15-494/694: Cognitive Robotics

Spring 2014

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What Is this course about?

A new approach to programming robots:

- Creating tools to make robot behavior *intuitive and transparent.*
- Borrowing ideas from cognitive science to make robots smarter.
- Building the infrastructure to teach “ten big ideas in robotics”.

Ten Big Ideas in Robotics

1. How do robots know what to do?
   - State machines (for now)
2. How do robots perceive the world?
   - Computer vision
3. How do robots know where they are?
   - Particle filters for localization
4. How do robots know where to go?
   - Path planning using RRTs

Ten Big Ideas (cont.)

5. How do robots control their bodies?
   - Kinematic chains and IK solvers
6. How do robotic systems manage complexity?
   - Abstraction; software engineering
7. How do robots calculate the quantities they need to function?
   - Trigonometry and linear algebra

Ten Big Ideas (cont.)

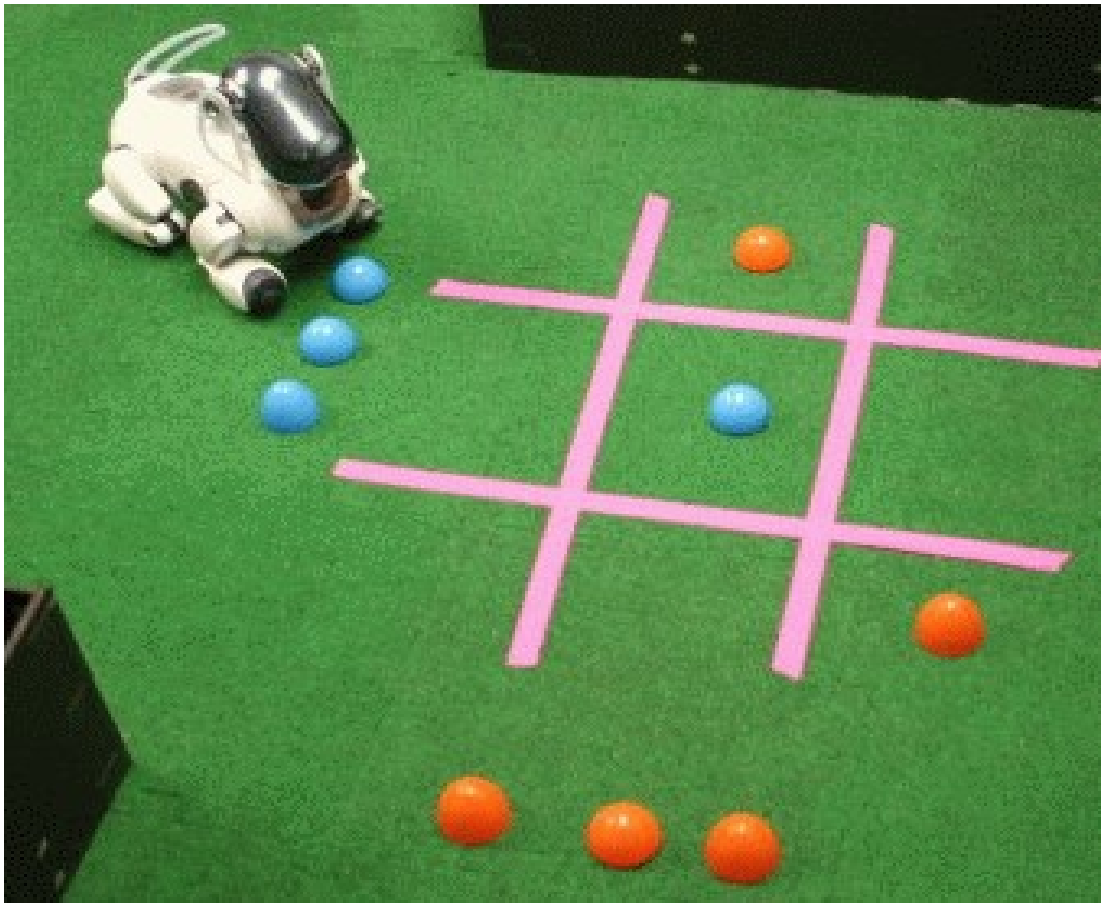
8. How can robots solve complex problems?
   - Task planners; domain description langs.

9. How should robots behave around people?
   - Human-tracking; speech and gesture recognition

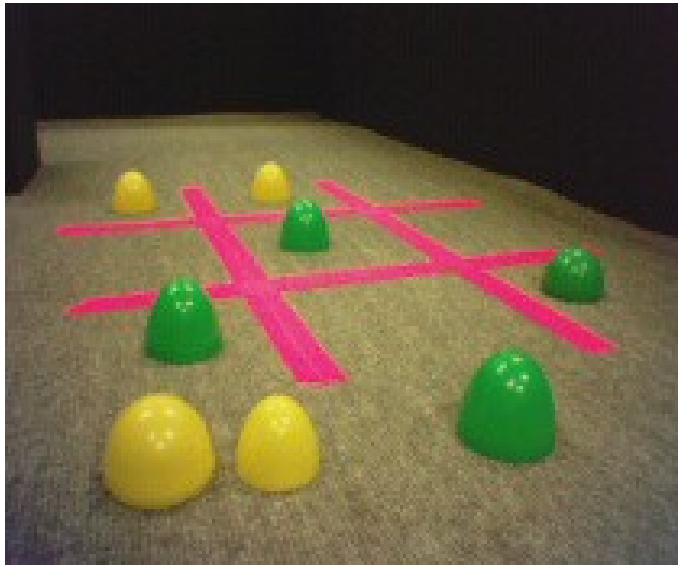
10. How can robots work together?
   - Communication primitives; multi-robot planners

