Artificial Intelligence
Chapter 1: Introduction

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Artificial Intelligence

Lesson 1
AI in Fiction

An intelligent killing robot

Smart machines that took over the human race and made them live in a simulated world
What’s interesting with AI

Labor

Science

Appliances

Search engines

Medicine/Diagnosis

Movies Recommendation

slide mostly borrowed from Laurent Itti
What’s interesting with AI

- Honda AISMO
  - Advanced Step in Innovation MObility
- Humanoid Robot
- Capable of recognizing:
  - Moving objects
  - Postures
  - Gestures
  - Handshake
  - Sounds
- Capable of walking and running

http://en.wikipedia.org/wiki/ASIMO
What’s interesting with AI

**Darpa Grand Challenge**
- To nurture the development of autonomous ground vehicles
- Competition of Driverless vehicles
- **2004**
  - 1 million
  - Mojave Desert
  - Follows a route of 240 km
  - No one won: best completed 12 km
- **2005**
  - 2 million dollar prize
  - 3 narrow tunnels, 100 sharp turns
  - Twisted pass with a drop-off one one side
  - Five succeeded
  - Winner: 6:54 hours, Stanford Racing Team – Stanely

**Urban Grand Challenge**
- **2007**
  - 2 million dollar
  - AirForce Base
  - To obey to all traffic rules
  - 96 km within less than 6 hours
  - CMU team won – with 4:10

What’s interesting with AI

- 1996, Deep Blue first machine to beat chess world champion
  - But lost in the series – 4 to 2
- 1997, won the series 3.5 to 2.5
- Search 6 to 8 moves a head
- The evaluation function is set by the system after examining thousands of master games

AI Paradigm

• Develop general, efficient, satisficing methods for tackling AI problems

• Given a real-world task,
  1. Convert it into a form that is well-defined and captures all relevant information necessary to solve it – this is a “modeling” process
     • Example: Model the “relevance” of a web page, $x$, to a user’s search query as:
       $$f(x) = 10 \times \text{QueryMatch}(x) + 3 \times \text{PageRank}(x)$$
  2. Given a formal model, develop an algorithm for solving the task efficiently
AI Architecture

Real World

Sensors

Agent

Model of World (being updated)

Prior Knowledge about the World

Reasoning & Decisions Making

List of Possible Actions

Goals/Utility

Effectors
Question Answering Systems

Apple Siri

Speech recognition and language understanding
IBM Watson

Jeopardy! game player in January 2011
- 4 TB of data analyzed

Now used as a clinical decision support system, e.g., for lung cancer treatment
Game Playing: Chess

- IBM Deep Blue vs. Kasparov, 1997/5
- 6 games: K, D, draw, draw, draw, D
- IBM stock up $18 billion

- Search: two-player zero-sum discrete finite games with perfect information.
News Aggregation and Summarization

- Automatically selects, summarizes, and arranges news from multiple sources
  - http://news.google.com

- Unsupervised machine learning: clustering
Navigation

- Goggle Maps, Bing Maps, MapQuest
- FedEx, UPS to plan package delivery

Search
Web Information Extraction

- Extract job info, free web text \(\rightarrow\) DB

- UW HAZY project: Extracts information from natural language text for knowledge base construction
- Fill in missing information
Collaborative Filtering

- Recommendations based on other users' behavior
  - e.g. Amazon
  - Unsupervised learning

- e.g. Netflix
Face Detection and Recognition

**Face Detection**

**Face Recognition**: Autotagging photos in Facebook, Flickr, Picasa, iPhoto, …
Face Recognition: Autotagging Photos in Facebook, Flickr, Picasa, iPhoto, …
Handwriting Recognition

- When you deposit a check at an ATM, handwriting recognition automatically “reads” the amount.
- When you mail a letter, the USPS automatically reads the address and zip code.
Flyable Cameras

- DJI Phantom 2 Vision Quadcopter
  - $1,200 (January 2014)
Autonomous Robots

- Key questions in mobile robotics
  - What is around me?
  - Where am I?
  - Where am I going?
  - How do I get there?

