15-494: Cognitive Robotics

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Why is robot programming hard?

- It's done at too low a level:
  - Joint angles and motor torques instead of gestures and manipulation strategies
  - Pixels instead of objects
- It's like coding in assembly language, when what you really want is Java or Scheme or ALICE or Mathematica.
- Robots are stupid.

What Is this course about?

A new approach to programming robots:

- Borrowing ideas from cognitive science to make robots smarter

- Creating tools to make robot behavior *intuitive and transparent*

What if robots were smarter?

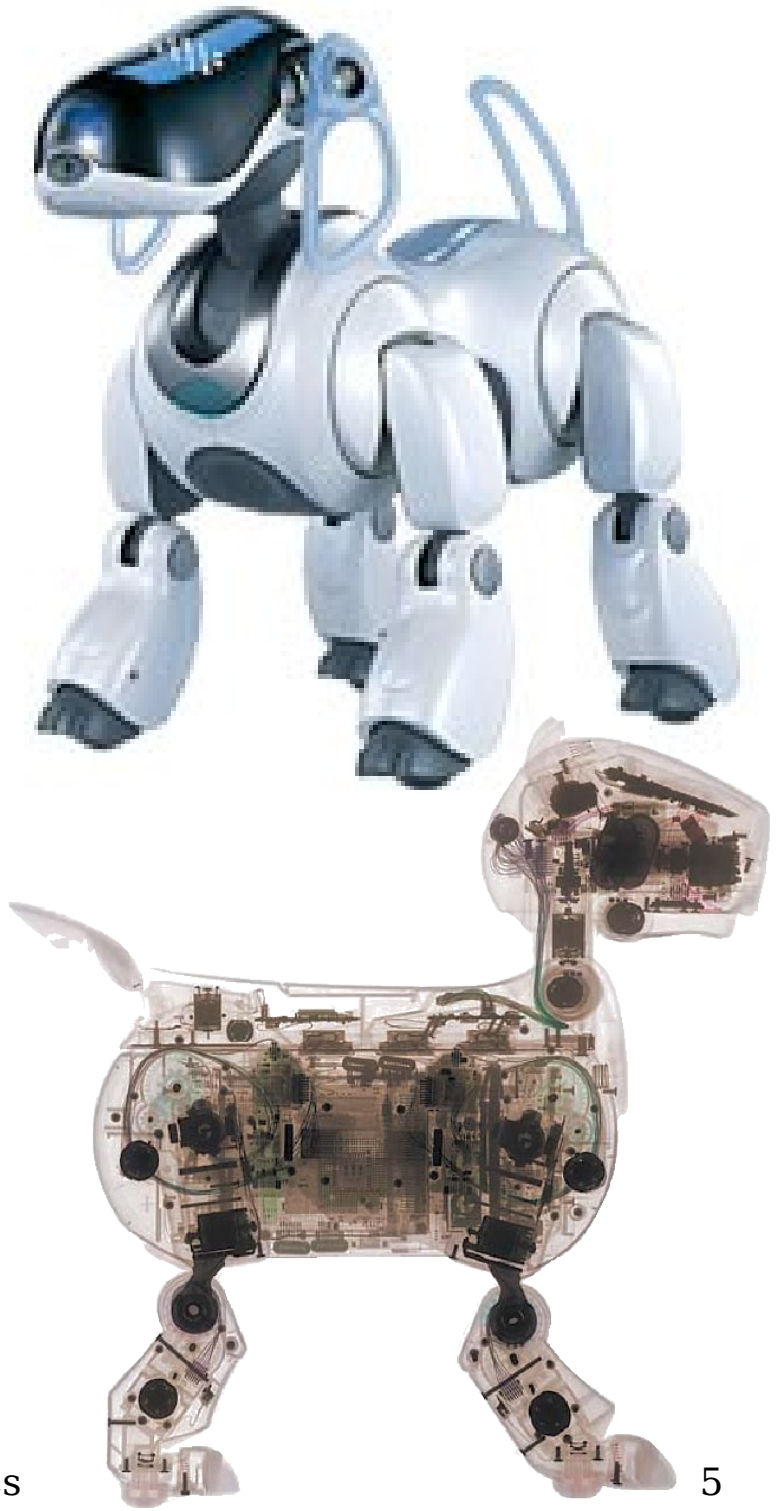
- Suppose robot could already see a bit, and navigate a bit, and manipulate objects a bit.
- What could you do with such a robot?

  We're going to find out!
- What primitives would allow you to easily program it to accomplish interesting tasks?

  Help us refine our design.

