Reference Guide for Stack Tracing Scala

April 5, 2022

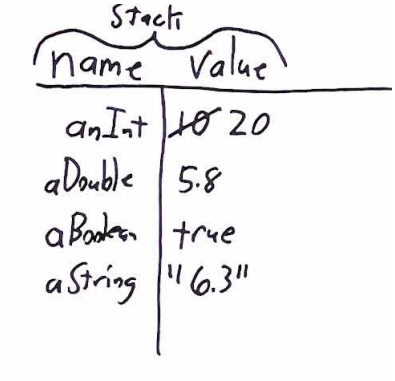
FYI

- Only a single color is required for memory diagrams, different colors are used (and order written into code) for greater clarity in this document

1 Basic variables

```
var anInt: Int = 10
var aDouble: Double = 5.8
var aBoolean: Boolean = true
var aString: String = "6.3"
anInt=20
```

- variable changes result in previous values being crossed out and new ones written in so that progression can be seen



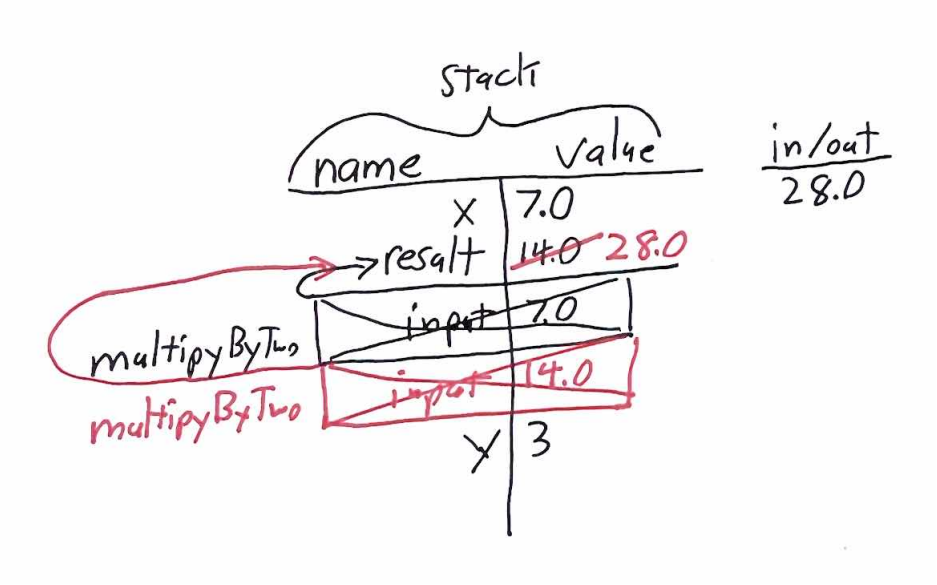
2 Function calls

2.1 Return value

```
def multipyByTwo(input: Double): Double={
  input * 2.0
}

def main(args: Array[String]): Unit = {
  var x: Double = 7.0
  var result = multipyByTwo(x)
  result = multipyByTwo(result)//done in red
  println(result)
  var y: Int = 3
}
```

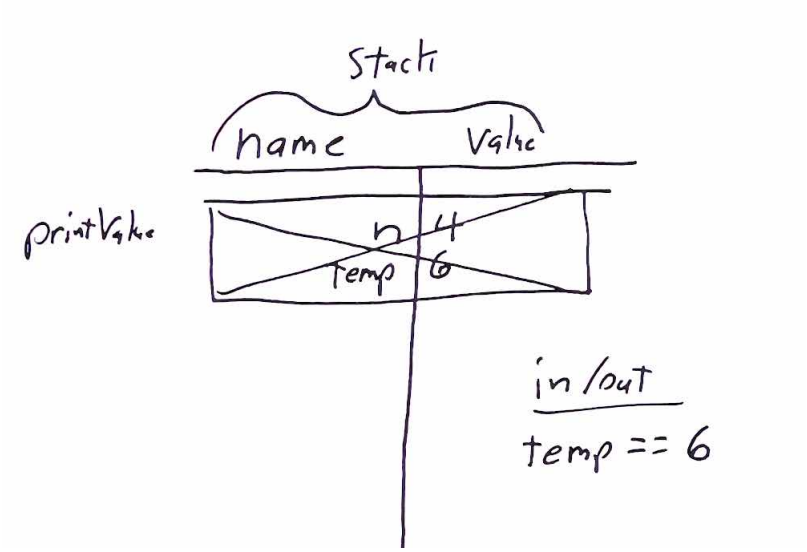
- each function call is put in its own stack frame
- variables created after the function call appear further down the stack
- in/out stands for input/output and is where any command line user input or outputs in terms of print statements appear



