CS 540

Introduction to Artificial Intelligence

Chuck Dyer
Fall 2019

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The Waiting List

- This class is currently completely full
- If you are enrolled but decide to drop, please do so ASAP
- More students from the waiting list may be admitted, but **priority will be given to CS majors who are close to graduation**

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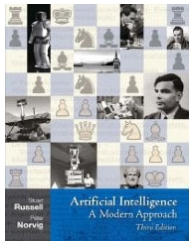
Course Information

http://pages.cs.wisc.edu/~dyer/cs540.html

- Textbook:



Artificial Intelligence: A Modern Approach, **3rd edition**, 2010

- Powerpoint slides
- **Piazza** for Q & A (you *cannot* be anonymous to instructor)
- **Canvas** for homework electronic hand-in

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Instructor

Chuck Dyer
- Chuck, Prof. Dyer, Dr. Dyer
- Ph.D., University of Maryland
- M.S., UCLA
- B.S., Stanford
- Hometown: San Diego
- Research: Computer vision
- Fun: Running (PRs: 4:22 mile, 2:41 marathon)
- Office Hours: TR 2:30 – 4:00 p.m.

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Teaching Assistants

Yunang Chen

Mehmet Demirel

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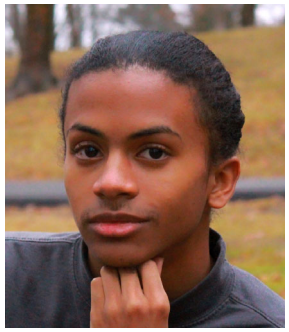
Teaching Assistants

Bastin Joseph

Ethan Sayles



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Teaching Assistants

Rohit Sharma

Young Wu

7

Peer Mentors

Tanmay Bagaria

Shrehit Goel

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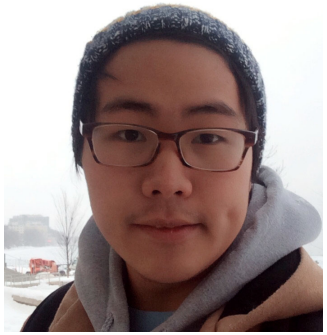
Peer Mentors

Steven Kan



Atharva Kulkarni

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Peer Mentors

Tushar Narang

Suyan Qu

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Prerequisites

- JAVA programming
- Data structures (CS 300 or 367)
- Calculus (Math 211, 217, 221 or 275)
- Curiosity, enthusiasm and dedication

- **Other Helpful Topics (though not prereqs)**
  - Discrete Math (CS/Math 240)
  - Probability and statistics (e.g., Stat 324)
  - Linear algebra (e.g., Math 340)
  - Logic

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Workload

- 5 homework assignments (40% of grade)
  - A programming problem and written problems
  - Due time: 11:59 p.m. on due date
  - Late penalties:
    - 1 day: 10% off (of total possible points)
    - 2 days: 25% off
    - 3 days: 50% off
    - 4 or more days: 100% off
    - **3 "free late days"**

- 2 examinations (each 30% of grade)
  - **Midterm: Thursday, October 24, 7:15 – 9:15 p.m.**
  - **Final: Tuesday, December 17, 12:25 – 2:25 p.m.**

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Things to Do

- Look at the course web page:
  - pages.cs.wisc.edu/~dyer/cs540
- Activate your CS instructional Linux workstation account
  - If you had an account in the spring, you do *not* need to re-activate your account; use same CS login
  - Otherwise, go to https://csl.cs.wisc.edu and click "Activate Account"
- Sign up on Piazza
  - piazza.com/wisc/fall2019/cs540/home
- Review Java
- Skim Chapters 1 and 2 (focusing on 1.1, 2.1, 2.2, 2.3), and read **3.1 – 3.4**

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Course Syllabus (approximate)

- Problem solving as search (4 weeks)
  - Heuristic search, game playing, …
- Machine learning (5 weeks)
  - Unsupervised and supervised
- Probabilistic reasoning (3 weeks)
- Speech recognition (1 week)
- Computer vision (1 week)
- Time permitting: Representation and inference using logic (1 week)

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Sample 540 Programming Projects

- Map route finding
- Puzzle solving
- Game playing: Checkers, Backgammon, Othello
- Face detection and recognition from images
- Character recognition from images
- E-mail spam detection
- Breast cancer diagnosis
- Semantic spell correction (e.g., "two" vs. "to" vs. "too")
- Movie rating system using sentiment analysis of text to extract subjective information such as "likes" or "dislikes"

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What is AI?

