15-494/694: Cognitive Robotics

Spring 2016

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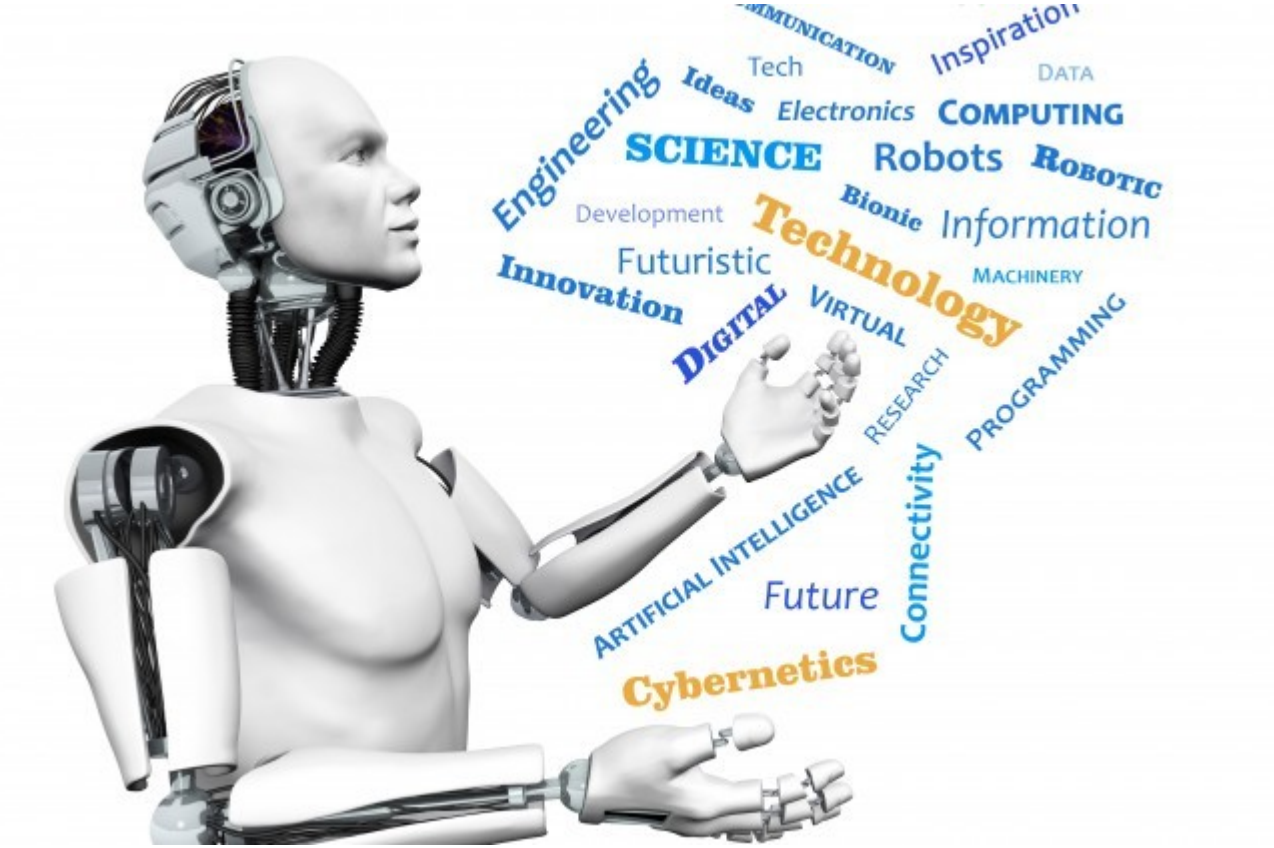


Image from http://www.futuristgerd.com/2015/09/10

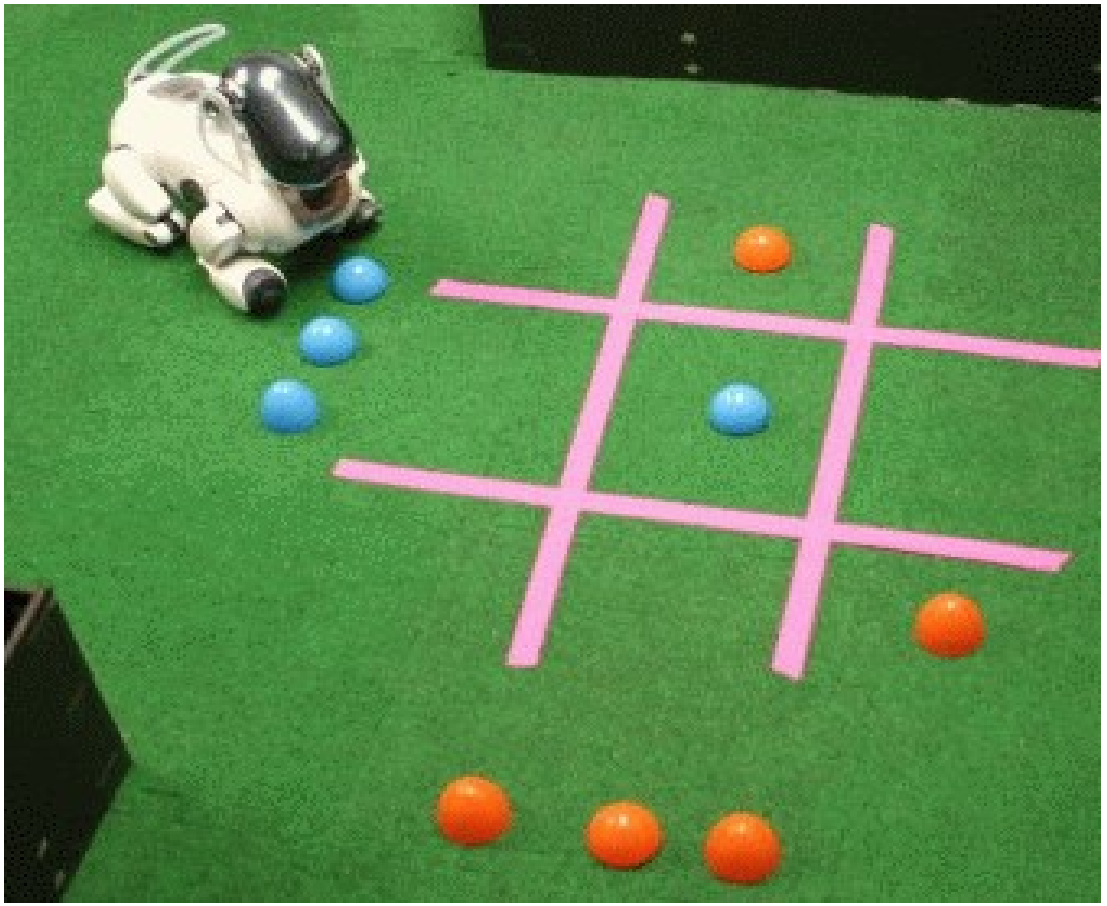
What Is This Course About?

