Super-fun with First-class Shapes in Quil

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The project

University of Minnesota, Morris (UMM) project on developing Clojure-based introductory CS course (*ClojurEd project*).
More general goal: making Clojure more accessible to beginners and those with no Java background.

1. Beginner-friendly error messages.
2. Libraries and tools that allow beginners to explore functional approaches, recursion, and abstraction.
3. Integration into a beginner-friendly IDE.

Beginner-friendly graphical library

Inspiration: Racket "universe" package http://racket-lang.org/

- Separation of Model, View, Control (MVC)
- Functional implementation of MVC: world state, functions:
  old world state $\rightarrow$ new world state
  world state $\rightarrow$ image
- First-class shapes (circles, rectangles, user-added jpegs, etc)
  not attached to any position
- Functions to combine simpler shapes into complex shapes:
  `above, beside, overlay, scale...`

World States in Quil

- Using Nikita Beloglazov's Quil fun-mode (functional MVC)
- State as a HashMap
- Producing a new state on each frame and in event handlers

```
(defn setup []
  {:screen 0
   :speed 1
   :level 1
   :box-1-points 0
   :box-2-points 0
   :box-1-pos {:x 0 :y (- (q/height) 50)}
   :box-2-pos {:x (- (q/width) 50) :y (- (q/height) 50)}
   :rocks []
   :hit-player 0})
```

- fun-mode + first class shapes = super-fun!

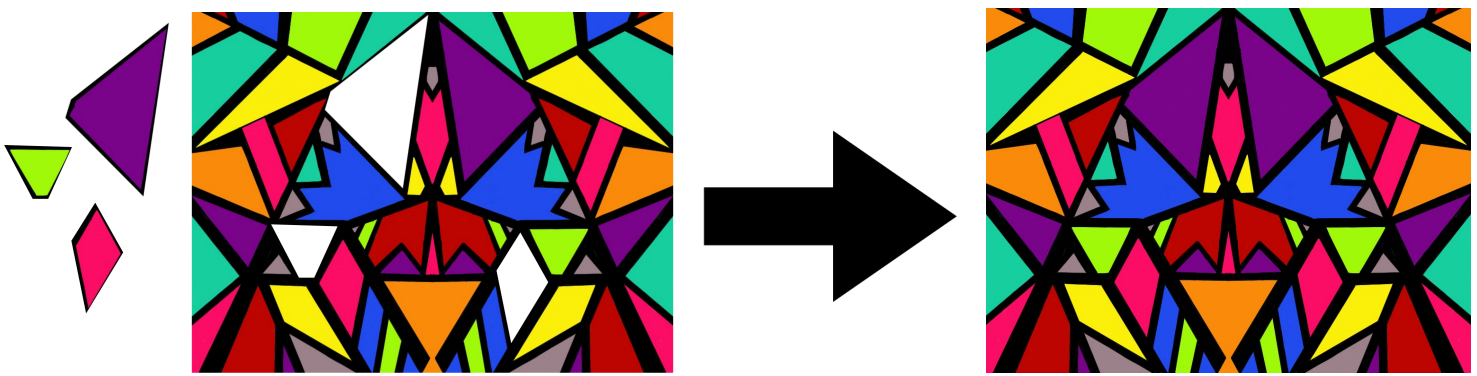
Shapes as First Class Objects

- Racket-style implementation of shapes
- Shapes are treated as objects, are combined with functions
- Shapes hold their specifications for drawing
- Easy to draw wherever needed
- Easier to understand conceptually for beginners

Creating a Collage

- Functional Quil uses paintbrush approach

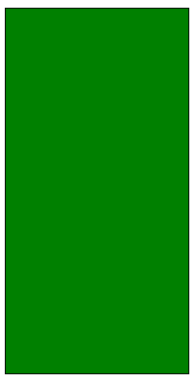
- Our firstclass-shapes use collage approach



Simple Shapes

- Quil shapes only exist in draw function, they are instructions, not objects
- Quil shapes do not exist until they are drawn
- They are not separable from their position