- "AI is the study of complex information processing problems that often have their roots in some aspect of biological information processing. The goal of the subject is to identify solvable and interesting information processing problems, and solve them."
  − David Marr
- The intelligent connection of perception to action
  − Rodney Brooks
- Actions that are indistinguishable from a human's
  − Alan Turing

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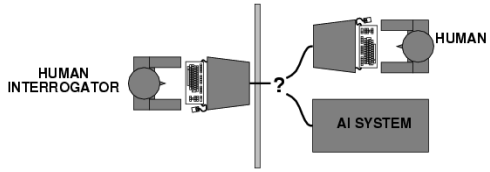
The Turing Test

- A. Turing, "Computing machinery and intelligence," 1950
- Can machines think? → Can we tell if a conversation is by a machine and not a human?
- text in, text out
- Operational test for intelligent behavior: aka the **Imitation Game**



- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Suggested major components of AI: knowledge rep., reasoning, natural language processing, learning

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Different Approaches to AI

- Philosophy, ethics, religion
  - What is intelligence?
- Cognitive science, neuroscience, psychology, linguistics
  - Understand natural forms of intelligence
  - Learn principles of intelligent behavior
- Engineering
  - Can we build intelligent devices and systems?
  - Autonomous and semi-autonomous systems for replicating human capabilities, enhancing human capabilities, improving performance, etc.

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Some Successful AI Applications

1. Language translation services (Google)
2. Translating Telephone (Skype)
3. News aggregation and summarization (Google)
4. Speech recognition (Nuance)
5. Song recognition (Shazam)
6. Face recognition (Recognizr, Google, …)
7. Image recognition (Google)
8. Question answering (Apple Siri, IBM Watson, …)
9. Chess playing (IBM Deep Blue)
10. 3D scene modeling from images (Microsoft Photosynth)
11. Driverless cars (Google)
12. Traffic prediction (Inrix)

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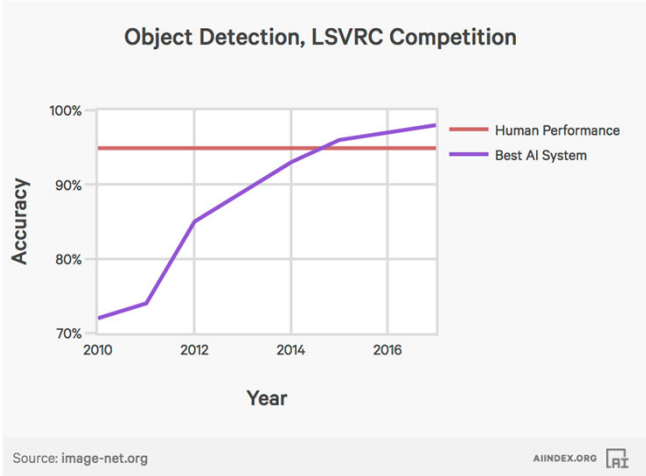

Object detection in images in the "Large Scale Visual Recognition Challenge" Competition

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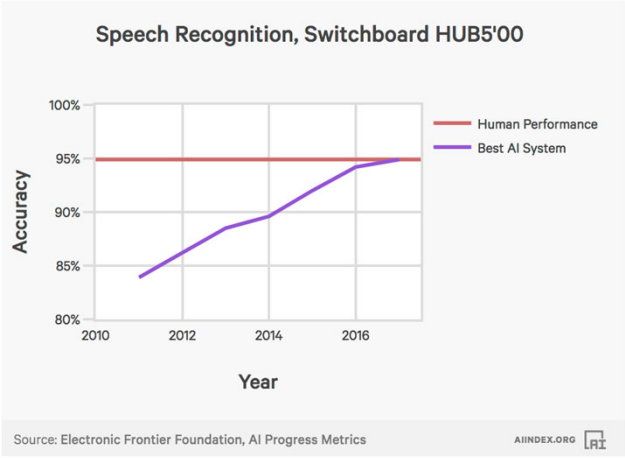

