CS1010S Programming Methodology

Lecture 2

Functional Abstraction

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20 Aug 2018

Expectations

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Tutorial Allocation

Coursemology Survey

- Choose your preferred slots
- As many slots as possible
- Updated with number of classes

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Recitation

Appeal on CORS

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classes starts

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on Thursday/Friday

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Late Policy

- < 10 min: OK
- < 30 min: -10%
- < 12 hours: -20%
- < 24 hours: -50%
- > 24 hours: -100%

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Ask early for extensions

Submission is Final

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But please remember to click

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Finalize Submission

Don’t Stress

But please do your work

Try NOT to submit at 23:58

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Operators

Assignment

a = 5

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Equality testing

a == 5

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Not equal

a != 5

Backslash \

Escape character

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```
print('That's')
print('That\'s')
```

#Comments

```
# this is not a hashtag!

print("Good to go")

#print("Good to go")
# whatever is after the # is ignored

if light == "red": # Check state of light
```

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What's this?

Python Imaging Library

```
from PIL import *
```

(Misison 0)

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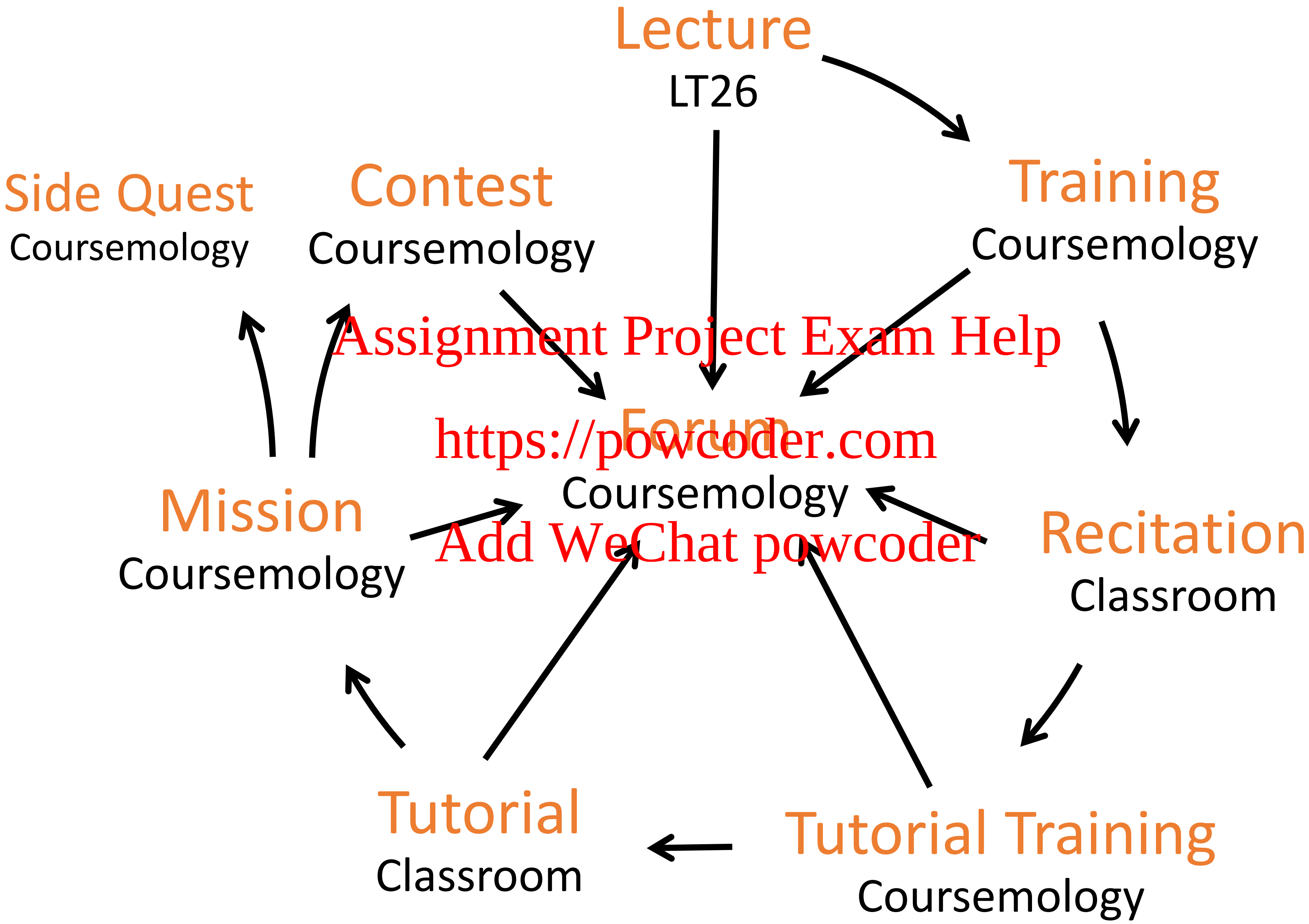

Lecture
LT26

Training
Coursemology

Side Quest
Coursemology

Contest
Coursemology

Forum
Coursemology

Mission
Coursemology

Recitation
Classroom

Tutorial
Classroom

Tutorial Training
Coursemology

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Forums

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Post reflections for EXP

Trainings

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Please don't anyhow hantam

Computational Thinking

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Fasten your seatbelt

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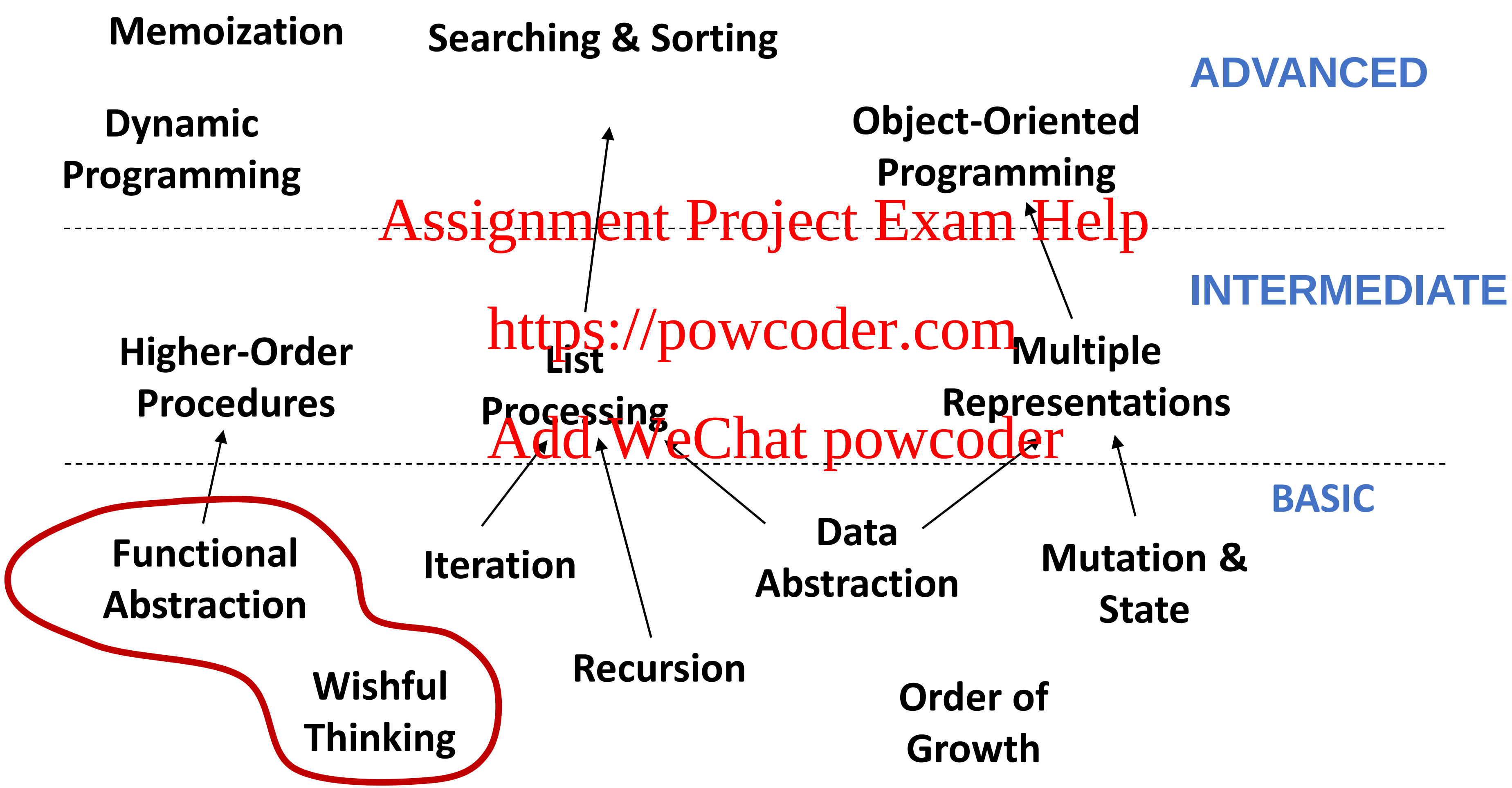
CS1010S Road Map



Memoization

Searching & Sorting

ADVANCED

Dynamic Programming

Object-Oriented Programming

INTERMEDIATE

Higher-Order Procedures

List Processing

Multiple Representations

BASIC

Functional Abstraction

Iteration

Data Abstraction

Mutation & State

Wishful Thinking

Recursion

Order of Growth

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Fundamental concepts of computer programming

Functional Abstraction

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WHAT

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HOW

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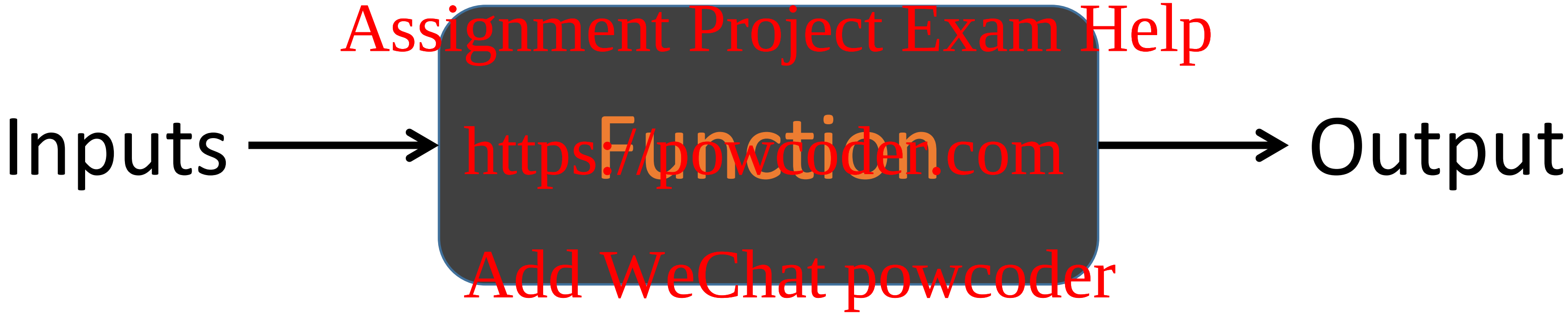
WHY

What is a function?



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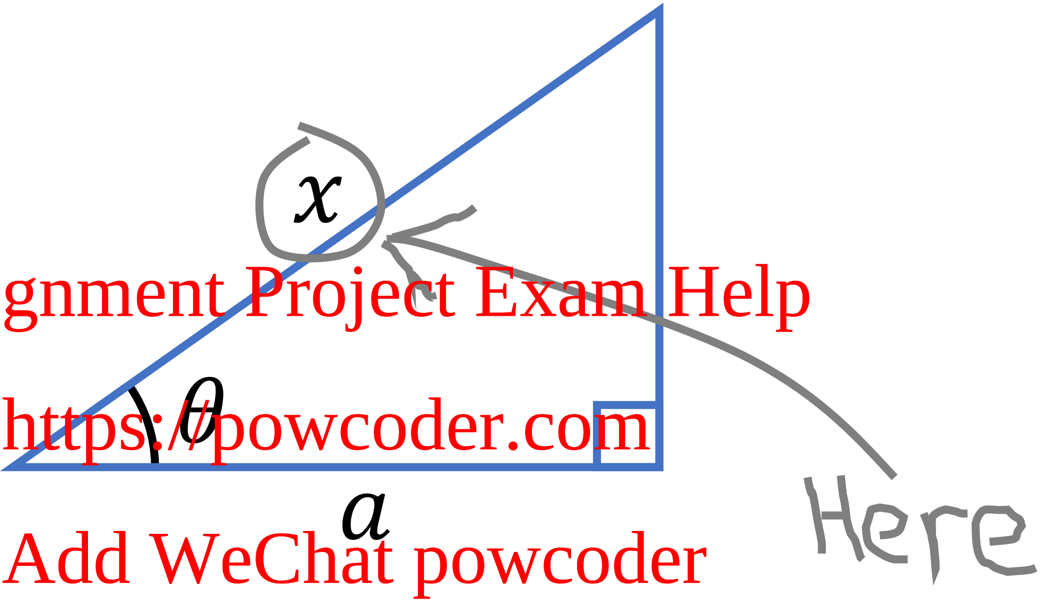
Functions are nothing new



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Find x?

input

$$x = \frac{\cos(\theta)}{a}$$

function

Let’s start with something easier

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Question

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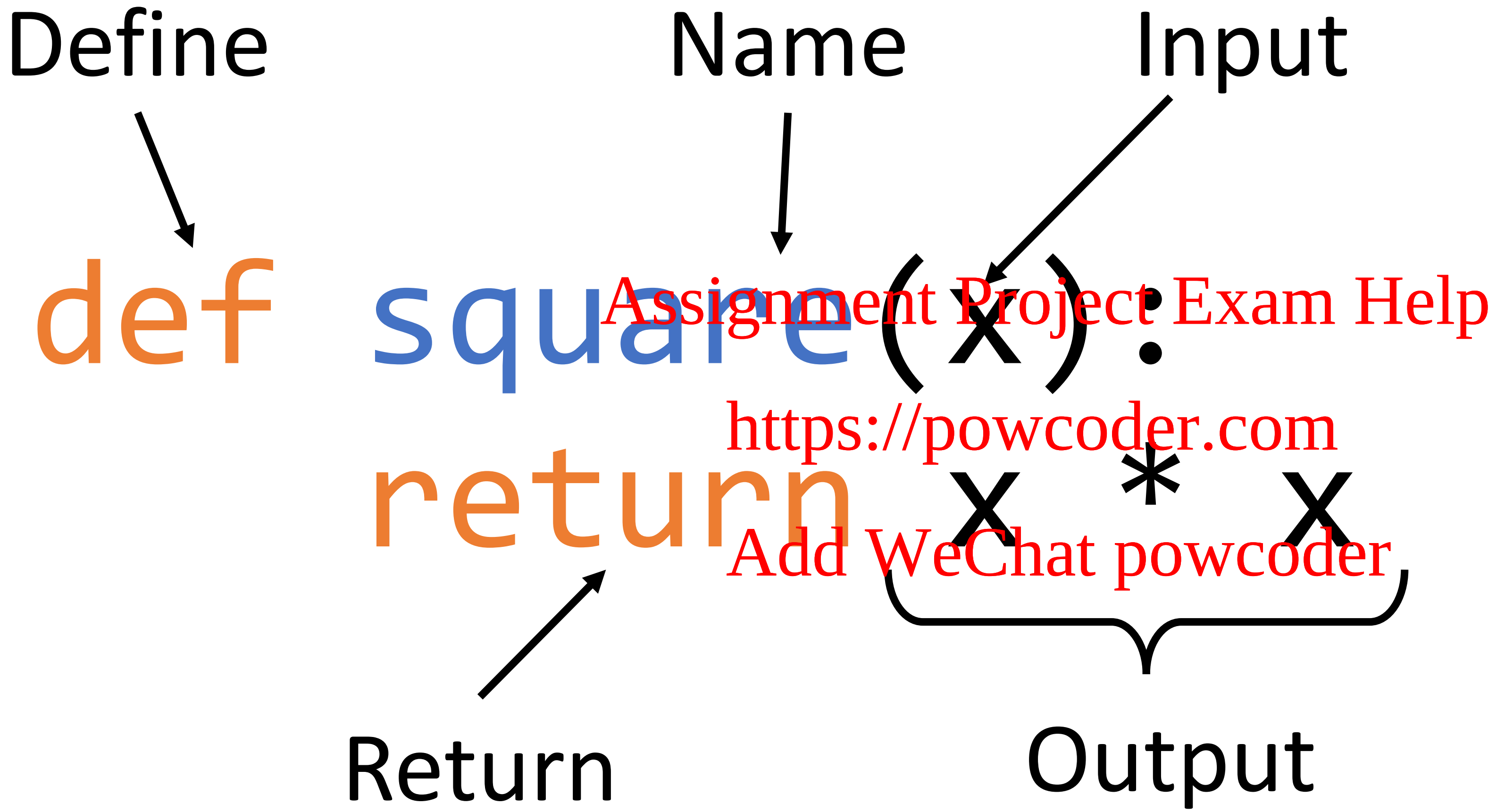
How do we square a number?

The square function



Define

Name

Input

```
def square(x):
    return x * x
```

Return

Output

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```
square(21)              441

square(2 + 5)           49

square(square(3)) 81
```

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Another function

```
def sum_of_squares(x, y):
    return square(x) + square(y)

sum_of_squares(3, 4)                25
```

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And another

```python
from math import sqrt

def hypotenuse(a, b):
    return sqrt(sum_of_squares(a, b))


hypotenuse(5, 12)
```

