COGS 200: Introduction to Cognitive Systems

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Lecture Notes 2014/2015 Term 1

14W1: September–December, 2014

Readings Summary

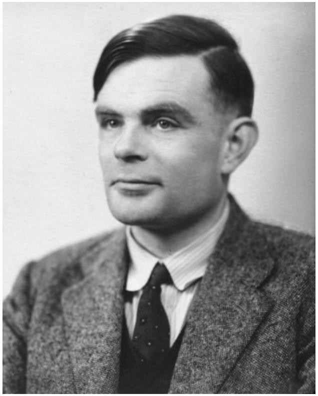
Today's assigned "reading" was to watch two talks from the History Panel session of the Computation and the Transformation of Practically Everything MIT150 symposium

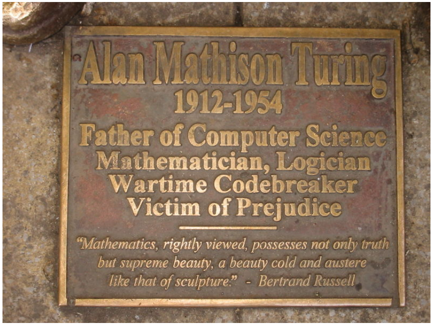
- Ed Lazowska tells us that
  - 1969 was an eventful year
  - Butler Lampson identifies three stages of computing:
    1. simulation (1940s–1970s)
    2. communication (1980s–2000s)
    3. embodiment (now)
  - computer scientists build complete systems (of ever increasing scale, integration and complexity)
- Pat Winston presents his view of both the history and "the way forward" in artificial intelligence, including his
  - strong story hypothesis
  - strong perception hypothesis
  - strong social animal hypothesis

Today’s Learning Goals

1. To share the “big picture” story of computation, in terms of:
    - theory
    - realization in actual computing devices
2. To identify questions to ask of any knowledge representation (KR) scheme:
    - What “language” is used?
    - What knowledge is explicit?
    - What inference mechanism(s) are available?
3. To introduce the artificial intelligence approach to building and understanding intelligent systems

Alan Turing


June 23, 1912 – June 7, 1954


Alan Mathison Turing
1912-1954
Father of Computer Science
Mathematician, Logician
Wartime Codebreaker
Victim of Prejudice
"Mathematics, rightly viewed, possesses not only truth but supreme beauty, a beauty cold and austere like that of sculpture." - Bertrand Russell
Statue Plaque in Sackville Park

http://en.wikipedia.org/wiki/Alan_Turing

Models of Computation

Bottom up:

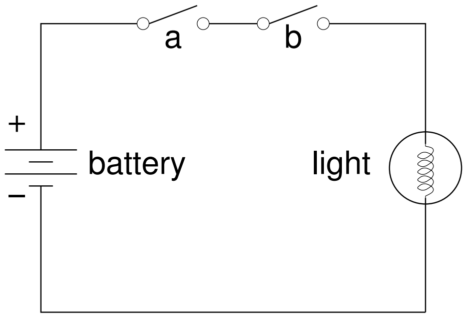
- switch
- logic gate
- combinational circuit
- sequential circuit
- Finite State Machine (FSM)

The roots of computer science stem from the study of many alternative mathematical “models” of computation, and from the study of the classes of computations they can represent

The elusive goal is to find an “ultimate” model, capable of representing all practical computations. . .

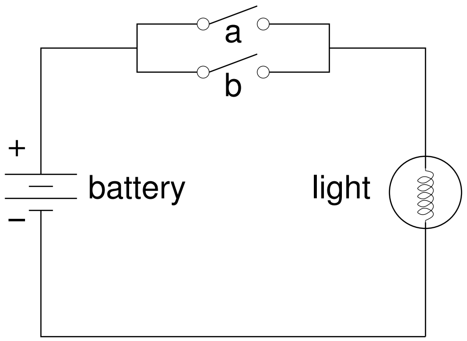
Question: Is a FSM the ultimate digital computing device?

“AND” Light Switch



switch a	switch b	light
closed	closed	on
closed	open	off
open	closed	off
open	open	off

“OR” Light Switch



switch a	switch b	light
closed	closed	on
closed	open	on
open	closed	on
open	open	off

Binary “Values”

on	off
closed	open
true	false
T	F
high	low
positive	negative
1	0

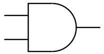
Binary “Values”

on	off	
closed	open	
true	false	
T	F	Formal logic
high	low	
positive	negative	
1	0	Boolean algebra

Switch Property “Wishlist”

- Small, simple, reliable
- Fast
  - High frequency (in ON/OFF cycles per second)
  - Rapid state transition ON to OFF and OFF to ON (i.e., minimal time in intermediate “invalid” state)
- Inexpensive (i.e., switches and connecting “wires” mass produced)
- Isolated (i.e., operation doesn’t interfere with neighbouring switches)
- Low power consumption

