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Loop and Substring Based Hybrid Classification for Nondeterministic Finite Automata

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***Abstract*—** Nondeterministic Finite Automata (NFA) has two primary components for accepting the string. Those are in the form of loop and substring. Loop also takes some substrings. Based on the product of triple loop and triple substring hybrid NFA divided into nine categories. 1) Single loop with single substring. 2) Single loop with double substring. 3) Dual loop with single substring. 4) Dual loop with double substring. 5) Double loop with triple substring. 6) Triple loop with double substring. 7) Triple loop with triple substring. 8) Zero loop with single substring. 9) Single loop with substring equal to string (Starting state and accepting state both are same).

***Keywords*—** Containing condition, Ending condition, Loop, NFA, Substring, Starting condition.

I. Introduction

In 1959 Michael O. Rabin and Dana Scott [1], introduced NFAs along with their equivalence to DFAs. An NFA, similar to a DFA, takes a collection of input symbols called as the string. For every input symbol, it performs transitions to a new state or the old state based on the condition. This process continues for all input symbols. Sometimes NFA is different from DFA, as it is non-deterministic, i.e., for some states and input characters, it may perform more than one transition in parallel.

In formal languages and automata theory, Finite automata are one of the important and initial topics. Many books [2, 3, 4] and research papers [5, 6, 7, 8, 9, 10] written on this topic. In operating systems and the text editors, pattern matching used. This pattern matching operation needs the notion of finite automata. A regular expression is the language used by the models. The relevant terminology used in the regular expression is an alphabet, string, and language. The physical system represented in the form of the mathematical model by finite automata.

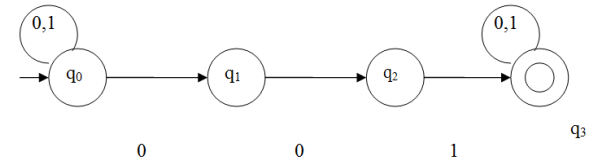
II. Construction Of Nfa And Dfa

For a given condition, it is plausible to construct NFA, DFA, and regular expression. A regular expression is like equation and NFA, and DFA is like picture and table. For human nature instead of representing the solution in the form of the equation, view best suited. Rather using the regular expression, there is a need for the solution in the form of NFA or DFA. Out of this two, we have to make one choice. For that, there is a need for constructing NFA and DFA for a given problem. Then the analysis of the solution, based on the complexity done.

Problem: Construct a Regular expression/NFA/DFA for the following condition. String contains a substring “001” over the alphabet {0, 1}.

Solution: 1.Regular Expression: (0+1)*001(0+1)* , as given in Figure 1 and 2.

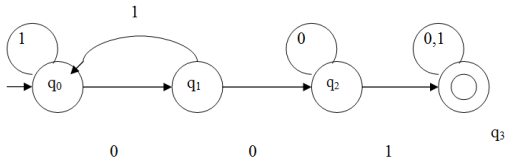
2. NFA (Transition Diagram)



q_0, q_1, q_2, q_3 Set of state
q_0 Starting state
q_3 Final state
Transition: as mentioned above
0,1 Input Characters

Fig.1. NFA for the given problem

3. DFA (Transition Diagram)



q_0, q_1, q_2, q_3 Set of state
q_0 Starting state
q_3 Final state
Transition: as mentioned above
0,1 Input Characters

Fig.2.DFA for the given problem

The regular expression compared with NFA and DFA. It shows that, construction of NFA is less complicated than DFA. Based on the given problem construction of NFA implemented. If NFA categorized into many forms then by analyzing the obtained solution, it is possible to construct required form rapidly and correctly.

III. Related Work

Ezhilarasu et. al. [2014] proposed a novel approach on NFA Classification based on single loop and its position into three types. Those are 1) NFA that accepts the string, that starts with particular Substring (String = Substring followed by self-loop at the ending state). 2) NFA that admits the string, that ends with particular string. (String = Self-loop followed

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by the given substring). 3) NFA which accepts the string. It starts with the particular string. Then ends with the particular string. (String = given substring1 followed by self-loop at the intermediate state and substring2), as in [8].

Ezhilarasu et. al. [2014] proposed a novel approach on NFA Classification that contains a dual loop. Those are 1) loop at the starting and ending state (String = Self loop at the starting state followed by given substring and self-loop at the ending state). 2) loop at starting and intermediate state (String = Self-loop at the starting state followed by given substring1 and self-loop at the intermediate state followed by substring2). 3) loop at ending and intermediate state (String = Substring1 followed by Self loop at the intermediate state followed by given substring2 and self-loop at the ending state), as in [9].

Ezhilarasu et. al. [2014] proposed a novel approach on NFA Classification that contains more than two loops. Those are 1) Containing two or more substrings. (String = Self-loop at starting, intermediate(greater than or equal to 1) and ending state). 2) Starting with a distinct substring and containing two or more substrings. (String = Self-loop at intermediate(greater than or equal to 1) and ending state). 3) Ending with a distinct substring and containing two or more substrings (String = Self-loop at starting and intermediate state(greater than or equal to 1)), as in [10].

