

# 15-494: Cognitive Robotics

Spring 2012

Professor:  
David S. Touretzky  
GHC 9013  
x8-7561

[dst@cs.cmu.edu](mailto:dst@cs.cmu.edu)

TA:  
Nan Li  
GHC 6505  
x8-3047

[nli1@cs.cmu.edu](mailto:nli1@cs.cmu.edu)



# 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 “seven big ideas in robotics”.

# Seven 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

# Seven Big Ideas (cont.)

5. How do robots control their bodies?

- Kinematic chains and IK solvers

6. How do robotic systems manage complexity?

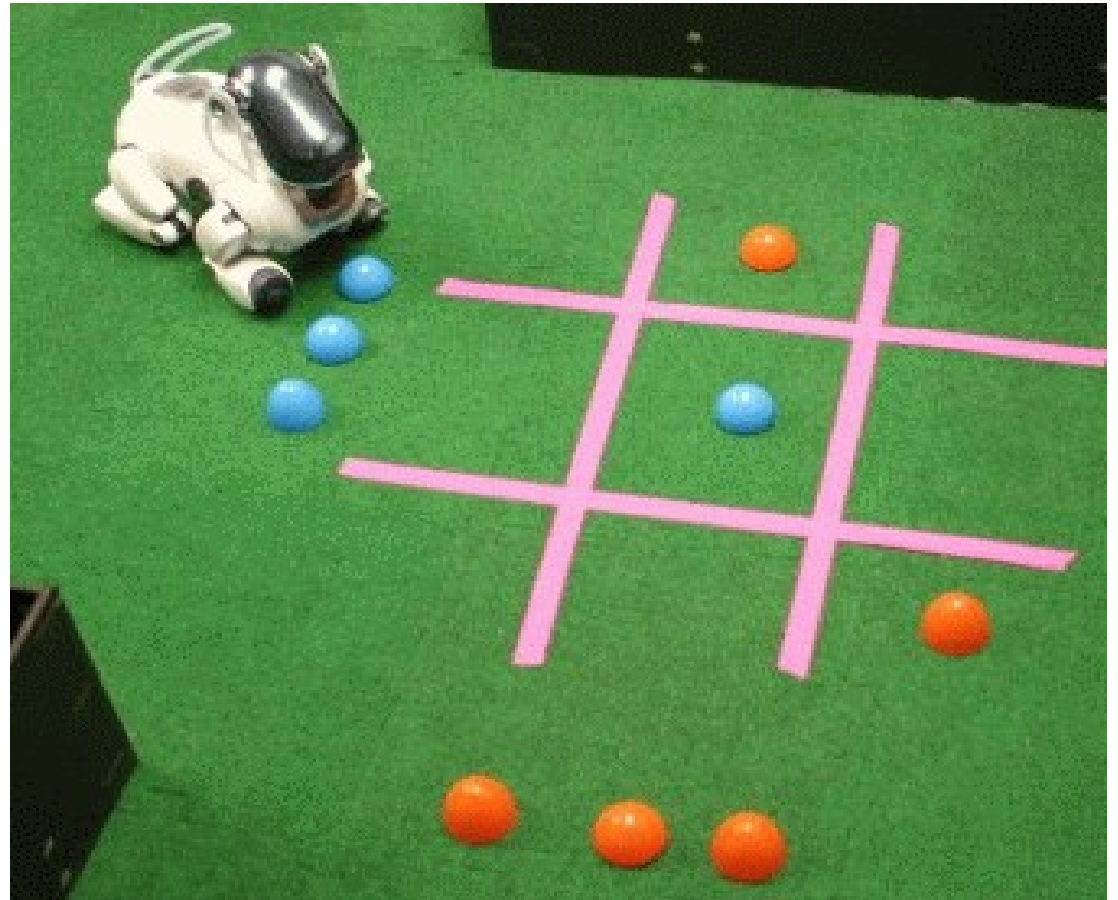
- Abstraction; software engineering

7. How do robots calculate the quantities they need to function?

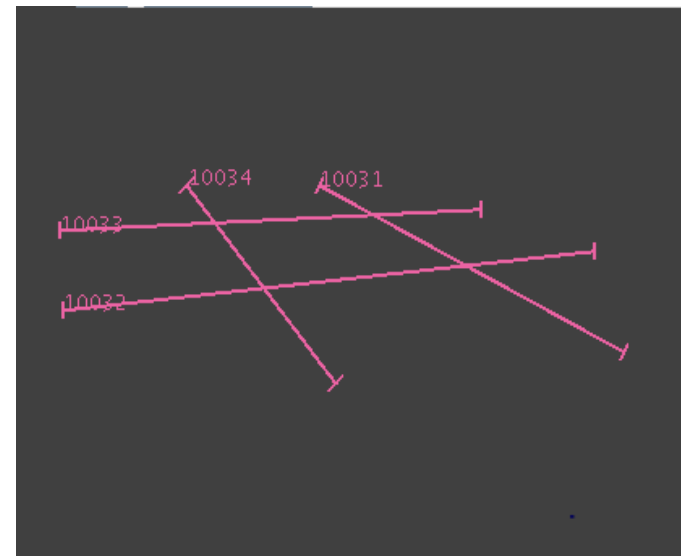
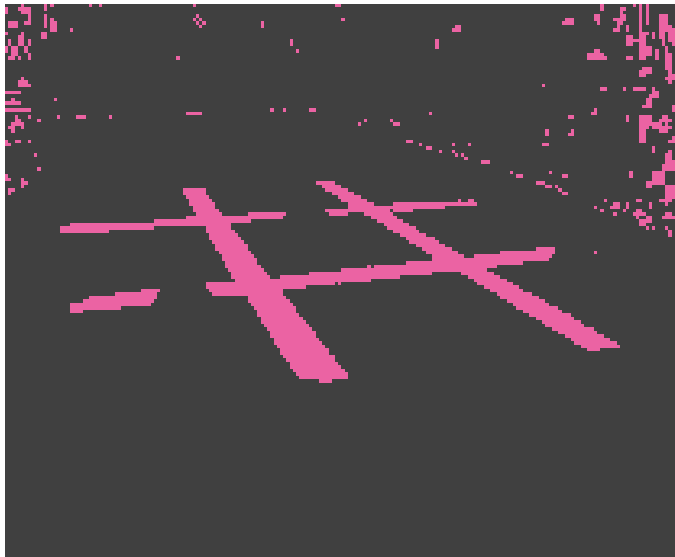
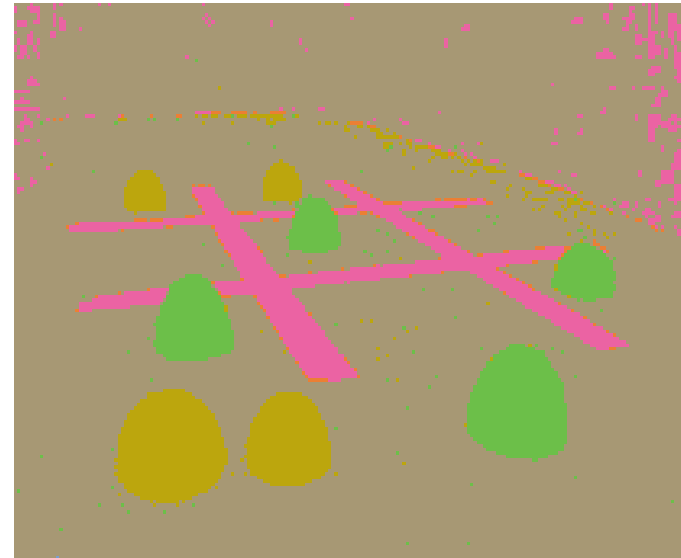
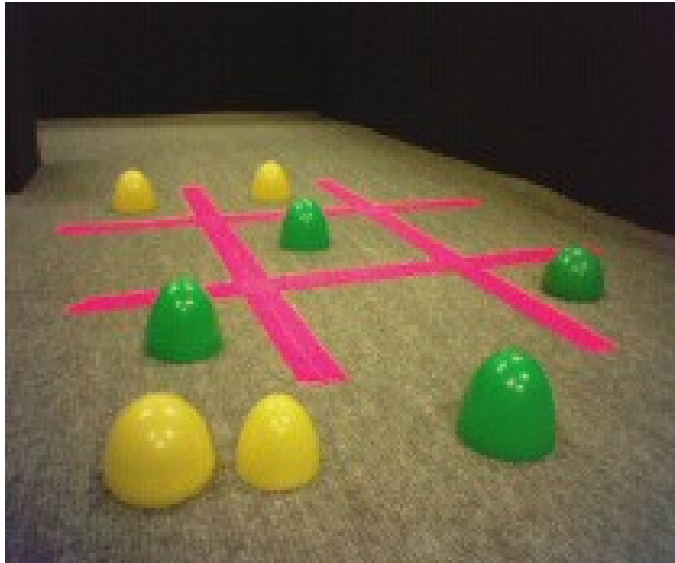
- Trigonometry and linear algebra

