ISSN 2394 - 9554

International Journal of Research in Science and Technology

Volume 4, Issue 3: July - September 2017

Indian Academicians and Researchers Association
www.iaraedu.com

International Journal of Research in Science and Technology

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Research Papers

International Journal of Research in Science and Technology
Volume 4, Issue 3 : July – September, 2017
ISSN 2394 - 9954

DESIGN OF MINIMAL STATES DETERMINISTIC FINITE AUTOMATON: A GRAPHICAL REPRESENTATION APPROACH

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ABSTRACT
In the field of algorithm design or framework, design Finite state machine (FSM) plays a significant role. In addition, the Finite state machine technique is applicable in many of other fields like Pattern Recognition, Natural language processing, Image processing etc. The Deterministic Finite Automaton also represents the Finite state machine, which accepts the infinite number of strings. These strings are accepted on the finite number of states, sometimes the group of states is behavior similarly so this states can reduce by applying the specific method. The given Research paper is Proposed Minimal states DFA Graphical representation using OpenGL platform. The current Research paper has categorized into III different sections. In Section I the Introduction of Minimum states Deterministic Finite Automata and OpenGL Programming Platform has mentioned, in section II the Methodology for Graphical Representation of Minimum states Deterministic Finite Automata has discussed and at last, in Section III the Conclusion based on proposed methodology is mention.

Keywords : Finite State Machine (FSM), Deterministic Finite Automata, OpenGL

I. INTRODUCTION

a. MINIMUM STATE DETERMINISTIC FINITE AUTOMATON

A deterministic finite automaton (DFA) considered as a basic computational device. It is also known as deterministic finite acceptor and deterministic finite state machine. Deterministic finite automaton is a finite state machine, which accepts/reject the string of symbols, apply the procedure on it and then produces a unique computation for each input string. It considered as deterministic because it refers to the uniqueness of the computation. Deterministic Finite Automation represented by 'M', which has five different tuples.

$M = (Q, \sum, \delta, q0, F)$

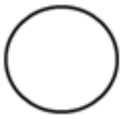
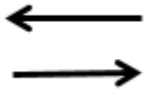
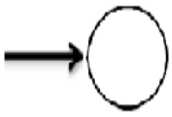
Q = It is a finite non-empty set of States.

$\sum$ = It is a finite set of input symbols.

δ = It is transition function that takes a state and an input symbol and returns a state $\delta : Q \times \sum \rightarrow Q$

q0 = It is a start state in where q0 is a element of set Q.

F = It is a non-empty set of final states where F is an element of set Q [1].

Sr. No.	DFA Graphical Notation	Meaning
1.		**States :** The circle is represent the States in DFA
2.		**Transition arrow:** With the help of this transition arrow, a transition-taking place from one state to another state, which carries any, inputted values like alphabet, numbers or any special characters.
3.		**Initial state or start state:** Initial state or start state is denoted by Transition arrow and state together for represent the starting of the DFA.

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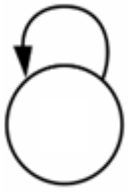
4.		**Final state :** Double circle denotes the Final state in DFA. It helps to show the acceptance of the string which is also called as an ending state.
5.		**Self-looping state:** Self-loop denotes that the state is connected to itself and form the single or multiple transitions.

Table -1: Graphical Notation of DFA

Table 1. is deposit the different graphical notation that used for drawing the Deterministic finite automaton and Minimized Deterministic finite automaton [2].

