Artificial Intelligence and Robotics for Intelligent Agents
- RoboCanes Demonstration -

The RoboCanes Team

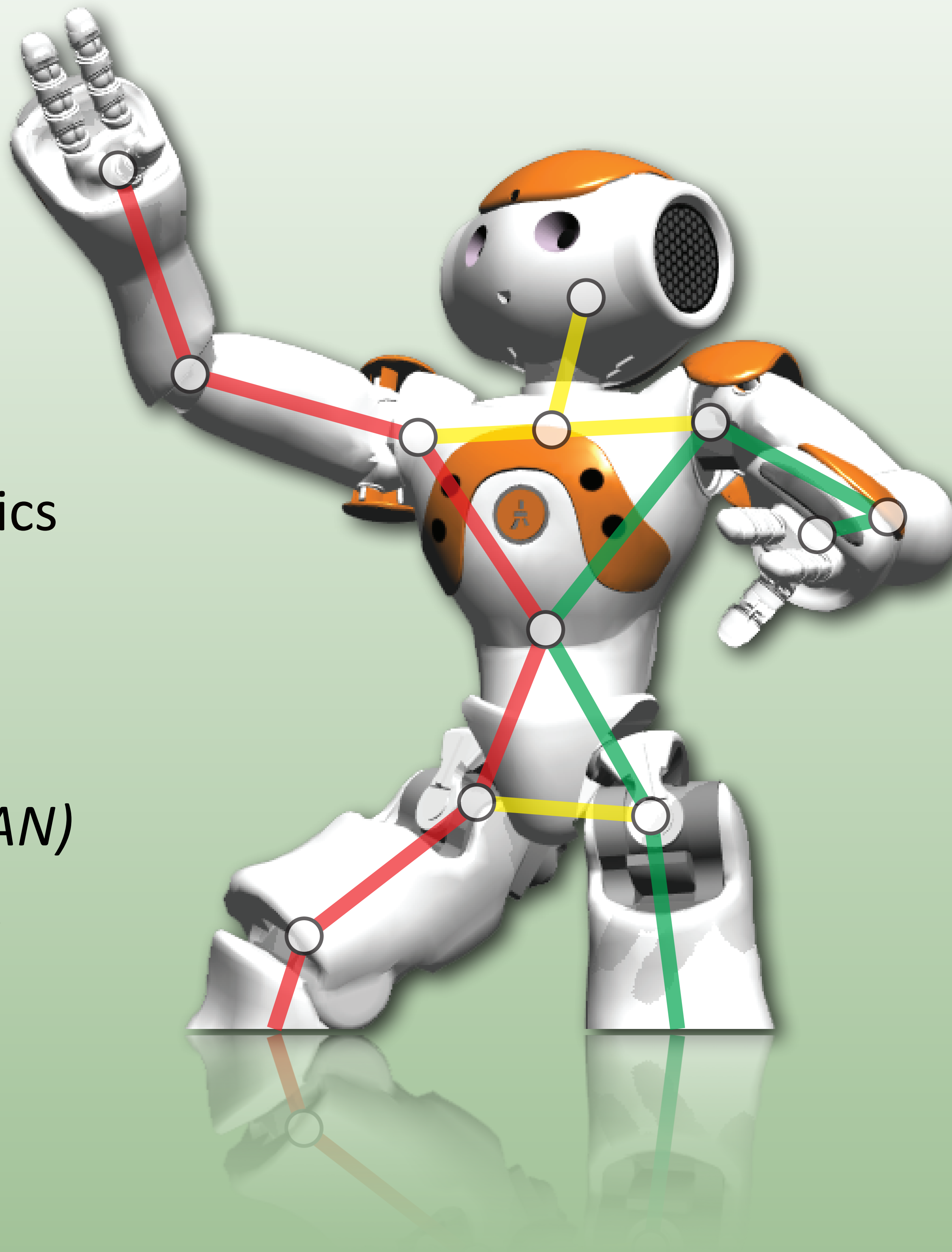
Department of Computer Science
College of Arts and Sciences
University of Miami

January 14, 2013

UNIVERSITY OF MIAMI
ROBOCANES

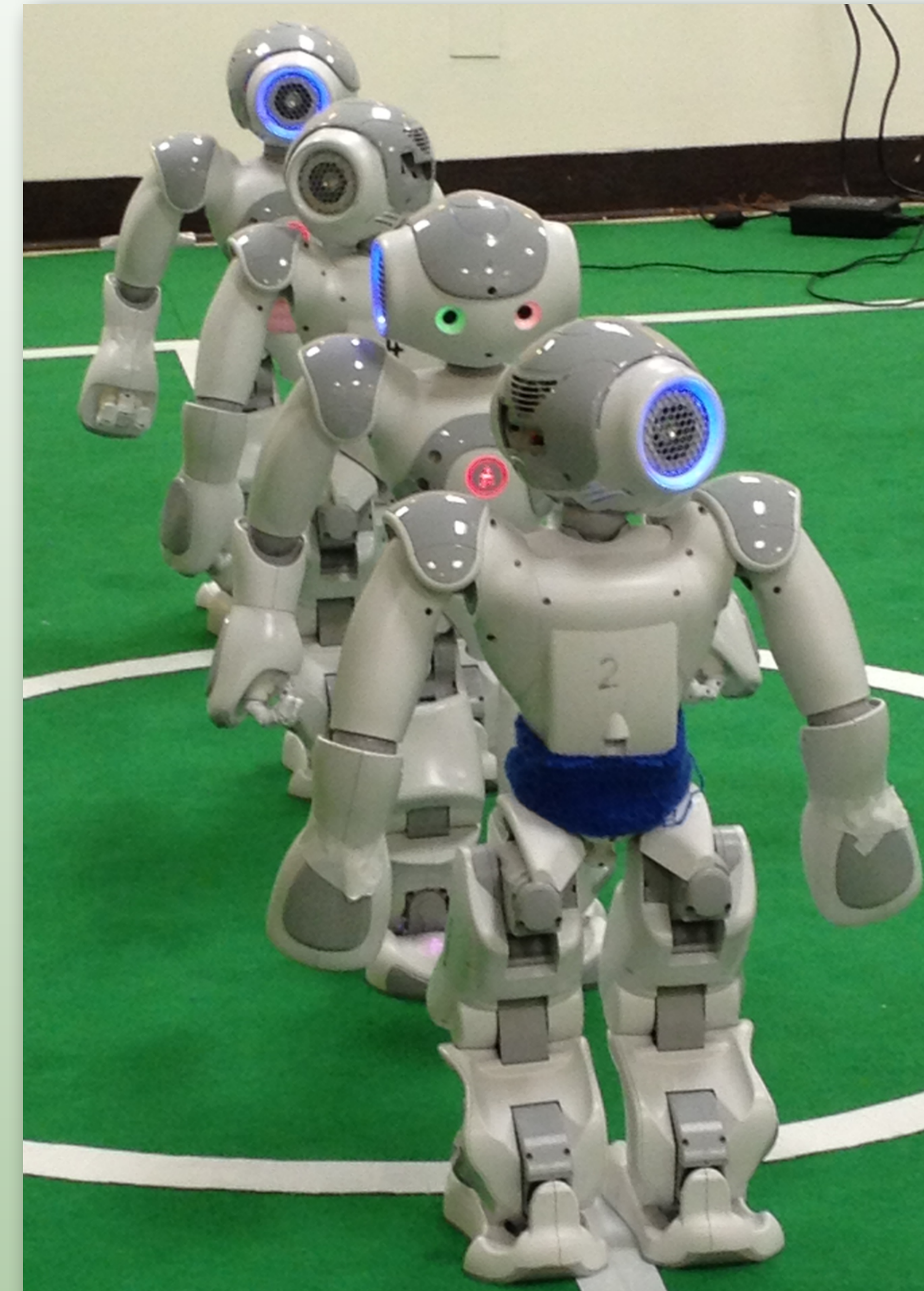
OUTLINE

- Motivation
  - Research Challenges & Tasks
  - RoboCup
- RoboCanes
  - Simulated 3D agents with full physics
  - Motion capture and optimization
  - Physical NAO live demo
    - *Real time vision and motions (LAN)*
    - *Real time motions and behavior (WLAN)*
  - Game



RESEARCH CHALLENGES

- Autonomous robots shall act appropriately in dynamic, real time, and adversarial environments
- One of the biggest challenges in AI and robotics
- Numerous examples: rescue scenarios, home assistance, device assistance (e.g. cars, planes)
- Playing soccer with biped robots as a testbed for development (RoboCup).
- RoboCup is a landmark project as well as a standard problem (as was chess in the 90s)



4 RoboCanes NAO players

RESEARCH TASKS

real time sensor fusion

reactive behavior

learning

learning

real time planning

multi-agent systems

context recognition

strategy acquisition

motor control

decision making

intelligent robot control

opponent modeling

and many more...

