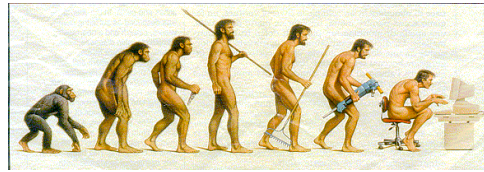## The Games Computers

(and People)
Play

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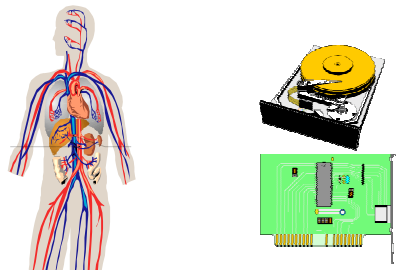
The Computer (R)Evolution

Need to re-think what it means to think.

AI and History

One of the most profound contributions of the 20th century is the realization that intelligent behavior can be realized by non-human information processing architectures.
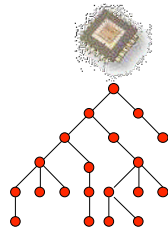
Different Architectures...

… Different Solving Methods

How?
Why?
What?
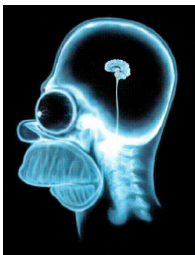Where?
When?

Looking Under the Hood…

Peek inside a "smart" program and you may find little that is "intelligent". Yet computers do "intelligent" things.

Is this a paradox?
What is intelligence?

AI creates the illusion of intelligence

… Looking Under the Hood

Of course, some humans try to create the illusion of intelligence too!

Disadvantage of the human architecture:

An architecture comparison:

Exploit the Strengths

- Brain architecture
  - language and vision processing
  - generalization
  - reasoning by analogy
- Computer architecture
  - calculations & exhaustive enumeration
  - repetitious tasks
  - large, infallible memory

Avoid the Weaknesses

- Brain architecture
  - calculations & exhaustive enumeration
  - repetitious tasks
  - large, infallible memory
- Computer architecture
  - language and vision processing
  - generalization
  - reasoning by analogy

Research and Games

- Games have been a popular choice for experimenting with artificial intelligence techniques, mathematical study and economic models.
- Success in building game-playing programs has resulted from exploiting the strengths of the computer, and down-playing the human example and the mathematical literature.

Progress in Computer Games

- Survey the astounding success in building programs capable of challenging human supremacy
- Bring a human side to Man versus Machine: The Experiment
- Discuss the computer's secrets of success

(1) Search

- Simple algorithmic solution for computing the game-theoretic value for two-person, zero-sum games…
- … but impractical for large search spaces
- Combine deep online and offline searches to approximate the game-theoretic value of a position

Checkers
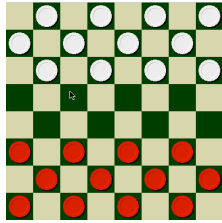
Chinook

Have to overcome the stigma of checkers being "solved" in 1963.

Project takes five years, 10 people, > 200 computers working around the clock, and terabytes of data.

Human Perfection!?


```
Name: Marion Tinsley
Profession: Teach
   mathematics.
Hobby: Checkers
Record: Over 42 years
   loses only 3 (!)
   games of checkers.
Crime: Too good
   at checkers.
```

The Verdict…

- The first computer to win a human world championship!
- Computers will never be overtaken by man at checkers.

The Secret?

- Endgame databases
  - searched all positions with 8 or fewer pieces
  - each identified with perfect win, loss, draw info
  - 444 billion positions in the program's memory
  - exceeds human abilities
  - introduces perfect knowledge into the search
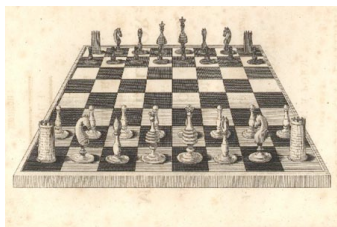 - factual knowledge, but without the ability to generalize it

Fallible Humans

The 100-Year Position
Give it to humans for 100 years… win!
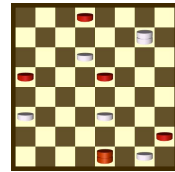
Give it to Chinook for 5 seconds… draw!
The 197-Year Position

Chess

Man Versus Machine

| Kasparov	Name	Deep Blue
5'10"	Height	6' 5"
176 lbs	Weight	2,400 lbs
34 years	Age	0.5 years
50 billion neurons	Computers	512 processors
2 pos/s	Speed	200,000,000 pos/s
Extensive	Knowledge	Primitive
Electrical/chemical	Power Source	Electrical
Enormous	Ego	None

Bravery and Bravado

Name: Garry Kasparov
Title: World Chess
   Champion.
Crime: Over confidence?