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```
13
```

General Form

```
def  <name>  (<formal parameters>):
         <body>
```

- name

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  - Symbol associated with the function

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- formal parameters
  - Names used in the body to refer to the arguments of the function

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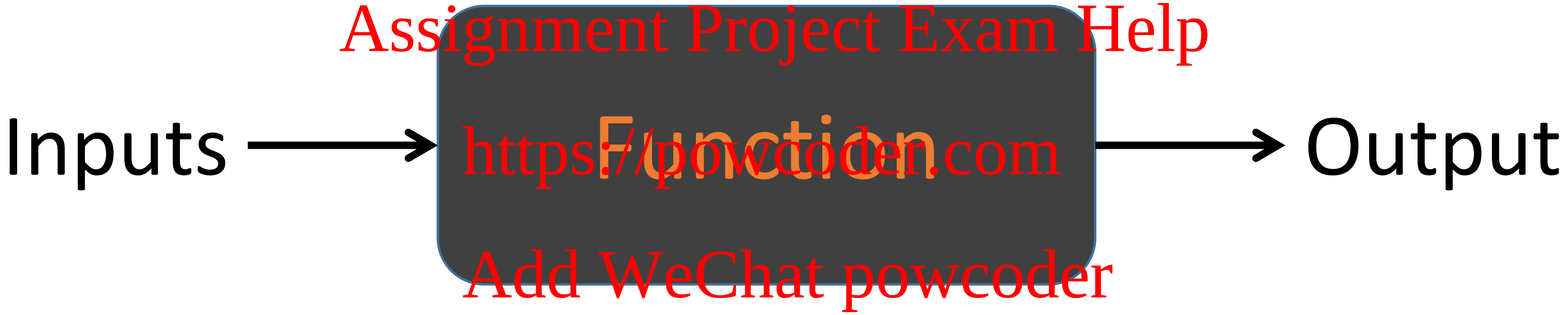
- body
  - The statement(s) to be evaluated
  - Has to be indented (standard is 4 spaces)
  - Can return values as output

Black Box



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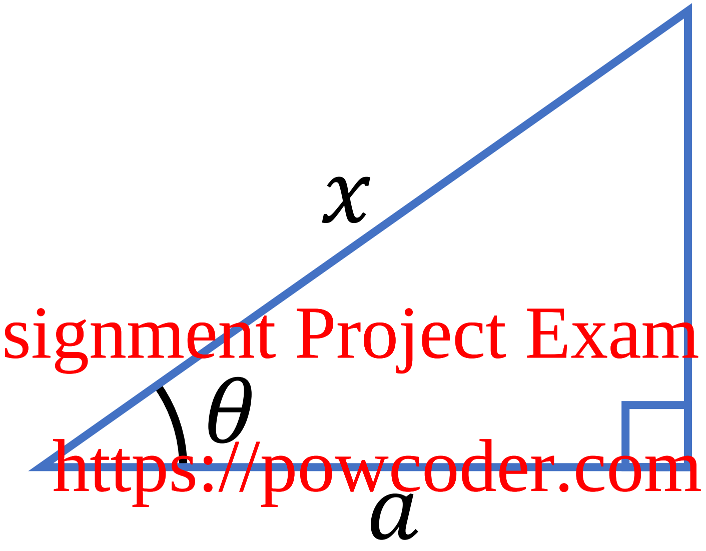
Don’t need to know how it works
Just know what it does

Black Box



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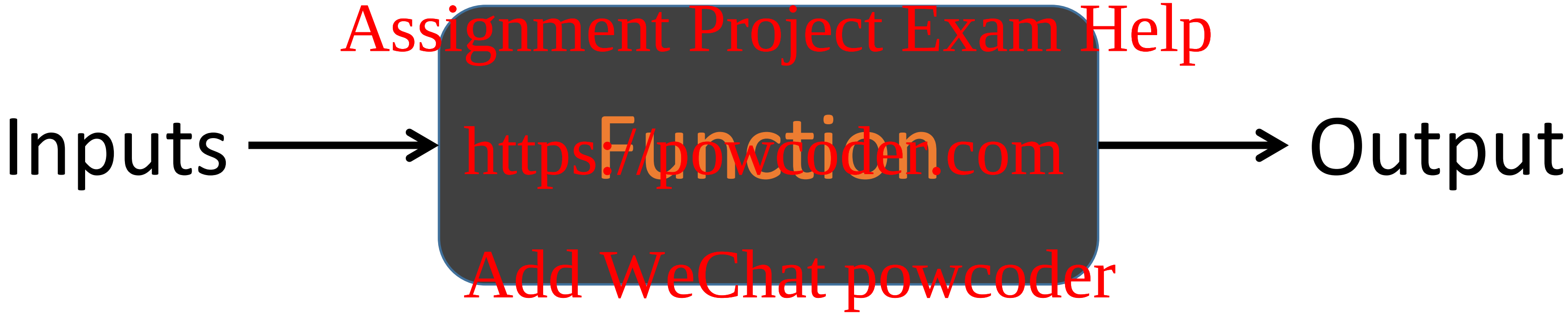
$$x = \frac{a}{\cos(\theta)}$$

Do you know how $\cos$ work?

Black Box



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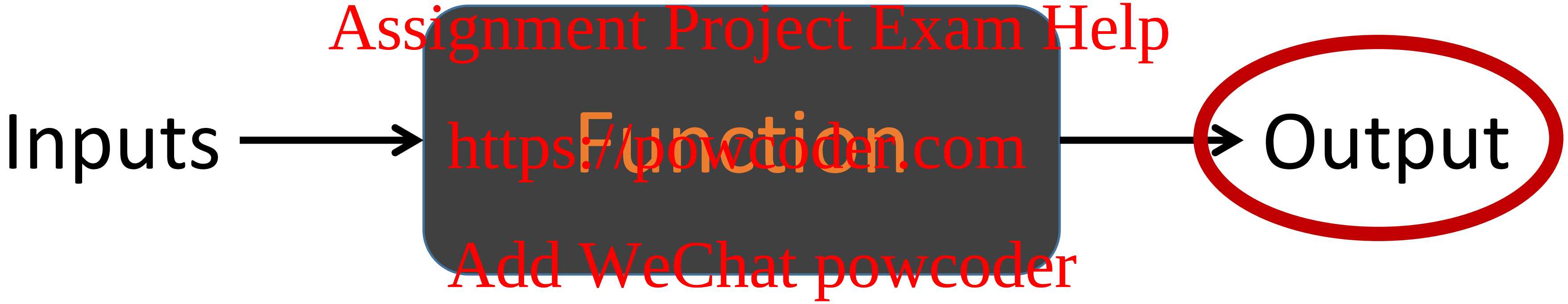
As long as we know what it does,
we can use it.

(the inputs
and output)

Return Type



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Output is returned with `return`

Return type can be None

Abstract Environment

Picture Language

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(runes.py)

Also graphics.py + PyGif.py

Elements of Programming

1. Primitives
2. Means of Combination
3. Means of Abstraction
4. Controlling Logic

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Primitives building block

```
show(rcross_bb)
```

Picture object

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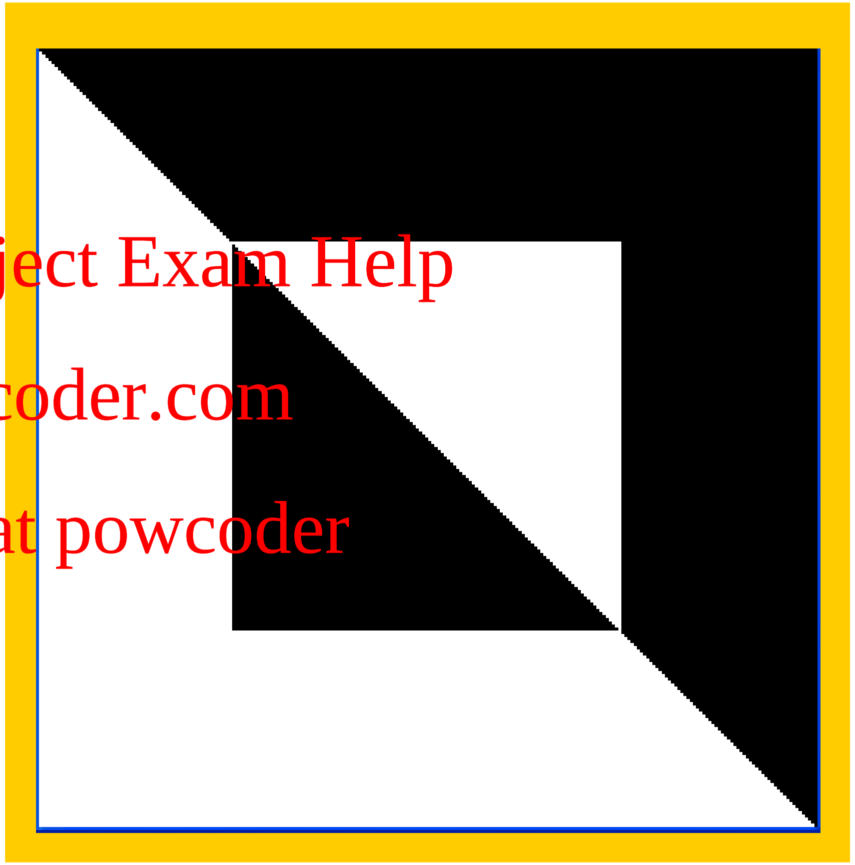
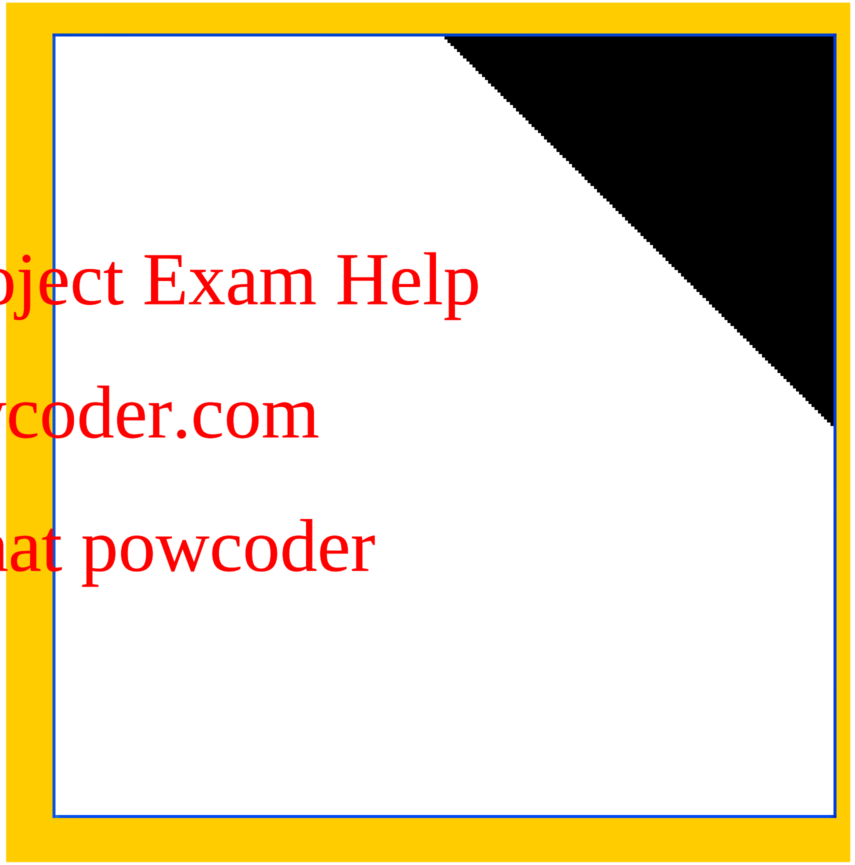


Primitives building block

```
show(corner_bb)
```



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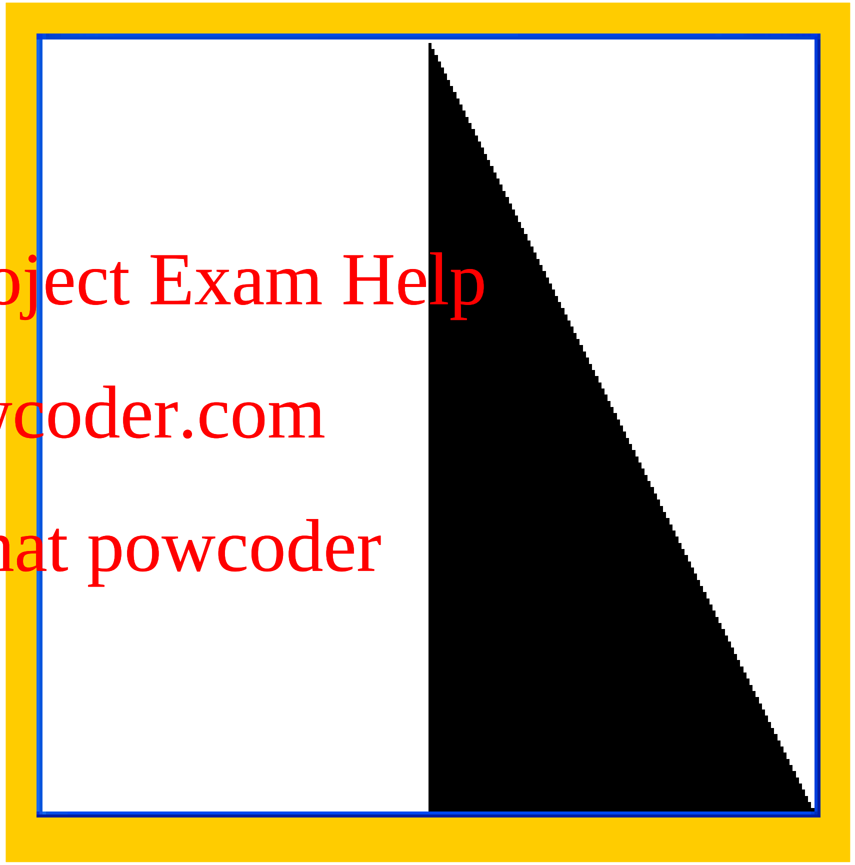
Primitives building block

```
show(sail_bb)
```



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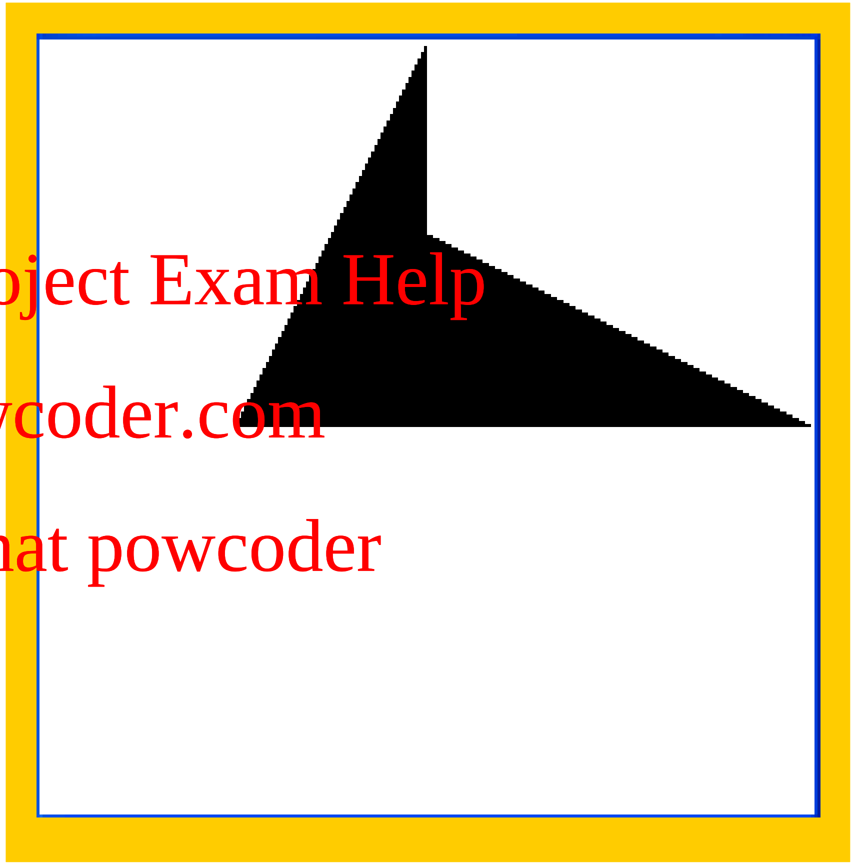
Primitives building block

