Tampere University

Artificial Intelligence

Winter 2023

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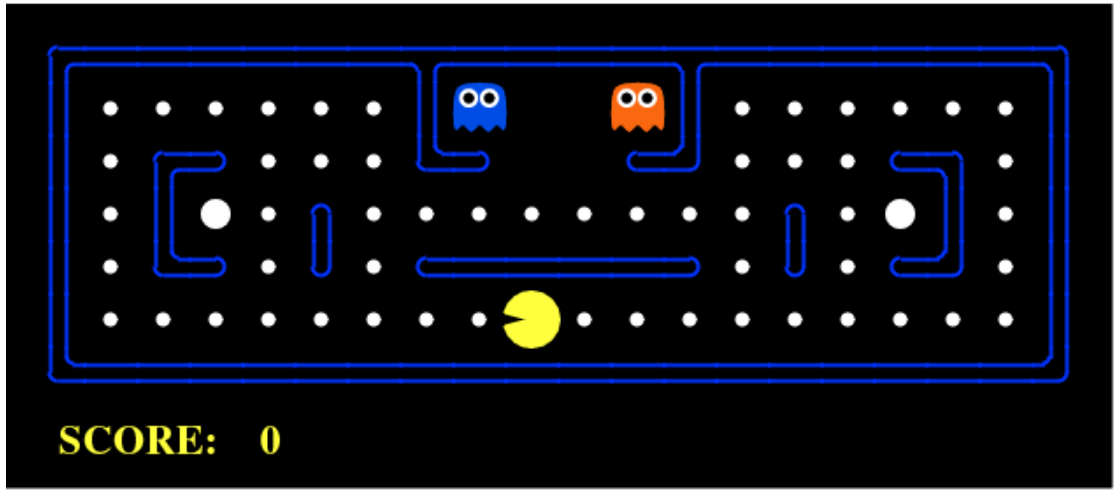
DATA.ML.310

Welcome!



http://ai.berkeley.edu/images/pacman_game.gif

AI techniques underlying Pac-Man®

Search

Depth-first, breadth-first, uniform cost, and A* search algorithms are used to solve navigation and traveling salesman problems in the Pac-Man world

Multi-Agent Search

Classic Pac-Man is modeled as both an adversarial and a stochastic search problem. Multiagent minimax and expectimax algorithms, as well as designed evaluation functions.

Reinforcement Learning

Model-based and model-free reinforcement learning algorithms, applied to the AIMA textbook's Gridworld, Pac-Man, and a simulated crawling robot.

Ghostbusters

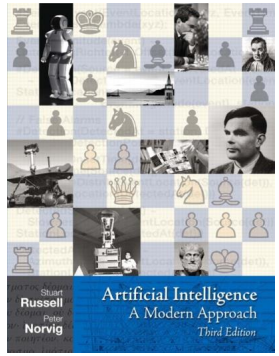
Probabilistic inference in a hidden Markov model tracks the movement of hidden ghosts in the Pacman world. Exact inference using the forward algorithm and approximate inference via particle filters.

Classification

Standard machine learning classification algorithms using Naive Bayes, Perceptron, and MIRA models to classify digits.

Thanks to

- Stuart Russell & Peter Norvig for the textbook *AI: A Modern Approach*, 3rd Global Ed.



- Dan Klein & Pieter Abbeel for *CS188 Intro to AI* at *UC Berkeley*, which is freely available for educational use http://ai.berkeley.edu

- Pac-Man® is a registered trademark of Namco-Bandai Games, used here for educational purposes

Course staff

Tapio Elomaa
Lecturer

Teaching assistants:

- Jenni Hukkanen `jenni.j.hukkanen@tuni.fi`
- Katri Korhonen `katri.leinonen@tuni.fi`

The lectures are organized remotely as prerecorded videos.
On-line Q & A sessions for the exercises will be offered weekly by the TAs.

