Cognitive Robotics: High-Level Robot Programming
Inspired by Cognitive Science

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An Analogy: Computer Graphics

• Early computer graphics courses taught low-level primitives:
  – anti-aliasing algorithms for line drawing
  – hidden surface elimination; rendering algorithms
  – tricks for quickly updating the video memory of a graphics display

• Limited by crude hardware: pen-based plotters, monochrome displays.
Graphics Education Today

• Classical graphics courses are still offered. But students can also study:

  – Scientific Visualization: using the drawing primitives provided by Matlab or Mathematica.

  – User Interface Design: how to make best use of the graphical primitives provided by a GUI toolkit.

  – Computer game design.
What About Robot Programming?

- Robot programming today is still done at a very low level, focusing on kinematics, localization, elementary vision (blob detection).

- What if you had a robot that could already see a bit, and navigate a bit, and manipulate objects?

- What primitives would allow you to program it to accomplish interesting tasks?
Primitives for Cognitive Robotics

• Perception (typically vision)
• Mapping
• Control (state machines; subsumption; others?)
• Manipulation
• Attention
• Learning
• Human-Robot Interaction
Sony AIBO ERS-7

- 18 degrees of freedom:
  - four legs (3 degs. each)
  - head(3), tail(2), mouth
- 576 MHz MIPS processor
- 64 MB RAM
- Color camera: 208x160
- Stereo microphones, IR sensors
- Wireless Ethernet
Tekkotsu = “Framework” in Japanese

- Written in C++.
- Provides a layer above Sony's OPEN-R.
- Event-based architecture.
- Extensive use of templates and inheritance.
- Open source, LGPLed.
- See Tekkotsu.org for code & documentation.
Tekkotsu Architecture: Ethan Tira-Thompson

Key:
- Pre-emptive Process
- Shared Memory Region
- Unshared Global Variable

Behaviors request lock on MotionCommands to make direct function calls on them.

System sends state information (~32ms)

System sends camera frames (~30fps)

Behaviors can play sounds anytime

Can access state anytime for reactive/open loop control

MotionCommands (dynamically created)

SoundManager

TinyFTPD

From Sony's sample code, allows you to FTP files during run time. Self contained
Perception: Tabletop World

- Simple colored objects
- Planar world assumption
- Goal: get AIBO to actually play tic-tac-toe.
Color Segmentation

Raw image

Color segmented image
“Visual Routines” (Ullman)

Select pink pixels

Skeletonize
“Dual-Coding” Representation

- Iconic plus symbolic representations
- Inspired by Paivio's theory of mental imagery
Parsing the Tic-Tac-Toe Board

Raw image

Color segmented image
Parsing the Tic-Tac-Toe Board

Extract shapes

Construct bounding lines
Parsing the Tic-Tac-Toe Board

Locate board regions

Find game piece bottoms
Parsing the Tic-Tac-Toe Board

Parsed board image

Original image
Viewing AIBO's Mental Imagery
Spelbots Soccer Team
(Spelman College)
C.A.R.E. Project


• Joint project between CMU and Spelman College, funded by the National Science Foundation.

• Establish Tekkotsu robotics labs at HBCUs
  – Set up equipment, install software, train staff.

• Build a community of educators and students who are proficient at cognitive robotics programming.
  – Share educational materials, software, and ideas.
C.A.R.E Schools

- Hampton University (Hampton, VA)
  - Chutima Boonthum: intro robotics course, REU activities

- University of the District of Columbia
  - LaVonne Manning, Lily Liang: LSAMP summer program; computer vision course

- Florida A&M (Tallahassee)
  - Clement Allen: will Tekkotsu in an introductory data structures course to “prime the pump” for a robotics/AI course
Demos

• Queue Behavior
  – Students implement a Queue class
  – Tekkotsu demo uses the class

• Tree Search
  – Use the robot to “walk the tree”
  – What can the robot see?
Queue Demo

• Press one of the three back buttons to push a number (1, 2, or 3) onto the queue
• Press the head button to “play” the queue. This does not erase the queue.
• Press the chin button to pop the front of the queue
• What happens if you try to pop an empty queue?
Recursive Tree Walk Is Easy

countLeaves(tree) =

if tree.isTerminal()
    then 1

else countLeaves(tree.leftBranch()) +
    countLeaves(tree.rightBranch())
What If You Don't Have a Stack?

Node Type?

Take Left Branch

Non-terminal

Incr. N

Back up

Node Type?

Take Right Branch

Left branch

Right branch

Root

Terminal

Done!
Future of Cognitive Robotics

• Manipulation primitives:
  – Applying forces to surfaces to achieve specific results
  – Intelligent control of the body (balance, center of mass, momentum)

• New interaction paradigms:
  – How can high school and middle school students “program” cognitive robots?

• New platforms to replace the AIBO
The Future of Cognitive Robotics