Humanoid Robot Soccer 101

B-Human

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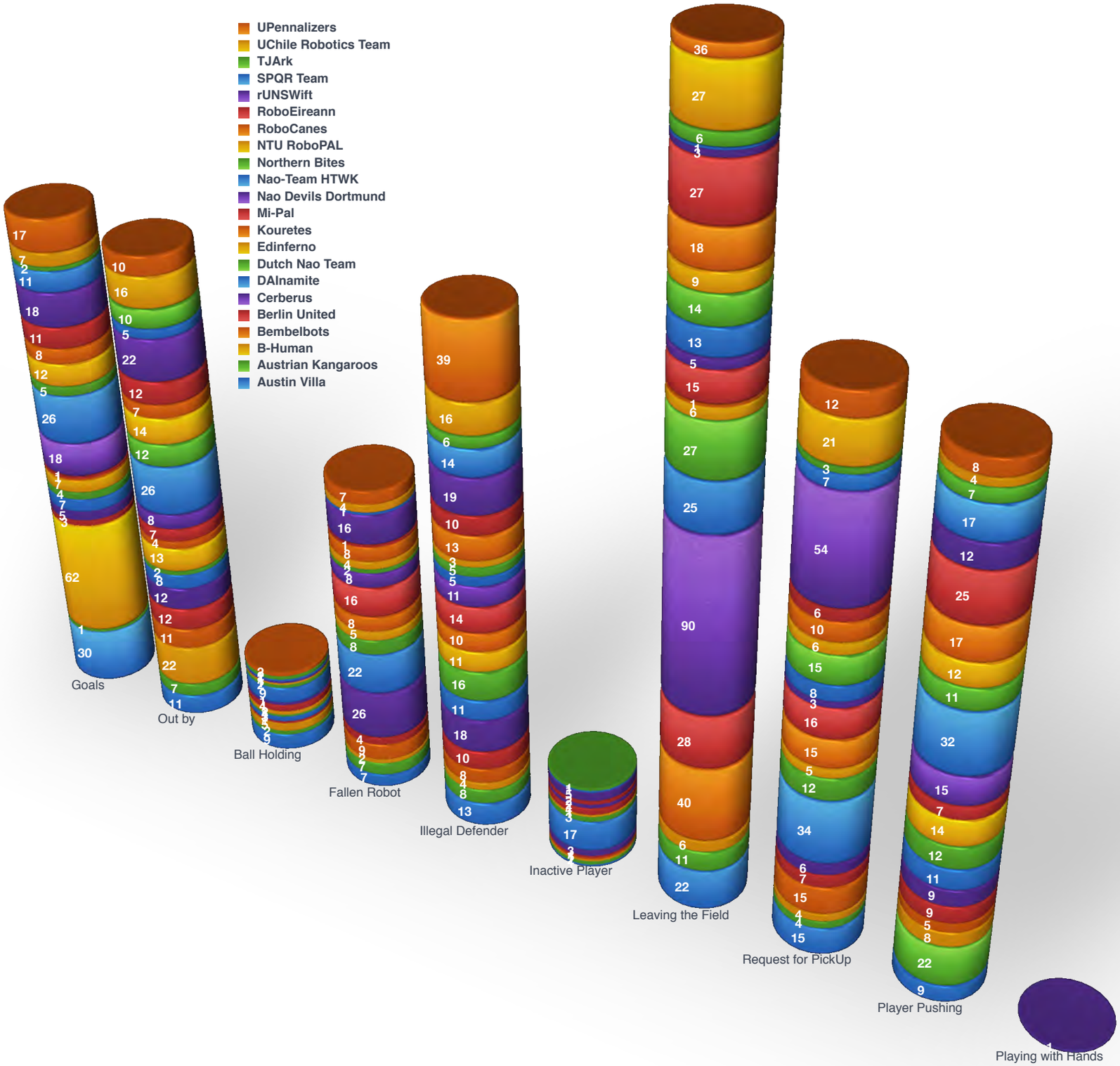
B-Human

RoboCup 2013: SPL Semifinal

RoboCup 2013: Statistics

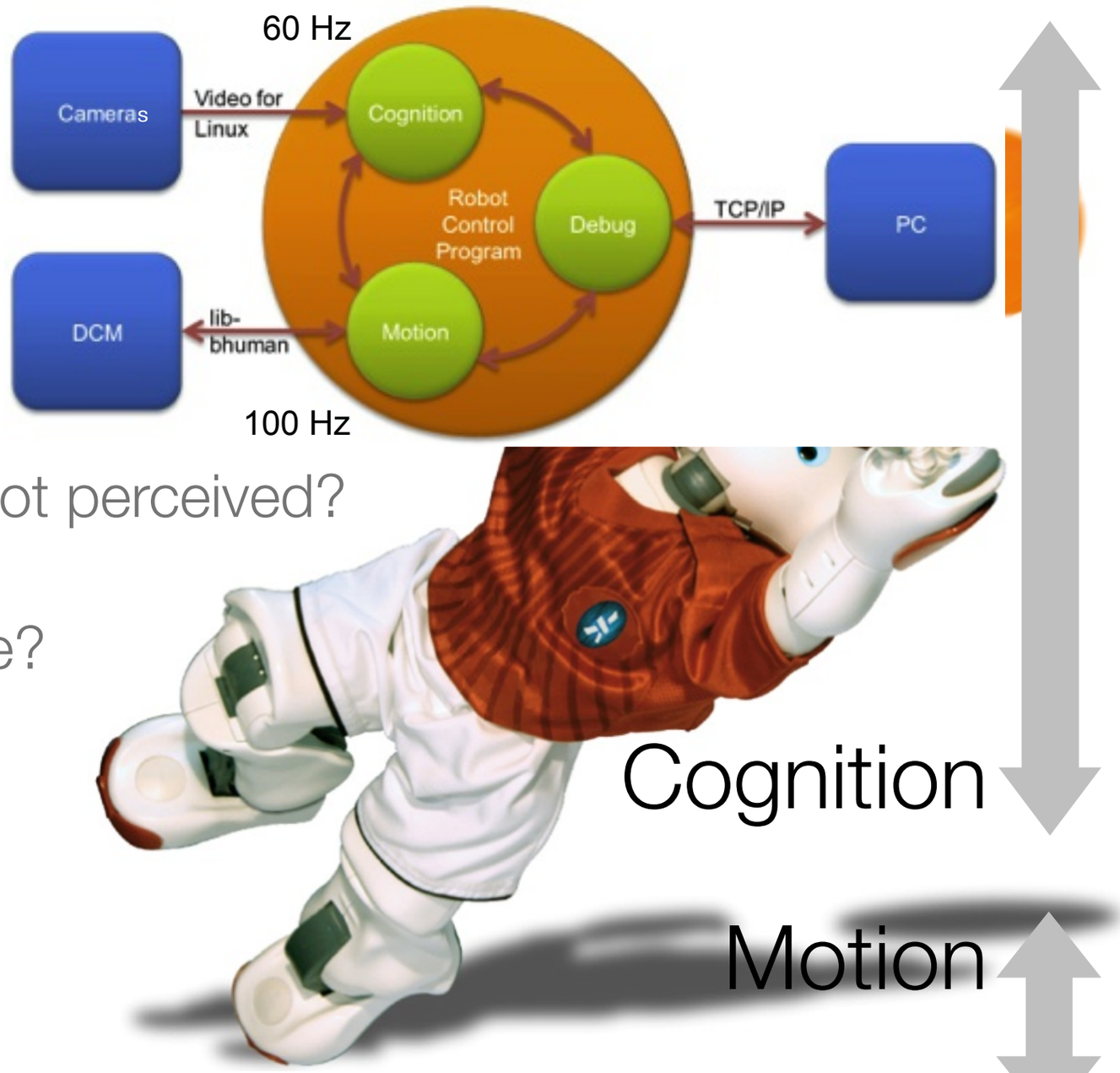


Standard Platform League

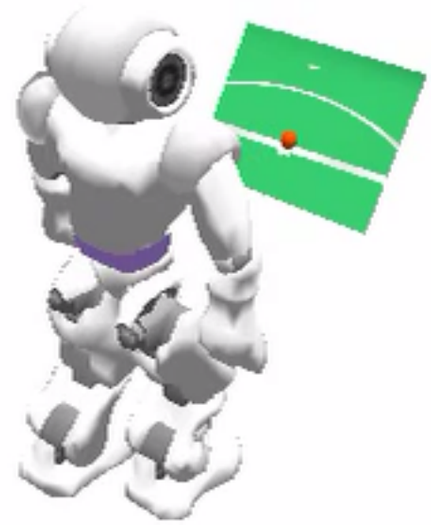
- Aldebaran Robotics NAO
  - 21-25 degrees of freedom
  - Height 57cm, weight 5 kg
  - Different sensors, on-board PC (1.6GHz Atom)
- Soccer Competition
  - 5 vs. 5
  - Robots are fully autonomous
  - Field size 9 m x 6 m

Controlling a Soccer Robot

- Perception: What do I see now?
- World Modeling
  - Where am I?
  - Where are objects currently not perceived?
  - What speeds do objects have?
- Behavior Control: What to do?
- Sensing: What am I feeling?
- Motion Control: Walking, kicking, standing up, looking



