AI Planning for Autonomy

1. Short Introduction to Automated (AI) Planning

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University of Melbourne

Winter Term, 2018

Intro: Nir Lipovetzky

I've completed my PhD on 2012 in Barcelona.

My main research interests are in the area of Automated planning, specifically:

- Planning technology (algorithms, inferences, and tools)
- Planning for Autonomy in industry
- Bounded General AI (Atari) $\neq$ AGI

I've been at Melbourne Uni since 2012. You can find me at DMD building, office 6.17.

Contact: nir.lipovetzky@unimelb.edu.au

Love Futbol, but not FC. Barcelona ;)

Intro: Tim Miller

I completed my PhD in 2005 at the University of Queensland.

My main research interests are in the area of artificial intelligence, specifically:

- Decision making in multi-agent environments
- Reasoning about action and knowledge
- Automated planning
- Human-agent interaction and collaboration

You can find me at DMD building, office 6.09.

I love coffee and all things related to it :)

Contact: tmiller@unimelb.edu.au

Intro: Tutors

Great Knowledge on COMP90054 topics.

Guang Hu, Prashan Mathugama, Shima Rashidi, Malcolm Angus Karutz, Ruixi Huo, and Justin Tan

- few former top-students of COMP90054, Phd and Research Students.

You can find Guang at DMD building, office 6.13

Contact: ghu1@student.unimelb.edu.au

Outline of the Course

1. Introduction to AI and (AI) Planning
2. Classical Planning as Heuristic Search and Width-Based Search
3. Beyond Classical Planning:
    - *Factored-Model-Free, Non Determinism, Uncertainty, Soft goals, Plan Recognition, Epistemic (social) Planning, Path-Planning, Control*
4. Reinforcement Learning: Learning through Experience
5. Multi agent Planning
6. Hot/Latest exciting discussions on AI Ethics

2 Assignments: 1 early project, 1 final project in the form of a competition

Acknowledgment:

$\rightarrow$ Slides based on earlier courses by Hector Geffner, Joerg Hoffmann, and Carmel Domshlak

Pacman Competition

Code released by Berkeley University, used widely for teaching purposes across best universities around the globe

We are in contact with current competitions run at RMIT, Future: University of Toronto, University of Basel, and UPF Barcelona.

$\rightarrow$ **Hall of Fame (best 8 teams each year will compete with best teams 2016-present, forever!)**
`https://sites.google.com/view/pacman-capture-hall-fame/`

Do not use online solutions, we are going to find out and it's not worth it!

It's an open-ended project, set your own goals.

Things you Should Know to Enjoy the Course

1. Algorithms such as Dynamic Programming
2. Basic Set Theory and Propositional Logic
3. Probabilistic Theory such as Conditional Probabilities
4. Python, start this week the recommended Tutorial (LMS->Resources)

and importantly, you need to stay up to date reviewing and understanding slides, as most lectures build up on previous knowledge

If you don’t understand...have a question...

SpeakUp!

Download `speakup.info`

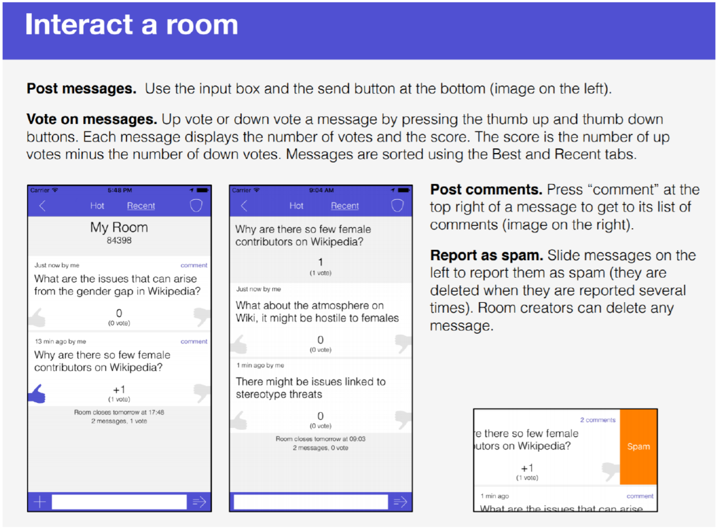
- google-play, apple-store, or webapp

Connect to room COMP90054 and ask questions **anonymously**, thumbs Up/Down your favorite ones.

It is location based, if you are not at Unimelb, click "+", and join channel: 04338

In class Quizzes + lecturer will look at the questions and answer them (end of class), as well as discussions at the tutorials

Speakup Instructions



Interact a room

Post messages. Use the input box and the send button at the bottom (image on the left).

Vote on messages. Up vote or down vote a message by pressing the thumb up and thumb down buttons. Each message displays the number of votes and the score. The score is the number of up votes minus the number of down votes. Messages are sorted using the Best and Recent tabs.

