Towards intelligent machines (Source: Prof. Itti)

Thanks to CSCI 561, we now know how to…

- Search (and play games)
- Represent problems in propositional logic where appropriate
- Build a knowledge base using FOL
- Use FOL inference to ask questions to the KB
- Plan
- Reason about uncertainty

Are we ready to build the next generation of super-intelligent robots?

Many problems remain…

- Vision
- Audition / speech processing
- Natural language processing
- Touch, smell, balance and other senses
- Motor control

Computer Perception

- Perception: provides an agent information about its environment. Generates feedback. Usually proceeds in the following steps.

1. Sensors: hardware that provides raw measurements of properties of the environment
   1. Ultrasonic Sensor/Sonar: provides distance data
   2. Light detectors: provide data about intensity of light
   3. Camera: generates a picture of the environment
2. Signal processing: to process the raw sensor data in order to extract certain features, e.g., color, shape, distance, velocity, etc.
3. Object recognition: Combines features to form a model of an object
4. And so on to higher abstraction levels

Perception for what?

- **Interaction** with the environment, e.g., manipulation, navigation
- **Process control**, e.g., temperature control
- **Quality control**, e.g., electronics inspection, mechanical parts
- **Diagnosis**, e.g., diabetes
- **Restoration**, of e.g., buildings
- **Modeling,** of e.g., parts, buildings, etc.
- **Surveillance**, banks, parking lots, etc.
- …
- And much, much more

Image analysis/Computer vision

1. Grab an image of the object (digitize analog signal)

2. Process the image (looking for certain features)
   1. Edge detection
   2. Region segmentation
   3. Color analysis
   4. Etc.

3. Measure properties of features or collection of features (e.g., length, angle, area, etc.)

4. Use some model for detection, classification etc.

Image Formation and Vision Problem

- **Image:** is a 2D projection of a 3D scene.
  Mapping from 3D to 2D, i.e., some information is getting lost.

- **Computer vision problem:** recover (some or all of) that information. The lost dimension 2D → 3D
  (Inverse problem of VR or Graphics)
  Challenges: noise, quantization, ambiguities, illumination, etc.

- Paradigms:
  - **Reconstructive vision**: recover a model of the 3D scene from 2D image(s) (e.g., shape from shading, structure from motion)
    More general
  - **Purposive vision:** recover only information necessary to accomplish task (e.g., detect obstacle, find doorway, find wall).
    More efficient

How can we see?

- Marr (1982): 2.5D primal sketch

1) pixel-based (light intensity)

2) primal sketch (discontinuities in intensity)

3) 2 ½ D sketch (oriented surfaces, relative depth between surfaces)

4) 3D model (shapes, spatial relationships, volumes)

State of the art

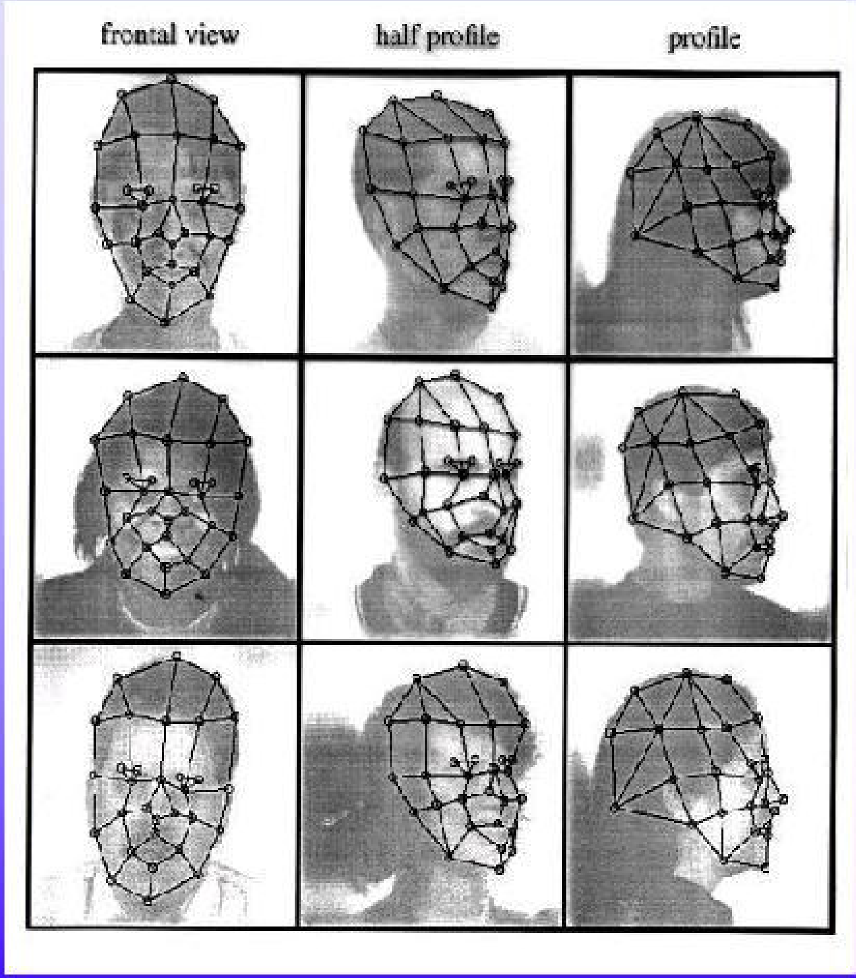
- Can recognize faces?
- Can find salient targets?
- Can recognize people?
- Can track people and analyze their activity?
- Can understand complex scenes?

