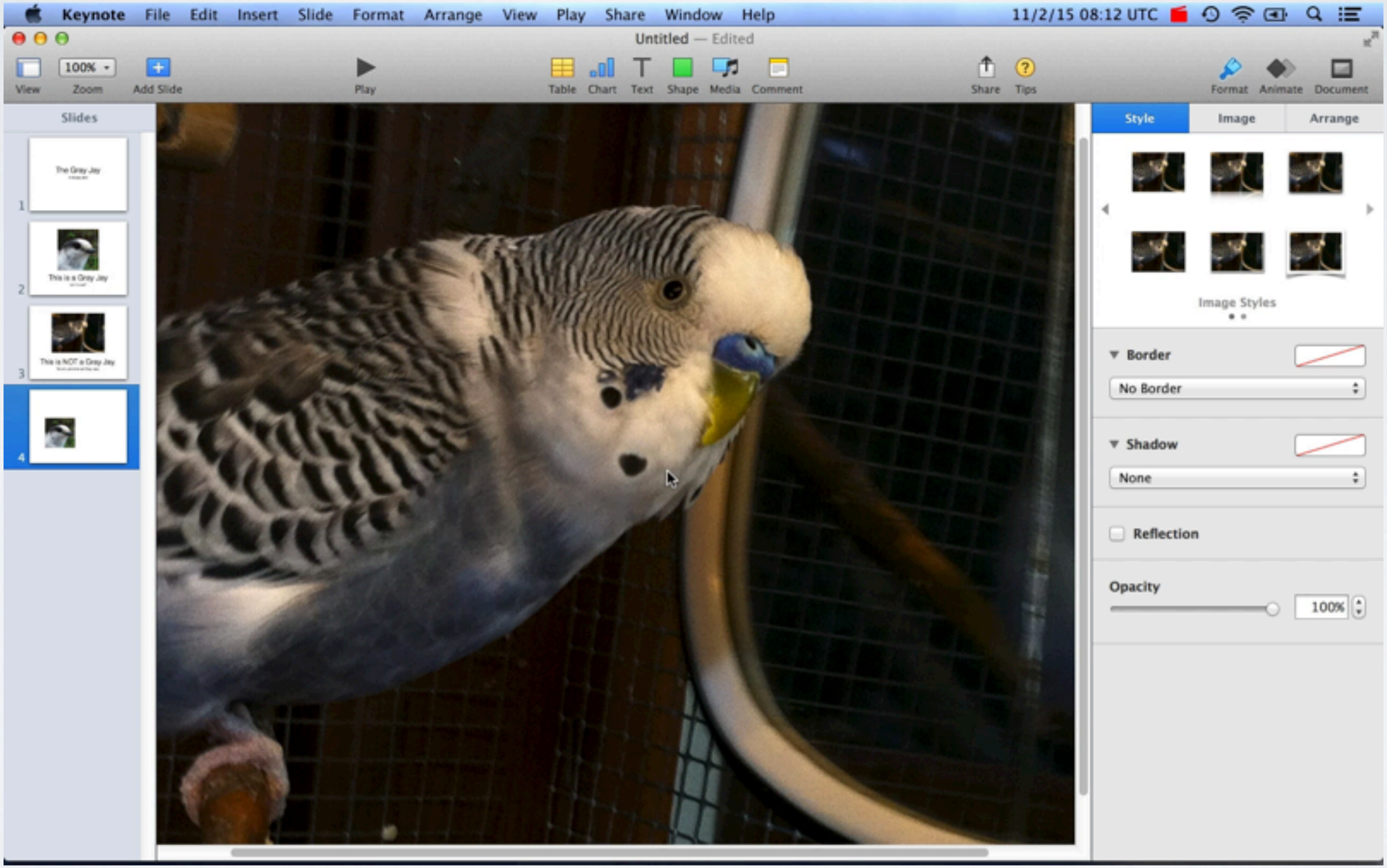
Semi-Automated SVG Programming via Direct Manipulation

Brian Hempel and Ravi Chugh

THE UNIVERSITY OF CHICAGO

Direct Manipulation



Border
No Border

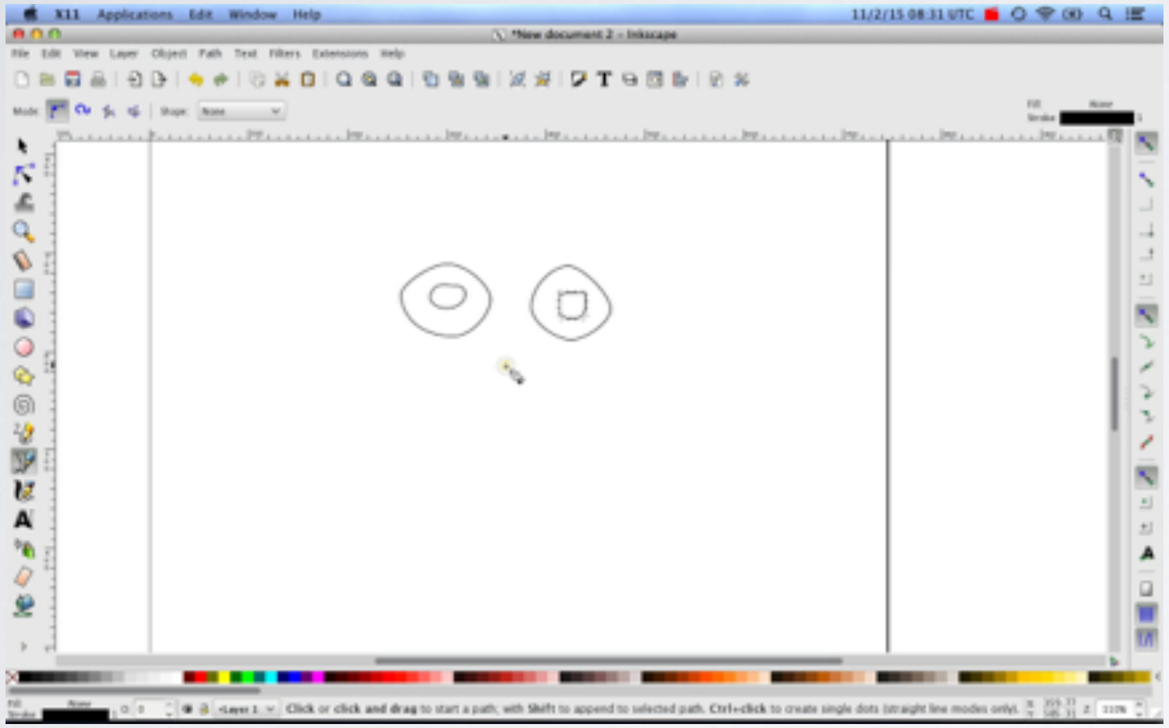
Shadow
None

□ Reflection

Opacity
100%

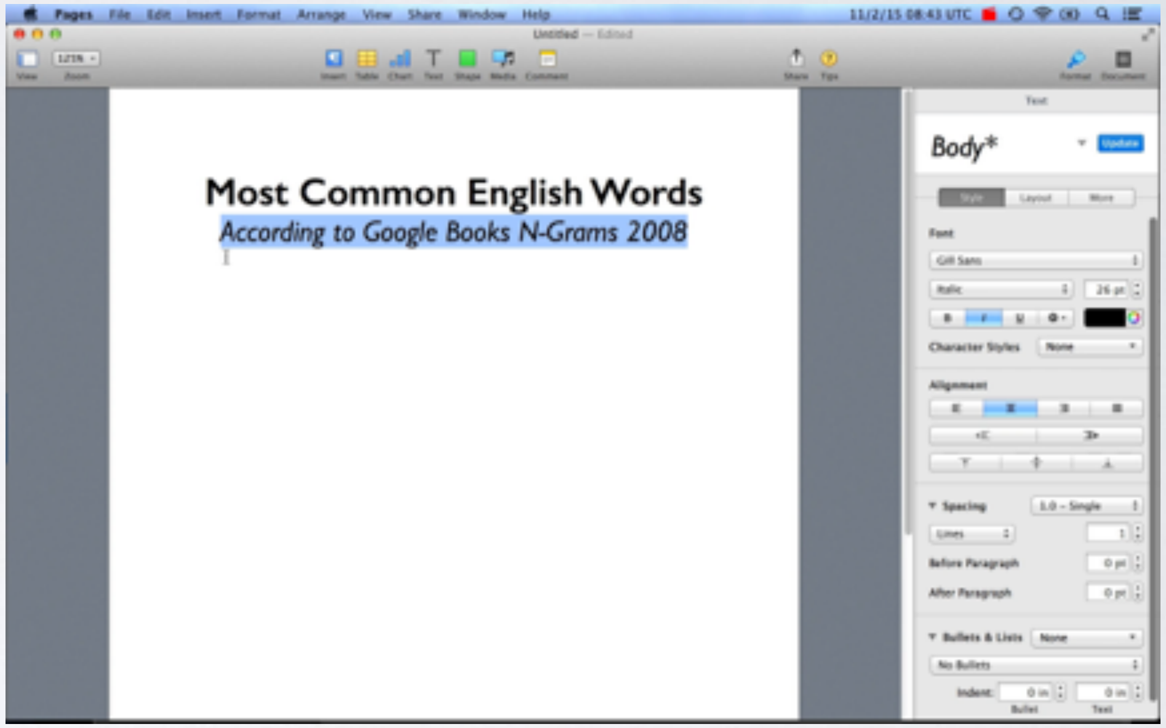
Direct Manipulation

Drawing


X11 Applications Edit Window Help
11/2/15 08:31 UTC
*New document 2 - Inkscape
File Edit View Layer Object Path Text Filters Extensions Help
Mode
Shape: None
Fill
Stroke
None
Layer 1

Click or click and drag to start a path; with Shift to append to selected path. Ctrl+click to create single dots (straight line modes only).

Documents



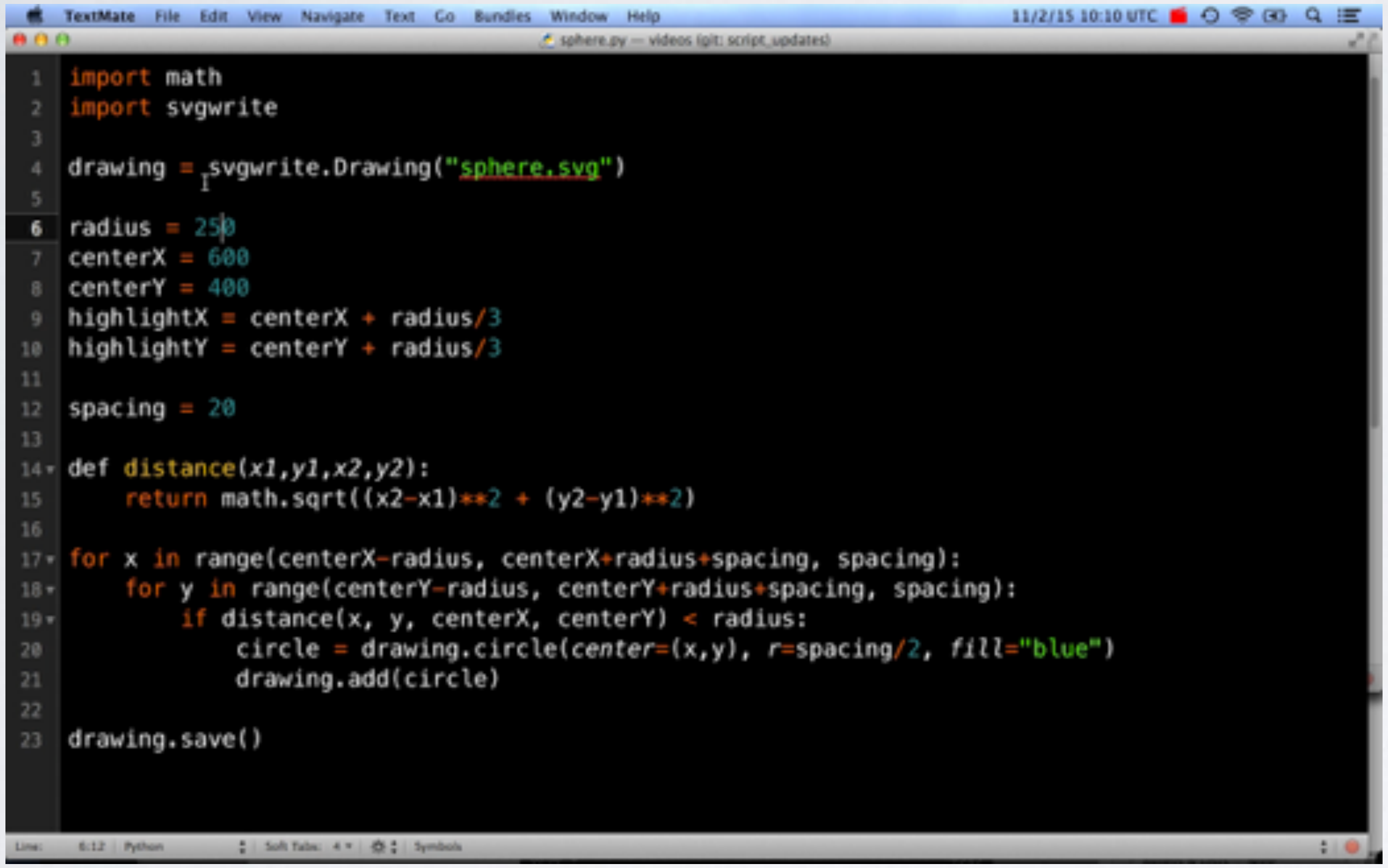
Most Common English Words

According to Google Books N-Grams 2008

And so many more…

But not for one application…

Programming


TextMate File Edit View Navigate Text Go Bundles Window Help
11/2/15 10:10 UTC
sphere.py — videos (git: script_updates)
Line: 6:12 | Python
Soft Tabs: 4
Symbols

```
import math
import svgwrite

drawing = svgwrite.Drawing("sphere.svg")

radius = 250
centerX = 600
centerY = 400
highlightX = centerX + radius/3
highlightY = centerY + radius/3

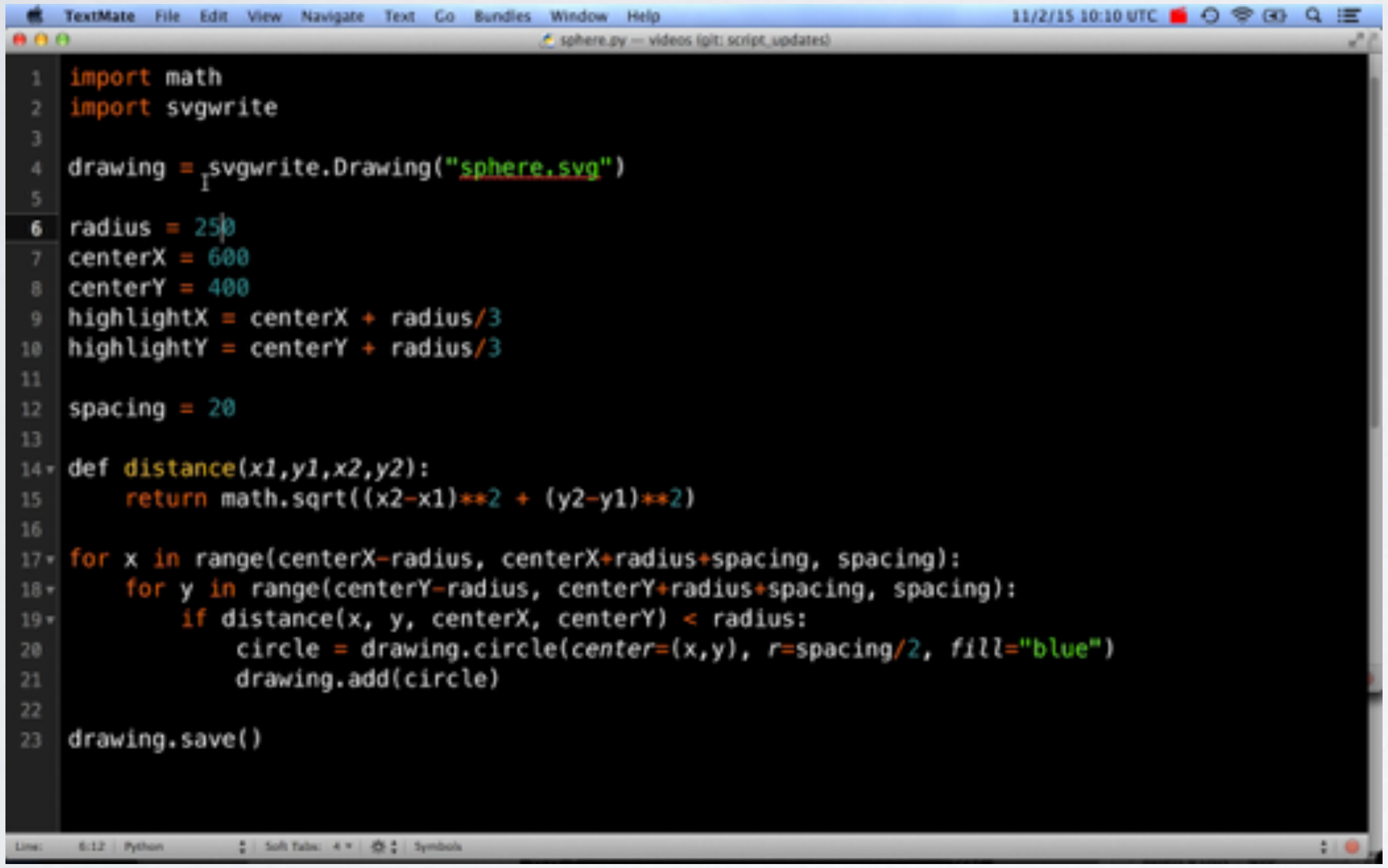
spacing = 20

def distance(x1,y1,x2,y2):
    return math.sqrt((x2-x1)**2 + (y2-y1)**2)

for x in range(centerX-radius, centerX+radius+spacing, spacing):
    for y in range(centerY-radius, centerY+radius+spacing, spacing):
        if distance(x, y, centerX, centerY) < radius:
            circle = drawing.circle(center=(x,y), r=spacing/2, fill="blue")
            drawing.add(circle)

drawing.save()
```

Programming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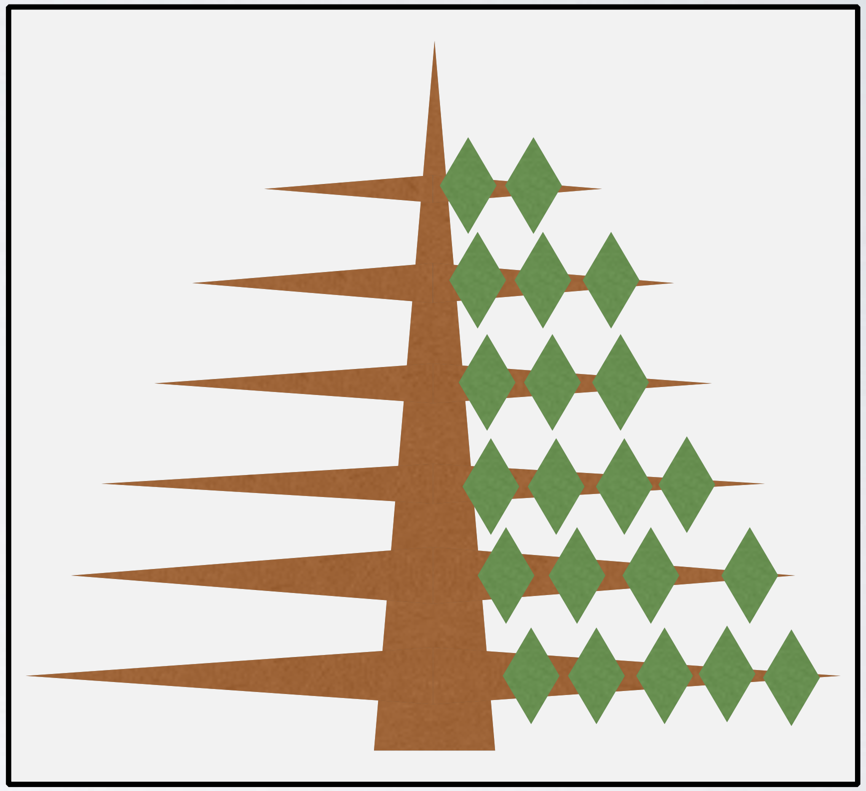
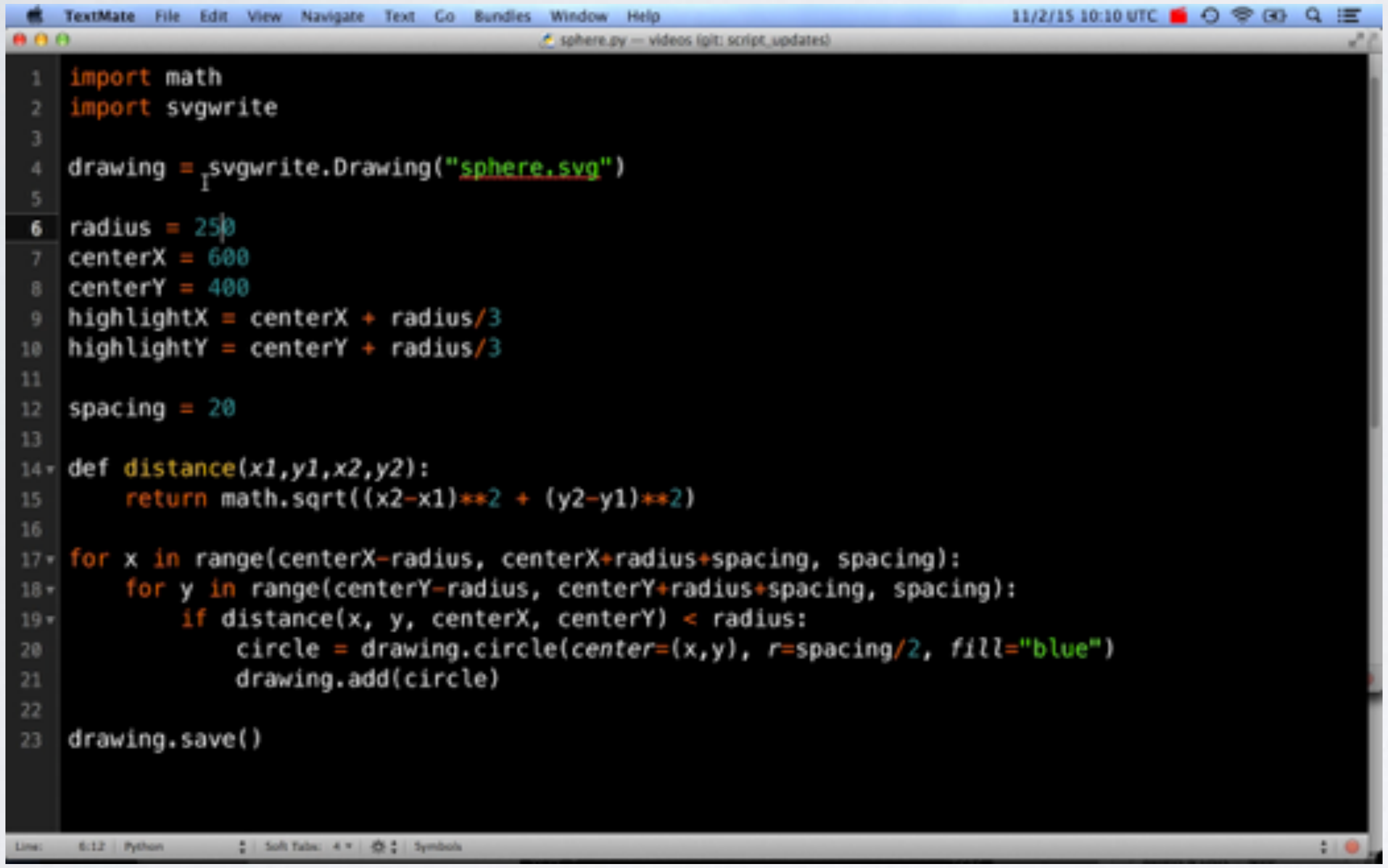


