertex, c)` Angle bisector at vertex

`(ctz.mediator)(p1, p2, a, b)` Perpendicular bisector of AB

11.4. Intersections

`(ctz.ll)(name, (a, b), (c, d))` Line-line intersection

`(ctz.lc)(names, (a, b), circle)` Line-circle intersections. Circle: `(center: "O", through: "A")` or `(center: "O", radius: r)`

`(ctz.cc)(names, circle1, circle2)` Circle-circle intersections

11.5. Triangle Centers

`(ctz.centroid)(name, a, b, c)` Center of mass (medians intersection)

`(ctz.circumcenter)(name, a, b, c)` Circumscribed circle center

`(ctz.incenter)(name, a, b, c)` Inscribed circle center

`(ctz.orthocenter)(name, a, b, c)` Altitudes intersection

`(ctz.euler)(name, a, b, c)` Nine-point circle center

`(ctz.lemoine)(name, a, b, c)` Lemoine point (symmedian point)

`(ctz.nagel)(name, a, b, c)` Nagel point

`(ctz.gergonne)(name, a, b, c)` Gergonne point

`(ctz.spieker)(name, a, b, c)` Spieker center

`(ctz.feuerbach)(name, a, b, c)` Feuerbach point

`(ctz.mittenpunkt)(name, a, b, c)` Mittenpunkt

`(ctz.excenter)(name, a, b, c, vertex: "a")` Excenter opposite to vertex

11.6. Special Triangles

`(ctz.medial)(ma, mb, mc, a, b, c)` Medial triangle (midpoints)

`(ctz.orthic)(ha, hb, hc, a, b, c)` Orthic triangle (feet of altitudes)

`(ctz.intouch)(ta, tb, tc, a, b, c)` Intouch triangle (incircle tangency points)

11.7. Transformations

`(ctz.rotate)(name, source, center, angle)` Rotate point around center (degrees)

`(ctz.reflect)(name, source, a, b)` Reflect point across line AB

`(ctz.translate)(name, source, vector)` Translate by vector `(dx, dy)` or `(a, b)`

`(ctz.scale)(name, source, center, factor)` Homothety (scale from center)

`(ctz.project)(name, source, a, b)` Orthogonal projection onto line AB

`(ctz.symmetry)(name, source, center)` Central symmetry

`(ctz.inversion)(name, source, center, radius)` Circle inversion

11.8. Drawing

`(ctz.points)(...)` Draw point markers: `(ctz.points)("A", "B", "C")`

`(ctz.labels)(...)` Label points with positioning: `(ctz.labels)("A", "B", A: "left", B: "right")`

`(ctz.polygon)(...)` Draw polygon: `(ctz.polygon)("A", "B", "C", close: true, stroke: black)`

`(ctz.segment)(a, b, ...)` Draw segment with optional arrows: `arrows: "<->"`, `dim: $5$`

`(ctz.line-add)(a, b, add: (n, m), ...)` Extended line beyond AB

`(ctz.circle-r)(center, radius, ...)` Circle with explicit radius

`(ctz.circle-through)(center, through, ...)` Circle through point

`(ctz.circle-diameter)(a, b, ...)` Circle with AB as diameter

`(ctz.circumcircle)(a, b, c, ...)` Circumscribed circle of triangle

`(ctz.incircle)(a, b, c, ...)` Inscribed circle of triangle

`(ctz.semicircle)(a, b, above: true, ...)` Semicircle with AB as diameter

`(ctz.sector)(center, start, end, ...)` Circular sector

`(ctz.arc)(center, start, end, ...)` Arc through two points

`(ctz.arc-r)(center, radius, start-angle, end-angle, ...)` Arc with explicit angles

11.9. Marking & Annotation

`(ctz.angle)(vertex, a, b, ...)` Mark angle at vertex. Options: `label`, `radius`, `fill`, `stroke`

`(ctz.mark-segment)(a, b, mark: n, ...)` Tick marks for equal segments (n = 1, 2, 3, …)