ROBOCUP

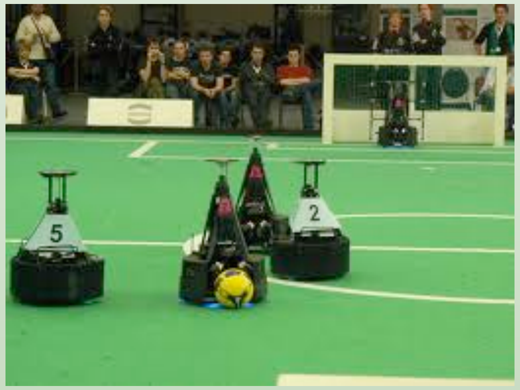
- International initiative fostering AI & Robotics
- By the year 2050, develop a team of fully autonomous humanoid robots that can win against the human world soccer champions
- Large community: approx. 500 teams from > 40 nations compete worldwide; > 15,000 scientists in RoboCup mailing list; > 5,000 active researchers every year
- RoboCanes active since 2010:
  - 1st place in European Open 2011
  - 2nd place in Asian Open 2011, 2012
  - 2nd place in World Cup in Mexico 2012
  - 1/4 finals in 2 leagues in World Cup in The Netherlands 2013

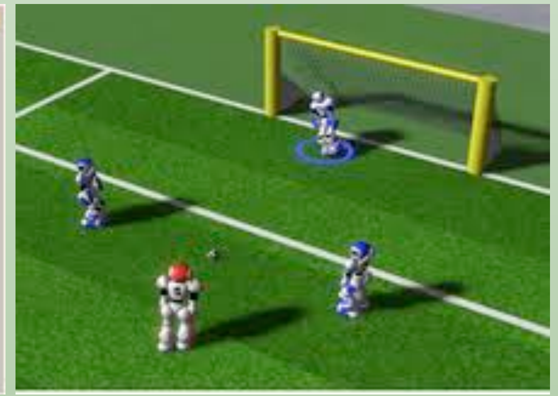
ROBOCUP-SOCCER

- Research goals: Cooperative multi-robot and multi-agent systems in dynamic adversarial environments
- All robots in this category are fully autonomous

- Various leagues
  - Humanoids
  - Middle Size Robots
  - Simulation (2D/3D)
  - Small Size Robots
  - Standard Platform







ROBOCUP-JUNIOR

next

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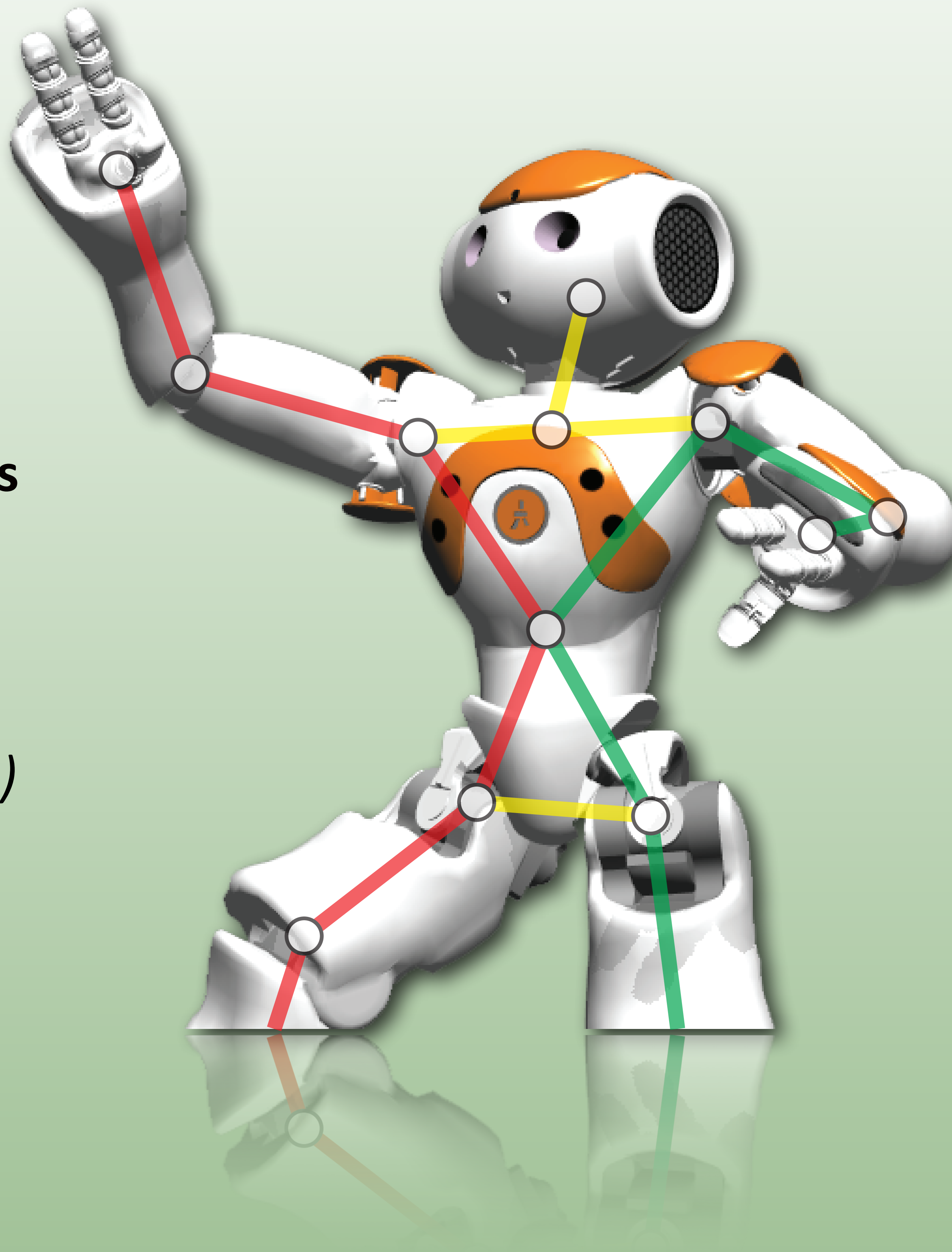


HARDWARE: NAO COMPONENTS OVERVIEW

Manufacturer:
Aldebaran Robotics
(France)

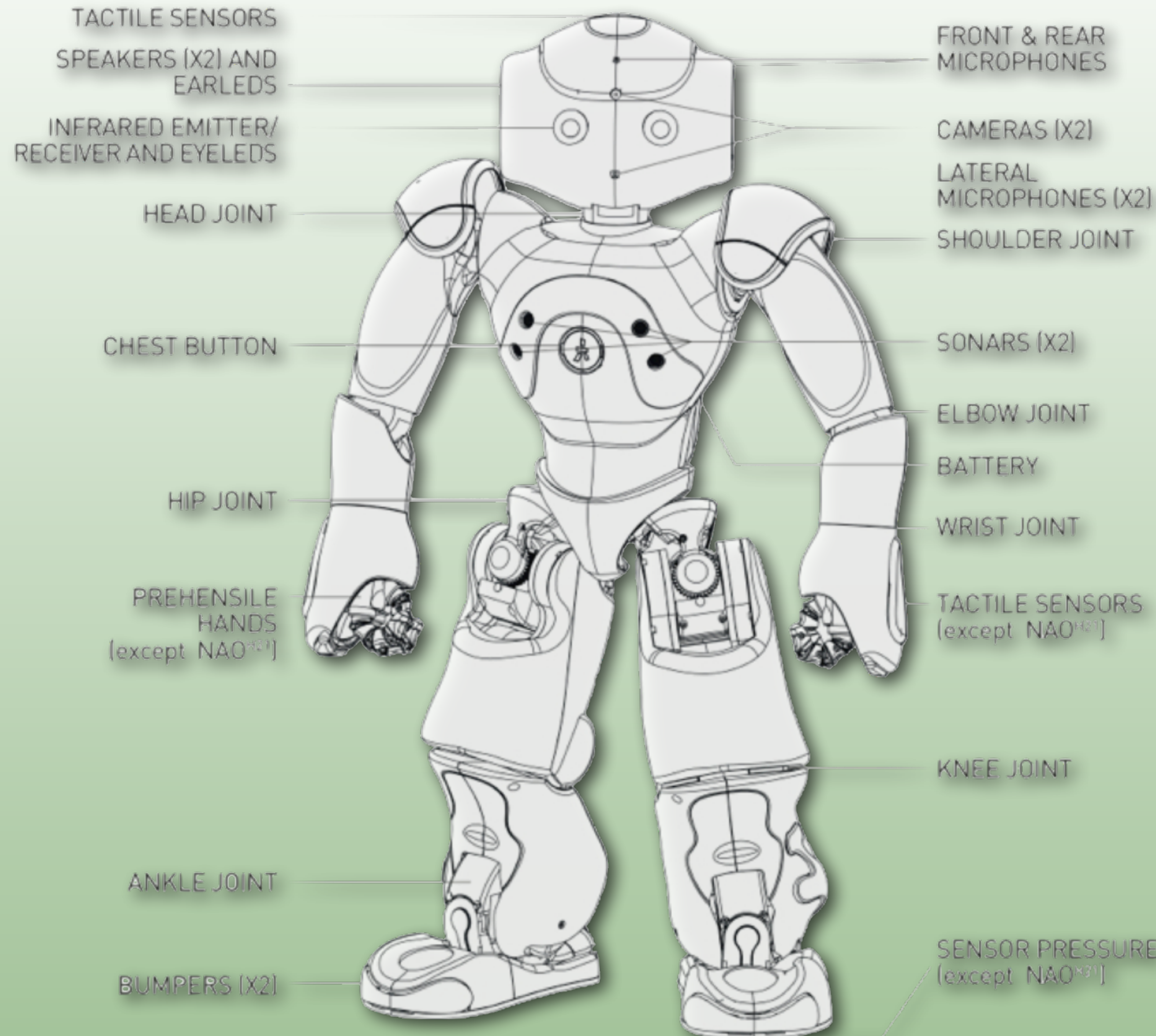
573x275x311mm
5.2kg (11.4lb)

