

$$A \xrightarrow{f} B$$

# fletcher

(noun) a maker of arrows

A Typst package for diagrams with lots of arrows, built on top of [CeTZ](#).

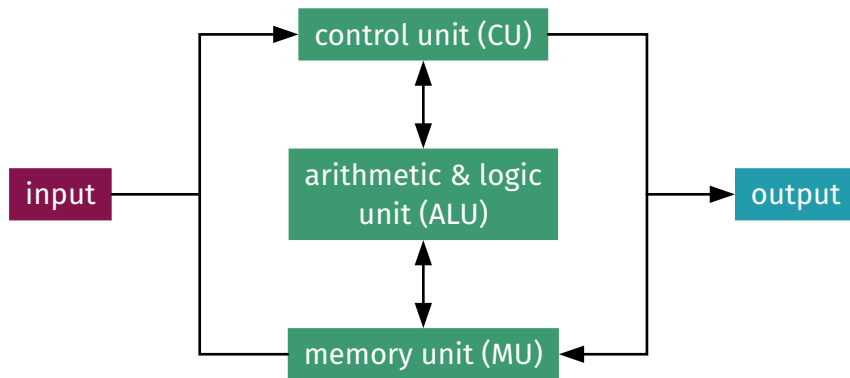
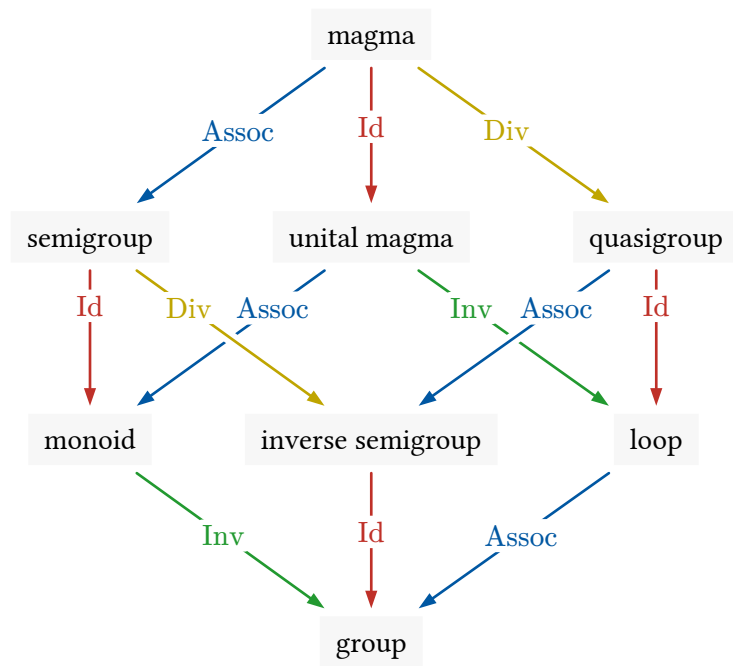
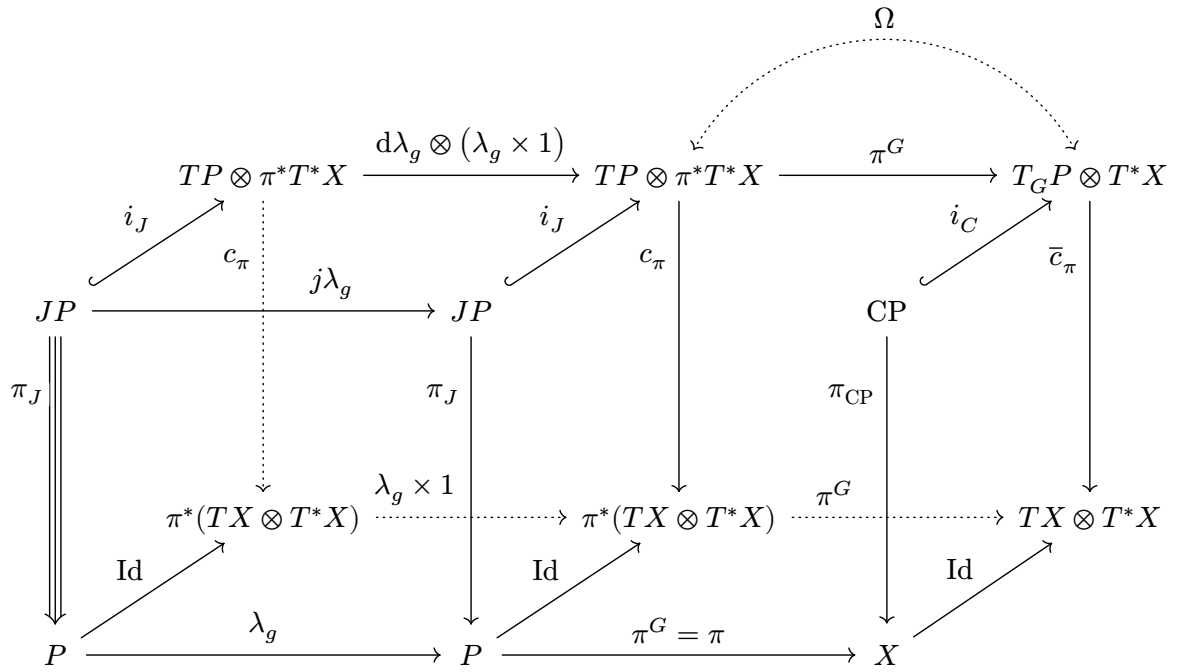
*Commutative diagrams, finite state machines, control systems block diagrams...*

