# Improving Clojure Usablilty for Introductory Course

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# Goals

- Integrate Clojure into an introductory CS class
- Currently use Racket
  - Limited teaching language
  - Difficult to make complex projects
  - Graphics performance issues

# Why use Clojure?

- Used in industry
- Better on resume
- Support for concurrency
- Large community and excellent resources
- Excellent libraries (data processing, image recognition, graphical, musical)

# Issues with Clojure

- Confusing error messages
- Lack of beginner-friendly graphics libraries in functional style
- Some misleading or confusing core functions (`conj`, `some`, `for`, string functions)

# Error Messages

- Computers are literal
- Error messages are the only way to communicate when something goes wrong
- By the time an error is detected, a lot of the context is lost

# Error Messages for Beginners

- Use terminology that beginners haven't been introduced to
- Beginner mistakes can lead to very complex errors
- Beginners don't read error messages
- Line number reporting needs to be accurate
- Very little (if any) systematic usability study of error messages
- Good error messages should lead to a correct fix (study of Racket error messages)

# Clojure Error Messages

- Java exceptions
- Use not only Java types, but Java terminology: "cannot be cast", "null pointer"
- Very verbose
- Stack traces are long
- Compiler messages come with a separate cause

# Example Clojure Error

```
Exception in thread "main" clojure.lang.ArityException:
Wrong number of args (3) passed to: core/cons, compiling:
(/tmp/form-init3025539740275626138.clj:1:72)
at clojure.lang.Compiler.load(Compiler.java:7142)
at clojure.lang.Compiler.loadFile(Compiler.java:7086)
at clojure.main$load_script.invoke(main.clj:274)
at clojure.main$init_opt.invoke(main.clj:279)
at clojure.main$initialize.invoke(main.clj:307)
at clojure.main$null_opt.invoke(main.clj:342)
at clojure.main$main.doInvoke(main.clj:420)
at clojure.lang.RestFn.invoke(RestFn.java:421)
at clojure.lang.Var.invoke(Var.java:383)
at clojure.lang.AFn.applyToHelper(AFn.java:156)
at clojure.lang.Var.applyTo(Var.java:700)
at clojure.main.main(main.java:37)
```

# Our Error Messages

- We are not changing language definition
- A combination of two approaches:
  - Approach 1: overwrite common functions (`map`, `filter`, `+`) to add pre-conditions for precise parameter reporting
  - Approach 2: catch exceptions, match and replace the error message
- Filter the stack trace
- Avoid unfamiliar terminology
- Consistency within error messages
- Readable and short
- Future direction: adding hints for common sources of errors

# Iterations of Error Message Phrasing

```
Exception in thread "main" clojure.lang.ArityException:
Wrong number of args (3) passed to: core/cons, compiling:
(intro.core/-main.clj:108:1)

Error: Wrong number of arguments (3) passed to a function cons.
Found in file core.clj on line 108 in function -main.
intro.core/-main (core.clj line 108)

Error: You cannot pass three arguments to a function cons, need
two.
Found in file core.clj on line 108 in function -main.
intro.core/-main (core.clj line 108)
```

# Unified Phrasing

Original:

- `let requires an even number of forms`
- `Vector arg to map conj must be a pair`

New:

- `Parameters for let must come in pairs, but one of them does not have a match.`
- `Each inner vector must be a pair: a key followed by a value.`

# Printing Arguments

- Asserts for functions:
  `Error: in function map the first argument 2 must be a function but is a number.`
- How about this?
  `Error: in function map the second argument clojure.core$_STAR_ must be a sequence, but is a function`
  Function name processing: `the second argument *...`

# Printing Arguments (cont.)

- But what about `(map (range) inc)`?
  `In function +, the second argument clojure.lang.LazySeq@22 must be a number but is a sequence.`
  `In function +, the second argument (0 1 2 3 4 5 6 7 8 9...) must be a number but is a sequence.`
- Challenges (work in progress):
  - `(repeat (range))` - infinite sequence of infinite sequences
  - How many levels do we evaluate?
  - Need to evaluate arguments recursively: `(clojure.core$_STAR_)` should be `(*)`.

# Current Work

- Syntax errors vs. runtime errors
- Reporting line numbers
  - Sometimes a part of the message
  - Sometimes a part of the stacktrace
  - Sometimes neither
  - Different line number reporting for different methods of evaluation
- Common sources of errors (hints)

# Future Work on Error Messages

- Integrating with an IDE and REPL
- User feedback loop
- Usability studies

# What is Quil?

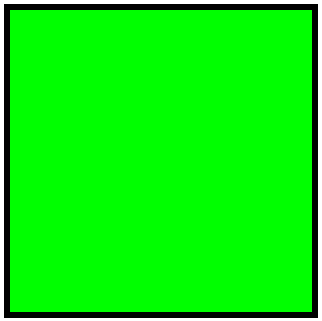
- Graphical Library for Clojure
- It can:
  - Draw shapes and images
  - Move objects on the screen
  - Make games, pictures, ect..

```
fun-mode
^

Quil
^

Clojure
^

Java
```

# Quil's fun-mode isn't enough

- Quil ONLY takes draw commands
- Quil doesn't separate the model from the view
- Quil code can get confusing and long

```
(q/fill 80 255 80)
(q/rect 100 100 50 50)
(q/no-fill)
(q/no-stroke)
```



# Designing super-fun-mode

- Built on top of fun-mode
- Gives students functions, colors, images, ect..
- Easy to read and change program code
- Allows for easy complex shapes

```
super-fun-mode
^
fun-mode
^
Quil
^
Clojure
^
Java
```