Battery: 60-90 min
Lithium-Ion

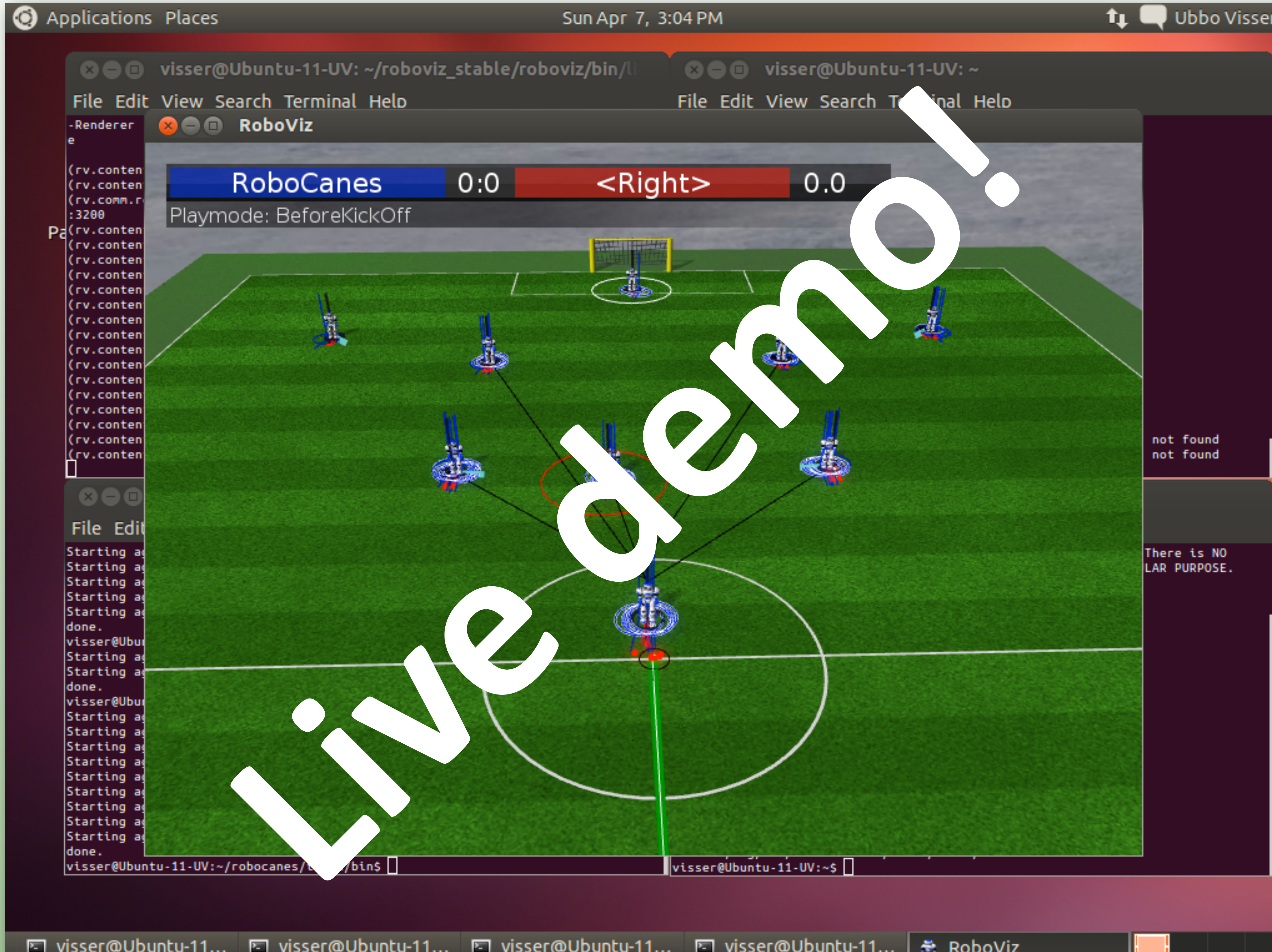
Ethernet 1xRJ45
10/100/1000 BASE T

WiFi IEEE 802.11.b/g

Degrees of freedom
Head : 2
Arm : 4 (x2)
Pelvis : 1
Leg : 5 (x2)
Total: 21



ROBOCANES: SIMULATED 3D AGENTS WITH FULL PHYSICS



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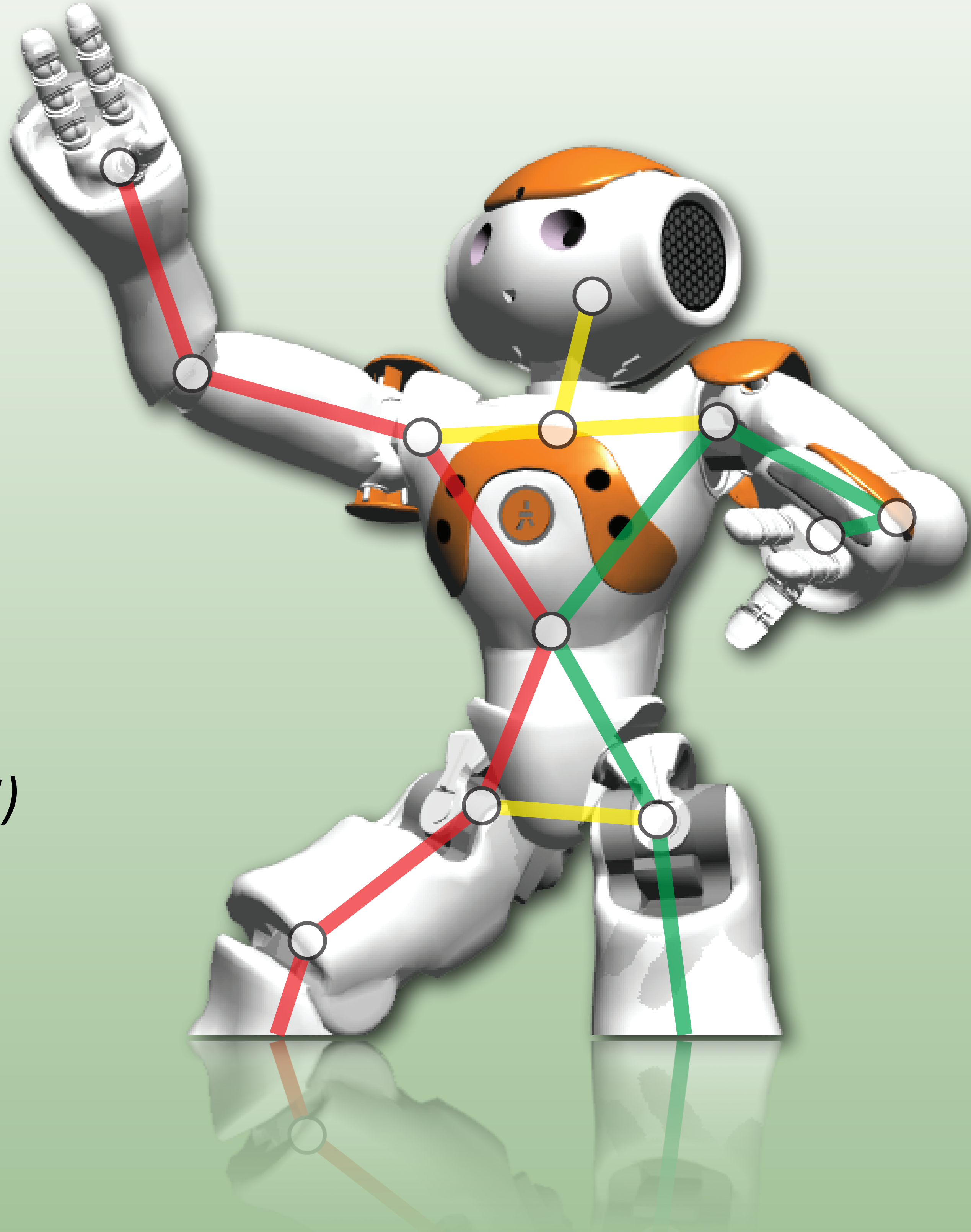
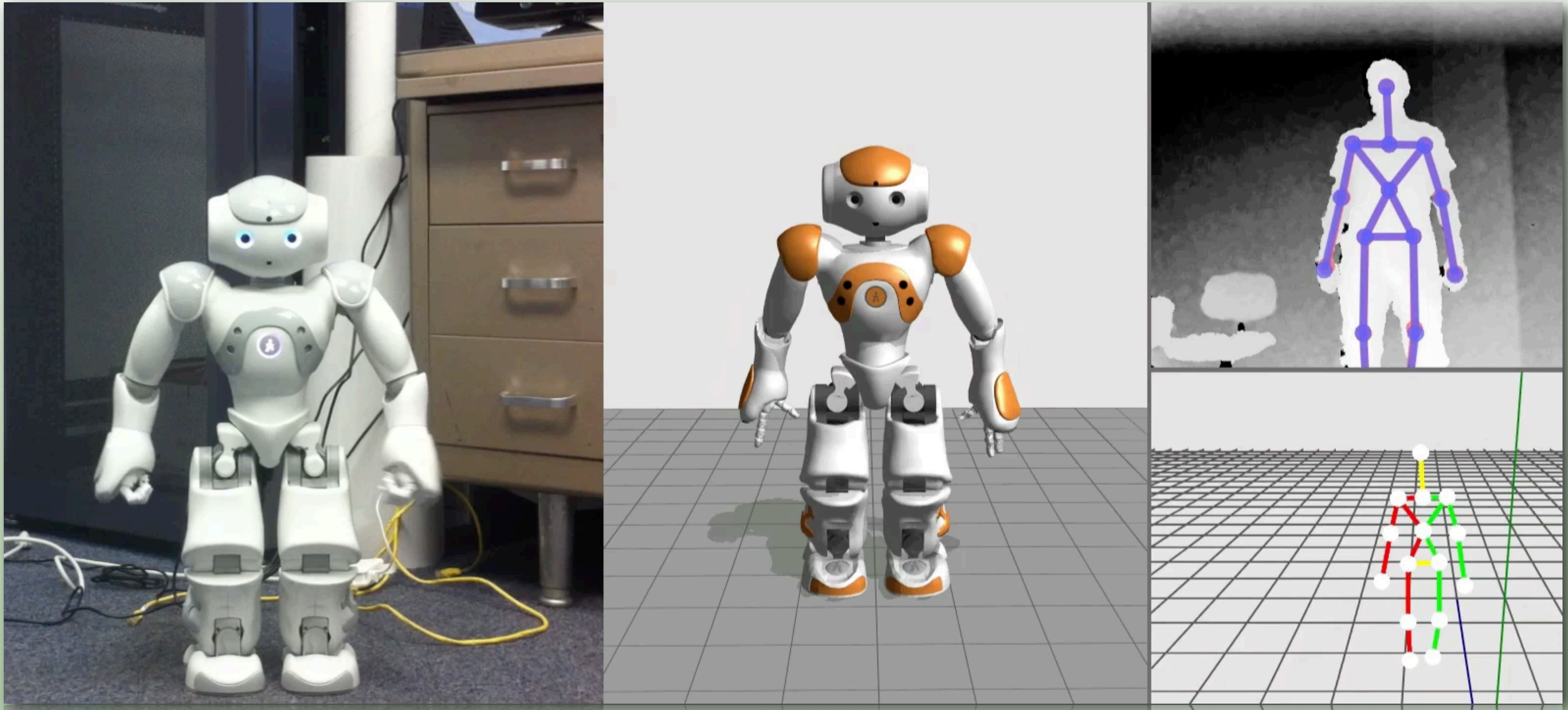