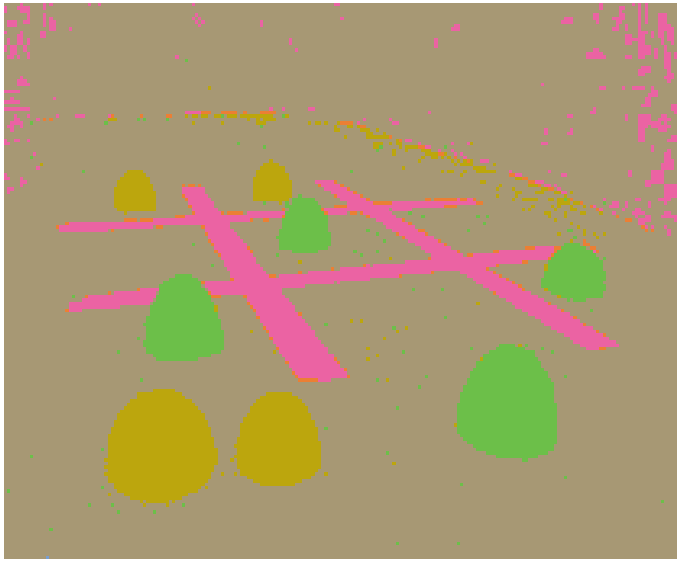
Primitives needed for tic-tac-toe

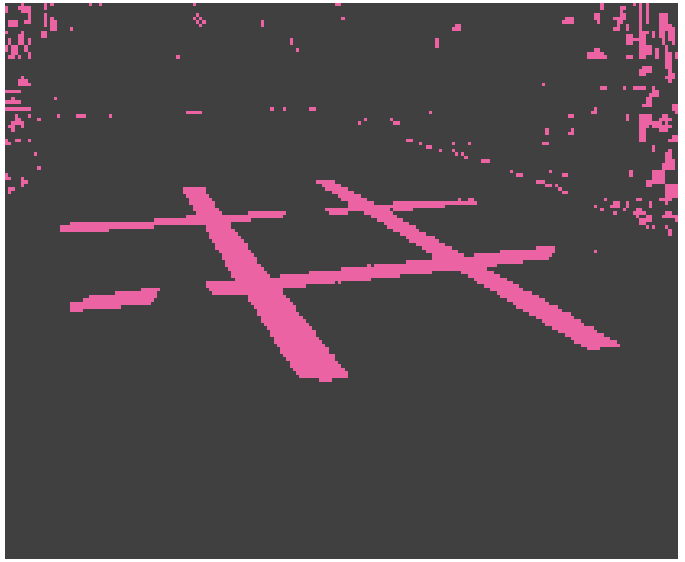
- See and understand the board (perception, mapping)
- Move the game pieces (manipulation)
- Take turns (control)