Perception



Perception:
Grid-based Scanning and Specialists

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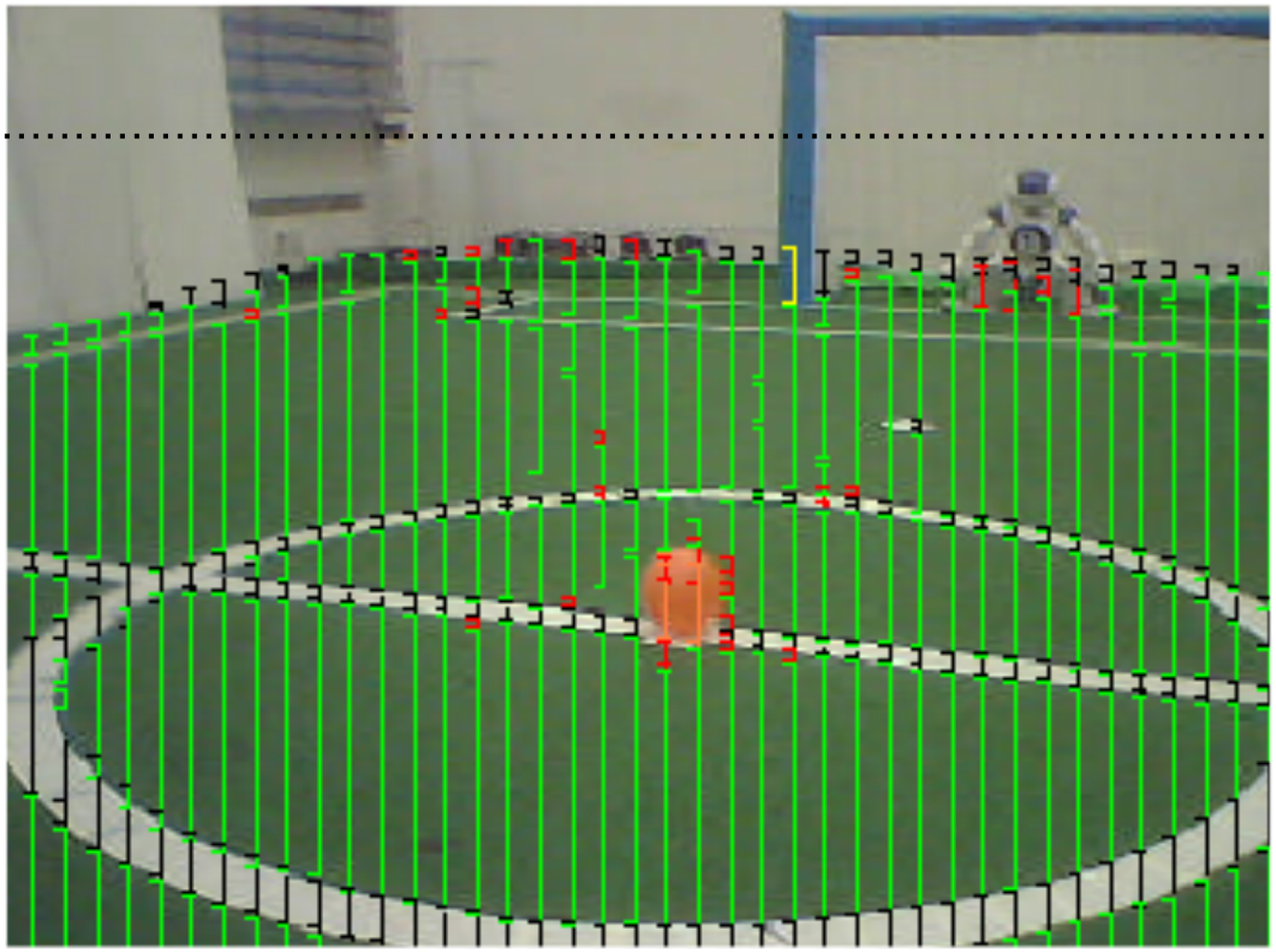

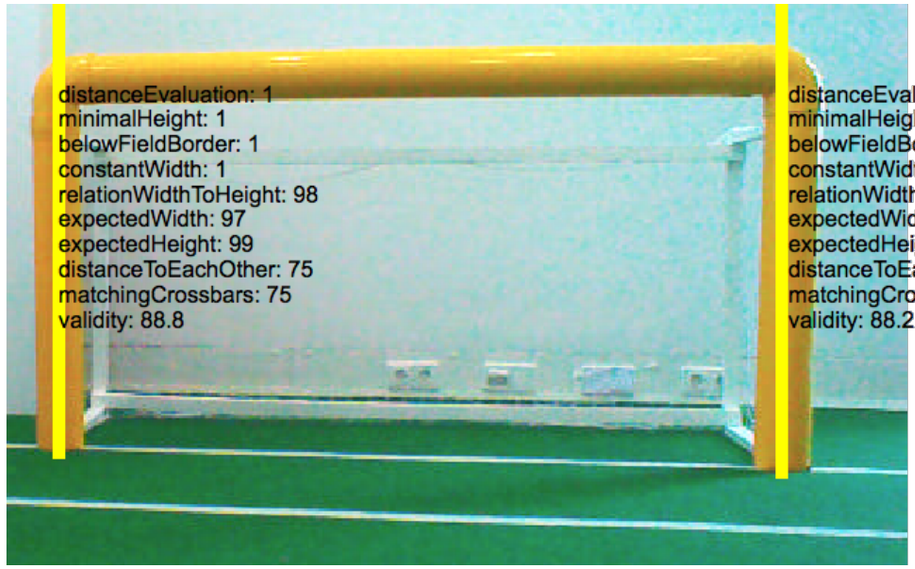

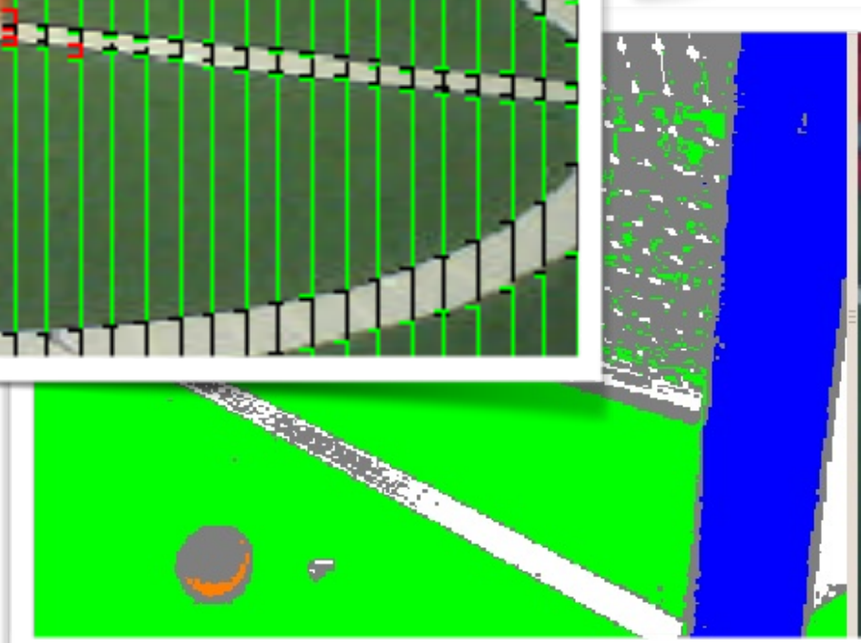

Perception: Determining Distance

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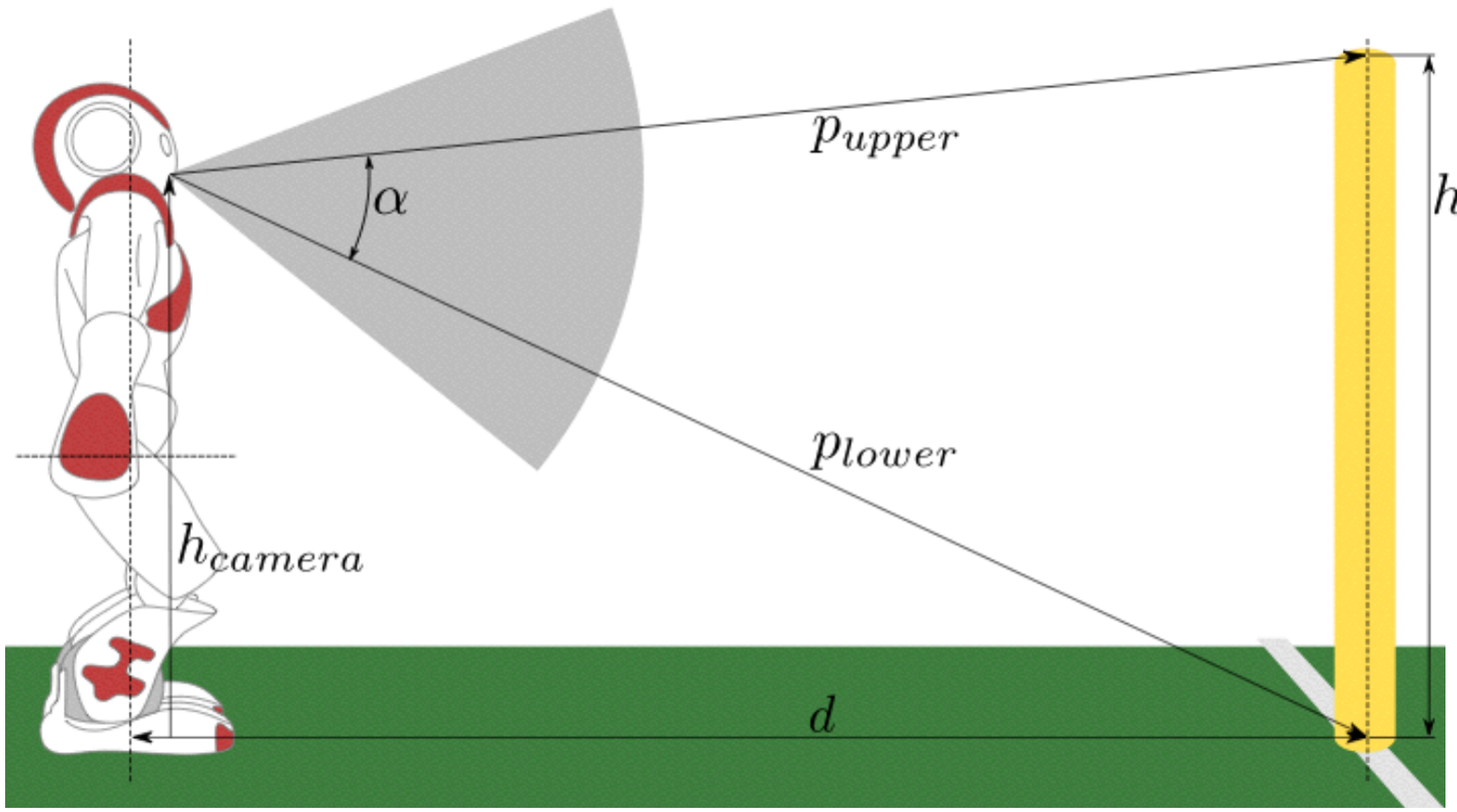
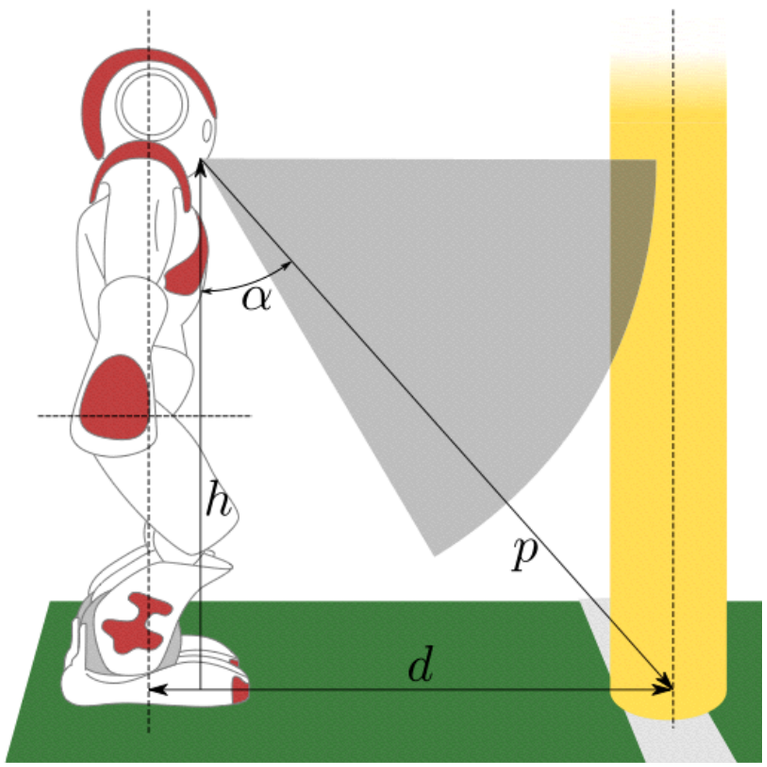


