Science in CSE — Theory of Computing

Th of Comp. Machines

Can be Computed ✓ "Solvable"

Cannot be Computed "unsolvable"

Machine	Solvable	Unsolvable
1) Simple calci	$a+b$, $a-b$	Div by '0', Fact(n), sin x

$n!$

I/p : int x

? $x/0$

$\Downarrow$

↳ I/p n

? $n!$

$1 \times 2 \times \ldots \times n =$

Simple Calci

Sol

Unsol

Div by 0

I/p: x

? $x/0$

=

Undefined

X Computation problem

Sci

$n!$, $\sin x$

$\log 0$

$\tan 90$

Undefined.

$2x + y = 5$

$x + 7y = 50$

unsol.

System of lin eqns

Matlab → yes → Machine

Computer

prog Lang

Wolfram (lin prog solves)

Servers / High perf Comp

DESMOS (I/p: fn O/p: Gh of fn)

Comp.

Calci

↓

Sci Calci

↓

Really Adv Calci

Computers.

↓

The ultimate Comp m/c

		n!, sin x
	n!, sin x	Sys of Lin eqn
	Sys of lin eqn	??. unsolvable prob in Modern day Comp
	✓✓✓✓✓	— NIL

I/p: Integer n

?

Find n^{th} prime

in Constant time

$\Theta(1)$ ✗

"Unsolvable"

For

1 to $\sqrt{n}$

$\Omega(\sqrt{n})$

$\geq c \cdot \sqrt{n}$

Int n

Find n^{th} prime

Solvable

Find n^{th} prime is in $\Theta(1)$??

"Unsolvable".

I/p: x

$1 + 1/2 + 1/4 + \ldots = ?$

Steps

① Is the prob well defined

I/p, O/p, Process

Algo

I/p: Some NP-Hard problem P

? Can we Solve P in poly-time.

~~open~~ solvable

⇓

Belief

NPH do not have poly-time Algo (Difficult)

As of today, we do not know whether

P = NP

P ≠ NP

NO

Solvable =

Yes

In 2430

P = NP

P ≠ NP

Δ1

4) DS - 1 unsol

Reasoning

Alg - 1

DLD - 1

Given a problem (a well defined)

I/p :

?

O/p :

Algorithm ?

- Solv
- Unsol

Science in CS Theory & Comp

Computing Models | Machines

0) Human beings ✓
1) Calculator
2) Sci Calci
3) Computer
4) HPC
5) Parallel Comp
6) Dist Comp.
7) Smart watch | washing

Language

Natural lang ← English, German

Digital lang

- +5V
- 0V

Theory of Comp | Computing | Computing Systems | Automaton

Models | Machines | Language | Computing Power | Representation

1) Finite State Automaton

?

Sol

unsol

"Inherent"

Theory of Comp | Computing | Computing Systems | Automaton

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1) Finite State Automaton

?

Sol

unsol

"Inherent"

'Cap Stone project'

? Algo | OS | CN | ML

DS

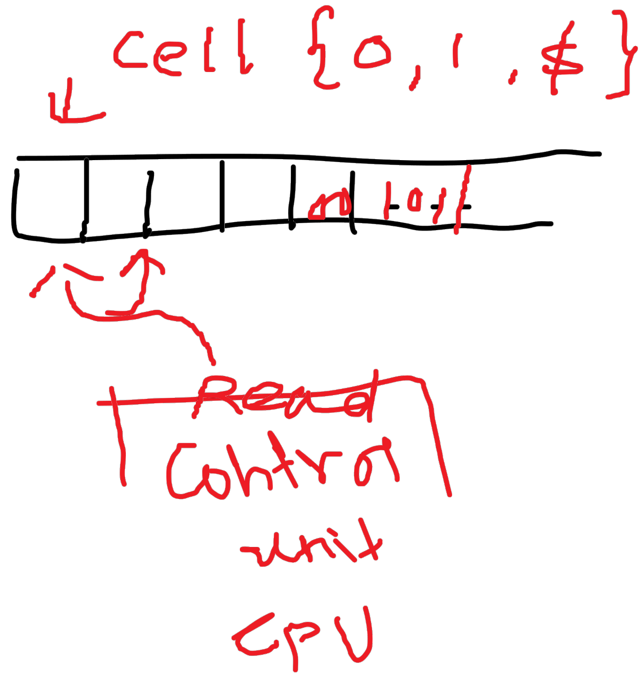
Project.