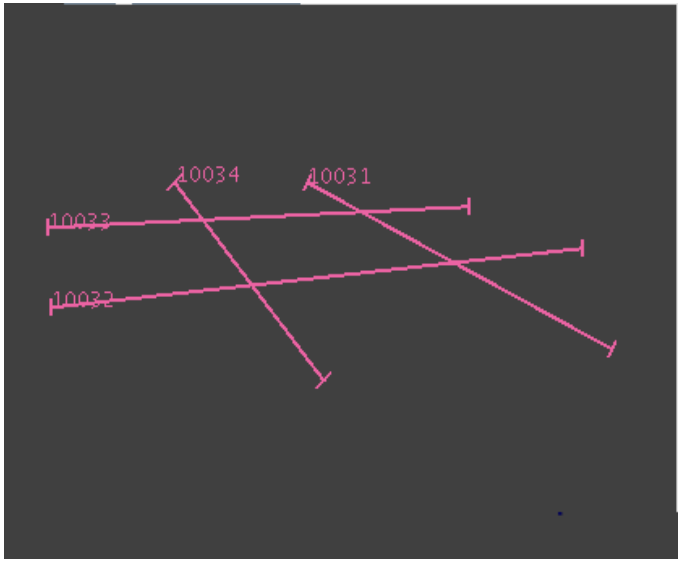


Visual Routines









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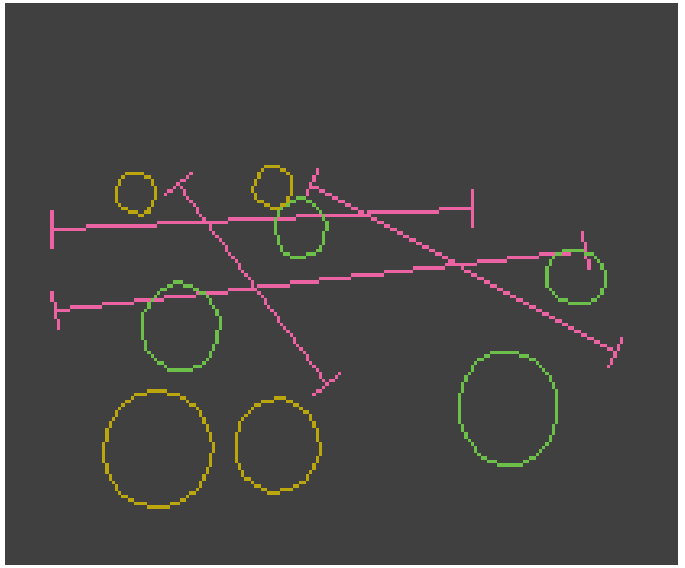
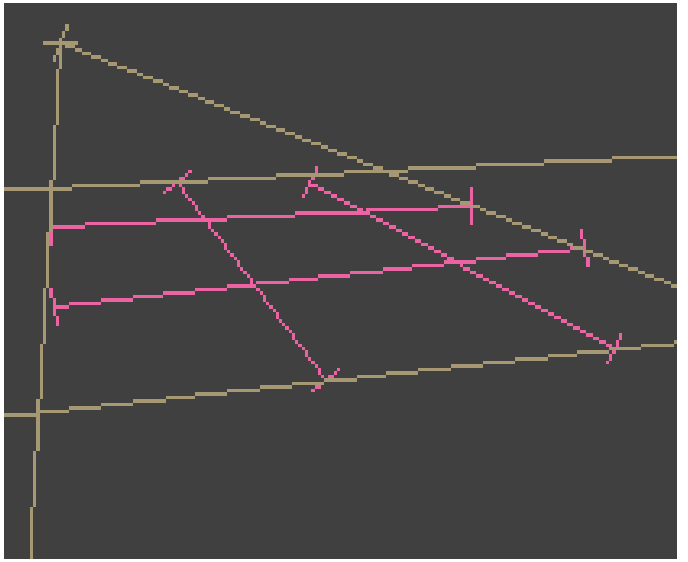
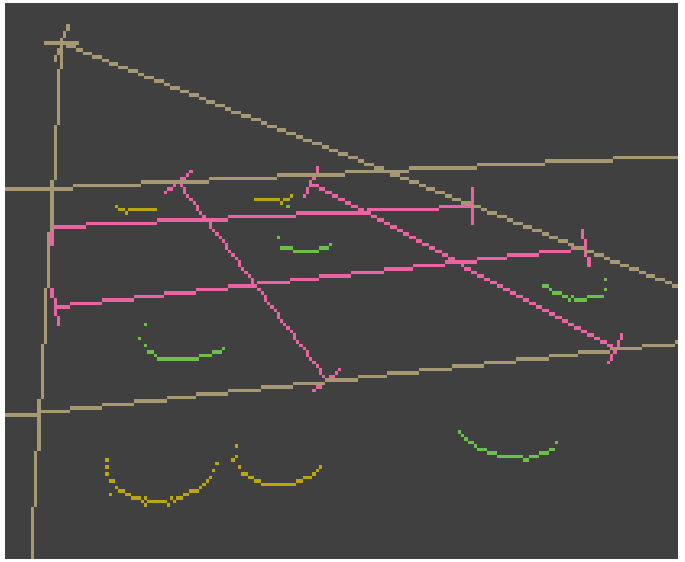
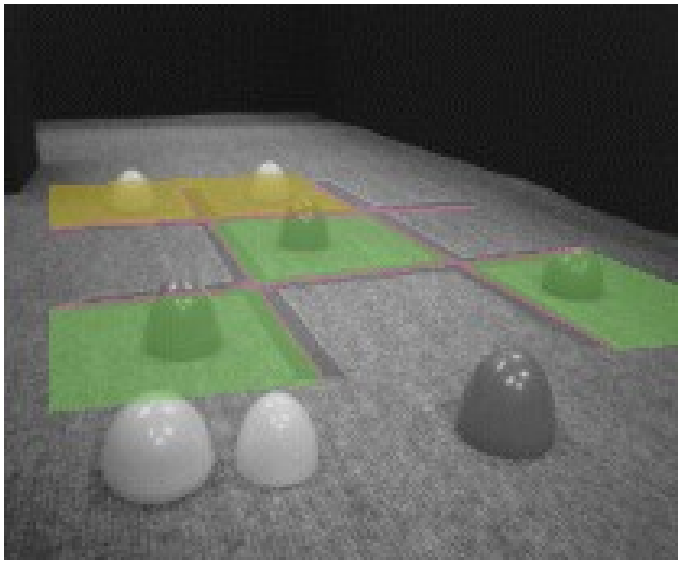
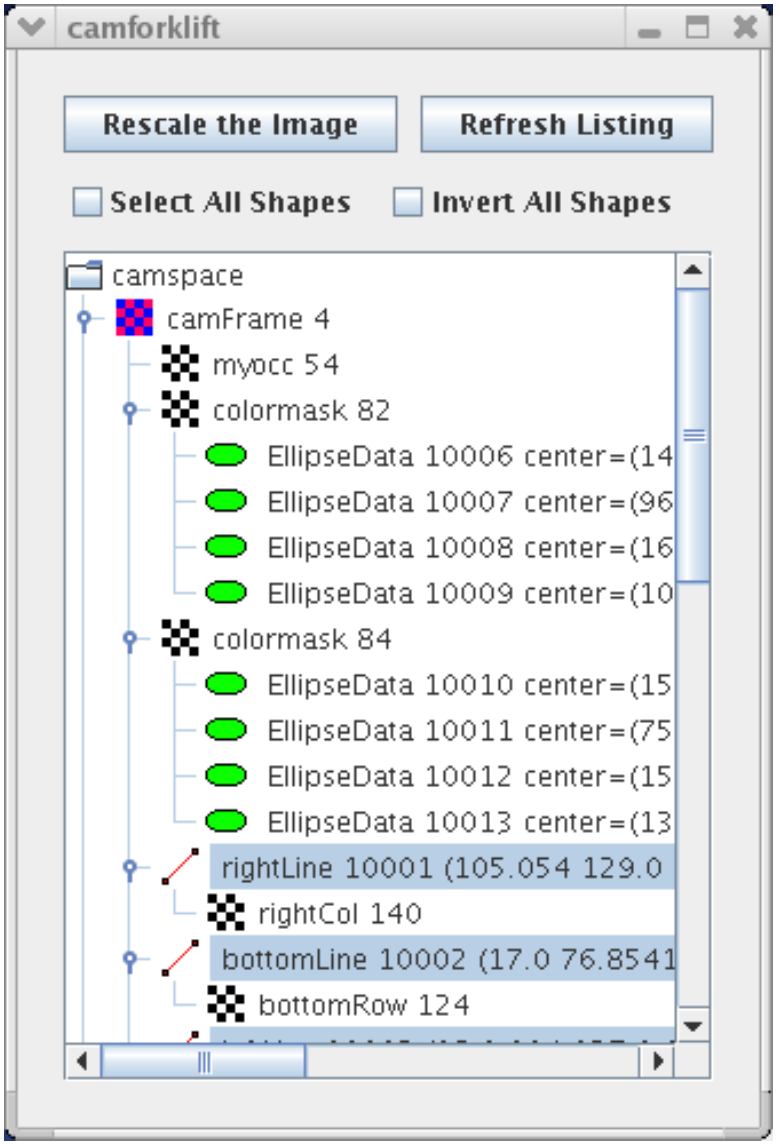