The AIBO ERS-7

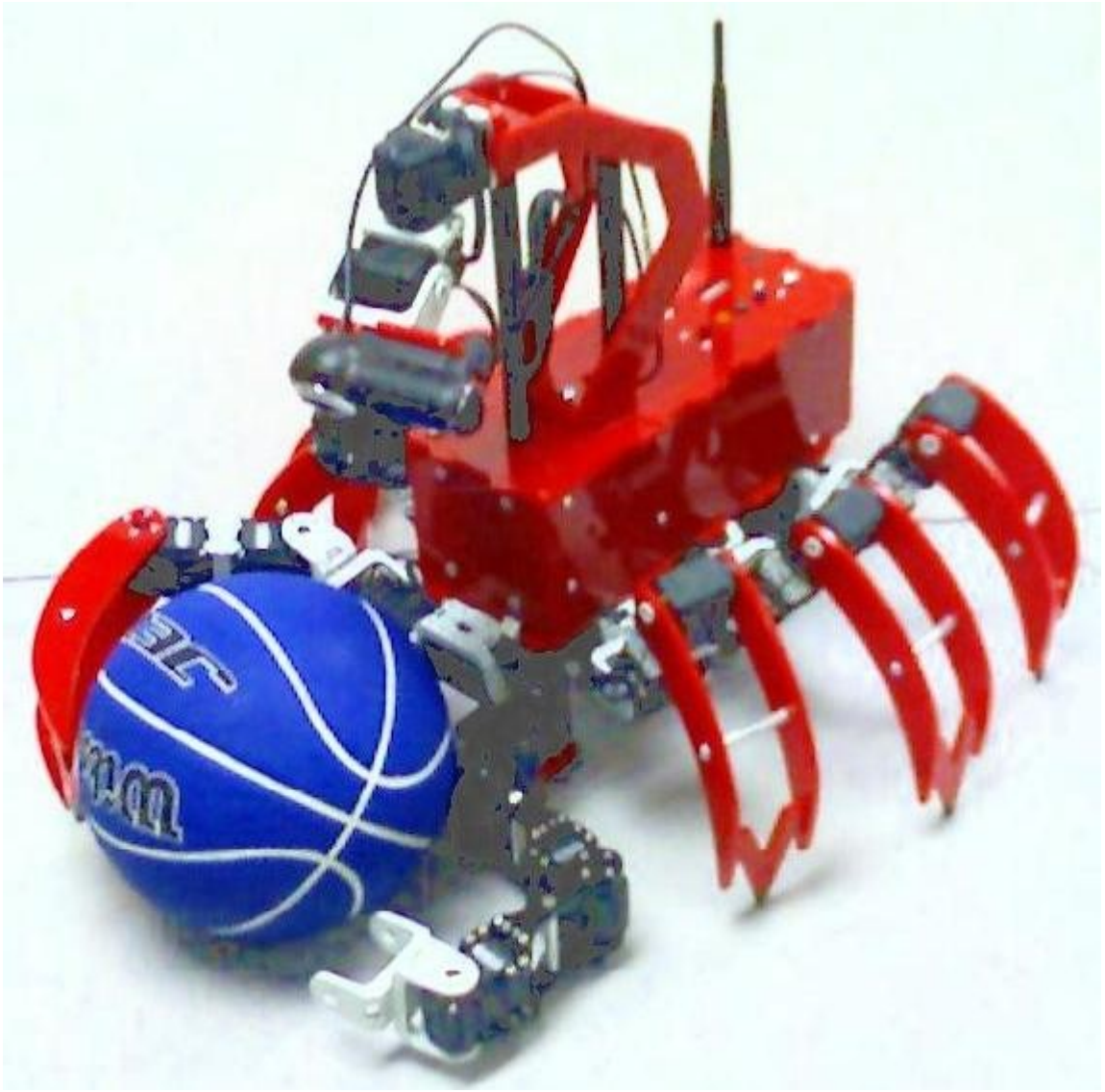
- 576 MHz RISC processor
- 64 MB of RAM
- Programmed in C++
- Color camera: 208x160
- 18 degrees of freedom:
  - Four legs (3 degs. Each)
  - Head (3), tail (2), mouth
- Wireless Ethernet



The Chiara Debuts at AAAI-08

- Pico-ITX processor:
  1 GHz, 1 GB, 80GB HD
  Ubuntu Linux
- 27 degrees of freedom:
  - 24 digital servos
  - 3 analog microservos
  - 6-dof arm with gripper
- Logitech webcam,
  Robotis IR rangefinder
- Ethernet and WiFi
- Open source, GPLed design

Gamma Series Chiara (2009)



- 21 built
- 6 are in your lab
- Fixed gripper (c-bracket)

See demo videos at
Chiara-Robot.org
or directly at
youtube.com/TekkotsuRobotics

Demo Videos

Mirage Stack Topple and
52 views
2 months ago

Denavit-Hartenbe Reference Frame
1,163 views
2 months ago

Mirage Camera Simulation
149 views
4 months ago

Chiara Maze Wander
97 views
5 months ago

Mirage HandEye Physics Demo
545 views
5 months ago

Chiara Robot: Ultimate Chase
183 views
5 months ago

Chiara Stanky Leg Dance
62 views
5 months ago

Chiara Robot Fetching An
95 views
5 months ago

Frustrated Chiara Robot at
143 views
5 months ago

Sherene Campbell's
43 views
5 months ago

Andrew's Leap: Chiara Rocks
64 views
5 months ago

Andrew's Leap: Chiara Dance
22 views
5 months ago

Tekkotsu Arm Path Planning
160 views
6 months ago

Chiara Robot pincer usage
187 views
6 months ago

Chiara walking in Mirage simulator
205 views
7 months ago

Chiara IR rangefinder demo
187 views
8 months ago

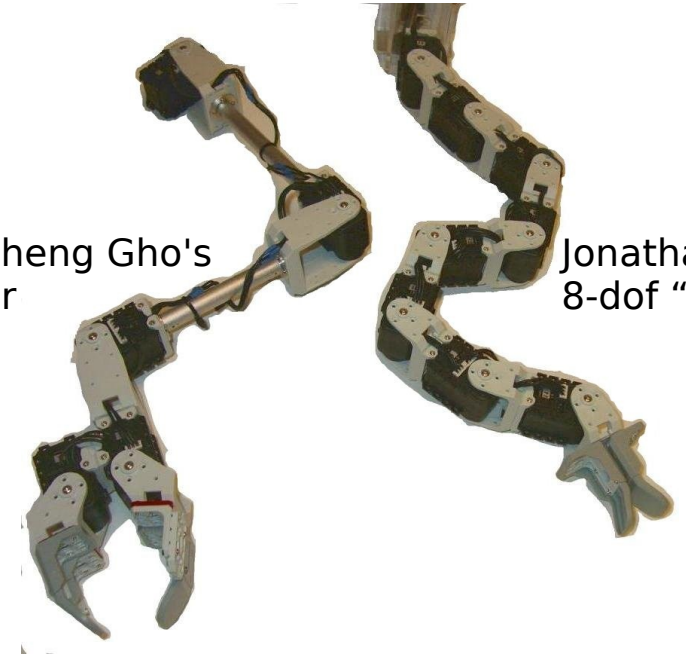
Chiara depth from stereo
4,914 views
8 months ago