AND OR NOT Logic Gates



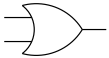
AND

AND

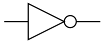
input		output
0	0	0
0	1	0
1	0	0
1	1	1

OR

input		output
0	0	0
0	1	1
1	0	1
1	1	1



OR

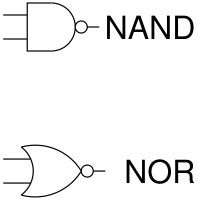


NOT

NOT

input	output
0	1
1	0

Two More Logic Gates



NAND

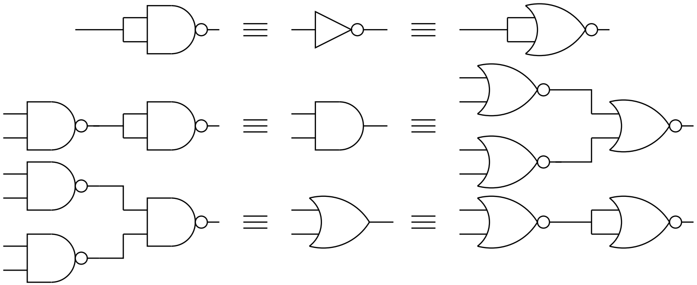
input		output
0	0	1
0	1	1
1	0	1
1	1	0

NOR

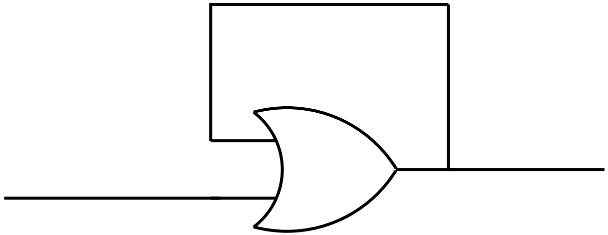
input		output
0	0	1
0	1	0
1	0	0
1	1	0

2-input NAND and NOR Gates Each are Universal

NOT, AND and OR gates (middle) can be implemented using only NAND gates (left side) or only NOR gates (right side)



What about this?

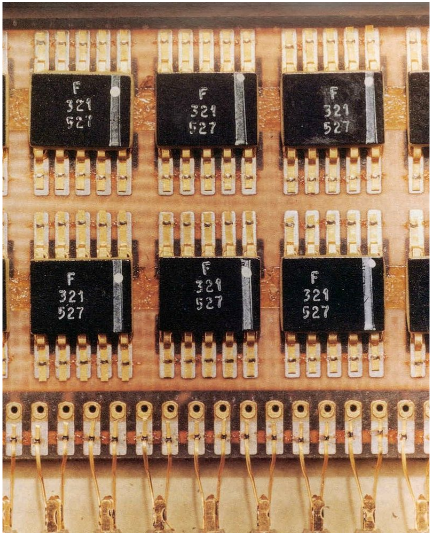


Example 1: Apollo Guidance Computer (AGC)

Invented by	MIT Instrumentation Laboratory
Manufactured by	Raytheon
Introduced	August, 1966
Discontinued	July, 1975
Processor technology	Discrete IC RTL based
Clock frequency	2.048 MHz
Memory	16–bit word
	2,048 words RAM (magnetic core memory)
	36,864 words ROM (core rope memory)
Power consumption	55W
Weight	32 kg (70 lb)
Dimensions	61×32×17 cm (24×12.5×6.5 inches)

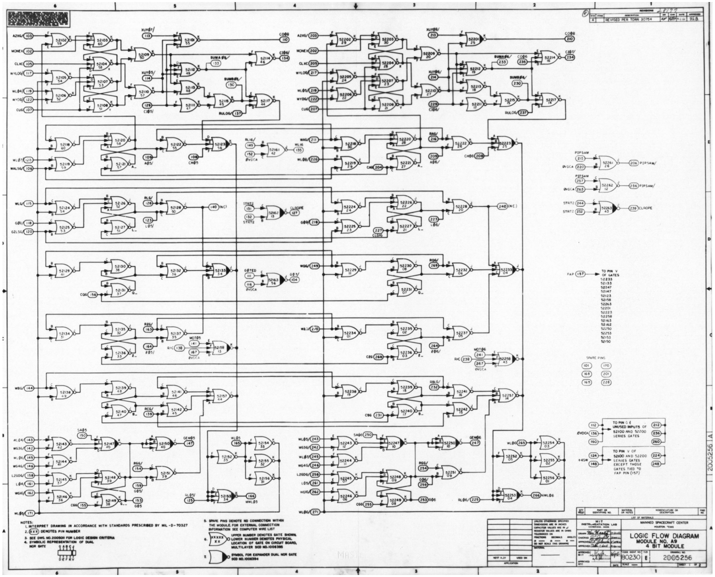
http://en.wikipedia.org/wiki/Apollo_Guidance_Computer

