香港中文大學(深圳)
The Chinese University of Hong Kong, Shenzhen

AIE 1001 Introduction to AI Programming

Midterm Review

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Part of the slides are adapted from NJU SICP

Scope & Reminders

- Lecture **1** – Lecture **6** (Recursion)
- Question:
  - Single Choice (one correct option, 4*10, 40 points), Multiple Choice (one or more correct options, 5*3, 15 points)
  - Short answer question (20+25, 45 points)
    - Including, but not limited to: Code Fault Localization, Code Completion, Function Design
- Exam Duration: 1 hr
- Remember to bring **your Student ID card,** and write your student ID number to the answer sheet.
- No cheat sheet, calculator, digital devices allowed

1. Data Representation

- **Positional Notation:** Understanding the concept of a base and a set of symbols for representing numbers.
- **Number Systems:**
  - Binary (base 2)
  - Octal (base 8)
  - Decimal (base 10)
  - Hexadecimal (base 16)

- **Number System Conversion:**
  - Converting from any number system (Binary, Octal, Hexadecimal) to the Decimal system.
  - Converting Decimal numbers to Binary numbers, including both integer and fractional parts.
  - Converting between Binary and Octal by grouping three digits.
  - Converting between Binary and Hexadecimal by grouping four digits.

Decimal number system

- In the decimal number system, the base is 10, the symbols include 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

- Every number can be decomposed into the sum of a series of numbers, each is represented by a positional value times a weight

- $N = a_n \times 10^n + a_{n-1} \times 10^{n-1} + a_{n-2} \times 10^{n-2} \ \ldots\ldots + a_0 \times 10^0 + a_{-1} \times 10^{-1} + a_{-2} \times 10^{-2} \ldots$

- a_n is the positional value (ranging from 0 to 9), while 10^n represents the weight

Binary number system

- In the binary system, the base is 2, we use only two symbols 0 and 1
- "10" is used when we hit 2 (逢二进一)
- $N = a_n \times 2^n + a_{n-1} \times 2^{n-1} + a_{n-2} \times 2^{n-2} \ \ldots\ldots + a_0 \times 2^0 + a_{-1} \times 2^{-1} + a_{-2} \times 2^{-2} \ldots$

$$9_{(10)} = 1\times 2^3 + 0\times 2^2 + 0\times 2^1 + 1\times 2^0 = 1001_{(2)}$$

- a_n is the positional value (ranging from 0 to 1), while 2^n represents the weight

Hexadecimal number system

- In the hexadecimal system, the base is 16, we use 16 symbols {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f}

- “10” is used when we hit 16 (逢十六进一)

- $N = a_n \times 16^n + a_{n-1} \times 16^{n-1} + a_{n-2} \times 16^{n-2} \ \ldots\ldots + a_0 \times 16^0 + a_{-1} \times 16^{-1} + a_{-2} \times 16^{-2} \ldots$

- a_n is the positional value (ranging from 0 to 15), while 16^n represents the weight

Notes:

Binary number <-> Hexadecimal number

<-> octal number

<-> decimal number

All the representations can be converted into each other

Converting binary number into decimal number

Example $(1101.01)_2$

$$=(1\times 2^3+1\times 2^2+0\times 2^1+1\times 2^0+0\times 2^{-1}+1\times 2^{-2})_{10}$$

$$=(13.25)_{10}$$

Practice $(10110.11)_2 = (?)_{10}$

Converting octal number into decimal number

Example $(24.67)_8=(2 \times 8^1+ 4 \times 8^0+6 \times 8^{-1}+7 \times 8^{-2})_{10}$

$=(20.859375)_{10}$

Practice $(35.7)_8= (?)_{10}$

Converting decimal fraction into binary fraction

Example: $(0.875)_{10} = (?)_2$

Higher position

$0.875 \times 2 = 1.75$ Integer part: 1

$0.75 \times 2 = 1.5$ Integer part: 1

$0.5 \times 2 = 1$ Integer part: 1

Lower position

Answer: $(0.875)_{10} = (0.111)_2$

Practice: $(0.6875)_{10} = (?)_2$

Converting decimal number into binary number

- For a decimal number that has both integer and fractional parts

- Convert the integer and fractional parts separately

- Example: $(215.6875)_{10} = (?)_2$

2. Fundamental Concepts

- **Programming Modes:**
  - **Interactive Mode:** Typing one line at a time in the Python Shell.
  - **Script Mode:** Writing code in a `.py` file and executing it.
- **Syntax:** Python has a strict set of rules. A `SyntaxError` means you violated them.
- **Program Flow:**
  - **Sequential:** Executing statements one after another.
  - **Conditional:** Skipping steps (e.g., `if`).
  - **Repeated (Loops):** Repeating code (e.g., `while`).
- **Comments:** Use `#` for notes or to temporarily disable code.

Interactive v.s. script

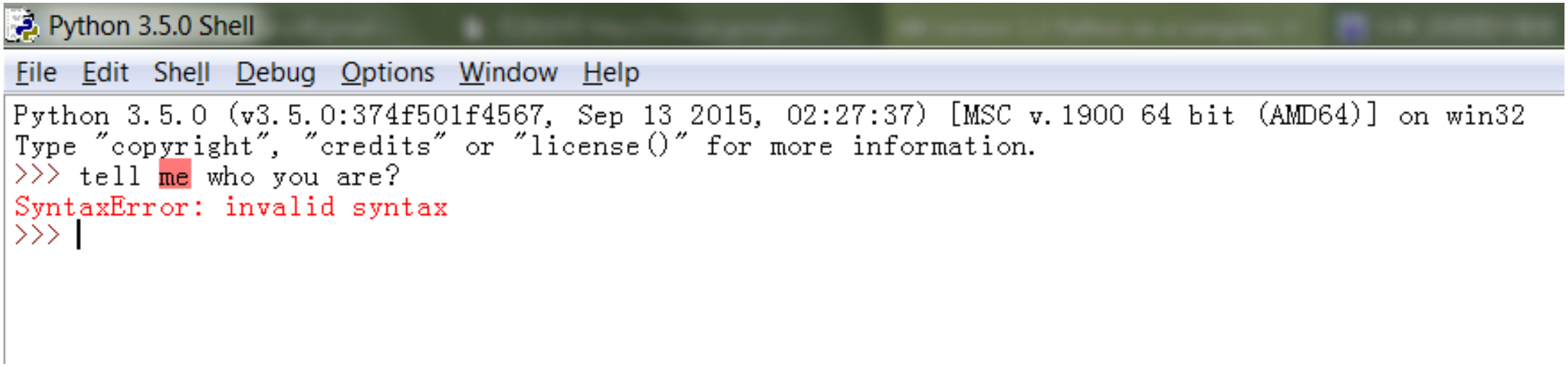
- Interactive

✓ You type directly to Python one line at a time and it responds

- Script

✓ You enter a sequence of statements (lines) into a file using a text editor and tell Python to execute the file

Syntax Error



Program steps or program flow

- Like a recipe, a program is a sequence of steps to be done in pre-determined order
- Some steps are conditional, i.e. they may be skipped
- Sometimes, we will repeat some steps
- Sometimes, we store a set of steps to be used over and over again in future as needed

Sequential flow

Execute sequentially

```
>>> x=2
>>> print(x)
2
>>> x=x*10
>>> print(x)
20
>>>
```

Outputs

- When a program is running, it flows from one step to the next
- We as programmers, set up “paths” for the program to follow

Conditional flow

Program

```
x=5
if x<10:
    print("smaller")
if x>20:
    print("bigger")
print("finished")
```

Outputs

Repeated flow

Program

```
n=5
while n>0:
    print(n)
    n = n - 1
print("Finish")
```

Outputs

- Loops (repeated steps) have iterative variables that change each time through a loop
- Often these iterative variables go through a sequence of numbers

3. Variables and Data Types

- **Variables:** A named space in memory to store data.
  - **Assignment:** `x = 10`
  - **Naming Rules:**
    - Must begin with a letter or `_`.
    - Can only contain letters, numbers, and `_`.
    - Case-sensitive (`apple` is not `Apple`).
- **Reserved Words:** You cannot use words like `if`, `while`, `False` as variable names.

- **Key Data Types:**
  - **Integers (`int`):** Whole numbers (`100` , `-50`).
  - **Floating-Point (`float`):** Numbers with decimals (`3.14` , `-0.5`).
  - **Strings (`str`):** Text in single `'` or double `"` quotes.
  - **Booleans (`bool`):** `True` or `False` .
- **Type Checking & Conversion:**
  - Check with `type()` .
  - Use `int()` , `float()` , `str()` to convert between types.
  - `input()` always returns a string!

Type conversion

- When an expression contains both integer and float, integers will be converted into float implicitly

- You can control this using functions int() and float()

- Example:

```
>>> print(float(99)/100)

>>> i=42
>>> type(i)

>>> f=float(i)
>>> print(f)

>>> type(f)

>>> print(1+2*float(3)/4-5)
```

String conversions

- You can also use int() and float() to convert strings into numbers

- You will get an error if the string contains characters other than numbers

Converting numbers into string

- We can convert numbers into string using function str()

```
>>> str(5)                    # Convert int to a string.
'5'
>>> str(1 + 10 + 100)         # Convert int expression to a string.
'111'
>>> str(-12.34)               # Convert float to a string.
'-12.34'
>>> str("Hello World!")       # str() accepts string arguments.
'Hello World!'
>>> str(divmod(14, 9))        # Convert tuple to a string.
'(1, 5)'
>>> x = 42
>>> str(x)                    # Convert int variable to a string.
'42'
```

4. Expressions and Operators

- **Expression:** A combination of values, variables, and operators that evaluates to a new value (e.g., `2 * (x + 3)`).
- **Arithmetic Operators:** `+`, `-`, `*`, `/`, `**`, `%`, `//`.
- **Comparison Operators:** `==`, `!=`, `<`, `>`, `<=`, `>=`.
- **Logical Operators:** `and`, `or`, `not`.

