Artificial Intelligence:
A History of Game-Playing Programs

Nathan Sturtevant
AI For Traditional Games

With thanks to Jonathan Schaeffer

UNIVERSITY OF DENVER

UNIVERSITY OF DENVER

What does it mean to be intelligent?

UNIVERSITY OF DENVER

How can we measure computer intelligence?

UNIVERSITY OF DENVER

Human strengths

- Intuition
- Visual patterns
- Deeply crafted knowledge
- Experience applied to new situations

UNIVERSITY OF DENVER

Computer Strengths

- Fast, precise computation
- Large, perfect memory
- Repetitive, boring tasks

UNIVERSITY OF DENVER

Why games?

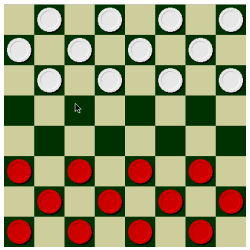
- Well defined
- Well known
- Measurable
- Only 60 years ago it was an open question whether computers could play games
  - Game play was thought to be a creative, human activity, which machines would be incapable of

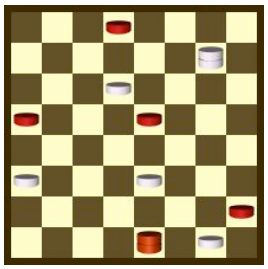
UNIVERSITY OF DENVER

Focus

- How did the computer AI win?
- How did the humans react?
- What mistakes were made in over-stating performance

Checkers





History

- Arthur Samuel began work on Checkers in the late 50's
  - Wrote a program that "learned" to play
  - Beat Robert Nealey in 1962
    - IBM advertised as "a former Connecticut checkers champion, and one of the nation's foremost players"
    - Nealey won rematch in 1963
    - Nealey didn't win Connecticut state championship until 1966
  - Crushed by human champions in 1966

Reports of success overblown

- "...it seems safe to predict that within ten years, checkers will be a completely decidable game." Richard Bellman, Proceedings of the National Academy of Science, 53(1965): p. 246.
- "So whereas computers can 'crunch' tick-tack-toe, and even checkers, by looking all the way to the end of the game, they cannot do this with chess." Lynn Steen, "Computer Chess: Mind vs. Machine," Science News, November 29, 1975.
- "Although computers had long since been unbeatable at such basic games as checkers...." Clark Whelton, Horizon, February 1978.
- "Computers became unbeatable in checkers several years ago." Thomas Hoover, "Intelligent Machines," Omni magazine, 1979, p. 162.
- "...an improved model of Samuel's checkers-playing computer today is virtually unbeatable, even defeating checkers champions foolhardy enough to 'challenge' it to a game." Richard Restak, The Brain: The Last Frontier, 1979, p. 336.
- "...the Duke program, Bierman believes, is already 'knocking at the door' of the world championship. Jensen and Truscott regard it as now being about the 10th strongest player in the world." Martin Gardner, Scientific American, January 1980, p. 25.

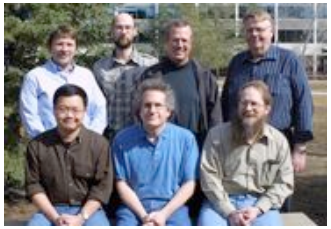
Human Champ: Marion Tinsley

- Closest thing to perfect human player
- Over 42 years loses only 3(!) games of checkers.

UNIVERSITY OF DENVER

Computer Challenger: 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.



UNIVERSITY OF DENVER

Outcome

- The first computer to win a human world championship (1994)
- Checkers is solved (2007)!
- Perfect play leads to a draw
- Humans will never win against Chinook again

UNIVERSITY OF DENVER

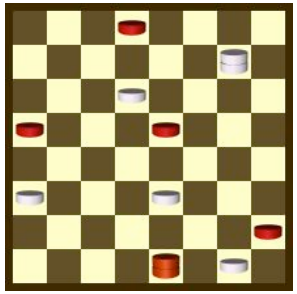
Secret: Endgame Databases

- Endgame databases
  - Searched all positions with 10 or fewer pieces
  - Each identified with perfect win, loss, draw info
  - 39 trillion positions in the program's memory
  - Exceeds human abilities
  - Introduces perfect knowledge into the search
  - Factual knowledge, but without the ability to generalize it

UNIVERSITY OF DENVER

The 100(?)-year position

The 100-Year Position (white to move)
Give it to humans for 100 years… win!