```
show(nova_bb)
```



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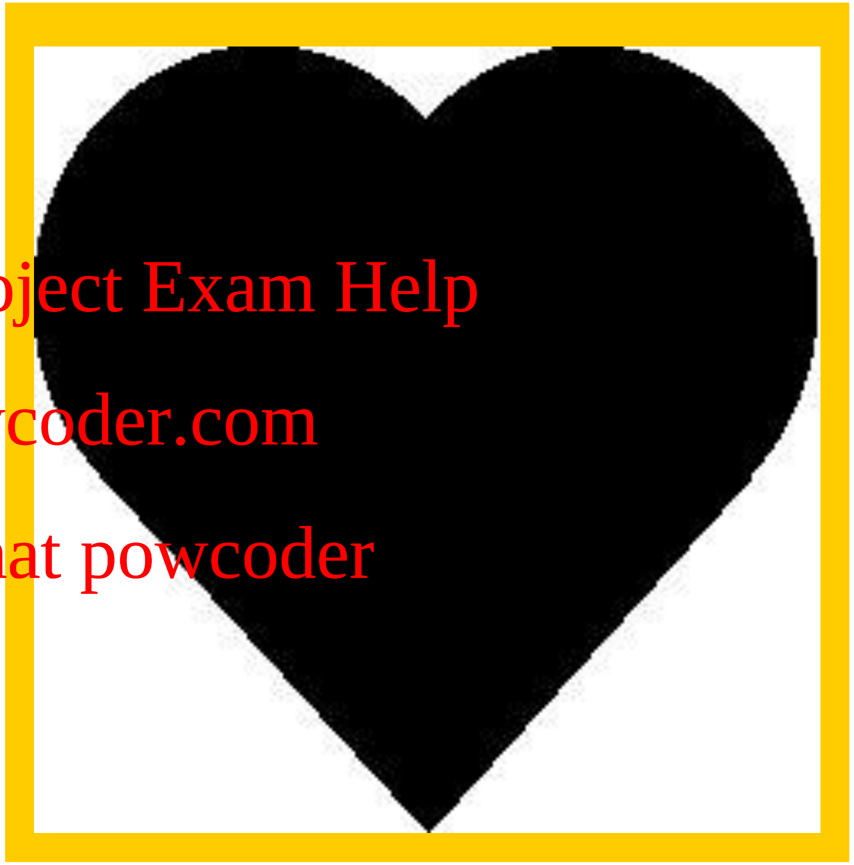
Primitives building block

```
show(heart_bb)
```



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Applying operations

```
op(picture)
```

function name

input(s)

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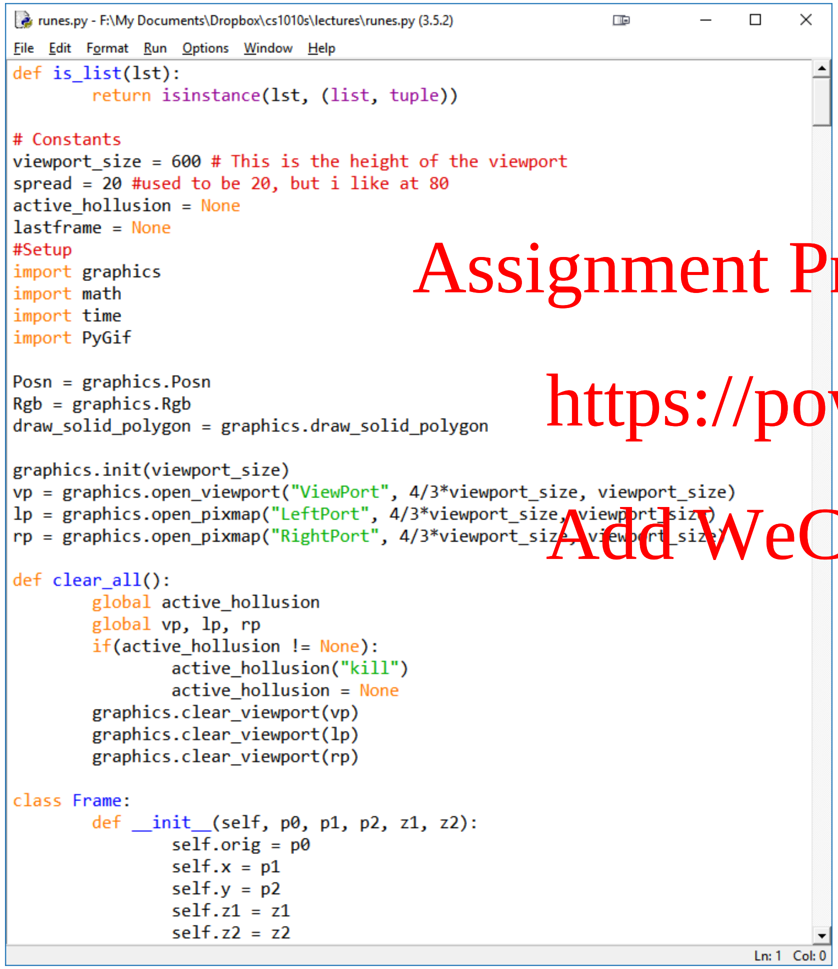
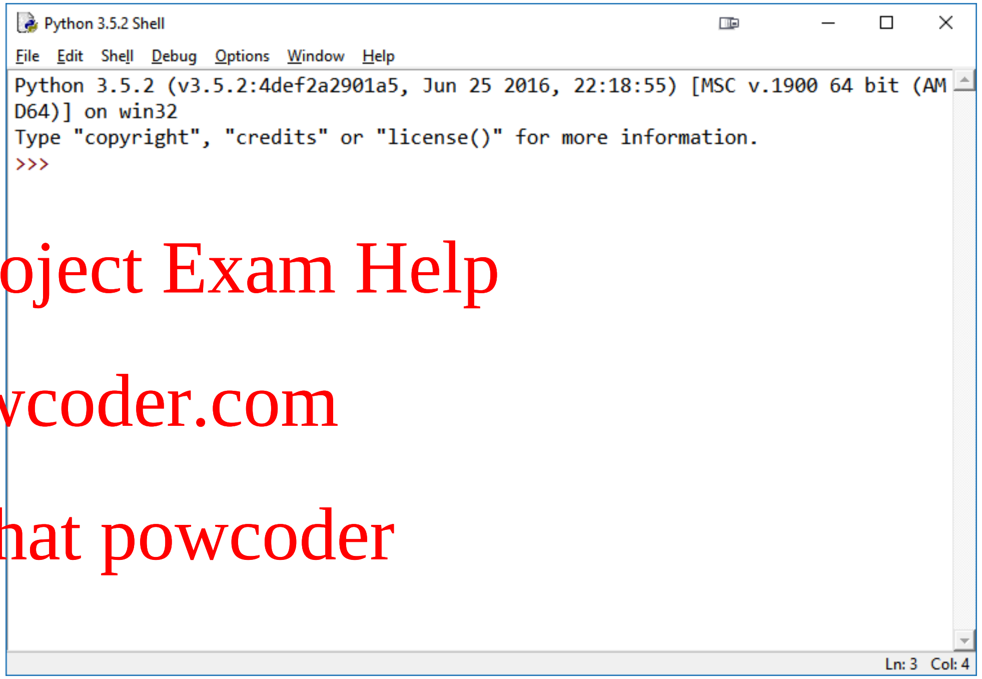
Example:

```
show(heart_bb)
```

Fun with IDLE


runes.py - F:\My Documents\Dropbox\cs1010s\lectures\runes.py (3.5.2)
File Edit Format Run Options Window Help
Ln: 1 Col: 0

```
def is_list(lst):
        return isinstance(lst, (list, tuple))

# Constants
viewport_size = 600 # This is the height of the viewport
spread = 20 #used to be 20, but i like at 80
active_hollusion = None
lastframe = None
#Setup
import graphics
import math
import time
import PyGif

Posn = graphics.Posn
Rgb = graphics.Rgb
draw_solid_polygon = graphics.draw_solid_polygon

graphics.init(viewport_size)
vp = graphics.open_viewport("ViewPort", 4/3*viewport_size, viewport_size)
lp = graphics.open_pixmap("LeftPort", 4/3*viewport_size, viewport_size)
rp = graphics.open_pixmap("RightPort", 4/3*viewport_size, viewport_size)

def clear_all():
        global active_hollusion
        global vp, lp, rp
        if(active_hollusion != None):
                active_hollusion("kill")
                active_hollusion = None
        graphics.clear_viewport(vp)
        graphics.clear_viewport(lp)
        graphics.clear_viewport(rp)

class Frame:
        def __init__(self, p0, p1, p2, z1, z2):
                self.orig = p0
                self.x = p1
                self.y = p2
                self.z1 = z1
                self.z2 = z2
```



```
Python 3.5.2 (v3.5.2:4def2a2901a5, Jun 25 2016, 22:18:55) [MSC v.1900 64 bit (AM
D64)] on win32
Type "copyright", "credits" or "license()" for more information.
>>>
```

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Font matters

Primitive Operation

Rotating to the Right

```
clear_all()
show(quarter_turn_right(sail_bb))
```

operation

picture

result is another picture

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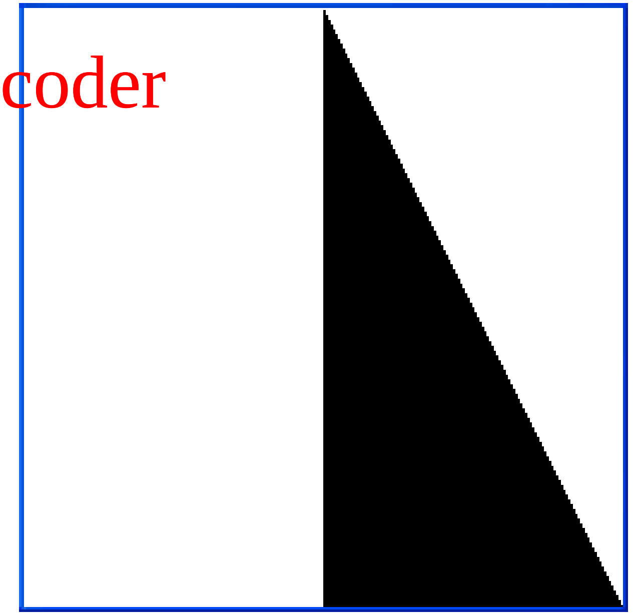

Derived Operation

Rotating Upside Down

```
def turn_upside_down(pic):
    return quarter_turn_right(
               quarter_turn_right(pic))
clear_all()
show(turn_upside_down(sail_bb))
```

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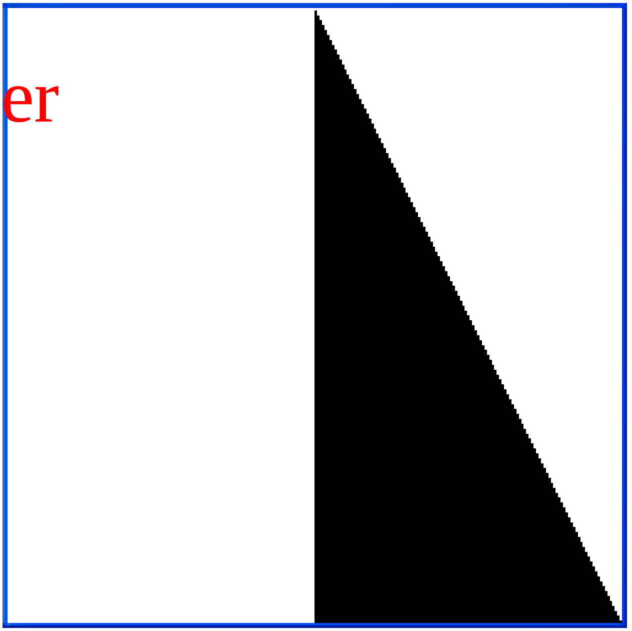

How about

Rotating to the Left?

```
def quarter_turn_left(pic):
    return quarter_turn_right(
               quarter_turn_upside_down(pic))

clear_all()
show(quarter_turn_left(sail_bb))
```

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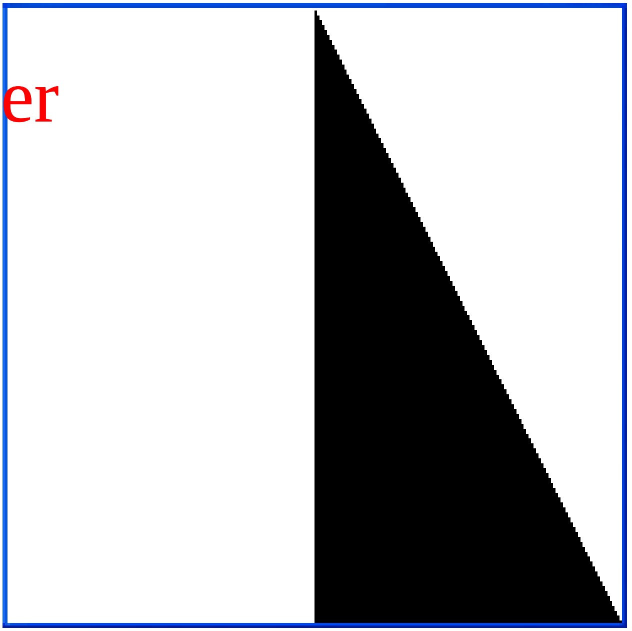

Means of Combination

Stacking

```
clear_all()
show(stack(rcross_bb, sail_bb))
```

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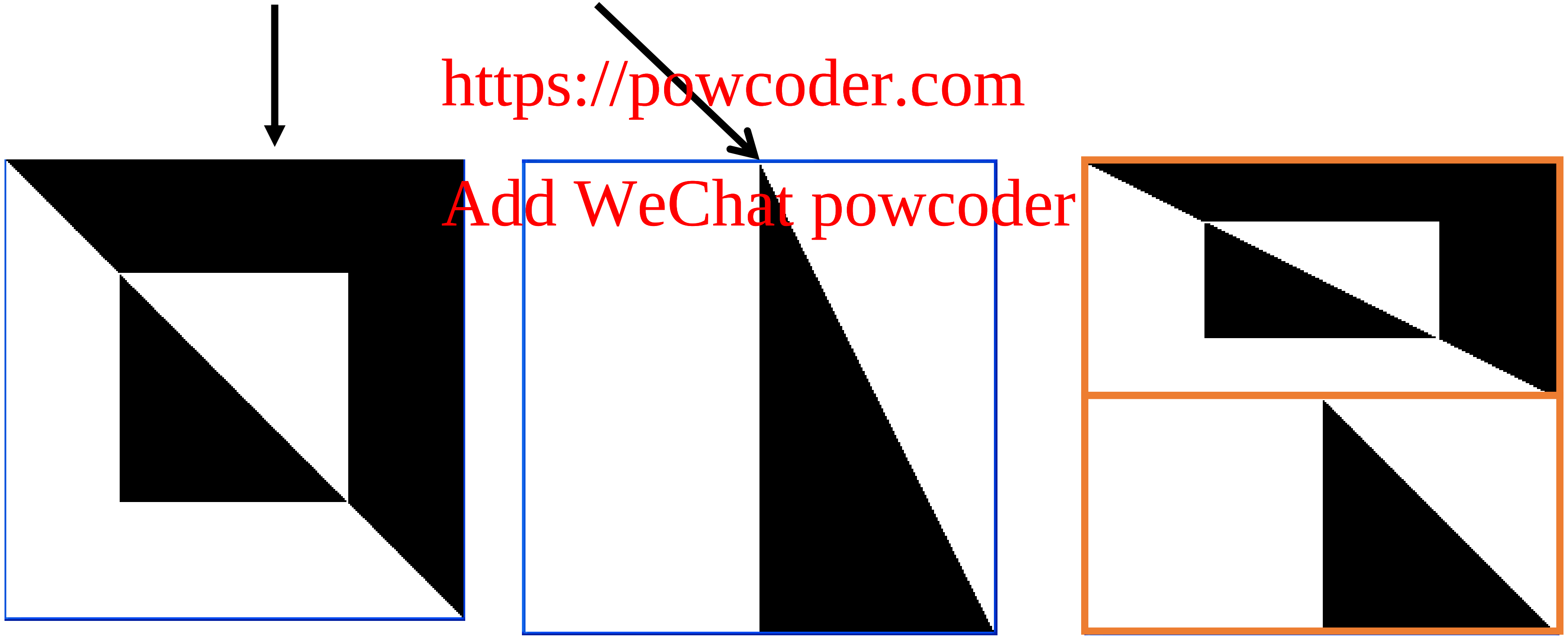

Multiple Stacking

```
clear_all()
show(stack(rcross_bb,
            stack(rcross_bb,
                  sail_bb)))
```

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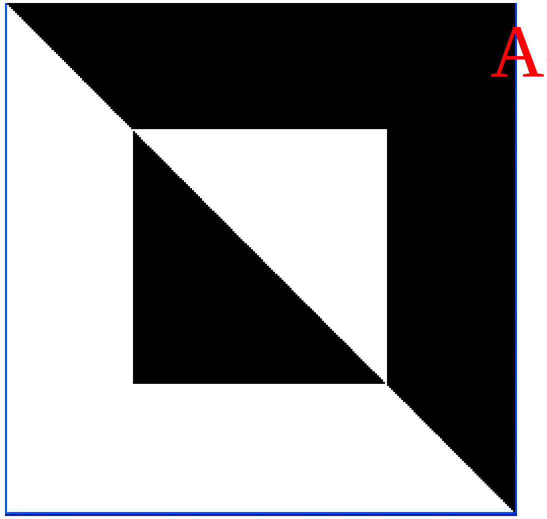

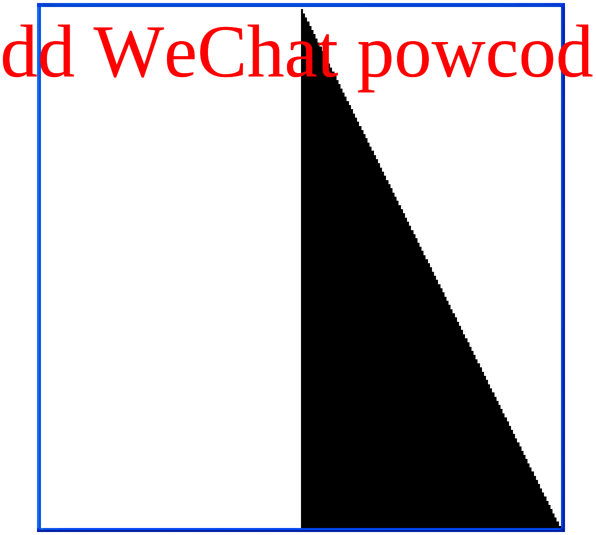

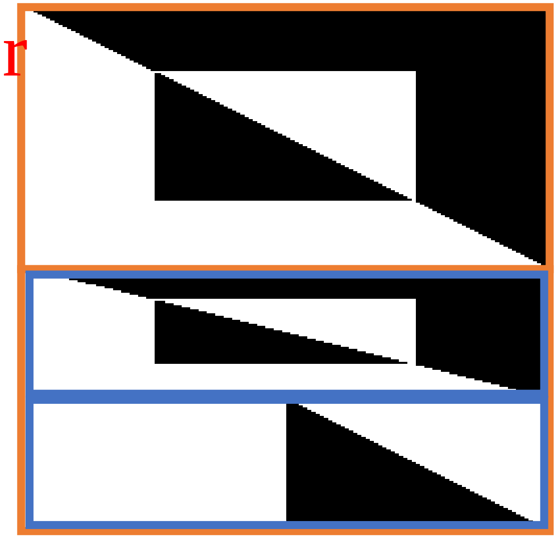

Means of Combination

Placing Beside