- Alternatively, these questions correspond to
  - **Sensor Interpretation**: what objects are in the vicinity?
  - **Position and Localization**: find your own position on a map (given or built autonomously) and position on road
  - **Map building**: how to integrate sensor information and your own movement?
  - **Path planning**: decide the actions to perform for reaching a target position.
Space Exploration Robots

Driving on Mars by Sojourner, Spirit, Opportunity, and Curiosity rovers
Cleaning Robots

- iRobot Roomba robot for vacuuming floors
Lawn Mowing Robots

Robomow
Mine Mapping and Rescue Robots
Driverless Vehicles

Cars, airplanes, helicopters, birds, insects
Driverless Cars
Driverless Cars: What’s Needed?

- **Car Information**
  - Position and orientation of car, velocity and turning rate of car

- **Environment Information**
  - Where is the road, curb, road signs, stop signs, other vehicles, pedestrians, bicyclists, …

- **Actions**
  - Velocity, steering direction, braking, …

- **Sensors**
  - Video cameras, radar, LIDAR, GPS, …
Driverless Cars: Sensors

- Video cameras
- LIDAR (depth/range) sensor
  - times how long it takes a beam of laser light to bounce off something
  - gives 3D info on environment to 5 cm accuracy
- Radar sensors on front and rear
- Position sensor on wheel
- GPS
- Inertial motion sensor (IMU)
- Position and orientation of vehicle updated in real-time with 50 cm position accuracy and 1/50 degree orientation accuracy
LIDAR-based Terrain
Google’s Driverless Car

Video camera on windscreen detects traffic lights and moving traffic

Rotating sensor on roof generates 3D map of surroundings

Radar sensors - three at the front and one at the back - help determine position

Two people in car - driver to take over in an emergency, and engineer to monitor software
The Future of Autonomous Driving?

• “In 20 years I will trust my autonomous car more than I trust myself”
  – Sebastian Thrun

• “It won’t truly be an autonomous vehicle until you instruct it to drive to work and it heads to the beach instead.”
  – Brad Templeton
**CAPTCHA**

**Completely Automated Public Turing test to tell Computers and Humans Apart**

- Yahoo!

  ![Yahoo CAPTCHA](image1.png)

- Google

  ![Google CAPTCHA](image2.png)
Data

• Data vs. Information
  – Data
    • Raw facts in any form
    • Distinct pieces of information, usually formatted in a special way
  – Information
    • A collection of facts organized in such a way that they have additional value beyond the value of the facts themselves
    • Processed data
Data

Data can exist in a variety of forms -- as numbers or text on pieces of paper, as bits and bytes stored in electronic memory, or as facts stored in a person's mind.

Strictly speaking, data is the plural of datum, a single piece of data
Knowledge

– Knowledge
  • An awareness and understanding of a set of information and how that information can be made useful to support a specific task

– Knowledge base
  • The collection of data, rules, procedures, and relationships that must be followed to achieve value or the proper outcome
What is Intelligence?

- Main Entry: **intelligence**
  - Pronunciation: in-'te-l&-j&n(t)s
  - Function: *noun*
  - Etymology: Middle English, from Middle French, from Latin *intelligentia*, from *intelligent-, intelligens* intelligent

- **1 a (1)**: the ability to learn or understand or to deal with new or trying situations: **REASON**; *also*: the skilled use of reason (2): the ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria (as tests)
  - b *Christian Science*: the basic eternal quality of divine Mind
  - c: mental acuteness: **SHREWDNESS**

- **2 a**: an *intelligent* entity; *especially*: **ANGEL**
  - b: *intelligent* minds or mind

- **3**: the act of understanding: **COMPREHENSION**

- **4 a**: **INFORMATION, NEWS**
  - b: information concerning an enemy or possible enemy or an area; *also*: an agency engaged in obtaining such information

- **5**: the ability to perform computer functions
What is Artificial Intelligence?

• Not just studying intelligent systems, but building them...