Programming



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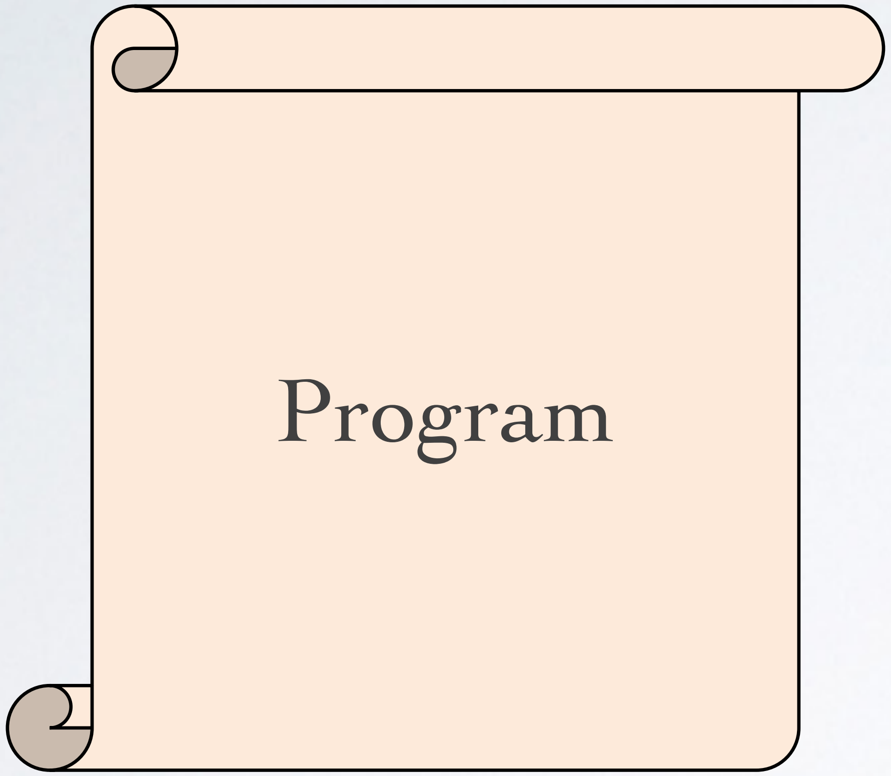
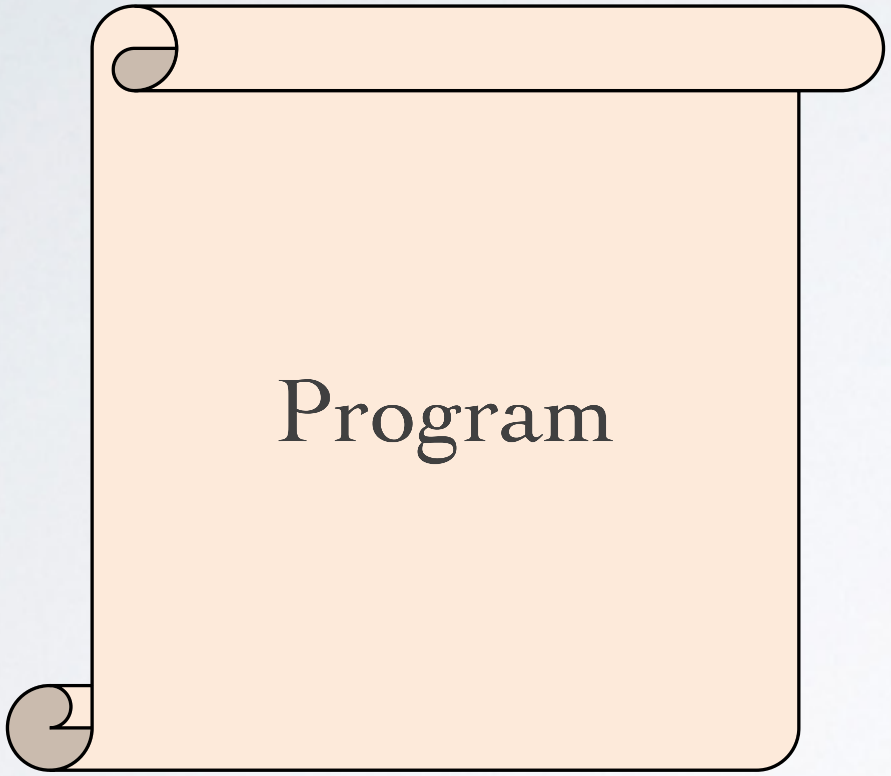
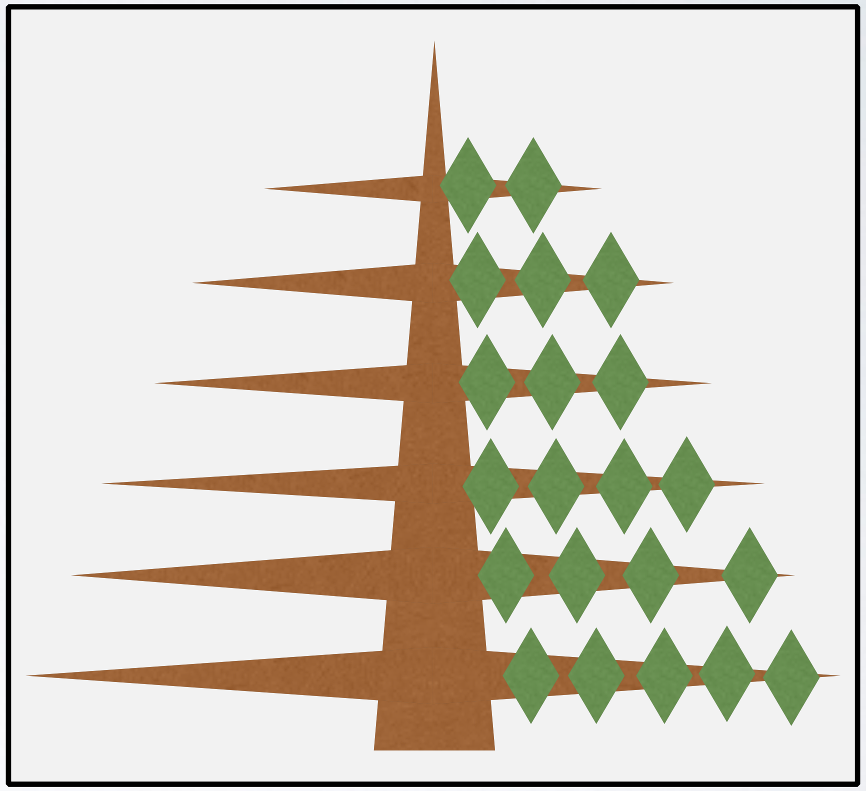
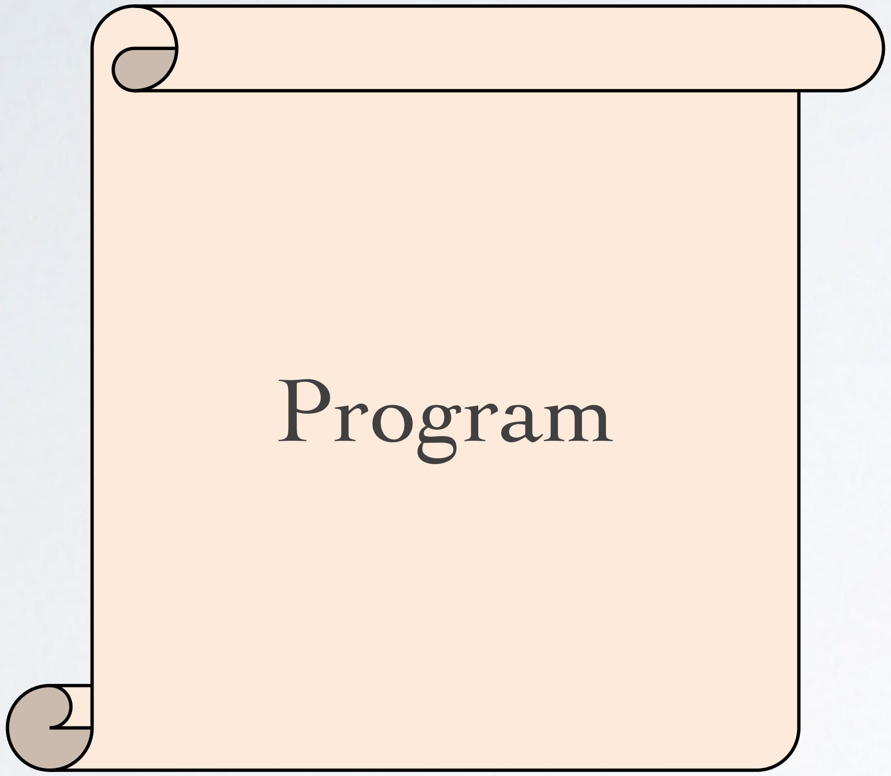


Program

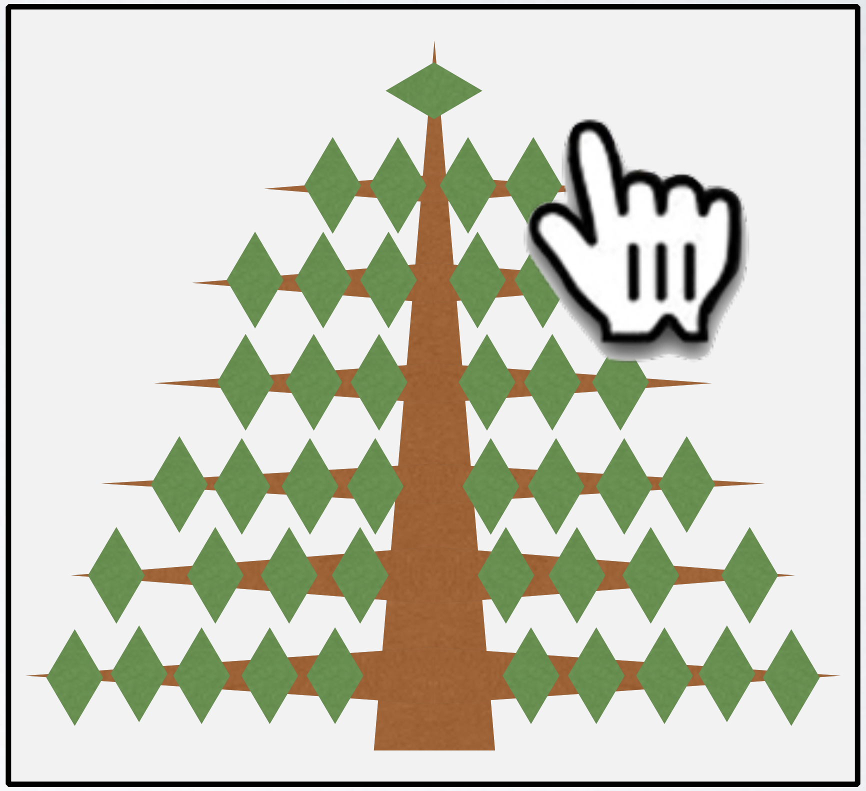


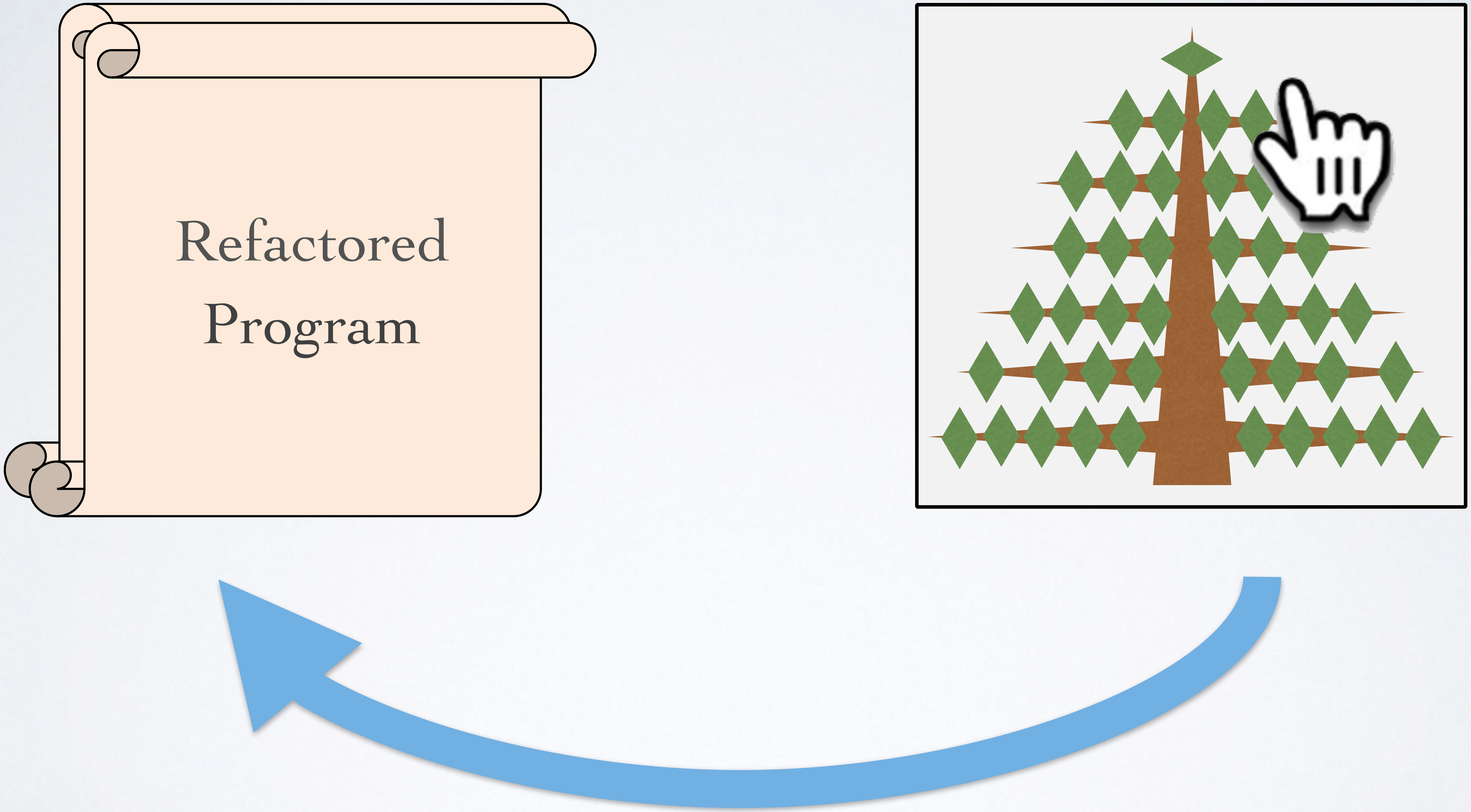
Program





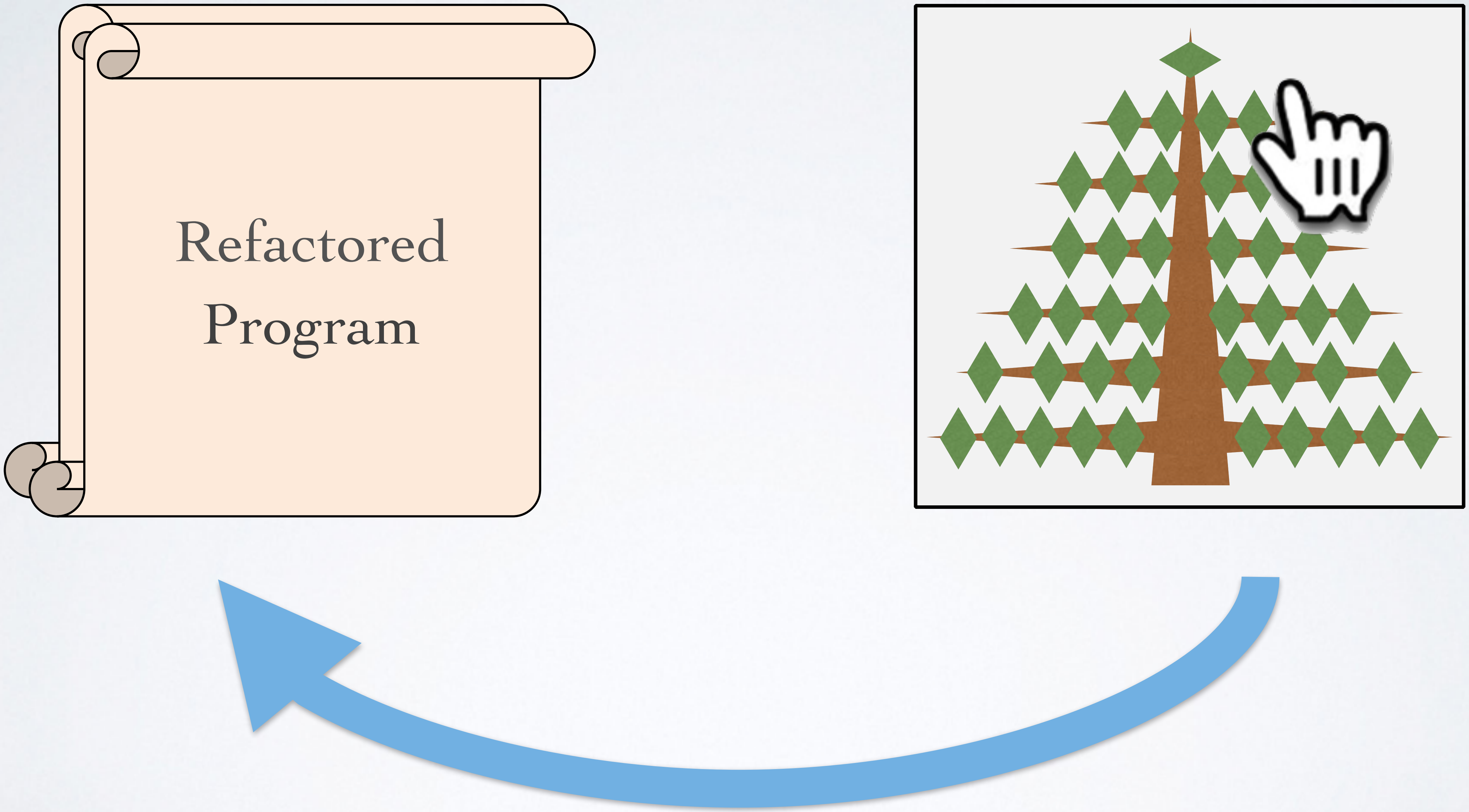
Program





Refactored Program

Better for both experts *and* non-experts



Refactored Program

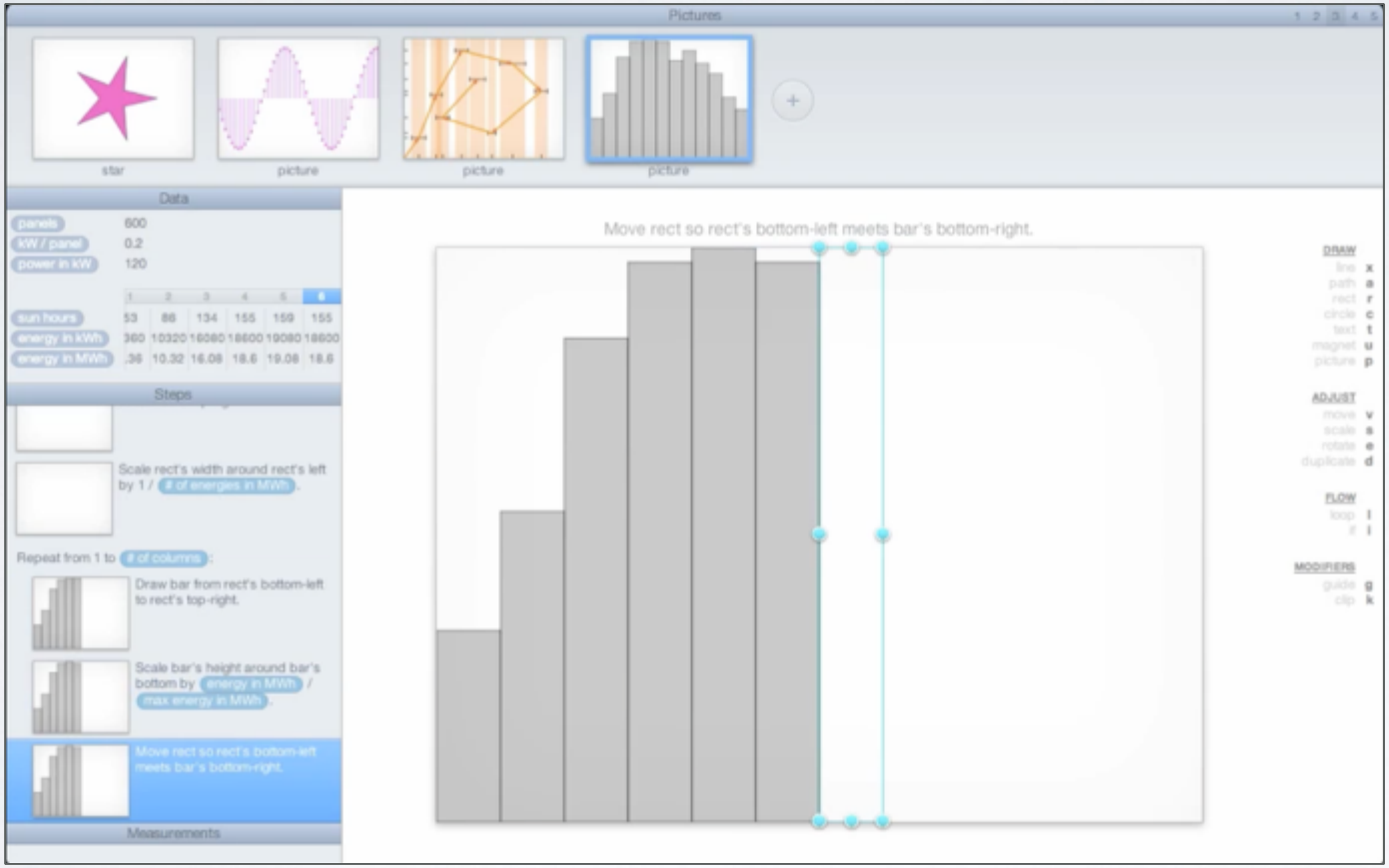
DM

DM + Code

Existing Approach: DM + Code

Existing Approach: DM + Code

Bret Victor, “Drawing Dynamic Visualizations”



panels	600					
kW / panel	0.2					
power in kW	120					
	1	2	3	4	5	6
sun hours	53	86	134	155	159	155
energy in kWh	360	10320	16080	18600	19080	18600
energy in MWh	.36	10.32	16.08	18.6	19.08	18.6

Scale rect's width around rect's left by 1 / # of energies in MWh.

Repeat from 1 to # of columns:

Draw bar from rect's bottom-left to rect's top-right.

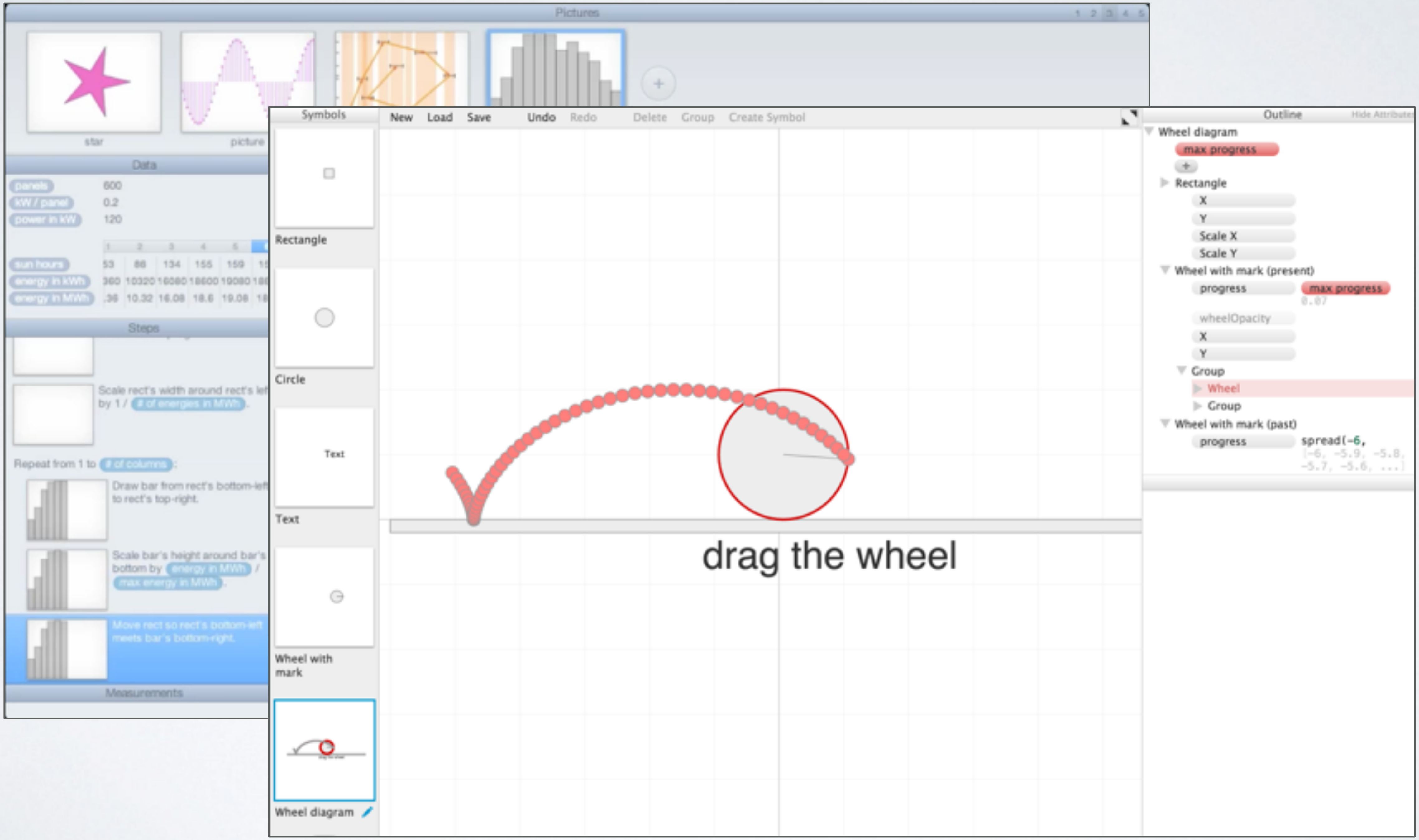
Scale bar's height around bar's bottom by energy in MWh / max energy in MWh.

Move rect so rect's bottom-left meets bar's bottom-right.

Move rect so rect's bottom-left meets bar's bottom-right.

Existing Approach: DM + Code

Bret Victor, “Drawing Dynamic Visualizations”



Scale rect's width around rect's lef by 1 / # of energies in MWh.

Repeat from 1 to # of columns:

Draw bar from rect's bottom-lef to rect's top-right.

Scale bar's height around bar's bottom by energy in MWh / max energy in MWh.

Move rect so rect's bottom-left meets bar's bottom-right.

