Tekkotsu

A Rapid Development Framework for Robotics

Masters Thesis Presentation
Ethan Tira-Thompson
Advisor: Dr. David S. Touretzky

Contents

Part I

Design Considerations

Design Dimensions

- Goal: provide a modular framework for developing robot behaviors
- Six fundamental classes of primitives:

1. User Interface	2. Perception	3. Manipulation
4. Control Structures	5. Mapping	6. Memory/ Learning

1. User Interface

- Two principles:
  - Multiple interfaces – remote and physical
    - Model-View-Controller – Abstract input method from implementation
    - Improves portability and accessibility
  - Transparency
    - Provide developer with access to monitor internal state
    - Reduces development time

2. Perception

- Primitives should convert real-time streams of data to event notifications
- Three main advantages:
  - Reduce recomputation – data is only processed once, regardless of number of dependancies
  - Lower learning curve – users don't need to know where data processing is being done, only that it is available
  - Modularity - weak linking, swap implementations

3. Control Structure

- Number of different control strategies
  - Subsumption (Brooks, 1986)
  - State machines (everybody)
  - Logical formalisms (e.g. Golog - Levesque, et.al 1997)

3. Control Structure (cont.)

- Hierarchical State Machine
  - Declarative construction
    - set parameters and connections
    - very easy to develop, especially with a graphical editor
  - Separates decisions (transitions) from actions (states)
    - Increases code reusability

4. Manipulation

- Motion primitives directly control physical machinery in real-time.
- Need to marry event driven processing with the real-time processing
- Conflicts can occur in complex behaviors
  - Serialize access?
  - Priority override?

5. Mapping

- Robots need to track current location as well as locations of objects in its environment
- No commercially available personal robotic platforms do mapping or localization

6. Memory/Learning

- Memory structures provide communication between states
- Memory of experiences is needed for learning

Advanced Features

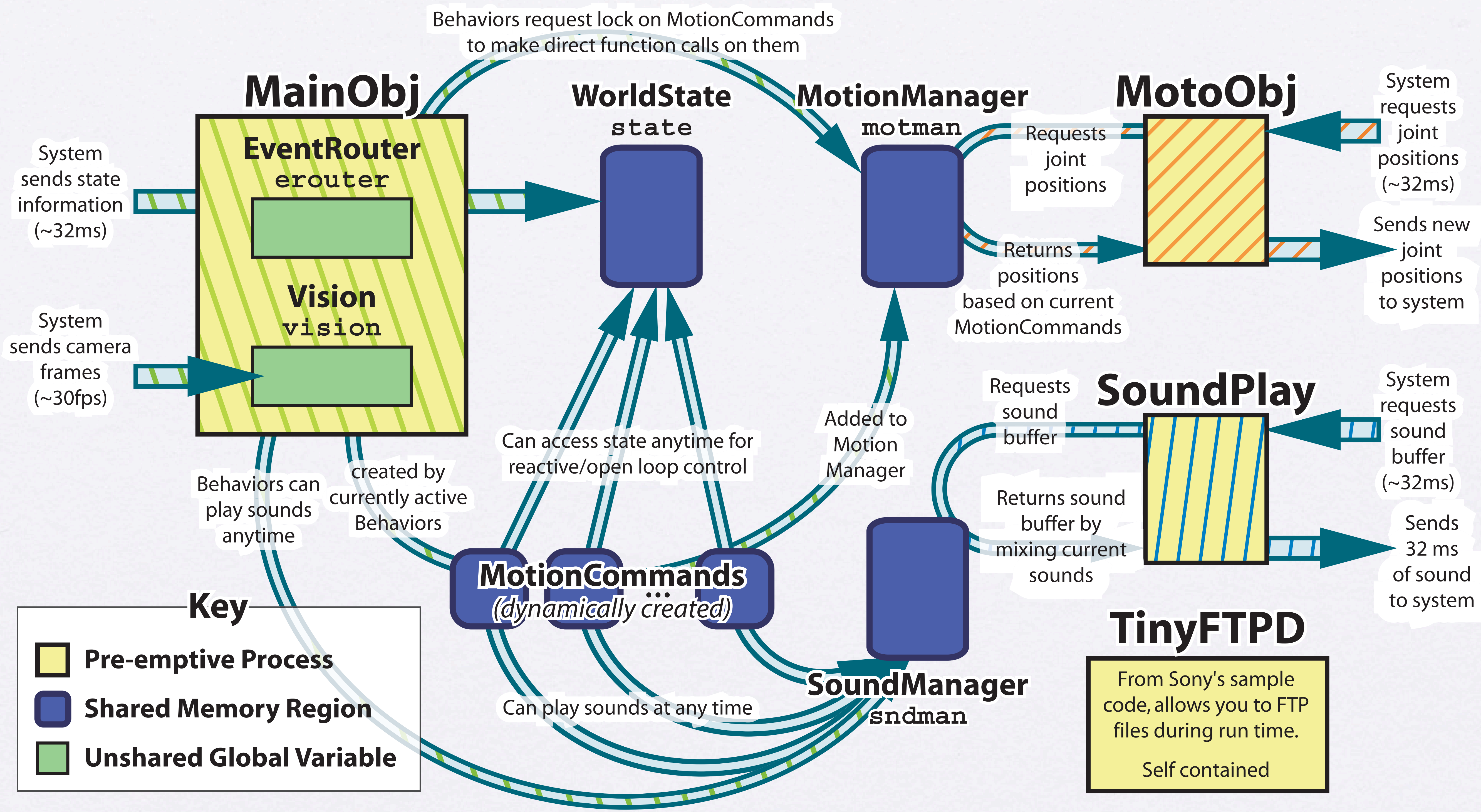
- Navigation
  - Follow a path, perhaps performing some task along the way
  - Combines perception with manipulation
- Attentional Control
  - Decide where to direct sensor resources
- Complex Behaviors
  - Search for an object, or monitor a condition and report when it changes

