Design and Analysis of Algorithms (DAA) - UE16CS251

Assignment 1

Develop a C library of an integer of arbitrary length (intal)

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11:59 PM on Apr 22nd (Sunday) is “the” deadline. We’ll stop receiving first thing on Monday morning because we’ll download all submissions and start evaluation. No exceptions after 11:59 PM on Sunday.

Test-cases:

Our test-cases will not test for "not a number" cases except for divide by zero. a^b is zero for 0^a even when a is zero. We are not going to feed invalid nonnegative integers into intal\_create(). All inputs and outputs will never be more than 10,000 decimal digits. One-mark for each of the following test-cases, which will be tested on your implementation file (library of "intal"). A correct answer for a test-case gets one-mark.

1. Addition of two intals in which at least one of them is large.

2. The difference of two intals in which at least one of them is large.

3. Multiplication of two intals in which at least one of them is large.

4. Division of two intals in which at least one of them is large.

5. Exponentiation in which the output is large.

6. Addition or difference of intals of not more than 100 decimal digits with corner cases.

7. Multiplication of intals of not more than 100 decimal digits with corner cases.

8. Multiplication function constrained by time.

9. Multiplication function tested for a memory leak.

10. Addition/Difference function tested for a memory leak.

New intal\_client\_sample.c is uploaded which should give some clarity on how the functions are expected to behave.

intal\_create() works more like atoi() which converts the initial portion of the string. That is, if considers only decimal digits, and as soon as it it parses a non-digit, it just processes whatever digits it has already received. If the first char is a non-digit, it returns 0. If you’ve already submitted with a different behavior, don’t worry because we are not going to test with invalid input string for this function. Intal.h is updated with this on intal\_create().

If a null pointer is passed as an input any function, which expects an intal, just return null. For example, if one of the inputs to intal\_add() is a null pointer, return null. intal\_compare() is an exception, which returns “-2” when one or more input intals are null.

Most of the functions which return an intal, returns a newly created intal. Client will call destroy\_intal() on that intal at a later stage.

**You can submit your assignment at** [**https://goo.gl/forms/EnQkwENUuaQKc4Vv1**](https://goo.gl/forms/EnQkwENUuaQKc4Vv1)

**Make sure the filename strictly follows the format intal\_YourSRN.c. Any submitted files not matching with their respective SRN would be ignored. You are allowed to re-submit any number of times before the due date, the last one would be considered.**

# FAQs

1. For intal\_multiply(), do we have to Karatsuba algorithm?
   1. One of the test-cases would expect Karatsuba algorithm because it expects an efficient implementation for a large input. Other than that, even a long multiplication algorithm should work all other test-cases.
2. Is it alright to make intal work for 8-digit long integers?
   1. No, mostly none of the test-cases will pass. All test-cases deal with 100 or digit long integers. We have a max limit of 10,000 digit long integers. The reason why we don’t test for 8-digit long integers is, even our fixed length data types like “long int” in C can handle them.
3. An intal being a null pointer.
   1. You know that the client looks at the intal as a void pointer. A null pointer is treated as not a number (NaN in short). NaN is not zero.
   2. “NaN”s are generated in instances like divide-by-zero.
   3. intal\_create() works more like atoi() which converts the initial portion of the string. That is, if considers only decimal digits, and as soon as it it parses a non-digit, it just processes whatever digits it has already received. If the is itself a non-digit, it returns 0. If you’ve already submitted with a different behavior, don’t worry because we are not going to test with invalid input string for this function.
   4. intal\_destroy(void\* intal) does nothing if the intal is null.
   5. char\* intal2str(void\* intal) returns "NaN" if the intal is null.
   6. intal\_increment(), intal\_decrement(), intal\_add(), intal\_diff(), intal\_multiply(), intal\_divide(), intal\_pow() returns a null pointer if the intal is null.
   7. intal\_compare() returns 0, but that doesn't both intals are equal.
4. Size of the intal.
   1. Even though there is no theoretical limit to the size of the intal, we make sure that you don't need to handle an intal having more 10,000 digits in decimal base system. All the functions, whenever they return an intal, it should have stripped off the leading zeros. For example, addition of "0123" and "55" should be returned as "178". Obviously, the length of the integer in decimal digits is excluding the leading zeros.
5. Deliverables?
   1. Your deliverable is only one file; the implementation file. It should be compliant with the latest header file "intal.h". Do not change the "intal.h" because we will compile your implementation file with our client file to test and both needs to agree with the same header file. If you have a "struct" definition for the intal, it should be at the top of your implementation file. Other than the functions asked in the header file, if you are writing some helper function, make it "static" so that there won't be name conflict with any function we have in the client.
6. If the inputs to a certain function yield a value that is not in the domain of intal, i.e. nonnegative integers (for example, decrement 1), what is to be done?
   1. Decrement function won’t yield a negative number because it returns ‘0’ on decrement of ‘0’ by definition of the function.
   2. There are no functions, which result in a negative number. Even the difference is of two intal ‘a’ and ‘b’ is nonnegative (it’s the absolute value of a-b). There is no “subtract” function.
7. Is “difference” function just another name for “subtract”?
   1. No, “difference” is always nonnegative. Difference of two numbers ‘a’ and ‘b’ is, essentially max{a, b} - min{a, b}. There is no explicit “subtract” function in our library. We are dealing with only nonnegative integers.
8. How do we deal with NaN (not a number) like division by zero?
   1. A null pointer represents a NaN. So, division by zero returns a null pointer. Even intal\_create() returns a null pointer if the string is not representing a nonnegative integer.

