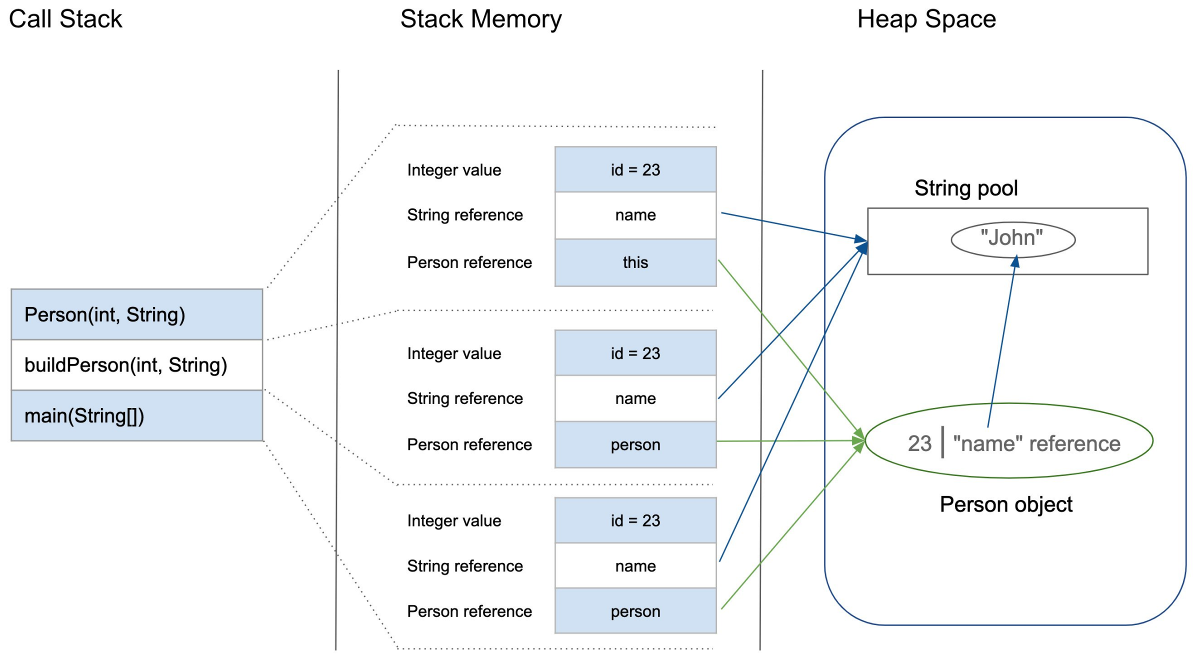
R and C/C++ notes for exam on 23^rd^ of May

C/C++

1. I/O device
    - I/O device is the device that transfers data to or from a computer
    - printers, hard disks, keyboards, and mouses
2. von Neumann architecture
    - A processing unit with both an arithmetic logic unit and processor registers
    - A control unit that includes an instruction register and a program counter
    - Memory that stores data and instructions
    - External mass storage
    - Input and output mechanisms
3. Low-Level language
    - is a programming language that provides little or no abstraction from a computer's instruction set architecture—commands or functions in the language map that are structurally similar to processor's instructions
    - Machine code, Assembly language...
4. high-level language
    - is a programming language with strong abstraction from the details of the computer
    - C/C++, python, R, MATLAB...
5. stack memory diagram



6. `malloc` and `free`
    - `malloc` **allocates** ==heap memory== for your program
    - `free` **releases** the ==heap memory== you just allocated
7. pointers

- A pointer is a variable whose value is the **address** of another variable, i.e., direct address of the memory location
- pointers are the variables that are denoted `variable_type *variable_name`, that will set this variable to an unique address
- `%p` can be writen in a print statement, it will let computer know that this variable will be print out as printer form

8. PP (Procedure Programming)
   - is a programming paradigm that uses a linear or top-down approach. It relies on procedures or subroutines to perform computations
   - PP divides your program into subtasks and you write procedures for each subtask
9. OOP (Object Oriented Programming)
   - is a programming paradigm based on the concept of **"objects"**, which can contain data and code
   - data in the form of ==fields== (often known as attributes or properties)
   - and code, in the form of procedures (AKA ==methods==).
   - OOP divides your program into objects which contains methods and fields
10. R programming
    - R is a high-level **tatistical programming language**
    - R is very effcient at vectors and matrices operations, large datasets processing and data visualization