[github.com/Jollywatt/typst-fletcher](https://github.com/Jollywatt/typst-fletcher)

Version 0.4.0 (not yet stable)

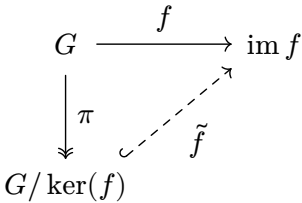
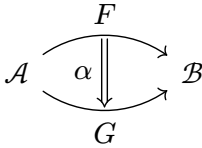
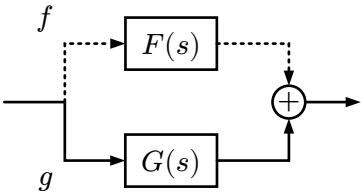
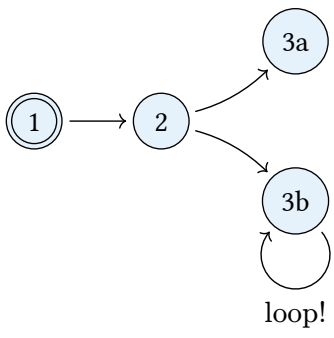
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## Examples

`#import "@preview/fletcher:0.4.0" as fletcher: node, edge`

<pre>#fletcher.diagram({   let (src, img, quo) = ((0, 1), (1, 1), (0, 0))   node(src, \$G\$)   node(img, \$im f\$)   node(quo, \$G slash ker(f)\$)   edge(src, img, \$f\$, "-&gt;")   edge(quo, img, \$\tilde{f}\$, "hook--&gt;", label-side: right)   edge(src, quo, \$\pi\$, "-&gt;&gt;") })</pre>	 <p>A commutative diagram with three nodes: <math>G</math> at the top left, <math>im\ f</math> at the top right, and <math>G/\ker(f)</math> at the bottom left. A solid arrow labeled <math>f</math> points from <math>G</math> to <math>im\ f</math>. A solid arrow labeled <math>\pi</math> points from <math>G</math> down to <math>G/\ker(f)</math>. A dashed arrow labeled <math>\tilde{f}</math> points from <math>G/\ker(f)</math> up to <math>im\ f</math>.</p>
<p>An equation <math>f: A \rightarrow B</math> and \</p> <pre>a diagram #fletcher.diagram(   node-inset: 4pt,   node((0,0), \$A\$),   edge((0,0), (1,0), text(0.8em, \$f\$), "-&gt;", label-sep: 1pt),   node((1,0), \$B\$), ).</pre>	<p>An equation <math>f: A \rightarrow B</math> and</p> <p>a diagram <math>A \xrightarrow{f} B</math>.</p>
<pre>#fletcher.diagram(spacing: 2cm, {   let (A, B) = ((0,0), (1,0))   node(A, \$cal(A)\$)   node(B, \$cal(B)\$)   edge(A, B, \$F\$, "-&gt;", bend: +35deg)   edge(A, B, \$G\$, "-&gt;", bend: -35deg)   let h = 0.21   edge((.5,+h), (.5,-h), \$\alpha\$, "=&gt;") })</pre>	 <p>A diagram with two nodes <math>A</math> and <math>B</math>. Two curved arrows, one labeled <math>F</math> (upper) and one labeled <math>G</math> (lower), point from <math>A</math> to <math>B</math>. A vertical double arrow labeled <math>\alpha</math> connects the two curved arrows.</p>
<pre>#fletcher.diagram(   spacing: (8mm, 3mm), // wide columns, narrow rows   node-stroke: 1pt,    // outline node shapes   edge-thickness: 1pt, // thickness of lines   mark-scale: 60%,    // make arrowheads smaller   edge((-2,0), (-1,0)),   edge((-1,0), (0,+1), \$f\$, ".. &gt;", corner: left),   edge((-1,0), (0,-1), \$g\$, "- &gt;", corner: right),   node((0,+1), \$F(s)\$),   node((0,-1), \$G(s)\$),   edge((0,+1), (1,0), ".. &gt;", corner: left),   edge((0,-1), (1,0), "- &gt;", corner: right),   node((1,0), \$+\$, inset: 1pt),   edge((1,0), (2,0), "- &gt;"), )</pre>	 <p>A block diagram showing a feedback control system. An input splits into two paths: one goes through a block labeled <math>F(s)</math> and the other through a block labeled <math>G(s)</math>. The outputs of these blocks are combined at a summing junction (a circle with a plus sign). The output of the summing junction is the final output of the system.</p>
<pre>#fletcher.diagram(   node-stroke: black + 0.5pt,   node-fill: blue.lighten(90%),   node-outset: 3pt,   spacing: (15mm, 8mm),   node((0,0), [1], extrude: (0, -4)), // double stroke effect   node((1,0), [2]),   node((2,1), [3a]),   node((2,-1), [3b]),   edge((0,0), (1,0), "-&gt;"),   edge((1,0), (2,+1), "-&gt;", bend: -15deg),   edge((1,0), (2,-1), "-&gt;", bend: +15deg),   edge((2,-1), (2,-1), "-&gt;", bend: +130deg, label: [loop!]), )</pre>	 <p>A state transition diagram with four nodes: node 1 (double circle), node 2 (single circle), node 3a (shaded circle), and node 3b (shaded circle). An arrow points from node 1 to node 2. Two arrows point from node 2 to nodes 3a and 3b. A self-loop arrow points from node 3b back to node 3b, labeled "loop!".</p>

