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4. TURING MACHINE

* Introduction to Turing Machine :-

→ "Turing m/c is mathematical model which consist of an infinite length tape divided into cells on which input is given. It consist of head which reads the i/p tape."

- A state register stores the state turing m/c. After reading an i/p symbol, it is replaced with another symbol, its internal state is changed and it moves from one cell to the right or left.
- If TM m/c reaches to final state, the i/p string is accepted otherwise rejected.

A TM m/c can be described as 7-tuple $(Q, X, \Sigma, \delta, q_0, B, F)$

where, Q is finite set of state.
X is tape alphabets
Σ is i/p alphabets
δ is transition function
q_0 is initial state.
B is Blank symbol
F is set of final state.

e.g.

--	B	B	a	b	#	C	a	b	B	B	---

↑ read-write head

Example of Turing Machine.

- Turing m/c is more powerful than PDA.
- Turing m/c is capable of performing computation on i/p and producing a new result.

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* Applications of Turing Machine :-

→ 1) To read or write infinite tape.
2) to solve problem in computer science & testing limit of Computation.
3) it is used to simulate other turing machine.
4) Turing m/c is used to reverse string of any character.
5) it is used in algorithmic information theory
6) Turing m/c is used for high performance Computing, m/c learning, s/w engg. and computer network.
7) Turing m/c is used to perform computation for computer system.
8) Turing m/c is used in theory of computation.

* Different way of Extension of TM :-

→ In std TM, the tape is semi-infinite. It is bounded on the left and unbounded on the right side.

Some of the Extension of TM :-
1) Tape is of infinite length in both the direction.
2) Multiple heads and single tape.
3) Multiple tape with each tape having it's own independent head.
4) K-dimensional tape.
5) Non-deterministic turing m/c.

1) Two-way infinite turing m/c :-
- In 2-way infinite TM, there is an infinite sequence of blank on each side of i/p string. In instantaneous description, these blocks are never shown.

2) A turing m/c with multiple head -
→ A TM with single tape can have multiple heads. let's consider TM with two head H1 & H2. Each head is capable of performing read/write operation

B a a b a a b a B B
↑H1 ↑H2 ← TM with two head

3] Multi-tape Turing Machine :-

→ - Multi-tape turing m/c has multiple ~~tape~~ tuples with each tape having it's own independent head.

- Let's consider case of two tape turing m/c as shown in fig.

Tape-1	B	a	b	a	a	b	b	a	B	B	B
				↑ head							

Tape-2	B	a	a	b	b	a	b	a	B	B	B
					↑ head						

Two Tape Turing Machine

- The transition behaviour of a two-tape turing m/c can be defined as given below.

$$\delta(q_1, a_1, a_2) = (q_2, (S_1, M_1), (S_2, M_2))$$

where,

q_1 is current state.

q_2 is next state.

a_1 symbol head on tape 1

a_2 symbol under head on tape 2.

S_1 is symbol written in current cell on tape 1.

S_2 is symbol written in current cell on tape 2.

M_1 is the movement (L, R, N) of head on tape 1

M_2 is the movement (L, R, N) of head on tape 2.

* limitation of Turing Machine :-

→ 1) Computational Complexity theory.

- limitation is that they do not model strength of particular arrangement

2) Concurrency :-

limitation is that they do not model concurrency well.

3) There are alway halting concurrent system with no i/p.

4) If two CFG's are given G1 & G2 then $L(G_1) \cap L(G_2) = \phi$ is undecidable

5) Recursively Enumerable lang. and the halting problem.

6) TM m/c is weak to describe the property the internet, evolution or robotics bcz it is closed model.

