COMP.2030 – Assembly HW 3: Scanner **DUE: 10/7 (Wed) 11:59 PM**

Scanner collects a coherent set of characters and save it as logical unit, called a token. Scanner first reads a line from the console and stores characters into an **input buffer of maximum 80 characters** (getline()). Scanner then combines these characters based on character types into tokens.

Scanner puts the tokens into a table with two columns. This is our **Token Table** (or **`TabToken`**).

The first column saves the **assembled tokens of maximum 8 characters**.
The second column saves their **token types**.

At each stage, the variable TOKEN holds the token string as it is being assembled. The variable TokSpace, is initialized to 8, and is decremented each time a new character (byte) is appended to the current token in TOKEN.

Each entry in the token table has 12 bytes (8 bytes for a token, and 4 bytes for its type).

Token types are identical to character types used in HW 2, but do not include the blank char type any longer.

```
Token type 1 --  Number       : 0 1 .. 9
Token type 2 --  Variable     : Alphabet followed by alpha-numeric characters
Token type 3 --  Operator     : * + - /
Token type 4 --  Delimiter    : . ( ) , : $
Token type 5 --  End of Line  :  #
```

e.g. the input line below,

```
THISLOOP:   LWU   R2,63       #
```

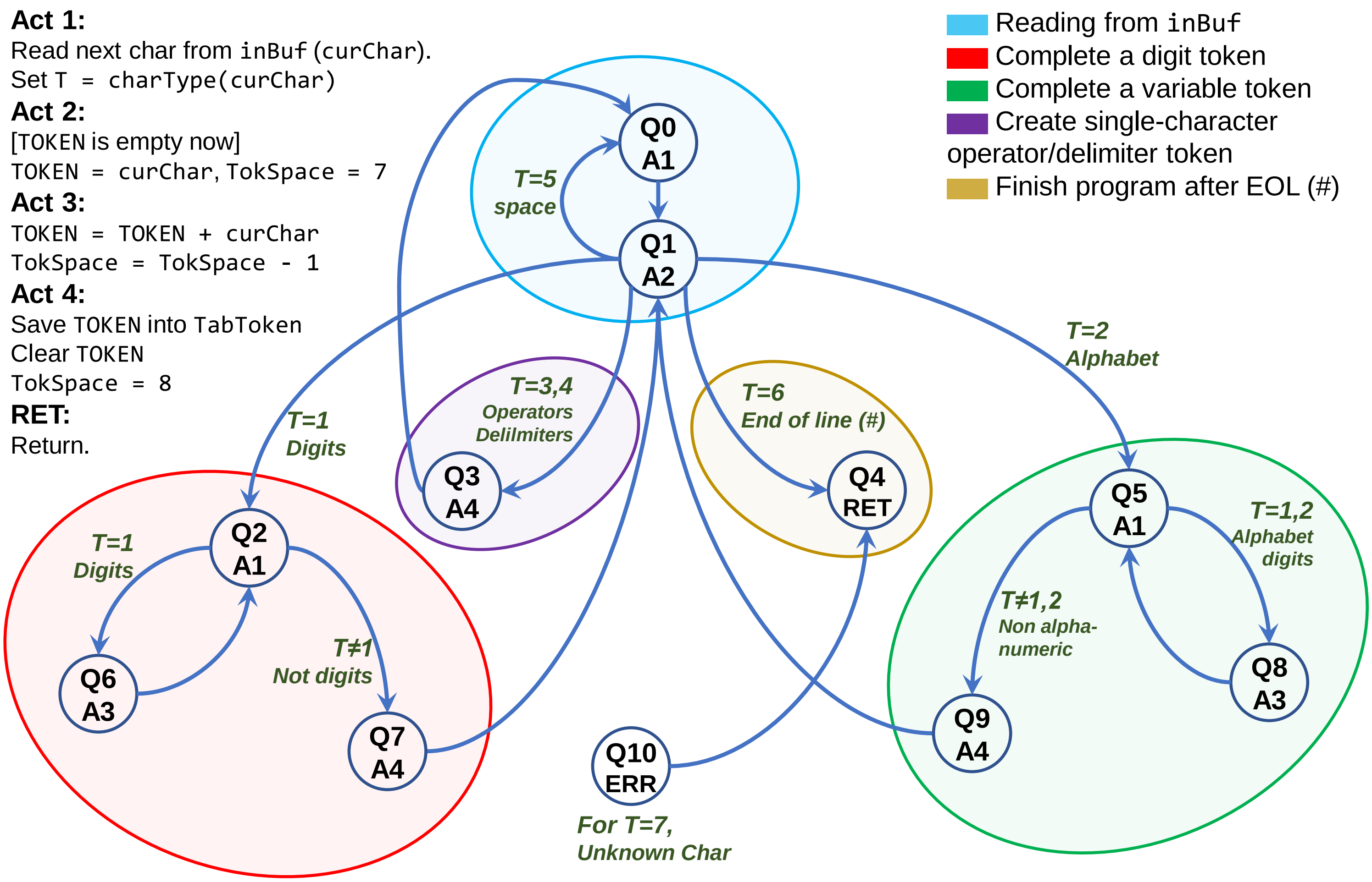
results in the following token table (table header may be skipped in the program).

```
Token             Token Type
----------------- ----------------
THISLOOP          2
:                 4
LWU               2
R2                2
,                 4
63                1
#                 5
```