## Details

The recommended way to load the package is:

```
#import "@preview/fletcher:0.4.0" as fletcher: node, edge
```

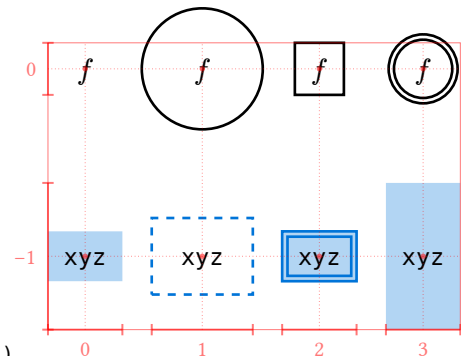
Other functions (including internal functions) are exported, so avoid importing everything with `*` and access them as needed with, e.g., `fletcher.diagram`.

## Nodes

```
node((x, y), label, ..options)
```

Nodes are content placed in the diagram at a particular coordinate. They fit to the size of their label (with an inset and outset), can be circular or rectangular (shape), and can be given a stroke and fill.

```
#fletcher.diagram(
  debug: 1,
  spacing: (1em, 3em), // (x, y)
  node((0, 0), $f$),
  node((1, 0), $f$, stroke: 1pt, radius: 8mm),
  node((2, 0), $f$, stroke: 1pt, shape: "rect"),
  node((3, 0), $f$, stroke: 1pt, extrude: (0, 2)),
  {
    let b = blue.lighten(70%)
    node((0,-1), `xyz`, fill: b, )
    let complex-stroke = (paint: blue, dash: "dashed")
    node((1,-1), `xyz`, stroke: complex-stroke, inset: 2em)
    node((2,-1), `xyz`, fill: b, stroke: blue, extrude: (0, -2))
    node((3,-1), `xyz`, fill: b, height: 5em)
  }
)
```

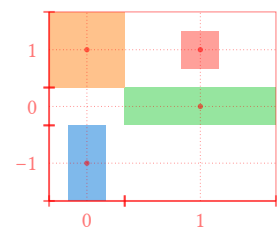


## Elastic coordinates

Diagrams are laid out on a flexible coordinate grid. When a node is placed, the rows and columns grow to accommodate the node's size, like a table. See the `diagram()` parameters for more control: `node-size` is the minimum row and column width, and `spacing` is the gutter between rows and columns, respectively.

Elastic coordinates can be demonstrated more clearly with a debug grid and no spacing.

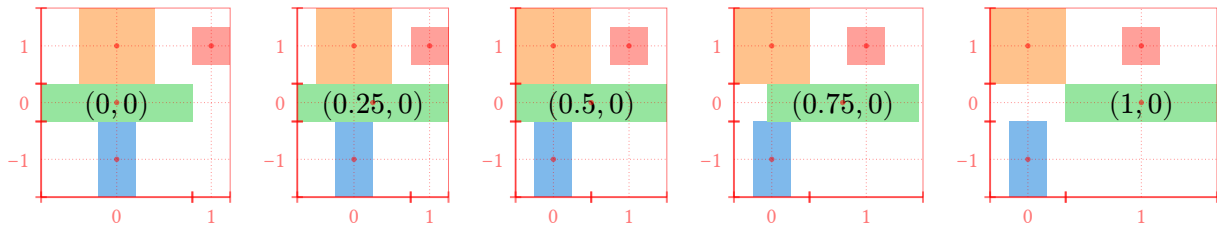
```
#let b(c, w, h) = box(fill: c.lighten(50%), width: w, height: h)
#fletcher.diagram(
  debug: 1,
  spacing: 0pt,
  node-inset: 0pt,
  node((0,-1), b(blue, 5mm, 10mm)),
  node((1, 0), b(green, 20mm, 5mm)),
  node((1, 1), b(red, 5mm, 5mm)),
  node((0, 1), b(orange, 10mm, 10mm)),
)
```



## Fractional coordinates

Rows and columns are at integer coordinates, but nodes may have fractional coordinates. These are dealt with by linearly interpolating the diagram between what it would be if the coordinates were rounded up or down. Both the node's position and its influence on row/column sizes are interpolated.