Parts of the Course

- The course covers five central topics of AI

- **Lectures** are broken down to small pieces and prerecorded
  - Lectures are from 2021, the administrative details are not up to date
- Exercises consist of **topical quizzes** and **programming assignments**
  - The questions are individual to the students
  - In particular, the programming tasks are somewhat demanding
  - Therefore, online student support is provided at designated times
- There is a possibility to record a **video presentation** on a topic of interest
- The **exam** is compulsory with pass / fail grading

Course Grading

- Tentative grading (may still be slightly adjusted)
  - Topic quizzes ≈ 40% of points
  - Programming assignments ≈ 60% of points
- Pass the course: score 50% of the points
- You can earn a maximum of 10% bonus points by recording a video presentation on a topic of interest
- You need to register and take part in a (pass-fail) exam
  - Planned exam time interval Feb. 20 – Mar. 8, 2023

Tentative schedule

- The course concentrates on five central topics of AI:
  1. CLASSICAL SEARCH AND BEYOND
  2. ADVERSARIAL SEARCH AND CSPs
  3. PROBABILITY AND BAYESIAN NETWORKS
  4. MDPs AND REINFORCEMENT LEARNING
  5. NATURAL LANGUAGE PROCESSING
- Machine Learning is one central AI topic that is left to other courses
- We make an exception on Reinforcement learning

- The schedule follows the topics rather than weeks

CLASSICAL SEARCH AND BEYOND

1. Chapter 3: Solving Problems by Searching
2. Chapter 4: Beyond Classical Search

ADVERSARIAL SEARCH AND CONSTRAINT SATISFACTION

- Chapter 5: Adversarial Search
- Chapter 6: Constraint Satisfaction Problems

PROBABILITY AND BAYESIAN NETWORKS

- Chapter 13: Quantifying Uncertainty
- Chapter 14: Probabilistic Reasoning
- Chapter 15: Probabilistic Reasoning over Time
- Chapter 20: Learning Probabilistic Models

MARKOV DECISION PROCESSES AND REINFORCEMENT LEARNING

- Chapter 17: Making Complex Decisions
- Chapter 21: Reinforcement Learning

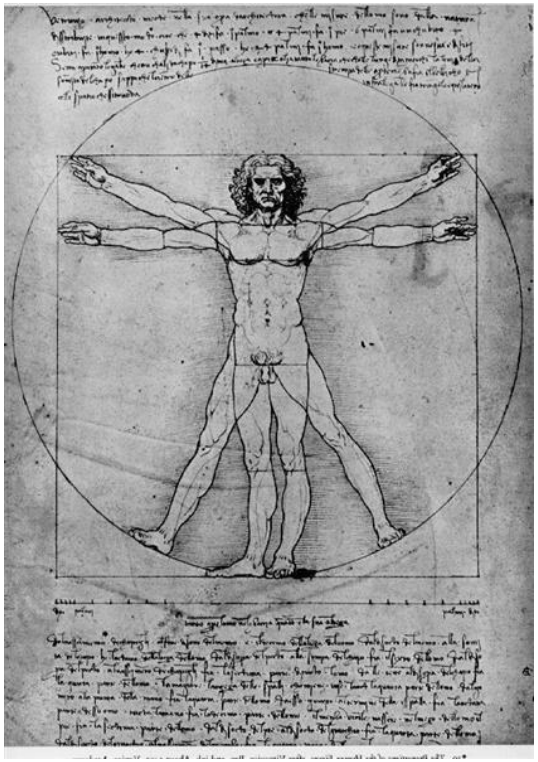
NATURAL LANGUAGE PROCESSING

- Chapter 22: Natural Language Processing
- Chapter 23: Natural Language and Communication

What is there to AI beyond PR & ML

- Intelligent behavior ≈ acting rationally
- Long-term operation
- Complex decisions (multiple)
- Planning
- Developing environment
- Uncertainty/reasoning
- Adversarial setting
- Information exchange/communication
- Autonomous
- Embodied

Humans vs. AI vs. Science Fiction



AI Concerns

Thinking vs. Acting
Human-like vs. Rational

Machines that think like humans
- Cognitive science
- Neuroscience
- Philosophy

Machines that think rationally
- Dating back to Aristotle
- Difficult to encode how to think
- In the end it's not about how you think,
- it's about how you end up acting