# Primitives needed for tic-tac-toe

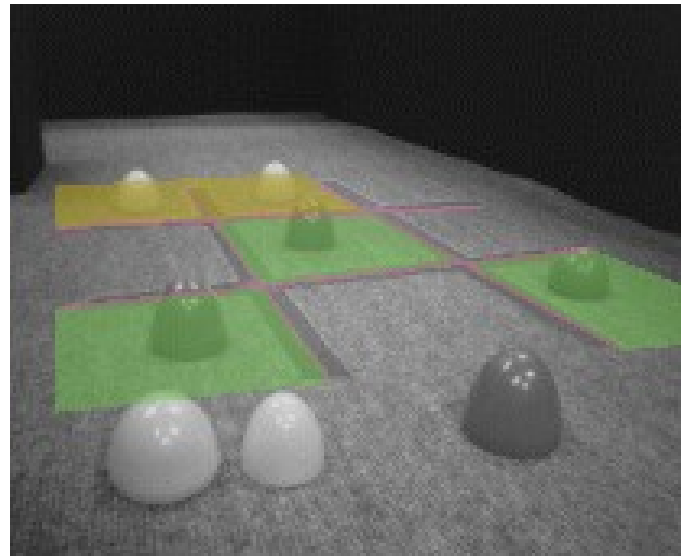
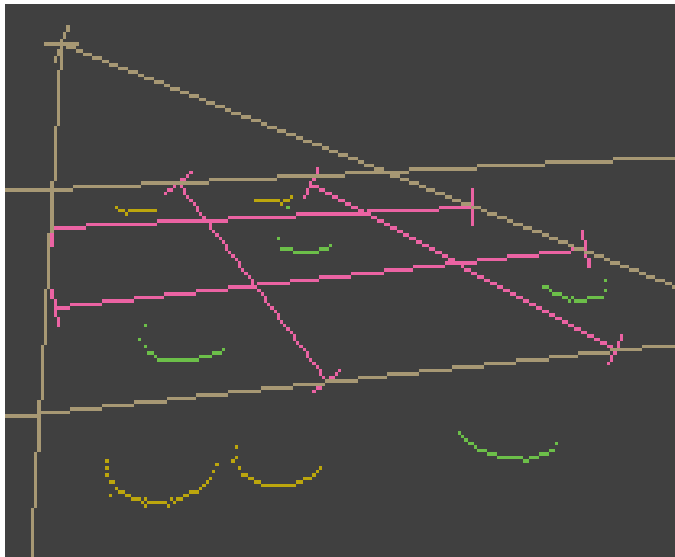
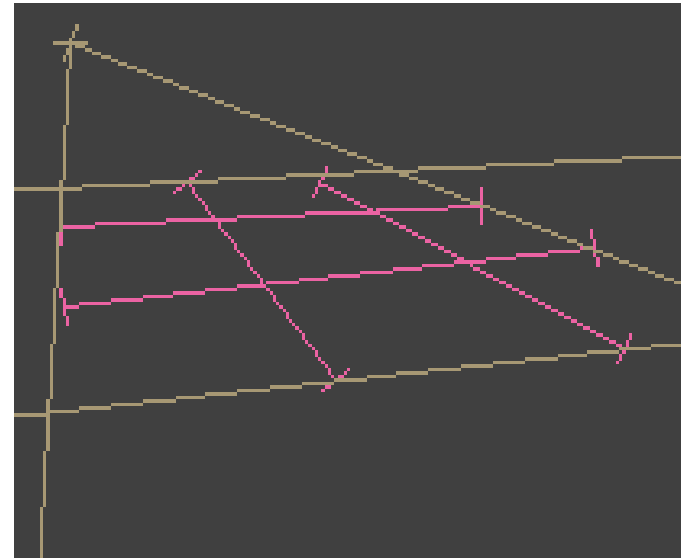
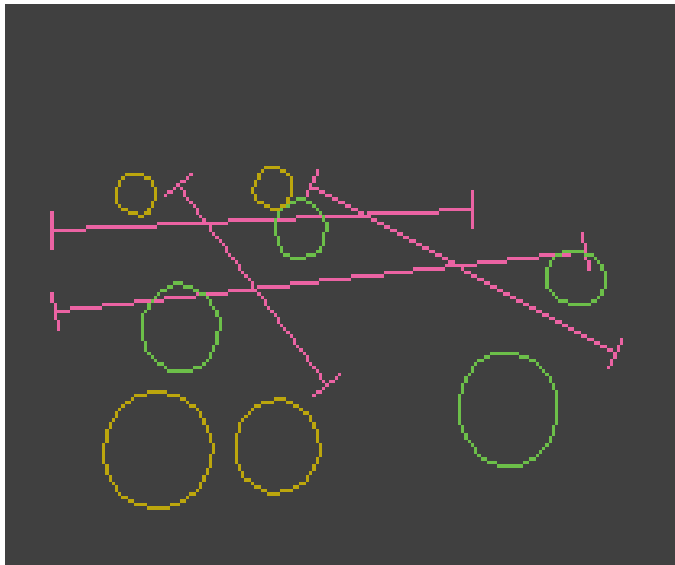
