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| **Assignment** | |
| **Course Code** | CSC209A |
| **Course Name** | Design and Analysis of Algorithms |
| **Programme** | B.Tech |
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| **Semester/Year** | 04/2017 |
| **Course Leader(s)** | Pallavi R Kumar |



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| Declaration Sheet | | | | | | | | |
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| Course Title | Design and Analysis of Algorithms | | | | | | | |
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| Course Leader | Pallavi R Kumar | | | | | | | |
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| Signature of the Course Leader and date | | | | | Signature of the Reviewer and date | | | |
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# Contents

[Declaration Sheet ii](#_Toc3490579)

[Contents iii](#_Toc3490580)

[List of Figures iv](#_Toc3490581)

[1 Question 1 5](#_Toc3490582)

[1.1 Introduction to amortized analysis 5](#_Toc3490583)

[1.2 Example illustrating amortized analysis 5](#_Toc3490584)

[1.3 Conclusion 6](#_Toc3490585)

[2 Question 2 8](#_Toc3490586)

[2.1 Algorithm 8](#_Toc3490587)

[2.2 A C Program 9](#_Toc3490588)

[2.3 Analysis of Time and Space complexity 10](#_Toc3490589)

[3 Question 3 11](#_Toc3490590)

[3.1 Design of the data structure QUACK 11](#_Toc3490591)

[3.2 Algorithms for operations on stack and queue 12](#_Toc3490592)

[3.3 C functions for stack and queue operations 14](#_Toc3490593)

[Bibliography 15](#_Toc3490594)

[Appendix 16](#_Toc3490595)

[quack.c 16](#_Toc3490596)

[quack.h 18](#_Toc3490597)

[stack.c 18](#_Toc3490598)

[stack.h 20](#_Toc3490599)

[vector.c 21](#_Toc3490600)

[vector.h 24](#_Toc3490601)

[main.c 26](#_Toc3490602)

[debug\_helper.h 27](#_Toc3490603)

# List of Figures

**No table of figures entries found.**

# Question 1

Solution to Question No. 1 Part A

## Introduction to amortized analysis

In an *amortized analysis*, we average the time required to perform a sequence of data-structure operations over all the operations performed. With amortized analysis, we can show that the average cost of an operation is small, if we average over a sequence of operations, even though a single operation within the sequence might be expensive. Amortized analysis differs from average-case analysis in that probability is not involved; an amortized *analysis guarantees the average performance of each operation in the worst case*.

Some of the most commonly used techniques in Amortized analysis are:

*Aggregate Analysis*: In which we determine an upper bound on the total cost of a sequence of n operations.

*Accounting Method*: In which we determine an amortized cost of each operation

*Potential Method*: This is like the accounting method; this method maintains the credit as the “potential energy” of the data structure as a whole instead of associating the credit with individual objects within the data structure.

## Example illustrating amortized analysis

In the consecutive example we will be using STACK operations to illustrate one of the techniques used in amortized analysis which is ***Potential Method***.

PUSH(S, x) pushed object x onto stack S.

POP(S) pops the top of stack S and returns the popped object. Calling POP on an empty stack generates an error.

MULTIPOP(S, k)

1. while not STACK-EMPTY(S) and k > 0
2. POP(S)
3. k = k – 1

The potential method works as follows. We perform n operations on the initial Data Structure . For each we let be the actual cost of the ith operation and be the result after the ith operation to the Data Structure . A ***potential function*** maps each data structure to real number , which is the ***potential*** associated with data structure . The ***amortized cost*** of the ith operation w.r.t the potential function is defined by

The amortized cost of the n operations is,

We define the potential function on a stack to be the number of objects in the stack. For the empty stack, we have . The stack after the ith operation has nonnegative potential thus,

Let us now compute the amortized cost of various stack operations. If the ith operation on the stack containing s objects is a PUSH operation, then the potential difference is

The amortized cost of this PUSH operation is

Suppose the ith operation on the stack is MULTIPOP(S, k) which causes k’=min(k, s) objects to be popped off the stack. The actual cost of the operation is k’, the potential difference is

Thus, the amortized cost of the MULTIPOP operation is

The amortized cost of each of the three operations is , and thus the total amortized cost of a sequence of n operations is .

