The Nature of Computing

ICOM 4036
Lecture 2

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Some Inaccurate Yet Popular Perceptions of Computing

- Computing = Computers
- Computing = Programming
- Computing = Software

Computing = Computers

Computing is about solving problems using computers

↓

A.K.A. The Computing Device View of Computing

Computing = Programming

Computing is about writing
programs for computers

⬇

A.K.A. The Programming Language view of Computing

Computing = Software

Computing is not concerned with hardware design

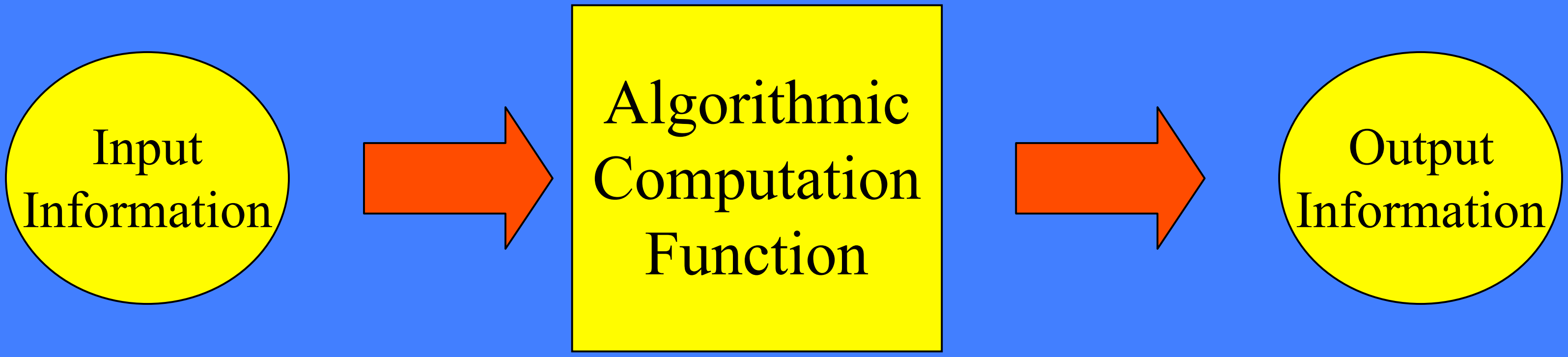
⬇

A.K.A. The “Floppy Disk” view of Computing

Part I - Outline

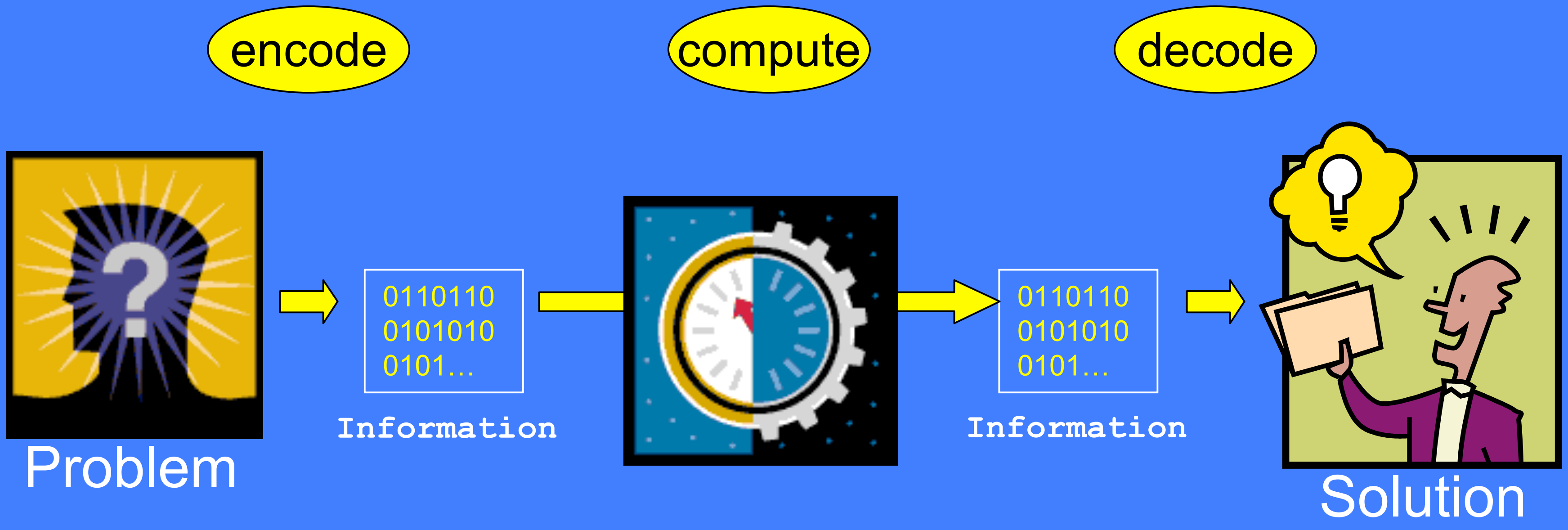
- What is Computing?
- Computing Models and Computability
- Interpretation and Universal Computers
- Church’s Thesis

What is computing then?



