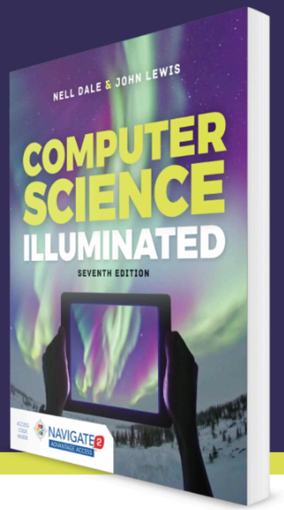

CHAPTER 13
LECTURE OUTLINE

Computer Science Illuminated, Seventh Edition

Nell Dale, PhD; John Lewis, PhD

Artificial Intelligence

13.1 Thinking Machines
- **The Turing Test**
- **Aspects of AI**

13.2 Knowledge Representation
- **Semantic Networks**
- **Search Trees**

13.3 Expert Systems

13.4 Neural Networks
- **Biological Neural Networks**
- **Artificial Neural Networks**

13.5 Natural-Language Processing
- **Voice Synthesis**
- **Voice Recognition**
- **Natural-Language Comprehension**

13.6 Robotics
- **The Sense–Plan–Act Paradigm**

Credits

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Authors

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Publisher

Eric Pogue
Audio commentary plus slides with the grey backgrounds

Chapter Goals (1 of 2)

- 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 (2 of 2)

- 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 (1 of 4)

Courtesy of Amy Rose

A computer might have trouble identifying the cat in this picture

Can you find the cat in this picture?

Thinking Machines (3 of 4)

Humans do best

Can you find the cat in this picture?

Computers do best

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

Thinking Machines (4 of 4)

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 (1 of 4)

Turing Test

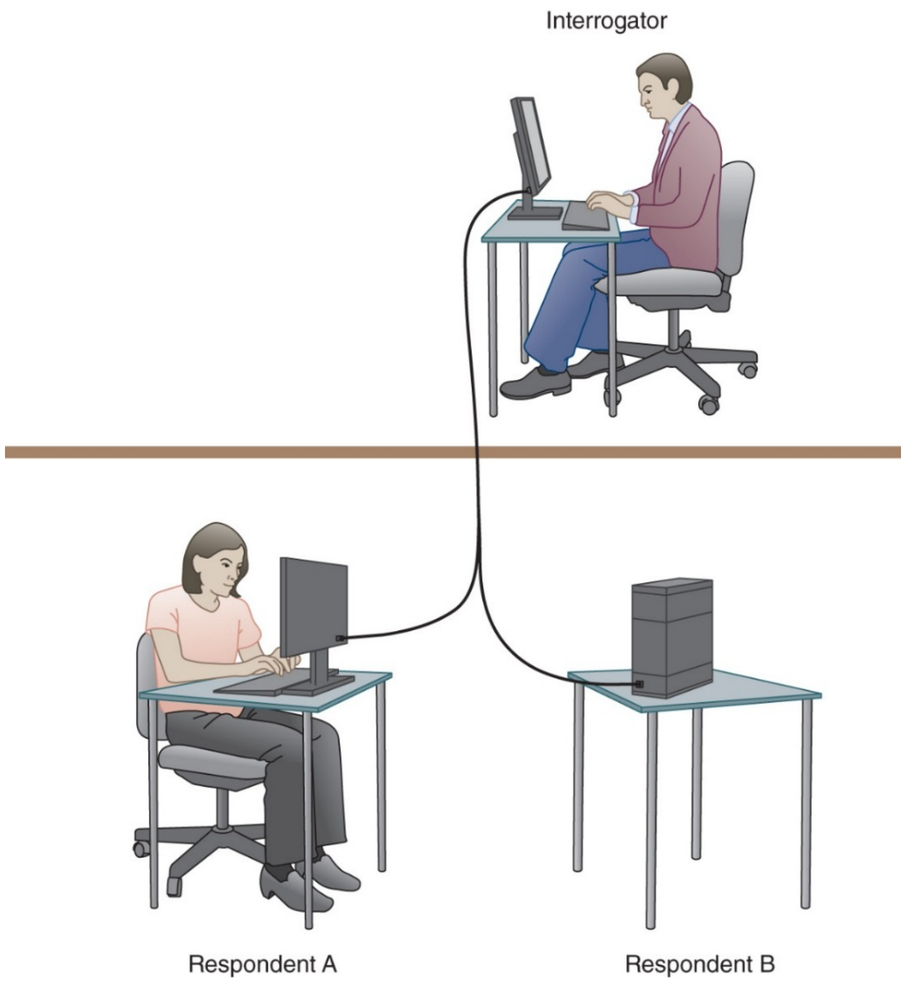
A test to empirically determine whether a computer has achieved intelligence