**(CLRS, Introduction to Algorithms, pp 451-459, Amortized Analysis)**

## Conclusion

As the debate goes by “Pessimistic approach in Amortized Analysis”, The worst case running time might give an overly pessimistic analysis for algorithms performing a sequence of operations on data structures. In amortized analysis, we average the time required to perform a sequence of operations over the number of operations performed.

Amortized analysis generally applies to a method that consists of a sequence of operations, where the vast majority of the operations are cheap, but some of the operations are expensive. If we can show that the expensive operations are particularly rare we can "charge them" to the cheap operations, and only bound the cheap operations.

# Question 2

Solution to Question 1 Part B

## Algorithm

To solve this problem we use Prim’s Algorithm, the basic idea behind being that the minimum spanning tree must be created such that all the vertices be connected with the minimum weight edge.

**Prim’s Algorithm**

1. Create a mst\_set that keeps track of vertices already included in MST
2. Assign a key value to all vertices in the input graph. Initialize all key values as INFINITE. Assign key value as 0 for the first vertex so that it is picked first
3. while mst\_set doesn’t include all vertices
   1. pick a vertex u which is not there in mst\_set and has minimum key value
   2. include u to mst\_set
   3. update key value of all adjacent vertices of u. To update the key values, iterate through all adjacent vertices. For every adjacent vertex v, if weight of edge u-v is less than the previous key value of v, update the key value as weight of u-v.

The idea of using key values is to pick the minimum weight edge from cut. The key values are used only for vertices which are not yet included in MST, the key value for these vertices indicate the minimum weight edges connecting them to the set of vertices included in MST.

The Original Algorithm given by RC Prim

1. T =
2. U =
3. while
4. let be the lowest cost edge such that and
5. T =
6. U =

**(RC Prim, Bell System Technical Journal, 1957)**

The Algorithm used in the Program

MST-PRIM(G, w, r)

1. for each u G, V
2. u.key =
3. u. = NIL
4. r.key = 0
5. Q = G.V
6. while Q
7. u = extract-min(Q)
8. for each v G.Adj[u]
9. if v Q and w(u, v) < v.key
10. v. = u
11. v.key = w(u, v)

**(CLRS, Introduction to Algorithms)**

## A C Program

int extract\_min(int V, int \*key\_val, bool \*mst\_set) {

int min = INT\_MAX;

int min\_index = 0;

for (int v = 0 ; v < V ; v++) {

if (mst\_set[v] == false && key\_val[v] < min) {

min = key\_val[v], min\_index = v;

}

}

return min\_index;

}

void find\_cost(int V, int graph[][MAX]) {

int parent[V], key\_val[V];

bool mst\_set[V];

for (int i = 0 ; i < V ; i++) {

key\_val[i] = INT\_MAX, mst\_set[i] = false;

}

parent[0] = -1;

key\_val[0] = 0;

for (int count = 0 ; count < V - 1 ; count++) {

int u = extract\_min(V, key\_val, mst\_set);

mst\_set[u] = true;

for (int v = 0 ; v < V ; v++) {

if (graph[u][v] && mst\_set[v] == false &&

graph[u][v] < key\_val[v]) {

key\_val[v] = graph[u][v];

parent[v] = u;

}

}

}

int cost = 0;

for (int v = 1 ; v < V ; v++)

cost += graph[parent[v]][v];

printf("minimum cost to reconnect all the computers : %d\n", cost);

}

int print\_mst(int parent[], int V, int graph[][MAX]) {

printf("Edge\tWeight\n");

for (int v = 1; v < V; v++)

printf("%d - %d \t%d \n", parent[v], v, graph[v][parent[v]]);

}

## Analysis of Time and Space complexity

The outer loop(i.e. the loop to add new node to MST) runs n times and in each iteration of the loop it takes O(n) time to find the minnode and O(n) time to update the neighboring nodes of u-th node. Hence the overall complexity is O(n2). Although this can be improved by using a Priority Queue to find the min-node, using which the time complexity for searching the min-node in the heap would be . Hence the total time complexity would be with the help of binary heap which is .

