Artificial Intelligence

- **Reading Materials:**
  - Ch 14 of [SG]
  - Also Section 9.4.2 Logic Programming

- **Contents:**
  - Different Types of Tasks
  - Knowledge Representation
  - Recognition Tasks
  - Reasoning Tasks

For Fall 2013 semester

- **Will only cover:**
  - Turing Test, Eliza
  - Division of Labour in AI
  - Formal Language for Knowledge Representation
  - Reasoning: Intelligent Search, Expert Systems
- **Parts of Ch. 14 covered**
  - Ch. 14.1 Introduction
  - Ch. 14.2 Division of Labour
  - Ch. 14.3 Only Formal Language (Predicates)
  - Ch. 14.5 Reasoning Tasks
- **Will not cover**
  - Knowledge Representation (except Formal Lang)
  - Recognition Tasks (Ch 14.4)
  - Robotics (Ch 14.6)

Artificial Intelligence…

- Context so far…
  - Use algorithm to solve problem
  - Database used to organize massive data
  - Algorithms implemented using hardware
  - Computers linked in a network

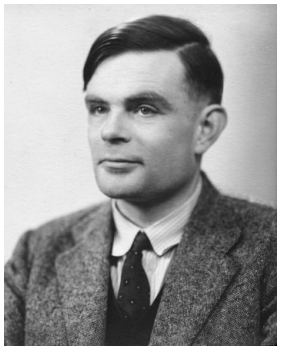
Educational Goals for this Chapter:

- The computer as a tool for
  - Solving more human-like tasks
  - Build systems that "think" independently
  - Can "intelligence" be encoded as an algorithm?

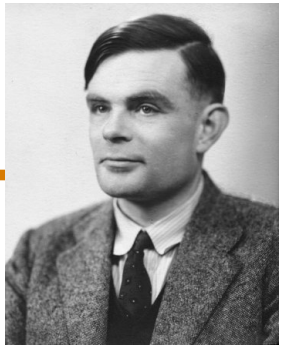
Introduction

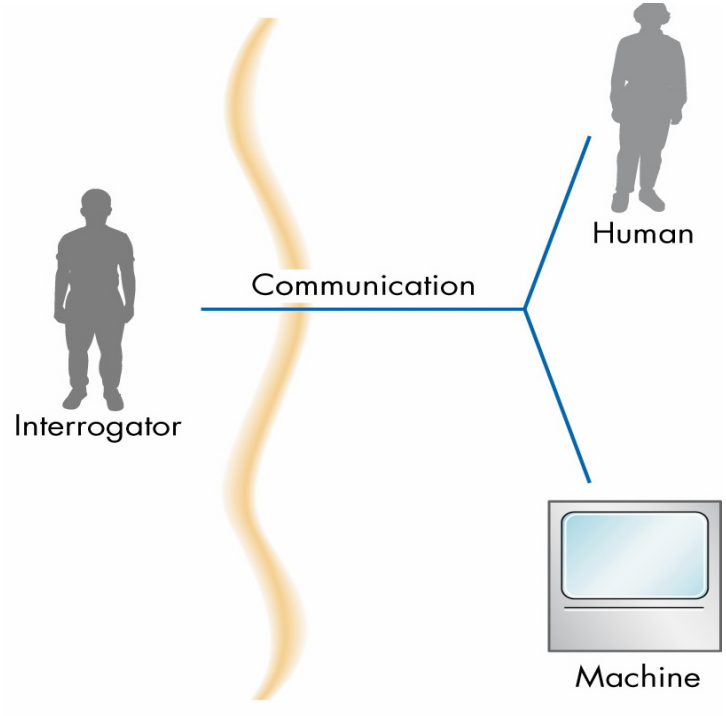
- **Artificial intelligence (AI)**
  - **Explores techniques for incorporating aspects of "*intelligence*" into computer systems**

- **Turing Test (Alan Turing, 1950)**
  - **A test for intelligent behavior of machines**



The Turing Test (Alan Turing, 1950)





If the interrogator is unable to determine which entity is the human and which is the machine,

then the machine has passed the Turing Test

Introduction (continued)

- **Artificial intelligence can be thought of as *constructing computer models* of human intelligence**

- **Early attempt: Eliza (see notes, website)**

Eliza Psychiatrist

- Seemingly human, but without understanding
- Implement via pattern matching of clever rules
- Understanding involves interpretation of information in light of knowledge already acquired

A Typical Conversation with Eliza

Men are all alike
IN WHAT WAY?
They're always bugging us about something or other
CAN YOU THINK OF A SPECIFIC EXAMPLE?
Well, my boyfriend made me come here
YOUR BOYFRIEND MADE YOU COME HERE
He says I'm depressed most of the time
I'M SORRY TO HEAR YOU ARE DEPRESSED
It's true, I am unhappy
DO YOU THINK COMING HERE WILL HELP YOU NOT TO BE UNHAPPY?
I need some help, that much seems certain
WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP?
Perhaps I could learn to get along with my mother
TELL ME MORE ABOUT YOUR FAMILY
My mother takes care of me
WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU?
My father
YOUR FATHER?
You are like my father in some ways
WHAT RESEMBLANCE DO YOU SEE?
You are not very aggressive, but I think you don't want me to notice that
WHAT MAKES YOU THINK I AM NOT VERY AGGRESSIVE?
You don't argue with me
WHY DO YOU THINK I DON'T ARGUE WITH YOU?
You are afraid of me
DOES IT PLEASE YOU TO BELIEVE I AM AFRAID OF YOU?
My father is afraid of everybody
WHAT ELSE COMES TO MIND WHEN YOU THINK OF YOUR FATHER?
Bullies
DOES THAT HAVE ANYTHING TO DO WITH THE FACT THAT YOUR BOYFRIEND MADE YOU COME HERE?

Is Eliza really "intelligent"?

- **How Eliza does it…**

Eliza rules

- Keywords: I, YOU, MOTHER, HATE ..etc
- Response:
  AAA You are BBB ==> I am (inversion BBB)
  inversion: ME/YOU, MY/YOUR
- Templates:
  T1: What makes you think XXX
  T2: Tell me more about XXX
  T3: Does it please you to believe XXX
- Encouragement to engage:
  "You don't seem very talkative today"

Eliza Conversation *revisited*

	Men are all alike
Encouragement	IN WHAT WAY?
	They're always bugging us about something or other
Encouragement	CAN YOU THINK OF A SPECIFIC EXAMPLE?
	Well, my boyfriend made me come here
simple inversion	YOUR BOYFRIEND MADE YOU COME HERE
	He says I'm depressed most of the time
template "I am .."	I'M SORRY TO HEAR YOU ARE DEPRESSED
	It's true, I am unhappy
template "do you..."	DO YOU THINK COMING HERE WILL HELP YOU NOT TO BE UNHAPPY?
	I need some help, that much seems certain
template "what ..."	WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP?
	Perhaps I could learn to get along with my mother
template "tell me..."	TELL ME MORE ABOUT YOUR FAMILY
	My mother takes care of me
template "who else..."	WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU?

Finish the rest yourself

What's YOUR verdict?

Does Eliza pass the Turing Test?

YES?

NO?

How would you "break" it?

Eliza, Chatterbots, & applications…

Many Eliza-like programs on the Web:

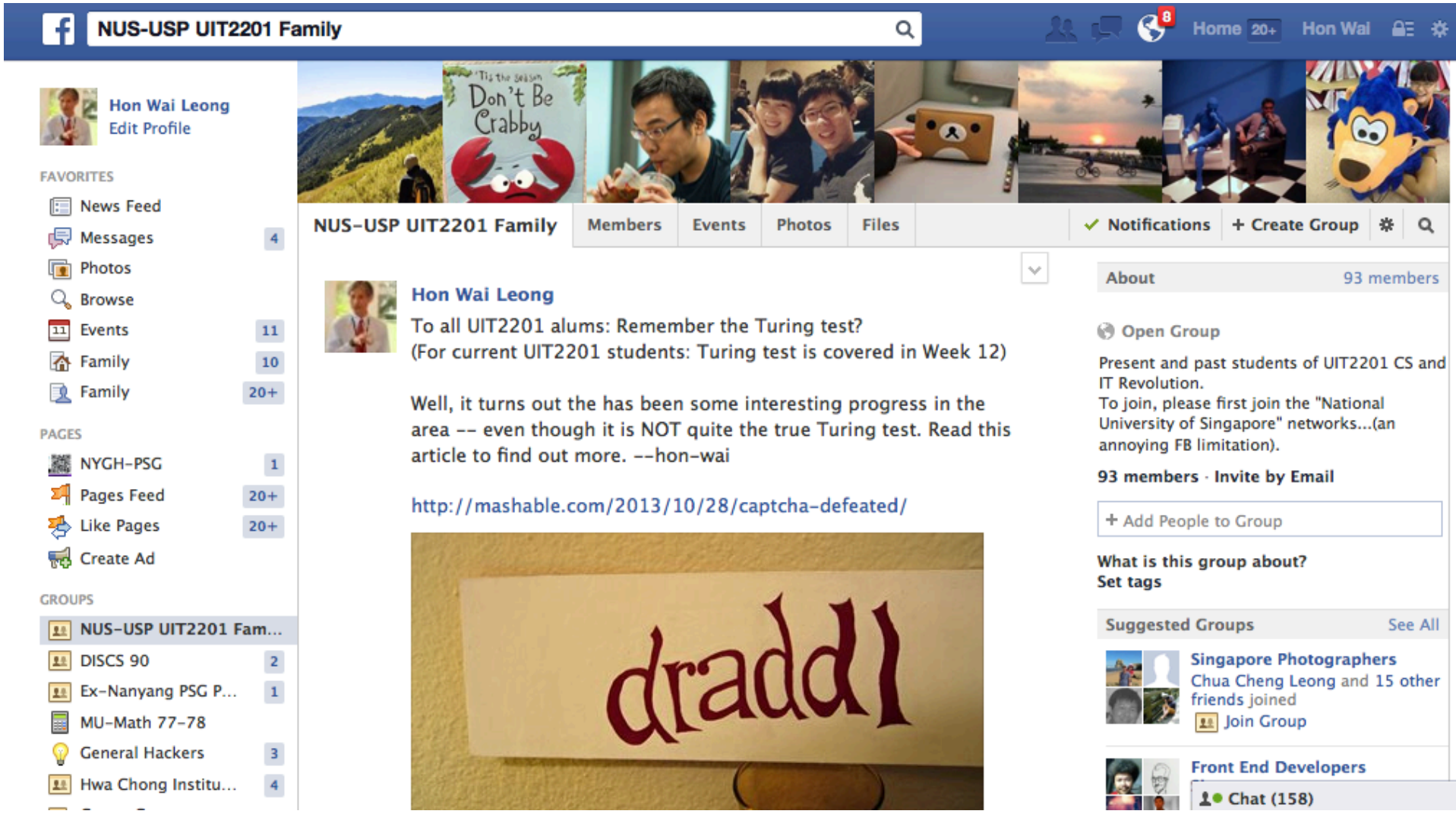
Also called "chatterbots"

- http://nlp-addiction.com/eliza/
- http://www.manifestation.com/neurotoys/eliza.php3
- http://www.chatbots.org/chatbot/eliza/
- http://en.wikipedia.org/wiki/ELIZA

Found applications in

Answer services, Automated Call Centers.