```
def beside(pic1, pic2):
    return quarter_turn_right(
        stack(quarter_turn_left(pic2),
              quarter_turn_left(pic1)))
```

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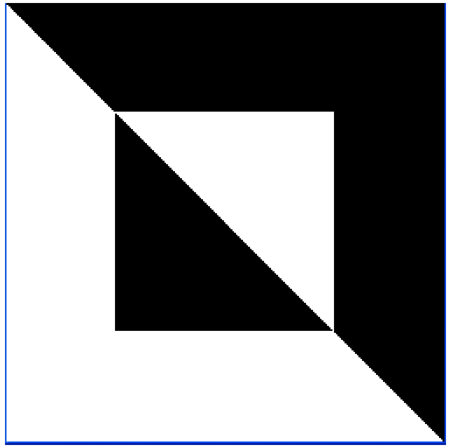
A complex object



```
clear_all()
show(
  stack(
    beside(
      quarter_turn_right(rcross_bb),
      turn_upside_down(rcross_bb)),
    beside(
      rcross_bb,
      quarter_turn_left(rcross_bb))))
```

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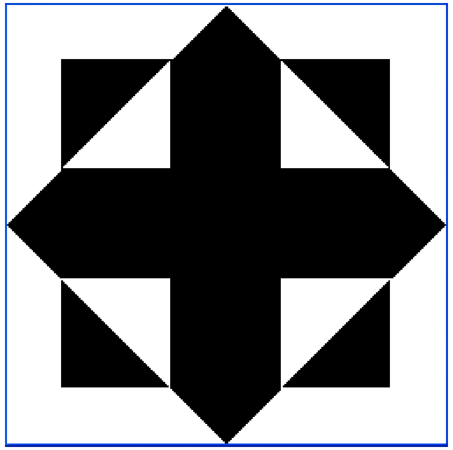
Let's give it a name

`make_cross`



```
stack(
  beside(
    quarter_turn_right(rcross_bb),
    turn_upside_down(rcross_bb)),
  beside(
    rcross_bb,
    quarter_turn_left(rcross_bb)))
```

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```
stack(
  beside(
    quarter_turn_right(pic),
    turn_upside_down(pic)),
  beside(
    pic,
    quarter_turn_left(pic)))
```

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```
def make_cross(pic):
  return stack(
    beside(
      quarter_turn_right(pic),
      turn_upside_down(pic)),
    beside(
      pic,
      quarter_turn_left(pic)))
```

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return vs show

Naming your objects

```
clear_all()
my_pic = make_cross(sail_bb)
show(my_pic)

my_pic_2 = make_cross(nova_bb)
show(my_pic_2)
```

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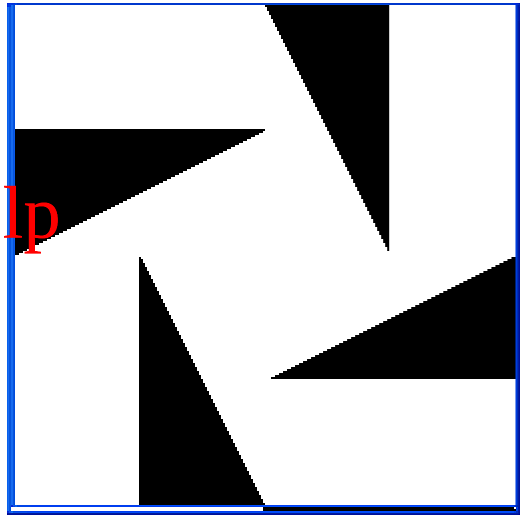
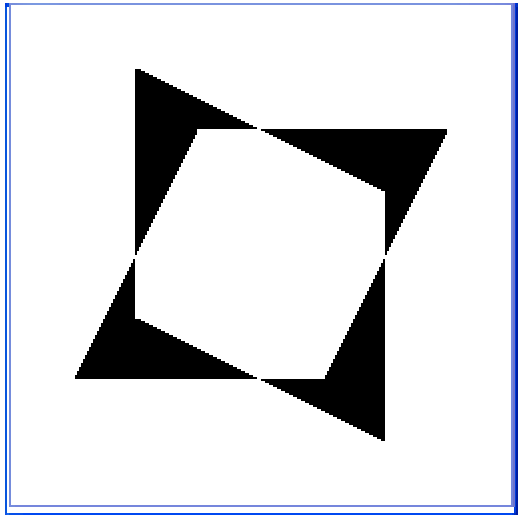
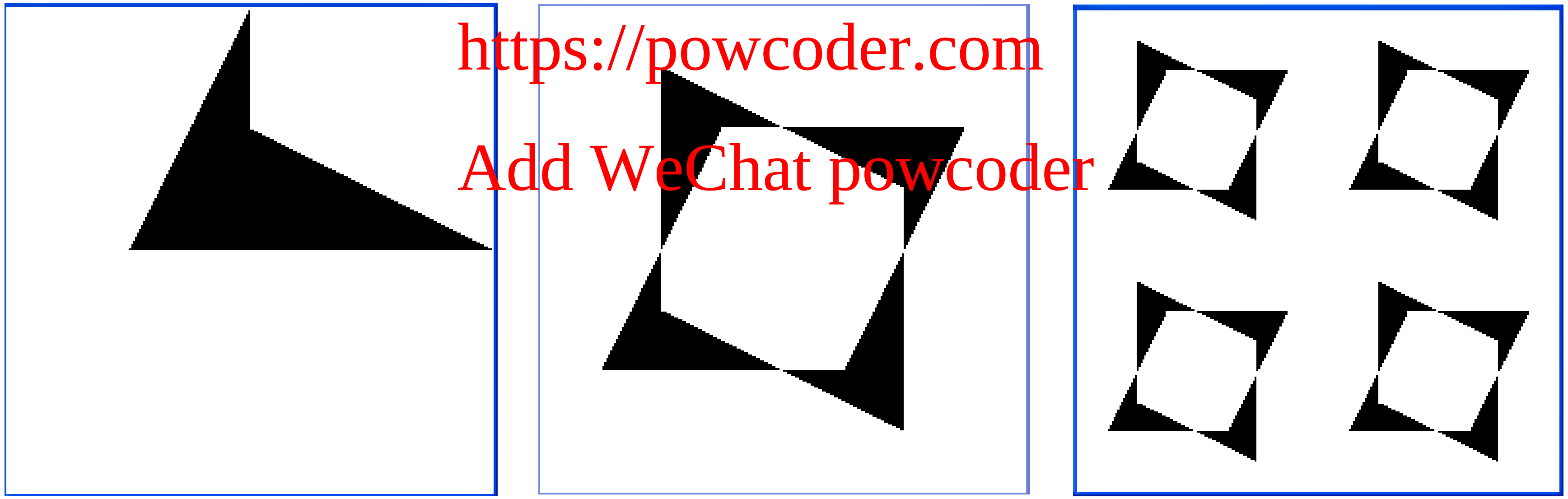




Repeating the pattern

```
clear_all()
show(make_cross(make_cross(nova_bb)))
```



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Repeating multiple times

```
clear_all()
def repeat_pattern(n, pat, pic):
    if n == 0:
        return pic
    else:
        return pat(repeat_pattern(n-1, pat, pic))
show(repeat_pattern(4, make_cross, nova_bb))
```

recursion

Qn: What does `repeat_pattern` return?

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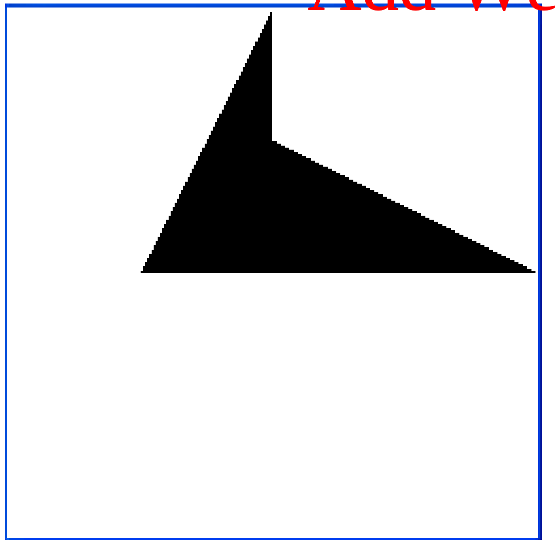
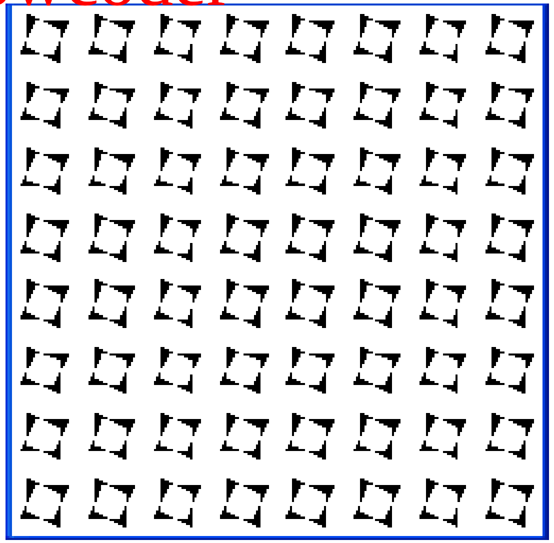
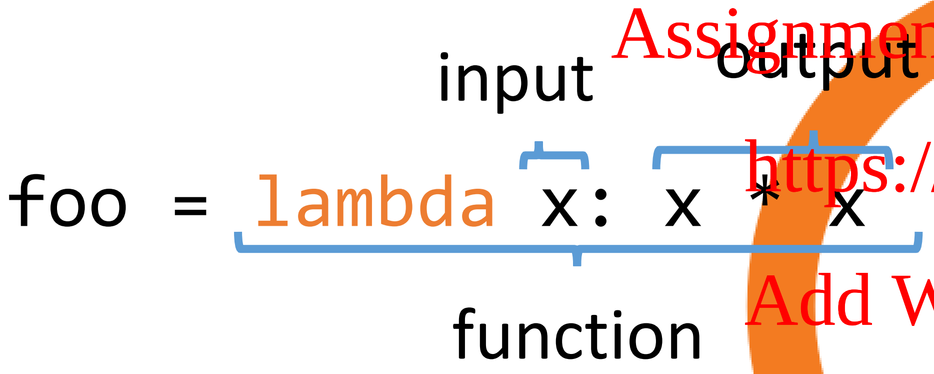




Anonymous Functions

```
def square(x):
    return x * x
```



```
foo = lambda x: x * x
```

```
foo(1)          1
foo(16)         256
```

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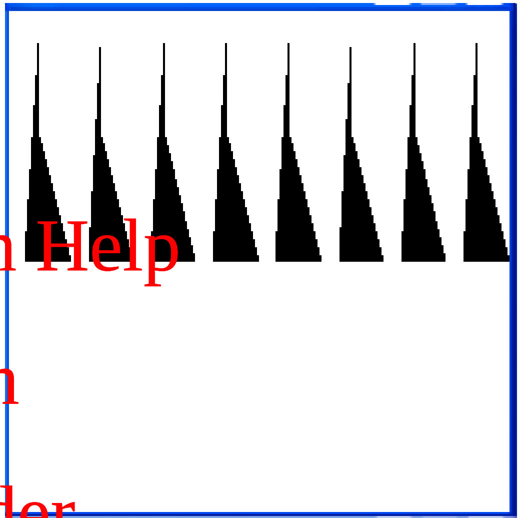
New Patterns

```
clear_all()
show(repeat_pattern(3,
    lambda pic: beside(pic, pic),
    nova_bb))
```

anonymous function



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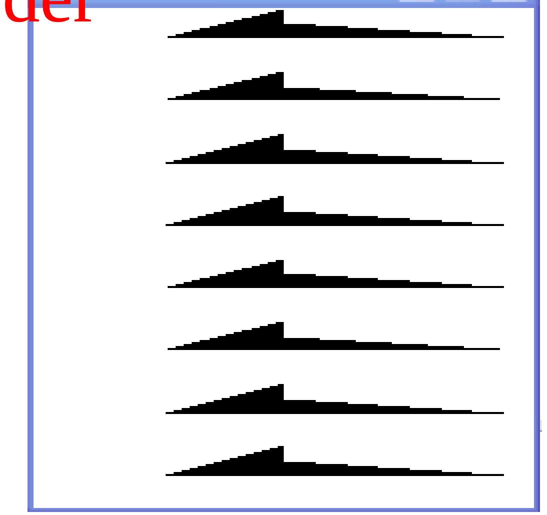
```
clear_all()
show(repeat_pattern(3,
      lambda pic: stack(pic, pic),
      nova_bb))
```



Another nice pattern

```
clear_all()
show(repeat_pattern(4, make_cross, rcross_bb))
```

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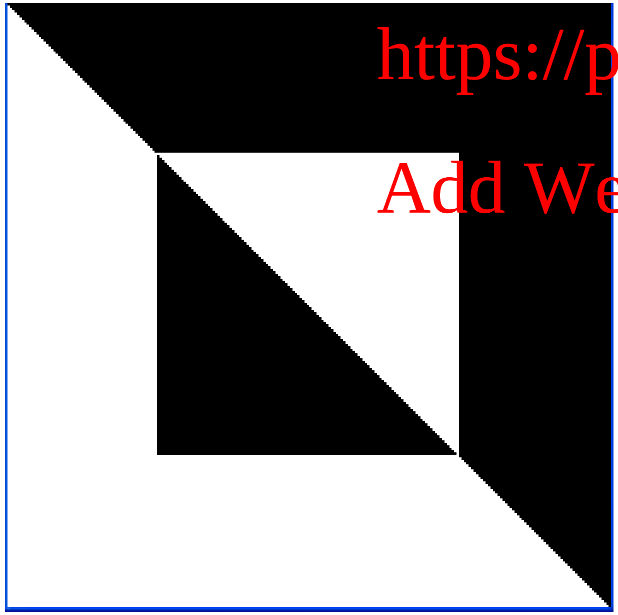

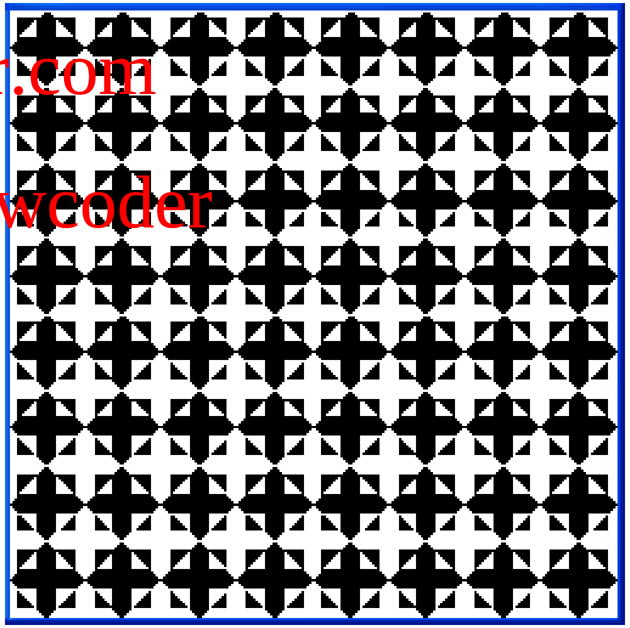

What about 3 rows?