Post comments. Press "comment" at the top right of a message to get to its list of comments (image on the right).

Report as spam. Slide messages on the left to report them as spam (they are deleted when they are reported several times). Room creators can delete any message.

Carrier
5:48 PM
Hot
Recent
My Room
84398
Just now by me
comment
What are the issues that can arise from the gender gap in Wikipedia?
0
(0 vote)
13 min ago by me
comment
Why are there so few female contributors on Wikipedia?
+1
(1 vote)
Room closes tomorrow at 17:48
2 messages, 1 vote
Carrier
9:04 AM
Hot
Recent
Why are there so few female contributors on Wikipedia?
1
(1 vote)
Just now by me
What about the atmosphere on Wiki, it might be hostile to females
0
(0 vote)
1 min ago by me
There might be issues linked to stereotype threats
0
(0 vote)
Room closes tomorrow at 09:03
2 messages, 0 vote
2 comments
e there so few female
utors on Wikipedia?
Spam
+1
(1 vote)
1 min ago
comment
What are the issues that can arise

Artificial + Intelligence?

- **AI Concepts**: What are we actually talking about?
  - Clarify what the (modern) research field of AI does, and does not, try to do.
- **AI History**: How did this come about?
  - Just a little background to illustrate how we came from ’classical AI’ to ’modern AI’.
- **AI Today**: What is the landscape of techniques and applications?
  - Rough overview, and some examples.

What is Intelligence?

Quiz@speakup! can choose multiple answers

What is *Artificial* Intelligence?

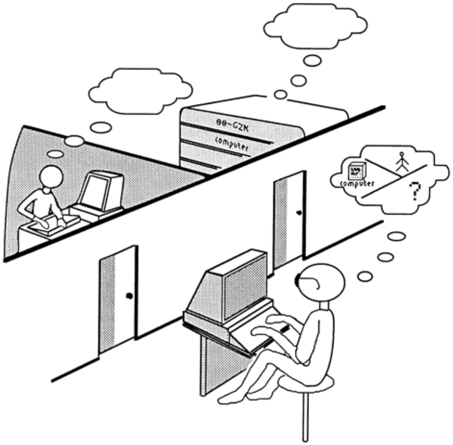
An engineering standpoint

The science of making machines do things that would require intelligence if done by humans. (M. Minsky)

Is this an operational definition? Hmm...

- How do we know what human activities require intelligence?
- BTW, what is human intelligence?

Acting Humanly with intelligence: Turing Test



- Not reproducible... only a proof of concept?

What is *Artificial* Intelligence?

Another perspective please

The exciting new effort to make computers think. Machines with minds, in the full and literal sense. (J. Haugeland)

Same problems as with Minsky's definition:

- what is thinking?
- what is mind?

What is *Artificial* Intelligence?

A Rational perspective

The branch of computer science that is concerned with the automation of intelligent behavior. (Luger and Stubblefield)

- **Intelligent behavior**: make ‘good’ (rational) action choices
- Are humans ‘rational’ agents?

Rational Agents

Agents:

- Perceive the environment through sensors (→percepts).
- Act upon the environment through actuators (→actions).

→ Examples? Humans, animals, robots, software agents (softbots), . . .

Rational Agents . . . do ‘the right thing’!

→ Any idea what that means, ‘do the right thing’?

Rational Agents

. . . **TRY to do 'the right thing'!**

→ The hypothetical best case ('the right thing') is often unattainable.

→ The agent might not be able to perceive all relevant information. (Is there dirt under this bed?)

Rationality vs. Omniscience:

- An omniscient agent knows everything about the enviroment, and knows the actual effects of its actions.
- A rational agent just makes the best of what it has at its disposal, maximizing expected performance given its percepts and knowledge.

→ Example? I check the traffic before crossing the street. As I cross, I am hit by a meteorite. Was I lacking rationality?

Mapping your input to the best possible output:

$$\text{Performance measure} \times \text{Percepts} \times \text{Knowledge} \rightarrow \text{Action}$$

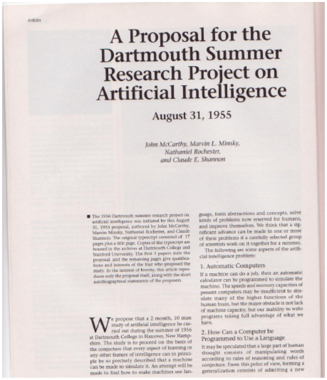
What Does AI Do?

$\rightarrow$ Artificial intelligence as an idea can be roughly classified along the dimensions thinking vs. acting and humanly vs. rationally.