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 (2 of 4)



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

The Turing Test (3 of 4)

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 (4 of 4)

Loebner Prize

The first formal instantiation of the Turing test, held annually

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 (1 of 4)

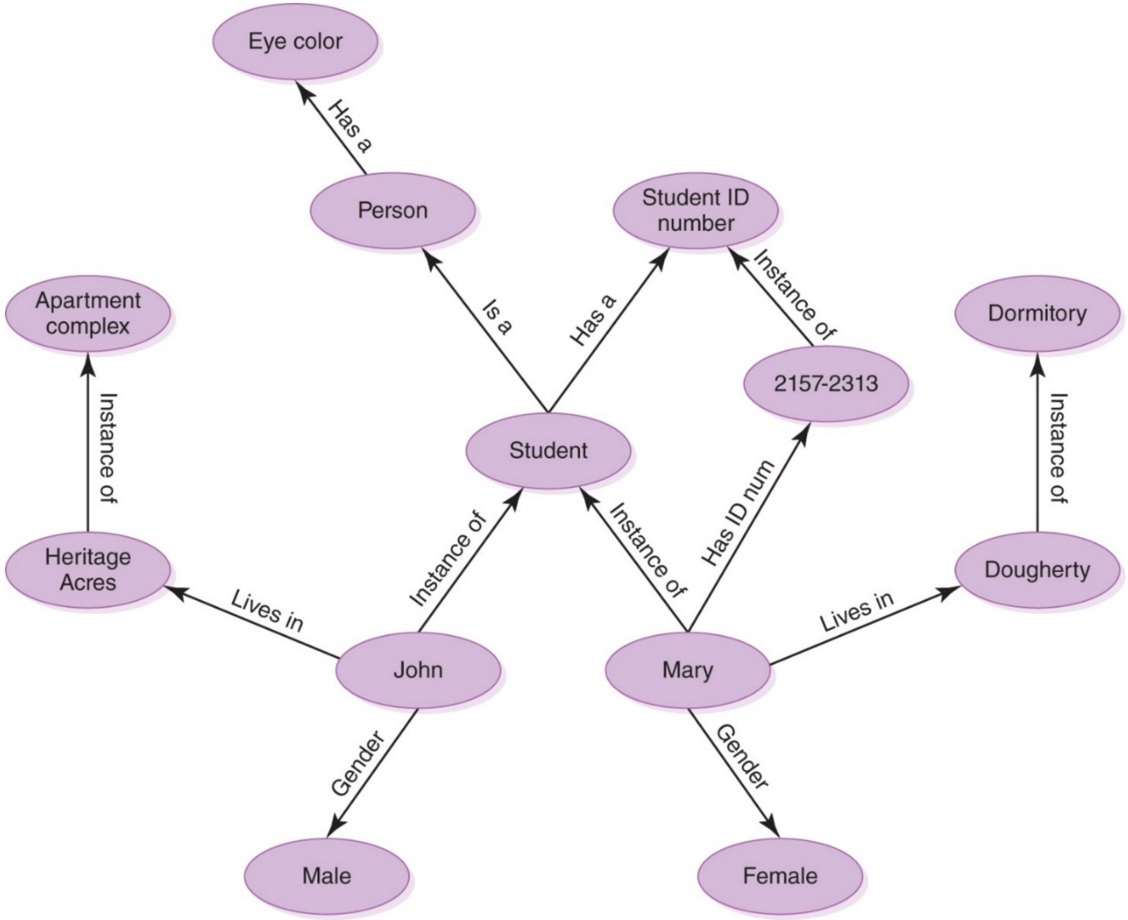
Semantic Network

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 (2 of 4)



A semantic network

Semantic Networks (3 of 4)

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

What questions can you not ask?

