Term Project

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CS 154: Formal Languages and Computability
Fall 2019

***"A good developer always reads the requirements at least 10 times!** Ahmad Y"*

Objective

To design and implement a **Universal Turing Machine (UTM)**[1] that simulates running any arbitrary FIFOA (**first in-first out automata**) against any arbitrary string w over Σ.

You can find FIFAOs description in the "**Canvas -> Files/Project** " folder.

Before Starting

Before implementing this project, you are highly recommended to **see the last year term project** that was simulating DPDAs by a TM.

All you'd need are zipped in "**PreviousSelectedProj.zip**" file that is uploaded in "**Canvas -> Files/Project** " folder.

This file contains:

1. Term project requirements
2. A selected implementation done by a team
3. Test data
4. **A version of JFLAP that I compiled from JFLAP source code for testing big TMs**. Please note that this version is only **compatible with JAVA 8**.

The zip file is compressed by 7-zip and it is not compatible with Windows built-in compressed program. Mac users need to find an equivalent program to 7-zip.

Please note that, to understand the design, you'd need to know about the concept of "**block**" (aka module) and some JFLAP's special characters such as '**!**' (=NOT) and '**~**' (=WHATEVER).

Project Description

You are going to design and implement a "Universal Turing Machine (UTM)" whose input is the definition of an arbitrary FIFOA called M and an arbitrary input string of M, called w.

The UTM inputs w to M and simulates M's entire operations against w until M halts. Then it shows **A** if M halts in an accepting state (= accepts w), or **R** if M halts in a non-accepting state (= rejects w).

[1] Universal Turing Machine (UTM) is a TM that simulates other TMs but here we are using it as a general name for a TM that simulates any other objects such as other machines like FIFOAs.

How can we put a FIFOA's definition on the tape of UTM?

As we know, the input of TMs (and other automata) are strings. Therefore, we need to describe M by a string.

Describing any kind of objects as a string is called "encoding". There are many ways to encode automata and we engaged one of them that will be explained in the next section.

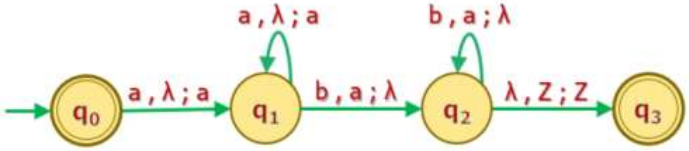
This idea of encoding can be extended to other data structures such as trees, graphs, matrices, functions, and so forth.

Encoding FIFOAs

We'd better to explain the whole process through an example.

Example

Let M be the following FIFOA and let w = ab.



As we learned, M can be defined mathematically by the septuple M = (Q, Σ, Γ, δ, q_0, Z, F), where:

Q = {q_0, q_1, q_2, q_3}, Σ = {a, b}, Z is the special symbol called Queue's start symbol, Γ = {Z, a, b}, q_0 = q_0, F = {q_0, q_3}, and the transition function δ is:

δ (q_0, a, λ) = (q_1, a)

δ (q_1, a, λ) = (q_1, a)

δ (q_1, b, a) = (q_2, λ)

δ (q_2, b, a) = (q_2, λ)

δ (q_2, λ, Z) = (q_3, Z)

We shall encode all elements of M and w by **unary numbers** as follows:

Q = {q_0, q_1, q_2, q_3}

The first element of Q is encoded as 1, the second one as 11, and so forth.
So, the encoded value of Q for this example would be: Q = {1, 11, 111, 1111}

q_0

We always put the **initial state as the first element of Q**.
So, q_0 (e.g. q_0 in this example) is **always** encoded as 1.

Σ = {a, b}

The first element of Σ is encoded as 1, the second one as 11 and so forth.
So, the encoded value of Σ for this example would be: Σ = {1, 11}.

Γ = {Z, a, b}

The first element of Γ is encoded as 1, the second one as 11 and so forth.
So, the encoded value of Γ for this example would be: Γ = {1, 11, 111}.

Notes for Γ and Σ

1. Since Z is always a member of Γ, so, **we put it always as the first element of Γ** and we encode it as 1.
2. Γ and Σ are encoded independently even though they have common symbols. For example, 'a' is encoded as 1 for Σ but is encoded as 11 for Γ.
3. There is another symbol that belongs to neither Σ nor Γ and that is **λ**.
   For simplicity, **we encode it as** '**m**'.

F = {q_0, q_3}

The elements of the set of final states are encoded by using the same codes of Q.
So, the encoded value of F for this example would be F = {1, 1111}.