- See and understand the board  
(perception, mapping)
- Move the game pieces  
(manipulation)
- Take turns  
(control)



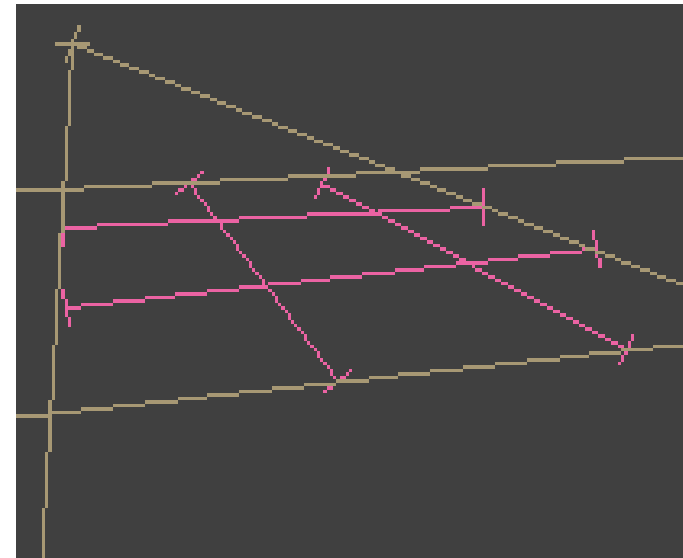
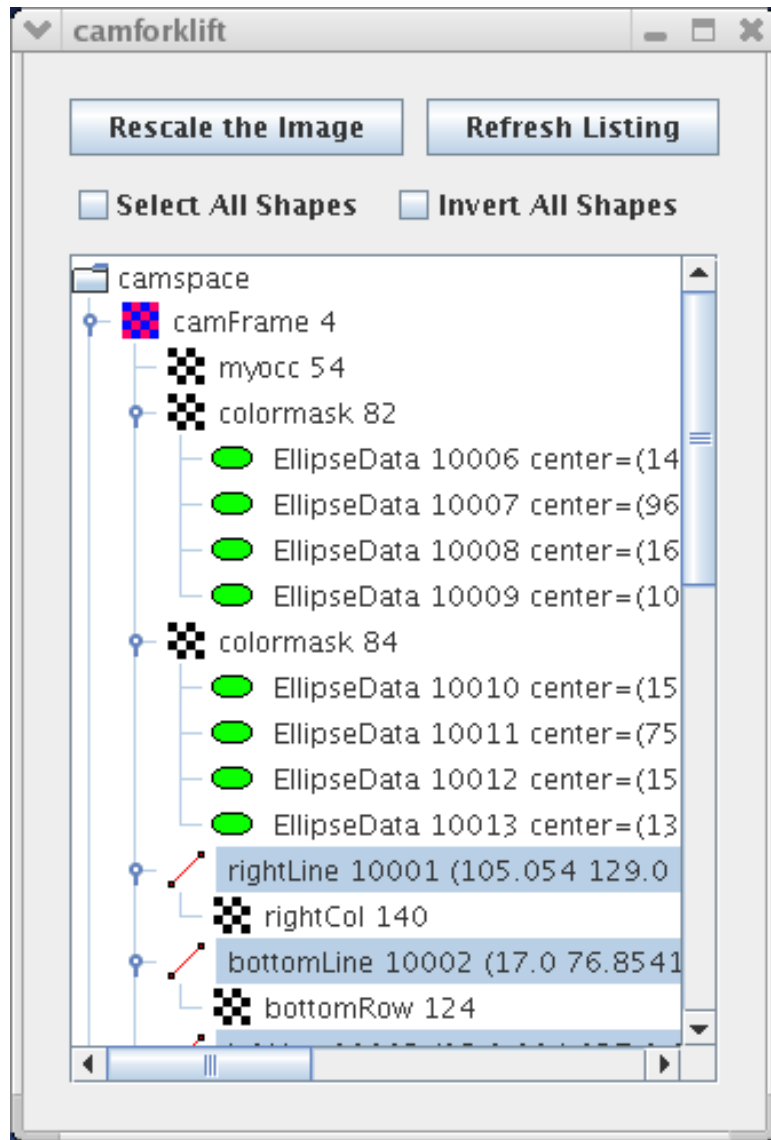
# Visual Routines



