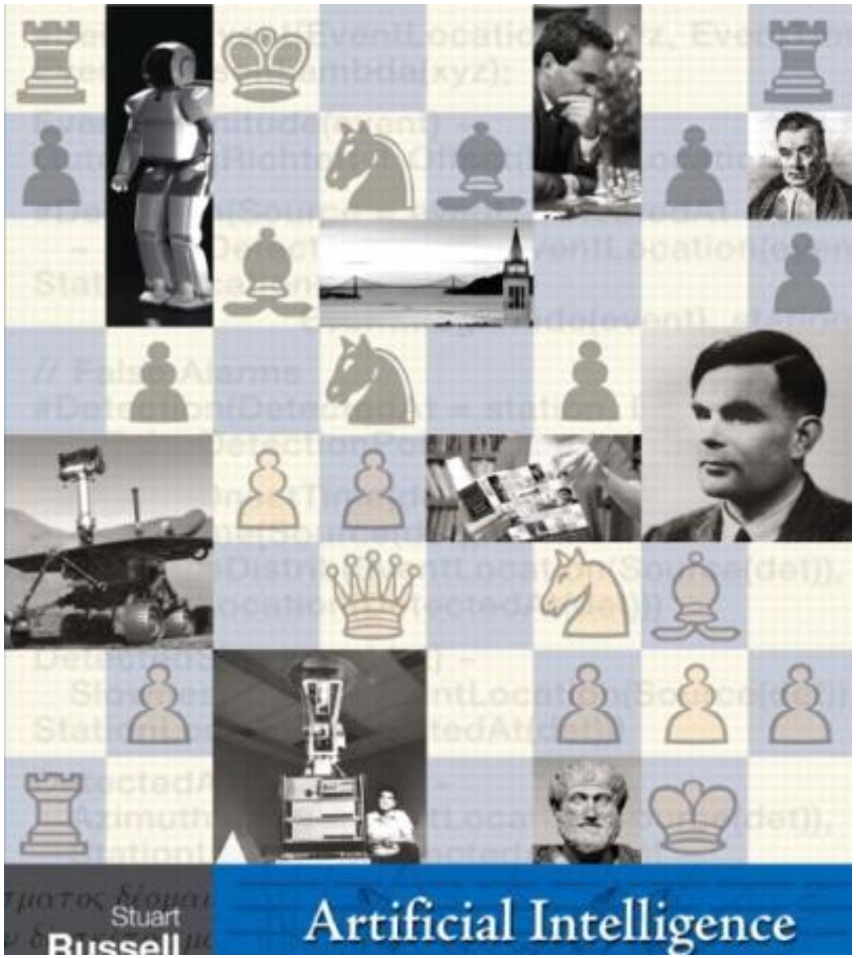
Lecture 1: Introduction to Artificial Intelligence
Russell and Norvig Chapters 1-2



CS-4820/5820

Tu/Th 12:15 PM-1:30 PM

Room: Centennial Hall 106

Instructor: Adham Atyabi

Office: Engineering 194

Office Hours: Mon 9:00 AM-14:00 PM.

Email: aatyabi@uccs.edu

Teaching Assistant: Ali Al Shami (aalshami@uccs.edu)

Preliminary discussions

Let’s check Canvas

Disclosure

- This course is inspired by Prof Jugal Kalita's teachings of the course in previous years at UCCS
- This course is also inspired by Prof Stuart Russell's lecture/presentation.

A Little about myself

- **Adham Atyabi**
  - PhD Flinders University of South Australia
  - Assistant Professor, Department of Computer science, University of Colorado Colorado Springs (Aug, 2019)

- **Contact Information**
  - Office: Eng 243
  - Phone 719-255-3772

- **Research Interests**
  - Cognitive and Computational Neuroscience
    - ***EEG-based Autism biomarker analysis***
    - ***functional Near Infrared Spectroscopy (fNIRS)-based Autism biomarker analysis***
    - ***EEG based Brain Computer Interface (BCI).***
  - Eye Tracking and Image Processing
  - Machine Learning
  - Evolutionary Optimization
  - Swarm and Cognitive Robotics
  - Autonomous Mission Planning and Management

My Journey -1

- **2003: BSc in Computer Engineering (Software) from Azad University of Mashhad - Iran:**
  - Chromosome segmentation and analysis
  - Thesis: “Imitation of human speech”

- **2009: MSc by Research in Information Technology and Computer Science from Multimedia University - Malaysia**
  - Thesis: “Navigating agents in Uncertain Environments using Particle Swarm Optimization”

- **2013: PhD in Computer Science under EIPRS scholarship from Flinders University - Australia**
  - Project manager of Magician team in Magic 2010 robotics challenge
  - University Relation Manager of Young IT- ACS (Australian Computer Society)
  - RA in Austalk Project
  - Thesis: “Evolutionary Optimization of Brain Computer Interface: Doing More with Less”

My Journey -2

- **Jul 2013 - Mar 2016:** 1st Postdoc at ASAR center (Autonomous Systems and Advance Robotics) at Salford University Manchester, UK:
  - Gamma Program
  - AZUR Challenge
  - Working with PhD and MSc students, teaching AI in MSc classes, ….

- **Mar-Oct 2016:** 2nd Postdoc at Yale Child Study Center, Yale University, New Haven, USA
  - Autism Biomarkers Consortium for Clinical Trials (ABCCT)

- **Oct 2016- Mar 2019 :** 3rd Postdoc at Seattle Children's Innovative Technologies Lab (SCITL) and University of Washington
  - Still ABCCT + many others

- **Mar 2019 – Aug 2019:** Research Scientist at SCITL.

Our next class on Thursday 28th (08/28/2025) will be **cancelled**.

We will hold a makeup **class online via MS Teams** on Saturday 30st of August at 12:15pm-13:30pm

Outline

- What is AI?
- A brief history
- The state of the art

What is AI?

Systems that think like humans	Systems that think rationally
Systems that act like human	Systems that act rationally

- Artificial Intelligence (AI) is usually defined as the science of making computers do things that require intelligence when done by humans.
- AI is the study of ideas that enable computers to be intelligent
- AI is the branch of computer science that is concerned with the automation of intelligent behavior (Luger 2009).

What is AI? (cont …)

Some attempted definitions are as follows:

- “The exciting new effort to make computers think ... machines with minds , in the full and literal sense”.

Haugeland, J. (Ed.). 1985. Artificial Intelligence: The Very Idea . MIT

- “The automation of activities that we associate with human thinking, activities such as decision making, problem solving, learning ...”.

Bellman, R. E. (1978). An Introduction to Artificial Intelligence: Can Computers Think? Boyd & Fraser Publishing Company.

- “The study of mental faculties through the use of computational models ”.

Charniak, E. and Mcdermott , D. (1985). Introduction to Artificial Intelligence . Addison Wesley.

- “The study of the computations that make it possible to perceive, reason , and act ”.

Winston, P. H. (1992). Artificial Intelligence (Third edition). Addison Wesley.

What is AI? (cont …)

- The art of creating machines that perform functions that require intelligence when performed by people”.

Kurzweil, R. (1990). The age of Intelligent Machines . MIT

- “The study of how to make computers do things at which, at the moment, people are better”.

Rich, E. Knight, K. (1991). Artificial Intelligence (Second edition). McGraw Hill.

- The branch of computer science that is concerned with the automation of intelligent behavior”.

Luger, G. F. (2009). Artificial Intelligence: Structures and Strategies for Complex Problem Solving (Sixth edition). Addison Wesley.

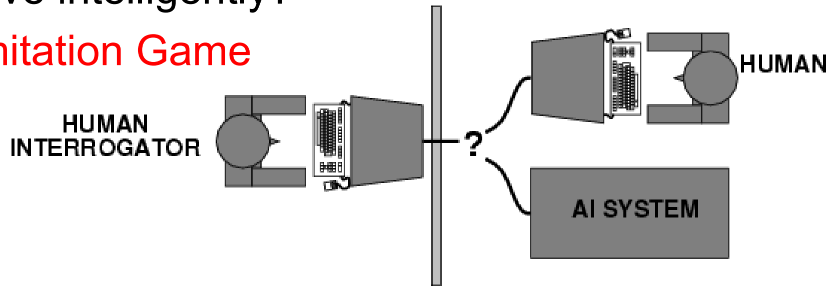
What is AI?