A new approach to programming robots:

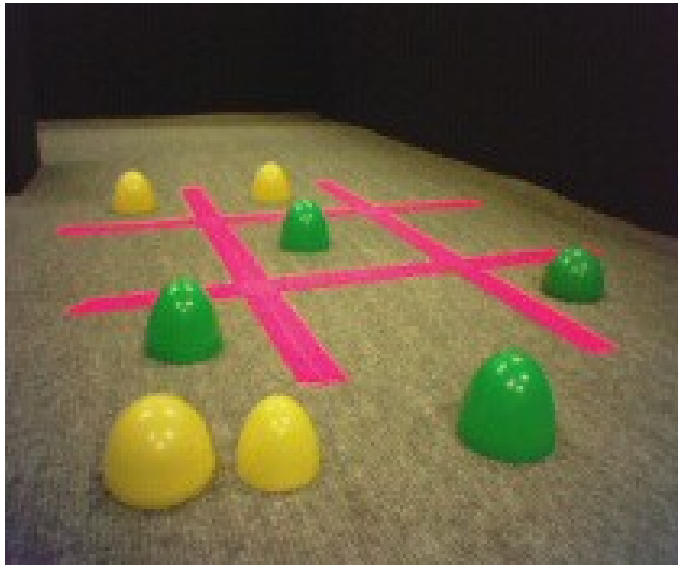
- Creating tools to make robot behavior *intuitive and transparent.*
- Borrowing ideas from cognitive science to make robots smarter.
- Building the infrastructure to teach “ten big ideas in robotics”.

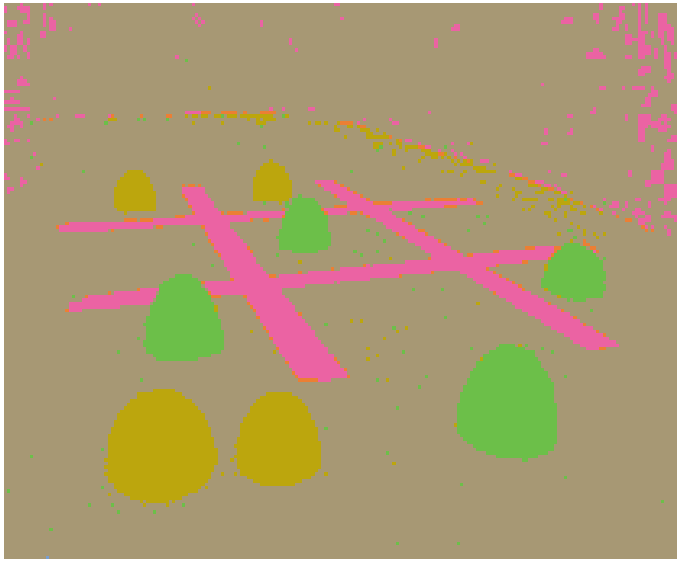
Primitives needed for tic-tac-toe

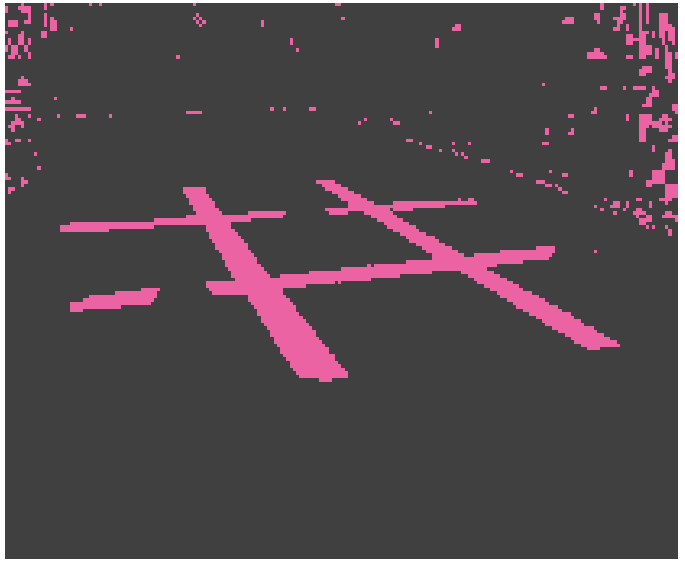
- See and understand the board (perception, mapping)
- Move the game pieces (manipulation)
- Take turns (control)