As a result, diagrams are responsive to node sizes (like tables) while also allowing precise positioning.



## Edges

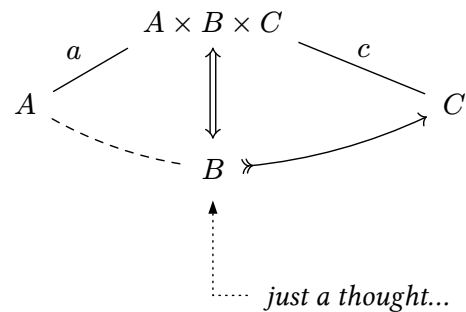
`edge(node-1, node-2, label, marks, ..options)`

Edges connect two coordinates. If there is a node at an endpoint, the edge attaches to the nodes' bounding circle or rectangle. Edges can have labels, can bend into arcs, and can have various arrow marks.

```
#fletcher.diagram(spacing: (12mm, 6mm), {
  let (a, b, c, abc) = ((-1,0), (0,-1), (1,0), (0,1))
  node(abc, $A \times B \times C$)
  node(a, $A$)
  node(b, $B$)
  node(c, $C$)

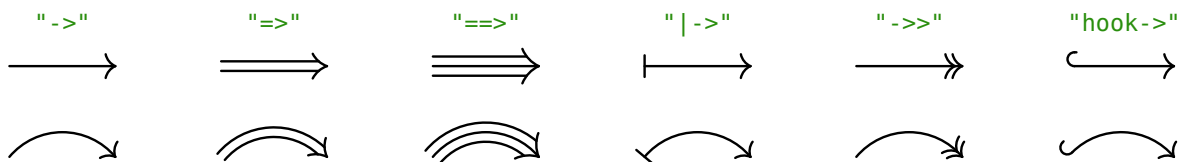
  edge(a, b, bend: -10deg, "dashed")
  edge(c, b, bend: +10deg, "<-<<")
  edge(a, abc, $a$)
  edge(b, abc, "<=>")
  edge(c, abc, $c$)

  node((0.6, -3), [_just a thought..._])
  edge(b, (0.6, -3), "<|..", corner: right)
})
)
```

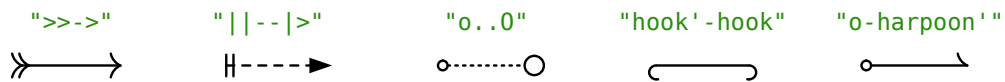


## Marks and arrows

A few mathematical arrow heads are supported, designed to match  $\rightarrow$ ,  $\Rightarrow$ ,  $\Rrightarrow$ ,  $\mapsto$ ,  $\twoheadrightarrow$ ,  $\hookrightarrow$ , etc.



In addition, some other miscellaneous caps are supported:



See the marks argument of `edge()` for details.

## Customised marks

While convenient shorthands exist for specifying marks and stroke styles, finer control is possible. Shorthands such as "<->" are shortcuts for specific combinations of `edge()` options. For example, `edge(a, b, "|=>")` is the equivalent to `edge(a, b, marks: ("bar", "doublehead"), extrude: (-2, 2))`. The expanded options can be seen by invoking `parse-arrow-shorthand()`:

```
#fletcher.parse-arrow-shorthand("|=>")      (marks: ("bar", "doublehead"), extrude: (-2, 2))
```

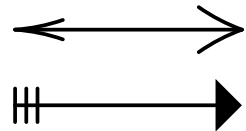
Furthermore, a mark name such as "bar" or "doublehead" is a shorthand for a dictionary defining the mark's geometry. The expanded form can be retrieved with `interpret-mark()`.

```
#fletcher.interpret-mark("doublehead")
// In this particular example:
// - `kind` selects the type of arrow head
// - `size` controls the radius of the arc
// - `sharpness` is (half) the angle of the tip
// - `delta` is the angle spanned by the arcs
// - `underhang` is approximately the distance from the arrow's tip to
//   the end of its arms. This is used to calculate a correction to the
//   arrowhead's bearing for tightly curved edges
// Distances are multiples of the stroke thickness.
```

```
(
  kind: "head",
  size: 10.56,
  sharpness: 19deg,
  delta: 43.7deg,
  underhang: 4.5,
)
```