MOTION CAPTURE AND OPTIMIZATION



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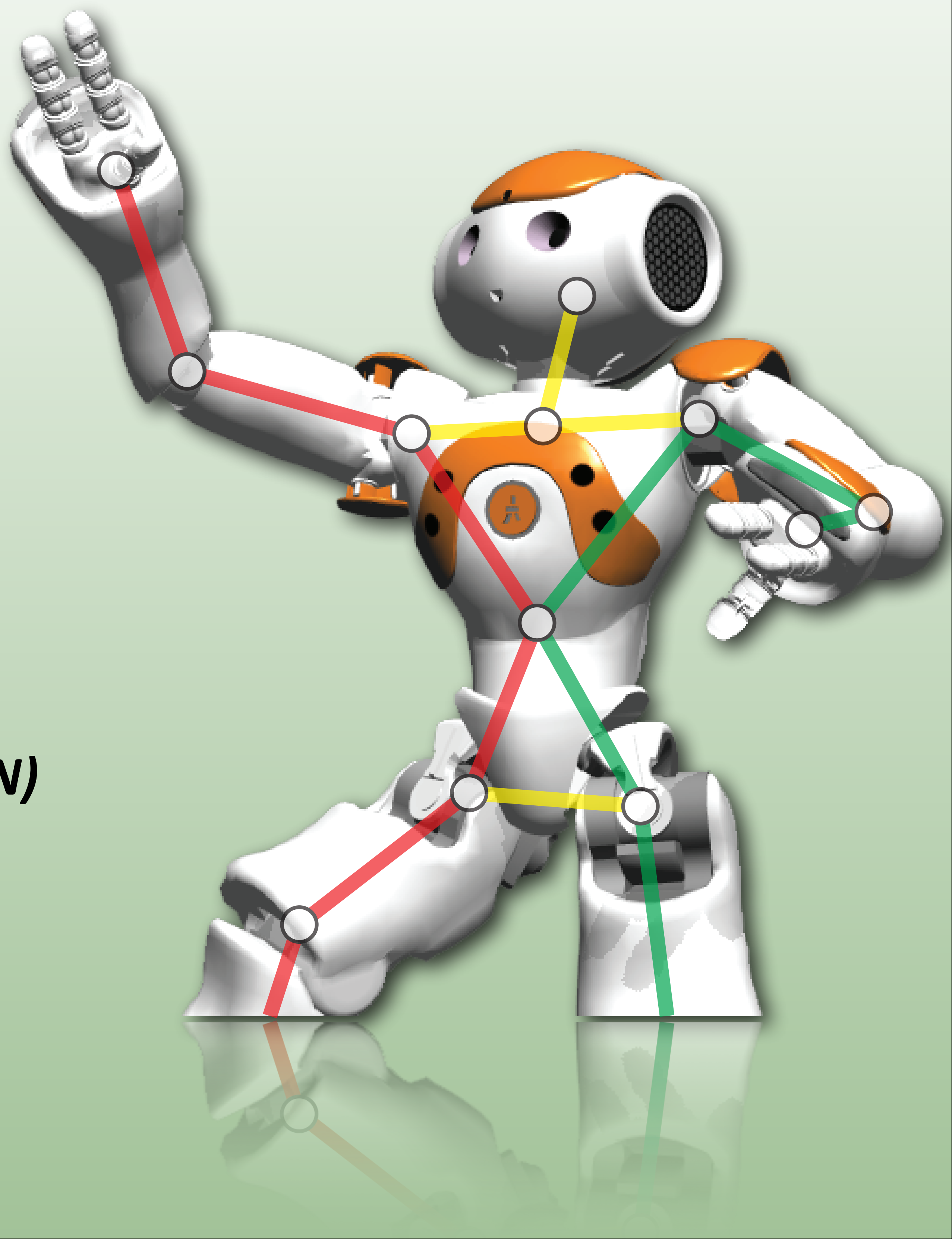
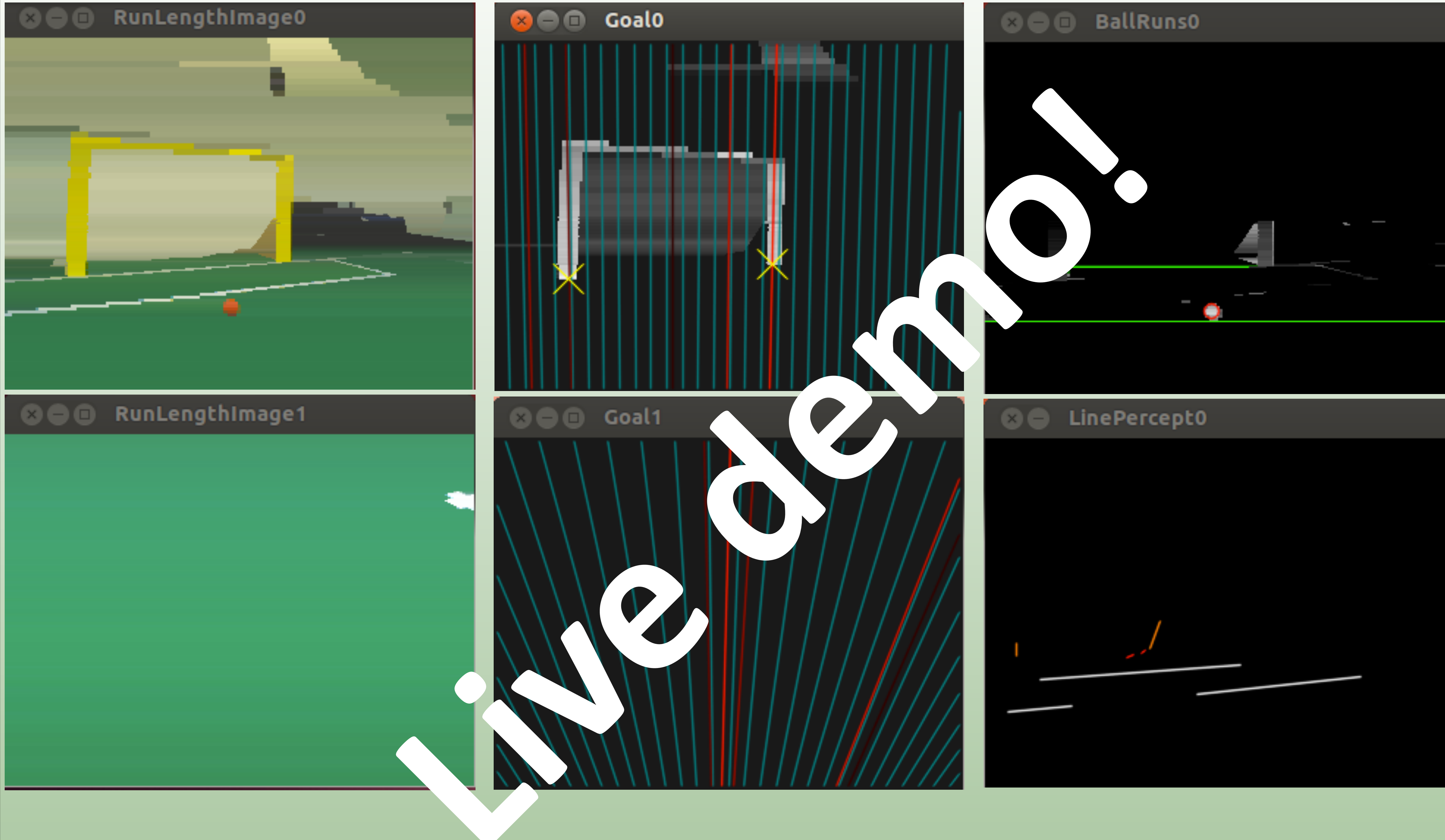


