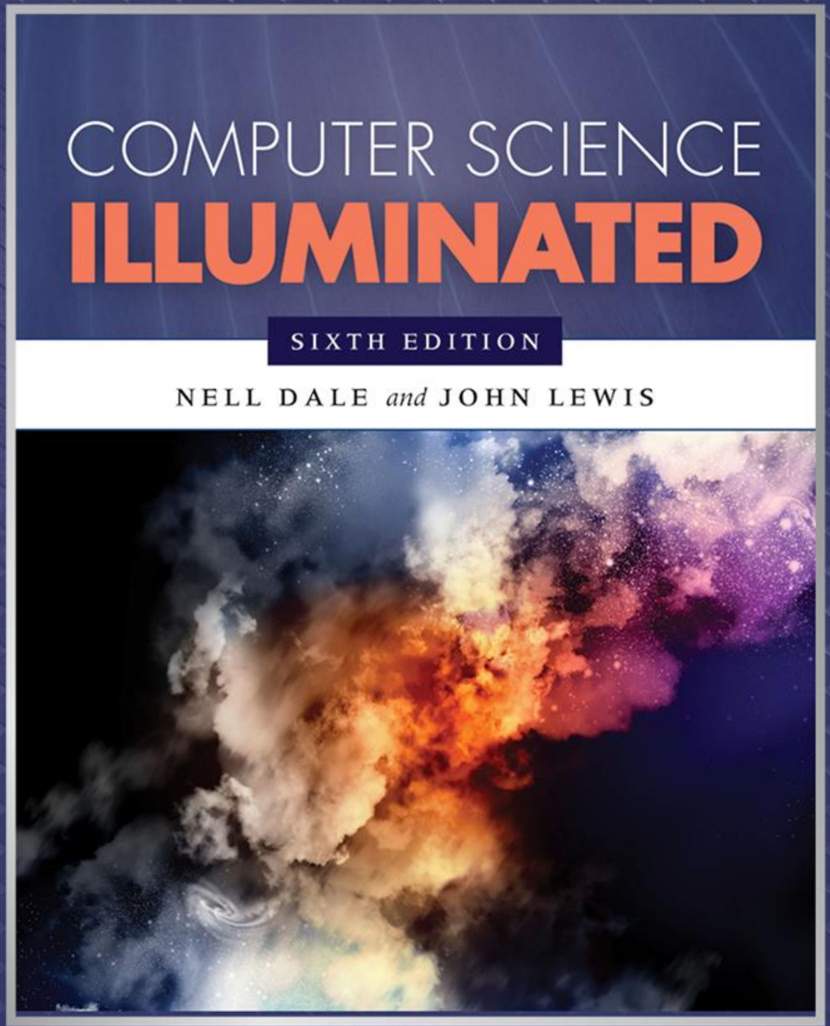
Chapter 13

Artificial Intelligence



Chapter Goals

- Distinguish between the types of problems that humans do best and those that computers do best
- Explain the Turing test
- Define what is meant by knowledge representation and demonstrate how knowledge is represented in a semantic network

Chapter Goals

- Develop a search tree for simple scenarios
- Explain the processing of an expert system
- Explain the processing of biological and artificial neural networks
- List the various aspects of natural language processing
- Explain the types of ambiguities in natural language comprehension

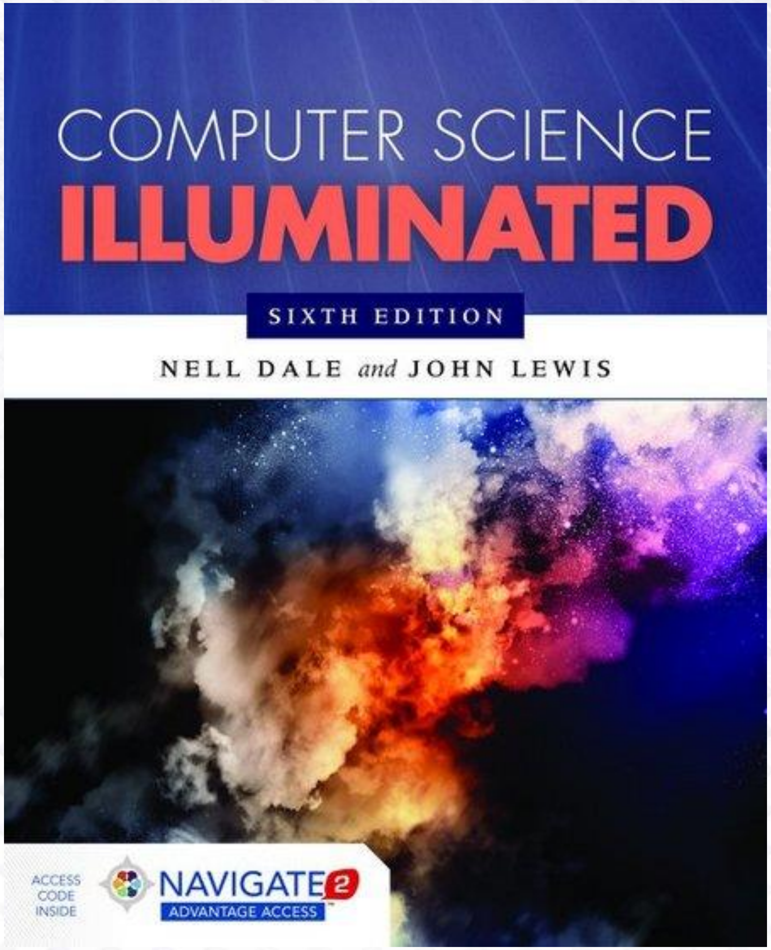
Thinking Machines

FIGURE 13.1 A computer might have trouble identifying the cat in this picture

Courtesy of Amy Rose

Can you list the items in this picture?