	Humanly	**Rationally**
Thinking	Systems that think like humans (Cognitive Science)	Systems that think rationally (Logics: Knowledge and Deduction)
Acting	Systems that act like humans (Turing Test)	Systems that act rationally (How to make good action choices)

$\leadsto$ A central aspect of intelligence (and one possible way to define it) is the ability to act successfully in the world

Origins of AI: Darmouth 1956



Articles

A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence

August 31, 1955

John McCarthy, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon

■ The 1956 Dartmouth summer research project on artificial intelligence was initiated by this *August 31, 1955* proposal, authored by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon. The original typescript consisted of 17 pages plus a title page. Copies of the typescript are housed in the archives at Dartmouth College and Stanford University. The first 5 papers state the proposal, and the remaining pages give qualifications and interests of the four who proposed the study. In the interest of brevity, this article reproduces only the proposal itself, along with the short autobiographical statements of the proposers.

We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.

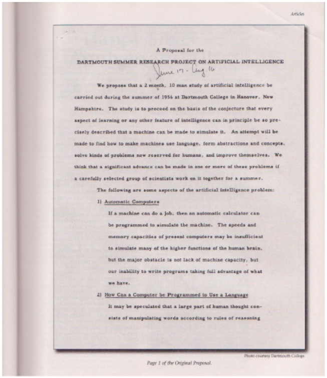
The following are some aspects of the artificial intelligence problem:

1. Automatic Computers

If a machine can do a job, then an automatic calculator can be programmed to simulate the machine. The speeds and memory capacities of present computers may be insufficient to simulate many of the higher functions of the human brain, but the major obstacle is not lack of machine capacity, but our inability to write programs taking full advantage of what we have.

2. How Can a Computer be Programmed to Use a Language

It may be speculated that a large part of human thought consists of manipulating words according to rules of reasoning and rules of conjecture. From this point of view, forming a generalization consists of admitting a new



Articles

A Proposal for the

DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

June 17 - Aug 16

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2) How Can a Computer be Programmed to Use a Language

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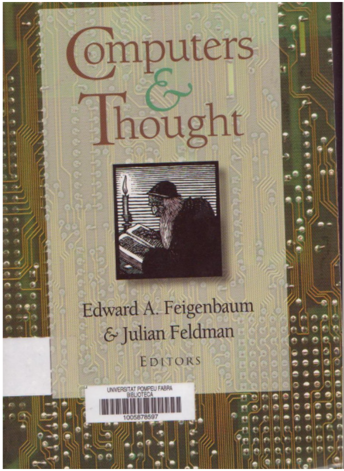
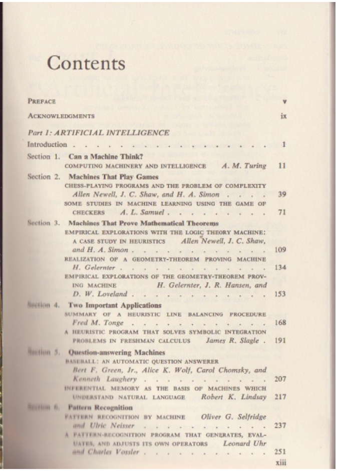
Photo courtesy Dartmouth College.

Page 1 of the Original Proposal.

The proposal (for the meeting) is to proceed on the basis of the conjecture that every aspect of . . . intelligence can in principle be so precisely described that a machine can be made to simulate it

Computers and Thought 1963





Contents

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An early collection of AI papers and programs for playing chess and checkers, proving theorems in logic and geometry, planning, etc.

AI: 60's, 70's, and 80's

Many of the key AI contributions in 60's, 70's, and early 80's had to to with programming and the representation of knowledge in programs:

- Lisp (Functional Programming)
- Prolog (Logic Programming)
- Rule-based Programming
- 'Expert Systems' Shells and Architectures

AI Methodology: Theories as Programs

For writing an AI dissertation in the 60's, 70's and 80's, it was common to:

- pick up a task and domain X
- analyze/introspect/find out how task is solved
- capture this reasoning in a program

The dissertation was then

- a theory about X (scientific discovery, circuit analysis, computational humor, story understanding, etc), and
- a program implementing the theory, tested over a few examples.

Many great ideas came out of this work . . . but there was a problem . . .

Methodology Problem

→ Theories expressed as programs cannot be proved wrong: when a program fails, it can always be blamed on ‘missing knowledge’

Three approaches to this problem

- narrow the domain (expert systems)
  - problem: lack of generality
- accept the program is just an illustration, a demo
  - problem: limited scientific value
- fill up the missing knowledge (intuition, commonsense)
  - problem: not successful so far

AI Winter: the 80's

$\rightarrow$ The knowledge-based approach reached an **impasse** in the 80's, a time also of debates and controversies:

- **Good Old Fashioned AI** is 'rule application' but intelligence is not (Haugeland)

Many criticisms of mainstream AI partially valid then; less valid now.