Chiara robot rolling a ball
836 views
8 months ago

Delta Series Mockup

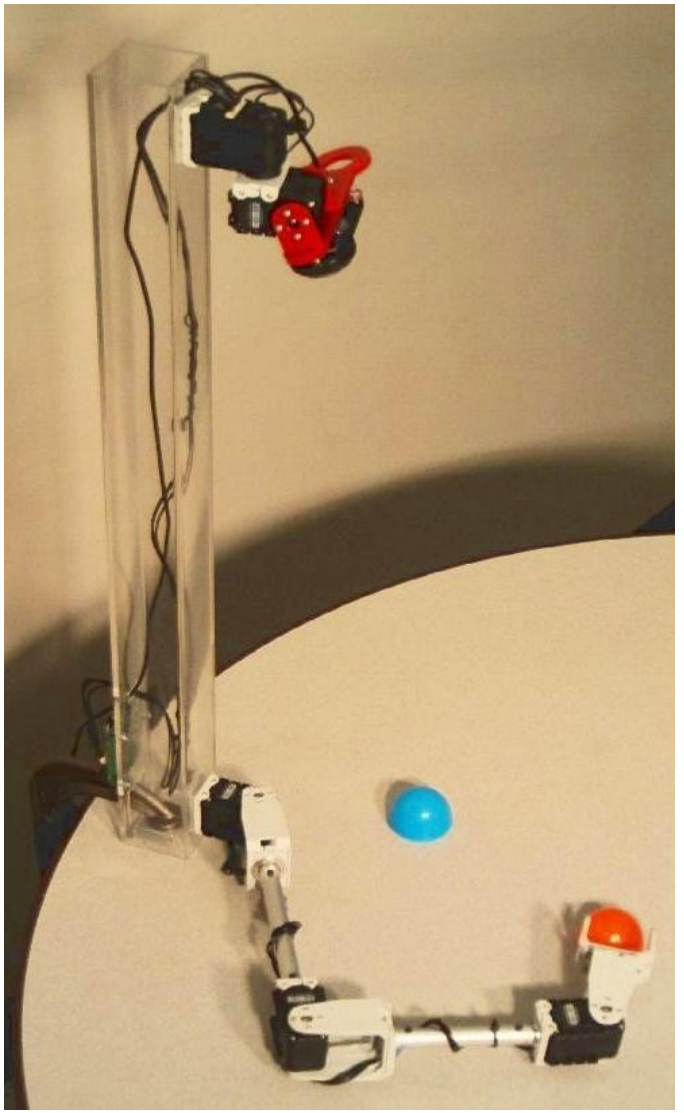
Tekkotsu Planar Hand-Eye System

- 3-dof planar arm
- Logitech webcam on a pan/tilt mount
- Connects to a PC via USB
- Many variations possible:



Zhengheng Gho's gripper

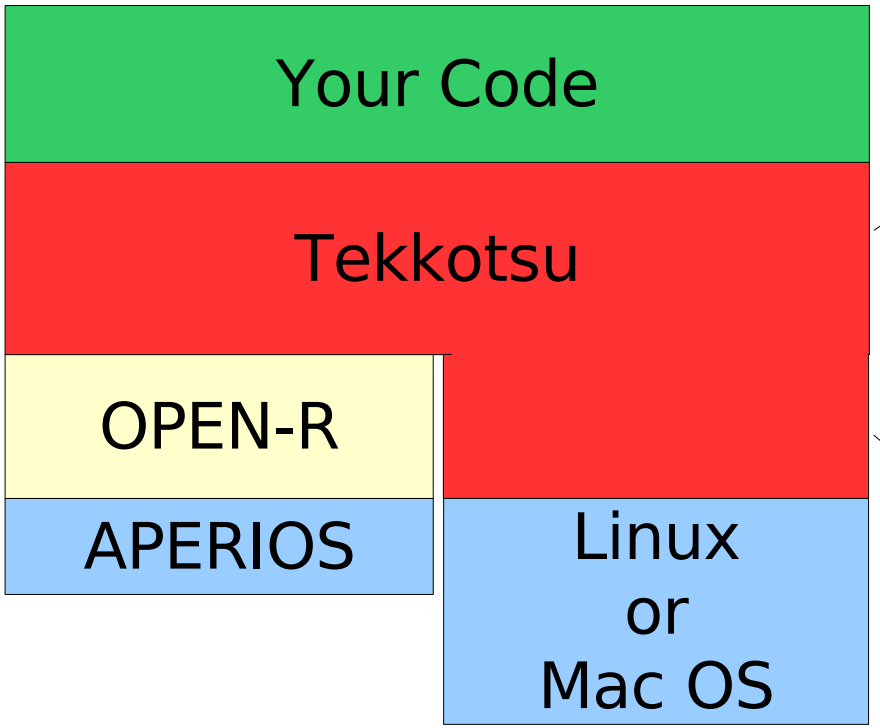
Jonathan Coens' 8-dof “tentacle”



Tekkotsu Means “Framework” in Japanese

(Literally “iron bones”)

Tekkotsu.org



Tekkotsu features:

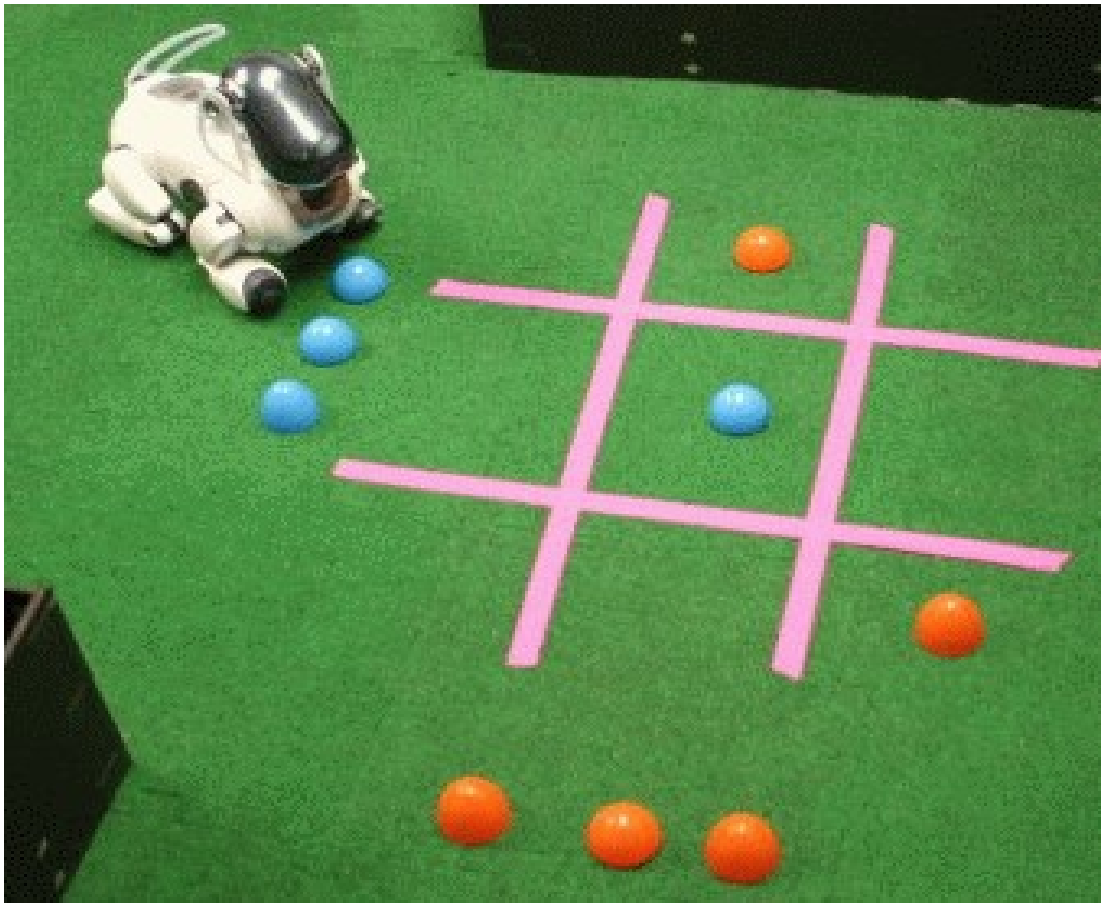
- Open source, LGPLed
- Event-based architecture
- Powerful GUI interface
- Documented with doxygen
- Extensive use of C++ templates, multiple inheritance, and polymorphism

Primitives for Cognitive Robotics

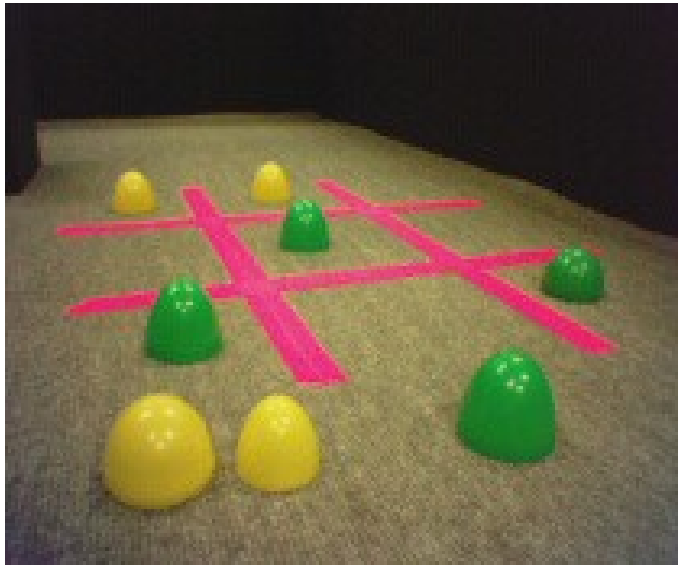
- Perception: see shapes, objects
- Mapping: where are those objects?
- Localization: where am I?
- Navigation: go there
- Manipulation: put that there
- Control: what should I do now?
- Learning: how can I do better?
- Human-robot interaction: can we talk?

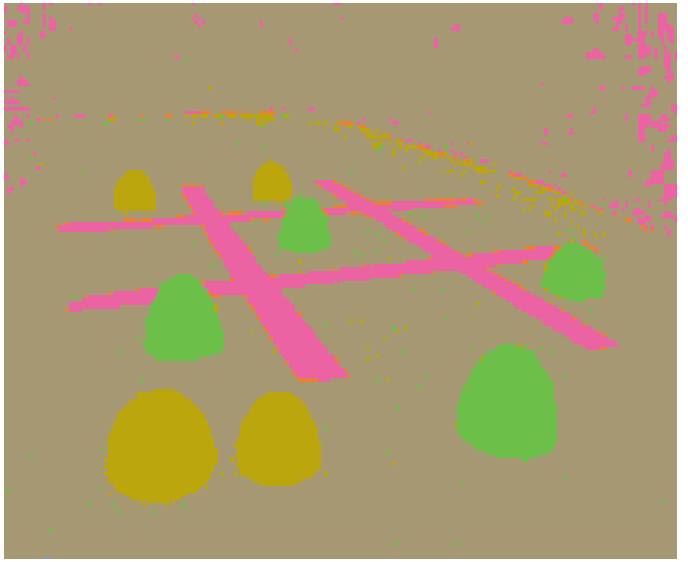
Primitives needed for tic-tac-toe

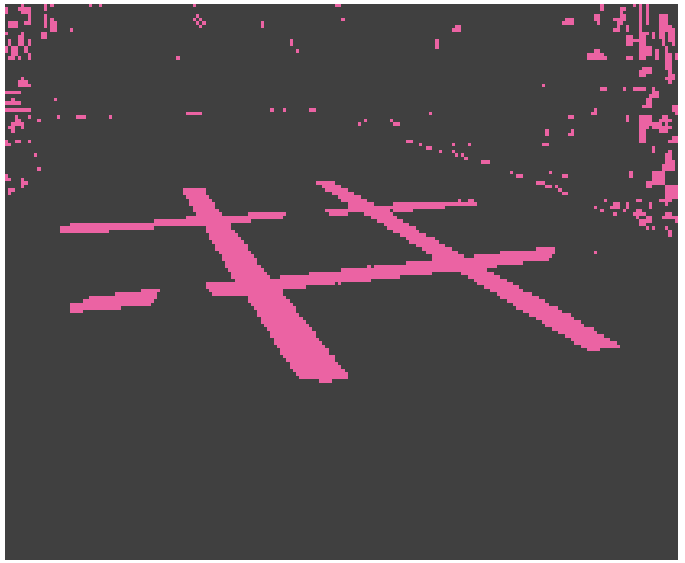
- See and understand the board (perception, mapping)
- Move the game pieces (manipulation)
- Take turns (control)