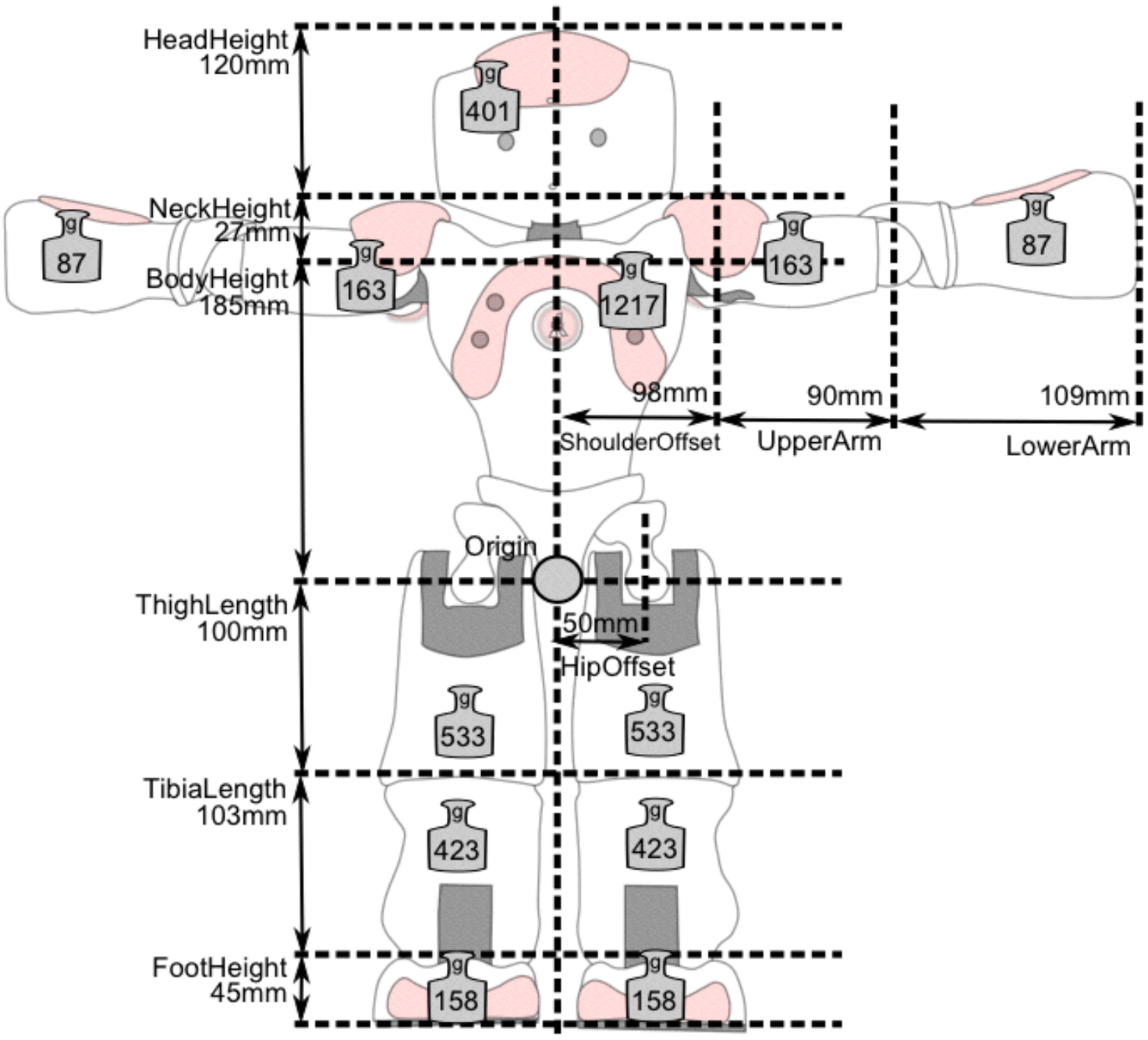
distance from size



distance from bearing

Sensing

- Center of Mass
- Ground contact
- Falls (with direction)
  - Robot is falling
- Torso pose
  - Camera poses



Sensing: Torso Pose

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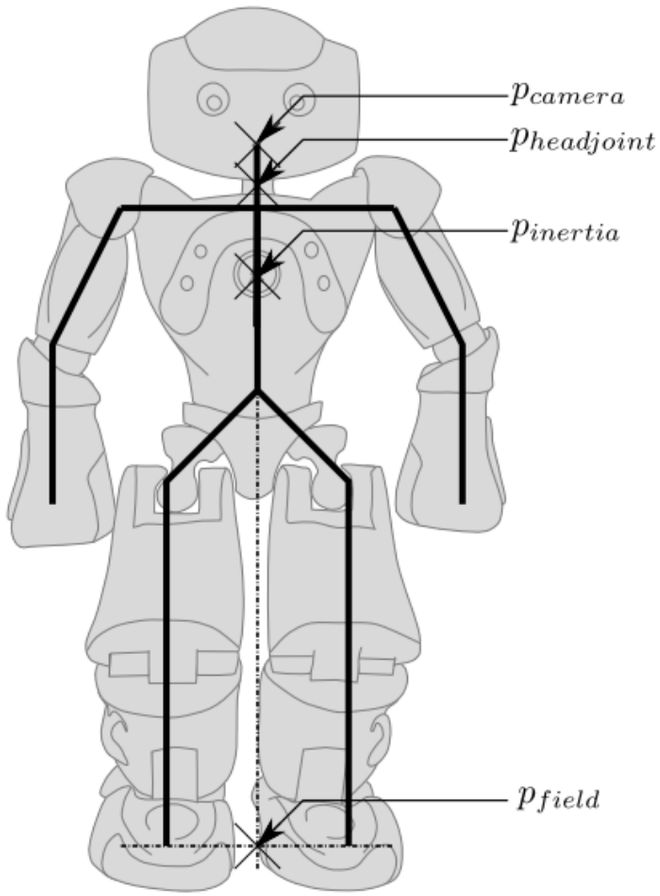
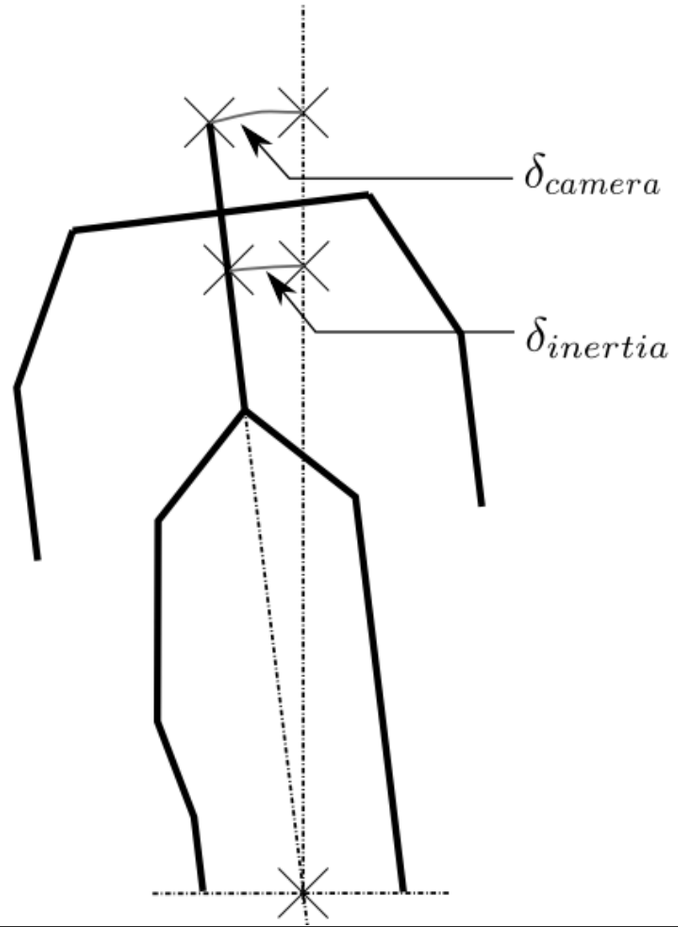
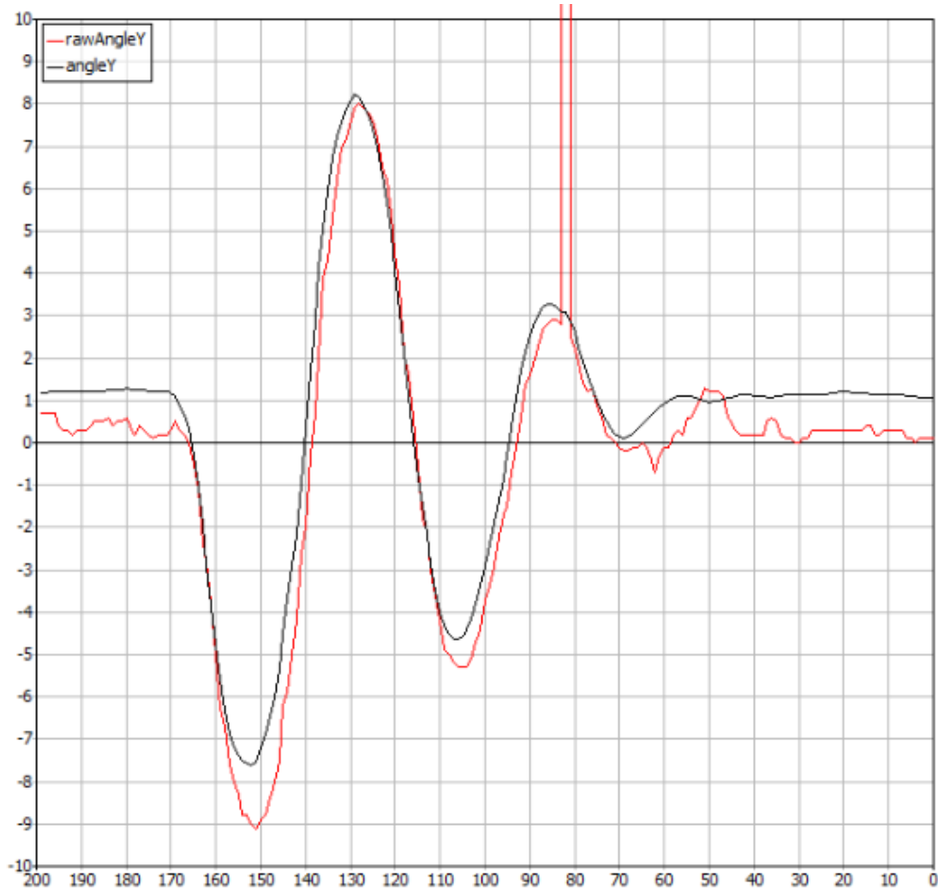
- Unscented Kalman Filter
  - Forward kinematics
  - Calibrated gyroscopes
- Compensation for gyroscope's bias drift