Part II

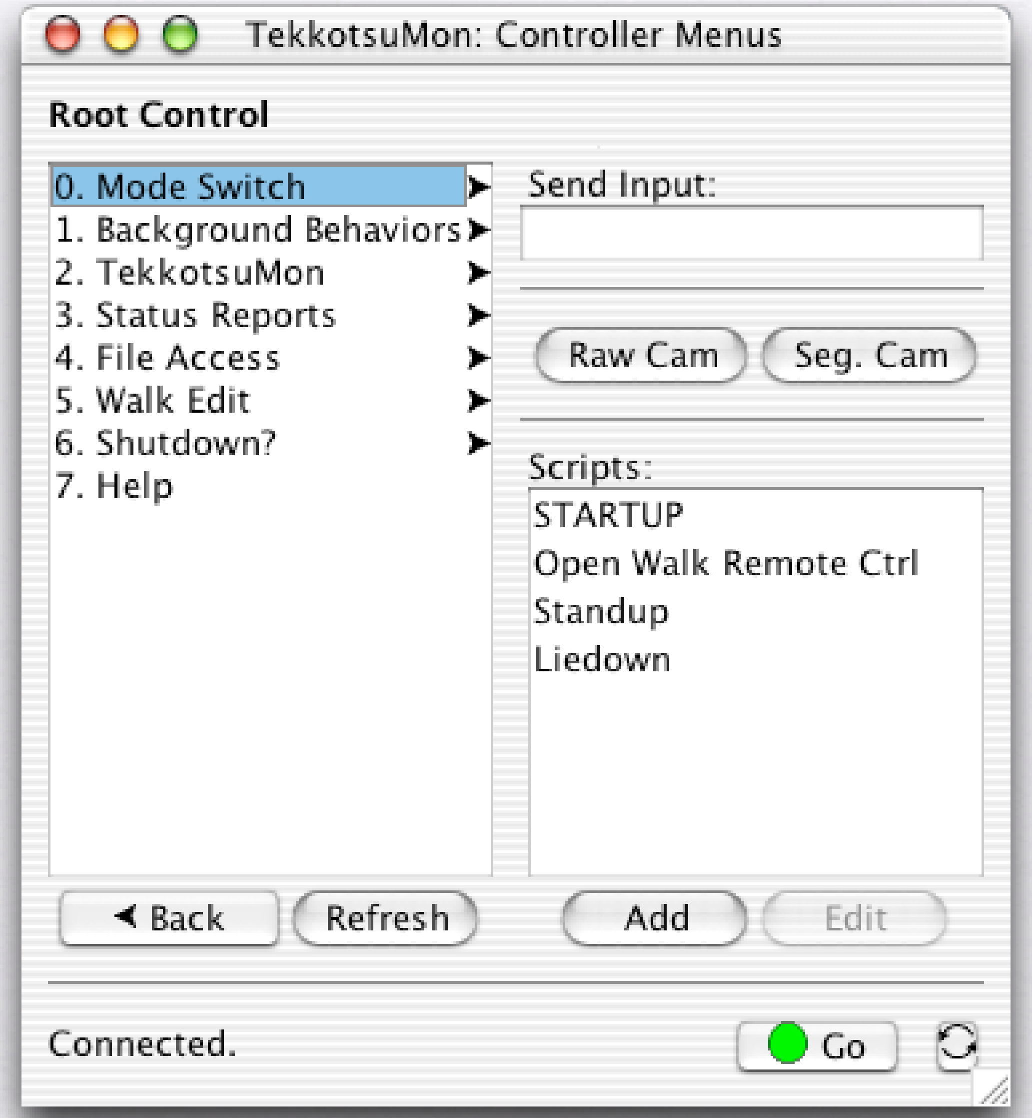
Implementation

Platform Information

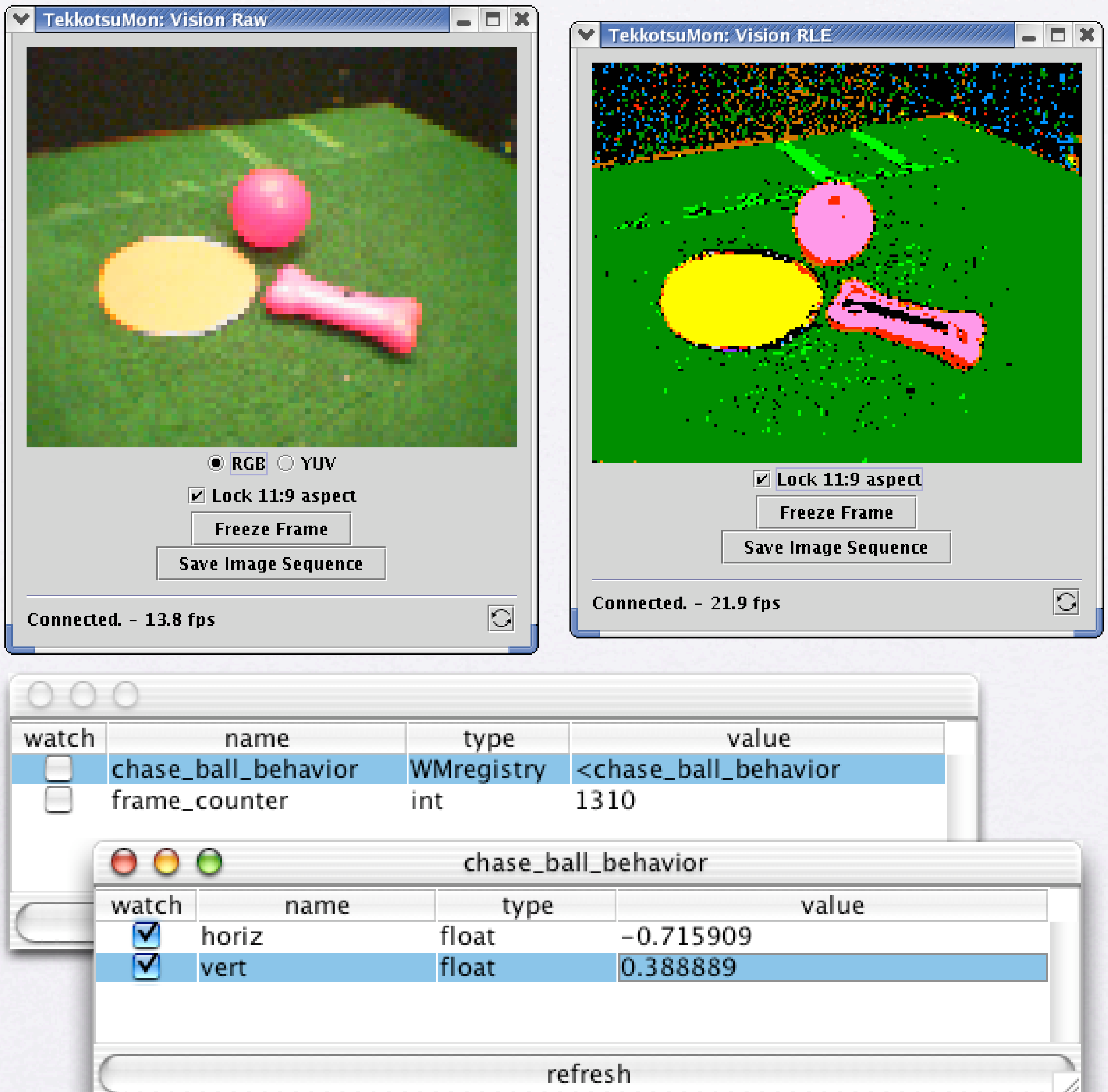
Tekkotsu Data Flow



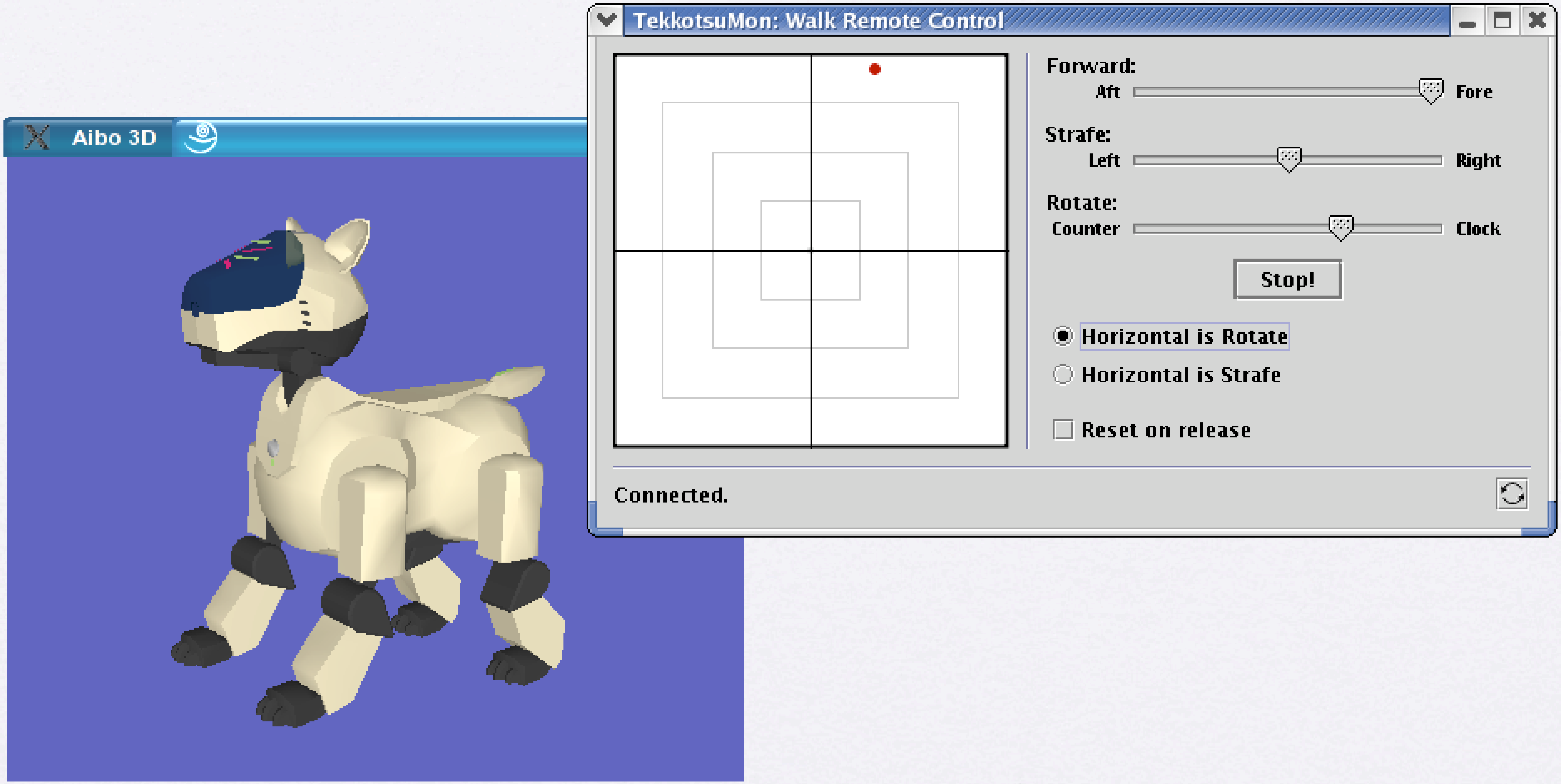
1. User Interface



1. User Interface



1. User Interface



2. Perception

- Global EventRouter maintains mapping of listeners to event streams
  - Centralized access is easy to learn
- Behaviors can subscribe to event streams at different granularities
  - Generator
  - Generator and Source
  - Generator, Source, and Type

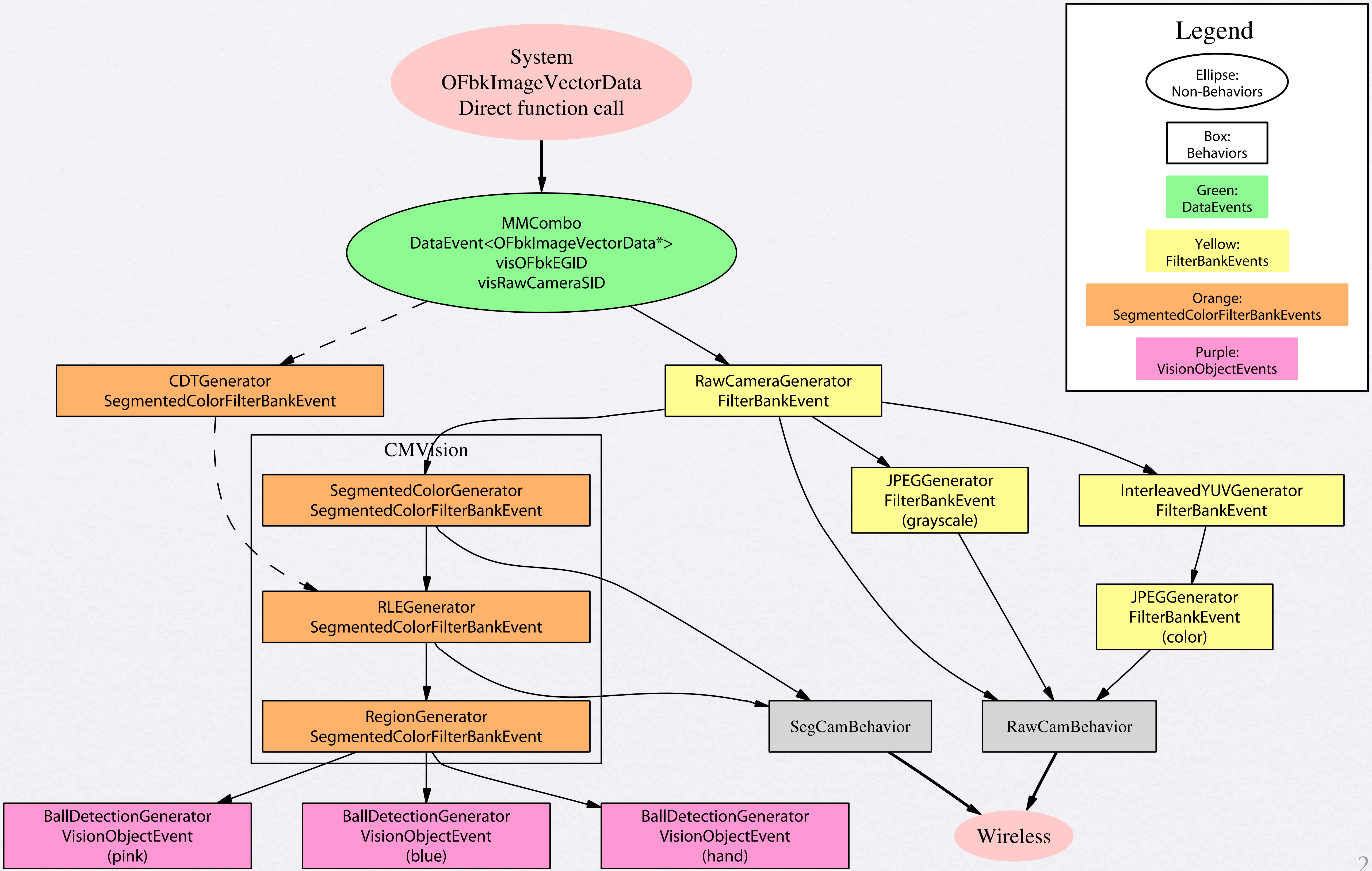
2. Perception (cont.)

- Available Generators:
  - sensor – new sensor readings available
    - button – button status
  - textMsg – user entered text from GUI or console
  - timer – timer has expired (not broadcast)
  - estop – emergency stop status
  - stateMachine – state transition occurred

2. Perception (cont.)

- Available Generators:
  - audio – sounds start/stop playback
  - motman – MotionCommands added/removed
  - locomotion – movement through world
  - power – battery and temperature status
  - vision generators – various stages of processing

2. Perception



3. Control Structure

- Supported Architectures:
  - Hierarchical State Machine
    - Supports “fork” of activation
  - Subsumption-like
    - Priority overrides allow motion primitives to override each other

