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 still pretty 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 degrs. 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-Hartenbel 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
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"
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
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
Visual Routines
SketchGUI: see inside the robot's head
Transparency: Storyboard tool
Mirage Simulator
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
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”
New Features for 2011

- Pilot integrated with path planner and particle filter
- The Grasper: manipulation planner
- Mirage simulator: world builder tool
- APRIL Tags: robust visual markers
- Enhanced state machine language
- Tekkotsu flash drive
ARTSI Alliance

See ARTSIAlliance.org

Advancing Robotics Technology for Societal Impact
Course Administrative Stuff

• Times/Locations:
  – Mon / Wed 3:30 to 4:20 in Wean Hall 5304
  – 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
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.
Syllabus and Lecture Schedule

- The syllabus/lecture schedule is linked from the course home page:
  
  www.cs.cmu.edu/afs/cs/academic/class/15494-s11

- 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.