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A Study on Pushdown Automata for Solving Simple Problems

Ezhilarasu P, Jayaraj R, Prakash J, Ananthi J

***Abstract*—** In this paper, we discuss the use of Pushdown Automata (PDA) as a problem solver for simple mathematical problems. The problems taken for the study are checking the input string length as 1.odd or even 2.multiples of n numbers. For each problem two cases are taken. First case considers entire string as an input. Second case considers individual characters in the input string. The transition diagram and the transition table also derived for the taken problem. The instantaneous description for taken input string also explained.

***Keywords*—** Pushdown Automata (PDA), odd or even, multiple of n, Transition Diagram, Transition Table, instantaneous description.

I. Introduction

Pushdown Automata (PDA) is an abstract machine that is placed between Finite Automata (FA) and the Turing Machine (TM). The construction of Finite Automata is too simple and for the Turing Machine is too complex. The Finite Automata has the limitation that it can read only the input symbols one at a time, but can't hold it. This problem needs to be solved. The Pushdown Automata serve as a solution for the above problem. It uses the stack for holding the input symbol.

A PDA is formally defined as a 7-tuple[1]:

$M=\{S, \Sigma, \Gamma, \delta, q_0, Z_0, F\}$

where

- S is a finite set of states
- Σ is a finite set which represents the collection of input alphabet
- Γ is a finite set which represents the collection of stack alphabet
- δ represents transition function
- q_0 is the start state
- Z_0 is the initial stack symbol
- F is the set of final or accepting states

Here the symbol Γ & Z_0 used to represent the stack. Hence we define Pushdown Automata(PDA)=Finite Automata (FA)+ Stack.

Ezhilarasu P, Professor, Department of Computer Science and Engineering, Hindusthan College of Engineering and Technology, Coimbatore - 641032, India. (Email: prof.p.ezhilarasu@gmail.com)

Jayaraj R, Associate Professor, Department of Computer Science and Engineering, Hindusthan College of Engineering and Technology, Coimbatore - 641032, India. (Email: jayarajme@gmail.com)

Prakash J, Ananthi J , Assistant Professor, Department of Computer Science and Engineering, Hindusthan College of Engineering and Technology, Coimbatore - 641032, India (Email: jeevaprakash86@gmail.com, ananthijesubalan@gmail.com)

II. Related Work

Ezhilarasu et.al [2014] classified Finite Automata based on the loop [2,3, and 4]. Ezhilarasu et.al [2015] classified Finite Automata based on the substring [5,6,7], and the combination of both [8]. Based on this combination Ezhilarasu et.al [2015] classified the variants of Automata[9], and constructed Finite Automata to implement the various problems [10,11,12,13, and 14]. Ezhilarasu et.al [2015] also implemented some problems in the Turing Machine [15, and 16]. These experience used as a base for construction of Pushdown Automata(PDA) for simple problems.

III. Construction Of PDA- Odd Or Even Length

The Transition Diagram of Pushdown Automata to find the odd or even length totally for the given input string with two input symbols is as given below in the figure 1. Here the input formed using the two input symbols 'a' and 'b'. Totally five states are used. In which the state q_0 represent the starting state. The state qf1 and qf2 represents the final states for odd and even length string. The top of the stack is by default z_0. The odd numbered transition performs push operation (first, third, fifth etc.). The even numbered transition performs pop operation (second, fourth, sixth etc.). The Transition Table for the above problem is as given in the table 1.