Recognize speech from phone call audio

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AI is Hard

- AI problems often involve large, complex data
  - Speech, images, natural languages, genomic data, …
  - What are the right primitives to use?
  - Data are often noisy, unstructured and have missing values
- Computationally (NP-) hard
- Very hard to define general, computational "competence theories" for specific tasks that say ***what*** is computed and ***why*** (***what*** to compute)
- Need algorithms that use domain-specific knowledge and constraints with incomplete models, while being time and space constrained, stable, and robust (***how*** to compute)

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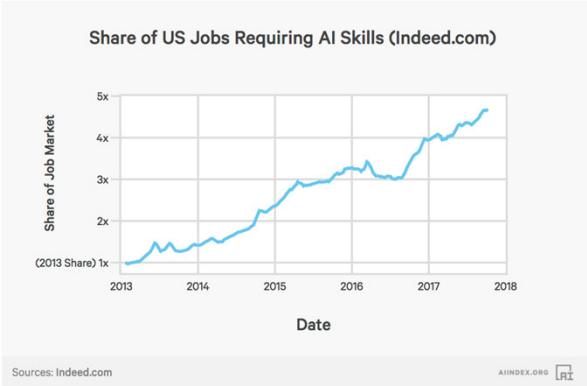
AI is Important



See: *Artificial Intelligence Index, 2017 Annual Report*

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AI Paradigm

- **Develop *general*, *efficient, satisficing* (i.e., acceptably good) 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:

       $f(x) = 10 * \text{QueryMatch}(x) + 3 * \text{PageRank}(x)$
  2. Given a formal model, develop an algorithm for solving the task efficiently

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AI Today

- A set of "tools" for computing a variety of useful classes of model types that represent information extracted from raw input data, and use associated algorithms to "solve" specific tasks
  - Neural networks, hidden Markov models, Bayesian networks, heuristic search, logic, …
- There's no magic in AI. It's all about models (i.e., representation), probability, statistics, optimization, and algorithms

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Models To Be Studied in CS 540

- **State-based Models (Search, Planning)**
  - Solutions are defined as a *sequence of steps*
  - Model a task as a graph of states and a solution as a path in the graph
  - A state captures all the relevant information about the past in order to act in the future
  - Apps: navigation, games
  - State-space graphs
- **Parametric, Reflex Models (Machine Learning)**
  - Given a set of (input, output) pairs of training data, learn a set of parameters that will map input to output for *future data*
  - Apps: classification, regression
  - Decision trees, neural networks, SVMs, k-NN

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Models to be Studied in CS 540

- **Variable-based Models (Uncertainty)**
  - Solution is an assignment of values for a set of variables
  - Apps: Sudoku, speech recognition, face recognition
  - Constraint satisfaction, Bayesian networks, Hidden Markov Models, CNNs
- **Logic-based Models (Logic)**
  - Symbolic representation of classes of objects
  - Deductive reasoning
  - Apps: Question answering systems, natural language understanding
  - Propositional logic, First-order logic

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Some AI Applications

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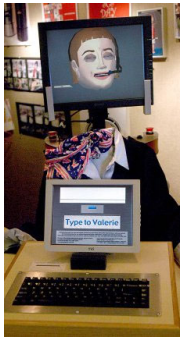
Natural Language Understanding: Chatbots



Valerie

ALICE: 2004 Loebner Prize winner

ELIZA: psychotherapist

Valerie: CMU Robot Receptionist

Natural language processing, pattern matching

Loebner Prize, awarded annually to best AI program

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A.L.I.C.E. Chatbot

www.alicebot.org

2004 Loebner Prize winner

Jerry: My name is jerry.
ALICE: Hey jerry.
Jerry: Do you know Turing?
ALICE: A brilliant and tragic figure in the history of computer science.
Jerry: Who else do you know?
ALICE: Hugh Loebner, Robby Garner, and Steven Spielberg
Jerry: Which film do you like?
ALICE: My favorite movie is Teknolust. Have you seen it?
Jerry: No.
ALICE: I would recommend you check it out.
Jerry: What is it about?
ALICE: Science fiction.
Jerry: Do you remember my name?
ALICE: Your name is Jerry, seeker.

