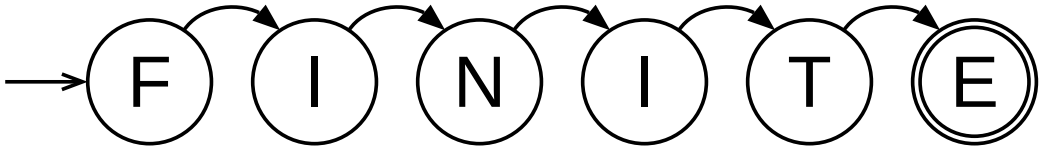


Version 0.5.0 2025-05-19 MIT

FINITE is a Typst package to draw transition diagrams for finite automata (finite state machines) with the power of CeTZ.

The package provides commands to quickly draw automata from a transition table but also lets you manually create and customize transition diagrams on any CeTZ canvas.

Table of Contents

Part I Usage

I.1 Importing the package

Import the package in your Typst file:

```
#import "@preview/finite:0.5.0": automaton
```

I.2 Manual installation

The package can be downloaded and saved into the system dependent local package repository.

Either download the current release from jneug/typst-finite[1] and unpack the archive into your system dependent local repository folder[2] or clone it directly:

```
git clone https://github.com/jneug/typst-finite finite/0.5.0
```

In either case, make sure the files are placed in a subfolder with the correct version number: `finite/0.5.0`

After installing the package, just import it inside your `typ` file:

```
#import "@local/finite:0.5.0": automaton
```

I.3 Dependencies

FINITE loads CETZ[3] and the utility package T4T[4] from the `preview` package repository. The dependencies will be downloaded by Typst automatically on first compilation.

Whenever a `coordinate` type is referenced, a CETZ coordinate can be used. Please refer to the CETZ manual for further information on coordinate systems.

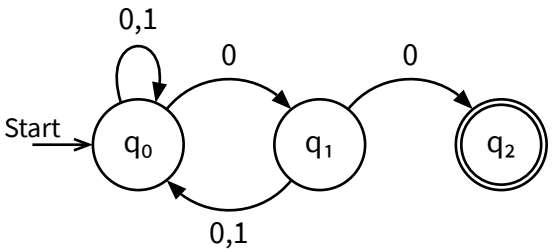
[1] https://github.com/jneug/typst-finite
[2] https://github.com/typst/packages#local-packages
[3] https://github.com/johannes-wolf/typst-canvas
[4] https://github.com/jneug/typst-tools4typst

Part II Drawing automata

FINITE helps you draw transition diagrams for finite automata in your Typst documents, using the power of CETZ.

To draw an automaton, simply import `#automaton` from FINITE and use it like this:

```
#automaton((
  q0: (q1:0, q0:"0,1"),
  q1: (q0:(0,1), q2:"0"),
  q2: none,
))
```



As you can see, an automaton ist defined by a dictionary of dictionaries. The keys of the top-level dictionary are the names of states to draw. The second-level dictionaries use the names of connected states as keys and transition labels as values.

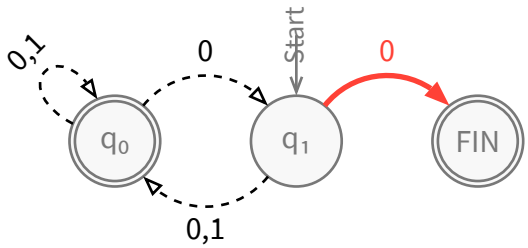
In the example above, the states `q0`, `q1` and `q2` are defined. `q0` is connected to `q1` and has a loop to itself. `q1` transitions to `q2` and back to `q0`. `#automaton` selected the first state in the dictionary (in this case `q0`) to be the initial state and the last (`q2`) to be a final state.

See Section II.1 for more details on how to specify automata.

To modify the layout and style of the transition diagram, `#automaton` accepts a set of options:

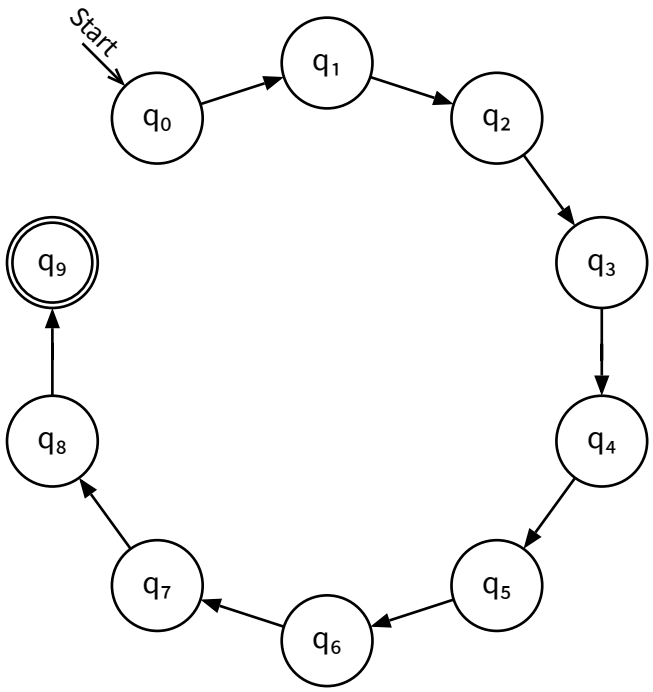
```
#automaton(
  (
    q0: (q1:0, q0:"0,1"),
    q1: (q0:(0,1), q2:"0"),
    q2: (),
  ),
  initial: "q1",
  final: ("q0", "q2"),
  labels:(
    q2: "FIN"
```

```
  ),
  style:(
    state: (fill: luma(248), stroke:luma(120)),
    transition: (stroke: (dash:"dashed")),
    q0-q0: (anchor:top+left),
    q1: (initial:top),
    q1-q2: (stroke: 2pt + red)
  )
)
```



For larger automatons, the states can be arranged in different ways:

```
#let aut = (:)
#for i in range(10) {
  let name = "q"+str(i)
  aut.insert(name, (:))
  if i < 9 {
    aut.at(name).insert("q" + str(i + 1), none)
  }
}
#automaton(
  aut,
  layout: finite.layout.circular.with(offset: 45deg),
  style: (
    transition: (curve: 0),
    q0: (initial: top+left)
  )
)
```



See Section II.5 for more on layouts.

II.1 Specifing finite automata

Most of FINITEs commands expect a finite automaton specification ("`spec`" in short) the first argument. These specifications are dictionaries defining the elements of the automaton.

If an automaton has only one final state, the spec can simply be a `transition-table`. In other cases, the specification can explicitly define the various elements.

A transition table is a `dictionary` with state names as keys and dictionaries as values. The nested dictionaries have state names as keys and the transition inputs / labels as values.

```
(
  q0: (q1: (0, 1), q2: (0, 1)),
  q1: (q1: (0, 1), q0: 0, q2: 1),
  q2: (q0: 0, q1: (1, 0)),
)
```

A specification (`spec`) is composed of these keys:

```
1  (
```

```
  transitions: (...),
  states: (...),
  inputs: (...),
  initial: "...",
  final: (...)
)
```

- `transitions` is a dictionary of dictionaries in the format:

```
(
  state1: (input1, input2, ...),
  state2: (input1, input2, ...),
  ...
)
```

- `states` is an optional array with the names of all states. The keys of `transitions` are used by default.
- `inputs` is an optional array with all input values. The inputs found in `transitions` are used by default.
- `initial` is an optional name of the initial state. The first value in `states` is used by default.
- `final` is an optional array of final states. The last value in `states` is used by default.

