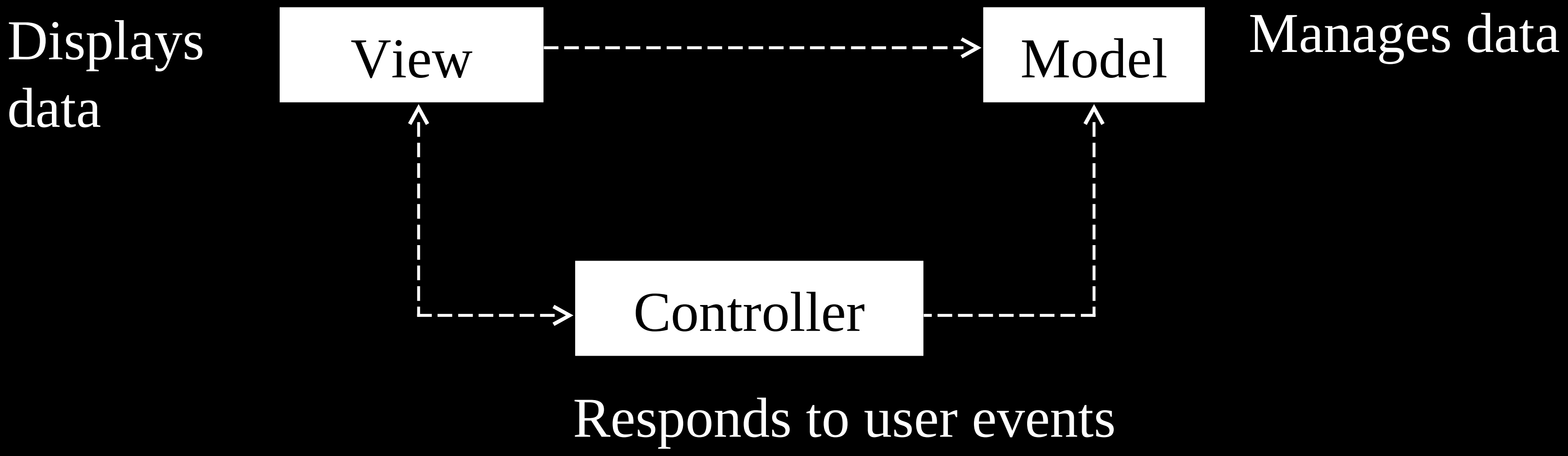
Special Topic: *Threading and Concurrency*

CSCI 250: Intro to Robotics

Prof. Levy

Recall: Model/View/Controller Pattern

GUI-based, event-driven programs can be further decomposed by gathering code to handle user interactions into a third component called the *controller*:



The Controller

- In Python, the controller consists of the methods that respond to user events

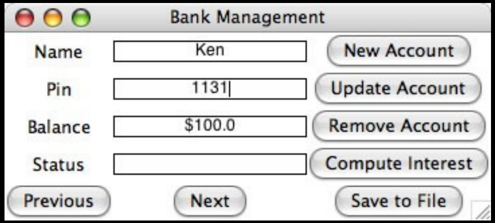
- These methods are defined in the main view class, and are associated with the **`command`** attribute of the buttons

- Other types of widgets can have their own event-handling methods

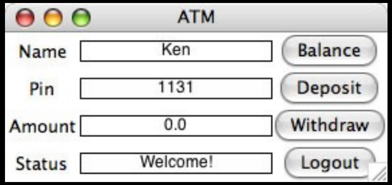
Event-Driven Programming

- Set up a window with its widgets
- Connect it to a data model
- Wait for users to press buttons, enter text, drag the mouse, etc.
- Respond to these events by running methods that update the data model and the view

