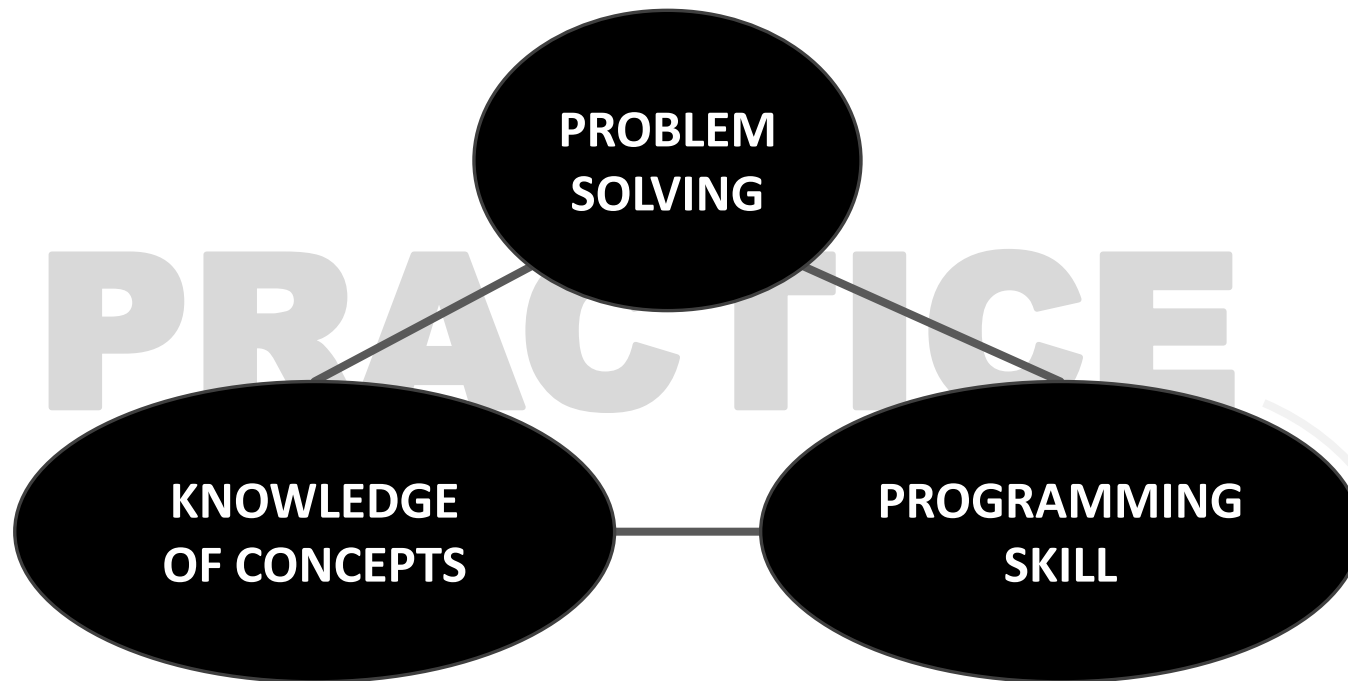

WELCOME!

(download slides and .py files and follow along!)

6.0001 LECTURE 1



TOPICS

- represent knowledge with **data structures**
- **iteration and recursion** as computational metaphors
- **abstraction** of procedures and data types
- **organize and modularize** systems using object classes and methods
- different classes of **algorithms**, searching and sorting
- **complexity** of algorithms

WHAT DOES A COMPUTER DO

- Fundamentally:
 - performs **calculations**
a billion calculations per second!
 - **remembers** results
100s of gigabytes of storage!
- What kinds of calculations?
 - **built-in** to the language
 - ones that **you define** as the programmer
- computers only know what you tell them

TYPES OF KNOWLEDGE

- **declarative knowledge** is **statements of fact**.
 - someone will win a Google Cardboard before class ends
- **imperative knowledge** is a **recipe** or “how-to”.
 - 1) Students sign up for raffle
 - 2) Ana opens her IDE
 - 3) Ana chooses a random number between 1st and nth responder
 - 4) Ana finds the number in the responders sheet. Winner!