`(ctz.mark-right-angle)(a, vertex, c, ...)` Mark 90° angle

`(ctz.fill-angle)(vertex, a, c, ...)` Fill angle without border

`(ctz.label-segment)(a, b, label: $5$, ...)` Label a segment

11.10. Styling

`(ctz.style)(...)` Set global defaults. Example: `(ctz.style)(point: (shape: "dot", size: 0.08))`

11.11. Grid & Axes

`(ctz.grid)(...)` Draw grid. Options: `xmin`, `xmax`, `ymin`, `ymax`, `xstep`, `ystep`, `sub`, `stroke`

`(ctz.axes)(...)` Draw axes with labels and ticks

`(ctz.hline)(y, xmin: ..., xmax: ..., stroke: ...)` Horizontal line

`(ctz.vline)(x, ymin: ..., ymax: ..., stroke: ...)` Vertical line

`(ctz.text)(x, y, content, ...)` Place text at coordinates

11.12. Clipping

`(ctz.set-clip)(xmin, ymin, xmax, ymax)` Set global clip region

`(ctz.show-clip)(stroke: ...)` Draw clip boundary

`(ctz.line)(a, b, add: (n, m), stroke: ...)` Auto-clipped extended line

`(ctz.seg)(a, b, stroke: ...)` Auto-clipped segment

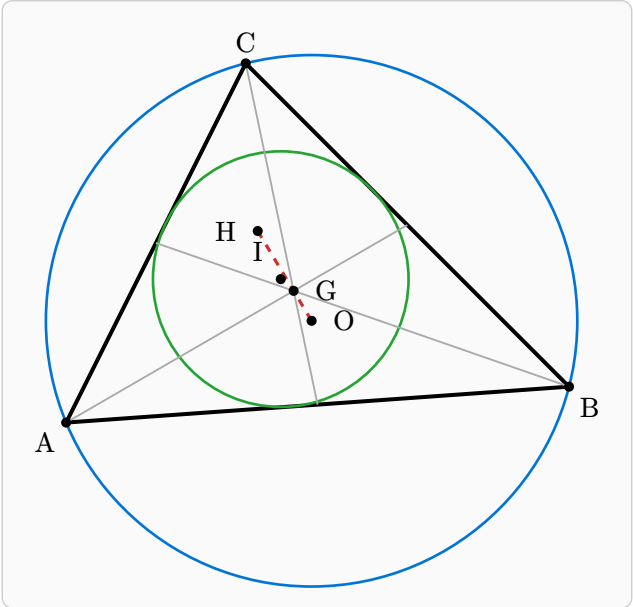
`(ctz.clear-clip)()` Remove global clipping

`(ctz.clipped-line-add)(a, b, xmin, ymin, xmax, ymax, ...)` Manual per-line clipping

12. Figures Gallery

The following pages showcase various geometric constructions and their capabilities.

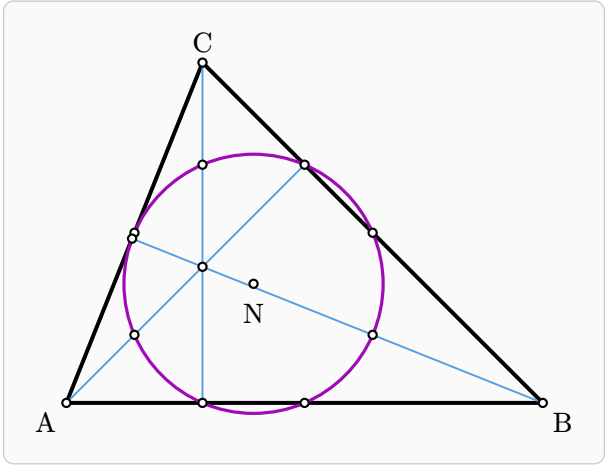
Complete Triangle Centers



Euler Line (red dashed): $O - G - H$
Circumcircle (blue), Incircle (green), Medians (gray)

```
(ctz.pts)(A: (0, 0), B: (7, 0.5), C: (2.5, 5))
(ctz.centroid)("G", "A", "B", "C")
(ctz.circumcenter)("O", "A", "B", "C")
(ctz.incenter)("I", "A", "B", "C")
(ctz.orthocenter)("H", "A", "B", "C")

line("A", "B", "C", "A", stroke: black + 1.5pt)
line("H", "O", stroke: (paint: red, dash: "dashed"))
circle("O", "A", stroke: blue + 1pt)
(ctz.incircle)("A", "B", "C", stroke: green + 1pt)
```