Machines that act like humans
- Turing test (total)

Machines that act rationally

Rationality

The term **rational** has a very specific, technical meaning:

- Rational: achieving pre-defined goals maximally
- Implies a measure of goodness
- Rationality only concerns what decisions are made
  (not the thought process behind them)
- Goals are expressed in terms of the **utility** of outcomes

Being rational means

maximizing your expected utility (MEU)

Computers vs. Humans

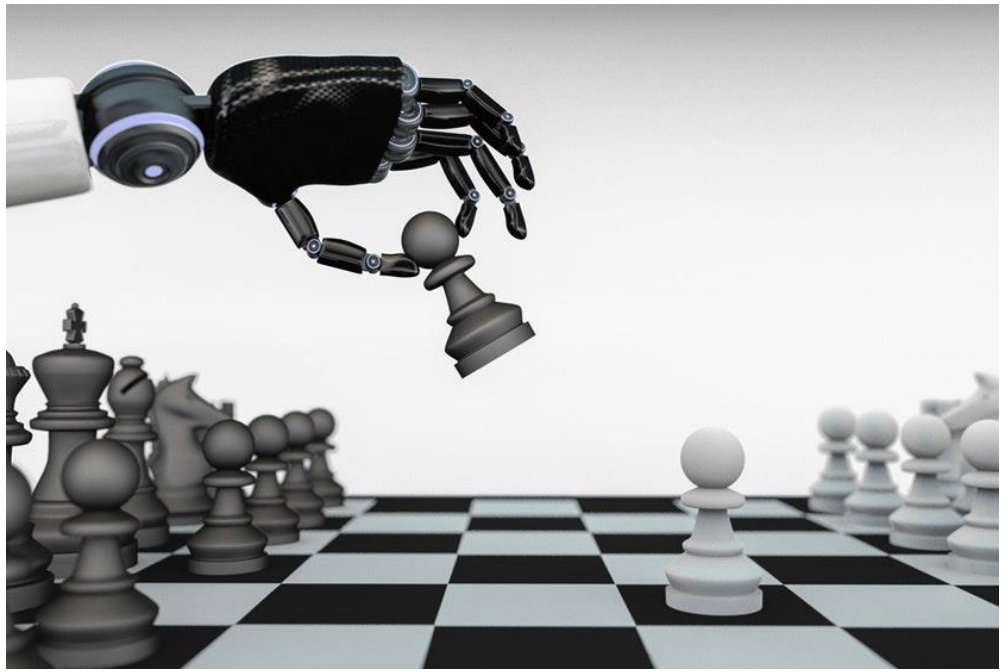
Board Game Playing

- Has been seen as a natural application area of AI since the advent of the research field in 1940's/1950's
- Chess in particular was seen to be challenging enough to require intelligence to be solved
- It took 50–60 years for computers to beat the best human play
- Required sophisticated-enough computers to be developed
- Now standard computers enough

Computer Chess

- Computer chess has come a long way over the past twenty years
- In 1997 IBM's Deep Blue managed to beat the reigning world champion, Garry Kasparov, in a six-game match
- In retrospect, there is little mystery in this achievement
- Deep Blue could evaluate 200 million positions per second
- It never got tired, blundered in a calculation or forgot what it had been thinking a moment earlier
- After chess Go challenge

Game-Playing Machines



- In 2016 Google's program AlphaGo won professional Go player Lee Sedol
- In 2017, DeepMind announced that AlphaZero (AZ), masters not only chess but shogi, or Japanese chess, and Go
- AZ starts with only basic rules of the games and plays against itself millions of times and learns from its mistakes
- In a matter of hours, the algorithm became the best player the world has ever seen
- **MuZero** (MZ) was developed by DeepMind in 2019 to master games without knowing their rules