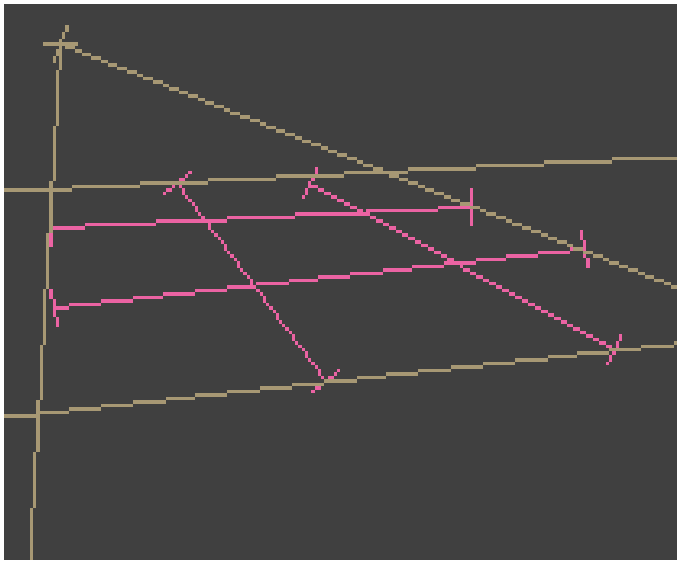




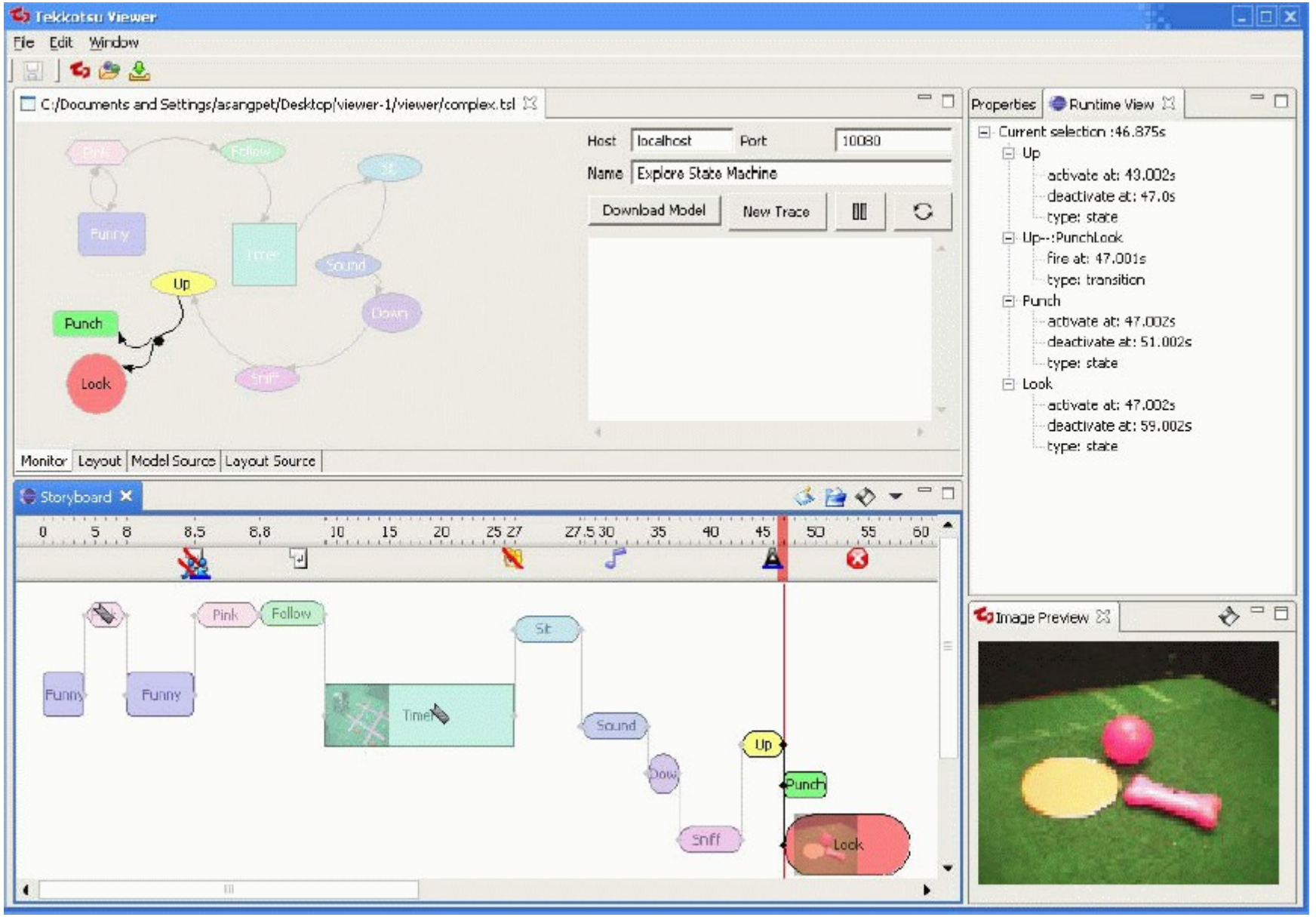


SketchGUI: see inside the robot's head

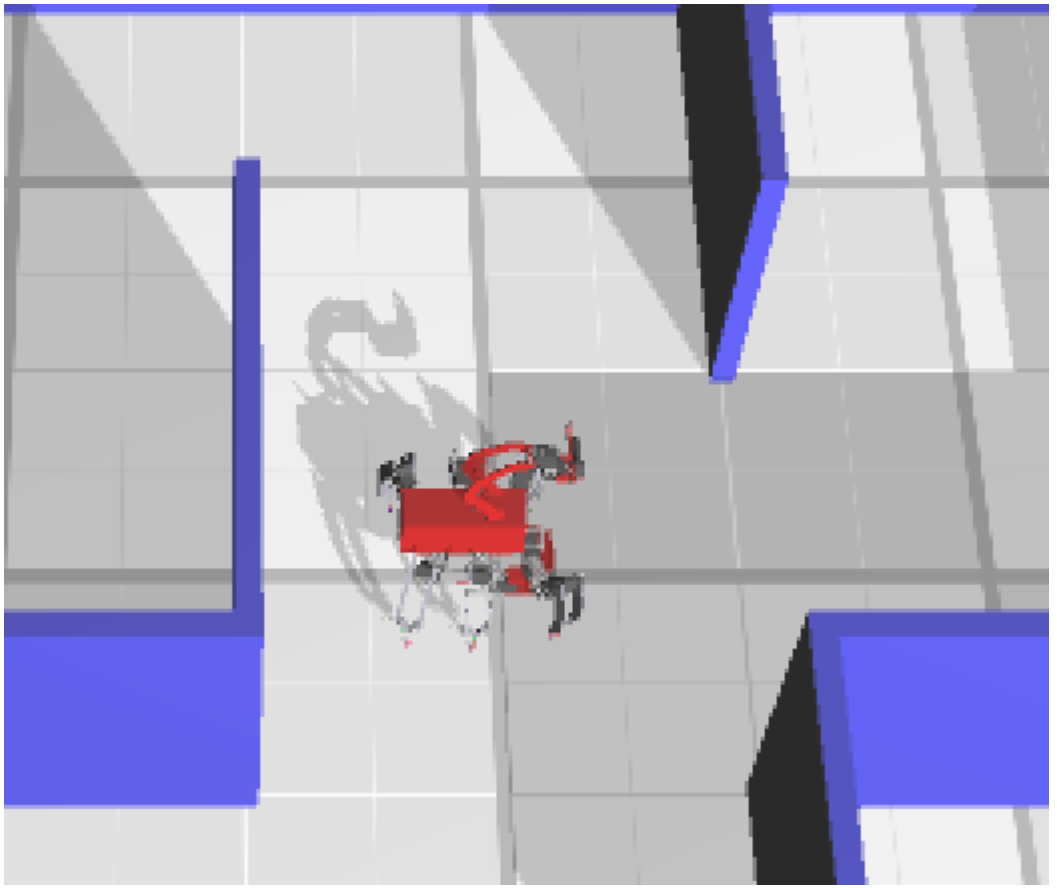




Transparency: Storyboard tool

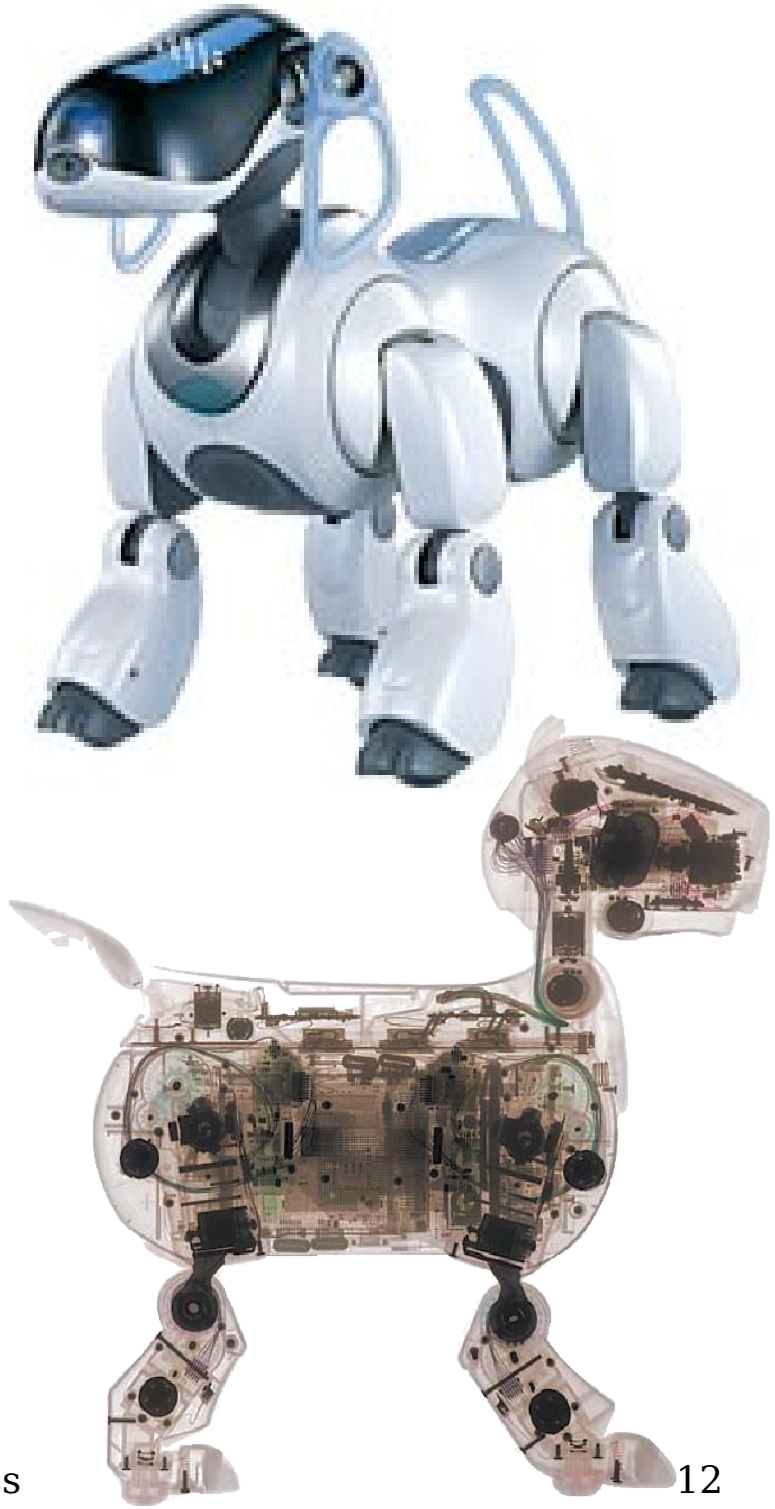


Mirage Simulator



Early Days: 2006
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