R programming

1. datatype
   - R have 5 datatypes, they are `intager`, `numerical (double)`, `characters`, `logical` and `complex`. Logical is `TRUE` or `FALSE`
   - to check the datatype, enter `typeof(variable_name)`
2. arithmetic
   - modular `num1%%num2`, intager division `num1%/%num2` or `num1/num2` and exponentiation `num1^num2`
3. functions
   - to write your own function, enter `function_name = function(argument1, argument2){#code here}`
   - to return a variable, enter `return(variable_name)`
4. vectors
   - vectors can be writen as `c()` in R, `vector1 = c(1, 2, 3, 4)`
5. indexing vectors
   - the indexing of a vector or array is ==start from 1 not 0==.
   - if the indexing of a vector is outside of the vector length, it will display `NA` as **not a number**
   - the negative indexing `-number` is the vector elements except the `number`th elements in a vector
   - to delete some elements, enter `c[c(-a, -b)]` where a and b are the indexing of the vector that you want to delete
6. smybols
   - `num1:num2` symbol is the same as the `for (int i=num1; i<num2; i++)` in C and `in range(num1, num2)` in Python

- to get the length of the vector or array, enter `length(variable_name)`

7. matrix
    - to set the variables in a matrix, enter `matrix(vector, nrow)`
    - to get the dimentions of the matrix, enter `dim(matrix_name)`, `dim(matrix_name)[1]` is the number of rows and `dim(amtrix_name)[2]` is the number of columns
    - indexing elements of matrix, `amrix_name[i, j]`, for i = nrow and j = ncol
    - to access row_{i} of matrix by using `matrix_name[i,]` and col_{j} of matrix by using `matrix_name[,j]`
8. `cbind` and `rbind`
    - `cbind(a, b)` can combined a and b at column side, `rbind(a, b)` can combined a and b at row side
    - to delete the rows or columns of matrix, enter `matrix[-a,]` or `matrix[,-b]` where a is the row indexing of the matrix and b is the column indexing of the matrix
9. `apply`
    - function `apply` can apply a function that are builtin functions i.e. mean, sd or your own functions for better calculation
10. graphs 101
    - `plot(a, b, type="n", xlab="x", ylab="y")` can plot a blank/empty graph that are set as range a x-axis and b y-axis with x-label x and y-label y
    - `points(a, b, col="<color>")` can plot the points for 1 `a` value and 1 `b` value for their x and y coordinates and `col` is the color ot plot with
11. logical operators
    - `&&` is the same as `and` in Python
    - `||` is the same as `or` in Python
    - these operators are normally used in if statements
12. list
    - to generate lists, enter `list(a, b)` to run `[[1]]` and `[[2]]`, if you want to note the names, enter `list(name1=a, name2=b)`, it will display `$name1` and `$name2`
    - if you want to run the spceific name for future variable setting, enter `variable_name = list_name$name1/name2`
    - to add an element to list, enter `list_name$name3 = variable`
    - to delete an element from list, enter `list_name$name_number = NULL`
13. dataframe
    - to create a dataframe, enter `data.frame(a, b, c, ...)` or simply using `list(a, b, c, ...)`
14. summary
    - to summary the dataframe, enter `summary(list)` or `summary(dataframe)`
    - indexing dataframe, is the same as the matrix indexing, `dataframe[i, j]`
15. OOP in R
    - to create your own class, enter `class(class_name)`, class_name have to be `list()` or `data.frame()`
    - make sure to create class with some sense, i.e., `cube = list(height=70, width=150, depth=50)`, `class(cube) = "student"`. it doesn't work on progrmming but it doesn't make any sense because the class of cube is student
    - it is very dangrous to change class for the variables of builtin classes i.e., `dataset = data.frame(1:4, 2:5)`, `class(dataset)` should be display `data.frame` but if you

change the class of the dataset `class(dataset) = "student"`, then it is not going to work