Today's AI hype

- AI research has been on the agenda since 1950's.
  - There have been ups and downs (AI winters). Hypes have preceded the winters: Marvin Minsky, small worlds, and expert systems
- There is no single AI technology.
  - Main schools are **data centered** and **symbolistic**, which emphasizes more the meaning and content. E.g., IBM Watson uses different methods than deep learning neural networks that are used for image recognition and prediction.
- The hype today is mainly based on **machine learning**, deep neural networks in particular. They are examples of the data-centric approach
- Modern AI can be characterized as narrow
  - It can be applied to a particular task – the one that it was built for. It does not understand anything about other tasks.
  - AI does not have any understanding of the contents of the data it is manipulating, they are simply numbers to it.
  - Furthermore, it does not want anything, it lacks its own will.
- The next step would be **strong AI** (also **AGI**, Artificial General Intelligence).
  - Understands matters and their interconnections significantly more broadly than current narrow AI.
  - Not necessarily its own will, but an understanding – to some degree – of the surrounding world.
  - The researchers have not been able to determine the research route leading to AGI.

Thinking machines

- Alan Turing 1950:
- "I propose to consider the question, 'Can machines think?'"
- *thinking* is difficult to define, so Turing chooses to “replace the question by another, which is closely related to it and is expressed in relatively unambiguous words."
- "Are there imaginable digital computers which would do well in the *imitation game*?“
- "Learning Machines“

Computing Machinery and Intelligence (Turing, 1950; p. 460)

Turing Test

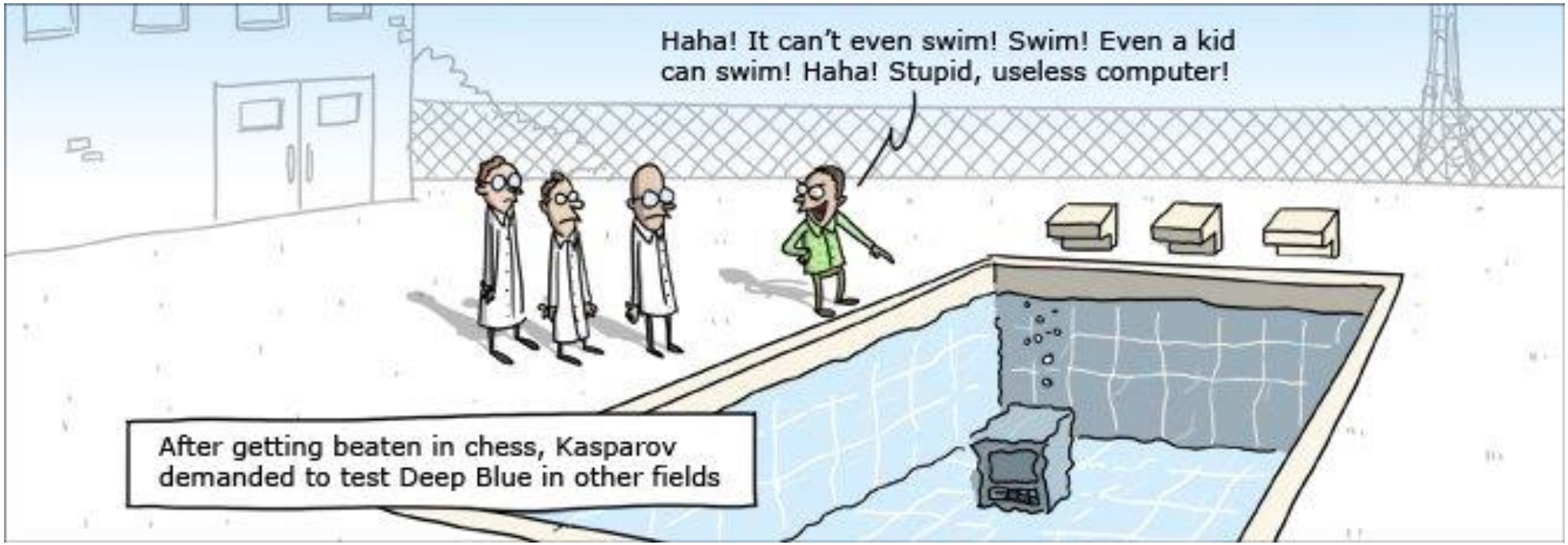
- **Question** Please write me a sonnet on the subject of the Forth Bridge.
- **Answer** Count me out on this one. I never could write poetry.
- **Question** Add 34957 to 70764.
- **Answer** <pause ~30 seconds> .105621.
- **Question** Do you play chess?
- **Answer** Yes.
- **Question** My King is on the K1 square, and I have no other pieces. You have only your King on the K6 square and a Rook on the R1 square. Your move.
- **Answer** <pause ~15 seconds>. . . Rook to R8, checkmate.