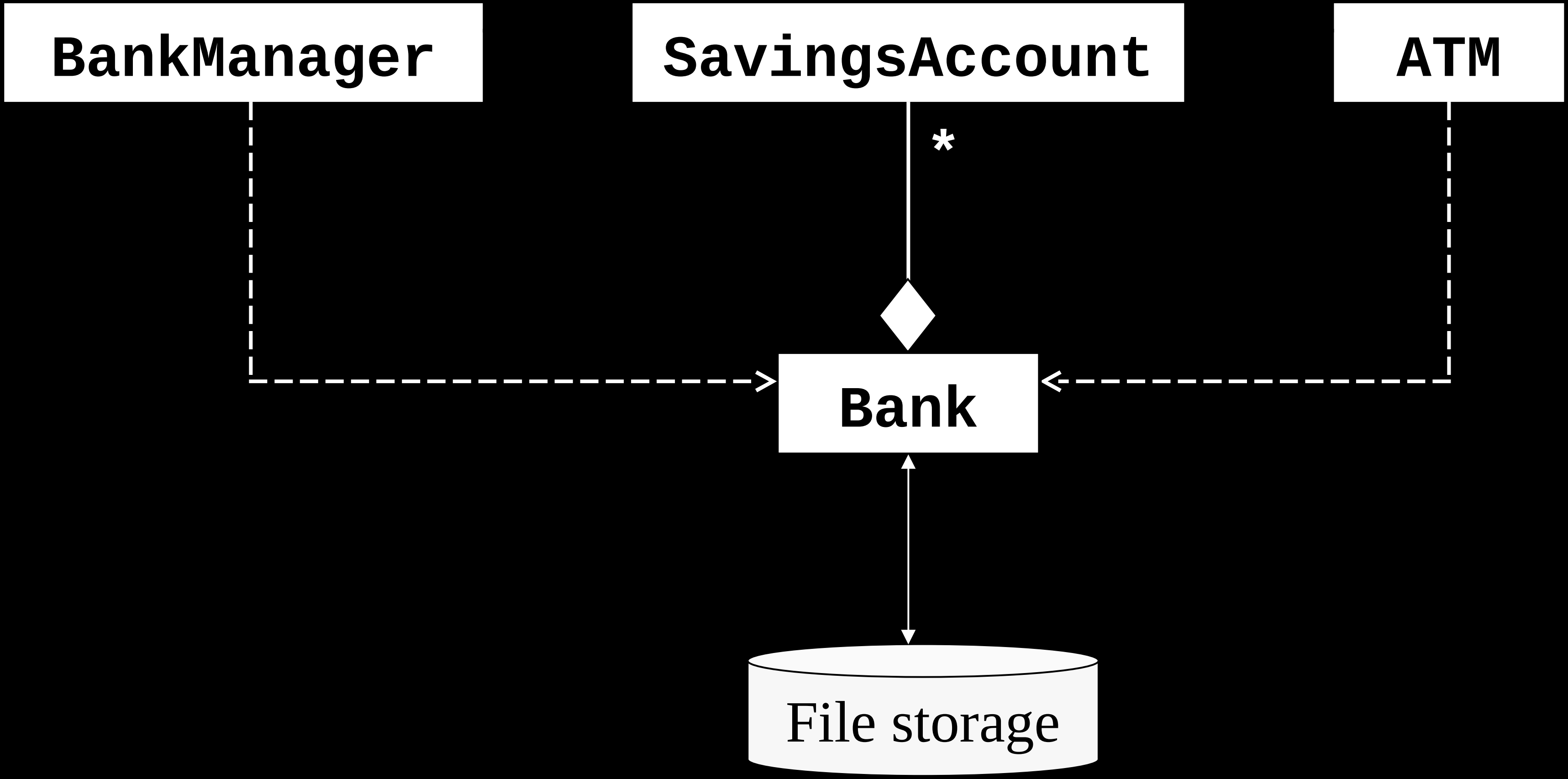
A Banking System


Bank Management

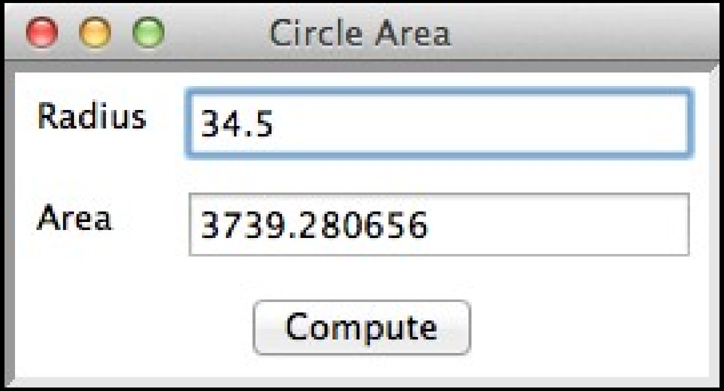
Name	Ken	New Account
Pin	1131	Update Account
Balance	$100.0	Remove Account
Status		Compute Interest
Previous	Next	Save to File


ATM

Name	Ken	Balance
Pin	1131	Deposit
Amount	0.0	Withdraw
Status	Welcome!	Logout



MVC / GUI: Behind the Scenes with a Simpler Example



MVC / GUI: Behind the Scenes

```python
class CircleWithGUI(EasyFrame):
    """Computes and displays the area of a circle."""

    def __init__(self):
        """Sets up the window and widgets."""
        EasyFrame.__init__(self, title = "Circle Area")

        # Label and field for the input
        self.addLabel(text = "Radius",
                      row = 0, column = 0)
        self.radiusField = self.addFloatField(value = 0.0,
                                              row = 0,
                                              column = 1)

        # Label and field for the output
        self.addLabel(text = "Area",
                      row = 1, column = 0)
        self.areaField = self.addFloatField(value = 0.0,
                                            row = 1,
                                            column = 1)

        # The command button
        self.addButton(text = "Compute", row = 2, column = 0,
                       columnspan = 2, command = self.computeArea)
```

```python
class CircleWithGUI(EasyFrame):
    """Computes and displays the area of a circle."""

    . . .


    # The event handling method for the button
    def computeArea(self):
        """Inputs the radius, computes the area,
        and outputs the result."""
        radius = self.radiusField.getNumber()
        area = math.pi * radius ** 2
        self.areaField.setNumber(area)

#Instantiate and pop up the window.
if __name__ == "__main__":
    CircleWithGUI().mainloop()
```

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What will happen now?

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        radius = self.radiusField.getNumber()
        area = math.pi * radius ** 2
        self.areaField.setNumber(area)

