علوم شناختی

جلسه ۳ (الف)

الگوریتم‌ها و محاسبه

Algorithms and Computation

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PART 1:
HISTORICL LANDMARKS

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Chapter 1:
The Prehistory of Cognitive Science

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Chapter 1.2:
Algorithms and Computation

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The theory of computation

Basic idea of cognitive science =
the mind is an information-processing machine

Several ideas already in place

- information-based accounts of cognitive activity (e.g. cognitive maps in rats)
- information-processing models of cognitive abilities (e.g. Broadbent's model)

Final piece – a viable model of how information-processing works

Background

Key theoretical breakthroughs in the development of the computer were actually motivated by problems in pure mathematics – general concern with the nature of mathematical proof

Hilbert’s 1923 challenge to provide a general solution to the Entscheidungsproblem (decision problem)

Also related to 2 of Hilbert’s 23 problems announced in 1900

The decision problem

Given a mathematical statement in some formal language, is there a formal method that will

1) tell us that the statement is provable when it really is provable
2) tell us that the statement is not provable when it is not provable

Not a problem within mathematics until we have a mathematical conception of what counts as a formal method/proof.

(Some of) Turing's contributions

1) Clarified the notion of a formal method through the twin ideas of algorithm and computation

2) Developed an idealized model of a computing machine

3) Showed the decision problem to be insoluble

Functions and numbers

Turing's primary focus was on functions in number theory

- the inputs to functions are numbers or n-tuples of numbers
- a function always generates a unique output for a given input
  - examples:
    - squaring
    - addition
    - exponentiation

Algorithm and computation

An algorithm for <u>effectively calculating</u> a number-theoretic function is a procedure that

a) can be specified in a finite number of steps
b) can be unambiguously followed by a human or mechanical computer
c) will always yield an output for any input for which the function is defined

But what counts as "specifying a procedure"?
And what is it to follow a procedure "unambiguously"?

The Church-Turing thesis

- Aimed to provide a precise mathematical equivalent for the intuitive notion of effective calculability

- Thesis: The effectively calculable functions are exactly the functions that can be computed by a Turing machine

- The Church-Turing machine cannot be *proven* – but it is almost universally accepted by logicians and computer scientists

Turing machines: Summary

- Idealized computing machines that can be specified purely mathematically
- Do not have to take any particular physical form (i.e. multiply realizable)
- The *machine table* of a Turing machine is the program, specifying the appropriate output for a given input
  - Algorithmic instructions

The machine

- Infinitely long tape divided into individual cells
- A finite alphabet of symbols, of which there must be exactly one in each cell
  - E.g. '1' and '0' (a punctuation mark) for a Turing machine working in unary
- A scanner/printer that can "read" what is in a given cell and "write" in it

The program (1)

- The machine table of the Turing machine specifies instructions for the scanner/printer