* Universal Turing Machine :-

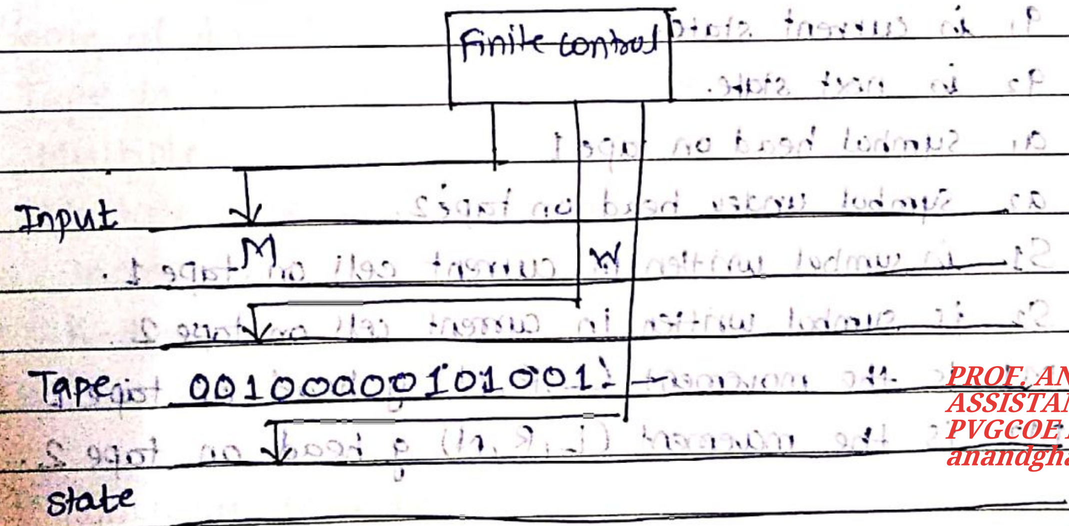
1) The universal lang. L_u is the set of binary string which can be modeled by turing m/c.

2) The universal lang is can be represented by pair (M, w) where M is a TM that accept this lang.
   W is binary string in $(0+1)^*$
   such that w belong to L(M).
   Thus, we can say that any binary string belongs to universal language.

3) The universal lang. can be represented by
   $L_u = L(U)$ where U is universal Turing m/c.

4) In fact, U is binary string. This binary string represent various codes of many turing machine.

5) Thus, the universal turing m/c is a turing m/c. which accepts many turing m/c.



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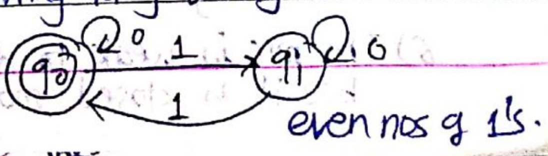
* Language acceptability by turing machine :-

- TM accepts all lang. even though there are recursively enumerable.
- Recursive means repeating the same set of rule for any nos of times.
  & enumerable means list of elements.
- TM also accepts computable function, such as Addition, multiplication, substruction, division, power fn, square fn & logarithmic function.
- we can solve some e.g. for accepting lang using TM.

e.g. | B | a | b | a | b | B | B |

↑head



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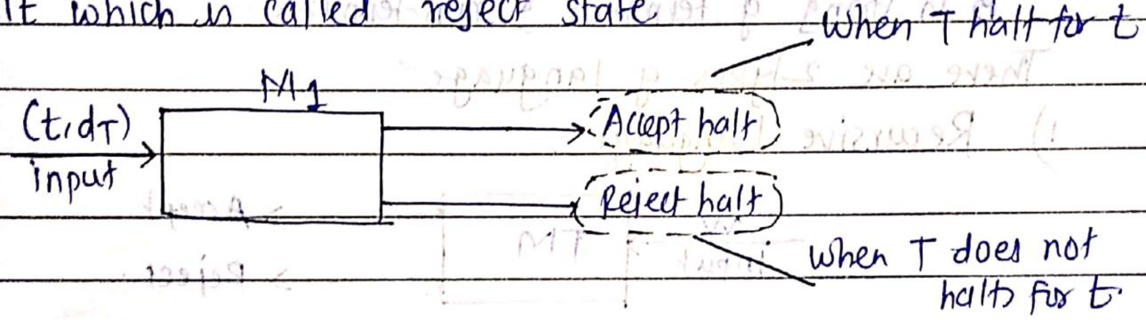
* TM's Halting Problem :-

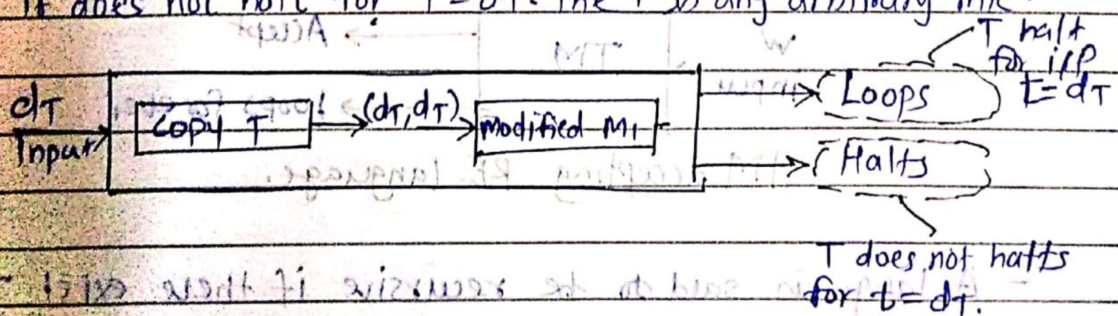
"Halting Problem is unsolvable"