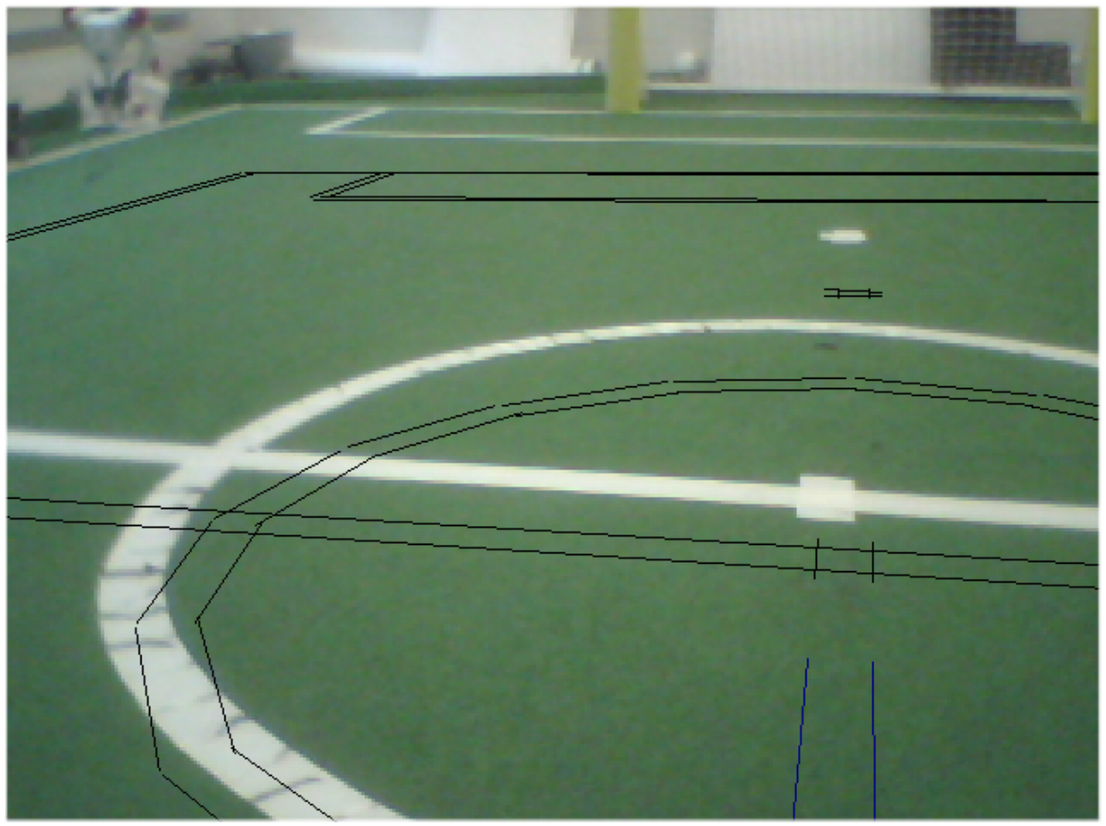


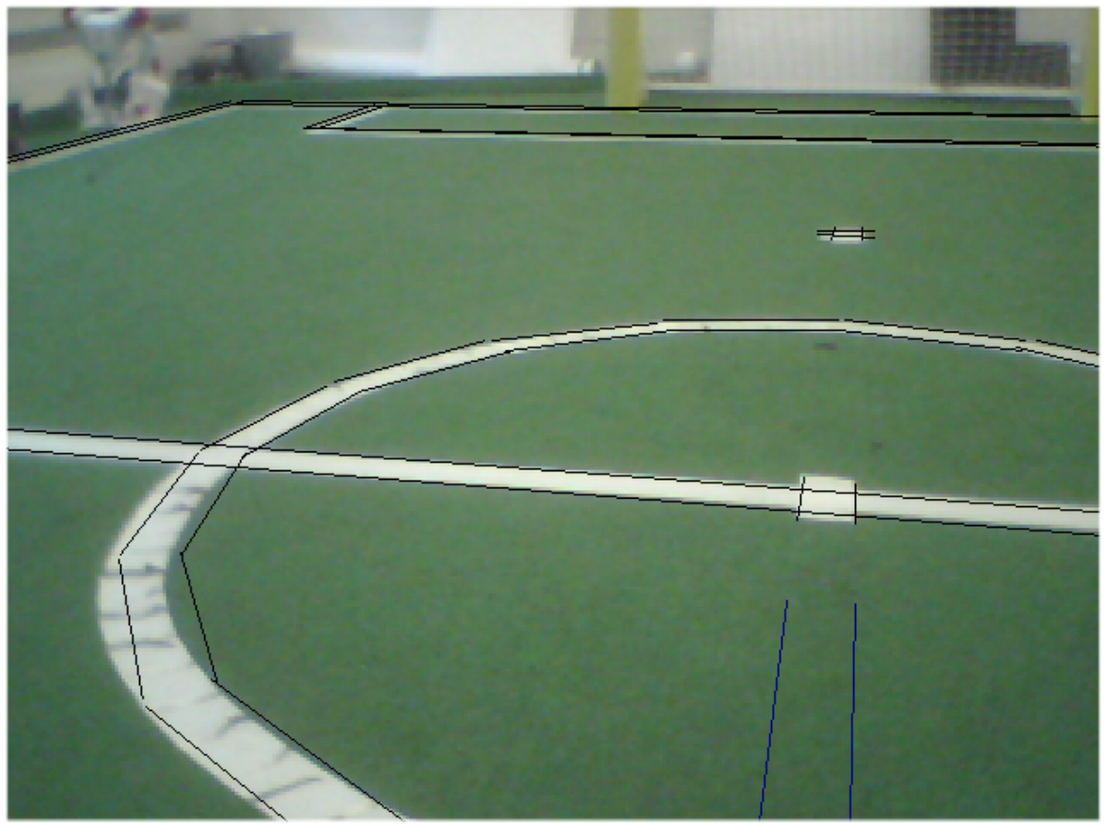




Sensing:
Calibrating Camera Pose

B-Human





- Before calibration
  - Misplaced camera
  - Backlash in joints
- After calibration
  - Camera roll / tilt
  - Overall body roll

Perception and Sensing: Synchronization

B-Human

- Rolling shutter (CMOS technology exposes pixel-by-pixel)
- Time differences between images and joint angles
- Correction
  - Using head joint velocities
  - Only perceptions, not whole image

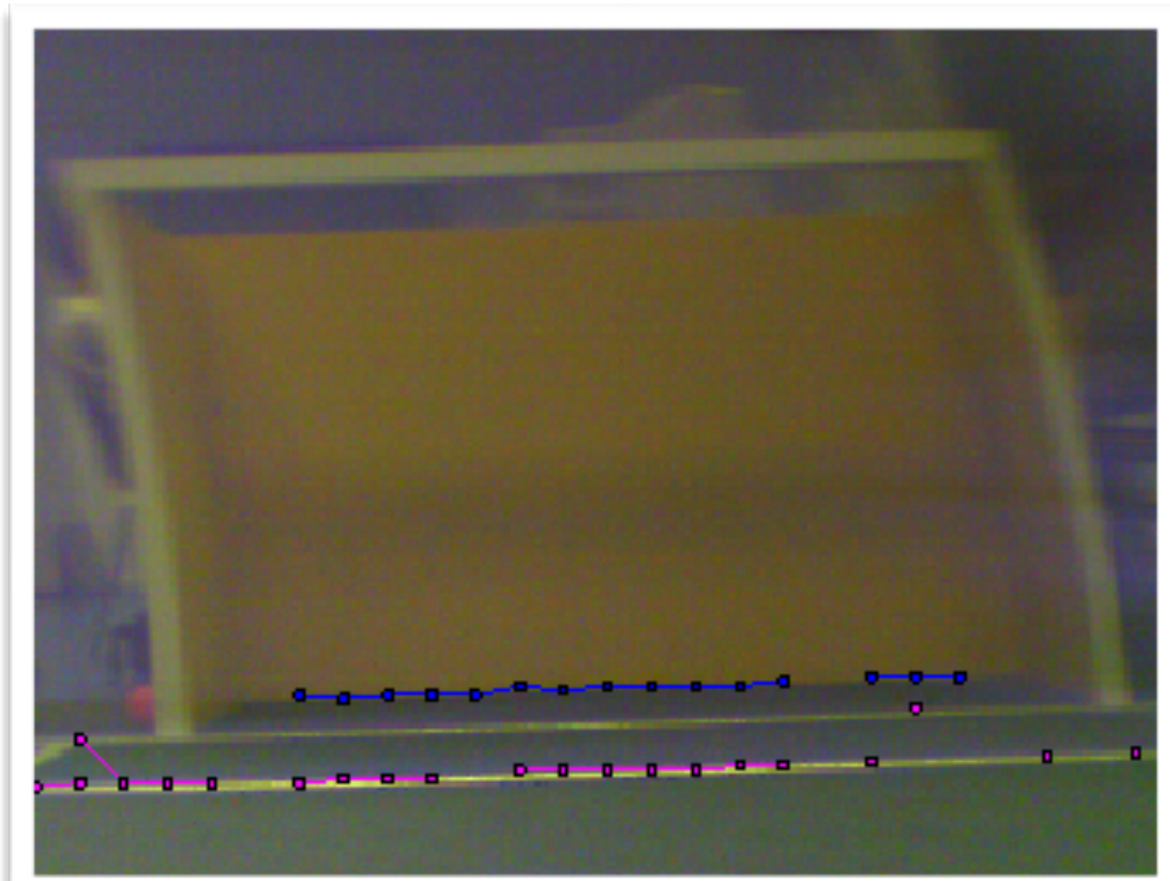
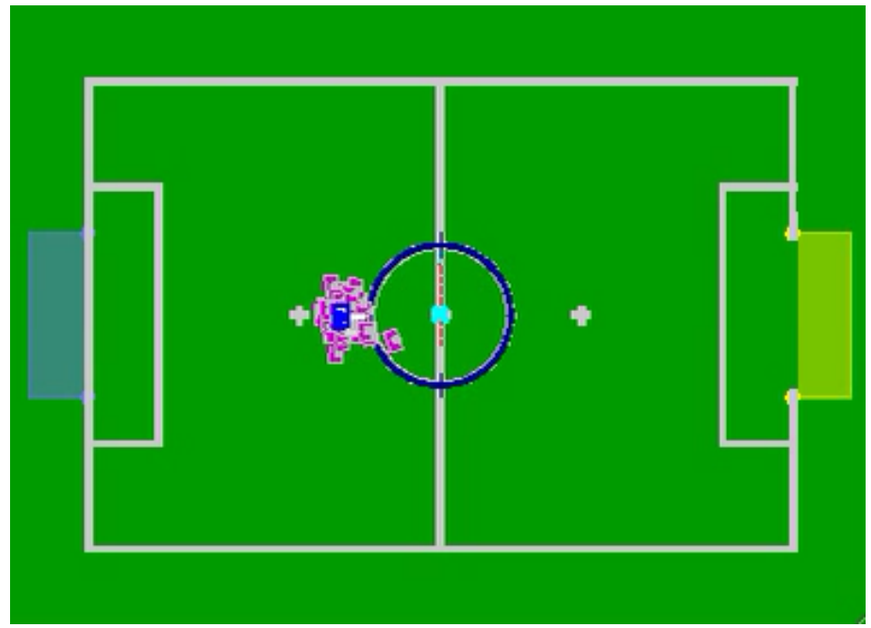