Computing is the study of Computation: the process of transforming information

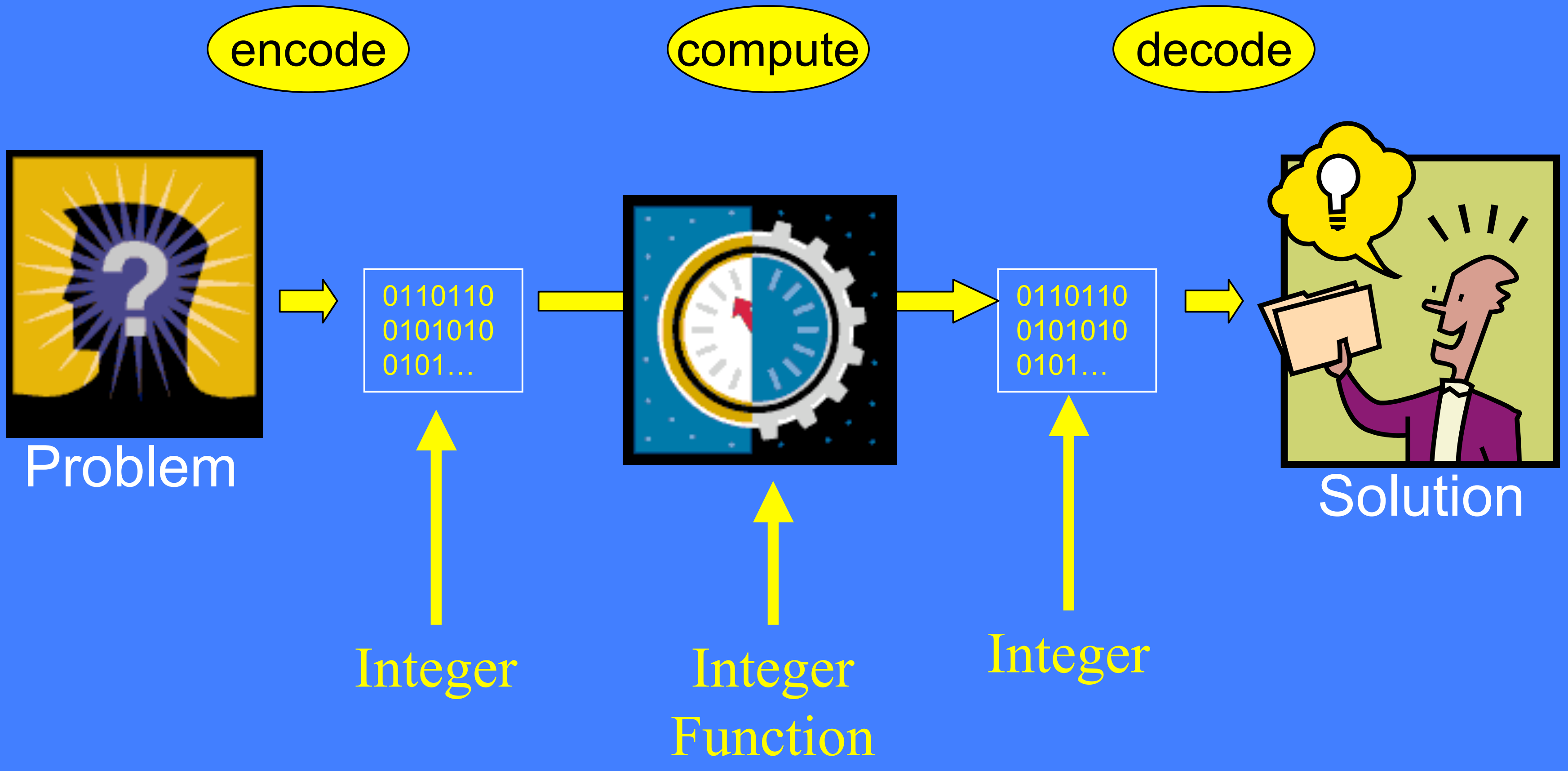
The Computation Process



Fundamental Questions Addressed by the Discipline of Computing

- What is the nature of computation?
- What can be computed?
- What can be computed efficiently?
- How can we build computing devices?