REAL TIME VISION AND MOTIONS (LAN)



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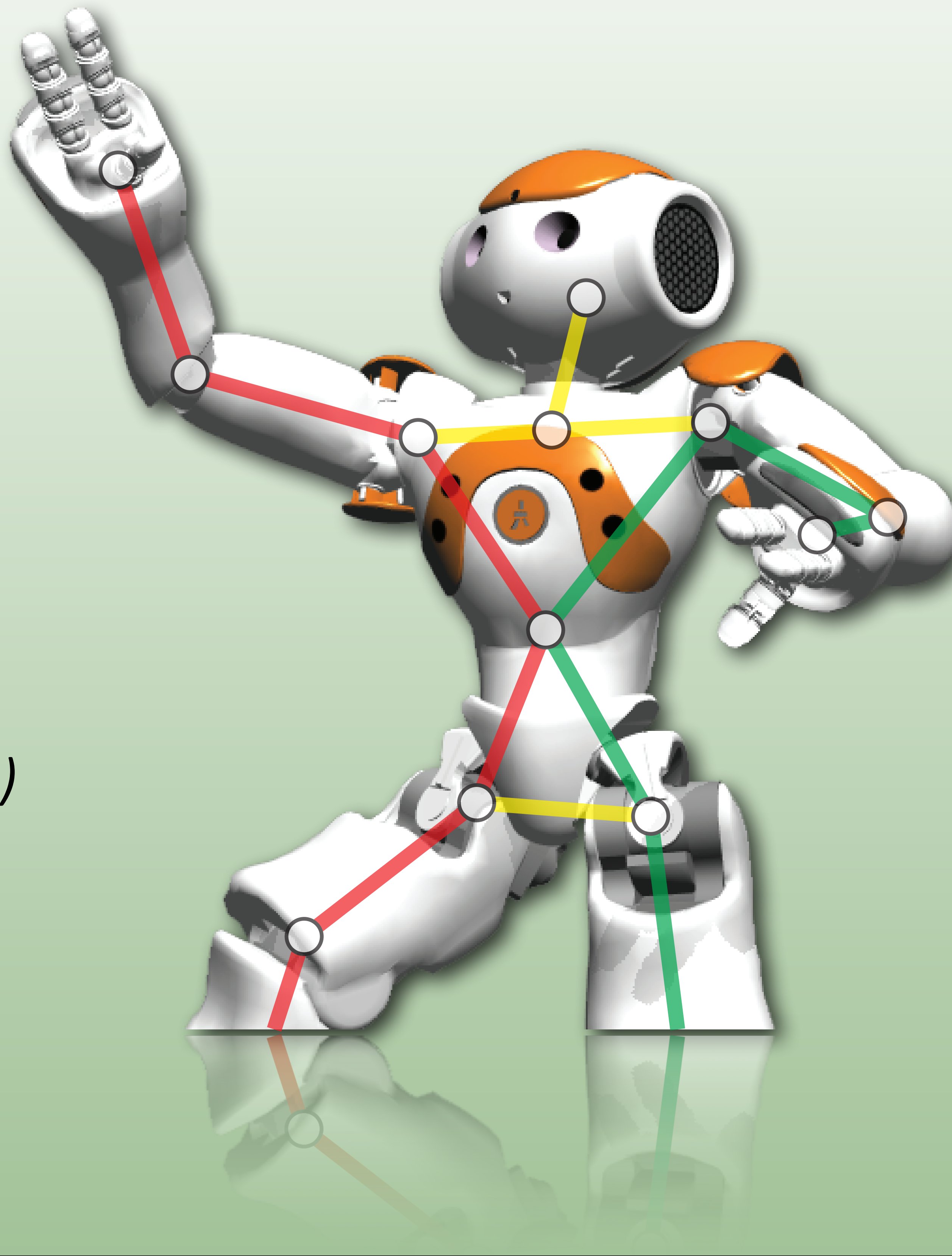
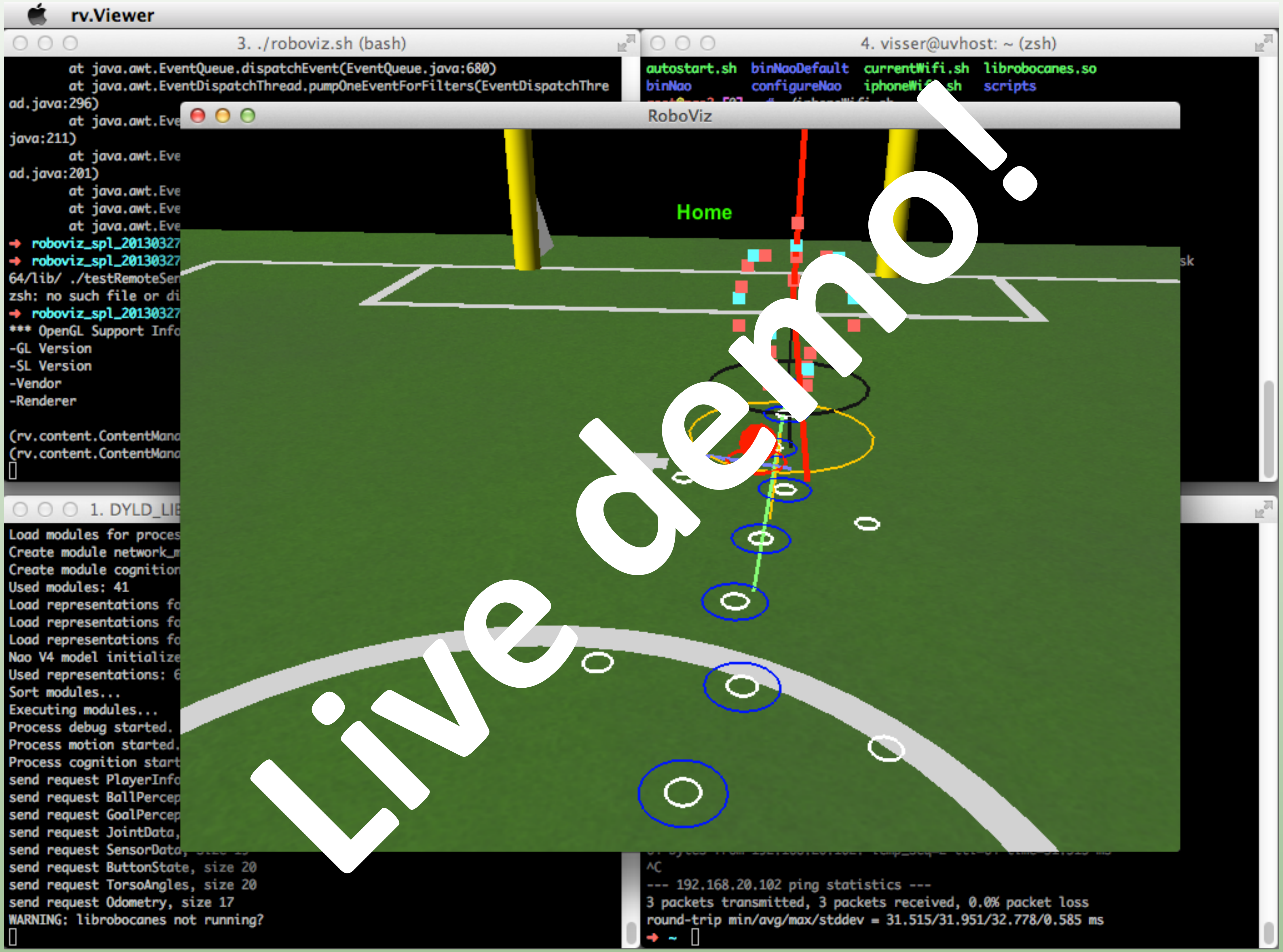


