UC Berkeley EECS
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## Computational Structures in Data Science

# Lecture #2: Programming Structures: Loops and Functions

February 4, 2019 http://inst.eecs.berkeley.edu/~cs88

## Administrivia

- If you are waitlisted: Please wait.
- If you are concurrent enrollment: Please wait.
- iClickers: Start next week.



## Solutions for the Wandering Mind

**A binary digit (bit) is a symbol from {0,1}.**

- **How many strings can you represent with N bits?**

Solution: $2^N$

With 0 symbols: $2^0$=1, this is ''

With 1 symbol : $2^1$=2, this is '0', '1'

With 2 symbols: $2^2$=4, this is '00', '01', '10', '11'

With 3 symbols: $2^3$=8, this is '000', '001', '010', '011', '100', '101', '110', '111'

- **Could you build a program that compresses all strings of N bits to strings of M bits (with M<N) such that you can go back to all original strings of length N? How or Why?**

Solution: No.

N bits represent $2^N$ strings. Assume M=N-1. M bits now represent $2^{N-1}$ strings. It is impossible to build a mapping from $2^{N-1}$ strings back to $2^N$ strings (pigeon hole principle). Example M=1, N=2: '00'->'0', '11'->'1' what do we do with '01' and '10'?

More on this:
https://www.youtube.com/watch?v=yZ--bbmIp_o&t=0s&index=5&list=PL17CtGMLr0Xz3vNK31TG7mJIzmF78vsFO



## Computational Concepts Today

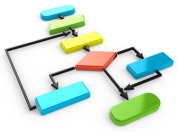
- Fundamentals: Algorithm, Code, Data, Information
- Conditional Statement
- Functions
- Iteration



## Algorithm

- **An algorithm (pronounced AL-go-rith-um) is a procedure or formula to solve a problem.**
- **An algorithm is a sequence of instructions to change the state of a system. For example: A computer's memory, your brain (math), or the ingredients to prepare food (cooking recipe).**

**Think Data 8: Change or retrieve the content of a table.**





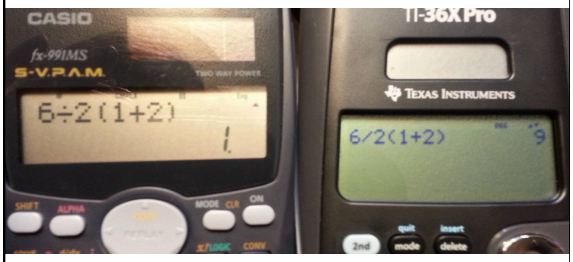
## Algorithm: Properties

- **An algorithm is a description that can be expressed within a finite amount of space and time.**
- **Executing the algorithm may take infinite space and/or time, e.g. ``calculate all prime numbers".**
- **In CS and math, we prefer to use well-defined formal languages for defining an algorithm.**

$$6 \div 2(1+2) = ?$$

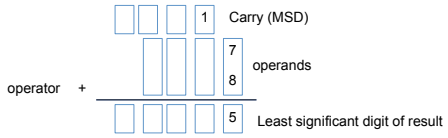
1 or 9

## Algorithm: Well-definition



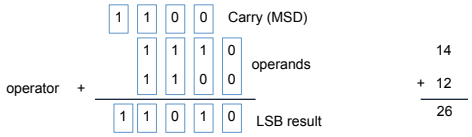



## Algorithms early in life (1st grade)






## Algorithms early in life (in binary)






## More Terminology (intuitive)

- **Code**

A sequence of symbols used for communication between systems (brains, computers, brain-to-computer)

- **Data**

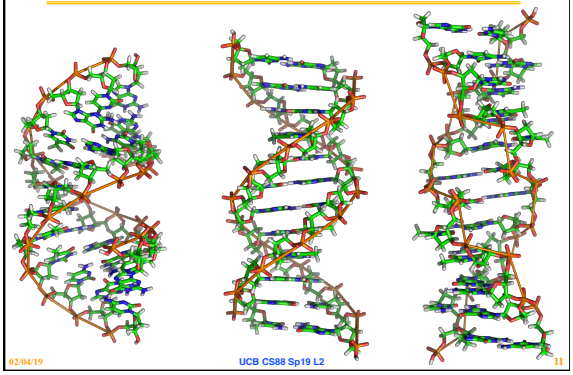
Observations

- **Information**

Reduction of uncertainty in a model (measured in bits)