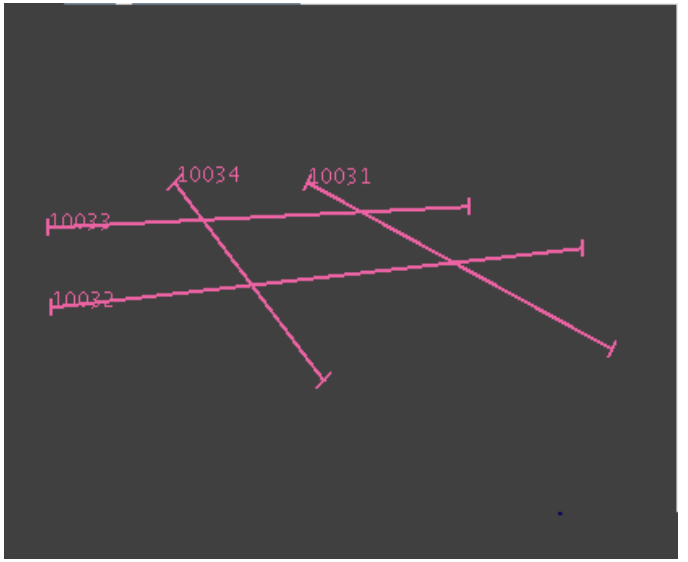


Visual Routines

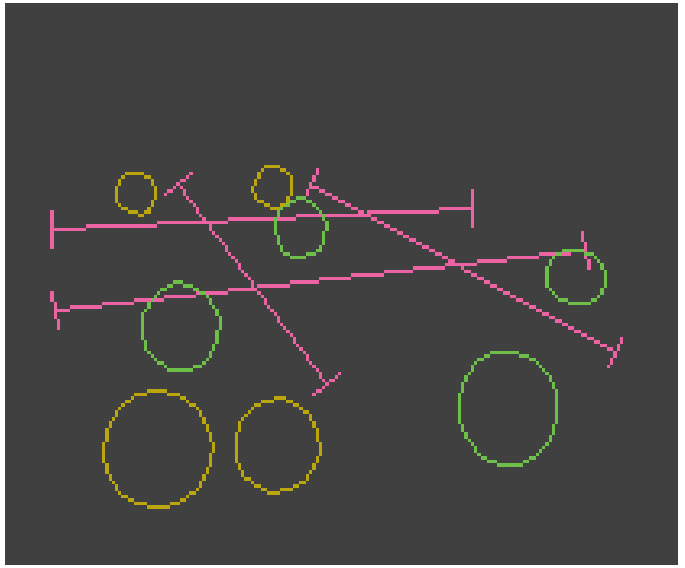


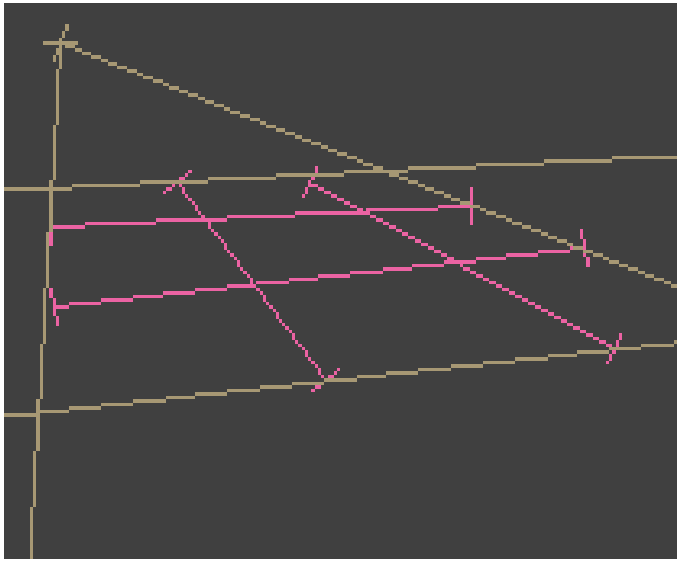


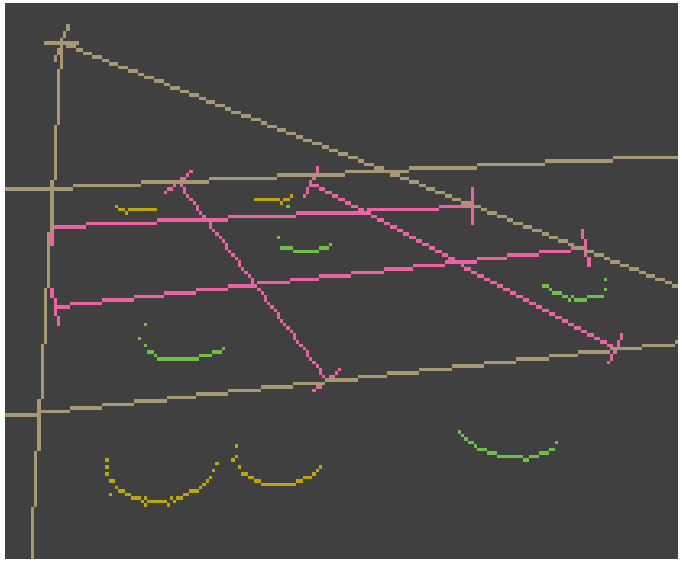


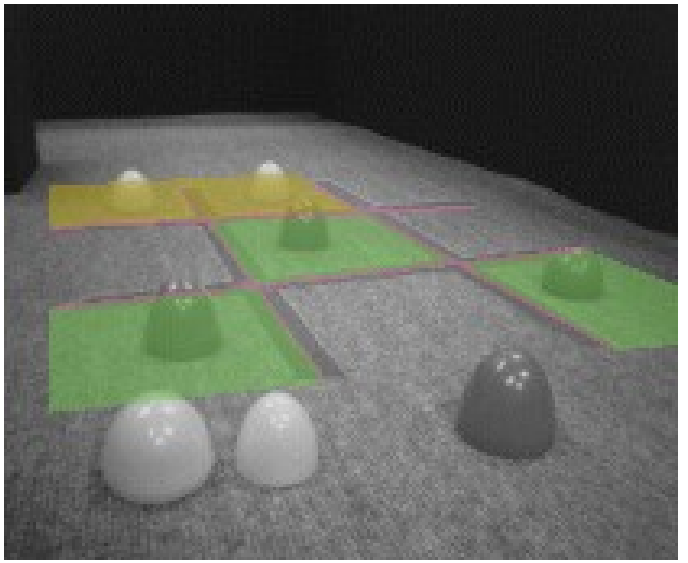


Visual Routines

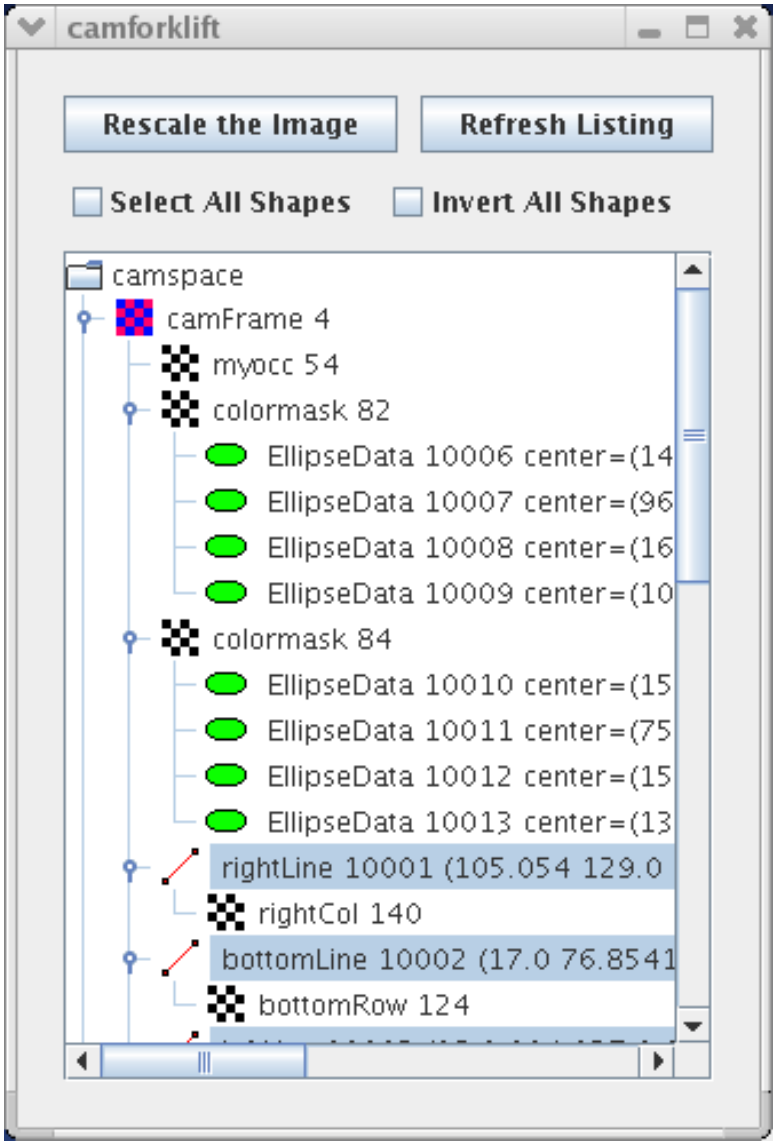