Nine-Point (Euler) Circle

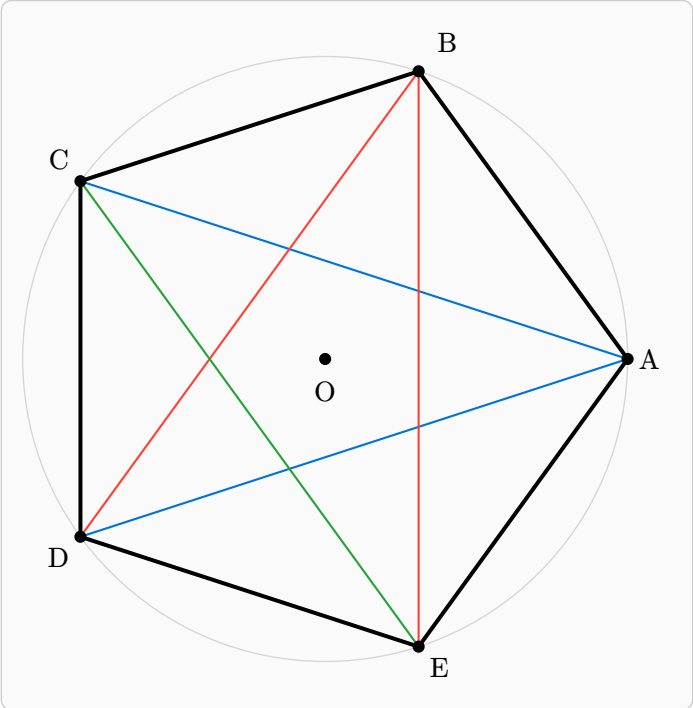


The nine-point circle passes through:

- Midpoints of sides (M_a, M_b, M_c)
- Feet of altitudes (H_a, H_b, H_c)
- Midpoints from H to vertices

```
(ctz.pts)(A: (0, 0), B: (7, 0), C: (2, 5))
(ctz.midpoint)("Ma", "B", "C")
(ctz.midpoint)("Mb", "A", "C")
(ctz.midpoint)("Mc", "A", "B")
(ctz.project)("Ha", "A", "B", "C")
(ctz.project)("Hb", "B", "A", "C")
(ctz.project)("Hc", "C", "A", "B")
(ctz.orthocenter)("H", "A", "B", "C")
(ctz.midpoint)("MHa", "H", "A")
(ctz.midpoint)("MHb", "H", "B")
(ctz.midpoint)("MHc", "H", "C")
(ctz.euler)("N", "A", "B", "C")
circle("N", "Ma", stroke: purple.darken(10%) + 1.2pt)
```

