

DATA ANALYTICS REFERENCE DOCUMENT	
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52960 - Multi-Paradigm Programming

Goals

- What is a programming paradigm?
- Why are there different paradigms?
- How does it relate the notions of State & Abstraction?

What is a Programming Paradigm?

- The term programming paradigm is the style or way of thinking about and approaching problems.
- The chosen paradigm affects how the code is written and structured.
- It can heavily influence how one thinks about the problem being solved
- Some problems map more easily to a particular paradigm
- Each paradigm has it's advocates and detractors, advantages and disadvantages etc.
- Different Language is not the same thing as a different Paradigm

MIPS Assembly

```
LUI R1, #1
LUI R2, #2
DADD R3, R1, R2
```

C or Java

(In fact this is syntactically valid in a lot of languages)

```
x = 1 + 2;
```

- Both examples show the addition of two numbers
- MIPS is very low level, one step above binary
- C is higher level, though most would consider C to be a low level language
- Both examples follow the same paradigm, such as it can be in a “one liner”

Abstraction

- In software engineering and computer science, abstraction is:
 - the process of removing **physical**, **spatial**, or **temporal** details or attributes in the study of objects or systems in order to focus attention on details of higher importance, it is also very similar in nature to the process of generalization;
- the creation of abstract concept-objects which are created by mirroring common features or attributes from various non-abstract objects or systems of study - the result of the process of abstraction.
- It is one of the most important concepts in Software Development
- So much of Computer Science is about Abstraction

Examples of Abstraction

- Concurrency Control
- Memory Management
- Virtual Machine
- Operating Systems
- Drivers
- APIs
- All Programming languages and Paradigms are attempts to abstract low-level details to allow the programmer to think about and solve problems at a higher level (or perhaps a different level!)
- Computers understand operations at a very low level
- i.e. Moving bits from one place to another
- Of course we wanted to do things at a higher level than bitwise operations
- Have a look at the following operation:
a := (1 + 2) * 5
- so it's “one plus two multiplied by five”
- The low level steps needed to
 - carry out this evaluation
 - return the result (15)
 - and perform assignment (to a)
- are actually quite complex
 - recall it's a rock we tricked into thinking

What is state?

- A program can store data in variables, which map to storage locations in memory. The contents of these memory locations, at any

given point in the program's execution, is called the program's state.

- State effects the behaviour of the program.
- The more state the more unpredictable the program
- “In programming mutable state is evil”
- Some paradigms would seek to do away with it completely.
- In others it is intrinsic, OOP without mutable state is not possible.

```
var total = 0;  
var a = 1;
```

```
var b = 5;  
total = a + b  
print total;
```

- In the beginning total is 0
- it's state is modified
- then printed
- No problems here but...
 - this can be complicated by control flow structures dependant on the value of variables, unpredictable values entered by users or coming from stored data

Various Programming Paradigms

- Imperative / Procedural
- Functional
- Object-oriented
- Declarative
- Data Flow

We shall have a brief look at each of these....

Sources

- <https://www.computerhope.com/jargon/a/al.htm>
- [https://en.wikipedia.org/wiki/Abstraction_\(computer_science\)](https://en.wikipedia.org/wiki/Abstraction_(computer_science))
- [https://en.wikipedia.org/wiki/C_\(programming_language\)](https://en.wikipedia.org/wiki/C_(programming_language))

Week 3 - Imperative: Procedural

Goals of this session

- Imperative programming
 - Procedural programming
 - Python Example
 - Procedural Programming Example
 - Imperative Programming Example
- Sources

Goals

- To Understand...
 - What is Imperative programming?
 - What is Procedural program?
 - How a procedural program is structured