16. polymorphism
    - polymorphism in computer science means **a single interface for different data type**
    - means same functions will behave differently for objects from different classes
17. R help
    - to get help from R programming, simply enter `help(function)` or `?function` to see more further details

to download the R programming book, press download button

C/C++

memory in C

- stack memory

```
int i = 10;
int arr[] = {1, 3, 5, 7, 9};
float price = 10.5;
```

you don't have to free the memory because stack memeory only store temporarily

- heap memory

```
int num;
int *number = malloc(num*sizeof(int)); // set them that they cannot be changed or overlapped with larger memeory size
free(number) //don't forget to free the memory after finish using this variable
```

you have to free the heap memory at the end of script

euclidean distance

$$dist(a, b) = \sqrt{\sum_{k=1}^{K}\left (a_{k} - b_{k} \right)^{2}}$$ code in R

```
n = 100
for (i in 1:n){
    for (j in 1:n){
        D[i,j] = sqrt(sum(A[i,]-B[j,])^2)
    }
}
```

code in C

```
#include <math.h>
void edist(A, B, C){
    for (int i=0; i<A[i,]; i++){
        for (int j=0; j<B[i,], j++){
            C[i, j] = 0;
            for (int k=0; k<A[,j]; k++){
                C[i, j] += (A[i, k]-B[j, k])*(A[i, k]-B[j, k]);
            }
            D[i, j] = sqrt(C[i, j]);
        }
    }
}
```

calculate length of an array in C

```
#include <math.h>
#include <stdio.h>
void cal_length(double a[], int len){
    double s = 0;
    for (int i=0; i<len; i++){
        s += a[i]*a[i];
    }
    sum = sqrt(s);
    return sum;
}
```

pointer in C

```
#include <stdio.h>
int main(){
    int a = 1; int *pa = &a;
    printf("%p", pa);
    //will display 0000000a6f3ffa0c
}

int main(){
    int a = 1; int *pa = &a;
    printf("%d", *pa);
    //will display 1
}
```

`a[k]` is equivalent to `*(a+k)` is equivalent to `pa[k]` to return a pointer, `return pa;` is fine `calloc` is to allocate and clear heap memory

```
//malloc
int *pvariable_name = malloc(num * sizeof(int));
```

```
//calloc
int *pavriable_name = calloc(num, sizeof(int));
```

`realloc` is to reallocate heap memory

```
int pnew_variable_name = realloc(variable_name, new_num*sizeof(int));
//for reallocate a new size
```

==don;t forget to **free** the heap memory!==

find the minimum in C

```
#include <stdio.h>
int find_minimum(int len, double array[len]){
    double min = ind_max;
    int ind = -1;
    for (int i=0; i<len; i++){
        if (array[i]<min){
            min = array[i];
            ind = i;
        }
    }
    return i;
}
```

find three top numbers in C

```
#include <stdio.h>
//set top[3] to three very big numbers i.e., top[3] = {999, 999, 999};
int find_top3(int len, double array[len], double top[3]){
    int top_index = find_minmum(len, array);
    for (int i=0; i<2; i++){
        for (int j=0; j<3; j++){
            top[j] = array[top_index];
        }
        array[top_index] = ind_max;
    }
    return array;
}
```

swap two numbers in C

```
#include <stdio.h>
int swap(int *a, int *b){
    int tmp = 0;
    if (a>b){
        tmp = *b;
        *b = *a;
        *a = tmp;
    }
}
```

OOP (Object Oriented Programming) in C++ and structure in C

OOP in C++

```
class __class__{
    int vars1, vars2, vars3;
public:
    void function_name1(vars1){# code here}
    void function_name2(vars2){# code here}
    void function_name3(vars3){# code here}
};

int main(){
    __class__ variable;
    variable.function_anme1(vars1);
    variable.function_name2(vars2);
    variable.function_anme3(vars3);
}
```

structure in C

```
struct __class__{
    int variable1;
    int variable2;
    int variable3;
};

typedef struct __class__ class;
```

R programming

start and end time in R

```
start = Sys.time()
# code block here
end = Sys.time()
```

```
final_time = end - start
cat("this block of code takes ",final_time,"s")
```

levels of vectorization

```
#level 1
dist1 = function(a, b){
    c = matrix(0, nrow=dim(a)[1], ncol=dim(b)[2])
    for (i in 1:dim(1)[1]){
        for (j in 1:dim(b)[2]){
            for (k in 1:dim(a)[2]){
                c[i, j] = c[i, j]+a[i, k]*b[k, j]
            }
        }
    }
    return(c)
}

#level 2
dist2 = function(a, b){
    c = matrix(0, nrow=dim(a)[1], ncol=dim(b)[2])
    for (i in 1:dim(a)[1]){
        for (j in 1:dim(b)[2]){
            c[i, j] = a[i,]*b[,j]
        }
    }
    return(c)
}

#level 3
dist3 = function(a, b){
    c = matrix(0, nrow=dim(a)[1], ncol=dim(b)[2])
    for (i in 1:dim(a)[1]){
        c[i,] = a[i,]%*%b
    }
    return(c)
}

#level 4
dist4 = function(a, b){
    return(sum(a-b)^2)
}
```