Thinking Humanly	Thinking Rationally
“[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . .” (Bellman, 1978) “The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense.” (Haugeland, 1985)	“The study of the computations that make it possible to perceive, reason, and act.” (Winston, 1992) “The study of mental faculties through the use of computational models.” (Charniak and McDermott, 1985)
Acting Humanly	**Acting Rationally**
“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 are better.” (Rich and Knight, 1991)	“Computational Intelligence is the study of the design of intelligent agents.” (Poole et al., 1998) “AI . . . is concerned with intelligent behavior in artifacts.” (Nilsson, 1998)

Acting humanly: The Turing test

Turing (1950) "Computing machinery and intelligence":

- "Can machines think?"→"Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game
- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes



- How Turing Test works:

  The interrogator asks any relevant question for a period of time of a computer and a human being at the same time. If based on the answers, the interrogator cannot distinguish between the two, the claim is that the computer has become intelligent.

- Turing test is not sidetracked by questions such as whether the computer uses appropriate internal processes, or if the machine is actually conscious.
- It eliminates any bias in favor of living organisms.
- But it doesn't provide any guidelines regarding what to ask and for how long.

Luger: Artificial Intelligence, 6th edition. © Pearson Education Limited, 2009

Problem:

- Turing test is **not** reproducible, constructive, or amenable to mathematical analysis

Thinking humanly: Cognitive Science

1960s "cognitive revolution": information-processing psychology

- Requires scientific theories of internal activities of the brain
  - How to validate? Requires
    1. ***Predicting and testing behavior of human subjects (top-down)***
    2. ***Direct identification from neurological data (bottom-up)***
- Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI

Thinking rationally: Laws of Thought

Aristotle: what are correct arguments/thought processes?

- Several Greek schools developed various forms of logic: notation and rules of derivation for thoughts; may or may not have proceeded to the idea of mechanization
- The so-called logicist tradition within AI hopes to build on programs that can solve any solvable problem if described in logical notation and through this process create intelligent systems.
- Direct line through mathematics and philosophy to modern AI
- Problems:
  - Not all intelligent behavior is mediated by logical deliberation
  - What is the purpose of thinking? What thoughts should I have?

Acting rationally: rational agent

- Rational behavior: doing the right thing

- The right thing: that which is expected to maximize goal achievement, given the available information

- Doesn't necessarily involve thinking – e.g., blinking reflex – but thinking should be in the service of rational action

Rational agents

- An agent is an entity that perceives and acts
- This course is about designing rational agents
- Abstractly, an agent is a function from percept histories to actions:

$$[f: P^* \rightarrow A]$$

- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Caveat: computational limitations make perfect rationality unachievable

  → design best program for given machine resources

Brief History of AI

Lady Lovelace (1850s), the first computer programmer who wrote programs 100 years before there were computers to run them

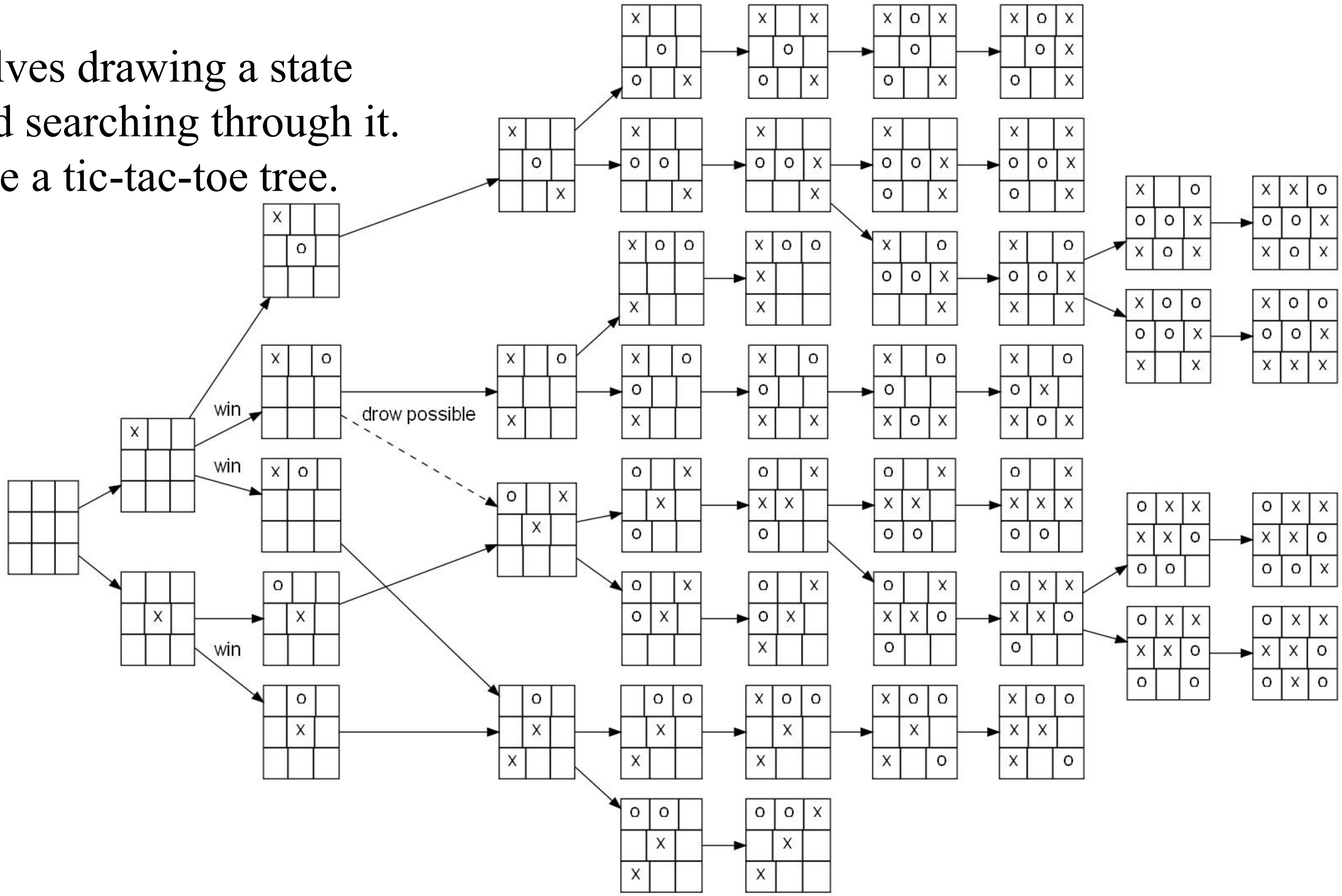
1943	McCulloch & Pitts: Boolean circuit model of brain
1950	**Turing introduced his famous Turing test in his paper: “Computing Machinery and Intelligence”**
1952–69	Look, Ma, no hands!
1950s	Early AI programs, including Samuel’s checkers program, Newell & Simon’s Logic Theorist, Gelernter’s Geometry Engine
1956	Dartmouth meeting: “Artificial Intelligence” adopted
1960	Beginning of modern AI by “Steps Toward Artificial Intelligence” by MARVIN MINSKY
1965	Robinson’s complete algorithm for logical reasoning
1966–73	AI discovers computational complexity Neural network research almost disappears
1969–79	Early development of knowledge-based systems
1980–88	Expert systems industry booms
1988–93	Expert systems industry busts: “AI Winter”
1985–95	Neural networks return to popularity
1988–	Probabilistic methods; enormous increase in technical depth “Nouvelle AI”: ALife, GAs, soft computing
1995–	The emergence of intelligent agents

Important Research and Application Areas

1 Game Playing
2 Automated Reasoning and Theorem Proving
3 Expert Systems
4 Natural Language Understanding and Semantic Modeling
5 Planning and Robotics:
6 Machine Learning
7 Computational methods inspired by Biology:
  Neural Nets and Genetic Algorithms
8 Human performance modeling (comparing with how humans work)
9 Agents and Society of agents
10 AI and Computational Medicine
11 Languages and Environments for AI
12 AI and Philosophy

Game Playing

- Usually involves drawing a state space graph and searching through it.
- Below, we see a tic-tac-toe tree.