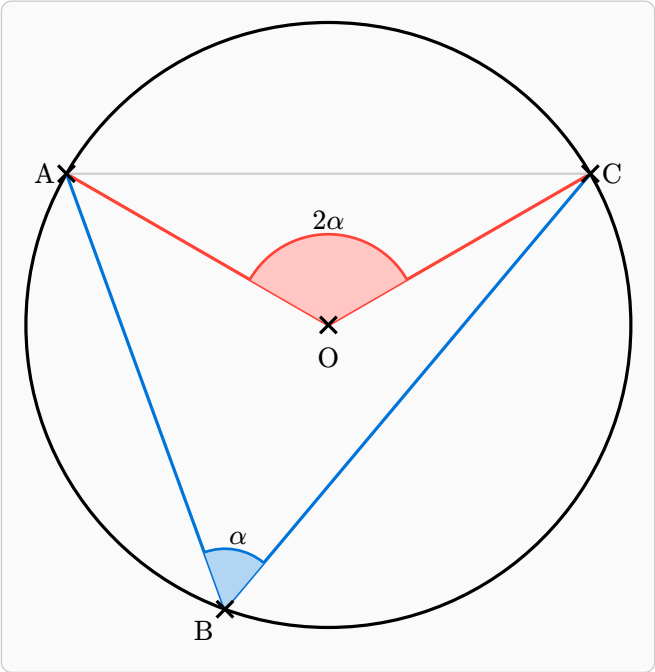
Regular Pentagon with Diagonals



Regular pentagon with all diagonals forming a pentagram

```
(ctz.pts)(O: (0, 0), V1: (4, 0))
(ctz.regular-polygon)(("A", "B", "C", "D", "E"), "O", "V1")
line("A", "B", "C", "D", "E", "A", stroke: black + 1.5pt)
line("A", "C", stroke: blue + 0.8pt)
line("A", "D", stroke: blue + 0.8pt)
line("B", "D", stroke: red + 0.8pt)
line("B", "E", stroke: red + 0.8pt)
line("C", "E", stroke: green.darken(20%) + 0.8pt)
circle("O", radius: 4, stroke: gray.lighten(50%) + 0.5pt)
```

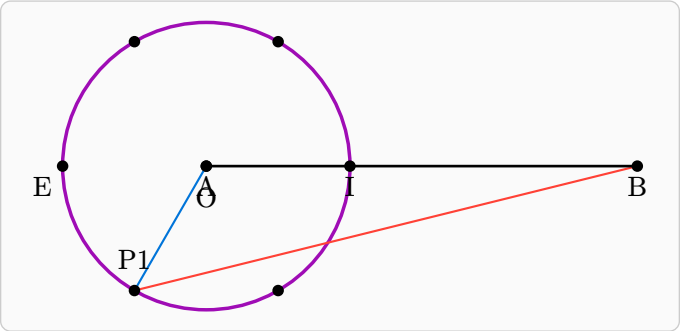
Inscribed Angle Theorem



Inscribed angle theorem: $\angle ABC = \frac{1}{2}\angle AOC$

```
(ctz.pts)(O: (0, 0), R: (4, 0))
circle("O", radius: 4, stroke: black + 1.2pt)
(ctz.rotate)("A", "R", "O", 150)
(ctz.rotate)("C", "R", "O", 30)
(ctz.rotate)("B", "R", "O", 250)
line("A", "B", stroke: blue + 1.2pt)
line("B", "C", stroke: blue + 1.2pt)
(ctz.angle)("B", "A", "C", label: $alpha$, radius: 0.8,
  fill: blue.lighten(70%), stroke: blue)
line("O", "A", stroke: red + 1.2pt)
line("O", "C", stroke: red + 1.2pt)
(ctz.angle)("O", "A", "C", label: $2alpha$, radius: 1.2,
  fill: red.lighten(70%), stroke: red)
```

