

Automata and LogicEngineering 1/2

ALE1/ALE2 Report

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| Version 2.0  ALE2 Report |
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# Introduction

I chose to work with C#, since I used it for my previous project for ALE1 and so I can follow similar principles for my code structure. I also feel the most comfortable using Visual Studio and building a Windows Forms application as I’m familiar with the GUI toolset and IDE.

# Parse & Check DFA

## Process

### parse

First, I needed to parse the values given from a text file, by creating objects to hold them to follow an object-oriented structure.

The simple type of text files looks like this:

Graphical user interface

Description automatically generated with medium confidence**Alphabet**: The ‘language’ indicating the letters within it

**States**: All the states involved in the graph

**Final:** All the states that are final/accepting states

**Transitions:** All the transitions involved in the graph

Example: **q0, a --> q1**

**- q0** 🡪 State **from** where the transition **starts**

**- a** 🡪 **label/value** of the transition

**- q1** 🡪 State **to** where the transition goes

**DFA:** Indicates whether the graph is a DFA (y = yes, n = no)

**Finite:** Indicates whether the graph is finite (y = yes, n = no)

**Words:** Lists words to run through the system along with whether they are accepted (y = yes, n = no)

Therefore, I created the following object classes to represent the **Graph**, its **states** and **transitions,** shown in the figures below.

Text

Description automatically generated

Figure 1. Source code of Graph object and its properties

A screenshot of a computer

Description automatically generated with medium confidenceText

Description automatically generated

Figure 2. Source code of State and Transition objects and their properties

Before parsing, the file needs to be read, preferably by letting the user browse a file from a file explorer dialog to get the path, and then use the IO library to read all the lines of the text file:

 A screenshot of a computer

Description automatically generated with medium confidence

Figure 3. Button which opens a File Explorer dialog box to access a file to parse

Next, the graph would host the operations for parsing the file into the objects with the following method in pseudo:

public string ParseDefaultFile(string[] contents) {

// foreach **line** in the text file

// if line starts with ‘#’, ignore it (it’s a comment)

// if line starts with **alphabet**

// save the alphabet string to the corresponding string property of the Graph object (GO)

// if line starts with **states**

// initialize a string array and store each state separating the line based on the ‘,’ char

// foreach state name in the string array

// create a State object (SO) with the state name as the label, that it is not a final state, and pass null for transitions which will automatically initialize a new list of transitions

// Add the SO to the GO’s list of states

// if line starts with **final**

// initialize a string array and store each state separating the line based on the ‘,’ char

// foreach state name in the string array

// if the name matches a state label in the state list, set that state’s isFinal property to true

// if line starts with **transitions**

// for every line in the file’s lines starting from the next line

// if it is equal to ‘end’, break the loop

// split the line’s contents:

// Based on ‘,’ = Gets FROM state

// Based on ‘,’ and ‘-->’ = Gets VALUE

// Based on ‘,’ and ‘-->’ = Gets TO state

// Create SOs for the from/to states to create a Transition object (TO)

// Add the TO to the Transition list of the GO

// if line starts with **dfa**

// Store bool value based on the line split by ‘:’, true for ‘y’ and false for ‘n’ for the file

// Call to method that will check from parsed values if graph is a DFA and store the bool value

// if the file and the method have the same truth value, indicate it on the GUI

[continue in next page…]

Figure 4. Pseudo-code for Parsing a default text file (Part 1)

[…continued]

// if line starts with **finite**

// Store bool value based on the line split by ‘:’, true for ‘y’ and false for ‘n’ for the file

// Call to method that will check from parsed values if graph is Finite and store the bool value

// if the file and the method have the same truth value, indicate it on the GUI

// if line starts with **words**

// for every line in the file’s lines starting from the next line

// if it is equal to ‘end’, break the loop

// Split the line based on ‘,’ and store the word as a key

in the GO’s string dictionary of words along with its truth value

// Return a method which returns a string in DOT format (for Graphviz) based on the parsed states and transitions

}

Figure 5. Pseudo-code for Parsing a default text file (Part 2)

And this is the method that creats a DOT string for the parsed values:

Text

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Figure 6. Method that returns a string in Graphviz DOT format, based on the parsed values.

### Check DFA

To check whether a graph is a DFA, it needs to follow these conditions:

* No empty characters
* Has an outgoing transition with every letter in the alphabet

Text

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Figure 7. Source code for checking DFA.

First, we check if any transitions have an empty label. Then we get each letter from the alphabet uniquely and then check if there are any states with a number of outgoing transitions that is **not equals** to the number of unique letters.

If either of these conditions is true, then the graph is NOT a DFA.

## Working Results

### Parse

Using the debug output from C# diagnostics library, I was able to display and check the parsed values:

Graphical user interface, text

Description automatically generatedText

Description automatically generatedText

Description automatically generated

Figure 8. Debugging parsed values, showing textfile contents and the DOT format equivalent.

Diagram

Description automatically generated

Figure 9. Successfully displaying graph using Graphviz.

### Check DFA

The figures below show the GUI showing a ‘tick’ or an ‘x’ when a graph is a DFA or not respectively, and have a gray background if the file is wrong.