Finite State Machine
Automata
Automaton.

"rep comp

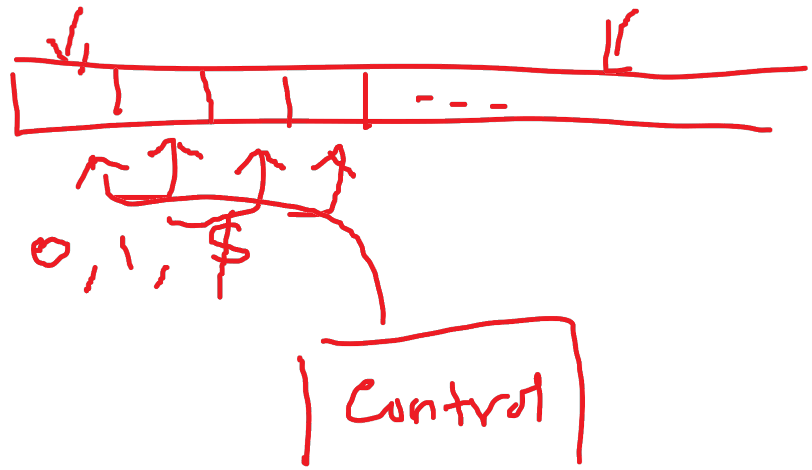
intermediate comp.