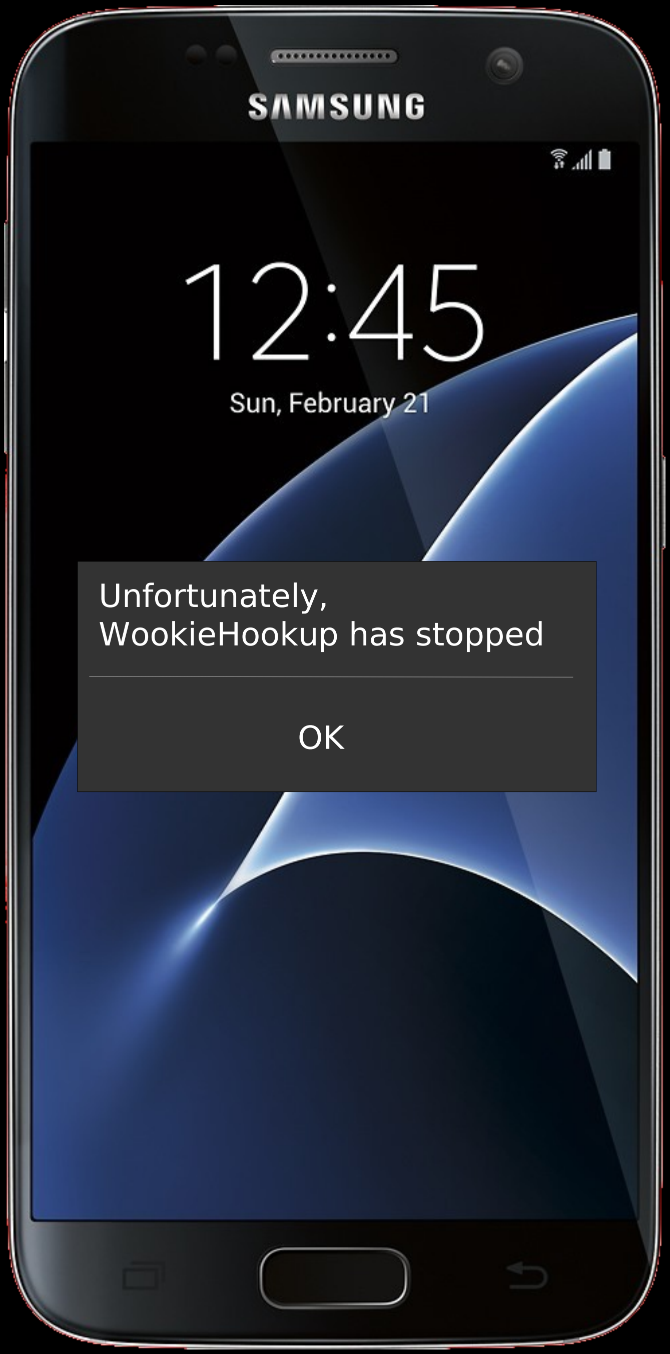
#Instantiate and pop up the window.
if __name__ == "__main__":
    print("About to enter mainloop ...")
    CircleWithGUI().mainloop()
    print("Here I am, rock you like a hurricane!")
```

So what’s the problem?

- The entire program (model / view / controller) is executing on a single *thread*.
- For a simple kind of interaction, this approach is fine:

$$\begin{tikzcd}\textit{Human action} \arrow[r, bend left] & \textit{GUI response} \arrow[l, bend left]\end{tikzcd}$$

- On a *real-time device* (phone, tablet, robot), this approach is too constraining and leads to ...



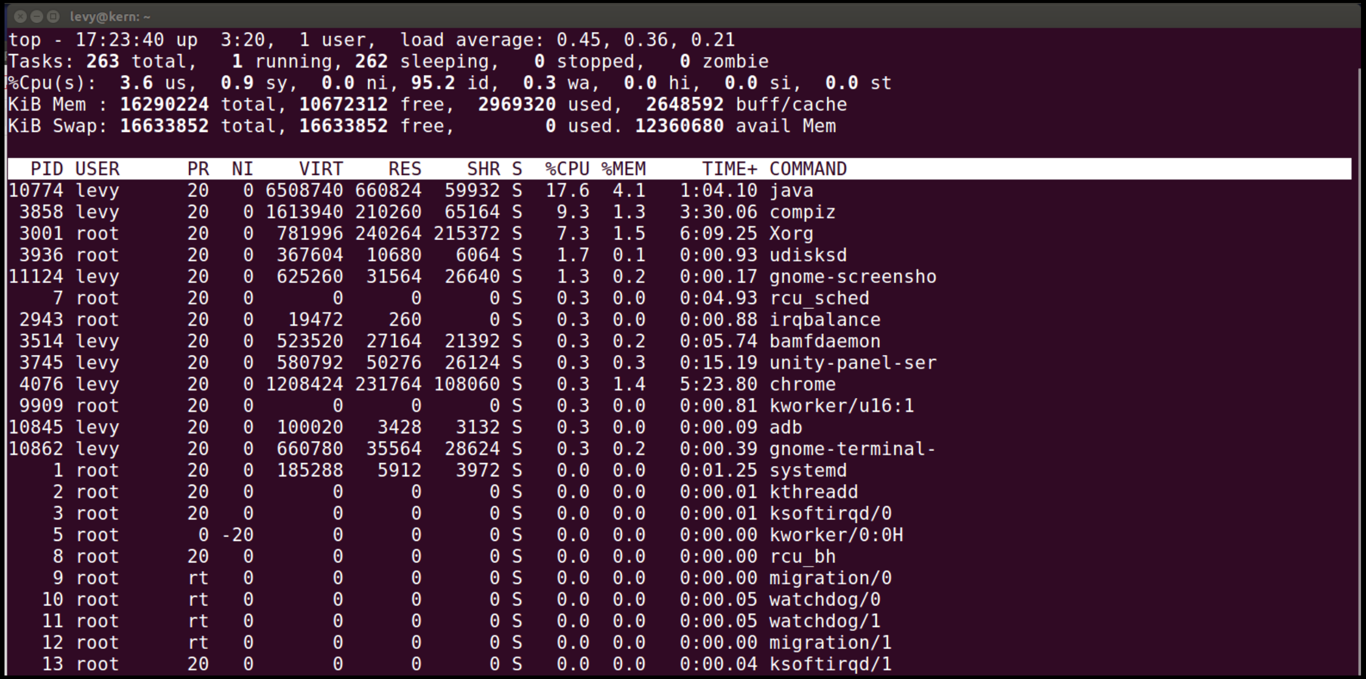
Unfortunately, WookieHookup has stopped

So what’s the solution?

- *Multi-threading* : The model (computation, downloading, communication, etc.) component must run *concurrently* with the view/controller component, each on its own thread.
- In brief: **threads execute independently of each other, but share the same data.**
- Let’s look at threading (a.k.a. *concurrency*) in more detail ...

Thread vs. Process

- *Process* : **an executing instance of a program***
- In Unix (Linux, OS X) we can use the **`top`** (or **`ps`**) command to tell us what processes are running:



```
top - 17:23:40 up  3:20,  1 user,  load average: 0.45, 0.36, 0.21
Tasks: 263 total,   1 running, 262 sleeping,   0 stopped,   0 zombie
%Cpu(s):  3.6 us,  0.9 sy,  0.0 ni, 95.2 id,  0.3 wa,  0.0 hi,  0.0 si,  0.0 st
KiB Mem : 16290224 total, 10672312 free,  2969320 used,  2648592 buff/cache
KiB Swap: 16633852 total, 16633852 free,        0 used. 12360680 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
10774 levy      20   0 6508740 660824  59932 S  17.6  4.1   1:04.10 java
 3858 levy      20   0 1613940 210260  65164 S   9.3  1.3   3:30.06 compiz
 3001 root      20   0  781996 240264 215372 S   7.3  1.5   6:09.25 Xorg
 3936 root      20   0  367604  10680   6064 S   1.7  0.1   0:00.93 udisksd
11124 levy      20   0  625260  31564  26640 S   1.3  0.2   0:00.17 gnome-screensho
    7 root      20   0       0      0      0 S   0.3  0.0   0:04.93 rcu_sched
 2943 root      20   0   19472    260      0 S   0.3  0.0   0:00.88 irqbalance
 3514 levy      20   0  523520  27164  21392 S   0.3  0.2   0:05.74 bamfdaemon
 3745 levy      20   0  580792  50276  26124 S   0.3  0.3   0:15.19 unity-panel-ser
 4076 levy      20   0 1208424 231764 108060 S   0.3  1.4   5:23.80 chrome
 9909 root      20   0       0      0      0 S   0.3  0.0   0:00.81 kworker/u16:1
10845 levy      20   0  100020   3428   3132 S   0.3  0.0   0:00.09 adb
10862 levy      20   0  660780  35564  28624 S   0.3  0.2   0:00.39 gnome-terminal-
    1 root      20   0  185288   5912   3972 S   0.0  0.0   0:01.25 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:00.01 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   0:00.01 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    8 root      20   0       0      0      0 S   0.0  0.0   0:00.00 rcu_bh
    9 root      rt   0       0      0      0 S   0.0  0.0   0:00.00 migration/0
   10 root      rt   0       0      0      0 S   0.0  0.0   0:00.05 watchdog/0
   11 root      rt   0       0      0      0 S   0.0  0.0   0:00.05 watchdog/1
   12 root      rt   0       0      0      0 S   0.0  0.0   0:00.00 migration/1
   13 root      20   0       0      0      0 S   0.0  0.0   0:00.04 ksoftirqd/1
```

* definition courtesy of Dr. J.S. Plank

Anatomy of a Process

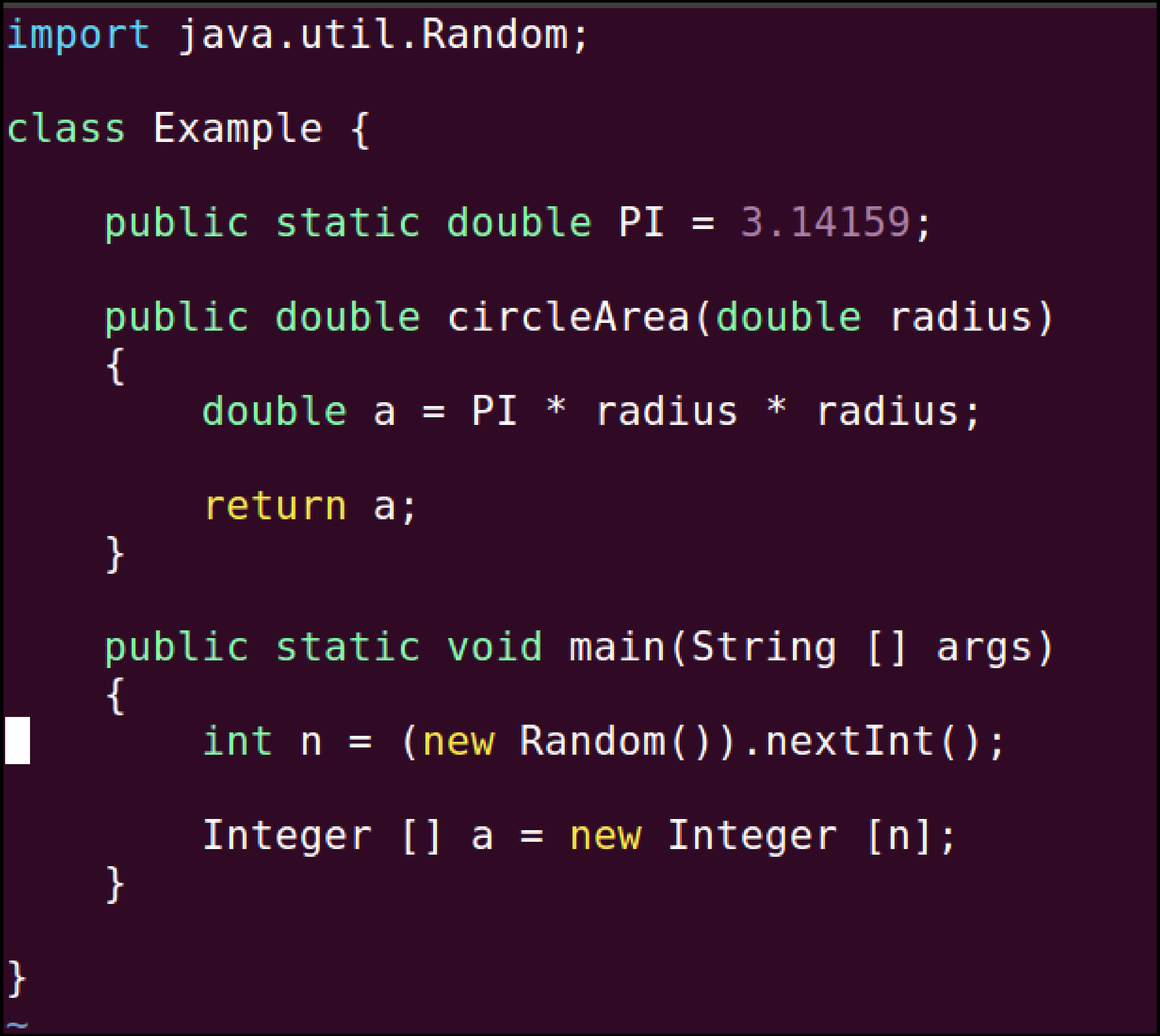
- Each process takes up its own space in the computer’s memory (RAM), sub-divided into **segments** based on how the process uses it:

  Stack: memory available locally in a function (automatically allocated / deallocated when the function is called / returns).

  Heap: *dynamic* memory; i.e., allocated at run-time

  Globals (a.k.a. **data**): allocated at compile time; available throughout process

- A precise example would require assembly language or C, but we can get a good sense use Java ...