Minimization of DFA is the process of converting a given deterministic finite automaton into an equivalent DFA that has minimum number of states. Minimizing a DFA increases efficiency by reducing the number of states. It can also check whether two States are behaving similarly or not on the basis of final and non-final states pair, if they satisfied the condition behaving similarly based on final and non-final states then merge these two states and represent the final minimized Deterministic finite automaton.

b. OPENGL PROGRAMMING PLATFORM

OpenGL (Open Graphics Library) is an application to render 2D and 3D graphics images. OpenGL is a software interface that allows a programmer to communicate with graphics hardware. OpenGL consists of a specific set of functions. It describes these set of functions and the precise behavior that they must perform. All these functions can be implemented to draw 2D or 3D graphics. OpenGL's basic operation is to accept elements such as points, lines, and polygons and convert them into pixels. Also for drawing, it can accept the dimension of geometrical shapes from the end user. OpenGL is widely used in CAD, virtual reality, scientific visualization, data simulation and video game development.

It is worked on the three libraries of OpenGL these are Basic GL which is responsible for handling the graphical primitives shapes, GLU is Graphic library utility which is responsible for handling the high-level functions, and third is GLUT i.e. Graphic library utility toolkit which is responsible for managed the all input/output interaction as well as window-related functions. OpenGL is device independent application program interface (API) which gives the more strength to do the interactive task[3].

II. METHODOLOGY FOR GRAPHICAL REPRESENTATION OF MINIMIZED DFA

In this section of Research paper, the methodology of minimized deterministic finite automaton is described. The whole methodology is categorized into three sections. In the first section the acceptance of input like number of states, number of input symbols, start state, final state and respective transitions are accepted also in this section the whole transition table with the respective start, final states, and transitions table is displayed. The second section of the methodology is the responsible for the calculation of the minimized state based on previous steps transition table. In this section, the pair of states is created, like (Qi, Qj) then after this these pair are checked whether they are satisfied the condition of ($Qi \in F$) and ($Qj \notin F$) or vice versa for all the pairs of transition table of the Deterministic finite automaton. If it is satisfied, the condition then marked as '1' if not then marked as a '0'.

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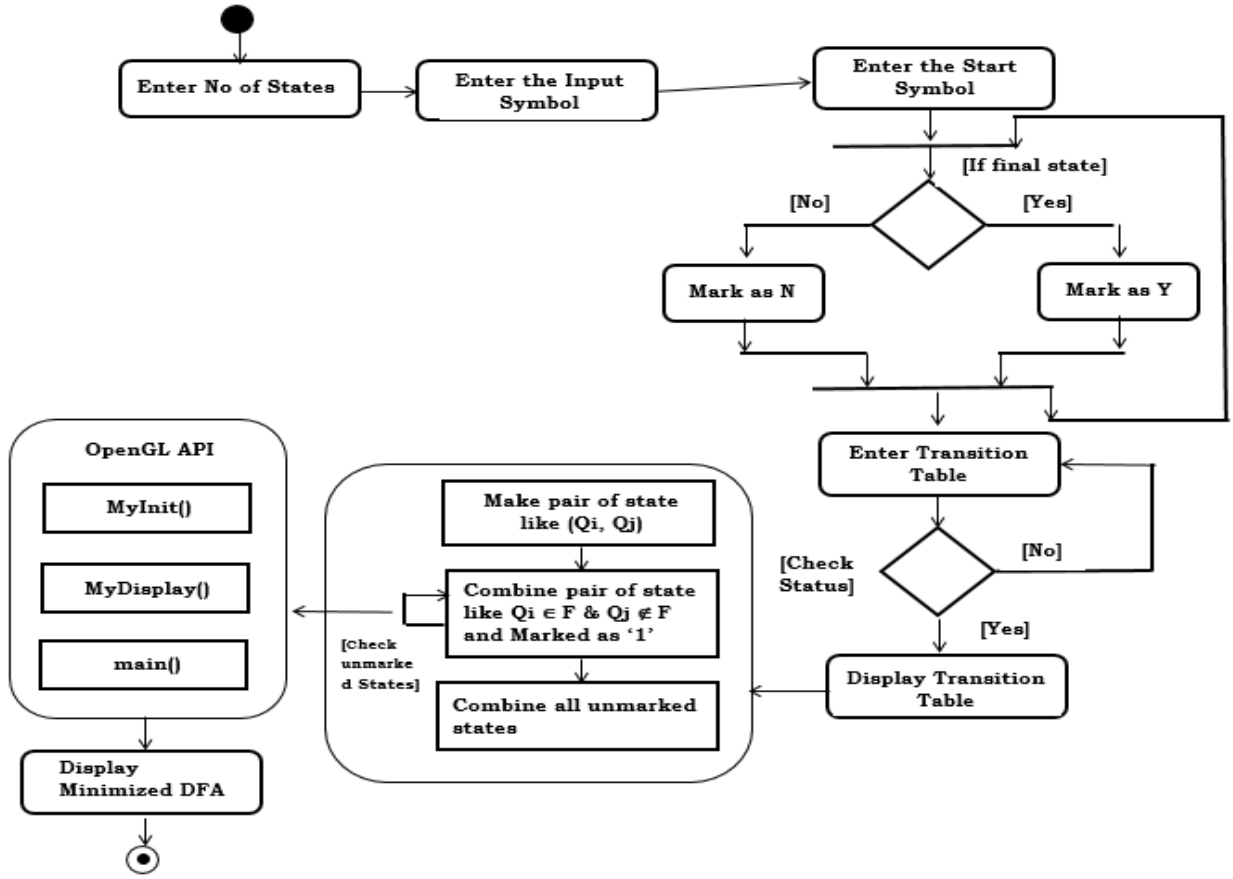