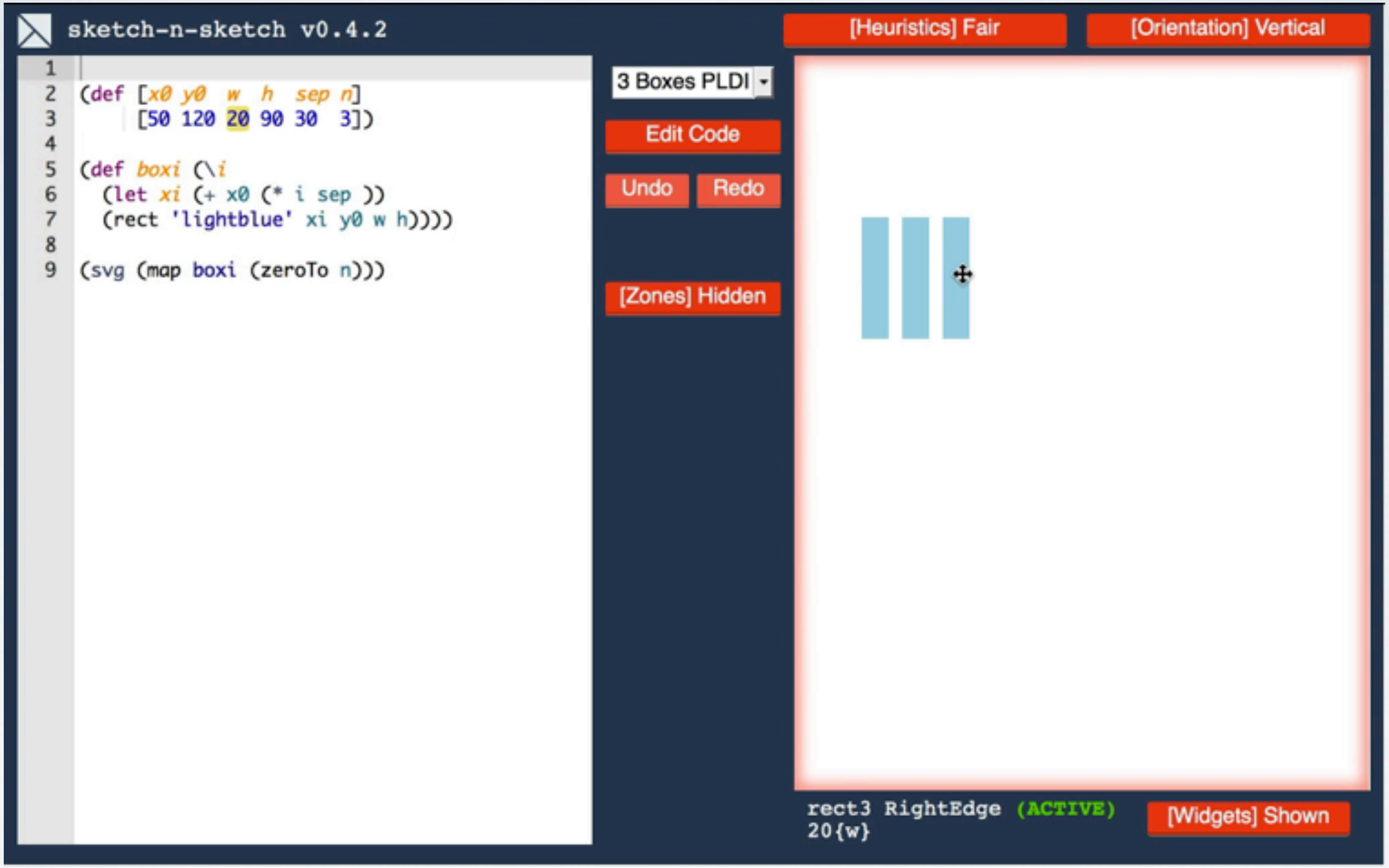
```
spread(-6,
[-6, -5.9, -5.8,
-5.7, -5.6, ...]
```

Toby Schachman, “Apparatus”

DM + Code

Code + DM

Our Approach: Code + DM



```

(def [x0 y0  w  h  sep n]
     [50 120 20 90 30  3])

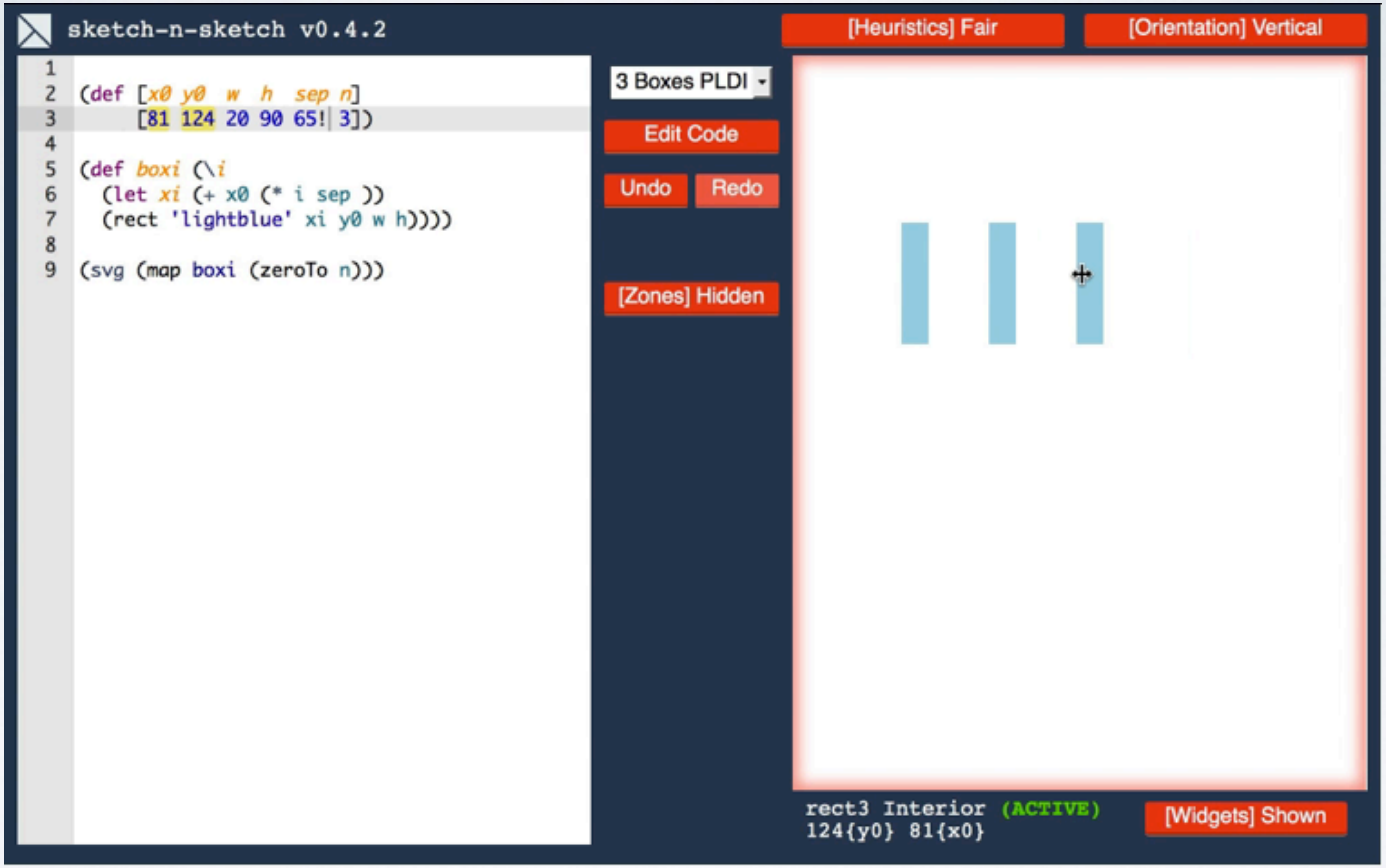
(def boxi (\i
  (let xi (+ x0 (* i sep ))
  (rect 'lightblue' xi y0 w h))))

(svg (map boxi (zeroTo n)))
```

```
rect3 RightEdge (ACTIVE)
20{w}
```

Chugh et al. [PLDI '16]

Our Approach: Code + DM



```

(def [x0 y0  w  h  sep n]
     [81 124 20 90 65! 3])

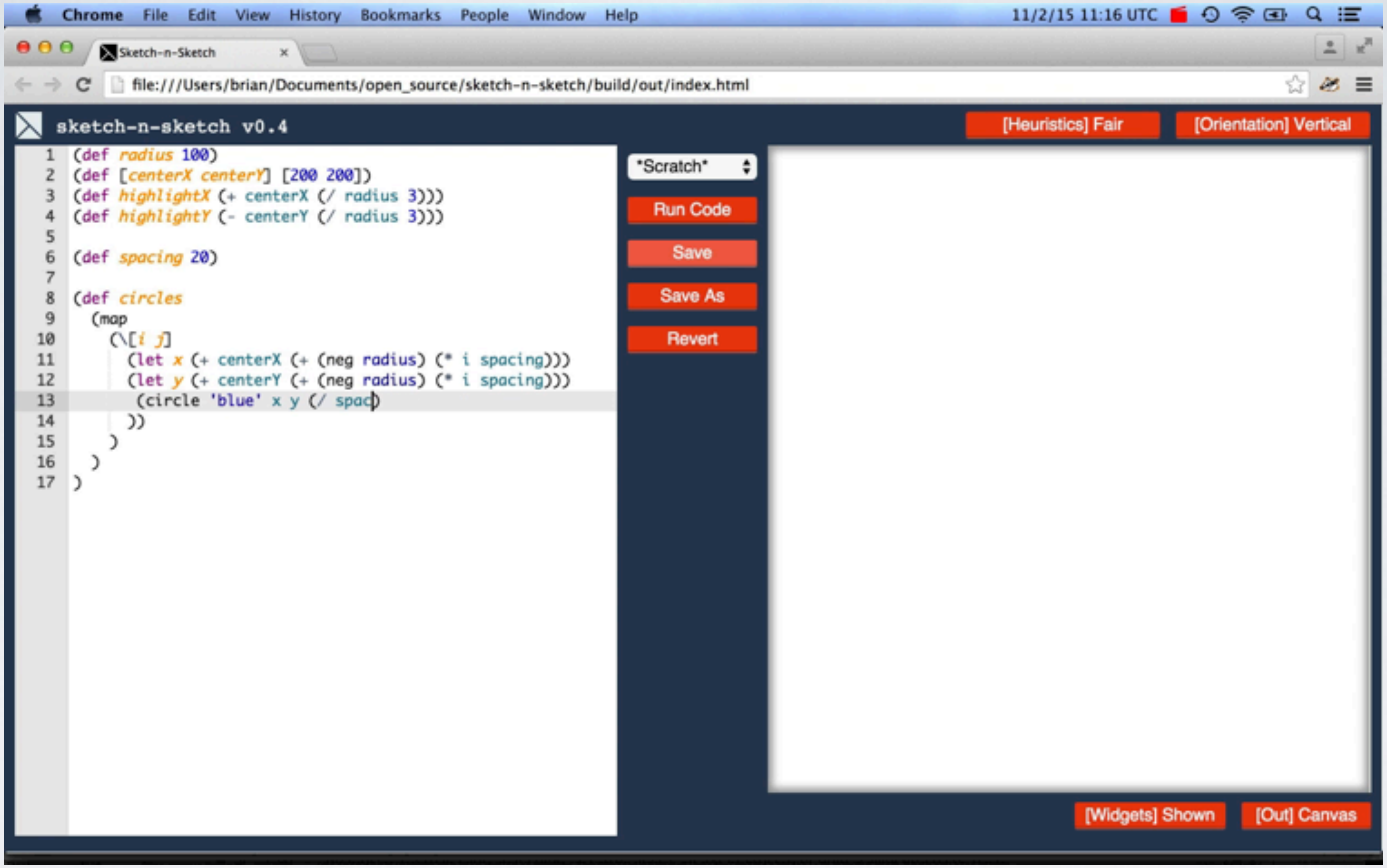
(def boxi (\i
  (let xi (+ x0 (* i sep ))
  (rect 'lightblue' xi y0 w h))))

(svg (map boxi (zeroTo n)))
```

```
rect3 Interior (ACTIVE)
124{y0} 81{x0}
```

Chugh et al. [PLDI ’16]

[PLDI ’16] Code First, Then DM



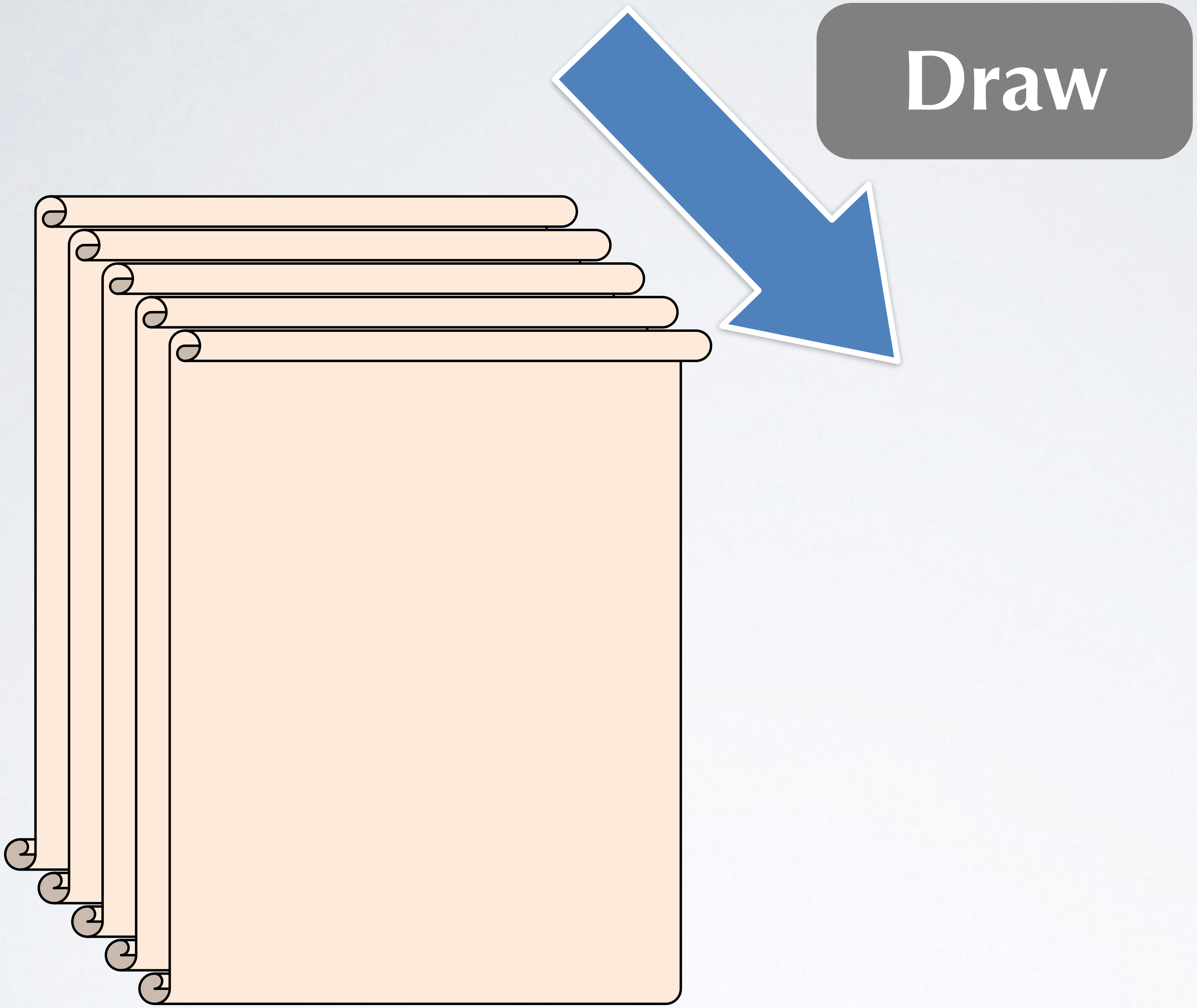
```
(def radius 100)
(def [centerX centerY] [200 200])
(def highlightX (+ centerX (/ radius 3)))
(def highlightY (- centerY (/ radius 3)))

(def spacing 20)

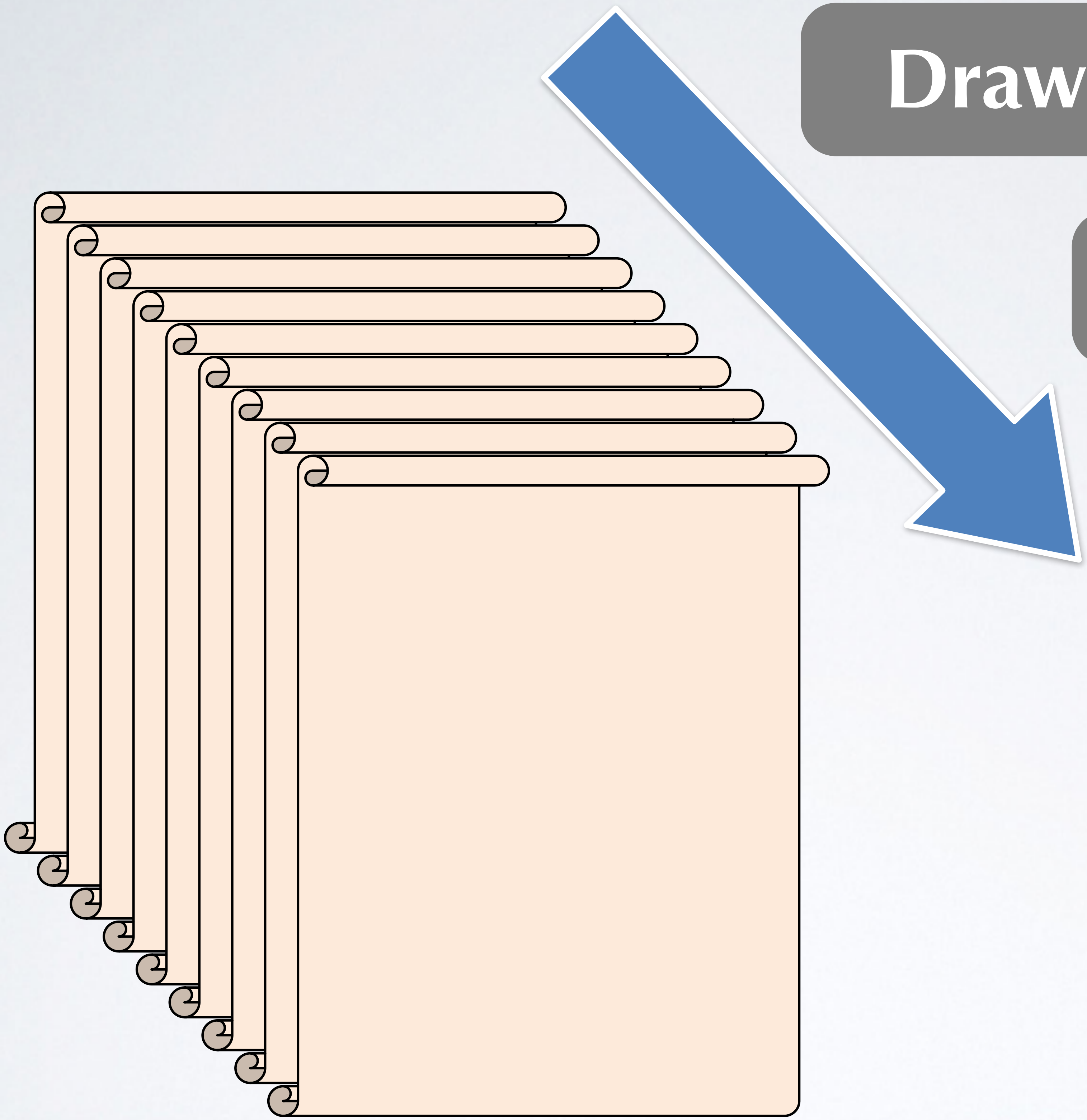
(def circles
  (map
    (\[i j]
      (let x (+ centerX (+ (neg radius) (* i spacing)))
      (let y (+ centerY (+ (neg radius) (* i spacing)))
       (circle 'blue' x y (/ spac)
      ))
    )
  )
)
```

Goal:

Less Keyboard, More Mouse.