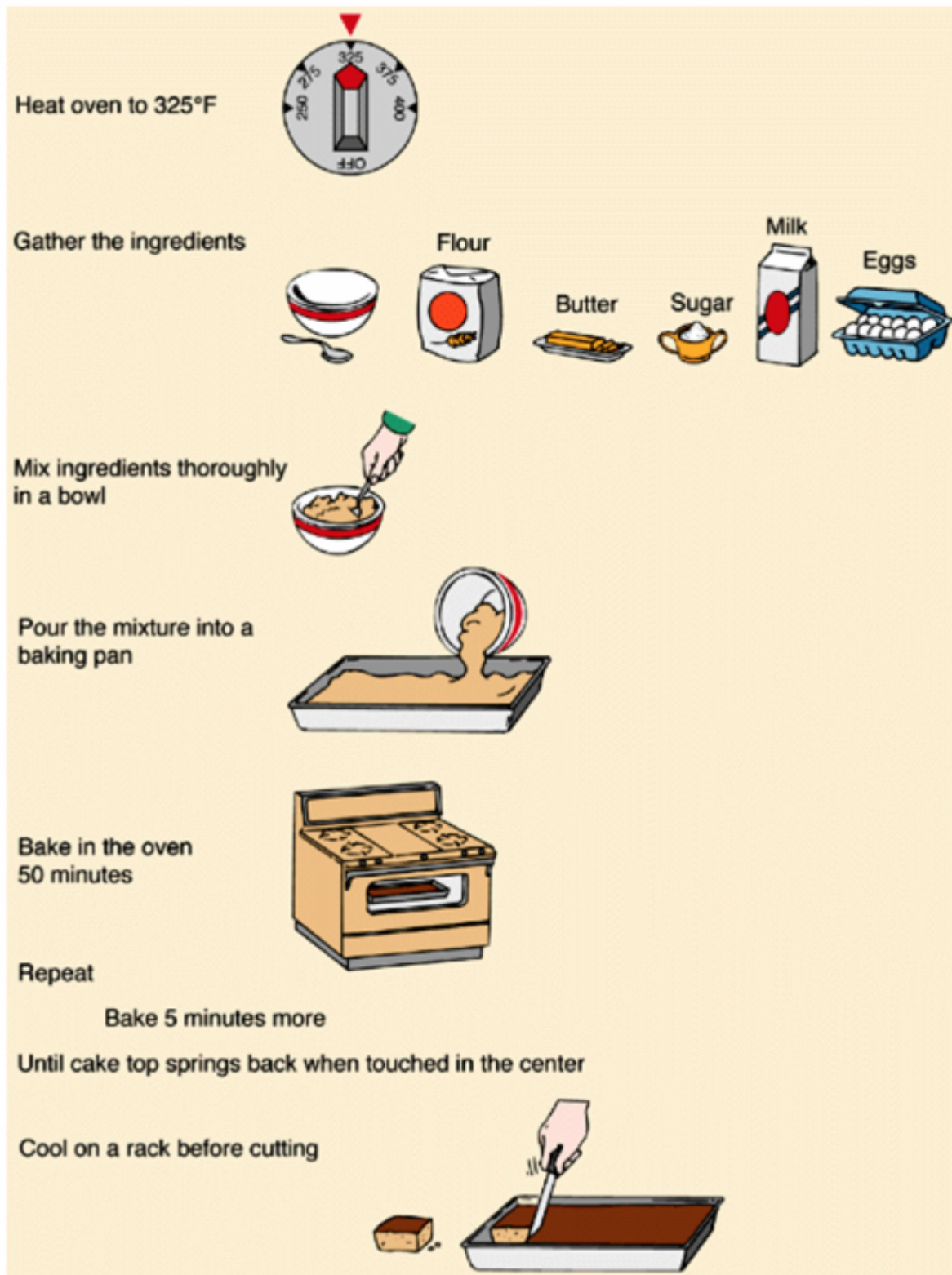
Imperative Programming

Imperative I

- Programming with an explicit sequence of commands that update state
- Says **how** to do something

- consider baking a cake (just good life advice really)
 - An imperative program says how to do something in the correct sequence it should be done
 - therefore order of execution(the order in which each statement is executed) is important.
 - Obviously you cannot add candles if you didn't bake the cake right?
 - You cannot eat no cake!

Imperative II



Imperative III

Very General Structure First **do this** and next **do that**, then **repeat this 10 times**, then **finish**

Imperative IV

- Is simply Imperative programming with procedure calls
 - AKA methods or functions or sub-routines
- To avoid repetition and to provide structure early programmers realized they should group instructions together into re-usable elements called procedures which can then be called when needed during program execution
- Imperative did provide a means of non-linear execution a “go-to” but it was messy.
 - This was one of the first advances in programming maintainability.
 - The idea was first implemented in ALGOL in the 1950's
- Mostly when someone say they are doing Imperative Programming they are really doing Procedural Programming

Imperative V

Listing 1: Very Simple Function in Python

```
def my_function():  
    print("Hello from a function")  
  
my_function()
```

Imperative VI

Listing 2: Slightly less simple Function in Python

```
def print_list(food):  
    for x in food:  
        print(x)  
  
fruits = ["apple", "banana", "cherry"]  
  
print_list(fruits)
```

Imperative VII

Listing 3: C Language Example (Procedural)

```
#print numbers from 1 to 10  
# include <stdio.h>  
  
int main(){  
    int i;  
    for (i=1; i<11; ++i)  
    {  
        printf("%d ", i);  
    }  
    return 0;  
}
```

Listing 3: Python Language Example (Procedural)

```
def myFunction():
    a = 0
    for a in range(0, 10):
        a += 1 # Same as a = a + 1
        print (a, sep=' ', end=' ', flush=True)

myFunction()
```

- Execution begins at **main()** the programs entry point
- Proceeds linearly (kinda)
- Loop repeats until condition is false
- **printf()** is a function taking args, defined as part of standard C
- Program terminates returning exit code 0

Imperative VIII

Listing 4: Imperative with go-to

```
result = []
i = 0
start:
    numPeople = length(people)
    if i >= numPeople goto finished
    p = people[i]
    nameLength = length(p.name)
    if nameLength <= 5 goto nextOne
    upperName = toUpper(p.name)
    addToList(result, upperName)
nextOne:
    i = i + 1
    goto start
finished:
    return sort(result)
```

Imperative IX

- Imperative Programs often compile to binary executables that run more efficiently since all CPU instructions are themselves imperative statements
- Imperative approaches and “lower level” languages are often used where efficiency and code-footprint are important such as in embedded systems.
 - “Low Level” refers to the closeness to the machine with regard to the level of abstraction
 - An approach like declarative programming would be more “high level”

Imperative X

- Procedural Languages
 - C
 - Python
 - ALGOL
 - JavaScript
 - PHP

Sources

- <https://www.computerhope.com/jargon/i/imp-programming.htm>

- [https://en.wikipedia.org/wiki/Abstraction_\(computer_science\)](https://en.wikipedia.org/wiki/Abstraction_(computer_science))
- <https://www.w3resource.com/c-programming-exercises/basic-algo/index.php>

Week 3 - The C Programming language

- **Goals of this session**
- **The C Programming Language**
 - Structuring Data in C
 - Comparison with Python
 - Installing C on Windows
 - C Practice Questions
- **Sources**
- To Understand...
 - The basics of the C programming language
 - How to write a procedural program in C

The C programming Language

The C programming Language I

- general-purpose & procedural computer programming language
- Supports structured programming, lexical variable scope, and recursion
- Static type system prevents unintended operations.
- By design, C provides constructs that **map efficiently** to typical **machine instructions**
 - Has found lasting use in applications previously coded in **assembly language**.
 - Including operating systems and application software for diverse platforms from supercomputers to embedded systems.
 - It has been around since 1972
 - Was developed at Bell Labs

The C programming Language II

Listing 1: Assembly Code for Hello World

```
global _main
extern _printf

section .text
_main:
    push message
    call _printf
    add esp, 4
    ret
message:
    db 'Hello, World!', 10, 0
```

The C programming Language III

- Designed to be compiled using a relatively straightforward compiler
- to provide low-level access to memory and language constructs that map efficiently to machine instructions.

- Designed to work cross-platform. A standards-compliant C program written with portability in mind can be compiled for a wide variety of computer platforms and operating systems with **few changes** to its source code.
 - Java was designed with even better cross platform support under the tagline “Write once, run anywhere”.
- The language is available on various platforms, from embedded microcontrollers to supercomputers.

The C programming Language IV

Listing 2: Hello World in Standards Compliant C

```
#include <stdio.h>
int main(void)
{
    printf("hello, world\n");
}
```

Listing 2: Hello World in Standards Compliant python

```
def helloworld():
    print("Hello, world")

helloworld()
```

The C programming Language V

- “#include” is a pre-processing directive, it is saying to pull the contents of the specified file and replace this line with that “stdio.h” is part of Standard C.
- “main()” is a function, but it is a very special function
 - It acts as the entry point of the program it is from here that execution begins. Main returns an int to the calling environment.
- The next line calls (diverts execution to) a function named printf
 - This is a function found in the system library of C which sends output to the “standard out” of the calling environment, typically this means it prints out to the terminal or command prompt
 - That said std out can be redirected to funnel information between scripts or into files.
- printf will output the character array to the standard output.
- We do not have to explicitly return a value for main it implicitly returns “0” which means the program executed successfully.