You can customise marks by adjusting these parameters. For example:

```
#let custom-head = (kind: "head", sharpness: 4deg, size: 50, delta: 15deg)
#let custom-bar = (kind: "bar", extrude: (0, -3, -6))
#let custom-solidhead = (kind: "solidhead", sharpness: 45deg)
#fletcher.diagram(
  edge-thickness: 1.4pt,
  spacing: (3cm, 1cm),
  edge((0,1), (1,1), marks: (custom-head, custom-head + (sharpness: 20deg))),
  edge((0,0), (1,0), marks: (custom-bar, custom-solidhead)),
)
```



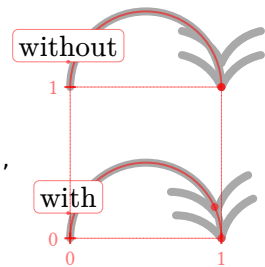
The exact parameters for each kind of arrow head will probably change often as this package is updated, so they are undocumented. However, you are encouraged to use the functions `parse-arrow-shorthand()` and `interpret-mark()` to discover the parameters if you want finer control.

## Underhang correction

All marks accept an underhang parameter, the effect of which can be seen below:

```
#fletcher.diagram(
  edge-thickness: 3pt,
  spacing: 2cm,
  debug: 3,

  edge((0,1), (1,1), paint: gray, bend: 90deg, label-pos: 0.1, label: [without],
    marks: (none, (kind: "twohead", underhang: 0))),
  edge((0,0), (1,0), paint: gray, bend: 90deg, label-pos: 0.1, label: [with],
    marks: (none, (kind: "twohead"))), // use default underhang
)
```



The underhang specifies the length (in multiples of the stroke thickness) that the arrow head visually extends backwards over the stroke. This is the distance between the two red dots on the second arrow head above. The mark is rotated so that both these points lie on the arc.

## CeTZ integration

Currently, only straight, arc and right-angled connectors are supported. However, an escape hatch is provided with the render argument of `diagram()` so you can intercept diagram data and draw things using CeTZ directly.

Here is an example of how you might hack together a Bézier connector using the same functions that fletcher uses internally to anchor edges to nodes and draw arrow heads:

```

#fletcher.diagram(
  node((0,0), $A$),
  node((2,1), [Bézier]),
  render: (grid, nodes, edges, options) => {
    // cetz is also exported as fletcher.cetz
    cetz.canvas({
      // this is the default code to render the diagram
      fletcher.draw-diagram(grid, nodes, edges, options)

      // retrieve node data by coordinates
      let n1 = fletcher.find-node-at(nodes, (0,0))
      let n2 = fletcher.find-node-at(nodes, (2,1))

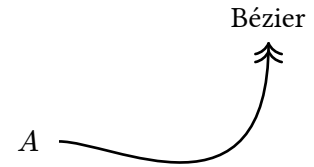
      // get anchor points for the connector
      let p1 = fletcher.get-node-anchor(n1, 0deg)
      let p2 = fletcher.get-node-anchor(n2, -90deg)

      // make some control points
      let c1 = cetz.vector.add(p1, (20pt, 0pt))
      let c2 = cetz.vector.add(p2, (0pt, -70pt))

      cetz.draw.bezier(p1, p2, c1, c2)

      // place an arrow head at a given point and angle
      fletcher.draw-arrow-cap(p2, 90deg, 1pt + black, "twohead")
    })
  }
)

```



### The defocus adjustment

For aesthetic reasons, lines connecting to a node need not focus to the node's exact center, especially if the node is short and wide or tall and narrow. Notice the difference the figures below. "Defocusing" the connecting lines can make the diagram look more comfortable.

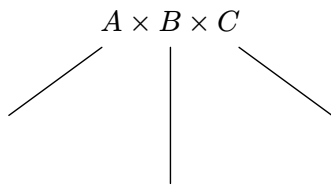


Figure 1: With defocus

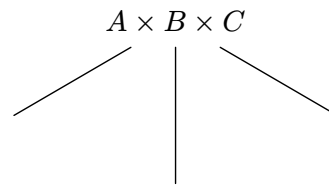


Figure 2: Without defocus

See the node-defocus argument of [diagram\(\)](#) for details.

## Function reference

---

### diagram()

Draw an arrow diagram.

#### Parameters

```
diagram(  
  ..objects: array,  
  debug: bool 1 2 3,  
  spacing: length pair of lengths,  
  cell-size: length pair of lengths,  
  node-inset: length pair of lengths,  
  node-outset: length pair of lengths,  
  node-stroke: stroke,  
  node-fill: paint,  
  node-defocus: number,  
  label-sep,  
  edge-thickness,  
  mark-scale,  
  crossing-fill: paint,  
  crossing-thickness: number,  
  render: function  
)
```

**..objects** array

An array of dictionaries specifying the diagram's nodes and connections.