Recent news (NUS-USP-UIT2201 FB Gp)



Headline on "Mashable" (28-Oct-2013)

http://mashable.com/2013/10/28/captcha-defeated/

What is a Captcha?

… is a program that can generate and grade tests that humans can pass but current computer programs cannot.

… in other words, to tell Humans and Computers Apart *Automatically*

Headline on "Mashable" (28-Oct-2013)

http://mashable.com/2013/10/28/captcha-defeated/

That's exactly what researchers at Vicarious AI say they've done. In trying to develop a machine that thinks like a human — a multi-decade project — the small team of computer scientists says they have their first breakthrough: A computer that can process visual information similar to a human. That brings with it the ability to solve Captcha from the major web services of Google, Yahoo and PayPal up to 90% of the time.

So, does this computer pass the Turing Test?

…major web services of Google, Yahoo, Paypal.

…up to 90% of the time,

A Division of Labor

- Categories of "human-like" tasks
  - Computational tasks
  - Recognition tasks
  - Reasoning tasks

A Division of Labor (continued)

- Computational tasks
  - Tasks for which algorithmic solutions exist
  - Computers are better (faster and more accurate) than humans
- Recognition tasks
  - Sensory/recognition/motor-skills tasks
  - Humans are better than computers
- Reasoning tasks
  - Require a large amount of knowledge
  - Humans are far better than computers

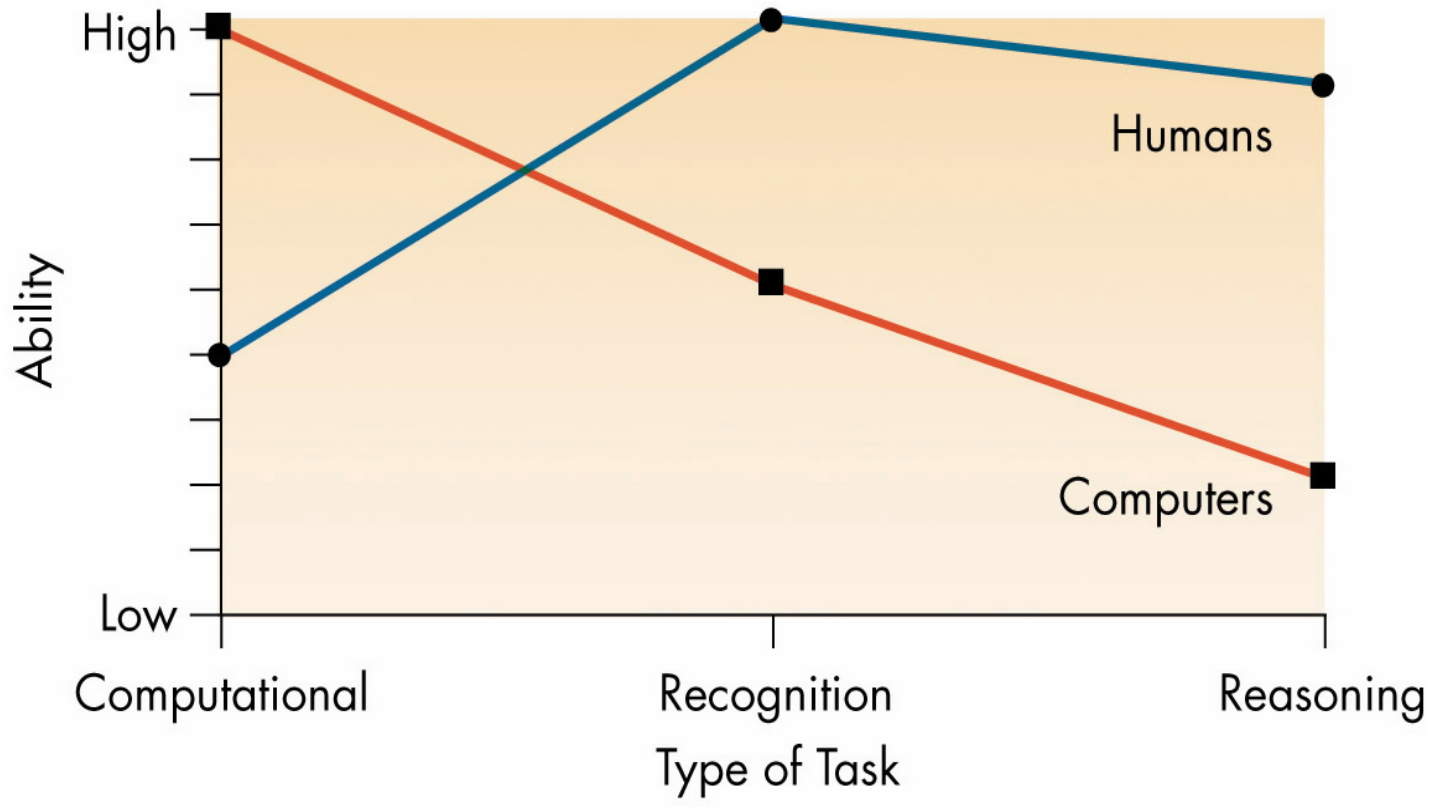


Figure 14.2: Human and Computer Capabilities

Artificial Intelligence

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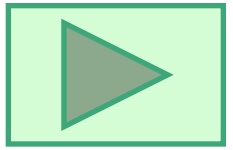
Contents:

- Different Types of Tasks
- Knowledge Representation
- Recognition Tasks
  - *Modeling of Human Brain*
  - *Artificial Neural Networks*
- Reasoning Tasks

Skip Forward: 

Recognition Tasks: Human

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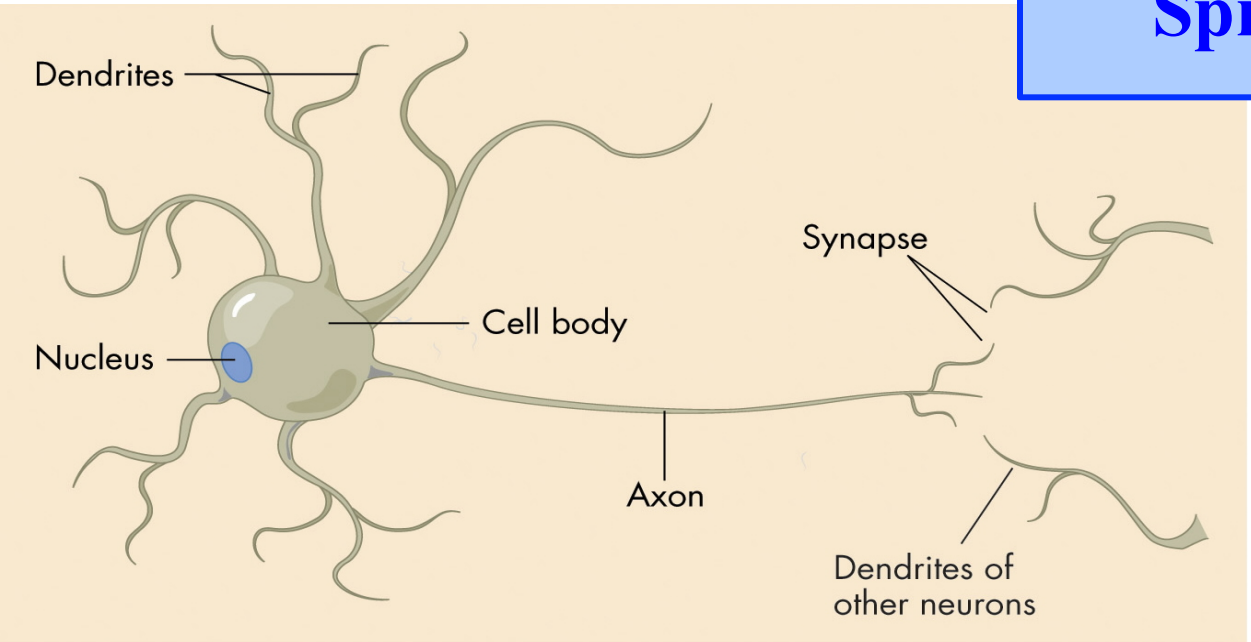

A Neuron

- **Neuron – a cell in human brain; capable of:**
  - **Receiving stimuli from other neurons through its dendrites**
  - **Sending stimuli to other neurons thru' its axon**

Human Neurons: How they

Skipped in Spring 2013

- Each neuron
  - Sums up activating and inhibiting stimuli it received – call the sum V
  - If the sum V equals or exceeds its "*threshold*" value, then neuron sends out its own signal (through its *axon*) [*fires*]

- Each neuron can be thought out as an extremely *simple computational device* with a single on/off output;

Recognition Tasks (continu

Skipped in Spring 2013

- Human brain: a connectionist architecture
  - A large number of simple "processors" with multiple interconnections
- Von Neumann architecture
  - A small number (maybe only one) of very powerful processors with a limited number of interconnections between them

Recognition Tasks (continu

Skipped in Spring 2013

- Artificial neural networks (neural networks)
  - Simulate individual neurons in hardware
  - Connect them in a massively parallel network of simple devices that act somewhat like biological neurons
- The effect of a neural network may be simulated in software on a sequential-processing computer

Modeling a single neuron

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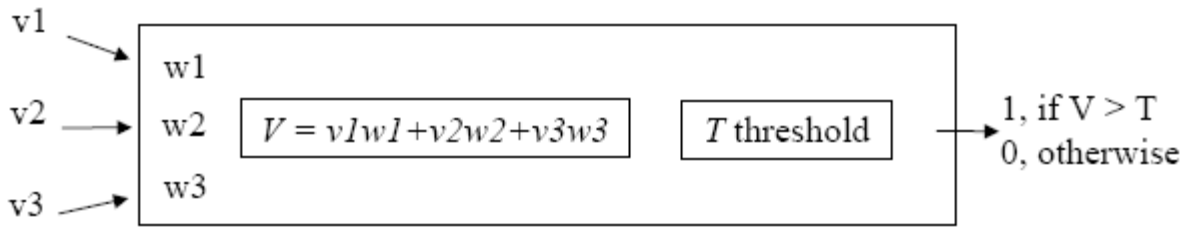
- Neural networks constructed from r
  simple processing units



An artificial neuron

- Each neuron has a threshold value
- Input lines carry weights that represent stimuli
- The neuron *fires* when the sum of the incoming weights equals or exceeds its threshold value

Operation of 1 neuron.