Robot Learning

Implementing learning algs. on the robot:

- TD learning for classical conditioning

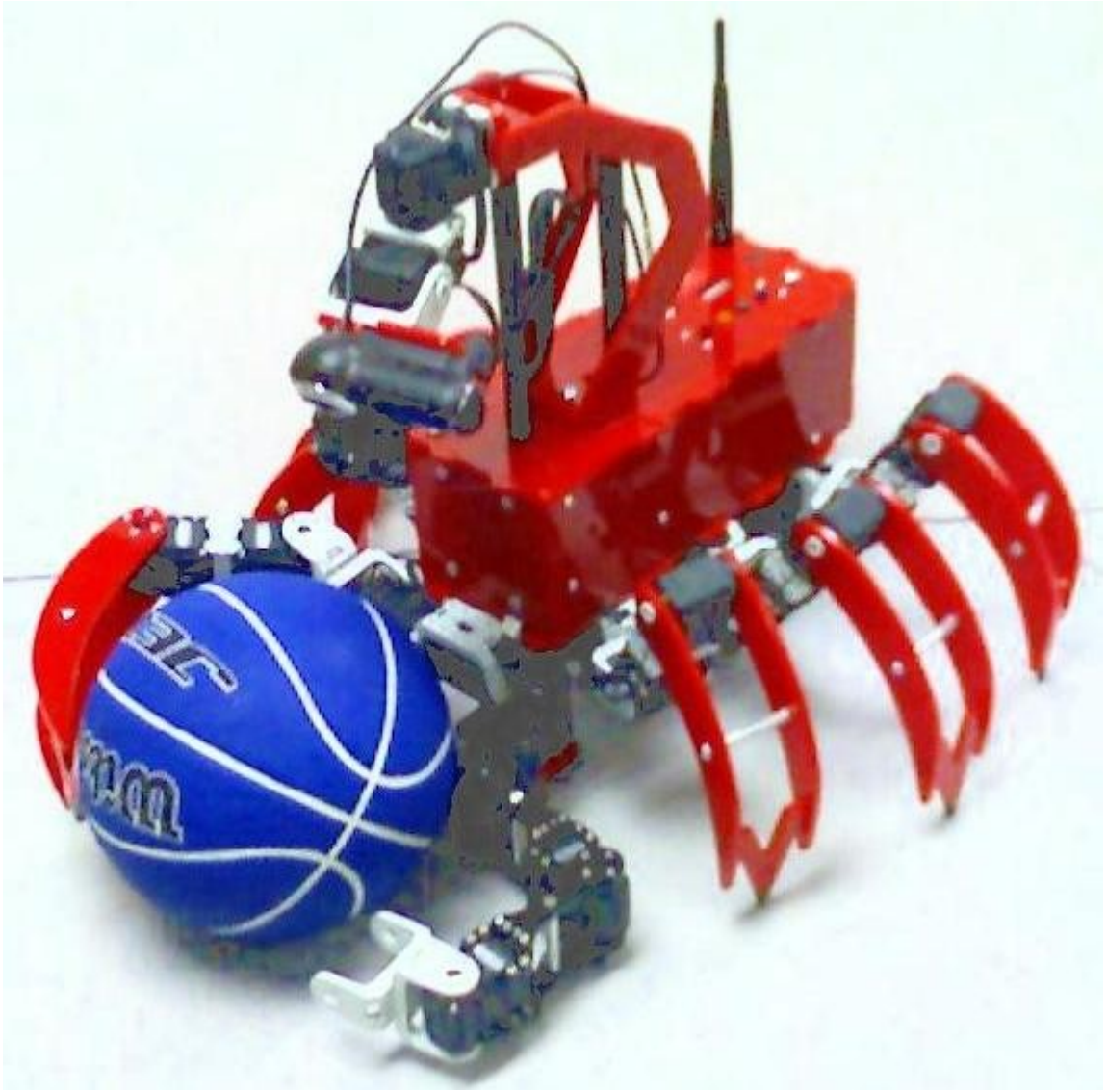
- Two-armed bandit learning problem

Video demos from Tekkotsu Robotics channel on YouTube

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)