Give it to Chinook for one I/O… draw!
The 197-Year Position

UNIVERSITY OF DENVER

Chess

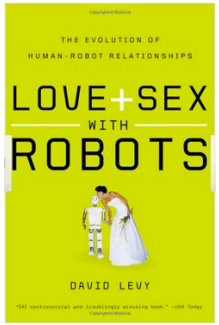
UNIVERSITY OF DENVER

1770 - The Turk

UNIVERSITY OF DENVER

Further Work

- 1910 - El Ajedrecista plays King+Rook vs. King endgames
- 1950's - Claude Shannon, Alan Turing, John McCarthy begin work on Chess
- 1968, David Levy bets that no computer program would win a chess match against him within 10 years
  - Wins his bet 10 years later



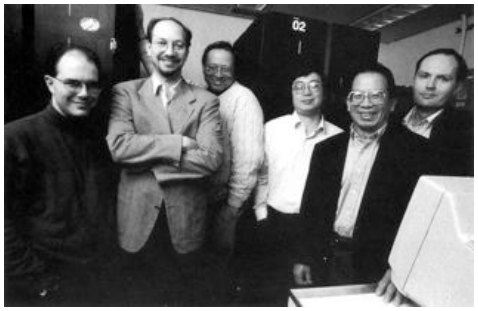
UNIVERSITY OF DENVER

Human Champ: Garry Kasparov

- Holds the record for the longest time as the #1 rated player (1986-2005)
- Reached a 2851 Elo rating, the highest rating ever achieved

Computer Challenger: Deep Blue

- 2,400 lbs
- 512 processors
- 200,000,000 pos/sec



The result of second match in 1997

- Kasparov won game 1
- Kasparov lost game 2
- Kasparov self-destructed in game 6 and lost the match
- In the video he rails on about game 2. He was crushed in the game but in the final position there is a miracle that saves the game. No one saw it at the time, and certainly not Kasparov, who resigned.
- Note that Deep Blue lost game 1 in a drawn position due to a bug.

Kasparov's Response

- Who is better?

Post-analysis

- Exhibition match; scientific data point can't be repeated.
- Man was superior in 1997 but by 2006 it appears that man is no longer competitive
- Deep Fritz played world chess champion Vladimir Kramnik in November 2006
- Used a personal computer containing two Intel Core 2 Duo CPUs, capable of evaluating only 8 million positions per second
- Searched to an average depth of 17 to 18 plies

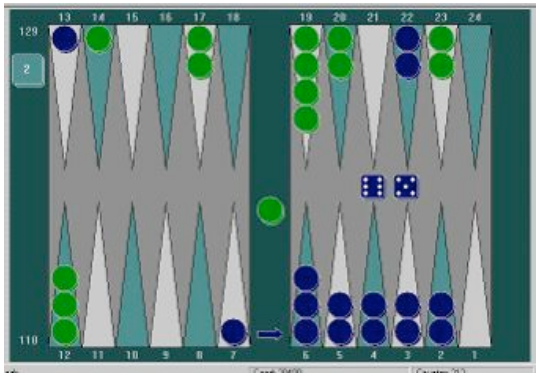
UNIVERSITY OF DENVER

Secret: Brute-Force

- 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

UNIVERSITY OF DENVER

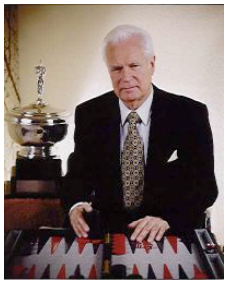
Backgammon



UNIVERSITY OF DENVER

Human Champ: Malcolm Davis

- World backgammon champion.
- Agrees to play exhibition matches against a computer; narrowly avoids becoming part of computing history.