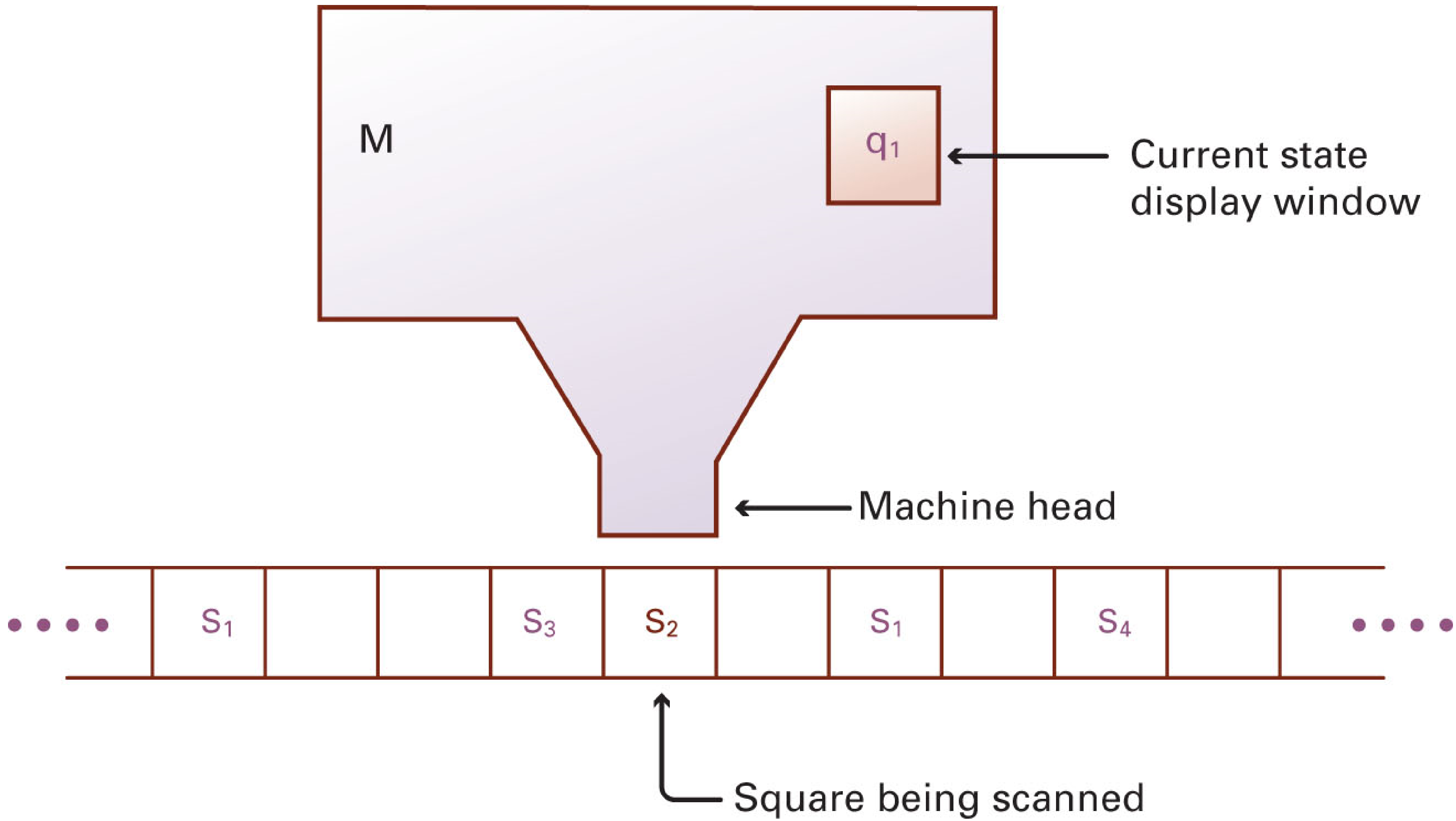
- When the scanner/printer is in a given state it can
  - Move one cell to the L or R
  - Erase what is in a cell
  - Write a new symbol in a cell
  - Enter a new state

The program (2)

- The instructions specify what action to carry out given (a) the internal state of the machine, (b) the input

- Each instruction has the same form: Q_i, S_j, A, Q_t

  - Q_i the internal state the machine is in
  - S_j the symbol in the square being examined
  - A the action the machine is to perform
  - Q_t the state in which the machine ends up


M
q1
Current state display window
Machine head
S1
S3
S2
S1
S4
Square being scanned