```java
import java.util.Random;

class Example {

    public static double PI = 3.14159;

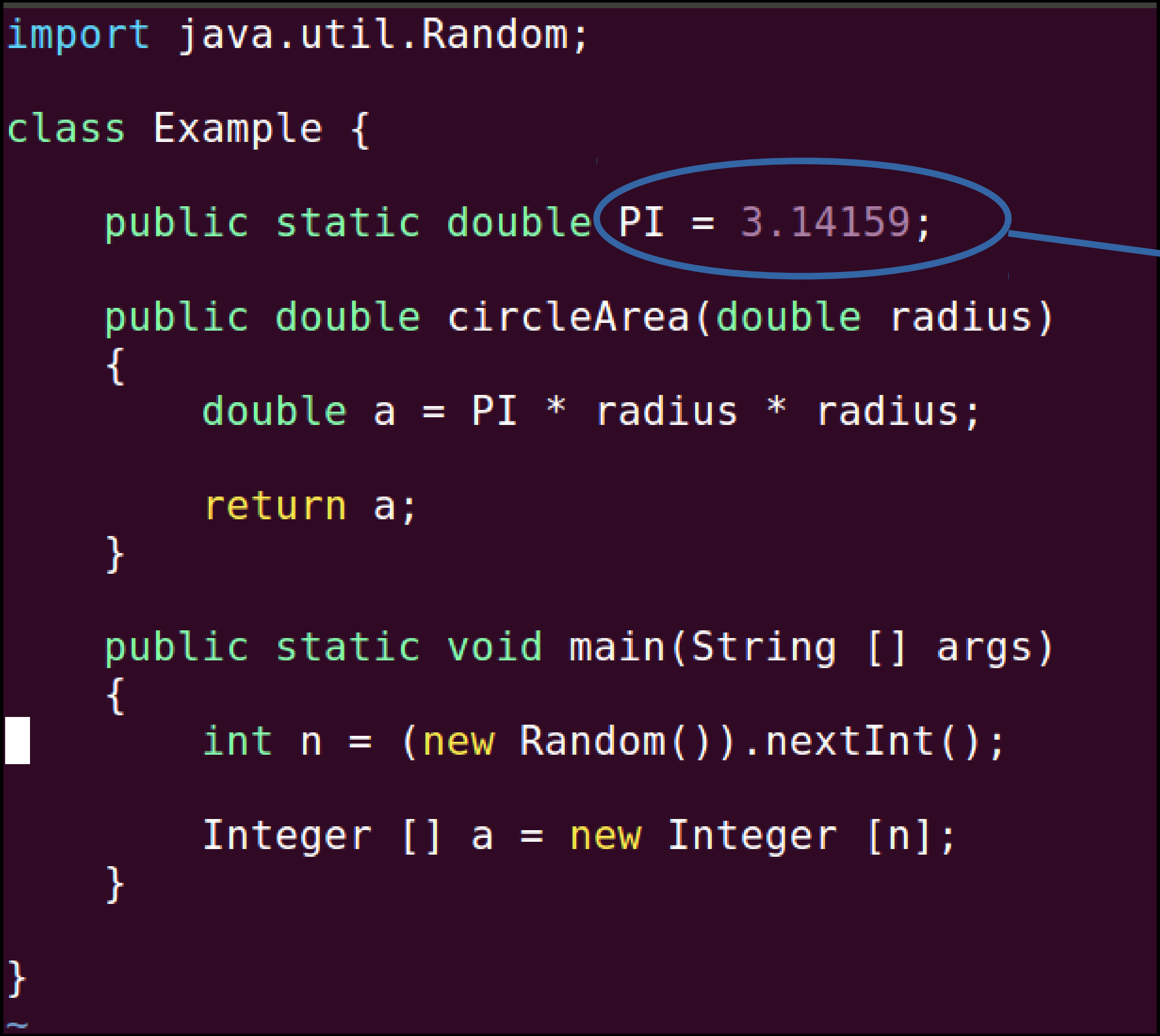
    public double circleArea(double radius)
    {
        double a = PI * radius * radius;

        return a;
    }

    public static void main(String [] args)
    {
        int n = (new Random()).nextInt();