3. Control Structure (cont.)

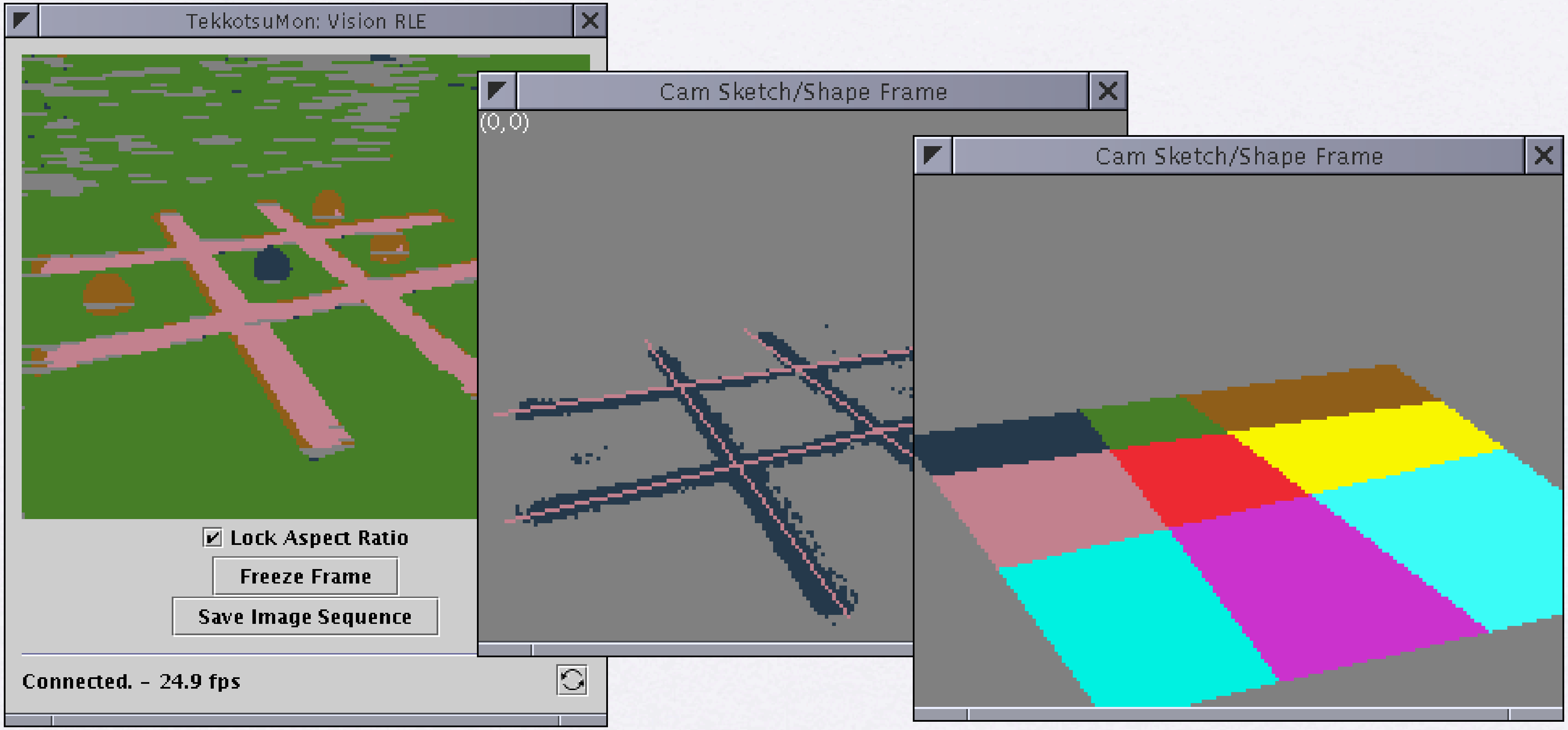
- Process Management
  - Each behavior can be thought of as a non-pre-emptive process
    - Low overhead
    - Must give up processor control
  - Events carry not only information, but also a token representing processor control

4. Manipulation

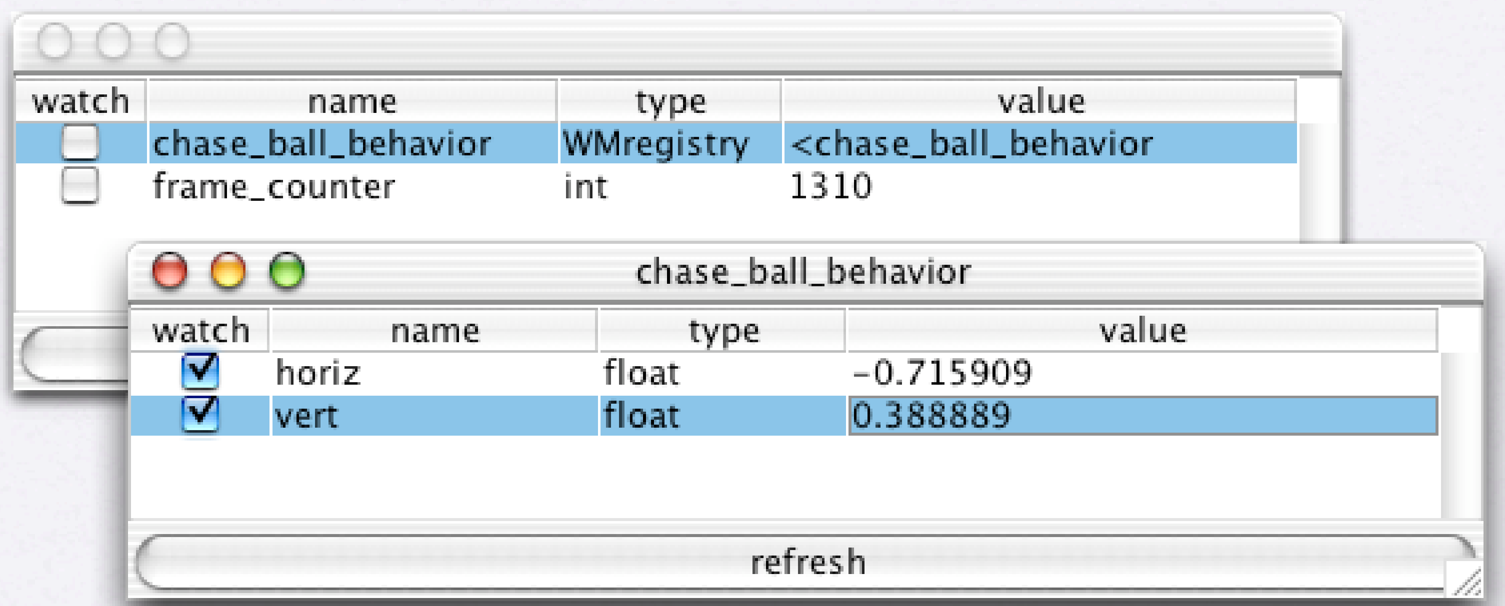
- Motion Manager uses priority levels to resolve conflicts between primitives
  - Ties are resolved with a weighted average
- Primitives include:
  - Walking, head pointing, LED special effects, motion script playback, PID control, direct posture control, emergency stop, tail wag