The utility function `#util.to-spec` can be used to create a full spec from a partial dictionary by filling in the missing values with the defaults.

II.2 Command reference

```
#create-automaton(
  (spec),
  (states): auto,
  (initial): auto,
  (final): auto,
  (inputs): auto
) → automaton
```

Creates a full automaton specification (`spec`) for a finite automaton. The function accepts either a partial specification and adds the missing keys by parsing the available information or takes a `transition-table` and parses it into a full specification.

```
#finite.create-automaton((
  q0: (q1: 0, q0: (0,1)),
  q1: (q0: (0,1), q2: "0"),
  q2: none,
))
```

```
(
  transitions: (
    q0: (q1: ("0",), q0: ("0", "1")),
    q1: (q0: ("0", "1"), q2: ("0",)),
    q2: (:),
  ),
  states: ("q0", "q1", "q2"),
  initial: "q0",
  final: ("q2",),
  inputs: ("0", "1"),
  type: "NEA",
  finite-spec: true,
)
```

If any of the keyword arguments are set, they will overwrite the information in ⟨spec⟩.

Argument

⟨spec⟩ spec | transition-table

Automaton specification.

Argument

⟨states⟩: auto array

The list of state names in the automaton. auto uses the keys of ⟨spec⟩.

Argument

⟨initial⟩: auto str

The name of the initial state. auto uses the first key in ⟨spec⟩.

Argument

⟨final⟩: auto array

The list of final states. auto uses the last key in ⟨spec⟩.

Argument

⟨inputs⟩: auto

The list of all inputs, the automaton uses. `auto` uses the inputs provided in ⟨spec⟩.

```
#automaton(
  ⟨spec⟩,
  ⟨initial⟩: auto,
  ⟨final⟩: auto,
  ⟨labels⟩: (:),
  ⟨style⟩: (:),
  ⟨state-format⟩: label => {
    let m = label.match(regex(`^(\D+)(\d+)$`.text))
    if m != none {
      [#m.captures.at(0)#sub(m.captures.at(1))]
    } else {
      label
    }
  },
  ⟨input-format⟩: inputs => inputs.map(str).join(","),
  ⟨layout⟩: _layout.linear,
  ..⟨canvas-styles⟩
) → content
```

Draw an automaton from a specification.

⟨spec⟩ is a dictionary with a specification for a finite automaton. See above for a description of the specification dictionaries.

The following example defines three states `q0`, `q1` and `q2`. For the input `0`, `q0` transitions to `q1` and for the inputs `0` and `1` to `q2`. `q1` transitions to `q0` for `0` and `1` and to `q2` for `0`. `q2` has no transitions.

```
#automaton((
  q0: (q1:0, q0:(0, 1)),
  q1: (q0:(0, 1), q2:0),
  q2: none
))
```

⟨inital⟩ and ⟨final⟩ can be used to customize the initial and final states.

> The ⟨inital⟩ and ⟨final⟩ will be removed in future versions in favor of automaton specs.

Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨initial⟩: auto `str` | `auto` | `none`

The name of the initial state. For `auto`, the first state in ⟨spec⟩ is used.

Argument

⟨final⟩: auto `str` | `auto` | `none`

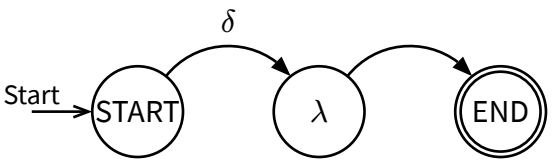
A list of final state names. For `auto`, the last state in ⟨spec⟩ is used.

Argument

⟨labels⟩: (:) `dictionary`

A dictionary with custom labels for states and transitions.

```
#finite.automaton(
  (q0: (q1:none), q1: (q2:none), q2: none),
  labels: (
    q0: [START], q1: $lambda$, q2: [END],
    q0-q1: $delta$
  )
)
```



Argument

⟨style⟩: (:) `dictionary`

A dictionary with styles for states and transitions.

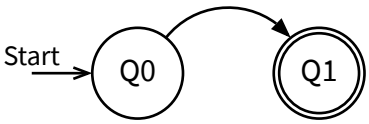
Argument

```
⟨state-format⟩: label => {
    let m = label.match(regex(`^(\D+)(\d+)$`.text))
    if m != none {
      [#m.captures.at(0)#sub(m.captures.at(1))]
    } else {
      label
```

```
  }
}
```
`function`

A function `(str)→content` to format state labels. The function will get the states name as a string and should return the final label as `content`.

```
#finite.automaton(
  (q0: (q1:none), q1: none),
  state-format: (label) => upper(label)
)
```

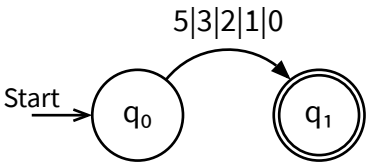


Argument

`⟨input-format⟩: inputs => inputs.map(str).join(",")` `function`

A function `(array)→content` to generate transition labels from input values. The functions will be called with the array of inputs and should return the final label for the transition. This is only necessary, if no label is specified.

```
#finite.automaton(
  (q0: (q1:(3,0,2,1,5)), q1: none),
                              input-format:              (inputs)
=> inputs.sorted().rev().map(str).join("|")
)
```

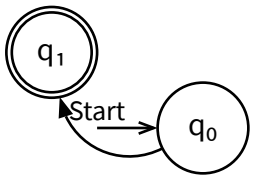


Argument

`⟨layout⟩: _layout.linear` `dictionary` | `function`

Either a dictionary with (`state`: `coordinate`) pairs, or a layout function. See below for more information on layouts.

```
#finite.automaton(
  (q0: (q1:none), q1: none),
  layout: (q0: (0,0), q1: (rel:(-2,1)))
)
```



Argument

`..⟨canvas-styles⟩` any

Arguments for `#cetz.canvas`.

```
#transition-table(
  ⟨spec⟩,
  ⟨initial⟩: auto,
  ⟨final⟩: auto,
  ⟨format⟩: (col, row, v) => raw(str(v)),
  ⟨format-list⟩: states => states.join(", "),
  ..⟨table-style⟩
) → content
```

Displays a transition table for an automaton.

`⟨spec⟩` is a `spec` for a finite automaton.

The table will show states in rows and inputs in columns:

```
#finite.transition-table((
  q0: (q1: 0, q0: (1,0)),
  q1: (q0: 1, q2: (1,0)),
  q2: (q0: 1, q2: 0),
))
```

	0	1
q0	q1, q0	q0
q1	q2	q0, q2
q2	q2	q0

> The ⟨inital⟩ and ⟨final⟩ arguments will be removed in future versions in favor of automaton specs.

Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨initial⟩: auto `str, auto, none`

The name of the initial state. For `auto`, the first state in ⟨states⟩ is used.