**Figure 10. a DFA graph and showing whether it is one in the GUI.**

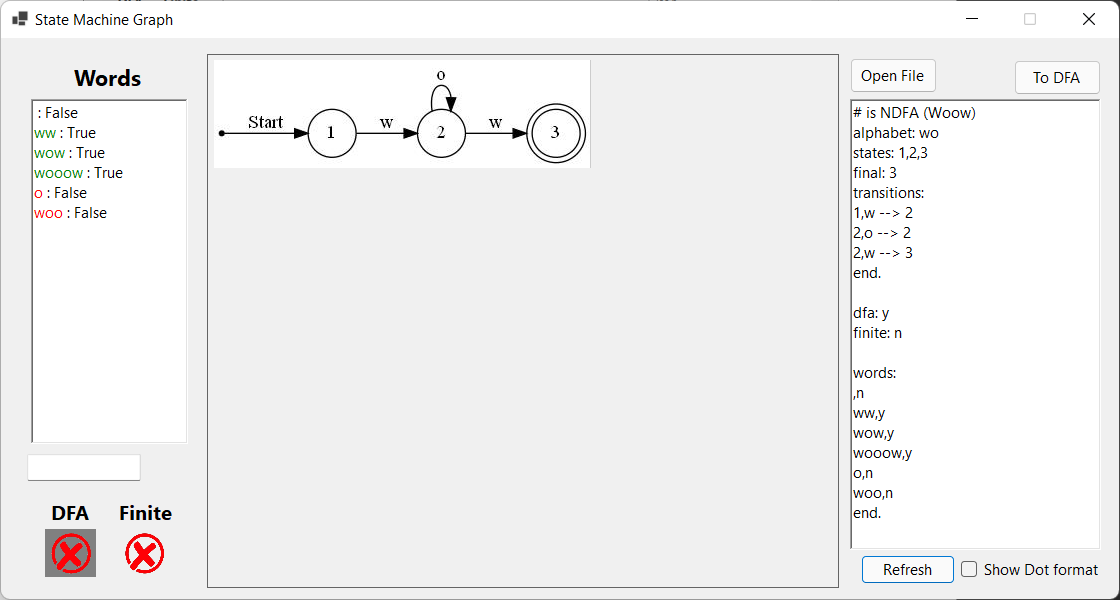
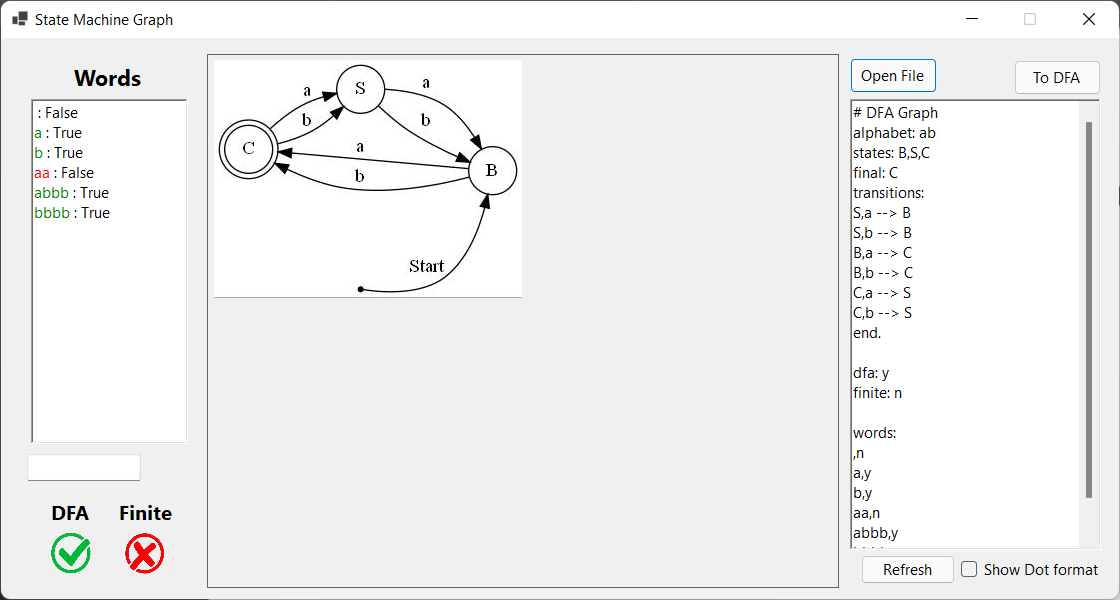


Figure 11. a NDFA graph with the file wrongly saying it is a DFA

## Conclusions

# Accept String – Word Check

## Process

All the words that have been parsed need to be iterated through and call a recursive method to check each word.

Text

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Figure 13. CheckWords() method that calls the recursive method CheckWord() on all the words parsed from the file.

Figure 12. Pseudo-code of recursive method CheckWord().

public bool CheckWord(string word, int letter\_index = 0)

{

// If starting new word, clear stacks and push first state

// Check possible transitions from current state (state on top of stack)

// If there are possible transitions

// foreach transition in possible transitions

// push the state the transition is point to, to the global state stack

// if the letter is the last one in the word

// if the state from the stack final?