REAL TIME MOTIONS AND BEHAVIOR (WLAN)



THANK YOU!

- Acknowledgements:
  - UM Department of Computer Science
  - College A&S
- RoboCanes Team 2013:
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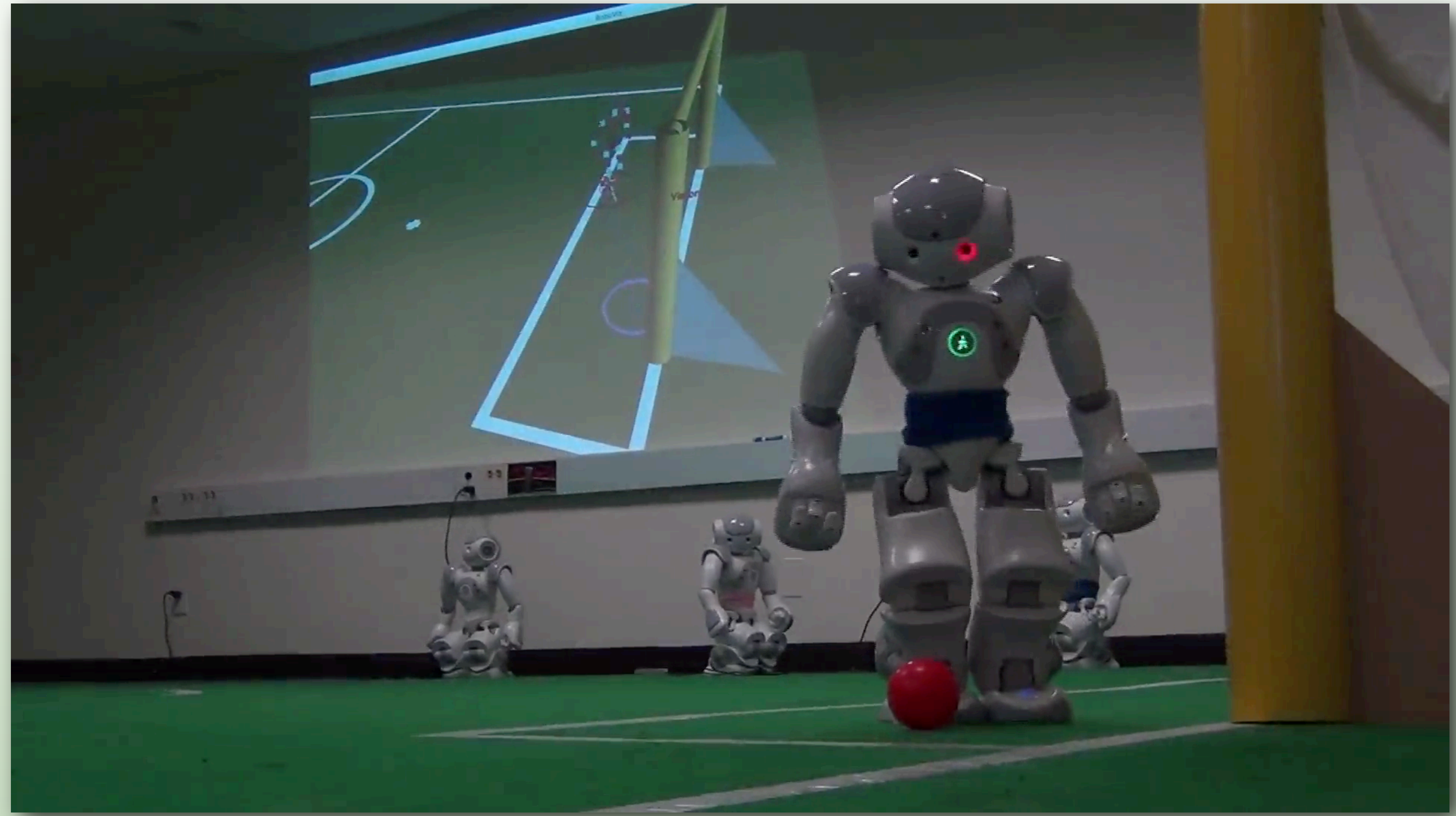
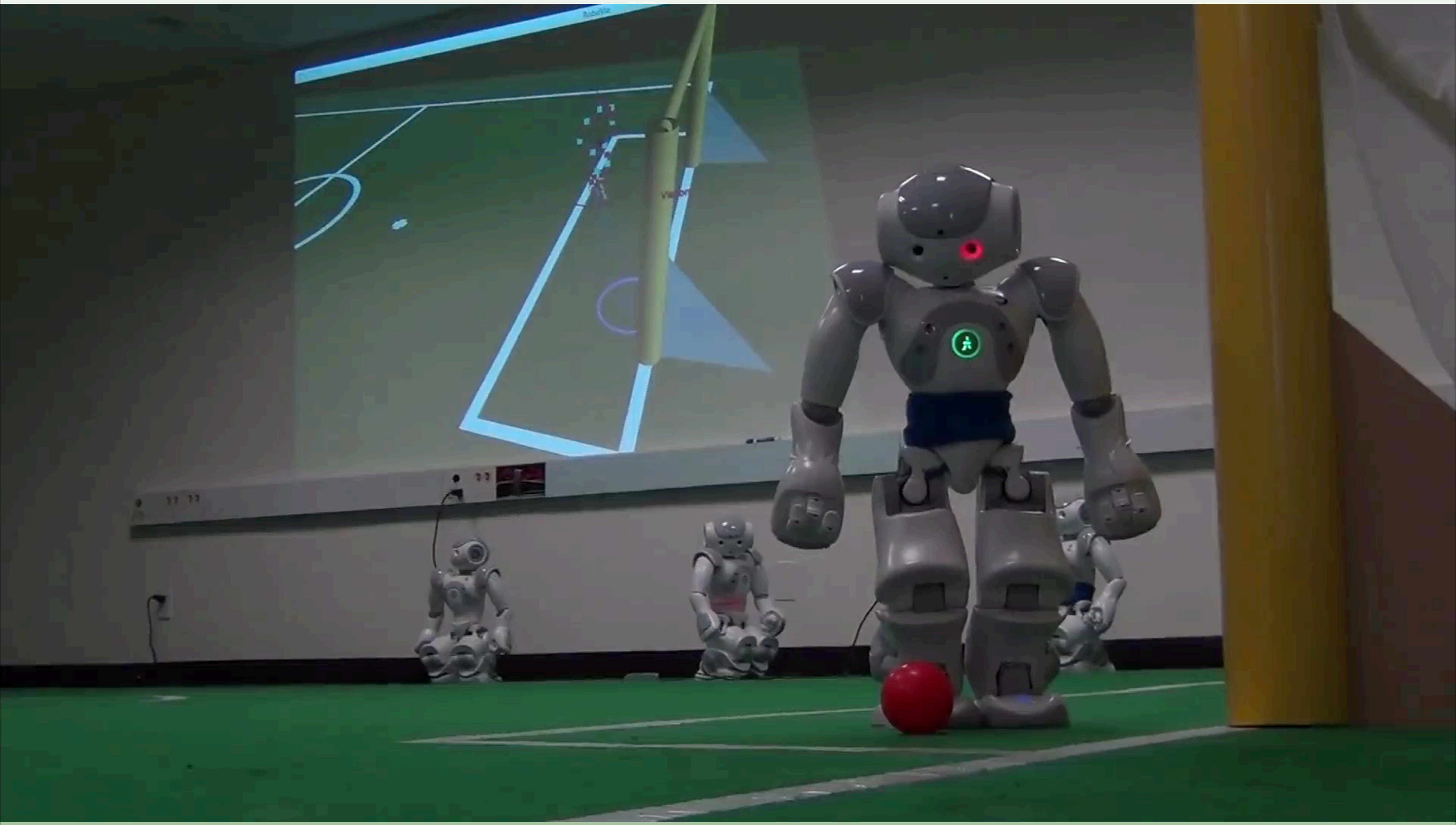