Argument

⟨final⟩: auto `array, auto, none`

A list of final state names. For `auto`, the last state in ⟨states⟩ is used.

Argument

⟨format⟩: (col, row, v) => raw(str(v)) `function`

A function to format the value in a table cell. The function takes a column and row index and the cell content as a `str` and generates content: `(int, int, str)→content`.

```
#finite.transition-table((
  q0: (q1: 0, q0: (1,0)),
  q1: (q0: 1, q2: (1,0)),
  q2: (q0: 1, q2: 0),
),
format: (col, row, value) => if col == 0 and row == 0 {
    $delta$
  } else if col == 1 {
    strong(value)
  } else [#value]
)
```

δ	**0**	1
q0	**q1, q0**	q0
q1	**q2**	q0, q2
q2	**q2**	q0

Argument

⟨format-list⟩: states => states.join(", ") function

Formats a list of states for display in a table cell. The function takes an array of state names and generates a string to be passed to #transition-table.format: (array)→ str

```
#finite.transition-table((
  q0: (q1: 0, q0: (1,0)),
  q1: (q0: 1, q2: (1,0)),
  q2: (q0: 1, q2: 0),
), format-list: (states) => "[" + states.join(" | ") + "]")
```

	0	1
q0	[q1 | q0]	[q0]
q1	[q2]	[q0 | q2]
q2	[q2]	[q0]

Argument

..⟨table-style⟩ any

Arguments for #table.

#powerset(⟨spec⟩, ⟨initial⟩: auto, ⟨final⟩: auto, ⟨state-format⟩: states => "{" + states.sorted().join(",") + "}") → spec

Creates a deterministic finite automaton from a nondeterministic one by using powerset construction.

See the Wikipedia article on powerset construction[5] for further details on the algorithm.

⟨spec⟩ is an automaton spec.

Argument

⟨spec⟩ spec

Automaton specification.

Argument

⟨initial⟩: auto str | auto | none

The name of the initial state. For auto, the first state in ⟨states⟩ is used.

[5] https://en.wikipedia.org/wiki/Powerset_construction

Argument

⟨final⟩: auto `str` | `auto` | `none`

A list of final state names. For `auto`, the last state in ⟨states⟩ is used.

Argument

⟨state-format⟩: states => "{" + states.sorted().join(",") + "}"
`function`

A function to generate the new state names from a list of states. The function takes an array of strings and returns a string: `(array)→str`.

#add-trap((spec), (trap-name): "TRAP")→ spec

Adds a trap state to a partial DFA and completes it.

Deterministic automata need to specify a transition for every possible input. If those inputs don't transition to another state, a trap-state is introduced that is not final and can't be left by any input. To simplify transition diagrams, these trap-states are usually not drawn. This function adds a trap-state to such a partial automaton and thus completes it.

```
#finite.transition-table(finite.add-trap((
  q0: (q1: 0),
  q1: (q0: 1)
)))
```

	0	1
q0	q1	TRAP
q1	TRAP	q0
TRAP	TRAP	TRAP

Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨trap-name⟩: "TRAP" `str`

Name for the new trap-state.

```
#accepts(⟨spec⟩, ⟨word⟩, ⟨format⟩: (spec, states) => states
    .map(((s, i)) => if i != none [
      #s #box[#sym.arrow.r#place(top + center, dy: -88%)[#text(.88em,
raw(i))]]
    ] else [#s])
    .join()) → content
```

Tests if ⟨word⟩ is accepted by a given automaton.

The result if either `false` or an array of tuples with a state name and the input used to transition to the next state. The array is a possible path to an accepting final state. The last tuple always has `none` as an input.

```
#let aut = (
  q0: (q1: 0),
  q1: (q0: 1)
)
#finite.accepts(aut, "01010")

#finite.accepts(aut, "0101")
```

---

q0 →(0) q1 →(1) q0 →(0) q1 →(1) q0 →(0) q1

```
false
```

Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨word⟩ `str`

A word to test.

Argument

⟨format⟩: (spec, states) => states
    .map(((s, i)) => if i != none [
      #s #box[#sym.arrow.r#place(top + center, dy: -88%)[#text(.88em,
raw(i))]]
    ] else [#s])
    .join() `function`

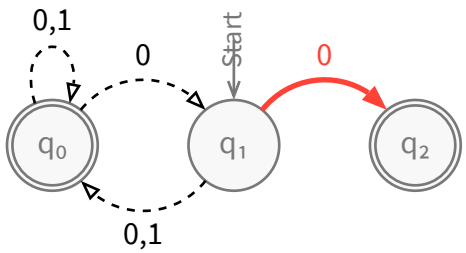
A function to format the result.

II.3 Styling the output

As common in CeTZ, you can pass general styles for states and transitions to the `#cetz.set-style` function within a call to `#cetz.canvas`. The elements functions `#state` and `#transition` (see below) can take their respective styling options as arguments to style individual elements.

`#automaton` takes a `⟨style⟩` argument that passes the given style to the above functions. The example below sets a background and stroke color for all states and draws transitions with a dashed style. Additionally, the state `q1` has the arrow indicating an initial state drawn from above instead from the left. The transition from `q1` to `q2` is highlighted in red.

```
#automaton(
  (
    q0: (q1:0, q0:"0,1"),
    q1: (q0:(0,1), q2:"0"),
    q2: (),
  ),
  initial: "q1",
  final: ("q0", "q2"),
  style:(
    state: (fill: luma(248), stroke:luma(120)),
    transition: (stroke: (dash:"dashed")),
    q1: (initial:top),
    q1-q2: (stroke: 2pt + red)
  )
)
```



Every state can be accessed by its name and every transition is named with its initial and end state joined with a dash (`-`), for example `q1-q2`.

The supported styling options (and their defaults) are as follows:

- states:
  `(fill)`: `auto` Background fill for states.
  `(stroke)`: `auto` Stroke for state borders.
  `(radius)`: `0.6` Radius of the states circle.

(extrude): 0.88

- label:
  (text): auto State label.
  (size): 1em Initial text size for the labels (will be modified to fit the label into the states circle).
  (fill): none Color of the label text.
  (padding): auto Padding around the label.
- initial:
  (anchor): auto Anchorpoint to point the initial arrow to.
  (label): auto Text above the arrow.
  (stroke): auto Stroke for the arrow.
  (scale): auto Scale of the arrow.

- transitions
  (curve): 1.0 "Curviness" of transitions. Set to `0` to get straight lines.
  (stroke): auto Stroke for transition lines.

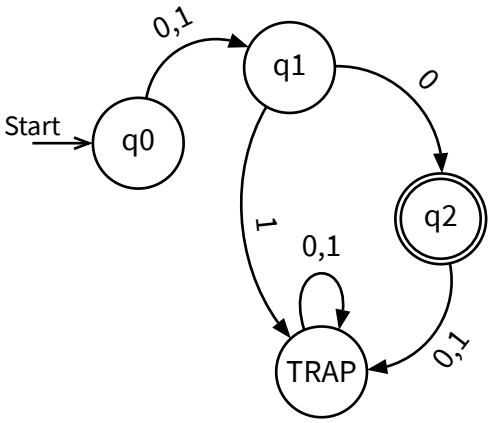
- label:
  (text): "" Transition label.
  (size): 1em Size for label text.
  (fill): auto Color for label text.
  (pos): 0.5 Position on the transition, between `0` and `1`. `0` sets the text at the start, `1` at the end of the transition.
  (dist): 0.33 Distance of the label from the transition.
  (angle): auto Angle of the label text. `auto` will set the angle based on the transitions direction.