// return true

// else

// pop stack to previous state

// else

// Call CheckWord() with next letter (letter\_index++)

// if it returns true

//return true

// else

// pop stack to previous state

// decrement letter\_index (letter\_index--)

}

## Working Results

Displayed the process in debug diagnostics:

Text

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Figure 14. Debugging of word checking in output terminal.

Diagram

Description automatically generated

Figure 15. Shows when a word is correct by the word’s text color and shows red color on truth value when file is wrong.

The user is also able to check a single word they input in a textbox below, which checks the string inputted every time the value in the box changes. It indicates whether it is accepted or not using a ‘tick’ and ‘x’ image next to it:

A picture containing graphical user interface

Description automatically generatedA picture containing graphical user interface

Description automatically generated

Figure 16. Checking if user input is an accepted word.

## Conclusions

# Regular Expression

## Process

The operators used in these regular expressions are shown in the figure below:

Text

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Figure 17. Regular expression and their ASCII equivalent.

The come with these equivalent state machine layouts:

Diagram

Description automatically generatedDiagram, schematic

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Diagram

Description automatically generated

Figure 18. Regular Expression State Machine Layout examples.

Due to my previous work in ALE1, I used a similar structure of a **NodeRegexManager** that controls the nodes, with node **OperantRegex** and **OperatorRegex** classes implementing an **INodeRegex** interface class.

Text

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Figure 19. INodeRegex interface properties.

Text

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Description automatically generated

Figure 20. OperatorRegex and OperantRegex classes and their properties, methods.

Text

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Figure 21. NodeRegexManager class and its properties, methods.

The pseudocode for the parsing of the nodes from a regex formula is:

private void AddNode(string formula){

// for every character in the formula

case '(':

// Add children

AddNode(formula);

case ')':

// Last parent has no more children to add so remove from stack

this.parent\_stack.Pop();

return; // to exit from child method (of recursion)

case ',':

// Just skipping works

case: // Operants/Operators

// Add the nodes to their respective list (Operants/Operators)

// Add this node as child to parent in global ‘parent stack’

// Push this node in parent stack if operator

// Add it to the global list of nodes

}

Figure 22. Pseudocode of AddNode() method.

Using the layouts, I was able to build a recursive method that parses the graph properties (eg., alphabet, states, transitions) using the parsed nodes from the regular expression:

public string ParseRegexFile(string[] contents)

{

// Create a NodeRegexManager Object (NRM)

// foreach line in string array contents

// if line starts with ‘**#**’

// ignore

// if line starts with **‘regex’**

// split the string by ‘:’ char and pass the string representing the regex formula to AddNode in NRM to parse the nodes

// Call a recursive method to parse the nodes into the Graph object (GO)

// In regex, always set the last state in the list as the final state

// add the state to final states list

// foreach operant in the operants list in NRM

// parse letter into GO’s alphabet string

// if line starts with **‘dfa’**

// Split the string by ‘:’ char and pass true if ‘y’ or false if ‘n’ and store what the file says.

// Call method to check if graph is a DFA (CheckDFA() method) and return a bool.

// if the file does not agree with method result

// show it in the GUI

// if line starts with **‘finite’**

// Split the string by ‘:’ char and pass true if ‘y’ or false if ‘n’ and store what the file says.

// Call method to check if graph is Finite (CheckFinite() method) and return a bool.

// if the file does not agree with method result

// show it in the GUI

// if line starts with **‘words’**

// for every line in the file’s contents starting from the next line

// if its equals to ‘end’

// break loop

// Split the string by ‘,’ char for each word

// Split the string by ‘,’ char for each word’s

truth/accepting value: true if ‘y’, false if ‘n’

// Return a DOT format based on parsed GO values

}

Figure 23. Pseudocode of ParseRegexFile() calling ParseRegexContents recursive method.

**ParseRegexContents() - Initialization**

Text

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Figure 24. Source code of recursive method ParseRegexContents() (Part 1)

**ParseRegexContents() - Concatenation**Text

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Figure 25. Source code of ParseRegexContents() (Part 2 - Concatenation)

**ParseRegexContents() – Choice**

Text

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Figure 26. Source code of ParseRegexContents() with left child operations (Part 3.1 - Choice)

Text

Description automatically generated

Figure 27. Source code of ParseRegexContents() with right child and rest of operations (Part 3.2 - Choice)

**ParseRegexContents() – Loop**

Text

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Figure 28. Source code of ParseRegexContents() (Part 4 - Loop)

## Working Results

Example: **.(a,|(b,c))**

Diagram

Description automatically generated

Figure 29. Regex graph result of concatenation with choice right child.

Example: **|(|(a,b),c)**

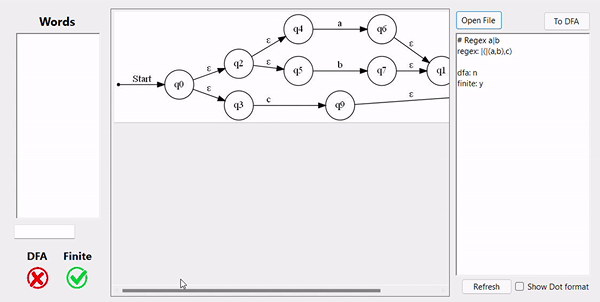


Figure 30. GIF of Regex graph result of choice with choice left child.