State of the art

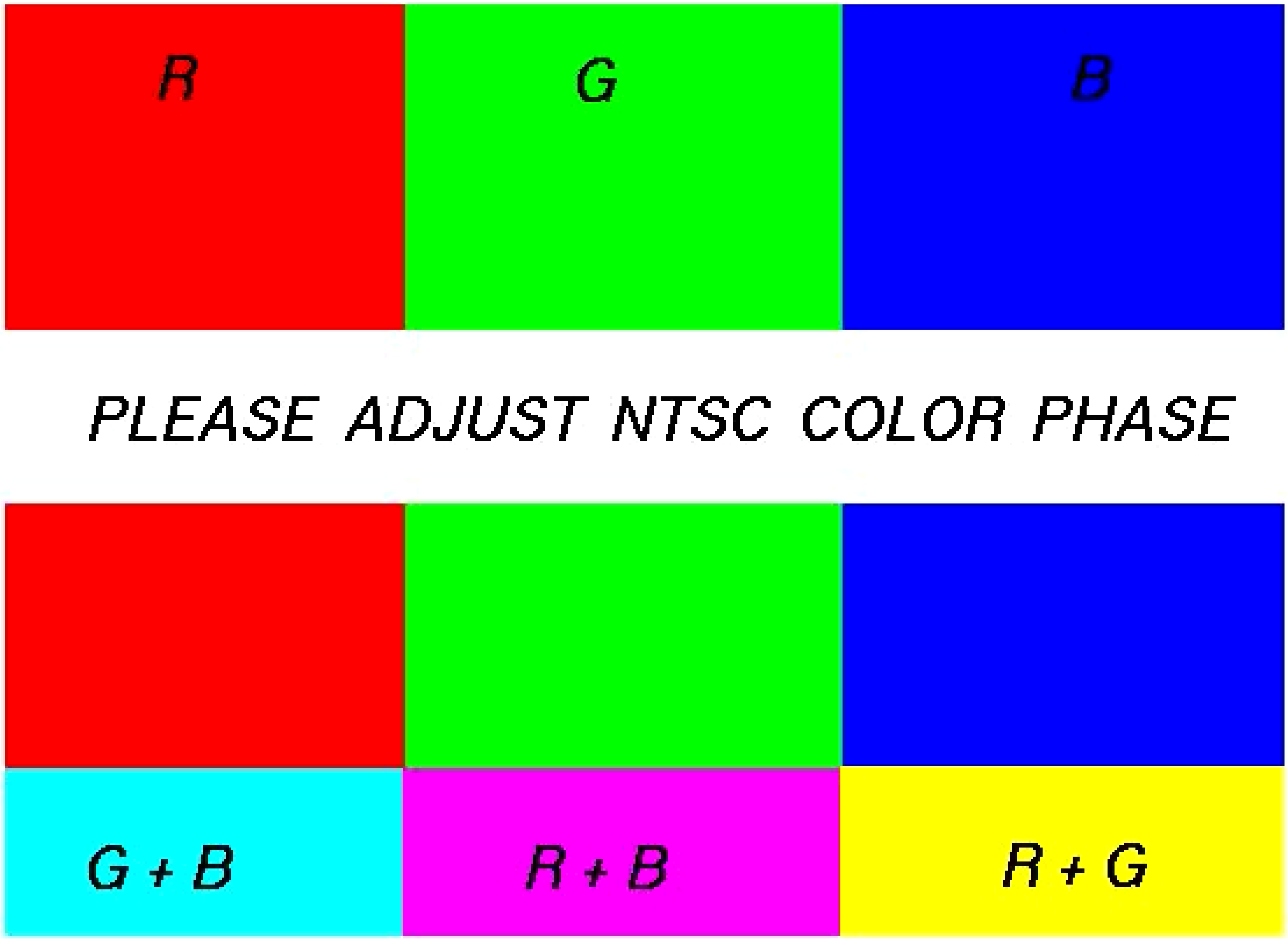
- Can recognize faces? – yes, e.g., von der Malsburg (USC)
- Can find salient targets? – sure, e.g., Itti (USC) or Tsotsos (York U)
- Can recognize people? – no problem, e.g., Poggio (MIT)
- Can track people and analyze their activity? – yep, we saw that (Nevatia, USC)
- Can understand complex scenes? – not quite but in progress