For the `TabToken`, 20 entries of 3 words each (=12 bytes) should be sufficient. The same token table will be overwritten each time a new input line is processed.

The behavior of the Scanner can be described (defined) by a state (transition) diagram shown below. One could write a huge subroutine for the entire diagram. This results in a large monolithic program which may be quite difficult to debug. Furthermore, the approach locks the programmer to the specifics of the diagram and makes later modification difficult. It may, however, improve execution efficiency somewhat.

The approach we are going to take is more general, resulting in small, easily debuggable functions. We treat the diagram as a finite state automata. We simply encode the diagram into a state table and have Scanner simulate the finite automata. Namely, Scanner simply traces through the states in the diagram beginning in state Q0. At each state, Scanner calls the action subroutine associated with the state and then computes the next state to make a transition to based on the value of the variable T.



The state-diagram table for our Scanner Program.

The same information specified through the state transition diagram of a state automation can be expressed in a tabular form.

STATE	ACT	T = 1	T = 2	T = 3	T = 4	T = 5	T = 6	T = 7
Q0	ACT1	Q1	Q1	Q1	Q1	Q1	Q1	Q10
Q1	ACT2	Q2	Q5	Q3	Q3	Q0	Q4	Q10
Q2	ACT1	Q6	Q7	Q7	Q7	Q7	Q7	Q10
Q3	ACT4	Q0	Q0	Q0	Q0	Q0	Q0	Q10
Q4	RET	Q4	Q4	Q4	Q4	Q4	Q4	Q10
Q5	ACT1	Q8	Q8	Q9	Q9	Q9	Q9	Q10
Q6	ACT3	Q2	Q2	Q2	Q2	Q2	Q2	Q10
Q7	ACT4	Q1	Q1	Q1	Q1	Q1	Q1	Q10
Q8	ACT3	Q5	Q5	Q5	Q5	Q5	Q5	Q10
Q9	ACT4	Q1	Q1	Q1	Q1	Q1	Q1	Q10

The value of variable T will be dependent upon the type of each character on the line according to the character types used in HW 2 (**not** to be confused with token types, although similar):

```
Characters        Type        Comment
----------        ------      -------------
01..9             1           Digits
AB..Z ab..z       2           Letters
* + - /           3           Operators
. ( ) , :         4           Delimiters
blank             5           blank
#                 6           End of the Line
```

The state transition table can be constructed as follows:

```
Q0:         .word       ACT1
            .word       Q1          # T=1
            .word       Q1          # T=2
            .word       Q1          # T=3
            .word       Q1          # T=4
            .word       Q1          # T=5
            .word       Q1          # T=6
            .word       Q11         # T=7
Q1:         .word       ACT2, Q2, Q5, ….
            ….
```

The algorithm for tracing through the states and a section of the state table are given below. CUR holds the current state and T has the current value of character type.

```
Scanner Algorithm

      1)    Call getLine
      2)    CUR = Q0;   T=1
      3)    ACT = STAB[CUR][0]

            CALL ACT

      4)    CUR = STAB[CUR][T]
      5)    GO TO 3
```