# Visual Routines



# SketchGUI: see inside the robot's head



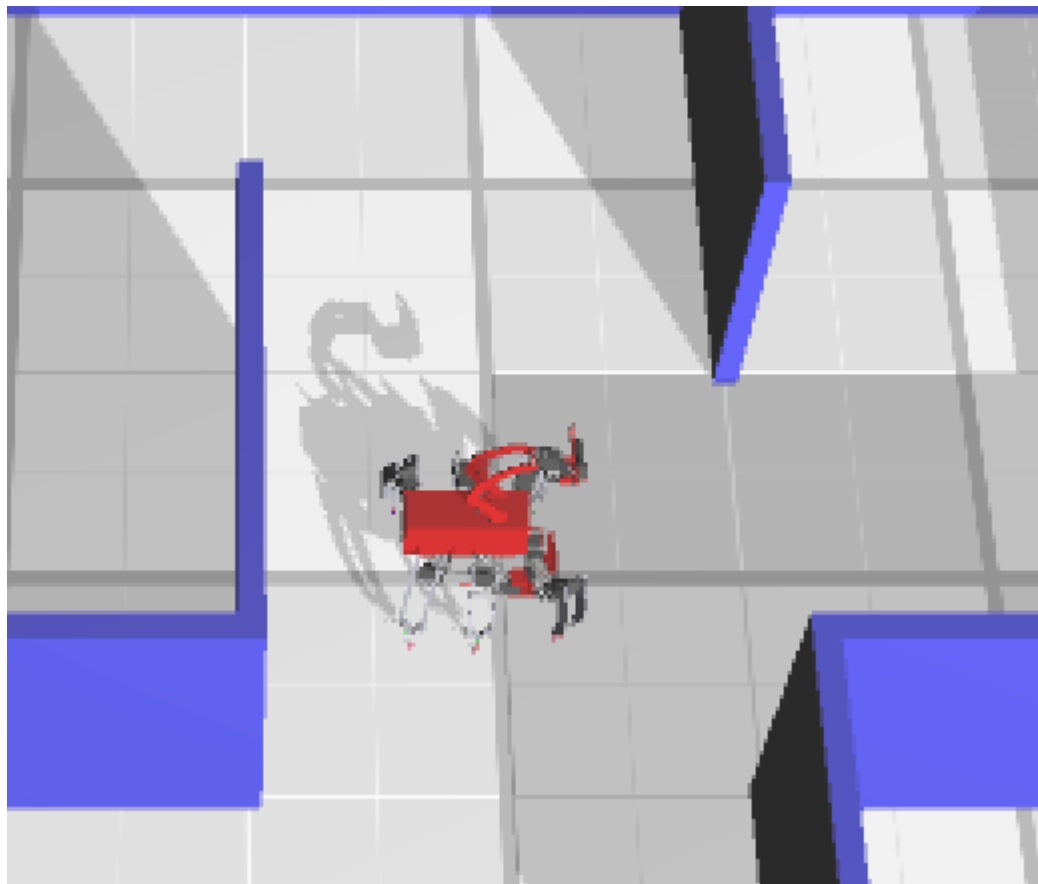


# Transparency: Storyboard tool

The screenshot displays the Tekkatsu Viewer application, which is used for visualizing and interacting with a state machine model. The interface is divided into several panels:

- Top Panel:** Contains the main state machine diagram. The diagram shows states (represented by colored ovals) and transitions (represented by arrows). States include 'Pink', 'Follow', 'Sit', 'Sound', 'Down', 'Up', 'Punch', 'Look', 'Sniff', 'Time', and 'Funny'. Transitions connect these states, such as 'Pink' to 'Follow', 'Follow' to 'Sit', 'Sit' to 'Sound', 'Sound' to 'Down', 'Down' to 'Up', 'Up' to 'Punch', 'Punch' to 'Look', 'Look' to 'Sniff', 'Sniff' to 'Up', and 'Up' to 'Punch'.
- Right Panel (Properties):** Displays the 'Runtime View' properties for the current selection. It shows the 'Current selection' as '46.875s'. The properties list includes:
  - Up:** activate at: 43.002s, deactivate at: 47.0s, type: state
  - Up->Punch:** fire at: 47.001s, type: transition
  - Punch:** activate at: 47.002s, deactivate at: 51.002s, type: state
  - Look:** activate at: 47.002s, deactivate at: 59.002s, type: state
- Bottom Panel (Storyboard):** Shows a timeline of the state machine execution. The timeline has a scale from 0 to 60 seconds. It displays the sequence of states and transitions over time, with a red vertical line indicating the current time. The storyboard shows states like 'Funny', 'Pink', 'Follow', 'Sit', 'Sound', 'Down', 'Up', 'Punch', and 'Look' plotted against the timeline.
- Bottom Right Panel (Image Preview):** Displays a 3D rendering of the environment. It shows a green field with a yellow ball, a pink ball, and a pink bone, which are the objects associated with the state machine.