- *Are the answers from a person or a computer*?

- **Question** In the first line of the sonnet which reads “Shall I compare thee to a summer’s day,” would not “a spring day” do as well or better?
- **Answer** It wouldn’t scan.
- **Question** How about “a winter’s day”? That would scan all right.
- **Answer** Yes, but nobody wants to be compared to a winter’s day.
- **Question** Would you say Mr. Pickwick reminded you of Christmas?
- **Answer** In a way.
- **Question** Yet Christmas is a winter’s day, and I don’t think Mr. Pickwick would mind the comparison.
- **Answer** I don’t think you’re serious. By a winter’s day one means a typical winter’s day, rather than a special one like Christmas.

- *These answers are probably from a person*!

Total Turing Test



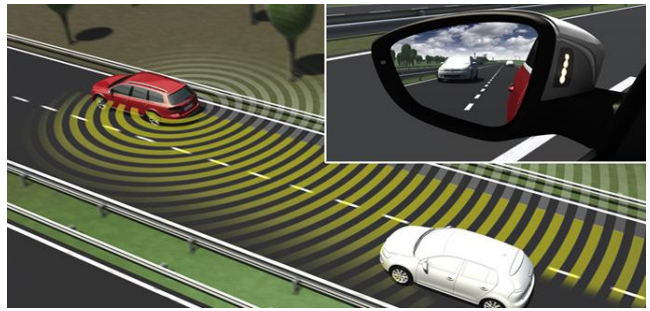
So far only in sci-fi

Common AI applications

Spam filtering

Recommender systems

Navigation



Driver support Systems in modern cars

More spectacular

- Watson
  - After Chess, IBM turned to solve the TV show quiz Jeopardy!
    https://www.youtube.com/watch?v=WFR3lOm_xhE

  Boston Dynamics
  - Skillful two- and four-legged robots

  https://www.youtube.com/watch?v=hMtABzjslXA
  https://www.youtube.com/watch?v=fn3KWM1kuAw

  Self-driving cars, ships, etc.

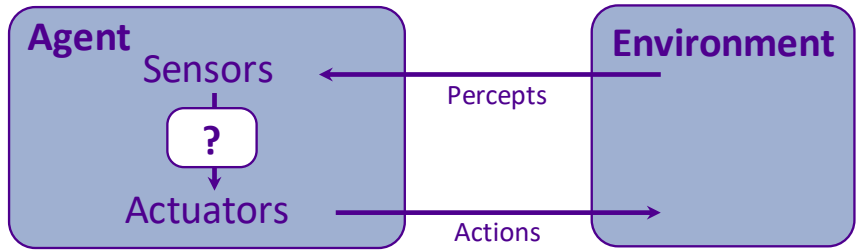
What Can AI Do Today?

Quiz: Which of the following can be done at present?

- ✓ Play a decent game of table tennis? https://www.youtube.com/watch?v=u3L8vGMDYD8
- ✓ Play a decent game of Jeopardy?
- ✓ Drive safely along a curving mountain road?
- ? Drive safely along Hervannan valtaväylä?
- ✓ Buy a week's worth of groceries on the web?
- ✗ Buy a week's worth of groceries at Duo shopping center?
- ? Discover and prove a new mathematical theorem?
- ✗ Converse successfully with another person for an hour?
- ? Perform a surgical operation?
- ✓ Put away the dishes and fold the laundry?
- ✓ Translate spoken Chinese into spoken English in real time?
- ✗ Write an intentionally funny story?