- **Operator Precedence:**
    i. Parentheses `()`
    ii. Exponentiation `**`
    iii. Multiplication `*`, Division `/`, Remainder `%`
    iv. Addition `+`, Subtraction `-`
    v. Comparison Operators
    vi. Logical Operators
- **Assignment:** `x = 5`. Note: `==` is for comparison, `=` is for assignment.
- **Augmented Assignment:** `x += 7` is the same as `x = x + 7`.

Assignment statement

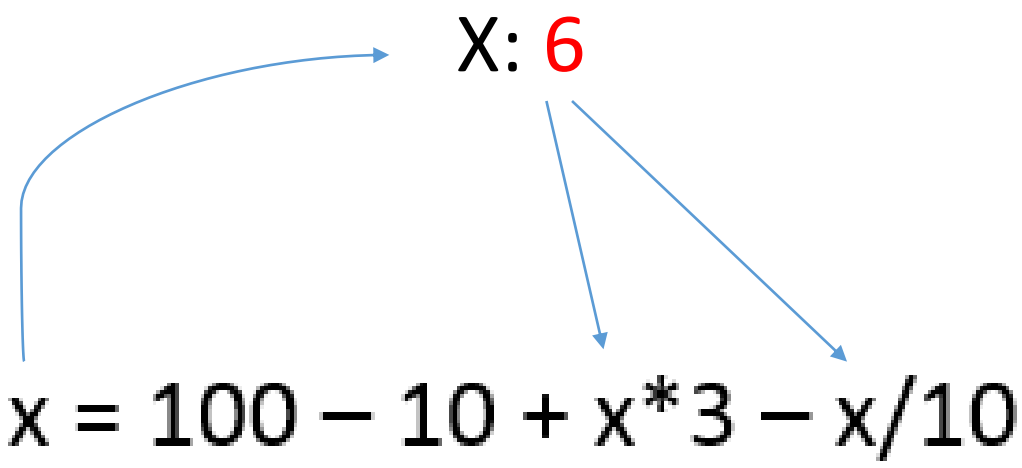
- We assign a value to a variable using the assignment operator (=)

- An assignment statement consists of an expression on the right hand side, and a variable to store the result

Example: x = 100 – 10 + x*3 – x/10

Assignment statement

- There is a location in the memory for x
- Whenever the value of x is needed, it can be retrieved from the memory
- After the expression is evaluated, the result will be put back into x



Assignment statement

- There is a location in the memory for x
- Whenever the value of x is needed, it can be retrieved from the memory
- After the expression is evaluated, the result will be put back into x

X: 107.4

x = 100 – 10 + x*3 – x/10

Cascaded assignment

- We can set multiple variables into the same value using a single assignment statement

Example

```
>>> z = y = x = 2 + 7 + 2
>>> x, y, z
(11, 11, 11)
```

Simultaneous assignment

- The values of two variables can be exchanged using simultaneous assignment

Example

```
>>> c = "deepSecret"          # Set current password.
>>> o = "you'll never guess" # Set old password.
>>> c, o                      # See what passwords are.
('deepSecret', "you'll never guess")
>>> c, o = o, c               # Exchange the passwords.
```

Bad use of simultaneous assignment

```
>>> # A bad use of simultaneous assignment.
>>> x, y = (45 + 34) / (21 - 4), 56 * 57 * 58 * 59
>>> x, y
(4.647058823529412, 10923024)
>>> # A better way to set the values of x and y.
>>> x = (45 + 34) / (21 - 4)
>>> y = 56 * 57 * 58 * 59
>>> x, y
(4.647058823529412, 10923024)
```

Operator precedence

Example: x = 1+2**3/4*5

Floor division

```
>>> time = 257              # Time in seconds.
>>> minutes = time // 60 # Number of complete minutes in time.
>>> print("There are", minutes, "complete minutes in", time, "seconds.")
There are 4 complete minutes in 257 seconds.
>>> 143 // 25
5
>>> 143.4 // 25
5.0
>>> 9 // 2.5
3.0
```

divmod()

```
>>> time = 257          # Initialize time.
>>> SEC_PER_MIN = 60 # Use a "named constant" for 60.
>>> divmod(time, SEC_PER_MIN)   # See what divmod() returns.
(4, 17)
>>> # Use simulataneous assignment to obtain minutes and seconds.
>>> minutes, seconds = divmod(time, SEC_PER_MIN)
>>> # Attempt to display the minutes and seconds in "standard" form.
>>> print(minutes, ":", seconds)
4 : 17
>>> # Successful attempt to display time "standard" form.
>>> print(minutes, ":", seconds, sep="")
4:17
>>> # Obtain number of quarters and leftover change in 143 pennies.
>>> quarters, cents = divmod(143, 25)
>>> quarters, cents
(5, 18)
```

5. Control Flow

- **Conditional Execution:**
  - `if`: Executes code only if a condition is `True`.
  - `if-else` **(Two-way):** Provides an alternative block if the condition is `False`.
  - `if-elif-else` **(Multi-way):** Tests multiple conditions in sequence.
  - **Nested Decisions:** An `if` statement inside another.
- **Indentation:** Defines code blocks. It is not just for style.
- **Truthiness:** `0`, `0.0`, and empty collections (`[]`, `""`) are treated as `False`. Most other values are `True`.

Conditional flow

Program

```
x=5
if x<10:
    print("smaller")
if x>20:
    print("bigger")
print("finished")
```

Outputs

```
smaller
finished
>>>
```

Comparison operators

- Boolean expressions ask a question and produce a Yes/No result, which we use to control program flow
- Boolean expressions use comparison operators to evaluate Yes/No or True/False
- Comparison operators check variables but do not change the values of variables
- Careful!! “=“ is used for assignment

x < y	Is x less than y?
x <= y	Is x less than or equal to y?
x == y	Is x equal to y?
x >= y	Is x greater than or equal to y?
x > y	Is x greater than y?
x != y	Is x not equal to y?

Comparison operators

```
x=5
if x==5:
    print("Equals 5")

if x>4:
    print("Greater than 4")

if x>=5:
    print("Greater than or equal to 5")

if x<=5:
    print("Less than or equal 5")

if x!=6:
    print("Not equal 6")
```

```
Equals 5
Greater than 4
Greater than or equal to 5
Less than or equal 5
Not equal 6
```

Examples of comparison

```
>>> 5 > 7                    # Is 5 greater than 7?
False
>>> x, y = 45, -3.0
>>> x > y                    # Is 45 greater than -3.0?
True
>>> result = x > y + 50 # Is 45 greater than -3.0 + 50?
>>> result
False
>>> if 1 + 1 > 1:
...     print("I think this should print.")
...
I think this should print.
```

Bool()

```
>>> x = 0; y = 0.0; z = 0 + 0j
>>> bool(x), bool(y), bool(z)
(False, False, False)
>>> x = -1; y = 1.e-10; z = 0 + 1j
>>> bool(x), bool(y), bool(z)
(True, True, True)
```

One way decisions

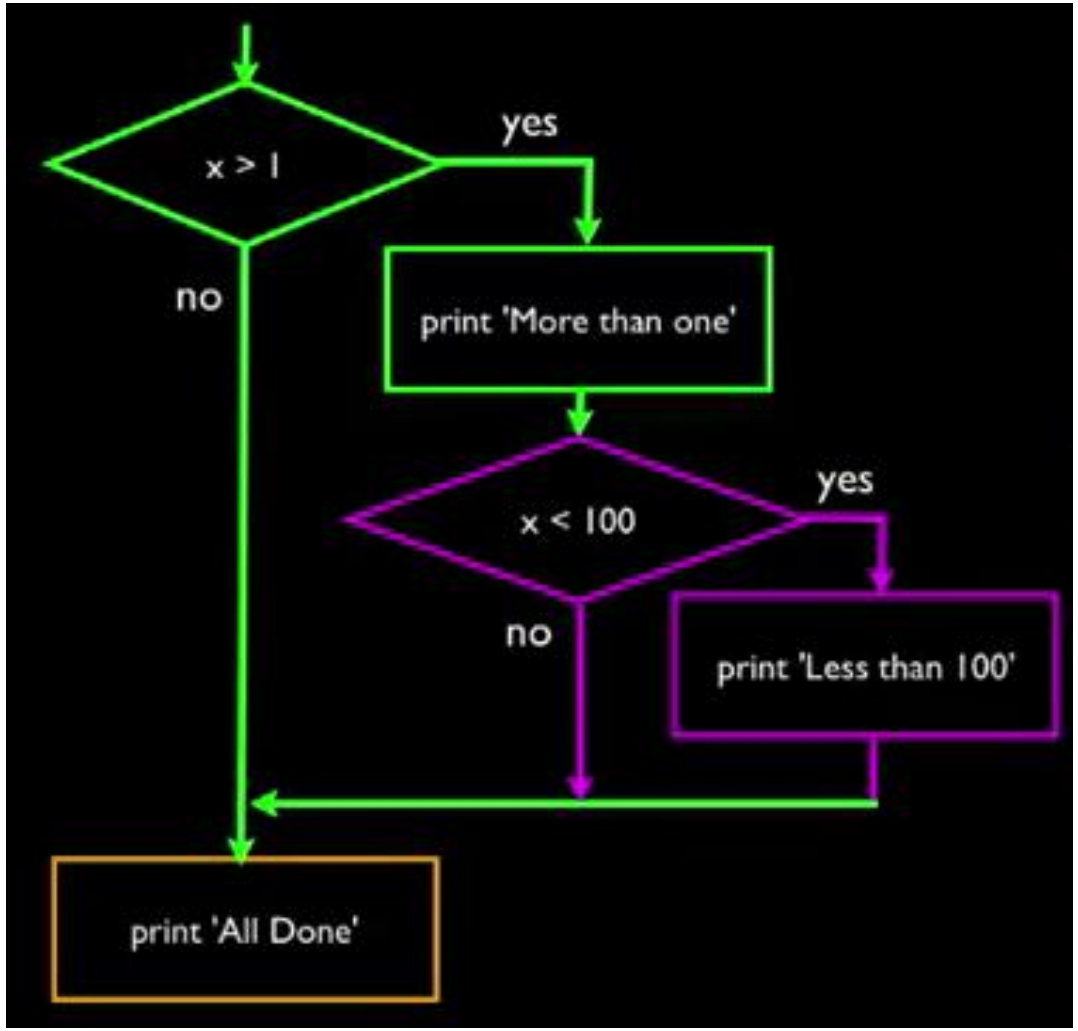
```
x=5
print('Before 5')
if x==5:
    print('Is 5')
    print('Is still 5')
    print('Third 5')

print('Afterwards 5')

print('Before 6')
if x==6:
    print('Is 6')
    print('Is still 6')
    print('Third 6')

print('Afterwards 6')
```

```
Before 5
Is 5
Is still 5
Third 5
Afterwards 5
Before 6
Afterwards 6
```