II.4 Using `#cetz.canvas`

The above commands use custom CeTZ elements to draw states and transitions. For complex automata, the functions in the `draw` module can be used inside a call to `#cetz.canvas`.

```
#cetz.canvas({
  import cetz.draw: set-style
  import finite.draw: state, transition

  state((0,0), "q0", initial:true)
  state((2,1), "q1")
  state((4,-1), "q2", final:true)
      state((rel:(0,   -3),   to:"q1.south"),   "trap",   label:"TRAP",
anchor:"north-west")

  transition("q0", "q1", inputs:(0,1))
```

```
  transition("q1", "q2", inputs:(0))
  transition("q1", "trap", inputs:(1), curve:-1)
  transition("q2", "trap", inputs:(0,1))
  transition("trap", "trap", inputs:(0,1))
})
```

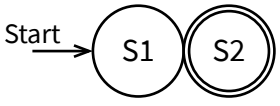


II.4.1 Element functions

```
#state(
  ⟨position⟩,
  ⟨name⟩,
  ⟨label⟩: auto,
  ⟨initial⟩: false,
  ⟨final⟩: false,
  ⟨anchor⟩: none,
  ..⟨style⟩
) → array
```

Draw a state at the given ⟨position⟩.

```
#cetz.canvas({
  import finite.draw: state
  state((0,0), "q1", label:"S1", initial:true)
  state("q1.east", "q2", label:"S2", final:true, anchor:"west")
})
```



Argument

⟨position⟩ coordinate

Position of the states center.

Argument
⟨name⟩ str

Name for the state.

Argument
⟨label⟩: auto str | content | auto | none

Label for the state. If set to auto, the ⟨name⟩ is used.

Argument
⟨initial⟩: false bool | alignment | dictionary

Whether this is an initial state. This can be either
- true,
- an alignment to specify an anchor for the inital marking,
- a str to specify text for the initial marking,
- an dictionary with the keys anchor and label to specifiy both an anchor and a text label for the marking. Additionally, the keys stroke and scale can be used to style the marking.

Argument
⟨final⟩: false bool

Whether this is a final state.

Argument
⟨anchor⟩: none str

Anchor to use for drawing.

Argument
..⟨style⟩ any

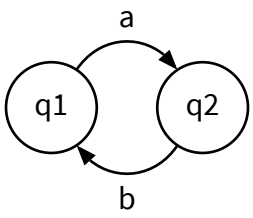
Styling options.

```
#transition(
  (from),
  (to),
  (inputs): none,
  (label): auto,
  (anchor): top,
  ..(style)
) → array
```

Draw a transition between two states.

The two states ⟨from⟩ and ⟨to⟩ have to be existing names of states.

```
#cetz.canvas({
  import finite.draw: state, transition
  state((0,0), "q1")
  state((2,0), "q2")
  transition("q1", "q2", label:"a")
  transition("q2", "q1", label:"b")
})
```



Argument

⟨from⟩ `str`

Name of the starting state.

Argument

⟨to⟩ `str`

Name of the ending state.

Argument

⟨inputs⟩: none `str` | `array` | `none`

A list of input symbols for the transition. If provided as a `str`, it is split at commas to get the list of input symbols.

Argument

⟨label⟩: auto `str` | `content` | `auto` | `dictionary`

A label for the transition. For `auto` the ⟨input⟩ symbols are joined with commas (`,`). Can be a `dictionary` with a `text` key and additional styling keys.

Argument

⟨anchor⟩: top `alignment`

Anchor for loops. Has no effect on normal transitions.

Argument

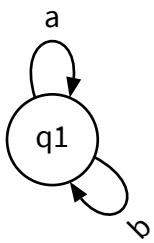
..⟨style⟩ any

Styling options.

```
#loop(
  ⟨state⟩,
  ⟨inputs⟩: none,
  ⟨label⟩: auto,
  ⟨anchor⟩: top,
  ..⟨style⟩
)
```

Create a transition loop on a state.

```
#cetz.canvas({
  import finite.draw: state, loop
  state((0,0), "q1")
  loop("q1", label:"a")
  loop("q1", anchor: bottom+right, label:"b")
})
```



This is a shortcut for #transition that takes only one state name instead of two.

Argument

⟨state⟩ str

Name of the state to draw the loop on.

Argument

⟨inputs⟩: none str | array | none

A list of input symbols for the loop. If provided as a str, it is split at commas to get the list of input symbols.

Argument

⟨label⟩: auto str | content | auto | dictionary

A label for the loop. For `auto` the ⟨input⟩ symbols are joined with commas (`,`). Can be a `dictionary` with a `text` key and additional styling keys.

Argument

⟨anchor⟩: top `alignment`

Anchor for the loop.

Argument

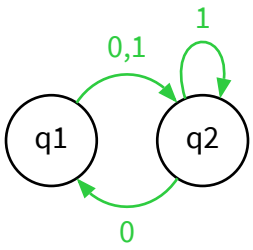
..⟨style⟩ `any`

Styling options.

#transitions(⟨states⟩, ..⟨style⟩) → content

Draws multiple transitions from a transition table with a common style.

```
#cetz.canvas({
  import finite.draw: state, transitions
  state((0,0), "q1")
  state((2,0), "q2")
  transitions(
    (
      q1: (q2: (0, 1)),
      q2: (q1: 0, q2: 1)
    ),
    transition: (stroke: green)
  )
})
```



Argument

⟨states⟩ `transition-table`

A transition table given as a `dictionary` of dictionaries.

Argument

..⟨style⟩ `any`

Styling options.

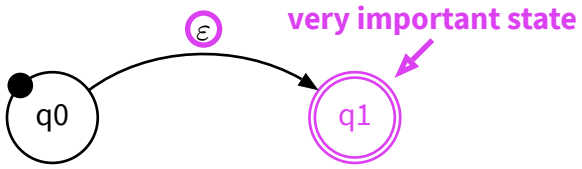
II.4.2 Anchors

States and transitions are created in a `#cetz.draw.group`. States are drawn with a circle named `state` that can be referenced in the group. Additionally they have a content element named `label` and optionally a line named `initial`. These elements can be referenced inside the group and used as anchors for other CeTZ elements. The anchors of `state` are also copied to the state group and are directly accessible.

> That means setting `⟨anchor⟩: "west"` for a state will anchor the state at the `west` anchor of the states circle, not of the bounding box of the group.