The C programming Language VI

Write a C program to print your name, date of birth. and mobile number

```
#include <stdio.h>
int main(void)
{
    printf("Name: Dominic Carr\n");
    printf("DOB: June 12th, 1920\n");
    printf("086-1910000\n");
}
```

Write a python program to print your name, date of birth. and mobile number

```
def personinfo():
    print("Name: Dominic Carr")
    print("DOB: June 12th, 1920")
    print("086-1910000")
```



```
personinfo()
```

The C programming Language VII

Write a C program to print a block F using hash (#), where the F has a height of six characters and width of five and four characters

```
#include <stdio.h>
int main()
{
    printf("#####\n");
    printf("#\n");
    printf("#\n");
    printf("#####\n");
    printf("#\n");
    printf("#\n");
    printf("#\n");
}
```

Python

```
def fpattern():
    print("#####")
    print("#")
    print("#")
    print("#####")
    print("#")
    print("#")
    print("#")

fpattern()
```

Listing 3: Another Answer this time with a function

```
#include <stdio.h>
void print(int times, char a)
{
    for(int i = 0; i < times; i++)
    {
        printf("%c", a);
    }
    printf("\n");
}
int main()
{
    print(6, '#');
    print(1, '#');
    print(1, '#');
    print(5, '#');
    print(1, '#');
    print(1, '#');
}
```

python

```
def fpattern(n):
    for i in range(n):
        print("#", end='', flush=True)
    print(" ")
```

```

fpattern(5)
fpattern(1)
fpattern(1)
fpattern(5)
fpattern(1)
fpattern(1)

```

The C programming Language X

Write a C program to compute the sum of the two given integer values. If the two values are the same, then return triple their sum.

```

#include <stdio.h>
int sum(int a, int b)
{
    if (a==b)
    {
        return (a+b)*3;
    } else {
        return (a+b);
    }
}

int main()
{
    int res = sum(1,2);
    printf("Result is %d\n", res);
    res = sum(3,3);
    printf("Result is %d\n", res);
}

```

Python

```

def sumUp(a, b):
    if(a==b):
        return(a+b)*3
    else:
        return(a+b)

result = sumUp(1,2)
print("Result is", result)

result = sumUp(3,3)
print("Result is", result)

```

Structs I

Listing 4: C Example of representing a Person

```

#include <stdio.h>
struct person
{
    int age;
    float weight;
};

int main()
{
    struct person *personPtr, person1;
}

```

```
personPtr = &person1;
printf("Enter age: ");
scanf("%d", &personPtr->age);
printf("Enter weight: ");
scanf("%f", &personPtr->weight);
printf("Age: %d\n", personPtr->age);
return 0;
}
```

Structs III

- A struct is a way of grouping individual variables together
- It can be used to create a representation of something like a person
- As defined above a person has an age and a weight
- We will contrast this with OOP approaches which we will learn about soon

C vs Python

- C is compiled, Python is interpreted
- C allows low level memory access, Python does not
- Python support OOP, C does not
- Python has a much larger set of built-in functionality than C
- C code execution is much faster than Python
 - Compilation is key
- Variable types must be declared in C, not so in Python
- C has a more verbose syntax than Python
 - Python would be considered easier to learn
- In C memory management is manual, Python has automated management
- There are many syntactical differences, but some commonalities

Installing C on Windows

- Install Cygwin, which gives us a Unix-like environment running on Windows.
- Install a set of Cygwin packages required for building GCC.
- From within Cygwin, download the GCC source code, build and install it.
- Then you should be able to compile and run C programs.
- Follow these steps which are detailed extensively @ <https://preshing.com/20141108/how-to-install-the-latest-gcc-on-windows/>
- See the wiki help section for more information installing cygwin

Online C compiler

https://www.onlinegdb.com/online_c_compiler and Compile our C code online!

C Practice Questions I

We will take a look at some of the “elementary” questions @ https://adriann.github.io/programming_problems.html Other

1.c

```
#include <stdio.h>
```

```
int main()
{
    printf("Hello, World\n");
    return 0;
}
```

1.py

```
print("Hello World")
```

2.c

```
#include <stdio.h>

int main()
{
    char name[20];

    printf("What is your name?");

    fgets(name,20,stdin);

    printf("Hello %s", name);

    return 0;
}
```

2.py

```
name = raw_input("What is your name?")
print("Hello %s, How are you?" %(name))
```

3.c

```
#include <stdio.h>
#include <string.h>

int main()
{
    char* name;

    printf("What is your name?");

    gets(name);

    if ((strcmp(name,"Alice")==0) || (strcmp(name,"Bob")==0))
    {
        printf("Hello %s\n", name);
    } else
    {
        printf("Hello lowly peasant!\n");
    }
}
```

```
    return 0;
}
```

3.py

```
name = raw_input("What is your name?")

if (name=="Bob") or (name=="Alice"):
    print("Hello %s, How are you?" %(name))
else:
    print("Hello lowly peasant!")
```

4.c

```
#include <stdio.h>
#include <string.h>

int main()
{
    int n;
    int sum = 0;

    printf("Please enter a Number: ");
    scanf("%d", &n);

    for(int i = 1; i<=n; i++)
    {
        sum += i;
    }

    printf("The sum of 1 to %d, was %d\n", n, sum);

    return 0;
}
```

4.py

```
n = input("Enter a number: ")

sum = 0

for i in range(1,n+1):
    sum = sum + i

print("The sum of 1 to %d, was %d" % (n, sum))
```

5.c

```
#include <stdio.h>
#include <string.h>

int main()
{
    int n;
    int sum = 0;
```

```

printf("Please enter a Number: ");
scanf("%d", &n);

for(int i = 1; i<=n; i++)
{
    if ((i%3)==0) || ((i%5)==0)
    {
        sum += i;
    }
}

printf("The sum of 1 to %d, was %d\n", n, sum);

return 0;
}

```

5.py

```

n = input("Enter a number: ")

sum = 0

for i in range(1,n+1):
    if ((i % 3)==0) or ((i % 5)==0):
        print i
        sum = sum + i

print("The sum of 1 to %d, was %d" % (n, sum))

```

6.c

```

#include <stdio.h>
#include <string.h>
#include <stdlib.h>

int main()
{
    int n, sum = 0;
    int product = 1;
    char* choice = (char*) malloc(10 * sizeof(char));

    printf("Please enter a Number: ");
    scanf("%d", &n);
    printf("Do you want to do product or sum?");
    scanf("%s", choice);

    if (strcmp(choice, "product")==0)
    {
        for(int i = 1; i<=n; i++)
        {
            product *= i;
        }

        printf("The product of 1 to %d, was %d\n", n, product);
    } else if (strcmp(choice, "sum")==0)
    {
        for(int i = 1; i<=n; i++)