2.2 No (Unit) return value

```
def printValue(n: Int): Unit = {
  var temp: Int=n+2
  println("temp == " + temp)
}

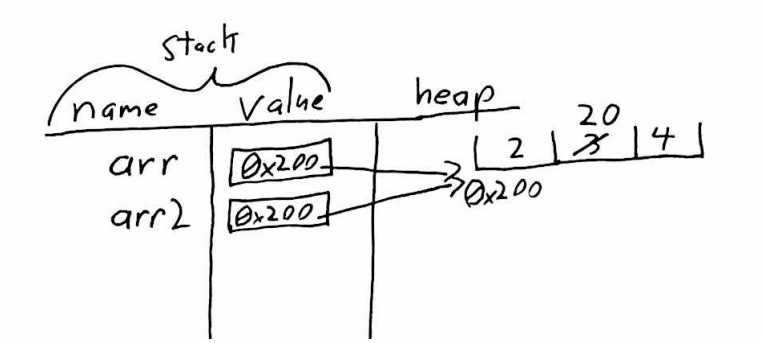
def main(args: Array[String]): Unit = {
  printValue(4)
}
```



3 Arrays

```
val arr: Array[Int] = Array(2, 3, 4)
val arr2: Array[Int] = arr
arr(1) = 20
```

- not that the assignment statement on the second line assigns the memory address and does not do a deep copy
  - this point is emphasized for newer programmers
- memory addresses all start with 0x to indicate that they are hexadecimal numbers.
  - heap addresses are typically given 3 digit numbers
  - numbers are typically written in decimal as it is easier for students to grasp at first (as they are not familiar with hexadecimal, this detail will be corrected in later courses)
  - numbers are randomly generated and just must agree on the stack and heap

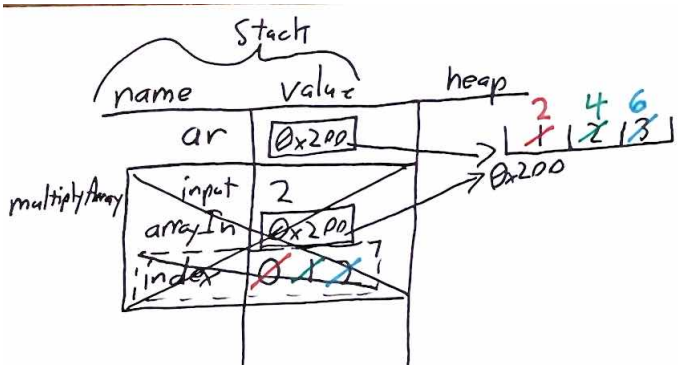


3.1 Passed to functions

```
def multiplyArray(input: Int,arrayIn: Array[Int]): Unit={
    for (index <-0 to (arrayIn.length -1)) {
      arrayIn(index)*=input //passes are red,green,blue in trace
    }
  }

  def main(args: Array[String]): Unit = {
    var ar : Array[Int]=Array(1,2,3)
    multiplyArray(2,ar)
  }
```