Nested decisions

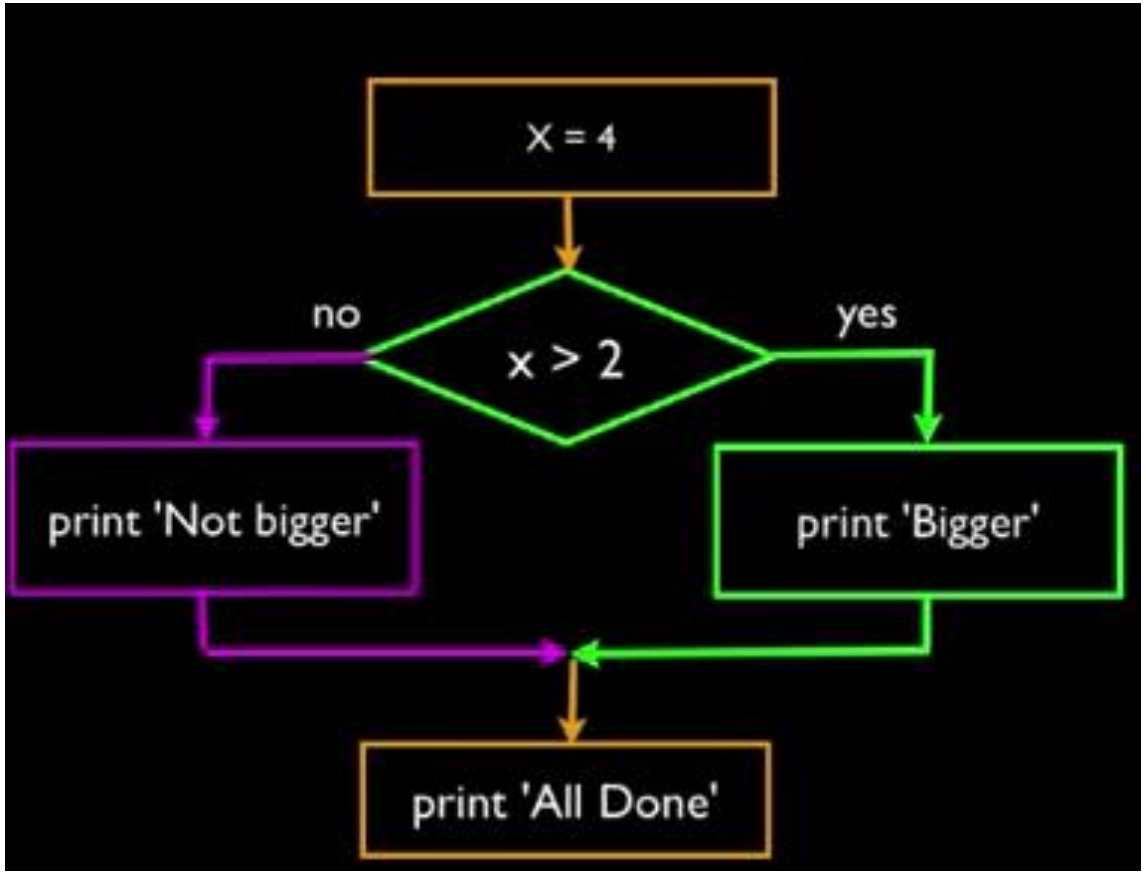
Example

```
x=42
if x>1:
    print('More than 1')

    if x<100:
        print('Less then 100')

print('Finished')
```



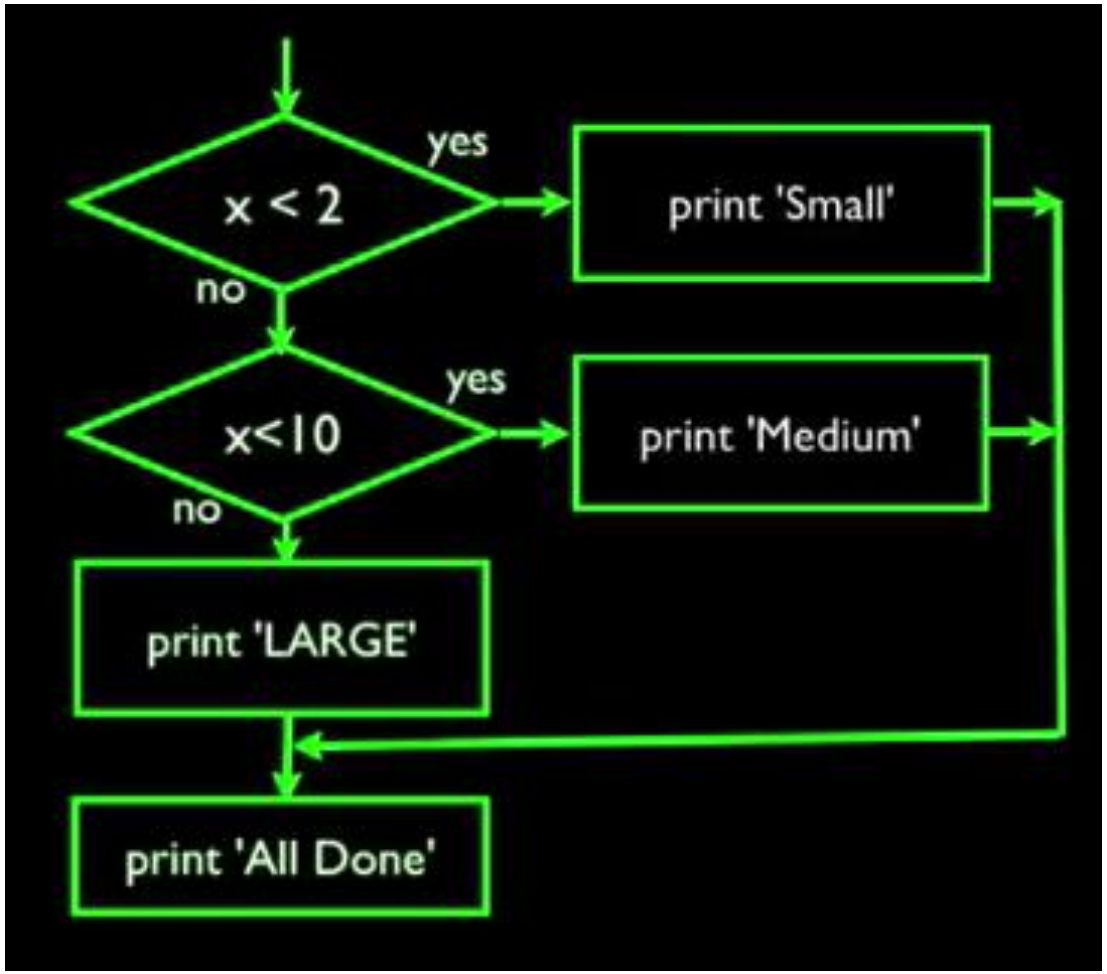
Two way decision using else

```
x=1

if x>2:
    print('Bigger')
else:
    print('Smaller')

print('Finished')
```



Multi-way decisions

```
x=2
if x<2:
    print('Small')
elif x<10:
    print('Medium')
else:
    print('Large')

print('Finished')
```



Which will never be printed?

```
x=4

if x<=2:
    print('Below 2')
elif x>2:
    print('Above 2')
else:
    print('Something else')
print('Finished')
```

```
x=8

if x<2:
    print('Below 2')
elif x<20:
    print('Below 20')
elif x<10:
    print('Below 10')
else:
    print('Something else')
print('Finished')
```

Example

```
>>> not True
False
>>> False and True
False
>>> not False and True
True
>>> (not False) and True      # Same as previous statement.
True
>>> True or False
True
```

Example

```
>>> not False or True          # Same as: (not False) or True.
True
>>> not (False or True)
False
>>> False and False or True   # Same as: (False and False) or True.
True
>>> False and (False or True)
False
```

6. Loops

- **`while` Loops (Indefinite):** Continues as long as a condition is `True`.
- **`for` Loops (Definite):** Iterates over each item in a sequence.
- **Loop Control Statements:**
  - **`break`:** Exits a loop immediately.
  - **`continue`:** Skips to the next iteration.
- **Common Loop Patterns:**
  - **Counting:** `count += 1`
  - **Summing (Accumulating):** `total += value`
  - **Finding Largest/Smallest:** Keep track of the "largest/smallest so far".
  - **Searching:** Use a boolean flag to check if a condition is met.