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Speech Recognition

- "say your card number" (very small vocabulary, high accuracy needed)
- call routing, airline reservations: "how can I help you?" (large vocabulary, low accuracy)
- dictation (large vocabulary, high accuracy)

IBM
ViaVoice

Nuance Dragon
NaturallySpeaking

- Hidden Markov Models, neural networks, heuristic search, …

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Machine Translation

The spirit is willing but the flesh is weak. [*Bible*, Matthew 26:41]

Дух охотно готов но плоть слаба	Spirit is willingly ready but flesh it is weak
精神是愿意的但骨肉是微弱的	The spirit is wants but the flesh and blood is weak
精神は喜んでであるが、肉は弱い	Mind is rejoicing,, but the meat is weak
El alcohol está dispuesto pero la carne es débil	The alcohol is arranged but the meat is weak
الكحول مستعدّة غير أنّ للحمة ضعيفة.	The alcohol is ready nevertheless the meat is weak.

- Statistical machine translation models

translate.google.com

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Question Answering Systems

Apple Siri

Speech recognition and language understanding

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Question Answering

- 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

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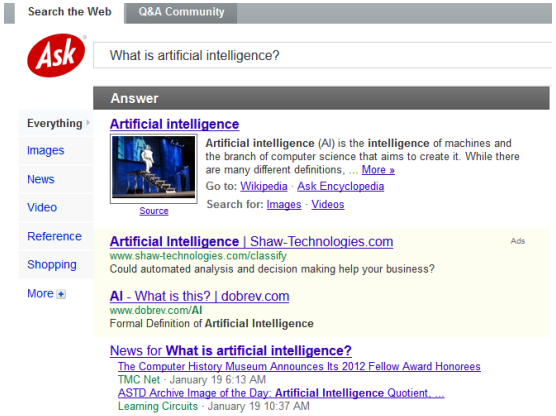
Question Answering



- Shallow natural language processing, heuristics

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Game Playing: Chess

- IBM Deep Blue vs. Kasparov, 1996
- 6 games: K, D, draw, draw, draw, D

- Search: two-player zero-sum discrete finite games with perfect information

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Game Playing: Go

Google AlphaGo beat Korean grandmaster Lee Sedol 4 games to 1 in 2016

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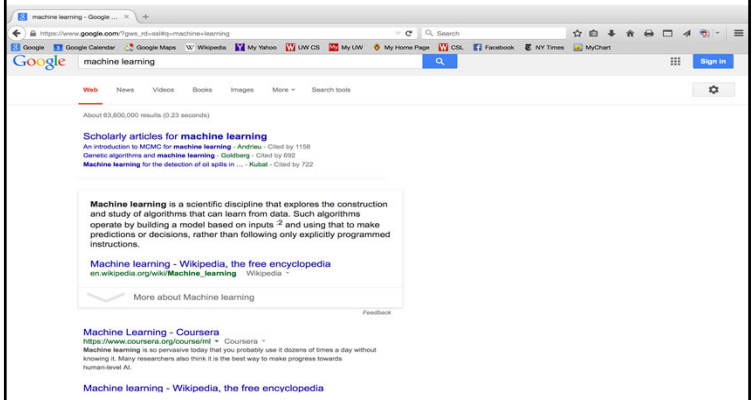
Web Page Ranking



- Google PageRank uses Machine Learning

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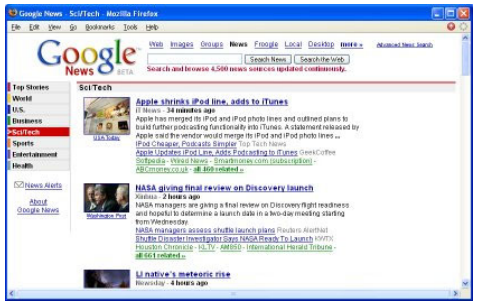
News Aggregation and Summarization

