Theory of Computer Games: An A.I. Oriented Introduction

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A.I. and game playing

  • Artificial Intelligence (A.I.) is the study of ideas that enable computers to be intelligent.
  • One central goal of A.I. is to make computers more useful (to human beings).
  • Another central goal is to understand the principles that make intelligence possible.
    ▶ Making computers intelligent helps us understand intelligence.
    ▶ Intelligent computers are more useful computers.

• Elaine Rich 1983.
  • Intelligence requires knowledge.
  • Games hold an inexplicable fascination for many people, and the notion that computers might play games has existed at least as long as computers.
  • Reasons why games appeared to be a good domain in which to explore machine intelligence.
    ▶ They provide a structured task in which it is very easy to measure success or failure.
    ▶ They did not obviously require large amount of knowledge.
Intelligence – Turing Test

- **How to define intelligence**
  - Cannot define “intelligence.”
  - Imitation of human behaviors.

- **The Turing test**
  - If a machine is intelligent, then it cannot be distinguished from a human.
    - Use this feature to filter out computer agents for online systems or online games.
    - CAPTCHA: Completely Automated Public Turing test to tell Computers and Humans Apart
    - It is a good test if designed “intelligently” to distinguish between human and non-human.
  - Loebner Prize Contest Yearly.

- **Problems:**
  - Are all human behaviors intelligent?
  - Can human perform every possible intelligent behavior?
  - Human intelligence \( = \) Intelligence.
Shifting goals

- **From Artificial Intelligence to Machine Intelligence.**
  - Lots of things can be done by either human and machines.
  - Something maybe better be done by machines.
  - Some other things maybe better be done by human.
  - Try to get the best out of every possible worlds!

- **From imitation of human behaviors to doing intelligent behaviors.**

- **From general-purpose intelligence to domain-dependent Expert Systems.**

- **From solving games, to understand intelligence, and then to have fun.**
  - *Recreational*
  - *Educational*
Early ages: The Maelzel’s Chess Automaton

- **Late 18th century.**
  - The *Turk*.
  - Invented by a Hungarian named Von Kempelen (\(\sim 1770\)).
  - Chess-playing “machine.”
    - Operated by a concealed human chess-master.
  - “Arguments” made by the famous writer Edgar Allen Poe in “Maelzel’s Chess Player”.
    - It is as easy to design a machine which will invariably win as one which wins occasionally.
    - Since the Automaton was not invincible it was therefore operated by a human.
  - Burned in a fire at an USA museum (year 1854).
  - “Recently” (year 2003) reconstructed in California, USA.
Early ages: Endgame chess-playing machine

- 1912
  - Made by Torres y Quevedo.
    - *El Ajedrecista (The Chess Player)*
    - *Debut during the Paris World Fair of 1914*
  - Plays an endgame of king and rook against king.
  - The machine played the side with king and rook and would force checkmate in a few moves however its human opponent played.
  - An explicit set of rules are known for such an endgame.
  - Very advanced automata for that period of time.
Early ages: China

- Not much materials can be found (by me)!
  - Some automatic machines in a human form for entertainments.
  - Not much for playing “games”.
- Shen, Kuo, (沈括 夢溪筆談) (~ 1086)
  - Analyzed the state space of the game Go.
Computer games are studied by the founding fathers of Computer Science

- C.E. Shannon, 1950, Computer Chess paper
- Arthur Samuel began his 25-year quest to build a strong checkers-playing program at 1952
  ▶ A human “simulation” of a chess algorithm given in the paper.

Computer games are also studied by great names of Computer Science who may not seem to have a major contribution in the area of Computer games or A.I.

- D. E. Knuth (1979)
- K. Thompson (1983)
- B. Liskov (2008)
- J. Pearl (2012)
Early days: A.I. was plagued by over-optimistic predictions.
- Mini-Max game tree search
- Alpha-Beta pruning

1970’s and 1980’s.
- Concentrated on Western chess.
- Brute-force approach.
  - The CHESS series of programs by the Northwestern University: CHESS 1.0 (1968), ..., CHESS 4.9 (1980)
- Theoretical breakthrough: Analysis of Alpha-Beta pruning by Knuth and Moore at 1975.
- Building faster search engines.
- Chess-playing hardware.

Early 1980’s until 1990’s.
- Advances in theory of heuristic searches.
  - Scout, NegaScout, Proof number search
  - Search enhancements such as null moves and singular extensions
  - Machine learning
1990’s until now

- Witness a series of dramatic computer successes against the best of humanity.
- Parallelization.
  - Computer Go: about 1 dan in the year 2010 and improve steadily since then.
  - The program Zen beat a 9-dan professional master at March 17, 2012.
  - First game: five stone handicap and won by 11 points.
  - Second game: four stones handicap and won by 20 points.
  - Try to find applications in other games.
Taxonomy of games

- According to number of players
  - Single player games: puzzles
  - Two-player games
  - Multi-player games

- According to state information obtained by each player
  - Perfect-information games: all players have all the information they need to make a correct decision.
    ▶ Imperfect-information games: some information is only available to selected players, for example you cannot see the opponent’s cards in Poker.

- According to rules of games known in advance
  - Complete information games: the “rules” of the game are fully known by all players in advance.
    ▶ Incomplete-information games: partial rules are not given in advance for some players.

- According to whether players can fully control the playing of the game.
  - Stochastic games: there is an element of chance such as dice rolls.
    ▶ Deterministic games: the players have a full control over the games.
Computational complexities of games

- **Single-player games are often called** puzzles.
  - They have a single decision maker.
  - They are enjoyable to play.
  - A puzzle should have a solution which
    - is aesthetically pleasing;
    - gives the user satisfaction in reaching it.
  - Many puzzles are proven to be NP-complete.
    - 24 puzzles including Light Up, Minesweeper, Solitaire and Tetris are NP-complete [G. Kendall et al. 2008].

- Many 2-player games are either PSPACE-complete or EXPTIME-complete.
  - Othello is PSPACE-complete, and Checkers and Chess are EXPTIME-complete [E.D. Demaine & R.A. Hearn 2001].
New frontiers

- **Traditional games**: using paper and pencil, board, cards, and stones.

- **Interactive computer games**
  - Text-based interface during early days.
  - 2-D graphics during the 1980’s with the advance of personal computers.
  - 3-D graphics with sound and special effects today.

- **Human with the helps of computer software and hardware.**

- **On-line games**: players compete against other humans or computer agents.

- **Challenges**:
  - Better user interface: such as Wii and holographic display.
  - Developing realistic characters.
    - *So far very primitive: simple rule-based systems and finite-state machines.*
    - *Need researches in “human intelligence.”*
  - Educational purpose.

- **Physical games played by machines**: RoboCup.
Concluding remarks

  - Programming computers to play games is but one stage in the development of an understanding of the methods which must be employed for the machine simulation of intellectual behavior.
  - As we progress in this understanding it seems reasonable to assume that these newer techniques will be applied to real-life situations with increasing frequency, and the effort devoted to games ... will decrease.
  - Perhaps we have not yet reached this turning point, and we may still have much to learn from the study of games.
References and further readings