Here is a tic-tac-toe player: http://neave.com/tic-tac-toe/
More sophisticated games with AI: Chess, Go, Othello, Card games, Video Games

Automated Reasoning

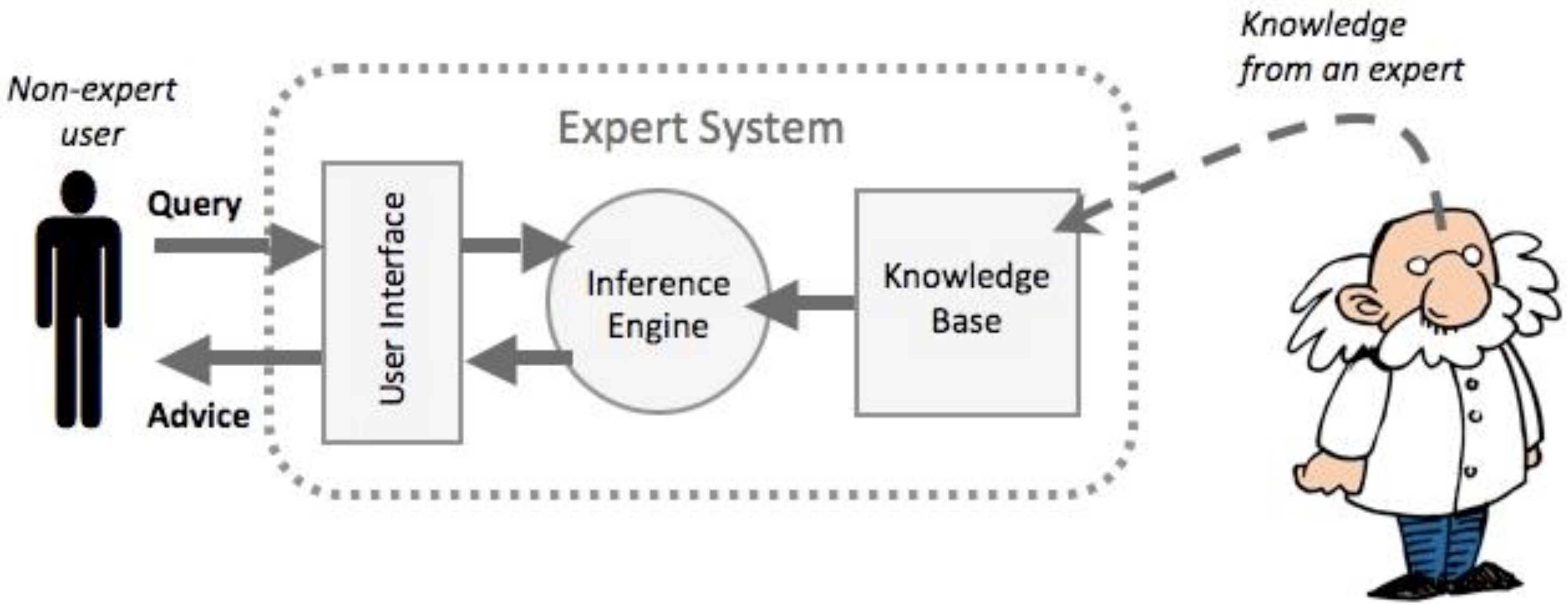
- Involves using a form of mathematical logic
- Using rules of logic to automatically make conclusions

$$\dfrac{\dfrac{\dfrac{p \to (q \to r) \qquad \dfrac{[p \wedge q]}{p}\,\wedge_{e1}}{q \to r}\,\to_e \qquad \dfrac{[p \wedge q]}{q}\,\wedge_{e2}}{r}\,\to_e}{p \wedge q \to r}\,\to_i$$

- Here is a program that proves theorems in geometry: http://www.activemath.org/workshops/MathUI/07/proceedings/Narboux-Geoproof-MathUI07.html
- Here is a call for papers for a conference on practical aspects of reasoning: http://www.eprover.org/EVENTS/PAAR-2012.html

Expert Systems

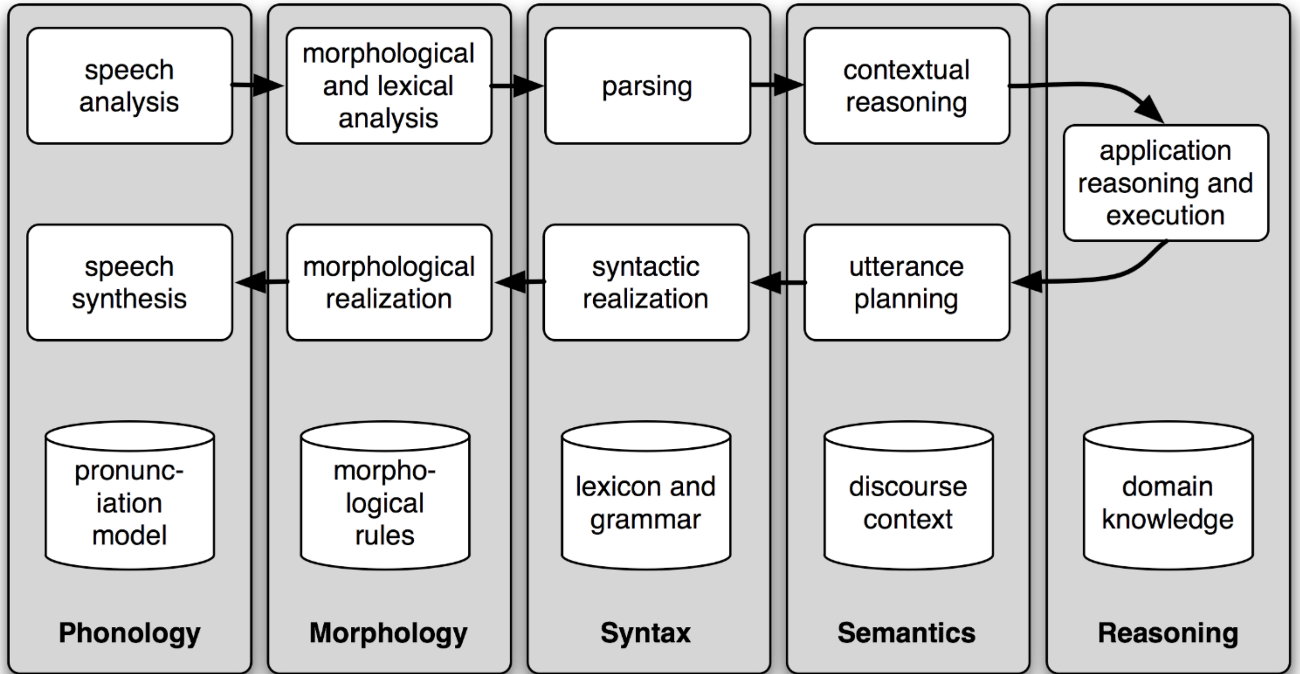
- Knowledge from experts is "captured" and is represented in a knowledge base.
- An inference engine is developed to reason with this knowledge and co-relate it to a query a user may ask.
- The inference engine is usually rule-based, but these rules can be sophisticated and other possibilities such as probabilistic reasoning is possible.



