Design new model of computing machine: Two Head Turing Machine(THTM)

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***Abstract*— In this paper, we describe how Turing machine(TM) with two head works. Similarly, STM, two head model has a read-write head which is scanning a single cell on infinite one-dimension tape. In Two head model of machine, we changed the design with two head in left and right of tape and based on that we defined the new formal definition which finally decreases the complexity, reducing the use of states in each problem and it is much faster than standard ones.**

I. Introduction

Regular languages and context-free languages can describe many practically important systems so they are heavily used in practice. They are, however, of limited capability and there are many languages that they cannot process, to solve this issue we shift to another language in Chomsky hierarchy, the phrase structure languages (also called Type 0 languages), and the machines that can process them called Turing machines.

The machine model defined by A.M Turing in 1936 and he called it computer and he claimed, what cloud naturally be called an effective procedure, can be realized by a Turing machine? This is known as Turing's thesis. Turing Machines describes a much larger class of languages, TMs have a "scratch" memory in the form of tape and this is making them more powerful than other models like PDA, FSM.

The first problem in TM model is when machine is going to start moving from a cell to another once, it's taking much time if the input is huge, in other word moving between cells without any change is consuming time, and second problem is sometimes input is huge and machine should work for plenty of time to figure out the string is acceptable or not ,in this case if machine halt suddenly because of the inconsistency between transition functions and string then in last part of computing, machine goes unaccepted mode and we lose time.

The principal objective of this paper is improving the capability of Turing machine and decreasing execution time. We introduce a formal model for Turing machine that make it faster, time consuming, reduce complexity of machine and we have more control over the problem.

II. Formal Definition

Formally two head Turing machine model is a 7-tuple M = (Q , Σ , Γ , δ , q0 , b , F) , where :

- Q : Is a finite, non-empty set of states
- Σ :Set of input symbols
- Γ :Non-empty set of the tape alphabet/symbols
- $\delta : Q\backslash F \times \Gamma_{(LH)} \times \Gamma_{(RH)} \rightarrow Q\backslash F \times \Gamma_{(LH)} \times \Gamma_{(RH)} \times \{L, R, N\}_{(LH)} \times \{L, R, N\}_{(RH)}$ is a partial function called the transition function, where L is left shift, R is right shift and N is no move that make TM more flexible. Γ (LH) is symbol under left head and Γ (RH) is symbol under right head.
- $q0 \in Q$ is the initial state
- $b \in \Gamma$ is the blank symbol
- $F \subseteq Q$ is the set of final or accepting states

The first part of transition function consist of triple tuple where (Q\F) is current state, ($\Gamma_{(LH)}$) is symbol under the left head and Γ(RH) is symbol under the right head . In second part we have designed four element in tuple where (Q\F) is a next state, $\Gamma_{(LH)}$ is a action which left head is going to do, $\Gamma_{(RH)}$ is a action which right head is going to do, $\{L, R, N\}_{(LH)}$ is move the left head one cell to the left , right or waiting which we will denote by the symbols L , R and N respectively and finally $\{L, R, N\}_{(RH)}$ is move the right head one cell to the left , right or waiting which we will denote by the symbols L , R and N respectively.

III. Why do we have used two head?

In the arithmetic and logical operations we often have two operands with one sign which determine what operation we are going to do e.g. (1+3), Even in complex mathematical operation we are dealing with this role that we have to calculate whole operation two by two e.g. ((1+2)*(10/12)+4), to solve this problem we have to look at priority of sign and parenthesizes. In this case in initial step: 1+2, second step is: 10/12, and then in third step (result first step)*(result of second step) and finally we have to add result number of third step by 4. In all steps we always have two operands and one sign, so we reached the conclusion that the machine to computing needs two head at the moment.

IV. Two head Turing machine

Likewise TM, this machine has also 7-Tuple but in the new model, we have used two head Read/Write (Fig.1) which in initial step they are in left and right side of tape. similar standard Turing Machine they can move "left & right" but we have used other feature for head "stop" to keep head waiting in current position, this additional feature makes machine more flexible to solve problems which needs one head waiting for one or more steps.

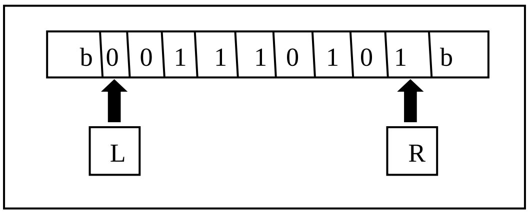


Fig.1 Two head Turing machine

V. TRANSITION FUNCTION EXAMPLES

A. Example

(Q1 , a , b) : (Q2 , X , X , R , L)

Transition function like Turing machine consists of two parts. Because we have two heads, we must control both heads at the same time. For instance, we are in state Q1 and under the left and right heads there are a and b respectfully. At the Second part, state Q1 changed to Q2 then symbol a,b converted to X respectfully, at the end left head moved one cell to right and right head moved one cell to left.

B. Example

(Q1 , a , b) : (Q1 , a , X , R , N)
(Q1 , b , b) : (F , X , X , N , N)

The goal of this example is how we can use single head and keep waiting another one in new model. In first line transition function we make a loop that right head is in waiting position and the left head doing its task.