Thinking Machines



Cover Image: © Sergey Nivens/Shutterstock, Inc.

Can you count the distribution of letters in a book?
Add a thousand 4-digit numbers?
Match finger prints?
Search a list of a million values for duplicates?

Thinking Machines

Computers do best

Humans do best

Can you list the items in this picture?

Can you count the distribution of letters in a book?
Add a thousand4-digit numbers?
Match finger prints?
Search a list of a million values for duplicates?

Thinking Machines

Artificial intelligence (AI)

The study of computer systems that attempt to model and apply the intelligence of the human mind

For example, writing a program to pick out objects in a picture

The Turing Test

Turing test

A test to empirically determine whether a computer has achieved intelligence

Alan Turing

An English mathematician who wrote a landmark paper in 1950 that asked the question: *Can machines think?*

He proposed a test to answer the question "How will we know when we’ve succeeded?"

The Turing Test

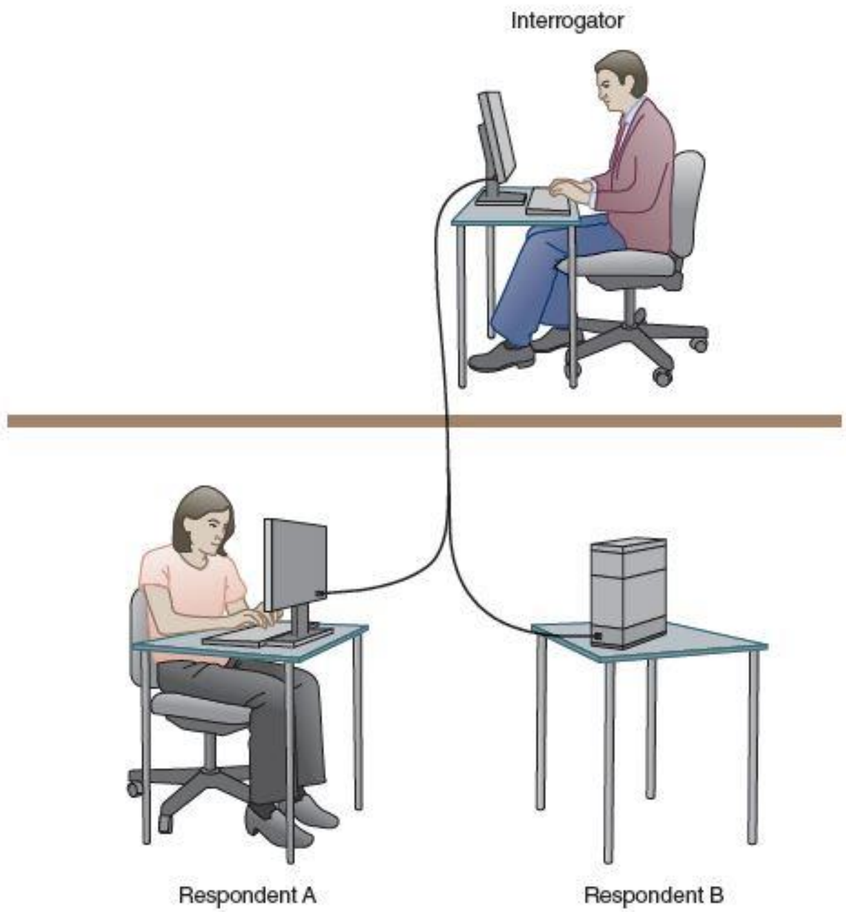


FIGURE 13.2 In a Turing test, the interrogator must determine which respondent is the computer and which is the human

The Turing Test

Weak equivalence

Two systems (human and computer) are equivalent in results (output), but they do not arrive at those results in the same way

Strong equivalence

Two systems (human and computer) use the same internal processes to produce results

The Turing Test

Loebner prize

The first formal instantiation of the Turing test, held annually

Has it been won yet?

Chatbots

A program designed to carry on a conversation with a human user

Knowledge Representation

How can we represent knowledge?

- We need to create a logical view of the data, based on how we want to process it
- Natural language is very descriptive, but does not lend itself to efficient processing
- **Semantic networks** and **search trees** are promising techniques for representing knowledge

Semantic Networks

Semantic network

A knowledge representation technique that focuses on the relationships between objects

A directed graph is used to represent a semantic network or net

Remember directed graphs?