Semantic Networks (4 of 4)

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 (1 of 5)

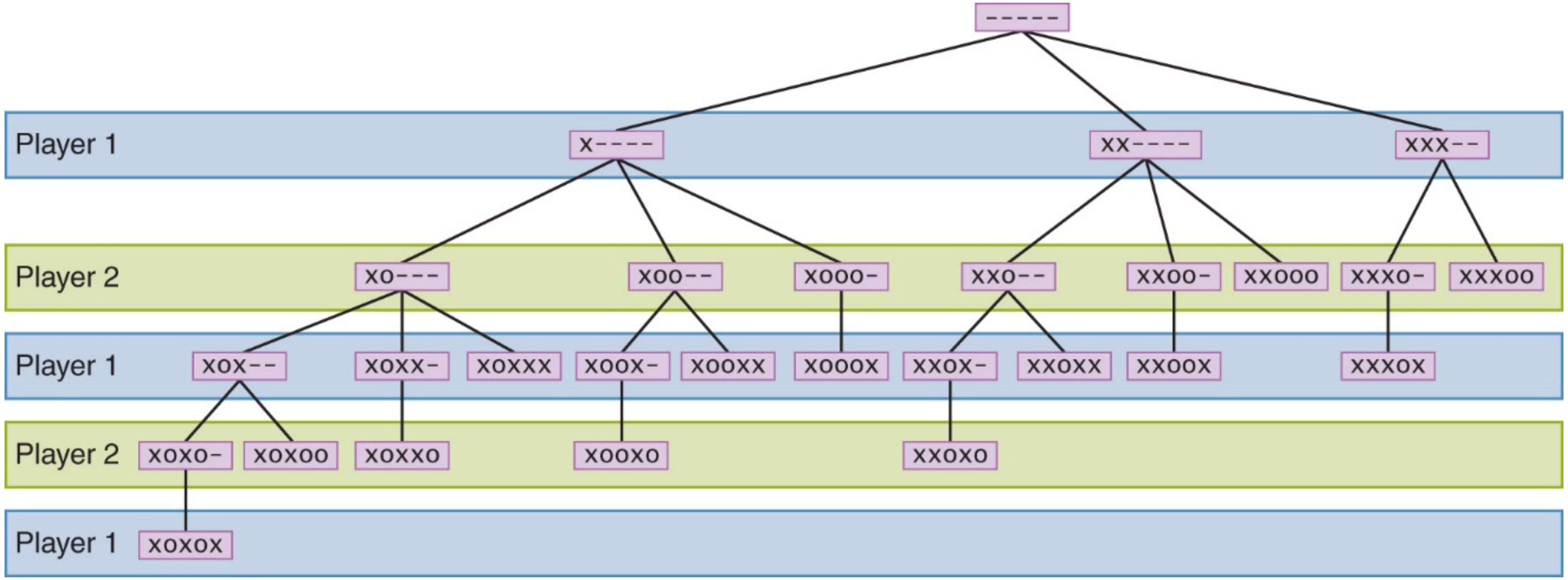
Search Tree

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 (2 of 5)



A search tree for a simplified version of Nim

Search Trees (3 of 5)

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 (4 of 5)