In second line the machine is in Q1 state (current state) with "b" under the left and right heads, it will move into final state (F) then both heads after converting b to X will go to halt position.

VI. COMPRESSION BETWEEN STANDARD TURING MACHINE AND TWO HEADS MODEL WITH EXAMPLE

$$L=\{a^n b^k a^n b^k : n \neq k\}$$

The language L is a rectangle language which number of a is unequal with b, we have tried to determine the compression between standard Turing machine and two head model. In table.1 and Table.2 we have written transition function for STM and two heads model .The number of states in STM model is 11 but the numbers of states in two heads model is 4. Number of transition function in STM is 31 but the two heads model has made by 9 transition function that it shows the complexity of STM is more than two heads model.

TABLE I. STANDARD TURING MACHINE TRANSITION FUNCTION

STM transition function	
("init","a"):("Q1", "x", "R")	("Q5","x"):("Q6", "x", "R")
("Q1","a"):("Q1", "a", "R")	("Q6","b"):("Q7", "y", "R")
("Q1","b"):("Q2", "b", "R")	("Q7","b"):("Q7", "b", "R")
("Q2","b"):("Q2", "b", "R")	("Q7","*"):("Q8", "*", "R")
("Q2","*"):("Q2", "*", "R")	("Q8","*"):("Q8", "*", "R")
("Q2","a"):("Q3", "*", "L")	("Q8","b"):("Q9", "m", "L")
("Q3","b"):("Q3", "b", "L")	("Q8","m"):("Q8", "m", "R")
("Q3","*"):("Q3", "*", "L")	("Q9","m"):("Q9", "m", "L")
("Q3","a"):("Q3", "a", "L")	("Q9","*"):("Q9", "*", "L")
("Q3","x"):("init", "x", "R")	("Q9","b"):("Q9", "b", "L")
("init","b"):("Q4", "b", "R")	("Q9","y"):("Q6", "y", "R")
("Q4","b"):("Q4", "b", "R")	("Q6","*"):("Q10", "*", "R")
("Q4","*"):("Q4", "*", "R")	("Q10","*"):("Q10", "*", "R")
("Q4"," "):("Q5", " ", "L")	("Q10","m"):("Q10", "m", "R")
("Q5","b"):("Q5", "b", "L")	("Q10"," "):("final"," ","N")
("Q5","*"):("Q5", "*", "L")	

TABLE II. TWO HEAD TURING MACHINE

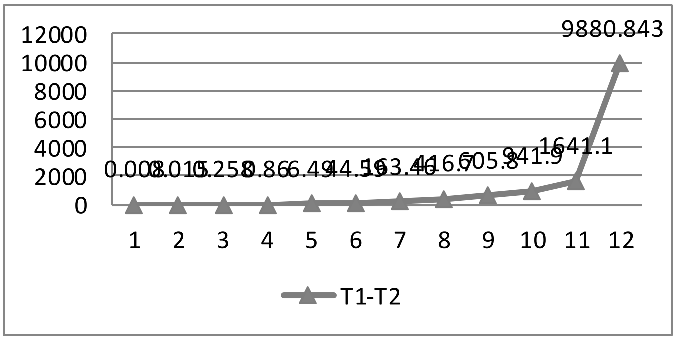
Two head TM transition function
("init","a","b"):("init","a","b","N","L")
("init","a"," "):("init","a"," ","N","L")
("init","a","a"):("Q1","a","a","N","L")
("Q1","a","a"):("Q1","a","a","N","L")
("Q1","a","b"):("Q2","a","b","N","R")
("Q2","a","a"):("Q2","*","*","R","R")
("Q2","b","b"):("Q3","y","y","R","R")
("Q3","b","b"):("Q3","y","y","R","R")
("Q3","*"," "):("final","*"," ","N","N")

TABLE III. EXECUTION TIME FOR BOTH MACHINE TO DETERMINE THE PERFORMANCE

	n	k	T1 (standard TM)/s	T2 (New)/s	T1-T2
1	5	3	0.051	0.043	0.008
2	20	12	0.085	0.07	0.015
3	40	50	0.35	0.092	0.258
4	100	80	0.98	0.12	0.86
5	300	200	6.7	0.21	6.49

6	800	500	44.98	0.39	44.59
7	1500	1000	164.3	0.84	163.46
8	3500	500	418.27	1.57	416.7
9	2000	2800	608	2.2	605.8
10	4000	2000	944.77	2.87	941.9
11	5000	2500	1646.45	5.35	1641.1
12	8000	10000	9894.94	14.097	9880.843

TABLE IV. IMPROVEMENT SLOP



In this experiment:

- T1 is execution time for standard Turing machine
- T2 is execution time for new model Turing machine
- T1-T2 is a differentiate between T1 and T2
- n,k are length of (a) and (b) symbols

At the T1-T2 column whatever the number of n and k are increase, difference between two machines became more highlighted. for instance, when (n=8000, k=10000) STM accepted this input in 9892 second but in two heads model executed much faster and we think this is power of machine. The graph.1 shows the differentiations between two models, this is obvious whatever we have increased length of input, two heads model got better performance when there was a significant increase in the 11 entry and the difference reached to almost 1000 seconds.

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