**Course: ENSF 694** – Summer 2025

**Lab #:** 04

**Instructor:** Dr. Mahmood Moussavi

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**Submission Date:** Wednesday, July 30th, 2025

**Exercise A Part I**

Source Code (lookupTable.cpp):

#include "lookupTable.h"

#include <iostream>

/\*

\* lookupTable.cpp

\* ENSF 694 Lab 4, exercise A

\* Created by Mahmood Moussavi

\* Completed by: Jack Shenfield

\* Development Date: July 29th, 2025

\*/

// constructor for LT\_Node struct

LT\_Node::LT\_Node(const Pair& pairA, LT\_Node \*nextA):pairM(pairA), nextM(nextA){}

// initialize all member variables to 0

LookupTable::LookupTable(){

sizeM = 0;

headM = nullptr;

cursorM = nullptr;

}

// copy ctor

LookupTable::LookupTable(const LookupTable & source):sizeM(source.sizeM), headM(nullptr), cursorM(nullptr){

if(source.headM == nullptr){

return; // list to be copied is empty

}

// copy head node into headM

headM = new LT\_Node(source.headM->pairM, nullptr);

LT\_Node \* src = source.headM->nextM; // track old list in iteration

LT\_Node \* dest = headM; // track new list

// point cursor to head

cursorM = headM;

while(src != nullptr){

dest->nextM = new LT\_Node(src->pairM, nullptr); // create new node using src data

dest = dest->nextM; // update pointer to new node

if(src == source.cursorM){

cursorM = dest;

}

src = src->nextM;

}

}

// assignment operator

LookupTable& LookupTable::operator =(const LookupTable& rhs){

// if it is the same object return it

if (this == &rhs){

return \*this;

}

// reset to initial values

sizeM = rhs.sizeM;

headM = nullptr;

cursorM = nullptr;

// If it is empty, return it

if (rhs.headM == nullptr){

return \*this;

}

// Create new node

headM = new LT\_Node(rhs.headM->pairM, nullptr);

LT\_Node\* src = rhs.headM->nextM;

LT\_Node\* dest = headM;

cursorM = headM;

// Loop through and create new list

while (src != nullptr) {

dest->nextM = new LT\_Node(src->pairM, nullptr);

dest = dest->nextM;

if (src == rhs.cursorM) {

cursorM = dest;

}

src = src->nextM;

}

return \*this;

}

// dtor

LookupTable::~LookupTable(){

make\_empty(); // call the make empty function created later on.

}

LookupTable& LookupTable::begin(){

cursorM = headM;

return \*this;

}

int LookupTable::size() const{

return sizeM;

}

int LookupTable::cursor\_ok() const{

if(cursorM == nullptr){ // pointing at nothing, return 0

return 0;

}

else{ // if not pointing at nothing, assume pointing at list

return 1;

}

}

const int& LookupTable::cursor\_key() const{

if(cursor\_ok() == 1){

return cursorM->pairM.key;

}

}

const Type& LookupTable::cursor\_datum() const{

if(cursor\_ok() == 1){

return cursorM->pairM.datum;

}

}

// inserts keys in order

void LookupTable::insert(const Pair& pairA) {

cursorM = headM;

LT\_Node\* prev = nullptr;

// Check if key already exists — if so, update the datum

while (cursorM != nullptr) {

if (cursorM->pairM.key == pairA.key) {

cursorM->pairM.datum = pairA.datum;

cursorM = nullptr;

return;

}

if (cursorM->pairM.key > pairA.key) {

break; // found insert position

}

prev = cursorM;

cursorM = cursorM->nextM;

}

// Create new node to insert

LT\_Node\* newNode = new LT\_Node(pairA, cursorM);

if (prev == nullptr) {

// Insert at head

headM = newNode;

} else {

prev->nextM = newNode;

}

cursorM = nullptr;

++sizeM;

}

int LookupTable::remove(const int& keyA){

cursorM = nullptr; // off-list

LT\_Node\* prev = nullptr;

cursorM = headM;

while (cursorM != nullptr) {

if (cursorM->pairM.key == keyA) {

// Remove node

if (prev == nullptr) {

// Node head

headM = cursorM->nextM;