Fig. 1: Proposed methodology of minimum state DFA

At the end of this section combined all the states pair whose are marked as '0' and merged them it considers as both states are behaving same and stop the calculations and pass the control to the third and last section of the methodology. In this section, all control of the merged and individual states are collected and based on the transitions the appropriate geometrical shape is selected. Based on the operation this control is transfer to the OpenGL API sub-functions like MyInit(), MyDisplay() is executed and combine these function in main() function. The Diagram show the proposed methodology of the minimum state deterministic finite automaton.

III. CONCLUSION

As described in the proposed research paper, the Deterministic finite automaton is used in various fields, like pattern recognition, image processing, natural language, machine learning and related fields. There may be chance that Deterministic finite automaton based methods unnecessarily use the large storage space and which states behave similarly. Therefore, by applying minimizing state deterministic finite automaton approach, it helps to achieve the objective of space storage reduction and smooth working without any conflicts. This research paper also focuses on the methodology of a minimized state Deterministic finite automaton and OpenGL, which is, represented the DFA graphically on the current window.

The current phase of research illustrates that the Graphical representation of the minimum state Deterministic Finite Automaton will perform well. It could have a scope for improving the present system. Hence, an effective and uncomplicated methodology for graphical representation of minimum state Deterministic Finite Automaton has been elucidating.

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International Journal of Research in Science and Technology
Volume 4, Issue 3 : July – September, 2017
ISSN 2394 - 9954

OPTIMAL BINARY SEARCH TREE (OBST)

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ABSTRACT
There are various methods to trace standard algorithm of OBST but to trace standard algorithm steps are lengthy and it becomes time consuming process while calculating minimum cost of the tree. The Proposed approach computes the minimum cost of the Optimal binary Search Tree (OBST) easily from the computation table itself which is based on standard algorithm without performing calculations manually stepwise mention in the algorithm. This approach is easy to calculate minimum cost of OBST and finding root of the OBST from last calculation using standard algorithm by making some observations and applying some easy steps to build a calculation table which is in shape of ɔ (Reverse L). This method gives a tree optimally with simple way in minimum time.

Keywords: Optimal Binary Search tree (OBST), cost, root, computation, minimum

INTRODUCTION
For searching a word from online dictionary and for every required word there is need of looking up in the dictionary then it becomes time consuming process. To perform this look up more efficiently it is necessary to build Binary Search Tree (BST) of common word as key elements. Again to make this BST efficient by arranging frequently used words nearer to the root and less frequently words away from the root. Such a BST makes our task more simplified as well as efficient. This type of BST is called OBST.