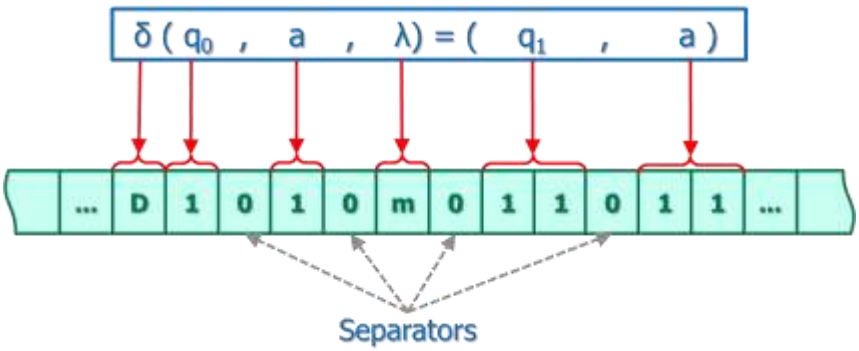
δ (q_i, a, x) = (q_j, u)

We encode **u ∈ Γ*** by using the codes of Γ and delimit the symbols by **0** (zero).

For example, if u = abb, then it would be encoded as: 11**0**111**0**111

The other elements of sub-rules are encoded by the codes of Q, Σ, and Γ and are formatted as the following figure shows.

We use **0** (zero) as the delimiter.



Note that in this example, $q_1 \in Q$, $b \in \Sigma$, and $a \in \Gamma$, all have the same code (i.e. 11), but **their locations in the string give them different meaning**.

The following table shows the encoded values of all sub-rules of this example.

Sub-Rule	Encode String
$\delta (q_0, a, \lambda) = (q_1, a)$	D1010m011011
$\delta (q_1, a, \lambda) = (q_1, a)$	D11010m011011
$\delta (q_1, b, a) = (q_2, \lambda)$	D11011011011110m
$\delta (q_2, b, a) = (q_2, \lambda)$	D111011011011110m
$\delta (q_2, \lambda, Z) = (q_3, Z)$	D1110m010111101

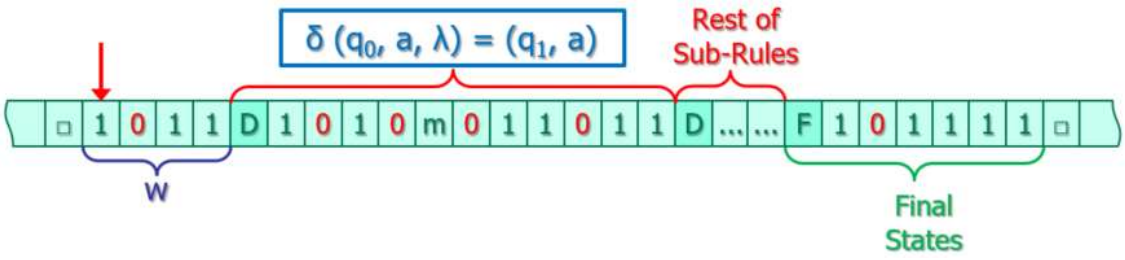
Encoding M's Input String w

The symbols of the w (w = ab in this example) are encoded by the codes of Σ and are delimited by **0** (zero). For example, w = **ab** is encoded as **1011**.

Encoded M and w On UTM's Tape

Now, we put all together and construct the UTM's input string that contains the M's description and its input string w.

The following figure shows partially encoded values of M and w, on UTM's tape. In fact, this string would be the UTM's input string.



Encoding Notes

1. The order of the elements of Q does not matter. The **only restriction**, as we mentioned earlier, is the first element of Q that must be always M's initial state q_0 that must be encoded as 1.
2. The **order of the elements of Γ and Σ does not matter**. The **only restriction**, as we mentioned earlier, is the first element of Γ that must be Z and is encoded as 1.

3. The **order of sub-rules does not matter**.
4. There might be zero, one or more final states. In the case of zero, there is only blank after F. In the case of more than one, the encoded Q's of the F are separated by **0** (zero) and **their order does not matter**.
5. If w, the input string of M, is **λ**, then nothing will be put in the w place. In that case, the UTM's input string starts with **D** of the first sub-rule.

If we apply above rules, the UTM's input string for this example would be:

1011D1010m011011D11010m011011D11011011011110mD11101101101110mD1110m010111101F101111

And as usual, when the UTM starts, the cursor is located on the first symbol of the string.

Your UTM is supposed to use this string and run M against w and show the appropriate output.

Note that what we explained was just an example. **Your UTM should be able to run any arbitrary FIFOA against any legal w**.