The results of `node()` and `edge()` can be joined, meaning you can specify them as separate arguments, or in a block:

```
#fletcher.diagram(  
  // one object per argument  
  node((0, 0), $A$),  
  node((1, 0), $B$),  
  {  
    // multiple objects in a block  
    // can use scripting, loops, etc  
    node((2, 0), $C$)  
    node((3, 0), $D$)  
  },  
)
```

**debug** bool or 1 or 2 or 3

Level of detail for drawing debug information. Level 1 shows a coordinate grid; higher levels show bounding boxes and anchors, etc.

Default: `false`



**spacing**   length or pair of lengths

Gaps between rows and columns. Ensures that nodes at adjacent grid points are at least this far apart (measured as the space between their bounding boxes).

Separate horizontal/vertical gutters can be specified with  $(x, y)$ . A single length  $d$  is short for  $(d, d)$ .

Default: **3em**

**cell-size**   length or pair of lengths

Minimum size of all rows and columns.

Default: **0pt**

**node-inset**   length or pair of lengths

Default padding between a node's content and its bounding box.

Default: **12pt**

**node-outset**   length or pair of lengths

Default padding between a node's boundary and where edges terminate.

Default: **0pt**

**node-stroke**   stroke

Default stroke for all nodes in diagram. Overridden by individual node options.

Default: **none**

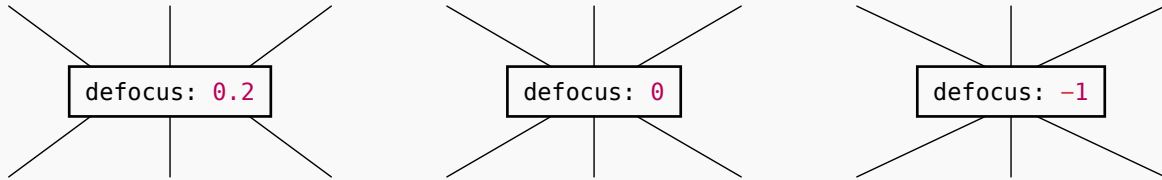
**node-fill**   paint

Default fill for all nodes in diagram. Overridden by individual node options.

Default: **none**

### **node-defocus** number

Default strength of the “defocus” adjustment for nodes. This affects how connectors attach to non-square nodes. If **0**, the adjustment is disabled and connectors are always directed at the node’s exact center.



Default: **0.2**

### **label-sep**

Default: **0.2em**

### **edge-thickness**

Default: **0.048em**

### **mark-scale**

Default: **100%**

### **crossing-fill** paint

Color to use behind connectors or labels to give the illusion of crossing over other objects. See the `crossing-fill` option of `edge()`.

Default: white

### **crossing-thickness** number

Default thickness of the occlusion made by crossing connectors. See the `crossing-thickness` option of `edge()`.

Default: **5**

## **render**    `function`

After the node sizes and grid layout have been determined, the render function is called with the following arguments:

- `grid`: a dictionary of the row and column widths and positions;
- `nodes`: an array of nodes (dictionaries) with computed attributes (including size and physical coordinates);
- `edges`: an array of connectors (dictionaries) in the diagram; and
- `options`: other diagram attributes.

This callback is exposed so you can access the above data and draw things directly with CeTZ.

```
Default: (grid, nodes, edges, options) => {  
  cetz.canvas(draw-diagram(grid, nodes, edges, options))  
}
```

---

## `edge()`

Draw a connecting line or arc in an arrow diagram.

### Parameters

```
edge(  
  from: elastic coord ,  
  to: elastic coord ,  
  ..args: any ,  
  label: content ,  
  label-side: left right center ,  
  label-pos: number ,  
  label-sep: number ,  
  label-anchor: anchor ,  
  paint: paint ,  
  thickness: length ,  
  dash: dash type ,  
  kind ,  
  bend: angle ,  
  corner ,  
  marks: pair of strings ,  
  mark-scale: percent ,  
  extrude: array ,  
  crossing: bool ,  
  crossing-thickness: number ,  
  crossing-fill: paint  
)
```

**from**    `elastic coord`

Start coordinate (x, y) of connector. If there is a node at that point, the connector is adjusted to begin at the node's bounding rectangle/circle.

**to** `elastic coord`

End coordinate (x, y) of connector. If there is a node at that point, the connector is adjusted to end at the node's bounding rectangle/circle.

**..args** `any`

The connector's label and marks named arguments can also be specified as positional arguments. For example, the following are equivalent:

```
edge((0,0), (1,0), $$, "->")
edge((0,0), (1,0), $$, marks: "->")
edge((0,0), (1,0), "->", label: $$)
edge((0,0), (1,0), label: $$, marks: "->")
```

**label** `content`

Content for connector label. See `label-side` to control the position (and `label-sep`, `label-pos` and `label-anchor` for finer control).

Default: `none`

**label-side** `left or right or center`

Which side of the connector to place the label on, viewed as you walk along it. If center, then the label is placed over the connector. When `auto`, a value of left or right is chosen to automatically so that the label is

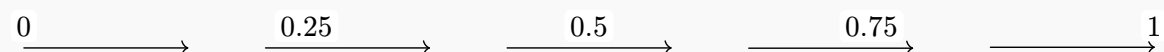
- roughly above the connector, in the case of straight lines; or
- on the outside of the curve, in the case of arcs.