FSA



I/P Tape

FSA



Reading a symbol

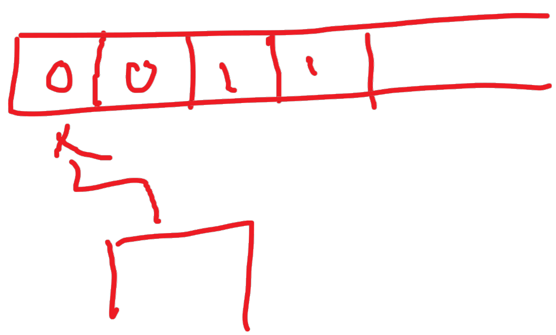
Cannot Store a word

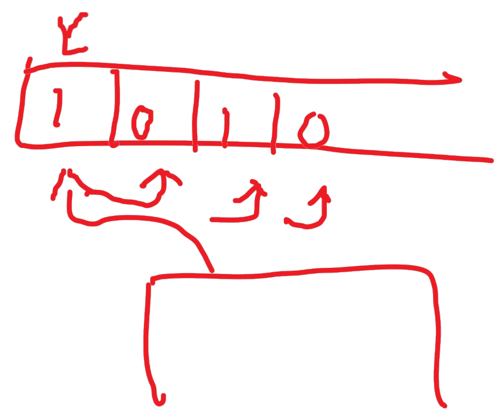
Cannot jump

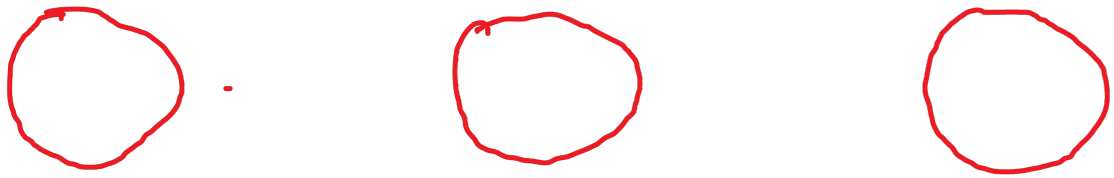
Cannot write

alphabet ; $\Sigma = \{0, 1, \$\}$

α-bet ⇒ $\Sigma = \{0, 1\}$

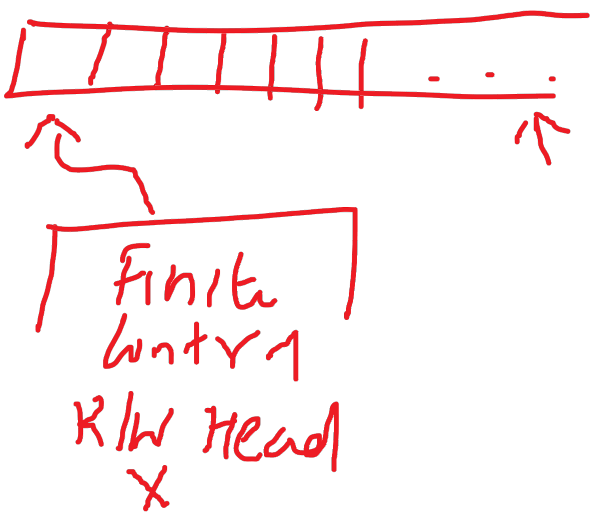






We use States (FSA) to rep/rem computation

record intermediate comp.



Can understand $\{0,1\}$

1) 0011, 1011, ...

I/p: $x \in \Sigma^*$

$\Sigma = \{0,1\}$

Σ^* A set of all strings over $\{0,1\}$

I/p: $x \in \Sigma^*$

? Does M accept x — Yes — Accept
— NO — No

$\Sigma = \{0, 1\}$, Σ^* a set of all substrings over Σ

ϵ, 0, 1, 00, 01, 11, ...

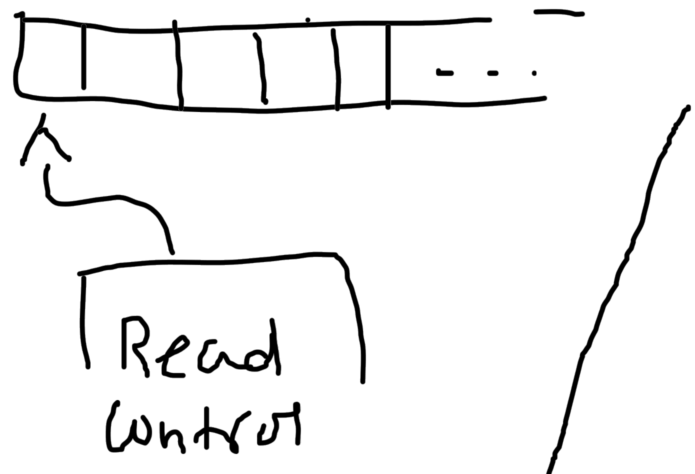
$S \subseteq \Sigma^*$ $S = \{\epsilon, 01, 001, 101, 1101, 0101, 1\text{-}1011\text{-}01,$

1111101$\underline{01}$

Can we think of FSA to recognize 'S'

I/p: x — $x \in S$ — yes
— $x \notin S$ — NO

(1) Strings Ending with $\underbrace{\qquad\qquad}$ $\underline{01}$



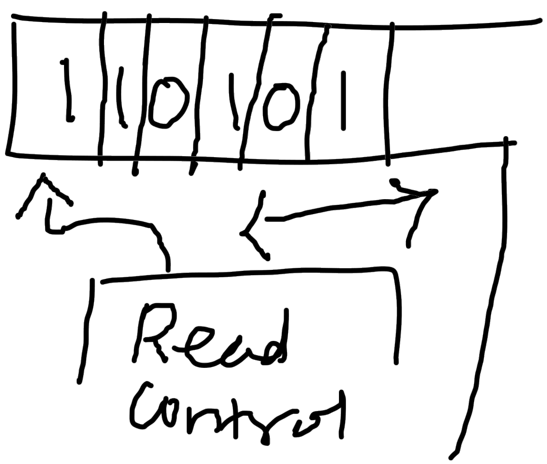
I/p: x

① Solvable prob.

'Parity checker'

? $S \subset \Sigma^*$ + any String in S ends with 01

Design a FSA to recognize|Accept S



① 'Some how' remember intermediate comp.

② Say yes if it ends with 01

No o/w " 00
10
11

Finite State Automaton.