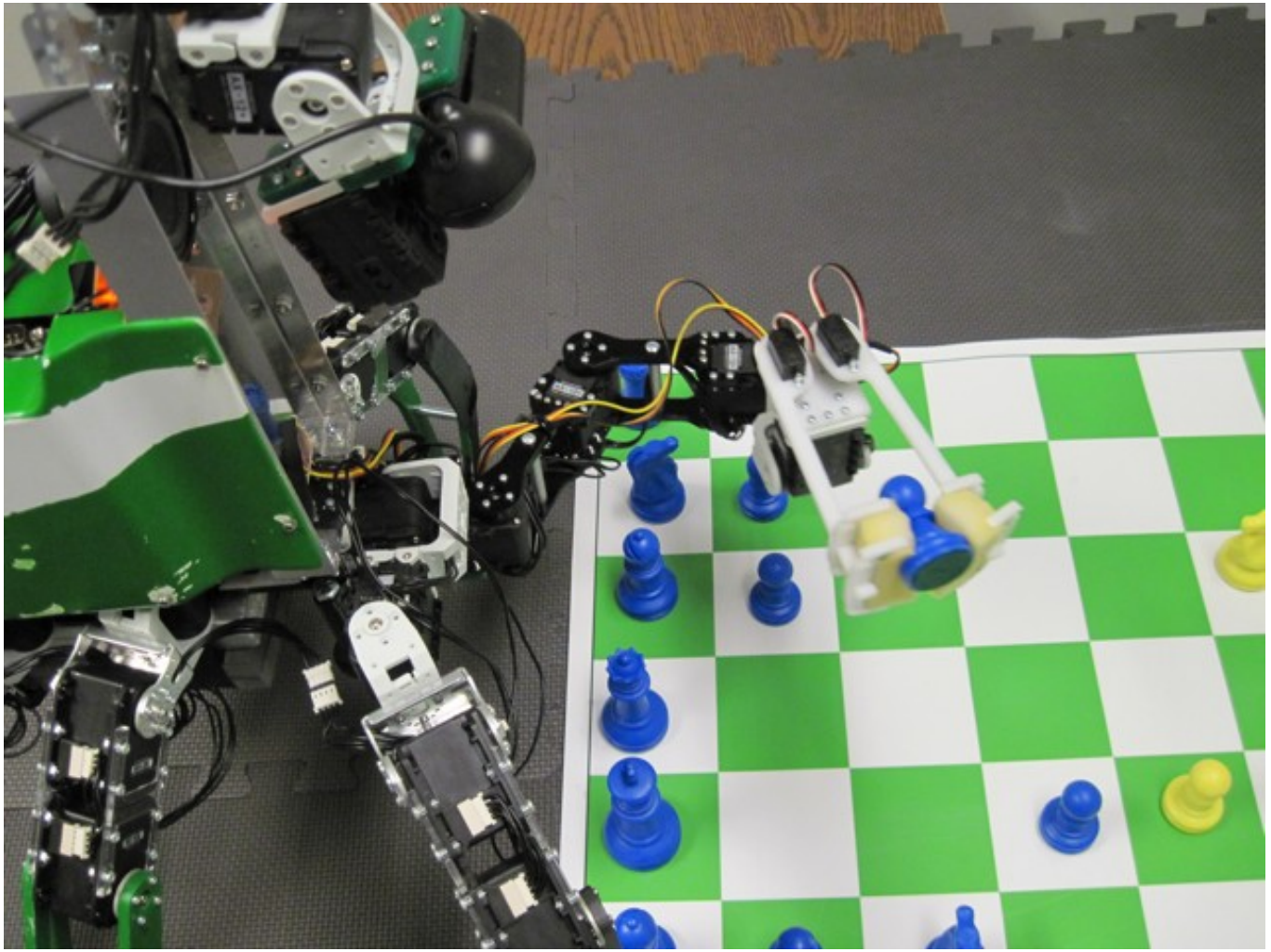


- 21 built
- Fixed gripper (c-bracket)

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

Delta Series Mockup

Chiaras Play Chess at AAAI-2010

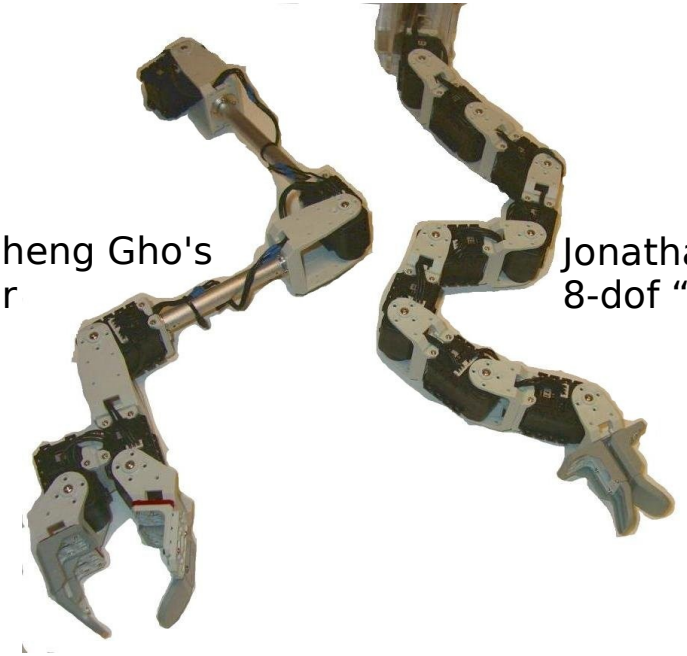


Chiara Playing "*Ode to Joy*"

Demo by high school student Ashwin Iyengar, August 2010.