An infinite loop

```
n=5
while n>0:
    print('Lather')
    print('Rinse')
n=n-1
print('Dry off!')
```

- What is wrong with this program?

Definite loop

- Quite often we have a finite set of items
- We can use a loop, each iteration of which will be executed for each item in the set, using the for statement
- These loops are called “definite loops” because they execute an exact number of times
- It is said that “definite loops iterate through the members of a set”

Practice

- **Given a set of numbers, write a program to calculate their sum using for loop**

Answer

```
numberSet = [3, 4, 98, 38, 9, 10, 199, 78]

total = 0
print('Before', total)
for num in numberSet:
    total = total + num
    print(total, num)
print('Last', total)
```

```
Before 0
3 3
7 4
105 98
143 38
152 9
162 10
361 199
439 78
Last 439
```

Practice

- **Given a set of numbers, write a program to calculate their average using for loop**

Answer

```
numberSet = [3, 4, 98, 38, 9, 10, 199, 78]

total = 0
count = 0
print('Before', total)
for num in numberSet:
    total = total + num
    count = count + 1
    print(count, total, num)
print('Last', total, total/count)
```

```
Before 0
1 3 3
2 7 4
3 105 98
4 143 38
5 152 9
6 162 10
7 361 199
8 439 78
Last 439 54.875
```

Search using a Boolean variable

Example

```
found = False

print('Before', found)

for value in [9, 41, 12, 3, 74, 15]:
    if value == 74:
        found = True
    print(found, value)
print('After', found)
```

Output

```
Before False
False 9
False 41
False 12
False 3
True 74
True 15
After True
```

- If we want to search in a set and double check whether a specific number is in that set
- We can use a Boolean variable, set it to False at the beginning, and assign True to it as long as the target number is found

Finding the largest number

Example

```
largest_so_far = -1
print('Before',largest_so_far)

for num in [9,39,21,98,4,5,100,65]:
    if num>largest_so_far:
        largest_so_far = num
    print(largest_so_far,num)

print('After',largest_so_far)
```

Output

```
Before -1
9 9
39 39
39 21
98 98
98 4
98 5
100 100
100 65
After 100
```

- Use a variable to store the largest number we have seen so far
- If the current number is larger, we assign it to the store variable

Finding the smallest number

```
smallest_so_far = -1
print('Before',smallest_so_far)

for num in [9,39,21,98,4,5,100,65]:
    if num < smallest_so_far:
        smallest_so_far = num
    print(smallest_so_far,num)

print('After',smallest_so_far)
```

- Use a variable to store the smallest number we have seen so far
- If the current number is smaller, we assign it to the store variable
- What is the problem with this program?

Finding the smallest number

Example

```
smallest_so_far = None
print('Before',smallest_so_far)

for num in [9,39,21,98,4,5,100,65]:
    if smallest_so_far == None:
        smallest_so_far = num
    elif num < smallest_so_far:
        smallest_so_far = num
    print(smallest_so_far,num)

print('After',smallest_so_far)
```

Output

```
Before None
9 9
9 39
9 21
9 98
4 4
4 5
4 100
4 65
After 4
```

- We still use a variable to store the smallest value seen so far
- In the first iteration, the smallest value is none, so we need to use an if statement to check this

The is and is not operator

```
smallest_so_far = None
print('Before',smallest_so_far)

for num in [9,39,21,98,4,5,100,65]:
    if smallest_so_far is None:
        smallest_so_far = num
    elif num < smallest_so_far:
        smallest_so_far = num
    print(smallest_so_far,num)

print('After',smallest_so_far)
```

- Python has a "is" operator which can be used in logical expression
- Implies "is the same as"
- Similar to, but stronger than ==
- "is not" is also an operator

More about Bool()

```
>>> x = 0; y = 0.0; z = 0 + 0j
>>> bool(x), bool(y), bool(z)
(False, False, False)
>>> x = -1; y = 1.e-10; z = 0 + 1j
>>> bool(x), bool(y), bool(z)
(True, True, True)
>>> x = []; y = [0]; z = "0"
>>> bool(x), bool(y), bool(z)
(False, True, True)
```

7. Functions

- **Defining and Calling:**
  - Use `def function_name(parameter1, parameter2):`.
  - Call with `function_name(arg1, arg2)`.
- **Return Values:**
  - Use `return` to send a result back.
  - **Fruitful functions** return a value; **void functions** do not (they return `None`).
- **Arguments:**
  - **Default Arguments:** `def greet(name, message="Hello"):`
- **Variable Scope:**
  - **Local:** Defined inside a function.
  - **Global:** Defined outside any function. Use the `global` keyword to modify one from inside a function.

A sample code

Program

```
x=5
print('Hello')


def print_lyrics():
    print('I am a lumberjack, and I am okay.')
    print('I sleep all night and I work all day.')

print('Yo')
print_lyrics()
x=x+2
print(x)
```

Output

```
Hello
Yo
I am a lumberjack, and I am okay.
I sleep all night and I work all day.
7
```

Argument, parameter, and result

```
>>> big = max('I am the one')
>>> print(big)
t
```

Parameter

Result

```
'I am the one'
```

```
def max(inp):
    blah
    blah
    for x in y:
        blah
        blah
    return 't'
```

```
t
```

Argument

Functions without return

- When a function has no return statement, it will return None

```
# Print grade for the score
def printGrade(score):
    if score >= 90.0:
        print('A')
    elif score >= 80.0:
        print('B')
    elif score >= 70.0:
        print('C')
    elif score >= 60.0:
        print('D')
    else:
        print('F')

def main():
    score = eval(input("Enter a score: "))
    print("The grade is ", end = " ")
    printGrade(score)

main() # Call the main function
```

Scope of variables

- The scope of a variable is the part of program where this variable can be accessed
- A variable created inside a function is referred to as a local variable
- Global variables are created outside all functions and are accessible to all functions in their scope

```
globalVar = 1
def f1():
    localVar = 2
    print(globalVar)
    print(localVar)

f1()
print(globalVar)
print(localVar) # Out of scope, so this gives an error
```

Scope of variables

- Different variables may share a name if they have different scopes

```
x = 1
def f1():
    x = 2
    print(x) # Displays 2

f1()
print(x) # Displays 1
```

Global variable

- In a function, you can use keyword global to specify that a variable is a global variable

- Be very careful when define and use global variable

```
x = 1
def increase():
    global x
    x =  x + 1
    print(x) # Displays 2

increase()
print(x) # Displays 2
```

```
print(...)
    print(value, ..., sep=' ', end='\n', file=sys.stdout, flush=False)

    Prints the values to a stream, or to sys.stdout by default.
    Optional keyword arguments:
    file:  a file-like object (stream); defaults to the current sys.stdout.
    sep:   string inserted between values, default a space.
    end:   string appended after the last value, default a newline.
    flush: whether to forcibly flush the stream.
```

Default argument

- Python allows you to define functions with default argument values
- The default argument values will be passed to the function, when it is invoked without arguments

```
def printArea(width = 1, height = 2):
    area = width * height
    print("width:", width, "\theight:", height, "\tarea:", area)

printArea() # Default arguments width = 1 and height = 2
printArea(4, 2.5) # Positional arguments width = 4 and height = 2.5
printArea(height = 5, width = 3) # Keyword arguments width
printArea(width = 1.2) # Default height = 2
printArea(height = 6.2) # Default width = 1
```

Return multiple values

- Python allows a function to return multiple values

- The sort function returns two values; when it is invoked, you need to pass the returned values in a simultaneous assignment

```
def sort(number1, number2):
    if number1 < number2:
        return number1, number2
    else:
        return number2, number1

n1, n2 = sort(3, 2)
print("n1 is", n1)
print("n2 is", n2)
```

8. Built-in Functions & Error Handling

- **Common Functions:**
  - `print()` : Outputs values to the console.
  - `input()` : Prompts the user for input (returns a string).
  - `len()` : Returns the length/size of an object.
  - `eval()` : Executes a string as a Python expression.
  - `divmod()` : Returns quotient and remainder as a pair.
- **Error Handling:**
  - **`try` and `except`** : Handle code that might fail without crashing.

```
try:
    value = int("abc")
except ValueError:
    print("That was not a number!")
```