Semantic Networks

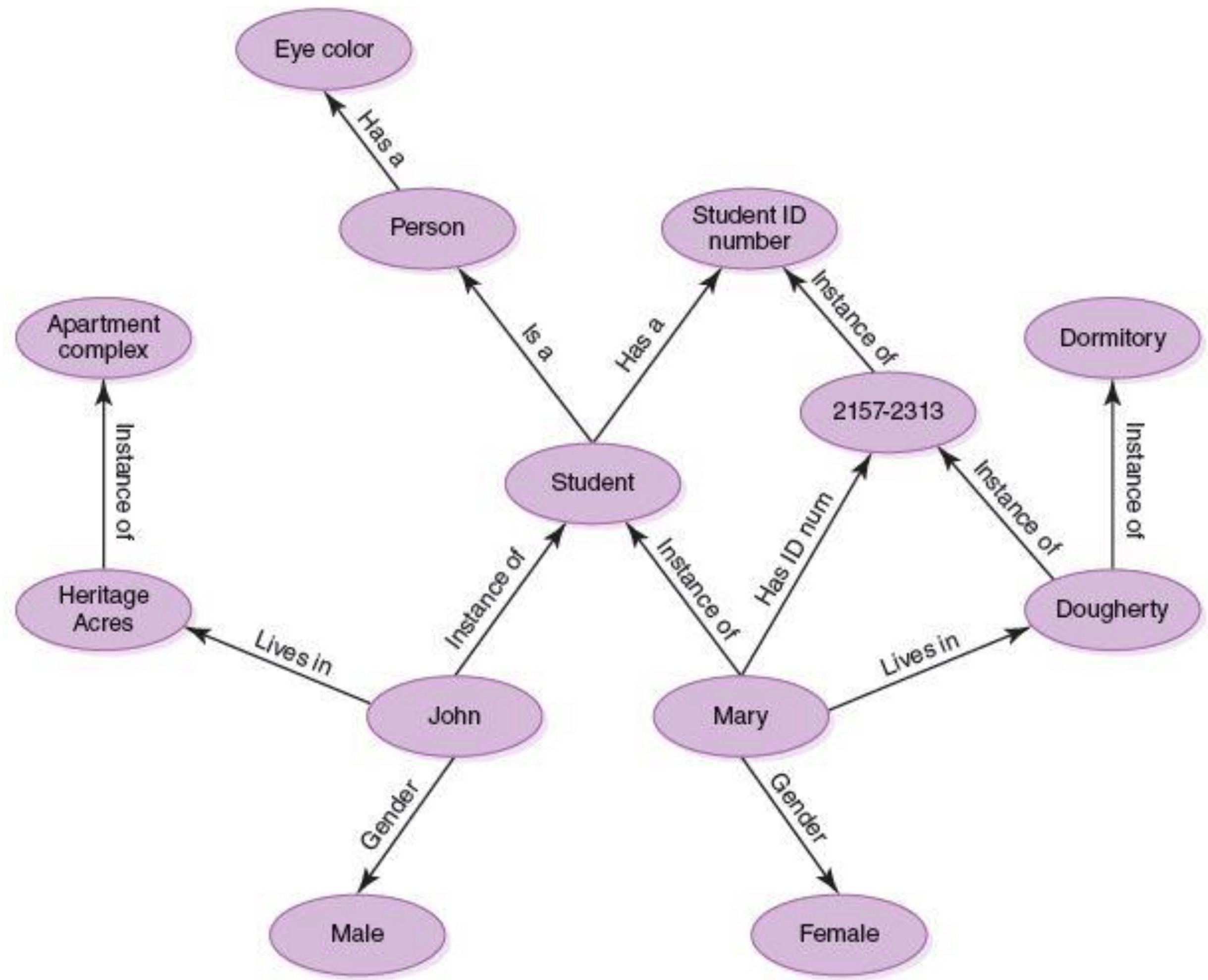


FIGURE 13.3 A semantic network

Semantic Networks

What questions can you ask about the data in Figure 13.3 (previous slide)?

What questions can you not ask?

Semantic Networks

Network Design

- The objects in the network represent the objects in the real world that we are representing
- The relationships that we represent are based on the real world questions that we would like to ask
- That is, the types of relationships represented determine which questions are easily answered, which are more difficult to answer, and which cannot be answered

Search Trees

Search tree

A structure that represents alternatives in adversarial situations such as game playing

The paths down a search tree represent a series of decisions made by the players

Remember trees?