Example 1 (cont'd): AGC Flatpack Integrated Circuits



http://en.wikipedia.org/wiki/Apollo_Guidance_Computer

Example 1 (cont'd): AGC Module A9 Sheet 1 (of 2)



http://klabs.org/history/ech/agc_schematics/

Four “Big Ideas” of Computer Science

Big Idea #1:
Finite State Machine (FSM)

Big Idea #2:
Turing Machine

Big Idea #3:
Computability

Big Idea #4:
Universality

Computability

Three attempts (in the first half of the 20th century) to formalize what it means for a function to be "effectively calculable:"

- λ–calculus (Alonzo Church)
- Turing machine (Alan Turing)
- General recursive (Alonzo Church, Stephen Kleene, J. Barkley Rosser)

All three formalisms were subsequently shown to be equivalent. A function is "computable" iff it can be computed by a Turing machine

"Effectively calculable" and "computable" need not be synonymous

The Church–Turing hypothesis states, "everything effectively calculable is computable by a Turing machine"

This cannot be formally proven. Nevertheless, it has near-universal acceptance (in Computer Science)

Universality

There exists a Turing machine that is able to simulate any other Turing machine. Such a machine is called a universal Turing machine (UTM)

This result, established by Turing in 1936, was considered astonishing at the time. We now take it for granted. But, many consider it to have been the fundamental theoretical breakthrough that led to the modern stored-program computer

Models of Computation: Summary

Formal models (computability, Turing machines, universality) provide the basis for modern computer science:

- Fundamental limits (on what can not be done, even given plenty of memory and time)
- Fundamental equivalence of computation models
- Representation of algorithms as data, rather than as machinery
- Programs, software, interpreters, compilers,...

There remain many practical issues to deal with:

- Cost: memory size, time performance, power consumption
- Programmability

Summary (cont'd):

- Computer science has theory and computer scientists build systems
- Switches are the "building block of life" in the world of digital computation
- The most general notion of computability, to date, is that of a Turing machine
- There are no technology gaps separating switches, from Turing machines, or from any current digital computer. There are "case–in–point" technologies for every step along the way
- Computers are the "Swiss army knife" of science. In particular, computers are ideal laboratory animals for testing theories of intelligence
- As Turing wrote in 1950, "We can only see a short distance ahead, but we can see plenty there that needs to be done"

Methodological Issues (Across Disciplines)

- What problems do each discipline address?
- What questions do each discipline ask about those problems?
- What tools and techniques do each discipline use to answer these questions?
- What defines “success” in each discipline?

Knowledge Representation (KR): Key Issues

Questions to ask of any KR scheme are:

1. What “language” is being used?
2. What knowledge is represented explicitly by a given set of expressions in the language?
3. What inference mechanism is available to make explicit knowledge which is implicit, but not yet explicit, in the given set of expressions?

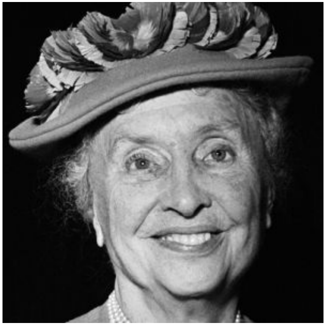
Inference mechanisms can be thought of as methods to reason about (or calculate with) knowledge in order to make explicit that which is only implicit

Artificial Intelligence

Artificial Intelligence…

…is the intelligent connection of perception to action

Who is this?



Who is this?

Helen Keller

June 27, 1880 – June 1, 1968

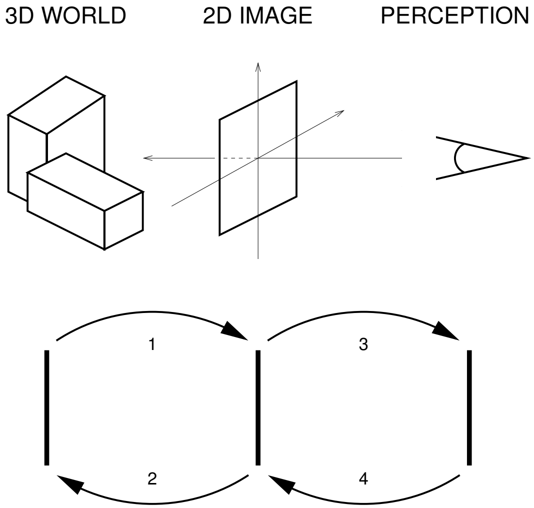
with Anne Sullivan (circa 1930)

http://en.wikipedia.org/wiki/Helen_Keller
https://www.youtube.com/watch?v=Gv1uLfF35Uw

Artificial Intelligence

$$\begin{tikzcd}
& \text{Artificial Intelligence} \arrow[dl] \arrow[dr] & \\
\text{Understanding Intelligence} \arrow[rr, bend left] & & \text{Making Machines Intelligent} \arrow[ll, bend left]
\end{tikzcd}$$

Computational Vision: Domains and Mappings



Computer Science: A Discipline with an Attitude

The person who says it cannot be done should not interrupt the person doing it

— Chinese proverb