The Computation Process



encode

compute

decode

Problem

0110110
0101010
0101…

0110110
0101010
0101…

Solution

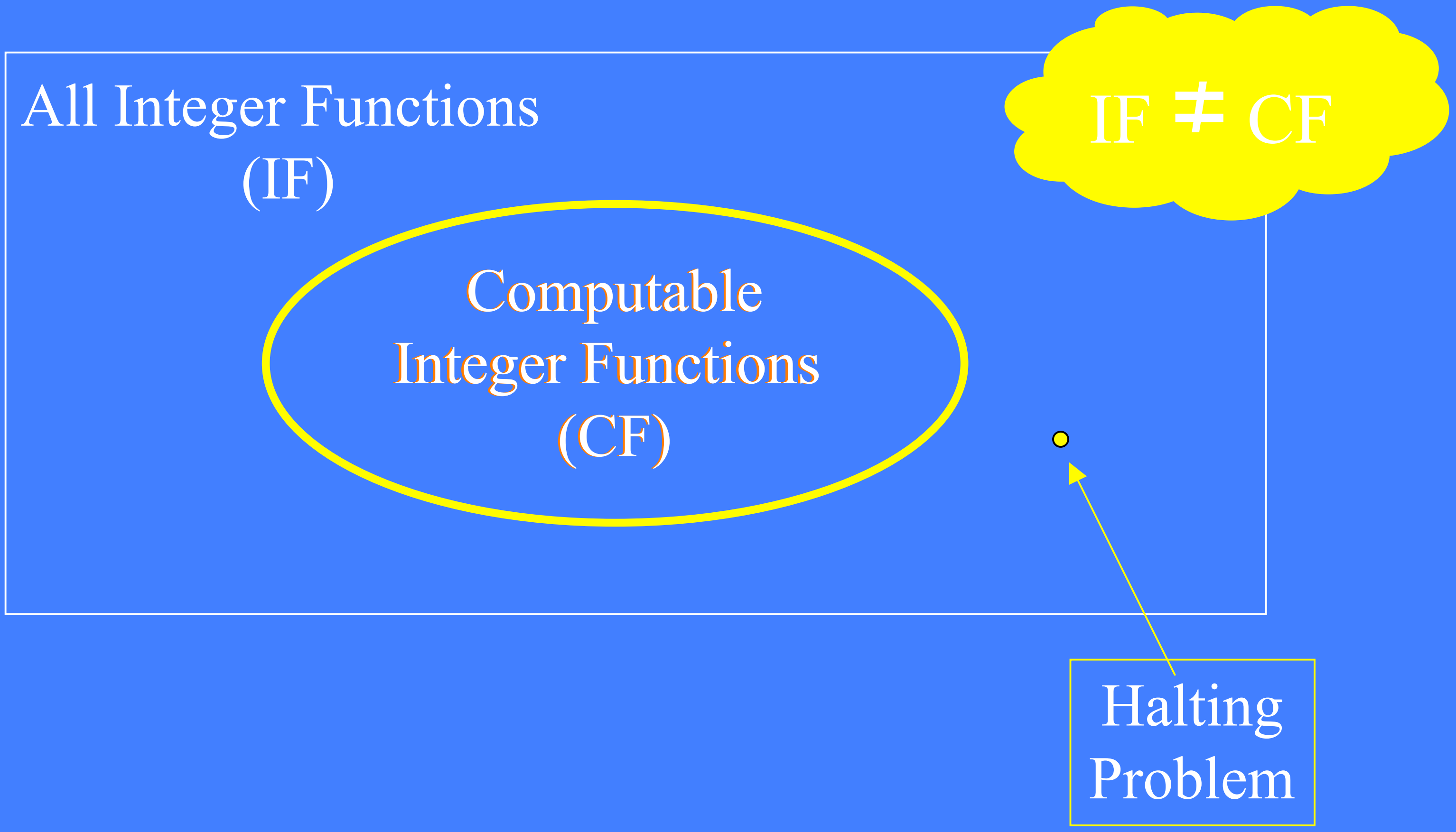
Integer

Integer
Function

Integer

Every Algorithm is in Essence and Integer Function

Computability



All Integer Functions (IF)