Here is a car repair adviser: http://expertise2go.com/webesie/car/Car.htm

Natural Language Understanding

- Understanding written or spoken human language

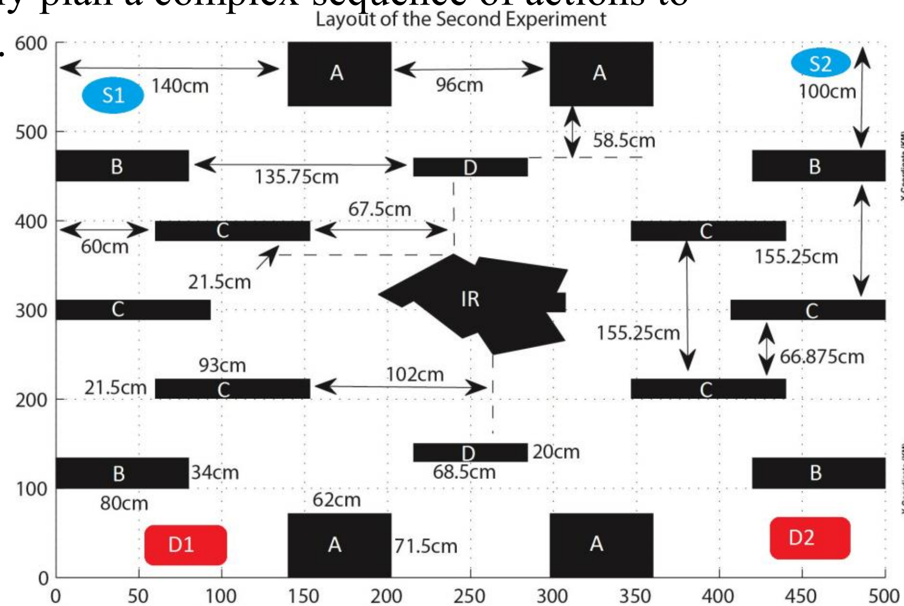


Pipeline for a spoken language understanding system

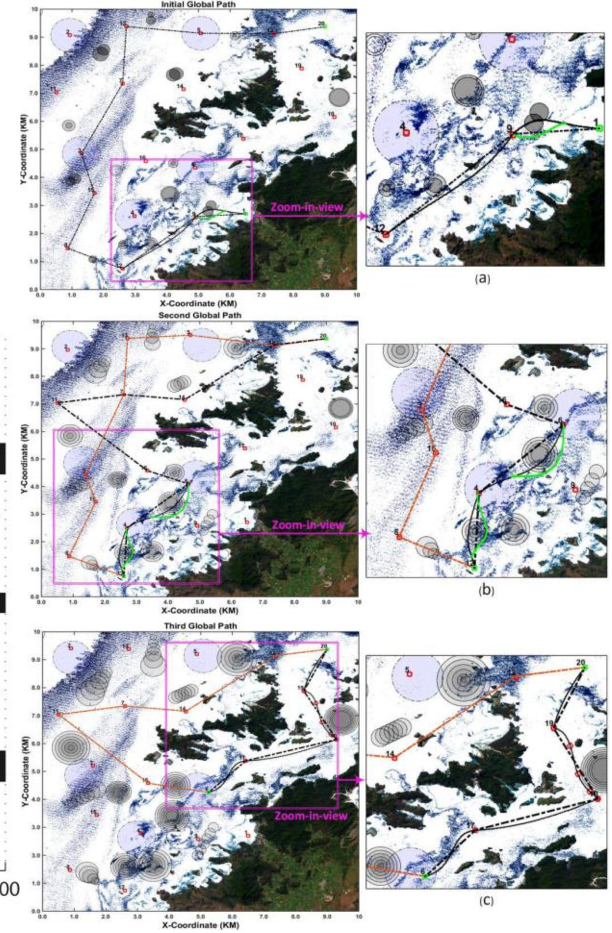
- Demo for a state-of-the-art parser: http://nlp.stanford.edu:8080/parser/index.jsp
- Here is an ad for a product called CLU, Clinical Language Understanding: http://www.youtube.com/watch?v=boQ2iscW7mI&list=PL5BDC1D3583E172FB
- A state-of-the-art machine translator: http://translate.google.com/

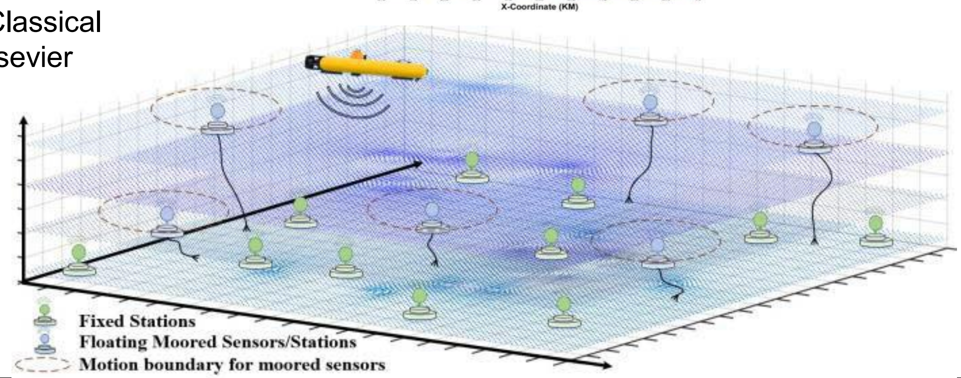
Planning and Robotics

- Planning: Given a set of primitive actions or capabilities, how to automatically plan a complex sequence of actions to achieve a goal.



Ab Wahab, Nefti-Meziani, Atyabi, Mobile Robot Path Planning: Classical or Meta-heuristic Methods, Expert Systems with Applications, Elsevier Under Review





- Here is a simple Blocks World planner in the STRIPS style: http://aispace.org/planning/

Mahmoudzadeh, Powers, and Atyabi, UUV's Hierarchical DE-Based Motion Planning in a Semi Dynamic Underwater Wireless Sensor Network, IEEE Trans on Cybernetics, Vol. 49, Issue 8, pp. 2992-3005 2019.

Planning and Robotics

- Robotics: Planning plays a big role in robotics, but so does hardware issues, computer vision, issues in controlling hardware (mechanics, control theory), humanoid robots, assistive robots, communication among agents, mobility, micro-sizing, etc.

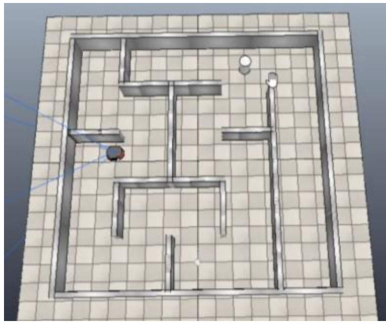
Examples of assistive robots: nursing, household activities

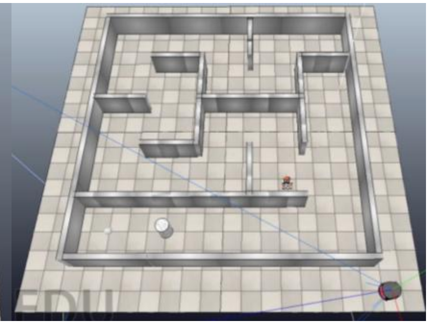
- DARPA Robotics Challenge Tasks: http://www.youtube.com/watch?v=diaZFIUBMBQ
- Robot Soccer Games: http://www.youtube.com/watch?v=1QiN6a73Sf4
- Running Robots: http://www.youtube.com/watch?v=wE3fmFTtP9g

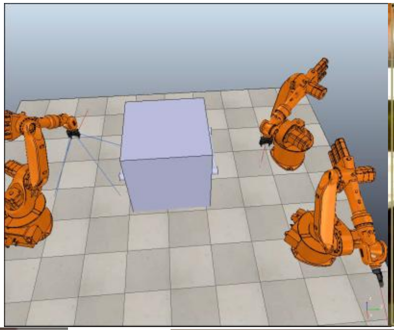
Robotics

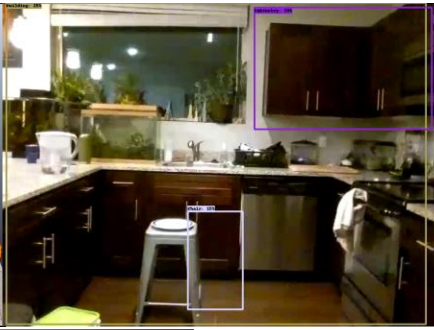
Path Planning

Intelligent
Robotics
Students









Social Robotics

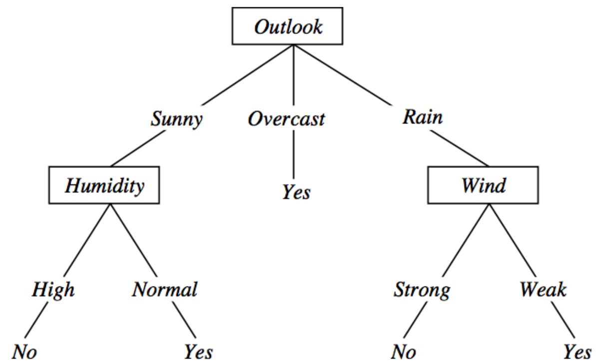
DASE Senior Design
students

Machine Learning

- Learning from data: Either in a supervised or unsupervised manner, or a mix of both

Suppose we are given a table of training examples. Here *PlayTennis* is the concept to be learned.