EXTRA SLIDES

ROBOCANES: SIMULATED 3D AGENTS WITH FULL PHYSICS

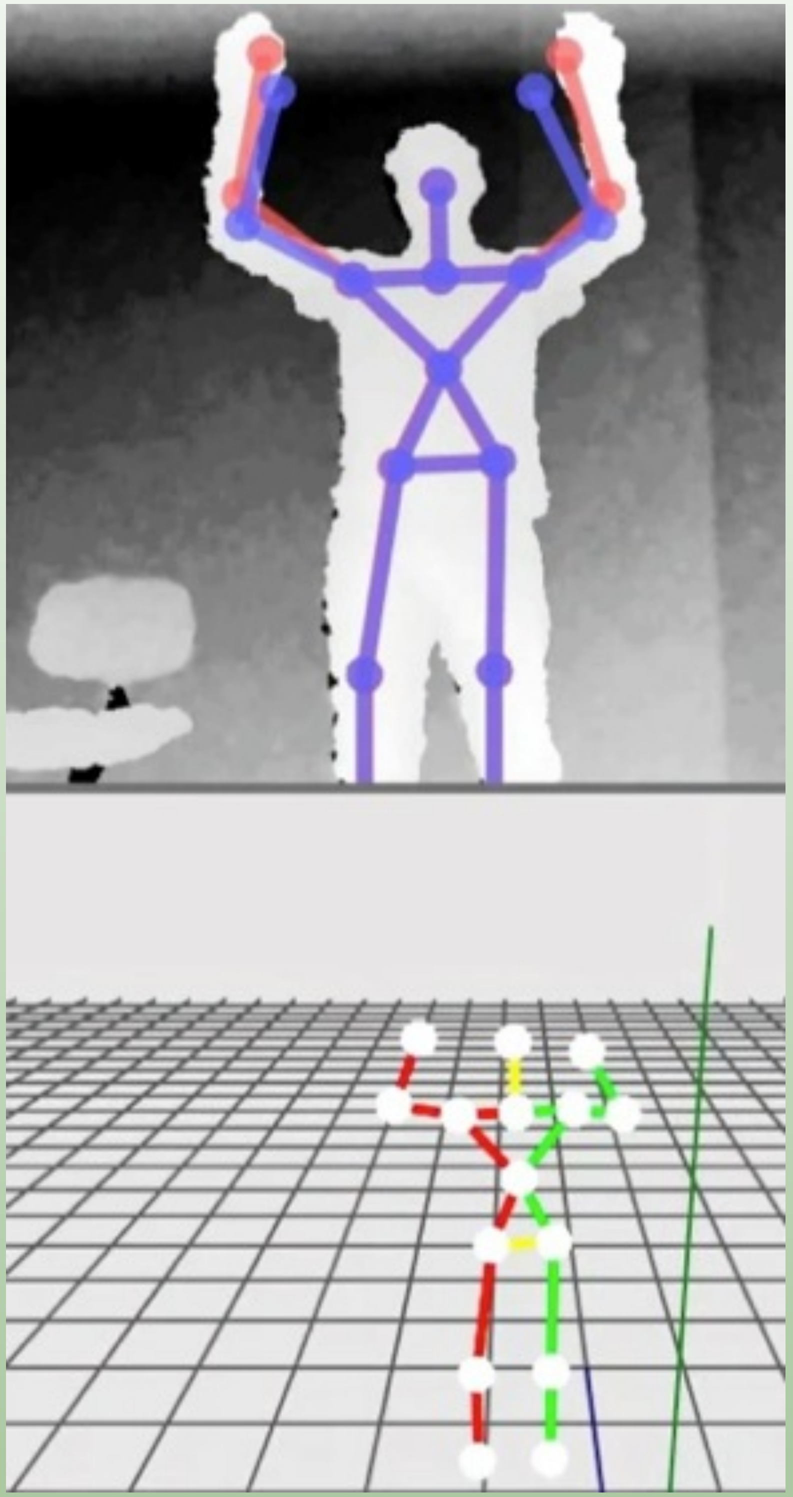
REAL TIME MOTIONS AND BEHAVIOR




RoboCanes
RoboCup 2013
SPL Qualification Material
November 8, 2012
Email: robocanes@cs.miami.edu