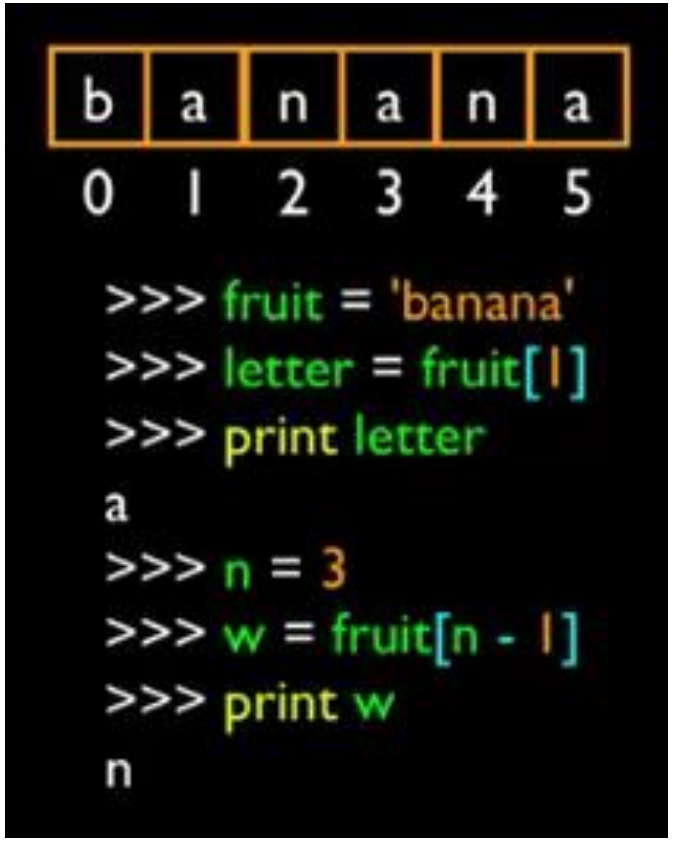
9. Strings

- Strings are **immutable** sequences of characters.
- **Indexing & Slicing:** `my_string[0]`, `my_string[start:end]`.
- **Operators:**
  - `+` (Concatenation): `'hello' + 'world'`
  - `*` (Repetition): `'Go' * 3`
  - `in` (Membership): `'sub' in 'substring'`

- **Common Methods:**
  - `.lower()` / `.upper()`: Change case.
  - `.strip()` / `.lstrip()` / `.rstrip()`: Remove whitespace.
  - `.startswith(prefix)` / `.endswith(suffix)`.
  - `.find(substring)`: Returns index or -1.
  - `.replace(old, new)`: Returns a new string with replacements.
  - `.split(delimiter)`: Breaks a string into a list.

Looking inside strings

- We can get any character in a string using an index specified in square brackets
- The index value must be an integer which starts from zero
- The index value can be an expression



Index out of range

- You will get an Python error if you attempt to index beyond the end of a string

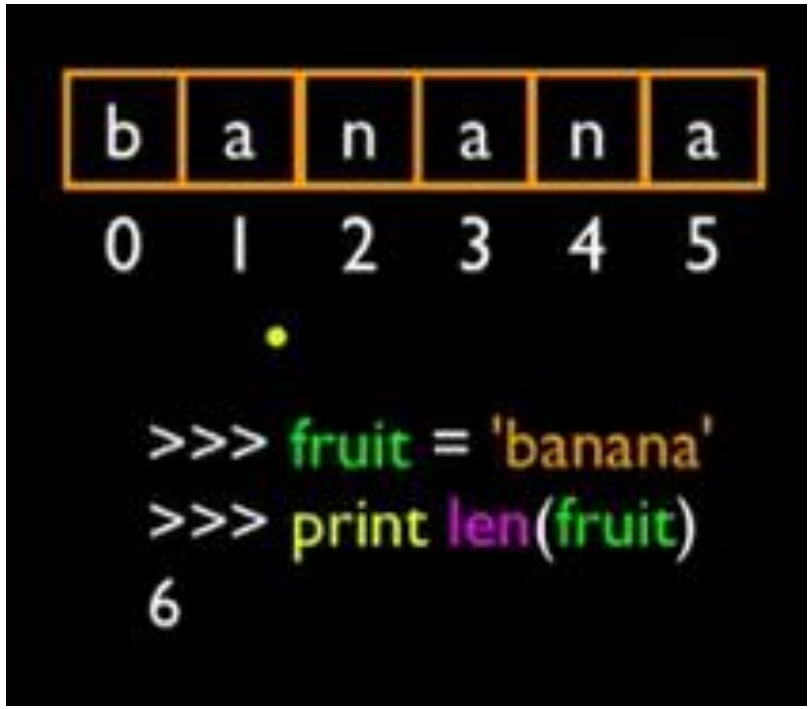
```
a = 'hi'
print(a[2])
```

```
Traceback (most recent call last):
  File "/Users/pinjia/Documents/aie1001/codes/week4.py", line 221, in <
  module>
    print(a[2])
IndexError: string index out of range
[Finished in 41ms with exit code 1]
```

- Be careful when specifying an index value

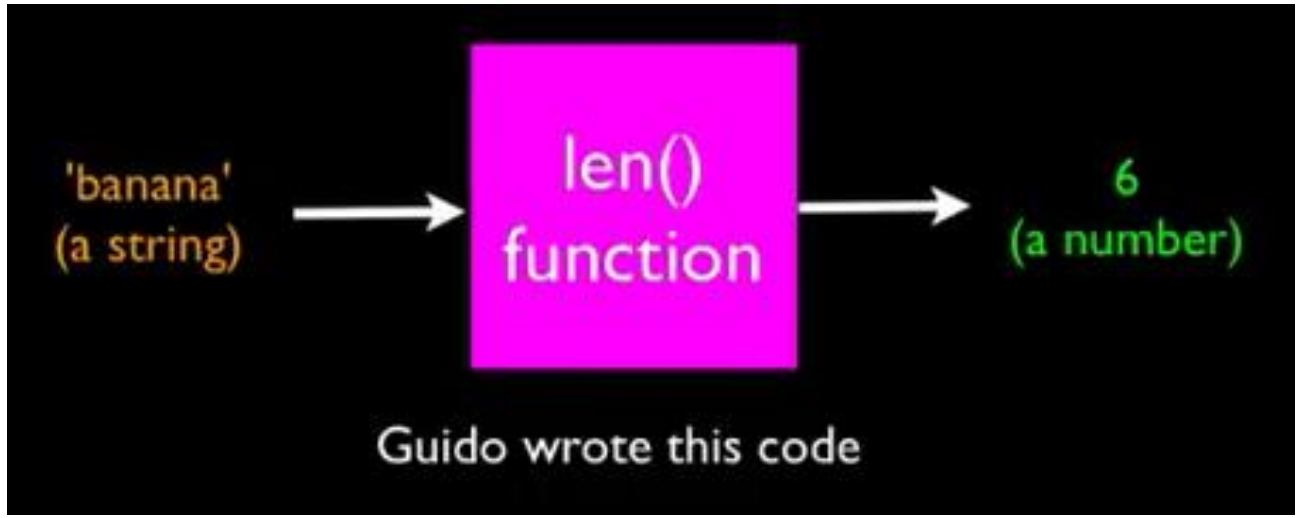
Strings have length

- There is a built-in function len() which gives us the length of a string



Len() function

```
>>> fruit = 'apple'
>>> length = len(fruit)
>>> print(length)
5
```



Looping through strings

- Using a for statement, we can easily loop through each character in a string

- String is essentially a list in Python

```
fruit = 'I am the one,Morpheus'

n = 0
for i in fruit:
    print(n, i)
    n=n+1

print('finished')
```

```
0 I
1
2 a
3 m
4
5 t
6 h
7 e
8
9 o
10 n
11 e
12 ,
13 M
14 o
15 r
16 p
17 h
18 e
19 u
20 s
finished
```

Practice

- Write a program to use a while statement together with len() function to loop through a given string

Example

```
>>> data = 'From stephen.marquard@uct.ac.za Sat Jan 5 09:14:16 2016'
>>> atpos = data.find('@')
>>> print(atpos)
21
>>> sppos = data.find(' ',atpos)
>>> print(sppos)
31
>>> host = data[atpos+1:sppos]
>>> print(host)
uct.ac.za
```

10. Collections: Lists, Tuples, Dictionaries

- **`is` vs. `==`:**
  - `==` checks if values are equal.
  - `is` checks if two variables refer to the exact same object in memory.
- **Simultaneous Assignment:** `x, y = 10, 20`. Can be used to swap variables: `x, y = y, x`.

Lists `[]`

- An ordered, **mutable** (changeable) collection.
- **Creation:** `my_list = [1, 'apple', 2.5]`
- **Access:** `my_list[0]`, `my_list[1:3]` (slicing).
- **Common Methods:**
  - `.append(item)`: Add to the end.
  - `.sort()`: Sort the list in-place.
  - `.reverse()`: Reverse the list in-place.

How long is a list?