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



- Unsupervised machine learning: clustering

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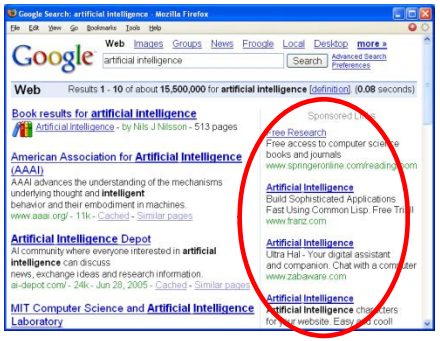
Web Advertising

- "Sponsored links"
- Show ads based on relevance and money



- Online algorithm, game, auction, multiple agents

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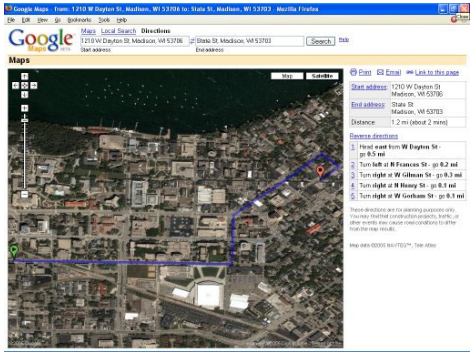
Navigation

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



- Search

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Collaborative Filtering

- Recommendations based on other users' behavior
- Amazon

- Netflix

- Unsupervised learning

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Visual Search: Google Goggles

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Face Detection in cameras for auto focusing

Also blink and smile detection!

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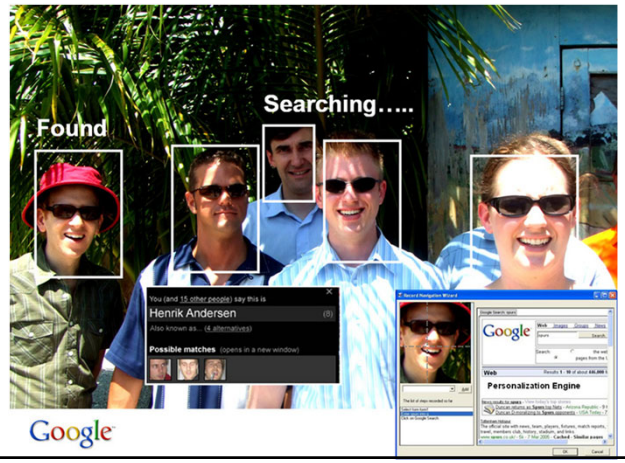
Face Recognition: Autotagging Photos in Facebook, Flickr, Picasa, iPhoto, …



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Face ID on iPhone X

- Unlocks phone using infrared and visible light images to uniquely identify your face

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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

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Body Part Detection and Tracking

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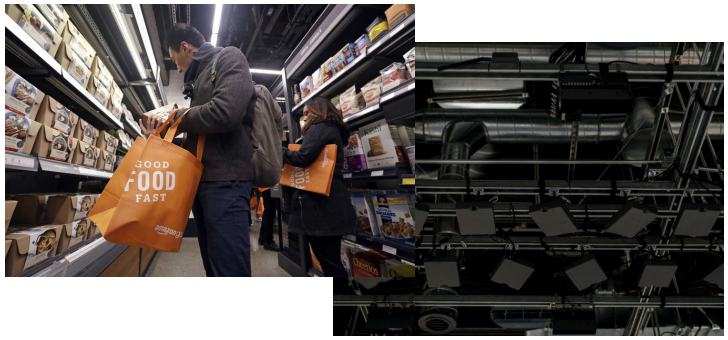
Cashierless Checkout

- Amazon Go
  - Sensors on shelves and ceiling cameras
  - Computer vision and machine learning detect items



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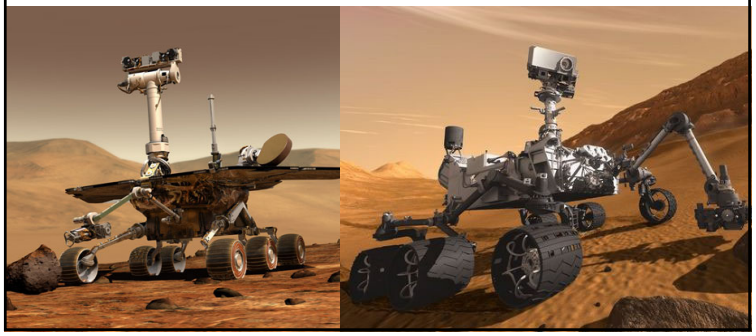
Space Exploration Robots

