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INTAL - INTegers of Arbitrary Length

Project Description

The maximum limit of Unsigned Long Int in C/C++ is 18446744073709551615, a 20 digit number. While languages like C++/Java support classes of BigIntegers (100 digit numbers). C by default has no such support. This project aims to bring that support to the C language along with basic arithmetic operations like Comparison, Addition, Subtraction, and Multiplication along with applications such as Factorial, Fibonacci, etc.

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Project Language(s)

C

Difficulty

Intermediate

Duration

12 hours

Prerequisite(s)

Arrays, Basic Mathematics

Skills to be learned

C, Low-Level implementation of arithmetic operations, BigIntegers

Overview

Objective

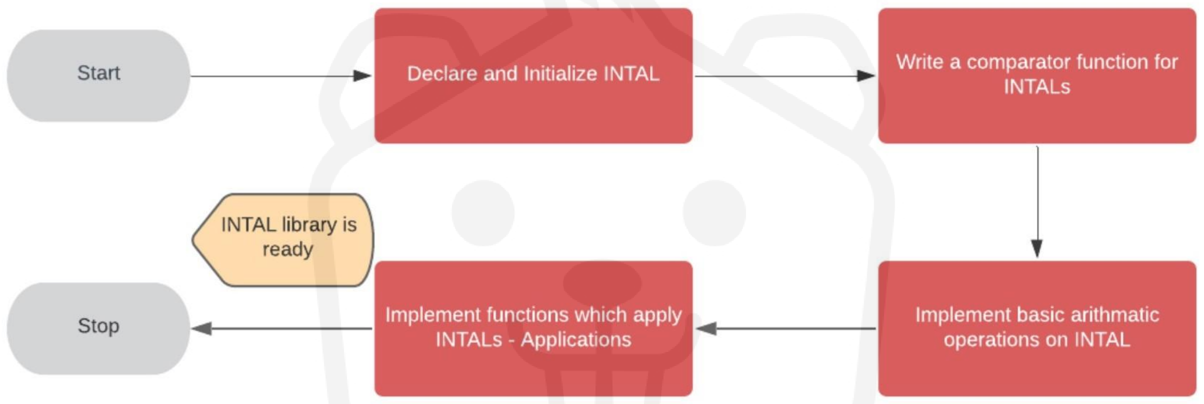
Add support for Big Integers (numbers greater than 18446744073709551615) in C along with basic mathematical operations and functions.

Project Context

Languages like C++/Java support classes like BigIntegers allowing developers to utilize numbers with up to 100 digits. INTAL aims to provide support up to 1000 digits in the C language along with basic mathematical operations (comparison, addition, subtraction, multiplication) and some mathematical functions (Fibonacci series, factorial).

Project Stages

The project consists of the following stages:


Start
Declare and Initialize INTAL
Write a comparator function for INTALs
Implement basic arithmatic operations on INTAL
Implement functions which apply INTALs - Applications
INTAL library is ready
Stop

High-Level Approach

- Write a function to declare and initialize INTALs
- Write a function to compare INTALs; returns equal, lesser than or greater than comparisons of inputted numbers.
- Implement basic arithmetic operations on INTAL: Addition, Subtraction, Multiplication
- Implement applications of INTAL: Fibonacci number, Factorial

Applications

- Calculate factorial of very large integers
- Calculate the very large nth Fibonacci number
- Calculate the binomial coefficient of very large numbers
- Perform binary exponentiation on very large numbers or raise numbers to very large powers
- Greatest Common Divisor

Task 1

Getting Started

Declare character arrays which are the data structure to be used to present INTALs and initialize elements to `0`.

Requirements

- You may assume all INTALs are at most 1000 digits long, hence using `malloc` function, declare a 1001 element character array. The 1 extra element will be for the null character `\0`.
- To avoid computing with garbage values, initialize all elements of the declared INTAL to `0`.
- The aforementioned guidelines can be treated as a single function which returns 1001 digit INTAL initialized with zeros. This will be useful later on when trying to instantly create an INTAL.

References

- Variable Declaration
- Arrays
- the for loop
- Dynamic memory allocation

Tip

- **Pseudo code**

```
//pseudo code
char* initializeINTAL()
startfunction
    //malloc syntax
    <datatype>* <pointer-name> =
(<datatype>*)malloc(n*sizeof(<datatype>);
    // n is number of pointers required
    for i = 0 to 1000
        do
            <pointer-name>[i] = '0'
        endfor
    <pointer-name>[1000] = '\0'
    return <pointer-name>
endfunction
```

Expected Outcome

You should have declared a function that takes no parameters and whose return type is `char*`. The function will create an INTAL, initialized to zero, and return it to the calling function.