- The len() function takes a list as input and returns the number of elements in that list

- Actually len() tells us the number of elements in any sequence (e.g. strings)

```
>>> greet = 'Hello Bob'
>>> print(len(greet))
9
>>> x=[1, 2, 'joe', 99]
>>> print(len(x))
4
```

Range() function

- The range() function returns a list of numbers

- We can construct an index loop using for and an integer iterator

```
>>> x=range(4)
>>> x
range(0, 4)
>>> x[0]
0
>>> x[1]
1
>>> x[2]
2
>>> x[3]
3
>>> x=range(2, 10, 2)
>>> x[0]
2
>>> x[3]
8
>>> x[4]
Traceback (most recent call last):
  File "<pyshell#31>", line 1, in <module>
    x[4]
IndexError: range object index out of range
```

Range() function

- What is the output of the following code?
- squares = [x * x for x in range(5) if x % 2 == 0]
  - A. [0, 1, 4, 9, 16]
  - B. [0, 2, 4]
  - C. [0, 4, 16]
  - D. [0, 4, 8]

A tale of two loops

Example

```
friends = ['Tom','Jerry','Bat']

for friend in friends:
    print('Happy new year,', friend)

for i in range(len(friends)):
    friend = friends[i]
    print('Happy new year,', friend)
```

Output

```
Happy new year, Tom
Happy new year, Jerry
Happy new year, Bat
Happy new year, Tom
Happy new year, Jerry
Happy new year, Bat
>>>
```

Concatenating lists using +

- Similar to strings, we can add two existing lists together to create a new list

```
>>> a=[1, 2, 3]
>>> b=[4, 5, 6]
>>> c=a+b
>>> print(c)
[1, 2, 3, 4, 5, 6]
>>> print(a)
[1, 2, 3]
```

Lists can be sliced using :

- Remember: similar to strings, the second number is "up to but no including"

```
>>> t=[9, 41, 12, 3, 74, 15]
>>> t[1:3]
[41, 12]
>>> t[:4]
[9, 41, 12, 3]
>>> t[3:]
[3, 74, 15]
>>> t[:]
[9, 41, 12, 3, 74, 15]
```

Built-in functions and lists

- There are a number of functions built into Python that take lists as inputs

- Remember the loops we built? These are much simpler

```
>>> numbers = [3, 41, 12, 9, 74, 15]
>>> print(len(numbers))
6
>>> print(max(numbers))
74
>>> print(min(numbers))
3
>>> print(sum(numbers))
154
>>> print(sum(numbers)/len(numbers))
25.666666666666668
```

Averaging with a list

```
total = 0
count = 0
while True:
    inp = input('Enter a number:')
    if inp == 'done': break
    value = float(inp)
    total = total + value
    count = count + 1

average = total/count
print('The average is:', average)
```

Practice

- Write a program to instruct the user to input several numbers and calculate their average using list methods

Practice

- The header of an email takes the following format:

From professor.xman@uct.edu Sat Jan 5 09:14:16 2008

For a given email header, write a program to find out the domain of email address, and the month in which this email is sent

The double split pattern

- Sometimes we split a line one way, and then grab one piece of the line and split it again

From professor.xman@uct.edu Sat Jan 5 09:14:16 2008

```
words = header.split()
address = words[1].split('@')
```

Tuples `( )`

- An ordered, **immutable** (not changeable) sequence.
- **Efficient:** More memory and performance efficient than lists.
- **Use Case:** Good for temporary data or data that should not change, like keys in a dictionary or returning multiple values from a function.
- Cannot sort, append, or reverse a tuple after creation.

Tuples are more efficient

- Since Python does not have to build tuple structures to be modifiable, they are simpler and more efficient in terms of memory use and performance than lists

- In our program when we are making “temporary variables” we prefer tuples over lists

Tuples and dictionaries

- The item() method in dictionaries returns a list of (key, value) tuples

```
>>> d=dict()
>>> d['csev']=2
>>> d['cwen']=4
>>> for (k,v) in d.items():
        print(k,v)


csev 2
cwen 4
>>> tups = d.items()
>>> print(tups)
dict_items([('csev', 2), ('cwen', 4)])
>>> print(list(tups))
[('csev', 2), ('cwen', 4)]

>>> tups = list(tups)
>>> tups[1]
('cwen', 4)
```

Tuples are comparable

- The comparison operators work with tuples and other sequences if the first item is equal. Python goes on to the next element, until it finds the elements which are different

```
>>> (0, 1, 2)<(5, 1, 2)
True
>>> (0, 1, 200000)<(0, 3, 4)
True
>>> ('Jones','Sally')<('Jones','Fred')
False
>>> ('Jones','Sally')>('Adams','Sam')
True
```

Using sorted()

- We can also do this using a built-in function sorted() which takes a sequence as a parameter and returns a sorted sequence

```
d = {'c':10, 'b':1, 'a':22}
t = d.items()

w = sorted(t)
print(w)
print(t)
```

```
[('a', 22), ('b', 1), ('c', 10)]
dict_items([('c', 10), ('b', 1), ('a', 22)])
```

Practice

- Write a program, which sorts the elements of a dictionary by the value of each element

Sort by values instead of key

- If we could construct a list of tuples of the form (key, value) we could sort by value

- We do this with a for loop that creates a list of tuples

```
>>> d={'a':10,'b':1,'c':22}
>>> tmp = list()
>>> for k,v in d.items():
        tmp.append((v,k))
```

```
>>> print(tmp)
[(22, 'c'), (1, 'b'), (10, 'a')]
>>> tmp.sort(reverse=True)
>>> print(tmp)
[(22, 'c'), (10, 'a'), (1, 'b')]
```

Example: Finding the 10 most common words in a file

```
fhand = open('myhost.txt','r')
counts = dict()
for line in fhand:
    words = line.split()
    for word in words:
        counts[word] = counts.get(word,0)+1

lst = list()
for key,val in counts.items():
    lst.append((val,key))

lst.sort(reverse = True)

for val,key in lst[:10]:
    print(key,val)
```

Dictionaries `{}`

- A collection of **key-value** pairs.
- Values are accessed via their **key**, not an index.
- **Working with Dictionaries:**
  - Add/Update: `my_dict['key'] = value`
  - Access: `my_dict['key']` (causes `KeyError` if key doesn't exist).
  - Safe Access: `my_dict.get(key, default_value)`.
- **Methods & Looping:**
  - `.keys()`, `.values()`, `.items()`.
  - `for key in my_dict:`
  - `for key, value in my_dict.items():`

List v.s. dictionary

- Dictionaries are similar to lists, except that they use keys instead of numbers to look up values

```
>>> lst = list()
>>> lst.append(21)
>>> lst.append(183)
>>> print(lst)
[21, 183]
>>> lst[0] = 23
>>> print(lst)
[23, 183]
```

```
>>> ddd = dict()
>>> ddd['age']=21
>>> ddd['course']=182
>>> print(ddd)
{'age': 21, 'course': 182}
>>> ddd['age']=23
>>> print(ddd)
{'age': 23, 'course': 182}
```

Counting with a dictionary

- A common use of dictionary is counting how often we “see” something

```
>>> ccc=dict()
>>> ccc['csev']=1
>>> ccc['cwen']=1
>>> print(ccc)
{'csev': 1, 'cwen': 1}
>>> ccc['cwen']=ccc['cwen']+1
>>> print(ccc['cwen'])
2
```

Dictionary tracebacks

- It is an error to reference a key which is not in the dictionary
- We can use the in operator to see if a key is in the dictionary

```
>>> ccc=dict()
>>> print(ccc['csev'])
Traceback (most recent call last):
  File "<pyshell#46>", line 1, in <module>
    print(ccc['csev'])
KeyError: 'csev'
>>> 'csev' in ccc
False
```

Practice

- Write a program to instruct the user to continuously input some words, and use dictionary to count how many times a word has been inputted before.

The get() method

- This pattern of checking to see if a key is already in a dictionary, and assuming a default value if the key is not there is so common, that there is a method called get() that does this for us

```
>>> counts = {'aaa':1,'bbb':2,'ccc':5}
>>> print(counts.get('eee',0))
0
```

Practice

- Write a program to instruct the user to input a line of texts, and use dictionary to count how many times a word has been seen in this line. You should use the get() method in this program.

Definite loops and dictionaries

- Even though dictionaries are not stored in order, we can write a for loop that goes through all elements in a dictionary – actually it goes through all the keys in that dictionary and looks up the values

```
counts = {'chuck':1,'fred':42,'jan':100}

for key in counts:
    print(key,counts[key])
```

```
jan 100
fred 42
chuck 1
```

Retrieving lists of keys and values

- You can get a list of keys, values or items (both) from a dictionary

```
>>> jjj = {'chuck':1,'fred':42,'jan':100}
>>> print(list(jjj))
['jan', 'fred', 'chuck']

>>> print(list(jjj.keys()))
['jan', 'fred', 'chuck']

>>> print(list(jjj.values()))
[100, 42, 1]
>>> print(list(jjj.items()))
[('jan', 100), ('fred', 42), ('chuck', 1)]
```

Bonus: two iteration variables

- We loop through the key-value pairs in a dictionary using two iteration variables

- Each iteration, the first variable is the key, and the second variable is the corresponding value for the key

```
counts = {'chuck':1,'fred':42,'jan':100}
for key,value in counts.items():
    print(key,value)
```

```
chuck 1
fred 42
jan 100
```

Question:

Which statement will cause an error?

- A. my_list = [1,2]; my_list.append(1)
- B. my_list = [1,2]; my_list[0] = 2
- C. my_tuple = (1,2); my_tuple[0] = 3
- D. my_dict = {'a':1}; my_dict['b'] = 2

Question:

Which of the following code **segments** will execute **without** raising an error?

A. d = {"name": "Alice"}; print(d["age"])

B. s = [1, 2]; s.append(2)

C. result = "hello" + ["world"]

D. my_list = [1]; my_list.append([1])

E. val = int("abc")

11. File Handling

- **Opening a File:**
  - `file_handle = open(filename, mode)`
  - **Modes:** `'r'` for reading (default), `'w'` for writing
- **Reading from a File:**
  - Loop line-by-line: `for line in file_handle:`
  - Read entire file: `contents = file_handle.read()`
- **Writing to a File:**
  - `file_handle.write("Some text\n")`
- **Closing a File:**
  - **Always** close the file to release resources: `file_handle.close()`
  - Better: Use `with open(...) as f:`, which closes the file automatically.