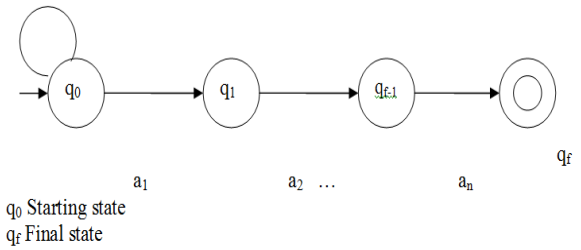


Fig.3.Mathematical Model of NFA with Single loop(Starting state) and single substring

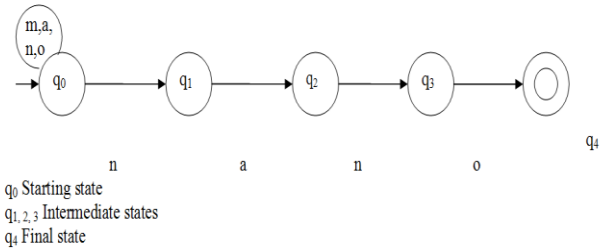


Fig. 4. NFA that ends with the substring "nano" over the alphabet {m, a,n,o}

Wei Cheng and Zhi-wen Mo [2000] classified fuzzy finite automata into two kinds. These two kinds are basic models. The first model has initial state with no output. The second model has output with no initial state. These types further used to classify important fuzzy finite automata, as in [11].

Henning Bordihn, Markus Holzer, and Martin Kutrib [2007] described hybrid extended finite automata. Extended finite automata based on current state apply the operation to the currently remaining word. The hybrid concept used for choosing from the limited set of the process. This automata considers five-word operations that related to reversal and shift operations. Each activity compared with others as in [12].

IV. HYBRID NFA

Based on [8, 9, 10], Loops (up to three) and substrings (up to three) applied for the various position. It will create hybrid NFA that comes under nine categories. Those are

A. Single Loop With Single Substring

This type hybrid NFA has the following components. Those are a loop (self) and a substring. It has two types 1. Single loop in starting state. 2. Single loop in ending state.

Single loop(Starting state)

Table. 1. State Transition Table for Figure 4

Input / States	m	a	n	o
q_0	q_0	q_0	q_0,q_1	q_0
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
$*q_4$	-	-	-	-

The mathematical model of this hybrid NFA given in the figure 3. The syntax for this NFA is a self-loop followed by the substring between starting state and ending state as given in the figure 4.The NFA depicts the ending condition. i.e., NFA will accept all the string that ends with the substring "nano" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is “maanano”, then the transition function by using the state transition table as given in the table 1 will be $q_0mq_0aq_0aq_0nq_1aq_2nq_3oq_4$. Here the given string length is seven. At the end of seven transition given string processed and the output, a state is q_4 that is the final state. Hence, the given string accepted by the NFA as presented in figure 4.

Rejecting condition: If the given string is "maananom" then the given string will be rejected by the NFA as given in the figure 4. It ends with the substring "anom". Hence, the string after performing eight transition won't reach the final state. As a result of that the given string rejected.

Single loop(Ending state)

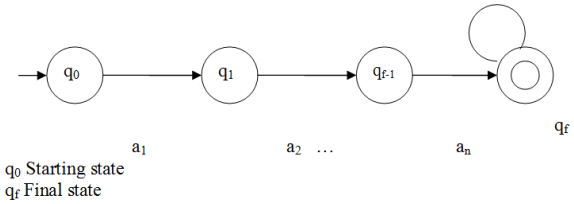


Fig.5.Mathematical Model of NFA with Single loop(Ending state) and single substring

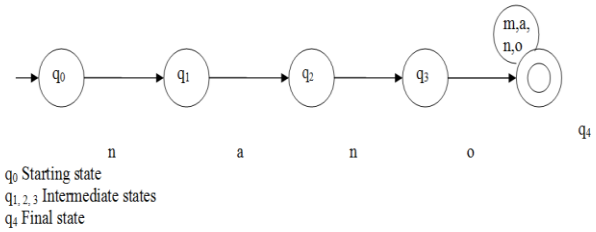


Fig. 6. NFA that starts with the substring "nano" over the alphabet {m, a,n,o}

Table. 2. State Transition Table for Figure 6

Input / States	m	a	n	o
q_0	-	-	q_1	-
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
$*q_4$	q_4	q_4	q_4	q_4

The mathematical model of this hybrid NFA given in the figure 5. The syntax for this NFA is the substring between starting state and ending state followed by a self-loop as presented in the figure 6.The NFA depicts the starting condition. i.e NFA will accept all the string that starts with the substring "nano" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is “nanoman”, then the transition function by using the state transition table as given in the table 2 will be $q_0nq_1aq_2nq_3oq_4mq_4aq_4nq_4$. Here the given string length is seven. At the end of seven transition given string processed and the output, the state is q_4 that is the final state. Hence, the given string accepted by the NFA as presented in figure 6.