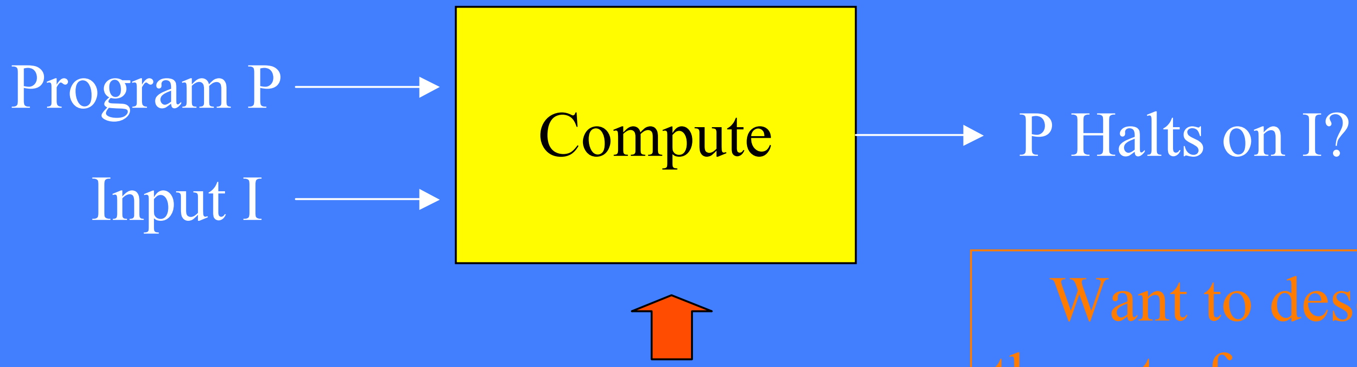
Computable Integer Functions (CF)

IF ≠ CF

Halting Problem

The Halting Problem
(Alan Turing 1936)

Given a program and an input to the program, determine if the program will eventually stop when it is given that input.

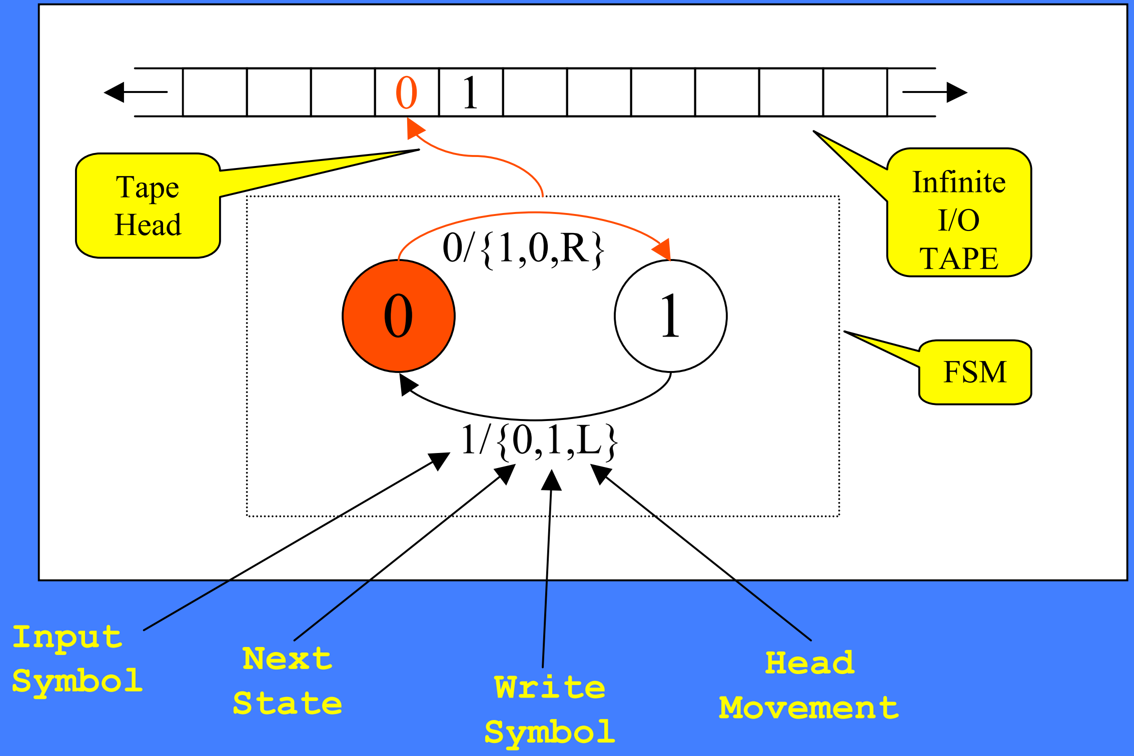


Cannot Build This

Want to describe the set of computable functions?