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



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Physical Assistants: Robots to Help the Elderly and Impaired

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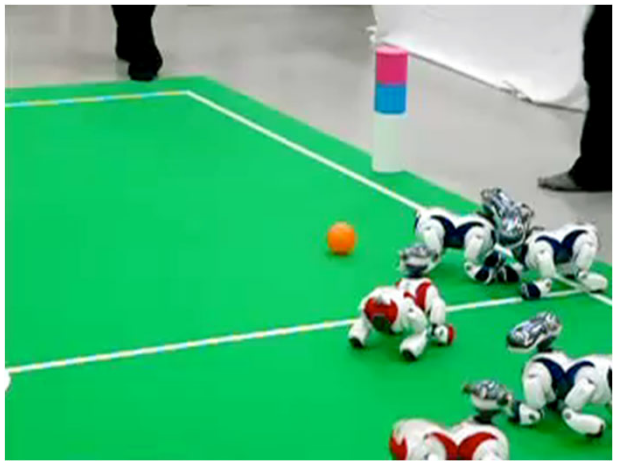
Robots Playing Soccer



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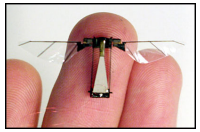
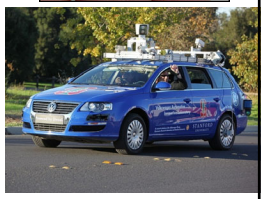
Driverless Vehicles

Cars, airplanes, helicopters, birds, insects





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Driverless Cars

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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, …

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Driverless Cars

DARPA Grand Challenges

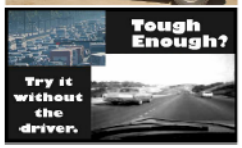
DARPA Grand Challenge I
Barstow to Primm
March 13, 2004

142 miles
10 hours

DARPA Grand Challenge II
Desert Classic
October 8, 2005

132 miles
10 hours

DARPA Grand Challenge III
Urban Challenge
November 3, 2007



60 miles
6 hours

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2005 DARPA "Grand Challenge" Race

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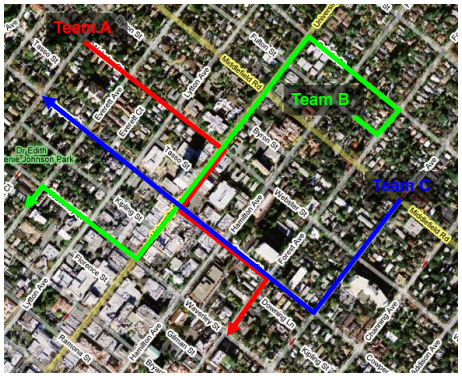
The 2007 "Urban Challenge"



- Driving in urban environments
- Obey all traffic laws
- Accommodate road blockages, other vehicles, etc.

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Google's Driverless Car

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Google's Driverless Car (2011)

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Autonomous Parking

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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

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Harvesting Human Intelligence:

Anti-AI: CAPTCHA

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Anti-AI

- Some AI problems are very hard
  - Vision, natural language understanding, …
- What do you do?
  - Give up?
  - Bang your head really hard?
  - Important lesson in life:
    - Turn hardness into something useful!
- Very hard for machine, trivial for human

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CAPTCHA

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CAPTCHA

Completely **A**utomated **P**ublic **T**uring test to tell **C**omputers and **H**umans **A**part

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CAPTCHA

- The "anti-Turing test"
- Tell human and machines apart, automatically
  - Deny spam-bots free email registration
  - Protect online poll from vote-bots
- By asking an "AI-complete" question

Random string: oamg → Distorted image:  → What do you see?

- Also audio Captcha's, e.g., superimposed speakers
- http://www.captcha.net/

[Luis von Ahn, IAAI/IJCAI 2003 keynote]

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Summary

AI *is* magical, but there's no magic in AI

It's about designing good models, and using optimization, probability, statistics, logic, etc. to develop efficient algorithms using (lots of complex) data

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