Rejecting condition: If the given string is "aaanan" then the given string will be rejected by the NFA as given in the figure 6. It starts with the substring "aaan". Hence, the string after performing six transition won't reach the final state. Because of that, the given string is rejected.

B. Single Loop With Double Substring

This type hybrid NFA has the following components. Those are a loop (self) in the intermediate state and two substrings in starting state and ending state.

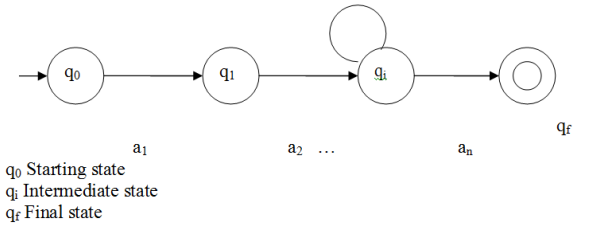


Fig.7. Mathematical Model of NFA with Single loop(Intermediate state) and Double substring

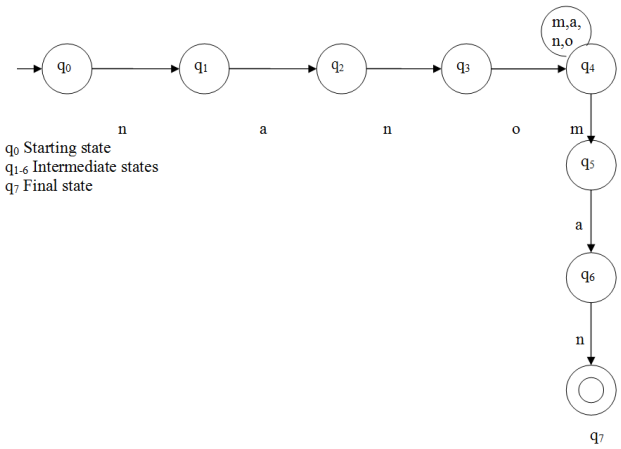


Fig. 8. NFA that starts with the substring "nano" and ends with the substring "man" over the alphabet {m, a,n,o}

Table. 3. State Transition Table for Figure 8

Input / States	m	a	n	o
q_0	-	-	q_1	-
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
q_4	q_4, q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	-	-	-	-

The mathematical model of this hybrid NFA given in the figure 7. The syntax for this NFA is the substring1 between starting state and Intermediate state, a self-loop in the intermediate followed by the substring2 between intermediate state and the final state as given in the figure 8.The NFA depicts the starting condition and ending condition. i.e NFA will accept all the string that starts with the substring "nano" and ends with the substring "man" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is “nanoaaaman”, then the transition function by using the state transition table as given in the table 3 will be $q_0nq_1aq_2nq_3oq_4aq_4aq_4aq_4mq_5aq_6nq_7$. Here the given string length is ten. At the end of ten transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 8.

Rejecting condition: If the given string is “anaananmmmaa” then the given string will be rejected by the NFA as given in the figure 8. It starts with the substring "anaa”. If the first condition is false then no need to check the remaining condition. Hence, the string after performing twelve transition

won't reach the final state. Because of that, the given string is rejected.

C. Dual Loop With Single Substring

This type hybrid NFA has the following components. Those are a two loop (self) in the starting and ending states and the substring between starting and ending state.

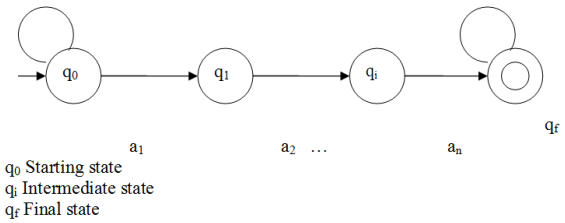


Fig.9. Mathematical Model of NFA with Dual loop(Starting state & Ending state) and Single substring

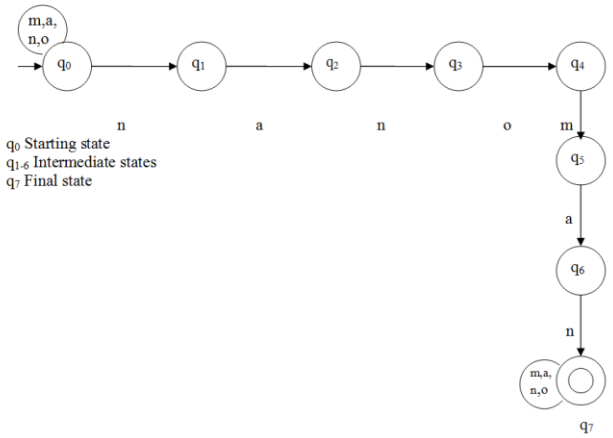


Fig. 10. NFA that contains the substring "nanoman"over the alphabet {m,a,n,o}

Table. 4. State Transition Table for Figure 10

Input / States	m	a	n	o
q_0	q_0	q_0	q_0,q_1	q_0
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
q_4	q_5			
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	q_7	q_7	q_7	q_7