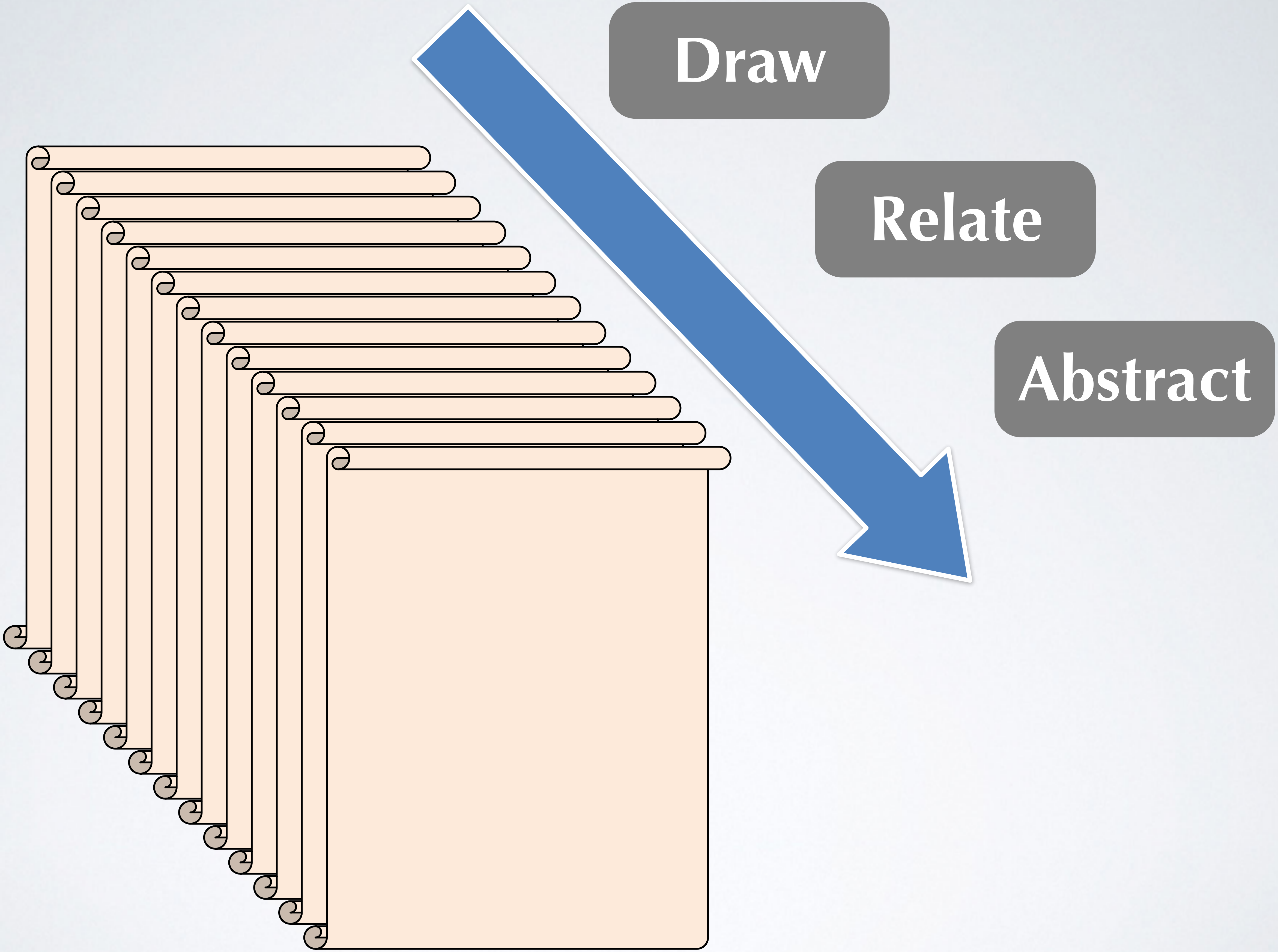


Draw



Draw

Relate



Draw

Relate

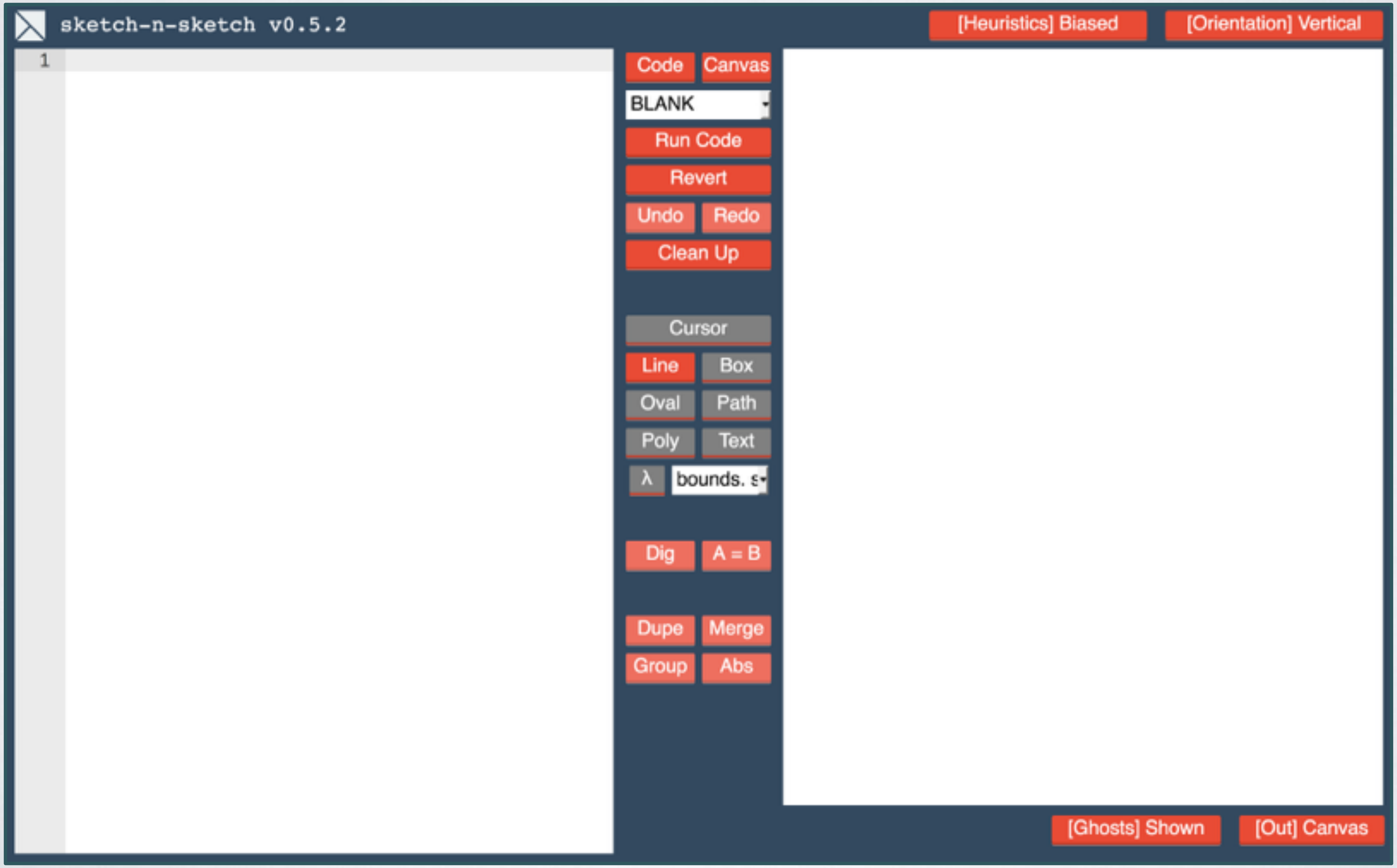
Abstract

New DM Tools

Draw

Relate

Abstract

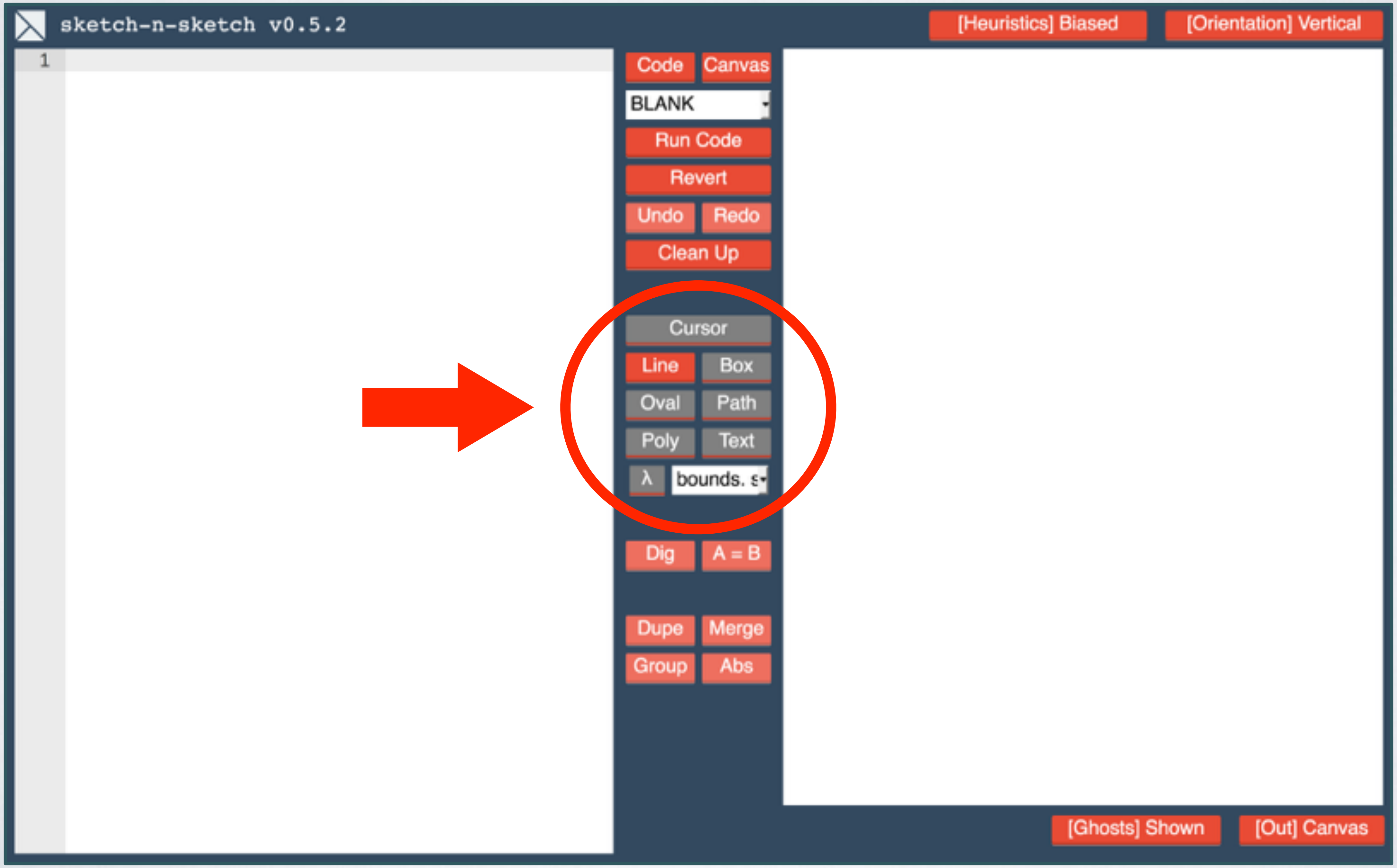


New DM Tools

Draw

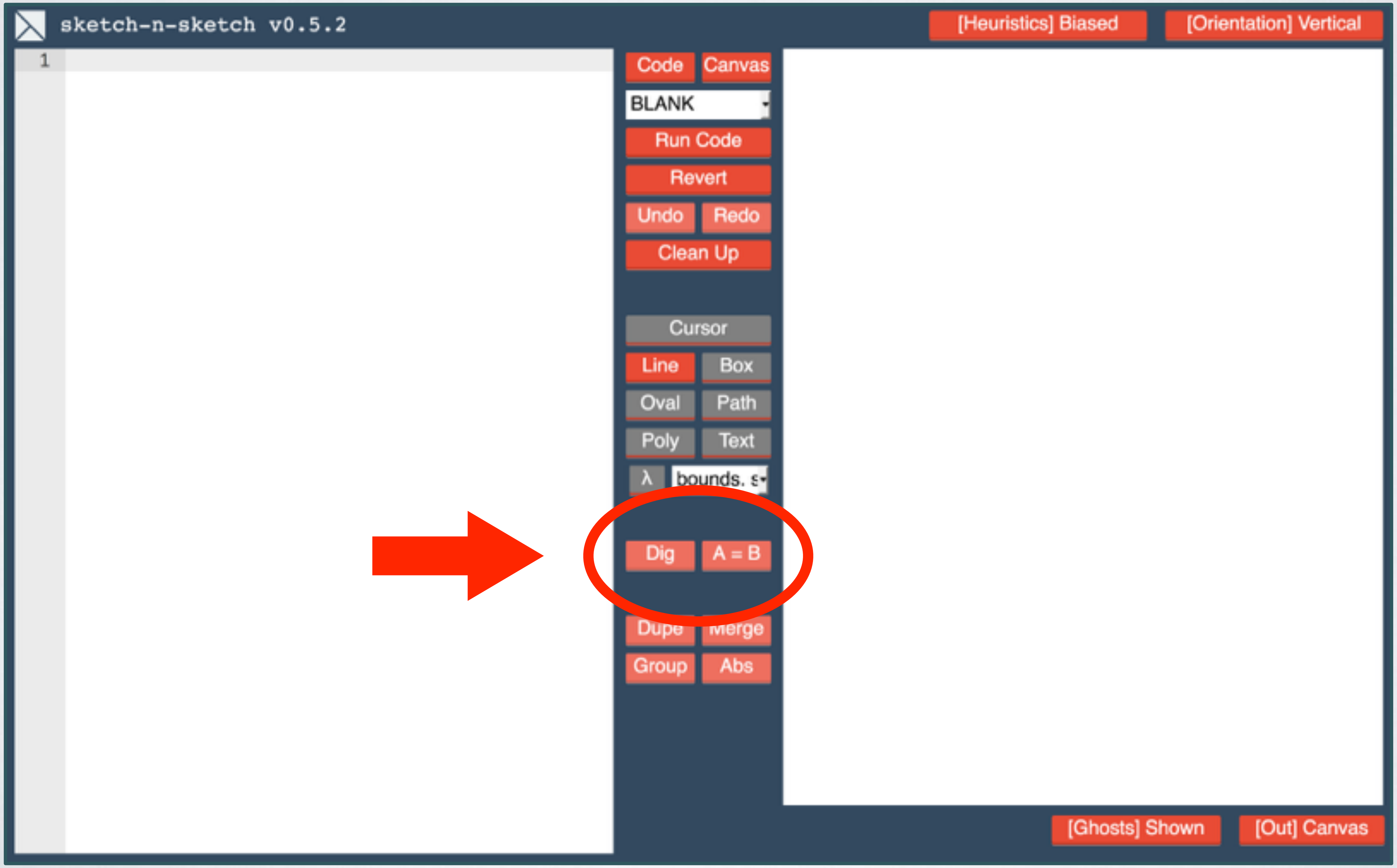
Relate

Abstract



New DM Tools

Draw | Relate | Abstract

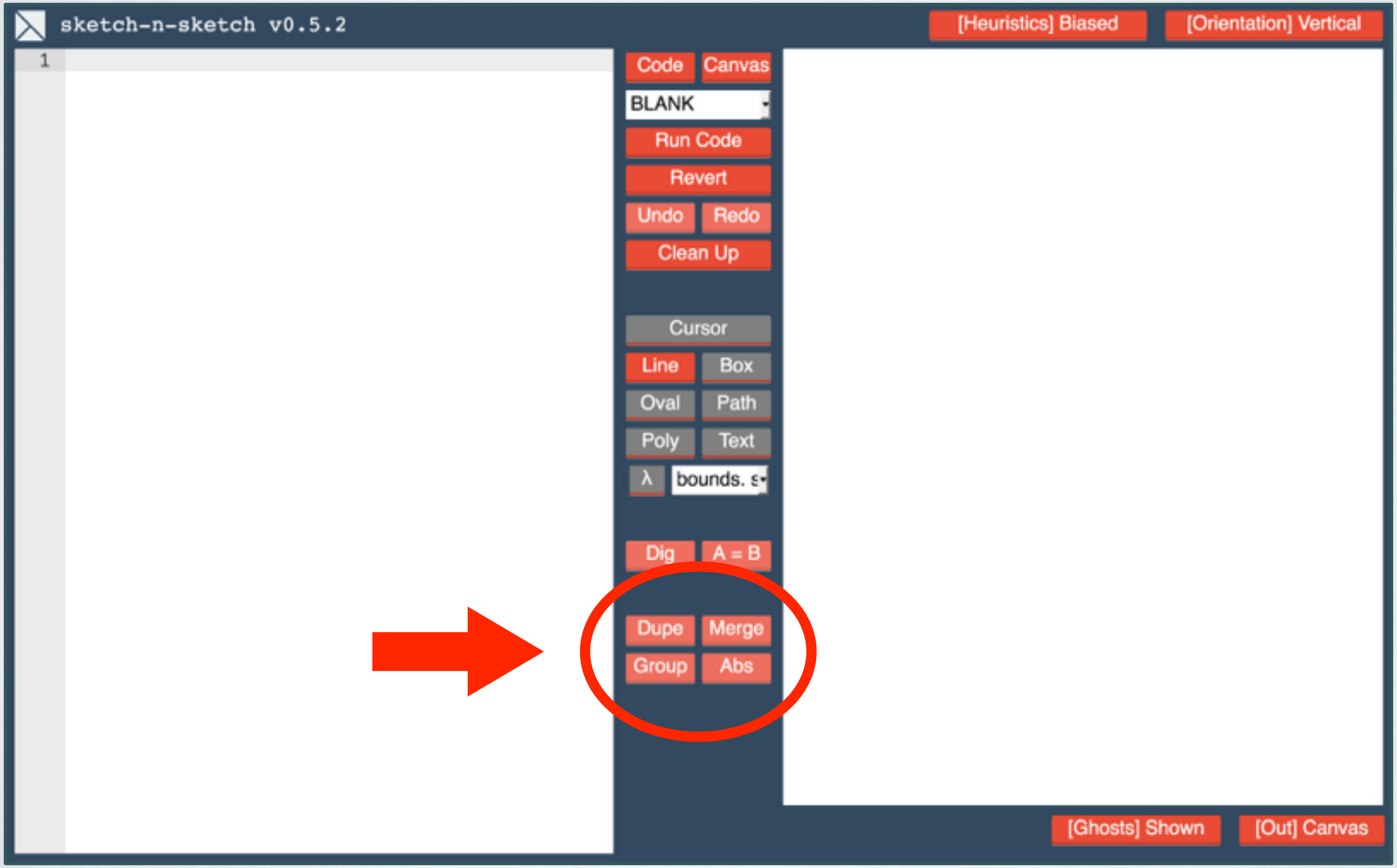


New DM Tools

Draw

Relate

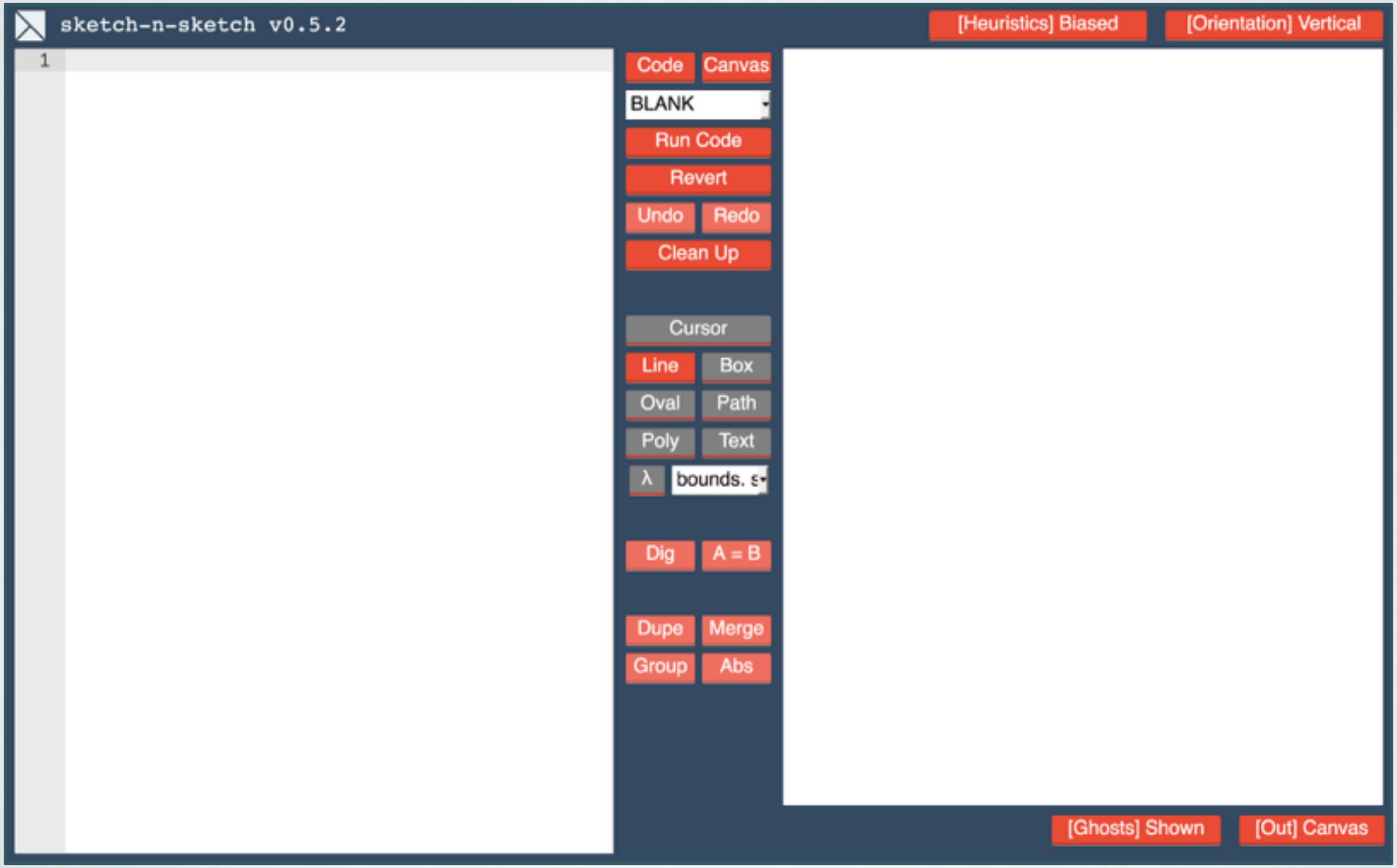
Abstract



Draw

Relate

Abstract

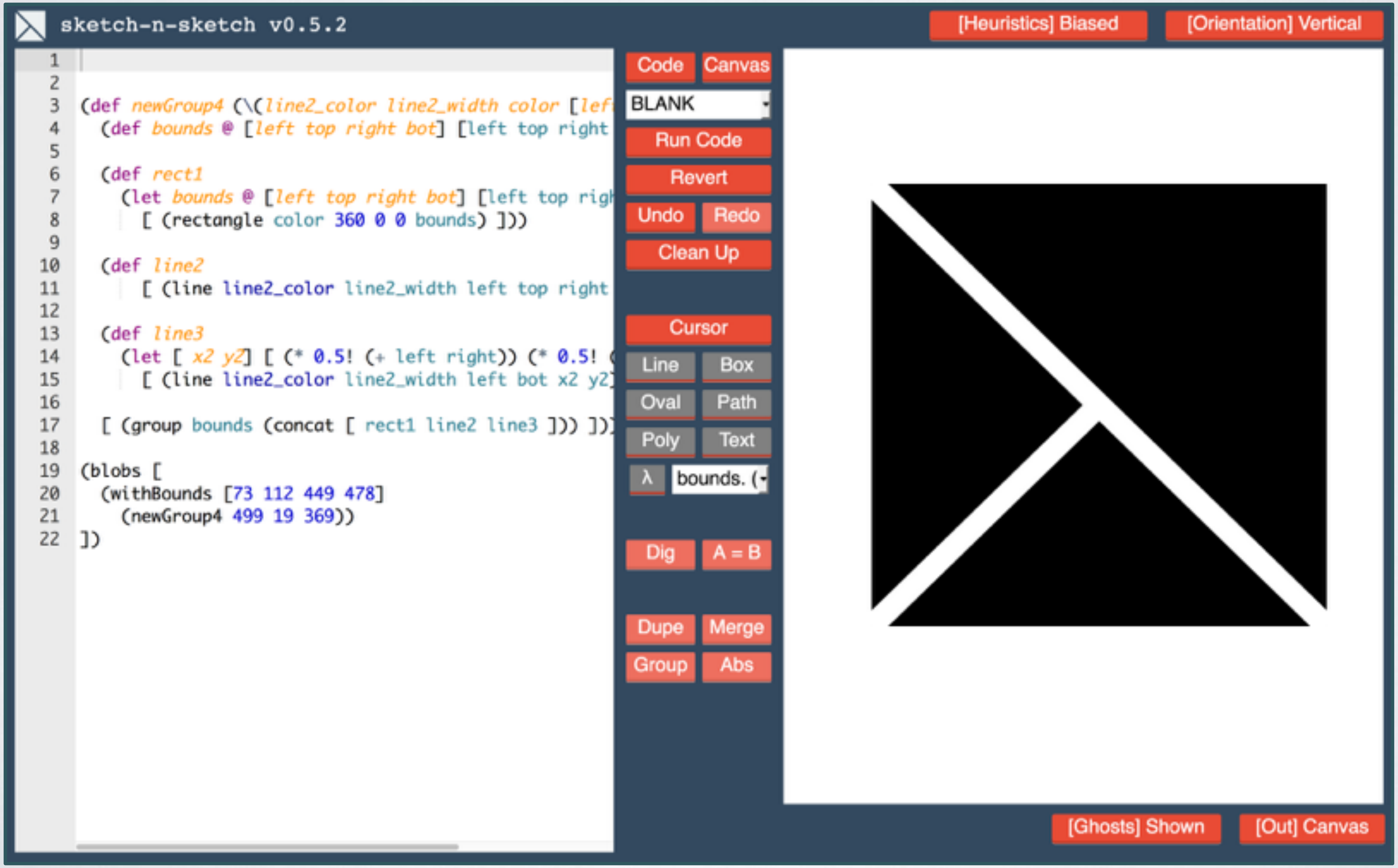


Demo

Draw

Relate

Abstract



```

(def newGroup4 (\(line2_color line2_width color [lef
  (def bounds @ [left top right bot] [left top right

  (def rect1
    (let bounds @ [left top right bot] [left top righ
    [ (rectangle color 360 0 0 bounds) ]))

  (def line2
    [ (line line2_color line2_width left top right

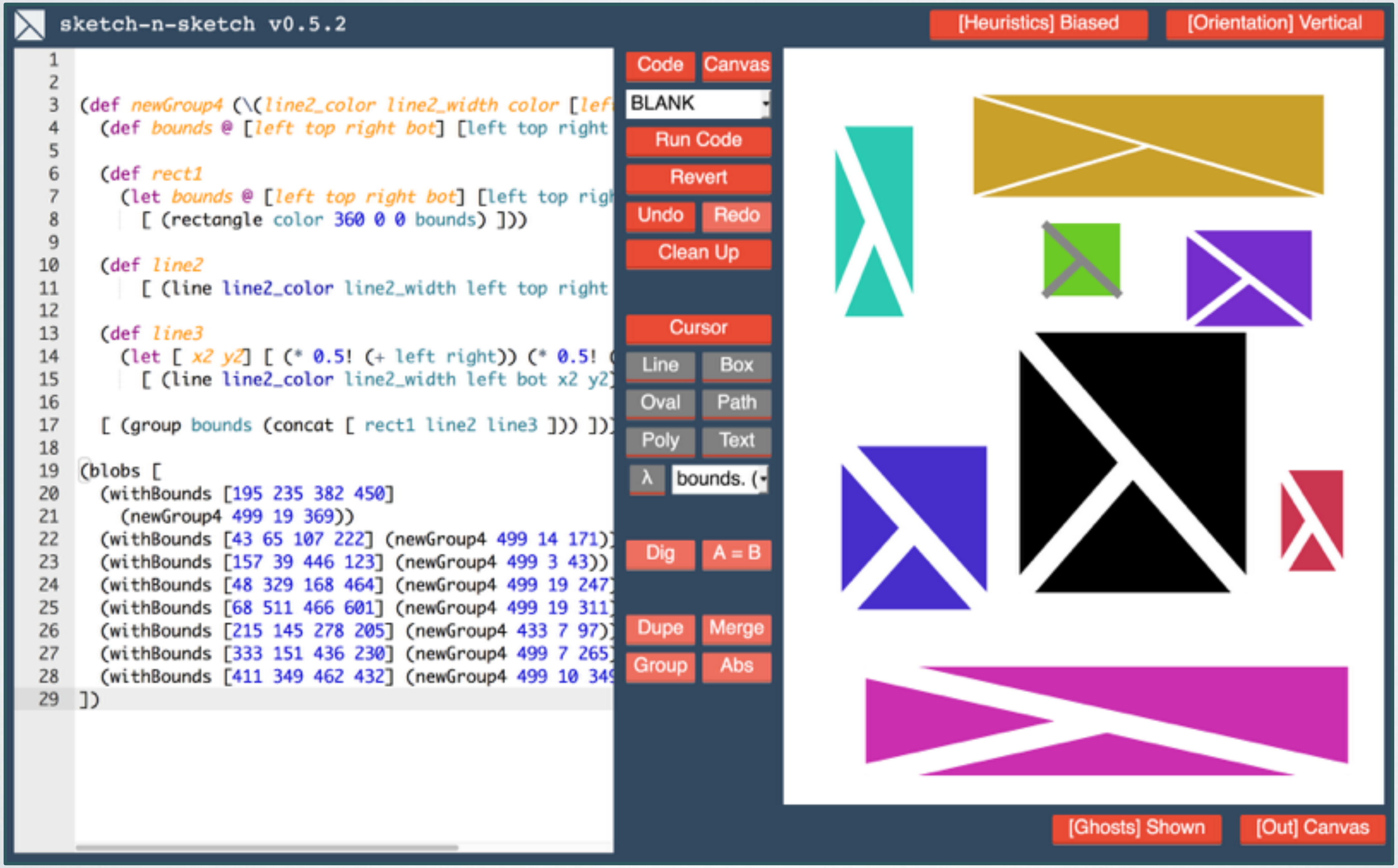
  (def line3
    (let [ x2 y2] [ (* 0.5! (+ left right)) (* 0.5! (
    [ (line line2_color line2_width left bot x2 y2]

  [ (group bounds (concat [ rect1 line2 line3 ])) ])]

(blobs [
  (withBounds [73 112 449 478]
    (newGroup4 499 19 369))
])
```

Demo

Draw **Relate** **Abstract**



[Heuristics] Biased

[Orientation] Vertical

```

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  [ (group bounds (concat [ rect1 line2 line3 ])) ])

(blobs [
  (withBounds [195 235 382 450]
    (newGroup4 499 19 369))
  (withBounds [43 65 107 222] (newGroup4 499 14 171)]
  (withBounds [157 39 446 123] (newGroup4 499 3 43))
  (withBounds [48 329 168 464] (newGroup4 499 19 247]
  (withBounds [68 511 466 601] (newGroup4 499 19 311]
  (withBounds [215 145 278 205] (newGroup4 433 7 97)]
  (withBounds [333 151 436 230] (newGroup4 499 7 265]
  (withBounds [411 349 462 432] (newGroup4 499 10 34
])
```