Mathematical Computers:
The Turing Machine (1936)

Alan Turing



Mathematical Computers:
The Turing Machine (1936)

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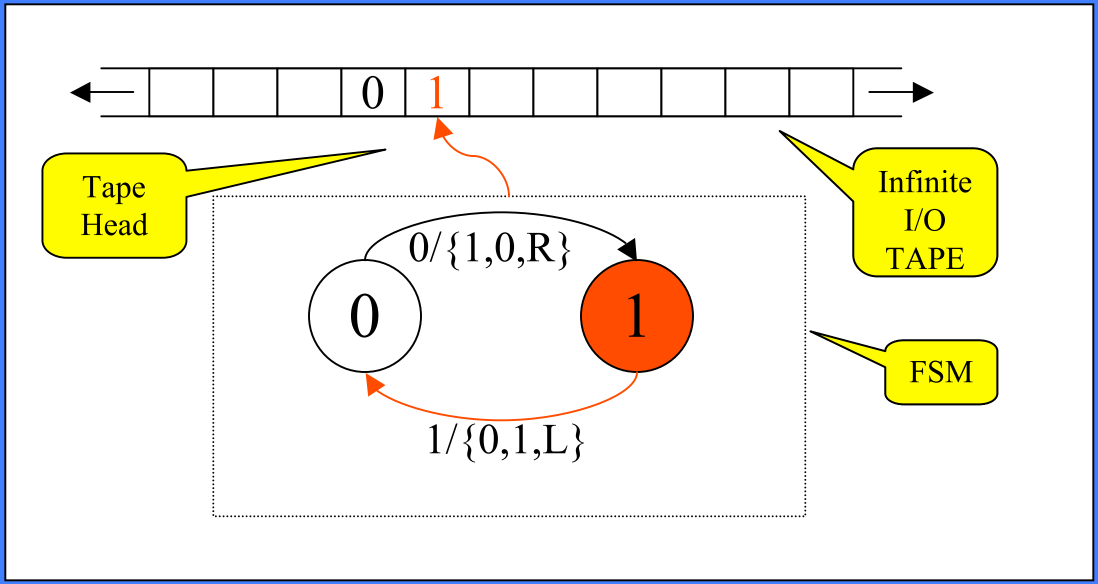
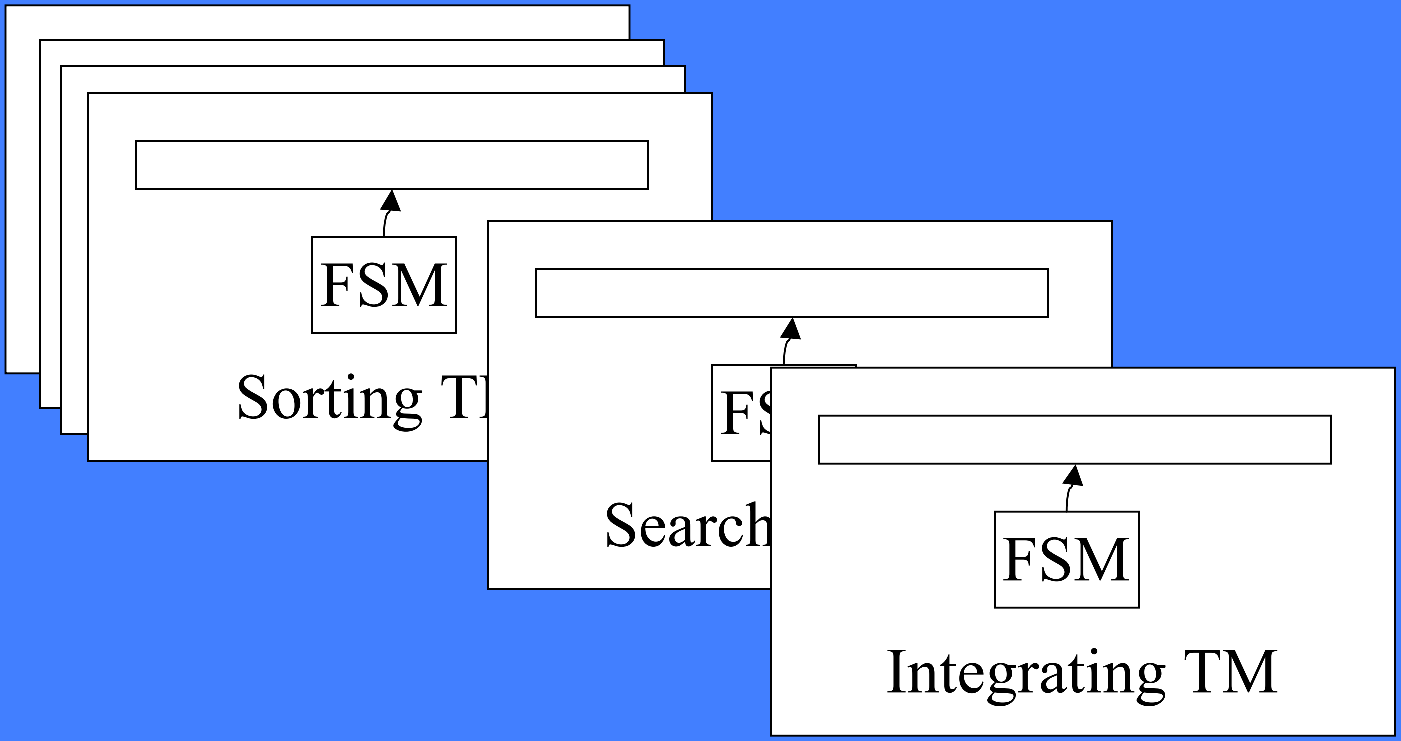