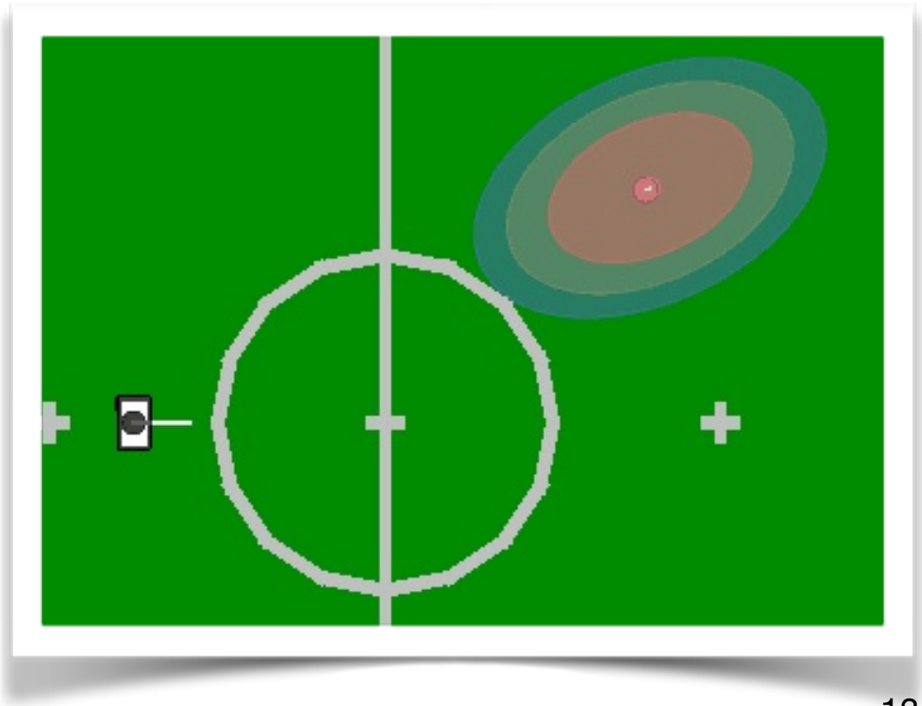
Image taken by Bioloid robot

World Modeling: Self-Localization, Ball

B-Human

- Self-localization
  - Particle filter with 16 Unscented Kalman Filters
  - Side confidence and own side model
  - Use ball for disambiguation
- Ball modeling
  - 6 Kalman Filters for static ball
  - 6 Kalman Filters for rolling ball

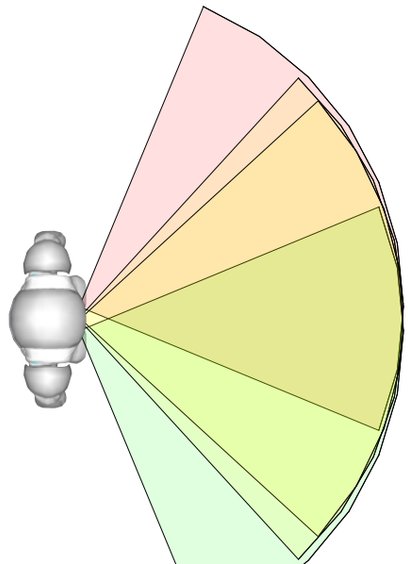


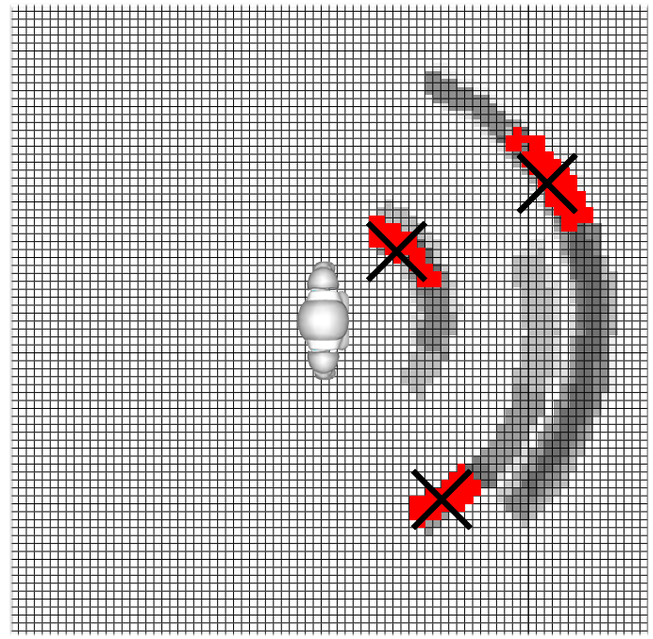


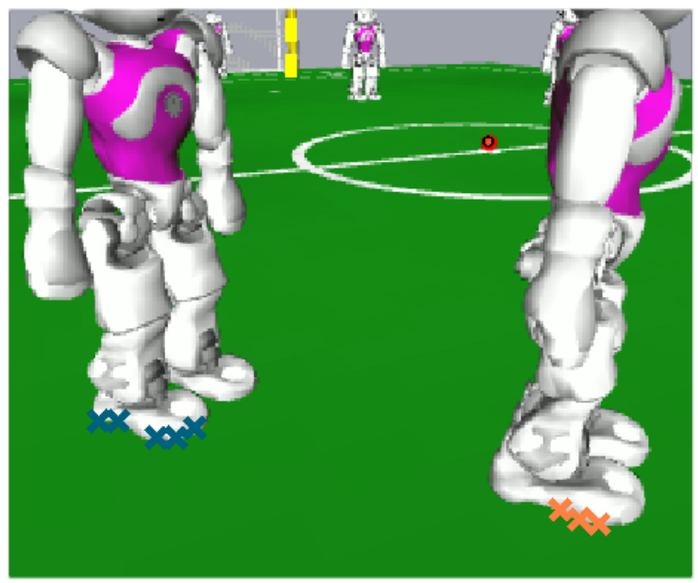
World Modeling: Obstacles

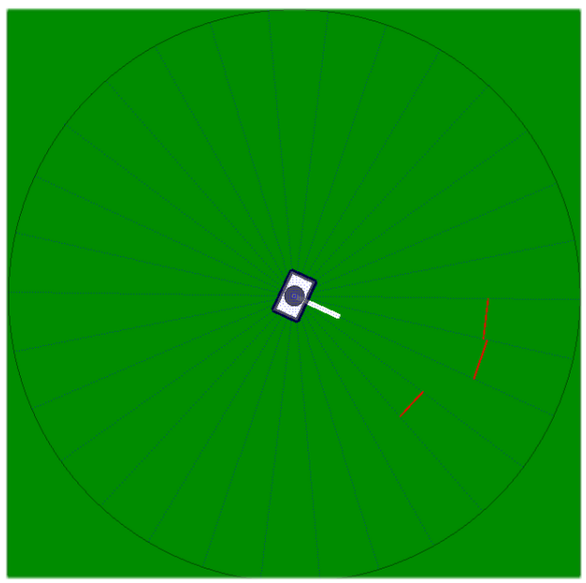
B-Human

- Sonar-based
  - Overlapping measurement areas
  - 2-D evidence grid of measurement history
- Vision-based
  - Edges between field and robots
  - Obstacle wheel



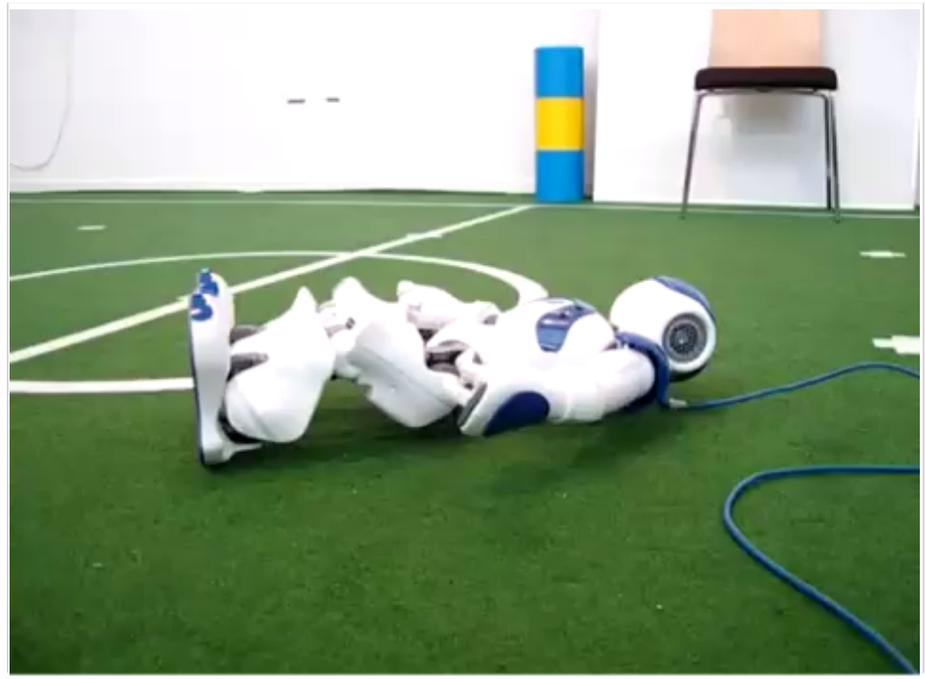






Motion Control

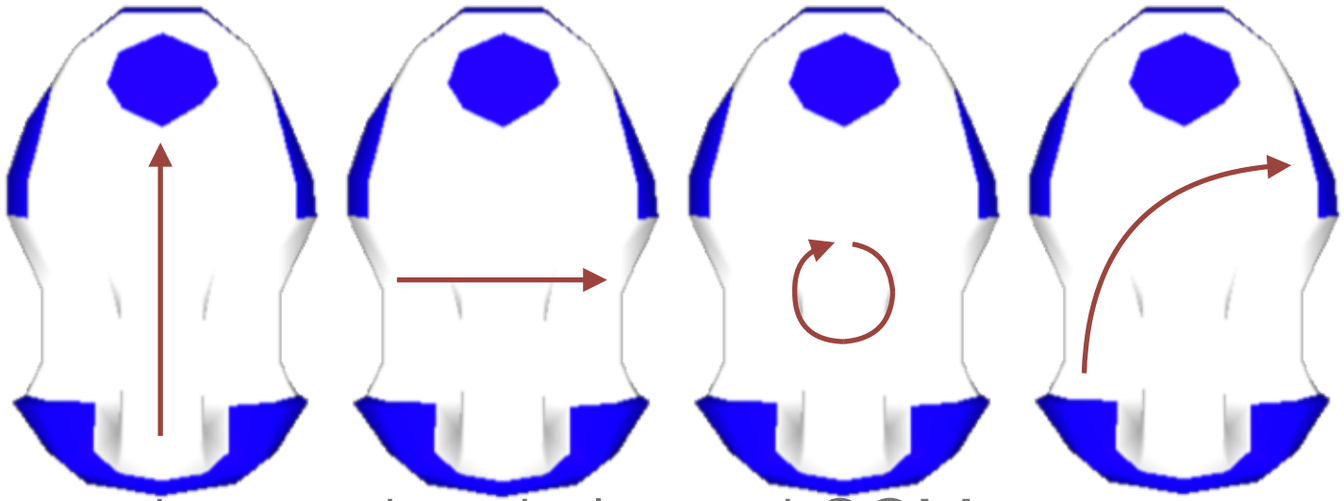
- Walking
- Kicking
- “Special actions”
- Getting up
- Head control
  - Scan interesting points on the field
  - Hard-coded modes