# Problem Definition:

Develop a C-library of an integer of arbitrary length, let us call it as “intal” in short. The functionalities to be implemented in the library are declared in the header file given at the end of the document.

Library "intal", short for integer of arbitray length, a library of nonnegative integers of

arbitrary length. The given header file "intal.h" declares the functionalities the library is

expected to provide except that there is no definition of the "intal" itself. That is left to

the implementation file, which should declare the structure of the intal along with defining

the functionalities declared in intal.h. Don't modify intal.h, all of your contribution must

be limited to one file; intal.c. When you submit the intal.c, we are going to compile it with

intal.h and a client file of our own to test the functionalities.

Client treats an intal (an integer of arbitrary length) as an object pointed by a pointer "void\*".

An intal can be created by intal\_create() by providing a char string of a nonnegative integer provided

in decimal digits. Some intals are created out of some functionalities like intal\_add(), which

creates a new intal. A new intal created must have allocated a dynamic memory (may be by a

malloc() call). Responsibility of destroying the intals created lies with the client by

calling intal\_destroy(), which will free whatever memory allocated during the creation of intal.

Client sees an intal as a "void\*". It could be a pointer to char array, int array, long int array,

double array, or a struct array. There is no theoretical limit to the size of the integer, but memory

limitations of the process (Operating System). If the OS allows, your library should be able to hold the

largest prime number known, which is 23,249,425 digits long (as of Feb 2018).

# Due Date

1st April, 2018 (we are not fooling about it even though it’s a Sunday!).

# Deliverables

The only deliverable is **“intal.c”**, which implements all the functionalities declared in the header file **“intal.h”**. After you submit, we will test against multiple clients (test-cases). The sample client file provided should clarify the problem statement.

# How to submit?

You will be asked to upload a copy of the “intal.c” file you have written along with printed copy.

# Team

It’s an individual effort. Each student needs to work on his/her own code. Plagiarism will be dealt strictly, but you are welcome to discuss the approach to solve a problem.

# Assessment

The library source code you submit (intal.c) will be compiled with our test-cases (client files). Assessment will be done on working of each functionality, coverage of border cases, duration of execution, and coding style (readability of the code).

# Associated documents:

## intal.h

// Library "intal" - Integer of arbitray length

// intal is a nonnegative integer of arbitrary length.

// The way the integer is stored is specific to the

// implementation as long as the interface (this header file) is intact.

// DO NOT modify this header file.

// As usual, an implementation file implements all the functionalities decalred here

// and a client file uses the functionalities declared here.

//String (array of chars with a null termination) of decimal digits converted to intal type.

//Input str has most significant digit at the head of the string.

//"void \*" abstracts out the format of intal.

//The returned pointer points to the intal "object". Client need not know the format of the intal.

//Even if you happen to use "char\*" as the format of the intal, just like the input string,

// it's expected to a create a new copy because the intal object should be modifiable, but

// the input could be a constant literal (that's why parameter is "const").

//The intal created here obviosuly needs some memory allocation, which would be freed in intal\_destroy().