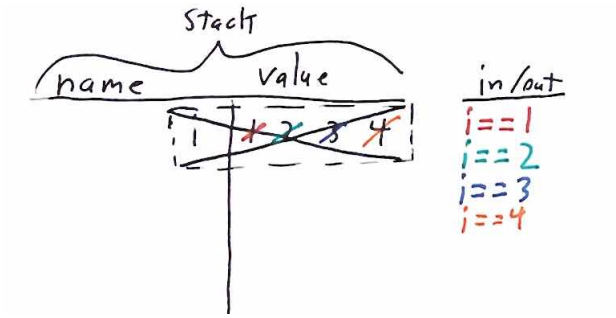
- multiplyArray is a function that utilizes sides effects
- when passing variables to functions as arguments the value on the stack associated with the variable name is the argument to the function that sets the parameter
- the dashed lines around index indicate that it is a scoped variable that only exists while the loop exists



4 For loops

4.1 basic

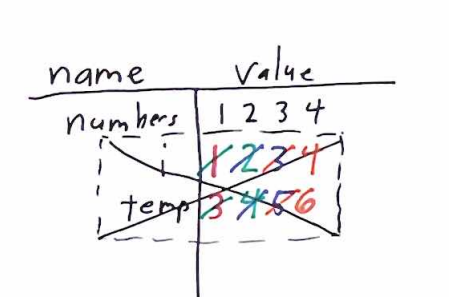
```
for(i <- 1 to 4){
  println("i == " + i)//passes are red,green,blue,orange in trace
}
```



4.2 over range

```
val numbers: Range = 1 to 4
for (i <- numbers) //passes are red,green,blue,orange in trace{
  var temp: Int=i+2
}
```

- range is a special case but we will simplify to draw it as a series of values on the stack
- scoped variables within the loop are crossed out after the loop completes



5 Lists

```
var list: List[Int] = List(2, 3, 4)

val x: Int = list.head

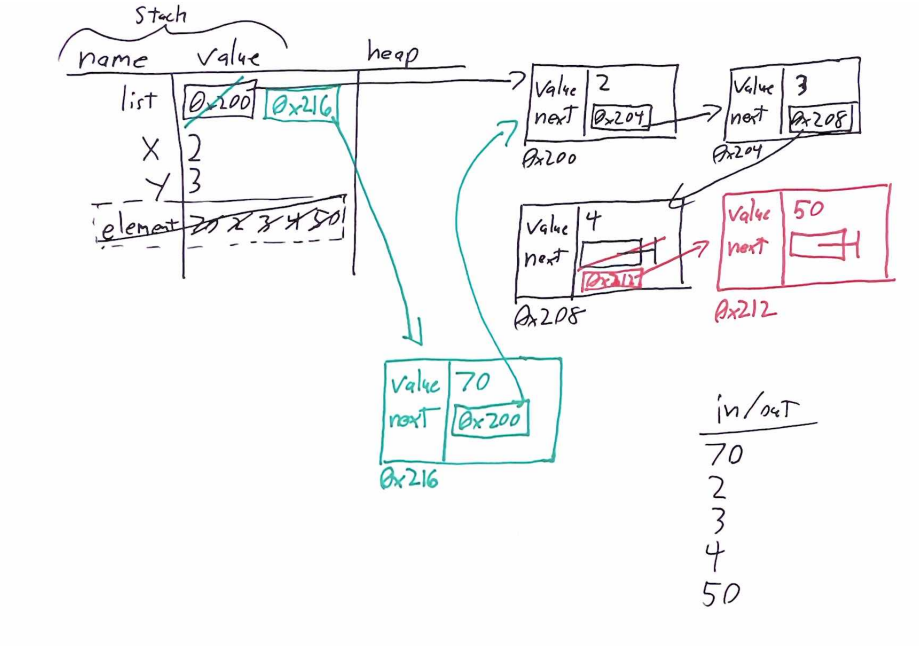
val y: Int = list.apply(1)

list = list :+ 50 //red

list = 70 :: list //green

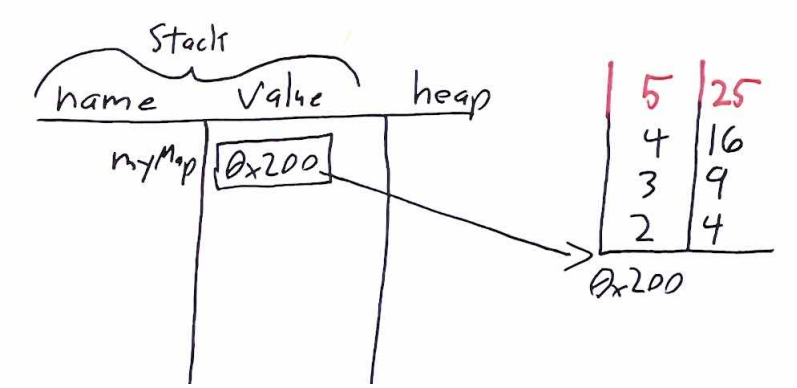
for(element <- list){
  println(element)
}
```