5. Mapping

- Under development
- Uses Visual Routines based processing



6. Memory/Learning



Part III

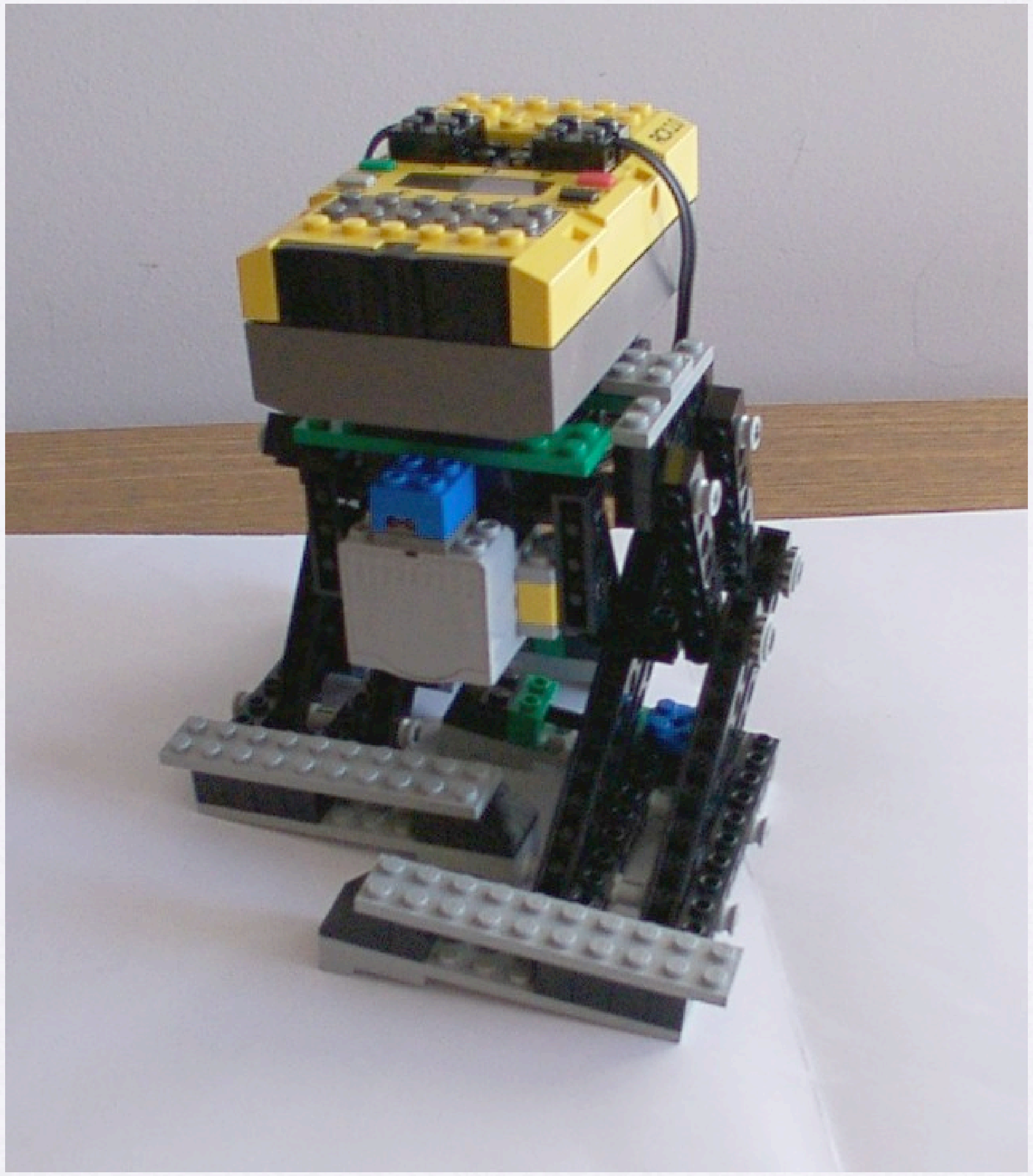
Evaluation

Comparison to Other Frameworks

- LEGO MindStorms
  - Standard Environment
  - Third-party firmware (legOS/leJOS)
- Sony Master Studio (AIBO)
- BeeSoft (Real World Interfaces B14/B21)

Comparison to LEGO MindStorms (Standard)

http://mindstorms.lego.com/eng/inventions/invention.asp?id={D56DB42C-2C7B-4BE4-A9BE-E0AA6CA0A224}&slotN=1

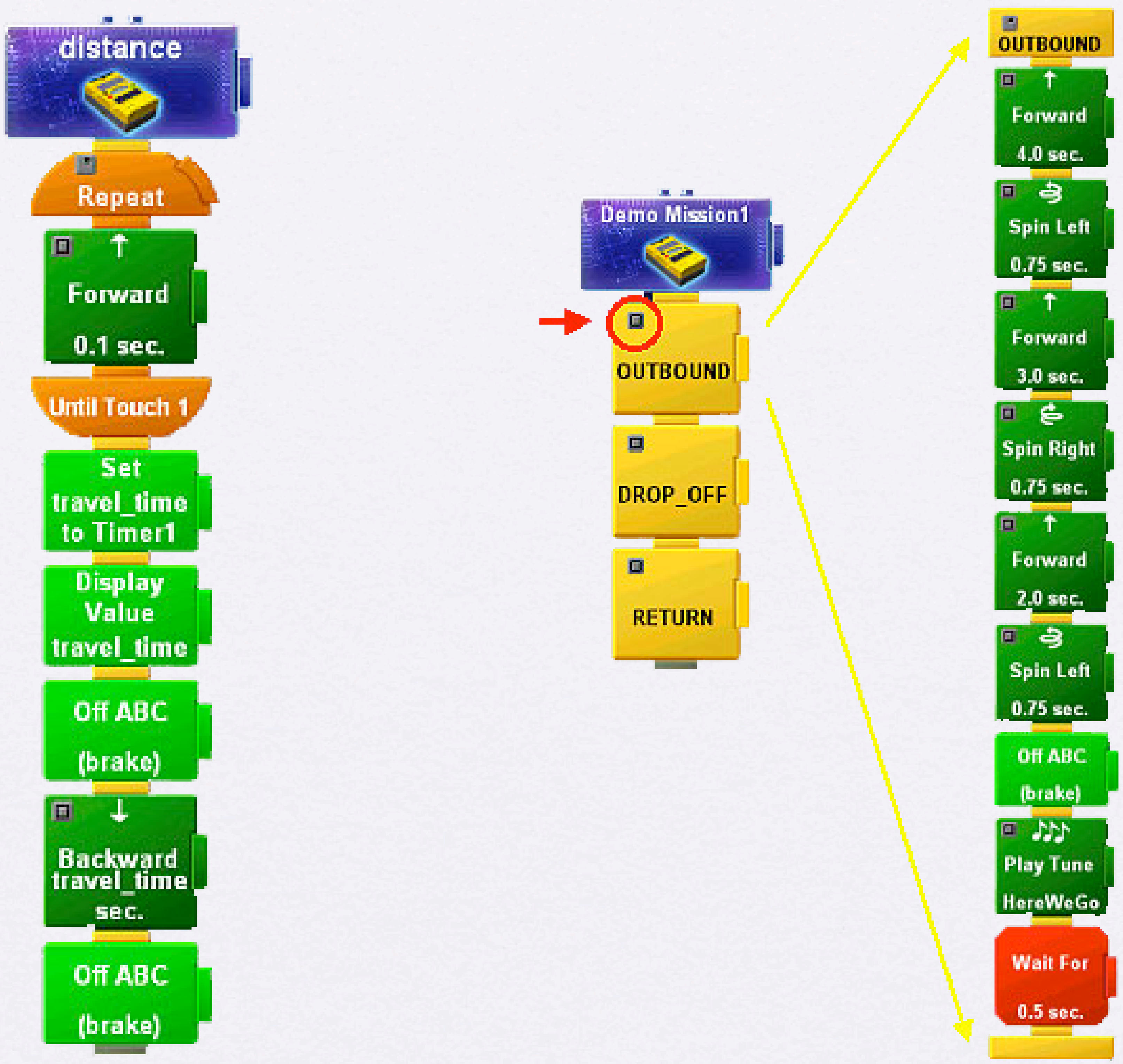


http://mindstorms.lego.com/eng/inventions/invention.asp?id={EE1A945A-FF21-4361-B192-E8ADB5D38F9F}&slotN=1

Comparison to LEGO MindStorms (Standard)

- Pros:
  - Graphical editor is very easy to learn
  - Large support community
  - Can also use source code – Not Quite C, Ada, Scheme

Comparison to LEGO MINDSTORMS (Standard)



Comparison to LEGO MindStorms (Standard)

- Cons:
  - Very limited number of variables, no dynamic memory
  - No call stack (no recursion or functions)
  - No floating point math

Comparison to LEGO MindStorms (Third-party)