[Ghosts] Shown

[Out] Canvas

Draw Relate Abstract

Programming in 2015

Sketch-n-Sketch

Draw

Relate

Abstract

Programming in 2015

Sketch-n-Sketch

Draw Relate Abstract

Programming in 2015

Sketch-n-Sketch

```
let rect1 = ...

let line2 = ...

let line3 = ...
```

Draw | Relate | Abstract

Programming in 2015

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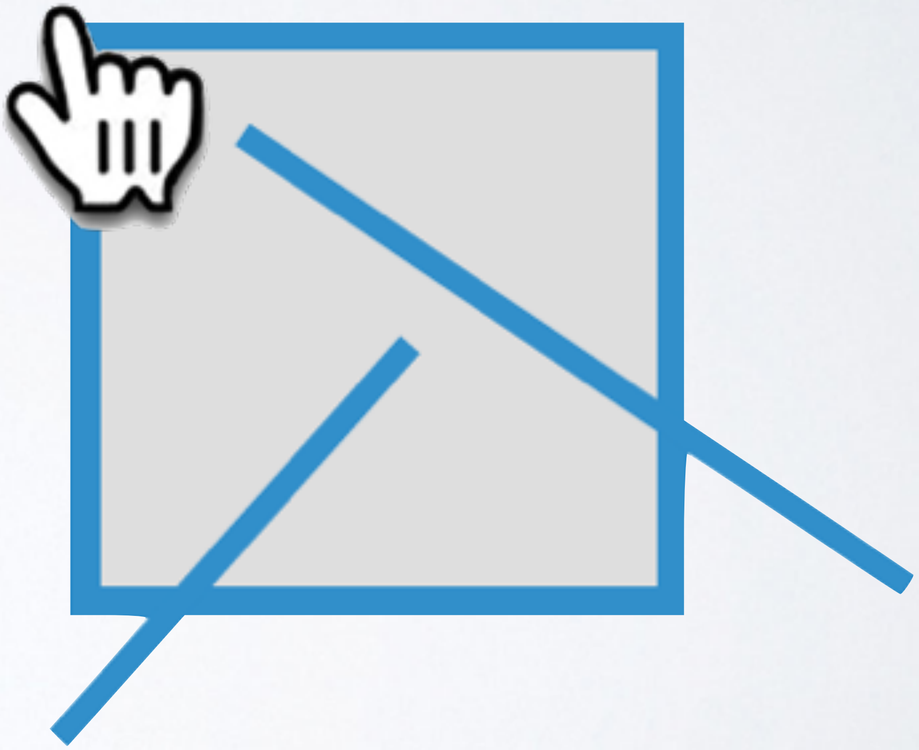
Sketch-n-Sketch



Draw Relate Abstract

Programming in 2015

Sketch-n-Sketch

Draw

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Abstract

Programming in 2015

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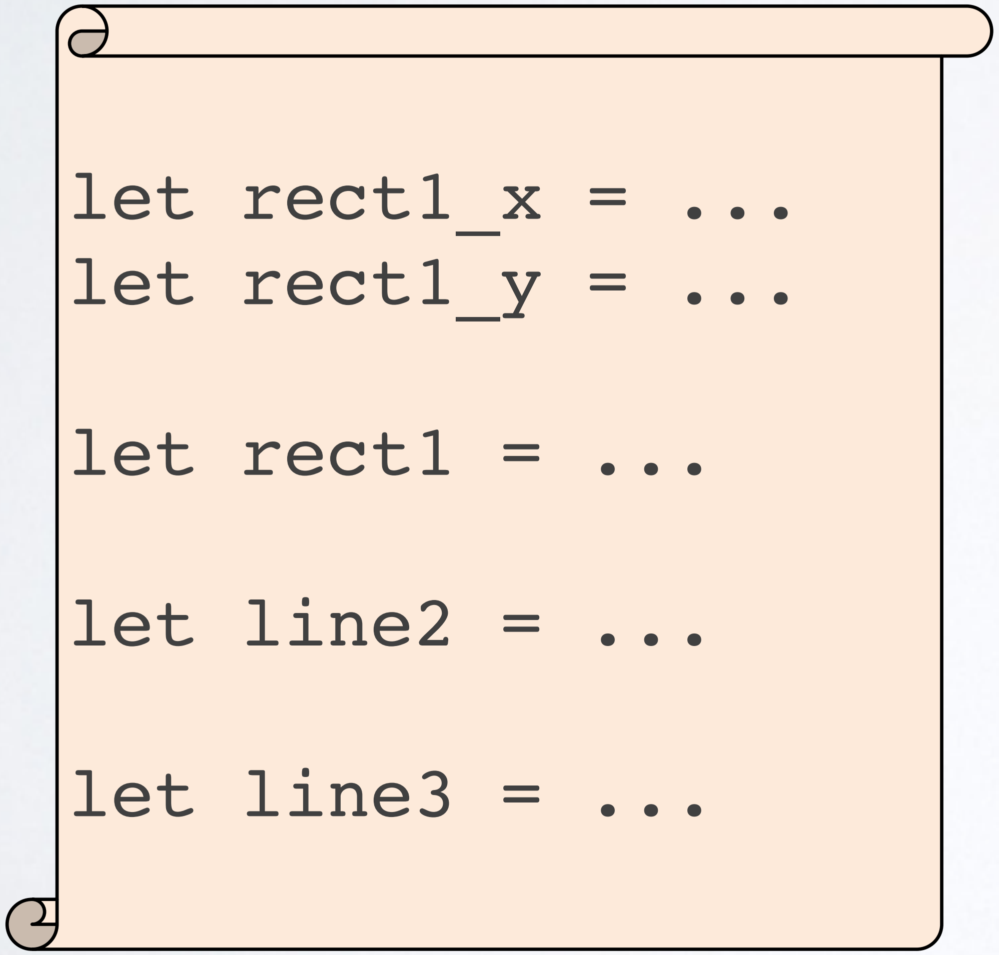

```
let rect1_x = ...
let rect1_y = ...

let rect1 = ...


let line2 = ...


let line3 = ...
```

Draw

Relate

Abstract

Programming in 2015

Sketch-n-Sketch

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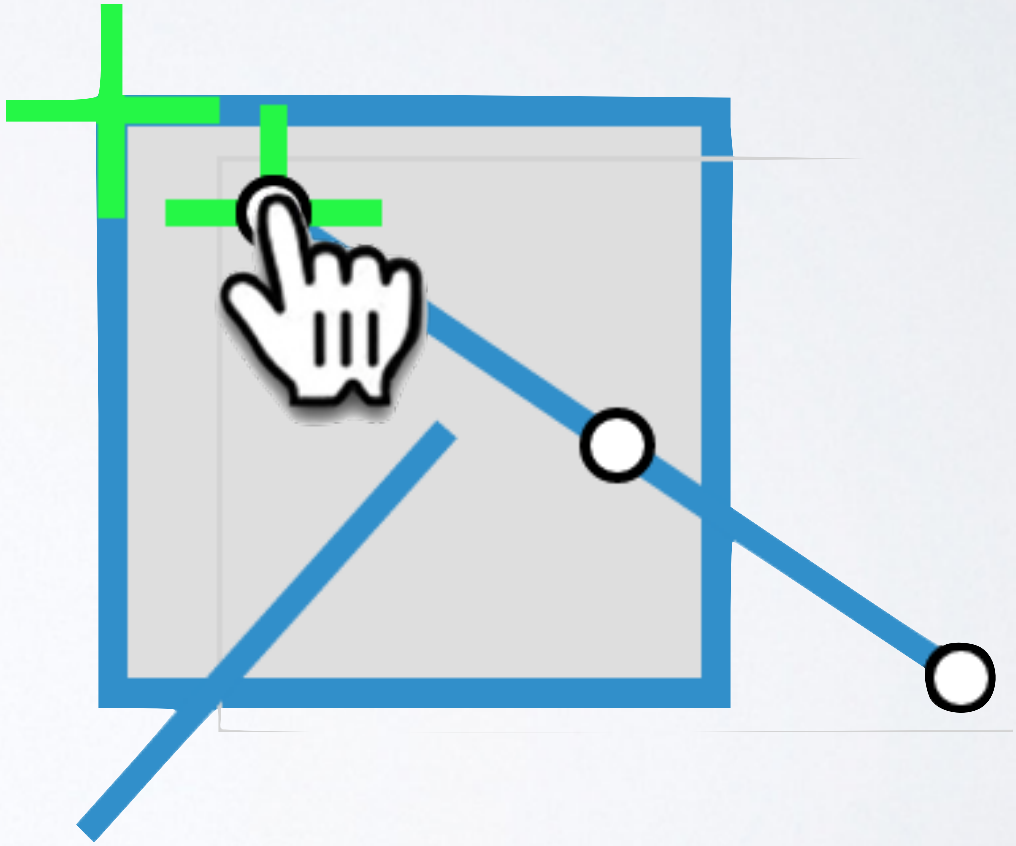

Draw

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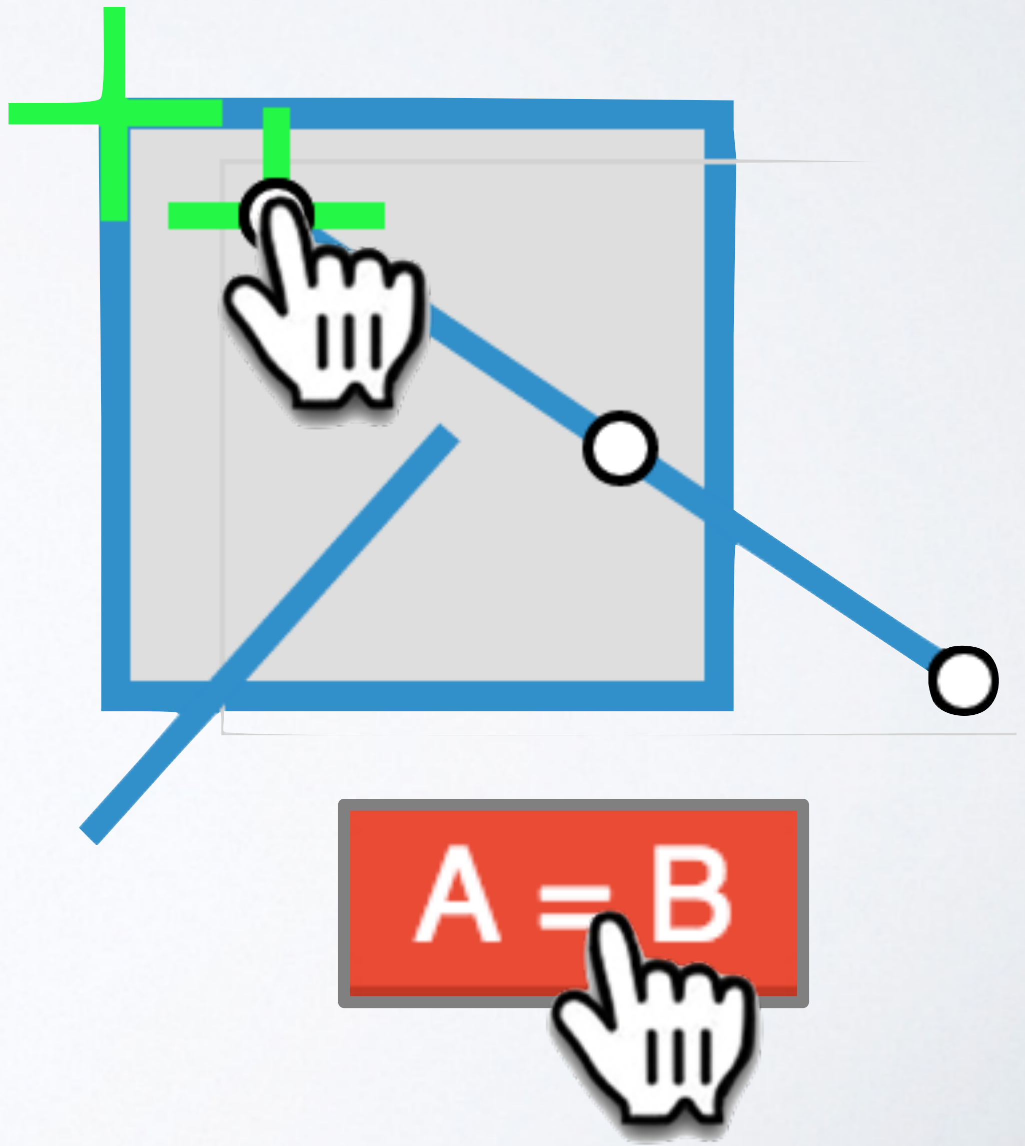
Sketch-n-Sketch



Draw Relate **Abstract**

Programming in 2015

Sketch-n-Sketch

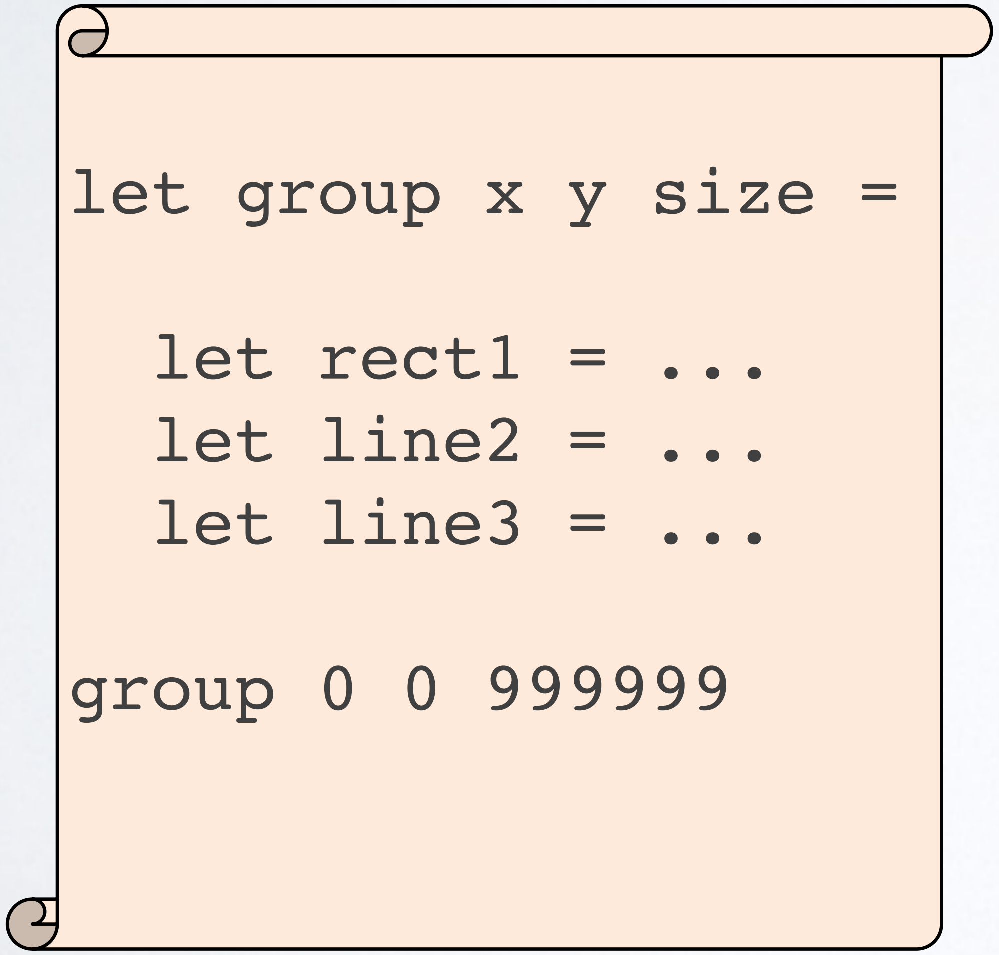
Draw

Relate

Abstract

Programming in 2015

Sketch-n-Sketch



```
let group x y size =

  let rect1 = ...
  let line2 = ...
  let line3 = ...

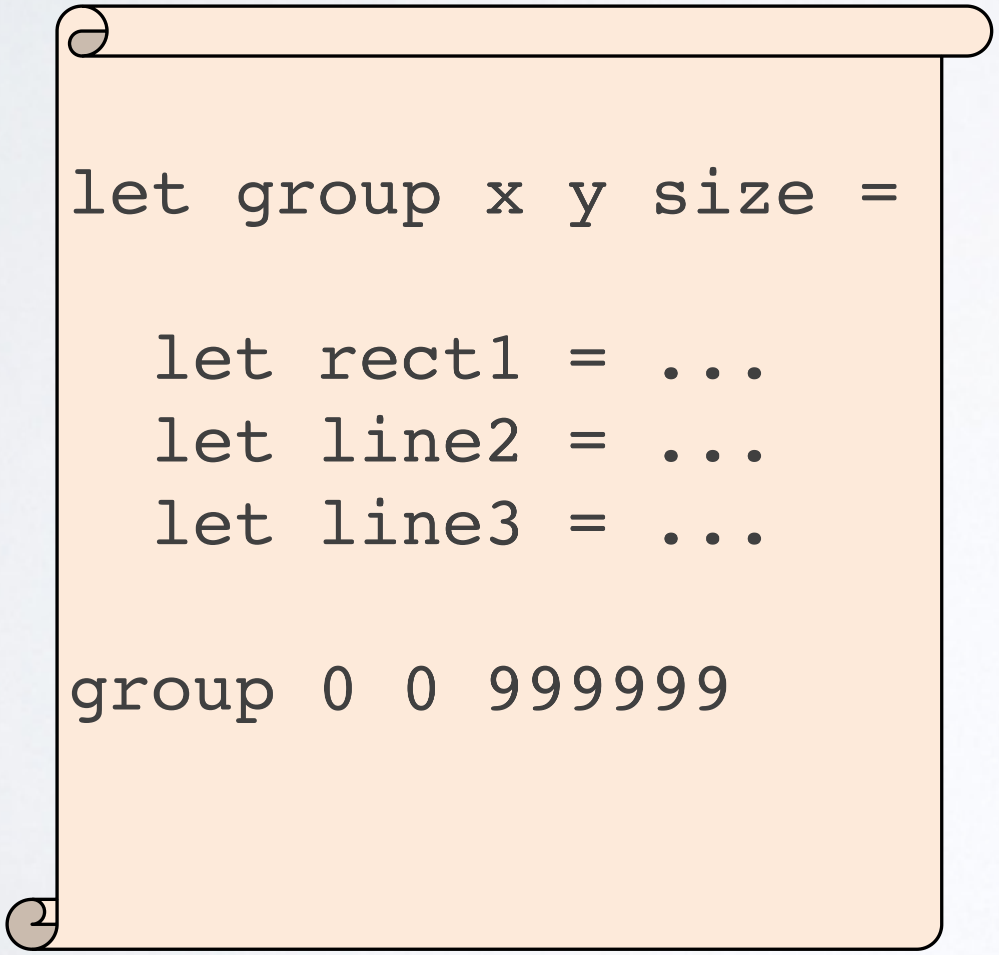
group 0 0 999999
```

Draw

Relate

Abstract

Programming in 2015



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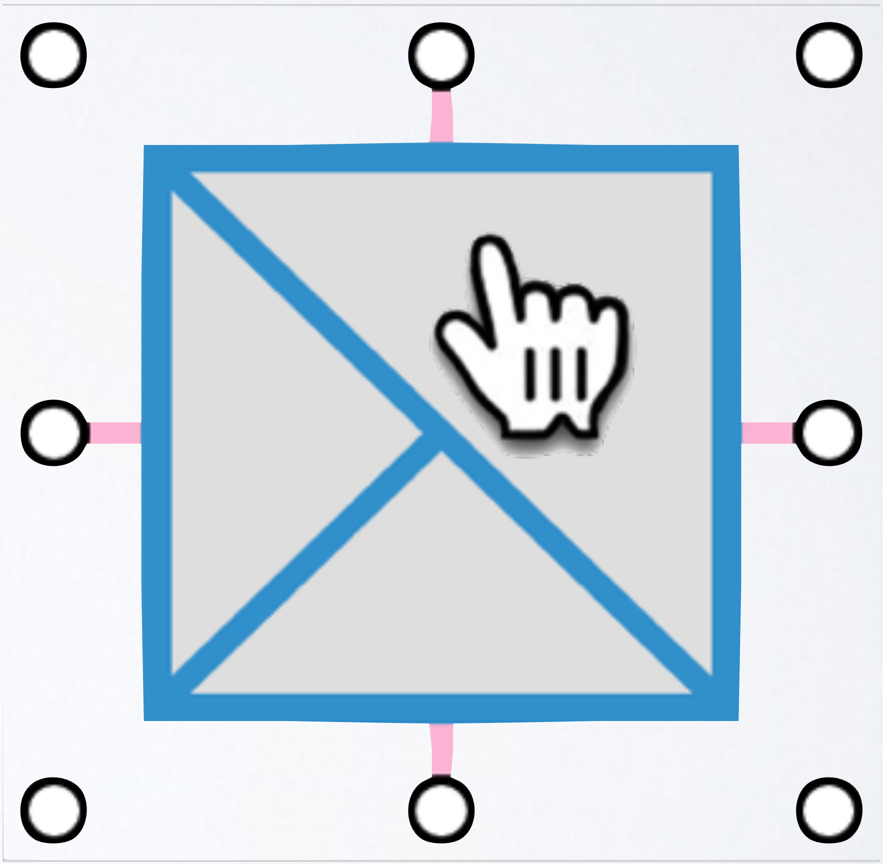

Draw | Relate | **Abstract**

Programming in 2015

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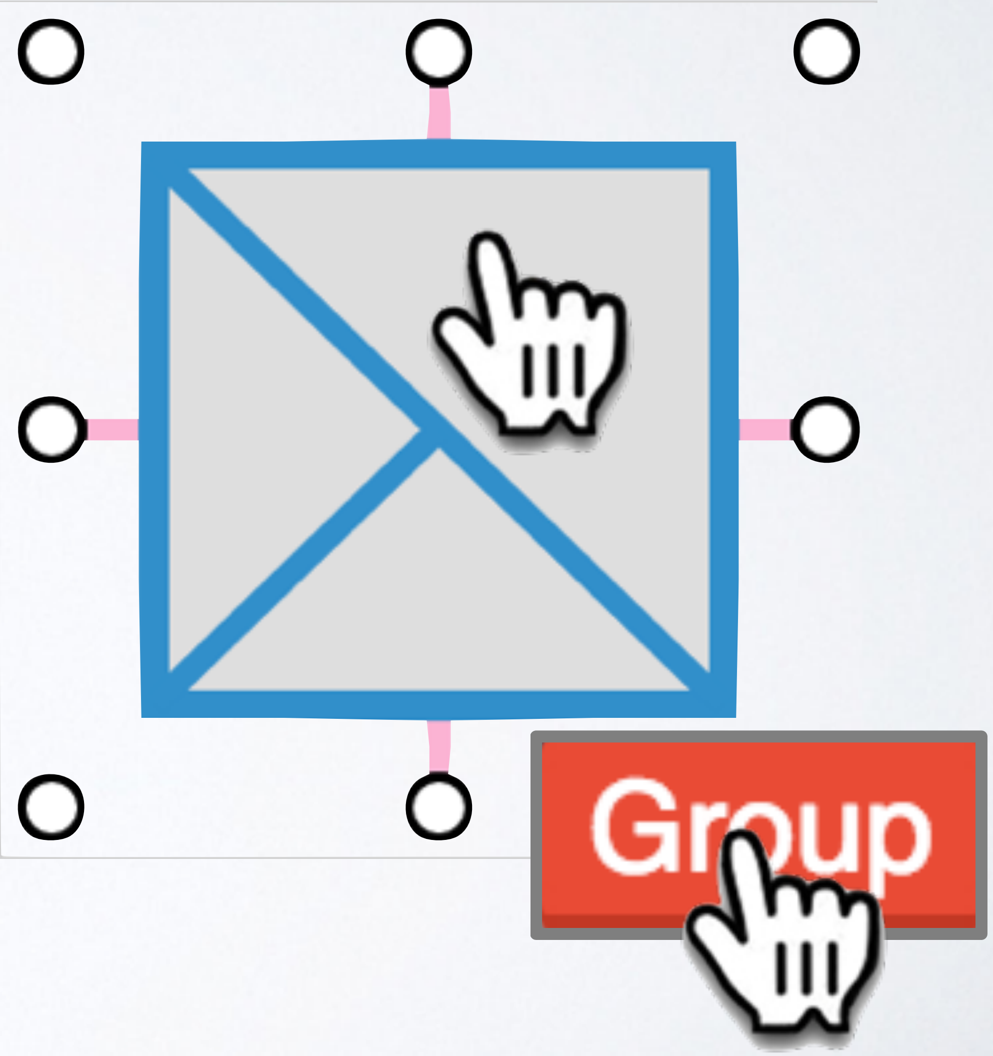
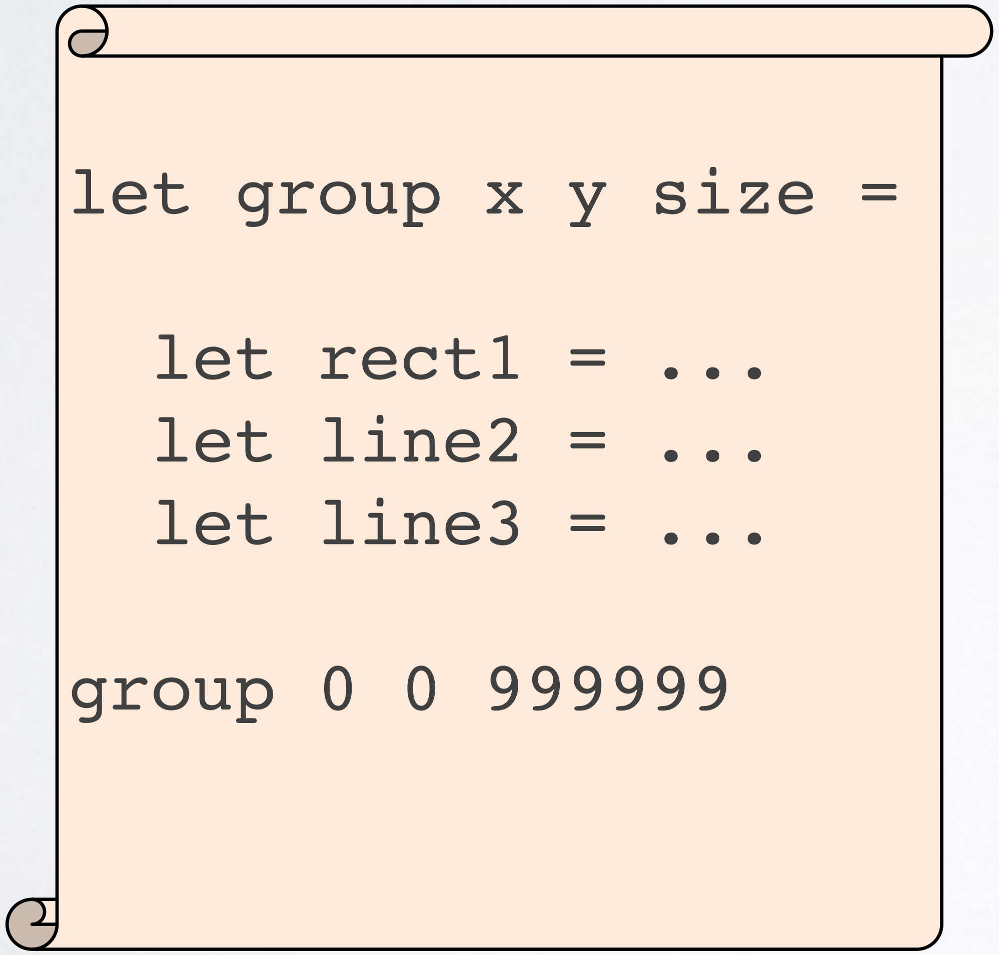
Sketch-n-Sketch