Reflex agents

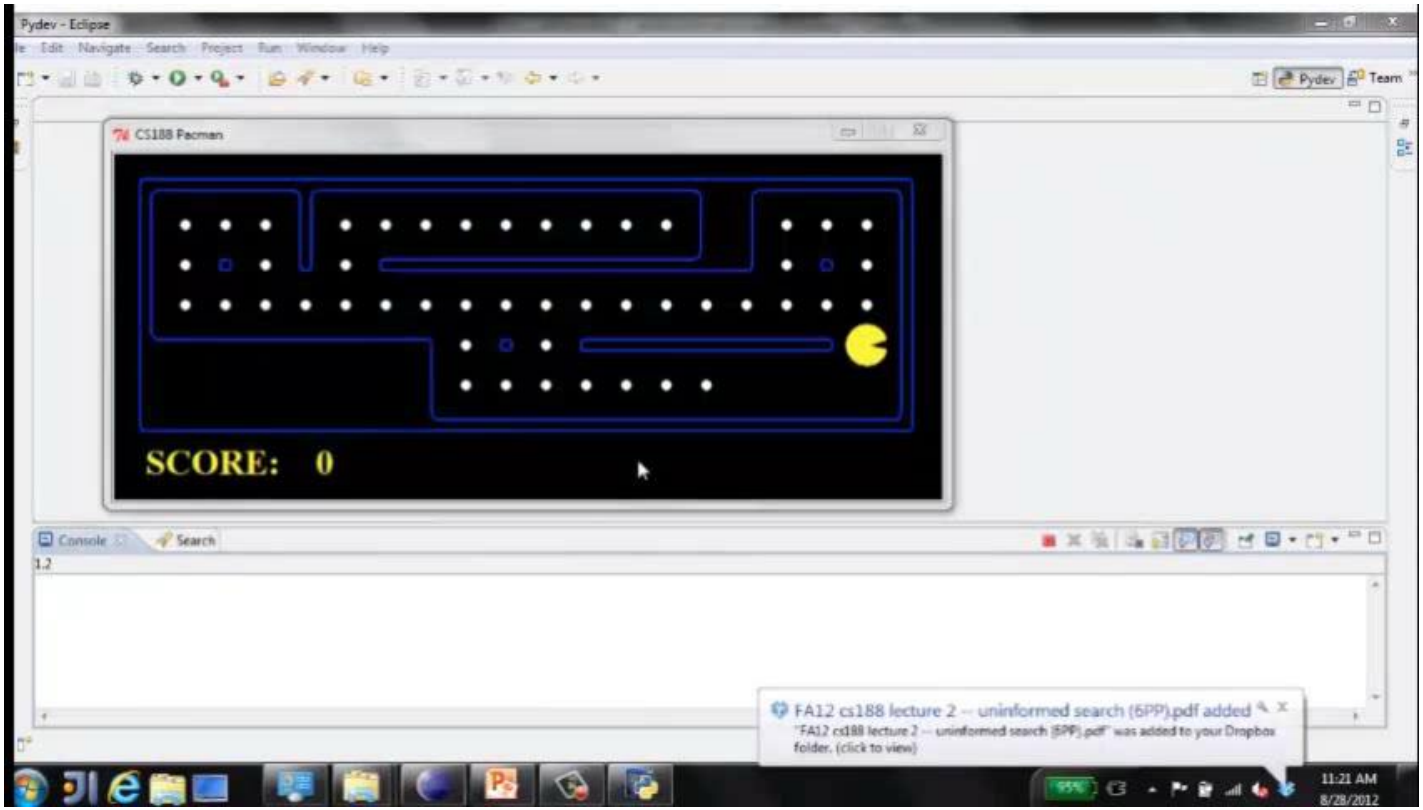
- Choose action based on current percept (and maybe memory)
- May have memory or a model of the world's current state
- Do not consider the future consequences of their actions
- Consider how the world IS