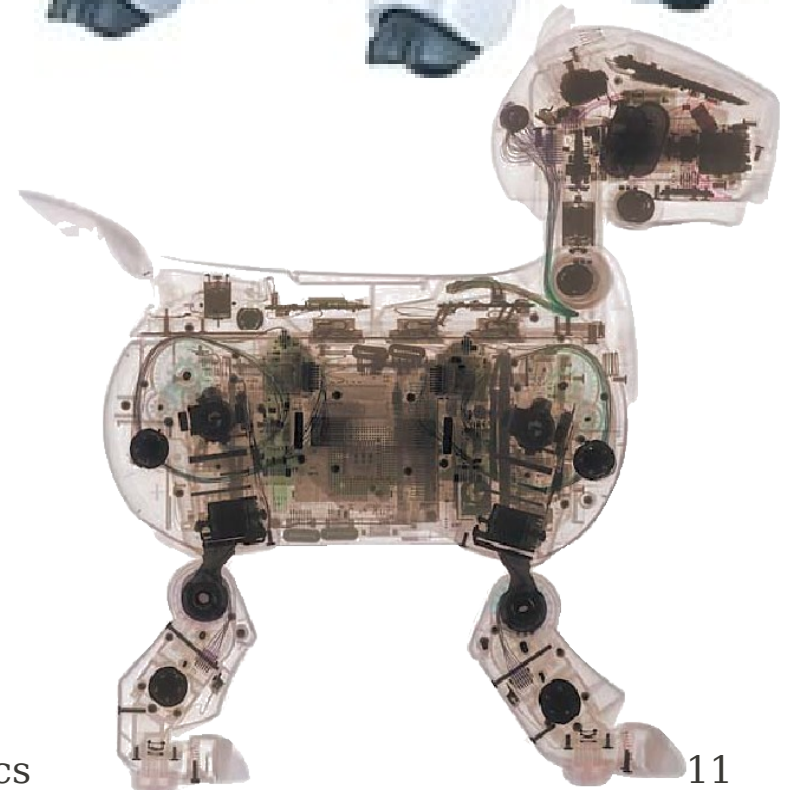
# Mirage Simulator



# 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 microsensors
  - 6-dof arm with gripper
- Logitech webcam,  
Robotis IR rangefinder
- Ethernet and WiFi
- Open source, GPLed  
design





# Gamma Series Chiara (2009)



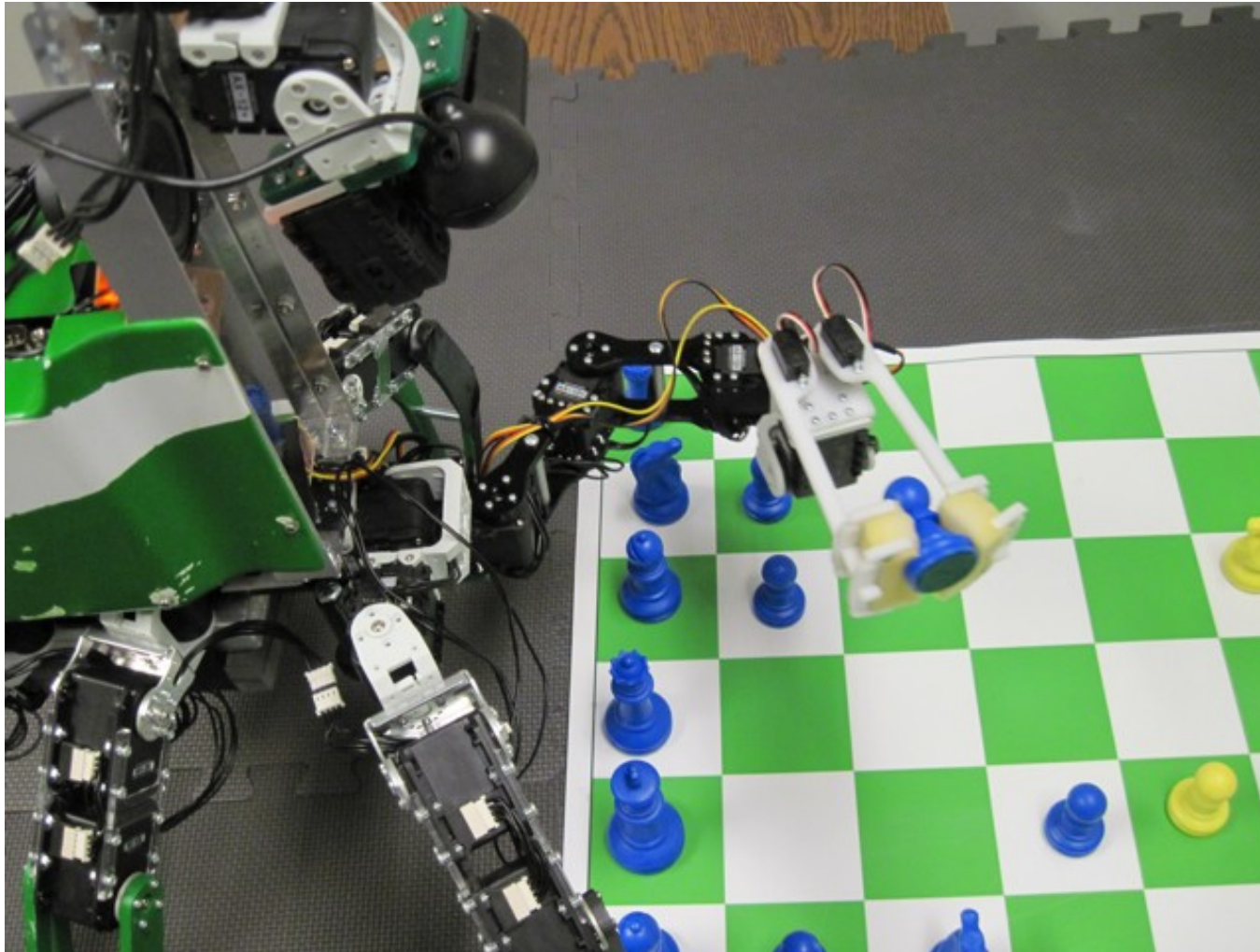
- 21 built
- Fixed gripper (c-bracket)