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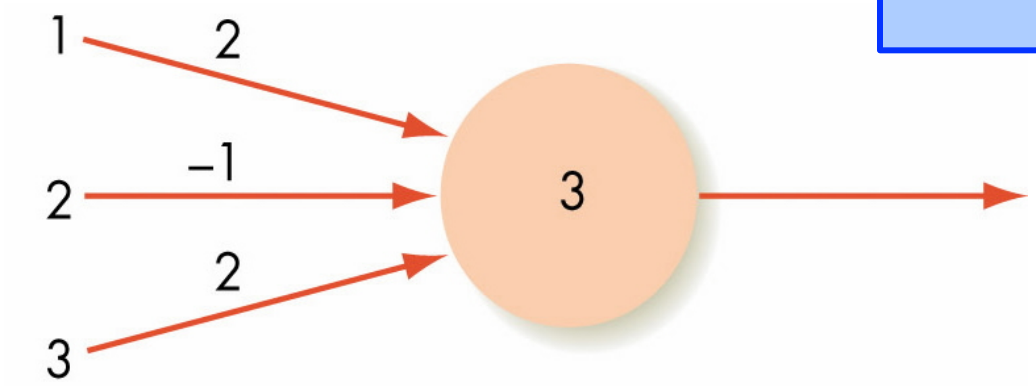

Figure 14.5: One Neuron with Three Inputs

- When can the output be 1? (neuron "fire")
- Can you modify the network and keep the same functionality?

An OR gate (using ANN)

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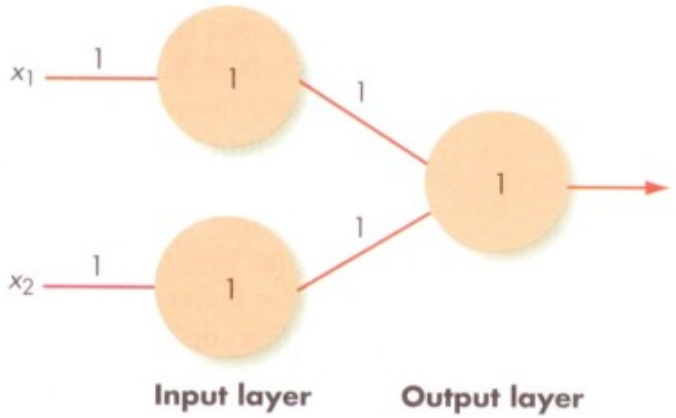

Figure 14.7 A simple neural network

- When can the output be 1? (neuron "fire")
- Can you draw a table for "x_1 x_2 Output"

What about XOR gate?

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Inputs		
X_1	X_2	
0	0	0
1	0	1
0	1	1
1	1	0

Figure 14.8. The Truth Table for XOR

- **Question: Can a simple NN be built to represent the XOR gate?**

More Simple Neural Network

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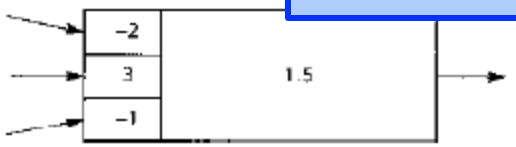
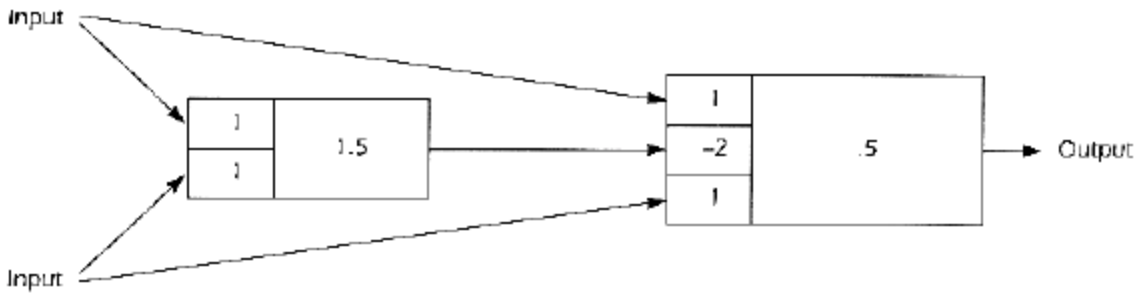
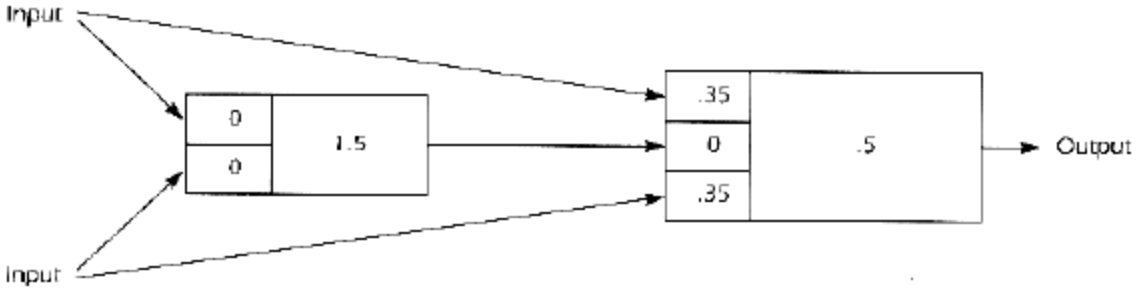
Example Networks





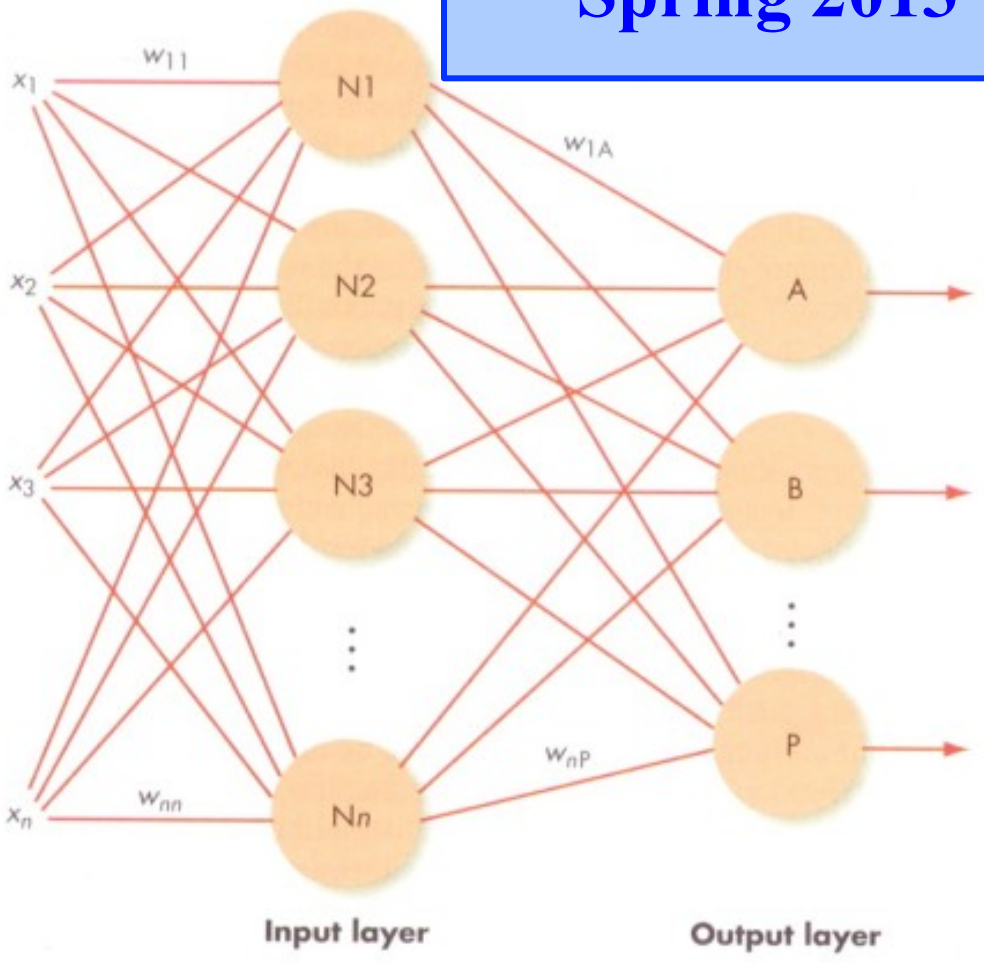


Your HW: Give the "truth table" for these NN;

Recognition Tasks (continu

Skipped in Spring 2013

- ANN (sample)