pair-wise distance in R

$$dist(a, b) := \left (\sum_{k}^{}\left| a_{k}-b_{k}\right|^{p} \right)^{\frac{1}{p}}$$

```
#version 1
pdist1 = function(A, B){
    D = matrix(0, nrow = dim(A)[1], ncol = dim(B)[1])
    for (i in 1:dim(A)[1]){
        for (j in 1:dim(B)[1]){
            for (k in 1:dim(A)[2]){
                D[i,j] = D[i,j]+(A[i,k]-B[j,k])^2
            }
            D[i,j] = sqrt(D[i,j])
        }
    }
    return(D)
}

#version 2
pdist2 = function(A, B){
    D = matrix(0, nrow = dim(A)[1], ncol = dim(B)[1])
    for (i in 1:dim(A)[1]){
        for (j in 1:dim(B)[1]){
            D[i, j] = sqrt(sum(A[i,]-B[j,])^2)
        }
    }
    return(D)
}
```

drawing an arrow in plot in R

```
set.seed(1)

update <- function(x,v){
    v[(x[,1] > 5 | x[,1] < -5),1] = -v[(x[,1] > 5 | x[,1] < -5),1]
    v[(x[,2] > 5 | x[,2] < -5),2] = -v[(x[,2] > 5 | x[,2] < -5),2]
    x <- x + v
    return(list(x,v))
}

x <- matrix(runif(50*2,-1,1), nrow = 50)
v <- matrix(runif(50*2,-.5,.5), nrow = 50)

while(T){
    plot(c(-5,5),c(-5,5), type = "n", xlab = "x1", ylab = "x2")
    points(x[,1], x[,2], col = 'red', lwd = 0, pch = 16)
    arrows(x[,1], x[,2], x[,1] + v[,1], x[,2] + v[,2], length = .05 , col
= "green")
    title("particle simulation. Press ESC to stop")

    xv <- update(x,v)

    print(x)
    print(v)
    x<- xv[[1]]
    v<- xv[[2]]
    Sys.sleep(.1)
}
```

`arrows` does the job for ploting an arrow into the graph, normally to show the direction of the particals, in this code, `arrows` is for showing the velocity of the ball/partical

calculating angle in R

```
angle = function(A, B){
    return(acos(v1%*%v2/dist(v1,0)/dist(v2,0))/2/pi*360)
}
```

`acos` is stand for $arccos$ in math, type `?acos` for more information

mock exam paper

print the following output in C

```
void main(){
    for (int i=0; i<9; i++){
        for (int j=0; j<i%3+1; j++){
            printf("*");
        }
        printf("\n");
    }
}
```

the final output is:

```
*
**
***
*
**
***
*
**
***
```

calculate the prime number with 2 apart in R

```
n = 100
last_prime = 2
for (i in 2:n){
    is_prime = TRUE
    for (j in 2:(i-1)){
        if (i%%j==0){
            is_prime = FALSE
        }
    }
    if (is_prime){
        if (i-last_prime==2){
            cat(paste(last_prime, ",", i))
        }
        last_prime = i
    }
}
```

to make this script run faster modify `for (i in 2:n)` to `for (i in c(2, seq(3, n, 2)))` or add `break` after `is_prime = FALSE` to breakdown if `is_prime` is ==**false**==

OOP in C++

Add three private fields in `shop_item` class: `name` stores a string, `quantity` stores a integer, `price` stores a decimal number Add public methods in `shop_item` class, so that you can set values to the fields you have just defined. Note, `quantity` and `price` must be positive Add code in main function, so that coke's name is set to `"coca cola"` , quantity is set to `100` and price is set to `1.2f`

```
class shop_item{
    char *name;
    int quantity;
    float price;
public:
    void set_name(char *name){name = n;}
    void set_quantity(int q){quantity = q;}
    void set_price(int p){price = p;}
}

int main(){
    shop_item coke;
    coke.set_name("coca cola");
    coke.set_quantity(100);
    coke.set_price(1.2f);
}
```