Search Trees

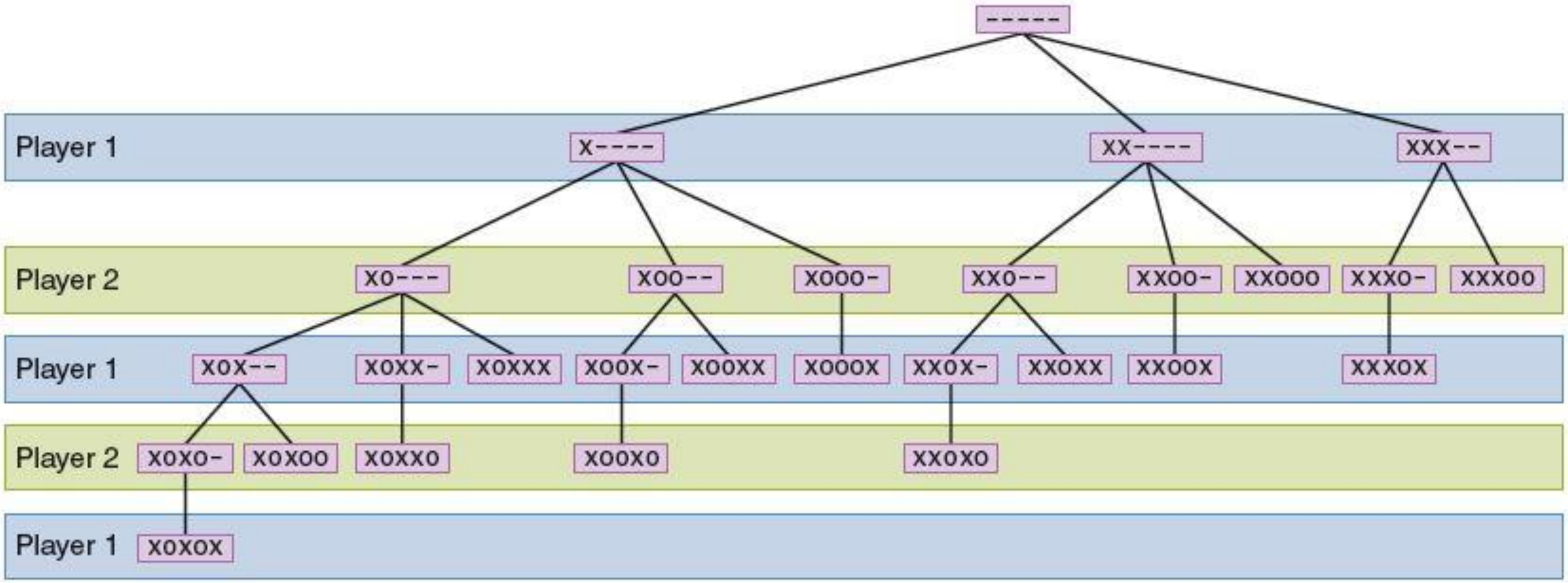


FIGURE 13.4 A search tree for a simplified version of Nim

Search Trees

Search tree analysis can be applied to other, more complicated games such as chess

However, full analysis of the chess search tree would take more than your lifetime to determine the first move

Because these trees are so large, only a fraction of the tree can be analyzed in a reasonable time limit, even with modern computing power

Therefore, we must find a way to prune the tree

Search Trees

Techniques for pruning search space

Depth-first

A technique that involves searching down the paths of a tree prior to searching across levels

Breadth-first

A technique that involves searching across levels of a tree prior to searching down specific paths

Breadth-first tends to yield the best results

Search Trees

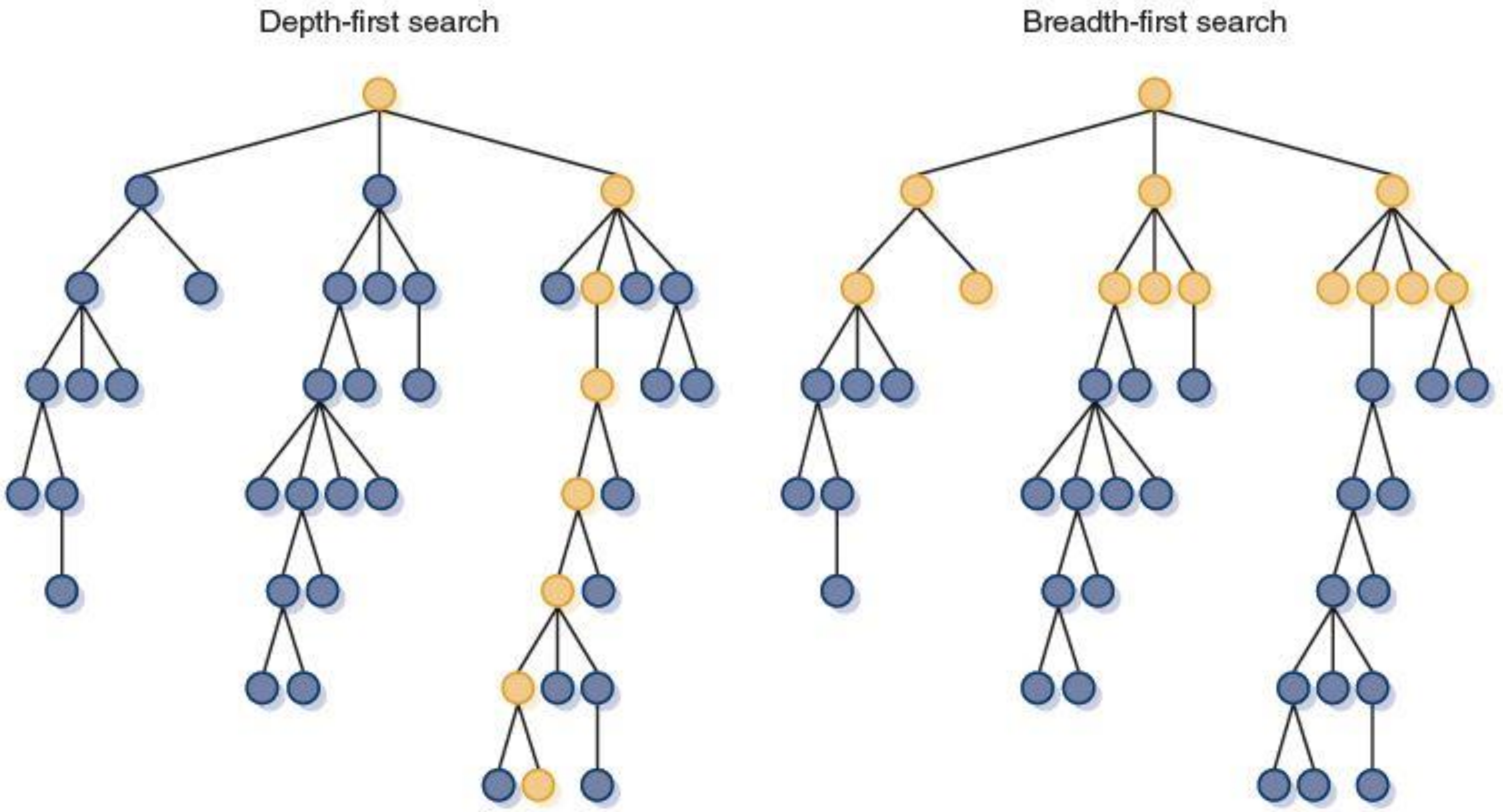


FIGURE 13.5 Depth-first and breadth-first searches

Expert Systems

Knowledge-based system

Software that uses a specific set of information, from which it extracts and processes particular pieces