Neural Network – with Lear

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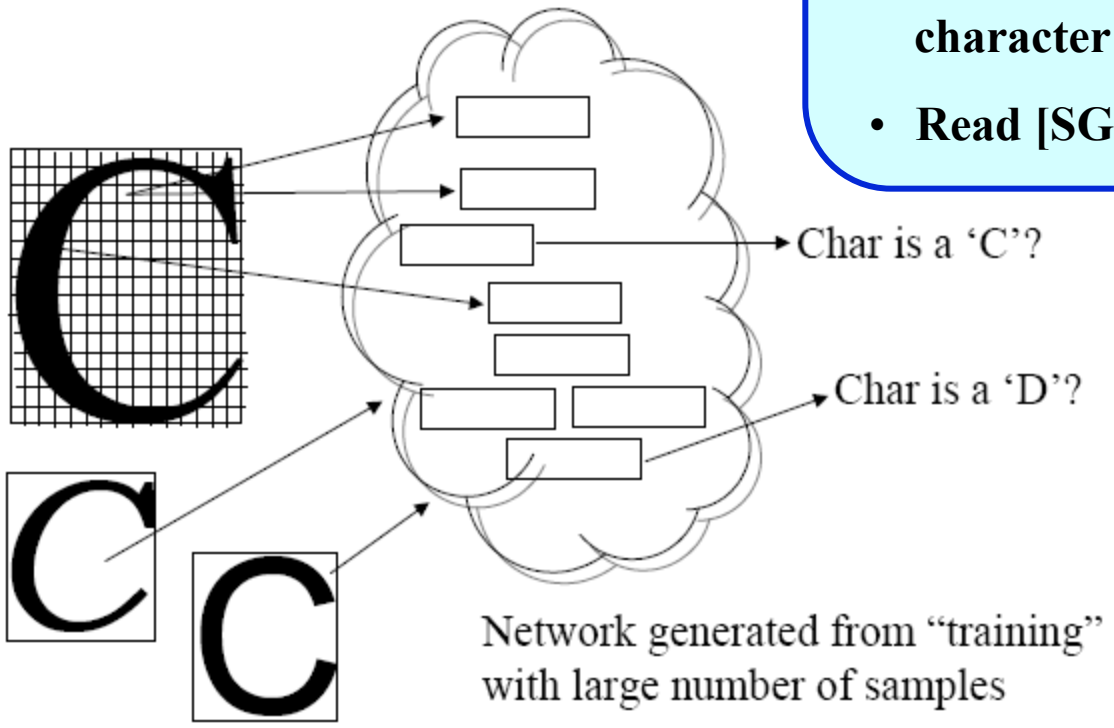
Real Ne

- **Uses back-propagation technique to train the NN;**
- **After training, NN used for character recognition;**
- **Read [SG] for more details.**

Character Recognition



Network generated from "training" with large number of samples

NN (continued)

Skipped in Spring 2013

Some Success stories…

- **NN successfully used for small-scale license plate recognition – of trucks at PSA gates;**
- **Between 2003-2006, NN also used for recognizing license plates at NUS carpark entrances.**

Recognition Tasks (summa

Skipped in Spring 2013

- Neural network
  - Both the knowledge representation and "programming" are stored as weights of the connections and thresholds of the neurons
  - The network can learn from experience by modifying the weights on its connections

Artificial Intelligence

Contents:

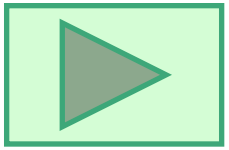
- Different Types of Tasks
- Knowledge Representation
- Recognition Tasks
- Reasoning Tasks
  - *Intelligent Search*
  - *Intelligent Agents*
  - *Knowledge-Based Systems*

Reasoning Tasks

- Human reasoning requires the ability to draw on a large body of facts and past experience to come to a conclusion

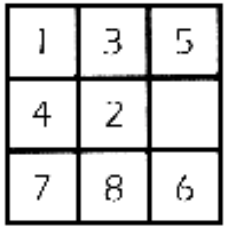
- Artificial intelligence specialists try to get computers to emulate this characteristic

Related Story:
Bill Gates and Pancake Flipping

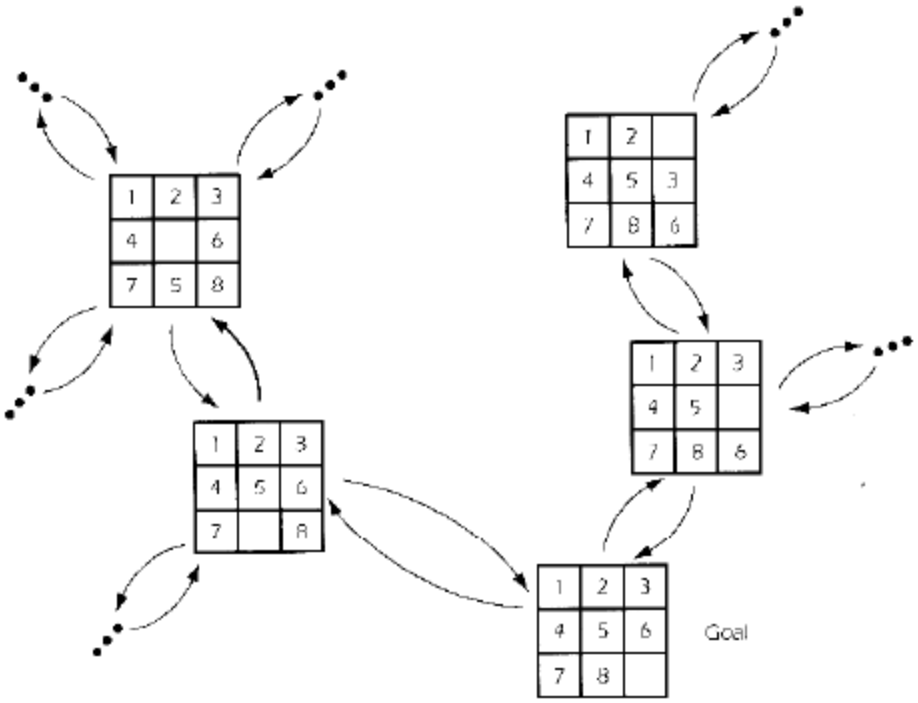


Intelligent Search Example (Ch. 14.5.1)

- Solving a Puzzle (the 9-Puzzle)
- Involves
  - Planning
  - Learning from past experience
- Simulated/Modelling by
  - Searching a State-graph
- State Graph can be Very BIG
  - Searching for "Goal State"
  - How to guide the search to make it more efficient.



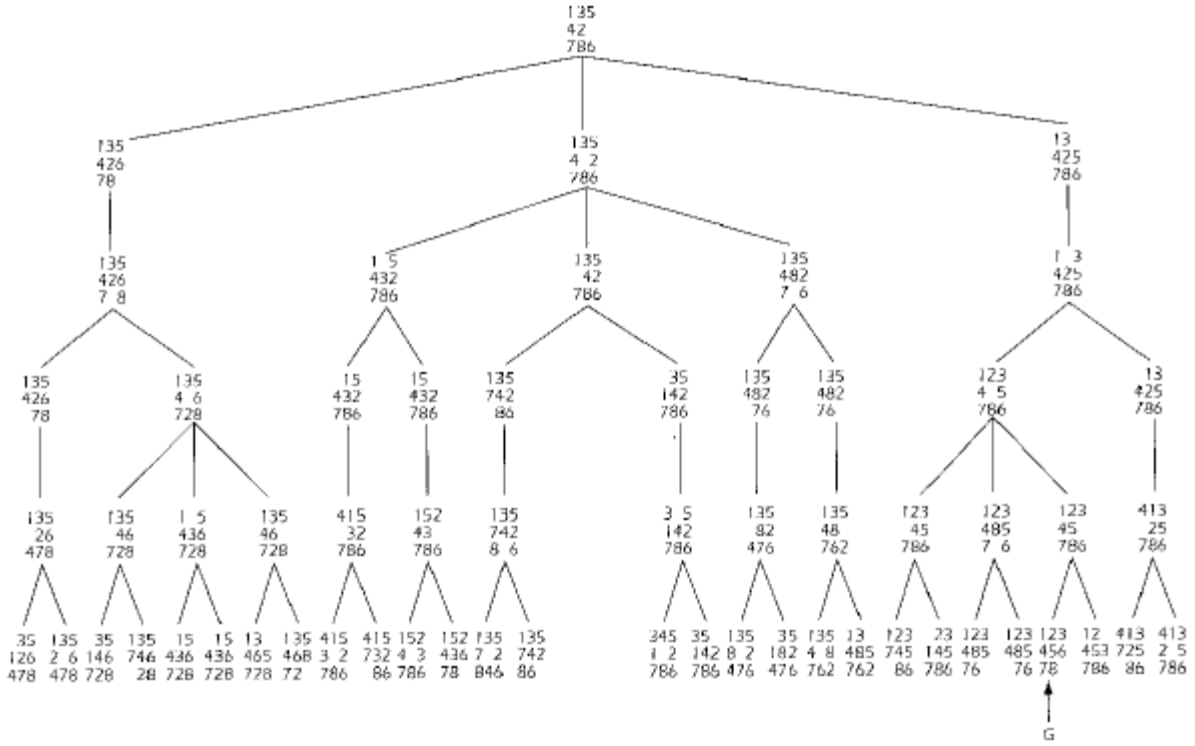
State Graph for 8-Puzzle



Intelligent Searching

- State-space graph:
  - After any one node has been searched, there are a huge number of next choices to try
  - There is no algorithm to dictate the next choice
- State-space search
  - Finds a solution path through a state-space graph

The Search Tree for the 9-Puzzle



Search Strategy for 9-Puzzle

Searching

- start with initial state
- state graph is extending during search
- searching remembers where we came from
  - does not make futile loops
- searching be improved by some evaluation function
- evaluation function might need to "peek ahead"