- input/output (in/out) can be anywhere on the page
- the positions and layout of material on the heap does not matter



6 Maps

```
var myMap: Map[Int, Int] = Map(2 -> 4, 3 -> 9, 4 -> 16)
myMap = myMap + (5 -> 25)//red
```



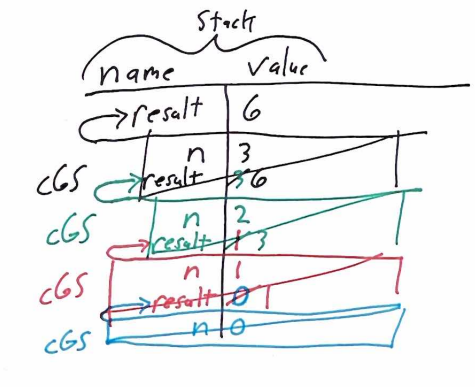
7 Recursion

7.1 standard recursion

```
def computeGeometricSum(n: Int): Int ={ //cGS in trace
  if(n>0) {
    var result: Int = computeGeometricSum(n - 1)
    result += n
    result
  }else{
    0
  }
}

def main(args: Array[String]): Unit = {
  val result: Int = computeGeometricSum(3)
  println(result)
}
```

- each new call of cGS is performed in a new color
  - returned values are kept in the color of the method that returns it

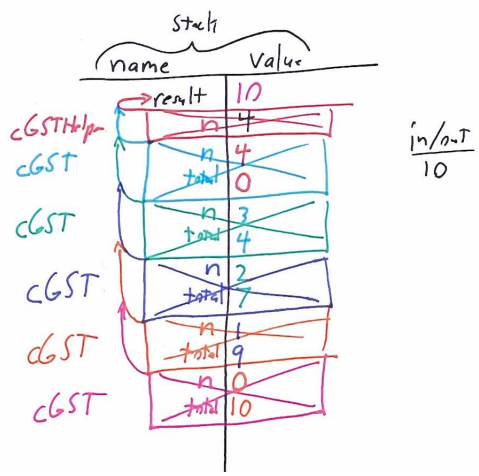


7.2 Tail recursion

```
def computeGeometricSumTail(n:Int, total:Int):Int={
  if (n>0){
    computeGeometricSumTail(n-1,total+n)
  } else {
    total
  }
}
def cGSTHelper(n:Int):Int={
  computeGeometricSumTail(n,0)
}

def main(args: Array[String]): Unit = {
  val result=cGSTHelper(4)
  println(result)
}
```

- each new call of cGST is performed in a new color
  - returned values are kept in the color of the method that returns it
- Note that the returns go to the previous functions return and not a variable
  - this is why the memory of a stack frame can be released before the following recursive function call finishes