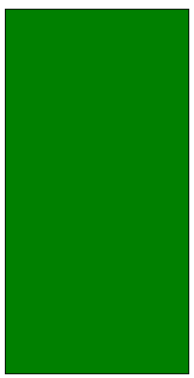
```
(defn draw-state [state]
  (q/background 100)
  (q/fill 0 255 0)
  (q/rect 300 300 100 200))
```



Our Shapes

- Our shapes are defined once in setup and reused when needed
- Our shapes are drawn through the ds (draw-shape) function

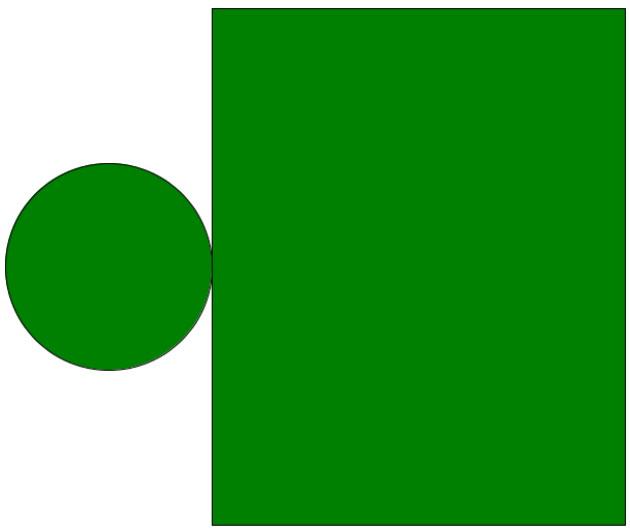
```
(def green-rectangle
  (create-rect 100 200 :green))

(defn draw-state [state]
  (q/background 100)
  (ds green-rectangle 300 300))
```



Complex Shapes

- Complex shapes are a collection of simple shapes
- Each simple shape holds their individual offsets
- Methods are used to create complex shapes from simple ones

```
(def object
  (beside green-circle
          green-rect))

(defn draw-state [state]
  (q/background 255)
  (ds object 500 500))
```

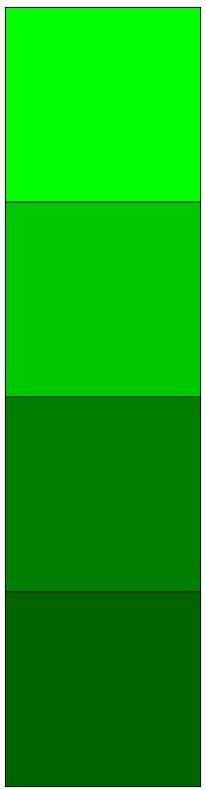


Above and Beside

- Complex shapes are constructed through calling above or beside
- Reduce can be used for similar effect

```
(def green-scale-rects
  (above lime-green-rectangle
         light-green-rectangle
         green-rectangle
         dark-green-rectangle))
```

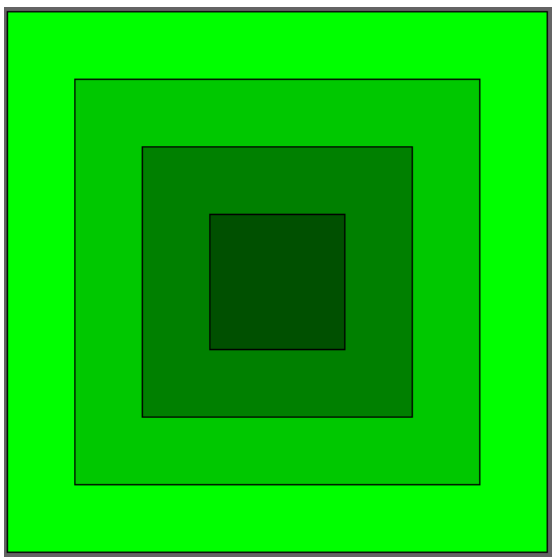
```
(def green-scale-rects-reduce
  (reduce above [lime-green-rectangle,
                 light-green-rectangle,
                 green rectangle,
                 dark-green-rectangle])
```