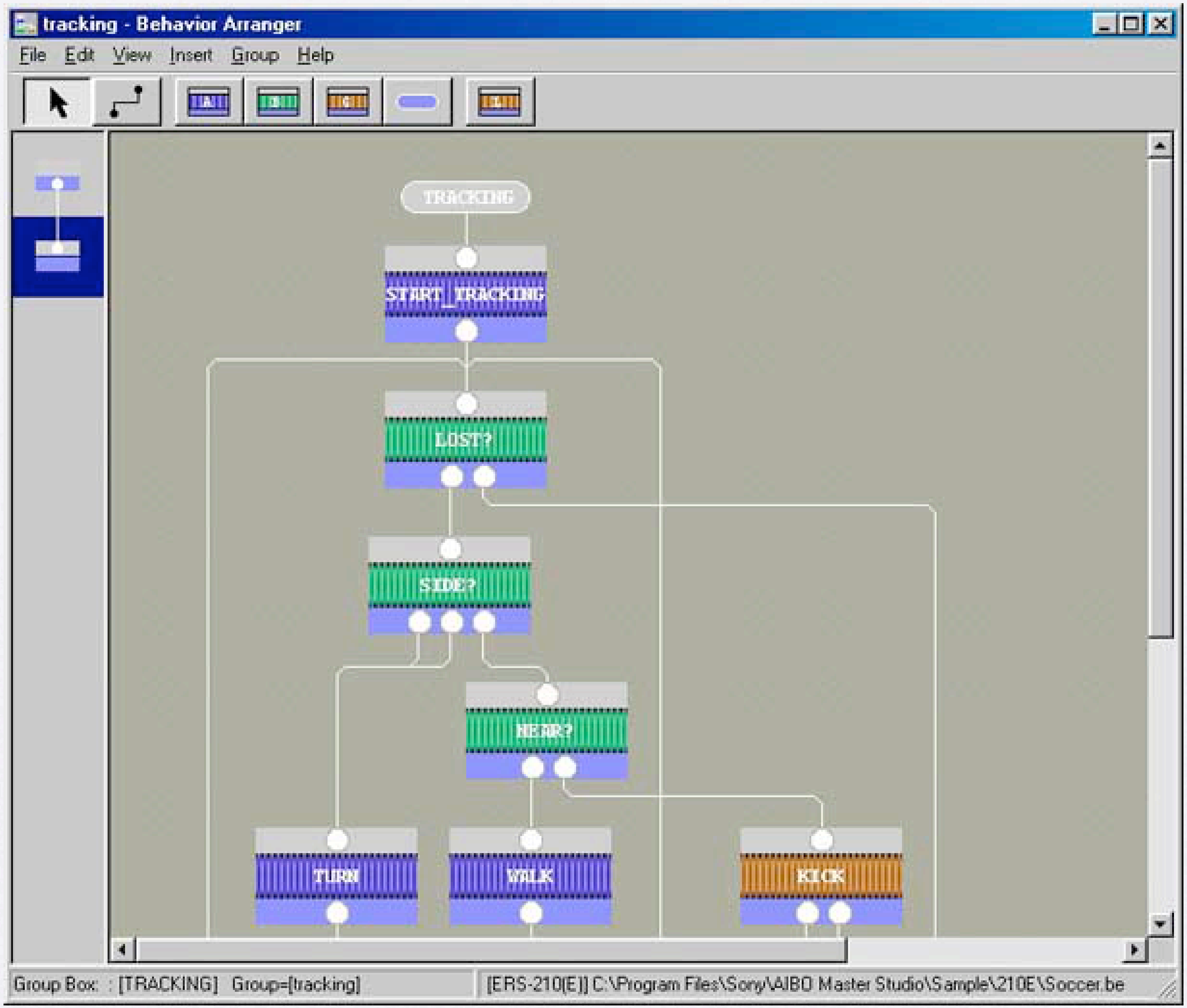
- Pros:
  - Enables nearly full support for common languages (C, Java)
- Cons:
  - Still running on very limited hardware
  - Minimal toolset

Comparison to Sony Master Studio

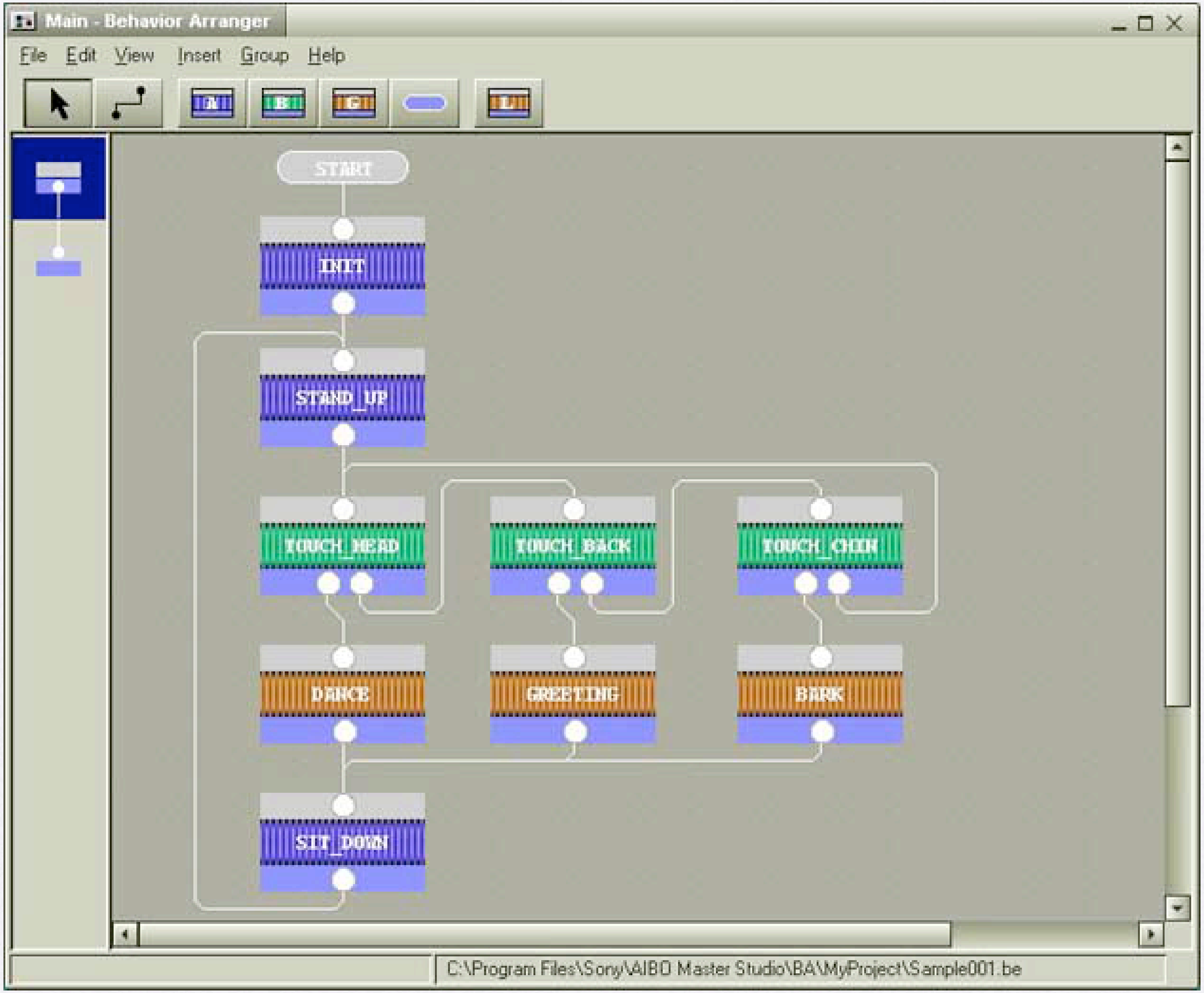
Comparison to Sony Master Studio

- Pros:
  - Graphical state machine editor is easy to use and more powerful than MindStorms
  - Includes primitives for on board visual and auditory processing
    - Recognition of pink ball, action cards
    - Speech recognition (static vocabulary)
  - Has a source code language – R-Code