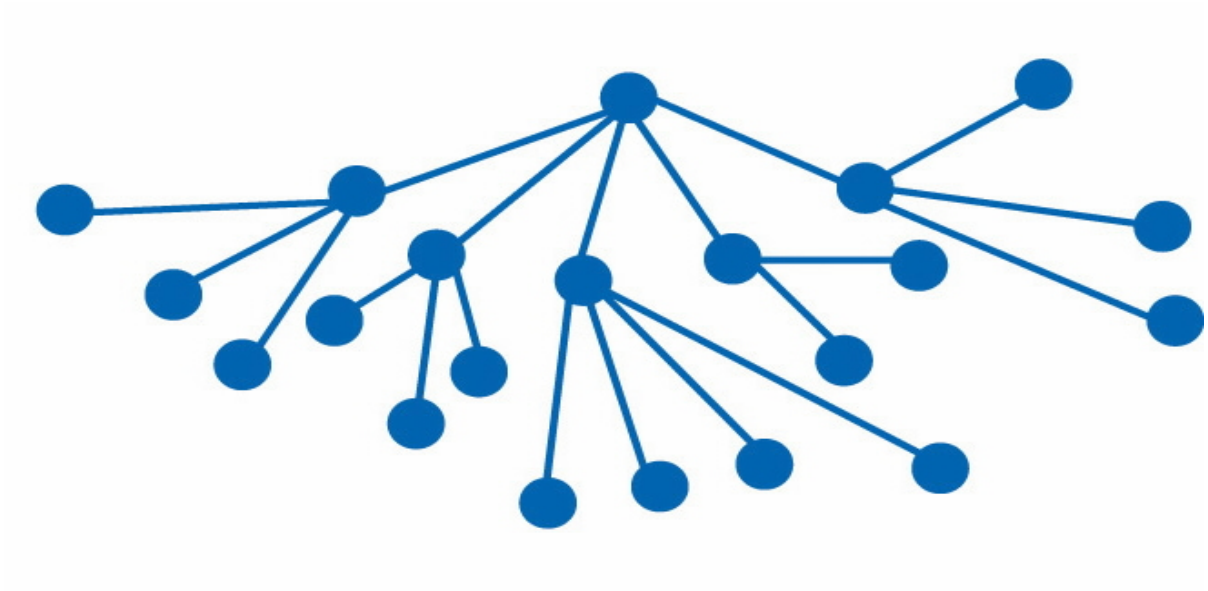


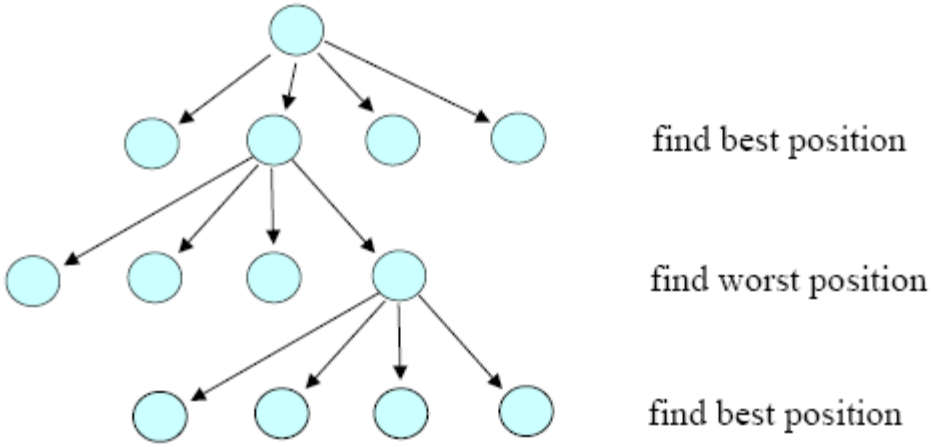
Figure 14.12

A State-Space Graph with Exponential Growth

AI in Game Playing

Game Playing

- like a puzzle but complicated by opponent
  - opponent undoes effort of player
  - evaluation function must be reversed



Intelligent Searching (continued)

- Each node represents a problem state
- Goal state: the state we are trying to reach
- Intelligent searching applies some heuristic (or an educated guess) to:
  - Evaluate the differences between the present state and the goal state
  - Move to a new state that minimizes those differences

Intelligent State Space search…

- See notes (pdf) for concrete example

Some Success stories…

- AI in chess playing – Deep Blue (1997)
  - Deep Blue evaluate 200M positions/sec, or 50B positions in 3min
- Other games: Othello, checkers, etc

Swarm Intelligence (Ch. 14.5

Skipped in Spring 2013

- Swarm intelligence
  - Models the behavior of a colony of ants

- Model with simple agents that:
  - Operate independently
  - Can sense certain aspects of their environment
  - Can change their environment
  - May "evolve" and acquire additional capabilities over time

Intelligent Agents (Ch. 14.5.3

Skipped in Spring 2013

- *An intelligent agent*:
  software that interacts collaboratively with a user
- Initially, an intelligent agent
  - simply follows user commands
- Over time, the intelligent agent
  - initiates communication, takes action, and performs tasks on its own
  - using its knowledge of the user's needs and preferences

Intelligent Agents (where us

Skipped in Spring 2013

- Wizards (assistants) for Office Software
- Personalized Web Search Engines
  - Push info, news, advertisements etc

Expert Systems (Ch. 14.5.4)

- Rule-based systems
  - Also called expert systems or knowledge-based systems
  - Attempt to mimic the human ability to engage pertinent facts and combine them in a logical way to reach some conclusion

- Read also Sect 9.4.2 of [SG2/3] (Logic Programming)

Expert Systems (continued)

- A rule-based system must contain
  - A knowledge base: set of facts about subject matter
  - An inference engine: mechanism for selecting relevant facts and for reasoning from them in a logical way
- Many rule-based systems also contain
  - An explanation facility: allows user to see assertions and rules used in arriving at a conclusion

Expert Systems (continued)

- A fact can be
  - A simple assertion
  - A rule: a statement of the form if . . . then . . .
- Modus ponens (method of assertion)
  - The reasoning process used by the inference engine

Knowledge Based System:

Logical inference

Knowledge encoded as a set of rules:

```
parent(x,y) if father(x,y).
```

x is the parent of *y* if *x* is the father of *y*

```
parent(x,y) if mother(x,y).
```

x is the parent of *y* if *x* is the mother of *y*

```
grandparent(x,y) if parent(x,z) and
                    parent(z,y).
```

x is the grandparent of *y* if *x* is the parent of *z* and *z* is the parent of *y*

Knowledge-Based System…

Logical inference

```
ancestor(x,y) if parent(x,y).
ancestor(x,y) if parent(x,z) and
                 ancestor(z,y).
```

Knowledge base:

```
father(andrew, tom).
mother(jane, tom).
father(tom, john).
```

Queries:

```
?ancestor(jane,tom)
```
Is jane an ancestor of tom?

```
?ancestor(X,john)
```
Who are ancestors of john?

Expert Systems (continued)

- Inference engines can proceed through
  - Forward chaining
  - Backward chaining
- Forward chaining
  - Begins with assertions and tries to match those assertions to “if” clauses of rules, thereby generating new assertions

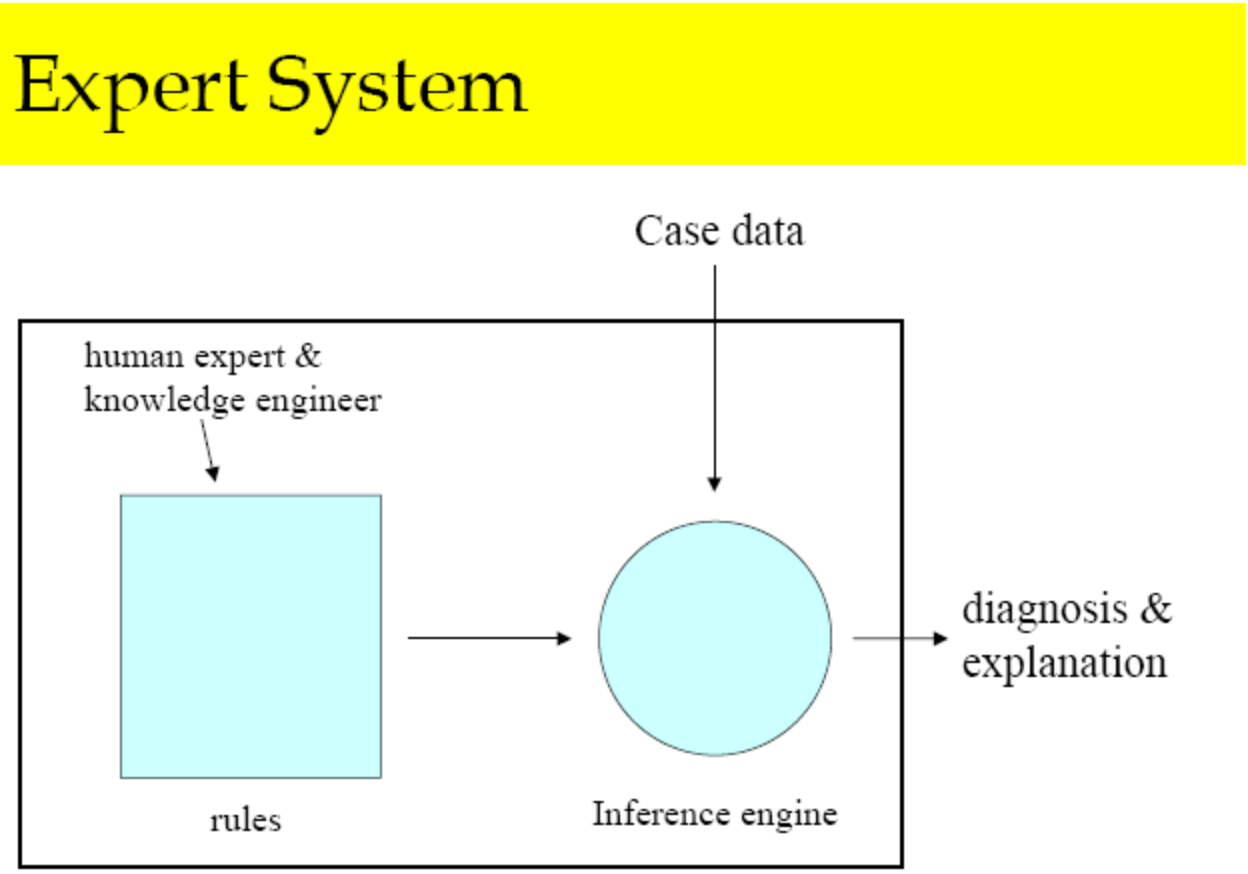
Expert Systems (continued)