Diagram

Description automatically generated

Figure 31. Regex graph result of loop.

## Conclusions

Regex was easier to implement than the rest so far but had some issues with passing the right parameters within the recursive method at first, until I realized I had to pass an ‘open’ and ‘final’ state for each recursion to know with what state to start growing the transitions from and where to end them.

# Finite

## Process

For a state machine (SM) to NOT be finite, it needs to follow these conditions:

* If SM **has a self-loop with a transition to a final state**, it is infinite.
* If **a final state is a part of a cycle** (states that are all connected through each other)

Thus, I added these properties in the Graph object:

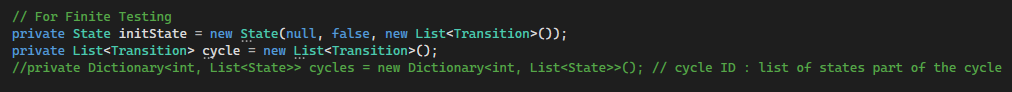


Figure 32. Graph Finite related properties.

The first figure below shows the **CheckFinite()** source code:

Text

Description automatically generated

Figure 33. Source code of CheckFinite() method.

The following figures show each method that returns a bool value based on whether the finite condition is true or false:

Text

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Figure 34. Source code for method checking if a state has a path to a final state.

Text

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Figure 35. Source code for method checking if state is part of a cycle.

## Working Results

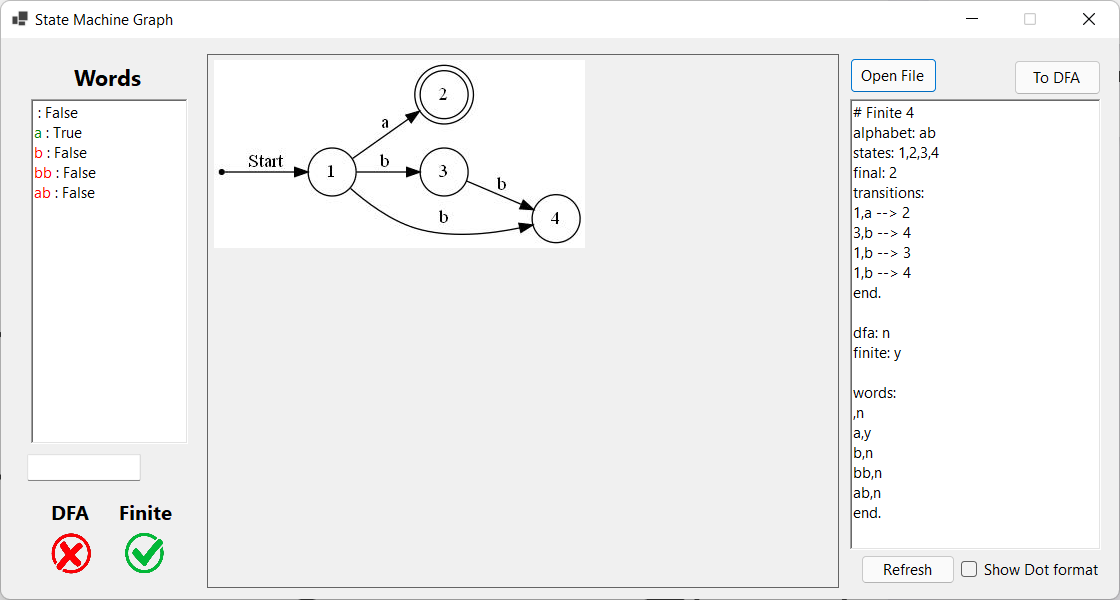


Figure 36. GUI showing Finite graph result (correct file).

