Term Project

CS 154: Formal Languages and Computability
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Objective

To **simulate** a simple microprocessor called **AYS17** by a **triple-tape Turing machine**.

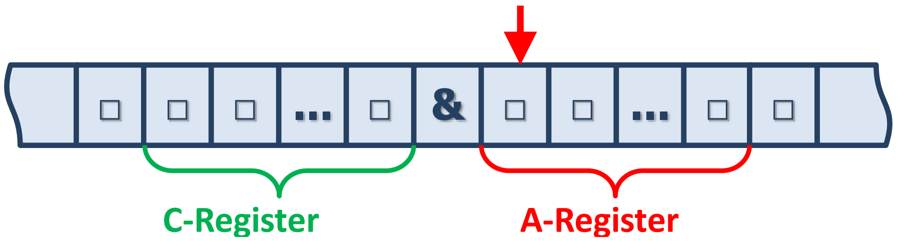
AYS17 Structure

AYS17 has four registers called **A, B, C, and D**. A-register (AR for short) is called "**accumulator**" because the results of all arithmetic operations go to AR.

These four registers can be simulated on the second and third tapes of the TM.

At startup, your machine initializes tape 2 and 3 with a symbol such as '&' to be the separator between two registers.

The following figure shows a possible implementation of two registers A and C on tape 2.



Registers B and D should be similarly implemented on tape 3.

The contents of AR and BR are the **output** of the programs. Therefore, they should be implemented in such a way that at the end of the program, their contents be shown appropriately.

AYS17 runs the programs from tape 1. The format of the programs, that should be encoded in a string, will be explained in the next sections.

Numbers

- All **numerical values** are prefixed with '$' and are represented in "unary notation".
- Negative numbers are prefixed with '$-'.
- There is NO limitation for the magnitude of the numbers!

Numbers Examples

AYS17 Representation	**Decimal Equivalent**
$	**zero**
$11	2
$11111	5
$-1	-1
$-111	-3
$-	error
11	error
$1A11	error
-$11	error

Assembly Language of AYS17

AYS17 has **nine distinct instructions** as the following table shows.

The values of X and Y might be: X ∈ {A, B, C, D}; Y ∈ {A, B, C, D, $NUM, NUM}

Mnemonic	**Meaning**	**Description**
LD X, Y	Load	Loads X register with Y. Y can be another register or a numerical value.
INC X	Increment	Increments the content of the register X by one
DEC X	Decrement	Decrements the content of the register X by one
ADD X	Add	Adds the operand X with the content of AR
SUB X	Subtract	Subtracts the operand X from the content of AR
JNZ X, L	Jump if not zero	Jumps to the label L if the content of the register X is **not zero** (can be positive or negative numbers)
JNG X, L	Jump if negative	Jumps to the label L if the content of the register X is **negative**
JMP L	Jump	Jumps unconditionally to the label L
HLT	Halt	Halts and prepares the appropriate outputs on AR and BR. All programs **should end** with HLT.

Note that we use **decimal numbers** prefixed with '$' (e.g. $13) when we write **assembly program** but we translate them into unary notation when we assemble the program to create object code.

For an example, refer to "Programming by AYS17" section.

Instructions Syntax

Syntax: **[label] operation operand1, operand2**

Syntax: **[label] operation operand1**

Syntax: **[label] operation**

The instructions of AYS17 have zero, one, or two operands and can be **optionally** preceded with a **unique** numerical label.

A label is **required** if the instruction is the destination of a jump instruction. If the required label is not provided, or if it is not unique or if it is not valid, then the behavior of the machine won't be predictable. Therefore, it is **AYS17 programmers'** responsibility to check the existence, validity, and uniqueness of the labels, **not you** as the implementer.

In general, an instruction may have 4 parts:

- **label**: is a **unique** positive, non-zero unary number without '$'
- **operation**: is an operation from the table mentioned in "assembly language of AYS17" section.
- **operand**: can be registers' letters (i.e. A, B, C, D), a numerical value, or a label.
  If it is a numerical value, we prefix it with '$' as described in "Numbers" section.
  If it is a label, for jump instructions, it does not need '$'.
  We represent numerical values with decimal notation prefixed with '$' when we write assembly programs but labels don't need to be prefixed with '$'.