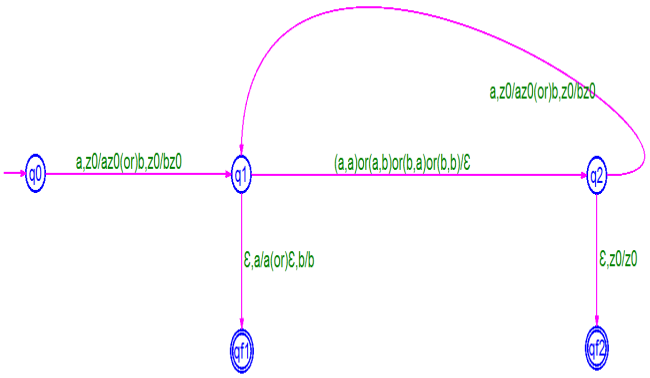

Fig.1.Transition Diagram of Pushdown Automata to find the odd or even length totally for the given input string with two input symbols

Table.1.Transition Table of Pushdown Automata to find the odd or even length totally for the given input string with two input symbols

Transition No	Current State	Input	Stack Top	String (operation)	Resultant State
1	→q_0	a	z_0	az_0(push)	q_1
2	→q_0	b	z_0	bz_0(push)	q_1
3	q_1	a	a	ε(pop)	q_2
4	q_1	a	b	ε(pop)	q_2
5	q_1	b	a	ε(pop)	q_2
6	q_1	b	b	ε(pop)	q_2
7	q_1	**ε**	a	a(accept-odd length)	*qf_1
8	q_1	**ε**	b	b(accept-odd length)	*qf_1
9	q_2	a	z_0	az_0(push)	q_1
10	q_2	b	z_0	bz_0(push)	q_1
11	q_2	**ε**	z_0	z_0(accept-even length)	*qf_2

Instantaneous Description: (q0,abba,z0)

The input taken here is abba. From the figure 1 we can find the starting state. Here the starting state is q_0. By default the top of the stack is z_0. The table 1 can be used to perform the transition operation. Initially the current state is q0, input symbol is a and top of the stack is z0. The transition number 1 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,bba,az0)

Now the current state is q1, input symbol is b and top of the stack is a. The transition number 5 matches given condition. Hence we need to perform pop operation and the resultant state will be q2.

Pop |- (q2,ba,z0)

Now the current state is q2, input symbol is b and top of the stack is z0. The transition number 10 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,a,bz0)

Now the current state is q1, input symbol is a and top of the stack is b. The transition number 4 matches given condition. Hence we need to perform pop operation and the resultant state will be q2.

Pop |- (q2, ε,z0)

Now the current state is q2, input symbol is ε and top of the stack is z0. The transition number 11 matches given condition. Hence we need to accept the input string which is even length.

Accept qf2.

The Transition Diagram of Pushdown Automata to find the odd or even length totally for the given input string with three input symbols is as given below in the figure 2. Here the input formed using the three input symbols 'a', 'b' and 'c'. Totally five states are used. In which the state q_0 represent the starting state. The state qf1 and qf2 represents the final states for odd and even length string. The top of the stack is by default z_0. The odd numbered transition performs push operation (first, third, fifth etc.). The even numbered transition performs pop operation (second, fourth, sixth etc.). The Transition Table for the above problem is as given in the table 2.

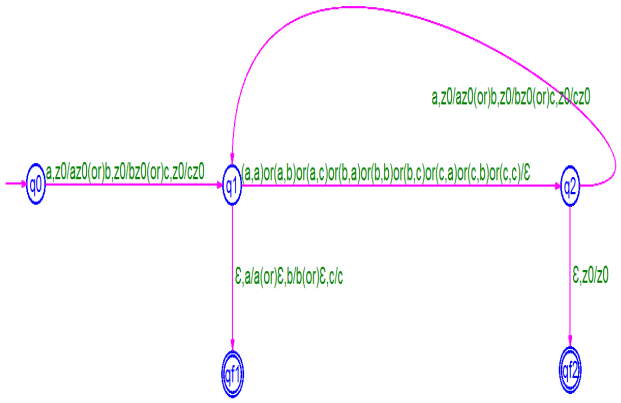

Fig.2. Transition Diagram of Pushdown Automata to find the odd or even length totally for the given input string with three input symbols

Table.2.Transition Table of Pushdown Automata to find the odd or even length totally for the given input string with three input symbols

