

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

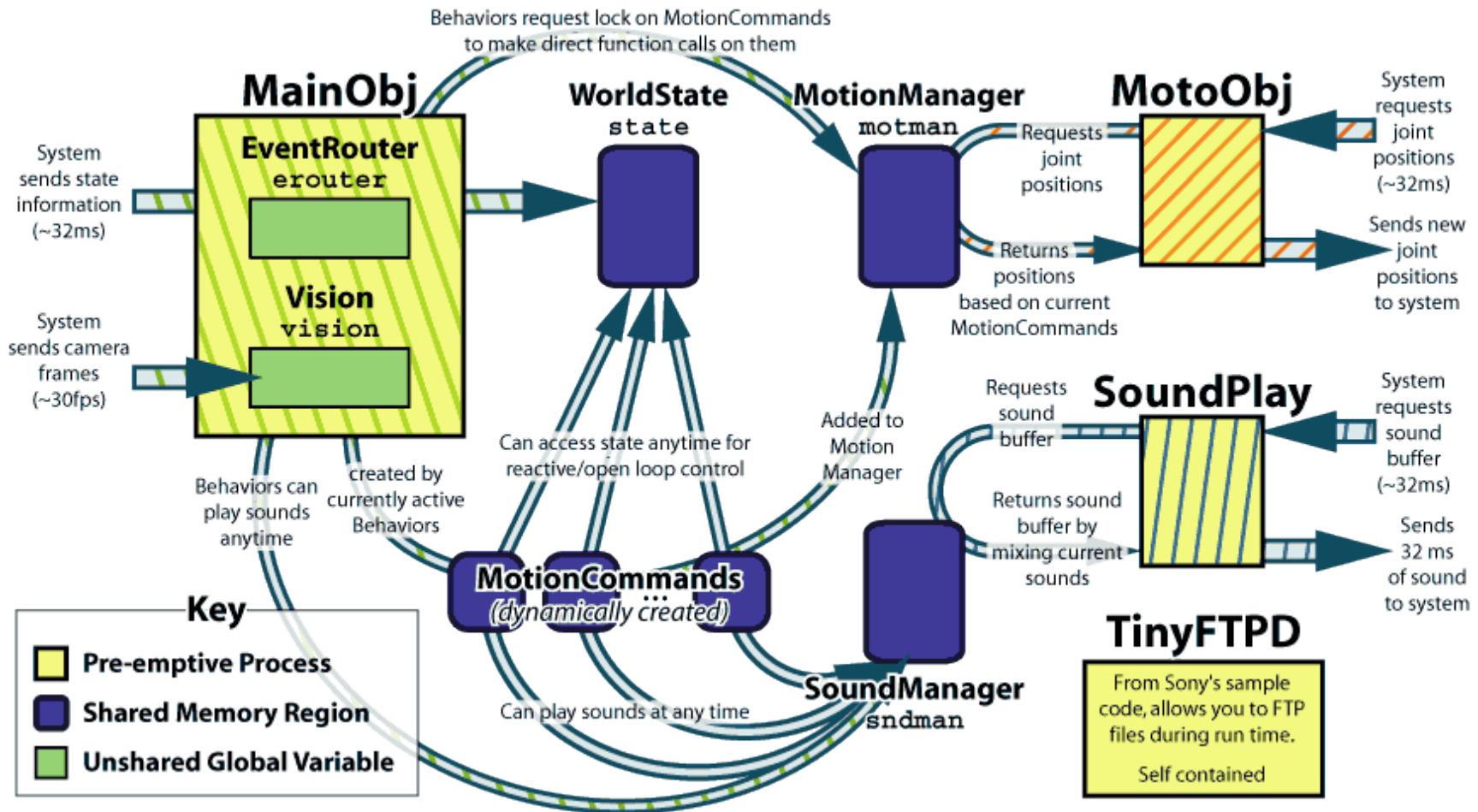


Tekkotsu = “Framework” in Japanese



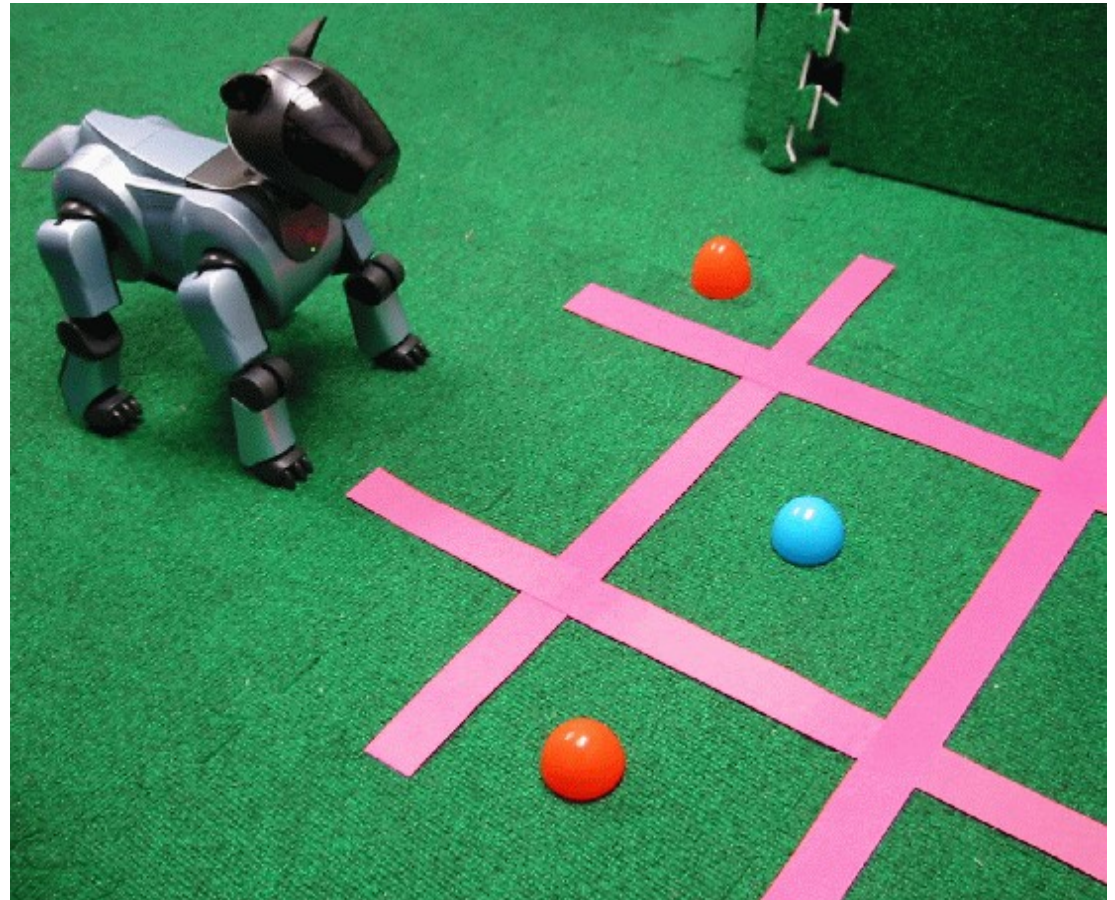
- Written in C++.
- Provides a layer above Sony's OPEN-R.
- Event-based architecture.
- Extensive use of templates and inheritance.