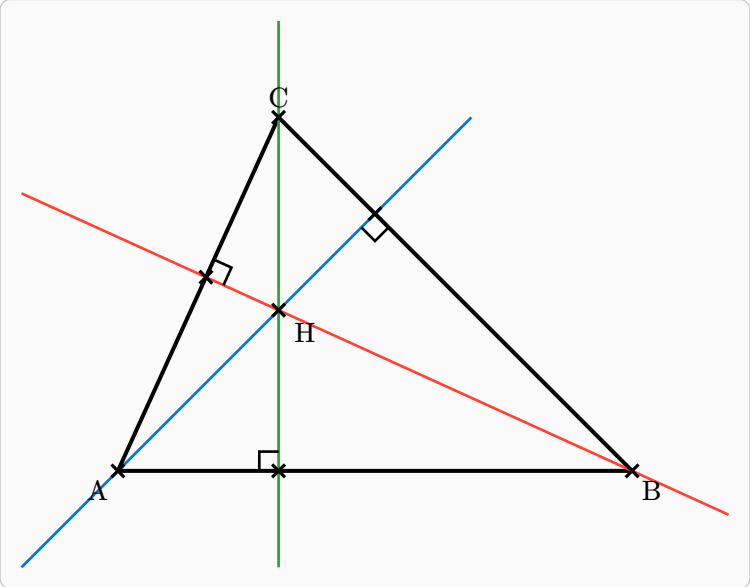
Geometric Locus: Apollonius Circle



Apollonius circle: locus of points P where $P\frac{A}{P}B = 2$
Points E (external) and I (internal) divide AB in ratio $2:1$

```
(ctz.pts)(A: (-3, 0), B: (3, 0))
let k = 2
(ctz.pts)(E: (-5, 0))
(ctz.pts)(I: (-1, 0))
(ctz.midpoint)("O", "E", "I")
circle("O", "E", stroke: purple.darken(10%) + 1.3pt)
(ctz.rotate)("P1", "E", "O", 60)
line("P1", "A", stroke: blue + 0.8pt)
line("P1", "B", stroke: red + 0.8pt)
line("A", "B", stroke: black + 1pt)
```

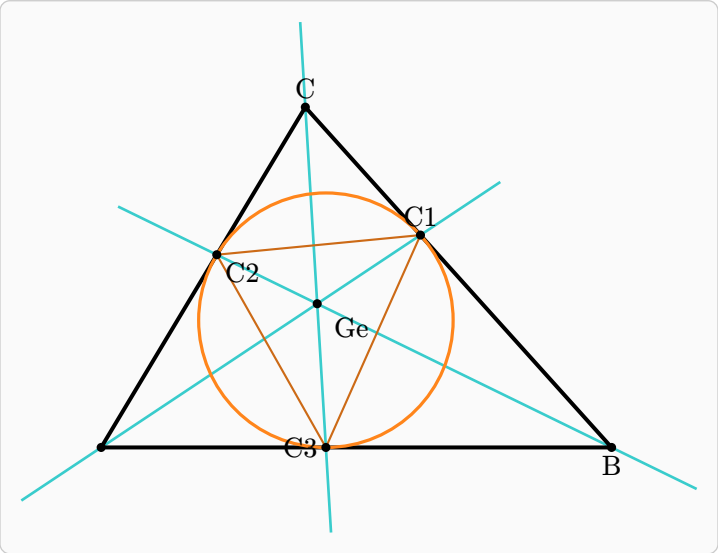
Orthocenter with Extended Altitudes



Altitudes extended beyond the triangle, clipped to viewing region

```
(ctz.pts)(A: (0, 0), B: (8, 0), C: (2.5, 5.5))
(ctz.set-clip)(-1.5, -1.5, 9.5, 7)
line("A", "B", "C", "A", stroke: black + 1.5pt)
(ctz.perp)("Ha1", "Ha2", ("B", "C"), "A")
(ctz.perp)("Hb1", "Hb2", ("A", "C"), "B")
(ctz.perp)("Hc1", "Hc2", ("A", "B"), "C")
(ctz.line)("A", "Ha1", add: (1, 1.5), stroke: blue + 1pt)
(ctz.line)("B", "Hb1", add: (1, 1.5), stroke: red + 1pt)
(ctz.line)("C", "Hc1", add: (1, 2.5), stroke: green.darken(20%) + 1pt)
(ctz.orthocenter)("H", "A", "B", "C")
(ctz.mark-right-angle)("A", "Ha", "B", size: 0.3)
```