Pac-Man’s percepts

- Food in a cell
- Power pellets
- Ghosts
- Status of the ghosts

Reflex Pac-Man



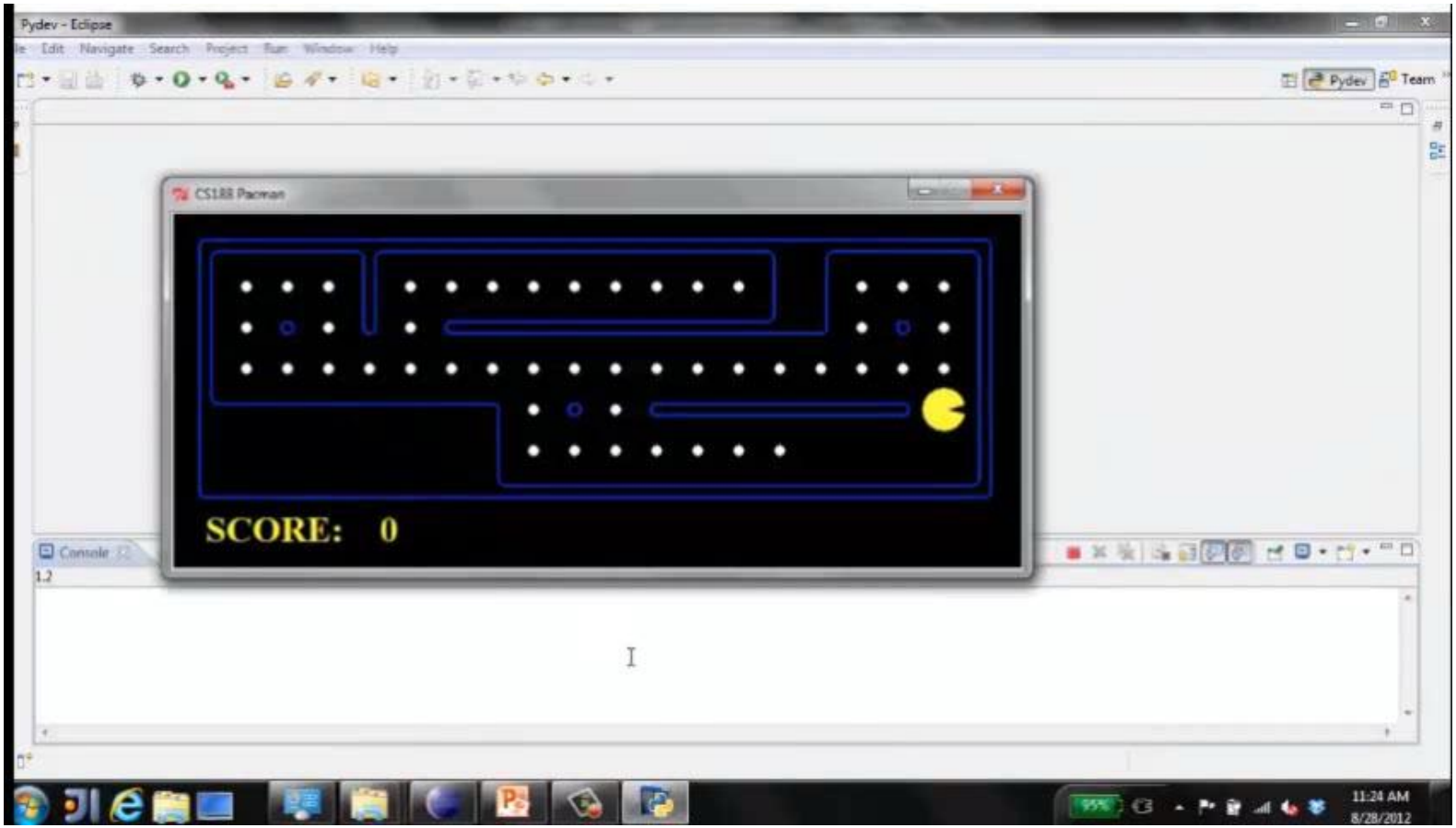
Planning agents

- Ask “what if”
- Decisions based on (hypothesized) consequences of actions
- Must have a model of how the world evolves in response to actions
- Must formulate a goal (test)
- Consider how the world WOULD BE

- Optimal vs. complete planning

- Planning vs. replanning

Replanning



Mastermind