## Data or Code?



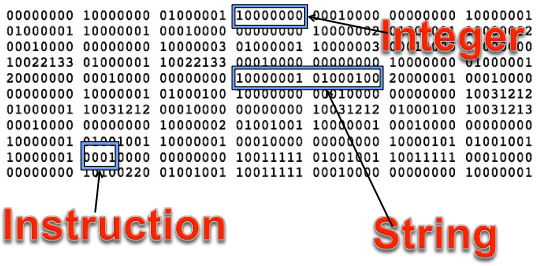


## Data or Code?

```
00000000 10000000 01000001 10000000 00010000 00000000 10000001
01000001 10000001 00010000 00000000 10000002 01000001 10000002
00010000 00000000 10000003 01000001 10000003 00010000 00000000
10022133 01000001 10022133 00010000 00000000 10000000 01000001
20000000 00010000 00000000 10000001 01000100 20000001 00010000
00000000 10000001 01000100 10000000 00010000 00000000 10031212
01000001 10031212 00010000 00000000 10031212 01000100 10031213
00010000 00000000 10000002 01001001 10000001 00010000 00000000
10000001 01001001 10000001 00010000 00000000 10000101 01001001
10000001 00010000 00000000 10011111 01001001 10011111 00010000
00000000 10100220 01001001 10011111 00010000 00000000 10000001
```

## Data or Code?

Here is some information!






## Data or Code? Abstraction!

**Human-readable code (programming language)**

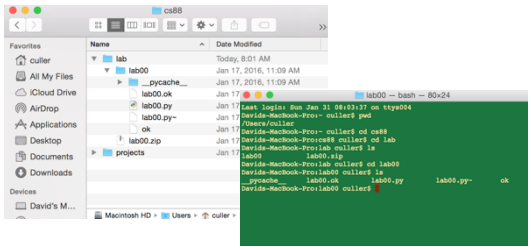
```
def add5(x):
    return x+5

def dotwrite(ast):
    nodename = getNodename()
    label=symbol.sym_name.get(int(ast[0]),ast[0])
    print ' %s [label="%s" % (nodename, label),
    if isinstance(ast[1], str):
        if ast[1].strip():
            print '= %s"];' % ast[1]
        else:
            print '"];'
    else:
        print '"];'
        children = []
        for n, child in enumerate(ast[1:]):
            children.append(dotwrite(child))
        print ' %s -> {' % nodename,
        for name in children:
            print '%s' % name,
```

**Machine-executable instructions (byte code)**

**Compiler or Interpreter**
**Here: Python**



## Code or GUI: More Abstraction!



- **Big Idea: Layers of Abstraction**
  - **The GUI look and feel is built out of files, directories, system code, etc.**



## Let's talk Python

- **Expression** `3.1 * 2.6`
- **Call expression** `max(0, x)`
- **Variables**
- **Assignment Statement** `x = <expression>`
- **Define Function:** `def` <function name> `(`<argument list>`) :`
- **Control Statements:** if …
  for …
  while …
  list comprehension



## Conditional statement

- **Do some statements, conditional on a *predicate* expression**

```
if <predicate>:
        <true statements>
else:
        <false statements>
```

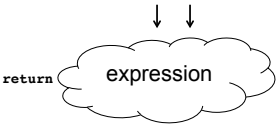
- **Example:**

```
if (temperature>37.2):
        print("fever!")
else:
        print("no fever")
```