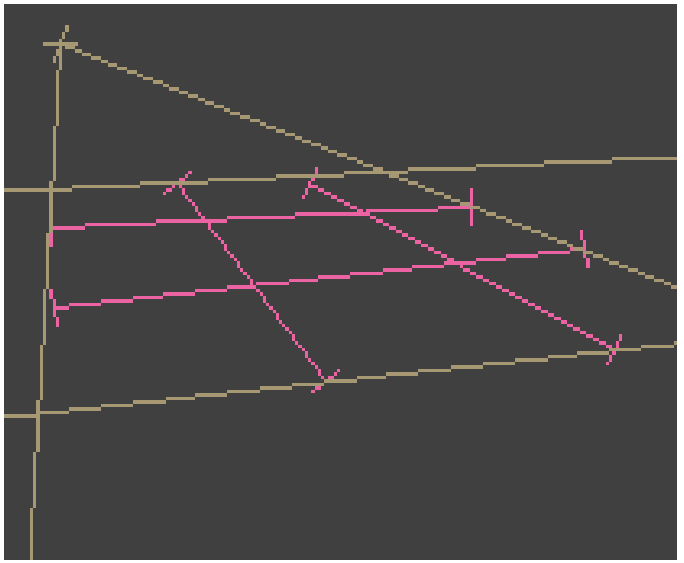




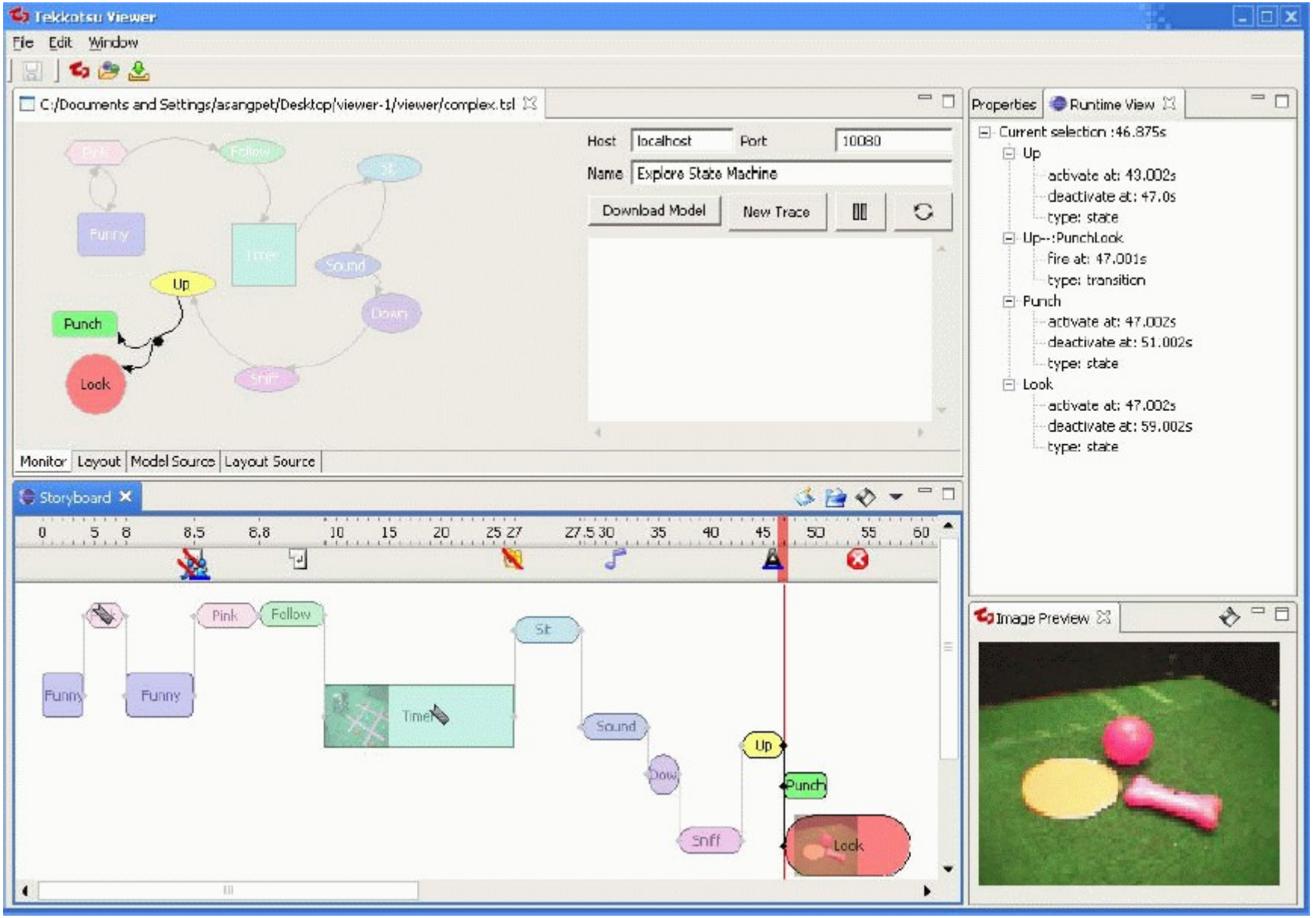


SketchGUI: see inside the robot's head

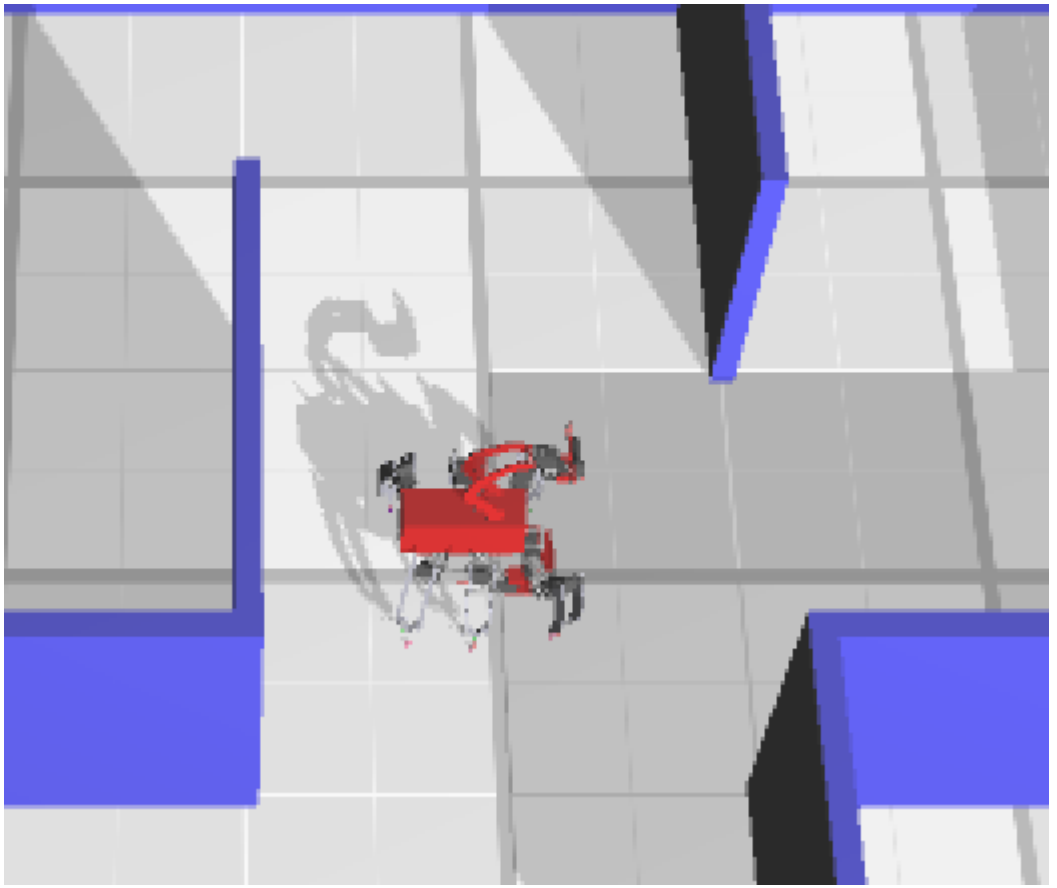




Transparency: Storyboard tool



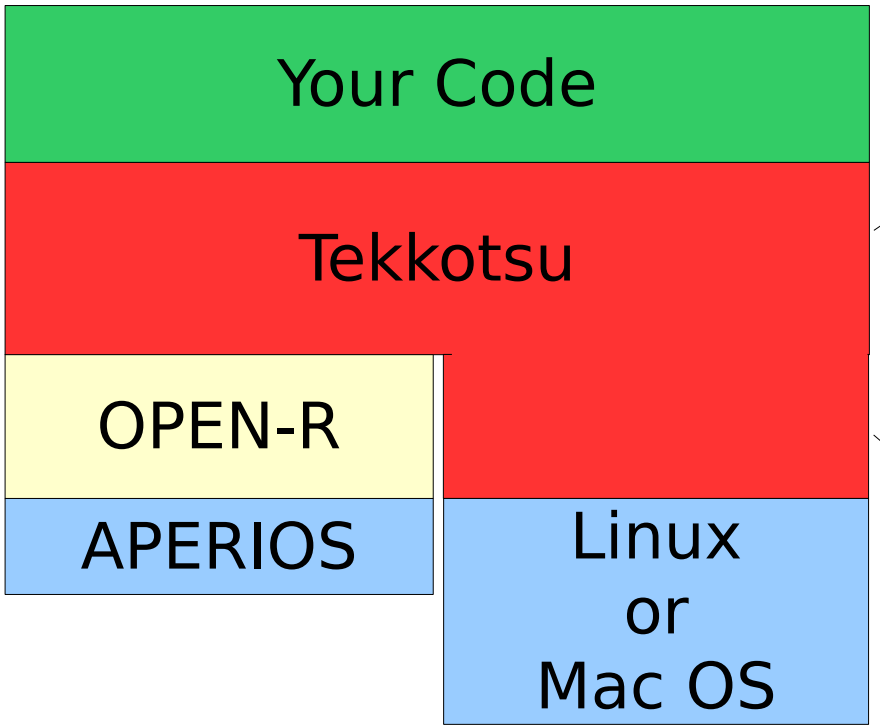
Mirage Simulator



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