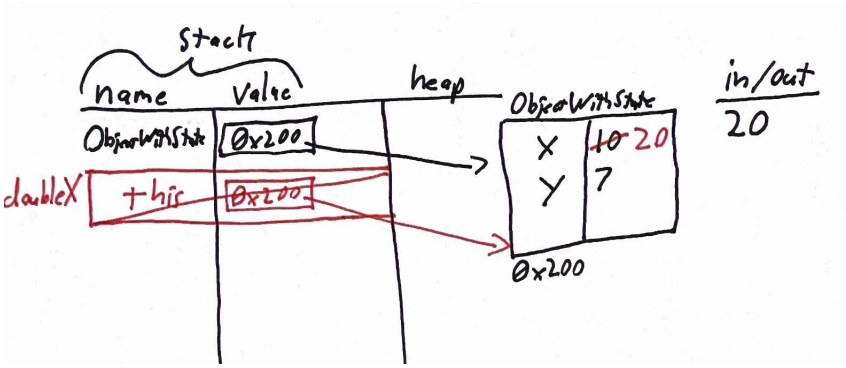
8 Objects-singleton

```
object ObjectWithState {
  // State of the object
  var x: Int = 10
  var y: Int = 7

  // Behavior of the object
  def doubleX(): Unit = {
    this.x *= 2
  }

  def main(args: Array[String]): Unit = {
    ObjectWithState.doubleX()
    println(ObjectWithState.x)
  }
}
```

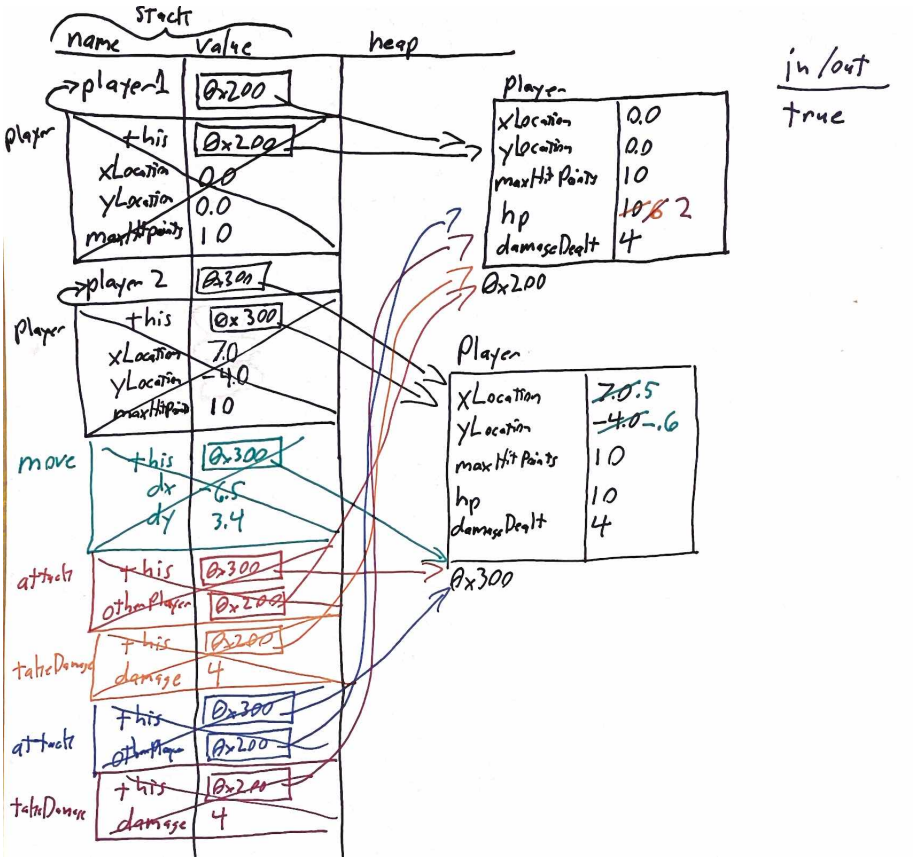
- objects that are singleton are created on the heap when first called and stack reference is made to them