• Psychological approach: an intelligent system is a model of human intelligence

• Engineering approach: an intelligent system solves a sufficiently difficult problem in a generalizable way
What is Intelligence?
- The ability of a system to
- Perceive the environment
- Calculate & reason from the percepts
- Learn from experience
- Store and retrieve information from memory
- Solve problems, comprehend complex ideas
- Use natural language fluently
- Classify, generalize, and adapt to new situations
• Signs of Intelligence
• Perception
• Reasoning
• Learning
• Problem Solving
AI – Alternative Definitions

- **Elaine Rich and Kevin Knight**: AI is the study of how to make computers do things at which, at the moment, people are better.
- **Stuart Russell and Peter Norvig**: [AI] has to do with smart programs, so let's get on and write some.
- **Claudson Bornstein**: AI is the science of common sense.
- **Douglas Baker**: AI is the attempt to make computers do what people think computers cannot do.
- **Astro Teller**: AI is the attempt to make computers do what they do in the movies.
• What is involved in an AI Course?
  • Searching
  • Logic
  • Knowledge Representation
  • Planning
  • Machine Learning
A Bit of AI History (section 1.3)

- **Gestation (1943-1955)**
  - Early learning theory, first neural network, Turing test
  - McCulloch and Pitts artificial neuron, Hebbian learning

- **Birth (1956)**
  - Name coined by McCarthy
  - Workshop at Dartmouth

- **Early enthusiasm, great expectations (1952-1969)**
  - GPS, physical symbol system hypothesis
  - Geometry Theorem Prover (Gelertner), Checkers (Samuels)
  - Lisp (McCarthy), Theorem Proving (McCarthy), Microworlds (Minsky et. al.)
  - “neat” (McCarthy @ Stanford) vs. “scruffy” (Minsky @ MIT)
A Bit of AI History (section 1.3)

- Dose of Reality (1966-1973)
  - Combinatorial explosion

- Knowledge-based systems (1969-1979)

- AI Becomes an Industry (1980-present)
  - Boom period 1980-88, then AI Winter

- Return of Neural Networks (1986-present)

- AI Becomes a Science (1987-present)
  - SOAR, Internet as a domain
What is Artificial Intelligence? (again)

- **Systems that think like humans**
  - Cognitive Modeling Approach
  - “The automation of activities that we associate with human thinking...”
  - Bellman 1978

- **Systems that act like humans**
  - Turing Test Approach
  - “The art of creating machines that perform functions that require intelligence when performed by people”
  - Kurzweil 1990

- **Systems that think rationally**
  - “Laws of Thought” approach
  - “The study of mental faculties through the use of computational models”
  - Charniak and McDermott

- **Systems that act rationally**
  - Rational Agent Approach
  - “The branch of CS that is concerned with the automation of intelligent behavior”
  - Lugar and Stubblefield
Acting Humanly

- The Turing Test (1950)
  - Can machines think?
  - Can machines behave intelligently?

- Operational test for intelligent behavior
  - The Imitation Game
Acting Humanly

• Turing Test (cont)
  – Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
  – Anticipated all major arguments against AI in following 50 years
  – Suggested major components of AI: knowledge, reasoning, language understanding, learning

• Problem!
  – The turning test is not reproducible, constructive, or amenable to mathematical analysis
Thinking Humanly

• 1960’s cognitive revolution
• Requires scientific theories of internal activities of the brain
  – What level of abstraction? “Knowledge” or “Circuits”
  – How to validate?
    • Predicting and testing behavior of human subjects (top-down)
    • Direct identification from neurological data (bottom-up)
• Cognitive Science and Cognitive Neuroscience
  – Now distinct from AI
Thinking Rationally

- Normative (or prescriptive) rather than descriptive
- Aristotle: What are correct arguments / thought processes?
- Logic notation and rules for derivation for thoughts
- Problems:
  - Not all intelligent behavior is mediated by logical deliberation
  - What is the purpose of thinking? What thoughts should I have?
Acting Rationally