Techniques for pruning search space

Depth-First

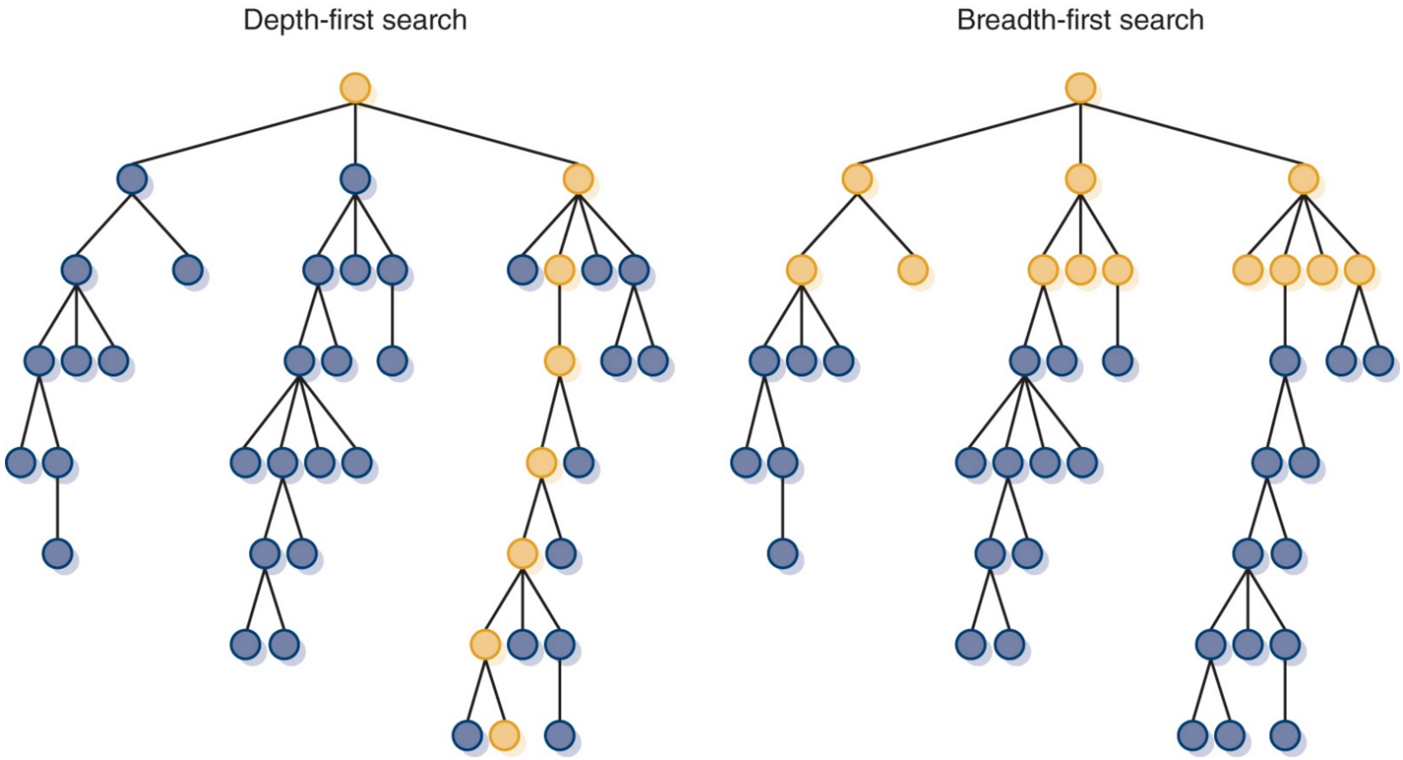
A technique that involves searching down the paths of a tree prior to searching across levels

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 (5 of 5)



Depth-first and breadth-first searches

Expert Systems (1 of 6)

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
- **An inference engine** The software that processes rules to draw conclusions

Expert Systems (2 of 6)

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 (3 of 6)

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 (4 of 6)

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 (5 of 6)

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 (6 of 6)

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.*

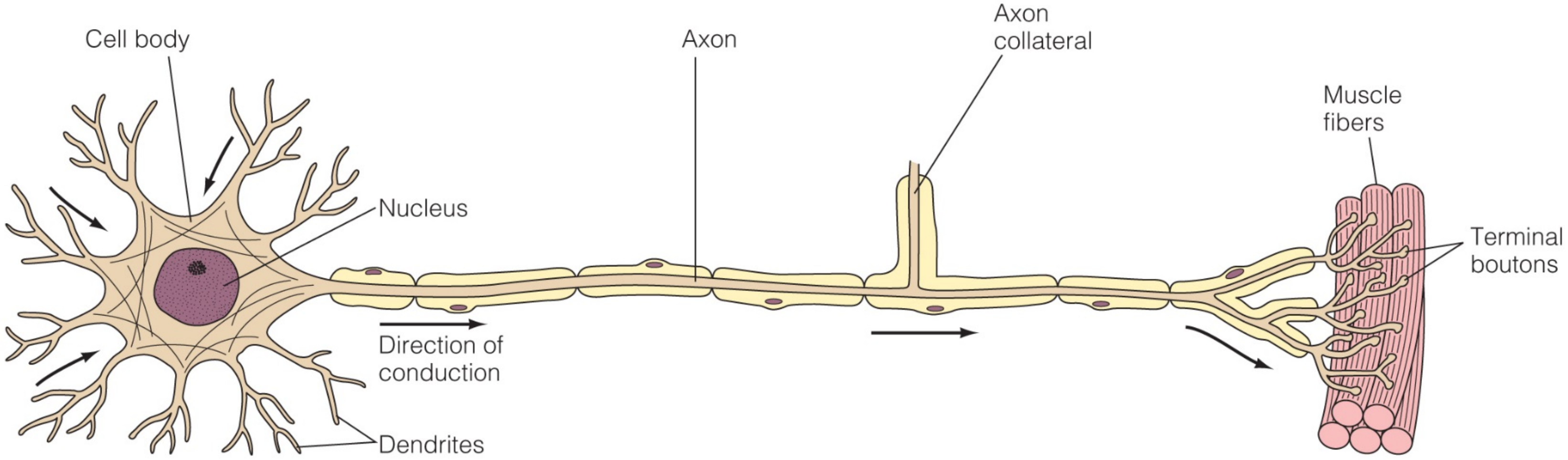
Artificial Neural Network (1 of 4)