The mathematical model of this hybrid NFA given in the figure 9. The syntax for this NFA is a self-loop in the starting state followed by substring between starting state and final state and finally a self-loop in the final state as given in the figure 10. The NFA depicts the containing condition. i.e NFA will accept all the string that contains the substring "nanoman" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is "aaananomannn", then the transition function by using the state transition table as given in the table 4 will be $q_0a\ q_0aq_0aq_0nq_1aq_2nq_3oq_4mq_5aq_6nq_7nq_7nq_7$. Here the given string length is twelve. At the end of twelve transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 10.

Rejecting condition: If the given string is "nanonanaaaa" then the given string will be rejected by the NFA as given in the figure 10. Because the string doesn't have the substring "nanoman" as a part of a string "nanonanaaaa". At the end of eleven transitions, the final state won't be reached. Because of that, the given string is rejected.

D. Dual Loop With Double Substring

This type hybrid NFA has the following components. Those are two loops (self) in the starting and intermediate state and two substrings in starting state and ending state.

Loop(Starting state, Intermediate state)

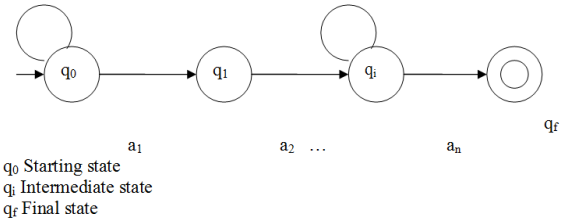


Fig.11. Mathematical Model of NFA with Dual loop(Starting state & Intermediate state) and Double substring

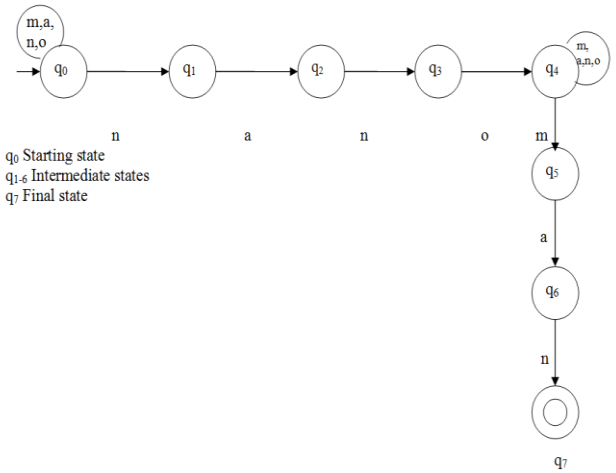


Fig. 12. NFA that contains the substring "nano" and ends with the substring "man" over the alphabet {m, a,n,o}

The mathematical model of this hybrid NFA given in the figure 11. The syntax for this NFA is a self-loop at the starting state. Then substring1 between starting state and Intermediate state; a self-loop in the intermediate followed by the

substring2 between intermediate state and the final state, as given in the figure 12.The NFA depicts the containing condition and ending condition. i.e NFA will accept all the string that contains the substring "nano" and ends with the substring "man" over the alphabet {m, a,n,o}.

Table. 5. State Transition Table for Figure 12

Input / States	m	a	n	o
q_0	q_0	q_0	q_0,q_1	q_0
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
q_4	q_4,q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	-	-	-	-

Accepting condition: If the given input string is "nanoaaman", then the transition function by using the state transition table as given in the table 5 will be $q_0nq_1aq_2nq_3oq_4aq_4aq_4mq_5aq_6nq_7$. Here the given string length is nine. At the end of nine transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 12.

Rejecting condition: If the given string is "anaananmmmaa" then the given string will be rejected by the NFA as given in the figure 12. Hence, the string after performing twelve transition won't reach the final state. Because of that, the given string is rejected.

Loop(Intermediate state, Ending state)

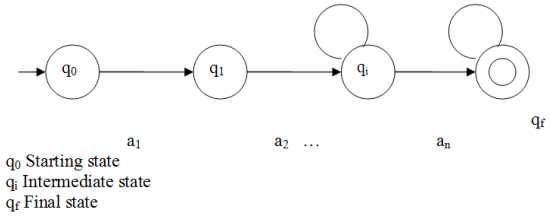


Fig.13. Mathematical Model of NFA with Dual loop(Intermediate state & Ending state) and Double substring