A sample program

Q_1	0	R	Q_2
Q_1	1	0	Q_1
Q_2	0	1	Q_3
Q_2	1	R	Q_2

Convention: the machine starts in Q_1 and halts in Q_3

Running the program

Q_1	0	1	1	0	1	1	0
Q_1	0	0	1	0	1	1	0
Q_2	0	0	1	0	1	1	0
Q_2	0	0	1	0	1	1	0
Q_3	0	0	1	1	1	1	0

Q_1	*0*	*R*	Q_2
Q_1	*1*	0	Q_1
Q_2	*0*	1	Q_3
Q_2	*1*	*R*	Q_2

Universal Turing machine

- There is a Turing machine (actually infinitely many) that computes every effectively calculable number-theoretic function
- Universal Turing Machines can mimic any individual Turing machine (because Turing machines can be characterized purely mathematically and so can be the inputs to a UTM)
- Modern digital computers are, in essence, UTMs with finite tapes

Implications for cognitive science

- The Turing machine is a model of how information-processing can take place
  - purely algorithmic process
  - even though cells on the tape carry information, they can be manipulated and transformed in a purely mechanical way
- Intelligent symbol manipulation without a "homunculus" – the stored program (TM table) does the job of the homunculus
- Computer model of the mind – mind as a UTM

Cognitive science and artificial intelligence

- The early development of CogSci was closely bound up with the emergence of AI
- computer models are obviously computational models
- specific example = Winograd’s computer model of natural language understanding