The Tekkotsu “Crew”

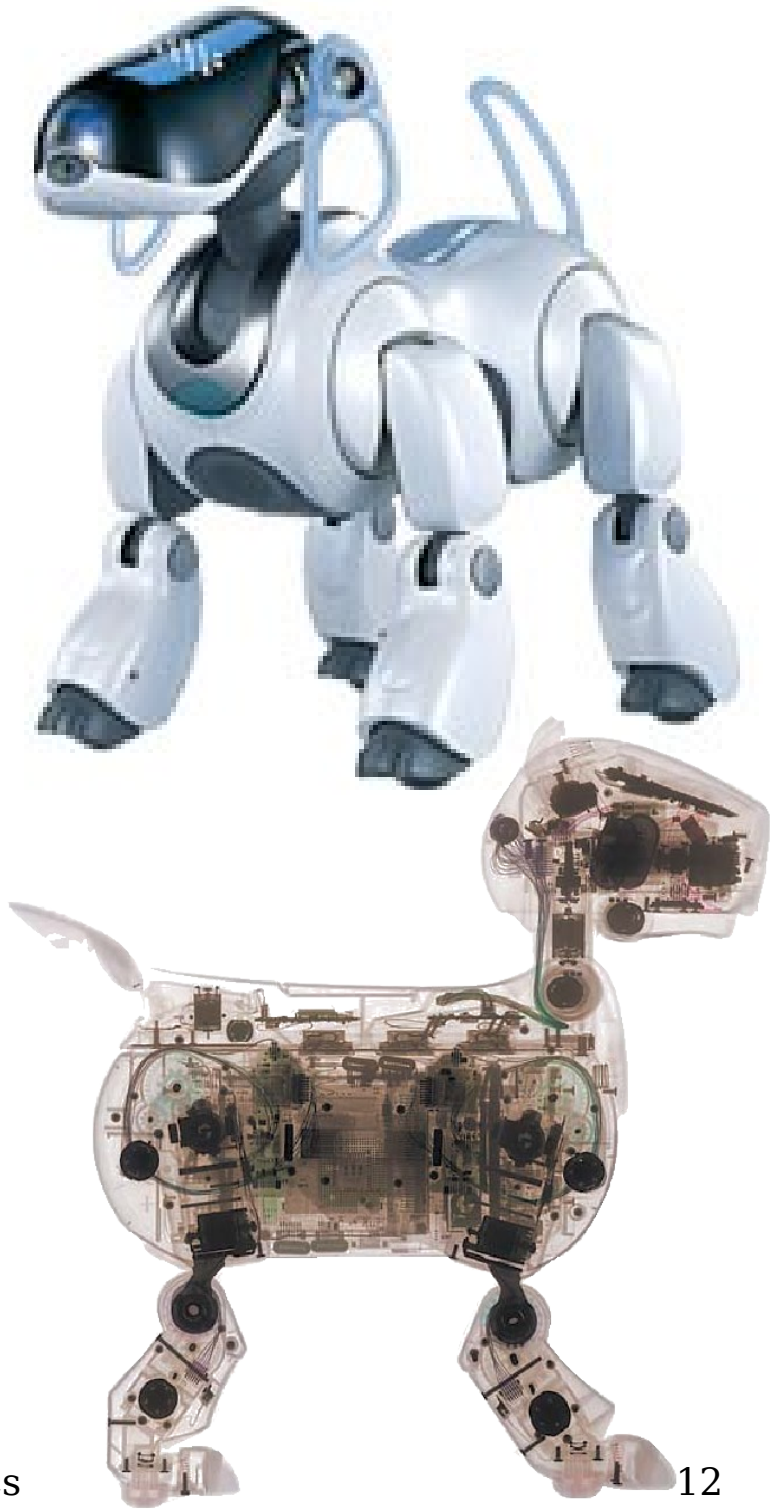
- MapBuilder does vision and maintains local and world maps.
- Lookout moves the head and controls the sensor package.
- Pilot is responsible for navigation and localization.
- Grasper controls the arm and is responsible for manipulation.