Use \$s0 and \$s1 to hold the value of T and CUR, respectively. Steps 2 through 4 can be coded in MIPS as follows:

```
            la    $s1, Q0
            li    $s0, 1
nextState:  lw    $s2, 0($s1)
            jalr  $v1, $s2          # Save return addr in $v1
            sll   $s0, $s0, 2       # Multiply by 4 for word boundary
            add   $s1, $s1, $s0
            sra   $s0, $s0, 2
            lw    $s1, 0($s1)
            b     nextState
```

In this assignment, you need to write four short functions (ACT1, ACT2, ACT3 and ACT4) and include the following state table, STAB, in the data section. You are free to handle ERROR function.

Notes:

- Instead of attempting to print the token table, it is easier to copy each entry of the token table into a separate outBuf. The outBuf has to have the last byte of the third word of a token (the word for the token type) set to '\n' to force the printer to move to the next line.
- At the same time, printing stops as soon as a byte in the outBuf has Null (0x00). Therefore, outBuf has to be (re-)initialized all ' ' (blank, 0x20) with the last byte to '\n.'

- State-table reference to be put in the data section of the code:

```
STAB:
Q0:     .word  ACT1
        .word  Q1   # T1
        .word  Q1   # T2
        .word  Q1   # T3
        .word  Q1   # T4
        .word  Q1   # T5
        .word  Q1   # T6
        .word  Q11  # T7

Q1:     .word  ACT2
        .word  Q2   # T1
        .word  Q5   # T2
        .word  Q3   # T3
        .word  Q3   # T4
        .word  Q0   # T5
        .word  Q4   # T6
        .word  Q11  # T7

Q2:     .word  ACT1
        .word  Q6   # T1
        .word  Q7   # T2
        .word  Q7   # T3
        .word  Q7   # T4
        .word  Q7   # T5
        .word  Q7   # T6
        .word  Q11  # T7

Q3:     .word  ACT4
        .word  Q0   # T1
        .word  Q0   # T2
        .word  Q0   # T3
        .word  Q0   # T4
        .word  Q0   # T5
        .word  Q0   # T6
        .word  Q11  # T7

Q4:     .word  ACT4
        .word  Q10  # T1
        .word  Q10  # T2
        .word  Q10  # T3
        .word  Q10  # T4
        .word  Q10  # T5
        .word  Q10  # T6
        .word  Q11  # T7

Q5:     .word  ACT1
        .word  Q8   # T1
        .word  Q8   # T2
        .word  Q9   # T3
        .word  Q9   # T4
        .word  Q9   # T5
        .word  Q9   # T6
        .word  Q11  # T7

Q6:     .word  ACT3
        .word  Q2   # T1
        .word  Q2   # T2
        .word  Q2   # T3
        .word  Q2   # T4
        .word  Q2   # T5
        .word  Q2   # T6
        .word  Q11  # T7

Q7:     .word  ACT4
        .word  Q1   # T1
        .word  Q1   # T2
        .word  Q1   # T3
        .word  Q1   # T4
        .word  Q1   # T5
        .word  Q1   # T6
        .word  Q11  # T7

Q8:     .word  ACT3
        .word  Q5   # T1
        .word  Q5   # T2
        .word  Q5   # T3
        .word  Q5   # T4
        .word  Q5   # T5
        .word  Q5   # T6
        .word  Q11  # T7

Q9:     .word  ACT4
        .word  Q1  # T1
        .word  Q1  # T2
        .word  Q1  # T3
        .word  Q1  # T4
        .word  Q1  # T5
        .word  Q1  # T6
        .word  Q11 # T7

Q10:   .word  RETURN
        .word  Q10  # T1
        .word  Q10  # T2
        .word  Q10  # T3
        .word  Q10  # T4
        .word  Q10  # T5
        .word  Q10  # T6
        .word  Q11  # T7

Q11:    .word  ERROR
       .word  Q4  # T1
       .word  Q4  # T2
       .word  Q4  # T3
       .word  Q4  # T4
       .word  Q4  # T5
       .word  Q4  # T6
       .word  Q4  # T7
```