9 Classes

```
class Player (var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {
  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4
  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }
  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damageDealt)
  }
  def conscious(): Boolean = {
    this.hp > 0
  }
  def move(dx: Double, dy: Double): Unit = {
    this.xLocation += dx
    this.yLocation += dy
  }
}
```

- ```
  object RunPlayer {
    def main(args: Array[String]): Unit = {
      val player1: Player = new Player(0.0, 0.0, 10)
      val player2: Player = new Player(7.0, -4.0, 10)
      player2.move(-6.5, 3.4)
      player2.attack(player1)
      player2.attack(player1)
      println(player1.hp == 2)
    }
  }
  ```


  ```

10 Inheritance

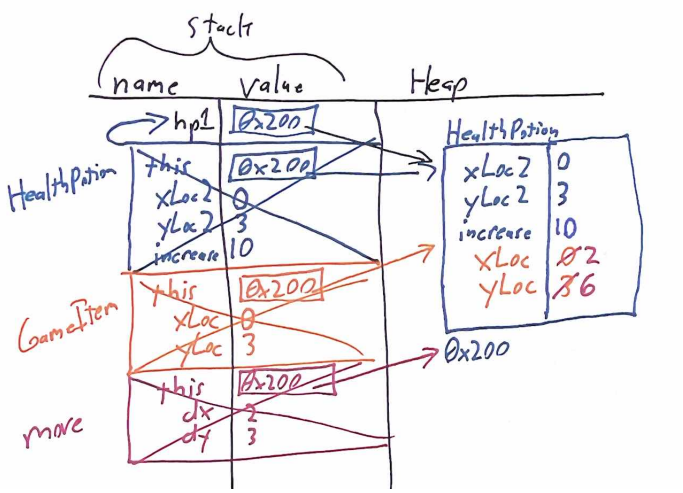
```
abstract class GameItem (var xLoc:Double, var yLoc:Double){
  def use(player: Player): Unit

  def move(dx:Double, dy:Double):Unit={
    this.xLoc+=dx
    this.yLoc+=dy
  }
}
```

- ```
  class HealthPotion (xLoc2:Double, yLoc2:Double, var increase:Int)
        extends GameItem (xLoc2, yLoc2){

    override def use(player: Player): Unit = {
      player.health+=this.increase
    }
  }

  object RunPlayer {
    def main(args: Array[String]): Unit = {
      var hp1:HealthPotion=
          new HealthPotion(0,3,10)
      hp1.move(2,3)
    }
  }
  ```


  ```

11 State Pattern

- runStudent

- ```
  object runStudent {
    def main(args: Array[String]): Unit = {
      var paul:Student=new Student()
      paul.study()
      paul.getCloserToExam()
    }
  }
  ```

- Student

- ```
  class Student {
    var mentalState:State=new Calm(this)

    def study():Unit={
      this.mentalState.study()
    }
    def getCloseToExam():Unit={
      this.mentalState.getCloseToExam()
    }
    def expressFeelings():Unit={
      this.mentalState.expressFeelings()
    }
    def passClass():Unit={
      this.mentalState=new Chillin(this)
    }
    def enrollInClass():Unit={
      this.mentalState=new Calm(this)
    }
  }
  ```

- State

- ```
  abstract class State (brain2:Student){
    def study()
    def getCloseToExam()
    def expressFeelings()
  }
  ```

- Calm

- ```
  class Calm (brain: Student) extends State (brain){
    override def study(): Unit = {
      println("I'm already calm")
    }

    override def getCloserToExam(): Unit = {
      brain.mentalState=new Panic(brain)
    }

    override def expressFeelings(): Unit = {
  ```