When it comes to the Space Complexity, since we are storing the graph in form of an adjacency matrix, we would require a maximum of space, but if we were to consider the upper bound then the max value of edges can be that of the vertices. Hence the total space complexity would be

# Question 3

Solution to Question 2 Part B

## Design of the data structure QUACK

source **quack.h**

struct Quack {

Stack \*s1, \*s2;

void (\*push)(struct Quack\*, void\*);

void\* (\*pop)(struct Quack\*);

void\* (\*pull)(struct Quack\*);

void (\*display)(struct Quack\*, void (\*)(void\*));

};

typedef struct Quack Quack;

*/\* To Initialize the Quack Structure \*/*

Quack\* newQuack(void);

void init\_quack(Quack\*);

*/\* Quack Operations \*/*

void enqueue\_quack(Quack\*, void\*);

void\* dequeue\_quack(Quack\*);

void\* pop\_quack(Quack\*);

*/\* print utility \*/*

void print\_quack(Quack\*, void (\*)(void\*));

Basically the QUACK structure consists of two stacks s1 and s2 for storing the data, further we will elaborate on why this is so, and four functions, push to add data to the structure, pop and pull to remove data and display to print the data. The way the structure is designed, it is highly generic and can store any form of data, without any size limitations.

The data is stored in stack s1, the other stack s2 is used as a temporary place to store the data when various operations are being performed. Push and Pull operations are basically Enqueue and Dequeue operations on a Queue, hence we design the structure to perform like a queue using these two stacks. Whereas Pop is a stack pop operation from the stack.

The time complexity for the above mentioned operations are mentioned in 3.2.

## Algorithms for operations on stack and queue

**STACK-PUSH(data)**

1. top = top + 1
2. stack[top] = data

Time Complexity :

**STACK-POP()**

1. if top == -1 display “ERROR: STACK UNDERFLOW”
2. return NULL
3. data = stack[top]
4. top = top – 1
5. return data

Time Complexity :

**STACK-DISPLAY()**

1. for i = top to 0
2. display stack[i]

Time Complexity :

**ENQUEUE(data)**

1. while(!s1.isEmpty())
2. s2.push(s1.pop())
3. s1.push(data)
4. while(!s2.isEmpty())
5. s1.push(s2.pop())

Time Complexity :

**DEQUEUE()**

1. if s1.isEmpty
2. display “ERROR: QUACK is empty”
3. return NULL
4. data = s1.pop()
5. return data

Time Complexity :

**QUACK-POP()**

1. if s1.isEmpty()
2. display “ERROR: QUACK is empty”
3. return NULL
4. while (!s1.isEmpty())
5. s2.push(s1.pop())
6. data = s2.pop()
7. while (!s2.isEmpty())
8. s1.push(s2.pop())
9. return data

Time Complexity :

**DISPLAY-QUACK()**

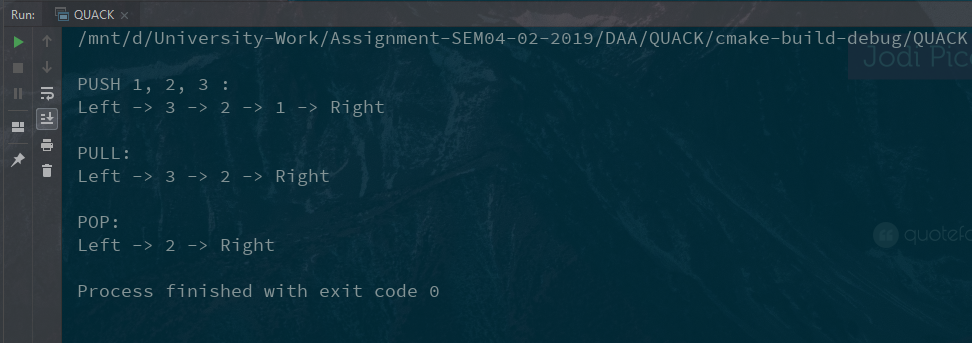
1. if s1.isEmpty()
2. display “ERROR: QUACK is empty”
3. return NULL
4. while (!s1.isEmpty())
5. s2.push(s1.pop())
6. s2.display()
7. while (!s2.isEmpty())
8. s1.push(s2.pop())