        Integer [] a = new Integer [n];
    }

}
~
```



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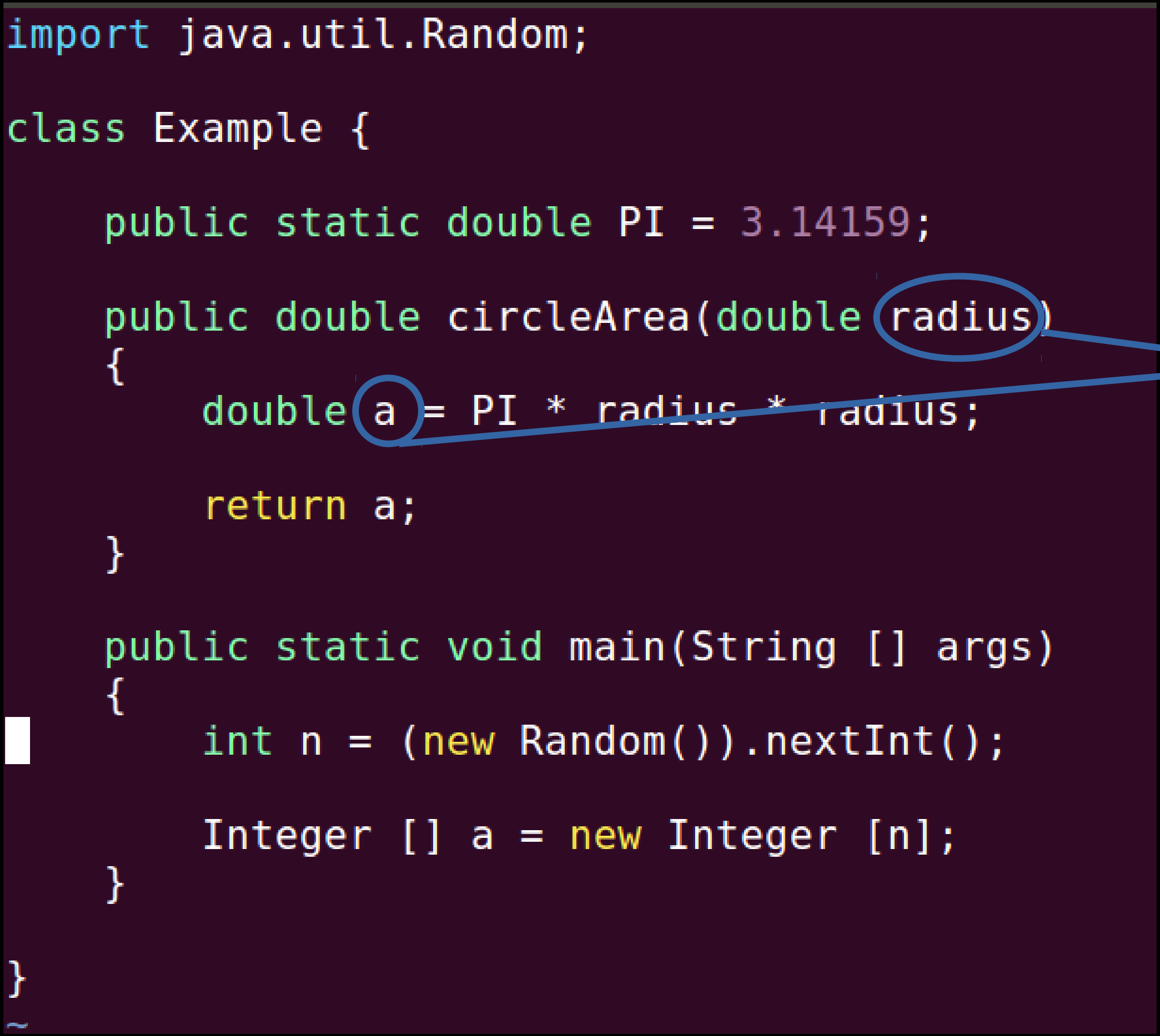
Global data (visible everywhere)



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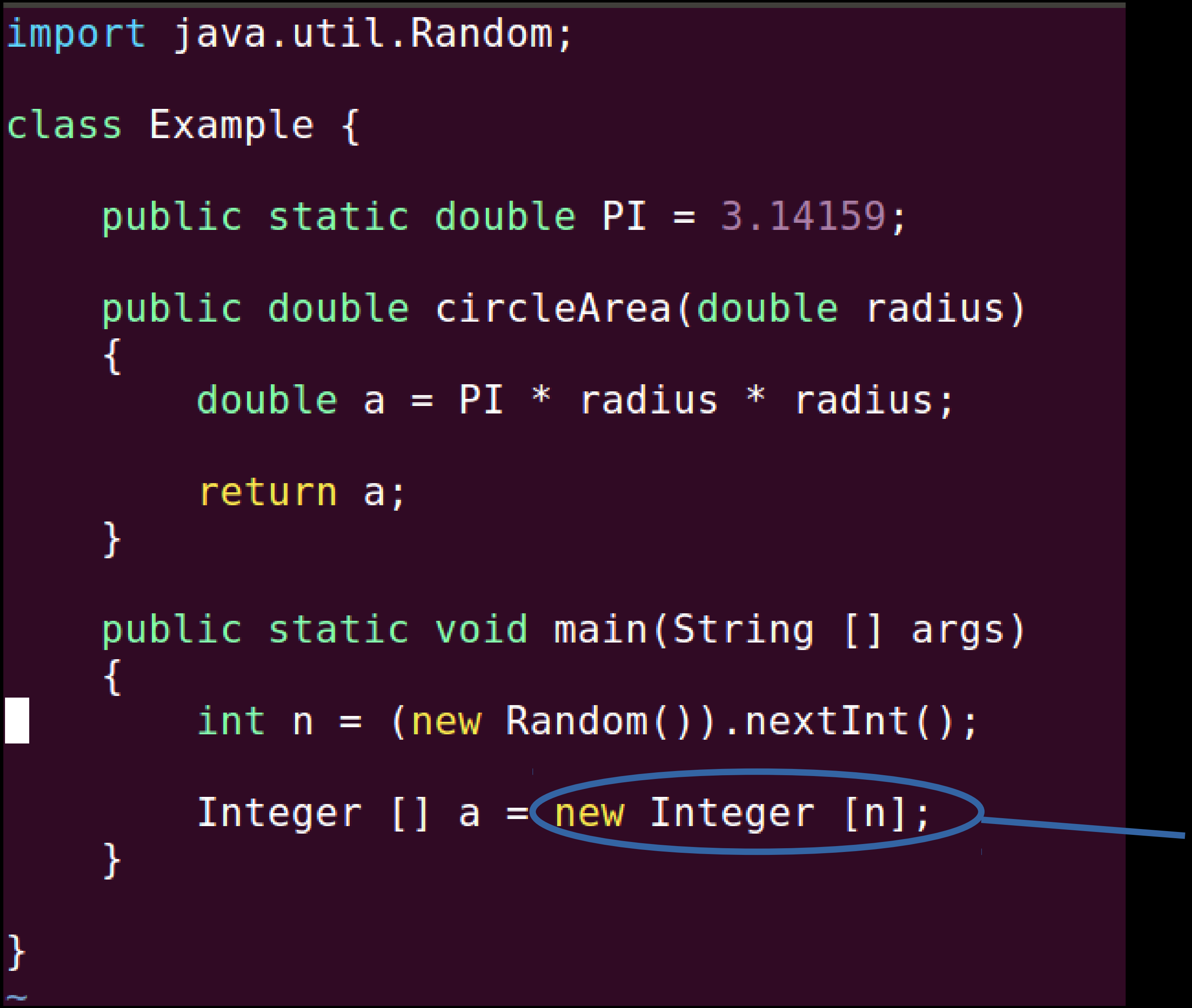
~
```