What went wrong?
Who is the better chess player?

The Verdict...

- Exhibition match.
- Scientific data point can't be repeated.
- Man was superior in 1997 but...
- Junior/Fritz matches give new insights
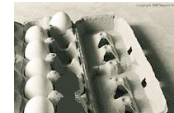
The Secret?

- Brute-force search
  - consider all moves as deeply as possible
  - some moves can be provably eliminated
  - 200,000,000 *per second* versus Kasparov's 2
  - 99.99% of the positions examined are silly by human standards
  - lots of search... and little knowledge
- *Tour de force* for engineering

(2) Knowledge... Sort Of

- Let computers discover their own knowledge about a domain
- Training with numerous examples and self-play allows the program to discover useful knowledge and tune it

Backgammon
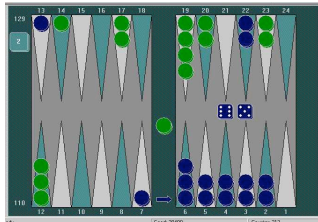
TD-Gammon

Had to overcome the stigma of backgammon being "solved" in 1979.

Gerry Tesauro builds TDGammon over 8 years. It can learn to play strong backgammon.

Fearless Fighter


```
Name: Malcolm Davis
Title: World backgammon
   champion.
Crime: Agrees to play
   exhibition matches
   against a computer.
Consequence: Narrowly
   avoids becoming part
   of computing history.
```
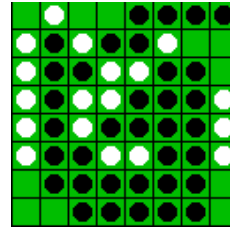
The Verdict...

World champion caliber but
hard to prove it is the world champion.

The Secret

- Pioneering success for temporal difference learning
- Combination of search, expert knowledge, and a neural net tuned using TD learning
- *Tour de force* for artificial intelligence

Reversi/Othello

Logistello

Had to overcome the stigma of Othello being "solved" in 1980 and 1990.

Michael Buro's one-man effort for five years produces Logistello.

Cold Blooded Murder

Name: Takeshi Murakami
Title: World Othello Champion
Crime: Man crushed by machine.

The Verdict...

Man will never be close to machine again.
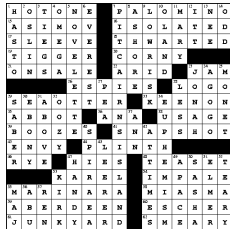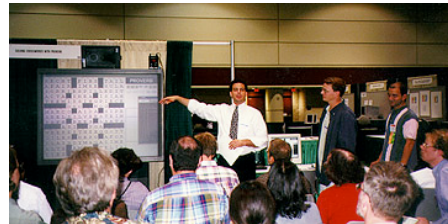

The Secret?

- Automatically discovered and tuned knowledge
  - samples patterns to see if its presence in a position can be correlated with success
  - identified 11 patterns (46 with rotations)
  - tuned 1.5 million parameters using self-play games with feedback
- "Knowledgeable" program but no one understands the knowledge

Crossword Puzzles

Proverb – Duke University

The Secret?

- Multiple agents
  - 34% of clues/answers are repeats
  - specialized solvers (puns, word plays)
  - specialized searches (dictionaries; geography, history, medical, movie databases; etc.)
- Proverb scores well on the NY Times puzzles *without understanding the clues*
- Information retrieval without understanding the information is a powerful technique!

(3) Statistical Sampling

- Search for games of non-deterministic and/or imperfect information
- Sample from the space of possibilities to approximate the true value

Bridge

Why is this Man Flying High?

- Matt Ginsberg develops the first expert-level bridge program, GIB (1998).

- Finishes 12th in the World Championship.

When the Going Gets Tough...

Name: Zia Mahmood
Motive: In 1990 offers
  £1,000,000 bet that
  no program can defeat
  him.
Crime: December 1, 1996
  cancels bet when faced
  with a possible
  challenger.

The Verdict...

- Man is better than machine!
- But… Ginsberg may be only a few years away from success

The Secret?