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**

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

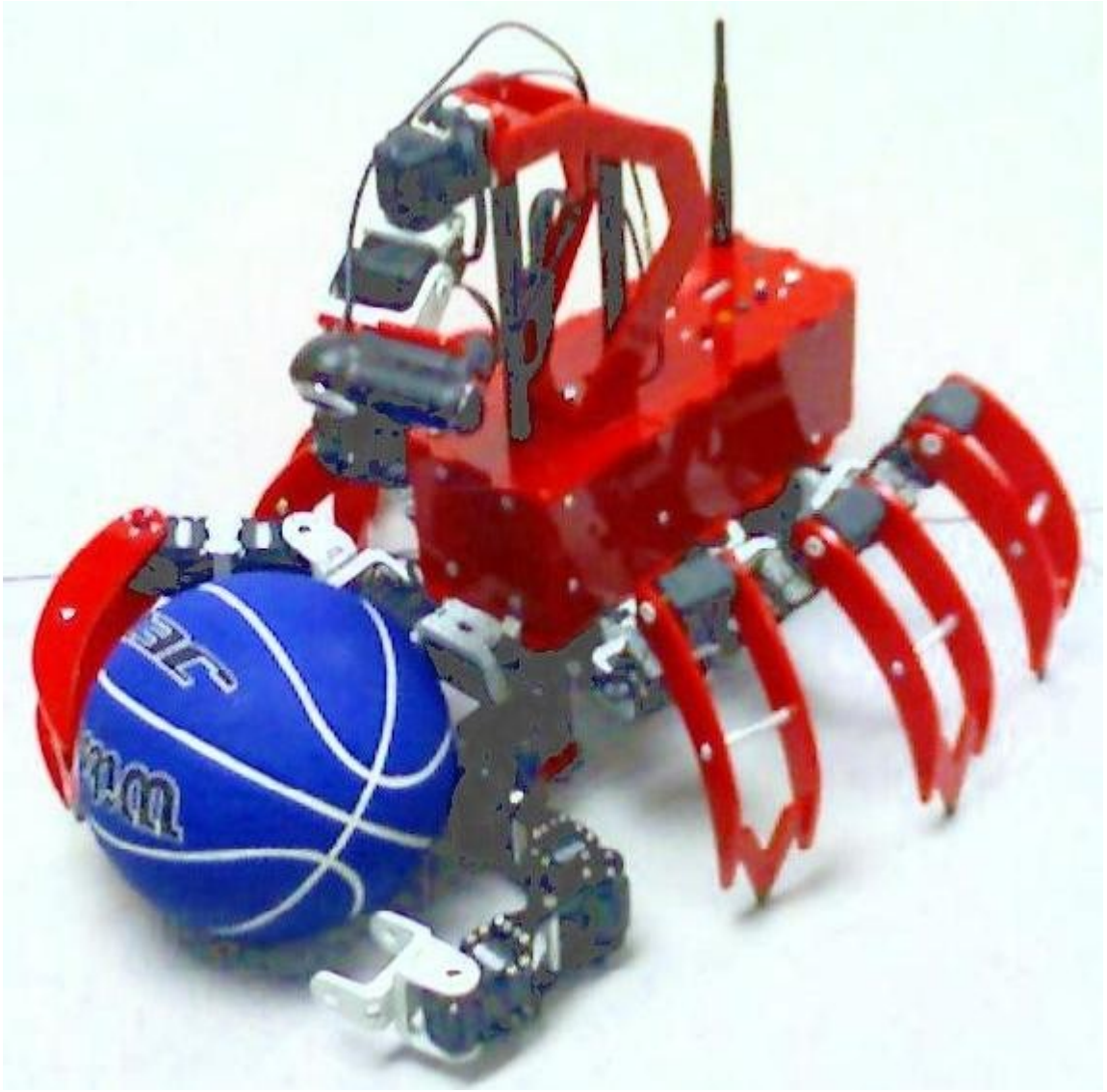
- Two-armed bandit learning problem

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

Gamma Series Chiara (2009)

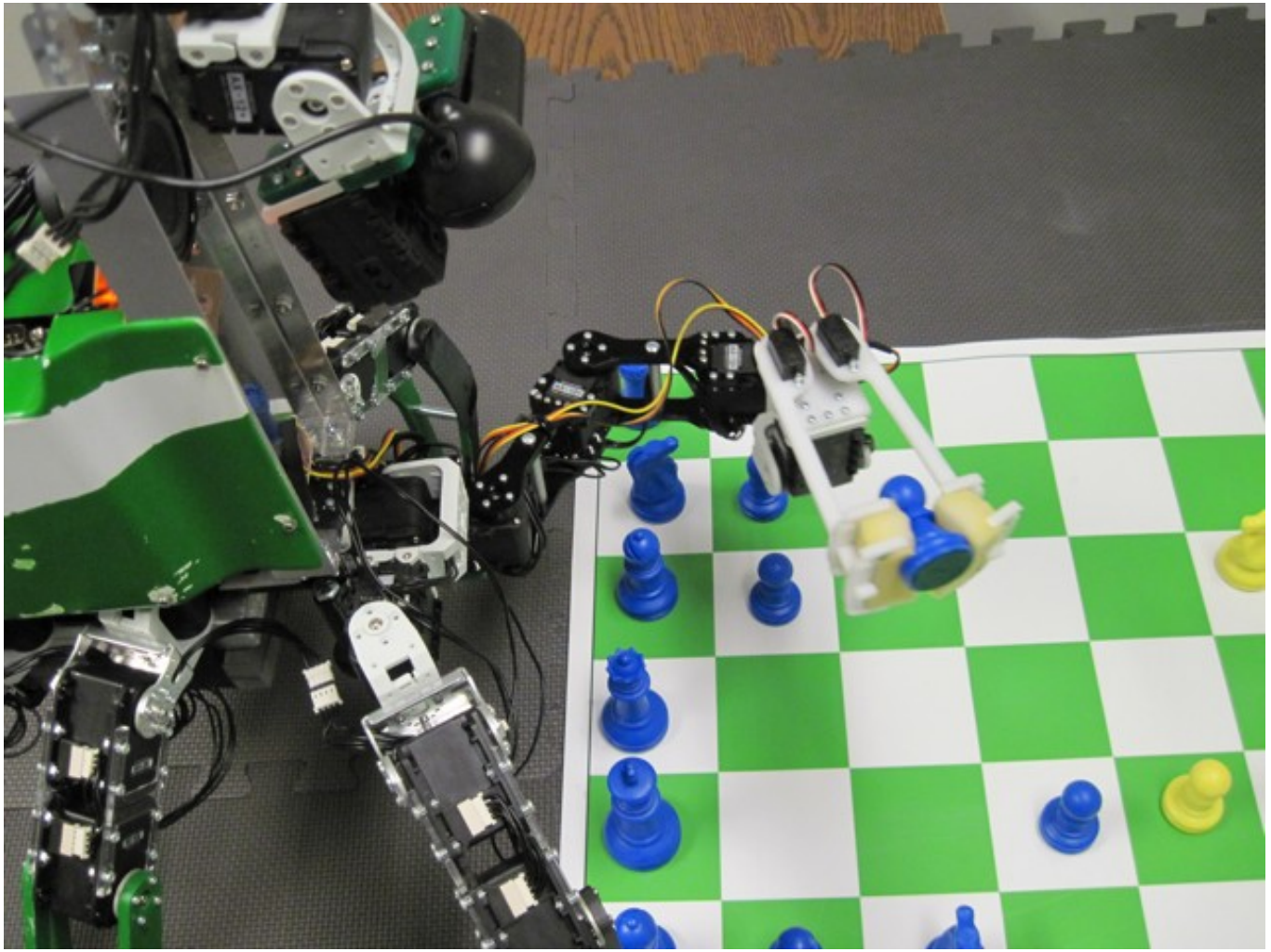


- 21 built
- Fixed gripper (c-bracket)