proof :-

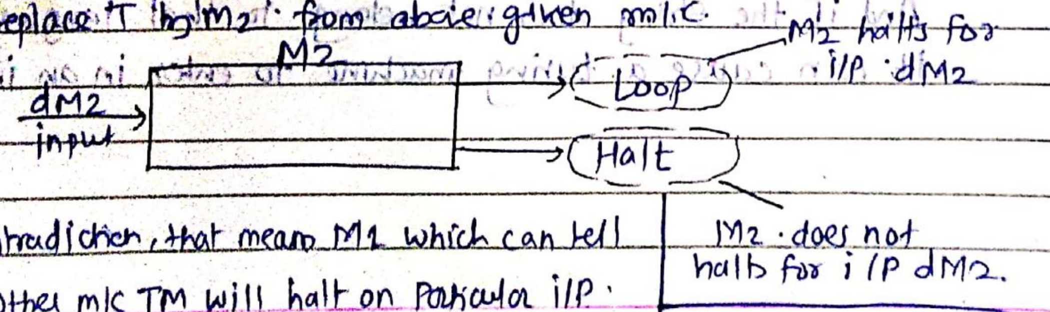
- Let there exist a TM M1 which decides whether or not any computation by a TM T will ever halt when a description dt of T and tape t of T is given.
- Then for every i/p (t, dT) to M1 if T halt for i/p t.
- M1 also halts which is called accept halt.
- similarly if T does not halt for i/p t then the M1 will halt which is called reject state.



When we will consider another TM M2 which takes i/p dT. ~~It~~ 1st copy dT and duplicate dT on it's tape and then this duplicate tape infor? is given as i/p m/c M1. But M1 is modified ~~m/c~~ m/c with the modification that whenever M1 is supposed to reach an accept halt, M2 loop forever. Hence behaviour of M2 is given. It loops if T halts for i/p t = dT and halts if it does not halt for T = dT. The T is any arbitrary m/c.



As M2 itself is one TM, we will take M2 = T, that means we will replace T by M2 from above given m/c.



This is contradiction, that means M1 which can tell whether any other m/c TM will halt on particular i/p does not exits. Hence halting problem is solvable.

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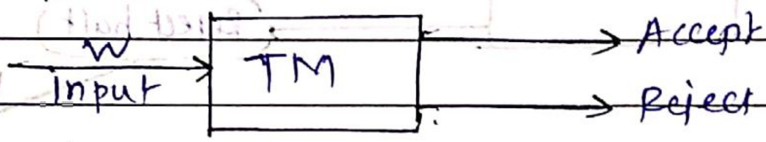
* TM and Type 0 Grammers:

→ TM ~~is~~ can accept Type 0 grammar.

- The type 0 grammar is said to be unrestricted grammar. e.g. of restricted lang are almost all natural lang.
- The class of lang. accepted by type 0 grammar are called recursively enumerable language.
- The prod^n can be of form $\alpha \rightarrow \beta$ where α is string of terminal and non-terminal with atleast one non-terminal and α cannot be null. β is string of terminal & non-terminal.

There are 2 types of language:

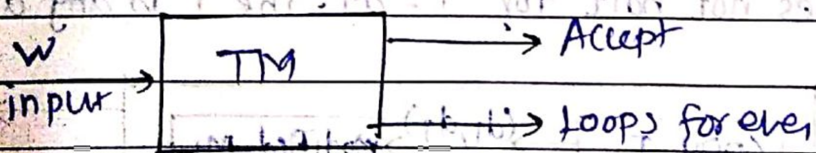
1) Recursive Language:



TM Accepting Recursive Language

A lang is said to be recursive if there exist a TM that accept every string of lang. and every string is rejected if it is not belonging to that lang.

2) Recursively Enumerable Language:



TM accepting RE language.

- A lang. is said to be recursive if there exist TM that accepts every string belonging to that language. And if the string does not belong to that language then it can cause a turing machine to enter in an infinite loop.

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