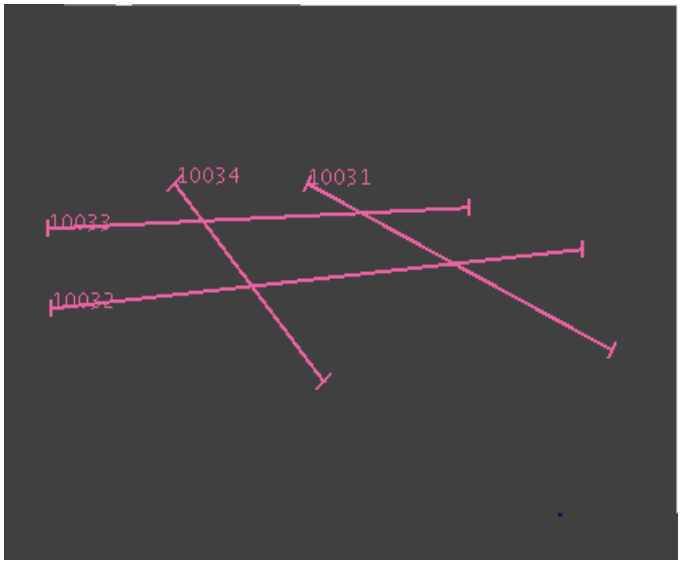


Visual Routines









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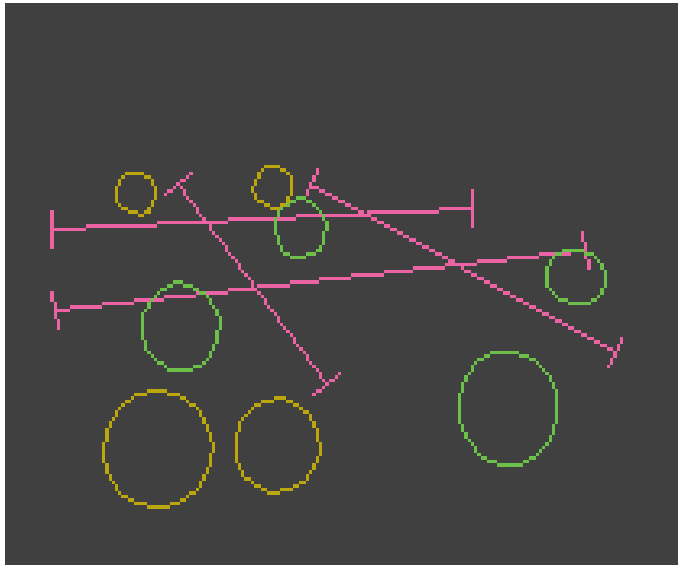
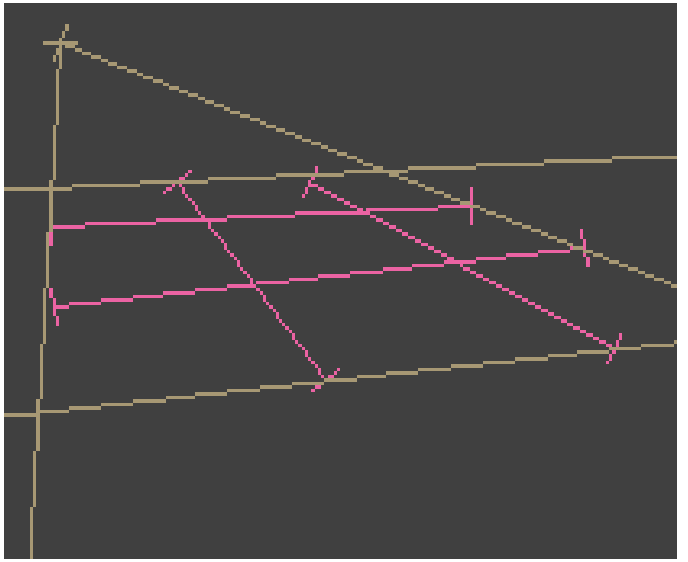
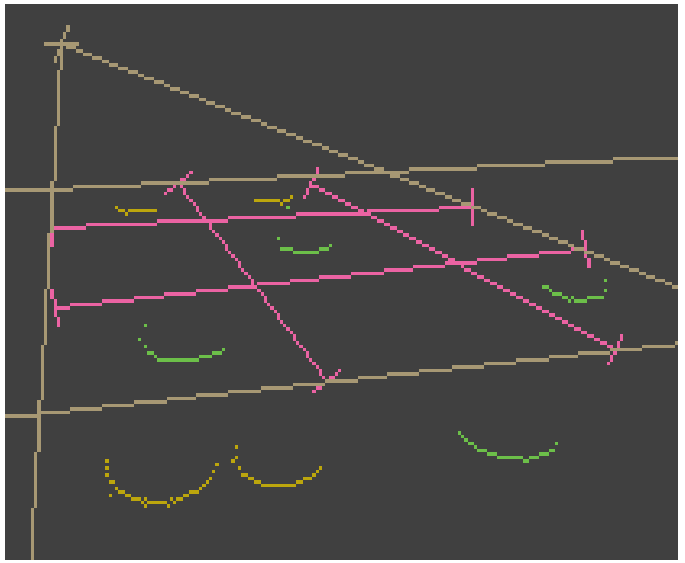
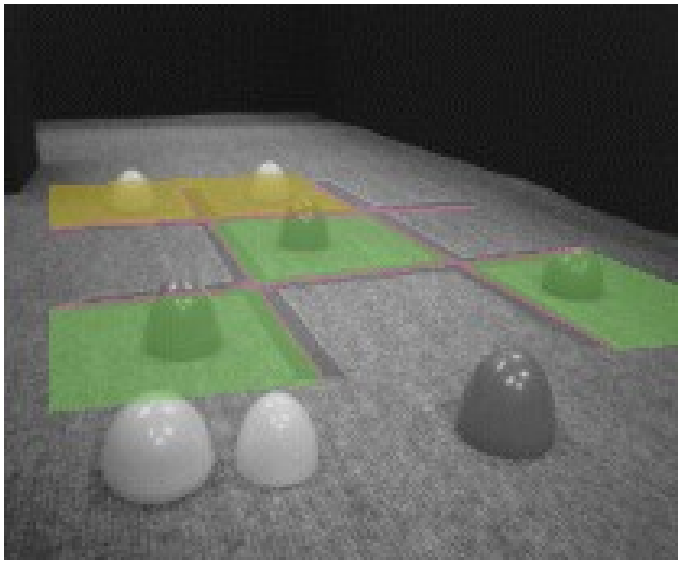
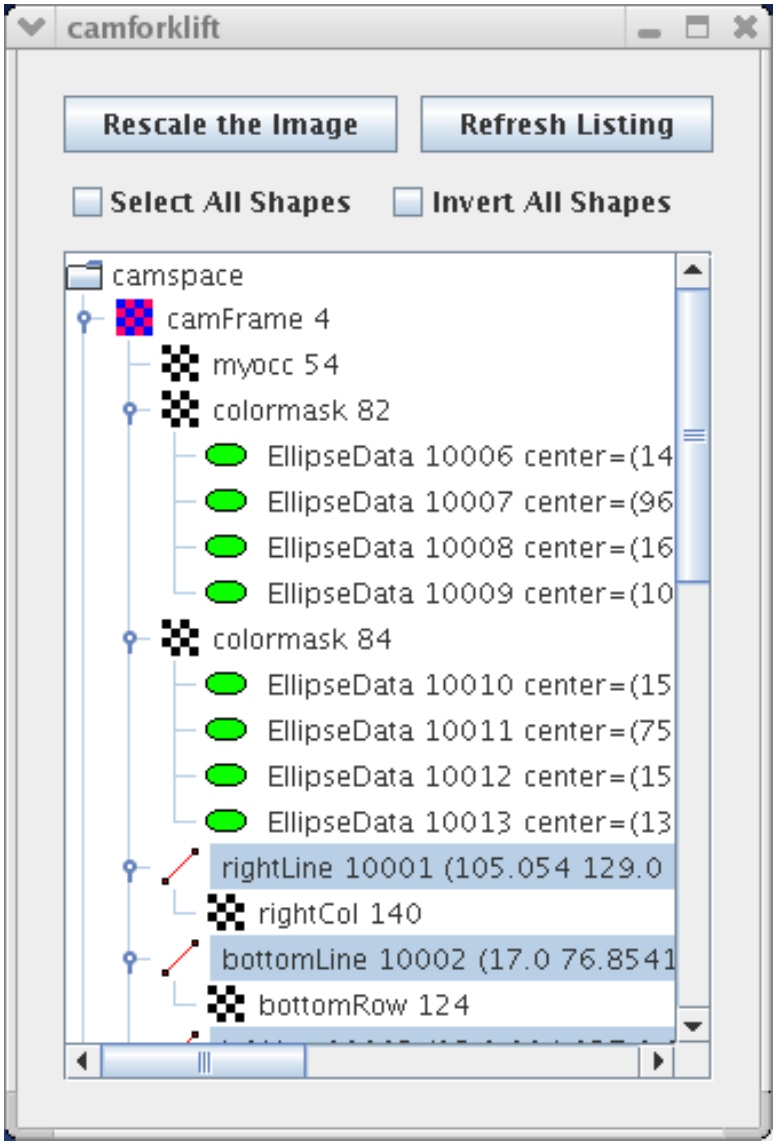