- Open source, LGPLed.
- See **Tekkotsu.org** for code & documentation.

Tekkotsu Architecture: Ethan Tira-Thompson



Perception: *Tabletop World*

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



Color Segmentation



Raw image

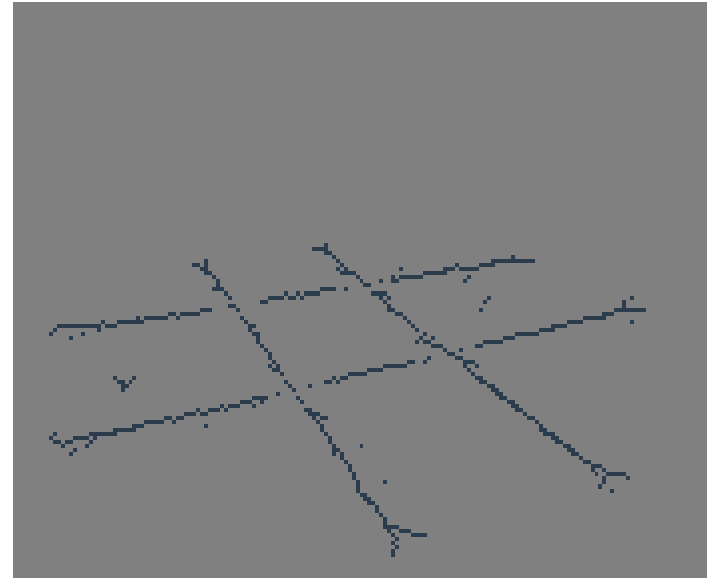


Color segmented image

“Visual Routines” (Ullman)