Comparison to Sony Master Studio



Comparison to Sony Master Studio



Comparison to Sony Master Studio

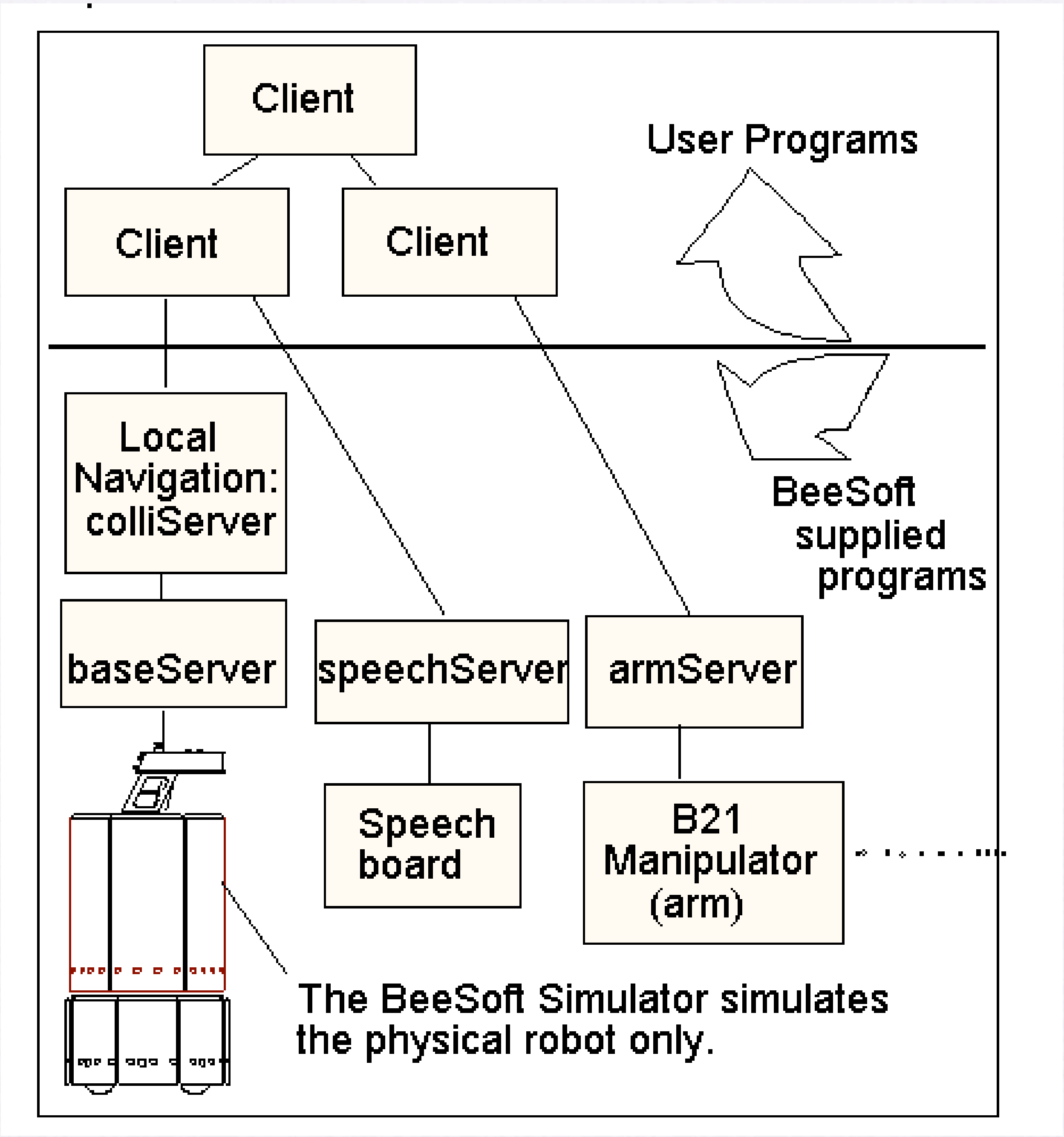
- Cons:
  - Even fewer variables than MindStorms
  - Very limited dynamic/real-time abilities

Comparison to BeeSoft

Comparison to BeeSoft

- Pros:
  - Designed with clustering in mind
  - Flexible hardware configurations
- Cons:
  - Little or no support included for manipulators, video, or audio processing

Comparison to BeeSoft



Tekkotsu

- Pros:
  - Extensive tools, libraries
  - Includes primitives for visual processing
  - Uses a well known language (C++)
  - Open Source
- Cons:
  - Requires advanced C++ knowledge (i.e. templates)
  - Large codebase

Tekkotsu

- State Machine Sample:

Declare states

```
virtual void setup() {
   StateNode *wait=start=addNode(new WaitNode("Wait",this,bandit));
   StateNode *left=addNode(new PressNode("Left",this,LFrLegOffset+KneeOffset));
   StateNode *right=addNode(new PressNode("Right",this,RFrLegOffset+KneeOffset));
   StateNode *decide=addNode(new DecideNode("Decide",this,bandit,left,right));
   StateNode *recoverl=addNode(new OutputNode("\nBadPressLeft",this,std::cout,wait));
   StateNode *recoverr=addNode(new OutputNode("\nBadPressRight",this,std::cout,wait));
   left->addTransition(new SmoothCompareTrans<float>(wait,&state->pidduties[LFrLegOffset+RotatorOffset], ...
   right->addTransition(new SmoothCompareTrans<float>(wait,&state->pidduties[RFrLegOffset+RotatorOffset], ...
   wait->addTransition(new TimeOutTrans(decide,2000));
   left->addTransition(new TimeOutTrans(recoverl,1500));
   right->addTransition(new TimeOutTrans(recoverr,1500));
   //     recover->addTransition(new TimeOutTrans(decide,500));
   StateNode::setup();
}
```

Connect Transitions

- State Node Sample:

```
//! walk in the direction the head is pointing, rotating as necessary to center ball
virtual void processEvent(const EventBase& event) {
  if(event.getGeneratorID()==EventBase::visObjEGID) {
    //in case the head isn't pointing straight forward, we'll straife
    float x=120.0f*cos(state->outputs[HeadOffset+PanOffset]);
    float y=120.0f*sin(state->outputs[HeadOffset+PanOffset]);
    float z=-static_cast<const VisionObjectEvent*>(&event)->getCenterX();
    MMAccessor<WalkMC>(walker_id)->setTargetVelocity(x,y,z);
  }
}
```

Scoring Rubric

- List of qualities for each of the six classes of primitives
- 1 point is assigned to each framework for each applicable quality
- The six classes are equally weighted and summed to calculate the final score

Scoring Rubric

- User Interface
  - Allows both remote and hands-on control
  - Transparency of robot state
  - Can create new interfaces
  - Includes tools for robot status reports
  - Portability

Scoring Rubric

- Perception
  - Event system
  - Can do visual processing
  - Can do auditory processing
  - Can add new sensor events
  - Portability

Scoring Rubric

- Control Structures
  - Loops
  - Arrays
  - Dynamic Memory
  - Recursion
  - Modularity
  - State Machine
  - Threads
  - Low Learning Curve
  - Portability