Turing demonstrated how to solve several problems using his computing model

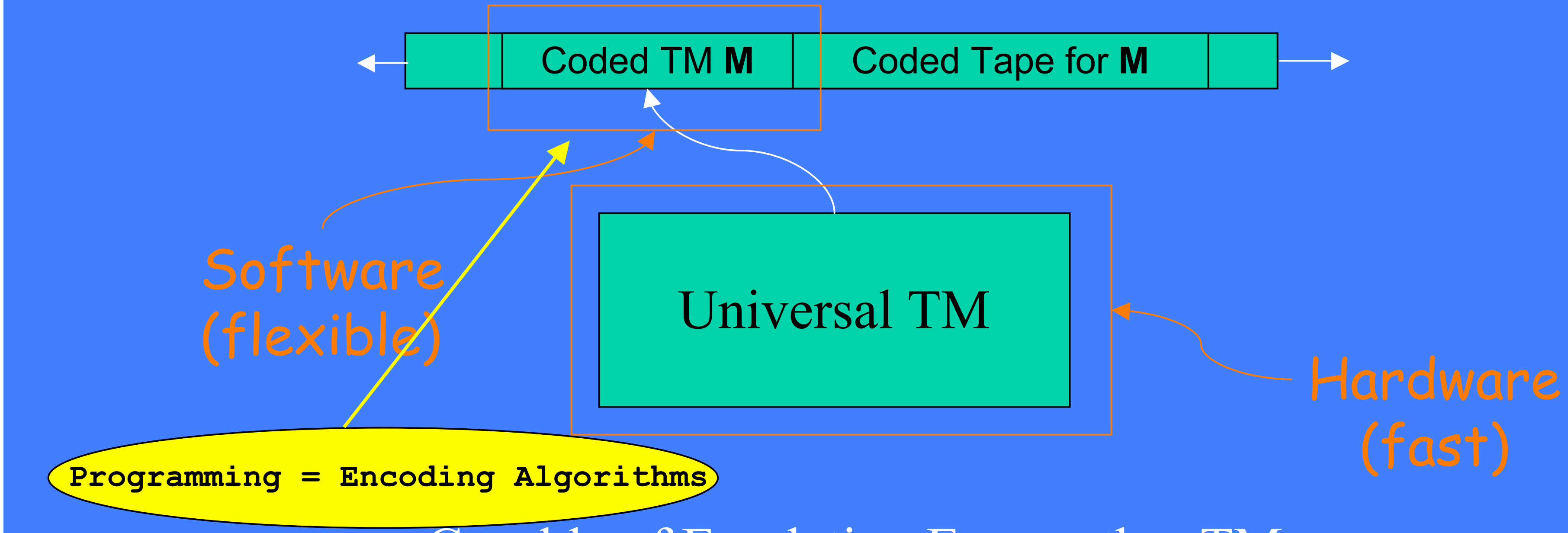
Ad-hoc Turing Machines



Can we build a general purpose TM?