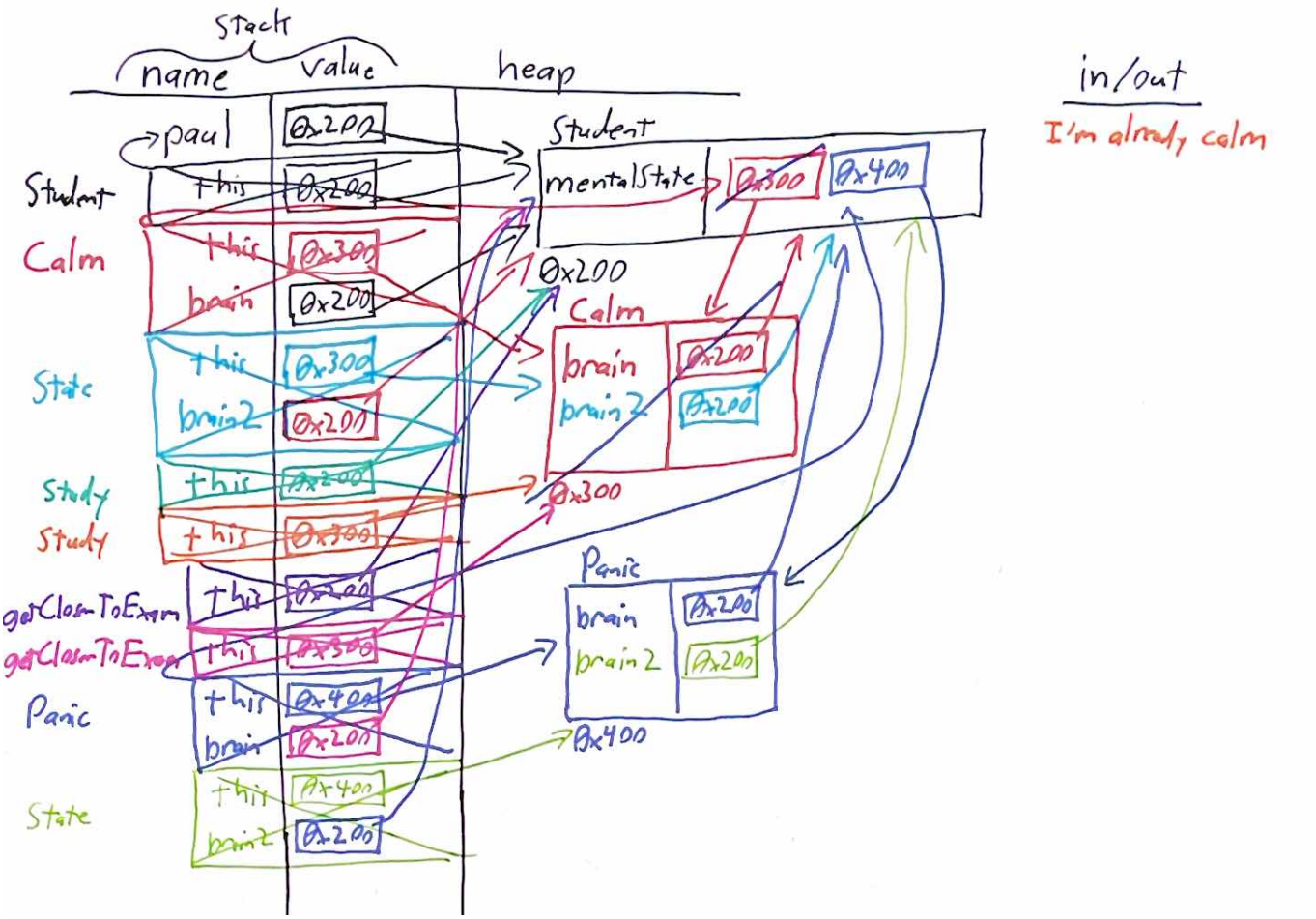
```
    println("I am a leaf on the wind")
  }
}
```