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

Delta Series Mockup

Chiaras Play Chess at AAAI-2010

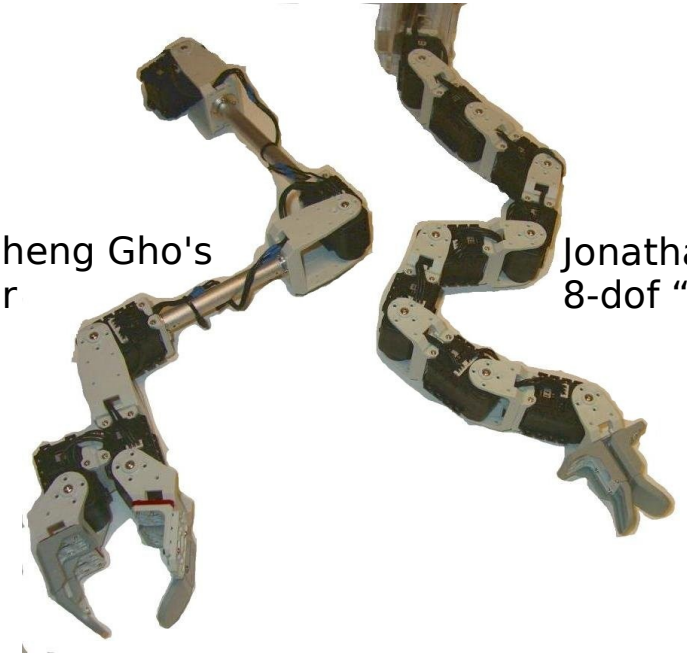


Chiara Playing "*Ode to Joy*"

Demo by high school student Ashwin Iyengar, August 2010.

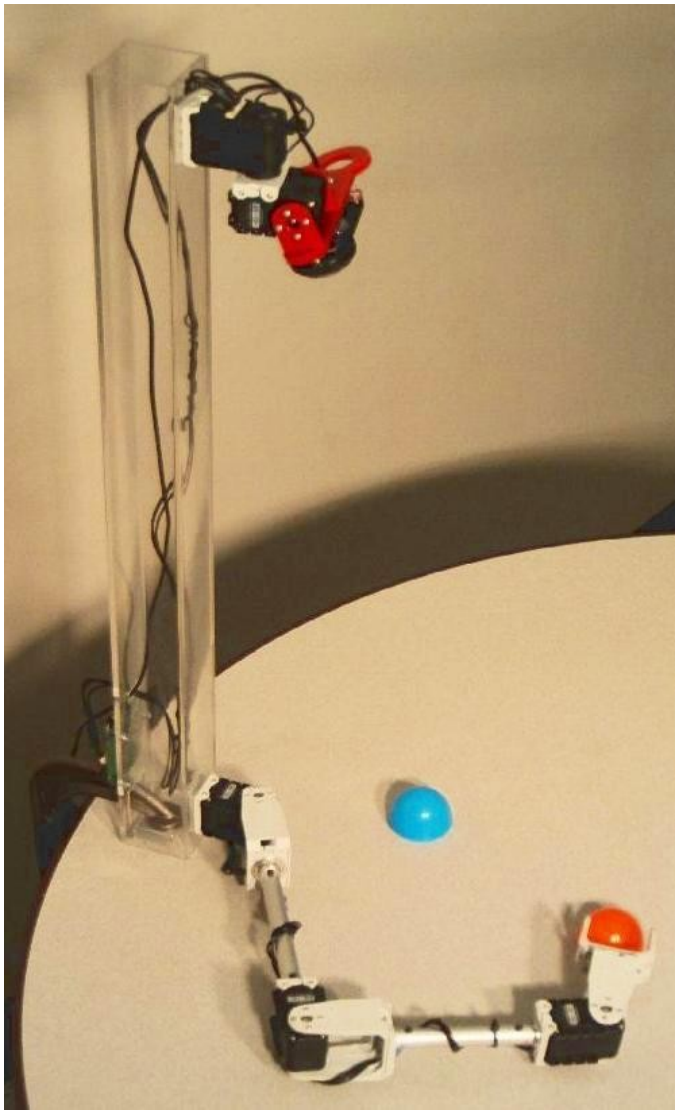
Tekkotsu Planar Hand-Eye System

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



Zhengheng Gho's gripper

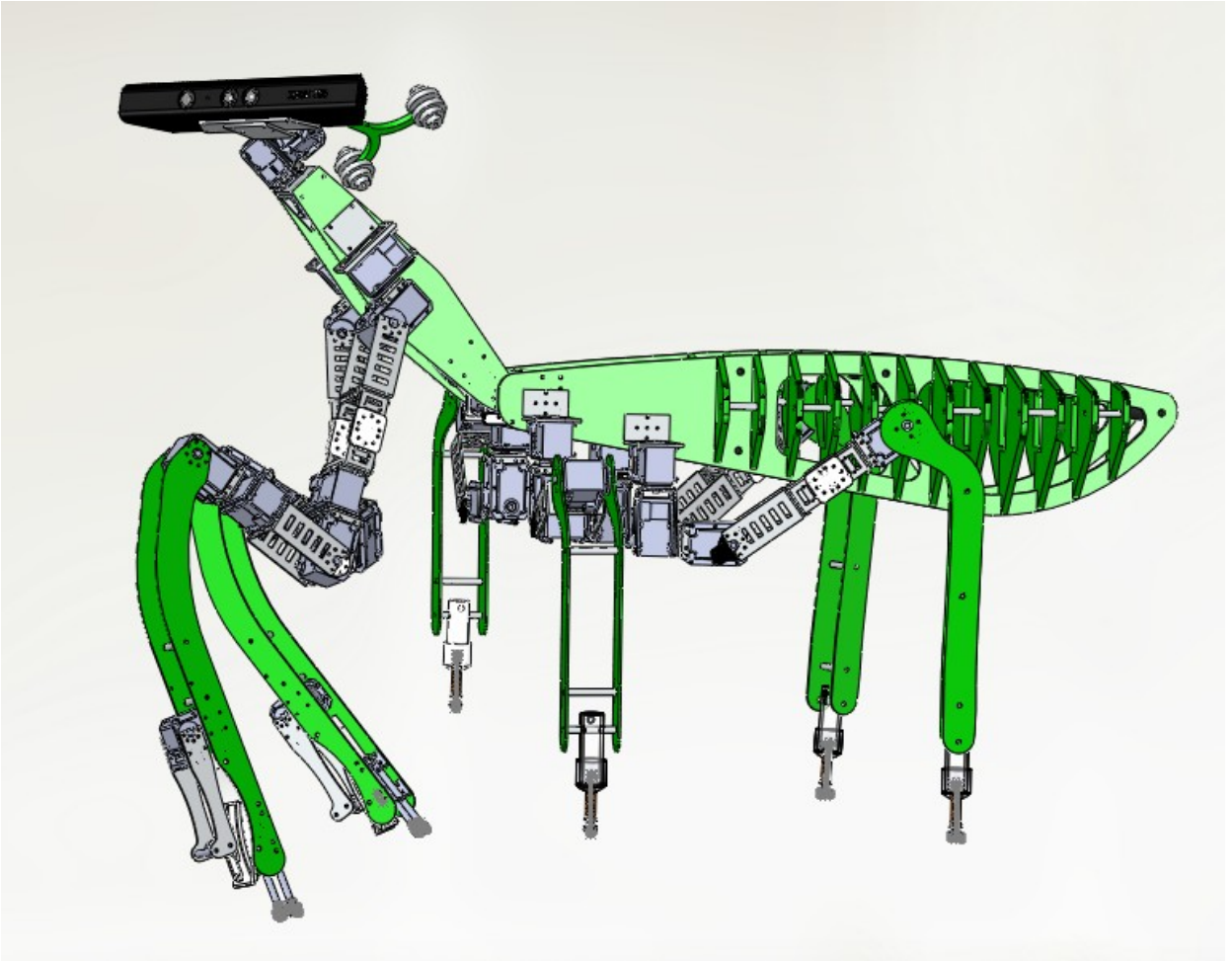
Jonathan Coens' 8-dof “tentacle”