See demo videos at  
[Chiara-Robot.org](http://Chiara-Robot.org)  
or directly at  
[youtube.com/TekkotsuRobotics](http://youtube.com/TekkotsuRobotics)

# Delta Series Mockup



# Chiaras Play Chess at AAAI-2010





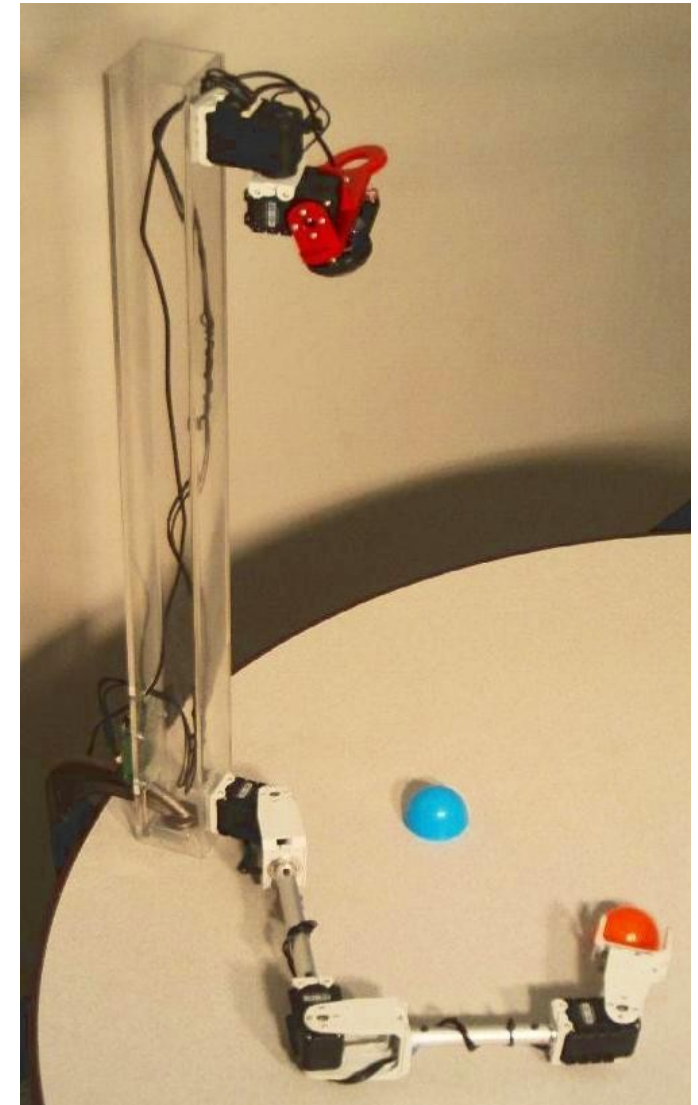
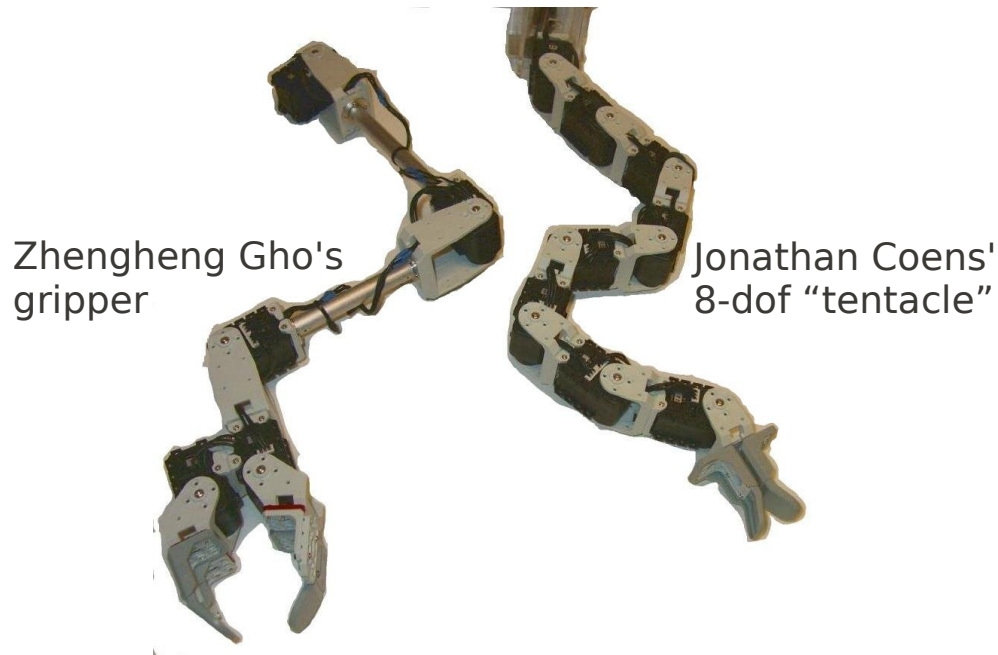
# Chiara Playing “Ode to Joy”