Transitions have an `arrow` (`#cetz.draw.line`) and `label` (`#cetz.draw.content`) element. The anchors of `arrow` are copied to the group.

```
#cetz.canvas({
  import cetz.draw: circle, line, content
  import finite.draw: state, transition

  let magenta = rgb("#dc41f1")

  state((0, 0), "q0")
  state((4, 0), "q1", final: true, stroke: magenta)

  transition("q0", "q1", label: $epsilon$)

  circle("q0.north-west", radius: .4em, stroke: none, fill: black)

  let magenta-stroke = 2pt + magenta
  circle("q0-q1.label", radius: .5em, stroke: magenta-stroke)
  line(
    name: "q0-arrow",
    (rel: (.6, .6), to: "q1.state.north-east"),
    (rel: (.1, .1), to: "q1.state.north-east"),
    stroke: magenta-stroke,
    mark: (end: ">"),
  )
  content(
    (rel: (0, .25), to: "q0-arrow.start"),
    text(fill: magenta, [*very important state*]),
  )
})
```



II.5 Layouts

> Layouts changed in FINITE version 0.5 and are no longer compatible with FINITE 0.4 and before.

Layouts can be passed to #automaton to position states on the canvas without the need to give specific coordinates for each state. FINITE ships with a bunch of layouts, to accomodate different scenarios.

II.5.1 Available layouts

#create-layout(⟨positions⟩: (:), ⟨anchors⟩: (:)) → array

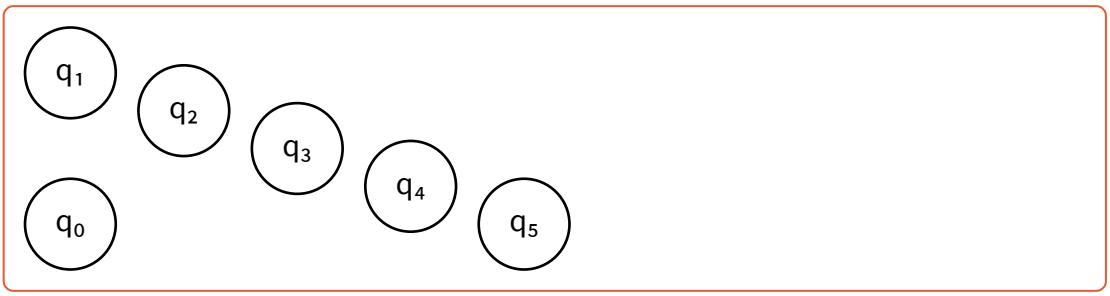
Helper function to create a layout dictionary by providing ⟨positions⟩ and/or ⟨anchors⟩.

#custom(⟨spec⟩, ⟨positions⟩: (:), ⟨position⟩: (0, 0), ⟨style⟩: (:)) → array

Create a custom layout from a `dictionary` with state `coordinate`s.

The result may specify a `rest` key that is used as a default coordinate. This is useful sense in combination with a relative coordinate like `(rel:(2,0))`.

```
#let aut = range(6).fold((:), (d, s) => {d.insert("q"+str(s), none);
d})
#finite.automaton(
  aut,
  initial: none, final: none,
  layout:finite.layout.custom.with(positions: (
    q0: (0,0), q1: (0,2), rest:(rel: (1.5,-.5))
  ))
)
```



Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨positions⟩: (:) `dictionary`

A dictionary with `coordinate`s for each state.

The dictionary contains each states name as a key and the new coordinate as a value.

Argument

⟨position⟩: (0, 0) `coordinate`

Position of the anchor point.

Argument

⟨style⟩: (:) `dictionary`

Styling options.

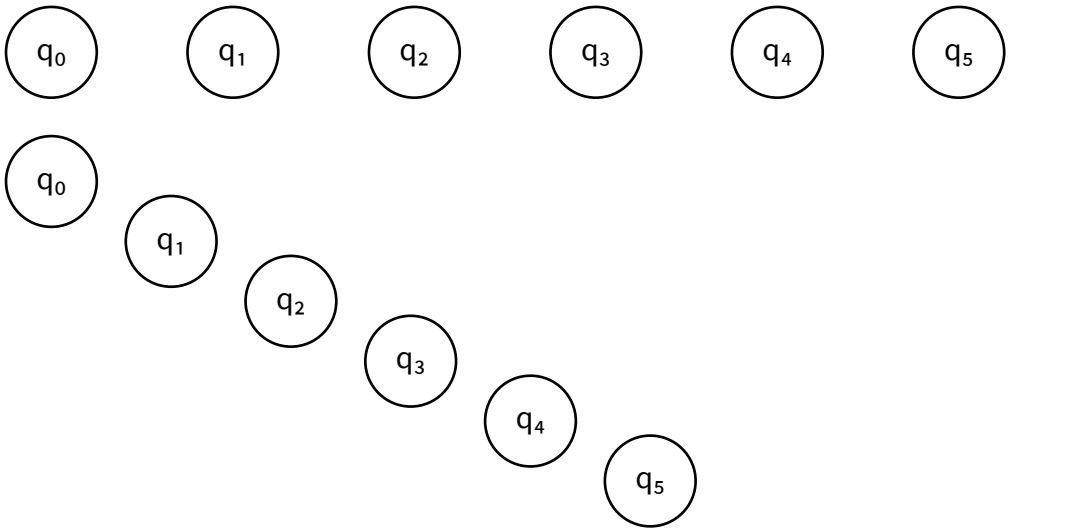
```
#linear(
  ⟨spec⟩,
  ⟨dir⟩: right,
  ⟨spacing⟩: default-style.state.radius * 2,
  ⟨position⟩: (0, 0),
  ⟨style⟩: (:)
) → array
```

Arrange states in a line.

The direction of the line can be set via ⟨dir⟩ either to an `alignment` or a direction vector with a x and y shift. Note that the length of the vector is set to ⟨spacing⟩ and only the direction is used.

```
#let aut = range(6).fold((:), (d, s) => {d.insert("q"+str(s), none); d})
```

```
#finite.automaton(
  aut,
  initial: none, final: none,
  layout:finite.layout.linear.with(dir: right)
)
#finite.automaton(
  aut,
  initial: none, final: none,
  layout:finite.layout.linear.with(spacing: .5, dir:(2,-1))
)
```



Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨dir⟩: right `vector` | `alignment` | `2d alignment`

Direction of the line.

Argument

⟨spacing⟩: default-style.state.radius * 2 `float`

Spacing between states on the line.

Argument

⟨position⟩: (0, 0) `coordinate`

Position of the anchor point.