Default: `auto`

**label-pos** `number`

Position of the label along the connector, from the start to end (from 0 to 1).

0                      0.25                      0.5                      0.75                      1

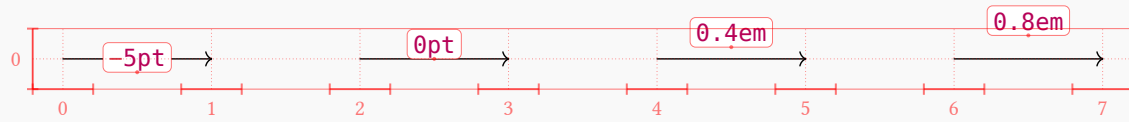


Default: `0.5`

## **label-sep**    number

Separation between the connector and the label anchor.

With the default anchor ("bottom"):



With label-anchor: "center":



Default: **auto**

## **label-anchor**    anchor

The anchor point to place the label at, such as "top-right", "center", "bottom", etc. If **auto**, the anchor is automatically chosen based on label-side and the angle of the connector.

Default: **auto**

## **paint**    paint

Paint (color or gradient) of the connector stroke.

Default: black

## **thickness**    length

Thickness the connector stroke. Marks (arrow heads) scale with this thickness.

Default: **auto**

## **dash**    dash type

Dash style for the connector stroke.

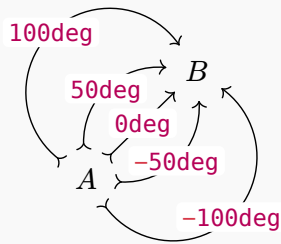
Default: **none**

## **kind**

Default: **auto**

## **bend**    angle

Curvature of the connector. If **0deg**, the connector is a straight line; positive angles bend clockwise.



Default: **0deg**

## **corner**

Default: **none**

## **marks**    pair of strings

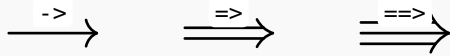
The start and end marks or arrow heads of the connector. A shorthand such as **"->"** can be used instead. For example, `edge(p1, p2, ">-")` is short for `edge(p1, p2, marks: (none, "head"))`.

Arrow	Shorthand	Arguments
	-	(marks: (none, none))
	--	(marks: (none, none), dash: "dashed")
	..	(marks: (none, none), dash: "dotted")
	->	(marks: (none, "head"))
	<=>	(marks: ("doublehead", "doublehead"), extrude: (-2, 2),)
	>>-->	(marks: ("twotail", "head"), dash: "dashed")
	..	(marks: ("bar", "bar"), dash: "dotted")
	hook->>	(marks: ("hook", "twohead"))
	hook'->>	(marks: ("hook'", "twohead"))
	>-harpoon	(marks: ("tail", "harpoon"))
	>-harpoon'	(marks: ("tail", "harpoon'"))

Default: (none, none)

### mark-scale percent

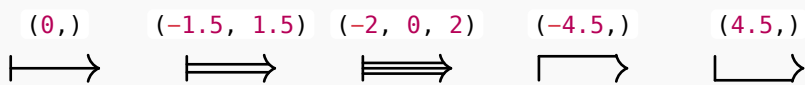
Scale factor for connector marks or arrow heads. This defaults to **100%** for single lines, **120%** for double lines and **150%** for triple lines. Does not affect the stroke thickness of the mark.



Default: **100%**

### extrude array

Draw a separate stroke for each extrusion offset to obtain a multi-stroke effect. Offsets may be numbers (specifying multiples of the stroke's thickness) or lengths.



Notice how the ends of the line need to shift a little depending on the mark. For basic arrow heads, this offset is computed with `round-arrow-cap-offset()`.

Default: **(0,)**

### crossing bool

If **true**, draws a white backdrop to give the illusion of lines crossing each other.



Default: **false**

### crossing-thickness number

Thickness of the white “crossing” background stroke, if `crossing: true`, in multiples of the normal stroke's thickness. Defaults to the `crossing-thickness` option of `diagram()`.



Default: **auto**

## **crossing-fill** `paint`

Color to use behind connectors or labels to give the illusion of crossing over other objects. Defaults to the `crossing-fill` option of `diagram()`.



Default: `auto`

---

## **node()**

Draw a labelled node in an arrow diagram.

### Parameters

```
node(  
  pos: point,  
  label: content,  
  inset: length auto,  
  outset: length auto,  
  shape: string auto,  
  width,  
  height,  
  radius,  
  stroke: stroke,  
  fill: paint,  
  defocus: number,  
  extrude: array  
)
```

## **pos** `point`

Dimensionless “elastic coordinates” ( $x$ ,  $y$ ) of the node, where  $x$  is the column and  $y$  is the row (increasing upwards). The coordinates are usually integers, but can be fractional.