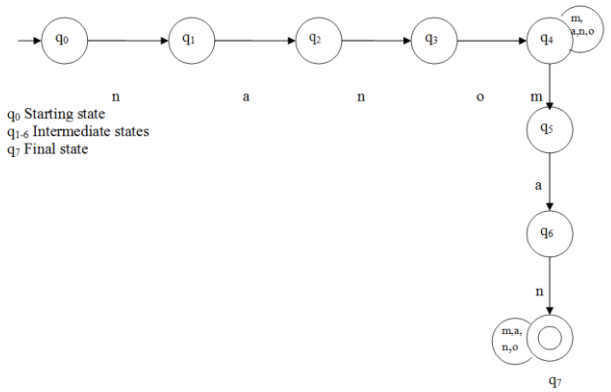


Fig. 14. NFA that starts the substring "nano" and contains the substring "man" over the alphabet {m, a,n,o}

Table. 6. State Transition Table for Figure 14

Input / States	m	a	n	o
q_0	-	-	q_1	-
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
q_4	q_4,q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	q_7	q_7	q_7	q_7

The mathematical model of this hybrid NFA given in the figure 13. The syntax for this NFA is the substring1 between starting state and Intermediate state. Then a self-loop in the intermediate, the substring2 between intermediate state and the final state followed by the self-loop in the final state as given in the figure 14.The NFA depicts the starting condition and containing the condition. i.e NFA will accept all the string that starts the substring "nano" and contains the substring "man" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is "nanoaaman", then the transition function by using the state transition table as given in the table 6 will be $q_0nq_1aq_2nq_3oq_4aq_4aq_4mq_5aq_6nq_7$. Here the given string length is nine. At the end of nine transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 14.

Rejecting condition: If the given string is "anaanman" then the given string will be rejected by the NFA as given in the figure 14. Hence, the string after performing eight transition won't reach the final state. Because of that, the given string is rejected.

E. Dual Loop With Triple Substring

This type hybrid NFA has the following components. Those are two loops (self) in the intermediate state1 and intermediate state2 and three substrings in between starting state and intermediate state1, intermediate state1 and intermediate state2 and intermediate state2 and final state.

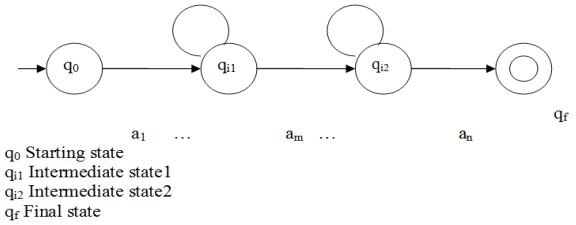


Fig.15. Mathematical Model of NFA with Dual loop(Intermediate state1 & Intermediate state2) and Triple substring

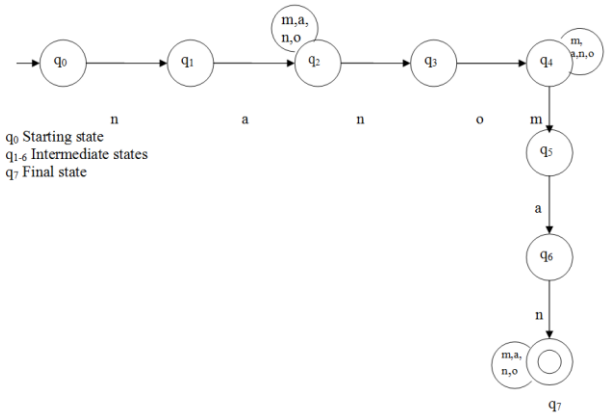


Fig. 16. NFA that starts the substring "na", contains the substring "no" and ends with the substring "man" over the alphabet {m, a,n,o}

Table. 7. State Transition Table for Figure 16

Input / States	m	a	n	o
q_0	-	-	q_1	-
q_1	-	q_2	-	-
q_2	q_2	q_2	q_2,q_3	q_2
q_3	-	-	-	q_4
q_4	q_4,q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
*q_7	q_7	q_7	q_7	q_7

The mathematical model of this hybrid NFA given in the figure 15. The syntax for this NFA is the substring1 between starting state and Intermediate state1. Then a self-loop in the intermediate state1, the substring between intermediate state1 and intermediate state2. Then a self-loop in the intermediate state2 followed by the substring2 between intermediate state and the final state as given in the figure 16.The NFA depicts the starting condition, containing and ending condition. i.e., NFA will accept all the string that starts with the substring "na". Then contains the substring "no" and ends with the substring "man" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is "nanoaaaman", then the transition function by using the state transition table as given in the table 7 will be $q_0nq_1aq_2nq_3oq_4aq_4aq_4aq_4mq_5aq_6nq_7$. Here the given string length is ten. At the end of ten transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 16.

Rejecting condition: If the given string is "anaananmmmaa" then the given string will be rejected by the NFA as given in the figure 8. Hence, the string after performing twelve transition won't reach the final state. Because of that, the given string is rejected.

F. Triple Loop With Double Substring

This type hybrid NFA has the following components. Those are three loops (self) in the starting. Intermediate and final state and two substrings between those three loops.

