

ASSIGNMENT DESIGN

Problem Statement

Write a MIPS Assembly Program for evaluating an expression in postfix format.

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COL216 - Assignment 1

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1 Approach and Design

1.1 Input - Output

- Source Code: **assignment_2.asm** takes input (postfix string) from the **keyboard** and prints the output on **console**.
- Tester Code: **tester.asm** takes input from the **Test Input text file** and prints output on **console**.
- **Integer registers** are used to store numbers and carry out arithmetic. Suitable **overflow** detection is done, whenever the computation exceeds the range of 32-bit signed integer. (error is generated by the code)
- **Maximum size** of character buffer is upper bounded at **159** characters. This also limits the total number of integers to 159. Hence, size of **stack** is initialized to **640** bytes (160 integers) as a safe upper bound.

1.2 Algorithm

- Input user string and store it in expression character buffer. Max length of buffer is, **n = 159**
- Initialize **Buffer_Counter** and **Array_Counter** to 0.
- **loop:**
 - . - If **Buffer_Counter** $\geq n$ then **Display_Result**, else load a character from `buffer[Buffer_Counter]`
 - . - If the character is a **Line Feed**, then **Display_Result**, else check if it is a valid character.
 - . If the character is a number, then store it in `stack[4*Array_Counter]`, and add 1 to **Array_Counter**.
 - . - If the character is an operator, then:
 - . - If the **Array_Counter** < 2 , then raise an error, as number of operators is more than or equal to the number of operands.
 - . - Else **pop** top two elements of the stack, and perform the required calculation. **Push** the result onto the stack and reduce **Array_Counter** by 1.
 - . If the character is some other character, then raise **invalid character** error.
 - . - Increment **Buffer_Counter** by 1.
 - . - **Jump** back to **loop**
- **Display_Result:**
 - . Check if the stack is containing a **single element** or not.
 - . If the stack is **not** containing only one element, then **raise error** as number of operators and operands are not balanced in the given expression.
 - . Else access the **top** element (result of postfix expression) of the stack and display it on the **console**.
- **Loop Invariant:** Before iteration **i**: I have processed the first **i - 1** characters of the postfix expression.
 - . $1 \leq i \leq \min(\text{length of expression} + 1, n + 1)$.

1.3 Design

1.3.1 Register

Integer Registers:

v0: used for making different syscalls

a0: used in making syscalls (outputting/inputting strings and integers)

a1: used in reading input string (buffer length)

t0: used to store the buffer counter (address of current character in buffer)

t1: used to store the number of elements in the array (stack)

t2: stores the integer counterpart of the character loaded from buffer (e.g. '0' - > 0)

t3: stores the character (byte) loaded from the expression buffer

t4: stores the array memory offset (to read/write to a particular address in array)

t5: stores the right operand while carrying out any computation

t6: stores the left operand while carrying out any computation

t7: temporarily stores the result of computation, and it is also used for making trivial comparisons

t8: used to detect overflow in case of multiplication

s0: stores ASCII code of 0 (48)

s1: stores ASCII code of 9 (57)

s2: stores ASCII code of * (42)

s3: stores ASCII code of + (43)

s4: stores ASCII code of - (45)

s5: stores ASCII code of \n (10)

s6: stores the offset factor for integers (4)

1.3.2 Main Memory

ASCII:

array used for implementing stack (max. 160 integers)

array: .space 640

character buffer used to store the input string

expression: .space 160

invalid character error

error_invalidChar: .asciiiz "\nERROR: There is an invalid character present in the expression.\nMake sure that the operands are in the range 0-9, and only +, - and * operators are used.\nProgram terminating!"

illegal expression error

error_illegalExp: .asciiiz "\nERROR: The number of operands and number of operators do not match.\nMake sure that the operands are in the range 0-9, and that for each operator exactly 2 operands are provided.\nProgram terminating!"