} else {

// Node is not at head

prev->nextM = cursorM->nextM;

}

int removed = cursorM->pairM.key;

delete cursorM;

cursorM = nullptr;

--sizeM;

return removed; // return the removed key

}

prev = cursorM;

cursorM = cursorM->nextM;

}

cursorM = nullptr;

return 0; // key not found

}

void LookupTable::find(const int& keyA){

cursorM = headM;

// search for key

while(cursorM != nullptr){

if(cursorM->pairM.key == keyA){

return;

}

cursorM = cursorM->nextM;

}

cursorM = nullptr;

}

void LookupTable::go\_to\_first(){

if(sizeM > 0){

cursorM = headM;

}

else{

cursorM = nullptr;

}

}

void LookupTable::step\_fwd(){

if(cursorM->nextM == nullptr || cursor\_ok() == 0){

cursorM = nullptr;

}

else{

cursorM = cursorM->nextM;

}

}

void LookupTable::make\_empty(){

// delete each node from memory going down the list

LT\_Node\* current = headM;

while (current != nullptr) {

LT\_Node\* temp = current;

current = current->nextM;

delete temp;

}

// reset variables

headM = nullptr;

cursorM = nullptr;

sizeM = 0;

}

void LookupTable::display()const{

LT\_Node\* ptr = headM;

// print lines

while (ptr != nullptr) {

std::cout << "[" << ptr->pairM.key << ": " << ptr->pairM.datum << "] ";

ptr = ptr->nextM;

}

std::cout << std::endl; // endline

}

bool LookupTable::isEmpty()const{

if(sizeM == 0){

return true;

}

else{

return false;

}

}

int LookupTable::retrieve\_at(int i){

if(i < 0 || i >= sizeM){

throw std::out\_of\_range("Index DNE"); // index doesn't exist

}

cursorM = headM;

int index = 0;

while(cursorM != nullptr && index < i){

cursorM = cursorM->nextM;

index++;

}

if(cursorM != nullptr){

return cursorM->pairM.key;

}

}

Output:

(base) jbs@Jacks-MacBook-Air Lab04\_ExA\_Part1 % g++ -std=c++17 lookupTable.cpp lookupTable\_tester-part1.cpp -o tester

lookupTable.cpp:114:1: warning: non-void function does not return a value in all control paths [-Wreturn-type]

114 | }

| ^

lookupTable.cpp:120:1: warning: non-void function does not return a value in all control paths [-Wreturn-type]

120 | }

| ^

lookupTable.cpp:280:1: warning: non-void function does not return a value in all control paths [-Wreturn-type]

280 | }

| ^

3 warnings generated.

(base) jbs@Jacks-MacBook-Air Lab04\_ExA\_Part1 % ./tester

Starting Test Run. Using input file.

Line 1 >> is comment

Line 2 >> Passed

Line 3 >> Passed

Line 4 >> Passed

Line 5 >> Passed

Line 6 >> Passed

Line 7 >> Passed

Line 8 >> Passed

Line 9 >> Passed

Line 10 >> Passed

Line 11 >> Passed

Line 12 >> Passed

Line 13 >> Passed

Line 14 >> Passed

Line 15 >> Passed

Line 16 >> Passed

Line 17 >> Passed

Line 18 >> Passed

Line 19 >> Passed

Line 20 >> Passed

Line 21 >> Passed

Reached End of Input File

MORE TESTS.....

Inserting 3 pairs:

Assert: three data must be in the list:

Okay. Passed.

Removing one pair with the key 8004:

Assert: one pair is removed.

Okay. Passed.

Printing table after inserting 3 and removing 1...

Expected to dispaly 8001 Tim Hardy and 8002 Joe Morrison:

[8001: Tim Hardy] [8002: Joe Morrison]

[8001: Tim Hardy] [8002: Joe Morrison]

Let's look up some keys 8001 and 8000...

Expected to find 8001 and NOT to find 8000...