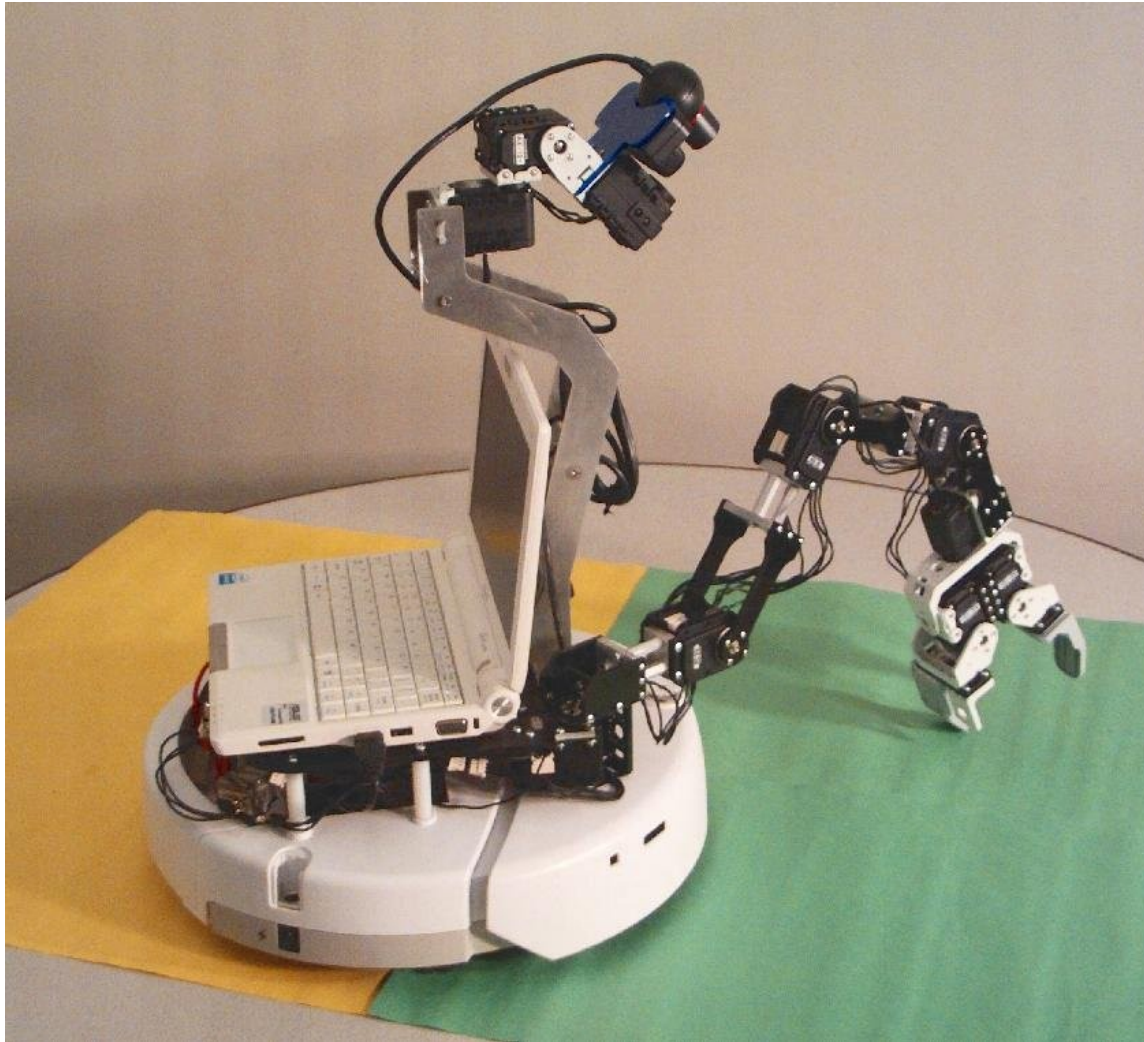
Demo by high school student Ashwin Iyengar, August 2010.

# 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:



# Calliope



iRobot Create base

ASUS netbook

Sony Playstation  
Eye webcam and  
Robotis AX-S1  
rangefinder on a  
pan/tilt mount