Tree with minimum cost is called as OBST. Its implementation concept used in Symbol table. An online dictionary heavily depends on the facilities which are given by optimal binary search trees. As the number of users increases by whom dictionary is used then it assign weights (frequencies) to the corresponding words according to their frequency. This approach is useful to provide quick answer by which search time gets decreases whenever storing word into binary search tree (BST).Normally in Word Prediction there is a problem of guessing next word in a sentence which is being entered and change this prediction as the word is entered. Word prediction implies both 'Word Completion and Word Prediction'. Word completion is defined as provide a list of words to the user after a letter has been entered by the user. While Word Prediction is defined as providing a list of probable words to the user after a word has been entered or selected which is based on previous word rather than on the basis of letter. It is easy to solve the problem of Word Completion since knowledge of some letters provides the predictor an opportunity to eliminate many of irrelevant words.

Now a day's Word prediction application are becoming increasingly popular which is implemented with the help of OBST through which word having highest frequency nearer to the root means on the top side of the dictionary or symbol table for example when you start typing a what's App message on your mobile or when you start typing any query in Google search a list of probable entries almost instantly appears because of this one can easily understand or getting idea what exact word required for their search which helps the user to avoid grammatical mistakes which increases productivity and text entry.

RELATED WORK
In routine method if user trace standard algorithm manually step by step to calculate minimum cost of optimal binary search tree then it becomes time consuming process which made the algorithm so difficult to trace and construct calculation table to calculate cost, weight and root of the tree. In some methods to calculate these values there is a use of 3 different tables for weight (frequency), cost and root. Its results in wastage of calculation time. In following algorithm frequency of particular Input symbol or a keyword is also considered.

ALGORITHM OF OBST
OBST(pi,qi,n)

Given n distinct identifiers $a_1<a_2<$ ------- $<a_n$ and probabilities $p_{i,L} \le i \le n$ and $q_{i,0} \le i \le n$ this algorithm computes the cost of optimal binary search trees T_{ij} for identifiers a_{i+1},-----,a_j.It computes r_{ij}, the root of T_{ij}. W_{ij} is the weight (frequency) of T_{ij}

for i:=0 to n-1 do

a) $(w_{ii},r_{ii},c_{ii}):=(q_i,0,0)$ //initialize

b) $(w_{i,i+1},r_{i,i+1},c_{i,i+1}):=(q_i+q_{i+1}+p_{i+1},i+1, q_i+q_{i+1}+p_{i+1})$ //optimal trees with one node

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End loop

$(w_{nn},r_{nn},c_{nn}):=(q_n,0,0)$

for m:=2 to n do //find optimal trees with m nodes

for i:=0 to n-m do

a) j:=i+m

b) $w_{ij}=w_{i,j-1}+p_j+q_j$

c) k:= a value of L in the range $r_{i,j-1} \le L \le r_{i+1,j}$ that minimizes $c_{i,L-1}+c_{L,j}$

d) $c_{ij}:=w_{ij}+c_{ik-1}+c_{k,j}$

e) $r_{ij}:=k$

End loop

End loop

End OBST

If user trace algorithm manually which is mention above to calculate minimum cost of OBST then it is lengthy because there is repetition using loops and while executing loops if user made any mistake in incrementing counter then all the calculations will go wrong. One more statement is difficult to understand in above algorithm is as follows

c) k:= a value of L in the range $r_{i,j-1} \le L \le r_{i+1,j}$ that minimizes $c_{i,L-1}+c_{L,j}$

From this user cannot decides value of k properly which is link with further statements.

PROPOSED WORK

Proposed work developing easy approach to construct table of calculations of Optimal Binary Search Tree and find out the OBST having minimal cost by applying some tricks on algorithm steps and using calculated values of first row for second row and so on from the table itself which saves calculation time means there is no need to refer the standard algorithm later. Following steps avoids repetition by the loops.