Found key:[8001: Tim Hardy] [8002: Joe Morrison]

Sorry, I couldn't find key: 8000 in the table.

Test copying: keys should be 8001, and 8002

[8001: Tim Hardy] [8002: Joe Morrison]

[8001: Tim Hardy] [8002: Joe Morrison]

Test assignment operator (key expected be 8001):

[8001: Tim Hardy]

Printing table for the last time: Table should be empty...

Table is EMPTY.

\*\*\*----Finished tests on Customers Lookup Table <not template>-----\*\*\*

PRESS RETURN TO CONTINUE.

Program terminated successfully.

(base) jbs@Jacks-MacBook-Air Lab04\_ExA\_Part1 %

**Exercise A Part II**

Source Code:

Source code for the changed files is attached.

Output:

(base) jbs@Jacks-MacBook-Air Lab04\_ExA\_Part2 % g++ -std=c++17 Point.cpp lookupTable.cpp lookupTable\_tester\_part2.cpp -o tester

lookupTable.cpp:115:1: warning: non-void function does not return a value in all control paths [-Wreturn-type]

115 | }

| ^

lookupTable.cpp:121:1: warning: non-void function does not return a value in all control paths [-Wreturn-type]

121 | }

| ^

lookupTable.cpp:281:1: warning: non-void function does not return a value in all control paths [-Wreturn-type]

281 | }

| ^

3 warnings generated.

(base) jbs@Jacks-MacBook-Air Lab04\_ExA\_Part2 % ./tester

Starting Test Run. Using input file.

Line 1 >> is comment

Line 2 >> Passed

Line 3 >> Passed

Line 4 >> Passed

Line 5 >> Passed

Line 6 >> Passed

Line 7 >> Passed

Line 8 >> Passed

Line 9 >> Passed

Line 10 >> Passed

Line 11 >> Passed

Line 12 >> Passed

Line 13 >> Passed

Line 14 >> Passed

Line 15 >> Passed

Line 16 >> Passed

Line 17 >> Passed

Line 18 >> Passed

Line 19 >> Passed

Line 20 >> Passed

Line 21 >> Passed

Exiting...

Finishing Test Run

Showing Data in the List:

Program terminated successfully.

(base) jbs@Jacks-MacBook-Air Lab04\_ExA\_Part2 %

**Exercise B**

Fcn Definition:

void print\_from\_binary(char\* filename){

ifstream stream(filename, ios::in | ios::binary); // same as above, but for input file stream

if (stream.fail()) {

cerr << "failed to open file: " << filename << endl;

exit(1);

}

City city;

while (stream.read(reinterpret\_cast<char\*>(&city), sizeof(City))) { // print all

cout << "City: " << city.name << ", x: " << city.x << ", y: " << city.y << endl;

}

stream.close();

}

Output:

se) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % ./lab4

The content of the binary file is:

City: Calgary, x: 100, y: 50

City: Edmonton, x: 100, y: 150

City: Vancouver, x: 50, y: 50

City: Regina, x: 200, y: 50

City: Toronto, x: 500, y: 50

City: Montreal, x: 200, y: 50

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 %

**Exercise C**

Source Code:

/\*

\* lab4exe\_C.cpp

\* ENSF 694 Lab 4, exercise C

\* Created by Mahmood Moussavi

\* Completed by: Jack Shenfield

\* Development Date: July 30th, 2025

\*/

#include <iostream>

using namespace std;

void insertion\_sort(int \*int\_array, int n);

/\* REQUIRES

\* n > 0.

\* Array elements int\_array[0] ... int\_array[n - 1] exist.

\* PROMISES

\* Element values are rearranged in non-decreasing order.

\*/

void insertion\_sort(const char\*\* str\_array, int n);

/\* REQUIRES

\* n > 0.

\* Array elements str\_array[0] ... str\_array[n - 1] exist.