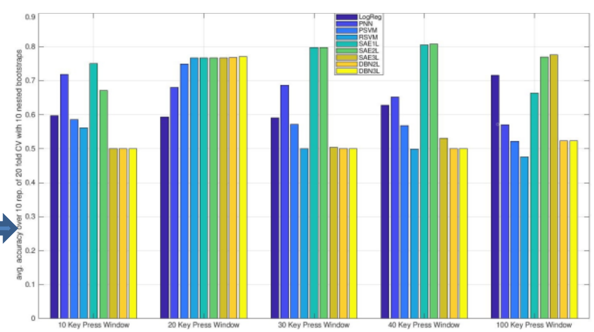
Day	Outlook	Temperature	Humidity	Wind	PlayTennis
D1	Sunny	Hot	High	Weak	No
D2	Sunny	Hot	High	Strong	No
D3	Overcast	Hot	High	Weak	Yes
D4	Rain	Mild	High	Weak	Yes
D5	Rain	Cool	Normal	Weak	Yes
D6	Rain	Cool	Normal	Strong	No
D7	Overcast	Cool	Normal	Strong	Yes
D8	Sunny	Mild	High	Weak	No
D9	Sunny	Cool	Normal	Weak	Yes
D10	Rain	Mild	Normal	Weak	Yes
D11	Sunny	Mild	Normal	Strong	Yes
D12	Overcast	Mild	High	Strong	Yes
D13	Overcast	Hot	Normal	Weak	Yes
D14	Rain	Mild	High	Strong	No



Decision Tree (supervised): Given tabular data, we can learn a tree to classify unseen examples; Trees are usually learned statically, but for most learning algorithms, online learning is possible. Online == learn incrementally as new data becomes available.

Recording user interaction with device

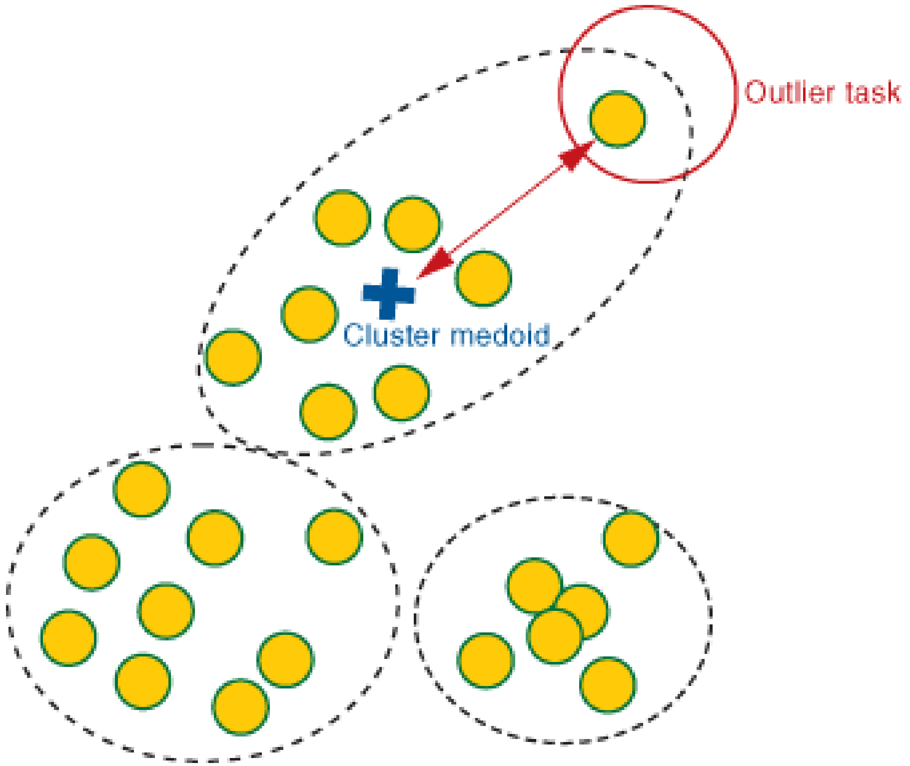
Predicting Autsim Diagnosis from usage patterns



Atyabi et al, Large-scale investigations of AAC Usage Patterns: Trends, Autism, and Stacked Autoencoders, , IEEE Trans on Cybernetics, Under Review 2019.

Machine Learning

- Automatically Clustering (unsupervised learning) a set of data points into separate groups.



Based on distance computation, an algorithm can find the best groups and outliers.

Machine Learning

•Reinforcement learning: Learning to perform tasks when given rewards and punishments, i.e., learning from successes and mistakes.

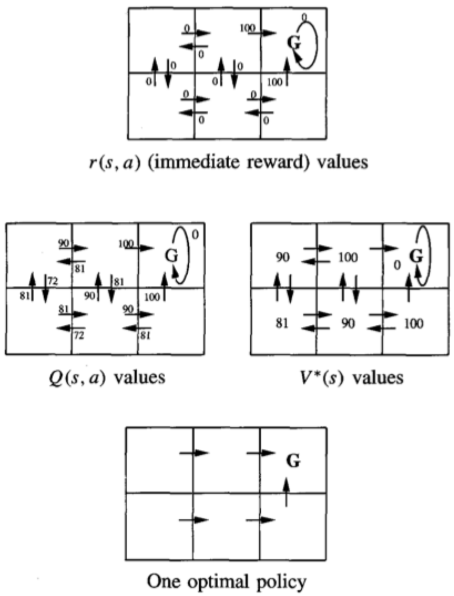


FIGURE 13.2
A simple deterministic world to illustrate the basic concepts of Q-learning. Each grid square represents a distinct state, each arrow a distinct action. The immediate reward function, $r(s, a)$ gives reward 100 for actions entering the goal state **G**, and zero otherwise. Values of $V^*(s)$ and $Q(s, a)$ follow from $r(s, a)$, and the discount factor $\gamma = 0.9$. An optimal policy, corresponding to actions with maximal Q values, is also shown.

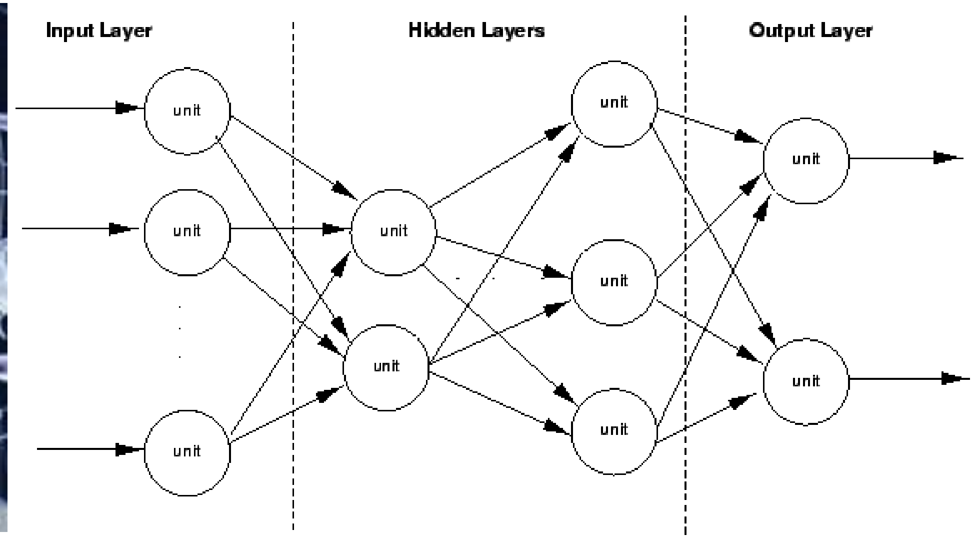
The states are "geographical" or spatial in this example, but it doesn't have to be in general.

However, imagine dividing a soccer or volleyball field into a "large" number of spatial states, assigning players to states and making players learn the best action to perform under various situations. Each player is a reinforcement learner.