Time Complexity :

## C functions for stack and queue operations

Refer to Appendix quack.c and quack.h for C source code

OUTPUT:



# Bibliography

1. R.C. Prim. Shortest connection networks and some generalizations. Bell System Technical Journal, Volume 36, pp. 1389-1401, 1957.
2. <https://www.geeksforgeeks.org/prims-minimum-spanning-tree-mst-greedy-algo-5/>
3. CLRS, Introduction to Algorithms, third edition, 2009.
4. http://www.cs.cornell.edu/courses/cs3110/2009sp/recitations/rec21.html

# Appendix

QUACK Data Structure complete “pure C99 std” C source code

WARNING: Contains a lot of memory leaks, a lot!, Valgrind was too far fetched for such a problem + strict memory management might complicate the code.

## quack.c

*//*

*// Created by shadowleaf on 05-Mar-19.*

*//*

#include <stdlib.h>

#include "quack.h"

#include "limits.h"

*/\* Initialize the Quack Structure \*/*

Quack\* newQuack(void) {

Quack\* myquack;

*// Make sure the allocation was successful*

if ((myquack = malloc(sizeof \*myquack)) != NULL) {

init\_quack(myquack);

return myquack;

}

return NULL;

}

void init\_quack(Quack\* myquack) {

*// Assuming my quack structure can handle a huge amount*

*// of data, lol.*

myquack -> s1 = newStack(INT\_MAX);

myquack -> s2 = newStack(INT\_MAX);

*//myquack -> enqueue = enqueue\_quack;*

*//myquack -> dequeue = dequeue\_quack;*

myquack -> push = enqueue\_quack;

myquack -> pop = pop\_quack;

myquack -> pull = dequeue\_quack;

myquack -> display = print\_quack;

}

void print\_quack(Quack\* myquack, void (\*print\_one)(void\*)) {

*// Get a nice little reference, meow*

Stack\* s1 = myquack -> s1;

Stack\* s2 = myquack -> s2;

while(!(s1 -> isEmpty(s1))) {

s2 -> push(s2, s1 -> peek(s1));

s1 -> pop(s1);

}

printf("Left -> ");

s2 -> display (s2, print\_one);

printf("Right");

while(!(s2 -> isEmpty(s2))) {

s1 -> push(s1, s2 -> peek(s2));

s2 -> pop(s2);

}

}

void enqueue\_quack(Quack\* myquack, void\* data) {

*// Get a nice little reference, meow*

Stack\* s1 = myquack -> s1;

Stack\* s2 = myquack -> s2;

while(!(s1 -> isEmpty(s1))) {

s2 -> push(s2, s1 -> peek(s1));

s1 -> pop(s1);

}

s1 -> push(s1, data);

while(!(s2 -> isEmpty(s2))) {

s1 -> push(s1, s2 -> peek(s2));

s2 -> pop(s2);

}

}

void\* dequeue\_quack(Quack\* myquack) {

Stack\* s1 = myquack -> s1;

Stack\* s2 = myquack -> s2;

if (s1 -> isEmpty(s1)) {

printf("QUACK is Empty");

return NULL;

}

void\* x = s1 -> peek(s1);

s1 -> pop(s1);

return x;

}

void\* pop\_quack(Quack\* myquack) {

Stack\* s1 = myquack -> s1;

Stack\* s2 = myquack -> s2;

if (s1 -> isEmpty(s1)) {

printf("QUACK is Empty");

return NULL;

}

while(!(s1 -> isEmpty(s1))) {

s2 -> push(s2, s1 -> peek(s1));

s1 -> pop(s1);

}

void\* x = s2 -> pop(s2);

while(!(s2 -> isEmpty(s2))) {

s1 -> push(s1, s2 -> peek(s2));

s2 -> pop(s2);

}

return x;