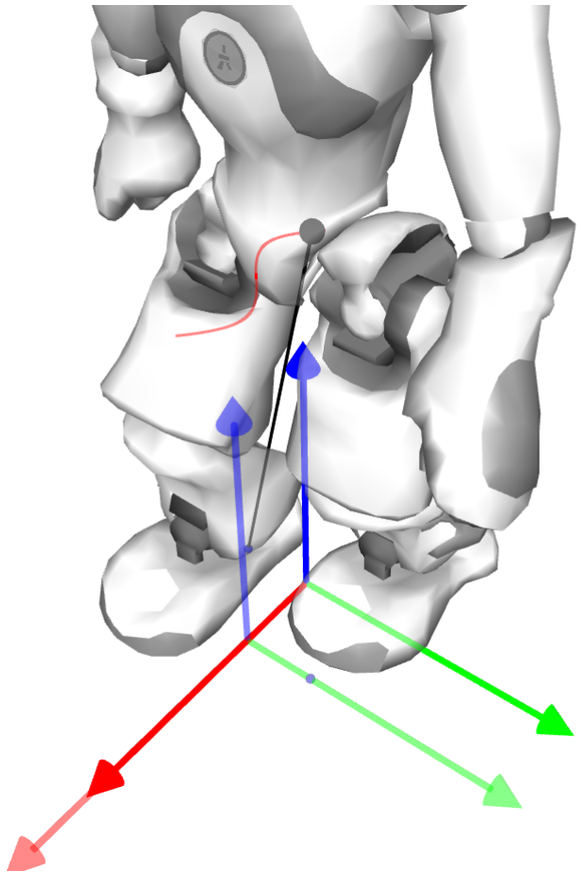
Motion Control: Walking

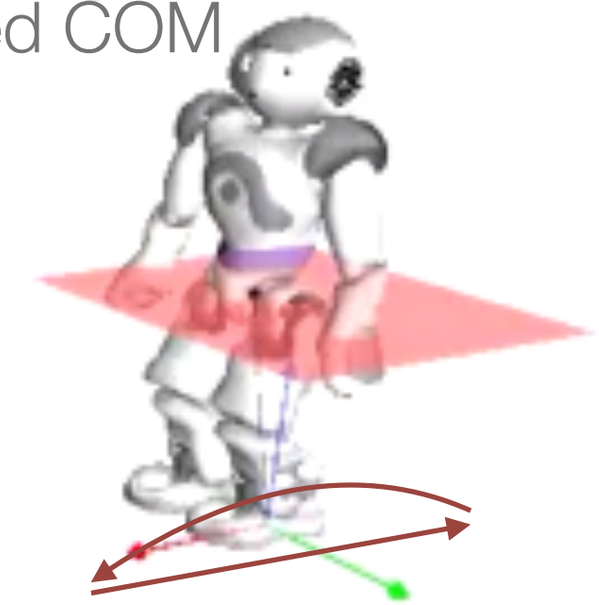
B-Human

- Omni-directional
- Modeling single support phase as linear inverted pendulum



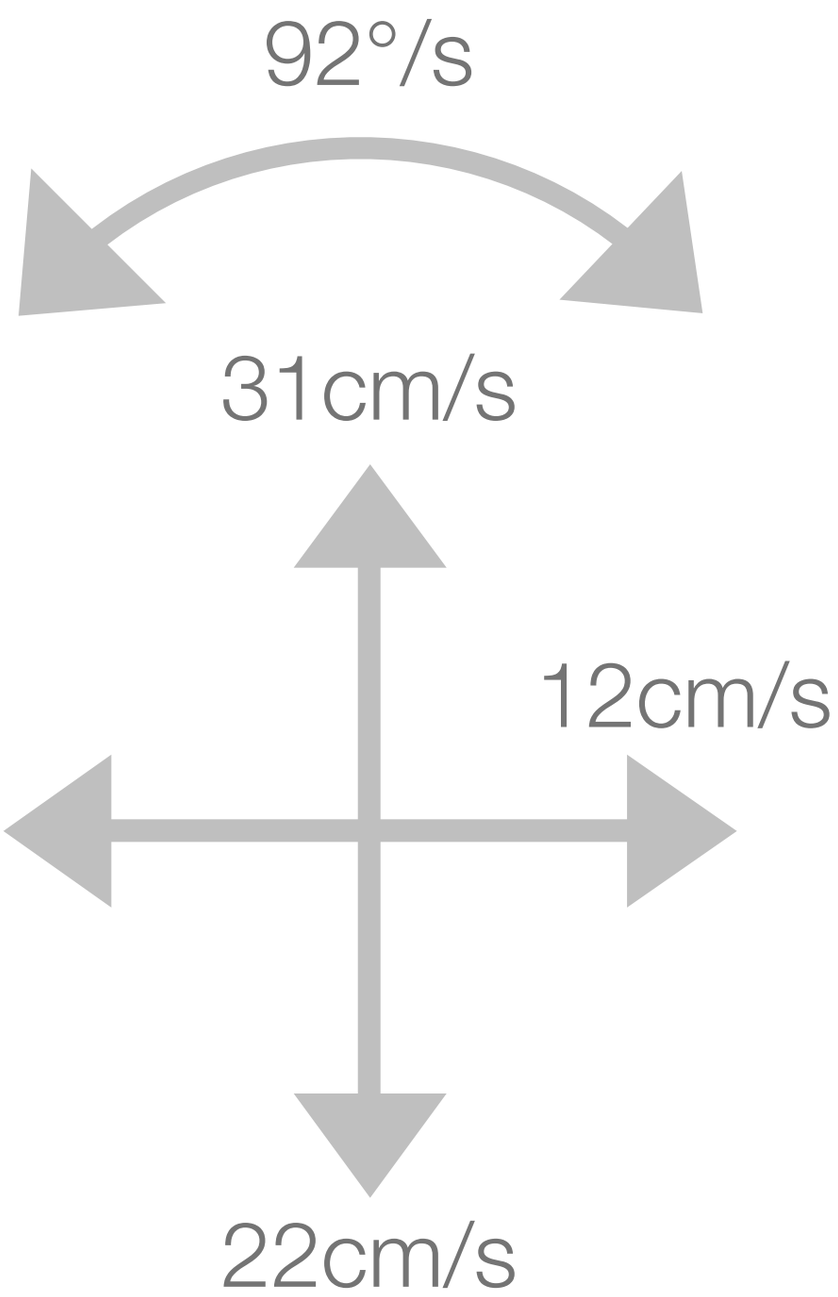
- Balancing with difference between observed and planned COM