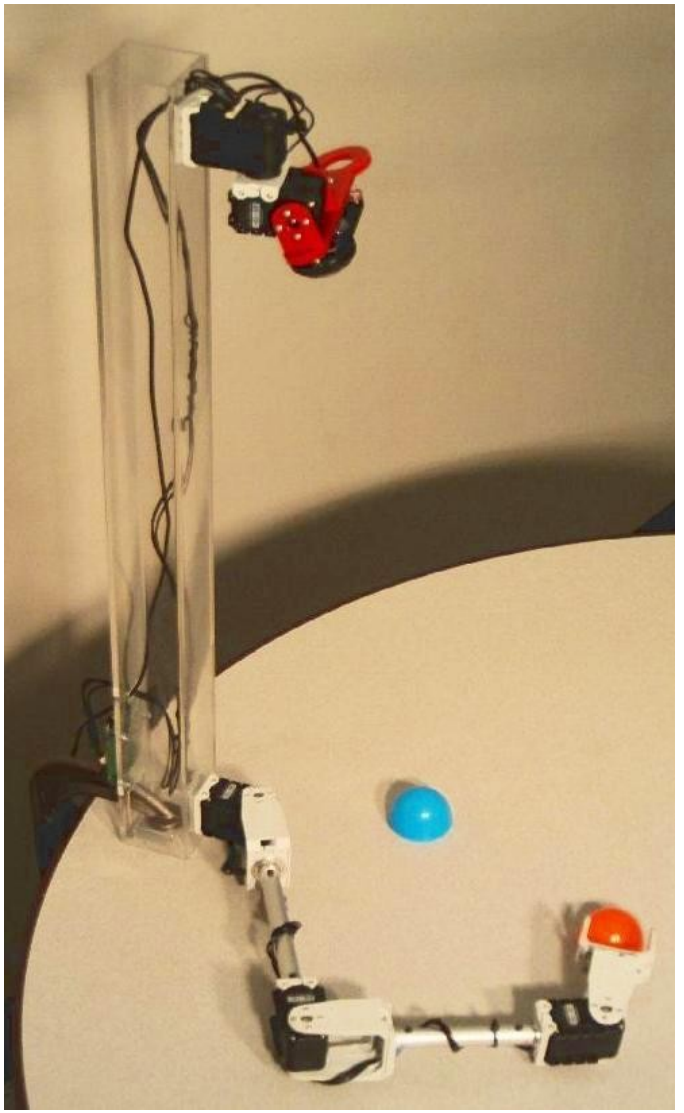
Tekkotsu Planar Hand-Eye System

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



Zhengheng Gho's gripper

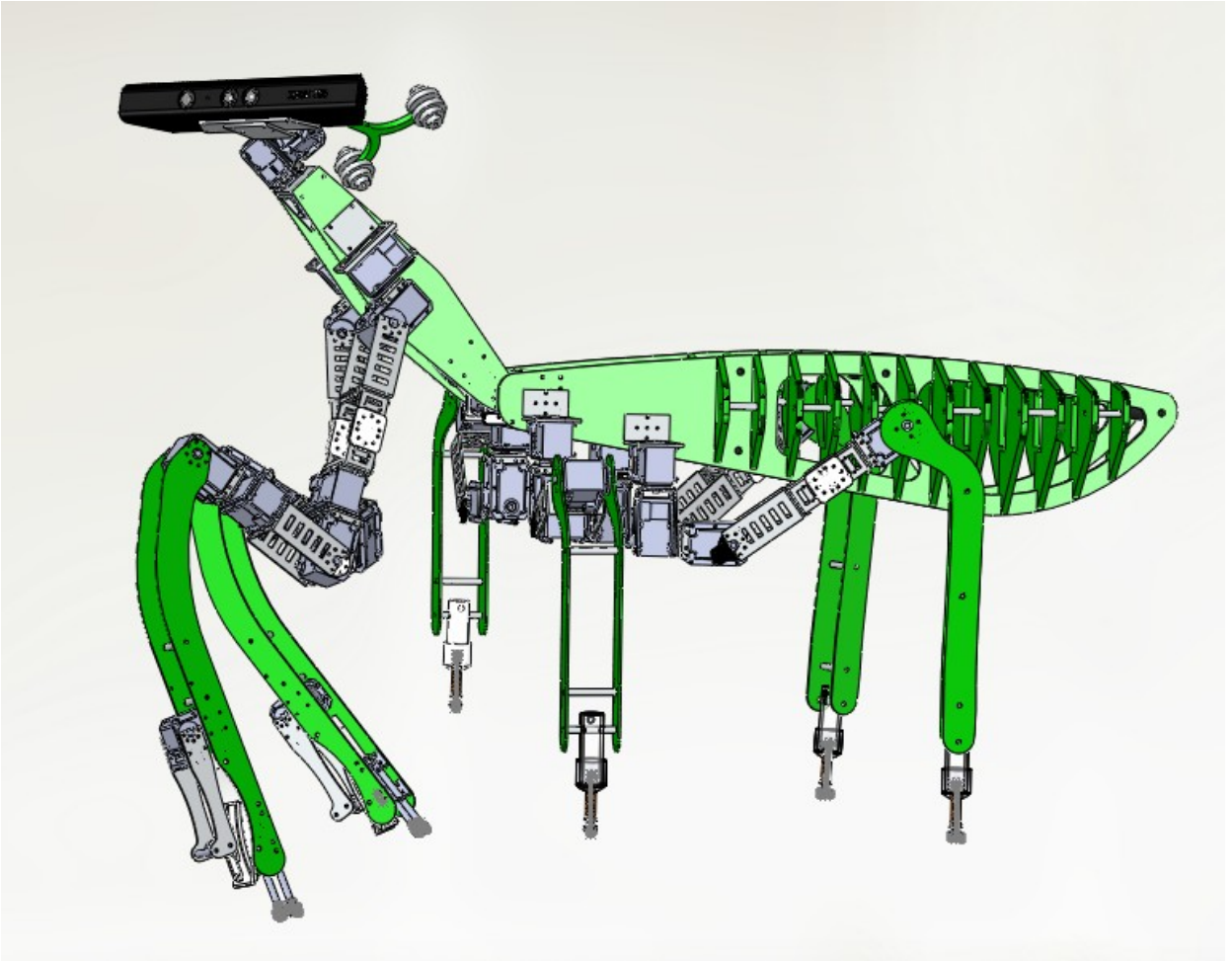
Jonathan Coens' 8-dof “tentacle”