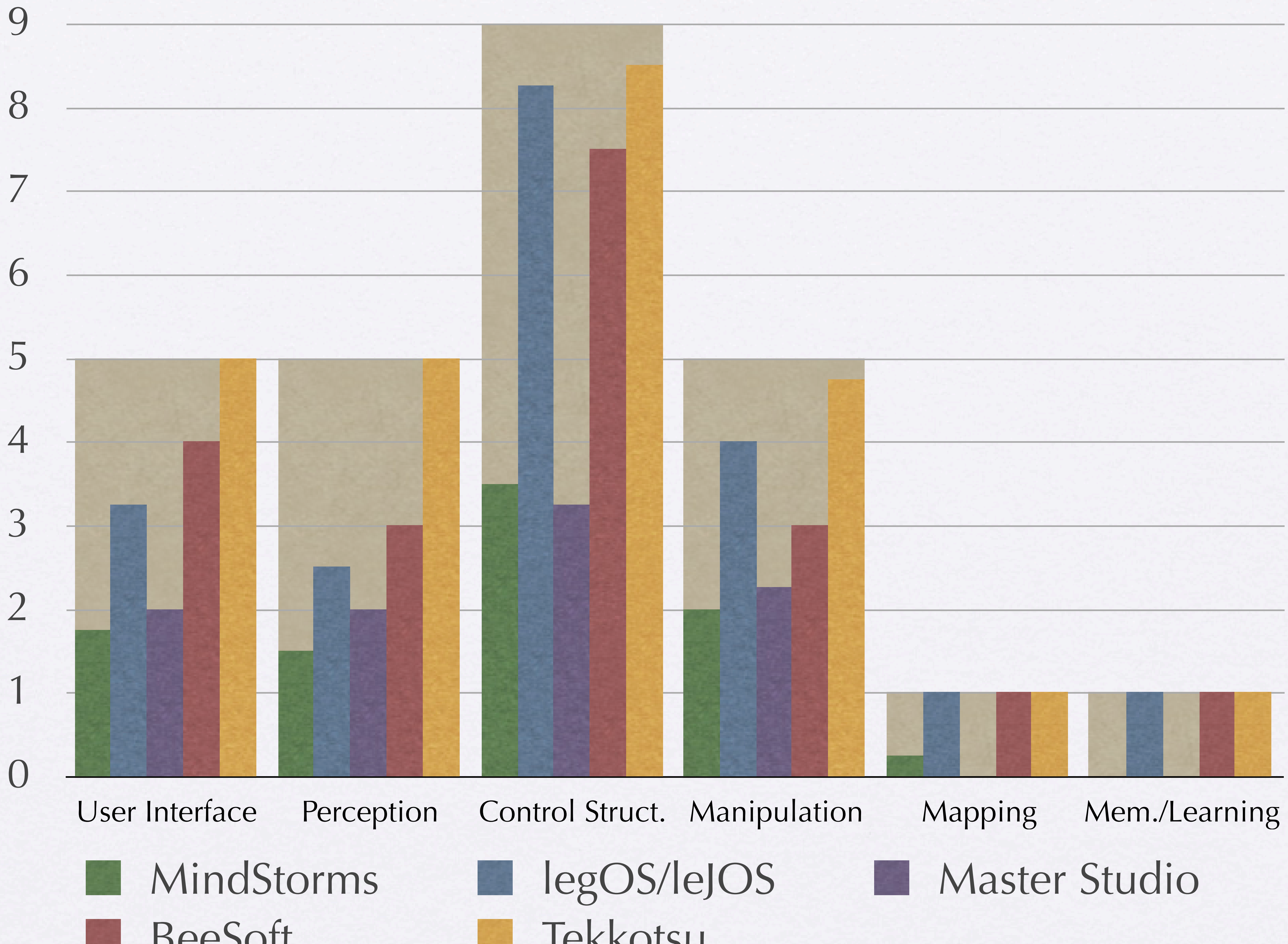
Scoring Rubric

- Manipulation
  - Canned script playback
  - Sensor access
  - Kinematics library
  - Real-time control
  - Portability

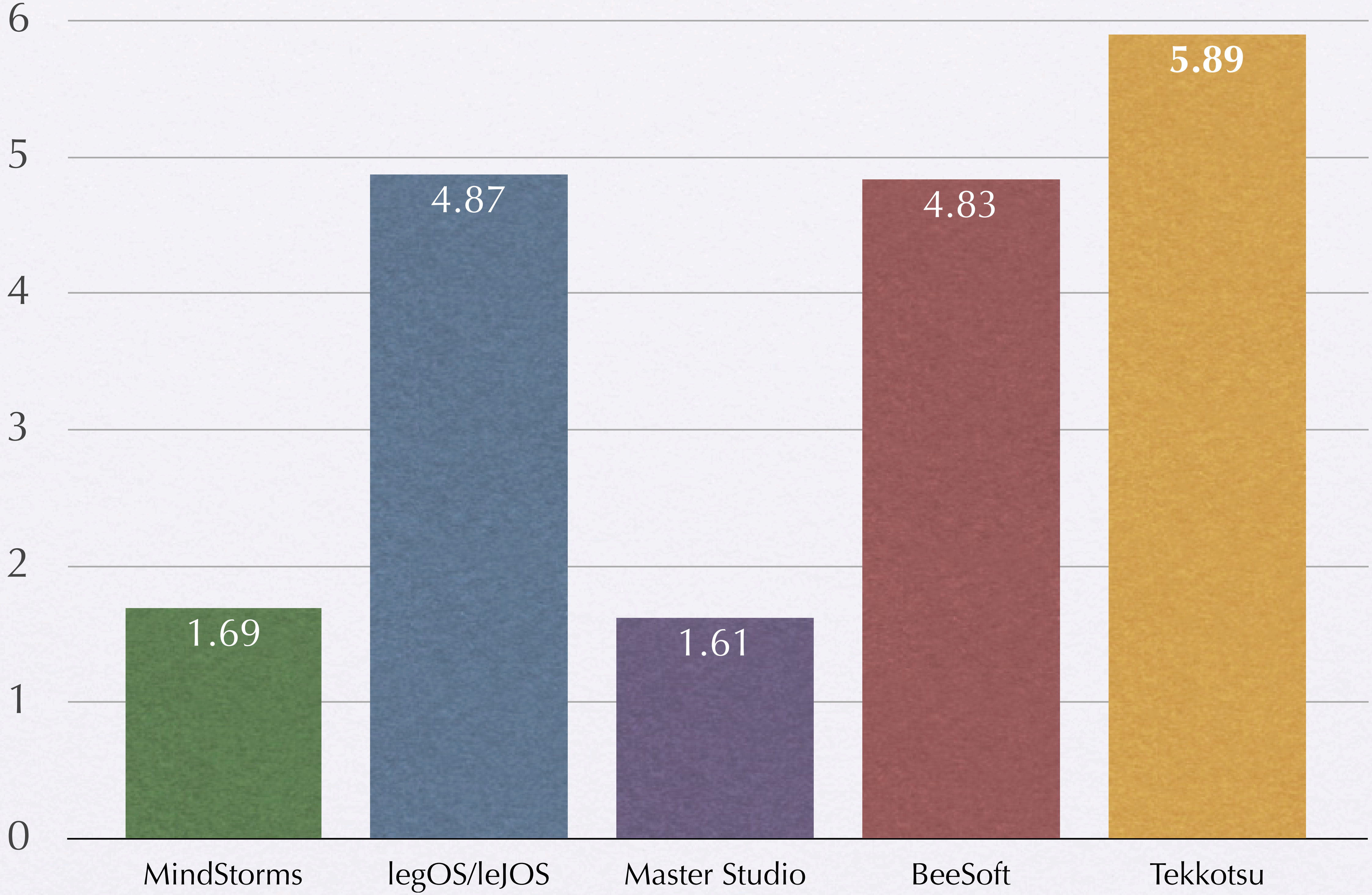
Scoring Rubric

- Mapping
    - Feasibility
- Machine Learning
    - Feasibility

Categorical Summary



Final Summary



Concluding Remarks

Future Development

- Multi-Robot Communications
- Graphical State Machine Editor/Viewer
- Applications in Education
- Training of Behaviors
- Standard Robotics Platform

Conclusions

- Robot manufacturers need to start considering a standard software platform
  - Attempts are under way, e.g. Webots
- We need more complete software libraries to propel robotics research (e.g. CMVision)
- Tekkotsu is now in use by at least a dozen universities around the world
- 109 member mailing list

Acknowledgements

- AIBO Lab: Alok Ladsariya, Thomas Stepleton, Neil Halelamien, Jordan Wales
  - Director: Professor David S Touretzky
- CORAL Group, particularly Scott Lenser, for helping to get us off the ground
  - Director: Professor Manuela Veloso
- My parents and Sylvia for keeping me sane
- This work partially funded by Sony Corp.

For Further Information

- Tekkotsu Homepage
  - http://www.tekkotsu.org
  - http://www-2.cs.cmu.edu/~tekkotsu