Transition No	Current State	Input	Stack Top	String (operation)	Resultant State
1	→q_0	a	z_0	az0(push)	q1
2	→q_0	b	z_0	bz0(push)	q1
3	→q_0	c	z_0	cz0(push)	q1
4	q_1	a	a	ε(pop)	q2
5	q_1	a	b	ε(pop)	q2
6	q_1	a	c	ε(pop)	q2
7	q_1	b	a	ε(pop)	q2
8	q_1	b	b	ε(pop)	q2
9	q_1	b	c	ε(pop)	q2
10	q1	c	a	ε(pop)	q2
11	q1	c	b	ε(pop)	q2
12	q1	**c**	c	ε(pop)	q2
13	q1	ε	a	a(accept-odd length)	*qf_1
14	q1	ε	b	b(accept-odd length)	*qf_1
15	q1	ε	c	c(accept-odd length)	*qf_1
16	q_2	a	z_0	az0(push)	q1
17	q2	b	z_0	bz0(push)	q1
18	q2	c	z_0	cz0(push)	q1
19	q2	ε	z_0	z_0(accept-even length)	*qf_2

Instantaneous Description: (q0,abcba,z0)

The input taken here is abcba. From the figure 2 we can find the starting state. Here the starting state is q_0. By default the top of the stack is z_0. The table 2 can be used to perform the transition operation. Initially the current state is q0, input symbol is a and top of the stack is z0. The transition number 1 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,bcba,az0)

Now the current state is q1, input symbol is b and top of the stack is a. The transition number 7 matches given condition. Hence we need to perform pop operation and the resultant state will be q2.

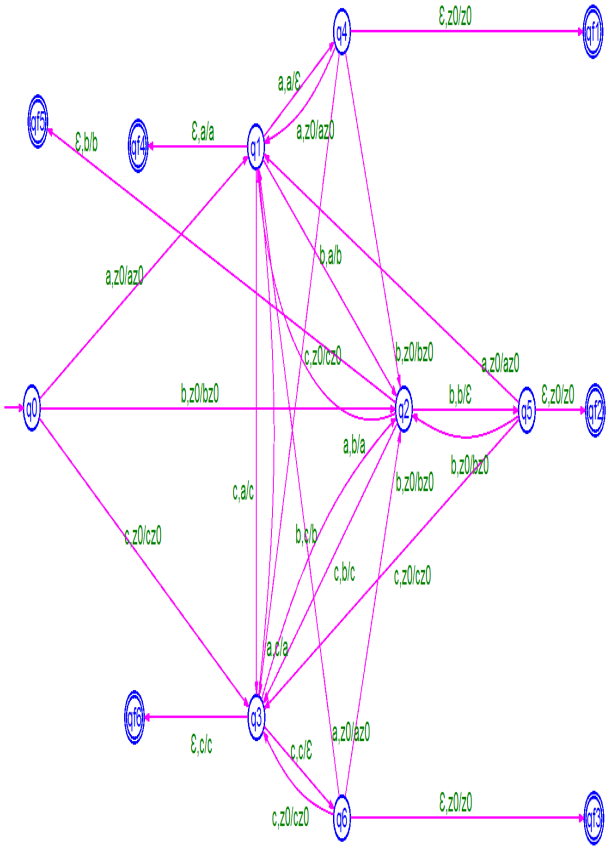

Fig.3. Transition Diagram of Pushdown Automata to find the odd or even length separately for the given input string with three input symbols

Pop |- (q2,cba,z0)

Now the current state is q2, input symbol is c and top of the stack is z0. The transition number 18 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,ba,cz0)

Now the current state is q1, input symbol is b and top of the stack is c. The transition number 9 matches given condition. Hence we need to perform pop operation and the resultant state will be q2.

Pop |- (q2, a,z0)

Now the current state is q2, input symbol is a and top of the stack is z0. The transition number 16 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Pop |- (q1, ε,az0)

Now the current state is q1, no input symbol left and top of the stack is a. The transition number 13 matches given condition. the resultant state will be qf1. Hence we need to accept the string which is odd length.