Practice

- Write a program to open a file and count how many lines are included in this file

Reading the whole file

- We can read the whole file into a single string

```
fhand = open('myhost.txt','r')
allText = fhand.read()
print('The length of the file:',len(allText))
print('The first 20 characters of the file:', allText[:20])
```

Searching through a file

- We can put an if statement in the for loop to print the lines which satisfy certain conditions

```
fhand = open('myhost.txt','r')

for line in fhand:
    if line.startswith('#')==True:
        print(line)

print('finished.')
fhand.close()
```

Writing to a file

- To write a file, use the open() function with ‘w’ argument

- Use the write() method to write to the file

```
fhand = open('test.txt','w')
fhand.write('The first line\n')
fhand.write('The second line\n')
fhand.write('The third line\n')
fhand.close()
```

12. Recursion

- **Definition:** A technique where a function calls itself to solve a problem.
- **Structure of a Recursive Function:**
  - **Base Case:** A condition that **stops** the recursion. Without it, you get infinite recursion.
  - **Recursive Step:** Breaks the problem down and calls the function on a smaller version.
- **Types of Recursion:**
  - **Linear Recursion:** Makes at most **one** new recursive call (e.g., Factorial, Binary Search).
  - **Multiple Recursion:** May make **two or more** recursive calls (e.g., Fibonacci).

Example: The factorial function

- The factorial of a positive integer n, denoted n!, is defined as follows:

$$n! = \begin{cases} 1 & \text{if } n = 0 \\ n \cdot (n-1) \cdot (n-2) \cdots 3 \cdot 2 \cdot 1 & \text{if } n \geq 1. \end{cases}$$

The recursive definition of factorial function

- The factorial function can be naturally defined in a recursive way, for example, $5! = 5 \cdot (4 \cdot 3 \cdot 2 \cdot 1) = 5 \cdot 4!$

- More generally, for a positive integer n, we can define n! to be $n \cdot (n-1)!$

- Therefore, the recursive definition of factorial function is:

$$n! = \begin{cases} 1 & \text{if } n = 0 \\ n \cdot (n-1)! & \text{if } n \geq 1. \end{cases}$$

Solution

$$n! = \begin{cases} 1 & \text{if } n = 0 \\ n \cdot (n-1)! & \text{if } n \geq 1. \end{cases}$$

```
def fact(n):
    if n == 0:
        return 1
    else:
        return n*fact(n-1)
```

What does the `factorial(4)` call return?

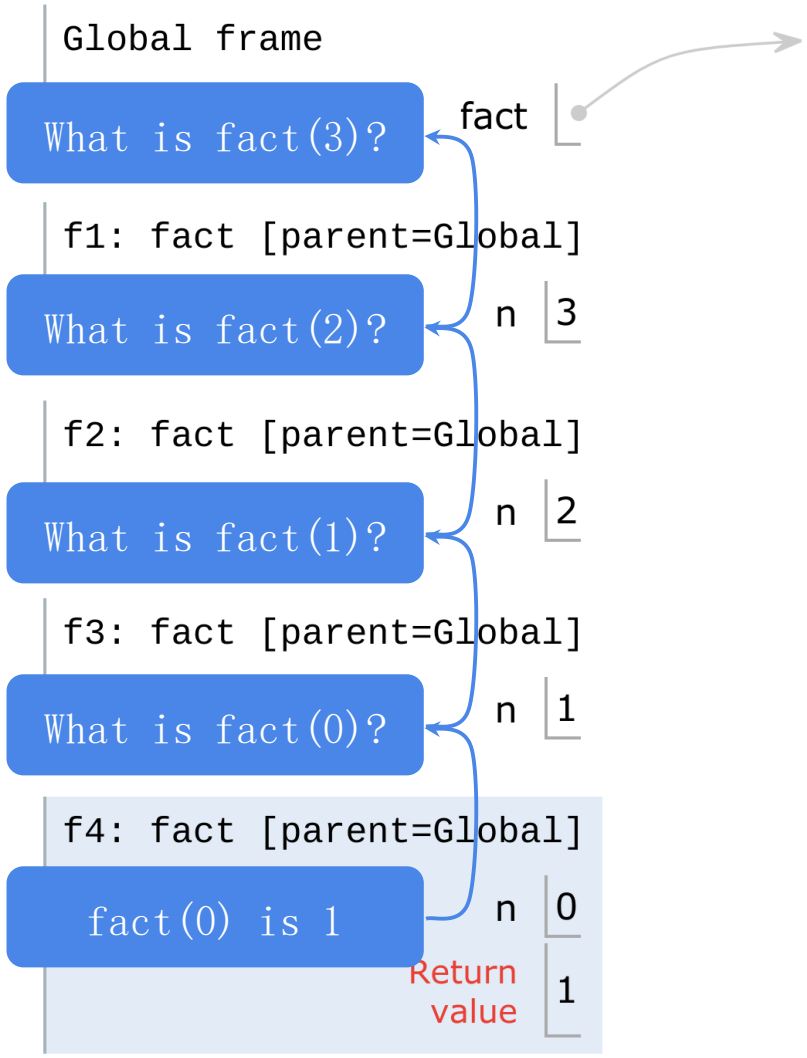
Recursion in environment diagram

```
1  def fact(n):
2      if n == 0:
3          return 1
4      else:
5          return n * fact(n - 1)
6
7  fact(3)
```

The same function fact is called multiple times, each time solving a simpler problem

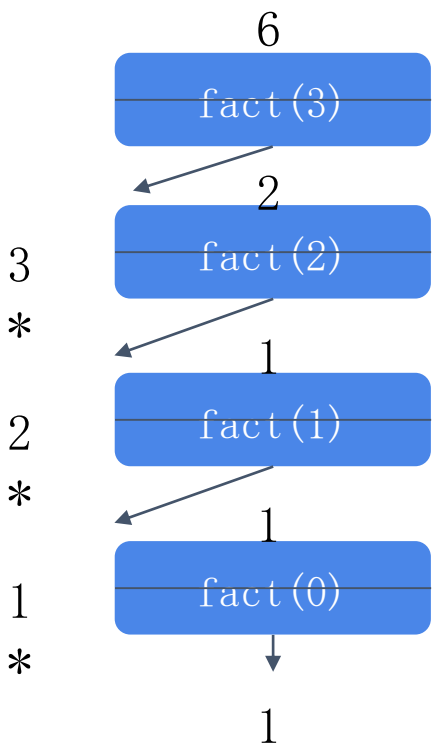
All the frames share the same parent - only difference is the argument

What n evaluates to depends upon the **current environment**



Recursive tree - another way to visualize recursion

```python
def fact(n):
    """Calculates n!"""
    if n == 0:
        return 1
    else:
        return n * fact(n-1)
```



Example: Binary Search

- **Purpose:** Efficiently search a **SORTED** sequence.
- **Strategy (Divide and Conquer):**
    i. Compare the target to the middle element.
    ii. If it's a match, you're done.
    iii. If the target is smaller, recur on the left half.
    iv. If the target is larger, recur on the right half.
- **Base Case:** The sequence is empty (target not found).

The strategy of binary search

- We call an element of the sequence a candidate if, at the current stage of the search, we cannot rule out that this item matches the target

- The algorithm maintains two parameters, low and high, such that all the candidate entries have index at least low and at most high

- Initially, low = 0 and high = n−1. We then compare the target value to the median candidate, that is, the item data[mid] with index

$$mid = \lfloor (low+high)/2 \rfloor$$

The strategy of binary search

- If the target equals data[mid], then we have found the item we are looking for, and the search terminates successfully

- If target < data[mid], then we recur on the first half of the sequence, that is, on the interval of indices from low to mid−1

- If target > data[mid], then we recur on the second half of the sequence, that is, on the interval of indices from mid+1 to high

Solution

```
def binarySearch(data, target, low, high):
    if low>high:
        print('Cannot find the target number!')
        return False
    else:
        mid = (low+high)//2
        if target==data[mid]:
            print('The target number is at position',mid)
            return True
        elif target<data[mid]:
            return binarySearch(data, target, low, mid-1)
        else:
            return binarySearch(data, target, mid+1, high)

def main():
    data = [1, 3, 5, 6, 16, 78, 100, 135, 900]
    target = 16
    binarySearch(data, target, 0, len(data)-1)
```

Practice: Power function

- Write a program to calculate the power function $f(x, n) = x^n$ using Recursion.

x*x*x* … *x ?

A better recursive definition of power function

$$power(x,n) = \begin{cases} 1 & \text{if } n = 0 \\ x \cdot \left(power\left(x, \left\lfloor \frac{n}{2} \right\rfloor\right)\right)^2 & \text{if } n > 0 \text{ is odd} \\ \left(power\left(x, \left\lfloor \frac{n}{2} \right\rfloor\right)\right)^2 & \text{if } n > 0 \text{ is even} \end{cases}$$

Solution:

```
def myPower(x,n):
    if n==0:
        return 1
    else:
        partial = myPower(x,n//2)
        result = partial * partial
        if n%2==1:
            result = result * x
        return result
```

Example: Drawing an English ruler

- We denote the length of the tick designating a whole inch as the ***major tick length***.

- Between the marks for whole inches, the ruler contains a series of ***minor ticks***, placed at intervals of 1/2 inch, 1/4 inch, and so on.