A NUMERICAL EXAMPLE

- square root of a number x is y such that $y * y = x$
- recipe for deducing square root of a number x (16)
 - 1) Start with a **guess**, g
 - 2) If $g * g$ is **close enough** to x , stop and say g is the answer
 - 3) Otherwise make a **new guess** by averaging g and x/g
 - 4) Using the new guess, **repeat** process until close enough

| g | $g * g$ | x/g | $(g + x/g) / 2$ |
|--------|---------|--------|-----------------|
| 3 | 9 | $16/3$ | 4.17 |
| 4.17 | 17.36 | 3.837 | 4.0035 |
| 4.0035 | 16.0277 | 3.997 | 4.000002 |

WHAT IS A RECIPE

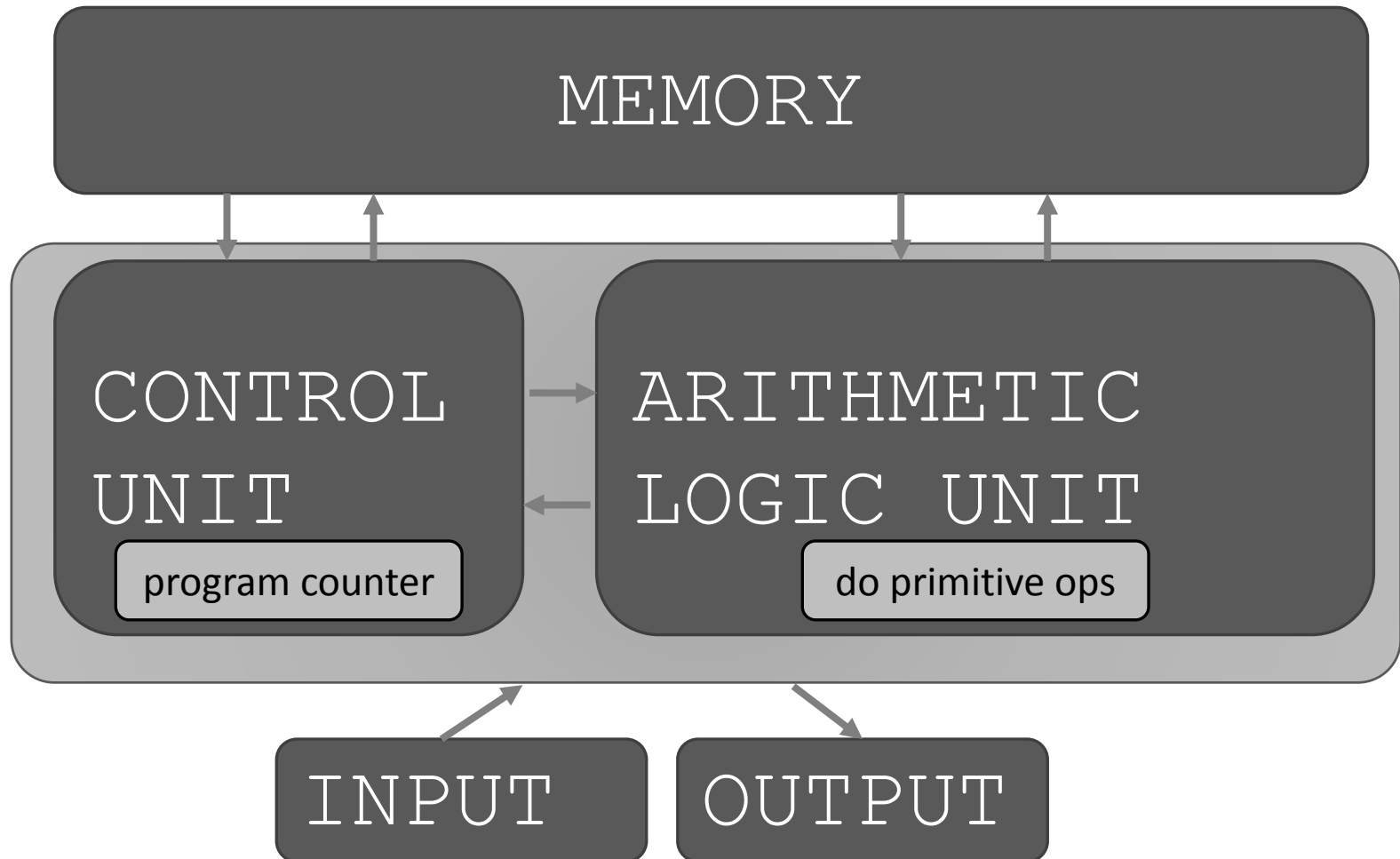
- 1) sequence of simple **steps**
- 2) **flow of control** process that specifies when each step is executed
- 3) a means of determining **when to stop**

$1+2+3$ = an **algorithm**!