Stack vars (available only in this method)



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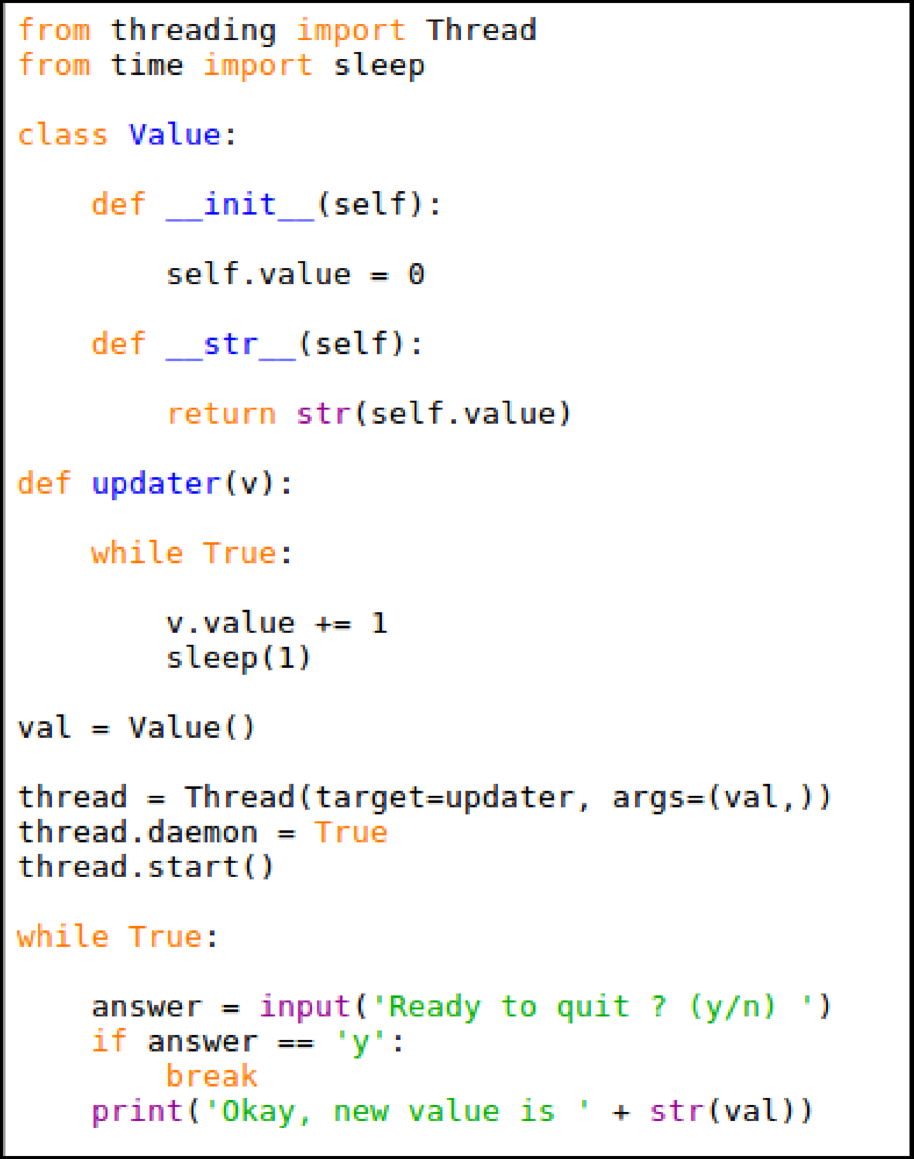
Thread: A “Lightweight” Process