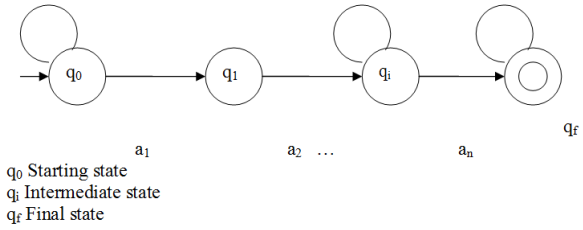


Fig.17. Mathematical Model of NFA with Triple loop(Starting state, Intermediate state & Ending state) and Double substring

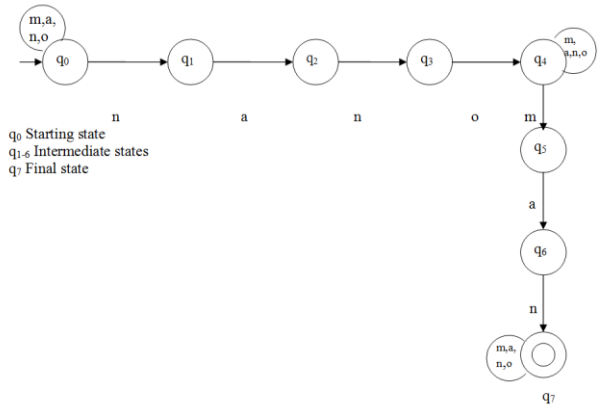


Fig. 18. NFA that contains the substring1 "nano" and substring2 "man"over the alphabet {m,a,n,o}

Table. 8. State Transition Table for Figure 18

Input / States	m	a	n	o
q_0	q_0	q_0	q_0,q_1	q_0
q_1	-	q_2	-	-

q_2	-	-	q_3	-
q_3	-	-	-	q_4
q_4	q_4,q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	q_7	q_7	q_7	q_7

The mathematical model of this hybrid NFA given in the figure 17. The syntax for this NFA is a self-loop in the starting state. Then the substring1 between starting state and Intermediate state, a self-loop in the intermediate state, the substring2 between intermediate state and final state followed by a self-loop in the final state as given in the figure 18.The NFA depicts the two containing conditions. i.e., NFA will accept all the string that contains the first substring "nano" then second substring "man" over the alphabet {m, a,n,o}. Accepting condition: If the given input string is "nanoaaaman", then the transition function by using the state transition table as given in the table 8 will be $q_0n\ q_1aq_2nq_3oq_4aq_4aq_4aq_4mq_5aq_6nq_7$. Here the given string length is ten. At the end of ten transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 8.Rejecting condition: If the given string is "anaananmmmaa" then the given string will be rejected by the NFA as given in the figure 8. Hence, the string after performing twelve transition won't reach the final state. Because of that, the given string is rejected.

G.Triple Loop With Triple Substring

This type hybrid NFA has the following components. Those are three loops (self) in the starting state, intermediate state1 and intermediate state2 and three substrings between starting state and intermediate state1, intermediate state1 and intermediate state2 and intermediate state2 and final state.

Loop(Starting state, Intermediate state 1 and 2)

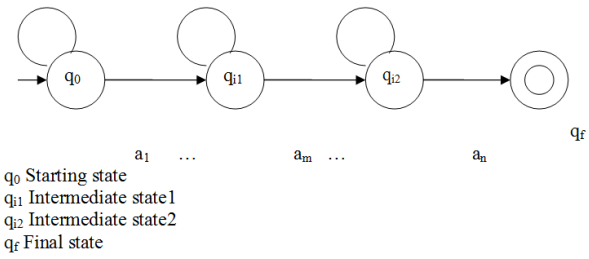


Fig.19. Mathematical Model of NFA with Triple loop(Starting state, Intermediate state1 & Intermediate state2) and Triple substring

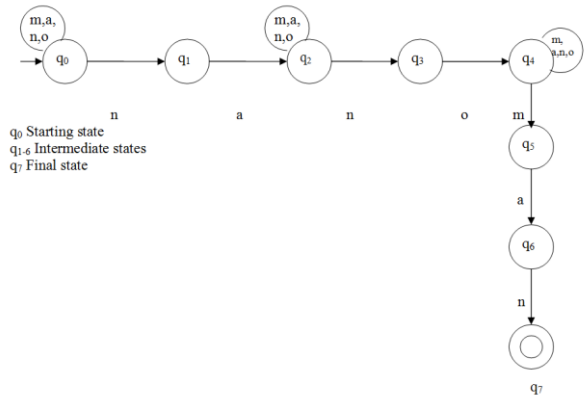


Fig. 20. NFA that contains the substring1 "na" ,substring2 "no" and ends with the substring "man"over the alphabet {m,a,n,o}

The mathematical model of this hybrid NFA given in the figure 19. The syntax for this NFA is a self-loop in the starting state. Then the substring1 between starting state and Intermediate state1. Then a self-loop in the intermediate state 1, the substring between intermediate state1 and intermediate state2. Then a self-loop in the intermediate state2 followed by the substring between intermediate state2 and the final state as given in the figure 20.The NFA depicts the two containing conditions and ending condition. i.e NFA will accept all the string that contains the substring "na","no" and ends with the substring "man" over the alphabet {m, a,n,o}.Accepting condition: If the given input string is "nanoaaaman", then the transition function by using the state transition table as given in the table 9 will be $q_0nq_1aq_2nq_3oq_4aq_4aq_4aq_4mq_5aq_6nq_7$. Here the given string length is ten. At the end of ten transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 8.Rejecting condition: If the given string is "nanomaaaa" then the given string will be rejected by the NFA as given in the figure 20. Hence, the string after performing nine transition won't reach the final state. Because of that, the given string is rejected.