Draw　Relate　**Abstract**

Programming in 2015



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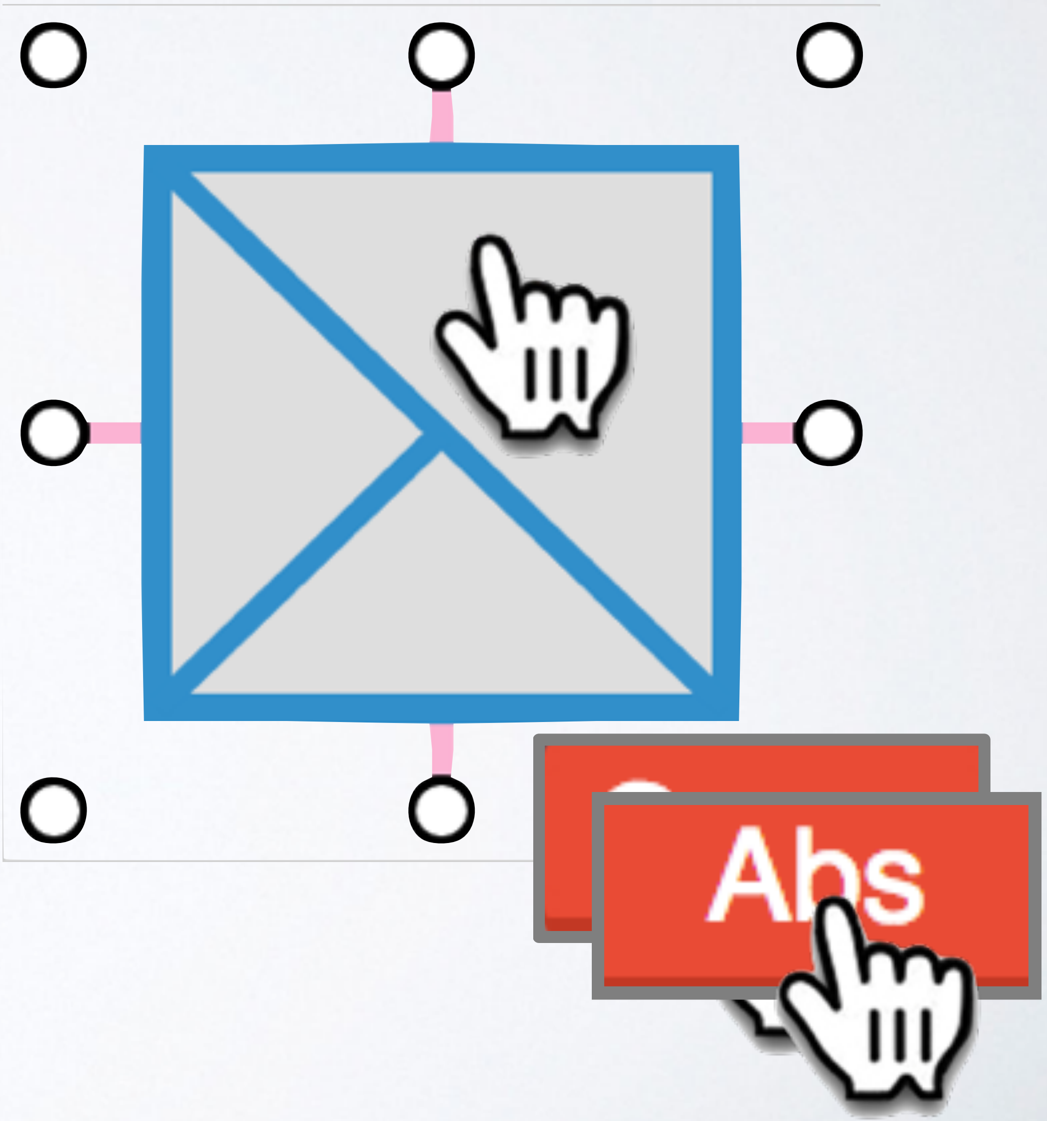
Sketch-n-Sketch



Draw

Relate

Abstract

Programming in 2015

Sketch-n-Sketch

Draw

Relate

Abstract

Sketch-n-Sketch

Sketch-n-Sketch++

Draw Relate Abstract

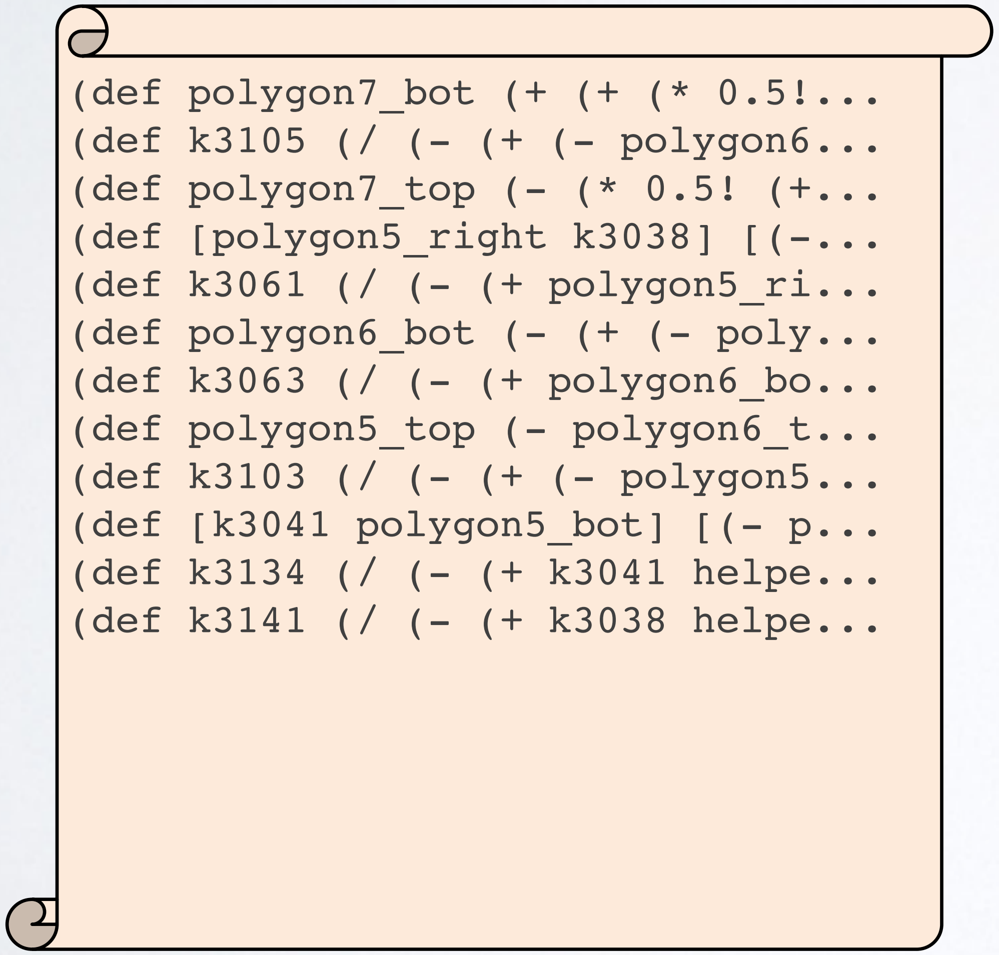
Sketch-n-Sketch

Sketch-n-Sketch++

Draw Relate Abstract

Sketch-n-Sketch

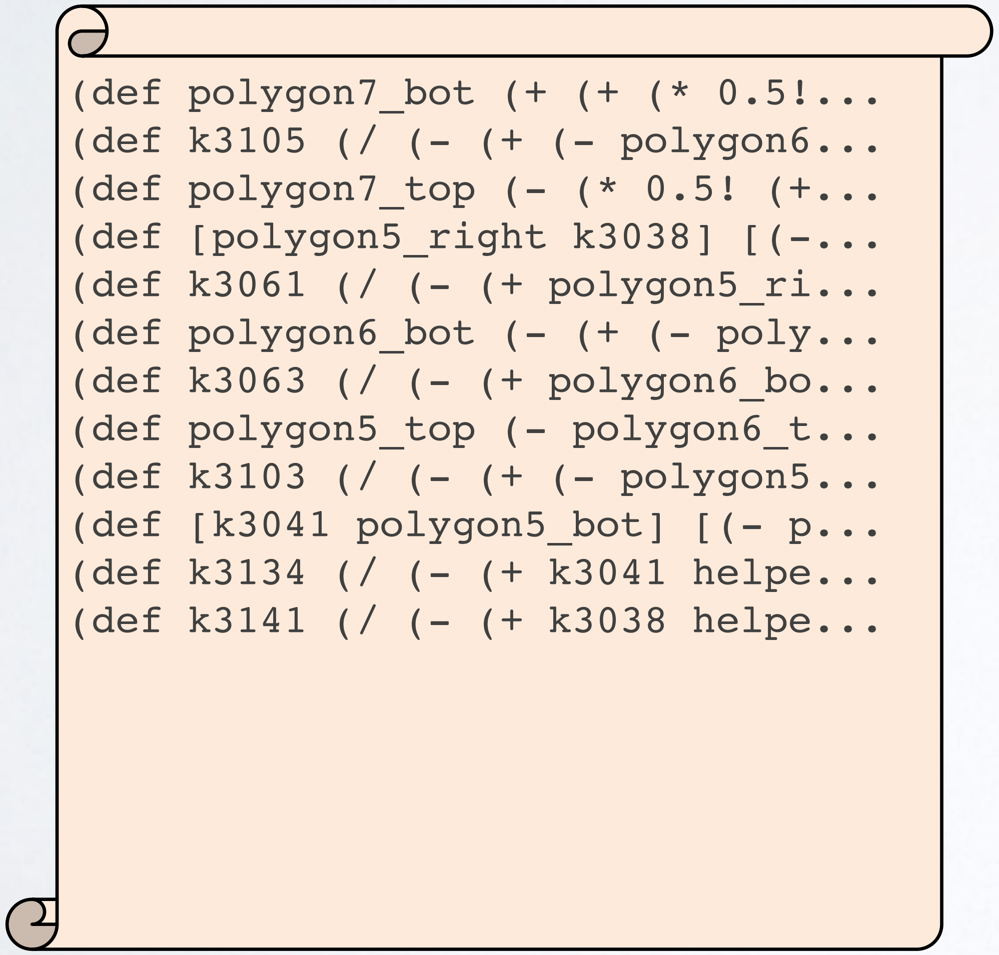
Sketch-n-Sketch++



```
(def polygon7_bot (+ (+ (* 0.5!...
(def k3105 (/ (- (+ (- polygon6...
(def polygon7_top (- (* 0.5! (+...
(def [polygon5_right k3038] [(-...
(def k3061 (/ (- (+ polygon5_ri...
(def polygon6_bot (- (+ (- poly...
(def k3063 (/ (- (+ polygon6_bo...
(def polygon5_top (- polygon6_t...
(def k3103 (/ (- (+ (- polygon5...
(def [k3041 polygon5_bot] [(- p...
(def k3134 (/ (- (+ k3041 helpe...
(def k3141 (/ (- (+ k3038 helpe...
```

Draw Relate Abstract

Sketch-n-Sketch



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(def k3134 (/ (- (+ k3041 helpe...
(def k3141 (/ (- (+ k3038 helpe...
```

Sketch-n-Sketch++

Smarter Algebra

+

Helper Functions

Draw

Relate

Abstract

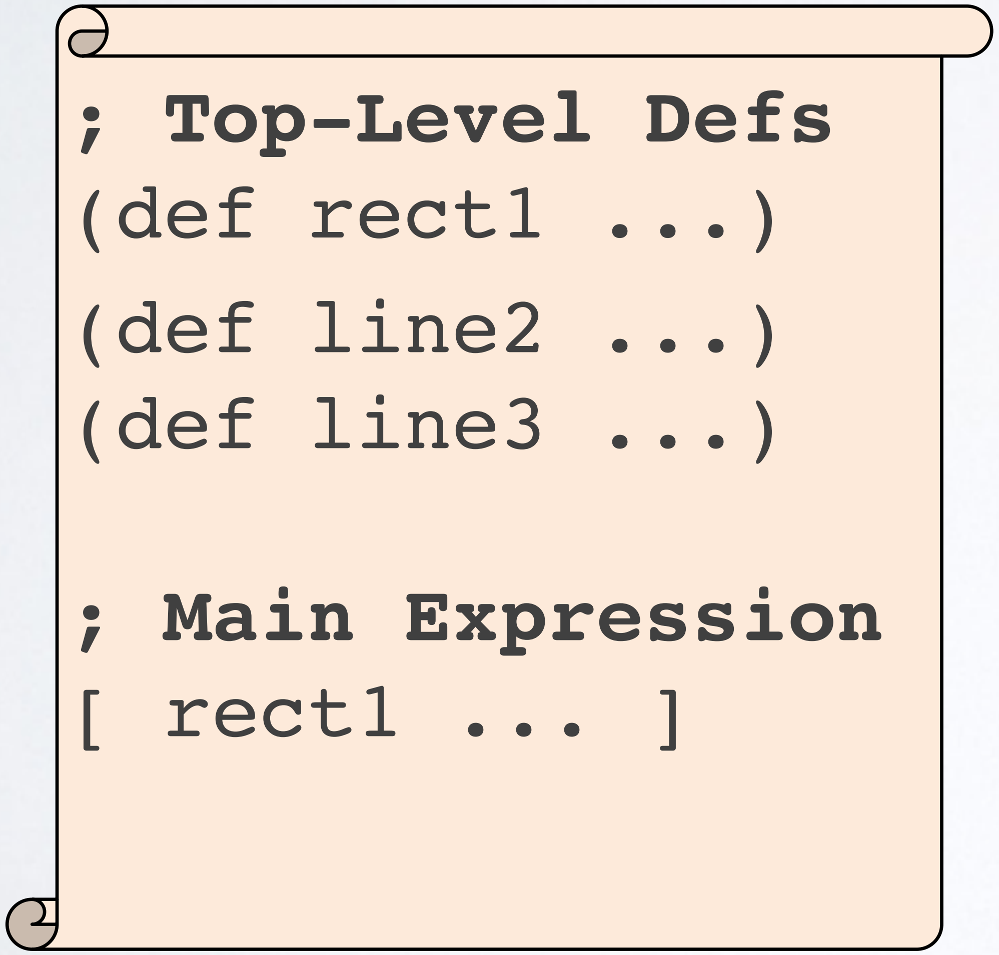
Sketch-n-Sketch

Sketch-n-Sketch++

Draw Relate **Abstract**

Sketch-n-Sketch

Sketch-n-Sketch++



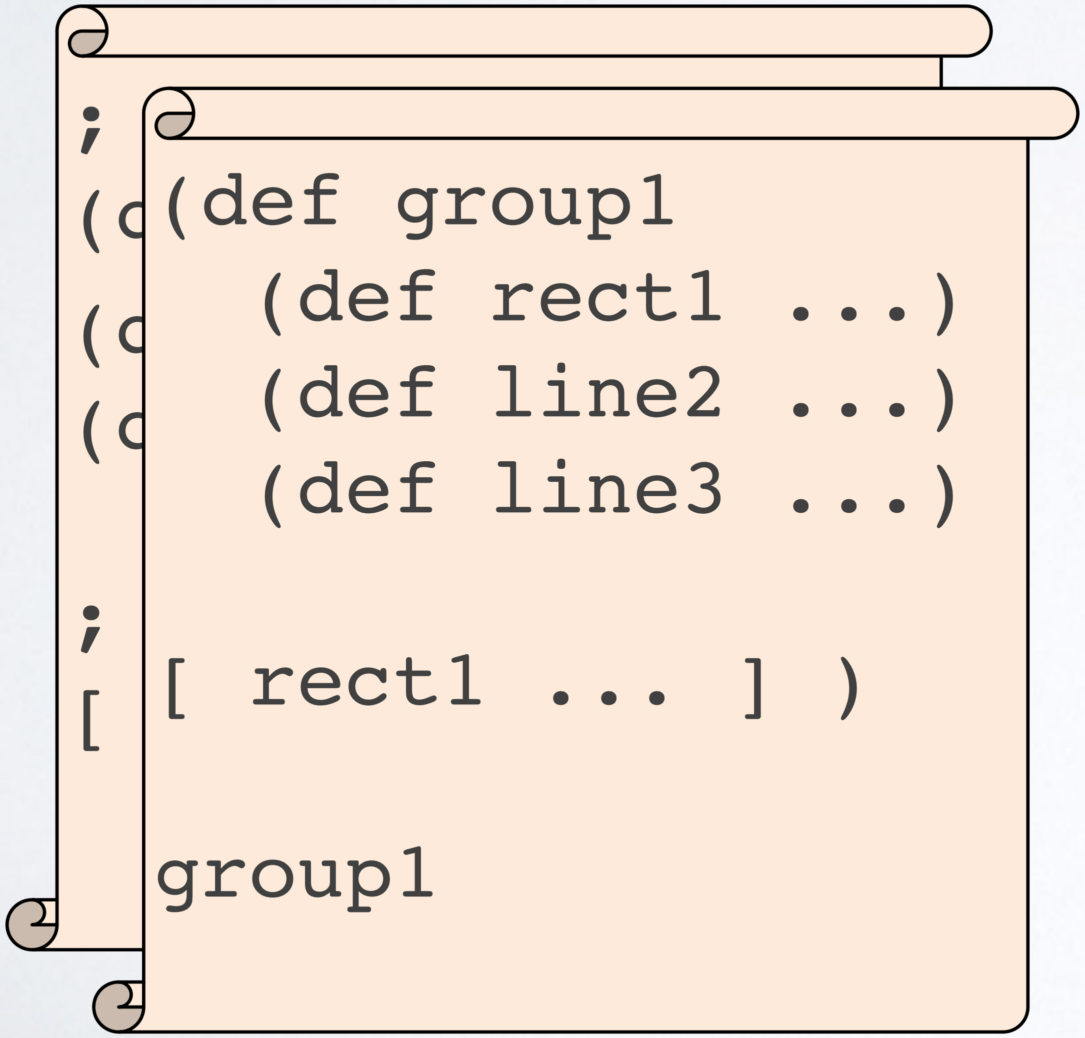
```
; Top-Level Defs
(def rect1 ...)
(def line2 ...)
(def line3 ...)

; Main Expression
[ rect1 ... ]
```

Draw Relate **Abstract**

Sketch-n-Sketch

Sketch-n-Sketch++



```
;
(d
(d
(d
;
[
```

```
(def group1
  (def rect1 ...)
  (def line2 ...)
  (def line3 ...)

[ rect1 ... ] )