The Universal Turing Machine (UTM)

The Paradigm for Modern General Purpose Computers



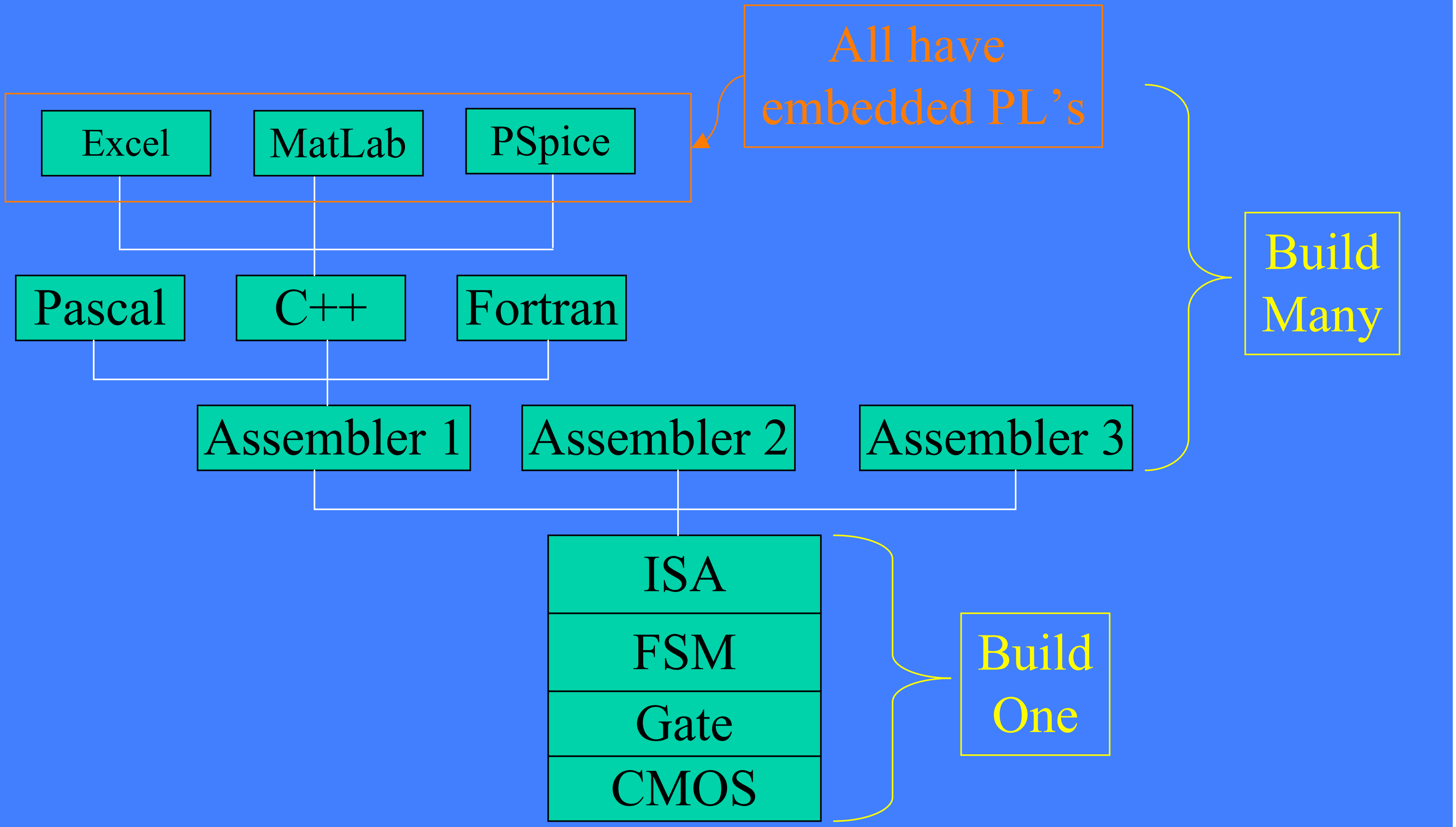
- Capable of Emulating Every other TM
- Shown possible by Alan Turing (1936)
- BIG IDEA: INTEPRETATION!!!

Other Familiar Models of Computation

- Combinational Circuits
- Sequential Circuits (FSM’s)
- Pentium Instruction Set Architectures
- Lambda Calculus
- Recursive Functions
- C++

Can you tell which ones are Turing Universal?
That is, which ones can emulate any other Turing Machine?