Overlay

- Complex shapes are also constructed through overlay

```
(def green-pyramid
  (overlay top-dark-green-rectangle
           middle-top-green-rectangle
           middle-bottom-green-rectangle
           bottom-green-rectangle))
```

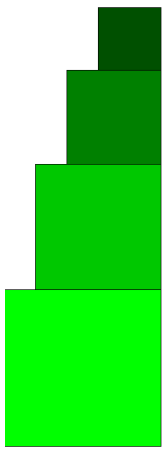


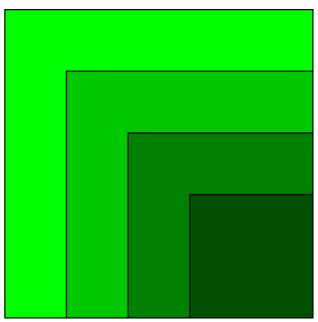
Align

- An align version of overlay, above, and beside exist

```
(def green-lean-right
  (above-align :right
               green-rectangle-top
               green-rectangle-middle
               green-rectangle-support
               green-rectangle-base))
```

```
(def green-align-bottom-right
  (overlay-align :bottom :right
                 dark-green-rectangle-close
                 green-rectangle-step-1
                 green-rectangle-step-2
                 green-rectangle-far))
```



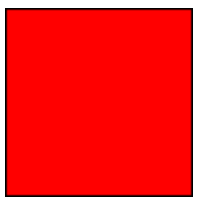


Rotation and Scaling

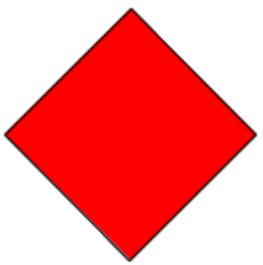
- You can modify the size and orientation of the shape

```
(rotate-shape red-square 45)
```

```
(scale-shape red-square 2 2)
```



```
(rotate-shape (scale-shape red-square 2 2) 45)
```



Images

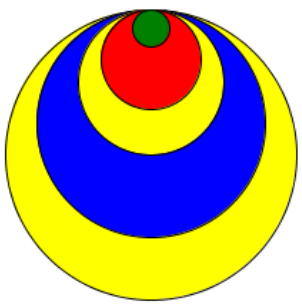
- images can be rotated and scaled similar to shapes

```
(def cool-picture
  (create-picture "src/images/kappa.png"))

(def black-box
  (create-rect 100 50 :black))

(def on-box
  (above (scale-shape cool-picture 2 2)
         black-box))
```

Code Comparison

- Quil code vs our code

```
(defn draw-state [state]
  (q/background 255)
  (q/fill 255 255 0)
  (q/ellipse 500 500 204 204)
  (q/fill 0 0 255)
  (q/ellipse 500 482 160 160)
  (q/fill 255 255 0)
  (q/ellipse 500 453 102 102)
  (q/fill 255 0 0)
  (q/ellipse 500 437 70 70)
  (q/fill 0 128 0)
  (q/ellipse 500 415 26 26)
  (q/no-fill))
```



```
(defn setup []
  (def green-ring (create-ellipse 26 26 :green))
  (def red-ring (create-ellipse 70 70 :red))
  (def yellow-ring (create-ellipse 102 102 :yellow))
  (def blue-ring (create-ellipse 160 160 :blue))

  (def color-ring
    (overlay-align :top :center
                   green-ring
                   red-ring
                   yellow-ring
                   blue-ring
                  (scale-shape yellow-ring 2 2))))
```

Simple Shape Structure

- As a data structure, simple shapes are hashes
- Shapes hold a variety of information within them

```
(defn create-rect
  [w h & colors]
  {:width w
   :height h
   :complex-width w
   :complex-height h
   :dx 0
   :dy 0
   :angle 0
   :internal-ds-function
   (fn [x-pos y-pos picture width height current-stroke angle]
     (if (> (count colors) 0)
       (apply f-fill colors)
       (no-fill))
     (with-translation [x-pos y-pos]
       (with-rotation [(/ (* PI angle) 180)]
         (f-rect 0 0 width height)))
     (no-fill))})
```