Calliope5KP

Calliope2SP

Chiara Mantis



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

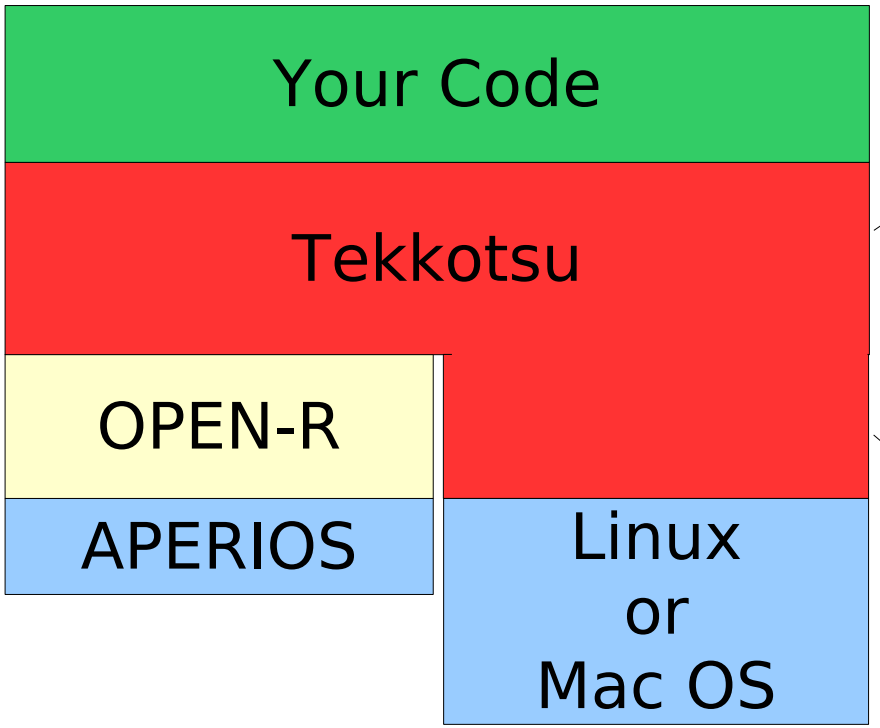
Chiara depth from stereo
4,914 views
8 months ago

Chiara robot rolling a ball
836 views
8 months ago

Tekkotsu Means “Framework” in Japanese

(Literally “iron bones”)

Tekkotsu.org



Tekkotsu features:

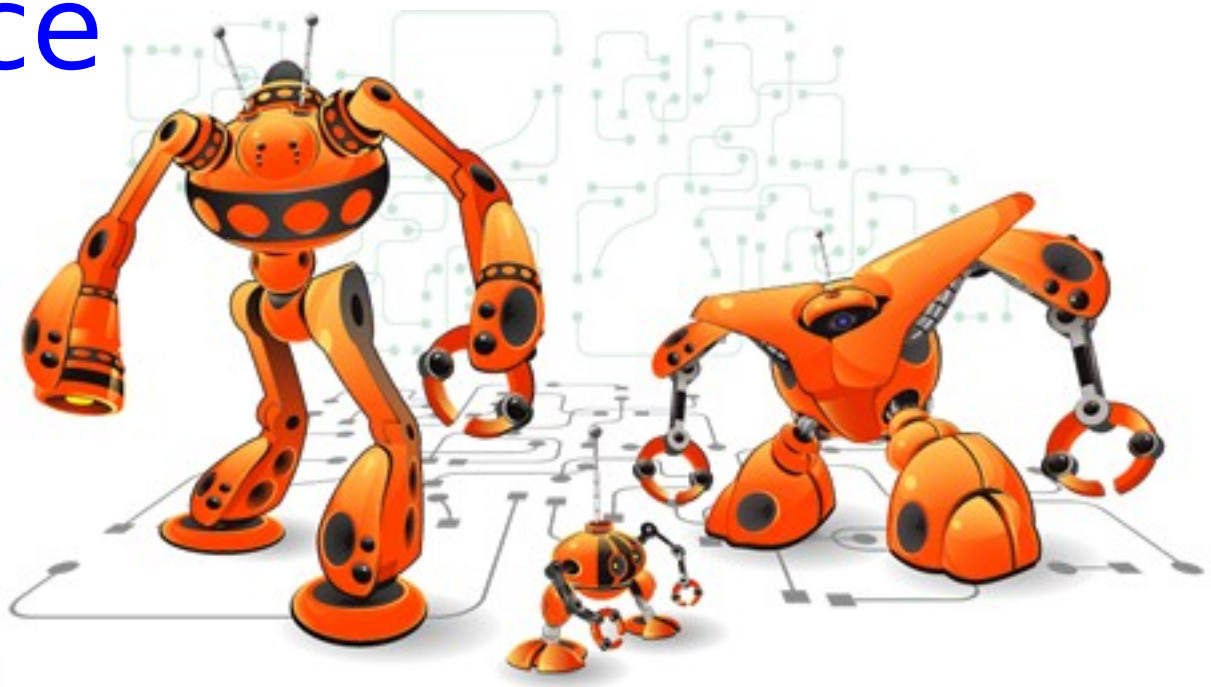
- Open source, LGPLed
- Event-based architecture
- Powerful GUI interface
- Documented with doxygen
- Extensive use of C++ templates, multiple inheritance, and polymorphism

Tekkotsu vs. ROS

• **Unified** framework for perception, navigation, and manipulation	• Emphasis on **orthogonality** of components: “mix and match”
• **Single** address space model simplifies coding & debugging	• **Multi**-process approach good for scalability (but with some costs)
• Designed for **education**	• Designed for **research**

ARTSI Alliance

See ARTSIAlliance.org



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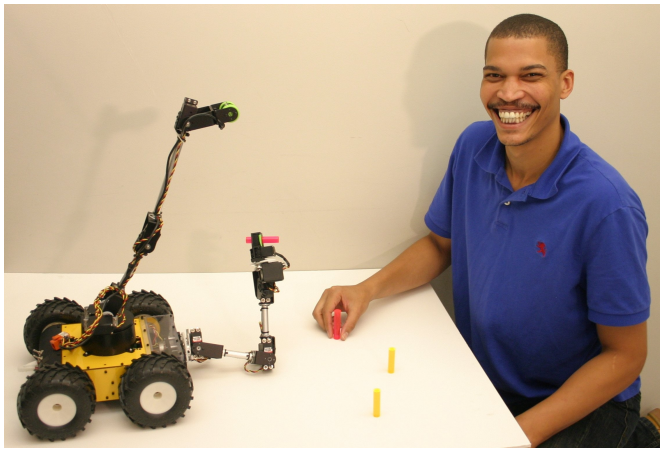
Advancing Robotics Technology for Societal Impact



Course Administrative Stuff

- Times/Locations:
  - Mon / Wed 3:30 to 4:20 in GHC 4101
  - Fri 3:00 to 4:20 in NSH 3206 (REL)
    REL = Robotics Education Lab
- Grading:
  - 35% homeworks and labs
  - 25% midterm exam
  - 40% 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-s14

- 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 wiki.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

Tekkotsu On Your Laptop

- If you run Linux on your laptop:
  - You can install Tekkotsu directly. See wiki.tekkotsu.org for instructions.
- For Windows users:
  - The Tekkotsu Flash Drive is a bootable flash drive with Ubuntu 10.04, Tekkotsu, and Mirage pre-installed.
  - Bring in a blank 8 GB flash drive and I will make it into a Tekkotsu flash drive.