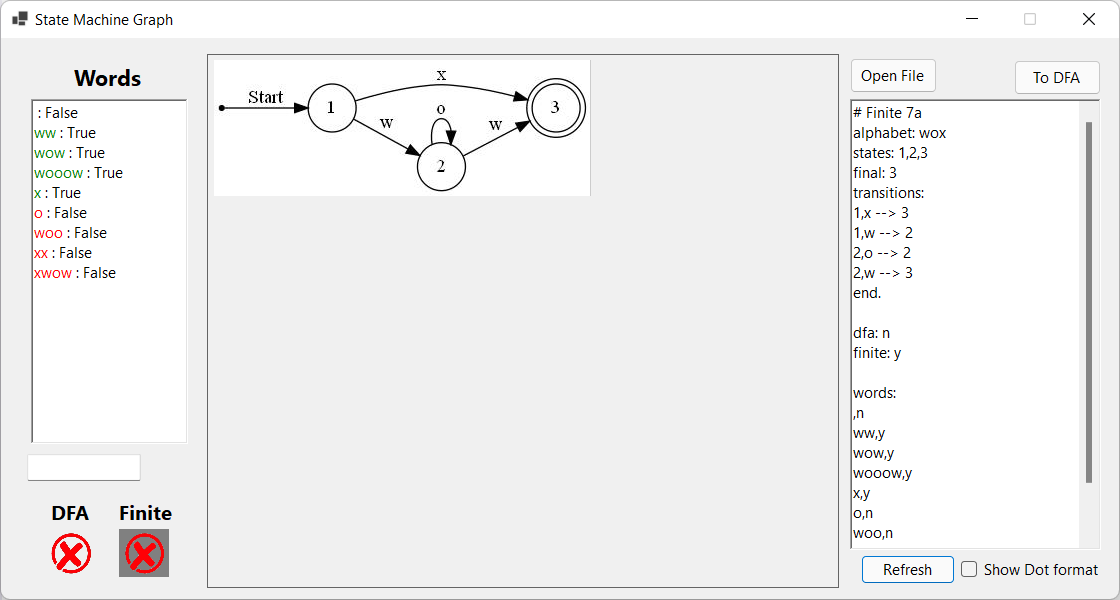


Figure 37. GUI showing an Infinite graph result (wrong file).

## Conclusions

This seemed to be one of the hardest tasks to complete, but when conditions are this clear and when the code is organized well, it becomes a lot simpler to map the process in your mind and implement it.

# NDFA

## Process

Added the following Graph properties for this:

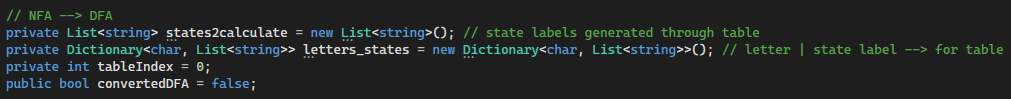


Figure 38. Graph properties added related to NDFA to DFA conversion.

public string NDFA2DFA()

{

// Reform states if epsilon transitions

CheckForEpsilonClosures();

tableIndex = 0;

this.letters\_states.Clear();

// Initialise groups dictionary (based on letters from alphabet)

foreach (char lt in this.alphabet.ToCharArray())

this.letters\_states.Add(lt, new List<string>());

states2calculate.Add(this.states[0].state\_label); // Add the initial state to start the table (label)

old\_states = this.states;

bool isDFAGraphReady = NDFA2DFA\_CalculateState(this.states[0]);

if (isDFAGraphReady)

{

DebugNDFA2DFA();

convertedDFA = true;

this.form.ui\_btn\_ndfa2dfa.Enabled = false;

this.form.ui\_btn\_ndfa2dfa.Text = "Refresh";

try

{

// Reparse values

this.states.Clear();

this.all\_transitions.Clear();

this.final\_states.Clear();

// Create all states available

foreach (string l\_state in states2calculate)

{

// isFinal if is the last state

State state\_temp = new State(l\_state, states2calculate.Last().Equals(l\_state) ? true : false, null);

this.states.Add(state\_temp);

}

// Create/Add appropriate transitions between the states

int letter\_states\_index = 0;

foreach (char letter in this.alphabet.ToCharArray())

{

foreach (State st\_from in this.states)

{

Debug.WriteLine($"index: {letter\_states\_index} - {this.letters\_states[letter][letter\_states\_index]}");

State st\_to = this.states.FirstOrDefault(s => s.state\_label.Equals(this.letters\_states[letter][letter\_states\_index]));

if (st\_to != null)

{

Transition transition\_temp = new Transition(st\_from, st\_to, letter.ToString());

st\_from.AddTransition(transition\_temp);

st\_to.AddTransition(transition\_temp);

this.all\_transitions.Add(transition\_temp);

}

letter\_states\_index++;

}

letter\_states\_index = 0;

}

// Add last found state as final state

this.final\_states.Add(this.states.Last());

DebugParsedValues();

// Return a dot format using the new values

return CreateDotFromParsedFile();

}

catch (Exception e)

{

this.form.ui\_btn\_ndfa2dfa.Text = "To DFA";

Debug.WriteLine($"Could not reparse values. - {e.ToString()}");

}

}

return null;

}

Figure 39. Pseudocode of NDFA2DFA() method which calls recursive method NDFA2DFA\_CalculateState().

private bool NDFA2DFA\_CalculateState(State curr\_state)

{

try

{

Debug.WriteLine($"Calculating state {curr\_state.state\_label}...");

// Go through every letter

foreach (char letter in this.alphabet.ToCharArray())

{

Debug.WriteLine($"Processing {letter}...");

List<Transition> poss\_transitions = new List<Transition>();

// Check what state the letter might have a transition to

string[] curr\_states = Array.Empty<string>();

if (curr\_state.state\_label.Contains(',')) // If state has multiple state values, check transitions from all of them

{

curr\_states = curr\_state.state\_label.Split(',');

foreach (string cs in curr\_states)

{

State sep\_state = this.states.Find(s => s.state\_label == cs);

if (sep\_state != null)

poss\_transitions.AddRange(sep\_state.FindTransitionsByValue(letter.ToString(), true));

}

}

else // Has single state value

// find outgoing transitions with the same letter

poss\_transitions = curr\_state.FindTransitionsByValue(letter.ToString(), true);