Here is a video showing how a robot is learning to stack blocks: http://www.cs.washington.edu/robotics/projects/robot-rl/

Machine Learning/Natural Computing:
Neural Networks and Evolutionary Algorithms
(GA, DE, PSO, CSA, ACO, and so on)

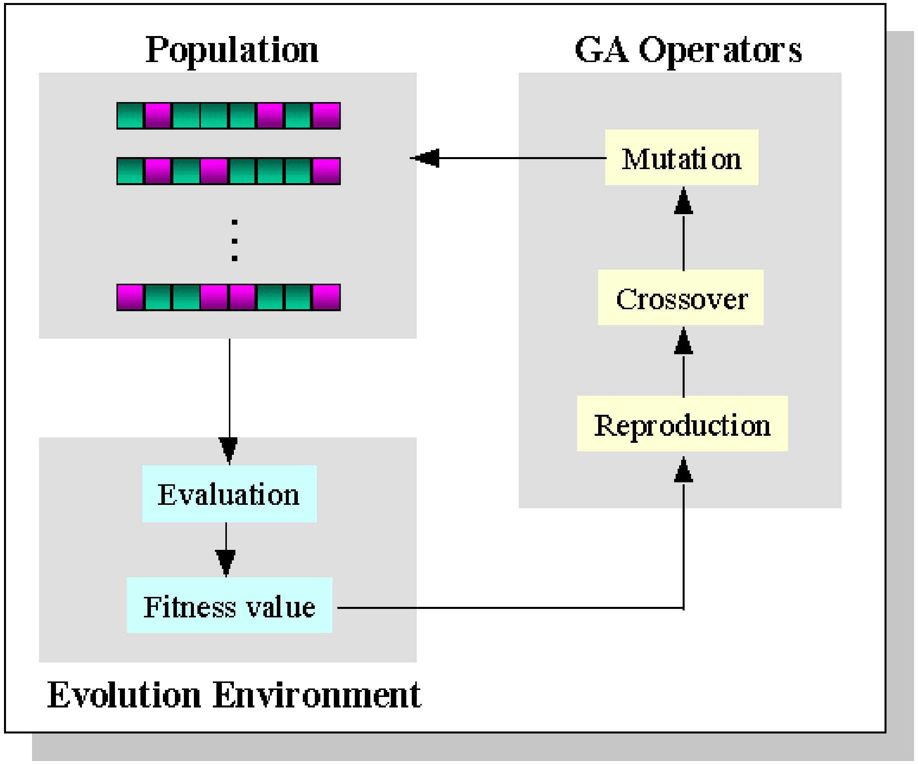
- Machine Learning requires us to solve optimization problems
- There are natural systems that solve optimization problems such as neural networks in the brain to solve real-life problems, Evolutionary algorithms to solve problems in evolution of species, ant systems foraging for food, flocks of birds flying long distances
- Evolutionary Algorithms mimic evolution to solve complex optimization problems.



An actual neural network and an artificial one. ANNs have been very successful in low-level problems such as computer vision (e.g., face recognition, object recognition, character recognition), speech, etc.

Machine Learning/Natural Computing:
Neural Networks and Evolutionary Algorithms
Genetics Algorithm (GA)

- Genetic Algorithms represent a problem's solution space in terms of "chromosomes" and solve problems using evolutionary operators such as cross-over and mutation, and allowing populations of solutions to evolve using fitness-based genetic selection. Remember here we are evloving a population of solutions at the same time, not one single solution. It's kinda "parallel".



Genetic algorithms are popular in engineering and a lot of other fields. Here is a list of applications of genetic algorithms. http://en.wikipedia.org/wiki/List_of_genetic_algorithm_applications

Society of Agents

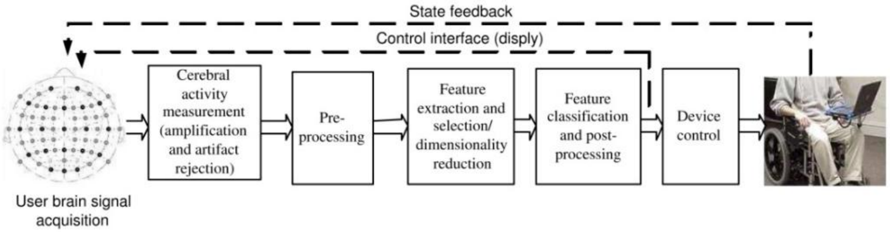
- It has become common to model solutions to a complex problem in terms of software/hardware agents that work together.
- We saw an example in the context of soccer. Or a bunch of agents cooperating to find intruders to a computer network.

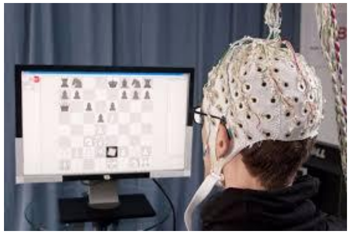
Issues in agent-oriented AI

- Agents are autonomous or semi-autonomous. Each agent has certain responsibilities in problem solving with little or some knowledge of what other agents are capable of or are doing. Each agent does its own independent piece and may report results to other agents.
- Agents are "situated", i.e., each agent is sensitive to its surroundings.
- Agents are interactional. They form a collection of agents and cooperate on a task. May compete too.
- The society of agents is structured in some manner for purposes of communication and problem solving.
- The phenomenon of intelligence is "emergent". Individual agents possess skills and capabilities, but the capability of overall society of agents is bigger than the sum of the individual agents' capabilities.

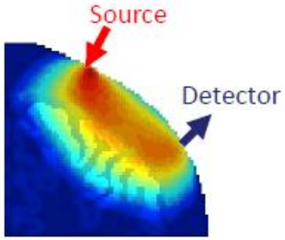
Cognitive & Computational Neuroscience

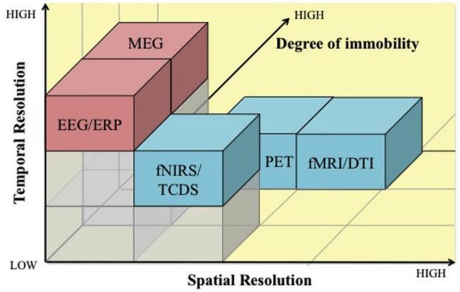
- **Brain Computer Interface**

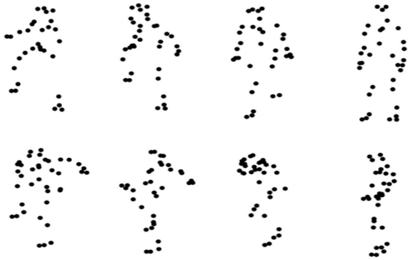


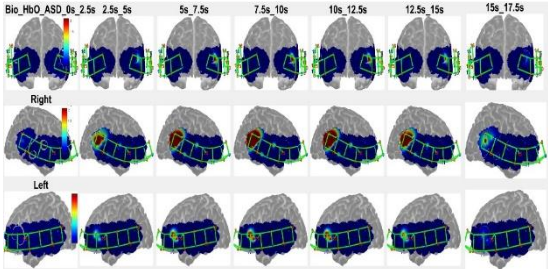


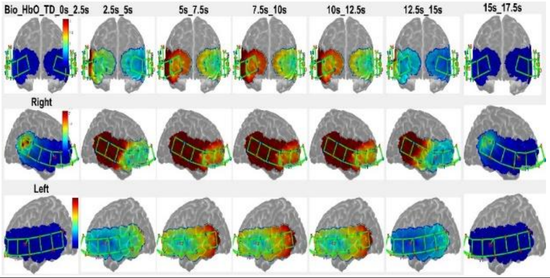
- **Functional Near Infrared Spectroscopy (fNIRS)**