```
clear_all()
show(stack_frac(1/3, rcross_bb, sail_bb))
clear_all()
show(stack_frac(1/3, rcross_bb,
                     stack(rcross_bb, rcross_bb)))
```

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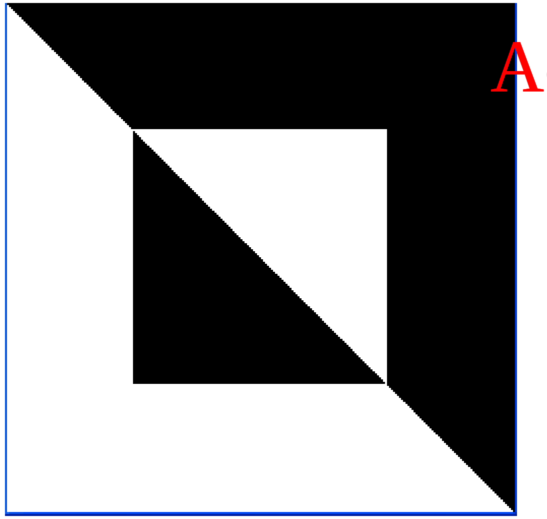

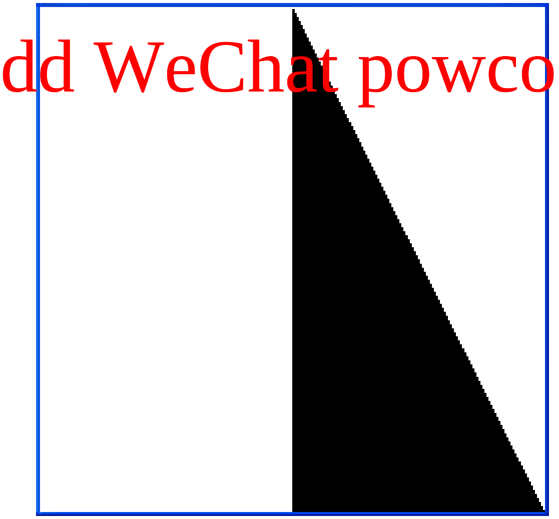

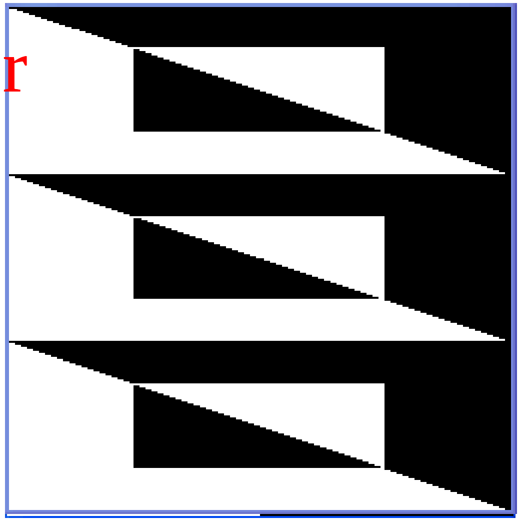

Repeating n times

```
def stackn(n, pic):
    if n == 1:
        return pic
    else:
        return stack_frac(1/n,
                          pic,
                          stackn(n-1, pic))

clear_all()
show(stackn(3, nova_bb))

clear_all()
show(stackn(5, nova_bb))
```

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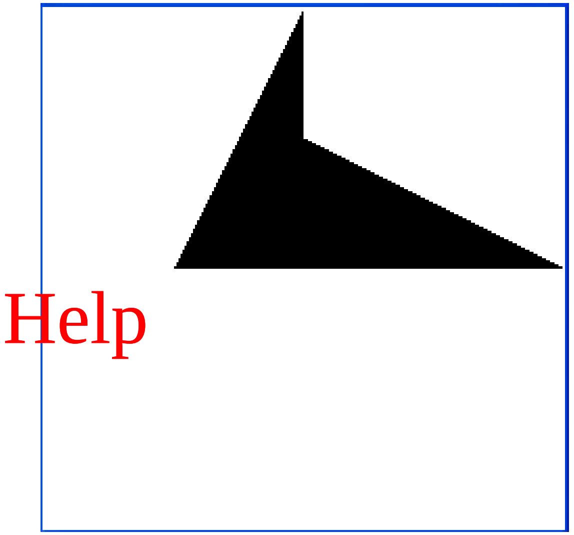

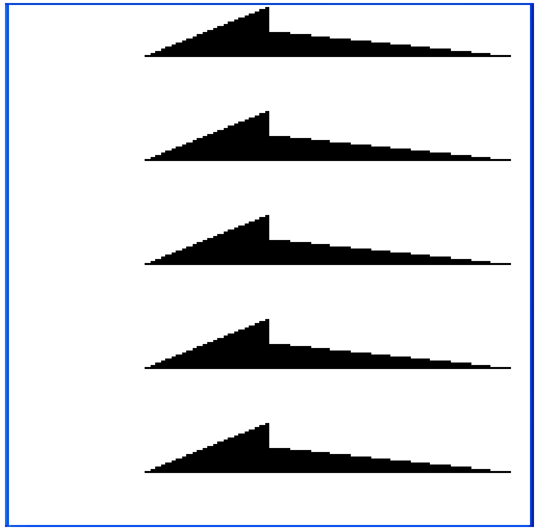

A rectangular quilting pattern

```
clear_all()
show(stackn(5, quarter_turn_right(
                   stackn(5, quarter_turn_left(nova_bb)))))
```

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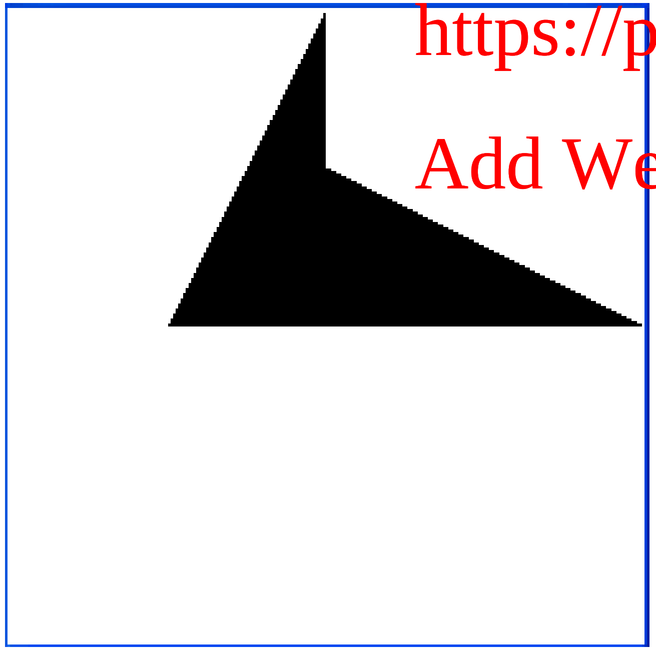

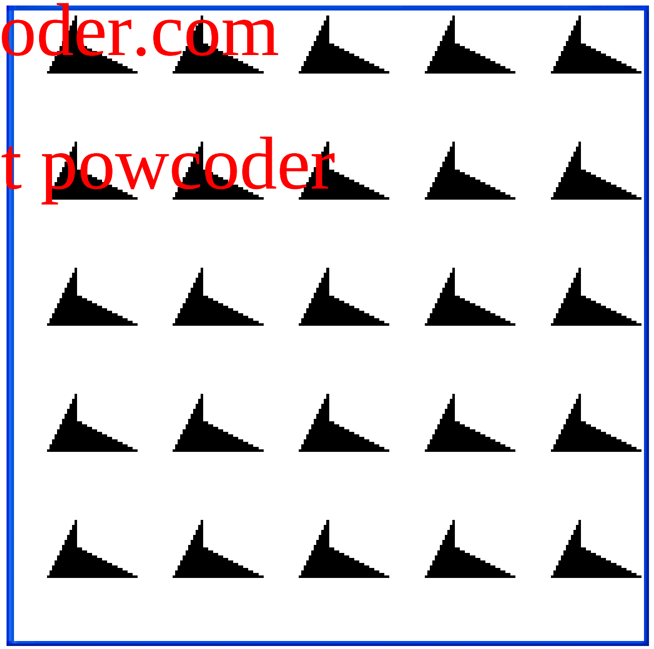

A rectangular quilting proc

```
def nxn(n, pic):
    return stackn(n, quarter_turn_right(
                    stackn(n, quarter_turn_left(pic))))
clear_all()
show(nxn(3, make_cross(rcross_bb)))
```

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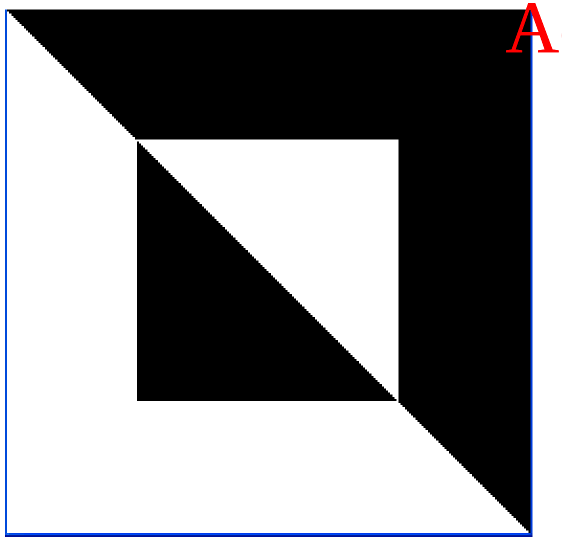

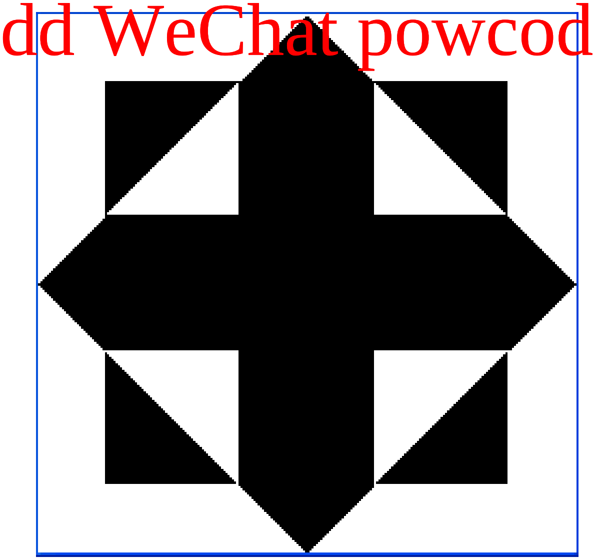

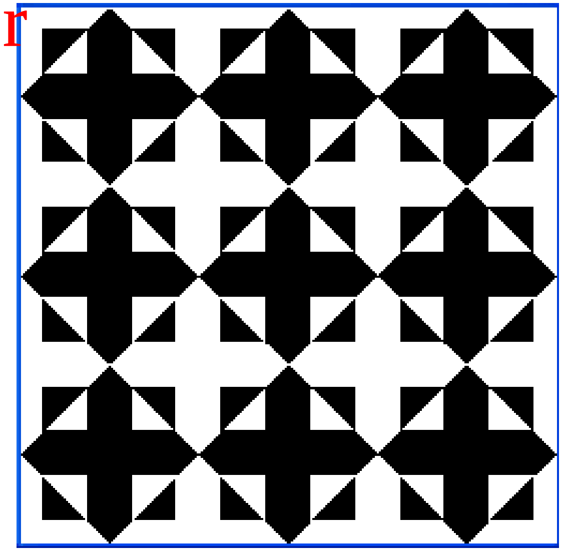

After all this…

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No idea how a picture is represented

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No idea how the operations do their work

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Yet, we can build complex pictures

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This is

Functional Abstraction

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We can make Sterograms!

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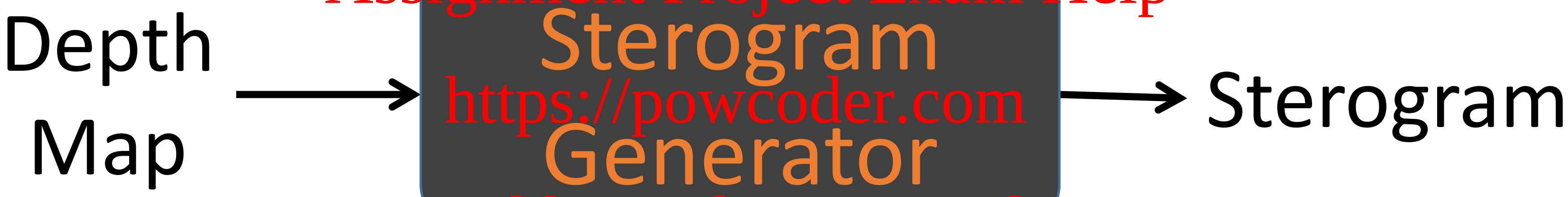
Black Box



Depth Map

Sterogram Generator

Sterogram

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Functional Abstraction

Can't see stereograms?

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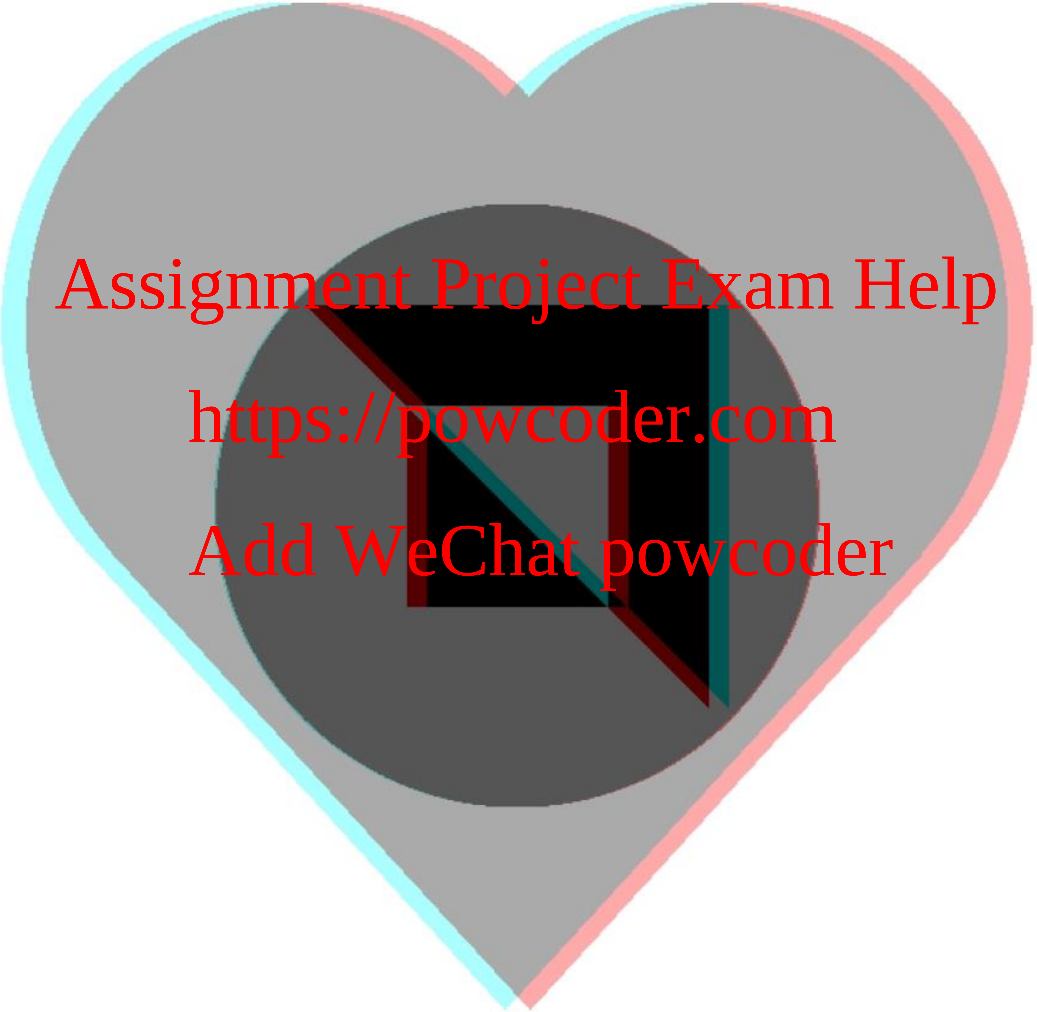
Anaglyphs



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And if you think this is cool…

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You ain't seen nothing yet!

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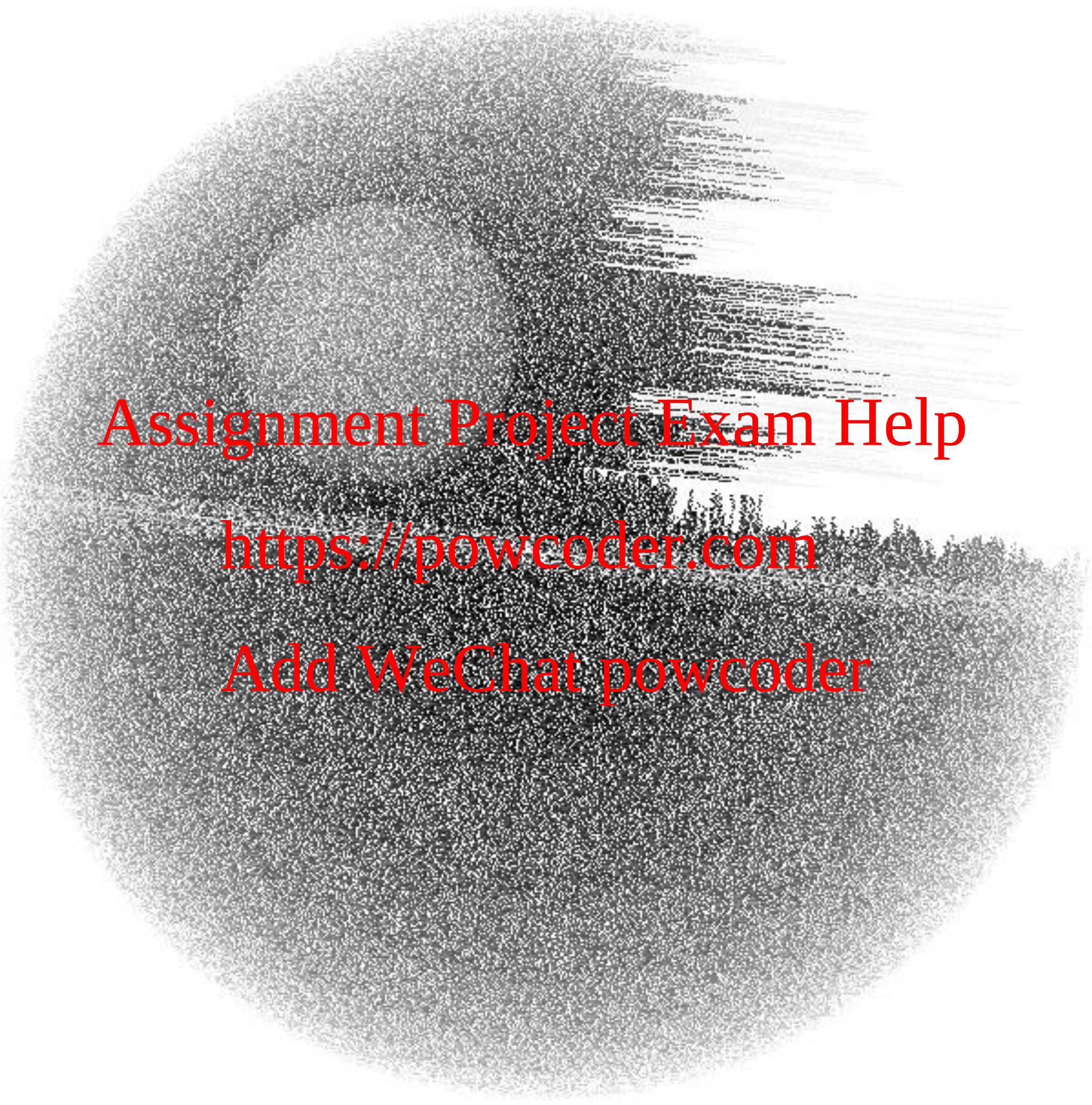

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What have we learnt?

WHAT

Functional Abstraction = Black-box

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HOW

`def` and `lambda`

Functions are objects

(in Python)

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WHY?

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Help us manage

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complexity

Allow us to focus on high-level problem solving

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Creating 3D objects

We use greyscale to represent depth

- Black is nearest to you
- White is furthest away

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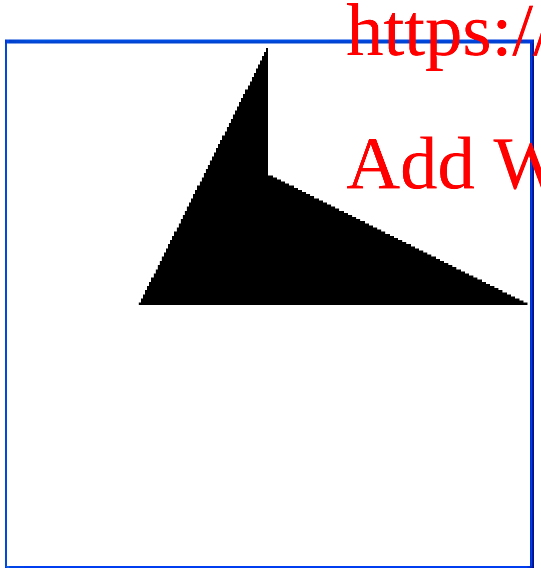
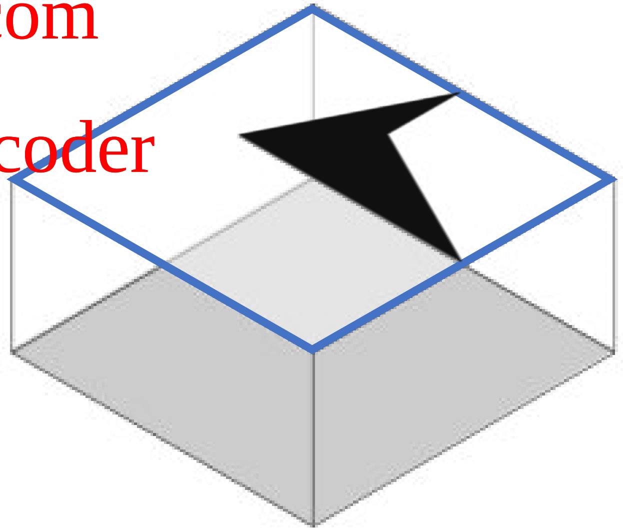
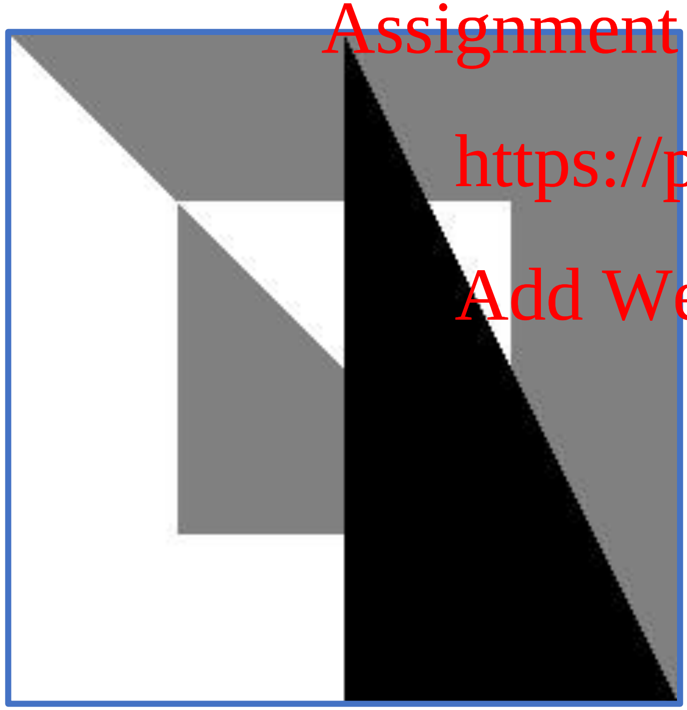


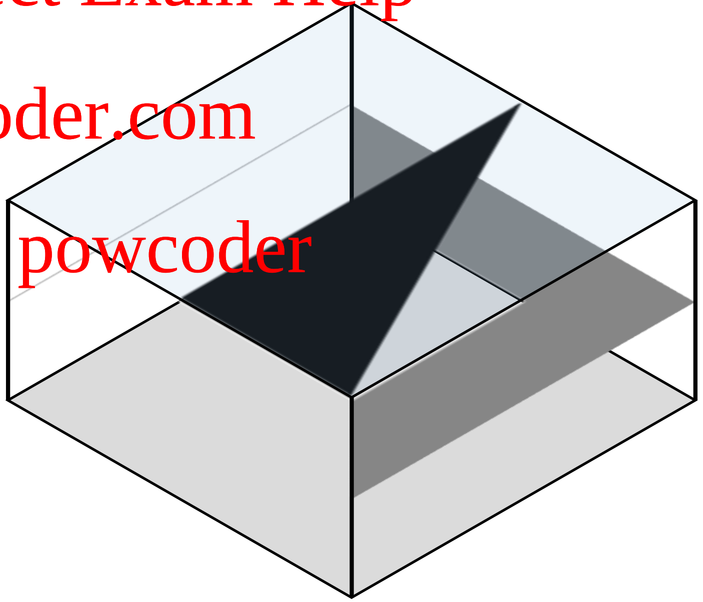
means



Overlay Operation