- Now we have the vocabulary to talk about threads: a *thread is a “lightweight” process that has its own stack but shares heap and globals with other threads in the same process*.
- Q: Why must each thread have its own stack?

Thread: A “Lightweight” Process

- Now we have the vocabulary to talk about threads: a *thread is a “lightweight” process that has its own stack but shares heap and globals with other threads in the same process*.
- Q: Why must each thread have its own stack?
- A: So it can execute function calls (i.e., do its own work) independently of other threads.

Threads in Python



```python
from threading import Thread
from time import sleep

class Value:

    def __init__(self):

        self.value = 0

    def __str__(self):

        return str(self.value)

def updater(v):

    while True:

        v.value += 1
        sleep(1)

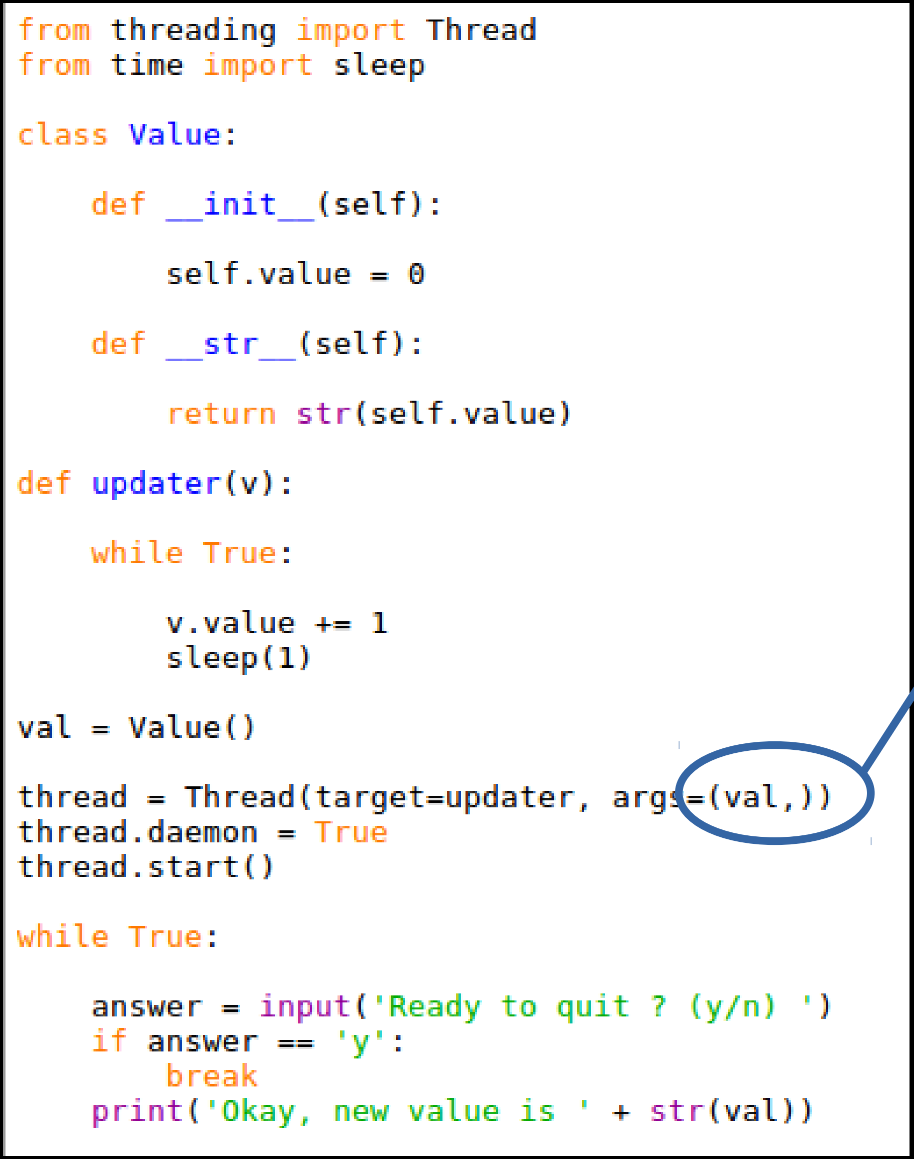
val = Value()

thread = Thread(target=updater, args=(val,))
thread.daemon = True
thread.start()

while True:

    answer = input('Ready to quit ? (y/n) ')
    if answer == 'y':
        break
    print('Okay, new value is ' + str(val))
```

Threads in Python



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```

Note that `args` must be a tuple: so if just one arg, it must end in a comma.

Threading: Additional Remarks

- As this Python example shows, threading is essential for **asynchronous** computing – i.e., when different kinds of activity have to be happening at their own time scales.
- Many apps won't need to use threading; however: *whenever you have some "heavy lifting" to do outside your main (GUI) thread (streaming data from a website or robot), you should think about threading*.
- Every solution creates another problem – can you think of what problem(s) threading creates?