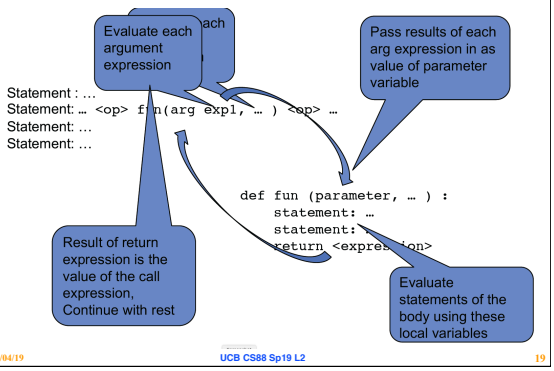
## Defining Functions

`def` <function name> `(`<argument list>`) :`



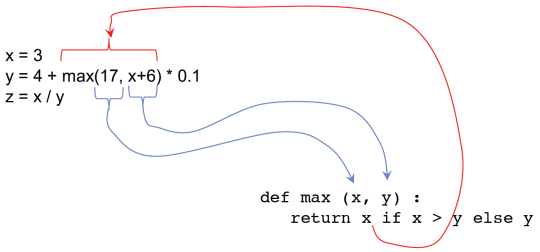

- **Abstracts an expression or set of statements to apply to lots of instances of the problem**
- **A function should *do one thing well***

## Functions: Calling and Returning Results






## Functions: Example






## How to write a good Function

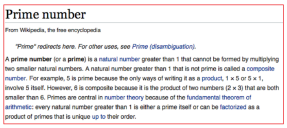
- **Give a descriptive name**
  - Function names should be lowercase. If necessary, separate words by underscores to improve readability. Names are extremely suggestive!
- **Chose meaningful parameter names**
  - Again, names are extremely suggestive.
- **Write the docstring to explain *what* it does**
  - What does the function return? What are corner cases for parameters?
- **Write doctest to show what it should do**
  - **Before** you write the implementation.

Python Style Guide: https://www.python.org/dev/peps/pep-0008/



## Example: Prime Numbers

```
def prime(n):
    """Return whether n is a prime number.

    >>> prime(2)
    True
    >>> prime(3)
    True
    >>> prime(4)
    False
    """

    return "figure this out"
```


Prime number

From Wikipedia, the free encyclopedia

*"Prime" redirects here. For other uses, see Prime (disambiguation).*

A **prime number** (or a **prime**) is a natural number greater than 1 that cannot be formed by multiplying two smaller natural numbers. A natural number greater than 1 that is not prime is called a composite number. For example, 5 is prime because the only ways of writing it as a product, 1 × 5 or 5 × 1, involve 5 itself. However, 6 is composite because it is the product of two numbers (2 × 3) that are both smaller than 6. Primes are central in number theory because of the fundamental theorem of arithmetic: every natural number greater than 1 is either a prime itself or can be factorized as a product of primes that is unique up to their order.

Why do we have prime numbers?
https://www.youtube.com/watch?v=e4kevnq2vPI&t=72s&index=6&list=PL17CtGMLr0Xz3vNK31TG7mJIzmF78vsFO



## `for` statement – iteration control

- **Repeat a block of statements for a structured sequence of variable bindings**

```
<initialization statements>
for <variables> in <sequence expression>:
    <body statements>

<rest of the program>
```

```
def cum_OR(lst):
    """Return cumulative OR of entries in lst.
    >>> cum_OR([True, False])
    True
    >>> cum_OR([False, False])
    False
    """
    co = False
    for item in lst:
        co = co or item
    return co
```



## `while` statement – iteration control

- **Repeat a block of statements until a predicate expression is satisfied**

```
<initialization statements>
while <predicate expression>:
    <body statements>

<rest of the program>
```

```
def first_primes(k):
    """ Return the first k primes.
    """
    primes = []
    num = 2
    while len(primes) < k :
        if prime(num):
            primes = primes + [num]
        num = num + 1
    return primes
```

## Data-driven iteration

- **describe an expression to perform on each item in a sequence**
- **let the data dictate the control**

```
[ <expr with loop var> for <loop var> in <sequence expr > ]
```

```
def dividers(n):
    """Return list of whether numbers greater than 1 that divide n.

    >>> dividers(6)
    [True, True]
    >>> dividers(9)
    [False, True, False]
    """
    return [divides(n,i) for i in range(2,(n//2)+1) ]
```



## Thoughts for the Wandering Mind

- **Could we build a complete computer that has no instructions, only data?**