PROPOSED STEPS TO COMPUTE THE COST OF OBST

Consider n number of nodes and $a_1,a_2,a_3,$------,a_n which are the labels denotes the keywords in the given data and $p_1,p_2,p_3,$------,p_n and $q_0,q_1,q_2,q_3,$------,q_n are the probabilities. This data can be classified into the text keywords, individual characters or digits.

Steps to calculate Computation Table

1. While building a computation table for each row increment row(i) and column(j) number by 1 for each individual cell horizontally and for each column keep row number same and increment column number by 1 for each individual cell vertically. for example in first row (first cell is w_{00}, second cell is w_{11}……., last is w_{nn} horizontally) and in first column(first cell is w_{00},second cell is w_{01}……,last is w_{0n} vertically) and deduct one cell calculation from each row as mention in the computation table given below.
2. Calculate the weight (frequency), cost and root as from w_{00} to w_{nn},c_{00} to c_{nn} and r_{00} to r_{nn} in first row and assign values of q_0 to w_{00}, q_1 to w_{11} upto q_n to w_{nn} and in this row values of cost and root for every column assign to zero like table given below.

   $w_{ij},c_{ij},r_{ij}:=(q_i,0,0)$ (Initialize first row using this formula) in this i means row number and j means column number.

3. From first row we can easily calculate second row and assign values as follows.
   $w_{ij}=w_{ij-1}+p_j+q_j$

   $c_{ij}=w_{ij}$

   $r_{ij}=j$

   for example

   $w_{01}=w_{00}+p_1+q_1$

   $c_{01}=w_{01}$

   $r_{01}=1$

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4. For next row use following formulas till last row calculation which is single cell and this is optimal cost and from this we will obtain root value.

   $w_{ij}=w_{ij-1}+p_j+q_j$

   $c_{ij}=w_{ij}$+select value of k from above two root valuesof current c_{ij} which is going to be calculate and minimizes value of c_{ij}(calculate value after selecting k using this $\{c_{ik-1} + c_{kj}\}$

   r_{ij}=k that minimizes $c_{ij.}$

EXPERIMENTAL RESULTS AND DISCUSSIONS

Based on knowledge of proposed work OBST for textual word is going to be constructed by taking standard algorithm as base logic is rewritten in order to reduce repetition.

Ex.Let n=3 where nodes are (a_1,a_2,a_3)=(if,read,while) and probabilities are $(p_1,p_2,p_3,p_4)=(3,3,1)$ and $(q_0,q_1,q_2,q_3)=(3,1,1,1)$ .Initially we have $w_{ij}=q_i,c_{ij}=0$ and $r_{ij}=0$, $0 \leq i \leq 3$.

Soln:- Perform proposed steps to calculate minimum cost of OBST .

1.From step 1 it is clear that to calculate first row increment row number as well as column number by 1 horizontally means w_{00},c_{00} and r_{00} in first cell,w_{11},c_{11},r_{11} in second cell and so on upto w_{nn},c_{nn} and r_{nn} as per given in the table below.

$w_{00}=q_0=3$

$c_{00}=0$

$r_{00}=0$ and so on…..

2. For second row keep row number same and increment column number by 1 vertically and increment row and column number by 1 horizontally for each cell and deduct one cell from each row means perform calculation from w_{01} to w_{23} as mention in the table.