• Rational behavior
  – Doing the right thing

• What is the “right thing”
  – That which is expected to maximize goal achievement, given available information

• We do many (“right”) things without thinking
  – Thinking should be in the service of rational action
AI Definition

- The exciting new effort to make computers thinks ... *machine with minds*, in the full and literal sense” (Haugeland 1985)
- The automation of activities that we associate with human thinking, activities such as decision-making, problem solving, learning,...(Bellman, 1978)

Think Like Humans
AI Definition

• “The art of creating machines that perform functions that require intelligence when performed by people” (Kurzweil, 1990)

• “The study of how to make computers do things at which, at the moment, people do better”, (Rich and Knight, 1991)

Act Like Humans
AI Definition

- “The study of mental faculties through the use of computational models”, (Charniak et al. 1985)
- “The study of the computations that make it possible to perceive, reason and act”, (Winston, 1992)

Think Rationally
AI Definition

- “Computational Intelligence is the study of the design of intelligent agents” (Poole et al, 1998)
- “AI....is concerned with intelligent behavior in artifact”, (Nilsson, 1998)

Act Rationally
How to Achieve AI?

- Acting humanly
- Thinking humanly
- Acting rationally
- Thinking rationally
• To be intelligent, a program should simply act like a human

http://en.wikipedia.org/wiki/Turing_test

Alan Turing
1912-1954
The Turing Test - Example

http://aimovie.warnerbros.com

http://www.ai.mit.edu/projects/infolab/

slide mostly borrowed from Laurent Itti
The Turing Test - Example


slide mostly borrowed from Laurent Itti
The Turing Test - Example

Hello, my name is Chatbot. What's your name?

Laurent

Nice to meet you Laurent.

Can you pass the Turing test?

http://www.ai.mit.edu/projects/infolab/

http://aimovie.warnerbros.com

slide mostly borrowed from Laurent Itti
The Turing Test - Example

Chatbot: Hello, my name is Chatbot. What's your name?
You: Laurent

Chatbot: Nice to meet you Laurent.
You: Can you pass the Turing test?

Chatbot: You be the judge of that, Laurent.
You: tell me about yourself


slide mostly borrowed from Laurent Itti
The Turing Test - Example

http://aimovie.warnerbros.com
http://www.ai.mit.edu/projects/infolab/

slide mostly borrowed from Laurent Itti
Acting Humanly

• To pass the Turing test, the computer/robot needs:
  – **Natural language processing** to communicate successfully.
  – **Knowledge representation** to store what it knows or hears.
  – **Automated reasoning** to answer questions and draw conclusions using stored information.
  – **Machine learning** to adapt to new circumstances and to detect and extrapolate patterns.

  – These are the main branches of AI.
Acting Humanly: The Turing Test

http://en.wikipedia.org/wiki/Turing_test

- To be intelligent, a program should simply act like a human

+ physical interaction => Total Turing Test
- Recognize objects and gestures
- Move objects

Alan Turing
1912-1954
Acting Humanly – for Total Turing

- To pass the Turing test, the computer/robot needs:
  - **Natural language processing** to communicate successfully.
  - **Knowledge representation** to store what it knows or hears.
  - **Automated reasoning** to answer questions and draw conclusions using stored information.
  - **Machine learning** to adapt to new circumstances and to detect and extrapolate patterns.
  - **Computer vision** to perceive objects. (Total Turing test)
  - **Robotics** to manipulate objects and move. (Total Turing test)

- These are the main branches of AI.
Thinking Humanly

• Real intelligence requires thinking → think like a human!
• First, we should know how a human think
  – Introspect ones thoughts
  – Physiological experiment to understand how someone thinks
  – Brain imaging – MRI...
• Then, we can build programs and models that think like humans
  – Resulted in the field of cognitive science: a merger between AI and psychology.
Problems with Imitating Humans

• The human thinking process is difficult to understand: how does the mind raise from the brain? Think also about unconscious tasks such as vision and speech understanding.