Face recognition case study

- C. von der Malsburg's lab at USC



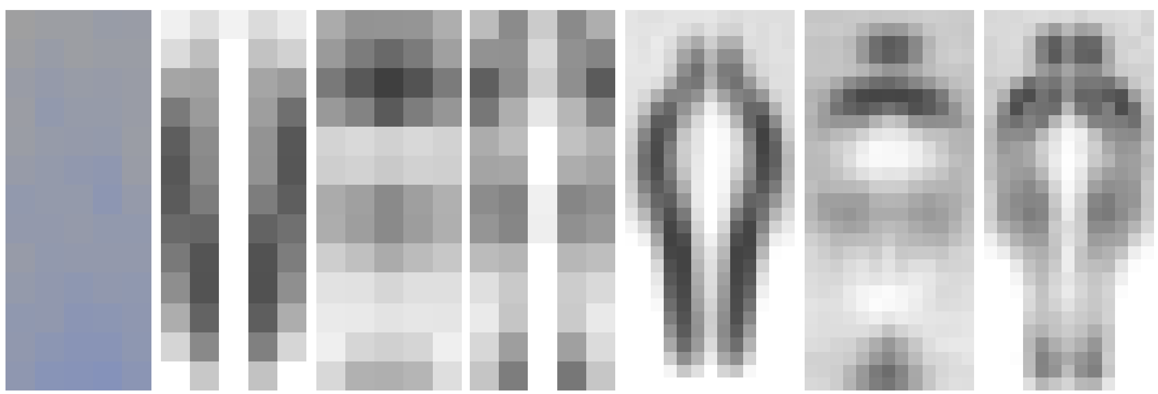
Finding “interesting” regions in a scene



Visual Attention

Pedestrian recognition

- C. Papageorgiou & T. Poggio, MIT



(a) (b) (c) (d) (e) (f) (g)

How about other senses?

- Speech recognition -- can achieve user-undependent recognition for small vocabularies and isolated words

- Other senses -- overall excellent performance (e.g., using gyroscopes for sense of balance, or MEMS sensors for touch) except for olfaction and taste, which are very poorly understood in biological systems also.

How about actuation

- Robots have been used for a long time in restricted settings (e.g., factories) and, mechanically speaking, work very well.

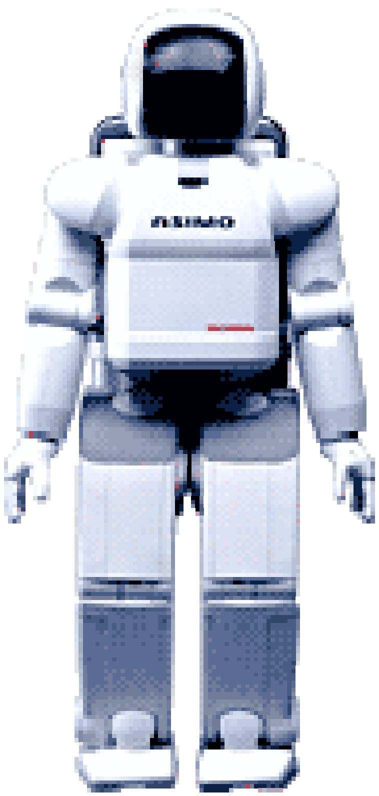
- For operation in unconstrained environments, **Biorobotics** has proven a particularly fruitful line of research:

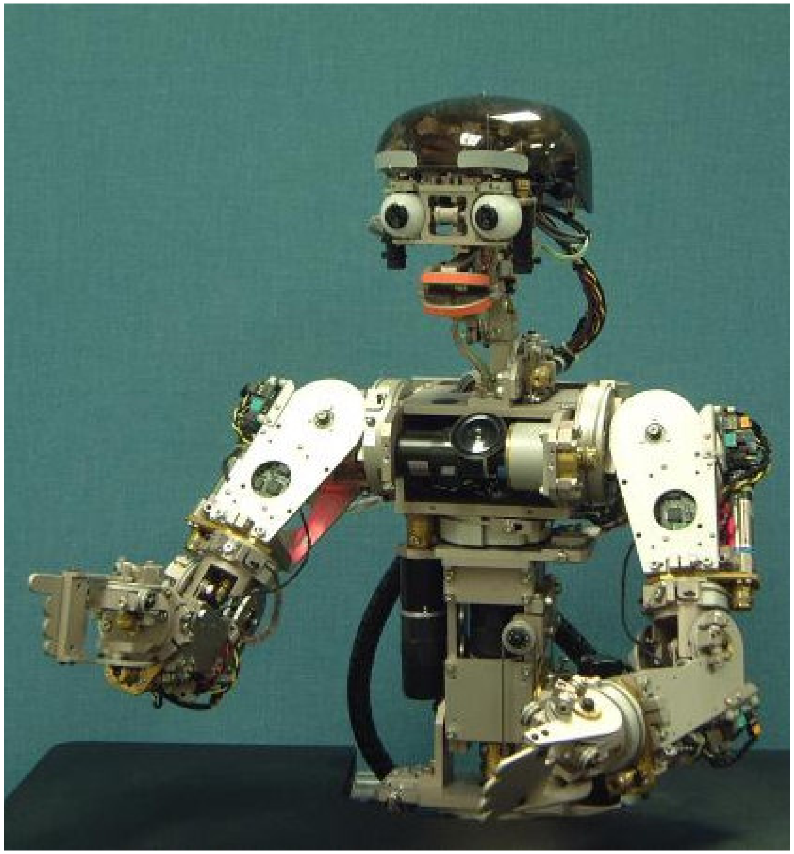
Motivation: since animals are so good at navigating through their natural environment, let's try to build robots that share some structural similarity with biological systems.

Robot examples: constrained environments

Robot examples: towards unconstrained environments

See Dr. Schaal's lab at http://www-clmc.usc.edu

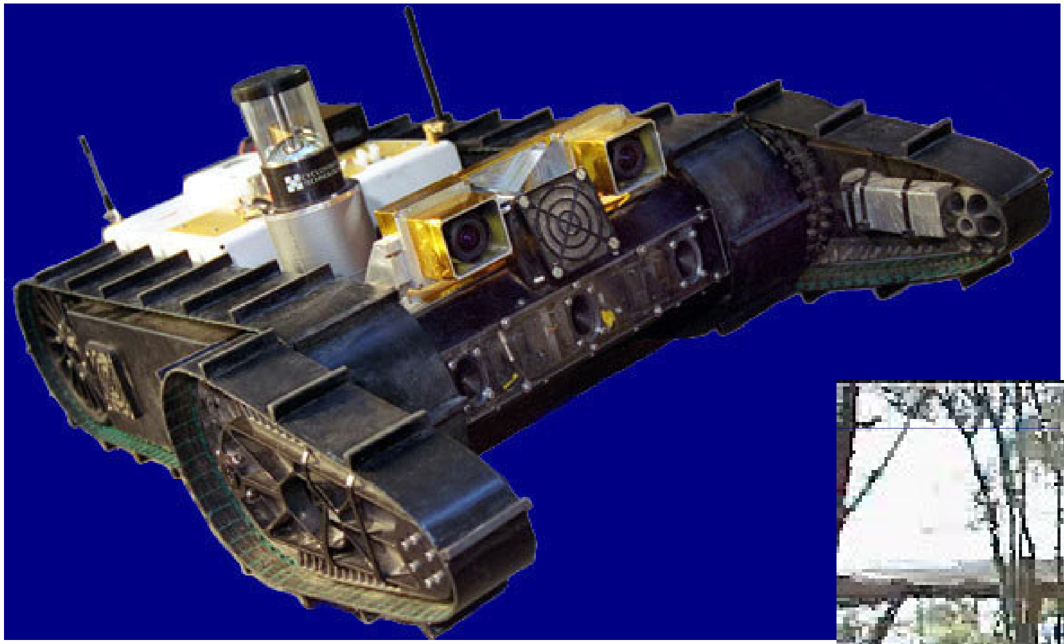




More robot examples

Rhex, U. Michigan

More robots



Urbie @ JPL and
robots from iRobots, Inc.