Accept qf1

The Transition Diagram of Pushdown Automata to find the odd or even length individually for the given input string with three input symbols is as given below in the figure 3. Here the input formed using the three input symbols ‘a’ , ‘b’ and 'c'. Totally thirteen states are used. In which the state q_0 represent the starting state. The state qf1,qf2 and qf3(q4,q5 and q6) represents the final states for even length for 'a' , 'b' and 'c'. The state qf4,qf5 and qf6(q1,q2 and q3) represents the final states for odd length for 'a' , 'b' and 'c'. The top of the stack is by default z_0. The odd numbered transition performs push operation (first, third, fifth etc.). The even numbered transition performs pop operation (second, fourth, sixth etc.). The Transition Table for the above problem is as given in the table 3.

Table.3.Transition Table of Pushdown Automata to find the odd or even length totally for the given input string with three input symbols

Transition No	Current State	Input	Stack Top	String (operation)	Resultant State
1	→q_0	a	z_0	az_0	q_1
2	→q_0	b	z_0	bz_0	q_2
3	→q_0	c	z_0	cz_0	q_3
4	q_1	a	a	ε(pop)	q_4
5	q_1	b	a	b(delete a)	q_2
6	q_1	c	a	c(delete a)	q_3
7	q_1	ε	a	a(accept)	*qf_4
8	q_2	a	b	a(delete b)	q_1
9	q_2	b	b	ε(pop)	q_5
10	q_2	c	b	c(delete b)	q_3
11	q_2	ε	b	b(accept)	*qf_5
12	q_3	a	c	a(delete c)	q_1
13	q_3	b	c	b(delete c)	q_5
14	q_3	c	c	ε(pop)	q_3
15	q_3	ε	c	c(accept)	*qf_6
16	q_4	a	z_0	az_0	q_1
17	q_4	b	z_0	bz_0	q_2
18	q_4	c	z_0	cz_0	q_3
19	q_4	ε	z_0	z_0(accept)	*qf_1
20	q_5	a	z_0	az_0	q_1
21	q_5	b	z_0	bz_0	q_2
22	q_5	c	z_0	cz_0	q_3
23	q_5	ε	z_0	z_0(accept)	*qf_2
24	q_6	a	z_0	az_0	q_1
25	q_6	b	z_0	bz_0	q_2
26	q_6	c	z_0	cz_0	q_3
27	q_6	ε	z_0	z_0(accept)	*qf_3

Condition

The default value of 'a','b' & 'c' is even. The state q1, q2 and q3 occurring before the states q4,q5 and q6 not considered. If the states occur twice(q1,q2 and q3) then it is equivalent to even length.

Instantaneous Description: (q0,abcba,z0)

The input taken here is abcba. From the figure 2 we can find the starting state. Here the starting state is q_0. By default the top of the stack is z_0. The table32 can be used to perform the transition operation. Initially the current state is q0, input symbol is a and top of the stack is z0. The transition number 1 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,bcba,az0)

Now the current state is q1, input symbol is b and top of the stack is a. The transition number 5 matches given condition. Hence we need to delete 'a' and the resultant state will be q2.

Delete top of the stack('a') |- (q2,cba,bz0)

Now the current state is q2, input symbol is c and top of the stack is z0. The transition number 10 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Delete top of the stack('b') |- (q3,ba,cz0)

Now the current state is q1, input symbol is b and top of the stack is c. The transition number 9 matches given condition. Hence we need to perform pop operation and the resultant state will be q2.

Delete top of the stack('c') |- (q5, a,bz0)

Now the current state is q2, input symbol is a and top of the stack is z0. The transition number 16 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Pop |- (q1, ε,az0)

Now the current state is q1, no input symbol left and top of the stack is a. The transition number 13 matches given condition. the resultant state will be qf1. Hence we need to accept the string which is odd length.

Accept qf1

IV. CONSTRUCTION OF PDA- MULTIPLES OF N NUMBERS

The Transition Diagram of Pushdown Automata to find the multiples of 3 individually for the given input string with two input symbols is as given below in the table 4. Here the input formed using the two input symbols 'a' and 'b'. Totally sixteen transition are used. In which the state q_0 represent the starting state and q_f represent the final state.