- As the size of the interval decreases by half, the tick length decreases by one

```
---- 0
-
--
-
---
-
--
-
---- 1
-
--
-
---
-
--
-
---- 2
```

(a)

```
----- 0
-
--
-
---
-
--
-
----
-
--
-
---
-
--
-
----- 1
```

(b)

```
--- 0
-
--
-
--- 1
-
--
-
--- 2
-
--
-
--- 3
```

(c)

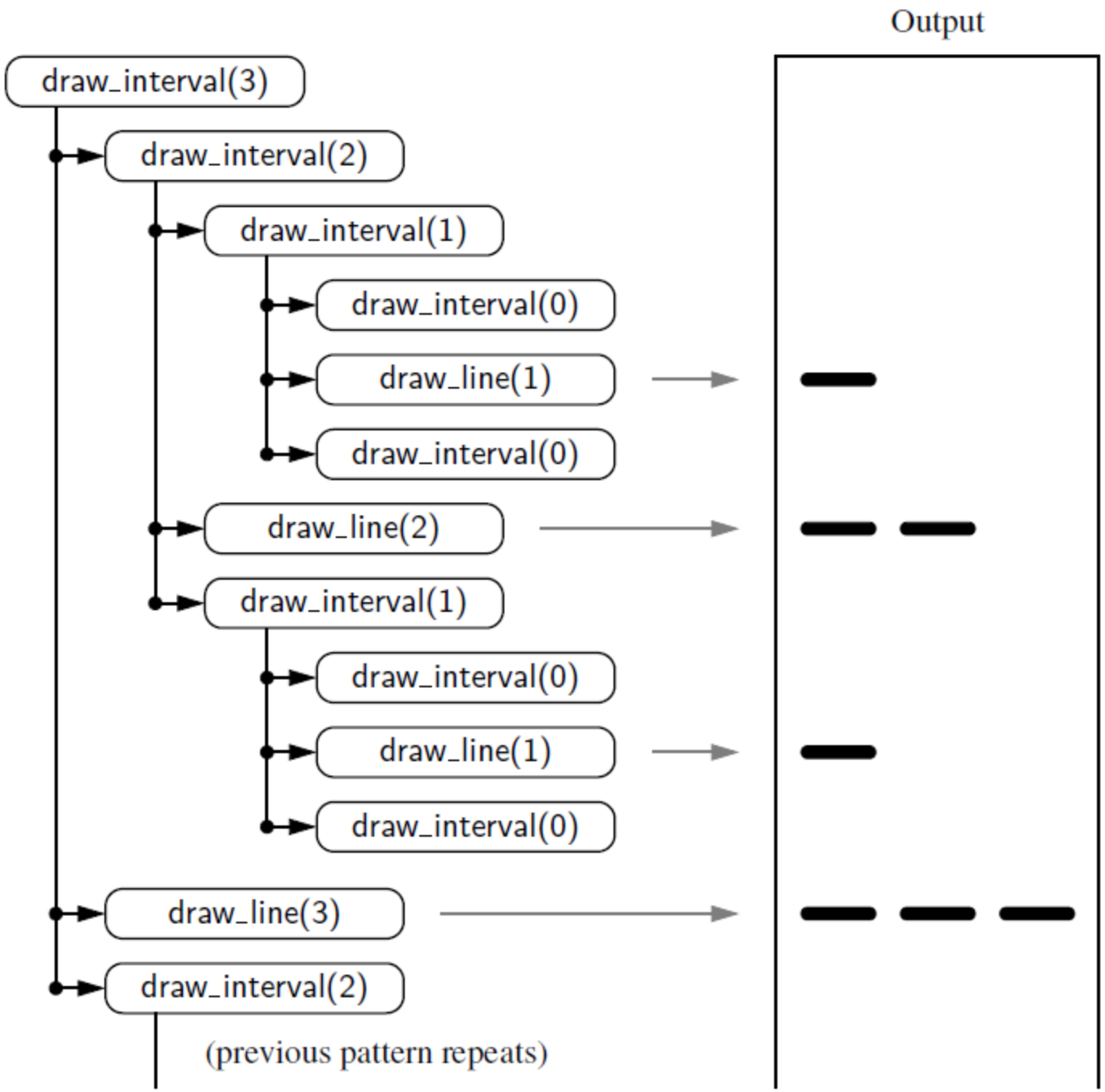
Recursive implementation of English ruler

- An interval with a central tick length $L \geq 1$ is composed of:
  - ✓ An interval with a central tick length $L-1$
  - ✓ A single tick of length L
  - ✓ An interval with a central tick length $L-1$

Solution

```
def draw_line(tickLen, tickLabel=''):
    line = '-'*tickLen
    if tickLabel:
        line+=' '+tickLabel
    print(line)

def draw_interval(centerLen):
    if centerLen>0:
        draw_interval(centerLen-1)
        draw_line(centerLen)
        draw_interval(centerLen-1)

def draw_ruler(numInch, majorLen):
    draw_line(majorLen, '0')

    for j in range(1, 1+numInch):
        draw_interval(majorLen-1)
        draw_line(majorLen, str(j))
```

The recursive trace for English ruler



Linear Recursion

- If a recursive function is designed so that each invocation of the body makes at most one new recursive call, this is known as linear recursion

- Finding the smallest number and binary search are both linear recursive algorithms

Linear Recursion

```
def binarySearch(data, target, low, high):
    if low > high:
        print ('Cannot find the target number!')
    else:
        mid = (low+high) // 2
        if target==data[mid]:
            print('The target number is at position', mid)
            return True
        elif target<data[mid]:
            # print ('We are searching position:', low, 'to', mid-1)
            return binarySearch(data, target, low, mid-1)
        else:
            # print ('We are searching position:', mid+1, 'to', high)
            return binarySearch(data, target, mid+1, high)
```

Practice: Sum of a list

- Given a list of numbers, write a program to calculate the sum of this list using recursion

Solution:

```
def linearSum(L, n):
    if n==0:
        return 0
    else:
        return linearSum(L, n-1)+L[n-1]

def main():
    L = [1, 2, 3, 4, 5, 9, 100, 46, 7]
    print('The sum is:', linearSum(L, len(L)))
```

Multiple recursion

- When a function makes two or more recursive calls, we say that it uses multiple recursion

- Drawing the English ruler is a multiple recursion program

Multiple recursion

- When a functio ve calls, we say that it us
- Drawing the Eng sion program

```
def draw_line(tickLen, tickLabel=''):
    line = '-'*tickLen
    if tickLabel:
        line+=' '+tickLabel
    print(line)

def draw_interval(centerLen):
    if centerLen>0:
        draw_interval(centerLen-1)
        draw_line(centerLen)
        draw_interval(centerLen-1)

def draw_ruler(numInch, majorLen):
    draw_line(majorLen, '0')

    for j in range(1, 1+numInch):
        draw_interval(majorLen-1)
        draw_line(majorLen, str(j))
```

Practice: Binary sum

- Write a function binarySum() to calculate the sum of a list of numbers. Inside binarySum() two recursive calls should be made

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	4	5	7	8	9	12	14	17	19	22	25	27	28	33	37

Practice: Binary sum

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	4	5	7	8	9	12	14	17	19	22	25	27	28	33	37

```
binarySum(L,start,mid)+binarySum(L,mid,stop)
```

Practice: Binary sum

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	4	5	7	8	9	12	14	17	19	22	25	27	28	33	37

```
elif start==stop-1:
    return L[start]
```

Solution:

```
def binarySum(L, start, stop):
    if start>=stop:
        return 0
    elif start==stop - 1:
        return L[start]
    else:
        mid = (start+stop)//2
        return binarySum(L,start,mid)+binarySum(L,mid,stop)

def main():
    L = [1,2,3,4,5,6,7]
    print(binarySum(L,0,len(L)))
```

Example: Fault localization

There are **four** errors in the following code, which is intended to find the most frequent number (mode) in a list. Identify the lines or concepts that are incorrect.

```
1  def find_mode(data_list):
2      counts = {}
3      for item in data_list:
4          counts[item] = counts.get(item) + 1
5
6      max_count = 0
7      mode = None
8      for key, value in counts.items:
9          if value > max_count
10             max_count = value
11             mode = key
12
13     print("The mode is: " + mode)
14     return mode
```

Example: Code Completion

This is a code completion question. Please fill in the **EIGHT** blanks in the given source code to make it functional and provide the final output for the given test case.

```python
"""
This program counts the frequency of each word in a given text.
The function should be case-insensitive and should ignore common punctuation.
"""
import string

def count_word_frequency(text):
    # 1. Convert text to lowercase to ensure case-insensitivity
    text = 1._______________(3 points)

    # 2. Remove all punctuation marks from the text
    for punc in string.punctuation:
        text = text.replace(punc, " ")

    # 3. Split the text into a list of individual words
    words = 2._______________(3 points)

    # 4. Use a dictionary to count the frequency of each word
    word_counts = {}
    for word in words:
        if word:  # Make sure the word is not an empty string
            current_count = 3._______________(4 points)
            word_counts[word] = current_count + 1

    return word_counts
```

```python
def find_most_frequent(word_counts):
    if not word_counts:
        return None, 0

    most_frequent_word = ""
    max_count = -1

    # 5. Iterate through the dictionary to find the word with the highest count
    for word, count in 4._______________(4 points):
        if count > max_count:
            5._______________(2 points) = count
            6._______________(2 points) = word

    return most_frequent_word, max_count

def main():
    test_case = "Go, team, go! We must, we must, we will win!"

    frequencies = 7._______________(3 points)
    word, count = find_most_frequent(frequencies)
    print(f"Most frequent word: '{word}', Count: {count}")

if __name__ == "__main__":
    main()

# Provide the final printed output of the program:
# 8. ____________________________________(4 points)
```