Outlook

- It is a particularly exciting time for AI because…

  - CPU power is not a problem anymore
  - Many physically-capable robots are available
  - Some vision and other senses are partially available
  - Many AI algorithms for constrained environment are available

So for the first time YOU have all the components required to build smart robots that interact with the real world.

Hurry, you are not alone…

Robot mowers and vacuum-cleaners are here already…

http://www.shopping-emporium-uk.com/mower/

http://www.roombavac.com/

What we have covered – Part I of 4

- Architecture of "Agents"
- Problem Solving: Representing States and Search Trees
- Uninformed Search Algorithms:
  - Breadth-First, Depth-First, Uniform Cost, Depth Limited, Iterative Deepening
- Informed Search Algorithms:
  - Best first, A*, Heuristic search algorithms, hill climbing, simulated annealing
- Constraint Satisfaction Problem

What we have covered – Part 2 of 4

- Adversarial games
  - Setting up game trees
  - MiniMax algorithm
  - Alpha/Beta Pruning
- Propositional Logic (PL) and Its Importance:
  - Knowledge Representation using PL
  - Entailment and Inference in PL
  - Forward and Backward Chaining
  - Canonical Forms in PL – Disjunctive and Conjunctive Normal Forms; Horn Form;
  - Modus Ponens for inference in PL with forward and backward chaining
  - Resolution in PL for inference using CNF

What we have covered – Part 3 of 4

- First Order Logic (FOL) and Its Importance:
  - Quantifiers – universal and existential
  - Knowledge Representation using FOL
  - Entailment and Inference in FOL
  - Unification to handle variables
  - Forward and Backward Chaining
  - Canonical Forms in FOL – Disjunctive and Conjunctive Normal Forms; Horn Form;
  - Extended Modus Ponens for inference in FOL with forward and backward chaining
  - Resolution in PL for inference using CNF
- Prolog and Horn Clauses; Logic Programming

What we have covered – Part 4 of 4

- Planning:
  - STRIPS notation and translating things into STRIPS
  - Partial Order Plans and working with them
- Uncertainty:
  - Joint probability distribution tables; conditional probability; Bayes rule and conditional independence
  - Bayesian networks and how to interpret them
  - Overview of Fuzzy Network
- Basics of Learning using decision tables and neural networks

Topics for Future

- Further details in several areas
- Neural Networks
- Learning using Self-organizing maps
- Support Vector machines
- Adaptive Learning methods
- Vision
- Robotics
- Planning in specific domains like task scheduling and manufacturing
- Natural Language

Final Overview

Final Format

- Final Date and Time:
  - Tuesday, Dec 13th, 2 to 3:30 pm
  - ROOM: GFS 106
- Open-book and Open-Notes – NO LAP TOPS or PDAs
- BYOB – Bring Your Own BOOKS!! No sharing of notes or books will be allowed during the test
- 5-6 questions over 90 minutes
- Main focus on material since midterm
- Only those portions emphasized in class, assignments, and homework are most critical
- Focus on the material in the lecture notes

Topics Included

- First Order Logic and Knowledge Representation in FOL
- Inference in FOL using Generalized Modus Ponens (GMP); forward and backward chaining
- FOL Horn Clauses and Prolog
- Conjunctive Normal Form and Resolution as inference for FOL
- Planning; STRIPS planning notation and formalisms; Partial Order Planning, conflict resolution, derivation of plans from partial order plans.
- Uncertainty in AI – probability distribution tables and answering queries using those; conditional probability; basic interpretation of Bayesian networks

Nature of Questions

- Category 1: Translating informal English language problem descriptions into formal structures more amenable to algorithmic manipulation:
  - 2-3 questions of this category
- Category 2: Testing knowledge and skills with different algorithms and procedures, given an already formalized problem:
  - 2-3 questions of this category
- First category is more open-ended in nature

How to Prepare

- Sample final will be posted. Please take the final and see how you do. This is the best preparation possible
- Practice homework problems and understand the solutions.
- All topics described in detail in class will be the primary focus
- Go over the exercises in the lecture notes
- We are here to help you:
  - IF YOU HAVE QUESTIONS, PLEASE EMAIL TA OR PROFESSOR ASAP
- Do not Wait for the last minute – we may not be available to help you at the last minute!