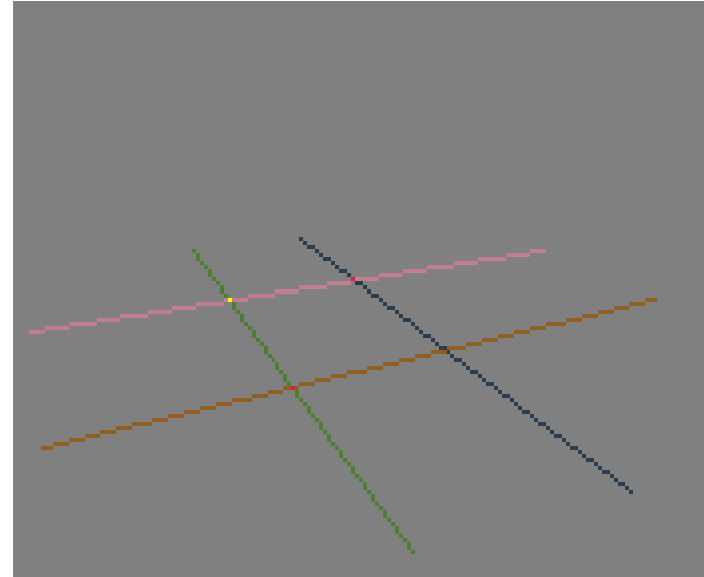
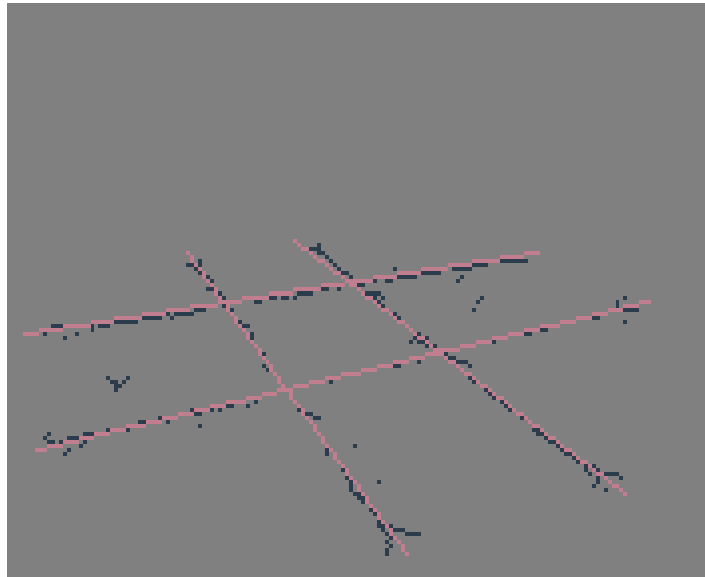


Select pink pixels



Skeletonize

“Dual-Coding” Representation



- Iconic plus symbolic representations
- Inspired by Paivio's theory of mental imagery