$w_{01}=w_{00}+p_1+q_1=3+3+1=7$

$c_{01}=w_{01}=7$

$r_{01}=1$

3. For third row

$W_{02}=w_{01}+p_2+q_2=7+3+1=11$

To calculate c_{02} select k first which minimizes value of c_{02}

Select value of k from from above two roots value of c_{02}

1.root r_{01}=1 means k=1 and assign r_{02}=1(k)

where {i=0,j=2 and k=1} calculate

$\{c_{ik-1} + c_{kj}\}$ means $\{c_{00}+c_{12}\}$=5

2.root r_{12}=2 means k=2 and assign r_{02}=2(k)

where {i=0,j=2 and k=2}calculate

$\{c_{ik-1} + c_{kj}\}$ means $\{c_{01}+c_{22}\}$=7

Take minimum from $\{c_{00}+c_{12}\}$=5 and $\{c_{01}+c_{22}\}$=7 that is 5 for c_{02}

$C_{02}=w_{02}+5 =11+5=16$ (5which minimizes c_{02})

$R_{02}=1$ means k (which minimizes c_{02})

Apply above step 3 to calculate rest of the cells upto last which is minimal cost of OBST as shown in the computation table.

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j → / i ↓	0	1	2	3
0	$w_{00}=3$ $c_{00}=0$ $r_{00}=0$	$w_{11}=1$ $c_{11}=0$ $r_{11}=0$	$w_{22}=1$ $c_{22}=0$ $r_{22}=0$	$w_{33}=1$ $c_{33}=0$ $r_{33}=0$
1	$w_{01}=7$ $c_{01}=7$ $r_{01}=1$	$w_{12}=5$ $c_{12}=5$ $r_{12}=2$	$w_{23}=3$ $c_{23}=3$ $r_{23}=3$	
2	$w_{02}=11$ $c_{02}=16$ $r_{02}=1$	$w_{13}=7$ $c_{13}=10$ $r_{13}=2$		
3	$w_{03}=13$ $c_{03}=23$ $r_{03}=1$			

Figure - 1: Computation Table

Root of tree $T_{03}$is $r_{03}=1$(i.ei=0,j=3,k=1) means root is a_1(if) and frequency means weight($w_{03}=13$) of root a_1 is highest than other nodes.

To decide left and right subtree node of root

To decide left subtree=r_{ik-1}

Right subtree=r_{kj}

Hence the left subtree is r_{ik-1}i.e $r_{00}=0$ means no left subtree and the right subtree is r_{kj}i.e $r_{13}=2$ means a_2(read), left subtree of a_2(i=1,j=3,k=2) is r_{ik-1} that Is $r_{11}=0$ means left subtree of a_2 is empty & right subtree of a_2(i=1,j=3,k=2) is r_{kj} that is $r_{23}=3$ means a_3(while) for a_3(i=2,j=3,k=3) left subtree is r_{ik-1} i.e. $r_{22}=0$ means empty and right subtree of a_3 is r_{kj}i.e $r_{33}=0$ means empty then optimal search tree is as follows.

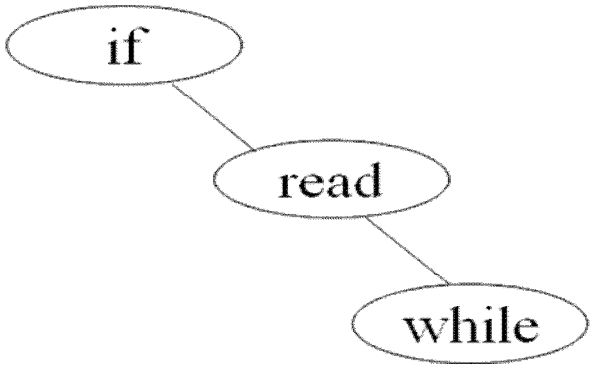

Figure – 2: OBST (Optimal Binary Search Tree)

CONCLUSION

Drawback of standard algorithm is that it is complicated and lengthy to trace manually and it takes more time to calculate computation table for minimum cost proposed approach is very useful in removing redundancy and later as it save manual tracing time. Above Optimal Binary Search Tree prove that node having highest weight means frequency is at root position (i.e. $w_{03}=13$ of $a_1$means of node if) and node having frequency $w_{13}=10$ means a_2 (that is read)nearer to the root and node having lowest frequency $w_{23}=7$ means a_3 away from the root as per the principle of OBST.

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1Author Designation, Department, Organization, City, email id

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