Task 2

INTAL Comparator

Write a function that compares two INTALs.

Requirements

- Write a function that accepts two INTALs as function parameters and returns `0` or `-1` or `1` if both INTALs are equal or the first INTAL is lesser than the second INTAL or second INTAL is lesser than the first INTAL respectively.
- The function must run in O(n) time (complexity), where n is the number of digits in INTAL or the number of characters in the array.
- INTALs passed to the comparator may be of unequal length and should be kept in mind while determining which INTAL is greater.

References

- the for loop
- Comparator in C

Tip

- **Pseudo code**

```
//pseudo code
int compareINTAL(intal_a, intal_b)
startfunction
    //intal_a = {'1','2','3','\0'}, intal_b = {'2','3','\0'}
    if length of intal_a > length of intal_b
        return 1
    //intal_a = {'2','3','\0'}, intal_b = {'1','2','3','\0'}
    if length of intal_a < length of intal_b
        return -1
    i = length of intal_a
    //intal_a = {'2','2','3','\0'}, intal_b = {'1','2','3','\0'}
    // equal length INTAL
    while i > -1:
        if intal_a[i] > intal_b[i]:
            return 1
        if intal_a[i] < intal_b[i]:
            return -1
        i-=1
    // all characters are equal
    return 0
endfunction
```

Expected Outcome

Your function should be able to correctly identify the larger INTAL.

Task 3

INTAL Adder

Write a function that adds two INTALs and returns their sum.

Requirements

- Write a function that accepts two INTALs as function parameters and returns the sum of both INTALs.
- The function must run in O(n) time, where n is the number of digits in INTAL or the number of characters in the array.
- INTALs passed to the adder may be of unequal length and should be kept in mind while determining the sum of INTALs.
- Use the same concept of elementary mathematical addition for adding the INTALs, i.e., basically in case the ith element exceeds 9, a carryover needs to be made to the next element.
- Example:

```
A = {'9','9','9','\0'}
B = {'1','\0'}
Result = {'1','0','0','0','\0'}
```

- Try visualizing the Additions link provided in references.

References

- Additions
- the for loop

Tip

- **Trouble with logic?**
  - Compare both the INTALs and find the larger INTAL
  - Initialize result INTAL
  - Sum of each digit will be `intal_a[i] + intal_b[j] + carry - 96`, where `intal_a[i]` is the ith digit and `intal_b[j]` is the jth and `carry` is a flag in case there has been a carryover from the previous digit addition. Finally, you subtract 96 to get the numerical value.
  - `result[k]` will be `48 + numerical value obtained in previous step mod 10`
  - `carry` will be `sum divided by 10`
  - Repeat the process through the entire INTAL.
  - In case there is a carry at the end, initialize `result[k]` to `48+carry`

Expected Outcome

Your function should be able to do basic addition on the given INTALs and return the result.

Task 4

INTAL Subtractor

Write a function that subtracts two INTALs and returns their difference.

Requirements

- Write a function that accepts two INTALs as function parameters and returns the difference.
- The smaller INTAL must always be subtracted from the larger INTAL; so that the result INTAL is always greater than or equal to zero.
- The function must run in O(n) time, where n is the number of digits in INTAL or the number of characters in the array.

- Use the same concept of elementary mathematical subtraction, i.e., basically in case the ith element of the subtrahend exceeds the ith element of the minuend, use the concept of borrow from the neighboring element of the subtrahend. Keep borrowing until found.
- The result INTAL must not contain any preceding zeros in the result unless the result is zero in which case the INTAL can contain only 1 zero.
- Example:

```
A = {'1','0','0','0',''}
B = {'1',''}
Result = {'9','9','9',''}

A = {'1','0','0','0',''}

B = {'1','0','0','0',''}

Result = {'0',''}
```

References

- Subtraction terms
- Subtraction examples
- the for loop

Tip

- **Trouble with logic?**
    - Compare both the INTALs and find the larger INTAL
    - Initialize result INTAL to zero
    - Start by subtracting elements of the subtrahend by minuend if all elements are less than of the subtrahend.
    - When an element greater than the subtrahend is encountered, look for the element to the right which can donate. Once found subtract one from that element and add 9 to all intermediate elements. Add 10 the element in need of borrowing.
    - Repeat the above steps until all elements are subtracted.
    - Write a separate function to which you pass the result and remove any preceding zeros.

Expected Outcome

Your function should be able to do basic subtraction on the given INTALs and return the result.

Task 5

INTAL Multiplier

Write a function which multiplies two INTALs and returns their product.

