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Theory of Computation

CS F351

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Agenda

- Is Turing Machine a Hardware or a Software ??

Conventions

- TM state is represented as $\{q\}\{0, 1\}^*$
- Tape symbol is represented as $\{a\}\{0, 1\}^*$
- Let $M = (K, \Sigma, \delta, s, H)$ be a TM. Let i and j be smallest integers such that:
$$2^i \geq |K| \quad \text{and} \quad 2^j \geq |\Sigma| + 2$$
- Now each state of TM is represented by symbol **“q”** followed by a binary string of length i ; and each $a \in \Sigma$ by symbol **“a”** followed by binary string of length j .

Conventions

- Fix the representation of special symbols as:

Symbol	Representation
blank	$a0^j$
Left end marker	$a0^{j-1}1$
←	$a0^{j-2}10$
→	$a0^{j-2}11$
Start state	$q0^i$


- Encoding of TM M (denoted as “ M ”) is the sequence of strings of the form (q, a, p, b) , with q and p representing states and a and b representing tape symbols.

Conventions

- Observe that we have not represented any halting state.
- Set of halting states will be determined indirectly; that is by the absence of halting states as a first component in any quadruple.

Example

- Show the encoding of the following Turing Machine M_{example} :



State	Symbol	Transition
s	\sqcup	$(q1, \rightarrow)$
q1	a	$(q1, \rightarrow)$
q1	b	$(q1, \rightarrow)$
q1	\sqcup	$(q2, \leftarrow)$
q2	a	$(q3, \leftarrow)$
q3	a	$(q4, \leftarrow)$
q4	a	(h, \leftarrow)

- $|K| = 6$, therefore $i = 3$.
- $|\Sigma| = 4$ (i.e. a, b, \sqcup , and \blacktriangleright). Therefore, $j = 3$

So now what is the encoding of TM M??

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Example

- Show the encoding of the following Turing Machine M_{example} :

State	Symbol	Transition
s	\sqcup	(q_1, \rightarrow)
q_1	a	(q_1, \rightarrow)
q_1	b	(q_1, \rightarrow)
q_1	\sqcup	(q_2, \leftarrow)
q_2	a	(q_3, \leftarrow)
q_3	a	(q_4, \leftarrow)
q_4	a	(h, \leftarrow)

- $|K| = 6$, therefore $i = 3$.
- $|\Sigma| = 4$ (i.e. a, b, \sqcup , and \triangleright). Therefore, $j = 3$

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$i = 3$
 $j = 3$

$\sqcup \Rightarrow a000$
 $\triangleright \Rightarrow a001$
 $\leftarrow \Rightarrow a010$
 $\rightarrow \Rightarrow a011$
 $a \Rightarrow a100$
 $b \Rightarrow a110$

$s \Rightarrow q000$
 $q_1 \Rightarrow q001$
 $q_2 \Rightarrow q010$
 $q_3 \Rightarrow q011$
 $q_4 \Rightarrow q101$
 $h \Rightarrow q110$

$(q000, a000, q001, a011),$
 $(q001, a100, q001, a011)$
 \vdots
 $\rightarrow (q101, a100, q110, a010)$

There would be no such quadruple with $q110$ as its first tuple.

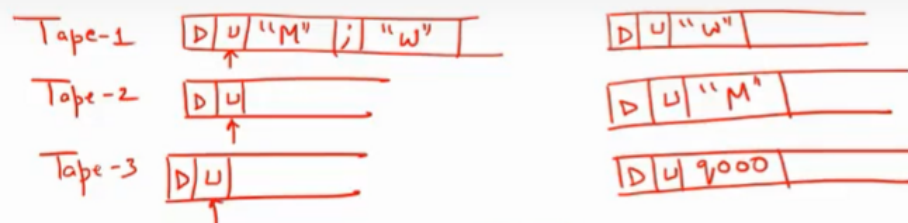


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Universal TM

- Now, we want a universal TM U to have following property: **U halts in input “ M ” w ” iff M halts in input w .**
- What is the design of such Universal TM ??

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- 1) Write Start State on Tape-3.
- 2) Move "M" onto Second Tape & shift "W" towards left.
- 3) Scan Second tape, find the quadruple with first entry as Tape-3 content & second entry as tape-1's content.
- 4) Copy third entry onto tape-3; & take action correspondingly to fourth entry.
- 5) Repeat 3 & 4 until —



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