COMPUTERS ARE MACHINES

- how to capture a recipe in a mechanical process
- **fixed program** computer
 - calculator
- **stored program** computer
 - machine stores and executes instructions

BASIC MACHINE ARCHITECTURE



STORED PROGRAM COMPUTER

- sequence of **instructions stored** inside computer
 - built from predefined set of primitive instructions
 - 1) arithmetic and logic
 - 2) simple tests
 - 3) moving data
- special program (interpreter) **executes each instruction in order**
 - use tests to change flow of control through sequence
 - stop when done

BASIC PRIMITIVES

- Turing showed that you can **compute anything** using 6 primitives
- modern programming languages have more convenient set of primitives
- can abstract methods to **create new primitives**
- anything computable in one language is computable in any other programming language

CREATING RECIPES

- a programming language provides a set of primitive **operations**
- **expressions** are complex but legal combinations of primitives in a programming language
- expressions and computations have **values** and meanings in a programming language

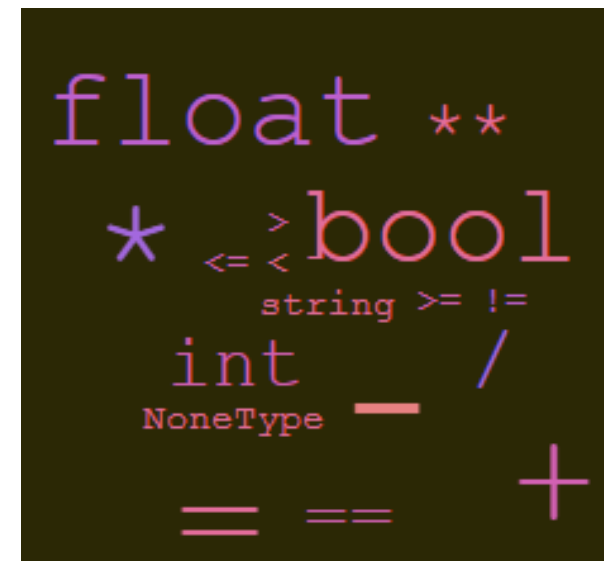
ASPECTS OF LANGUAGES

■ primitive constructs

- English: words
- programming language: numbers, strings, simple operators



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ASPECTS OF LANGUAGES

■ **syntax**

- English: "cat dog boy" → not syntactically valid
"cat hugs boy" → syntactically valid
- programming language: "hi"5 → not syntactically valid
3.2*5 → syntactically valid

ASPECTS OF LANGUAGES

- **static semantics** is which syntactically valid strings have meaning
 - English: "I are hungry" → syntactically valid
but static semantic error
 - programming language: $3.2 * 5$ → syntactically valid
 $3 + "hi"$ → static semantic error

ASPECTS OF LANGUAGES

- **semantics** is the meaning associated with a syntactically correct string of symbols with no static semantic errors
 - English: can have many meanings "Flying planes can be dangerous"
 - programming languages: have only one meaning but may not be what programmer intended

WHERE THINGS GO WRONG

- **syntactic errors**

- common and easily caught

- **static semantic errors**

- some languages check for these before running program
- can cause unpredictable behavior

- no semantic errors but **different meaning than what programmer intended**

- program crashes, stops running
- program runs forever
- program gives an answer but different than expected

PYTHON PROGRAMS

- a **program** is a sequence of definitions and commands
 - definitions **evaluated**
 - commands **executed** by Python interpreter in a shell
- **commands** (statements) instruct interpreter to do something
- can be typed directly in a **shell** or stored in a **file** that is read into the shell and evaluated
 - Problem Set 0 will introduce you to these in Anaconda

OBJECTS

- programs manipulate **data objects**
- objects have a **type** that defines the kinds of things programs can do to them
 - Ana is a human so she can walk, speak English, etc.
 - Chewbacca is a wookiee so he can walk, “mwaaarhrhh”, etc.
- objects are
 - scalar (cannot be subdivided)
 - non-scalar (have internal structure that can be accessed)