// Once we know all possible transitions, form the states as needed

Debug.WriteLine($"{poss\_transitions.Count()} possible transitions");

if (poss\_transitions != null && poss\_transitions.Count > 0)

{

string out\_label = "";

foreach (Transition poss\_tr in poss\_transitions)

{

// Check if state was already written (avoid duplicates)

if (out\_label.Contains(poss\_tr.pointsTo.state\_label))

break;

Debug.WriteLine($"Transition {poss\_tr.label} points to {poss\_tr.pointsTo.state\_label}");

// Add the state the transition is pointing to to the new state's label

out\_label += poss\_tr.pointsTo.state\_label + ",";

}

// delete extra comma at the end

out\_label = out\_label.Substring(0, out\_label.Length - 1);

Debug.WriteLine($"Final new state label: {out\_label}");

// Add state to letters\_states under the letter

//this.letters\_states[letter] = out\_label;

this.letters\_states[letter].Add(out\_label);

}

// If no possible transitions with that letter, create a sink state to transition to

else

{

Debug.WriteLine($"Creating SINK state for letter {letter} from {curr\_state.state\_label}");

State sink\_state = new State("SINK", false, null);

Transition sink\_trans = new Transition(curr\_state, sink\_state, letter.ToString());

sink\_state.AddTransition(sink\_trans);

curr\_state.AddTransition(sink\_trans);

this.states.Add(sink\_state);

this.all\_transitions.Add(sink\_trans);

this.letters\_states[letter].Add("NaN");

}

}

Debug.WriteLine($"Number of states under letters: {this.letters\_states.Count()}");

Debug.WriteLine($"\nChecking for new formed states...");

// Check if any new states in table

foreach (KeyValuePair<char, List<string>> l\_state in this.letters\_states)

{

if (l\_state.Value.Count > tableIndex)

{

Debug.WriteLine($"{tableIndex}: Letter {l\_state.Key} now points to state '{l\_state.Value[tableIndex]}'");

// If there are no states with the same label

if (l\_state.Value[tableIndex] != "NaN" && this.old\_states.All(s => s.state\_label != l\_state.Value[tableIndex])) //this.states

{

// Create new state

State new\_state = new State(l\_state.Value[tableIndex], false, null);

this.states.Add(new\_state);

Debug.WriteLine($"New state found: {l\_state.Value[tableIndex]}");

// Add new state to table (states2calculate)

this.states2calculate.Add(l\_state.Value[tableIndex]);

// call this method again with new state

NDFA2DFA\_CalculateState(new\_state);

tableIndex++; // Increase the index that refers to which table row we are currently focused on

}

else

Debug.WriteLine("No new states found.");

}

}

return true;

}

catch (Exception e)

{

Debug.WriteLine("Could not convert graph to DFA - " + e.Message + " - " + e.ToString());

return false;

}

}

Figure 40. Pseudocode of NDFA2DFA\_CalculateState() method.

Text

Description automatically generated

Figure 41. Source code for CheckForEpsilonClosures() method.

## Working Results

Could not make it properly work in time with a SINK state. Only state machines that all of its states have a state to fall into can currently be converted into a DFA

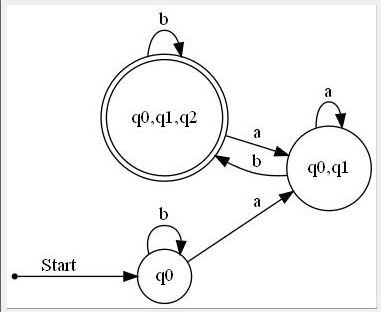
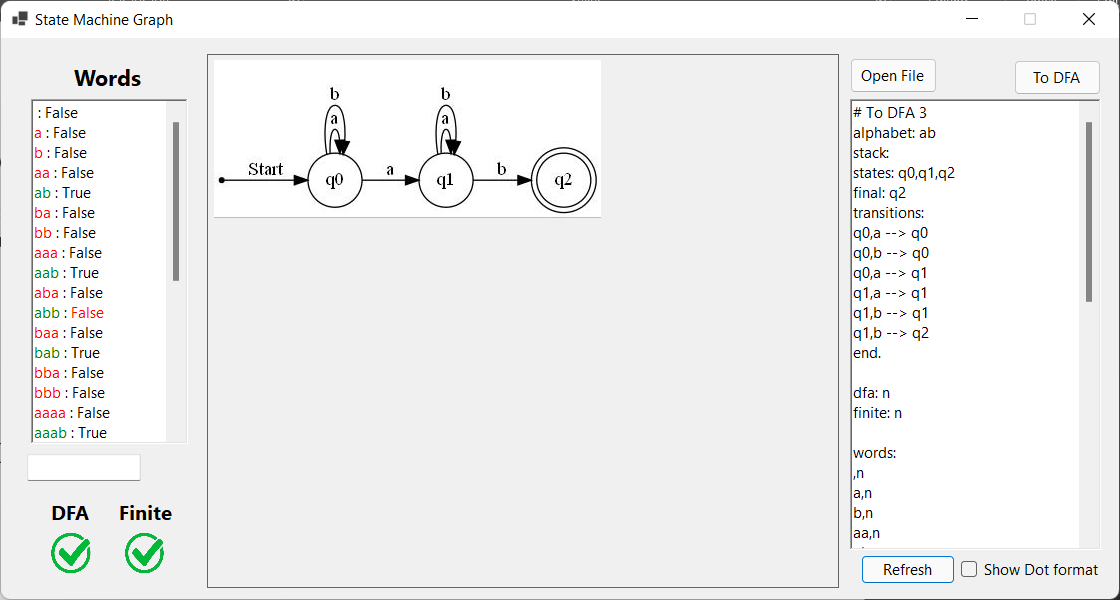


Figure 42. GUI showing conversion of an NDFA to DFA (no SINK).