group1
```

Refactor
Programs
of Arbitrary
Structure

Draw

Relate

Abstract

Sketch-n-Sketch

Sketch-n-Sketch++

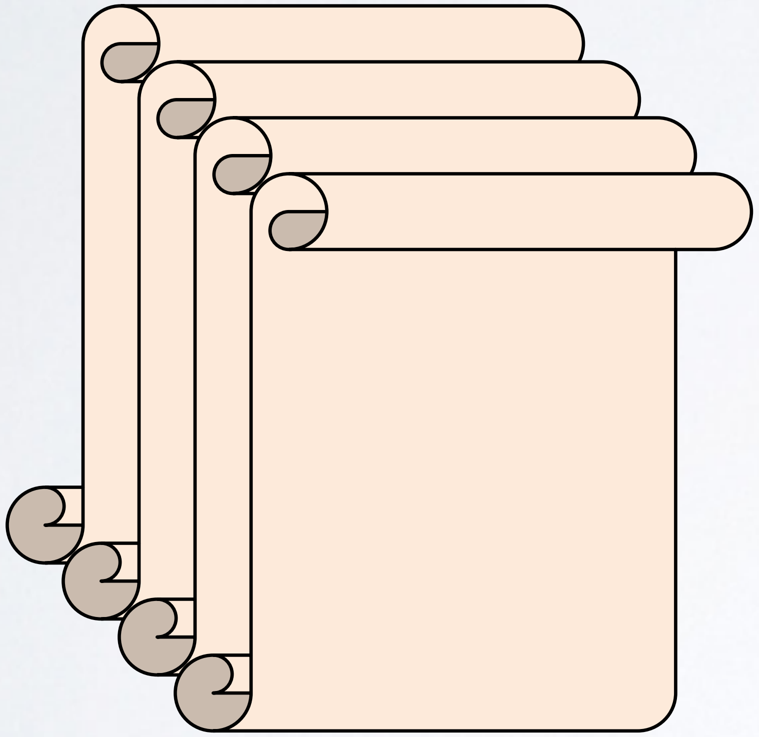
Draw

Relate

Abstract

Sketch-n-Sketch

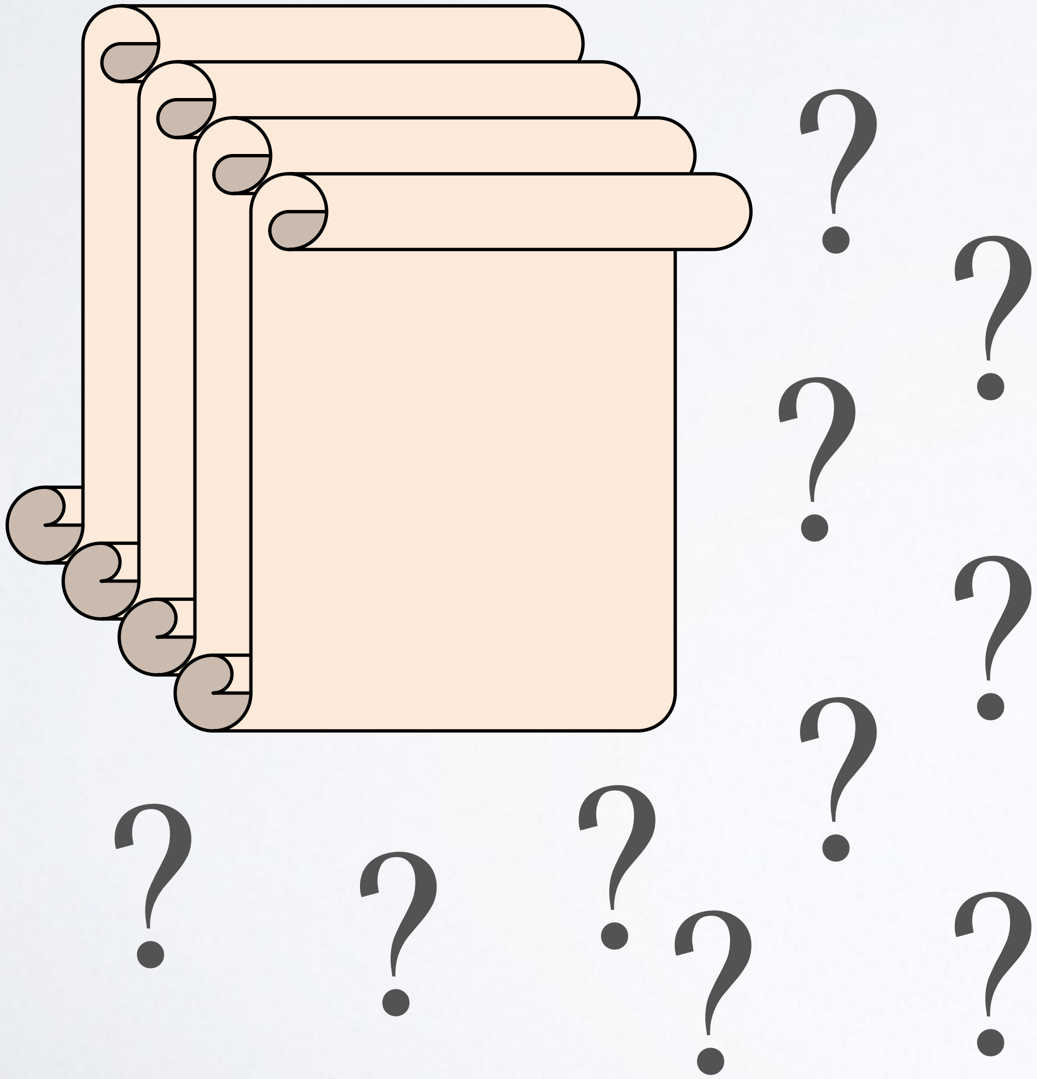
Sketch-n-Sketch++



Draw Relate Abstract

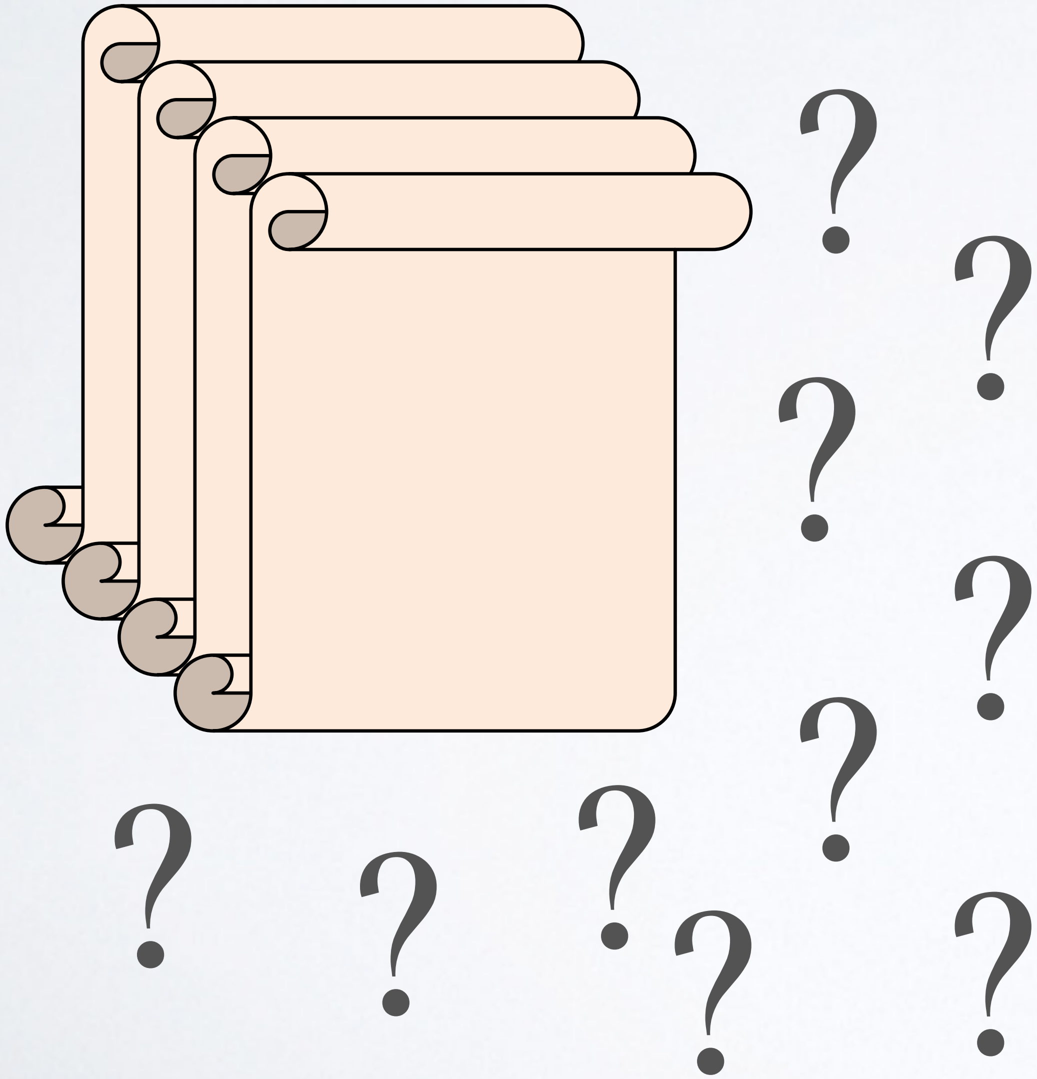
Sketch-n-Sketch

Sketch-n-Sketch++



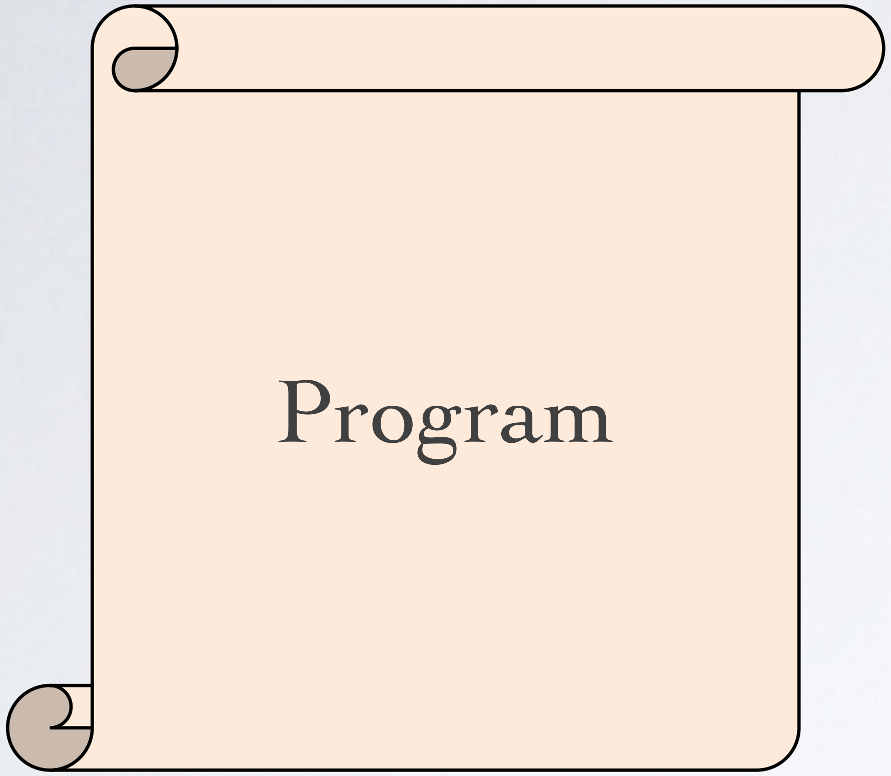
Draw | Relate | Abstract

Sketch-n-Sketch

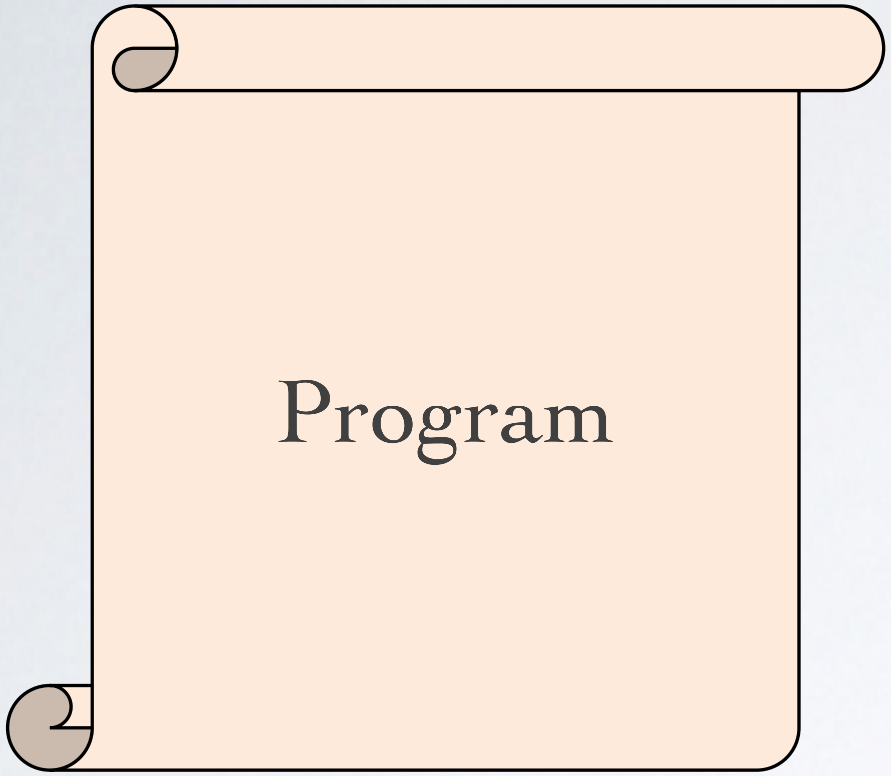


Sketch-n-Sketch++

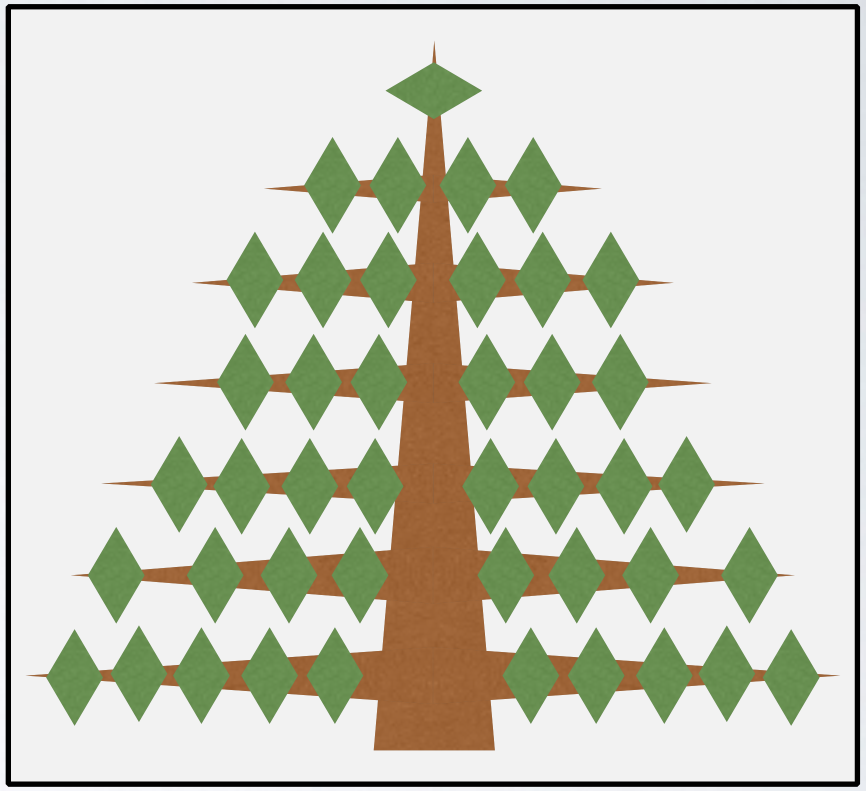
Additional Interaction to Resolve User Intent

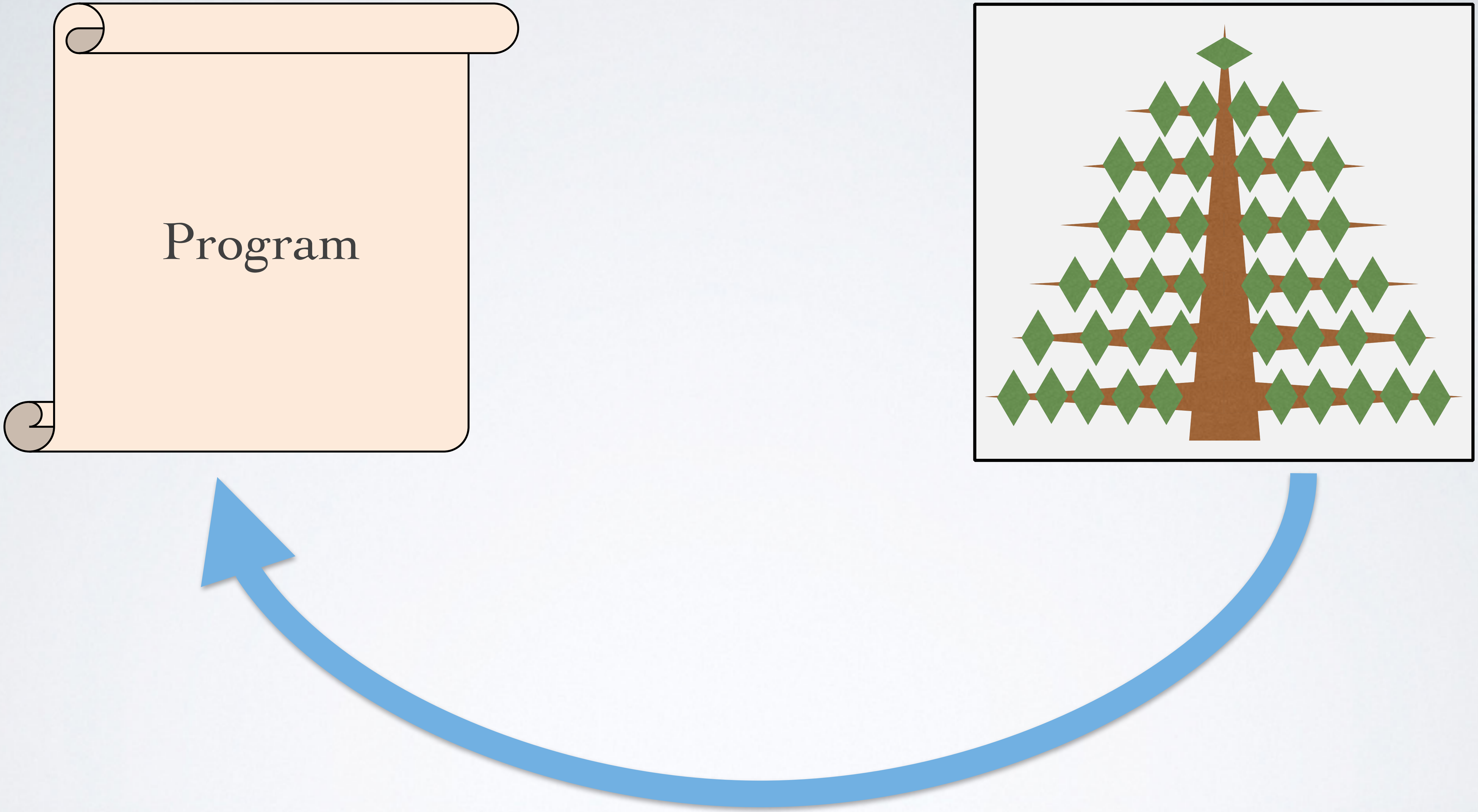


Program



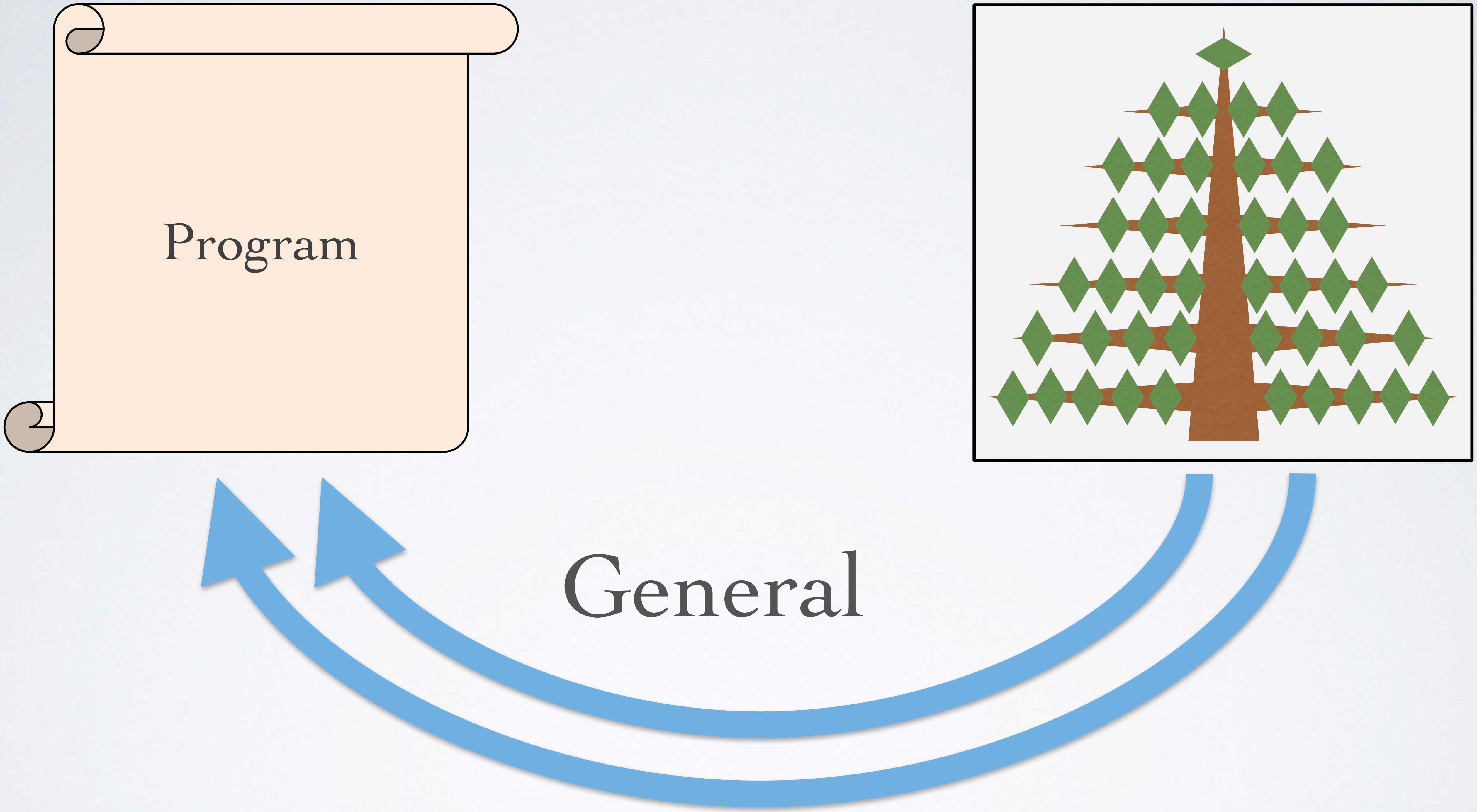
Program





Program

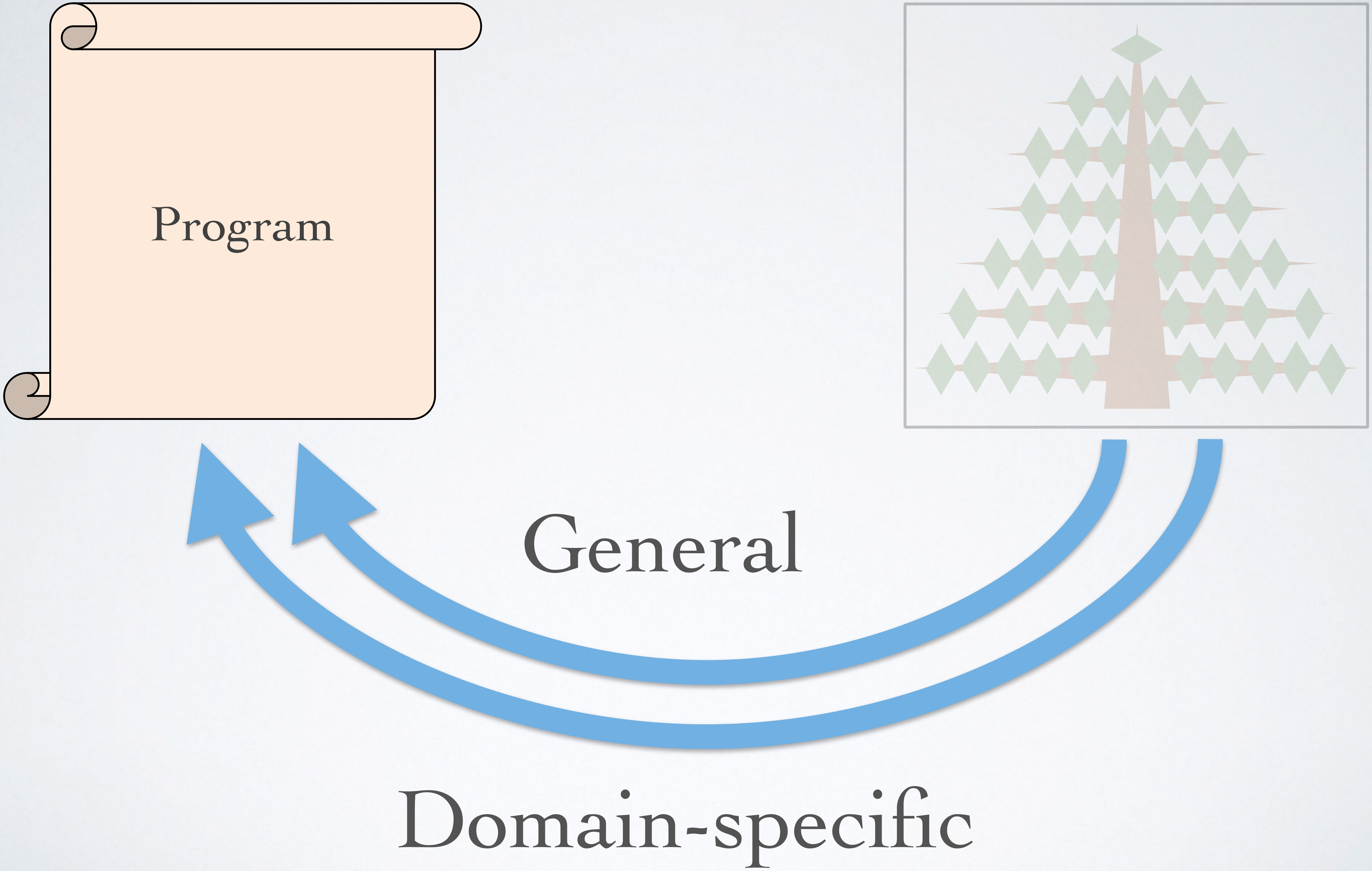
Domain-specific



Program

General

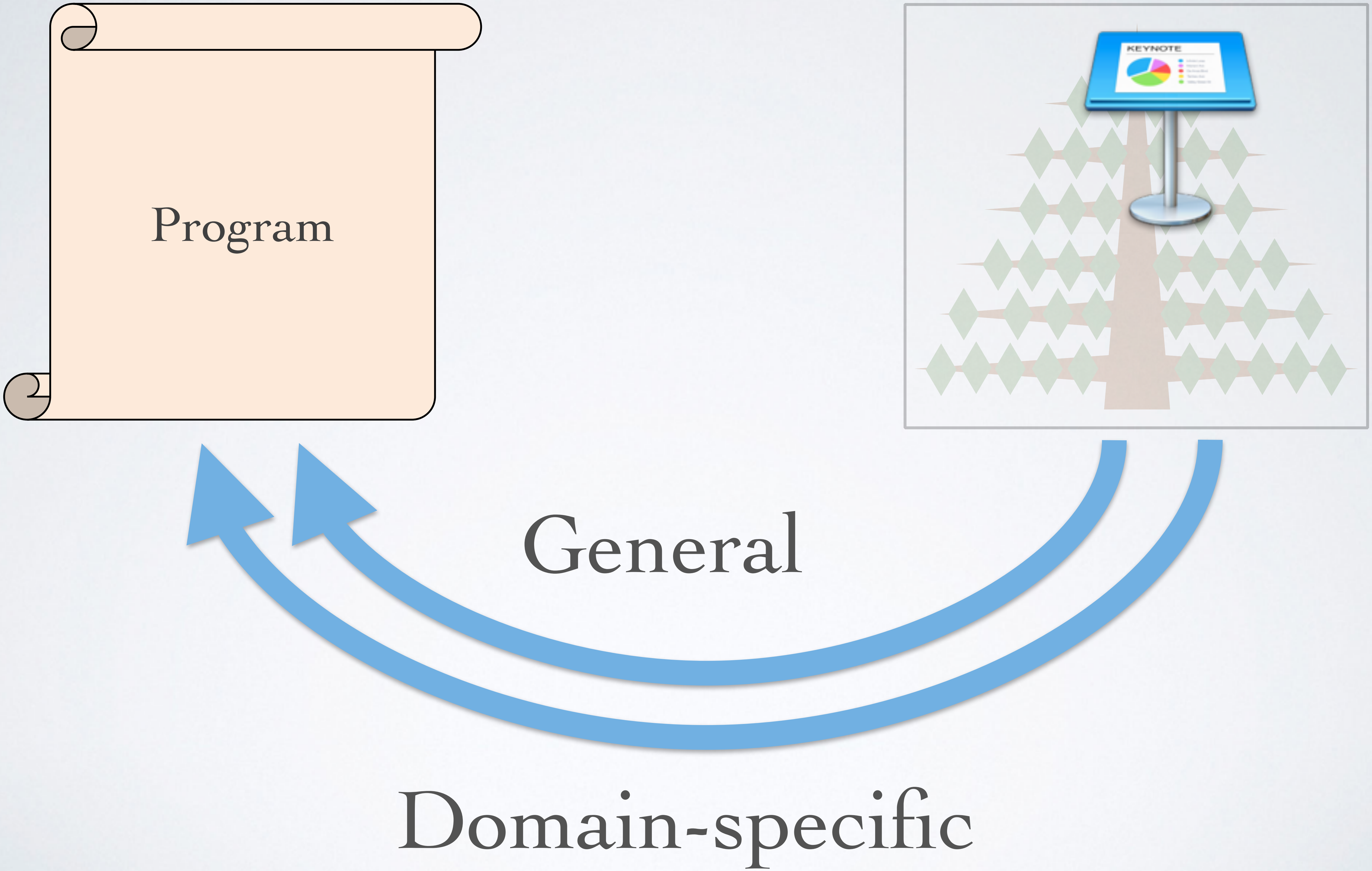
Domain-specific



Program

General

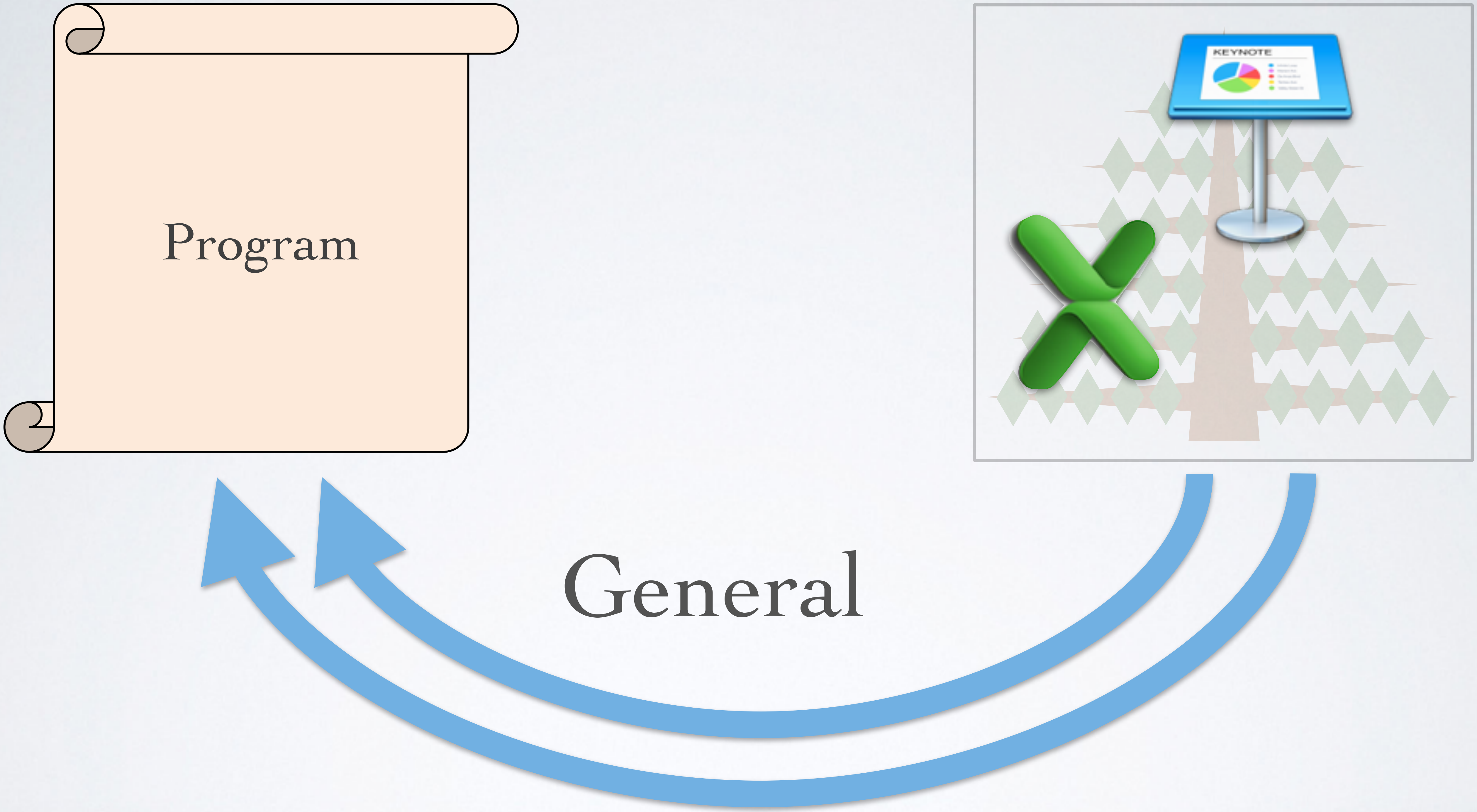
Domain-specific



Program

General

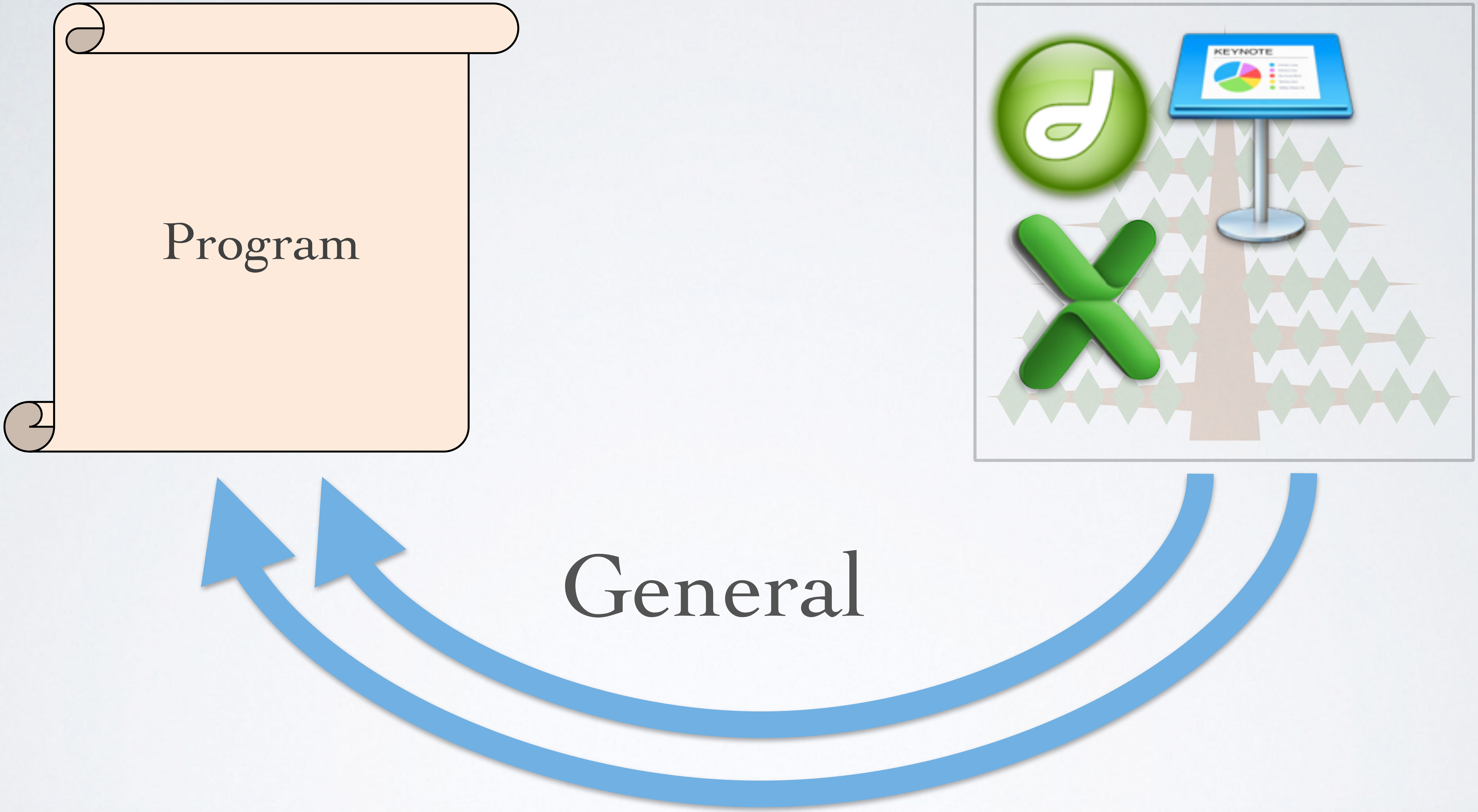
Domain-specific



Program

General

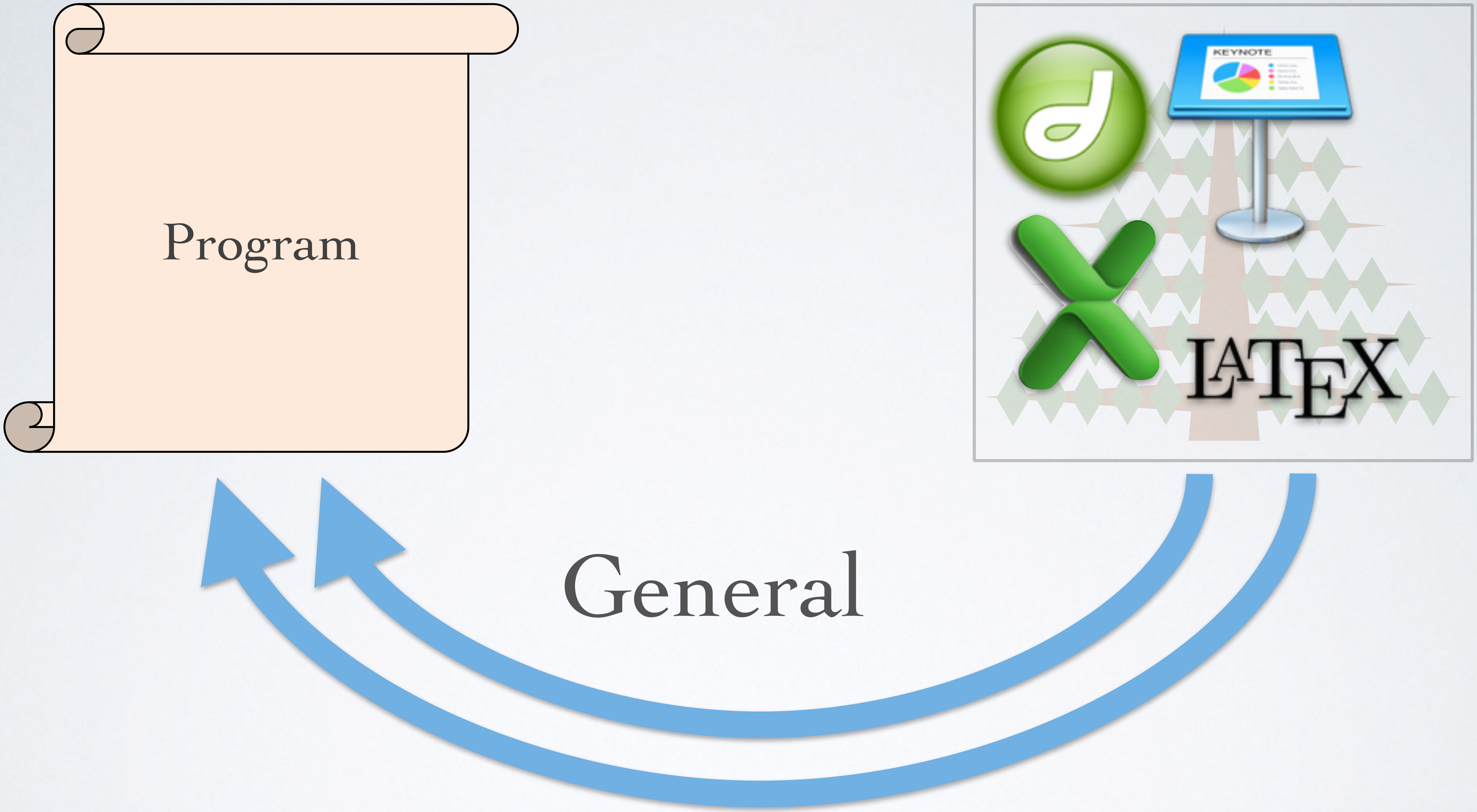
Domain-specific



Program

General

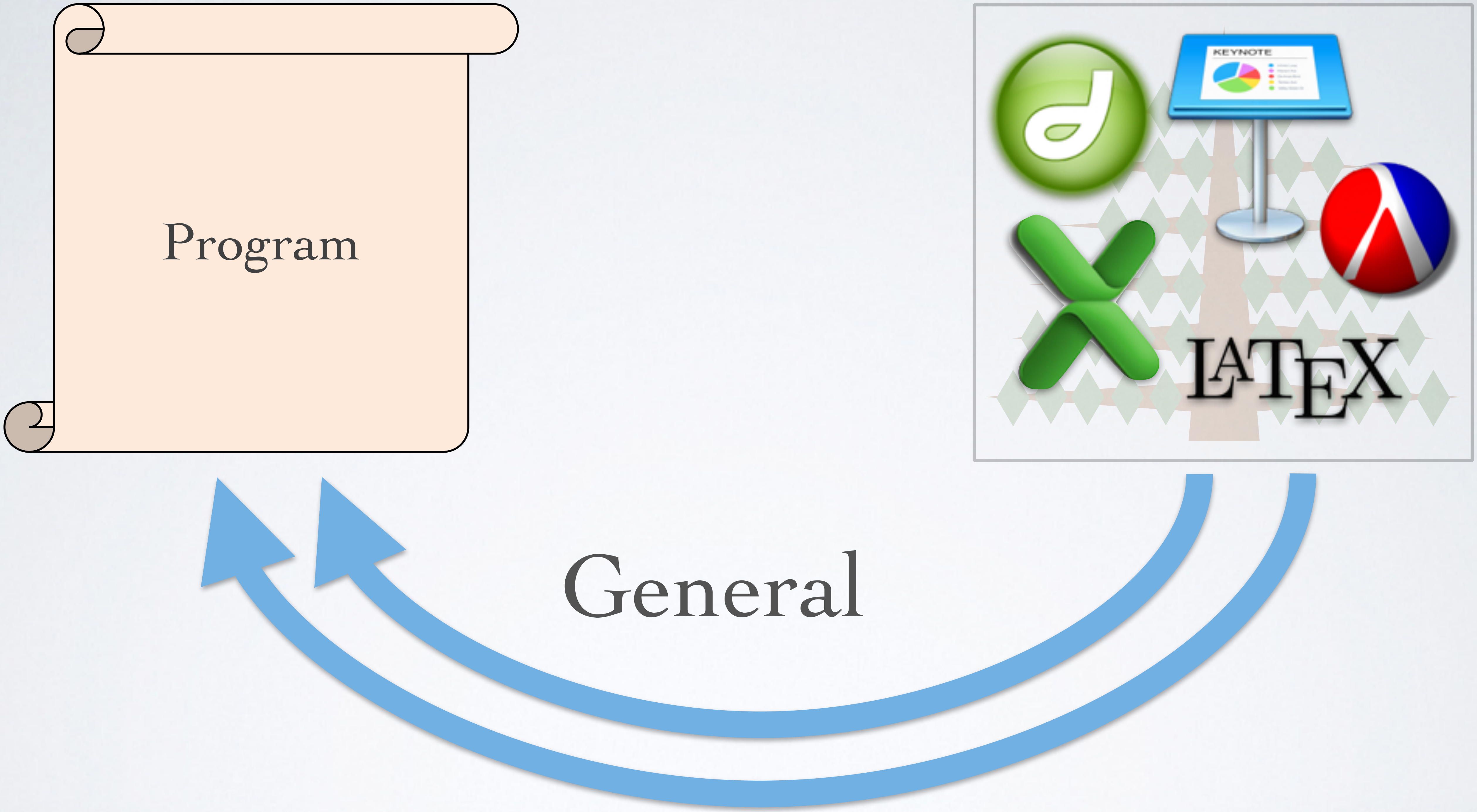
Domain-specific



Program

General

Domain-specific



Program

General

Domain-specific

Related Work

Related Work

DM + Code

DDV
Apparatus

Related Work

DM + Code

DDV
Apparatus

Programming by Example

Chimera
Metamouse
Mondrian

Related Work

DM + Code

DDV
Apparatus

Programming by Example

Chimera
Metamouse
Mondrian

Domain Apps

Parametric CAD
Procedural modeling

Related Work

DM + Code

DDV
Apparatus

Programming by Example

Chimera
Metamouse
Mondrian

Domain Apps

Parametric CAD
Procedural modeling

Constraint Oriented Systems

Sketchpad
ThingLab
Juno-2

Related Work

DM + Code

DDV
Apparatus

Programming by Example

Chimera
Metamouse
Mondrian

Domain Apps

Parametric CAD
Procedural modeling

Constraint Oriented Systems

Sketchpad
ThingLab
Juno-2

Code + DM

Wang et al.
Live PBE
McDirmid's Demos
Sketch-n-Sketch

Our Approach

Start with *general-purpose* language

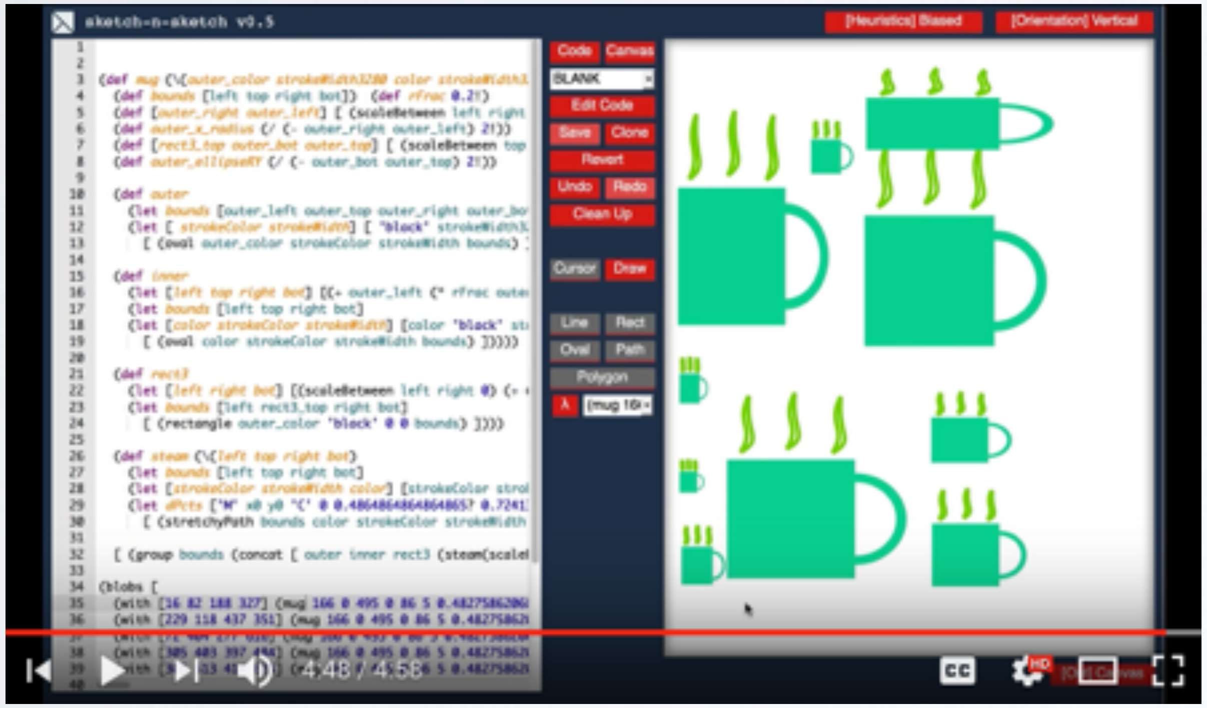
add D.M. features.

Goal:

Less Keyboard, More Mouse.

Sketch-n-Sketch

https://ravichugh.github.io/sketch-n-sketch