• Humans are not perfect! We make a lot of systemic mistakes:
Thinking Rationally

• Instead of thinking like a human: think rationally.
• Find out how correct thinking must proceed: the laws of thought.
• Aristotle syllogism: “Socrates is a man; all men are mortal, therefore Socrates is mortal.”
• This initiated logic: a traditional and important branch of mathematics and computer science.
• Problem: it is not always possible to model thought as a set of rules; sometimes there uncertainty.
• Even when a modeling is available, the complexity of the problem may be too large to allow for a solution.
Acting Rationally

- Rational agent: acts as to achieve the best outcome
- Logical thinking is only one aspect of appropriate behavior: reactions like getting your hand out of a hot place is not the result of a careful deliberation, yet it is clearly rational.
- Sometimes there is no correct way to do, yet something must be done.
- Instead of insisting on how the program should think, we insist on how the program should act: we care only about the final result.
- Advantages:
  - more general than “thinking rationally” and more
  - Mathematically principled; proven to achieve rationality unlike human behavior or thought
Acting Rationally

This is how birds fly

Humans tried to mimic birds for centuries

This is how we finally achieved “artificial flight”
Relations to Other Fields

- **Philosophy**
  - Logic, methods of reasoning and rationality.

- **Mathematics**
  - Formal representation and proof, algorithms, computation, (un)decidability, (in)tractability, probability.

- **Economics**
  - Utility, decision theory (decide under uncertainty)

- **Neuroscience**
  - Neurons as information processing units.

- **Psychology/Cognitive Science**
  - How do people behave, perceive, process information, represent knowledge.

- **Computer engineering**
  - Building fast computers

- **Control theory**
  - Design systems that maximize an objective function over time

- **Linguistics**
  - Knowledge representation, grammar

slide mostly borrowed from Max Welling
AI History

• Gestation of AI (1934 - 1955)
  – In 1943, proposed a binary-based model of neurons
  – Any computable function can be modeled by a set of neurons
  – A serious attempt to model brain
  – 1950, Turing’s “Computing Machinery and Intelligence”: turing test, reinforcement learning and machine learning

• The Inception of AI (1956)
  – Dartmouth meeting to study AI
  – an AI program “Logic Theorist” to prove many theorems

• Early Enthusiasm and great Expectation (1952-1969)
  – General Problem Solver imitates the human way of thinking
  – LISP (AI programming language) was defined
  – 1965, Robinson discovered the resolution method – logical reasoning

• AI Winter (1966-1973)
  – Computational intractability of many AI problems
  – Neural Network starts to disappear
AI History

- Knowledge-based systems (1969-1979)
  - Use domain knowledge to allow for stronger reasoning
- Becomes an Industry (1980-now)
  - Digital Equipment Corporation selling R1 “expert system”
  - From few million to billions in 8 years
- The return of neural network (1986-now)
  - With the back-propagation algorithm
- AI adopts scientific method (1987-now)
  - More common to base theorems on previous ones or rigorous evidence rather than intuition
  - Speech recognition and HMM
- Emergence of intelligent agent (1995-now)
  - Search engines, recommender systems,....
- Availability of very large data sets (2001 – now)
  - Worry more about the data
The State of the Art

- Robotics Vehicle
  - DARPA Challenge
- Speech Recognition
  - United Airlines
- Autonomous Planning and Scheduling
  - Remote Agent: Plan and control spacecraft
  - MAPGEN: daily planning of operations on NASA’s exploration Rover
- Game Playing
  - IBM Deep Blue
- Spam Fighting
- Logistic Planning
  - DART – Dynamic Analysis and Replacing Tool
  - Gulf War 1991
  - To plan the logistic for transportation of 50k vehicles, cargo and people
  - Generated in hour a plan that could take weeks
- Robotics
- Machine Translation
  - Statistical models
Applied Areas of AI

- Heuristic Search
- Computer Vision
- Adversarial Search (Games)
- Fuzzy Logic
- Natural Language Processing
- Knowledge Representation
- Planning
- Learning
Examples

- Playing chess
- Driving on the highway
- Mowing the lawn
- Answering questions
- Recognizing speech
- Diagnosing diseases
- Translating languages
- Data mining
Heuristic Search

• Very large search space
  – Large databases
  – Image sequences
  – Game playing

• Algorithms
  – Guaranteed best answer
  – Can be slow – literally years

• Heuristics
  – “Rules of thumb”
  – Very fast
  – Good answer likely, but not guaranteed!