Table.4.Transition Table of Pushdown Automata to find the odd or even length totally for the given input string with three input symbols

Transition No	Current State	Input	Stack Top	String (operation)	Resultant State
1	→q_0	a	z_0	az_0	q_1
2	→q_0	b	z_0	bz_0	q_1
3	q_1	a	a	aa	q_2
4	q_1	a	b	ab	q_2
5	q_1	b	a	ba	q_2
6	q_1	b	b	bb	q_2
7	q_2	a	a	aa	q_3
8	q_2	a	b	ab	q_3
9	q_2	b	a	ba	q_3
10	q_2	b	b	bb	q_3
11	q_3	a	a	aa	q_1
12	q_3	a	b	ab	q_1
13	q_3	b	a	ba	q_1
14	q_3	b	b	bb	q_1
15	q_3	ε	a	accept	$*q_f$
16	q_3	ε	b	accept	$*q_f$

Instantaneous Description: (q0,ababaa,z0)

The input taken here is ababaa. From the table 4 we can find the starting state. Here the starting state is q_0. By default the top of the stack is z_0. The table 4 can be used to perform the transition operation. Initially the current state is q0, input symbol is a and top of the stack is z0. The transition number 1 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,babaa,az0)

Now the current state is q1, input symbol is b and top of the stack is a. The transition number 5 matches given condition. Hence we need to perform push operation and the resultant state will be q2.

Push |- (q2,abaa,baz0)

Now the current state is q2, input symbol is a and top of the stack is b. The transition number 8 matches given condition. Hence we need to perform push operation and the resultant state will be q3.

Push |- (q3,baa,abaz0)

Now the current state is q3, input symbol is b and top of the stack is a. The transition number 13 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Table.5.Transition Table of Pushdown Automata to find the odd or even length totally for the given input string with three input symbols

Transition No	Current State	Input	Stack Top	String (operation)	Resultant State
1	→q_0	a	z_0	az_0	q_1
2	→q_0	b	z_0	bz_0	q_1
3	→q_0	c	z_0	cz_0	q_1
4	q_1	a	a	aa	q_2
5	q_1	a	b	ab	q_2
6	q_1	a	c	ac	q_2
7	q_1	b	a	ba	q_2
8	q_1	b	b	bb	q_2
9	q_1	b	c	bc	q_2
10	q_1	c	a	ca	q_2
11	q_1	c	b	cb	q_2
12	q_1	c	c	cc	q_2
13	q_2	a	a	aa	q_3
14	q_2	a	b	ab	q_3
15	q_2	a	c	ac	q_3
16	q_2	b	a	ba	q_3
17	q_2	b	b	bb	q_3
18	q_2	b	c	bc	q_3
19	q_2	c	a	ca	q_3
20	q_2	c	b	cb	q_3
21	q_2	c	c	cc	q_3
22	q_3	a	a	aa	q_1
23	q_3	a	b	ab	q_1
24	q_3	a	c	ac	q_1
25	q_3	b	a	ba	q_1
26	q_3	b	b	bb	q_1
27	q_3	b	c	bc	q_1
28	q_3	c	a	ca	q_1
29	q_3	c	b	cb	q_1
30	q_3	c	c	cc	q_1
31	q_3	ε	a	a	$*q_f$
32	q_3	ε	b	b	$*q_f$
33	q_3	ε	c	c	$*q_f$

Push |- (q1,aa,babaz0)

Now the current state is q1, input symbol is a and top of the stack is b. The transition number 4 matches given condition. Hence we need to perform push operation and the resultant state will be q2.

Push |- (q2,a,ababaz0)

Now the current state is q2, input symbol is a and top of the stack is a. The transition number 7 matches given condition. Hence we need to perform push operation and the resultant state will be q3.

Push |- (q3, ε,aababaz0)

Now the current state is q3, input symbol is ε and top of the stack is a. The transition number 15 matches given condition. Hence we need to accept the input string whose length is multiples of 3.