Parsing the Tic-Tac-Toe Board

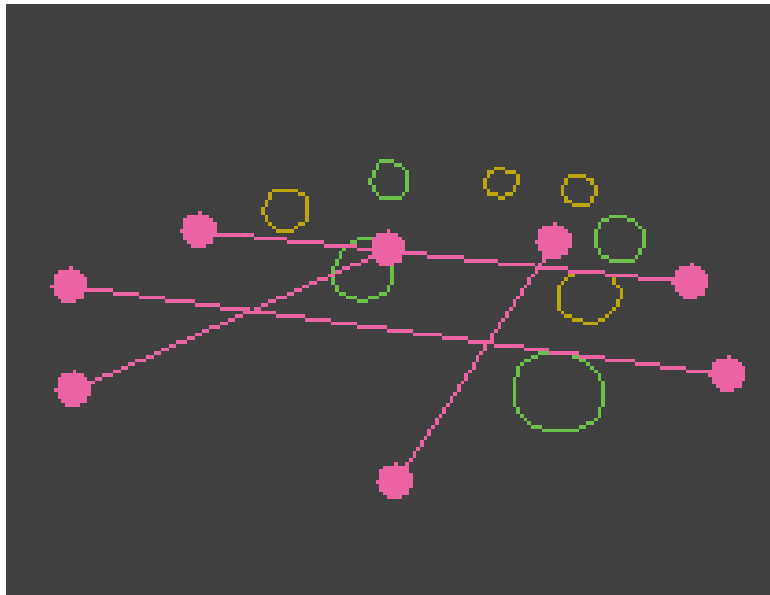


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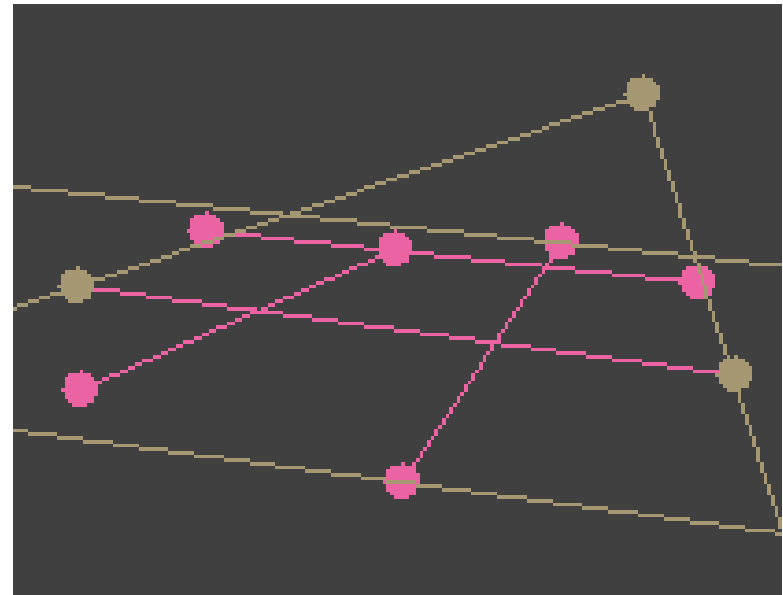