```

```

    {
        sum += i;
    }

    printf("The sum of 1 to %d, was %d\n", n, sum);

}
return 0;
}

```

6.py

```

n = input("Enter a number: ")
kind = raw_input("Do you want to do sum or product? ")

sum = 0
product = 1

if (kind == "sum"):
    for i in range(1,n+1):
        sum = sum + i
    print("The sum of 1 to %d, was %d" % (n, sum))
elif (kind == "product"):
    for i in range(1,n+1):
        product = product * i
    print("The product of 1 to %d, was %d" % (n, product))
else:
    print("I did not understand your request")

```

C Practice Questions II

Questions:

1. Write a C program to get the absolute difference between n and 51. If n is greater than 51 return triple the absolute difference.
2. Write a C program to check two given integers, and return true if one of them is 30 or if their sum is 30.
3. Write a C program to compute the sum of the two given integers. If the sum is in the range 10..20 inclusive return 30
4. Write a C program that accept two integers and return true if either one is 5 or their sum or difference is 5.
5. Write a C program to check if y is greater than x, and z is greater than y from three given integers x,y,z
6. Write a C program to check if two or more non-negative given integers have the same rightmost digit.

Abs Diff

abs_diff.c

```

1. // Write a C program to get the absolute difference between n and 51.
2. // If n is greater than 51 return triple the absolute difference.
3.
4. #include <stdio.h>
5. #include <string.h>
6. #include <stdlib.h>
7.
8. int main()
9. {
10.     char* choice = (char*) malloc(10 * sizeof(char));
11.     int n, val;

```

```
12.
13.  printf("Please enter a Number: ");
14.  scanf("%d", &n);
15.  printf("Number entered is : %d\n", n);
16.  if (n>51){
17.      val=(abs(n-51))*3;
18.  }
19.  else {
20.      val=(abs(n-51));
21.  }
22.  printf("result: %d\n", val);
23.  return val;
24. }
```

Sum of integers

[two_integers.c](#)

```
1.  // Write a C program to check two given integers, and return
2.  // true if one of them is 30 or if their sum is 30
3.
4.  #include <stdio.h>
5.  #include <string.h>
6.  #include <stdlib.h>
7.  #include <stdbool.h>
8.
9.  int main()
10. {
11.     char* choice = (char*) malloc(10 * sizeof(char));
12.     int n1,n2,val;
13.
14.
15.     printf("Please enter first Number: ");
16.     scanf("%d", &n1);
17.     printf("Please enter second Number: ");
18.     scanf("%d", &n2);
19.
20.     printf("Numbers entered is : %d and %d \n", n1,n2);
21.     if (n1==30 || n2==30 || n1+n2==30){
22.         val=true;
23.     }
24.     else {
25.         val=false;
26.     }
27.     printf("val is: %d\n", val);
28.     if(val==1){
29.         printf("Either values or sum of both equals 30, therefore....");
30.         printf("result: %s\n","TRUE");
31.     }
32.     else {
33.         printf("Neither values or the sum of both equals 30, therefore....");
34.         printf("result: %s\n","FALSE");
35.     }
36.     return val;
37. }
```


Sources

- <https://www.computerhope.com/jargon/i/imp-programming.htm>
- [https://en.wikipedia.org/wiki/Abstraction_\(computer_science\)](https://en.wikipedia.org/wiki/Abstraction_(computer_science))
- <https://www.w3resource.com/c-programming-exercises/basic-algo/index.php>

Week 4 - Shop in C

c code

shop.c

```
1. #include <stdio.h>
2. #include <string.h>
3. #include <stdlib.h>
4.
5. struct Product {
6.     char* name;
7.     double price;
8. };
9.
10. struct ProductStock {
11.     struct Product product;
12.     int quantity;
13. };
14.
15. struct Shop {
16.     double cash;
17.     struct ProductStock stock[20];
18.     int index;
19. };
20.
21. struct Customer {
22.     char* name;
23.     double budget;
24.     struct ProductStock shoppingList[10];
25.     int index;
26. };
27.
28. void printProduct(struct Product p)
29. {
30.     printf("PRODUCT NAME: %s \nPRODUCT PRICE: %.2f\n", p.name, p.price);
31.     printf("-----\n");
32. }
33.
34. void printCustomer(struct Customer c)
35. {
36.     printf("CUSTOMER NAME: %s \nCUSTOMER BUDGET: %.2f\n", c.name, c.budget);
37.     printf("-----\n");
38.     for(int i = 0; i < c.index; i++)
39.     {
40.         printProduct(c.shoppingList[i].product);
41.         printf("%s ORDERS %d OF ABOVE PRODUCT\n", c.name,
42.             c.shoppingList[i].quantity);
43.         double cost = c.shoppingList[i].quantity *
```

```

        c.shoppingList[i].product.price;
43.     printf("The cost to %s will be €%.2f\n", c.name, cost);
44. }
45. }
46.
47. struct Shop createAndStockShop()
48. {
49.     struct Shop shop = { 200 };
50.     FILE * fp;
51.     char * line = NULL;
52.     size_t len = 0;
53.     ssize_t read;
54.
55.     fp = fopen("stock.csv", "r");
56.     if (fp == NULL)
57.         exit(EXIT_FAILURE);
58.
59.     while ((read = getline(&line, &len, fp)) != -1) {
60.         // printf("Retrieved line of length %zu:\n", read);
61.         // printf("%s IS A LINE", line);
62.         char *n = strtok(line, ",");
63.         char *p = strtok(NULL, ",");
64.         char *q = strtok(NULL, ",");
65.         // create variables from the strings to populate the structures
66.         int quantity = atoi(q);
67.         double price = atof(p);
68.         // create a variable to make a permanent copy of the string that
        is pointed to only in n
69.         char *name = malloc(sizeof(char) * 50);
70.         strcpy(name, n);
71.         // instanssiate the first structure to go into the second
        structure and insert the values in
72.         struct Product product = { name, price };
73.         struct ProductStock stockItem = { product, quantity };
74.         // as pointed out in the video, a lot happens in this line, see
        the detailed description below
75.         shop.stock[shop.index++] = stockItem;
76.         // printf("NAME OF PRODUCT %s PRICE %.2f QUANTITY %d\n", name, price,
        quantity);
77.     }
78.
79.     return shop;
80. }
81.
82. void printShop(struct Shop s)
83. {
84.     printf("Shop has %.2f in cash\n", s.cash);
85.     for (int i = 0; i < s.index; i++)
86.     {
87.         printProduct(s.stock[i].product);
88.         printf("The shop has %d of the above\n", s.stock[i].quantity);
89.     }
90. }
91.
92. int main(void)
93. {
94.     // struct Customer dominic = { "Dominic", 100.0 };
95.     //
96.     // struct Product coke = { "Can Coke", 1.10 };
97.     // struct Product bread = { "Bread", 0.7 };
98.     // // printProduct(coke);
99.     //