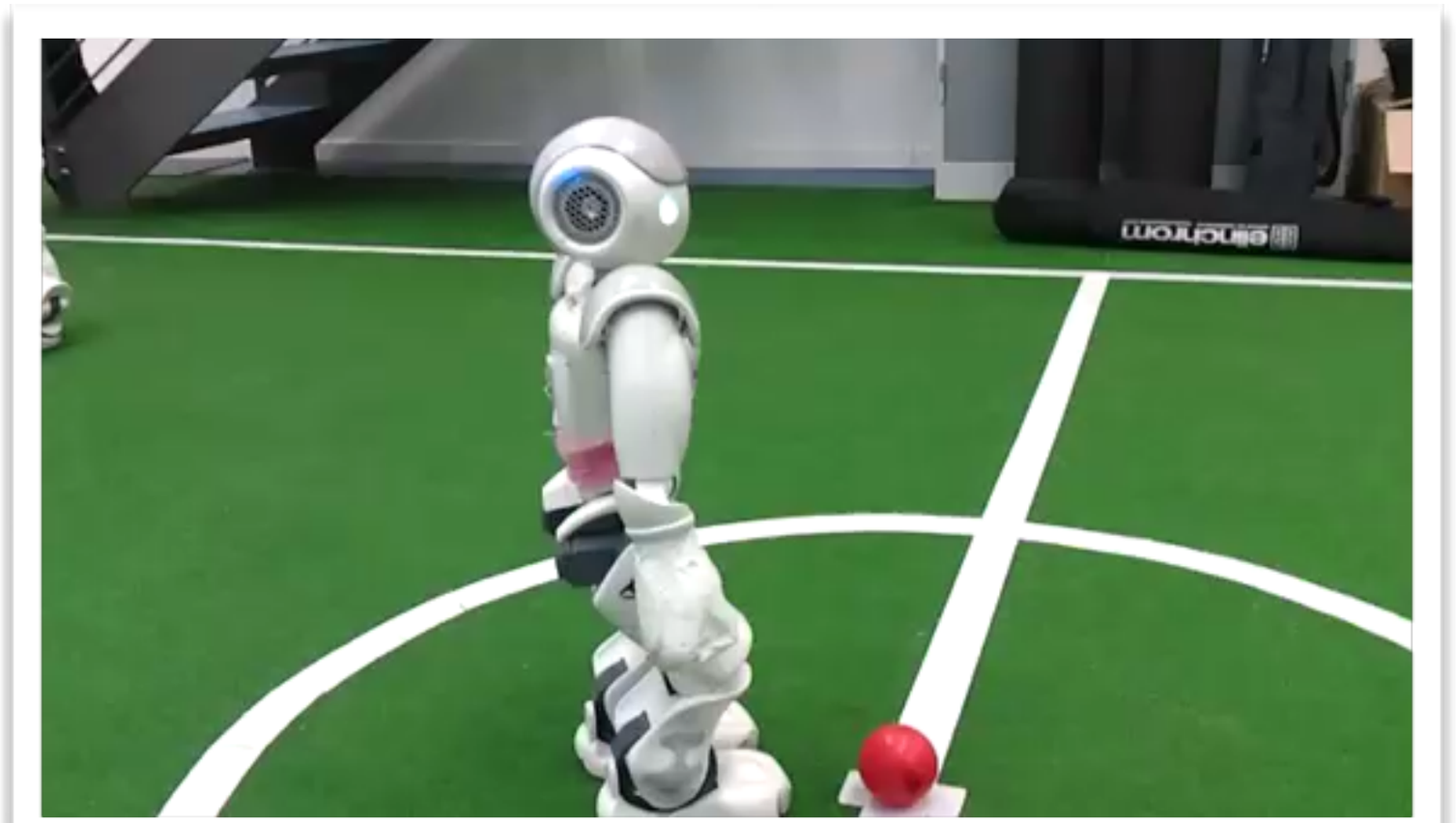




Motion Control: Walking and Kicking

B-Human

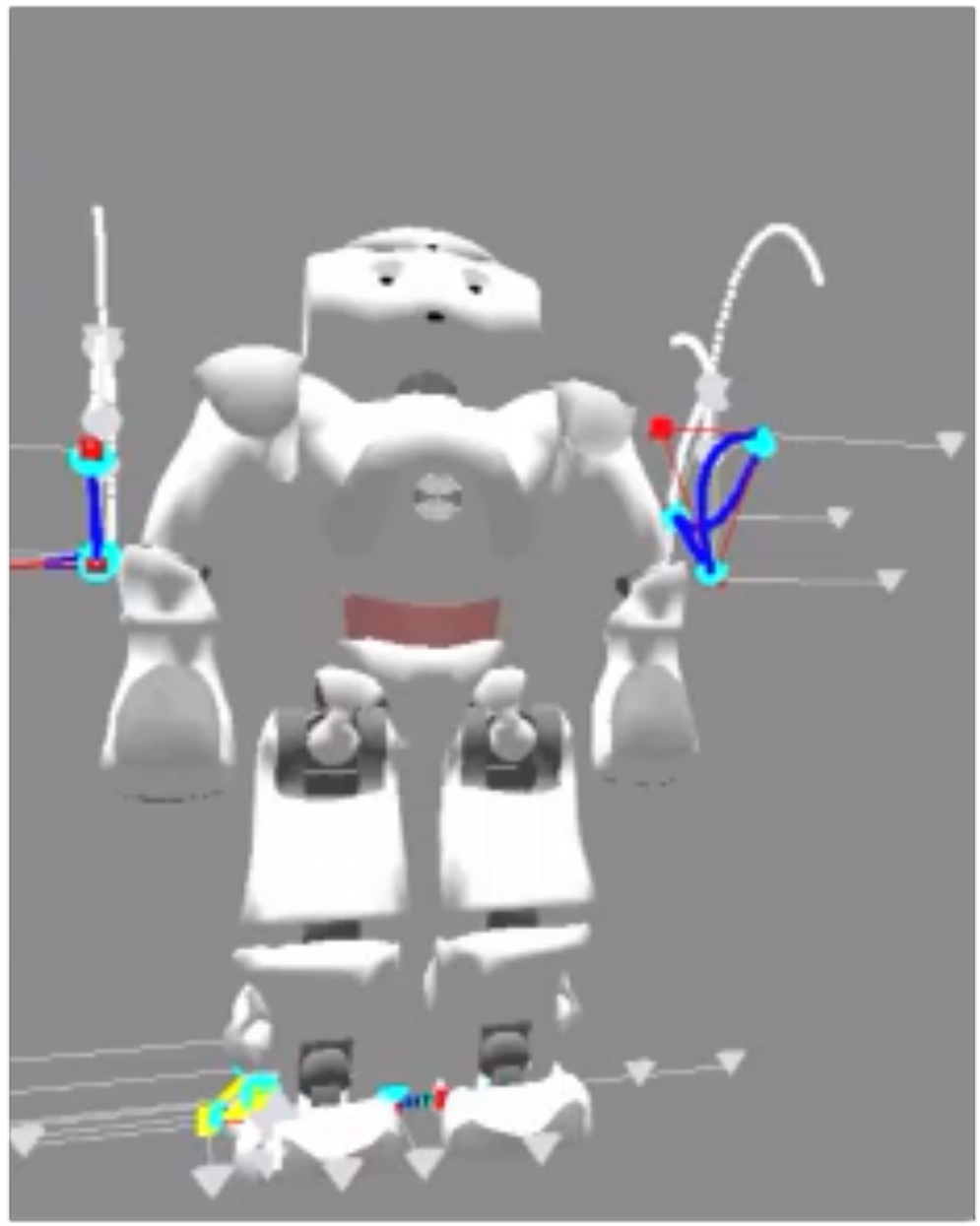




Motion Control: Balanced Dynamic Kicks

B-Human

- Modeled as a sequence of Bezier curves
  - 2x foot positions, 2x foot rotations, 2x arm positions
  - Transitions continuous in place and gradient
  - Control points are adapted during kick
- Balancing based on
  - Preview of COM
  - Gyroscopes

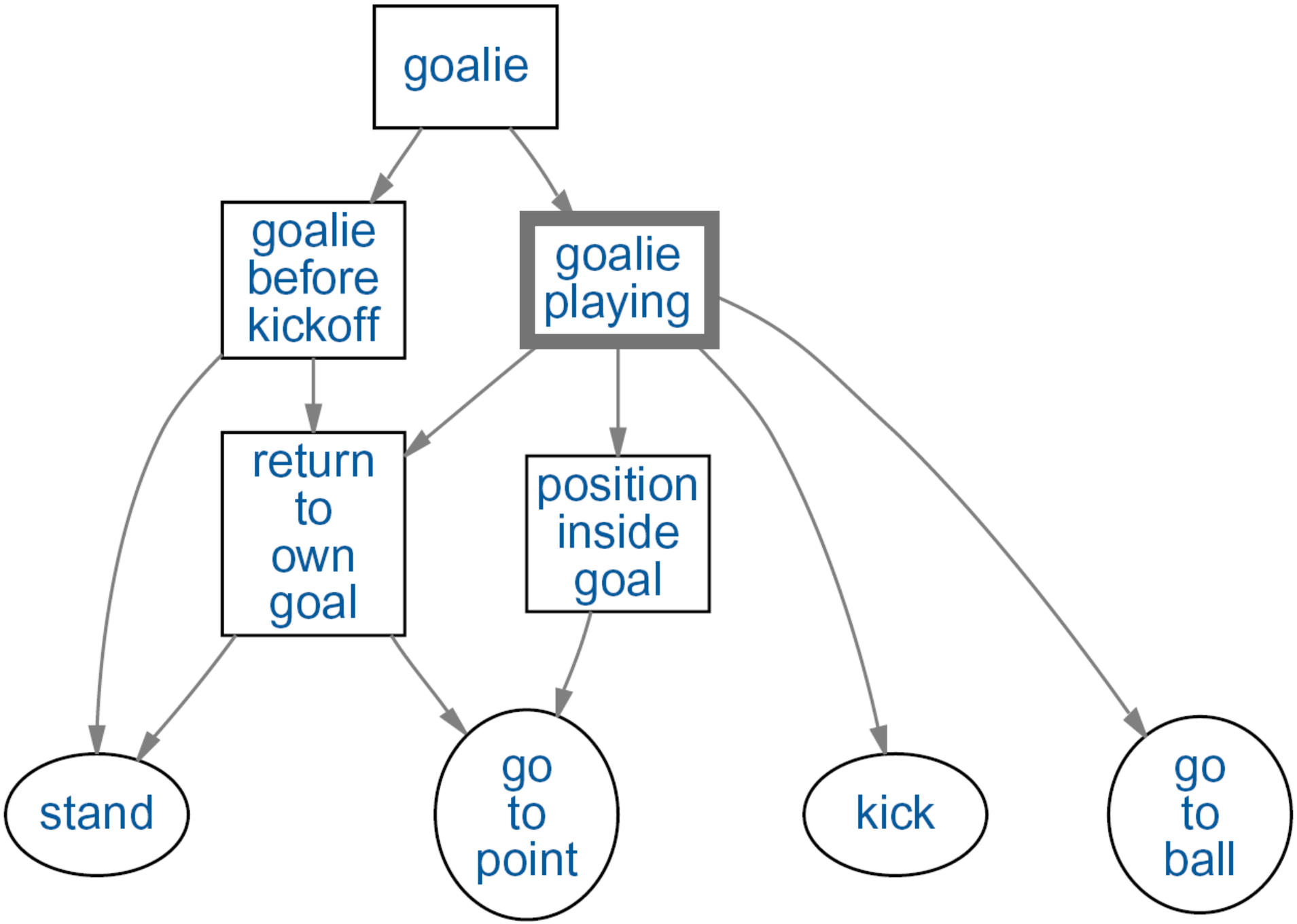


Motion Control:
Balanced Dynamic Kicks

B-Human

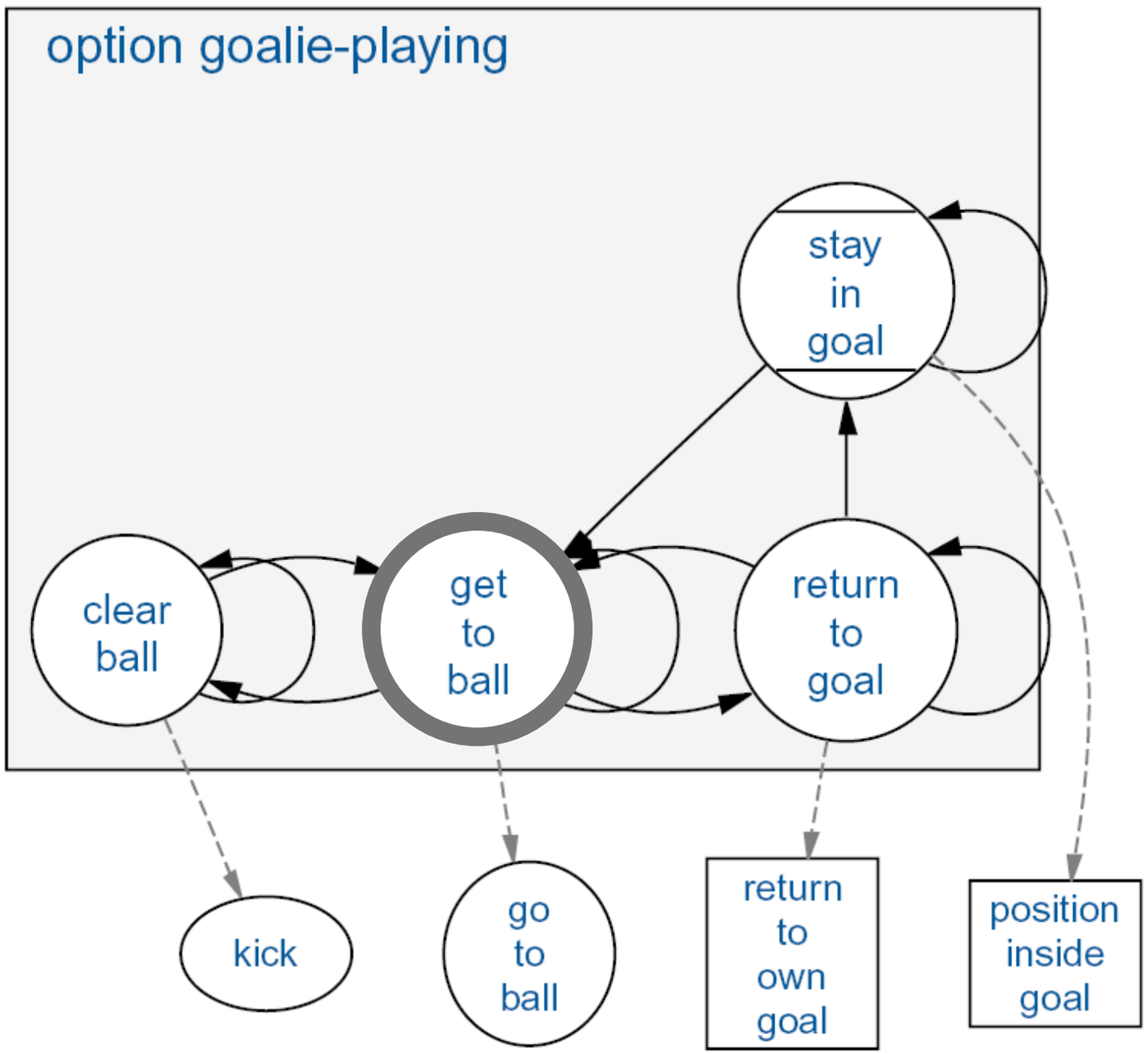
Behavior Control: Hierarchical State Machines (Options)