## Conclusions

I wish I had more time in order to fully implement the other types of NDFA’s.

# PDA

## Process

The following properties were added to the Graph object:

Graphical user interface, text

Description automatically generated

Figure 43. Graph properties added related to PDA.

Added two more properties for each transition to hold a string for a pop and push value:

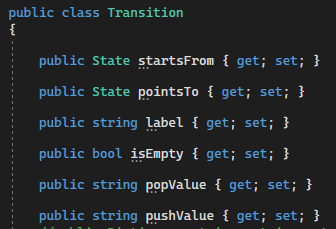


Figure 44. Transition class with added popValue and pushValue properties for PDA.

public string ParsePDAFile(string[] contents)

{

Debug.WriteLine($"Parsing PDA file...");

this.isPDA = true;

try

{

int sfrom = 0;

int line\_index = -1;

foreach (string line in contents)

{

line\_index++;

if (line.StartsWith('#'))

continue;

// Get alphabet

else if (line.StartsWith("alphabet"))

{

sfrom = line.IndexOf("alphabet") + "alphabet:".Length;

this.alphabet = line.Substring(sfrom, line.Length - sfrom).Trim();

Debug.WriteLine($"Alphabet parsed: {this.alphabet}");

}

// Get stack values

else if (line.StartsWith("stack"))

{

sfrom = line.IndexOf("stack") + "stack:".Length;

this.stack\_val = line.Substring(sfrom, line.Length - sfrom).Trim();

Debug.WriteLine($"Stack parsed: {this.stack\_val}");

}

// Get states (name only)

else if (line.StartsWith("states"))

{

sfrom = line.IndexOf("states") + "states:".Length;

string[] states = line.Substring(sfrom, line.Length - sfrom).Trim().Split(',');

foreach (string state in states)

{

this.states.Add(new State(state, false, null)); // A null transitions param will initialise a new List()

Debug.WriteLine($"State Name parsed: {state}");

}

}

// Get and set final state

else if (line.StartsWith("final"))

{//final: q2,q4

sfrom = line.IndexOf("final") + "final:".Length;

string[] finalstates = line.Substring(sfrom, line.Length - sfrom).Trim().Split(',');

foreach (State state in this.states.Where(s => finalstates.Contains(s.state\_label)))

{

state.isFinal = true;

this.final\_states.Add(state);

Debug.WriteLine($"Set '{state.state\_label}' as final state.");

}

}

// Get and set transitions

else if (line.StartsWith("transitions"))

{

for (int i = line\_index + 1; i < contents.Length; i++)

{

if (contents[i] == "end.")

break;

// Separate the line's contents

// TODO: Find how to split

string[] comma\_split = contents[i].Split(",");

string trans\_from = "";

string trans\_value = "";

string pop\_val = "";

string push\_val = "";

string trans\_to = "";

if (comma\_split.Length == 2) // 1 comma --> 2 elements | eg., A,b --> A == { A },{ b --> A }

{

// Separate the line's contents

trans\_from = contents[i].Split(",")[0].Trim();

trans\_value = contents[i].Split(",")[1].Split("-->")[0].Trim();

trans\_to = contents[i].Split(",")[1].Split("-->")[1].Trim();

}

else // Most likely 2 commas --> 3 elements | eg., A,b [\_,x] --> A == { A },{ b [\_ },{ x] --> A }

{

// { A }

trans\_from = contents[i].Split(",")[0].Trim();

// { b [\_ } : Split at [

trans\_value = contents[i].Split(",")[1].Split("[")[0].Trim();

pop\_val = contents[i].Split(",")[1].Split("[")[1].Trim();

//{ x] --> A } : Split at ] for push val and --> for state-to val

push\_val = contents[i].Split(",")[2].Split("]")[0].Trim();

trans\_to = contents[i].Split(",")[2].Split("-->")[1].Trim();

}

// Add them to the states + new transition class objects

State tfrom = this.states.FirstOrDefault(s => s.state\_label == trans\_from);

State tTo = this.states.FirstOrDefault(s => s.state\_label == trans\_to);

Transition transition = new Transition(tfrom, tTo, trans\_value);

if (transition != null)

{

transition.AddStack(pop\_val, push\_val);

//tfrom.AddTransition(transition);

//// Only add to the destination state if its not a self-loop transition

//// (or else same state gets duplicate transition in list)

//if (!tfrom.Equals(tTo))

// tTo.AddTransition(transition);

all\_transitions.Add(transition);

}

}

}

// Get words

else if (line.StartsWith("words"))

{

for (int i = line\_index + 1; i < contents.Length; i++)

{

if (contents[i] == "end.")

break;

// If line is empty

if (contents[i] == "")

continue;

this.words[contents[i].Split(",")[0].Trim()] = contents[i].Split(",")[1].Trim() == "y" ? true : false;

}

}

}

return this.CreateDotFromParsedFile("PDA2Dot");

}

catch (Exception ex) {

Debug.WriteLine("Could not parse PDA file.\n\t-" + ex.ToString());

return null;

}

}

Figure 45. Pseudocode for ParsePDAFile() method .