Table. 9. State Transition Table for Figure 20

Input / States	m	a	n	o
q_0	q_0	q_0	q_0,q_1	q_0
q_1	-	q_2	-	-
q_2	q_2	q_2	q_2,q_3	q_2
q_3	-	-	-	q_4
q_4	q_4,q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	-	-	-	-

Loop(Intermediate state 1 and 2, Ending state)

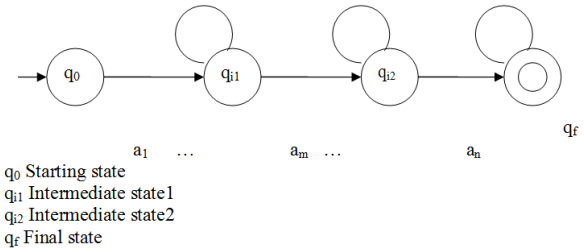


Fig.21. Mathematical Model of NFA with Triple loop(Intermediate state1, Intermediate state2 & Ending state) and Triple substring

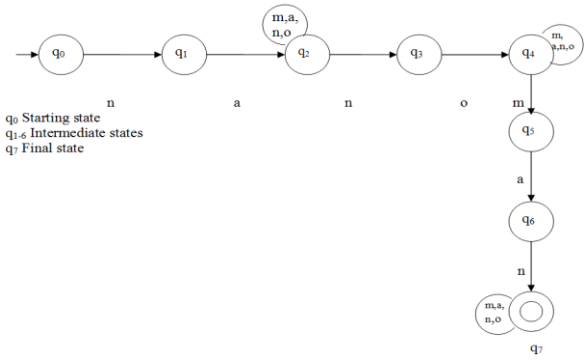


Fig. 22. NFA that starts with the substring "na"and contains the substring1 "n0" ,substring2 "man" over the alphabet {m,a,n,o}

Table. 10. State Transition Table for Figure 22

Input / States	m	a	n	o
q_0	-	-	q_1	-
q_1	-	q_2	-	-
q_2	q_2	q_2	q_2,q_3	q_2
q_3	-	-	-	q_4
q_4	q_4,q_5	q_4	q_4	q_4
q_5	-	q_6	-	-
q_6	-	-	q_7	-
$*q_7$	q_7	q_7	q_7	q_7

The mathematical model of this hybrid NFA given in the figure 21. The syntax for this NFA is the substring1 between starting state and Intermediate state1. Then a self-loop in the intermediate state1 followed by the substring2 between intermediate state1 and the intermediate state2. Then a self-loop at the intermediate state 2, followed by substring3 between intermediate state2 and the final state. Then finally self-loop at the ending state as given in the figure 8.The NFA depicts the starting condition and two containing condition. i.e., NFA will accept all the string that starts with the substring "na" and contains the substring1 "no" and substring2 "man" over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is "nanoaaaman", then the transition function by using the state transition table as given in the table 10 will be q_0n q_1aq_2nq_3oq_4aq_4aq_4mq_5aq_6nq_7. Here the given string length is ten. At the end of ten transition given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as presented in figure 22.

Rejecting condition: If the given string is "anaananmmmaa" then the given string will be rejected by the NFA as given in the figure 22. Hence, the string after performing twelve transition won't reach the final state. Because of that, the given string is rejected.

H.Single Substring Without Loop

This type hybrid NFA has the following components. The substring is equal to string.

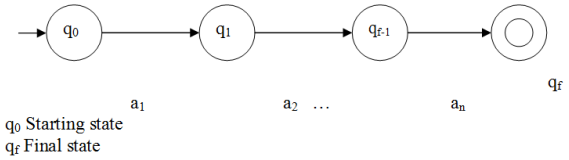


Fig.23. Mathematical Model of NFA with Single substring and without loop

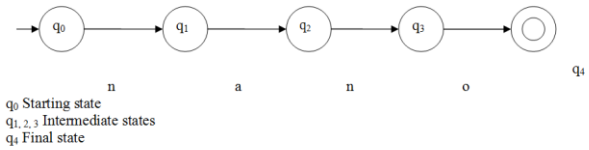


Fig. 24. NFA that accept the substring(string) "nano" over the alphabet {m,a,n,o}

Table. 11. State Transition Table for Figure 24

Input / States	m	a	n	o
q_0	-	-	q_1	-
q_1	-	q_2	-	-
q_2	-	-	q_3	-
q_3	-	-	-	q_4
$*q_4$	-	-	-	-

The mathematical model of this hybrid NFA given in the figure 23. The syntax for this NFA is the substring between starting state and ending state as given in the figure 24. The NFA depicts the starting condition, containing condition and ending condition all are same. i.e NFA will accept all the string "nano" over the alphabet {m,a,n,o}.