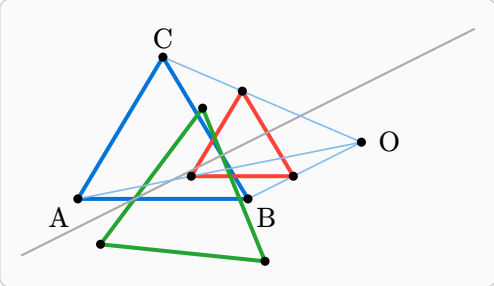
Gergonne Point and Contact Triangle



Gergonne point G_e: concurrence of lines from vertices to contact points of incircle with opposite sides

```
(ctz.pts)(A: (0, 0), B: (9, 0), C: (3.6, 6))
(ctz.set-clip)(-1.5, -1.5, 10.5, 8)
(ctz.gergonne)("Ge", "A", "B", "C")
(ctz.intouch)("C1", "C2", "C3", "A", "B", "C")
(ctz.line)("A", "C1", add: (0.25, 0.25), stroke: teal + 1pt)
(ctz.line)("B", "C2", add: (0.25, 0.25), stroke: teal + 1pt)
(ctz.line)("C", "C3", add: (0.25, 0.25), stroke: teal + 1pt)
line("A", "B", "C", "A", stroke: black + 1.5pt)
(ctz.incircle)("A", "B", "C", stroke: orange + 1.2pt)
line("C1", "C2", "C3", "C1", stroke: orange.darken(20%) + 0.8pt)
```

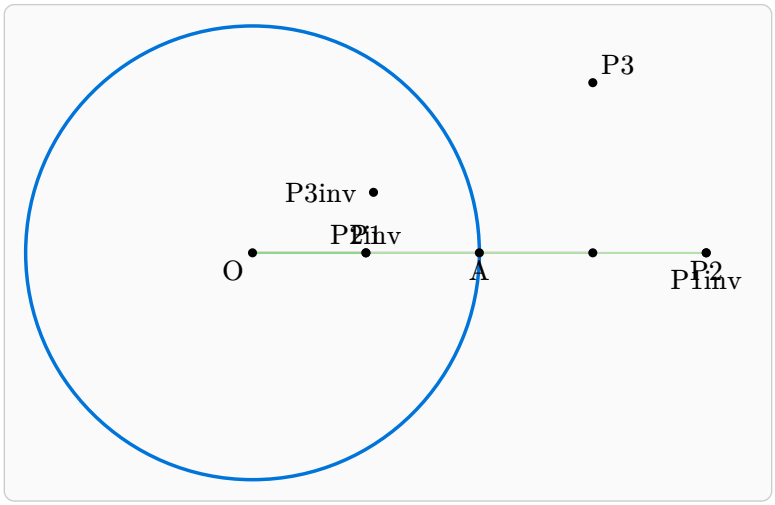
Homothety and Symmetry Transformations



Blue: original $\triangle ABC$ Red: homothety (center O, ratio 0.6)
Green: reflection across gray line

```
(ctz.pts)(A: (0, 0), B: (3, 0), C: (1.5, 2.5))
(ctz.pts)(O: (5, 1))
(ctz.scale)("Ah", "A", "O", 0.6)
(ctz.scale)("Bh", "B", "O", 0.6)
(ctz.scale)("Ch", "C", "O", 0.6)
(ctz.pts)(L1: (-1, -1), L2: (7, 3))
(ctz.reflect)("As", "A", "L1", "L2")
(ctz.reflect)("Bs", "B", "L1", "L2")
(ctz.reflect)("Cs", "C", "L1", "L2")
line("A", "B", "C", "A", stroke: blue + 1.5pt)
line("Ah", "Bh", "Ch", "Ah", stroke: red + 1.5pt)
line("As", "Bs", "Cs", "As", stroke: green.darken(20%) + 1.5pt)
```

Circle Inversion Transformation



Circle inversion: $OP \cdot OP' = r^2$ where r is the inversion radius
Points outside the circle map to inside, and vice versa

```
(ctz.pts)(O: (0, 0), A: (4, 0), P: (6, 0))
circle("O", "A", stroke: blue + 1.3pt)
(ctz.pts)(P1: (2, 0), P2: (8, 0), P3: (6, 3))
(ctz.inversion)("P1inv", "P1", "O", 4)
(ctz.inversion)("P2inv", "P2", "O", 4)
(ctz.inversion)("P3inv", "P3", "O", 4)
line("O", "P", stroke: gray + 0.8pt)
line("O", "P1", stroke: red.lighten(40%) + 0.7pt, stroke-dasharray: (3, 3))
line("O", "P2", stroke: green.lighten(40%) + 0.7pt, stroke-dasharray: (3, 3))
line("P1", "P1inv", stroke: red.lighten(60%) + 0.5pt)
line("P2", "P2inv", stroke: green.lighten(60%) + 0.5pt)
```