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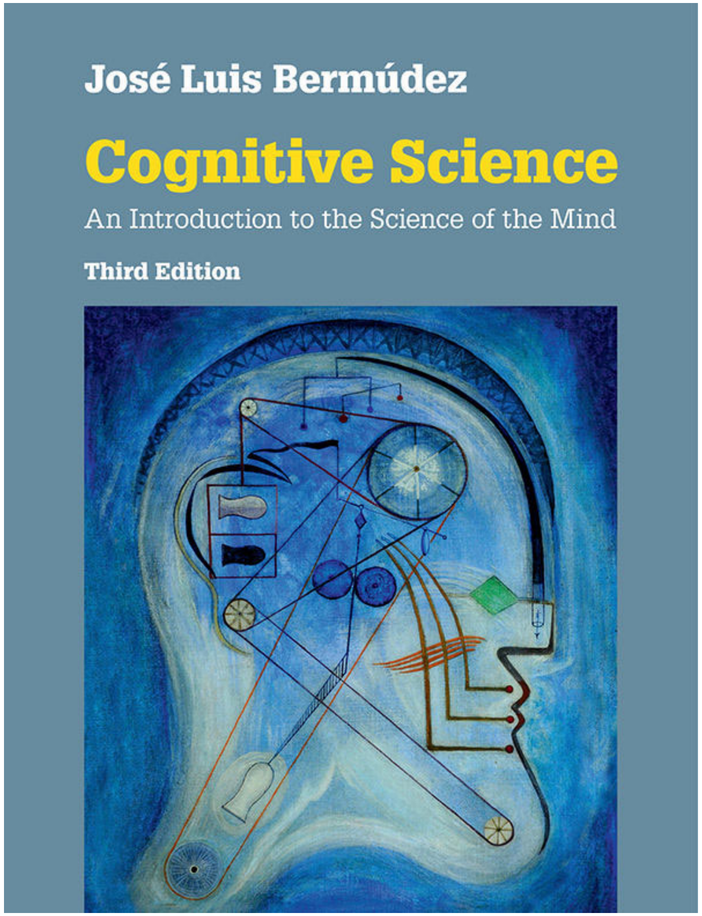
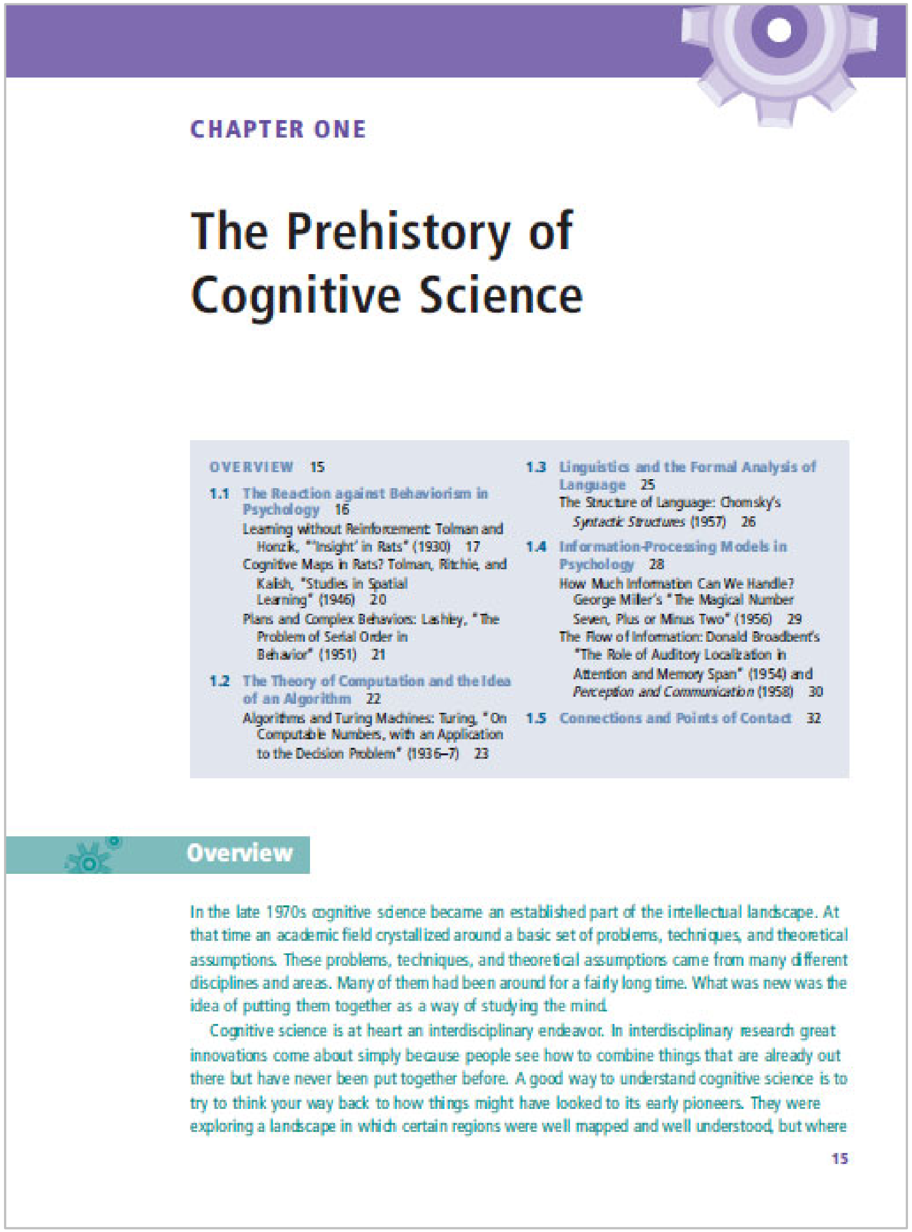


José Luis Bermúdez,
Cognitive Science:
An Introduction to the Science of the Mind,
3rd ed., Cambridge University Press, 2020.
Chapter 1 (Section 1.2)



CHAPTER ONE

The Prehistory of Cognitive Science

Overview

In the late 1970s cognitive science became an established part of the intellectual landscape. At that time an academic field crystallized around a basic set of problems, techniques, and theoretical assumptions. These problems, techniques, and theoretical assumptions came from many different disciplines and areas. Many of them had been around for a fairly long time. What was new was the idea of putting them together as a way of studying the mind.

Cognitive science is at heart an interdisciplinary endeavor. In interdisciplinary research great innovations come about simply because people see how to combine things that are already out there but have never been put together before. A good way to understand cognitive science is to try to think your way back to how things might have looked to its early pioneers. They were exploring a landscape in which certain regions were well mapped and well understood, but where

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