AI 90's - 2013

Formalization of AI techniques and increased use of mathematics. Recent issues of AIJ, JAIR, AAAI or IJCAI shows papers on:

1. SAT and Constraints
2. Search and Planning
3. Probabilistic Reasoning
4. Probabilistic Planning
5. Inference in First-Order Logic
6. Machine Learning
7. Natural Language
8. Vision and Robotics
9. Multi-Agent Systems

$\rightarrow$ Areas 1 to 4 often deemed about techniques, but more accurate to regard them as models and solvers.

Solver Example

$$\textit{Problem} \Longrightarrow \boxed{\textit{Solver}} \Longrightarrow \textit{Solution}$$

Example:

- **Problem:** The age of John is 3 times the age of Peter. In 10 years, it will be only 2 times. How old are John and Peter?
- **Expressed as:** $J = 3P$; $J + 10 = 2(P + 10)$
- **Solver:** Gauss-Jordan (Variable Elimination)
- **Solution:** $P = 10$; $J = 30$

Solver is **general** as deals with any problem expressed as an instance of **model** Linear Equations Model, however, is **tractable**, AI models are not . . .

AI Solver

$$\textit{Problem} \Longrightarrow \boxed{\textit{Solver}} \Longrightarrow \textit{Solution}$$

- The basic models and tasks include
  - **Constraint Satisfaction/SAT:** find state that satisfies constraints
  - **Planning Problems:** find action sequence that produces desired state
  - **Planning with Feedback:** find strategy for producing desired state
- Solvers for these models are **general**; not tailored to specific instances
- All of these models are **intractable**, and some extremely powerful (POMDPs)
- The challenge is mainly computational: **how to scale up**
- For this, solvers must **recognize and exploit structure** of the problems
- Methodology is **empirical**: benchmarks and competitions

SAT and CSPs

- **SAT**: determine if there is a **truth assignment** that satisfies a set of clauses

$$x \vee \neg y \vee z \vee \neg w \vee \ldots \tag{1}$$

- Problem is NP-Complete, which in practice means worst-case behavior of SAT algorithms is **exponential** in number of variables ($2^{100} = 10^{30}$)
- Yet current SAT solvers manage to solve problems with **thousands of variables** and clauses, and used widely (circuit design, verification, planning, etc)
- **Constraint Satisfaction Problems (CSPs)** generalize SAT by accommodating non-boolean variables as well, and constraints that are not clauses
- Key is **efficient (poly-time) inference** in every node of search tree: **unit resolution, conflict-based learning**, ...
- Many other ideas **logically possible**, but **do not work** (don't scale up): pure search, pure inference, etc.

Classical Planning Model

- Planning is the **model-based approach** to autonomous behavior,
- A system can be in one of many **states**
- States assign **values** to a set of **variables**
- **Actions** change the values of certain variables
- **Basic task**: find **action sequence** to drive **initial** state into **goal** state

$$\textit{Model} \Longrightarrow \boxed{\textit{Planner}} \Longrightarrow \textit{Action Sequence}$$

- **Complexity**: NP-hard; i.e., exponential in number of vars in **worst case**
- **Planner** is generic; it should work on any domain no matter what variables are about

Why do we need such an AI?

- **Cheess**: 2 player zero-sum game
- **Music/Speech Recognition**
- **Recommender systems**
- **Medical Diagnosis**: decission support systems
- **Self-driven car**
- **Playing Atari Games** Deep Learning
- ...

Poster by
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BOOKS & COFFEE
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Communications Triage
Machine Translation
Ecocomputing
See the AI timeline and more at www.aaai.org/AILandscape
The AI Landscape
David Leake, Indiana University, Poster Development Committee Chair
Poster Design: Giacomo Marchesi, www.GiacomoMarchesi.com

Why do we need such AI Planning?

Settings where greater autonomy required:

- **Space Exploration**: (RAX) first artificial intelligence control system to control a spacecraft without human supervision (1998)
- **Business Process Management**
- **First Person Shooters & Games:** classical planners playing Atari Games
- **Interactive Storytelling**
- **Network Security**
- **Logistics/Transportation/Manufacturing**: Multi-model Transportation, forest fire fighting, PARC printer
- ...

Find out more at Special Interest Group for Applications of AI Planning and Scheduling

Summary: AI and Automated Problem Solving

- A **research agenda** that has emerged in last 20 years: **solvers** for a range of **intractable models**
- **Solvers** unlike other programs are **general** as they do not target individual problems but families of problems (**models**)
- The challenge is **computational**: how to scale up
- Sheer **size of problem** shouldn't be impediment to meaningful solution
- **Structure** of given problem must recognized and **exploited**
- Lots of room for **ideas** but methodology **empirical**
- Consistent **progress**
  - effective inference methods (derivation of h, conflict-learning)
  - islands of tractability (treewidth methods and relaxations)
  - transformations (compiling away incomplete info, extended goals, . . .)