Argument

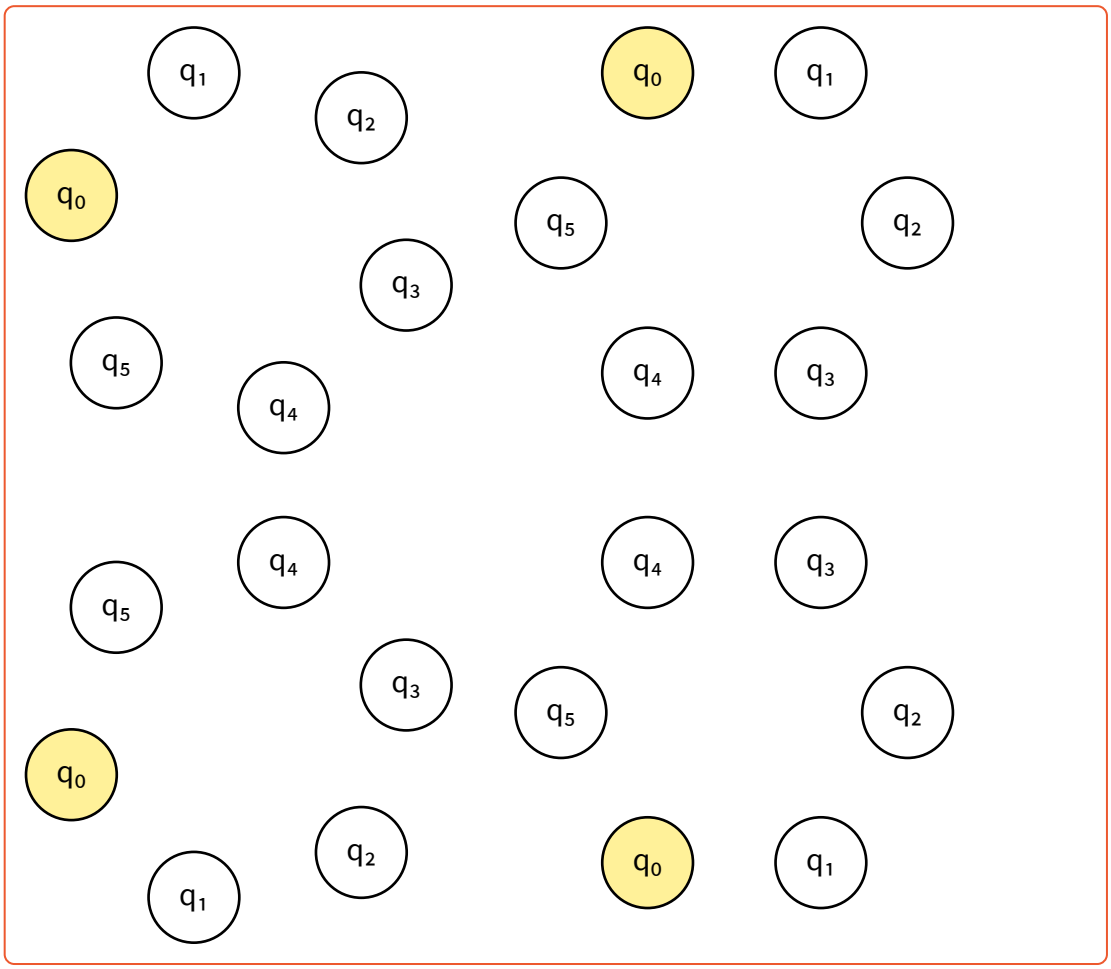
⟨style⟩: (:) `dictionary`

Styling options.

```
#circular(
  ⟨spec⟩,
  ⟨dir⟩: right,
  ⟨spacing⟩: default-style.state.radius * 2,
  ⟨radius⟩: auto,
  ⟨offset⟩: 0deg,
  ⟨position⟩: (0, 0),
  ⟨style⟩: (:)
)
```

Arrange states in a circle.

```
#let aut = range(6).fold((:), (d, s) => {d.insert("q"+str(s), none);
d})
#grid(columns: 2, gutter: 2em,
  finite.automaton(
    aut,
    initial: none, final: none,
    layout:finite.layout.circular,
    style: (q0: (fill: yellow.lighten(60%)))
  ),
  finite.automaton(
    aut,
    initial: none, final: none,
    layout:finite.layout.circular.with(offset:45deg),
    style: (q0: (fill: yellow.lighten(60%)))
  ),
  finite.automaton(
    aut,
    initial: none, final: none,
    layout:finite.layout.circular.with(dir:left),
    style: (q0: (fill: yellow.lighten(60%)))
  ),
  finite.automaton(
    aut,
    initial: none, final: none,
    layout:finite.layout.circular.with(dir:left, offset:45deg),
    style: (q0: (fill: yellow.lighten(60%)))
  )
)
```



Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨dir⟩: `right` `alignment`

Direction of the circle. Either `left` or `right`.

Argument

⟨spacing⟩: `default-style.state.radius * 2` `float`

Spacing between states on the line.

Argument

⟨radius⟩: `auto` `float` | `auto`

Either a fixed radius or `auto` to calculate a suitable radius.

Argument

`(offset): 0deg` `angle`

An offset angle to place the first state at.

Argument

`(position): (0, 0)` `coordinate`

Position of the anchor point.

Argument

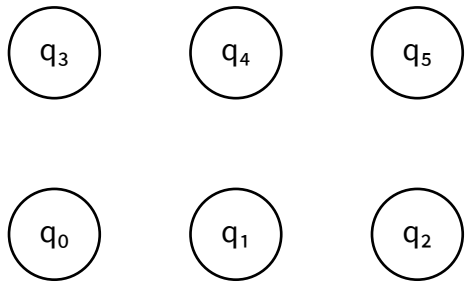
`(style): (:)` `dictionary`

Styling options.

```
#grid(
  (spec),
  (columns): 4,
  (spacing): default-style.state.radius * 2,
  (position): (0, 0),
  (style): (:)
) → array
```

Arrange states in rows and columns.

```
#let aut = range(6).fold((:), (d, s) => {d.insert("q"+str(s), none);
d})
#finite.automaton(
  aut,
  initial: none, final: none,
  layout:finite.layout.grid.with(columns:3)
)
```



Argument

`(spec)` `spec`

Automaton specification.

Argument

⟨columns⟩: 4 `int`

Number of columns per row.

Argument

⟨spacing⟩: default-style.state.radius * 2 `float`

Spacing between states on the grid.

Argument

⟨position⟩: (0, 0) `coordinate`

Position of the anchor point.

Argument

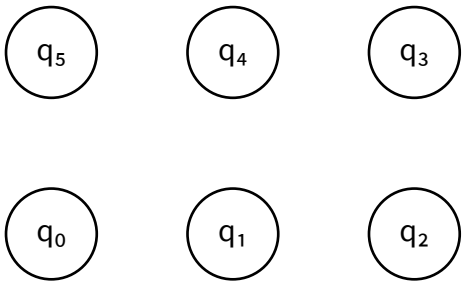
⟨style⟩: (:) `dictionary`

Styling options.

```
#snake(
  ⟨spec⟩,
  ⟨columns⟩: 4,
  ⟨spacing⟩: default-style.state.radius * 2,
  ⟨position⟩: (0, 0),
  ⟨style⟩: (:)
) → array
```

Arrange states in a grid, but alternate the direction in every even and odd row.

```
#let aut = range(6).fold((:), (d, s) => {d.insert("q"+str(s), none);
d})
#finite.automaton(
  aut,
  initial: none, final: none,
  layout:finite.layout.snake.with(columns:3)
)
```



Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨columns⟩: 4 `int`

Number of columns per row.

Argument

⟨spacing⟩: default-style.state.radius * 2 `float`

Spacing between states on the line.

Argument

⟨position⟩: (0, 0) `coordinate`

Position of the anchor point.

