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

Tsan-sheng Hsu

徐讚昇

tshsu@iis.sinica.edu.tw

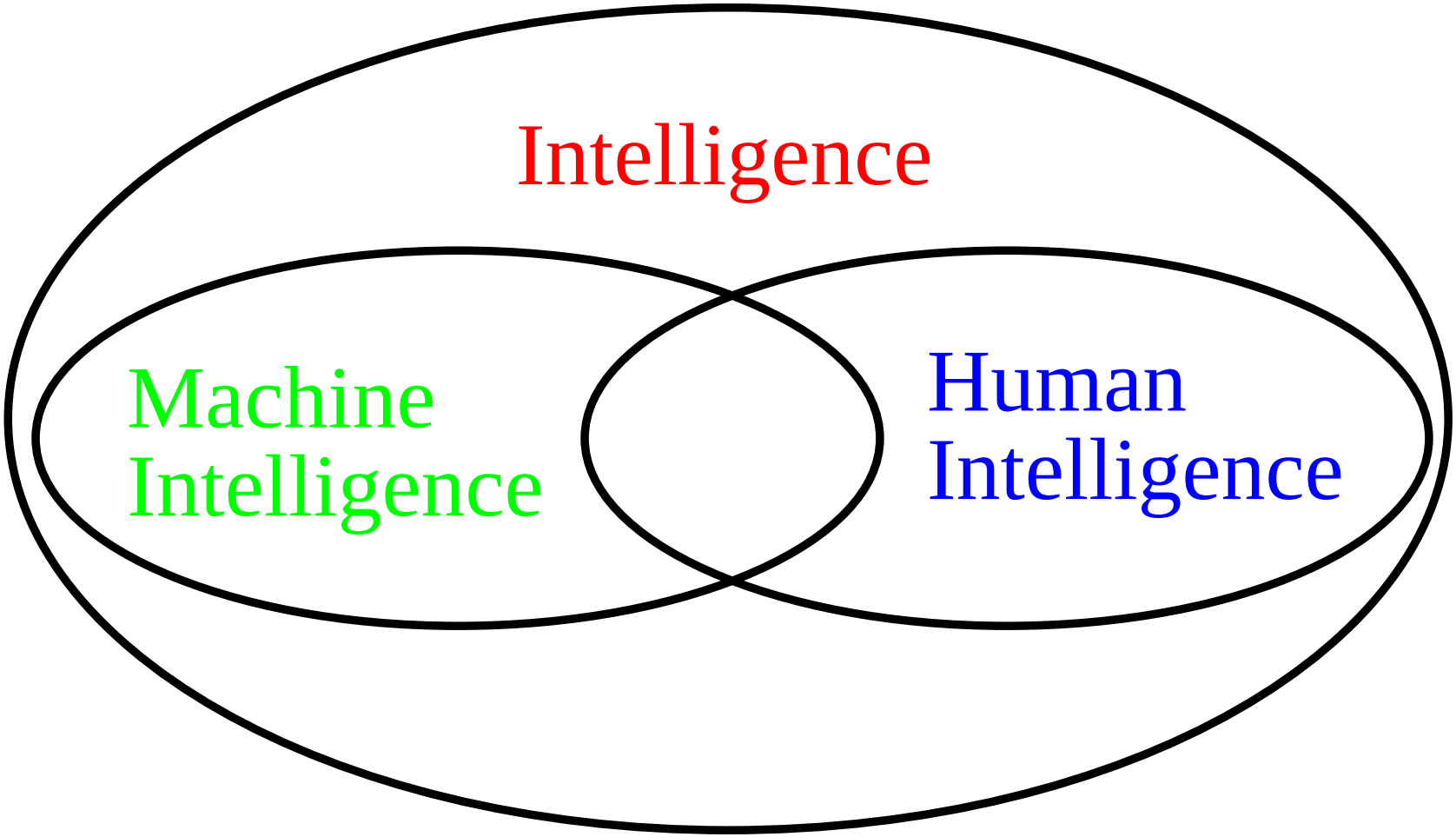
`http://www.iis.sinica.edu.tw/~tshsu`

A.I. and game playing

- **Patrick Henry Winston 1984.**
  - *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.***
    - ▷ ***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.**


Intelligence
Machine
Intelligence
Human
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.**

History (1/3)

- **Computer games are studied by the founding fathers of Computer Science**
  - **J. von Neumann, 1928, "Math. Annalen"**
  - **C.E. Shannon, 1950, Computer Chess paper**
  - **Arthur Samuel began his 25-year quest to build a strong checkers-playing program at 1952**
  - **Alan Turing, 1953, chapter 25 of the book "Faster than thought", entitled "Digital Computers Applied to Games"**
    - ▷ ***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)**

History (2/3)

- **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*

History (3/3)

- **1990's until now**
  - **Witness a series of dramatic computer successes against the best of humanity.**
    - ▷ ***CHINOOK, checkers, 1994.***
    - ▷ ***DEEP BLUE, chess, 1997.***
    - ▷ ***LOGISTELLO, Othello, 1997.***
  - **Parallelization.**
  - **A "new" search technique based on Monte Carlo simulation ($\sim$ 1993).**
    - ▷ ***Computer Go: about 1 dan in the year 2010 and improve steadily since then.***
    - ▷ ***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 know all moves that have been taken.**
    - ▷ ***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

- **Arthur Samuel, 1960.**
  - **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

* J. Schaeffer and H. J. van den Herik. Games, computers, and artificial intelligence. *Artificial Intelligence*, 134:1–7, 2002.
- Jonathan Schaeffer. The games computers (and people) play. *Advances in Computers*, 52:190–268, 2000.
- E. Demaine and R. A. Hearn. Playing games with algorithms: Algorithmic combinatorial game theory. Technical report, Massachusetts Institute of Technology, USA, 2001. http://arxiv.org/abs/cs.CC/0106019, last revised 22 April 2008.
- G. Kendall, A. Parkes, and K. Spoerer. A survey of NP-complete puzzles. *International Computer Game Association (ICGA) Journal*, 31(1):13–34, 2008.