- **Backward chaining**
  - **Begins with a proposed conclusion**
    - ***Tries to match it with the "then" clauses of rules***
  - **Then looks at the corresponding "if" clauses**
    - ***Tries to match those with assertions, or with the "then" clauses of other rules***

Expert Systems (continued)

- A rule-based system is built through a process called knowledge engineering
  - Builder of system acquires information for knowledge base from experts in the domain

Expert Systems: Structure



Expert Systems: Rules

Sample Rules

1. IF engine_getting_petrol & engine_turns_over
   THEN problem_with_spark_plugs
2. IF NOT engine_turns_over & NOT lights_come_on
   THEN problem_with_battery
3. IF NOT engine_turns_over & lights_come_on
   THEN problem_with_starter
4. IF petrol_in_fuel_tank
   THEN engine_getting_petrol

Summary

- Artificial intelligence explores techniques for incorporating aspects of intelligence into computer systems
- Categories of tasks: computational tasks, recognition tasks, reasoning tasks
- Neural networks simulate individual neurons in hardware and connect them in a massively parallel network

Summary

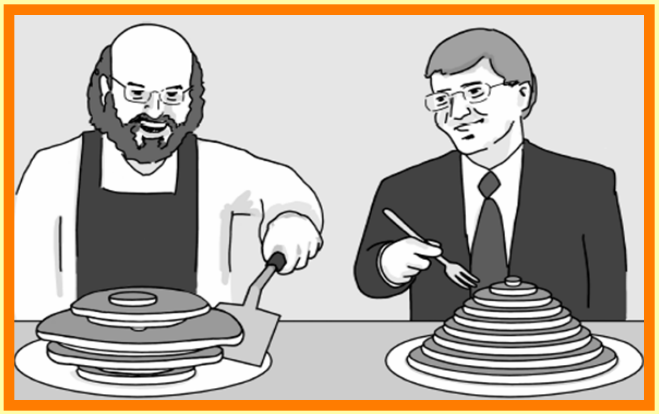
- Swarm intelligence models the behavior of a colony of ants
- An intelligent agent interacts collaboratively with a user
- Rule-based systems attempt to mimic the human ability to engage pertinent facts and combine them in a logical way to reach some conclusion

Did you know that …

I used to flip pancakes.

Bill Gates [比尔 盖茨] , Microsoft

Did Bill Gates *really* flip pancakes?



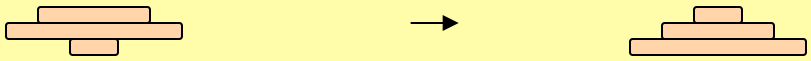
Source: Neil Jones and Pavel Pevzner, 2004 "Introduction to BioInformatics Algorithms".

Given an initial pancake configuration...

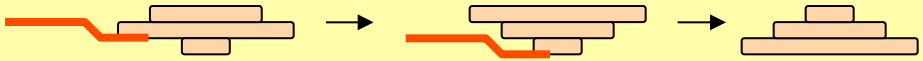
You want to get a "*sorted*" configuration …

Constraints: can only flip …

(*using a spatula*)



Example …



Bill Gates & Christos Papadimitriou:, "Bounds For Sorting By Prefix Reversal." *Discrete Mathematics*, Vol 27, pp 47-57, 1979.

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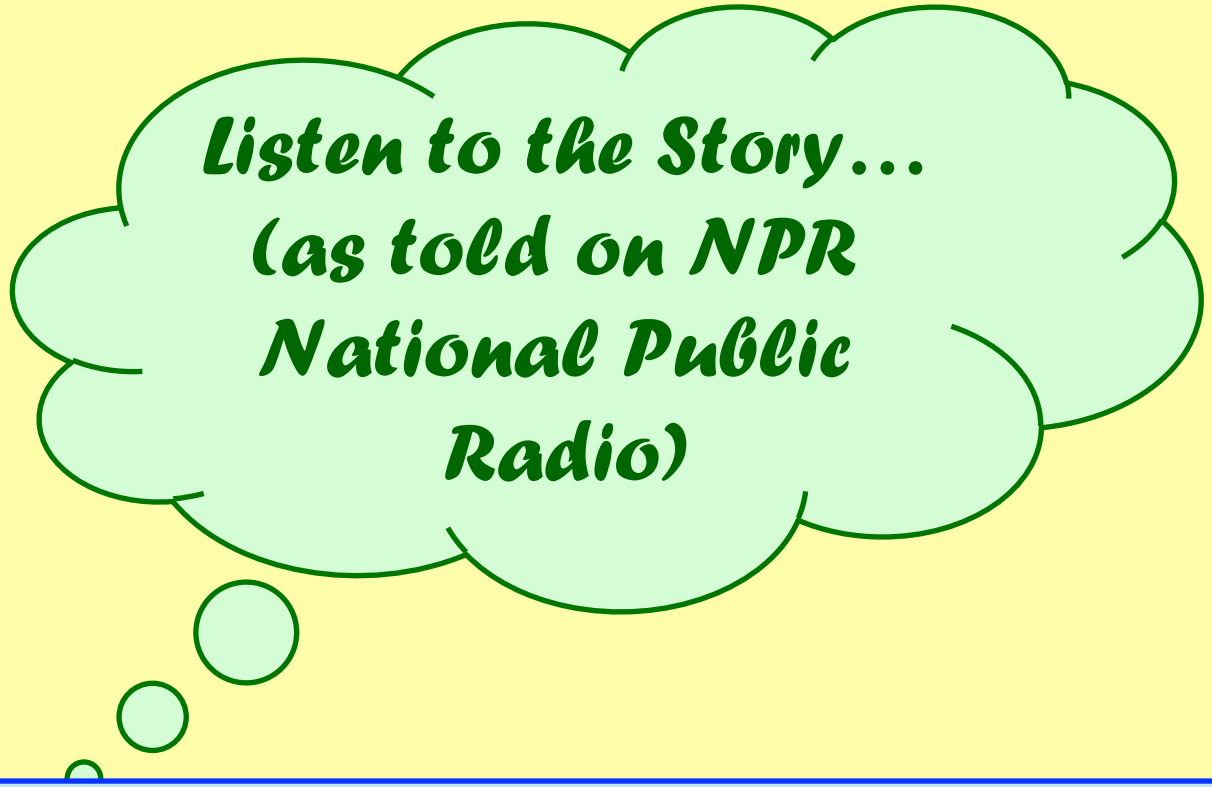
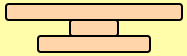
Pancake Flipping Problem…



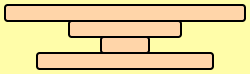
http://www.npr.org/templates/story/story.php?storyId=92236781

More pancake-flipping examples…



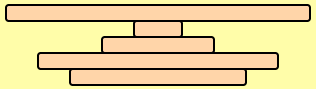
2 flips

Abstraction skills,
Problem Solving skills



3 flips

Need a systematic approach… an algorithm!

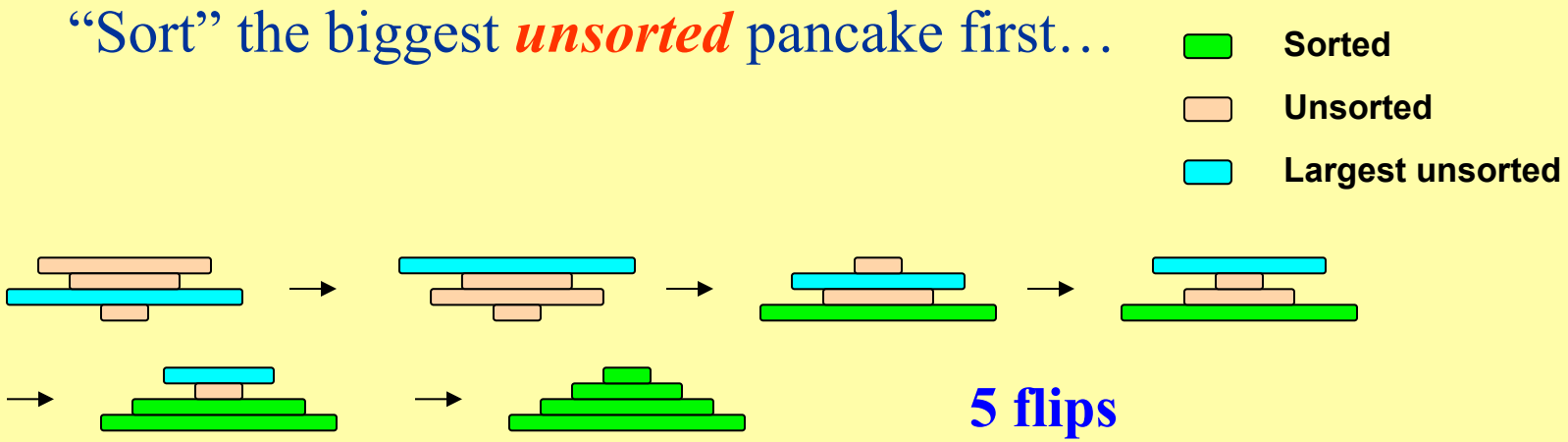


? flips

An Initial Algorithm (Greedy)

Simple Idea:

"Sort" the biggest ***unsorted*** pancake first…



Greedy Algorithm:

Repeatedly "sort" the biggest pancake;

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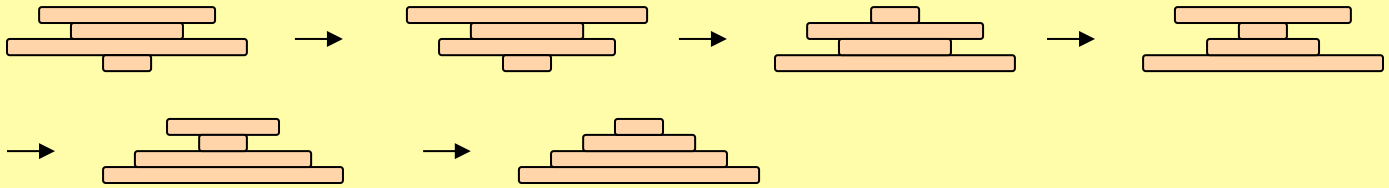
http://www.cut-the-knot.org/SimpleGames/Flipper.shtml

Is Greedy "the best" possible?