```
clear_all()
show(overlay(sail_bb, rcross_bb))
```





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Advanced Overlay Operation

```
clear_all()
show(overlay_frac(1/4, corner_bb, heart_bb))
```

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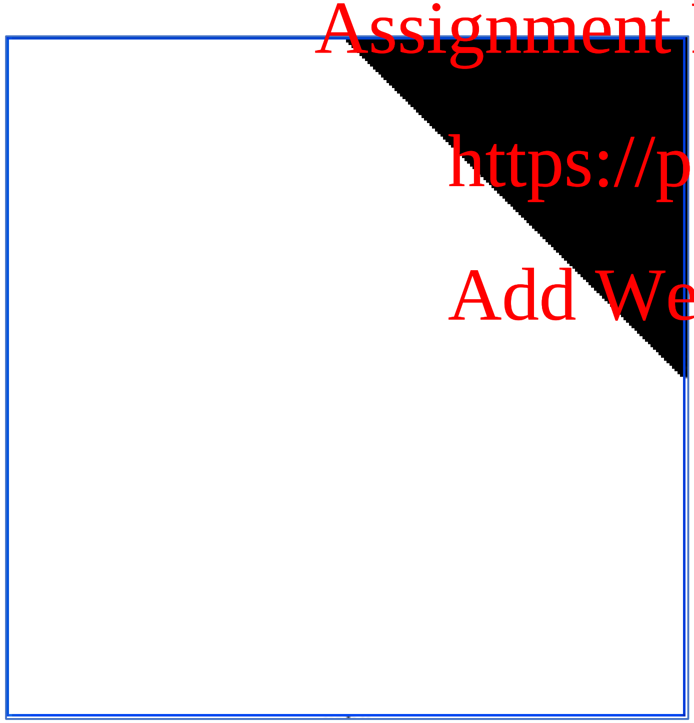
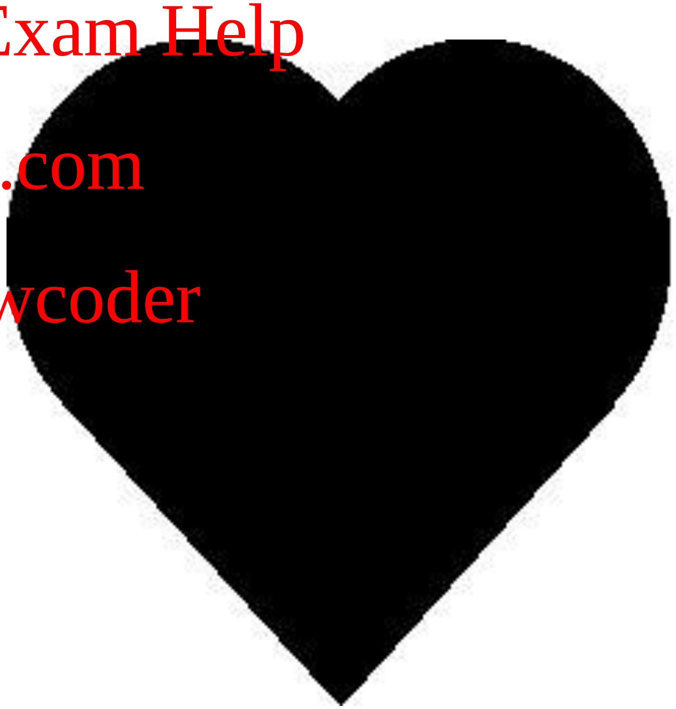
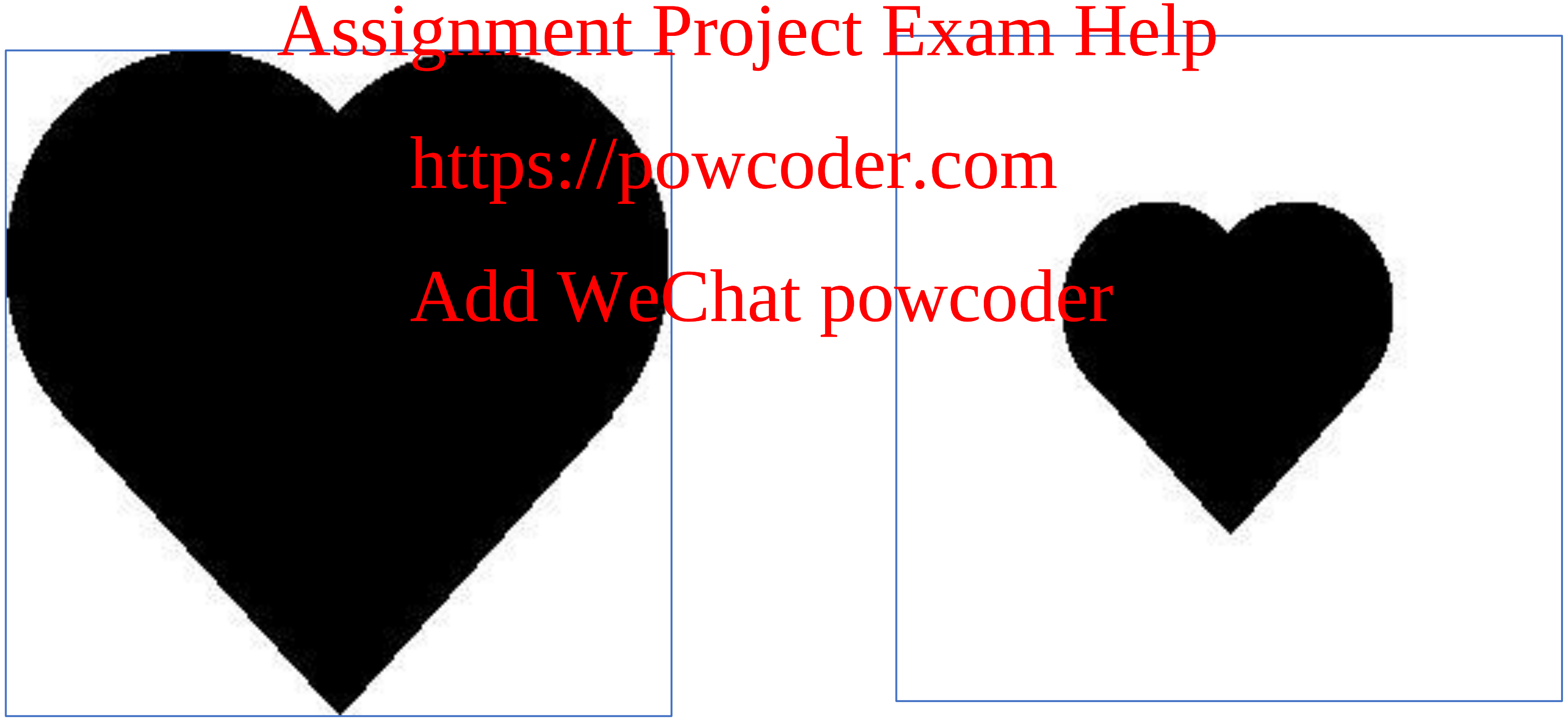




Scaling

```
clear_all()
show(scale(1/2, heart_bb))
```



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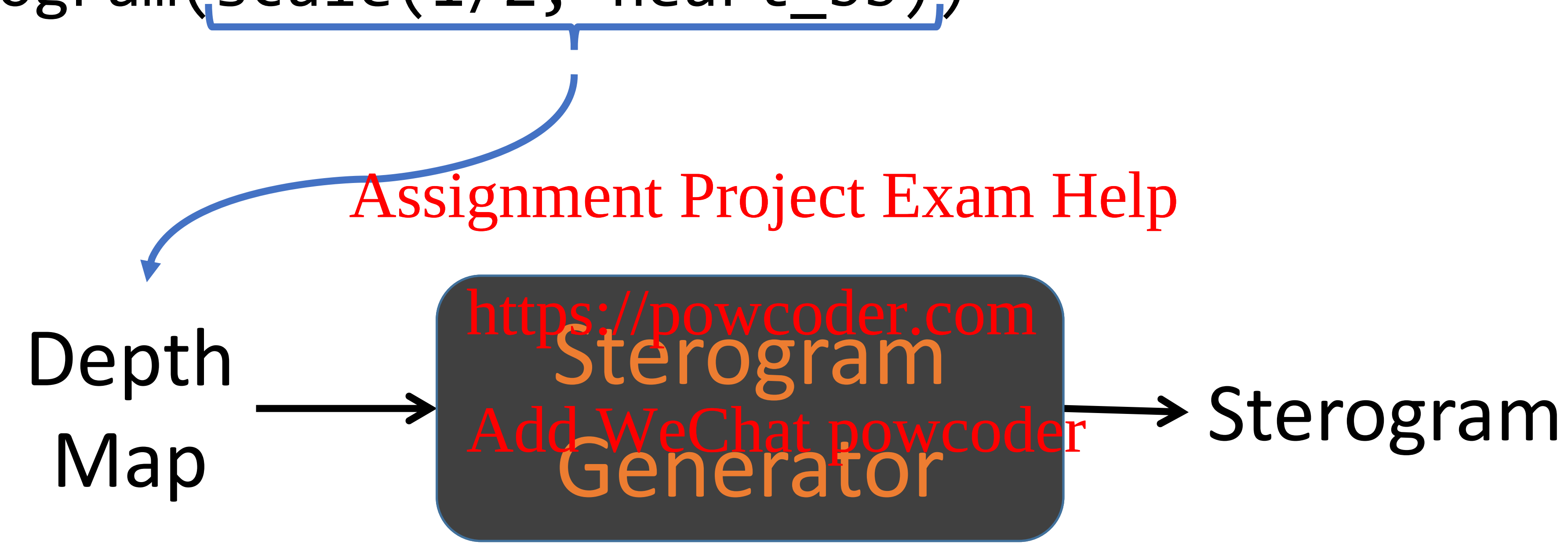
Recall