Complex Shape Structure

- Complex shapes are vectors of simple shapes
- Each shape knows its position from the center of the shape
- This is different from Racket's implementation
- This allows for the ability to alter individual simple shapes

Draw-Shape Structure

- Draw-shape calls the internal Quil draw function within the shape object
- Draw-shape also works on image objects

```
(defn ds
  [shape x-pos y-pos]
  (if (not (vector? shape))
    ((:internal-ds-function shape) x-pos y-pos
     (:real-picture shape) (:width shape) (:height shape)
     (current-stroke) (:angle shape))

    (doall (map #((:internal-ds-function %) (+ x-pos (:dx %))
                  (+ y-pos (:dy %)) (:real-picture %) (:width %)
                  (:height %) (current-stroke) (:angle %)) shape))))
```

Future Work

- Fix bugs!
- Make it easy to get the color information from shapes (currently color is hard-wired in drawing function)
- Add more functionality
  - Add the ability to get the color of a simple shape
  - Rotate complex shapes
  - Pixel-detail Overlay and Overlay-Align
  - Add support for text, textareas, etc.
  - More seamless integration with Quil fun-mode
- Add examples to the git repo
- Wish-list: Integrate overtone (music library)

Where to find it

- Clojars Page https://clojars.org/org.clojars.quil-firstclass-shapes/firstclassshapes [org.clojars.quil-firstclass-shapes/firstclassshapes "0.0.1"]
- Github Page https://github.com/Clojure-Intro-Course/quil-firstclass-shapes

Related and Similar Work

Similar (completely independent) work: first-class shapes by Tom Hall, EuroClojure 2014, based on geomlab library. Used for educational purposes (just like ours).

Prior work: Max Magnuson and Paul Schliep (UMM CS 2015 alums) developed earlier ideas for this project in 2013/14.

Acknowledgments

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hhmi | Howard Hughes Medical Institute

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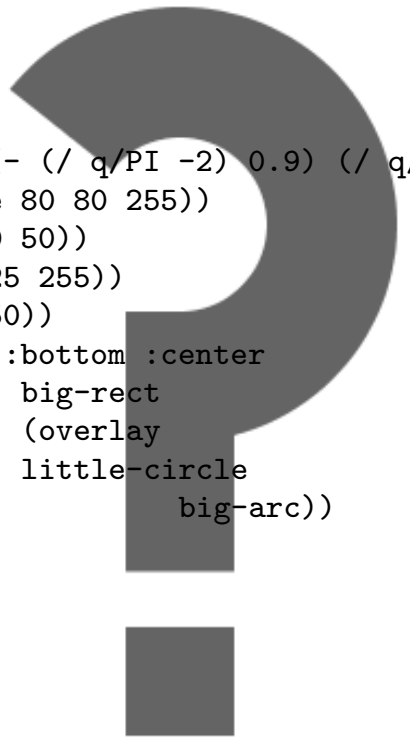
Questions?



```
(defn setup []
   (q/frame-rate 60)
   (q/color-mode :rgb)
   (def big-arc (create-arc 200 200 (- (/ q/PI -2) 0.9) (/ q/PI 2) 50))
   (def little-circle (create-ellipse 80 80 255))
   (def small-rect (create-rect 50 50 50))
   (def white-space (create-rect 50 25 255))
   (def big-rect (create-rect 50 60 50))
   (def q-mark (above (overlay-align :bottom :center
                                     big-rect
                                     (overlay
                                     little-circle
                                             big-arc))
                      big-rect
                      white-space
                      small-rect))
    {})

  (defn update-state [state] {})


 (defn draw-state [state]
  (q/background 255)
  (q/no-stroke)
  (ds q-mark 500 500))
```