UTM's Output

If M accepts w, the UTM shows **A** and if it rejects w, the UTM shows **R**.
For the given M and w of our example, your UTM should show **A**.

Please refer to my lecture notes and/or JFLAP's documents for **how JFLAP shows outputs**.

Technical Notes

1. **We assume that the input string of UTM is 100% correct.** It means, M and w are encoded and formatted correctly. Therefore, **your UTM is not supposed to have any error detection and/or error reporting**.
2. **You are required** to use "block" feature of JFLAP. This feature is located in "**Turing Machine with Building Blocks**" button of JFLAP.
3. You are going to design your UTM with a **single-tape TM**.
4. Test your UTM in **transducer** mode of JFLAP.
5. Organize your design in such a way that it shows different blocks (aka modules) clearly. Also, document very briefly your design by using **JFLAP's notes**.
   These are for maintainability purpose only and **do NOT affect your grade**.

JFLAP Notes

1. Be careful when you work with JFLAP's block feature. **It is a buggy** software, **especially when editing and saving a block inside another block**. So, always have a backup of your current work before modifying it. For more information about this, please refer to the section "working with JFLAP" of this document.
2. Before implementing and testing your code, **make the following changes in JFLAP's preferences**:
   In the Turing Machine Preferences: uncheck "Accept by Halting" and check the other options. JFLAP creates the XML file jflapPreferences.xml in the folder where you ran JFLAP.
3. You are highly recommended to use **extra features of JFLAP** such as:
   '**S**' (stay option), and JFLAP's special characters '**!**' and '**~**'.
   These are great features that tremendously facilitate the design process and make your life easier.
   For more information, please refer to the JFLAP's documentations and tutorials.

What You Submit

1. Design and test your program by the provided JFLAP in Canvas. Note that **your final submission is only one file**.
2. Save it as: **Team**_CourseSection_TeamNumber.jff
   (e.g.: Team_2_5.jff is for team number 5 in section 2. The word "**Team**" is constant for all teams.)
3. Upload it in the Canvas before the due date.
4. **One submission per team is enough.**

Rubrics

- I'll test your design with 20 test cases (different FIFOAs against different input strings) and you'll get +10 for every success pass (**200 points total**).
- If your code is not valid (e.g. there is no initial state, it is implemented by JFLAP 7.0, 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 project several times, Canvas adds a number at the end of your file name. **I won't consider that number as the file name**.

General Notes

1. **Always read the requirements at least 10 times!** An inaccurate developer is unacceptable!
2. **Always set the due date for your team 3-5 days before the official due date**.
3. After submitting your work, always download it and test it to make sure that the process of submission was fine.
4. This is a **team-based project**. So, the members of a team can share all information about the project, but you are **NOT allowed to share** the solution with other teams.
5. The only info that you can share with other teams is your test cases via Canvas discussion. **I might use them for grading If your test cases are good and tricky!**
6. Always make sure that you have the latest version of this document. Sometimes, based on your questions and feedback, I need to add some **clarifications**. If there is a new version, it will be announced via Canvas.
7. For **late submission policy**, please refer to the Greensheet.
8. If you have **any issue with your teammates**, you need to talk to me at the beginning of the project. At the end, **no excuse will be accepted**.
9. Again, this is a team-based project. Therefore, **the whole team get one grade** regardless of who did what. It's the **teams' leaders' responsibility** to fairly distribute the tasks between the teammates.
   This will be a very **bad and unacceptable behavior** if at the end, a student tells me he/she did all tasks and would expect extra credit!
10. If there is any ambiguity, question, and/or concern, **please open a discussion in Canvas**.

Working with JFLAP

- Always have separate file for each block (aka module).
- If block A has a problem and you need to modify it, change its original file and save it. Then, if block B is using block A, you need to re-inject block A in the block B and save B again.
- Be careful about these procedures and always have a working backup of every blocks. It would be safer if you can use a **version control** for this project.

Hints about Teams

The roles you'd need for your team:

1. Project manager
    a. Breaking down the whole project into smaller activities and tasks
    b. Scheduling activities and tasks
    c. Controlling the schedule and making sure that the project is on track.
2. Architect
    a. Designing the top level of the modules
    b. Integrating the modules and testing
3. Developer
    a. Breaking down the top-level modules into lower level
    b. Implementing and unit-testing the smaller modules
    c. Integrating the smaller modules into higher level modules and integration-testing
4. Tester
    a. Testing every module and trying to break them
    b. Testing the entire project

Everybody needs to have one role but note that everybody should have the role developer as well. In other words, everybody should pick at least one role plus developing.