Expert system

A software system based on the knowledge of human experts; it is a

- **Rule-based system** A software system based on a set of *if-then* rules
- **Inference engine** The software that processes rules to draw conclusions

Expert Systems

Named abbreviations that represent conclusions

- NONE—apply no treatment at this time
- TURF—apply a turf-building treatment
- WEED—apply a weed-killing treatment
- BUG—apply a bug-killing treatment
- FEED—apply a basic fertilizer treatment
- WEEDFEED—apply a weed-killing and fertilizer combination treatment

Expert Systems

Boolean variables needed to represent state of the lawn

- BARE—the lawn has large, bare areas
- SPARSE—the lawn is generally thin
- WEEDS—the lawn contains many weeds
- BUGS—the lawn shows evidence of bugs

Expert Systems

Data that is available

- LAST—the date of the last lawn treatment
- CURRENT—current date
- SEASON—the current season

Now we can formulate some rules for our gardening expert system.

Rules take the form of *if-then* statements

Expert Systems

Some rules

- if (CURRENT – LAST < 30) then NONE
- if (SEASON = winter) then not BUGS
- if (BARE) then TURF
- if (SPARSE and not WEEDS) then FEED
- if (BUGS and not SPARSE) then BUG
- if (WEEDS and not SPARSE) then WEED
- if (WEEDS and SPARSE) then WEEDFEED

Expert Systems

An execution of our inference engine

- **System**: Does the lawn have large, bare areas?
- **User**: No
- **System**: Does the lawn show evidence of bugs?
- **User**: No
- **System**: Is the lawn generally thin?
- **User**: Yes
- **System**: Does the lawn contain significant weeds?
- **User**: Yes
- **System**: You should apply a weed-killing and fertilizer combination treatment.

Artificial Neural Network

Artificial neural networks

A computer representation of knowledge that attempts to mimic the neural networks of the human body

Yes, but what is a human neural network?

Neural Network

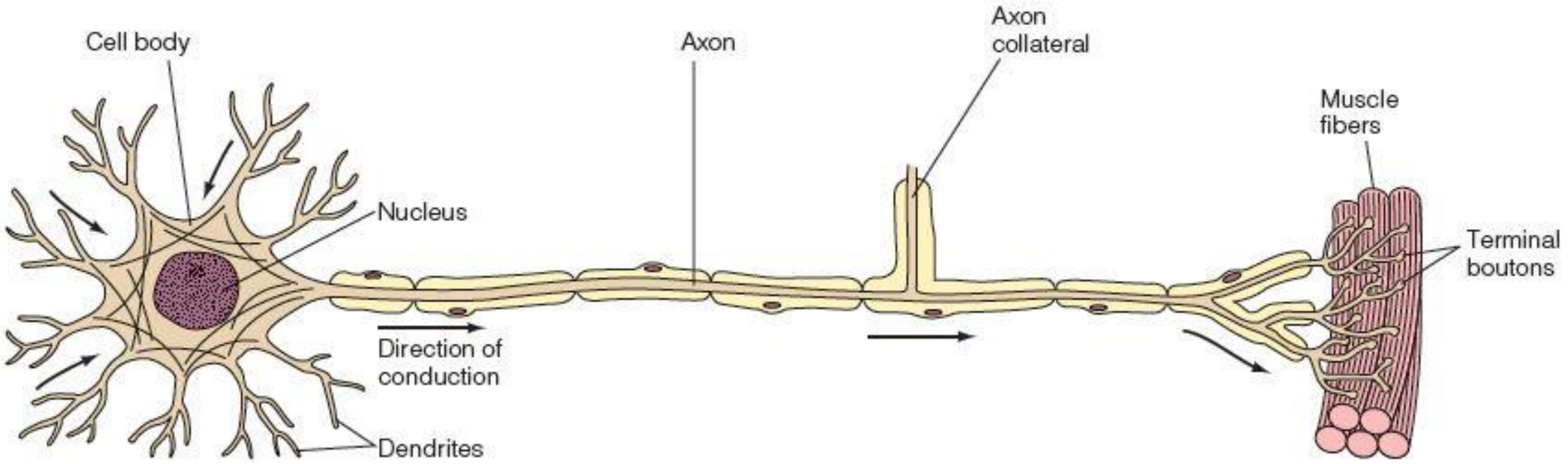


FIGURE 13.6 A biological neuron

Neural Network

Neuron

A single cell that conducts a chemically-based electronic signal

At any point in time a neuron is in either an **excited** state or an **inhibited** state