Accept qf1

The Transition Diagram of Pushdown Automata to find the multiples of 3 individually for the given input string with three input symbols is as given below in the table 5. Here the input formed using the three input symbols 'a' 'b', and 'c'. Totally thirty three transition are used. In which the state q_0 represent the starting state and q_f represent the final state.

Instantaneous Description: (q0,abccab,z0)

The input taken here is abccab. From the table 5 we can find the starting state. Here the starting state is q_0. By default the top of the stack is z_0. The table 5 can be used to perform the transition operation. Initially the current state is q0, input symbol is a and top of the stack is z0. The transition number 1 matches given condition. Hence we need to perform push operation and the resultant state will be q1.

Push |- (q1,bccab,az0)

Now the current state is q1, input symbol is b and top of the stack is a. The transition number 7 matches given condition. Hence we need to perform pushp operation and the resultant state will be q2.

Push |- (q2,ccab,baz0)

Now the current state is q2, input symbol is c and top of the stack is b. The transition number 20 matches given condition. Hence we need to perform pushp operation and the resultant state will be q3.

Push |- (q3,cab,cbaz0)

Now the current state is q3, input symbol is c and top of the stack is c. The transition number 30 matches given condition. Hence we need to perform pushp operation and the resultant state will be q1.

Push |- (q1,ab,ccbaz0)

Now the current state is q1, input symbol is a and top of the stack is c. The transition number 6 matches given condition. Hence we need to perform pushp operation and the resultant state will be q2.

Push |- (q2,b,accbaz0)

Now the current state is q2, input symbol is b and top of the stack is a. The transition number 16 matches given condition. Hence we need to perform pushp operation and the resultant state will be q3.

Push |- (q3, ε,baccbaz0)

Now the current state is q3, input symbol is ε and top of the stack is b. The transition number 32 matches given condition. Hence we need to accept the input string whose length is multiples of 3.

Accept qf1

V. RESULT AND DISCUSSION

The Pushdown Automata from the table 1-5 analyzed. Based on that, it possible to derive the formula for other input also. It is given as in the table 6 & 7.

Table.6.Transition of Pushdown Automata to find the odd or even length totally for the given input string with two – eleven input symbols

S.NO	PROBLEM	NUMBER OF INPUT(I)	NUMBER OF STATES (3+2(ONE FOR ODD, ONE FOR EVEN)	TOTAL NUMBER OF TRANSITION (3*I+I*I+1)
1	ODD OR EVEN	2	5	11
2		3	5	19
3		4	5	29
4		5	5	41
5		6	5	55
6		7	5	71
7		8	5	89
8		9	5	109
9		10	5	131
10		11	5	155

Table.7.Transition of Pushdown Automata to find the multiples of n (3-6) numbers totally for the given input string with two and three input symbols.

S.NO	PROBLEM	NUMBER OF INPUT(I)	NUMBER OF STATES P+1+1	TOTAL NUMBER OF TRANSITION (2*I+P*I*I)
1	MULTIPLES OF 3(P)	2	5	16
2		3	5	33
3	MULTIPLES OF 4(P)	2	6	20
4		3	6	42
5	MULTIPLES OF 5(P)	2	7	24
6		3	7	51
7	MULTIPLES OF 6(P)	2	8	28
8		3	8	60
9	MULTIPLES OF 7(P)	2	9	32
10		3	9	69

VI. CONCLUSION

Pushdown Automata is an interesting topic. It can be used to solve the problems that are solvable and sometimes not solvable by the Finite Automata. The problem odd or even and multiples of n numbers can be solved using the certain formula. The formula for finding total number of transition for odd or even length is (3*I+I*I+1). The formula for finding total number of transition for multiples of n numbers is (2*I+P*I*I). Here I stand for total number of input symbol and P stands for multiples of n number. If we are finding multiples of 3 then the value for P=3. There exist formula for many problems those are similar to the given problem. This can be even extended for the turing machine.

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