UNIVERSITY OF DENVER

Computer Challenger: TDGammon

- Gerry Tesauro builds TDGammon over 8 years. Learned to play strong backgammon
- Unable to beat champion in match; too many games needed for statistical significance

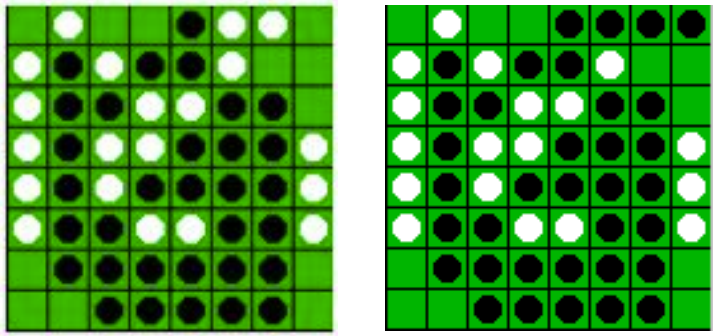
UNIVERSITY OF DENVER

Secret: TD-Learning

- 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
- Backgammon happens to be very well suited for these techniques

UNIVERSITY OF DENVER

Othello (Reversi)



UNIVERSITY OF DENVER

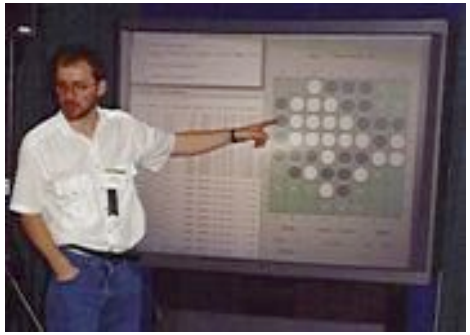
Human Champ: Takeshi Murakami

- World Othello Champion

UNIVERSITY OF DENVER

Computer Challenger: 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.
- 6 game match
  - Aug. 4-7, 1997
- Logistello wins 6-0



Secret: Machine Learning

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

Scrabble

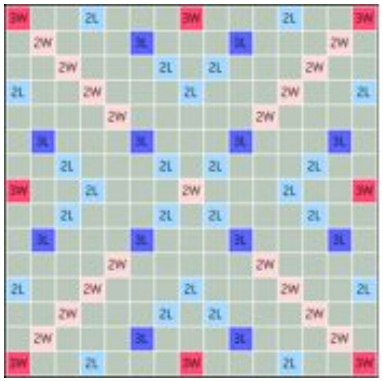
Human Champion: Adam Logan

- Math professor.
- 1997 Canadian and North American scrabble champion

Computer Challenger: Maven

Brian Sheppard spends 14 years developing his Scrabble program.

Maven versus Logan: A Classic



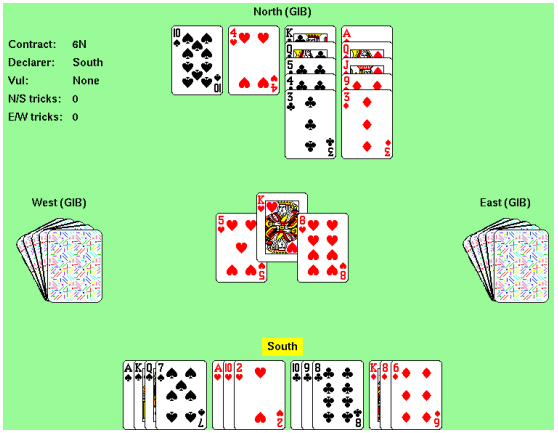
Brian Sheppard's commentary:

- The following game is in the author's opinion the best Scrabble board game ever played in a tournament or match.
- The game is the 12th game in the AAAI-98 exhibition match between MAVEN and Adam Logan.
- After losing three of the first four games, MAVEN had come back strongly to take a 7 to 4 lead.
- In total, there were 14 games scheduled.
  - *First player to win 8 games wins the match.*

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)!

Bridge



Human Champ: Zia Mahmood

- In 1990 offers £1,000,000 bet that no program can defeat him.
- December 1, 1996
  - Cancels bet when faced with a possible challenger.

Computer Challenger: GIB

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

- Finishes 12th in the World Championship.

The Verdict...

- Man is better than machine!
- Likely to remain that way for a while yet
  - Difficulties in understanding the bidding

UNIVERSITY OF DENVER

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

UNIVERSITY OF DENVER

Poker

UNIVERSITY OF DENVER

Human Champion: Phil Laak

- Phil Laak (aka the unibomber) holds a World Poker Title
  - Stronger at no-limit texas hold’em
- Ali Eslami was invited by Phil to play against University of Alberta computers

UNIVERSITY OF DENVER

Computer Challenger: Polaris

- Poker is a hard problem because of multiple opponents, imperfect information, and deception
- Ongoing project at the UofA (~20 years)

from Wired Magazine

The result (part 1)

- 2007 first man-machine match
- Narrow loss for UofA programs

The result (part 2)

- 2008, second match
  - Played against a team of 2-player experts
  - Polaris wins

Matt Hawrilenko

IJay Palansky

The Secret?