Answer: **NO**

A Counter Example:

Greedy method **[5 flips]**



Better way **[3 flips]**

Question: **Design an algorithm that solve the pancake flipping Problems using the *minimum number of flips.***

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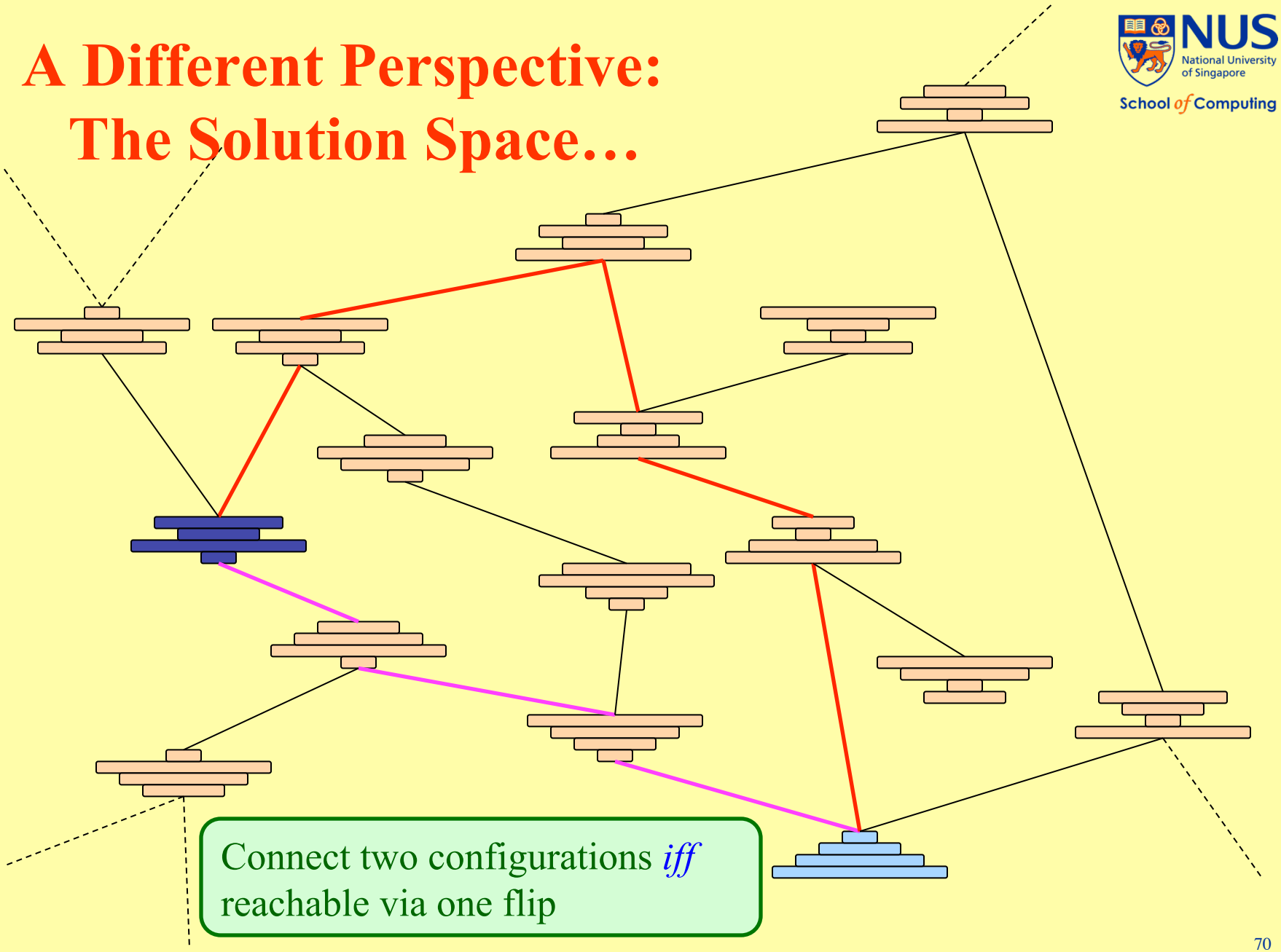
Pancake Flipping Problem…

A Different Perspective: The Solution Space…

Pertinent Question:
How many different configurations are there?
Answer:

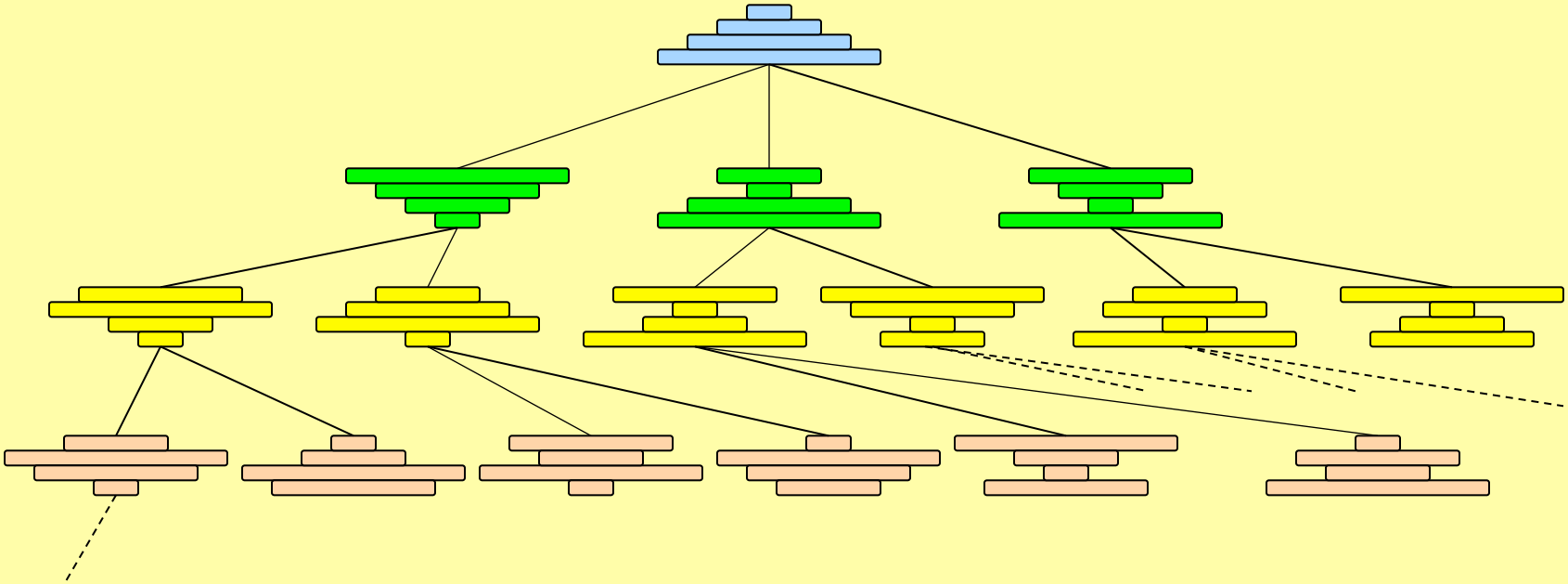
A Different Perspective: The Solution Space…



Connect two configurations *iff* reachable via one flip

A Search Tree Method:

(systematically search the search space)



Want a smart method (algorithm) to search this space to find the optimal flipping solution.

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Pancake Flipping Problem…

Pancake Flipping Problem: Known Results

- Greedy Algorithm uses at most $2n$-3 flips
- For n pancakes, at most $5n/3$ flips are needed
  [Bill Gates and Papadimitriou, 1979] ~$1.666n$
- 2008 (almost 30 years later), at most $18n/11$ needed
  [a team from UT-Dallas, 2008] ~$1.6363n$

More on Pancake Flipping

Have some fun with pancake flipping:

http://www.cut-the-knot.org/SimpleGames/Flipper.shtml

Listen to the story:

http://www.npr.org/templates/story/story.php?storyId=92236781

Search more with your "private investigator":