}

## quack.h

*//*

*// Created by shadowleaf on 05-Mar-19.*

*//*

#ifndef QUACK\_QUACK\_H

#define QUACK\_QUACK\_H

#include "stack.h"

struct Quack {

Stack \*s1, \*s2;

void (\*push)(struct Quack\*, void\*);

void\* (\*pop)(struct Quack\*);

void\* (\*pull)(struct Quack\*);

void (\*display)(struct Quack\*, void (\*)(void\*));

};

typedef struct Quack Quack;

*/\* To Initialize the Quack Structure \*/*

Quack\* newQuack(void);

void init\_quack(Quack\*);

*/\* Quack Operations \*/*

void enqueue\_quack(Quack\*, void\*);

void\* dequeue\_quack(Quack\*);

void\* pop\_quack(Quack\*);

*/\* print utility \*/*

void print\_quack(Quack\*, void (\*)(void\*));

#endif *//QUACK\_QUACK\_H*

## stack.c

*//*

*// Created by shadowleaf on 05-Mar-19.*

*//*

#include "stack.h"

#include <stdio.h>

#include <stdlib.h>

#include <stdbool.h>

#include "input\_helper.h"

#include "debug\_helper.h"

Stack\* newStack(int max\_size) {

Stack\* mystack = malloc(sizeof \*mystack);

init\_stack(mystack, max\_size);

return mystack;

}

void init\_stack(Stack\* mystack, int max\_size) {

mystack -> top = -1;

mystack -> data = NULL;

mystack -> MAX = max\_size;

mystack -> push = push;

mystack -> pop = pop;

mystack -> display = display;

mystack -> peek = peek;

mystack -> isEmpty = isEmpty;

}

void push(Stack\* mystack, void\* data) {

if (mystack -> top >= mystack -> MAX) {

printf("\n\*Stack Overflow Detected !\*\n");

return;

}

*/\* This code sucks, you know it and i know it.*

*\* Move on and call me an idiot later*

*I’m sure you haven’t read this, and the teacher doesn’t know it\*/*

mystack -> data = realloc(mystack -> data, (mystack -> top + 2) \* sizeof \*(mystack -> data));

if (mystack -> data != NULL) {

(mystack -> data)[(++mystack -> top)] = data;

} else {

printf("\n\*cannot allocate memory !\*\n");

}

}

void\* pop(Stack\* mystack) {

if (mystack -> top < 0) {

printf("\n\*Stack Underflow detected !\*\n");

return NULL;

}

mystack -> top--;

*/\* Resize the data array as the elements are removed \*/*

mystack -> data = realloc(mystack -> data, (mystack -> top + 2) \* sizeof \*(mystack-> data));

return (mystack -> data)[(mystack -> top)+1];

}

void display(Stack\* mystack) {

for (int i = mystack -> top ; i >= 0 ; i--) {

printf("%s ", \*(char\*\*)(mystack->data + i));

}

}

void\* peek(Stack\* mystack) {

return (mystack -> data)[mystack -> top];

}

bool isEmpty(Stack\* mystack) {

if (mystack -> top < 0)

return true;

return false;

}

## stack.h

*//*

*// Created by shadowleaf on 05-Mar-19.*

*//*

#ifndef QUACK\_STACK\_H

#define QUACK\_STACK\_H

#include <stdio.h>

#include <stdbool.h>

#include "input\_helper.h"

*/\* Why not use a Vector and delete first element, anyways*

*\* it adds elements to the end of the list, using Vectors method*

*\* there will be no size limitations \*/*

struct Stack {

int top;

void \*\*data;

int MAX;

void (\*push)(struct Stack\*, void\*);

void\* (\*pop)(struct Stack\*);

void (\*display)(struct Stack\*);

void\* (\*peek)(struct Stack\*);

bool (\*isEmpty)(struct Stack\*);

};

typedef struct Stack Stack;

*/\* Initialize the Stack \*/*

Stack\* newStack(int);

void init\_stack(Stack\*, int);

*/\* Stack Operations \*/*

void push(Stack\*, void \*);

void\* pop(Stack\*);

void display(Stack\*);

void\* peek(Stack\*);

bool isEmpty(Stack\*);