```

```

100.    // struct ProductStock cokeStock = { coke, 20 };
101.    // struct ProductStock breadStock = { bread, 2 };
102.    //
103.    // dominic.shoppingList[dominic.index++] = cokeStock;
104.    // dominic.shoppingList[dominic.index++] = breadStock;
105.    //
106.    // printCustomer(dominic);
107.
108.    struct Shop shop = createAndStockShop();
109.    printShop(shop);
110.
111.    // printf("The shop has %d of the product %s\n", cokeStock.quantity,
112.        cokeStock.product.name);
113.
114.    return 0;
115. }

```

This line of code on **line 75** is packed with functionality and important to understand in order to reproduce the functionality for the assignments.

```
shop.stock[shop.index++] = stockItem;
```

You need to refer to the Shop structure defined on line 15 in the c code sample above. This structure is then instantiated on line 49 and named shop. This structure shop contains another structure ProductStock named stock and an array of 20 of this is defined.



So in order to loop through this array the index is created that needs to be maintained and used to fill the right indexed positions.

So in summary shop contains three named values, cash, stock and index therefore lines 72 and 73 creates the new structured values that is required to populate into the stock variable.

So in the line `shop.stock[shop.index++] = stockItem;` we insert into `shop.stock` at indexed position `shop.index` the new value created in lines 72 and 73 `stockItem` and while doing this incrementing `shop.index` by one by appending the `++` in the line of code.

stock csv file

stock.csv

```

Coke Can, 1.10, 100
Bread, 0.7, 30
Spaghetti, 1.20, 100
Tomato Sauce, 0.80, 100
Big Bags, 2.50, 4

```

Week 6 - Object Oriented Programming

1. Goals of this Session

2. Object-Oriented

- What is it?
- Examples of OOP
- Contrasted with Procedural
- Message Passing
- Impurity in OOP
- Inheritance
- Polymorphism
- Interface
- Composition
- OOP Languages

Goals of this Session

- To understand....
 - What is Object Oriented programming?
 - How is it different?
 - How does OOP achieve abstraction, isolation, and reusability?
 - The basics of the Java programming language
 - Difference from Python
 - How to write an OOP Program in Java

Paradigms I

Recall

- The term **programming paradigm** is the style or way of **thinking about and approaching problems**.
- The chosen paradigm affects how the code is **written and structured**.
- It can heavily influence how **one thinks** about the problem being solved

Object-Oriented

Object-Oriented I

- Objects are representation entities e.g. Lists, Animals etc.
- An object has both state and functionality
- The class of an object can be thought of as it's template
 - Can specify what sort of states the object can have
 - What functionality the object can perform
- For example a Person is a class of Object, and "Dominic" is an instance of that class
 - State could include name, age, occupation, gender etc.
 - Each person will vary in these states

Object-Oriented II

- Object-Oriented programming builds up libraries of reusable Objects(code)
- Some OOP languages are “pure”, everything in the language is an object
 - Ruby is a pure OOP language
 - One of it's design goals was to have “everything as an object” and to be more OOP than python
 - Though since 2.2 python has increased it's purity
<http://www.python.org/download/releases/2.2/descrintro/>
 - Java and C++ are impure OOP languages
 - As “primitive” data types are not objects in those languages

Object-Oriented III

Listing 1: Person Class in Java

```
public final class Person {
    private final String name;
    private final int age;

    public Person(String name, int age) {
        this.name = name;
        this.age = age;
    }
    public String toString() {
        return name + " " + info;
    }
    public static void main(String[] args) {
        Person a = new Person("Alice", 12);
        Person b = new Person("John", 34);
    }
}
```

Object-Oriented IV

Listing 2: Person Class in Ruby

```
class Person
    def initialize(name, age)
        @name = name
        @age = age
    end

    def name
        # labelname is only in scope within the name
        method
        labelname = "Fname:"
        return labelname + @name
    end
end
```

Object-Oriented V

- Different languages, same paradigm
- We see some syntactic differences
- Ruby is dynamically typed
- Java is strongly typed

- Java is more verbose
- The first method shown in each is a special one
 - Referred to commonly as the constructor
 - Creates new instances of objects

Object-Oriented VI

Listing 3: C Example of representing a Person

```
#include <stdio.h>
struct person
{
    int age;
    float weight;
};
int main()
{
    struct person *personPtr, person1;
    personPtr = &person1;
    printf("Enter age: ");
    scanf("%d", &personPtr->age);
    printf("Enter weight: ");
    scanf("%f", &personPtr->weight);
    printf("Age: %d\n", personPtr->age);
    return 0;
}
```

Object-Oriented VII

- A struct is a grouping of variables under a single name
- It is a data-type itself, variables can be declared of it's type
- A struct has state, but not functionality
- Modifications to the state of a struct would be done by methods outside of the struct
- This is a major difference when the complexity of the programs grow.

Object-Oriented VIII

Message Passing

- Message passing is the means by which objects communicate with each other
- Most typically realised as method calls
 - written before runtime
 - but this is not always the case, some languages have more flexibility
- The format is typically:

```
receiver_object.method_name(argument1, argument2, ...)
```

- This can be understand as we are send a message to the receiver object to perform method name with our given input.

Object-Oriented IX

Message Passing

- For Example:

```
math_solver.add(12, 30)
```

- We shall discuss in future cases where the object need not explicitly define the exact message handler ahead of time.