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 (1 of 5)



A biological neuron

Neural Network (2 of 5)

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 (3 of 5)

Pathway

A series of connected neurons

Dendrites

Input tentacles

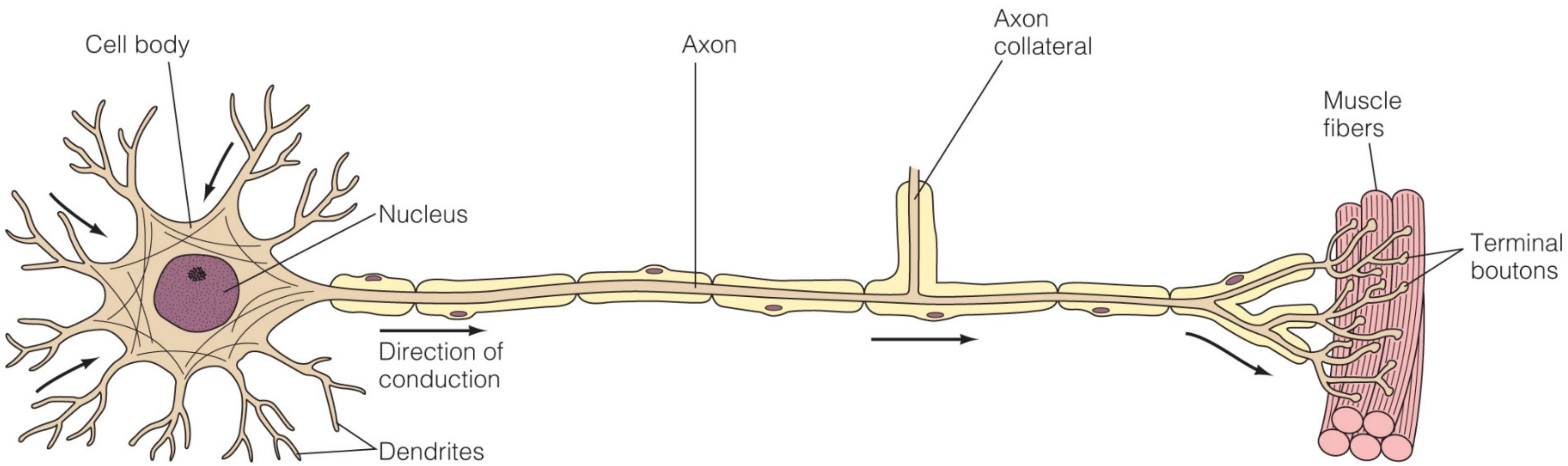
Axon

Primary output tentacle

Synapse

Space between axon and a dendrite

Neural Network (4 of 5)



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 (5 of 5)

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 (2 of 4)

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 (3 of 4)

- 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 (4 of 4)

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 (1 of 3)

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 (2 of 3)

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
ɪ	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

Phonemes for American English

Voice Synthesis (3 of 3)

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

Voice Recognition (1 of 3)

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 (2 of 3)

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 (3 of 3)

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

(1 of 3)

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

(2 of 3)

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

(3 of 3)

Lexical ambiguity

Stand up for your country.

Take the street on the left.

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.

Can you think of some others?