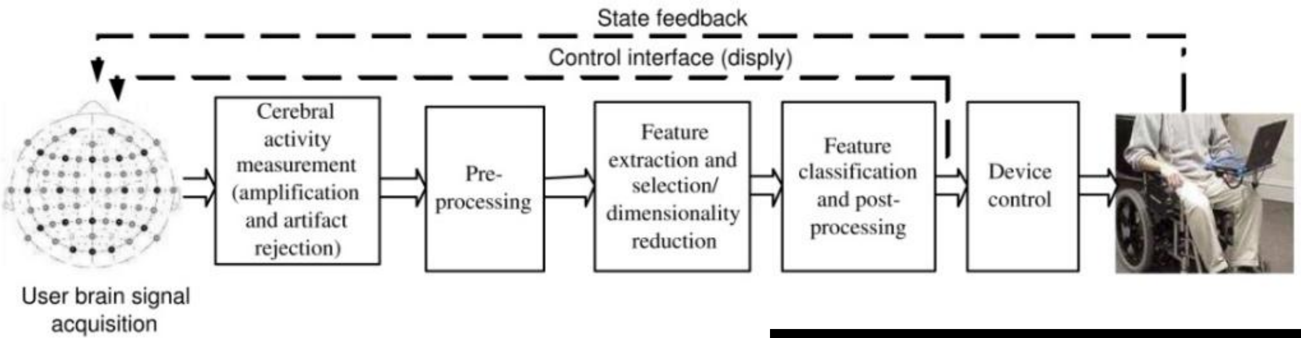


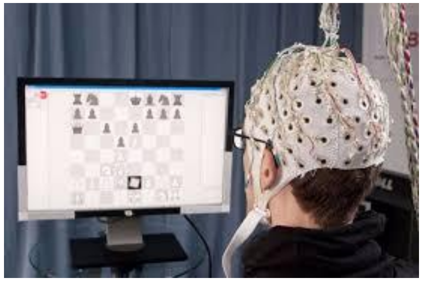




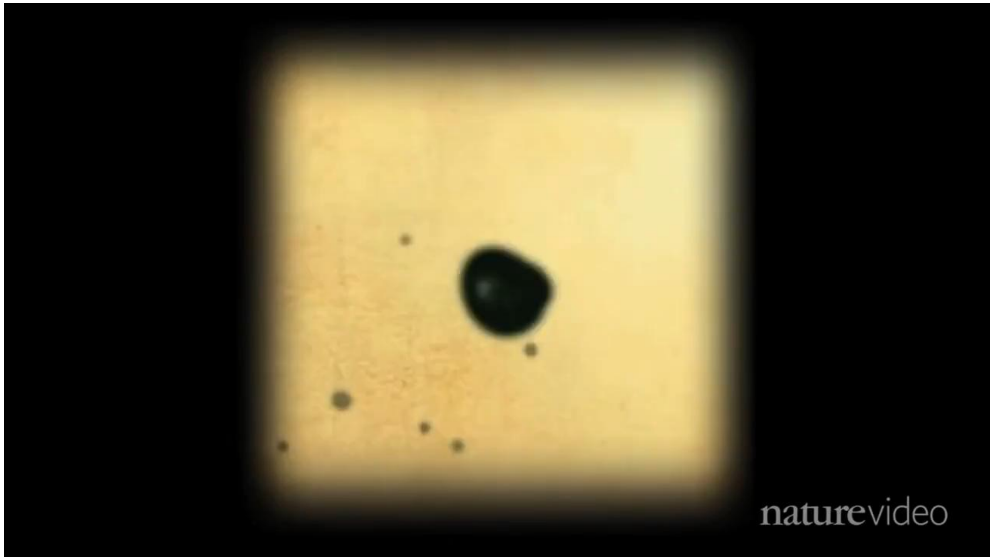
Cognitive & Computational Neuroscience

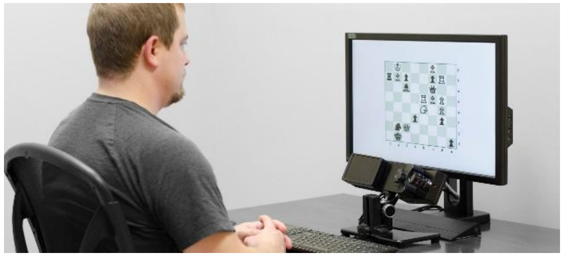
- **Brain Computer Interfacing**



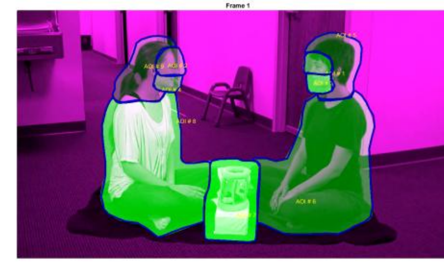


- **Brain Decoding**

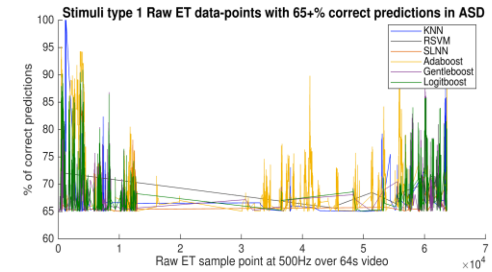


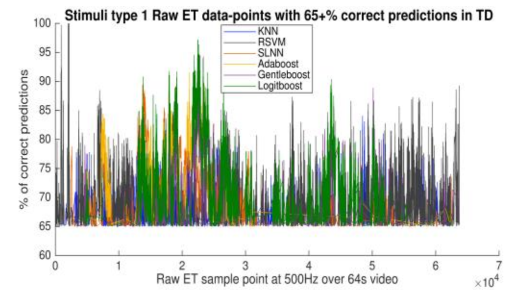


Eye Tracking

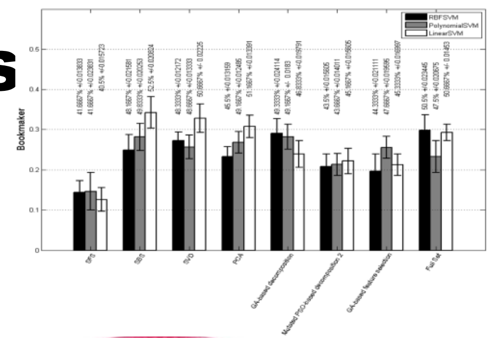


- **Where is the differen**

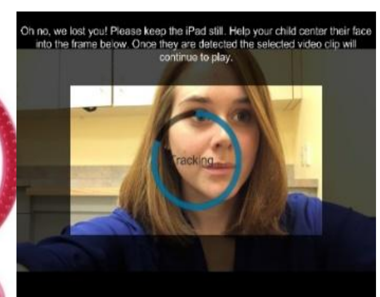


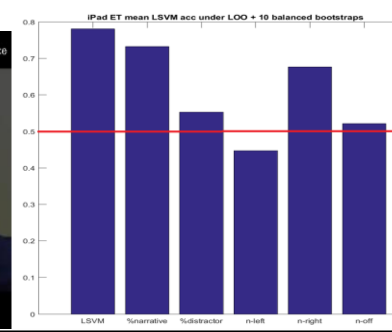


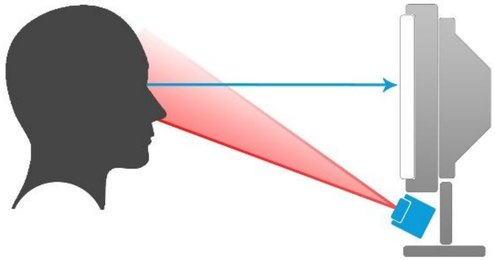
- **Emotional eyes**



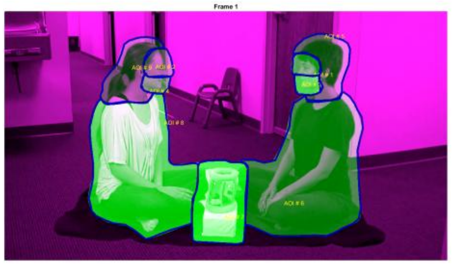
- **iPad eye track**



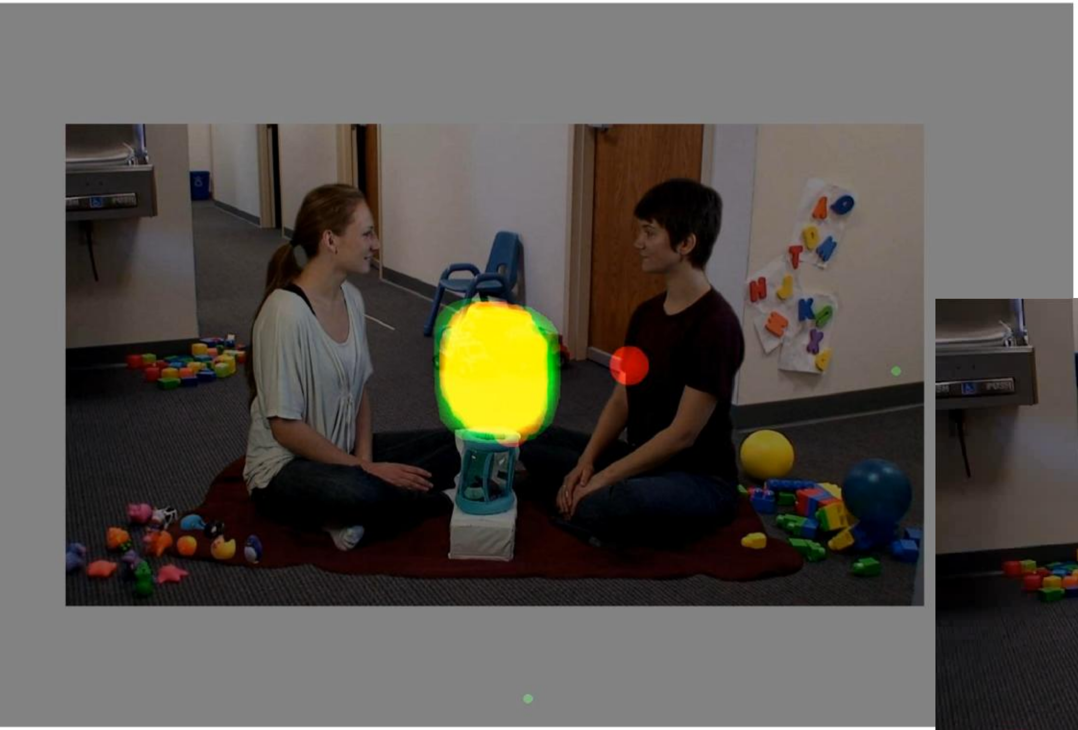


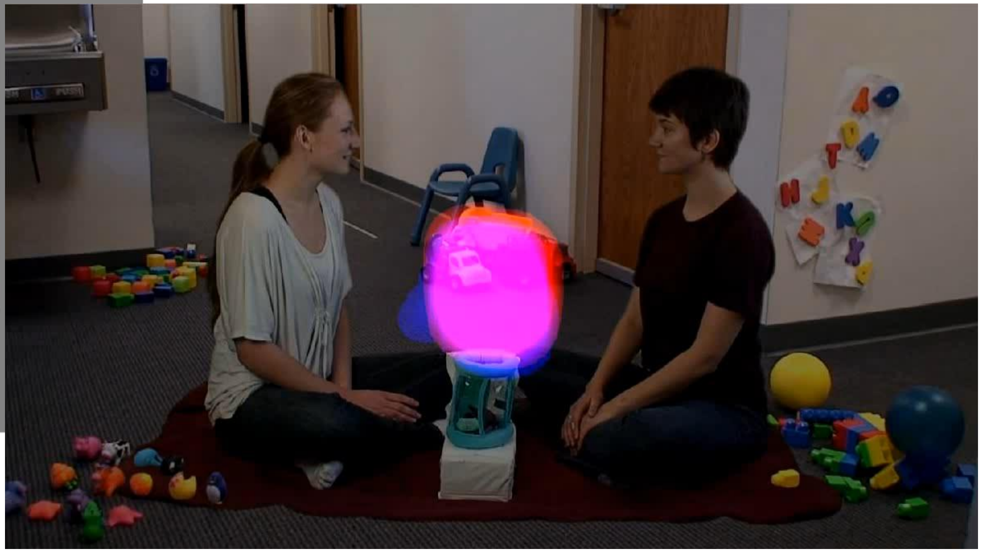


Eye Tracking

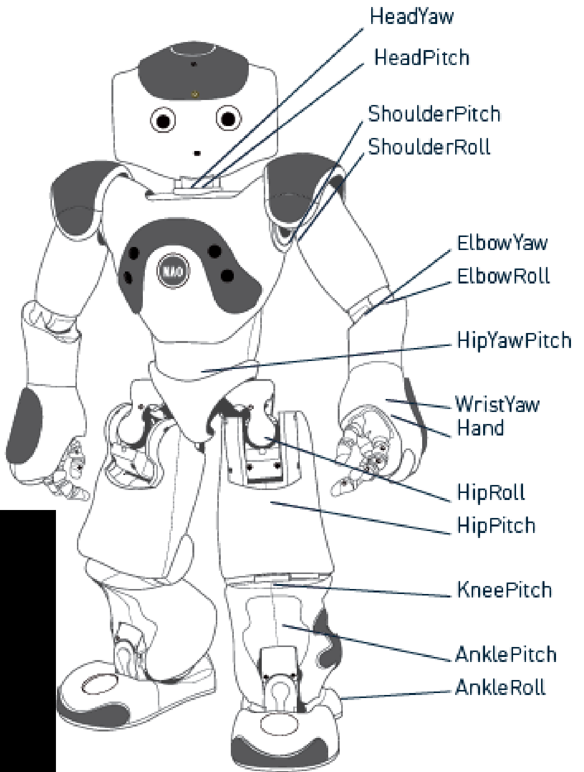


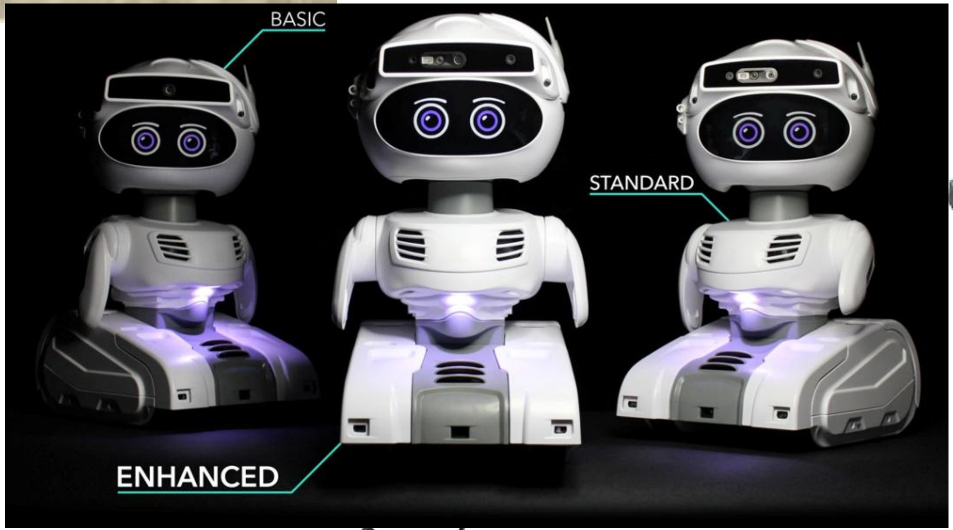
- **Where is the difference**





UCCS robotic platforms





Important Features of Artificial Intelligence

- The use of computers to do reasoning, pattern recognition, learning, or some other form of inference.
- A focus on problems that do not respond to algorithmic solutions. This underlies the reliance on heuristic search as an AI problem-solving technique.
- A concern with problem-solving using inexact, missing, or poorly defined information and the use of representational formalisms that enable the programmer to compensate for these problems.
- Reasoning about the significant qualitative features of a situation.
- An attempt to deal with issues of semantic meaning as well as syntactic form.
- Answers that are neither exact nor optimal but are in some sense “sufficient”. This is a result of the essential reliance on heuristic problem-solving methods in situations where optimal or exact results are either too expensive or not possible.
- The use of large amounts of domain-specific knowledge in solving problems. This is the basis of expert systems.
- The use of meta-level knowledge to effect more sophisticated control of problem-solving strategies. Although this is a very difficult problem, addressed in relatively few current systems, it is emerging as an essential are of research.

UCCS

University of Colorado
Colorado Springs

University of Colorado

Boulder | Colorado Springs | Denver | Anschutz Medical Campus