Object-Oriented X

Java: Impure

- In Java Primitives are not objects.
 - This includes the data-types: int, char, float, and double.
- This was done for efficiency purposes.
- What is the consequence?
 - We cannot pass them messages, we cannot invoke a method on primitives
 1. toString()
- The above would not be valid Java, however in Ruby
 1. to_s()
- Is perfectly valid as "1" is an object.
- This is arguable nicer for the programmer as it brings consistency to the language

Object-Oriented XI

Java: Impure

- This impurity was "dealt with" somewhat with the introduction of object wrappers for the primitives
 - Such as "Double" which is an object version of "double".
 - When Java needs to treat them as objects "auto-boxing" is performed to convert them
- Such wrappers are a special kind of object, they are **immutable objects**
 - When it has a value, the value cannot be changed.
 - Another example would be the **String** class in Java
- Immutability is sometimes a very useful property for certain objects

Object-Oriented XII

Inheritance

- Inheritance is a relation between two classes.
- Superclass is inherited from
- Subclass is the inheritor, it gets the properties of the superclass
- Inheritance promotes reusability

```
class Mammal
  def breathe
    puts "inhale and exhale"
  end
end

class Lion < Mammal
  def speak
```

```
puts "Roar!!!"  
end  
end
```

Object-Oriented XIII

- Many OOP languages will allow only single inheritance, where a sub-class inherits state and functionality from only one parent class
 - There are cases where multiple inheritance is supported through mixins
 - Also it is possible for an object to take on additional roles by implementing an interface or through "ducktyping"

Object-Oriented XIV

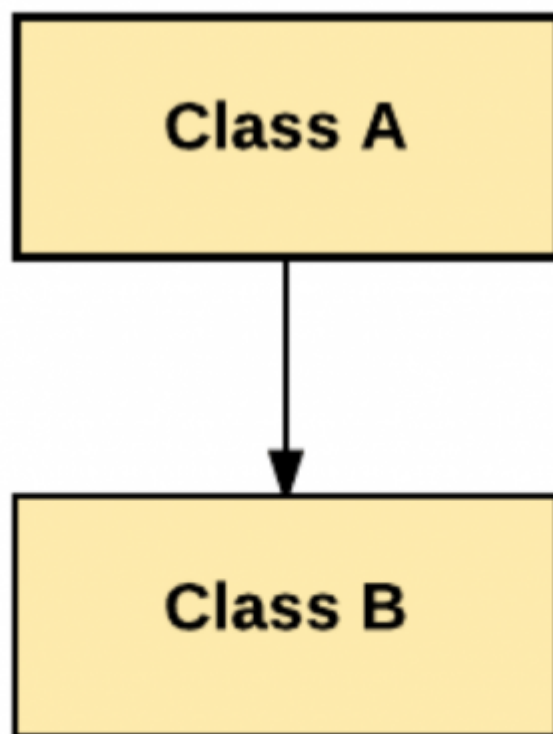


Figure: Single Inheritance

Object-Oriented XV

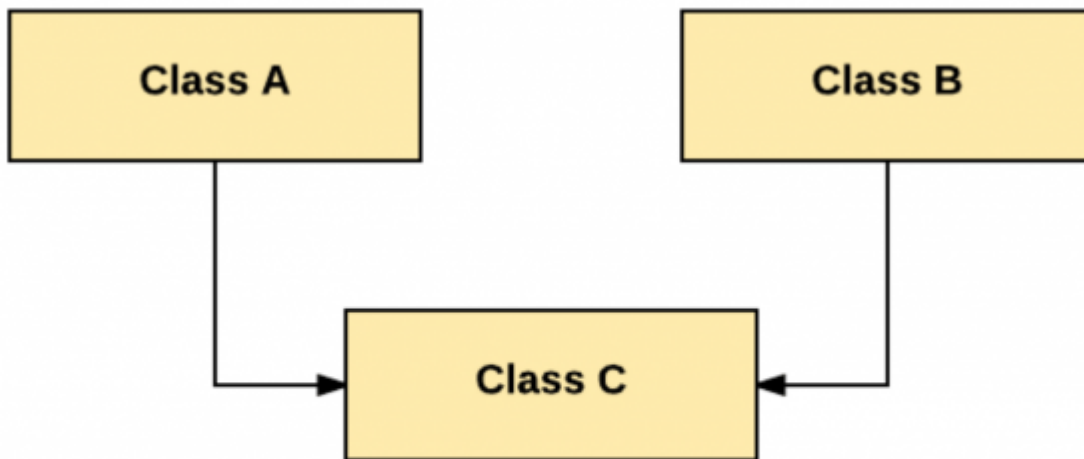


Figure: Multiple Inheritance

Object-Oriented XVI

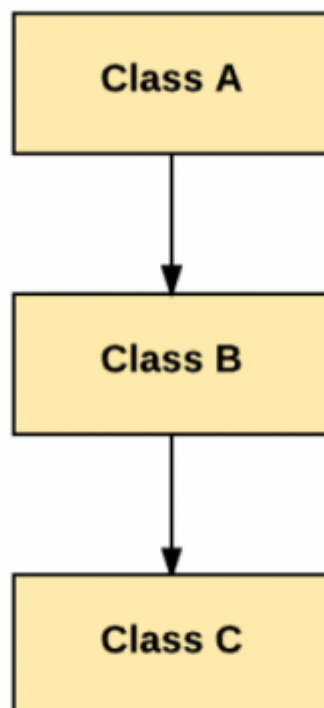


Figure: Multi-level Inheritance

- Class C inherits from B and it gets what B inherited from A
- In Ruby and Java (many others) all objects **implicitly** inherit from some base type.
 - In Java this is the class **Object**

Object-Oriented XVII

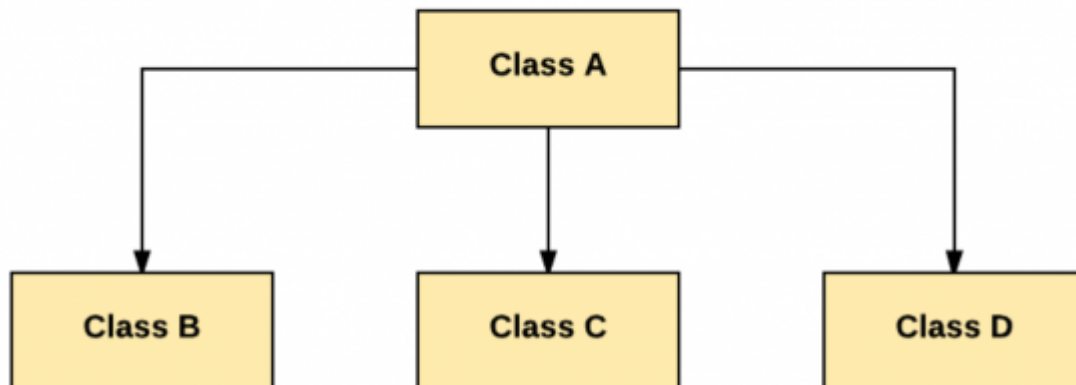


Figure: Hierarchical Inheritance

Object-Oriented XVIII

- The hierarchy is like what we had with the Mammal class

```
class Mammal
  def breathe
    puts "inhale and exhale"
  end
end

class Lion < Mammal
  .....
end

class Monkey < Mammal
  .....
end
```

- Both the Lion and the Monkey are Mammal and they both inherit from the Mammal class.