//The memory allocated by this function is pointed by the pointer it returns. The client has no idea

// what kind of object it is. It could be a pointer to char array, int array, long int array, double array, or

// a struct array. There is no theoretical limit to the size of the integer, but memory limitations of the

// process (Operating System). If the OS allows, your library should be able to hold the largest prime number

// known, which is 23,249,425 digits long (as of Feb 2018).

//Returns "null" is str is not representing a valid nonnegative integer. A "null" pointer

// represents a NaN (not a number).

void\* intal\_create(const char\* str);

//Destroy the created "object".

//It mainly frees the memory allocated by intal\_create().

//Returns doing nothing if the intal is null.

void intal\_destroy(void\* intal);

//Converts intal to a string of decimal digits for mostly display purpose.

//Returned string has most significant non-zero digit at the head of the string.

//Returns "NaN" if the intal is null.

char\* intal2str(void\* intal);

//Increments the integer by one and returns the incremented intal.

//In most cases, it'll return the same object. But in some cases, it may create a

// new object to accommodate the incremented value. In that case, this function

// destroys the older intal and returns the new one.

void\* intal\_increment(void\* intal);

//Decrements the integer by one and returns the decremented intal.

//No change if the intal is zero because it is nonnegative integer.

//In most cases, it'll return the same object. But in some cases, it may create a

// new object to accommodate the decremented value. In that case, this function

// destroys the older intal and returns the new one.

void\* intal\_decrement(void\* intal);

//Adds two intals and returns their sum.

void\* intal\_add(void\* intal1, void\* intal2);

//Returns the difference (obviously, nonnegative) of two intals.

void\* intal\_diff(void\* intal1, void\* intal2);

//Multiplies two intals and returns the product.

void\* intal\_multiply(void\* intal1, void\* intal2);

//Integer division

//Returns the integer part of the quotient of intal1/intal2.

//Returns "null" if intal2 is zero. A "null" pointer represents a NaN (not a number).

void\* intal\_divide(void\* intal1, void\* intal2);

//Returns -1, 0, +1

//Returns 0 when both are equal.

//Returns +1 when intal1 is greater, and -1 when intal2 is greater.

int intal\_compare(void\* intal1, void\* intal2);

//Returns intal1^intal2.

//It could be a really long integer for higher values of intal2.

//0^n = 0. where n is any intal.

void\* intal\_pow(void\* intal1, void\* intal2);

## Sample client file:

//A sample client for intal.h

//Expected output for this client:

/\*

First intal: 4999

Second intal: 2001

Two intals after increment and decrement:

5000

2000

Max of two intals: 5000

Sum: 7000

Diff: 3000

Product: 10000000

Quotient: 2

5000 ^ 2: 25000000

\*/

#include <stdio.h>

#include "intal.h"

int main(int argc, char const \*argv[]) {

char \*str1 = "4999";

char \*str2 = "2001";

void \*intal1;

void \*intal2;

void \*sum;

void \*diff;

void \*product;

void \*quotient;

void \*exp;

intal1 = intal\_create(str1); //4999

intal2 = intal\_create(str2); //2001

printf("First intal: %s\n", intal2str(intal1)); //4999

printf("Second intal: %s\n", intal2str(intal2)); //2001

intal1 = intal\_increment(intal1); //5000

intal2 = intal\_decrement(intal2); //2000

printf("Two intals after increment and decrement:\n");

printf("%s\n", intal2str(intal1)); //5000

printf("%s\n", intal2str(intal2)); //2000

printf("Max of two intals: %s\n", //5000

(intal\_compare(intal1, intal2) > 0) ? intal2str(intal1) : intal2str(intal2));

sum = intal\_add(intal1, intal2); //7000

printf("Sum: %s\n", intal2str(sum));

diff = intal\_diff(intal1, intal2); //3000

printf("Diff: %s\n", intal2str(diff));

product = intal\_multiply(intal1, intal2); //10000000

printf("Product: %s\n", intal2str(product));

quotient = intal\_divide(intal1, intal2); //2

printf("Quotient: %s\n", intal2str(quotient));

exp = intal\_pow(intal1, quotient); //5000^2 = 25000000

printf("%s ^ %s: %s\n", intal2str(intal1), intal2str(quotient), intal2str(exp));

//Make sure you destroy all the intals created.

intal\_destroy(sum);

intal\_destroy(diff);

intal\_destroy(product);

intal\_destroy(quotient);

intal\_destroy(exp);

intal\_destroy(intal1);

intal\_destroy(intal2);

return 0;

}