Instructions Examples

Instruction	**Description**
3 HLT	Halts and shows the content of AR and BR
8 ADD $-2	Adds the negative number -2 with the content of AR
SUB $3	Subtracts the number 3 from the content of AR
5 JMP 8	Jumps to the instruction that is labeled by 2.

Assembly Codes of Instructions

In the following tables, the values of X and Y might be:

X ∊ {A, B, C, D}; Y ∊ {A, B, C, D, $NUM, NUM}

Load Operations

	A	**B**	**C**	**D**	**V**alue
LD A, Y	-	LAB	LAC	LAD	LAV
LD B, Y	LBA	-	LBC	LBD	LBV
LD C, Y	LCA	LCB	-	LCD	LCV
LD D, Y	LDA	LDB	LDC	-	LDV

Arithmetic Operations

	A	**B**	**C**	**D**	**V**alue
INC X	IA	IB	IC	ID	-
DEC X	DA	DB	DC	DD	-
ADD Y	-	AB	AC	AD	AV
SUB Y	-	SB	SC	SD	SV

Control Operations

	A	**B**	**C**	**D**	**L**abel
JNZ X, L	ZA	ZB	ZC	ZD	
JNG X, L	NA	NB	NC	ND	
JMP L	-	-	-	-	J
HLT	-	-	-	-	H

AYS17 has **9 distinct instructions** that can be written in **42 different forms**.

Programming by AYS17

We write the programs in assembly language. Then we encode the assembly program by the assembly codes provided in "assembly codes of instructions" section.

We input the encoded program, that is one string, on **tape 1** of AYS17.

The following is a simple assembly language program along with its assembly encoded string.

Example

Write a program to add up numbers 1 to 10.

```
    LD B, $10      ; Loads BR with positive integer 10
2   ADD B          ; Adds BR with the content of AR and puts the result in AR
    DEC B          ; Decrements the content of BR
    JNZ B, 2       ; Checks the content of BR and jumps to label 2 (ADD B) if BR is not zero
    HLT            : Halts and prepares the content of AR to show it correctly in JFLAP
```

Now let's assemble this program.

Encoding Assembly Programs

The object codes of all instructions are prefixed with '**#**' as the instructions separator.

Example (cont'd)

Instructions	**Assembly Codes**
LD B, $10	#LBV$1111111111
2 ADD B	#11AB
DEC B	#DB
JNZ B, 2	#ZB11
HLT	#H

All parts of the instructions codes are concatenated and there is **NO space** between them. Therefore, the object code of the above program that should be put on tape 1 is:

#LBV$1111111111#11AB#DB#ZB11#H

Technical Notes

1. The **output** of the program should go to AR and BR that are located on **tape 2 and 3**. The content of **tape 1 should be blank** at the end of a valid program.
2. This version of AYS17 is for numerical operations and it cannot process strings.
3. You might use "S" (= stay option), variable assignments, and special characters such as '!' and '~' of JFLAP. For more information, refer to the JFLAP's documentations and tutorials. (note: JFLAP does not support "block feature" when using multiple-tape!)
4. In JFLAP preferences → Turing Machine Preferences: uncheck "Accept by Halting" and check the rest before writing and testing your code.
5. Test your Turing machine as a transducer.
6. The look of the design is important for debugging purpose. Therefore, organize your design in such a way that it shows different modules clearly. Also, document very briefly your design by using JFLAP notes on the TM design page.

Rubrics

- I'll test your design with 4 programs and you'll get +50 for every success pass (**200 points**).
- If your code is not valid (e.g. there is no initial state, it is implemented by JFLAP 8, or so forth) you'll get 0 but you'd have chance to resubmit it with -20% penalty.
- You'll get -10 for wrong filename!
- Note that if you resubmit your assignment several times, Canvas adds a number at the end of your file name. I won't consider that number as the file name.

What you submit?

1. Design and test your program by JFLAP
2. Save it as: Team_Name.jff
   (e.g.: SJSUAwesome.jff)
3. Upload it in the Canvas before the due date.

General Notes

- This is a team-based project.
- Teams can share "**test programs**" via Canvas discussion.
- For late submission policy, please read the greensheet.
- Always read the requirements at least 10 times! It is unacceptable if an engineer is not accurate enough.
- If there is any question or concern, please open a discussion in Canvas.