#endif *//QUACK\_STACK\_H*

## vector.c

#include <stdio.h>

#include <string.h>

#include <stdarg.h>

#include "vector.h"

#include "debug\_helper.h"

typedef int (\*Comparator)(const void\*, const void\*);

Vector\* newVector(void (\*print\_util)(Vector\*),

int (\*compare)(const void\*, const void\*),

int (\*compare\_r)(const void\*, const void\*)) {

Vector\* myVector = malloc(sizeof \*myVector);

init(myVector, print\_util, compare, compare\_r);

return myVector;

}

Vector\* newMinimalVector(Comparator comparator,

void (\*printOne)(void\*)) {

Vector\* myVector = malloc(sizeof \*myVector);

myVector -> length = 0;

myVector -> data = NULL;

myVector -> get = get;

myVector -> add = add;

myVector -> remove = del;

myVector -> print = print\_vector;

myVector -> printOne = printOne;

myVector -> search = linear\_search\_vector;

myVector -> comparator = comparator;

return myVector;

}

Vector\* \_newMinimalVectorWithArgs(Comparator comparator, void (\*printOne)(void\*), size\_t argc, ...) {

Vector\* thisVector = newMinimalVector(comparator, printOne);

va\_list valist;

*// va\_start takes the valist and the last parameter before the "..."*

va\_start(valist, argc);

for (int i = 0 ; i < argc ; i++) {

*// printf("\*%d\*", va\_arg(valist, int));*

thisVector -> add (thisVector, va\_arg(valist, void\*));

}

va\_end(valist);

return thisVector;

}

void init(Vector \*list,

void (\*print\_util)(Vector\*),

int (\*compare)(const void\*, const void\*),

int (\*compare\_r)(const void\*, const void\*)) {

list -> get = get;

list -> length = 0;

list -> data = NULL;

list -> print = print\_util;

list -> add = add;

list -> remove = del;

list -> comparator = compare;

list -> comparator\_r = compare\_r;

list -> sort = sort;

list -> search = linear\_search\_vector;

}

void\* get(Vector \*list, int loc) {

return (list -> data)[loc];

}

void add(Vector \*list, void \* DATA) {

list -> data = realloc(list -> data, sizeof \*(list -> data) \* (list -> length + 1));

(list -> data)[(list -> length)] = DATA;

list -> length++;

}

void del(Vector \*list, int index) {

for (int i = index ; i < list -> length - 1 ; i++) {

(list -> data)[i] = (list -> data)[i+1];

}

list -> length --;

list -> data = realloc(list -> data, sizeof \*(list -> data) \* (list -> length));

}

void sort(Vector \*list, bool descending) {

if (descending)

qsort(list -> data, (size\_t)list -> length,

sizeof \*(list -> data),

list -> comparator\_r);

else

qsort(list -> data, (size\_t)list -> length,

sizeof \*(list -> data),

list -> comparator);

}

*/\* Searching Algorithms \*/*

int linear\_search\_vector(Vector\* list, void\* param, int (\*comparator)(const void\*, const void\*)) {

for (int i = 0 ; i < list -> length ; i++) {

if (comparator(list -> data[i], param) == 0) {

list->printOne(list->data[i]);

return i;

}

}

return -1;

}

*/\* Comparator Functions \*/*

int int\_compare(const void \* a1, const void \* a2) {

*// di(\*\*((const int\*\*)a1));*

if (\*\*((const int\*\*) a1) > \*\*((const int\*\*) a2)) return 1;

if (\*\*((const int\*\*) a1) < \*\*((const int\*\*) a2)) return -1;

return 0;

}

int int\_compare\_r(const void \* a1, const void \* a2) {

*// di(\*\*((const int\*\*)a1));*

if (\*\*((const int\*\*) a1) > \*\*((const int\*\*) a2)) return -1;

if (\*\*((const int\*\*) a1) < \*\*((const int\*\*) a2)) return 1;

return 0;

}

int string\_compare(const void \* s1, const void \* s2) {

return strcmp(\*(const char\*\*)s1, \*(const char\*\*)s2);

}

int string\_compare\_r(const void \* s1, const void \* s2) {

return (-1)\*strcmp(\*(const char\*\*)s1, \*(const char\*\*)s2);