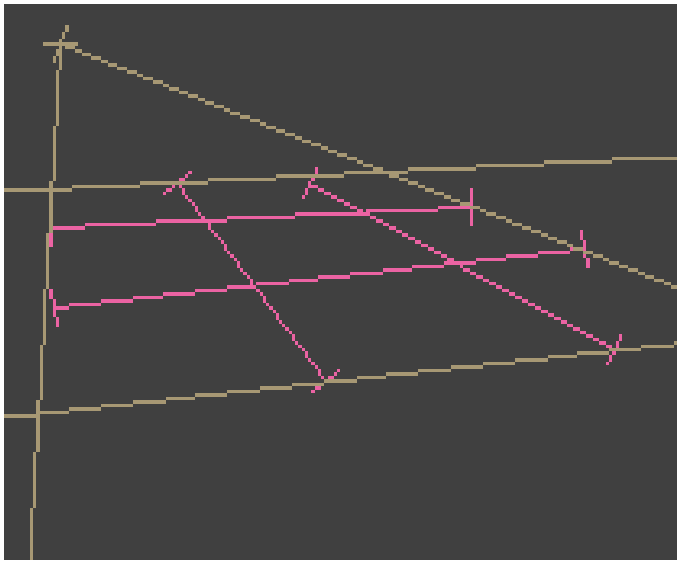




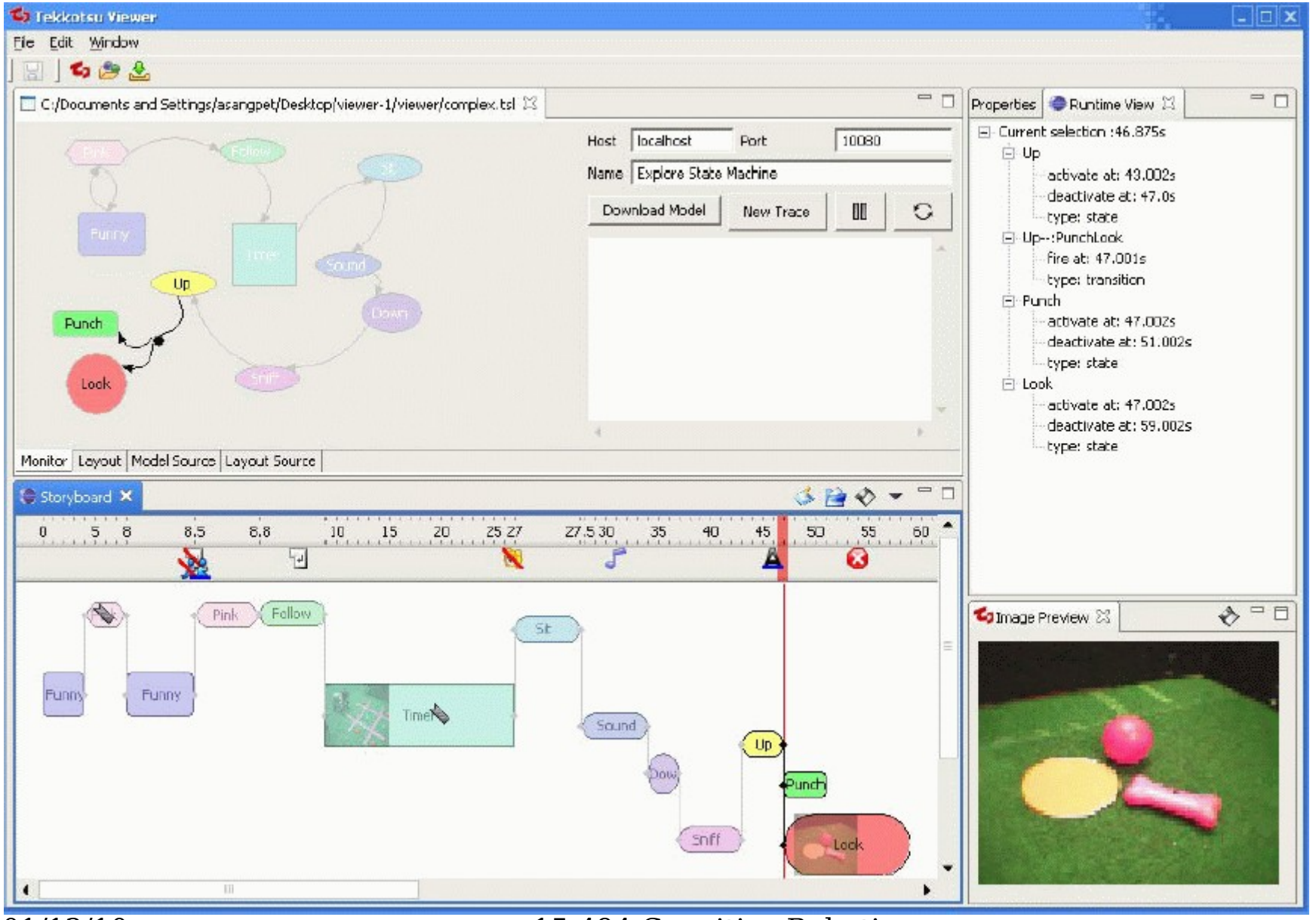


SketchGUI: see inside the robot's head

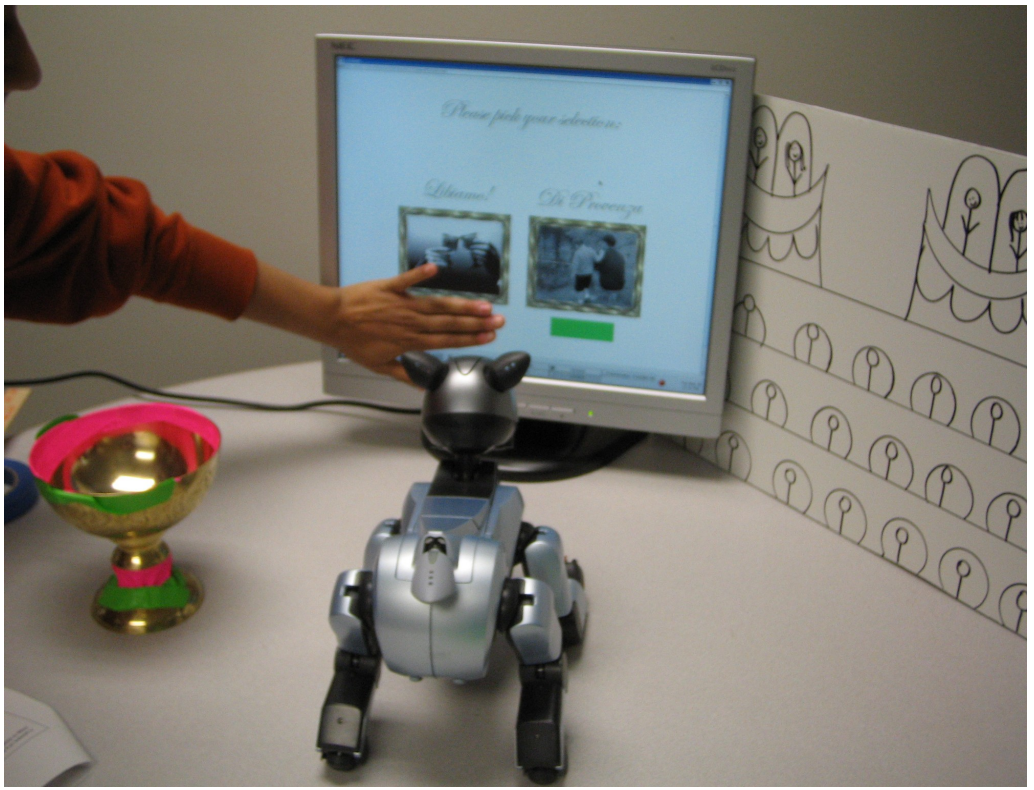




Transparency: Storyboard tool