Requirements

- Since our INTALs support a maximum of 1000 digits, the sum of digits of both multipliers must not exceed 1000.
- Write a function that accepts two INTALs as function parameters and returns the product.
- In case either of the INTALs is zero, return zero.
- In case either of the INTALs is 1, return the other INTAL.
- The function must run in O(n2) time, where n is the number of digits in INTAL
- We assume intal_b is smaller than intal_a, then perform a check and pass the larger INTAL to a helper function for multiplication as parameter 1 and smaller INTAL as parameter 2.
- Visualize the multiplication of 3 digit numbers to understand the implementation better. Refer to the multiplication video in references.

References

- Multiplication Video.
- The for loop

Tip

- **Pseudo Code**

```
char* multiplyINTAL(intal_a, intal_b):
startfunction
    initialize result
    if intal_a is zero or intal_a is one:
        copy intal_b to result
        return result
    if intal_b == 0 or intal_b is one:
        copy intal_a to result
        return result
    l2 = length of intal_b
```

```
        l1 = length of intal_a

    for i = l2-1 to 0:
    do
        sum = 0, carry = 0, ptr1 = 1
        ptr2 = l1+l2-ptr1
        for j = l1-1 to 0:
        do
            sum = (intal_a[j]-'0')*(intal_b[i]-'0') +
    (result[ptr2]-'0')+carry
            result[ptr2] = 48+sum%10
            carry = sum/10
            --ptr2
        endfor
        if carry:
            res[ptr2] += carry
        endif
    ++ptr1
    endfor
    return result
    endfunction
```

Expected Outcome

Your function should be able to do basic multiplication on the given INTALs and return the product. By the end of this milestone, you have a basic library of arithmetic functions for INTALs. The coming milestones apply most of the current implemented functions, so make sure you successfully implement these first.

Task 6

INTAL Fibonacci

Write a function that returns the nth Fibonacci INTAL.

Requirements

- Write a function to take an `unsigned int n` as a parameter and return the nth Fibonacci INTAL.
- Refer to the algorithm to compute the nth Fibonacci number. The only additional logic is required to deal with INTALs.
- Have 2 INTALs initialized to Zero and One respectively.
- Until n terms are generated, keep adding the previous 2 Fibonacci terms as is with the Fibonacci algorithm.
- It is recommended to compute the nth Fibonacci INTAL in **constant space** because computing all intermediate results and not reusing them may deplete system memory. Refer to Method 3 of Fibonacci in references. ### References
- Fibonacci
- The for loop

Tip

- **Pseudo Code**

```
char* FibonacciINTAL(unsigned int n):
startfunction
    initialize intal_a to zero
    if n is zero:
        return intal_a
    endif
    initialize intal_b to one:
    if n is one:
        free intal_a
        return intal_b
    endif
    initialize intal_temp to zero
    for i = 2 to n:
    do
        temp = addINTAL(intal_a, intal_b)
        free intal_a
        intal_a = intal_b
        intal_b = temp
    endfor
    free intal_a
    return intal_b
endfunction
```

Expected Outcome

Your function should return the nth Fibonacci INTAL. You should have your first working application of implementing INTALs in C.

Task 7

INTAL Factorial

Write a function that returns the factorial of that number.

Requirements

- Write a function to take an `unsigned int n` as a parameter and return the factorial represented as an INTAL.
- The concept of the factorial of a number remains unchanged. Your part is to incorporate INTAL computations into the algorithm.
- It is recommended to compute the factorial INTAL in **constant space** because computing all intermediate results and not reusing them may deplete system memory and take longer than expected.

References

- Factorial
- The for loop

Tip

- **Pseudo Code**

```
char* factorialINTAL(unsigned int n):
startfunction
    initialize intal_result to one
    if n is zero or one:
        return intal_result
    endif
    initialize intal_num to one
    create a temporary pointer temp
    for i = 2 to n:
    do
        temp = addINTAL(intal_num,"1")
        intal_num = temp
        temp = multiplyINTAL(intal_num, intal_result)
        free intal_result
        intal_result = temp
    endfor
    free intal_num
    return intal_result
endfunction
```

Bring it On!

To test your implementation of the above functions, refer to my Github repository INTAL, specifically the `intal_sampletest.c` file which contains a suite of test cases for the above-implemented functions. You may clone the repo and have to comment out some of the function calls in the file as they are not part of this project.

You can always modify my `intal_sampletest.c` with any other inputs you wish to test. The only limitation is that even most modern calculators switch to exponential format after a certain number of digits, giving approximated values for really large numbers. In such cases to build the test case, you can refer to this link. This is an example of addition but the website supports all operations done in this project.

Expected Outcome

Your function should return the factorial of the given input number. This milestone marks your second implemented application of INTAL. Feel free to explore the applications of INTAL in the domain of dynamic programming, such as finding the Greatest Common Divisor, etc.