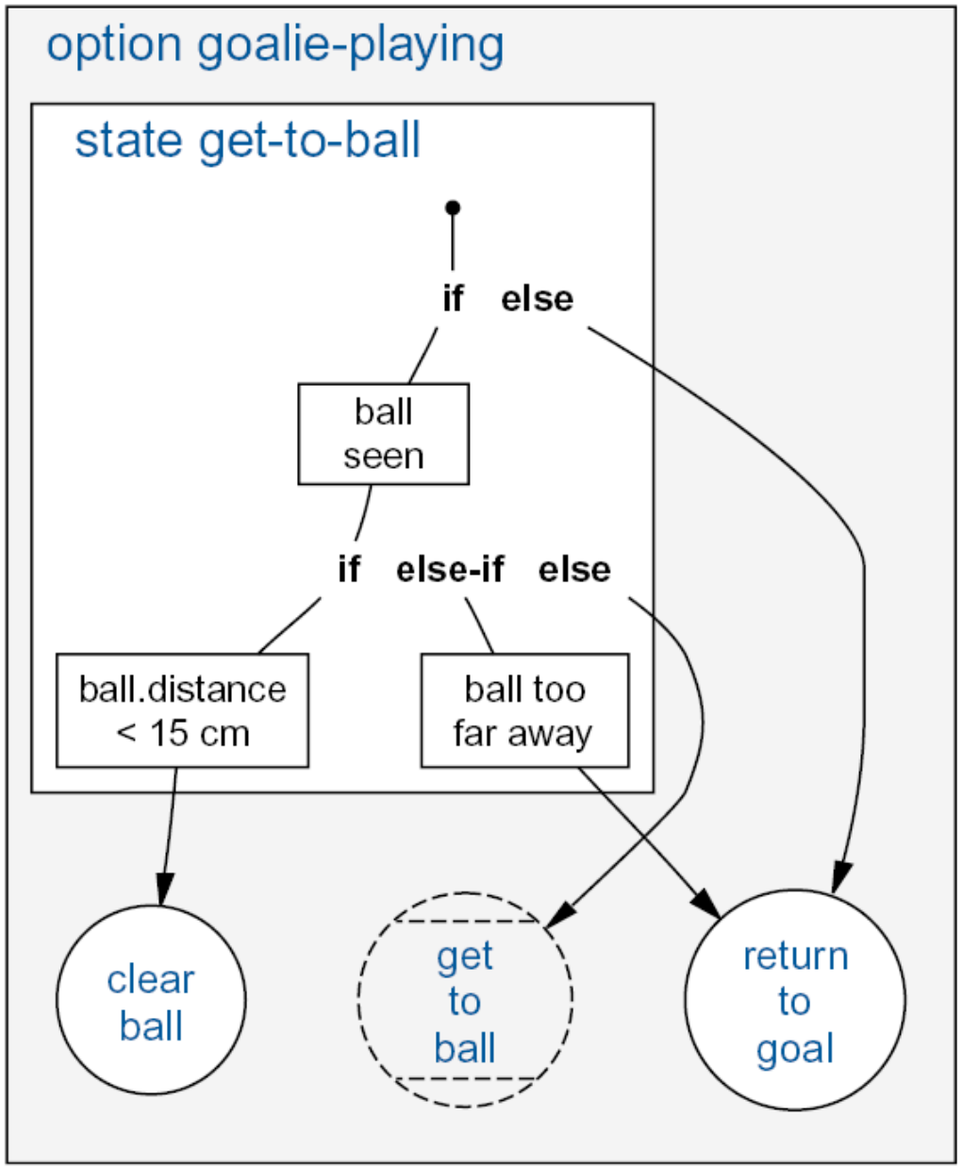
B-Human



Behavior Control: States and Decision Trees

B-Human





Behavior Control: CABSL – C-based Agent Behavior Specification Language

B-Human

- Directly compiled by C++ compiler
- Modeling behavior with hierarchical state machines (**option**s)
- Each **option** contains **state**s
- Each **state** contains
  - conditional **transition**s to other states
  - **action**s (C++, calls to other options)
- Each **option** can only switch its state once per execution cycle

```
option(goaliePlaying) {
    initial_state(stayInGoal) // ...

    state(getToBall) {
        transition {
            if(ball.notSeenFor > 500 ||
               ball.distance > 600)
                goto returnToGoal;
            else if(ball.distance < 150)
                goto clearBall;
        } action {
            GoToBall();
        }
    }
}
```

Behavior Control:
CABSL – Special States and Symbols

B-Human

- **initial_state** (mandatory): Option returns to this state when it was not executed in the previous cycle

- **target_state**: Caller's symbol **action_done** becomes true if the last sub option it called reaches this state

- **aborted_state**: Caller's symbol **action_aborted** becomes true if the last sub option it called reaches this state

- **option_time**: How long since entering the **initial_state**?

- **state_time**: How long since entering the current state?

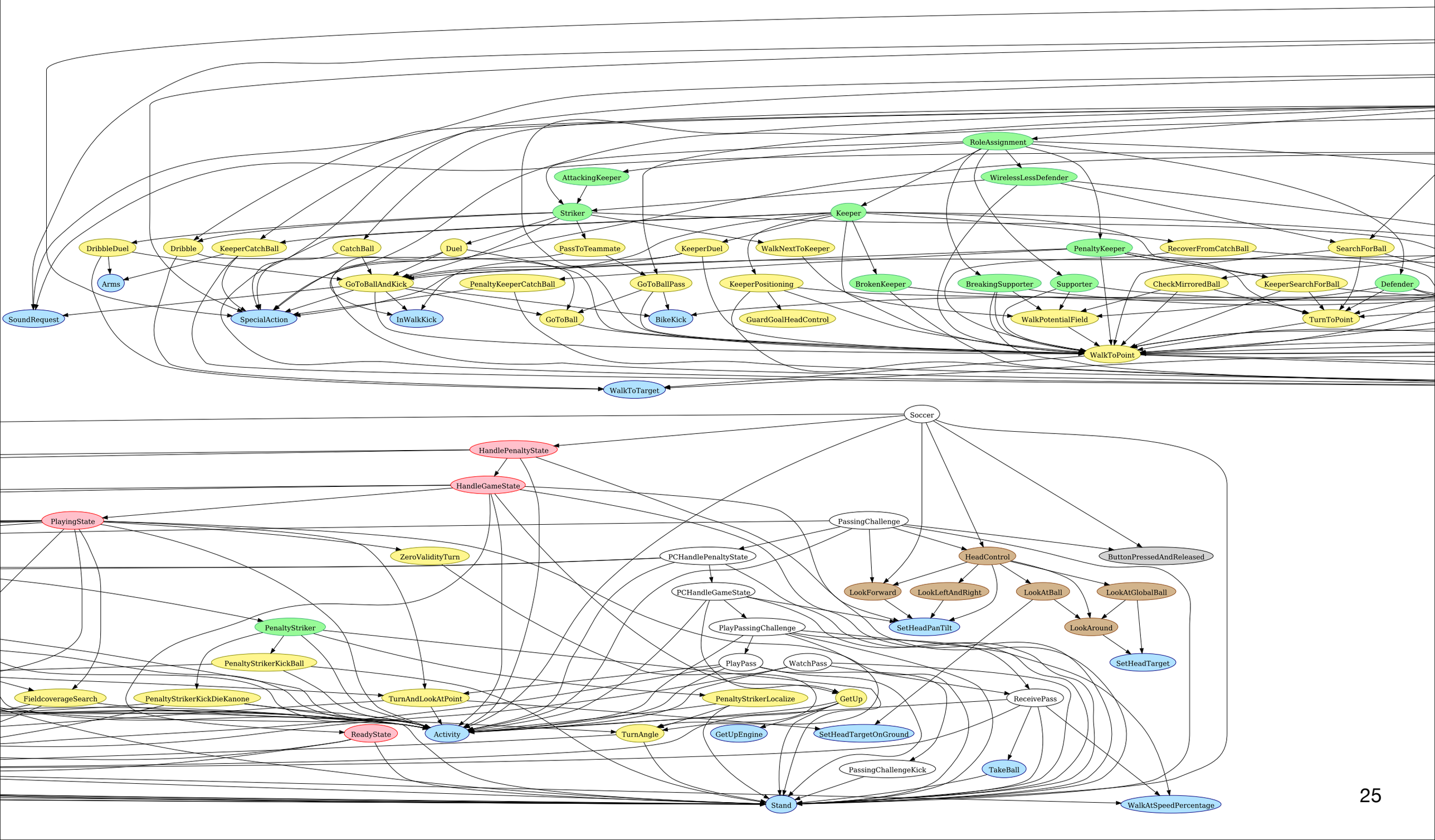
Behavior Control: Team Play

B-Human

- Roles: Striker, supporter, breaking supporter, defender, keeper
- Global world model
  - Global ball for role switching
  - Teammate positions for path planning
- Joint actions
  - Kick-off, passing
  - Synchronized ball tracking and searching

Behavior Control: B-Human 2013

B-Human



Conclusions

- Doing the right things
  - Grid-based vision
  - Probabilistic world modeling (often based on textbook methods)
  - Hierarchical state machines for behavior control
  - Balanced walks and kicks
- Doing things right
  - Keeping 60Hz/100Hz
  - Synchronization and calibration

Exercise:
www.tzi.de/spl/bin/view/Website/HSS2013