Check words for PDA:

Text

Description automatically generated

Figure 46. Source code for added code in CheckWord() method.

## Working Results

A picture containing diagram

Description automatically generated

Figure 47. GUI shows PDA graph.

A picture containing diagram

Description automatically generated

Figure 48. GUI shows PDA graph with file wrong about accepted words.

## Conclusions

This took the least amount of time to complete, probably because I am very familiar with stacks, since I’ve been using them for a lot of the ALE courses methods I made.

# Software Design

## System Overview

The project is a Visual Studio Win Forms program in C#. It’s formed using Object Oriented Design principles to store and manipulate its data.

## System Architecture

Diagram

Description automatically generated

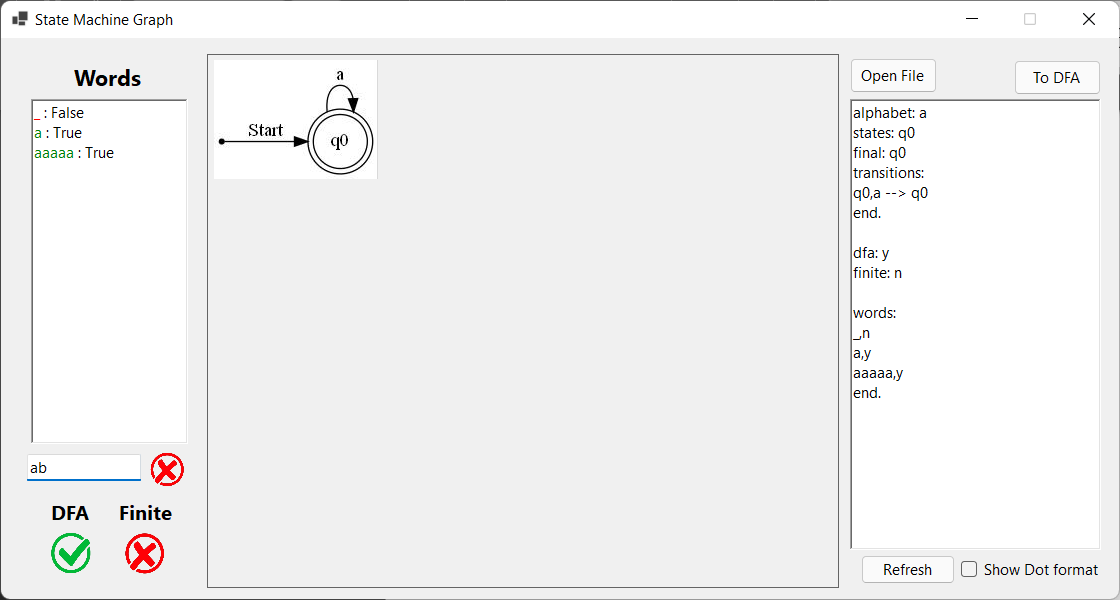
Figure 49. UML

<<Explain the classes and their dependency a bit>>

# GUI

Below is an explanation of the graphical user interface:

Figure 50. GUI Explanation



Words from the file appear here with their truth states (accepted or not):

Green/Red Letter = accepted or not

Green/Red Truth State = File is right/wrong

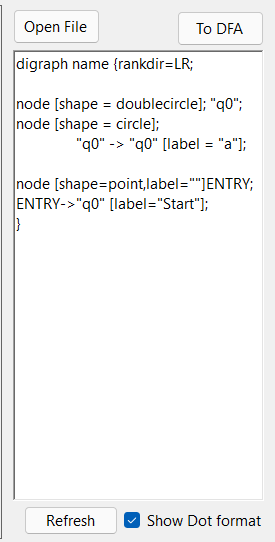
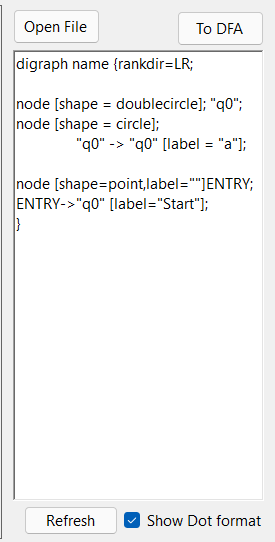
Graph

User can type custom words to check if they are accepted by the system.



Shows if it is a DFA and if it is a Finite system.

If the file is wrong, the image displays grayed out.



Shows contents of file

Opens a text file

Convert current graph into a DFA

Re-draw the graph with the current file contents

# Testing

# Conclusions and recommendations