Robotics

Mobile Robotics

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

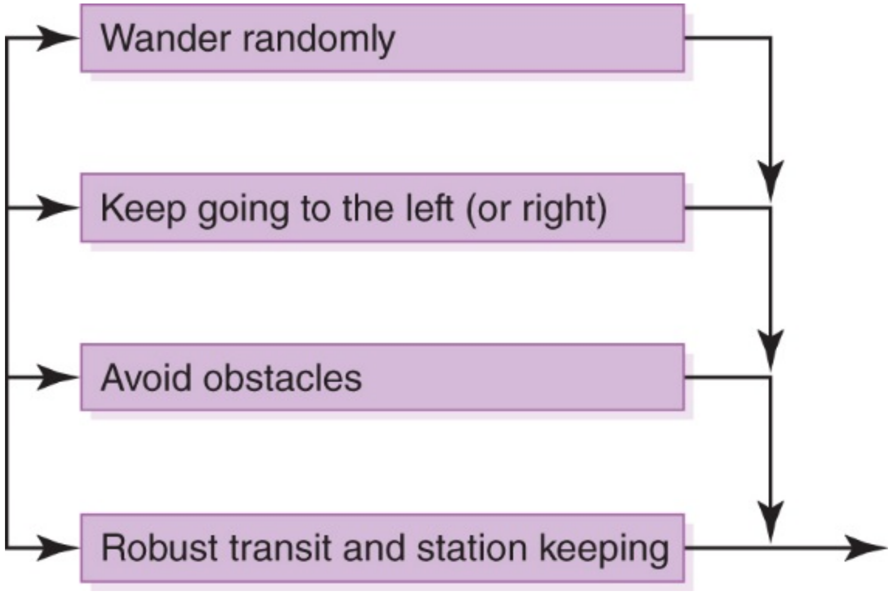
Sense-Plan-Act (SPA) Paradigm

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

The sense-plan-act (SPA) paradigm

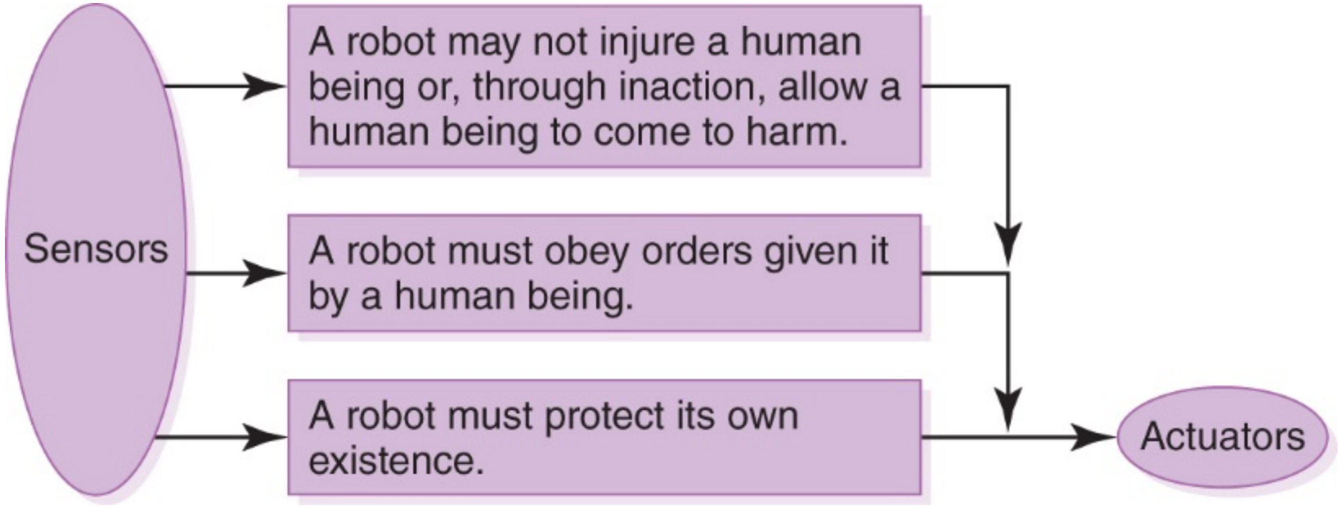
Subsumption Architecture (1 of 2)

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



The new control paradigm

Subsumption Architecture (2 of 2)



Asimov's laws of robotics are ordered

Chapter 13 Lecture