SCALAR OBJECTS

- `int` – represent **integers**, ex. 5
- `float` – represent **real numbers**, ex. 3.27
- `bool` – represent **Boolean** values `True` and `False`
- `NoneType` – **special** and has one value, `None`
- can use `type()` to see the type of an object

```
>>> type(5)
```

```
int
```

```
>>> type(3.0)
```

```
float
```

*what you write into
the Python shell*

*what shows after
hitting enter*

TYPE CONVERSIONS (CAST)

- can **convert object of one type to another**
- `float(3)` converts integer 3 to float 3.0
- `int(3.9)` truncates float 3.9 to integer 3

PRINTING TO CONSOLE

- to show output from code to a user, use `print` command

In [11]: 3+2
Out [11]: 5

*“Out” tells you it’s an
interaction within the
shell only*

In [12]: `print(3+2)`
5

*No “Out” means it is
actually shown to a user,
apparent when you
edit/run files*

EXPRESSIONS

- **combine objects and operators** to form expressions
- an expression has a **value**, which has a type
- syntax for a simple expression
`<object> <operator> <object>`

OPERATORS ON ints and floats

- $i + j$ → the **sum**
 - $i - j$ → the **difference**
 - $i * j$ → the **product**
 - i / j → **division**
- if both are ints, result is int
if either or both are floats, result is float
- result is float
-
- $i \% j$ → the **remainder** when i is divided by j
 - $i ** j$ → i to the **power** of j

SIMPLE OPERATIONS

- parentheses used to tell Python to do these operations first
- **operator precedence** without parentheses
 - **
 - *
 - /
 - + and – executed left to right, as appear in expression

BINDING VARIABLES AND VALUES

- equal sign is an **assignment** of a value to a variable name

variable
`pi` = `3.14159`
value

`pi_approx = 22/7`

- value stored in computer memory
- an assignment binds name to value
- retrieve value associated with name or variable by invoking the name, by typing `pi`

ABSTRACTING EXPRESSIONS

- why **give names** to values of expressions?
- to **reuse names** instead of values
- easier to change code later

```
pi = 3.14159  
radius = 2.2  
area = pi*(radius**2)
```

PROGRAMMING vs MATH

- in programming, you do not “solve for x”

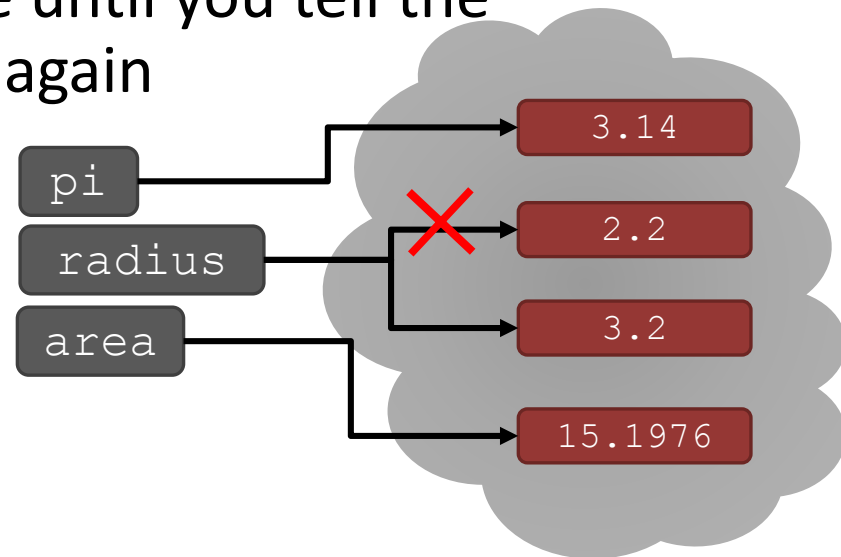
```
pi = 3.14159
radius = 2.2
# area of circle
area = pi*(radius**2)
radius = radius+1
```

*an assignment
* expression on the right, evaluated to a value
* variable name on the left
* equivalent expression to `radius = radius + 1`
is `radius += 1`*

CHANGING BINDINGS

- can **re-bind** variable names using new assignment statements
- previous value may still stored in memory but lost the handle for it
- value for area does not change until you tell the computer to do the calculation again

```
pi = 3.14
radius = 2.2
area = pi*(radius**2)
radius = radius+1
```



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