Calliope5KP

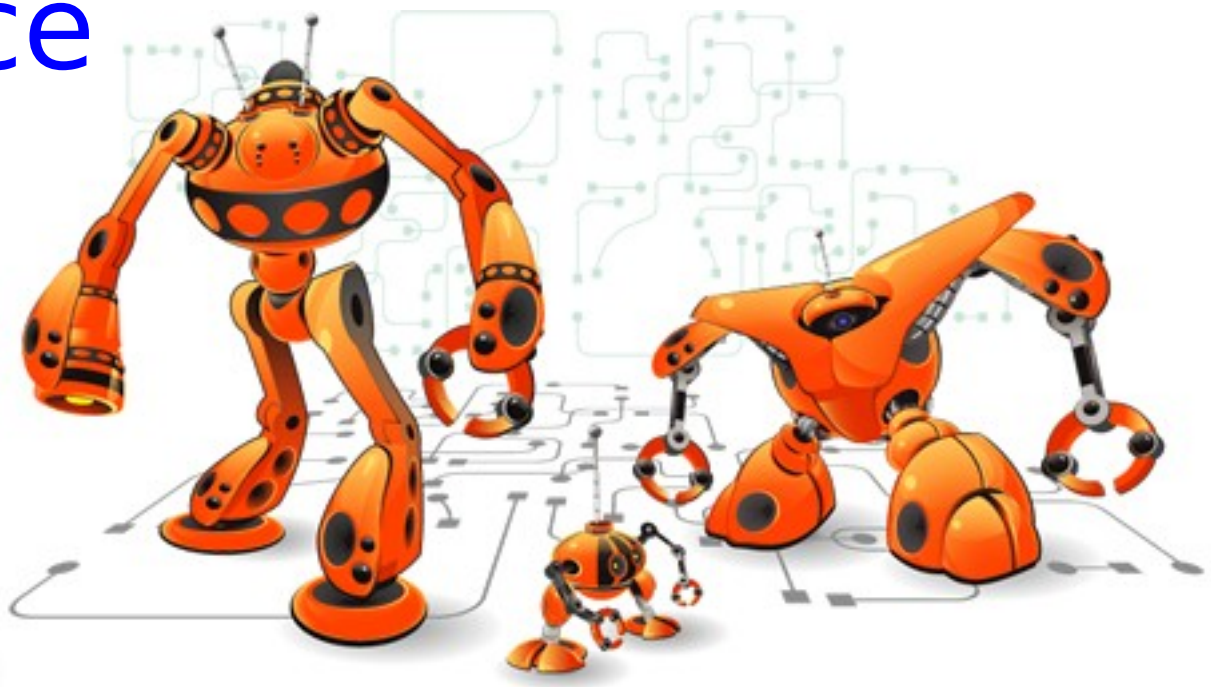
Calliope2SP

Chiara Mantis



ARTSI Alliance

See ARTSIAlliance.org



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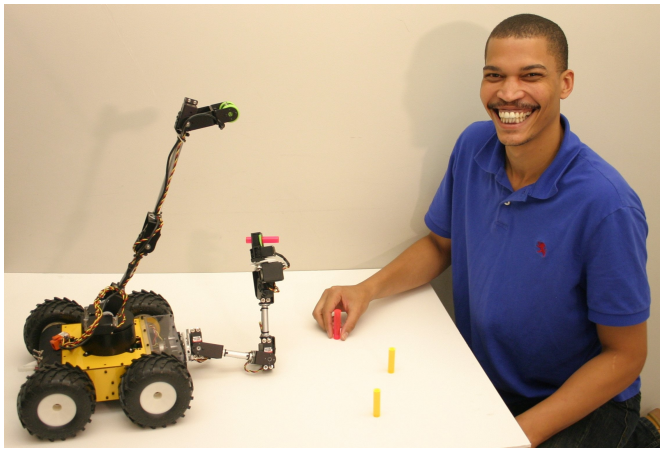
Advancing Robotics Technology for Societal Impact



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

Ten “Big Ideas” in Robotics: The Essential Questions (1/3)

1. How do robots know what to do?

2. How do robots see the world?

3. How do robots know where they are?

4. How do robots know where to go?

5. How do robots control their bodies?

Ten “Big Ideas” in Robotics: The Essential Questions (2/3)

6. What can we do when a robot becomes too complex for one person to fully understand it?

7. How do we calculate the quantities needed to make a robot function?

8. How can robots solve complex problems?

Ten “Big Ideas” in Robotics: The Essential Questions (3/3)

9. How should robots behave around people?

10. How can robots work together?

Goals For This Semester (1)

- Learn the Tekkotsu software platform and explore the 10 Big Ideas in Robotics.

- Develop some enhancements to Tekkotsu as we pursue goals (2) and (3).

Goals For This Semester (2)

Work on Calliope3, the successor to the Calliope2SP as a common platform for robotics research and education:

- Assemble 4 robots
- **Compelling demos**
  - Interactive tic-tac-toe
  - Stick-tac-toe (dominoes)
- Kickstarter planned for April/May

Goals For This Semester (3)

Kodu Robots: The Next Generation of Robotic Toys

- Kodu programming language implemented on top of Tekkotsu
- Interact via tablet and game controller
- Multi-robot and human-robot interaction
- Create mock-ups and demo videos to sell the idea.

Course Administrative Stuff

- Times/Locations:
  - Mon / Wed 3:30 to 4:20 in WEH 5310
  - Fri 3:00 to 4:20 in NSH 3206 (REL)
    REL = Robotics Education Lab
- Course home page:
  http://www.cs.cmu.edu/afs/cs/academic/class/15494-s16
- Tekkotsu wiki: http://wiki.Tekkotsu.org

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 14.04, Tekkotsu, and Mirage pre-installed.
  - See the Tekkotsu wiki for instructions for creating a Tekkotsu Flash Drive; ask me for help if you need it.

For Wednesday

- Read the “Big Ideas” paper.
- Prepare a 3 minute presentation on one of the big ideas (see signup sheet) **or** suggest a big idea of your own and prepare a presentation on that.
- You should have 1-3 slides to present your big idea:
  - What are the key concepts?
  - What is the current state of the art?