Strings Ending with 01
prefix

$\underbrace{\qquad}_{} \; 0\,1$

$\underbrace{0}_{} \; 0\,1$

1 01

00 01

111011 01

001011 01

Any prefix over {0, 1}

01

$\Sigma = \{0,1\}$

01110101 0 1

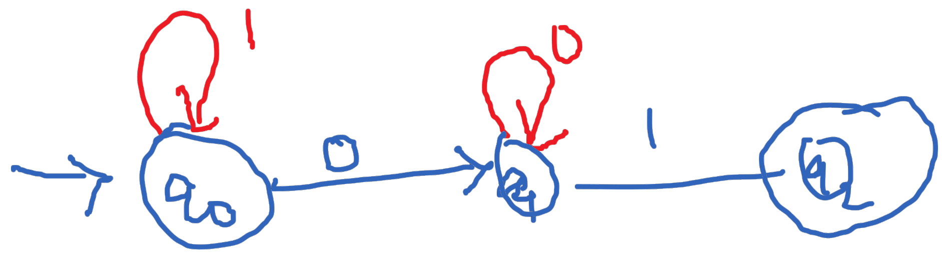
0 1

00 0 1

Any binary string

Any st $\{0,1\}$

$\{0,1\}^*$



1 . . . . 01 ✓

1000 ---- 001

1010011101

11 --- 101 11 -. 10 --- 01

1 - - 1

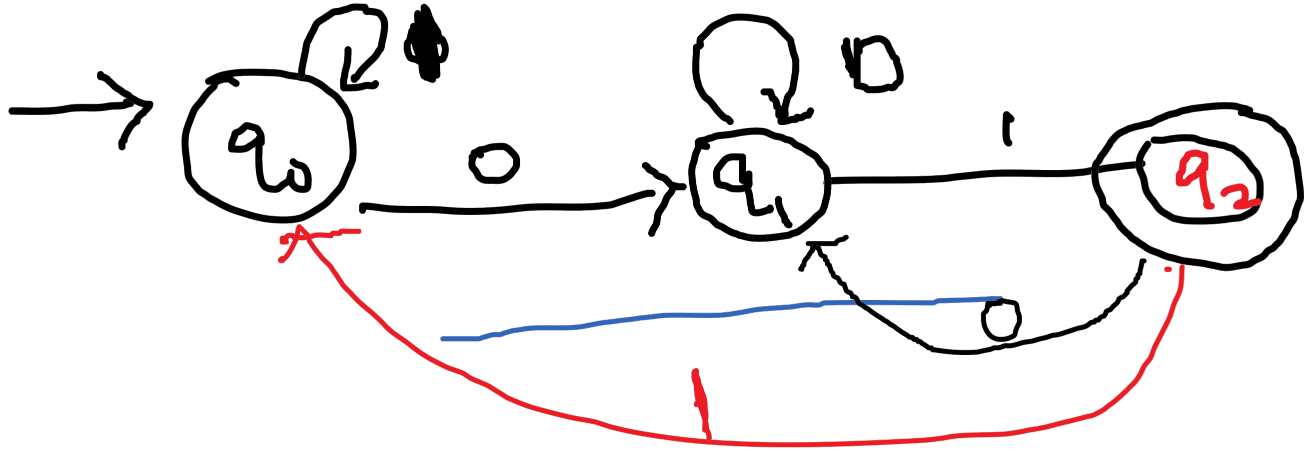
01

101

1111 01

1 - - - - 101

1 --- 10 0 01



0 111111 11

∞

0 0 1.

0

0100

Invalid

– Accepted by FSA

0 1 0 1 0 1

0 1 1 1 1 1 0 1

0 1 0 - - 0 0 1 1 1 0 0 . . 0 1

1 . . 1 0 . . . 0 1

1 1 0 0 1

1 1 1 1 0 0 0 . . 0 1 0 0 . . 0 1 ✓

1 1 0 0 1 0 1

$x \in \{0,1\}^*$

0 1 0 1 0 1 0 1

$q_0 \to q_1 \to q_2 \to q_1 \to q_2 \to q_1 \to q_2 \cdots q_2$ Accept

Reject

$101010 = q_0 \to q_0 \to q_1 \to q_2 \to q_1 \to q_2 \to q_1 \to q_2 \to q_1$

Simulate x on FSA, on Exhaustiy I/p
if FSA is in a Final

Accept

State

Accept

001001

01 — Valid

q_2

101010

11..1 Invalid

0...0

100...01..1

q_0, q_1

Non Final

Reject.

$\underbrace{\qquad\qquad}$ 10 Endiy with 10

$\underbrace{0110}$ 101 $\underbrace{110 \cdots 0111}$ Containg 101