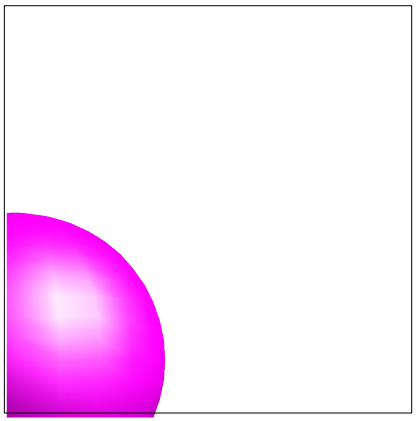
Human-Robot Interaction



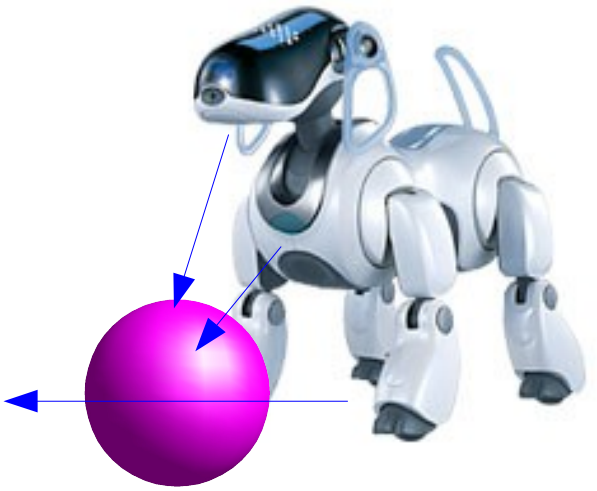
A duet from Verdi's *La Traviata*
(LookingGlass project by Kirtane & Libby)

Ideas from Cognitive Science?