- Precise probability calculations
- Game theoretic solutions
- Use short-term and long-term statistics to model each opponent

- **Not playing most popular form of game**

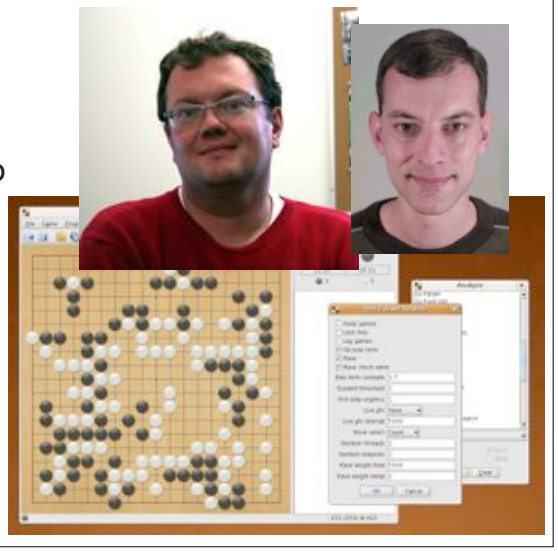
Go

Human Champion: Zhou Junxun

- Ranked 9-dan (professional)
  - Winner of 43 domestic and 2 international titles

Computer Challenger: Fuego

- Written by Markus Enzenberger and Martin Müller
  - Both had strong Go programs
  - Teamed up to write stronger program



Result

- Fuego was the first computer program to win an official game of 9x9 Go against a 9-Dan professional player in 2009
  - Thought to be impossible 10 years ago
  - Not yet playing at this strength 19x19 board
  - Collaborating with IBM and Gerry Tesauro

The secret?

- Monte-Carlo Tree Search
  - Use heuristic to choose good *actions*
  - Play out millions of games guessing the best actions for each player
  - Working with IBM on massively parallel hardware to improve performance

Jeopardy

Human Champion: Ken Jennings

- Won 74 games straight
  - Lost the 75th game
  - Won a total of $2,522,700
- Has won $3.8 million on game shows

Computer Challenger: Watson

- 2880 POWER7 processor cores
- 16 Terabytes of RAM
- ~$3 million
- Stored copy of wikipedia in memory

Result

- Watson scores $77,147
- Jennings scores $24,000
- Rutter scores $21,600

- Watson can buzz in faster and more accurately than humans
- Watson still misses many basic questions

Response to Watson's win

The Secret?

- Massive hardware optimization reduced days of computation to a few seconds
- Many tuned experts able to answer particular question types
- A high-level controller which weights experts
- The ability to 'learn' from answers in a category
- Some similarities to PROVERB program which solves crossword puzzles

Perspective

- Watson is only the latest Artificial Intelligence in a long line of game-playing programs
- Gradually more difficult problems have been tackled
  - Perfect Information
  - Chance (dice)
  - Hidden Information (cards/tiles)
  - Natural language processing

Is there intelligence in games?

"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
New York Times
May 14, 1997

Is human intelligence surpassed?

Poll: One in four Americans clueless about July 4th

Mon Jul 4, 2011 3:23PM

Like Tweet 2

According to a new poll by Marist, more than a quarter of Americans couldn't correctly identify the country from which the United States declared its independence. While 74 percent correctly named Great Britain, 20 percent said they weren't sure and six percent named other countries. In the South, 32 percent of respondents either responded incorrectly or weren't sure. Infowars.com

http://www.presstv.com/usdetail/187531.html

Where is the intelligence?

- In the designers of the AI software
- Ok, invent General Game Playing!

A point of view

- Computers are advanced machines/tools
  - They only do what we tell them to do
  - Only the best programmers are good at getting computers to do what they want
- Artificial Intelligence is not computer intelligence
  - It is human-designed intelligence

Intelligence Summary

- The 'illusion' of intelligence
- Any computer intelligence is fundamentally created by humans, and is a product of human intelligence