```
(def mug (\[outer_color strokeWidth3280 color strokeWidth3
  (def bounds [left top right bot])  (def rfrac 0.2!)
  (def [outer_right outer_left] [ (scaleBetween left right
  (def outer_x_radius (/ (- outer_right outer_left) 2!))
  (def [rect3_top outer_bot outer_top] [ (scaleBetween top
  (def outer_ellipseRY (/ (- outer_bot outer_top) 2!))

  (def outer
    (let bounds [outer_left outer_top outer_right outer_bo
    (let [ strokeColor strokeWidth] [ 'black' strokeWidth3
      [ (oval outer_color strokeColor strokeWidth bounds) ]

  (def inner
    (let [left top right bot] [(+ outer_left (* rfrac oute
    (let bounds [left top right bot]
    (let [color strokeColor strokeWidth] [color 'black' st
      [ (oval color strokeColor strokeWidth bounds) ]))))

  (def rect3
    (let [left right bot] [(scaleBetween left right 0) (+
    (let bounds [left rect3_top right bot]
      [ (rectangle outer_color 'black' 0 0 bounds) ])))

  (def steam (\[left top right bot])
    (let bounds [left top right bot]
    (let [strokeColor strokeWidth color] [strokeColor strol
    (let dPcts ['M' x0 y0 'C' 0 0.486486486486486S? 0.7241
      [ (stretchyPath bounds color strokeColor strokeWidth

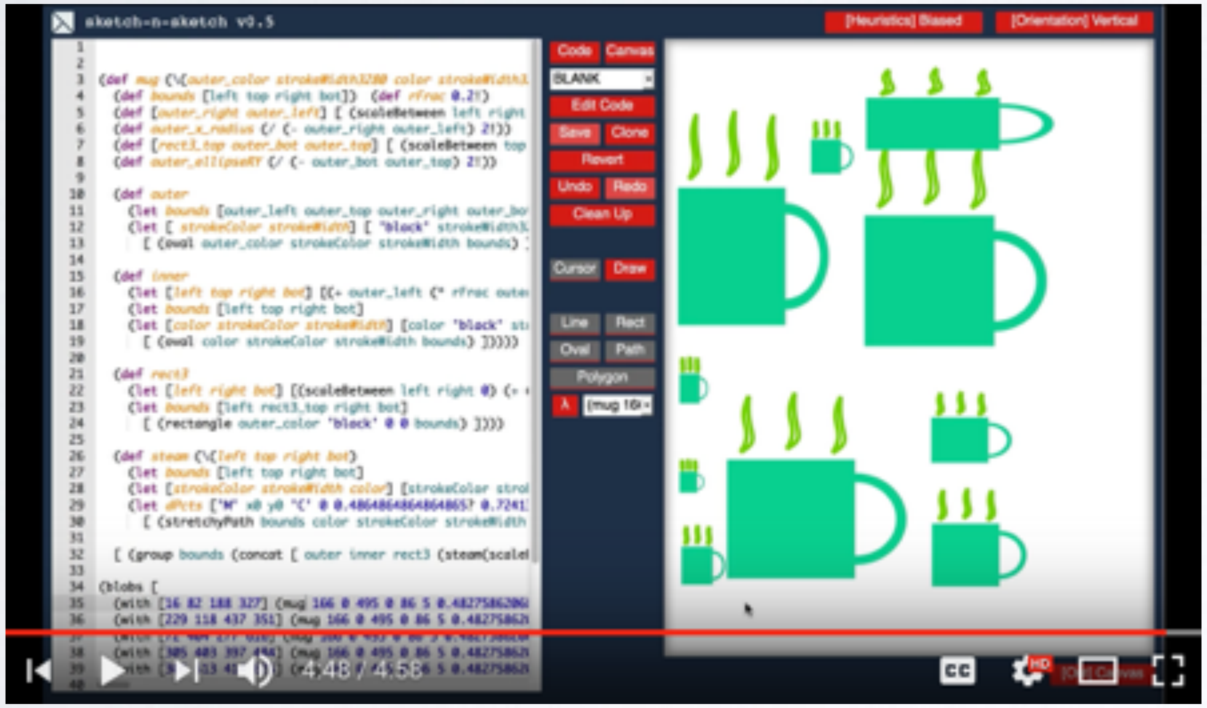
  [ (group bounds (concat [ outer inner rect3 (steam(scale

(blobs [
  (with [16 82 188 327] (mug 166 0 495 0 86 5 0.4827586206
  (with [229 118 437 351] (mug 166 0 495 0 86 5 0.4827586
  [illegible]
  (with [305 403 397 494] (mug 166 0 495 0 86 5 0.4827586
  (with [[illegible]] ([illegible] 6 5 0.4827586
```

Demos on YouTube

Sketch-n-Sketch

https://ravichugh.github.io/sketch-n-sketch



```
(def mug (\[outer_color strokeWidth3280 color strokeWidth1
  (def bounds [left top right bot]) (def rfrac 0.2!)
  (def [outer_right outer_left] [ (scaleBetween left right
  (def outer_x_radius (/ (- outer_right outer_left) 2!))
  (def [rect3_top outer_bot outer_top] [ (scaleBetween top
  (def outer_ellipseRY (/ (- outer_bot outer_top) 2!))

  (def outer
    (let bounds [outer_left outer_top outer_right outer_bo
    (let [ strokeColor strokeWidth] [ 'black' strokeWidth3
      [ (oval outer_color strokeColor strokeWidth bounds) ]

  (def inner
    (let [left top right bot] [(+ outer_left (* rfrac oute
    (let bounds [left top right bot]
    (let [color strokeColor strokeWidth] [color 'black' st
      [ (oval color strokeColor strokeWidth bounds) ]))))

  (def rect3
    (let [left right bot] [(scaleBetween left right 0) (+
    (let bounds [left rect3_top right bot]
      [ (rectangle outer_color 'black' 0 0 bounds) ])))

  (def steam (\[left top right bot])
    (let bounds [left top right bot]
    (let [strokeColor strokeWidth color] [strokeColor strol
    (let dPcts ['M' x0 y0 'C' 0 0.48648648648648657 0.7241
      [ (stretchyPath bounds color strokeColor strokeWidth

  [ (group bounds (concat [ outer inner rect3 (steam(scale

(blobs [
  (with [16 82 188 327] (mug 166 0 495 0 86 5 0.48275862068
  (with [229 118 437 351] (mug 166 0 495 0 86 5 0.4827586
  [illegible]
  (with [305 403 397 494] (mug 166 0 495 0 86 5 0.4827586
  (with [illegible] (mug 166 0 495 0 86 5 0.4827586
```

Demos on YouTube

Just google "sketch n sketch"

Thank you!

Extra Slides

Traces

Traces

```
let a = 3 in
```

Traces

```
let a = 3 in
let b = 5 in
```

Traces

```
let a = 3 in
let b = 5 in
  a + b
```

Traces

```
let a = 3 in
let b = 5 in
    a + b
```

$$\Downarrow$$

Traces

```
let a = 3 in
let b = 5 in
   a + b
```

$\Downarrow$

```
8
```

Traces

$$\texttt{let a = 3}^{\texttt{a}}\texttt{ in}$$

```
let b = 5 in
a + b
```

$$\Downarrow$$

8

Traces

$$\texttt{let a = } 3^{a} \texttt{ in}$$

$$\texttt{let b = } 5^{b} \texttt{ in}$$

$$\texttt{a + b}$$

$$\Downarrow$$

$$8$$

Traces

let a = 3^{a} in

let b = 5^{b} in

a + b

$$\Downarrow$$

$$8^{a+b}$$