Excited state

Neuron conducts a strong signal

Inhibited state

Neuron conducts a weak signal

Neural Network

Pathway

A series of connected neurons

Dendrites

Input tentacles

Axon

Primary output tentacle

Synapse

Space between axon and a dendrite

Neural Network

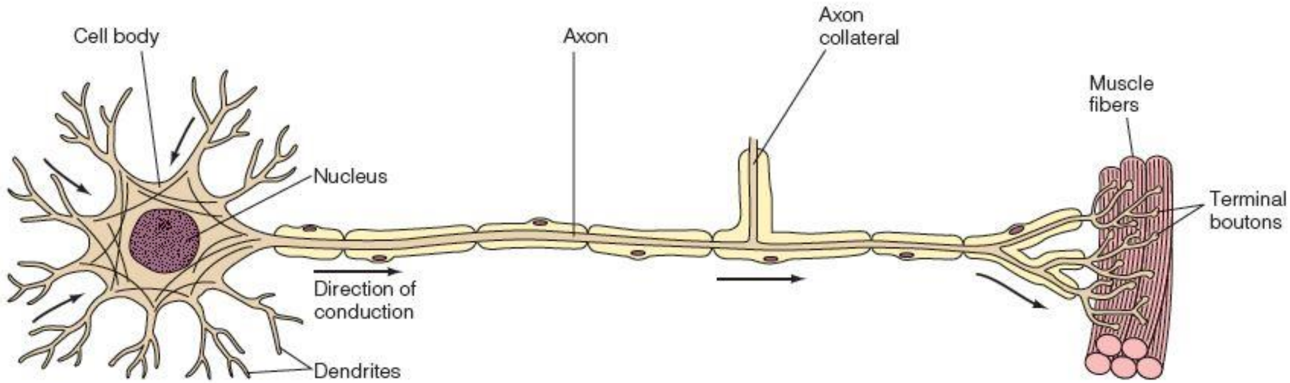


FIGURE 13.6 A biological neuron

Chemical composition of a synapse tempers the strength of its input signal
A neuron accepts many input signals, each weighted by corresponding synapse

Neural Network

The pathways along the neural nets are in a constant state of flux

As we learn new things, new strong neural pathways in our brain are formed

Artificial Neural Networks

Each processing element in an artificial neural net is analogous to a biological neuron

- An element accepts a certain number of input values (dendrites) and produces a single output value (axon) of either 0 or 1
- Associated with each input value is a numeric weight (synapse)

Artificial Neural Networks

- The **effective weight** of the element is the sum of the weights multiplied by their respective input values

  v1 * w1 + v2 * w2 + v3 * w3

- Each element has a numeric threshold value
- If the effective weight exceeds the threshold, the unit produces an output value of 1
- If it does not exceed the threshold, it produces an output value of 0

Artificial Neural Networks

Training

The process of adjusting the weights and threshold values in a neural net

How does this all work?

Train a neural net to recognize a cat in a picture

Given one output value per pixel, train network to produce an output value of 1 for every pixel that contributes to the cat and 0 for every one that doesn't

Natural Language Processing

Three basic types of processing occur during human/computer voice interaction

Voice synthesis

Using a computer to recreate the sound of human speech

Voice recognition

Using a computer to recognize the words spoken by a human

Natural language comprehension

Using a computer to apply a meaningful interpretation to human communication

Voice Synthesis

One Approach to Voice Synthesis

Dynamic voice generation

A computer examines the letters that make up a word and produces the sequence of sounds that correspond to those letters in an attempt to vocalize the word

Phonemes

The sound units into which human speech has been categorized

Voice Synthesis

Consonants			
Symbols	Examples	Symbols	Examples
p	Pipe	k	Kick, cat
b	Babe	g	Get
m	Maim	ŋ	Sing
f	Fee, phone, rough	š	Shoe, ash, sugar
v	Vie, love	ž	Measure
θ	Thin, bath	č	Chat, batch
ð	The, bathe	ǰ	Jaw, judge, gin
t	Tea, beat	d	Day, bad
n	Nine	ʔ	Uh uh
l	Law, ball	s	See, less, city
r	Run, bar	z	Zoo, booze

Vowels	
Symbols	Examples
i	Eel, sea, see
I	Ill, bill
e	Ale, aim, day
ɛ	Elk, bet, bear
æ	At, mat
u	Due, new, zoo
ʊ	Book, sugar
o	Own, no, know
ɔ	Aw, crawl, law, dog
a	Hot, bar, dart
ə	Sir, nerd, bird
ʌ	Cut, bun

Semi-vowels	
w	We
h	He
j	You, beyond

Diphthongs	
aj	Bite, fight
aw	Out, cow
ɔj	Boy, boil

FIGURE 13.7 Phonemes for American English

Voice Synthesis

Another Approach to Voice Synthesis

Recorded speech

A large collection of words is recorded digitally and individual words are selected to make up a message

Many words must be recorded more than once to reflect different pronunciations and inflections

Common for phone message:
For Nell Dale, press 1
For John Lewis, press 2

Voice Recognition

Problems with understanding speech

- Each person's sounds are unique
- Each person's shape of mouth, tongue, throat, and nasal cavities that affect the pitch and resonance of our spoken voice are unique
- Speech impediments, mumbling, volume, regional accents, and the health of the speaker are further complications

Voice Recognition

Other problems

- Humans speak in a *continuous, flowing* manner, stringing words together
- Sound-alike phrases like “ice cream” and “I scream”
- Homonyms such as “I” & “eye” or “see” & “sea”

Humans clarify these situations by context, but that requires another level of comprehension

Voice-recognition systems still have trouble with continuous speech

Voice Recognition

Voiceprint

The plot of frequency changes over time representing the sound of human speech

A human *trains* a voice-recognition system by speaking a word several times so the computer gets an average voiceprint for a word

Used to authenticate the declared sender of a voice message

Natural Language Comprehension

Natural language is ambiguous!