\* PROMISES

\* pointers in str\_array are rearranged so that strings:

\* str\_array[0] points to a string with the smallest string (lexicographicall) ,

\* str\_array[1] points to the second smallest string, ..., str\_array[n-2]

\* points to the second largest, and str\_array[n-1] points to the largest string

\*/

int main(void)

{

const char\* s[] = { "AB", "XY", "EZ"};

const char\*\* z = s;

z += 1;

cout << "The value of \*\*z is: " << \*\*z << endl;

cout << "The value of \*z is: " << \*z << endl;

cout << "The value of \*\*(z-1) is: " << \*\*(z-1)<< endl;

cout << "The value of \*(z-1) is: " << \*(z-1)<< endl;

cout << "The value of z[1][1] is: " << z[1][1]<< endl;

cout << "The value of \*(\*(z+1)+1) is: " << \*(\*(z+1)+1)<< endl;

// point 1

int a[] = { 413, 282, 660, 171, 308, 537 };

int i;

int n\_elements = sizeof(a) / sizeof(int);

cout << "Here is your array of integers before sorting: \n";

for(i = 0; i < n\_elements; i++)

cout << a[i] << endl;

cout << endl;

insertion\_sort(a, n\_elements);

cout << "Here is your array of ints after sorting: \n" ;

for(i = 0; i < n\_elements; i++)

cout << a[i] << endl;

#if 1

const char\* strings[] = { "Red", "Blue", "pink","apple", "almond","white",

"nut", "Law", "cup"};

n\_elements = sizeof(strings) / sizeof(char\*);

cout << "\nHere is your array of strings before sorting: \n";

for(i = 0; i < n\_elements; i++)

cout << strings[i] << endl;

cout << endl;

insertion\_sort(strings, 9);

cout << "Here is your array of strings after sorting: \n" ;

for(i = 0; i < n\_elements; i++)

cout << strings[i] << endl;

cout << endl;

#endif

return 0;

}

void insertion\_sort(int \*a, int n)

{

int i;

int j;

int value\_to\_insert;

for (i = 1; i < n; i++) {

value\_to\_insert = a[i];

/\* Shift values greater than value\_to\_insert. \*/

j = i;

while ( j > 0 && a[j - 1] > value\_to\_insert ) {

a[j] = a[j - 1];

j--;

}

a[j] = value\_to\_insert;

}

}

void insertion\_sort(const char\*\* str\_array, int n){ // same logic as above, but changed to strings.

int i;

int j;

const char\* str\_to\_insert;

for (i = 1; i < n; i++) {

str\_to\_insert = str\_array[i];

/\* Shift values greater than value\_to\_insert. \*/

j = i;

while ( j > 0 && strlen(str\_array[j - 1]) > strlen(str\_to\_insert) ) {

str\_array[j] = str\_array[j - 1];

j--;

}

str\_array[j] = str\_to\_insert;

}

}

/\* REQUIRES

\* n > 0.

\* Array elements str\_array[0] ... str\_array[n - 1] exist.

\* PROMISES

\* pointers in str\_array are rearranged so that strings:

\* str\_array[0] points to a string with the smallest string (lexicographicall) ,

\* str\_array[1] points to the second smallest string, ..., str\_array[n-2]

\* points to the second largest, and str\_array[n-1] points to the largest string

\*/

AR Diagram of Point 1:

A diagram of a string diagram

AI-generated content may be incorrect.

Output:

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % ./lab4\_C

The value of \*\*z is: X

The value of \*z is: XY

The value of \*\*(z-1) is: A

The value of \*(z-1) is: AB

The value of z[1][1] is: Z

The value of \*(\*(z+1)+1) is: Z

Here is your array of integers before sorting:

413

282

660

171

308

537

Here is your array of ints after sorting:

171

282

308

413

537

660

Here is your array of strings before sorting:

Red

Blue

pink

apple

almond

white

nut

Law

cup

Here is your array of strings after sorting:

Red

nut

Law

cup

Blue

pink

apple

white

almond

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 %

**Exercise D**

Source Code:  
  
// matrix.cpp

#include "matrix.h"

Matrix::Matrix(int r, int c):rowsM(r), colsM(c)

{

matrixM = new double\* [rowsM];

assert(matrixM != NULL);

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

matrixM[i] = new double[colsM];

assert(matrixM[i] != NULL);