- Panic

- ```
  class Panic(brain: Student) extends State(brain){
    override def study(): Unit = {
      brain.mentalState=new Calm(brain)
    }

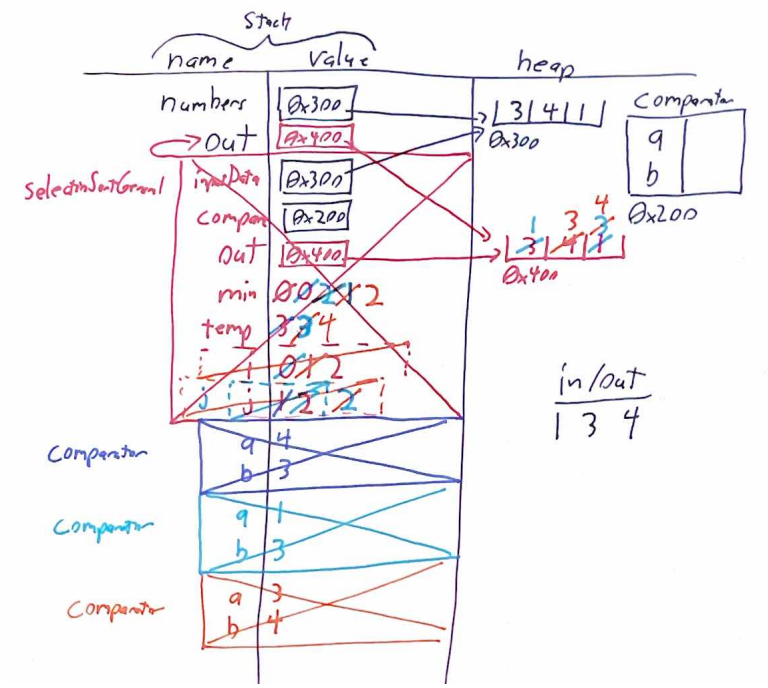
    override def getCloserToExam(): Unit = {
      println("all of my drinks are shaken and not stirred")
    }

    override def expressFeelings(): Unit = {
      println("I AM FREAKING OUT MAN")
    }
  }
  ```


  ```

12 First-Order Functions

```
object SelectionSortExample {
  def comparator(a:Int,b:Int):Boolean={
    if (a<b){
      true
    } else {
      false
    }
  }
  def selectionSortGeneral[T](inputData: Array[T],compare:(T,T) => Boolean):Array[T]={
    var out:Array[T]=inputData.clone()
    var min:Int=0
    var temp:T=out(0)
    for (i <- out.indices){
      min=i
      for (j <- i+1 until out.length){
        if (compare(out(j),out(min) )){
          min=j
        }
      }
      temp=out(i)
      out(i)=out(min)
      out(min)=temp
    }
    out
  }
  def main(args: Array[String]): Unit = {
    var numbers:Array[Int]=Array(3,4,1)
    var out=selectionSortGeneral(numbers,comparator)
    println(out.mkString(" "))
  }
}
```


Stack
name
value
heap
numbers
0x300
out
0x400
selectionSortGeneral
inputData
0x300
compare
0x200
out
0x400
min
temp
Comparator
a
b
0x200
0x400
in/out
1 3 4
Comparator
Comparator
Comparator

13 Immutable Objects

```
class ImmutableCounter(counter: Int) {
  def increase(): ImmutableCounter = {
    new ImmutableCounter(this.counter + 1)
  }
}
object RunImmutableCounter {
  def main(args: Array[String]): Unit = {
    var counter: ImmutableCounter = new ImmutableCounter(10)
    val counter2: ImmutableCounter = counter.increase()
    counter=counter.increase()
    counter=counter.increase()
  }
}
```

- ImmutableCounter is shortened to IC in the trace
- Note
  - When a constructor is returned it is like tail recursion where one stack frame is returning a value to the return from a previous stack frame and the first stack frame closes and the memory is released before the next begins
  - Even through counter is increased from the 0x200 location twice, each call creates a new instance of IC because of the constructor
  - If there no longer exists a variable that stores an object on the heap it can be crossed, this is because the object is deleted in a language like Scala with garbage collection