Accepting condition: If the given input string is "nano", then the transition function by using the state transition table as given in the table 11 will be q_0n q_1aq_2nq_3oq_4. Here the given string length is four. At the end of four transition given string

processed and the output, a state is q_4 that is the final state. Hence, the given string accepted by the NFA as presented in figure 24.

Rejecting condition: If the given string is "anaoo" then the given string will be rejected by the NFA as given in the figure 24. Hence, the string after performing five transition won't reach the final state. Because of that, the given string is rejected.

I. Single Loop With Substring Equal To String (Starting State And Accepting State Both Are Same)

This type hybrid NFA has only a self-loop as a component.

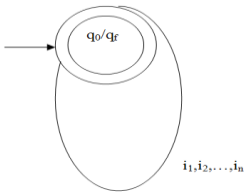
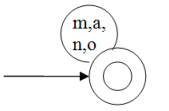


Fig.25. Mathematical Model of NFA with Single Loop



q_0 Starting state and Accepting state

Fig. 26. NFA that accept any string over the alphabet {m, a,n,o}

Table. 12. State Transition Table for Figure 26

Input / States	m	a	n	o
*q_0	q_0	q_0	q_0	q_0

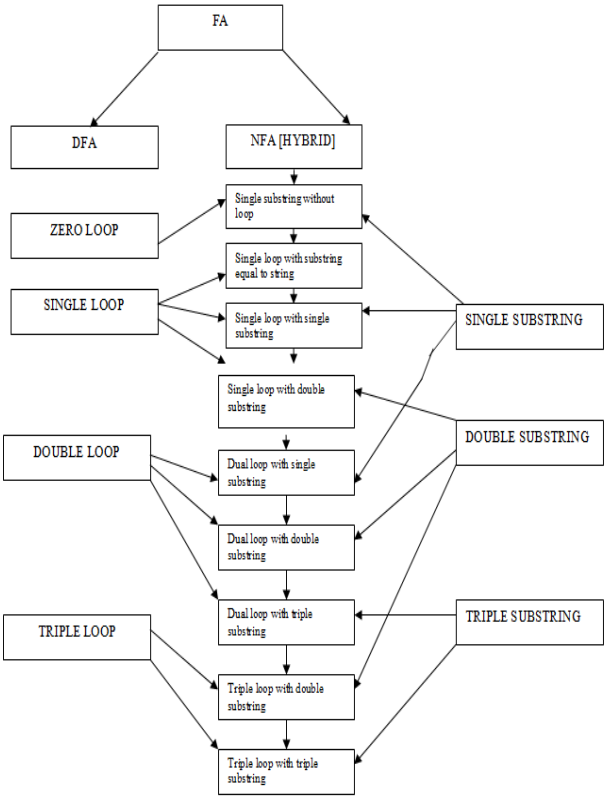


Fig.27. Hybrid NFA classification

The mathematical model of this hybrid NFA given in the figure 25. The syntax for this NFA is a self-loop in the starting state. Here we don't have any substring condition. There is only one state in this type of NFA. The starting state and final state both are same as given in the figure 26.The NFA depicts that it doesn't have any starting condition, containing condition and ending condition. i.e., NFA will accept any string over the alphabet {m, a,n,o}.

Accepting condition: If the given input string is "nano", then the transition function by using the state transition table as given in the table 12 will be $q_0nq_0aq_0nq_0oq_0$. Here the given string length is four. At the end of four transitions given string processed and the output, the state is q_7 that is the final state. Hence, the given string accepted by the NFA as given in figure 26.

Rejecting condition: Here we don't have any rejecting condition.

V. Results And Discussion

The obtained results show that there twelve secondary categories that fit into nine primary categories for Hybrid NFA. It uses Loops (up to three) and Substrings (up to three). Hybrid NFA summarized as in the following figure 27

VI. Conclusion

Nondeterministic Finite Automata equal to Deterministic Finite Automata and that is equivalent to Regular Expression.

Categorization of Nondeterministic Finite Automata is also applicable to Deterministic Finite Automata and Regular Expression. Based on the combination of loops(up to three) and substrings(up to three) we get hybrid NFA of 9 types with some types also having subtypes.

VII. FUTURE WORK

In case of Loop and Substring sometimes it may be more than three. This research work can be employed as a base for further extension to build Nondeterministic Finite Automata, Deterministic Finite Automata and Regular Expression for any number of loops and substrings. In this paper self-loop used. This concept extended to loop between one state and another state. Dividing the problem into many categories it is possible to convert one form into another quickly through analyzing the problems and solutions obtained from the usual method.

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