```
stereogram(scale(1/2, heart_bb))
```



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<Break>

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Managing Complexity

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Computers will follow orders precisely

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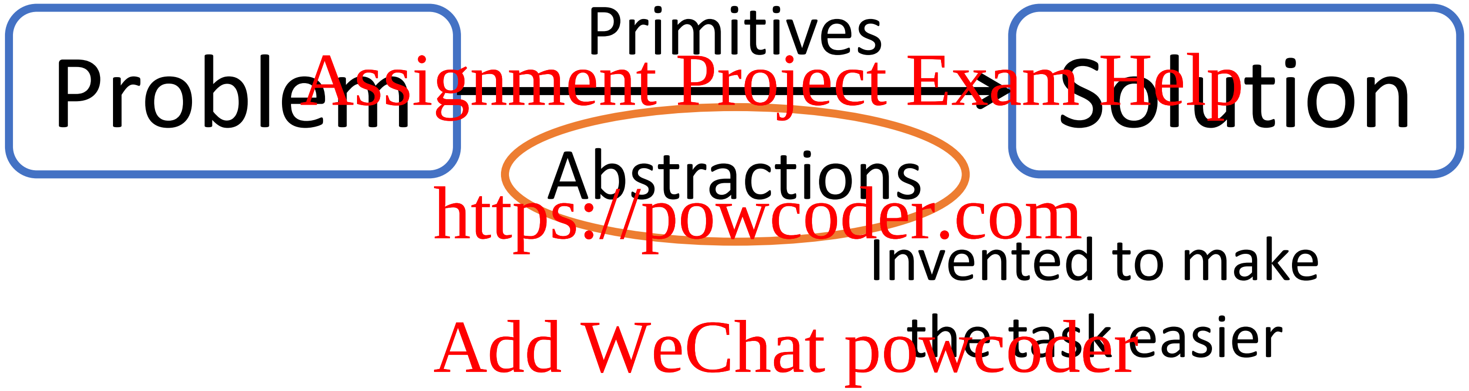
Abstractions



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What makes a good abstraction?

Good Abstraction

1. Makes it more natural to think about tasks and subtasks

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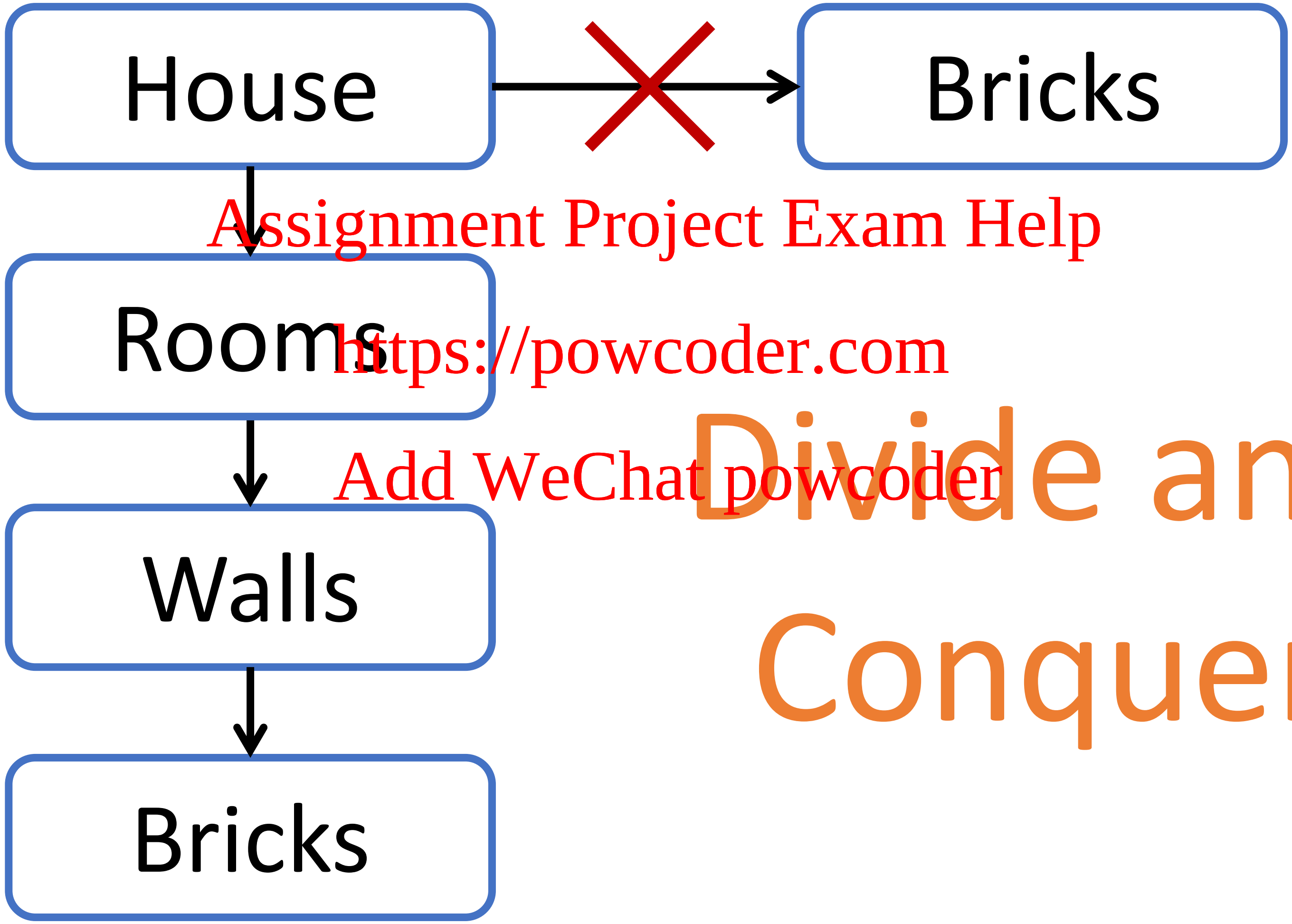
Example



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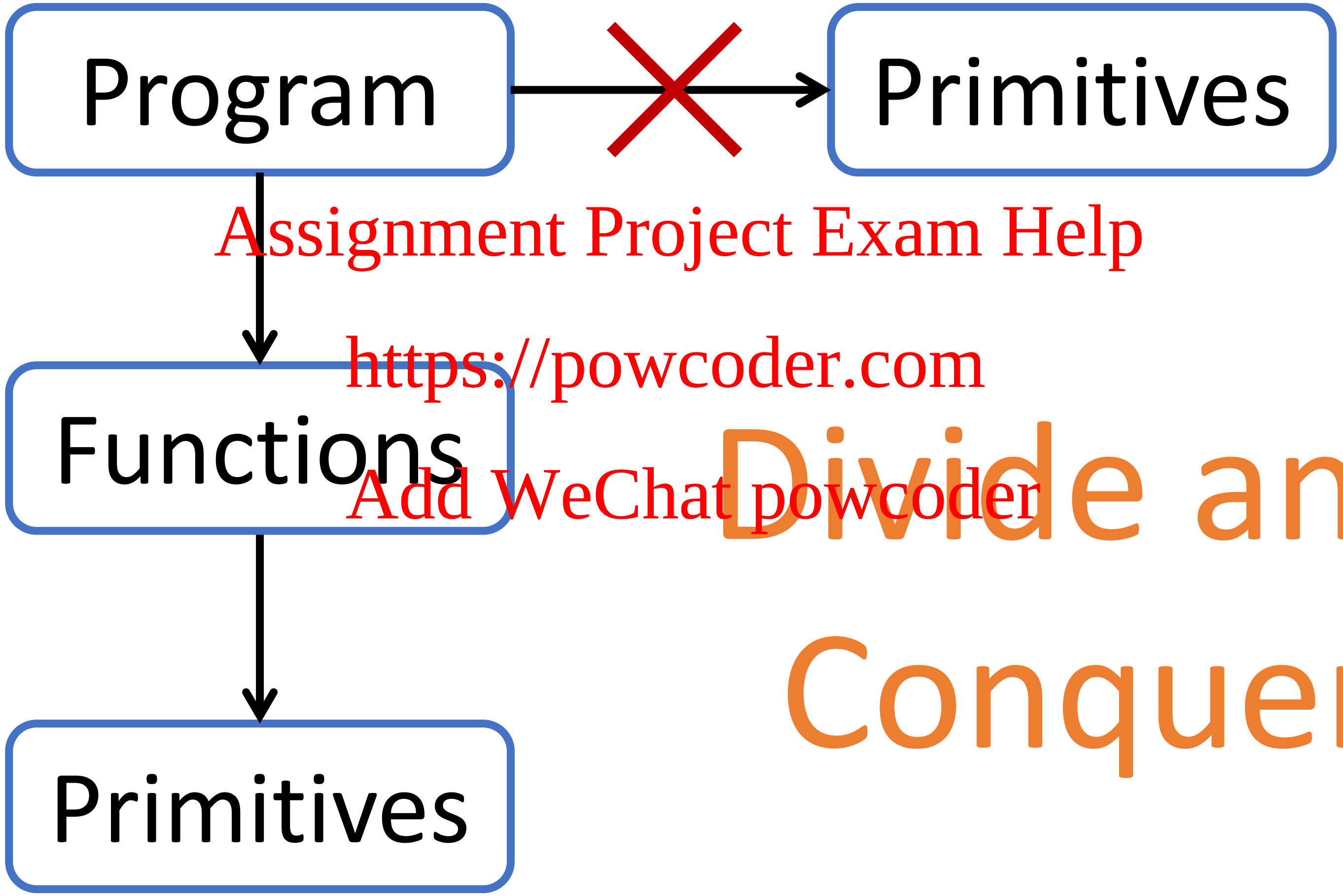
Divide and Conquer

Programming



Divide and Conquer

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Good Abstraction

1. Makes it more natural to think about tasks and subtasks
2. Makes programs easier to understand

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Compare:

```
def hypotenuse(a, b):
    return sqrt((a*a) + (b*b))
```

Versus:

```
def hypotenuse(a, b):
    return sqrt(sum_of_squares(a, b))
def sum_of_squares(x, y):
    return square(x) + square(y)
def square(x):
    return x * x
```

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Good Abstraction

1. Makes it more natural to think about tasks and subtasks
2. Makes programs easier to understand
3. Captures common patterns

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```
stack(
  beside(
    quarter_turn_right(rcross_bb),
    turn_upside_down(rcross_bb)),
  beside(
    rcross_bb,
    quarter_turn_left(rcross_bb)))
```

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```
stack(
  beside(
    quarter_turn_right(pic),
    turn_upside_down(pic)),
  beside(
    pic,
    quarter_turn_left(pic)))
```

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```
def make_cross(pic):
  return stack(
    beside(
      quarter_turn_right(pic),
      turn_upside_down(pic)),
    beside(
      pic,
      quarter_turn_left(pic)))
```

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Allows Code Reuse

Good Abstraction

1. Makes it more natural to think about tasks and subtasks
2. Makes programs easier to understand
3. Captures common patterns
4. Allows for code reuse

- Function `square` used in `sum_of_squares`.
- `square` can also be used in calculating area of circle.

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Another Example

Function to calculate area of circle given the radius

```
pi = 3.14159
def circle_area_from_radius(r):
  return pi * square(r)
```

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given the diameter:

```
def circle_area_from_diameter(d):
  return circle_area_from_radius(d/2)
```

Good Abstraction

1. Makes it more natural to think about tasks and subtasks
2. Makes programs easier to understand
3. Captures common patterns
4. Allows for code reuse
5. Hides irrelevant details

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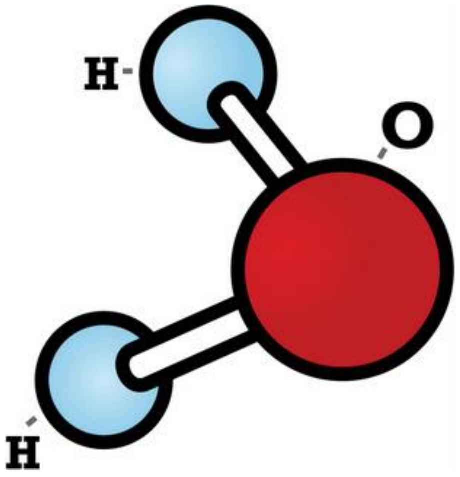
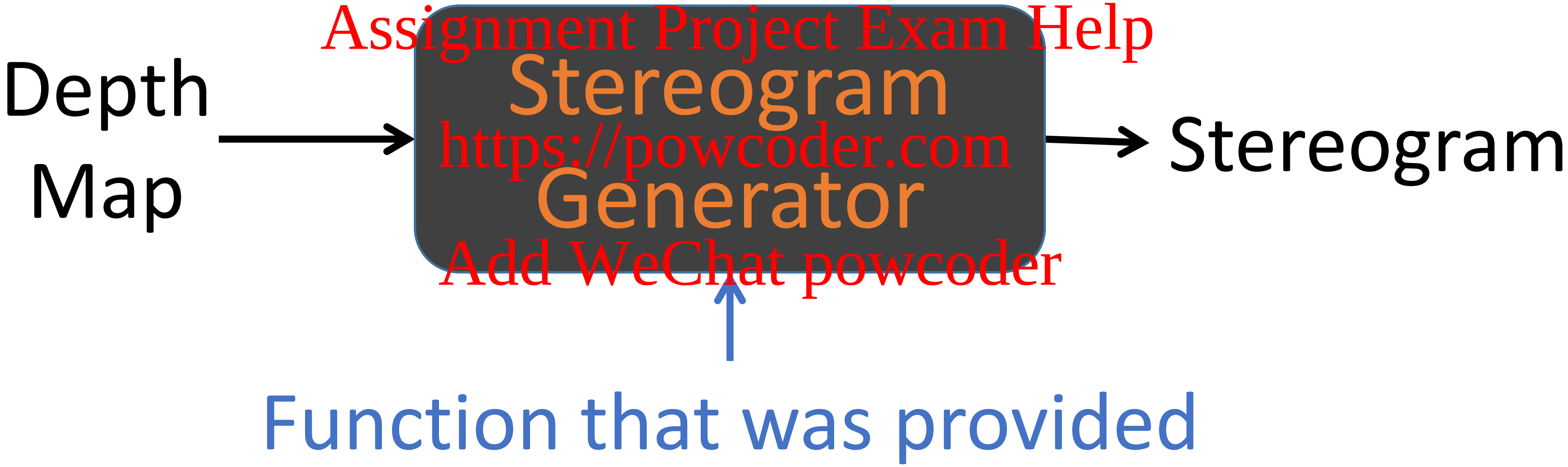


Water molecule represented as 3 balls

Ok for some chemical analyses, inadequate for others.



Depth Map

Stereogram Generator

Stereogram

Function that was provided

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Good Abstraction

1. Makes it more natural to think about tasks and subtasks
2. Makes programs easier to understand
3. Captures common patterns
4. Allows for code reuse
5. Hides irrelevant details
6. Separates specification from implementation

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Recap

Functional Abstraction

=

Black Box

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No need to know how a car works to drive it!

Functional Abstraction

Separates specification from implementation

Specification: WHAT

Implementation: HOW

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Example

```
def square(x):
    return x * x
```

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```
def square(x):
    return exp(double(log(x)))
```

```
def double(x): return x + x
```

To think about

Why would we want to implement a function in different ways?

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Good Abstraction

1. Makes it more natural to think about tasks and subtasks
2. Makes programs easier to understand
3. Captures common patterns
4. Allows for code reuse
5. Hides irrelevant details
6. Separates specification from implementation
7. Makes debugging (fixing errors) easier

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Good Abstraction

Where is the bug?

```
def hypotenuse(a, b):
  return sqrt(sum_of_squares(a, b))

def sum_of_squares(x, y):
  return square(x) + square(y)

def square(x): return x + x
```

```
def hypotenuse(a, b):
  return sqrt((a + a) * (b + b))
```

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Variable Scope

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Variable Scope

```
x = 10
def square(x): return x * x
def double(x): return x + x
def addx(y): return y + x

square(20)
square(x)
addx(5)
```

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Which x ?

Variable Scope

formal parameter

```
def square(x):
    return x * x
```

body

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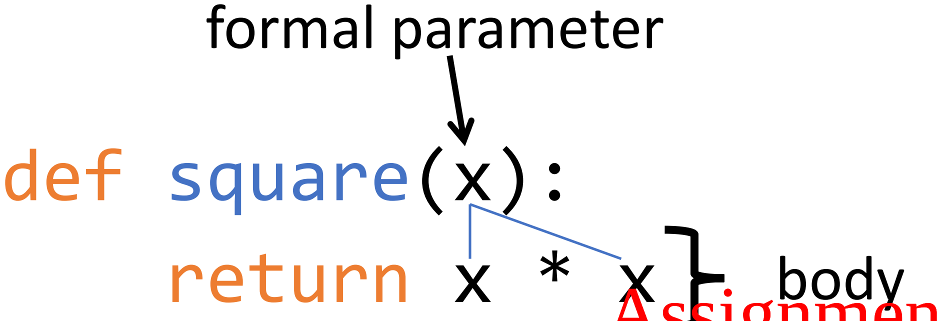
A function definition binds its formal parameters.

i.e. the formal parameters are visible only inside the definition (body), not outside.

Variable Scope



formal parameter