Lexical ambiguity

The ambiguity created when words have multiple meanings

Syntactic ambiguity

The ambiguity created when sentences can be constructed in various ways

Referential ambiguity

The ambiguity created when pronouns could be applied to multiple objects

Natural Language Comprehension

What does this sentence mean?

Time flies like an arrow.

– Time goes by quickly

– Time flies (using a stop watch) as you would time an arrow

– Time flies (a kind of fly) are fond of an arrow

Silly?
Yes, but a computer wouldn't know that

Natural Language Comprehension

Lexical ambiguity

- Stand up for your country.
- Take the street on the left.

Can you think of some others?

Syntactic ambiguity

- I saw the bird watching from the corner.
- I ate the sandwich sitting on the table.

Referential ambiguity

- The bicycle hit the curb, but it was not damaged.
- John was mad at Bill, but he didn't care.

Robotics

Mobile robotics

The study of robots that move relative to their environment, while exhibiting a degree of autonomy

Sense-plan-act (SPA) paradigm

The world of the robot is represented in a complex semantic net in which the sensors on the robot are used to capture the data to build up the net

FIGURE 13.8 The sense–plan–act (SPA) paradigm

Subsumption Architecture

Rather than trying to model the entire world all the time, the robot is given a simple set of behaviors each associated with the part of the world necessary for that behavior