Argument

⟨style⟩: (:) `dictionary`

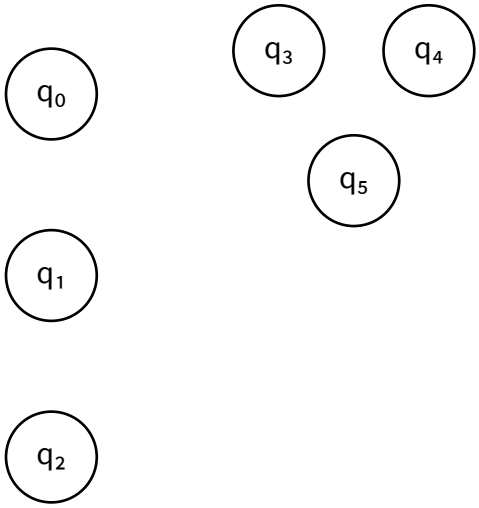
Styling options.

```
#group(
  ⟨spec⟩,
  ⟨grouping⟩: auto,
  ⟨spacing⟩: default-style.state.radius * 2,
  ⟨layout⟩: linear.with(dir: bottom),
  ⟨position⟩: (0, 0),
  ⟨style⟩: (:)
) → array
```

Creates a group layout that collects states into groups that are positioned by specific sub-layouts.

```
#let aut = range(6).fold((:), (d, s) => {d.insert("q"+str(s), none);
d})
#finite.automaton(
  aut,
  initial: none, final: none,
  layout: finite.layout.group.with(
    grouping: 3,
    spacing: 4,
    layout: (
      finite.layout.linear.with(dir: bottom),
```

```
      finite.layout.circular,
    )
  )
)
```



See Section VI for a more comprehensive example.

Argument

⟨spec⟩ `spec`

Automaton specification.

Argument

⟨grouping⟩: auto `int` | `array`

Either an integer to collect states into roughly equal sized groups or an array of arrays that specify which states (by name) are in each group.

Argument

⟨spacing⟩: default-style.state.radius * 2 `float`

Spacing between states on the line.

Argument

⟨layout⟩: linear.with(dir: bottom) `array`

An array of layouts to use for each group. The first group of states will be passed to the first layout and so on.

Argument

⟨position⟩: (0, 0) `coordinate`

Position of the anchor point.

Argument

⟨style⟩: (:) `dictionary`

Styling options.

II.6 Utility functions

#align-to-anchor	#get-inputs	#transition-pts
#align-to-vec	#is-dea	#transpose-table
#call-or-get	#label-pt	#vector-normal
#cubic-normal	#loop-pts	#vector-rotate
#cubic-pts	#mark-dir	#vector-set-len
#fit-content	#mid-point	

#align-to-anchor(⟨align⟩)

Return anchor name for an `alignment`.

#align-to-vec(⟨a⟩)

Returns a vector for an alignment.

#call-or-get(⟨value⟩, ..⟨args⟩)

Calls ⟨value⟩ with ..⟨args⟩, if it is a `function` and returns the result or ⟨value⟩ otherwise.

```
#cubic-normal(
  ⟨a⟩,
  ⟨b⟩,
  ⟨c⟩,
  ⟨d⟩,
  ⟨t⟩
)
```

Compute a normal vector for a point on a cubic bezier curve.

#cubic-pts(⟨a⟩, ⟨b⟩, ⟨curve⟩: 1)

Calculate the control point for a transition.

```
#fit-content(
  (ctx),
  (width),
  (height),
  (content),
  (size): auto,
  (min-size): 6pt
)
```

Fits (text) content inside the available space.

- ctx (dictionary): The canvas context.
- content (string, content): The content to fit.
- size (length,auto): The initial text size.
- min-size (length): The minimal text size to set.

#get-inputs((table), (transpose): true)

Gets a list of all inputs from a transition table.

Argument

(table) `transition-table`

A transition table.

Argument

(transpose): true `bool`

If (table) needs to be transposed first. Set this to `false` if the table already is in the format (`input`: `states`).

#is-dea((table)) → bool

Checks if a given `spec` represents a deterministic automaton.

```
#util.is-dea((
  q0: (q1: 1, q2: 1),
))
#util.is-dea((
  q0: (q1: 1, q2: 0),
))
```

```
false  true
```

Argument

(table) `transition-table`

A transition table.

```
#label-pt(
  ⟨a⟩,
  ⟨b⟩,
  ⟨c⟩,
  ⟨d⟩,
  ⟨style⟩,
  ⟨loop⟩: false
)
```

Calculate the location for a transitions label, based on its bezier points.

```
#loop-pts(⟨start⟩, ⟨start-radius⟩, ⟨anchor⟩: top, ⟨curve⟩: 1)
```

Calculate start, end and ctrl points for a transition loop.

- start (vector): Center of the state.
- start-radius (length): Radius of the state.
- curve (float): Curvature of the transition.
- anchor (alignment): Anchorpoint on the state

```
#mark-dir(
  ⟨a⟩,
  ⟨b⟩,
  ⟨c⟩,
  ⟨d⟩,
  ⟨scale⟩: 1
)
```

Calculate the direction vector for a transition mark (arrowhead)

```
#mid-point(⟨a⟩, ⟨b⟩, ⟨c⟩, ⟨d⟩)
```

Compute the mid point of a quadratic bezier curve.

```
#transition-pts(
  ⟨start⟩,
  ⟨end⟩,
  ⟨start-radius⟩,
  ⟨end-radius⟩,
  ⟨curve⟩: 1,
  ⟨anchor⟩: top
)
```

Calculate start, end and ctrl points for a transition.

- start (vector): Center of the start state.
- end (vector): Center of the end state.
- start-radius (length): Radius of the start state.
- end-radius (length): Radius of the end state.
- curve (float): Curvature of the transition.

#transpose-table(⟨table⟩) → **dictionary**

Changes a `transition-table` from the format (`state`: `inputs`) to (`input`: `states`) or vice versa.

Argument

⟨table⟩ `transition-table`

A transition table in any format.

#vector-normal(⟨v⟩)

Compute a normal for a 2d cetz.vector. The normal will be pointing to the right of the original cetz.vector.

#vector-rotate(⟨vec⟩, ⟨angle⟩)

Rotates a vector by ⟨angle⟩ degree around the origin.

#vector-set-len(⟨v⟩, ⟨len⟩)

Set the length of a cetz.vector.

Part III Simulating input

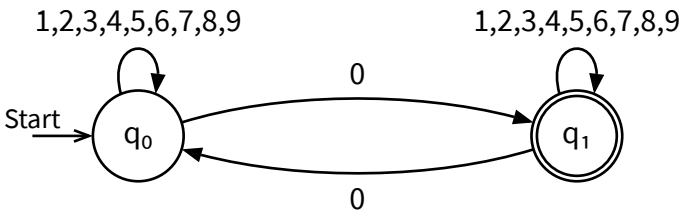
FINITE has a set of functions to simulate, test and view finite automata.

Part IV FLACI support

FINITE was heavily inspired by the online app FLACI[6]. FLACI lets you build automata in a visual online app and export your creations as JSON files. FINITE can import theses files and render the result in your document.

> FINITE currently only supports DEA and NEA automata.

```
#finite.flaci.automaton(read("flaci-export.json"))
```



> **Important**
> Read the FLACI json-file with the `#read` function, not the `#json` function. FLACI exports automatons with a wrong encoding that prevents Typst from properly loading the file as JSON.