```
def square(x):
    return x * x
```

body

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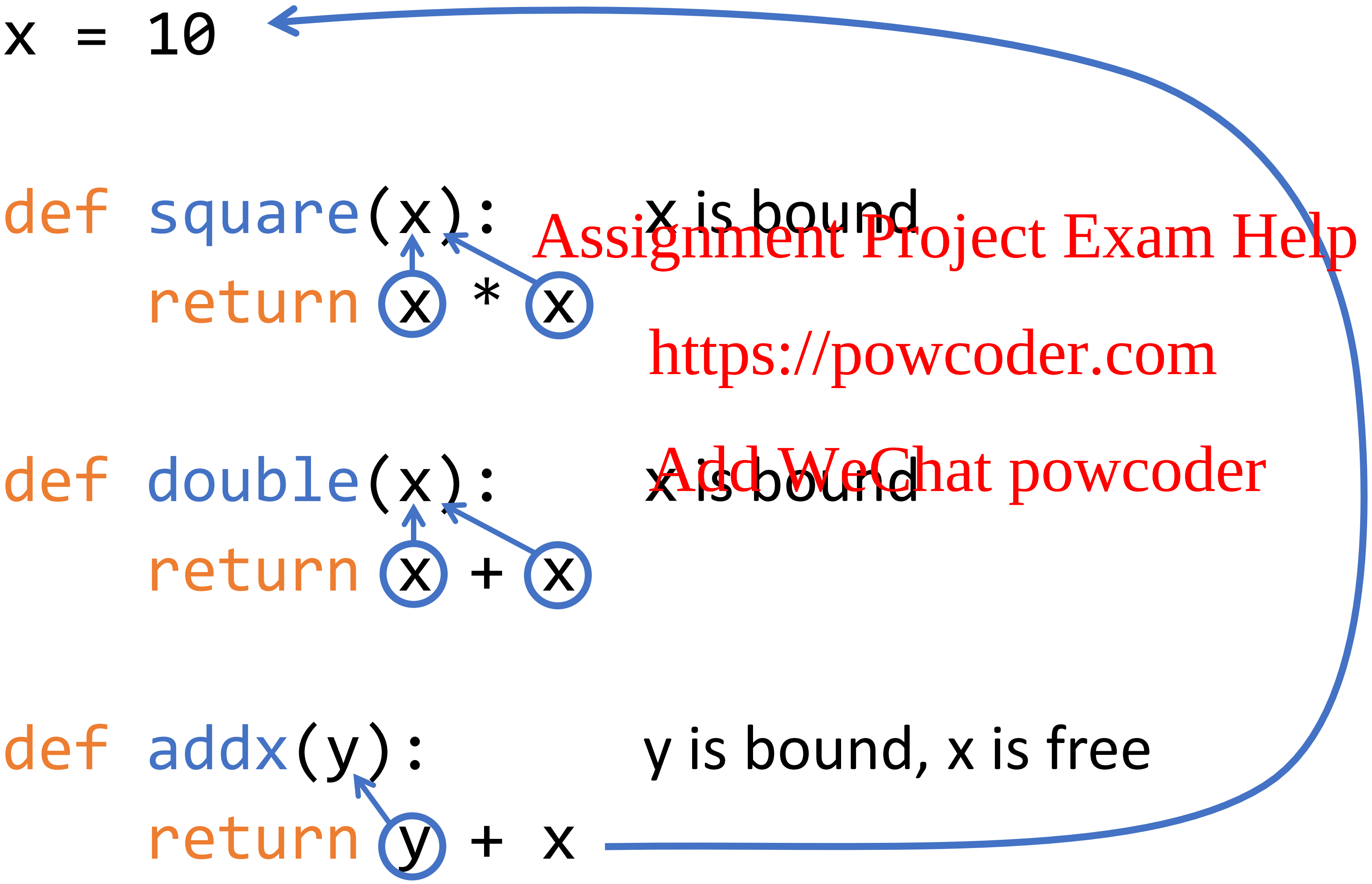
- Formal parameters are bound variables.
- The region where a variable is visible is called the scope of the variable.
- Any variable that is not bound is free.

Variable Scope



```
x = 10

def square(x):
    return x * x

def double(x):
    return x + x

def addx(y):
    return y + x
```

x is bound

x is bound

y is bound, x is free

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Example

```
pi = 3.14169

def circle_area_from_radius(r):
    pi = 22/7   #local pi
    return pi * square(r)
```

Which pi?

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Block Structure

```
def hypotenuse(a, b):

    def sum_of_squares():
        return square(a) + square(b)

    return math.sqrt(sum_of_squares())
```

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The variables a and b in sum_of_squares refer to the formal parameters of hypotenuse.

Hides irrelevant details (sum_of_squares) from the user of hypotenuse.

Wishful Thinking

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WHAT

Top-down design approach:

Pretend you have whatever you need

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WHY

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Easier to think with in the goal in mind

Analogy

Suppose you are to build a house.

Where do you start?

Individual bricks

Building plan

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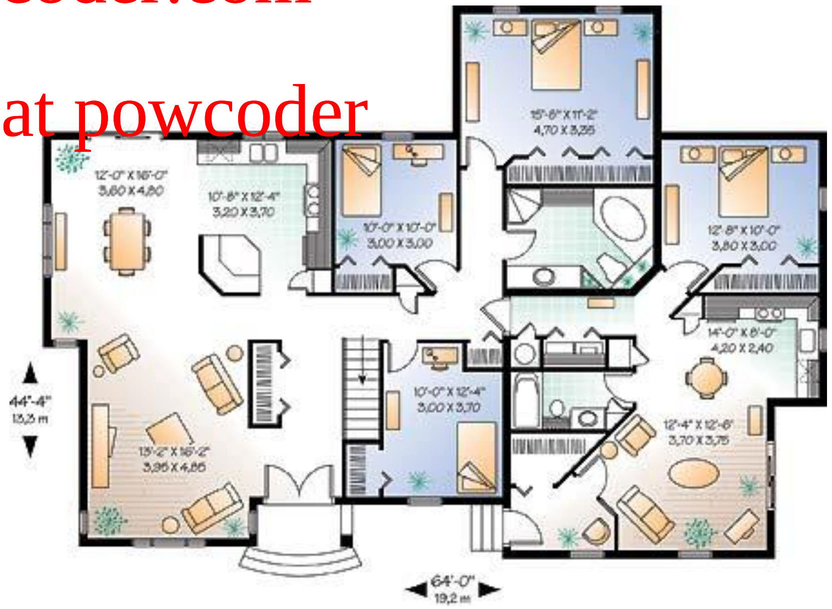

Example

Suppose you want to compute hypotenuse

```
def hypotenuse(a, b):
    return sqrt(sum_of_squares(a, b))

def sum_of_squares(x, y):
    return square(x) + square(y)

def square(x):
    return x * x
```

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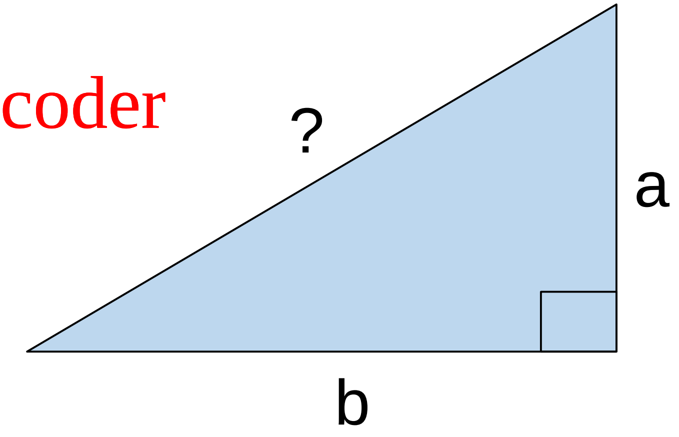

Another Example

Comfort Delgro, the largest taxi operator in Singapore, determines the taxi fare based on distance traveled as follows:

• For the first kilometre or less:	$2.40
• Every 200 metres thereafter or less up to 10 km:	$0.10
• Every 150 metres thereafter or less after 10 km:	$0.10

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Problem:

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Write a Python function that computes the taxi fare from distance travelled.

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How do we start?

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Formulate the problem

Function

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Needs a name

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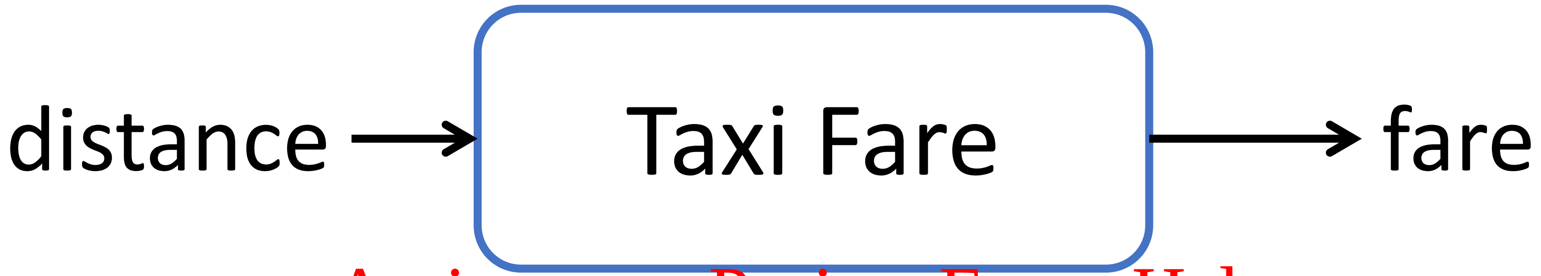
Pick an appropriate name

(not foo)

Formulate the problem



- What data do you need? (be thorough)
- Where would you get it? (argument/ computed?)

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Results should be unambiguous

- What other abstractions may be useful?
- Ask the same questions for each abstraction.

How can the result be computed from data?

1. Try simple examples
2. Strategize step by step
3. Write it down and refine

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Solution

- What to call the function? taxi_fare
- What data are required? distance
- Where to get the data? function argument
- What is the result? fare

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How can the result be computed from data?

- e.g. #1: distance = 800 m, fare = \$2.40
- e.g. #2: distance = 3,300 m

  $\text{fare} = \$2.40 + \lceil 2300/200 \rceil \times \$0.10$

  $= \$3.60$

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- e.g. #3: distance = 14,500 m

  $\text{fare} = \$2.40 + \lceil 9000/200 \rceil \times \$0.10 + \lceil 4500/150 \rceil \times \$0.10 = \$9.90$

Pseudocode

```
Case 1:  distance <= 1000
        fare = $2.40

Case 2: 1000 < distance <= 10,000
        fare = $2.40 + $0.10 * $\lceil$(distance – 1000)/200$\rceil$

Case 3: distance > 10,000
        fare = $6.90 + $0.10 * $\lceil$(distance – 10,000)/150)$\rceil$
```

What's this?

Note: the Python function `ceil` rounds up its argument. `math.ceil(1.5) = 2`

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Solution

```
def taxi_fare(distance):  # distance in metres
  if distance <= 1000:
    return 2.4
  elif distance <= 10000:
    return 2.4 + (0.10 * ceil((distance – 1000) / 200))
  else:
    return 6.9 + (0.10 * ceil((distance – 10000) / 150))

# check: taxi_fare(3300) = 3.6
```

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Can we improve this solution?

Coping with Change

What if…

1. the starting fare increases?
2. stage distance changes?
3. increment amount changes?

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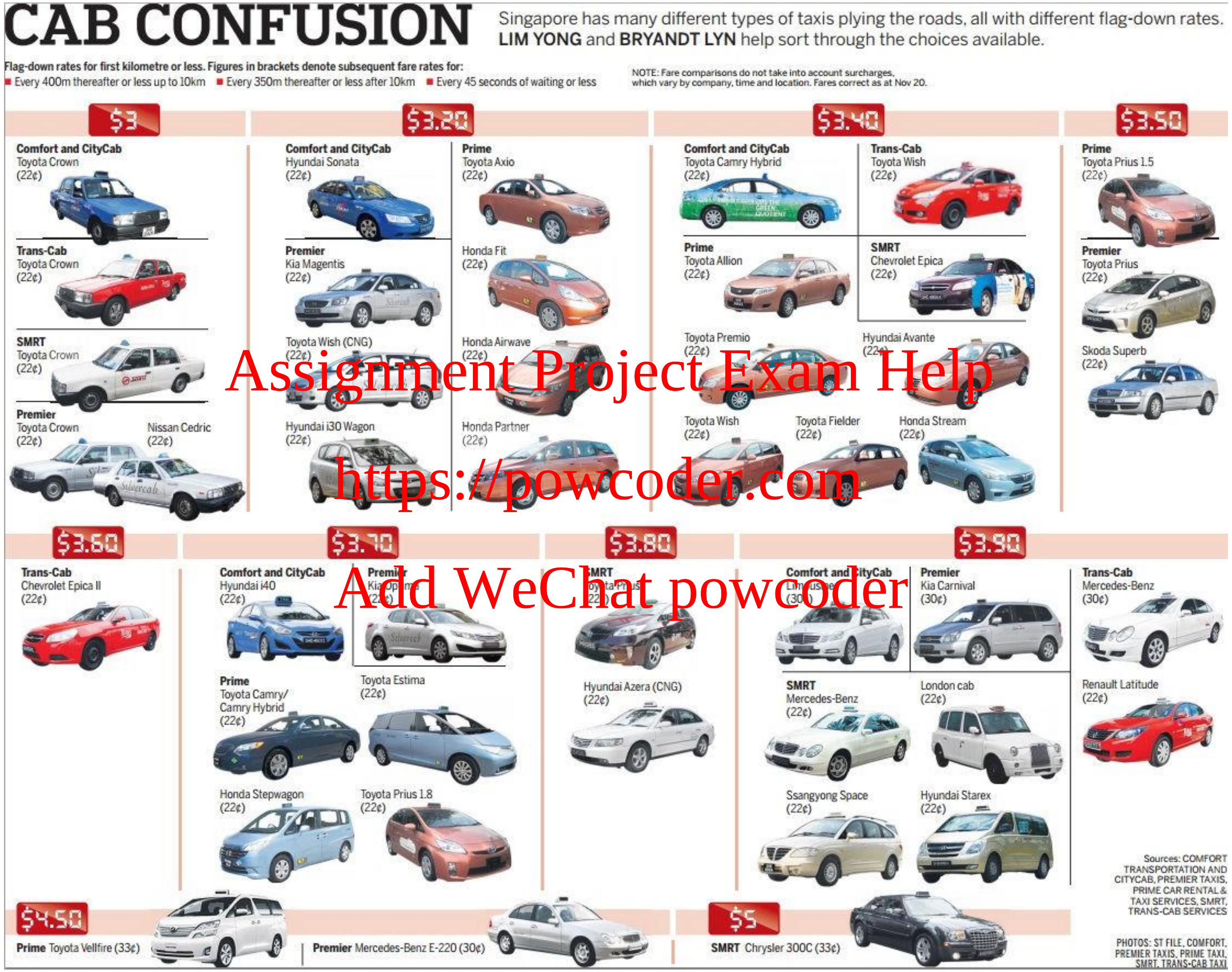

CAB CONFUSION

Singapore has many different types of taxis plying the roads, all with different flag-down rates. **LIM YONG** and **BRYANDT LYN** help sort through the choices available.

Flag-down rates for first kilometre or less. Figures in brackets denote subsequent fare rates for:

- Every 400m thereafter or less up to 10km
- Every 350m thereafter or less after 10km
- Every 45 seconds of waiting or less

NOTE: Fare comparisons do not take into account surcharges, which vary by company, time and location. Fares correct as at Nov 20.

$3

Comfort and CityCab
Toyota Crown
(22¢)

Trans-Cab
Toyota Crown
(22¢)

SMRT
Toyota Crown
(22¢)

Premier
Toyota Crown
(22¢)

Nissan Cedric
(22¢)

$3.20

Comfort and CityCab
Hyundai Sonata
(22¢)

Premier
Kia Magentis
(22¢)

Toyota Wish (CNG)
(22¢)

Hyundai i30 Wagon
(22¢)

Prime
Toyota Axio
(22¢)

Honda Fit
(22¢)

Honda Airwave
(22¢)

Honda Partner
(22¢)

$3.40

Comfort and CityCab
Toyota Camry Hybrid
(22¢)

Trans-Cab
Toyota Wish
(22¢)

Prime
Toyota Allion
(22¢)

SMRT
Chevrolet Epica
(22¢)

Toyota Premio
(22¢)

Hyundai Avante
(22¢)

Toyota Wish
(22¢)

Toyota Fielder
(22¢)

Honda Stream
(22¢)

$3.50

Prime
Toyota Prius 1.5
(22¢)

Premier
Toyota Prius
(22¢)

Skoda Superb
(22¢)

$3.60

Trans-Cab
Chevrolet Epica II
(22¢)

$3.70

Comfort and CityCab
Hyundai i40
(22¢)

Premier
Kia Optima
(22¢)

Prime
Toyota Camry/
Camry Hybrid
(22¢)

Toyota Estima
(22¢)

Honda Stepwagon
(22¢)

Toyota Prius 1.8
(22¢)

$3.80

SMRT
Toyota Prius
(22¢)

Hyundai Azera (CNG)
(22¢)

$3.90

Comfort and CityCab
Limousine
(30¢)

Premier
Kia Carnival
(30¢)

SMRT
Mercedes-Benz
(22¢)

London cab
(22¢)

Ssangyong Space
(22¢)

Hyundai Starex
(22¢)

Trans-Cab
Mercedes-Benz
(30¢)

Renault Latitude
(22¢)

$4.50

Prime Toyota Vellfire (33¢)

Premier Mercedes-Benz E-220 (30¢)

$5

SMRT Chrysler 300C (33¢)

Sources: COMFORT TRANSPORTATION AND CITYCAB, PREMIER TAXIS, PRIME CAR RENTAL & TAXI SERVICES, SMRT, TRANS-CAB SERVICES

PHOTOS: ST FILE, COMFORT, PREMIER TAXIS, PRIME TAXI, SMRT, TRANS-CAB TAXI

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Avoid Magic Numbers

It is a terrible idea to hardcode numbers (magic numbers):

- Hard to make changes in future

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Define abstractions to hide them!

Solution v2

```
def taxi_fare(distance): # distance in metres
    if distance <= stage1:
        return start_fare
    elif distance <= stage2:
        return start_fare + (increment * ceil((distance - stage1) / block1))
    else:
        return taxi_fare(stage2) + (increment * ceil((distance - stage2) / block2))
stage1 = 1000
stage2 = 10000
start_fare = 2.4
increment = 0.1
block1 = 200
block2 = 150
```

recursive call

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in 2018

```python
def taxi_fare(distance): # distance in metres
    if distance <= stage1:
        return start_fare
    elif distance <= stage2:
        return start_fare + (increment * ceil((distance - stage1) / block1))
    else:
        return taxi_fare(stage2) + (increment * ceil((distance - stage2) / block2))
stage1 = 1000
stage2 = 10000
start_fare = 3.7
increment = 0.22
block1 = 400
block2 = 350
```

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Summary

- Functional Abstraction
- Good Abstractions
- Variable Scoping
- Wishful Thinking

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Recitation Thursday/Friday

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