Color segmented image

Parsing the Tic-Tac-Toe Board

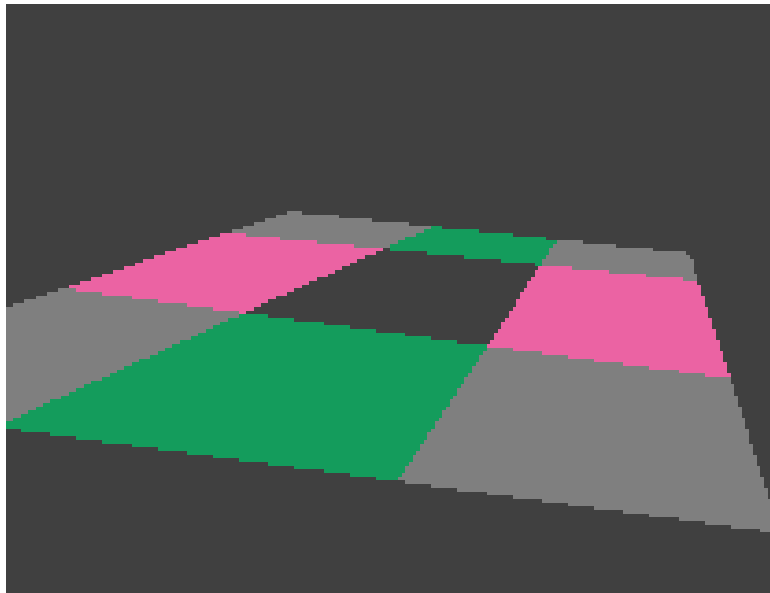


Extract shapes

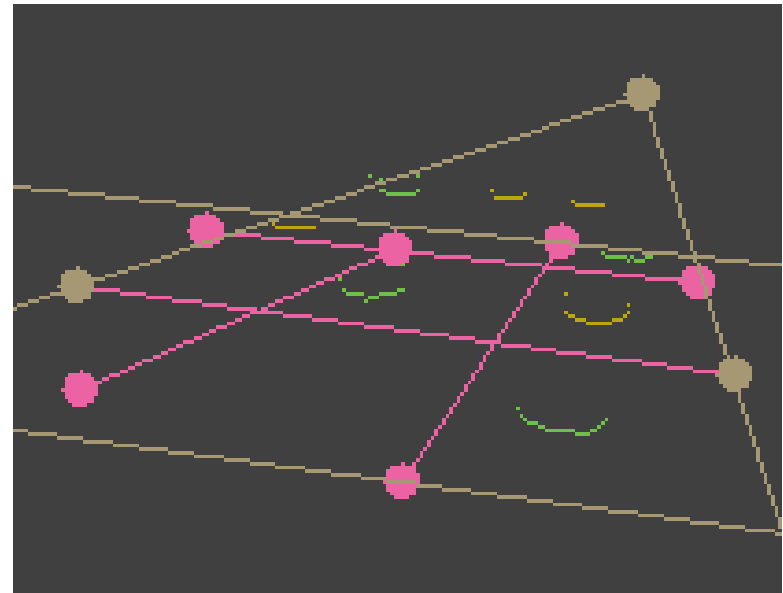


Construct bounding lines

Parsing the Tic-Tac-Toe Board

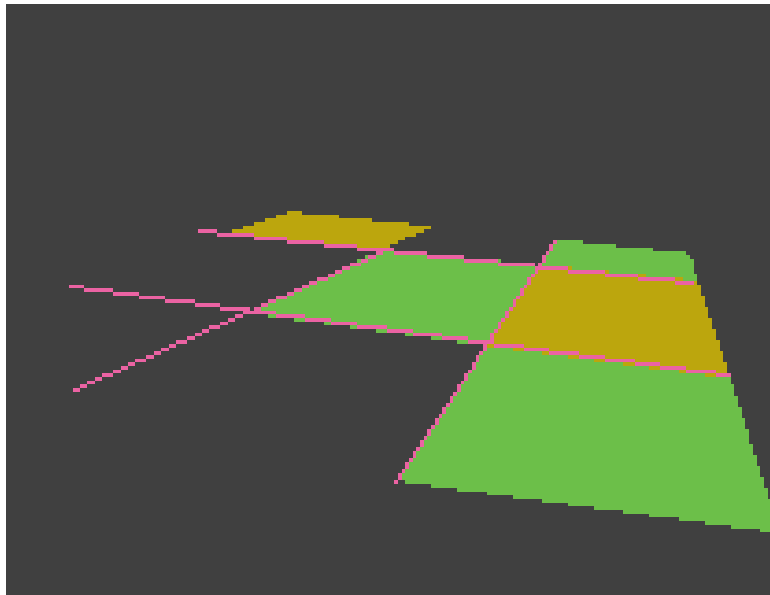


Locate board regions



Find game piece bottoms

Parsing the Tic-Tac-Toe Board

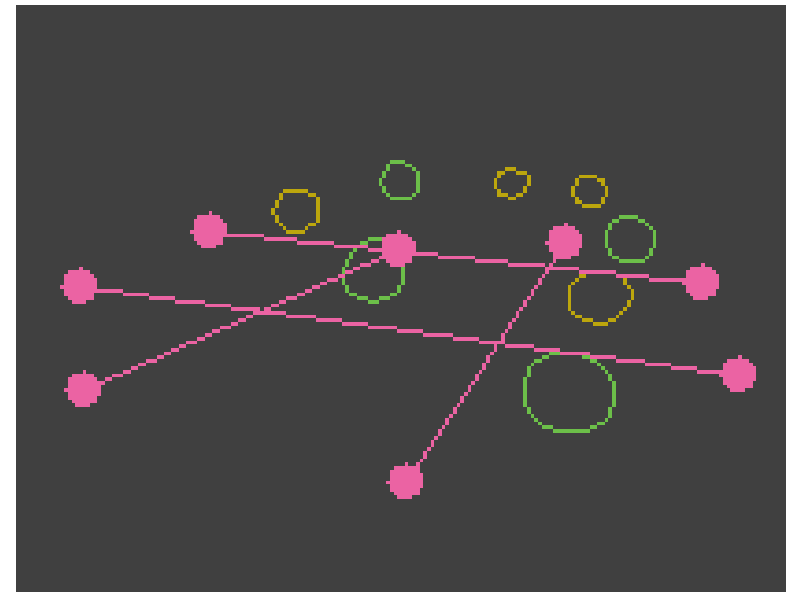
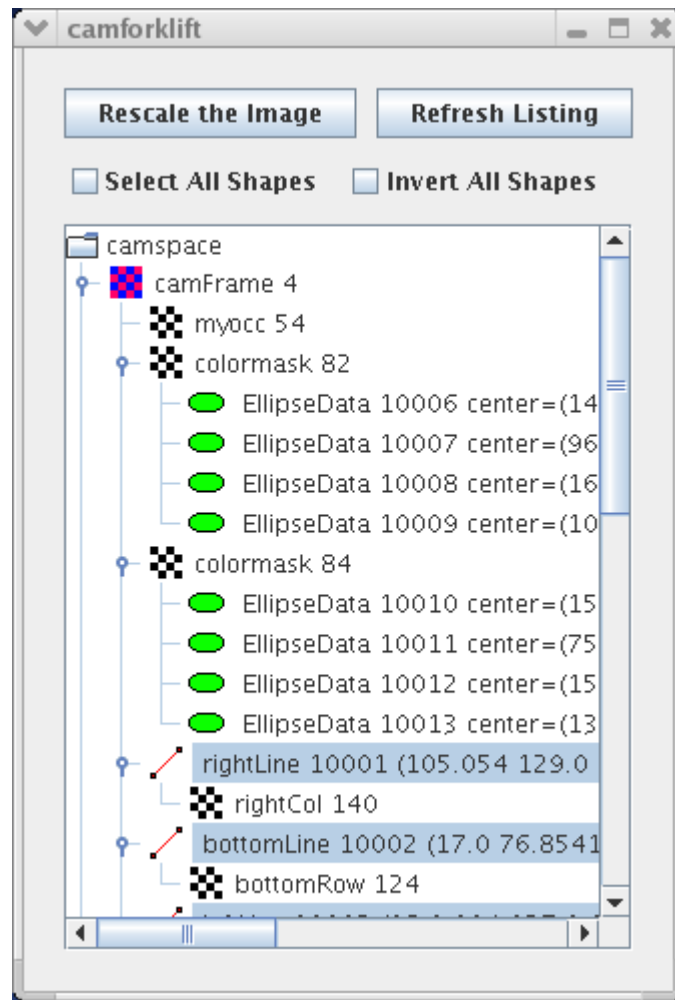


Parsed board image



Original image

Viewing AIBO's Mental Imagery



Spelbots Soccer Team (Spelman College)



C.A.R.E. Project

- C.A.R.E. = “Computer and Robotics Education for African-American Students”
- 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.

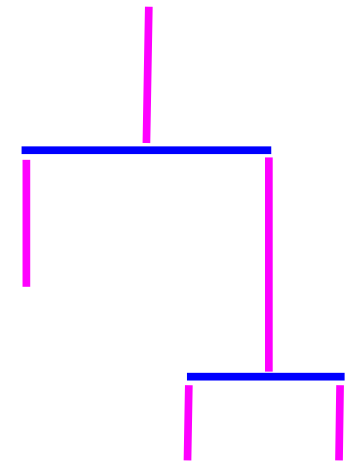


C.A.R.E Schools

- 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?