overflow error (integer overflow, over 32 bits)

error_overflow: .asciiiz "\nERROR: Arithmetic Overflow"

input message

msg_input: .asciiiz "Enter the postfix expression that needs to be evaluated: "

output message

msg_output: .asciiiz "\nThe value of the postfix expression is: "

separator and newline string

msg_separator: .asciiiz "\n \n-----\n\n"

msg_lf: .asciiiz "\n"

1.4 Raising Errors

- if **number of operators and operands** don't match we raise *Error: The number of operands and number of operators do not match. Make sure that the operands are in the range 0-9, and that for each operator exactly 2 operands are provided.*

- if an **invalid character** is entered we raise *Error: There is an invalid character present in the expression. Make sure that the operands are in the range 0-9, and only +, - and * operators are used.*

- if **no input** is provided then we raise *Error: The number of operands and number of operators do not*

match. Make sure that the operands are in the range 0-9, and that for each operator exactly 2 operands are provided.

- if there is **overflow in addition or subtraction** MIPS raises the *Error Arithmetic Overflow*.
- if there is **overflow in multiplication** we raise *Error: Arithmetic Overflow*.

2 Testing Strategy

- Total of **245** test cases were generated and tested against as a part our extensive testing strategy
- use *TestCaseGenerator.py* to generate **randomized** test case files with correct output.
- *tester.asm* reads file and prints output on console. We then copy it into a text file and run *Checker.py*.
- *Checker.py* calculates the difference and stores it in "Difference.txt"
- We store count of cases with 0 difference and total number of cases to calculate **accuracy**.

- Types of Test Cases Used:
 - . - **Single:** 10 cases with only single digit is provided and no operator.
 - . - **Add:** only + operator is used. 10 test cases each of varying size- Small: 5, Medium: 25 and Large: 50
 - . - **Sub:** only - operator is used. 10 test cases each of varying size - Small: 5, Medium: 25 and Large: 50
 - . - **Mul:** only * operator is used. 10 test cases each of varying size - Small: 5, Medium: 25 and Large: 50
 - . - **AddSub:** only + and - operator are used. 10 test cases of sizes - Small: 5, Medium: 25 and Large: 50
 - . - **SubMul:** only - and * operator are used. 10 test cases of sizes - Small: 5, Medium: 25 and Large: 50
 - . - **AddMul** only + and * operator are used. 10 test cases of sizes - Small: 5, Medium: 25 and Large: 50
 - . - **Mixed:** all operators used. 10 test cases of sizes - Small: 5, Medium: 25, Large: 50 and XLarge: 80
 - . - **Manual:** 8 manually generated cases for extensive testing
 - . - **Corner Cases:** 1. **No Input** 2. **Invalid Post-Order Input** 3. **Invalid Character** 4. **Overflow**

3 Result

We achieved a **100%** accuracy across all our test cases, with **0** difference in all outputs.

Console Interface -

```
Console
Enter the postfix expression that needs to be evaluated: 5
The value of the postfix expression is: 5

Enter the postfix expression that needs to be evaluated: 23+56*-
The value of the postfix expression is: -25

Enter the postfix expression that needs to be evaluated: 23&33*8++
ERROR: There is an invalid character present in the expression.
Make sure that the operands are in the range 0-9, and only +, - and * operators are used.
Program terminating!

Enter the postfix expression that needs to be evaluated: 33+33*
ERROR: The number of operands and number of operators do not match.
Make sure that the operands are in the range 0-9, and that for each operator exactly 2 operands are provided.
Program terminating!

Enter the postfix expression that needs to be evaluated: 34**
ERROR: The number of operands and number of operators do not match.
Make sure that the operands are in the range 0-9, and that for each operator exactly 2 operands are provided.
Program terminating!

Enter the postfix expression that needs to be evaluated:
ERROR: The number of operands and number of operators do not match.
Make sure that the operands are in the range 0-9, and that for each operator exactly 2 operands are provided.
Program terminating!
```