Object-Oriented XIX

- “Poly” means “many”
- Polymorphism is the ability of an object to take on many forms.
- The most common use of polymorphism in OOP occurs when a parent class reference is used to refer to a child class object.
- For example a Monkey is a Mammal so when a reference is needed to a Mammal any Monkey can be substituted in.
- If a Lion was explicitly required then only it’s sub-types could be substituted.
- It is a very important concept and we will discuss it further we we take a deeper look at the Java language

Object-Oriented X

Interface

“an interface is a shared boundary across which two or more separate components of a computer system exchange information”

- Your mouse is an interface to the computer
- It moves the pointer around the screen
- But the same can be achieved with a track pad, or some kind of eye tracker etc.
- The point is the machine doesn't care what is moving the pointer as long as the correct signals are sent from the input device (mouse, trackpad) to control the machine (OS).
- Developers regularly use Application Programming Interfaces (API) to communicate with webservices such as Twitter, Facebook, TVMaze, Weather etc.

Object-Oriented XXI

- A class which implements an interface does not gain any state from the interface, it merely takes on the requirement to implement the “contract” of the interface. It must do (or delegate) that which the interface promises to it's users.
- It is possible for an object to inherit from a parent and implement a separate interface at the same time.
- We will see examples of this when we look at Java and other languages.

Object-Oriented XXII

- An object can contain another object as an instance variable
 - Known as Object Composition
 - For example An Employee Object may have an Address object to represent their address
 - This stops the Employee class from being too complex as the Address class can deal with maintaining the address information and providing suitable methods for modifying.
- Object composition is used to represent “has-a” relationships
 - Every employee has an address
 - Every Student has many classes (So a Student object may have an Array of Module objects)

Object-Oriented XXIII

- OOP Languages
 - Python
 - Java
 - Ruby
 - PHP
 - C#
 - Objective C
 - Go
 - and many more!

Sources

<https://www.computerhope.com/jargon/i/imp-programming.htm>

[https://en.wikipedia.org/wiki/Abstraction_\(computer_science\)](https://en.wikipedia.org/wiki/Abstraction_(computer_science))

Java

1. Goals of this Session
2. 2 The Java Language
 1. Hello World in Java
 2. Inheritance in Java
 3. OOP Example in Java
3. 3 Comparison with Python
4. 4 Java Virtual Machine
5. 5 Sources

Goals of this Session

- To Understand...
 - The Java Programming Language
 - The Java Virtual Machine
 - How to write programs in Java
 - How Inheritance works in Java

The Java Language

Java I

“Write once, run anywhere” - Java Language Tagline

Java II

- General-purpose programming language
- Class-based and object-oriented
 - Not a pure object-oriented language, as it contains primitive types
- Intended to let application developers write once, run anywhere(WORA)
 - compiled Java code can run on all platforms that support Java without the need for recompilation.
 - Java applications are typically compiled to bytecode that can run on any Java virtual machine (JVM)
- Syntax similar to C and C++
- but it has fewer low-level facilities than either of them
 - For example Java does automatic memory management

Java III

Listing 1: Hello Java World!

```
public class HelloWorldApp {  
    public static void main(String[] args) {  
        System.out.println("Hello World!"); // Prints the string  
to the console.  
    }  
}
```

Java IV

- So much to learn from this one snippet!
- the “.java” files must be named after the public class they contain so the above code must be in a file called “HelloWorldApp.java”.
 - Don’t forget this! Common source of errors!
- Java files are compiled into “bytecode”, so when compiled this will result in “HelloWorldApp.class”
- The bytecode can be run by the JVM, we will talk in greater depth about the JVM later on.
- The keyword public denotes that a method can be called from code in other classes
- The keyword static in front of a method indicates a static method, which is associated only with the class and not with any specific instance of that class
 - Most methods we write will be instance methods and we will see the difference later on.

Java V

- The keyword void indicates that the main method does not return any value to the caller. If a Java program is to exit with an error code, it must call System.exit() explicitly.
 - This is quite similar to the main method in C, and there are many commonalities between C and Java syntactically.
 - Like in C the main method is the entry point into the program, though it may not be the first thing to execute.
- The main method accepts an array of strings as arguments to the program
 - this can be used to capture command line flags and other user input
- Printing is part of a Java standard library
 - The class System has a static variable “out” which represents the output stream, and you invoke the method println() on it to print your desired message to the screen
 - This is an OOP version of the printf function we seen in C.

Java VI

- Inheritance represents an “is-a” relationship between two classes for example all students are humans
 - so it makes sense to model students as a sub class of human
 - A student will have everything a human has but they will have some specific state of their own such as their grades!
- In Java the parent class is termed super class and the inherited class is the sub class
 - The keyword “extends” is used by the sub class to inherit the features of super class
 - Inheritance is important since it leads to reusability of code

```
class subClass extends superClass
{
    //methods and fields
}
```

Java VII

Listing 2: Person Object in Java

```
public class Person {
    private int age;
    private String name;

    public Person(String name, int age){
        this.name = name;
        this.age = age;
    }

    public void setAge(int age){
```

```

    if (!(age <= 0 || age >= 110)){
        this.age = age;
    }
}

```

Example I

```

public class Person {
    private int age;
    private String name;

    public Person(String name, int age){
        this.name = name;
        this.age = age;
    }

    public String toString(){
        return "Name:" + this.name + " Age: " + this.age;
    }

    public static void main(String[] args) {
        Person a = new Person("John", 23);
        Person b = new Person("Paul", 51);
        System.out.println(a);
        System.out.println(b);
    }
}

```

Java IX

How to run a java file on a mac in terminal?

Compiling and Running

```

$ javac Person.java
$ java Person

```

output:

```
# Name:John Age: 23
```

```
# Name:Paul Age: 51
```

- When the variables are private they cannot be accessed by callers
 - Modify the code to see what happens if you try to call any of the instance variables (Age and Name)
- We have access control on those variables and there is a method to modify the state of age
 - But it has custom logic so we cannot enter a silly value like "-1" for an age
 - OOP makes such "encapsulation" very easy.
- All objects in Java extend from Object, and from there we inherit some methods
 - toString is one! but why did I write it then?
 - We can override to provide our own implementation

Java X

Example II

Person.java

```
public class Person {
    private String name;
    private int age;

    public Person(String n, int a){
        this.name = n;
        this.age = a;
    }

    public String toString(){
        return "Name:" + this.name + " Age: " + this.age;
    }

    public void setAge(int n){
        if (n < 0){
            // this line is a comment, we want to finish method and not modify the age
            return;
        }
        this.age = n;
    }
}
```