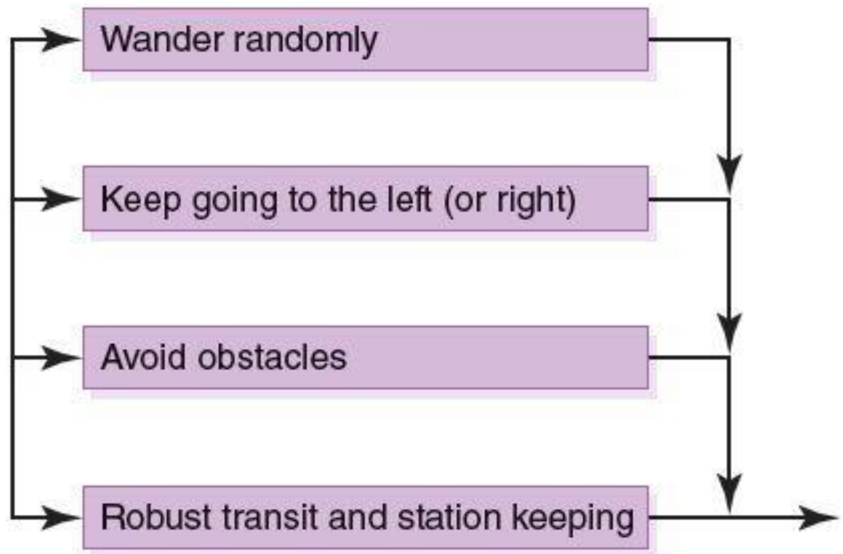


FIGURE 13.9 The new control paradigm

Subsumption Architecture

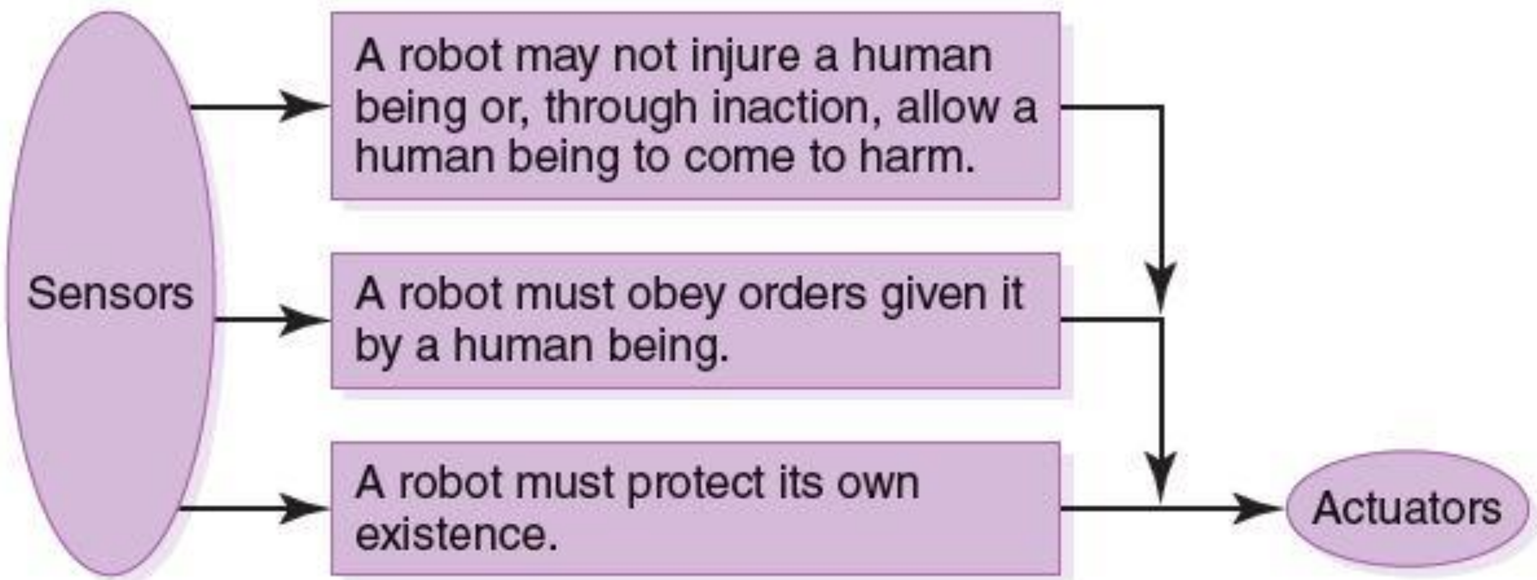


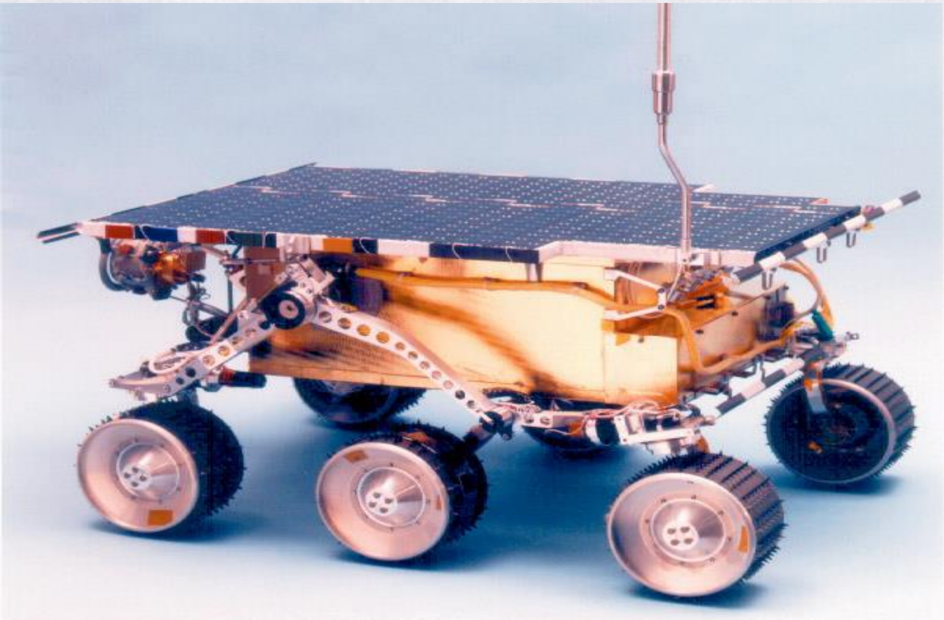
FIGURE 13.10 Asimov's laws of robotics are ordered

Robots

© Chris Willson/Alamy

Sony's Aibo

Robots



Courtesy of NASA/JPL-Caltech.

Sojourner Rover

Robots

Courtesy of NASA/JPL-Caltech

Spirit or Opportunity Rover

Ethical Issues

Initial Public Offerings (IPOs)

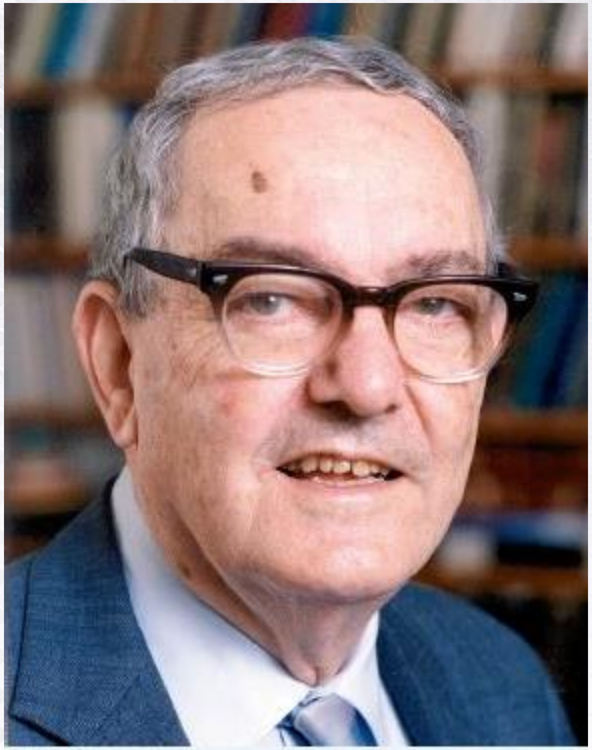
What is the purpose of an IPO?

How is the opening price determined?

How likely is an individual investor to be able to buy the stock at the opening price?

What happened to initial investors in Facebook? Twitter?

Who am I?



Courtesy of Carnegie Mellon University

I'm another of those who looks like I don't belong in a CS book. *For what did I win a Nobel Prize? In what other fields did I do research?*

Do you know?

Why has television been accused of "robbing something from the democratic process," and the Internet credited for giving it back?

What language is known as the AI language?

Did natural language translation prove to be as easy as early experts predicted?

What is the name of the program that acts as a neutral psychotherapist?