- Visual routines, dual coding theory, gestalt perception, affordances, ...
- Active research area. You can help!



Camera view:
“I see a pink blob”



Affordances:
“I see something I can push”

Robot Learning

Implementing learning algs. on the robot:

- TD learning for classical conditioning

- Two-armed bandit learning problem

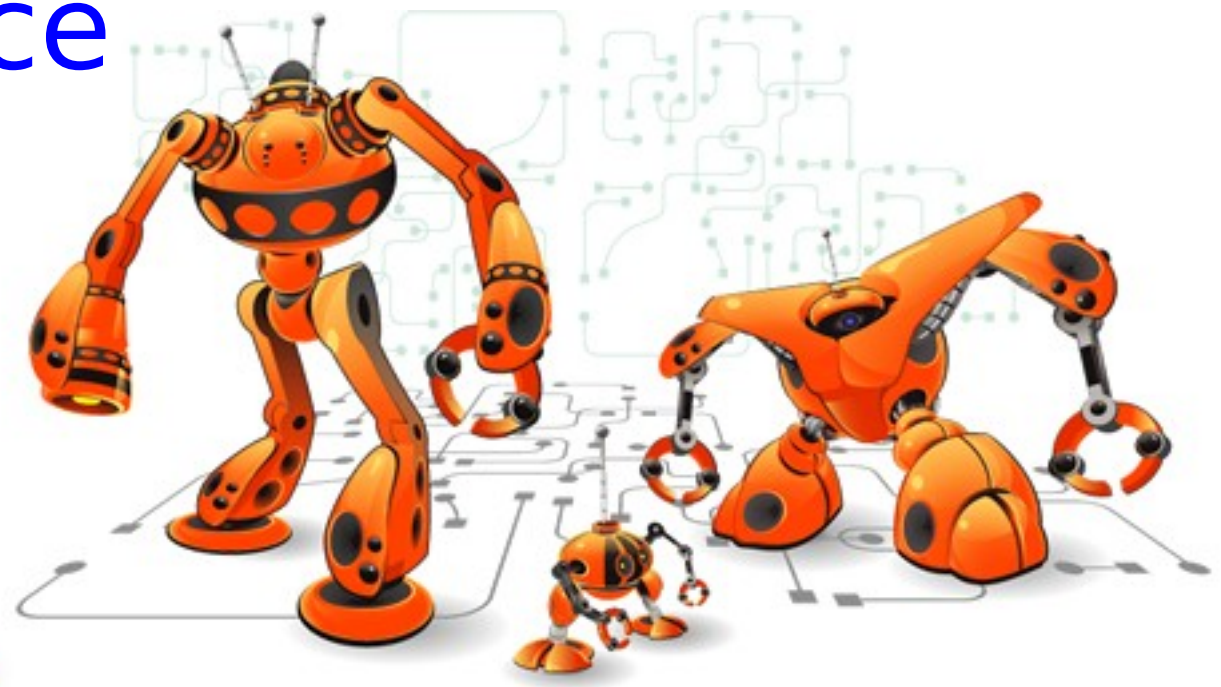
Video demos from Tekkotsu Robotics channel on YouTube

New Features

- Chiara and hand-eye system support
- Much better Create support
- New kinematics engine
- Mirage simulator
- SIFT object recognition tool
  - Based on Xinghao Pan's senior thesis project

ARTSI Alliance

See ARTSIAlliance.org



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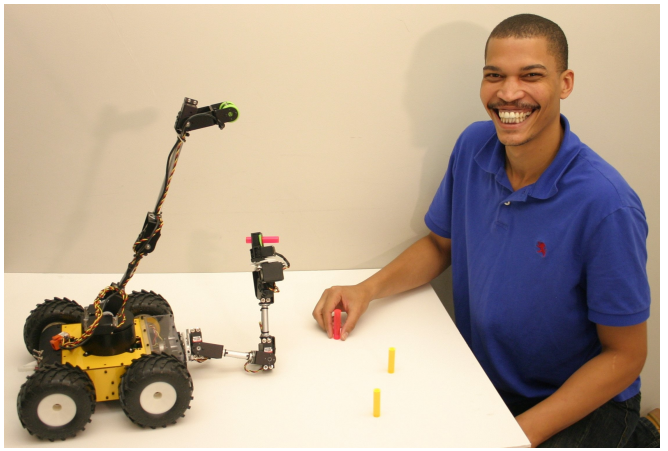
Advancing Robotics Technology for Societal Impact



Course Administrative Stuff

- Times/Locations:
  - Mon / Wed 3:30 to 4:20 in Wean Hall 5320
  - Fri 3:00 to 4:20 in NSH 3206 (REL)
    REL = Robotics Education Lab
- Grading:
  - 25% homeworks and labs
  - 25% midterm exam
  - 25% final exam
  - 25% course project and presentation

Syllabus and Lecture Schedule

- The syllabus/lecture schedule is linked from the course home page:

  www.cs.cmu.edu/afs/cs/academic/class/15494-s10

- Check weekly for updates, links to readings, links to homeworks/labs.
- Some readings should be done before the lecture, some afterwards. Follow the order in the schedule.
- For Friday's lab: review the syllabus and check out Tekkotsu.org.

Teamwork

- You are permitted, but not required, to work in teams.
- A team may have at most 3 members.
- When handing in an assignment, only one copy need be handed in per team. Everyone's name should be on it.

Final Projects

- Proposal stage:
  - Pick something cool (we'll give suggestions); convince us that you can carry it off.
  - Previous years' projects are on the web.
- Development stage:
  - We'll have project clinics to help you work on your projects.
- Presentation stage:
  - Develop a presentation and demo.
  - Public demonstrations on last day of class