# How super-fun-mode works

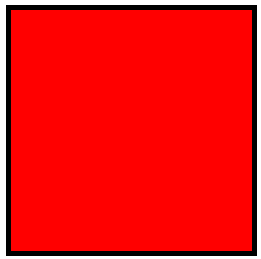
- You start by creating a shape

```
(def red-square
  (create-rect 50 50 :red))
```

- Note that creating a shape does not draw it

- From there, you can draw the shape

```
(draw-shape red-square 500 500)
```



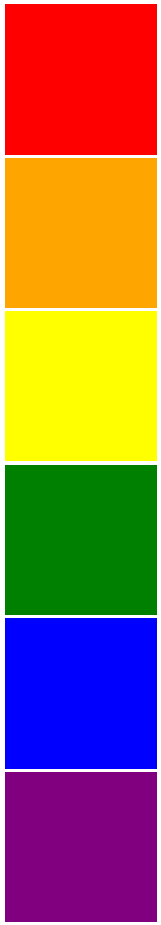
# How super-fun-mode works technically

- Underneath, super-fun-mode builds a hashmap or a vector of hashmaps (in the case of complex shapes) with holds relevant information including:
  - The shape's width and height
  - The complex shape's width and height
  - The rotation angle of the shape
  - The function to draw the shape

# super-fun-mode complex shapes

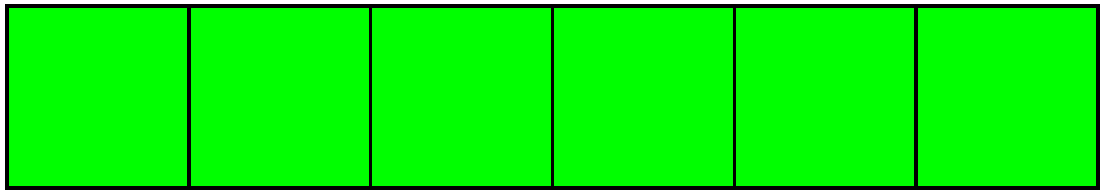
- You can put shapes together to make complex shapes

```
(def tower
     (above red-square
            orange-square
            yellow-square
            green-square
            blue-square
            violet-square))
```



# Six squares

- The difference becomes quite apparent with complexity



# Quil code

```
(let [x 100
      numb 6
      dist (+ 100 (* (\ numb 2) 50))]
  (q/fill 80 255 80)
  (q/rect (- dist (* 1 50)) 100 50 50)
  (q/rect (- dist (* 2 50)) 100 50 50)
  (q/rect (- dist (* 3 50)) 100 50 50)
  (q/rect (- dist (* 4 50)) 100 50 50)
  (q/rect (- dist (* 5 50)) 100 50 50)
  (q/rect (- dist (* 6 50)) 100 50 50))
(q/no-fill)
```

# Our code

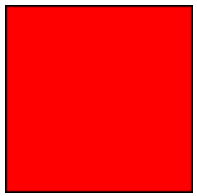
```
(def lime-rect
  (create-rect 50 50 :lime))

(def lime-rectangles
  (beside
    lime-rect lime-rect lime-rect
    lime-rect lime-rect lime-rect))
```

# Rotation and scaling

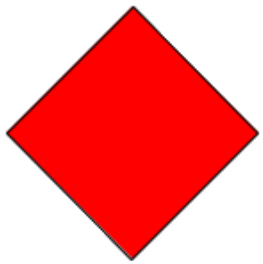
- You can modify the size and orientation of the shape

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

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



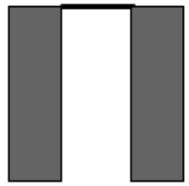
```
(rotate-shape
  (scale-shape red-square 2 2)
 45)
```



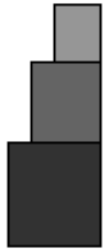
# Other complex functions

- You can orient your besides and aboves as well

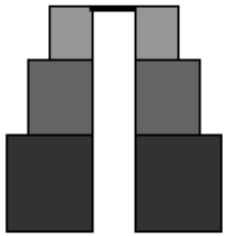
```
(beside-align :top
              tower
              tight-rope
              tower)
```



```
(above-align :right
             block1
             block1.3
             block1.6)
```



```
(beside-align :top
              tower-aligned-R
              tight-rope
              tower-aligned-L)
```



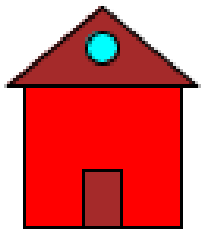
# Overlaying and complex shapes

- You can put shapes on top of each other

```
(overlay window roof)
```

```
(overlay-align :bottom :center
     door
     red-rect)
```

```
(scale-shape
  (above top bottom)
1.4 1.4)
```



# The draw-shape function

- Draw-shape (or ds, either work) is the function that takes in these shapes objects and draws them at a given x y position.

```
(draw-shape
   (create-rect 200 200 :red)
   400 400)

(ds (above circle
            triangle)
     100 100)

(draw-shape
 (beside box1
         box2)
  400 200)
```

# Inside a rectangle

```
{:w w
 :h h
 :tw w
 :th h
 :dx 0
 :dy 0
 :angle 0
 :ds (fn [x y pict wid hei cs angle]
       (*large cond to check fill/stroke here*)
       (with-translation [x y]
         (with-rotation
           [(/ (* PI angle) 180)]
           (f-rect 0 0 wid hei)))
       (no-fill))}
```

# Our direction

- Less paintbrush, more collage
- Create shapes, not just draw them
- Easier student code
- Give students an idea of how good software should be built

# A few examples

Please Enjoy a Few Live Examples

# Future work

- Fill out more functionality
  - Rotate more complex shapes
  - Pixel-detail Overlay and Overlay-Align
  - More seemless integration with Quil fun-mode
- Open Source the project
- Integrate a Clojure sound library

# Acknowledgments

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Thank you!
Any questions?