}

*/\* Generic Print Utility \*/*

void print\_vector(Vector\* list) {

for (int i = 0 ; i < list -> length ; i++) {

list -> printOne(list -> data[i]);

}

}

*/\*Print Utils\*/*

void print\_int\_vector(Vector \*list) {

for (int i = 0 ; i < list -> length ; i++) {

di(\*(int \*)((list -> data)[i]));

}

}

void print\_string\_vector(Vector \*list) {

for (int i = 0 ; i < list -> length ; i++) {

ds((char \*)((list -> data)[i]))

}

}

*/\* Single Data Print Utils \*/*

void print\_int(void\* data) {

printf("%d", (\*(int\*)data));

}

void print\_string(void\* data) {

printf("%s", ((char\*)data));

}

*/\* New Data of Specific DataType Methods \*/*

void\* new\_int(int data) {

int\* new\_data = malloc(sizeof \*new\_data);

\*new\_data = data;

return new\_data;

}

void\* new\_double(double data) {

double\* new\_data = malloc(sizeof \*new\_data);

\*new\_data = data;

return new\_data;

}

void\* new\_string(char\* data) {

char\* new\_data = malloc(strlen(data) \* sizeof \*new\_data);

strcpy(new\_data, data);

return new\_data;

}

*/\* Other Sorting Techniques \*/*

void insertion\_sort(void\*\* arr, size\_t length, size\_t ele\_size, int (\*comparator)(const void\* data1, const void\* data2)) {

void\* key;

for (int i = 1 ; i < length ; i++) {

key = arr[i];

int j = i - 1;

while (j >= 0 && comparator(arr[j], key) >= 0) {

arr[j+1] = arr[j];

j--;

}

arr[j+1] = key;

}

}

## vector.h

#ifndef VECTOR\_H

#define VECTOR\_H

#include <stdio.h>

#include <stdlib.h>

#include <stdbool.h>

#include "vector.h"

*/\* For vargs without a list count \*/*

#define PP\_NARG(...) \

PP\_NARG\_(\_\_VA\_ARGS\_\_,PP\_RSEQ\_N())

#define PP\_NARG\_(...) \

PP\_ARG\_N(\_\_VA\_ARGS\_\_)

#define PP\_ARG\_N( \

\_1, \_2, \_3, \_4, \_5, \_6, \_7, \_8, \_9,\_10, \

\_11,\_12,\_13,\_14,\_15,\_16,\_17,\_18,\_19,\_20, \

\_21,\_22,\_23,\_24,\_25,\_26,\_27,\_28,\_29,\_30, \

\_31,\_32,\_33,\_34,\_35,\_36,\_37,\_38,\_39,\_40, \

\_41,\_42,\_43,\_44,\_45,\_46,\_47,\_48,\_49,\_50, \

\_51,\_52,\_53,\_54,\_55,\_56,\_57,\_58,\_59,\_60, \

\_61,\_62,\_63,\_64,\_65,\_66,\_67,\_68,\_69,\_70, \

\_71,\_72,\_73,\_74,\_75,\_76,\_77,\_78,\_79,\_80, \

\_81,\_82,\_83,\_84,\_85,\_86,\_87,\_88,\_89,\_90, \

\_91,\_92,\_93,\_94,\_95,\_96,\_97,\_98,\_99,\_100, \

\_101,\_102,\_103,\_104,\_105,\_106,\_107,\_108,\_109,\_110, \

\_111,\_112,\_113,\_114,\_115,\_116,\_117,\_118,\_119,\_120, \

\_121,\_122,\_123,\_124,\_125,\_126,\_127,N,...) N

#define PP\_RSEQ\_N() \

127,126,125,124,123,122,121,120, \

119,118,117,116,115,114,113,112,111,110, \

109,108,107,106,105,104,103,102,101,100, \

99,98,97,96,95,94,93,92,91,90, \

89,88,87,86,85,84,83,82,81,80, \

79,78,77,76,75,74,73,72,71,70, \

69,68,67,66,65,64,63,62,61,60, \

59,58,57,56,55,54,53,52,51,50, \

49,48,47,46,45,44,43,42,41,40, \

39,38,37,36,35,34,33,32,31,30, \

29,28,27,26,25,24,23,22,21,20, \

19,18,17,16,15,14,13,12,11,10, \

9,8,7,6,5,4,3,2,1,0

typedef int (\*Comparator)(const void\*, const void\*);