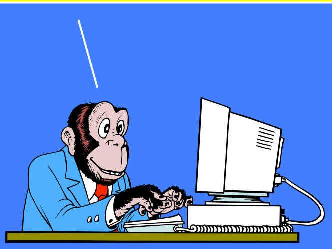
Computing in Perspective



Interpreter Design Demands Programming Language Design

Why Abstraction Layers?

- Resilience to change:
  - Each layer provides a level of indirection
- Divide and Conquer Approach:
  - Can work on one small semantic gap at a time
- Building Block Approach:
  - Can build many higher layer on same l



Because we know of no other way of doing anything

Church's Thesis

Alonso Church

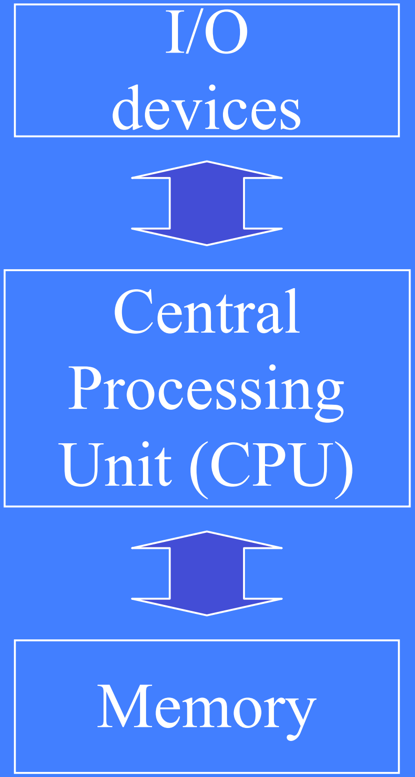
"Any realizable computing device can be simulated by a Turing machine"

"All the models of computation yet developed, and all those that may be developed in the future, are equivalent in power."

Issues not considered: Size, Programmability, Performance
But they must be considered if one is to build …

The (John) Von Neumann Architecture
(late 40’s)

John von Neumann, 1950's



Allow communication with outside world

Interprets instructions

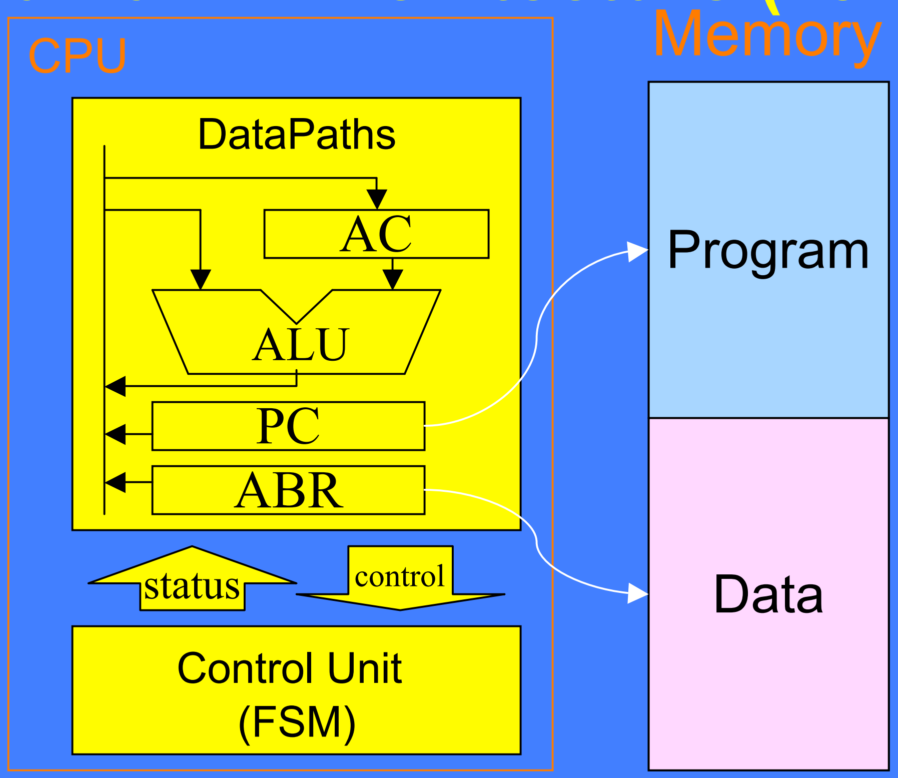
Stores <u>both</u> programs and data

After 60 years … most processors still look like this!

Practical Universal Computers

(John) Von Neumann Architecture (1945)

John von Neumann, 1950's



This looks just like a TM Tape

CPU is a universal TM

An interpreter of some programming language (PL)

End of Lecture 2