- GIB does 100 simulations for each decision
  - deals cards to opponents consistent with available information
  - chooses the action that leads to the highest expected return
  - program does not understand things like "finesse" or "squeeze"
  - simulations contain implicit knowledge

Poker

Poki – University of Alberta

Have to overcome the stigma of poker being "solved" in 1985.

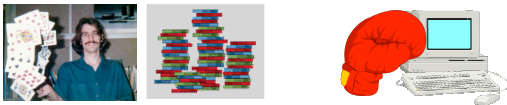Poker is a hard problem because of multiple opponents, imperfect information, and deception

Know When to Hold'em...

... and if you are 3-time World Champion Stu Ungar, you don't want to fold'em just yet!

The Verdict...

- Poker is safe for a few years to come.
- Quickly adapting to changing opponents is a challenging problem.

The Secret?

- Seeds of human defeat are present...
- Precise probability calculations
- Game theoretic solutions (Koller & Pfeffer)
- Simulations to approximate probability distributions
- Use short-term and long-term statistics to model each opponent

Rock, Paper, Scissors

- 1st & 2nd International RoShamBo Championships
- Deceptively simple problem that illustrates the differences between optimal and maximal play

Iocaine Powder

The Priorities of Life

- Theorem (F. Gump):
  - "Life is a box of chocolates"

Corollary (M. Ginsberg)
  "Winning a box of chocolates is life."

Bet: Ginsberg can't achieve his goal by 2003

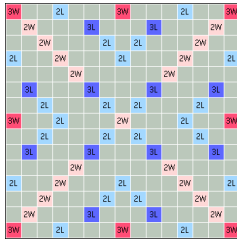Bet: Schaeffer can't achieve his goal by 2003

Scrabble

Maven

Brian Sheppard spends 14 years developing his Scrabble program.

Should this Man Be Happy?

Name: Adam Logan
Profession: Math
   professor.
Qualifications:1997
   Canadian and North
   American champion.

Maven versus Logan: A Classic

The Verdict...

Computers are better than humans and the gap will only grow with faster computers

The Secret?

- Memory
  - Maven has the entire dictionary in its memory
  - over 100,000 words
- Simulations
  - simulates 1,000 game scenarios per decision
  - typically 700 legal moves (more with a blank)!
  - becomes a constraint–satisfaction and optimization problem

(4) Help!

- Some games are resistant to all known techniques
  - mathematics is of little help
  - too hard for search alone
  - knowledge is inadequate
- Hex, amazons, octi, and…
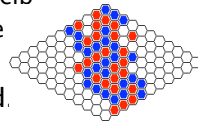
Go

Why is this Man Pensive?

```
Name: Chen Zhixing
Author: Handtalk (Goemate)
Profession: Retired
Computer skills: self-
  taught assembly
  language programmer.
Accomplishments:
  dominated computer go
  for 4 years.
```

Why is this Boy Happy?

Because he can give Goemate a 9 stone handicap and still easily beat the program, thereby winning $15,000.

The Verdict...

$1,000,000 prize is safe
for many decades to come.

The Problem?

- Brute-force search will not work
  - the only approaches we know of involve extensive knowledge
  - roughly 60 major knowledge-based components needed
  - program is only as good as the weakest link
- We have no idea how to tackle this domain effectively with computers

Challenges!

- Explaining computer calculations
  - have computers write the definitive books (Frank)
- Annotating games
  - annual ICCA competition
- Extending learning
  - knowledge, search control, algorithm
- Feature discovery
  - data mining looks promising

Commercial Games

- Hard problems!
- Real-time, limited memory, limited time, must work, must provide complete coverage

Perspective on Games: Pro

"Saying Deep Blue doesn't really think about chess is like saying an airplane doesn't really fly because it doesn't flap its wings"

Drew McDermott

Perspective on Games: Con

"Chess is the Drosophila of artificial intelligence. However, computer chess has developed much as genetics might have if the geneticists had concentrated their efforts starting in 1910 on breeding racing Drosophila. We would have some science, but mainly we would have very fast fruit flies."

John McCarthy

The Reality

- Most of these projects took tens of man years to solve "easy" problems.
- What does this say about the difficulty of building high-performance solutions to important real-world problems?

For More Information

- Special issue of *Artificial Intelligence*
  - January, 2002
- *Chips Challenging Champions*
  - Schaeffer and van den Herik (editors)

University of Alberta

- Host for AAAI National Conference
- Host for Computers and Games 2002
  - www.cs.ualberta.ca/cg2002
- Looking for students interested in…
  - AI using games as an experimental test-bed
  - board and card games
  - Electronic Arts and BioWare products