Custom-built 5-dof  
arm and 2-dof  
gripper



# Demo Videos



**Mirage Stack Topple and**

52 views  
2 months ago



**Denavit-Hartenberg 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

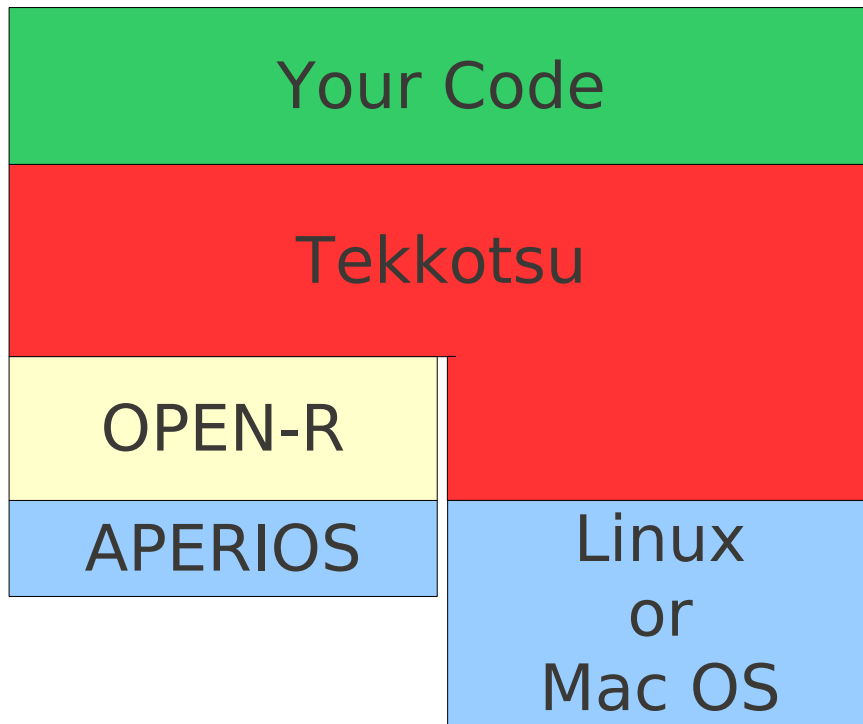


# Tekkotsu Means “Framework” in Japanese

(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

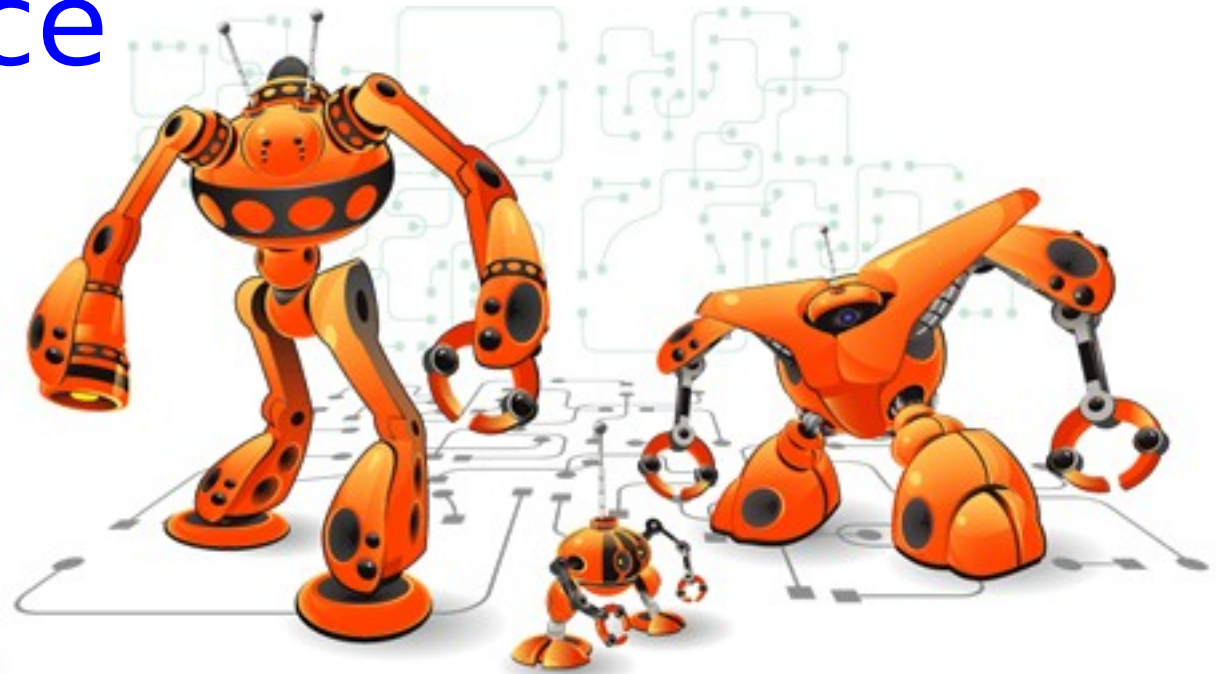
- **Unified** framework for perception, navigation, and manipulation
- **Single** address space model simplifies coding & debugging
- Designed for **education**
- Emphasis on **orthogonality** of components: “mix and match”
- **Multi**-process approach good for scalability (but with some costs)
- Designed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



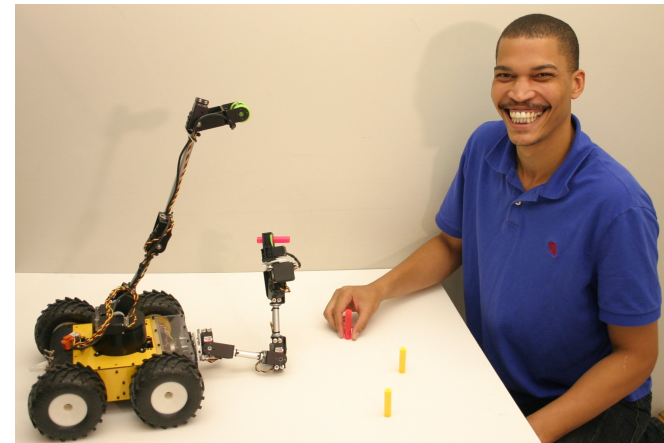
# ARTSI Alliance

See [ARTSIAlliance.org](http://ARTSIAlliance.org)

artsi



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-s12](http://www.cs.cmu.edu/afs/cs/academic/class/15494-s12)
- 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](http://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](http://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.