• Searching foreign intelligence for terrorist activity.
Computer Vision

- Computationally taxing
  - Millions of bytes of data per frame
  - Thirty frames per second

- Computers are scalar / Images are multidimensional

- Image Enhancement vs. Image Understanding

- Can you find the terrorist in this picture?
Adversarial Search

• Game theory...
  – Two player, zero sum – checkers, chess, etc.
• Minimax
  – My side is MAX
  – Opponent is MIN
• Alpha-Beta
  – Evaluation function...“how good is board”
  – Not reliable...play game (look ahead) as deep as possible and use minimax.
  – Select “best” backed up value.
• Where will Al-Qaeda strike next?
Adversarial Search

MIN

MAX

1

2

3 4 5

6

7 8 9

1-0=1 1-2=-1 1-1=0

*91*

0 10

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Example: Tic Tac Toe #1

- Precompiled move table.

- For each input board, a specific move (output board)

- Perfect play, but is it AI?
Example: Tic Tac Toe #2

- Represent board as a magic square, one integer per square
- If 3 of my pieces sum to 15, I win
- Predefined strategy:
  - 1. Win
  - 2. Block
  - 3. Take center
  - 4. Take corner
  - 5. Take any open square
Example: Tic Tac Toe #3

• Given a board, consider all possible moves (future boards) and pick the best one

• Look ahead (opponent’s best move, your best move...) until end of game

• Functions needed:
  – Next move generator
  – Board evaluation function

• Change these 2 functions (only) to play a different game!
Fuzzy Logic

• Basic logic is binary
  – 0 or 1, true or false, black or white, on or off, etc...

• But in the real world there are of “shades”
  – Light red or dark red
  – 0.64756

• Membership functions
Fuzzy Logic

Appetite

Light

Moderate

Heavy

Calories Eaten Per Day

Membership Grade

0 1

Linguistic Variable

Linguistic Values

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Natural Language Processing

- Speech recognition vs. natural language processing
  - NLP is after the words are recognized
- Ninety/Ten Rule
  - Can do 90% of the translation with 10% time, but 10% work takes 90% time
- Easy for restricted domains
  - Dilation
  - Automatic translation
  - Control your computer
    - Say “Enter” or “one” or “open”
  - Associative calculus
- Understand by doing
Natural Language Processing

“The big grey dog”

Net for Basic Noun Group

Net for Prepositional Group

“by the table in the corner”

Net for Basic Noun Group

“The big grey dog by the table in the corner”

Net for Basic Noun Group

26-Feb-19
AI: Chapter 1: Introduction
Knowledge Representation

• Predicate Logic
  – On(table, lamp)
  – In(corner, table)
  – Near(table, dog)
  – Prolog

• Graph Based
  – Semantic Networks
  – Frames

• Rule Based
  – Expert Systems
Planning

• Robotics
  – If a robot enters a room and sits down, what is the “route”.

• Closed world
• Rule based systems
• Blocks world
Planning

- **Pickup(x)**
  - Ontable(x), clear(x), handempty(),
  - Holding(x)
- **Putdown(x)**
  - Holding(x)
  - Ontable(x), clear(x), handempty()
- **Stack(x, y)**
  - Holding(x), clear(y)
  - Handempty(), on(x, y), clear(x)
- **Unstack(x, y)**
  - Handempty(), clear(x), on(x, y)
  - Holding(x), clear(x)

Goal: \([\text{On}(B, C) \land \text{On}(A, B)]\)
Learning

- Neural Networks
- Evolutionary Computing
- Knowledge in Learning
- Reinforcement Learning