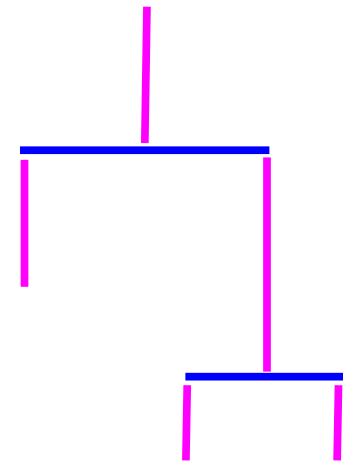


Queue Demo

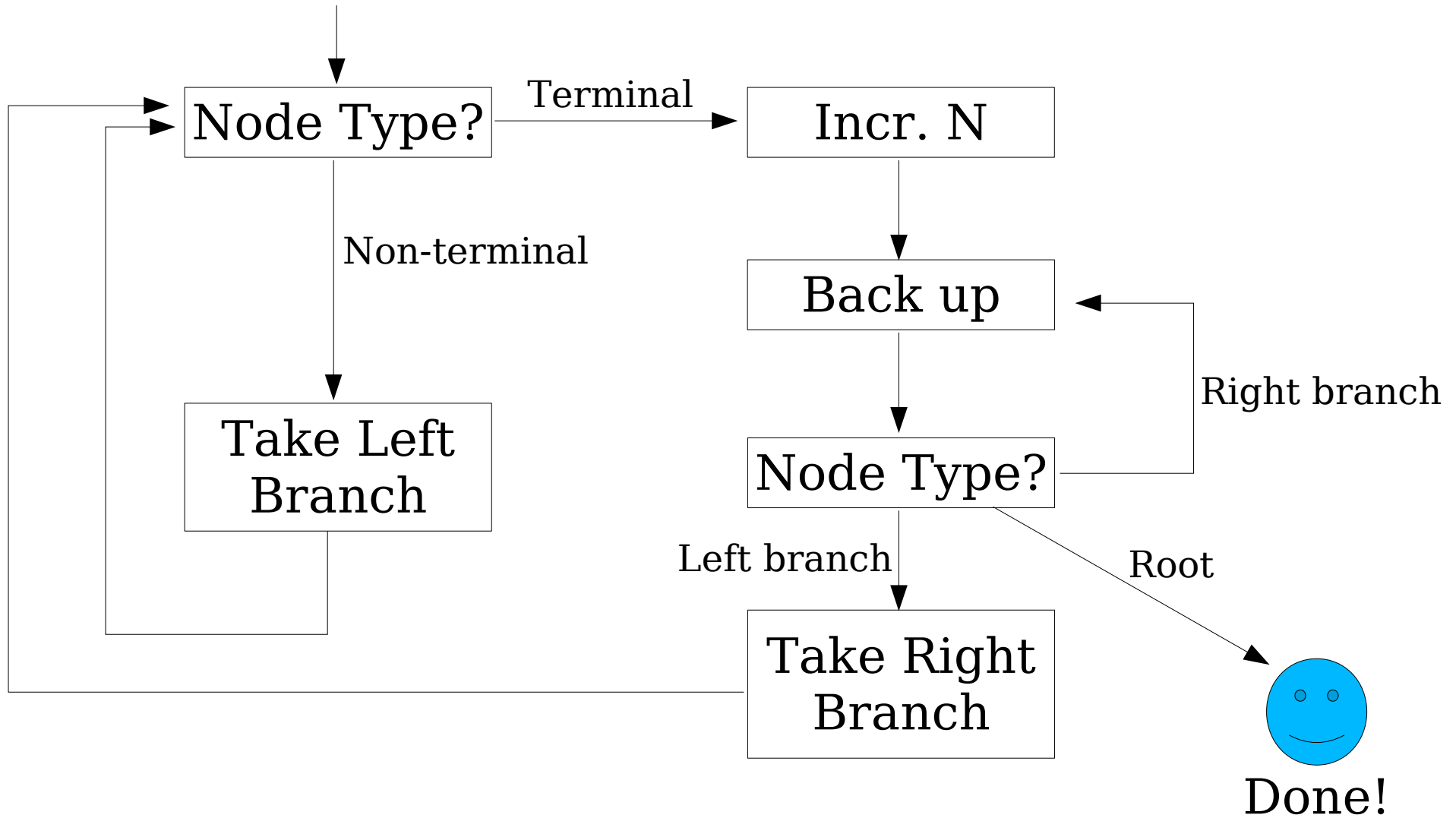
- Press one of the three back buttons to push a number (1, 2, or 3) onto the queue
- Press the head button to “ play” the queue. This does not erase the queue.
- Press the chin button to pop the front of the queue
- What happens if you try to pop an empty queue?

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?



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