}

sum\_rowsM = new double[rowsM];

assert(sum\_rowsM != NULL);

sum\_colsM = new double[colsM];

assert(sum\_colsM != NULL);

}

Matrix::~Matrix()

{

destroy();

}

Matrix::Matrix(const Matrix& source)

{

copy(source);

}

Matrix& Matrix::operator= (const Matrix& rhs)

{

if(&rhs != this){

destroy();

copy(rhs);

}

return \*this;

}

double Matrix::get\_sum\_col(int i) const

{

assert(i >= 0 && i < colsM);

return sum\_colsM[i];

}

double Matrix::get\_sum\_row(int i) const

{

assert(i >= 0 && i < rowsM);

return sum\_rowsM[i];

}

void Matrix::sum\_of\_rows()const

{

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

sum\_rowsM[i] = 0; // initialize sum at 0

for(int j = 0; j < colsM; j++)

sum\_rowsM[i] += matrixM[i][j]; // sum each data point in the row

}

// COMMENT OUT THE FOLLOWING LINE AND COMPLETE THE DEFINITION OF THIS FUNCTION

//cout << "\nSorry I don't know how to calculate sum of rowsM in a matrix. ";

}

void Matrix::sum\_of\_cols()const

{

// same logic as above, but swap rows/cols

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

sum\_colsM[i] = 0; // initialize sum at 0

for(int j = 0; j < rowsM; j++)

sum\_colsM[i] += matrixM[j][i]; // sum each data point in the row

}

// COMMENT OUT THE FOLLOWING LINE AND COMPLETE THE DEFINITION OF THIS FUNCTION

//cout << "\nSorry I don't know how to calculate sum of columns in a matrix. ";

}

void Matrix::copy(const Matrix& source)

{

// THIS FUNCITON IS DEFECTIVE AND DOSEN'T PROPERLY MAKE THE COPY OF SROUCE

if(source.matrixM == NULL){

matrixM = NULL;

sum\_rowsM = NULL;

sum\_colsM = NULL;

rowsM = 0;

colsM = 0;

return;

}

rowsM = source.rowsM;

colsM = source.colsM;

sum\_rowsM = new double[rowsM];

assert(sum\_rowsM != NULL);

for (int i = 0; i < rowsM; ++i) { // initialize proper row sums

sum\_rowsM[i] = source.sum\_rowsM[i];

}

sum\_colsM = new double[colsM];

assert(sum\_colsM != NULL);

for (int j = 0; j < colsM; ++j) { // initialize proper column sums

sum\_colsM[j] = source.sum\_colsM[j];

}

matrixM = new double\*[rowsM];

assert(matrixM !=NULL);

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

matrixM[i] = new double[colsM];

assert(matrixM[i] != NULL);

for(int j = 0; j < colsM; j++){

matrixM[i][j] = source.matrixM[i][j];

}

}

// STUDENTS MUST COMMENT OUT THE FOLLOWING LINE AND FIX THE FUNCTION'S PROBLEM

//cout << "\nSorry copy fucntion is defective. ";

}

void Matrix::destroy()

{

// destroy each row

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

delete [] matrixM[i];

}

// delete leftover array

delete [] matrixM;

// reset member variables

matrixM = nullptr;

rowsM = 0;

colsM = 0;

// COMMENT OUT THE FOLLOWING LINE AND COMPLETE THE DEFINITION OF THIS FUNCTION

//cout << "\nProgram ended without destroying matrices.\n";

}

Output:  
  
(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % g++ matrix.cpp lab4exe\_D.cpp -o matrix

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % ./matrix

Error: too few arguments% (base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % ./matrix 3 4

The values in matrix m1 are:

2.3 3.0 3.7 4.3

2.7 3.3 4.0 4.7

3.0 3.7 4.3 5.0

The values in matrix m2 are:

2.7 3.3 4.0 4.7 5.3 6.0

3.0 3.7 4.3 5.0 5.7 6.3

3.3 4.0 4.7 5.3 6.0 6.7

3.7 4.3 5.0 5.7 6.3 7.0

The new values in matrix m1 and sum of its rows and columns are

2.7 3.3 4.0 4.7 5.3 6.0 | 26.0

3.0 3.7 4.3 5.0 5.7 6.3 | 28.0

3.3 4.0 4.7 5.3 6.0 6.7 | 30.0

3.7 4.3 5.0 5.7 6.3 7.0 | 32.0

------------------------------------

12.7 15.3 18.0 20.7 23.3 26.0

The values in matrix m3 and sum of its rows and columns are:

5.0 3.3 4.0 4.7 5.3 6.0 | 28.3

3.0 15.0 4.3 5.0 5.7 6.3 | 39.3

3.3 4.0 25.0 5.3 6.0 6.7 | 50.3

3.7 4.3 5.0 5.7 6.3 7.0 | 32.0

------------------------------------

15.0 26.7 38.3 20.7 23.3 26.0

The new values in matrix m2 are:

-5.0 3.3 4.0 4.7 5.3 6.0 | 18.3

3.0 -15.0 4.3 5.0 5.7 6.3 | 9.3

3.3 4.0 -25.0 5.3 6.0 6.7 | 0.3

3.7 4.3 5.0 5.7 6.3 7.0 | 32.0

------------------------------------

5.0 -3.3 -11.7 20.7 23.3 26.0

The values in matrix m3 and sum of it rows and columns are still the same:

5.0 3.3 4.0 4.7 5.3 6.0 | 28.3

3.0 15.0 4.3 5.0 5.7 6.3 | 39.3

3.3 4.0 25.0 5.3 6.0 6.7 | 50.3

3.7 4.3 5.0 5.7 6.3 7.0 | 32.0

------------------------------------

15.0 26.7 38.3 20.7 23.3 26.0

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 %

**Exercise E**

**a)**

/\*

\* lab4exe\_E.cpp

\* ENSF 694 Lab 4, exercise E

\* Created by Mahmood Moussavi

\* Completed by: Jack Shenfield

\* Development Date: July 30th, 2025

\*/

#include "HashTable.h"

// function definitions

int HashTable::hashFunction(const std::string &flightID) const{ // inspired by chatGPT

unsigned int hash = 0;

for (char c : flightID) {

hash = hash \* 31 + c; // prime number multiplier is 31

}

return hash % tableSize; //

}

// constructor, initialize most values at 0. size at inputted size.

HashTable::HashTable(int size):tableSize(size), totalRecords(0), nonCollisionCount(0), elementsUsed(0) {

table = new List\*[tableSize];

for (int i = 0; i < tableSize; ++i)

table[i] = nullptr; // fill table with null pointers

}

HashTable::~HashTable(){

for (int i = 0; i < tableSize; ++i) { // delete each value

if (table[i] != nullptr)

delete table[i];

}

delete[] table; // delete the leftover empty table

}

void HashTable::insert(const Flight &flight){

int ind = hashFunction(flight.getFlightID()); // compute hash # (useable index) with my prime function

if (table[ind] == nullptr) { // If there is no value at this index

table[ind] = new List(); // create a new List at the computed hash #

table[ind]->insert(flight); // insert the flight into that list

nonCollisionCount++; // There was no collision here. increment

elementsUsed++; // new element

} else {

table[ind]->insert(flight); // there is already a flight here, chain to previous one.

}

totalRecords++; // increment total records

}

Flight\* HashTable::search(const std::string &flightID)const{

int index = hashFunction(flightID); // compute hash # from inputted flight ID

if (table[index] == nullptr){

return nullptr; // If there is nothing at the index, return nullptr

}

Node\* result = table[index]->search(flightID);

return result ? &result->data : nullptr; // return the result or nullptr depending on result

}

void HashTable::printTable() const{

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

std::cout << "Chain " << i << ": ";

if (table[i]) // print if there is values

table[i]->printList();

else // else, print empty

std::cout << "Empty";

std::cout << std::endl;

}

}

double HashTable::getNonCollisionEfficiency() const{

if (totalRecords == 0){

return 0.0; // no values, return nothing.