IV.0.1 FLACI functions

`#flaci.load(⟨data⟩)` → `spec`

Loads `⟨data⟩` into an automaton `spec`. `⟨data⟩` needs to be a string and not a JSON dictionary.

Argument

`⟨data⟩` `str`

FLACI data read as a string via `#read`.

```
#flaci.automaton(
  ⟨data⟩,
  ⟨layout⟩: auto,
  ⟨merge-layout⟩: true,
  ⟨style⟩: auto,
  ⟨merge-style⟩: true,
  ..⟨args⟩
) → content
```

[6] https://flaci.org

Show a FLACI file as an `#automaton`.

> Read the FLACI json-file with the `#read` function, not the `#json` function. FLACI exports automatons with a wrong encoding that prevents Typst from properly loading the file as JSON.

> Currently only DEA and NEA automata are supported.

Argument

`⟨data⟩` `str`

FLACI data read as a string via `#read`.

Argument

`⟨layout⟩: auto` `function`

Custom layout for the automaton. Will overwrite state positions from `⟨data⟩`.

Argument

`⟨merge-layout⟩: true` `dictionary`

Custom state positions to merge with the ones found in `⟨data⟩`. This allows the placement of some states while the rest keeps their positions.

Argument

`⟨style⟩: auto` `dictionary`

Custom styles to overwrite the defaults.

Argument

`⟨merge-style⟩: true`

Custom styles to merge with the styles from `⟨data⟩`.

Argument

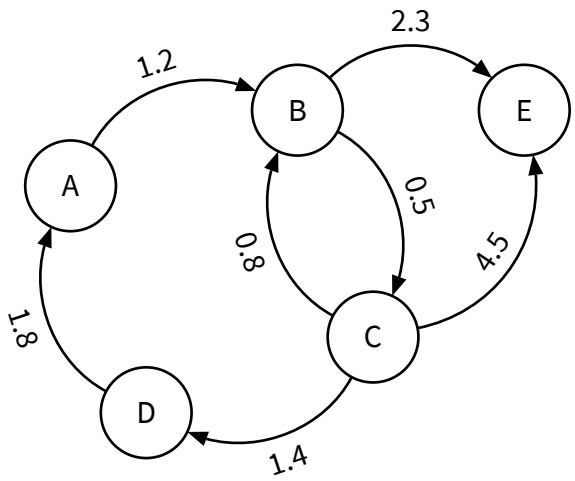
`..⟨args⟩` `any`

Further arguments for `#automaton`.

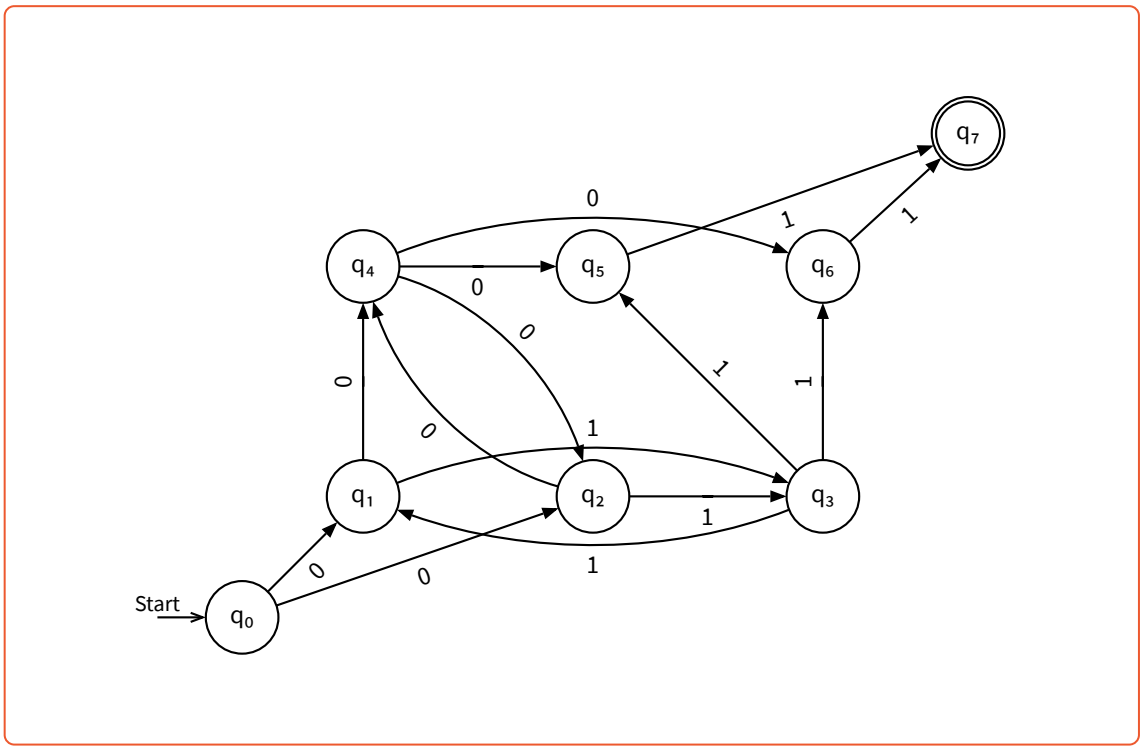
Part V Doing other stuff with FINITE

Since transition diagrams are effectively graphs, FINITE could also be used to draw graph structures:

```
#cetz.canvas({
  import cetz.draw: set-style
  import finite.draw: state, transitions

  state((0,0), "A")
  state((3,1), "B")
  state((4,-2), "C")
  state((1,-3), "D")
  state((6,1), "E")

  transitions((
      A: (B: 1.2),
      B: (C: .5, E: 2.3),
      C: (B: .8, D: 1.4, E: 4.5),
      D: (A: 1.8),
      E: (:)
    ),
    C-E: (curve: -1.2))
})
```



```
#scale(80%, automaton((
    q0: (q1: 0, q2: 0),
    q2: (q3: 1, q4: 0),
    q4: (q2: 0, q5: 0, q6: 0),
    q6: (q7: 1),
    q1: (q3: 1, q4: 0),
    q3: (q1: 1, q5: 1, q6: 1),
    q5: (q7: 1),
    q7: ()
  ),
  layout: finite.layout.group.with(grouping: (
      ("q0",),
      ("q1", "q2", "q3", "q4", "q5", "q6"),
      ("q7",)
    ),
    spacing: 2,
    layout: (
      finite.layout.custom.with(positions: (q0: (0, -2))),
     finite.layout.grid.with(columns:3, spacing:2.6, position: (2, 1)),
      finite.layout.custom.with(positions: (q7: (8, 6)))
    )
  ),
  style: (
    transition: (curve: 0),
    q1-q3: (curve:1),
    q3-q1: (curve:1),
    q2-q4: (curve:1),
    q4-q2: (curve:1),
    q1-q4: (label: (pos:.75)),
    q2-q3: (label: (pos:.75, dist:-.33)),
    q3-q6: (label: (pos:.75)),
    q4-q5: (label: (pos:.75, dist:-.33)),
    q4-q6: (curve: 1)
  )
))
```


q7
q4
q5
q6
q1
q2
q3
q0
Start
0
1

Part VII Index