*/\* The Vector structure \*/*

struct Vector {

int length;

void \*\*data;

void\* (\*get)(struct Vector\*, int);

void (\*print)(struct Vector\*);

void (\*add)(struct Vector\*, void \*);

void (\*remove)(struct Vector\*, int);

int (\*comparator)(const void \*, const void \*);

int (\*comparator\_r)(const void \*, const void \*);

void (\*sort)(struct Vector\*, bool);

int (\*search)(struct Vector\*, void\*, int (\*)(const void\*, const void\*));

void (\*printOne)(void\* data);

};

typedef struct Vector Vector;

#define \_COMPARATOR\_ int (\*)(const void\*, const void\*)

#define \_PRINTONE\_ void (\*)(void\*)

Vector\* \_newMinimalVectorWithArgs(\_COMPARATOR\_, \_PRINTONE\_, size\_t argc, ...);

#define newMinimalVectorWithArgs(\_COMPARATOR\_, \_PRINTONE\_, ...) \

\_newMinimalVectorWithArgs(\_COMPARATOR\_, \_PRINTONE\_,PP\_NARG(\_\_VA\_ARGS\_\_), \_\_VA\_ARGS\_\_)

*/\* Generic methods \*/*

Vector\* newVector(void (\*)(Vector\*), \_COMPARATOR\_, \_COMPARATOR\_);

Vector\* newMinimalVector(\_COMPARATOR\_, \_PRINTONE\_);

void\* get(Vector \*, int);

void add(Vector \*, void \*);

void init(Vector \*, void (\*)(Vector \*), \_COMPARATOR\_, \_COMPARATOR\_);

void del(Vector\*, int);

void sort(Vector\*, bool descending);

void print\_vector(Vector\* list);

*/\* DataType specific methods \*/*

void\* new\_int(int);

void\* new\_double(double);

void\* new\_string(char\*);

*/\* Print Utils \*/*

void print\_int\_vector(Vector \*);

void print\_string\_vector(Vector \*);

void print\_int(void\* data);

void print\_string(void\* data);

*/\* Comparator methods \*/*

int int\_compare(const void \*, const void \*);

int int\_compare\_r(const void \*, const void \*);

int string\_compare(const void \*, const void \*);

int string\_compare\_r(const void \*, const void \*);

*/\* Sorting Methods \*/*

void insertion\_sort(void\*\* arr, size\_t length, size\_t ele\_size, \_COMPARATOR\_);

*/\* Searching Algorithms \*/*

int linear\_search\_vector(Vector\*, void\* param, \_COMPARATOR\_);

#endif

## main.c

#include <stdio.h>

#include "vector.h"

#include "stack.h"

#include "quack.h"

#include "debug\_helper.h"

int main() {

Quack\* myquack;

if ((myquack = newQuack()) == NULL) {

return -1;

}

myquack -> push(myquack, new\_int(1));

myquack -> push(myquack, new\_int(2));

myquack -> push(myquack, new\_int(3));

printf("\nPUSH 1, 2, 3 :\n");

myquack -> display(myquack, print\_int);

printf("\n");

printf("\nPULL:\n");

myquack -> pull(myquack);

myquack -> display(myquack, print\_int);

printf("\n");

printf("\nPOP:\n");

myquack -> pop(myquack);

myquack -> display(myquack, print\_int);

printf("\n");

return 0;

}

## debug\_helper.h

#ifndef DEBUG\_HELPER\_H

#define DEBUG\_HELPER\_H

#define ds(s) printf("\nDEBUG--\*"#s " : %s\*\n", s);

#define dc(c) printf("\nDEBUG--%"#c " : %c$\n", c);

#define di(i) printf("\nDEBUG--#"#i " : %d#\n", i);

#endif