See the `diagram()` options to control the physical scale of elastic coordinates.

## **label** `content`

Node content to display.

## **inset** `length` or `auto`

Padding between the node’s content and its bounding box or bounding circle. If `auto`, defaults to the `node-inset` option of `diagram()`.

Default: `auto`



**outset**    `length` or `auto`

Margin between the node's bounds to the anchor points for connecting edges.

Default: `auto`

**shape**    `string` or `auto`

Shape of the node, one of `"rect"` or `"circle"`. If `auto`, shape is automatically chosen depending on the aspect ratio of the node's label.

Default: `auto`

**width**

Default: `auto`

**height**

Default: `auto`

**radius**

Default: `auto`

**stroke**    `stroke`

Stroke of the node. Defaults to the `node-stroke` option of `diagram()`.

Default: `auto`

**fill**    `paint`

Fill of the node. Defaults to the `node-fill` option of `diagram()`.

Default: `auto`

**defocus**    `number`

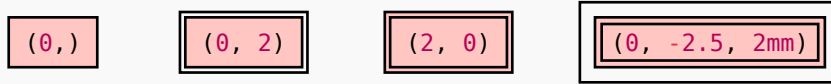
Strength of the “defocus” adjustment for connectors incident with this node. If `auto`, defaults to the `node-defocus` option of `diagram()`.

Default: `auto`

## **extrude** `array`

Draw strokes around the node at the given offsets to obtain a multi-stroke effect. Offsets may be numbers (specifying multiples of the stroke's thickness) or lengths.

The node's fill is drawn within the boundary defined by the first offset in the array.



See also the `extrude` option of `edge()`.

Default: `(0, )`

---

## **compute-grid()**

Determine the number, sizes and positions of rows and columns.

### **Parameters**

```
compute-grid(  
  nodes,  
  options  
)
```

### **nodes**

### **options**

---

## **expand-fractional-rects()**

Convert an array of rects with fractional positions into rects with integral positions.

If a rect is centered at a fractional position `floor(x) < x < ceil(x)`, it will be replaced by two new rects centered at `floor(x)` and `ceil(x)`. The total width of the original rect is split across the two new rects according to which one is closer. (E.g., if the original rect is at `x = 0.25`, the new rect at `x = 0` has 75% the original width and the rect at `x = 1` has 25%.) The same splitting procedure is done for y positions and heights.

### **Parameters**

```
expand-fractional-rects(rects: array of rects) -> array of rects
```

### **rects** `array of rects`

An array of rectangles of the form `(pos: (x, y), size: (width, height))`. The coordinates `x` and `y` may be floats.

---

## get-edge-anchors()

Get the points where a connector between two nodes should be drawn between, taking into account the nodes' sizes and relative positions.

### Parameters

```
get-edge-anchors(  
  edge: dictionary,  
  nodes: pair of dictionaries  
) -> pair of points
```

**edge** dictionary

The connector whose end points should be determined.

**nodes** pair of dictionaries

The start and end nodes of the connector.

---

## get-node-anchor()

Get the point at which a connector should attach to a node from a given angle, taking into account the node's size and shape.

### Parameters

```
get-node-anchor(  
  node: dictionary,  
  θ: angle  
) -> point
```

**node** dictionary

The node to connect to.

**θ** angle

The desired angle from the node's center to the connection point.

---

## interpret-mark()

Take a string or dictionary specifying a mark and return a dictionary, adding defaults for any necessary missing parameters.

### Parameters

```
interpret-mark(mark)
```

**mark**

---

## parse-arrow-shorthand()

### Parameters

`parse-arrow-shorthand(str)`

**str**

---

## round-arrow-cap-offset()

Calculate cap offset of round-style arrow cap,  $r \left( \sin \theta - \sqrt{1 - \left( \cos \theta - \frac{|y|}{r} \right)^2} \right)$ .

### Parameters

```
round-arrow-cap-offset(  
  r: length,  
  θ: angle,  
  y: length  
)
```

**r**    `length`

Radius of curvature of arrow cap.

**θ**    `angle`

Angle made at the the arrow's vertex, from the central stroke line to the arrow's edge.

**y**    `length`

Lateral offset from the central stroke line.

---

## get-arc-connecting-points()

Determine arc between two points with a given bend angle

The bend angle is the angle between chord of the arc (line connecting the points) and the tangent to the arc and the first point.

Returns a dictionary containing:

- center: the center of the arc's curvature
- radius
- start: the start angle of the arc
- stop: the end angle of the arc

## Parameters

```
get-arc-connecting-points(  
  from: point ,  
  to: point ,  
  angle: angle  
) -> dictionary
```

**from**    point

2D vector of initial point.

**to**    point

2D vector of final point.

**angle**    angle

The bend angle between chord of the arc (line connecting the points) and the tangent to the arc and the first point.