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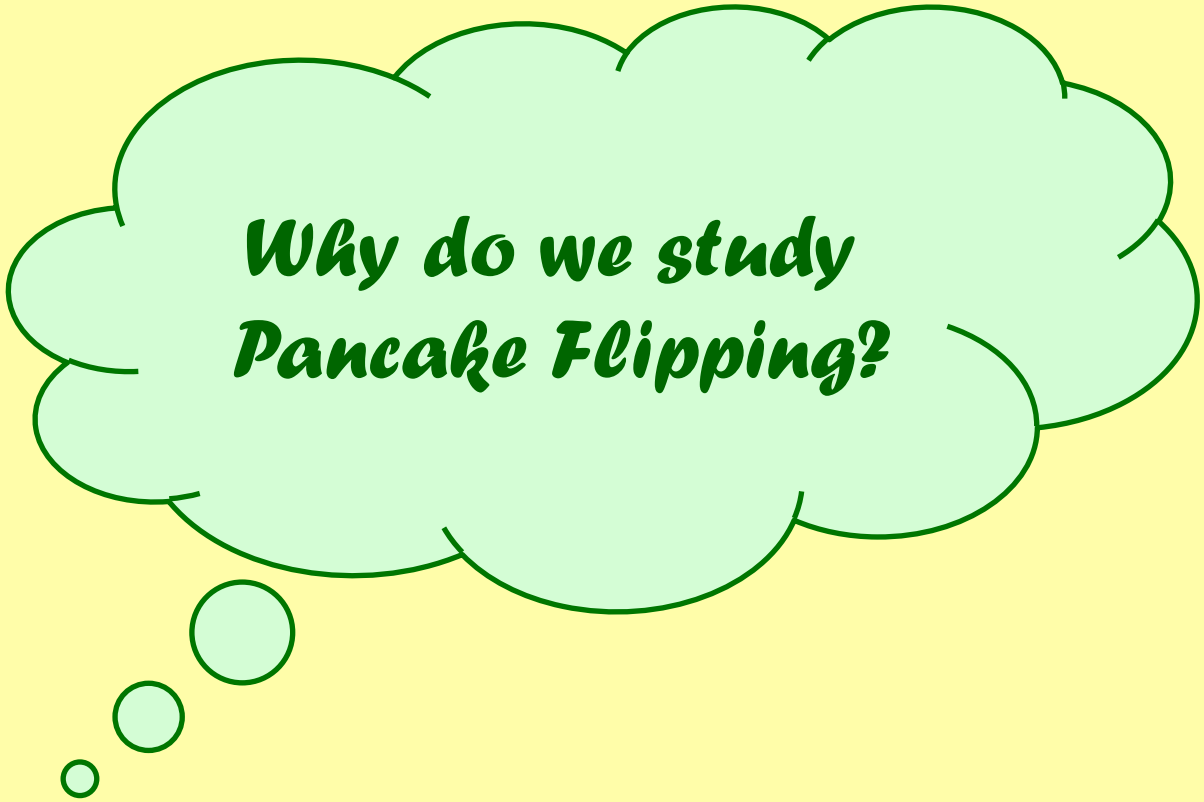
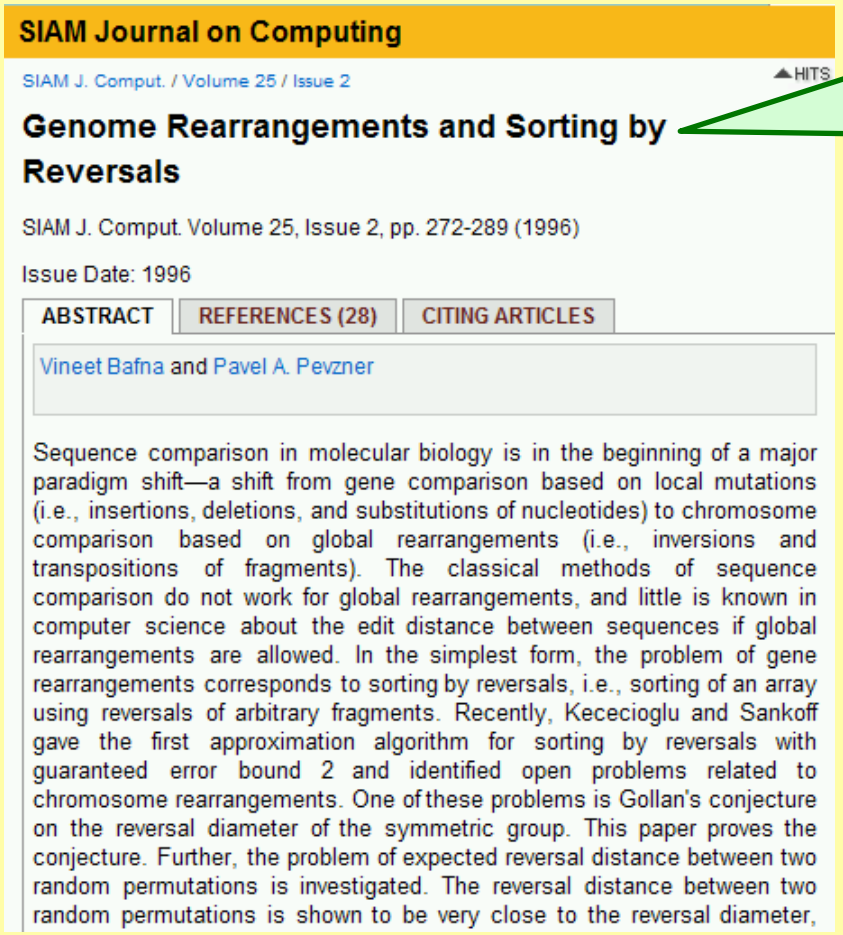
Pancake Flipping Problem…



Why study pancake flipping

- **Mathematics – Study its properties**
  - define $f(n)$ to be the min. of number of flip for n pancakes
- **Computing – Want an algorithm to solve it**
  - solve it with *minimum* number of flips
- **Applications**
  - sorting by prefix reversal
  - used to study evolution of species in biology

Application of Sorting by Reversals



SIAM Journal on Computing

SIAM J. Comput. / Volume 25 / Issue 2 ▲HITS

Genome Rearrangements and Sorting by Reversals

SIAM J. Comput. Volume 25, Issue 2, pp. 272-289 (1996)

Issue Date: 1996

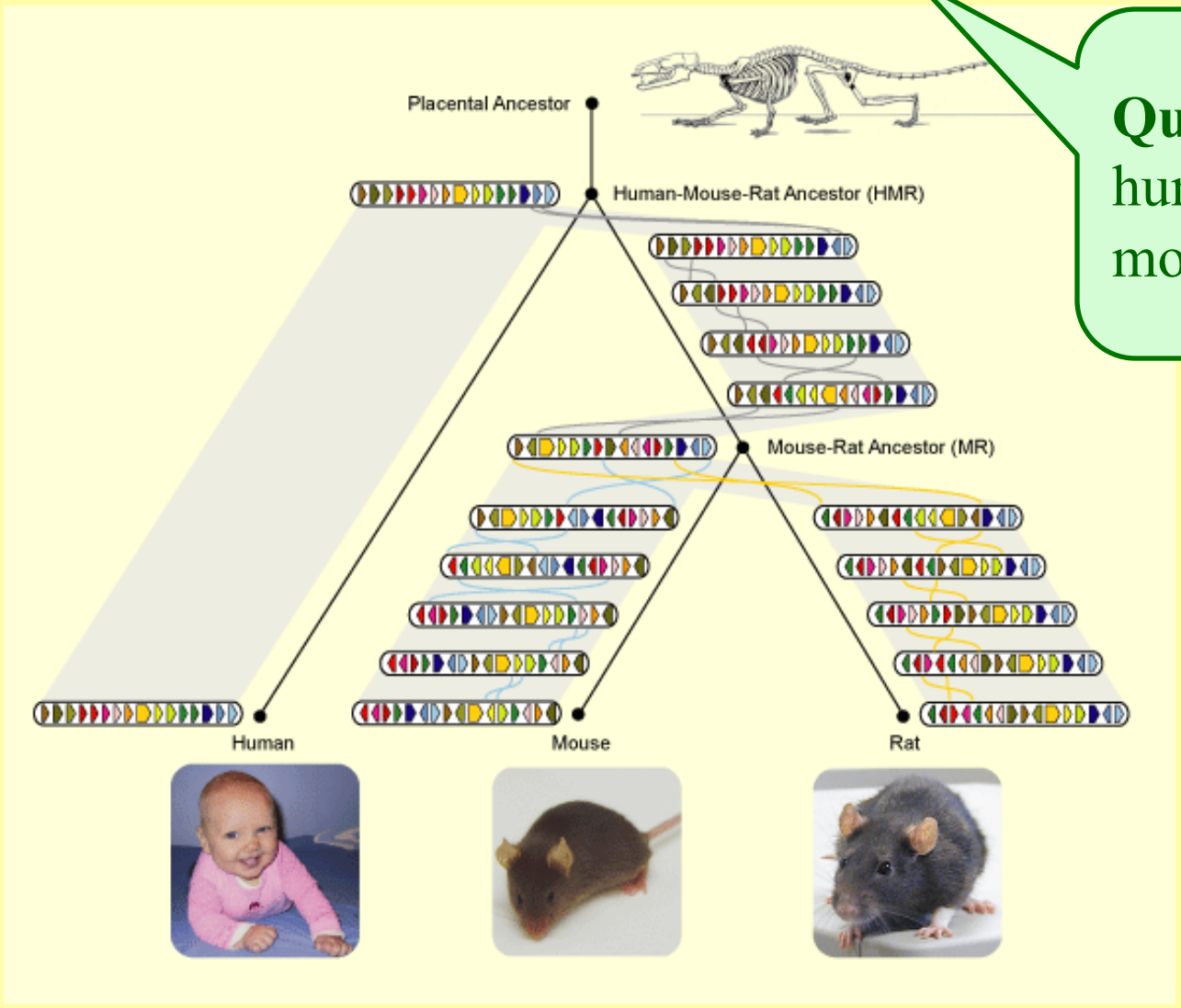
ABSTRACT | REFERENCES (28) | CITING ARTICLES

Vineet Bafna and Pavel A. Pevzner

Sequence comparison in molecular biology is in the beginning of a major paradigm shift—a shift from gene comparison based on local mutations (i.e., insertions, deletions, and substitutions of nucleotides) to chromosome comparison based on global rearrangements (i.e., inversions and transpositions of fragments). The classical methods of sequence comparison do not work for global rearrangements, and little is known in computer science about the edit distance between sequences if global rearrangements are allowed. In the simplest form, the problem of gene rearrangements corresponds to sorting by reversals, i.e., sorting of an array using reversals of arbitrary fragments. Recently, Kececioglu and Sankoff gave the first approximation algorithm for sorting by reversals with guaranteed error bound 2 and identified open problems related to chromosome rearrangements. One of these problems is Gollan's conjecture on the reversal diameter of the symmetric group. This paper proves the conjecture. Further, the problem of expected reversal distance between two random permutations is investigated. The reversal distance between two random permutations is shown to be very close to the reversal diameter,

Important Application in Computational Biology:
Used to study the evolution from one species to another.

Sorting by Reversals used here…



Question: Is human closer to mouse or rat?

Relevant Skills and Courses

- **Pancake flipping is a *model* for**
  - sorting by prefix-reversals
- **Many CS problems are model in *similar* ways**
  - sending files over internet (routing problems)
  - time table scheduling (graph colouring, 图着色问题)
- **Courses to learn these things**
  - CS1231 (Discrete Mathematics, 离散数学) [Blogs: 1, 2,]
  - CS3230 (Analysis of Algorithms, 算法设计与分析)