PersonAppRunner.java

```
public class PersonAppRunner{

    public static void main(String[] args) {
        Person a = new Person("John", 23);
        Person b = new Person("Paul", 51);
        System.out.println(a);
        //a.age = -1;
        a.setAge(40);
        System.out.println(a);
        System.out.println(b);
    }
}
```

Student.java

```
//inheritance example
public class Student extends Person{

    private String[] classes;

    public Student(String n, int a, String[] c){
        super(n, a);
        this.classes = c;
    }

    public String toString(){
        String repr = super.toString() + "\nCLASSES: \n";
        for(int i=0; i<classes.length; i++){
            repr += classes[i] + "\n";
        }
        return repr;
    }

    public static void main(String[] args){
        String[] classes = new String[] {"Introduction to Maths", "Management for Computing", "Programming 1"};
        Student s = new Student("Pramod", 58, classes);
        s.setAge(59);
        System.out.println(s);
    }
}
```

}

Java XI

- A student “is-a” Person
- So a Student has a name and age like a Person
 - We pass these up to the superclass (Person) and set up the new instance variable ourselves
- What will happen if we try to print out the student?
 - Lets Try!

Java XII

Paul is 25

* It looks like the student prints out just like a Person as it calls the superclass toString method

- Let’s modify it

```
@Override
public String toString(){
    String val = super.toString() + "\nTaking:\n";
    for(int i = 0; i<classes.length; i++){
        val += classes[i] + "\n";
    }
    return val;
}
```

- We used the superclass method and added to it to print out the students classes
- Now the toString() is better suited

Java XIII

- but did we ever actually call toString?
 - Doesn’t look like it in the code right?
 - println method automatically calls toString()

Java XIV

- We were using an array in the Student class
- This is much like you would be used to in Python
- You can only add items of the same type
 - actually it is okay as long as they have a “is-a” relationship

Comparison with Python

Python OOP I

person.py

```
class Person:
```



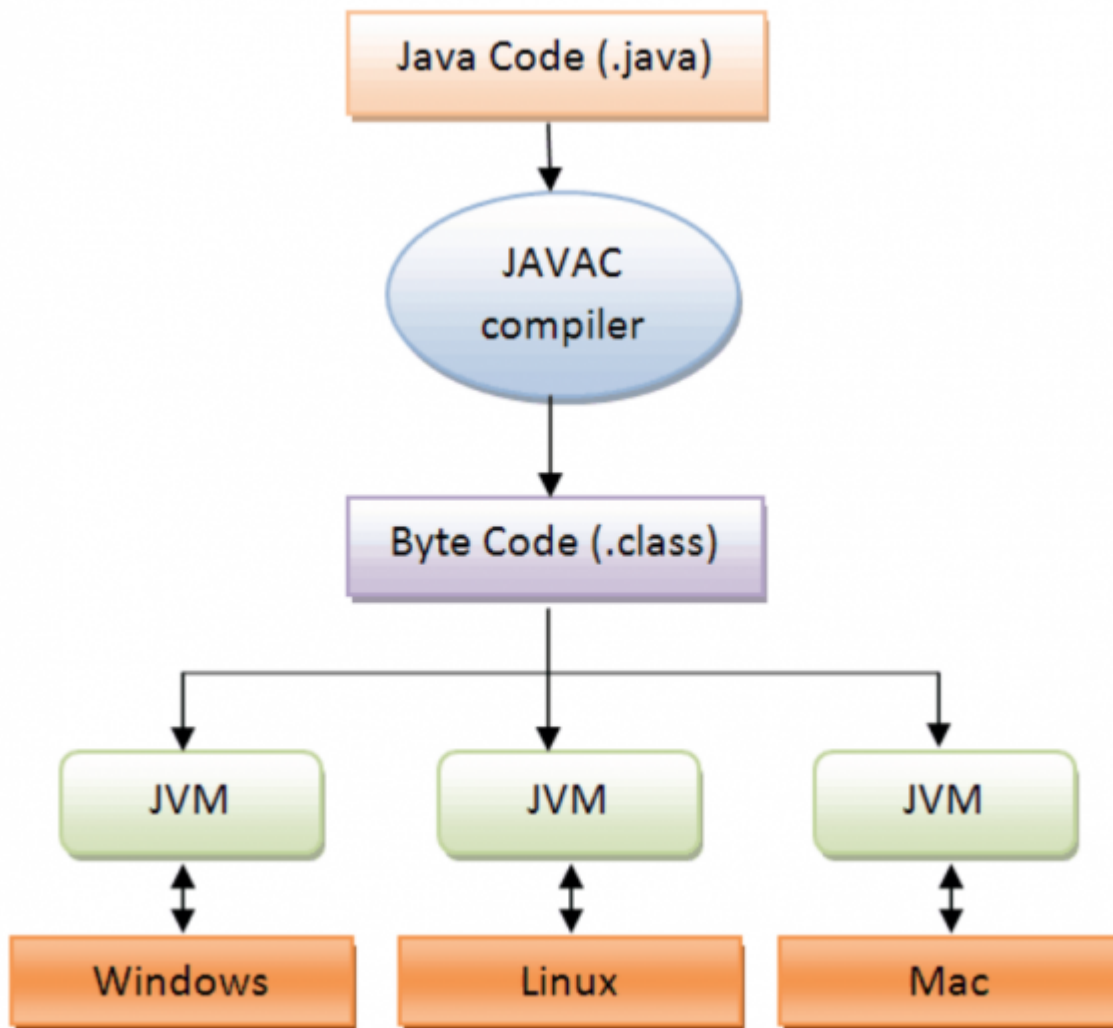
```
def __init__(self, name, age):  
    self.name = name  
    self.age = age  
  
p1 = Person("John", 36)  
  
print(p1.name)  
print(p1.age)
```

Python OOP II

- Java is compiled, python is interpreted
- Java is more verbose than Python
- They both support OOP
- They have different syntax
- Java is statically typed, Python is dynamically typed
- Java is more rigid on structure, Python more flexible

Java Virtual Machine

JVM I



JVM II

- You write the code in Java
- The Java compiler produces bytecode
- The byte code is executed by the JVM
- Therefore Java code can run on any machine which supports the JVM
 - The same code can run on any OS supported by JVM
- This is a form of Abstraction
 - The JVM hides the differences between for example Windows, Linux, and MacOS.
 - With some caveats this works really well
- Java is the language in which most Android applications are written

Sources

<https://www.computerhope.com/jargon/i/imp-programming.htm> [https://en.wikipedia.org/wiki/Abstraction_\(computer_science\)](https://en.wikipedia.org/wiki/Abstraction_(computer_science))
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