}

// otherwise, return non collision %

return ((double)nonCollisionCount / totalRecords \* 100.0);

}

int HashTable::calculateTotalSearchCost()const{

int totalCost = 0; // initialize at 0;

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

List\* chain = table[i]; //

if (chain != nullptr) {

Node\* current = chain->getHead(); // point at head index of chain

int position = 1;

while (current != nullptr) { // for each real value

totalCost += position; // search cost is the position

current = current->next; // move to next value

++position; // increment

}

}

}

return totalCost;

}

double HashTable::getTableDensity() const{

return(static\_cast<double>(elementsUsed) / tableSize); // number of elements used / total table size

}

double HashTable::getPackingDensity() const{

return(static\_cast<double>(totalRecords) / tableSize); // number of total records / table size

}

double HashTable::getHashEfficiency() const{

if (totalRecords == 0) return 0.0; // if empty, return 0.0

return(static\_cast<double>(calculateTotalSearchCost()) / totalRecords); // otherwise, return search cost / total table size

}

b)  
(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % g++ -std=c++17 HashTable.cpp Flight.cpp List.cpp HashTable\_tester.cpp -o hashtest

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 % ./hashtest input.txt

Number of Records: 12

Table Size: 12

Table Density: 75%

Non-collision Efficiency: 7500%

Packing Density: 1

Hash Efficiency: 133.3%

Chain 0: Flight Number: AMA11232, Origin: Otawa, Destination: Toronto, Date: 2024-05-30, Time: 00:45, Capacity: 576

Flight Number: WJ12301, Origin: Calgary, Destination: Toronto, Date: 2024-05-30, Time: 2:45, Capacity: 476

Flight Number: AC123, Origin: Calgary, Destination: Edmonton, Date: 2024-05-30, Time: 1:45, Capacity: 376

Chain 1: Flight Number: WJ12302, Origin: Otawa, Destination: Toronto, Date: 2024-05-30, Time: 2:45, Capacity: 476

Flight Number: AC1231, Origin: Calgary, Destination: Toronto, Date: 2024-05-30, Time: 1:45, Capacity: 376

Chain 2: Flight Number: AC1232, Origin: Otawa, Destination: Toronto, Date: 2024-05-30, Time: 1:45, Capacity: 376

Chain 3: Flight Number: DELTA2331, Origin: Calgary, Destination: Toronto, Date: 2024-05-30, Time: 10:45, Capacity: 200

Chain 4: Flight Number: DELTA2332, Origin: Otawa, Destination: Toronto, Date: 2024-05-30, Time: 10:45, Capacity: 200

Chain 5: Flight Number: WJ1230, Origin: Calgary, Destination: Edmonton, Date: 2024-05-30, Time: 2:45, Capacity: 476

Chain 6: Flight Number: AMA1123, Origin: Calgary, Destination: Edmonton, Date: 2024-05-30, Time: 00:45, Capacity: 576

Chain 7: Empty

Chain 8: Empty

Chain 9: Empty

Chain 10: Flight Number: DELTA233, Origin: Calgary, Destination: Edmonton, Date: 2024-05-30, Time: 10:45, Capacity: 200

Chain 11: Flight Number: AMA11231, Origin: Calgary, Destination: Toronto, Date: 2024-05-30, Time: 00:45, Capacity: 576

Interactive Search ...

Enter flight number to search (or 'exit' to quit): exit

(base) jbs@Jacks-MacBook-Air ENSF694\_LabAssignment4 %

c)

double HashTable::getPackingDensity() const{

return(static\_cast<double>(totalRecords) / tableSize); // number of total records / table size

}

double HashTable::getHashEfficiency() const{

if (totalRecords == 0) return 0.0; // if empty, return 0.0

return(static\_cast<double>(calculateTotalSearchCost()) / totalRecords); // otherwise, return search cost / total table size

}

d)

The technique I chose multiplies the current hash by a prime number (31) and then adds the current character in the string (ASCII value) to that number, iteratively. I found it by looking up “simple hash functions for c++”, consulting AI, and reading the lecture slides. It could be improved by potentially using a more complicated hash function that spread the data more evenly, or resulted in less collisions.