MOTION CAPTURE

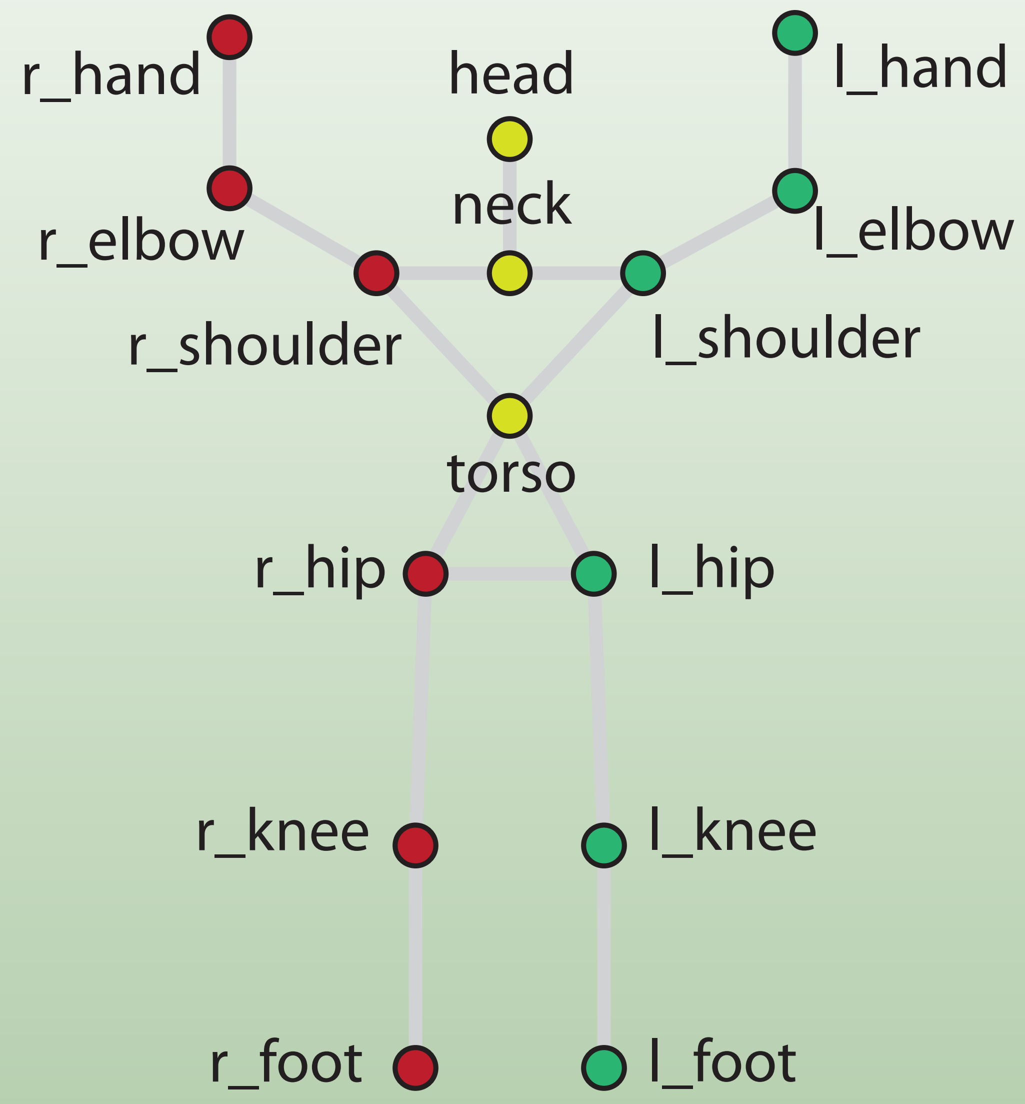
- Many choices for motion capture
  - *Optical (marker, marker-less, ...)*
  - *Mechanical*
  - *Inertial*
- Quality vs. cost and setup time
- How to represent motion data?
  - *Markers*
  - *Angles*
  - *Skeleton*



Seekircher, A., Stoecker, J., Abeyruwan, S., & Visser, U. (2013). Motion capture and contemporary optimization algorithms for robust and stable motions on simulated biped robots. In X. Chen, P. Stone, L. E. Sucar, & T. Van der Zant (Eds.), RoboCup 2012: Robot Soccer World Cup XVII. Mexico City: Springer Berlin / Heidelberg.

MOTION CAPTURE

- OpenNI is a framework for using *natural interaction* (NI) devices
  - RGB-D sensors (Kinect, Xtion Pro)
  - PrimeSense NITE skeleton tracking algorithm for Kinect
  - 3D joint positions must be used to calculate robot joint angles
- Mapping approach
  - Vector/angle calculation
  - IK drawbacks
    - *Limb lengths change*
    - *End effector positioning vs. angles*



MOTION MAPPING: ARMS

$$\mathbf{B} = \text{l\_elbow} - \text{l\_shoulder}$$

$$\mathbf{B_P} = \mathbf{X}(\mathbf{X} \cdot \mathbf{B}) + \mathbf{Z}(\mathbf{Z} \cdot \mathbf{B})$$

$$\mathbf{B_N} = \frac{\mathbf{B_P} \times \mathbf{B}}{|\mathbf{B_P} \times \mathbf{B}|}$$

$$\mathbf{F} = \text{l\_hand} - \text{l\_elbow}$$

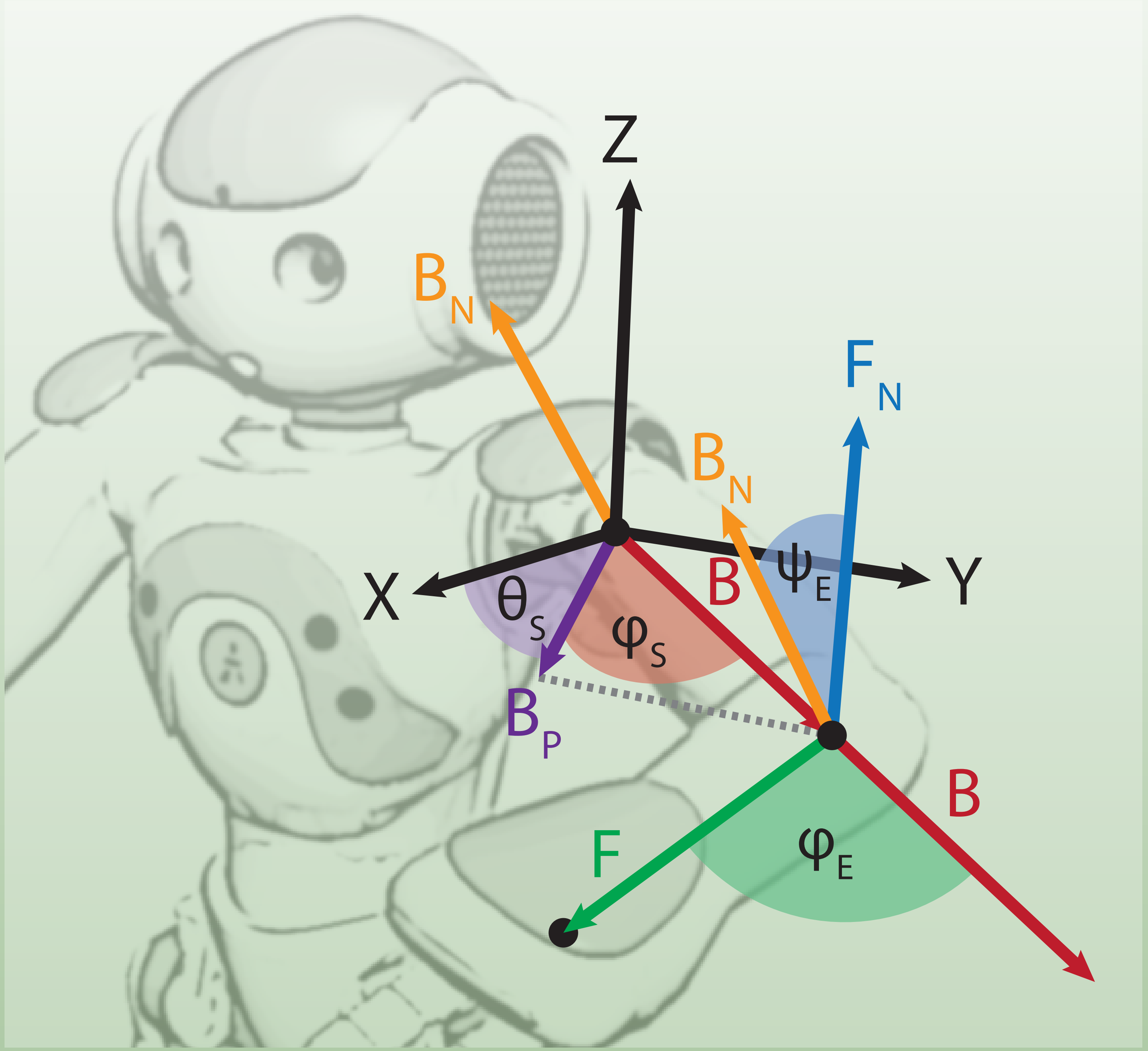
$$\mathbf{F_N} = \frac{\mathbf{F} \times \mathbf{B}}{|\mathbf{F} \times \mathbf{B}|}$$

$$\theta_S = \angle(\mathbf{X}, \mathbf{B_P}, \mathbf{Y})$$

$$\varphi_S = \angle(\mathbf{B_P}, \mathbf{B}, \mathbf{B_N})$$

$$\psi_E = \angle(\mathbf{B_N}, \mathbf{F_N}, \mathbf{B})$$

$$\varphi_E = \angle(\mathbf{B}, \mathbf{F}, \mathbf{F_N})$$



MOTION MAPPING: LEGS

Pre-compute hip configurations with forward kinematics

$$\mathbf{T} = \text{l\_knee} - \text{l\_hip}$$

$$\mathbf{S} = \text{l\_foot} - \text{l\_knee}$$

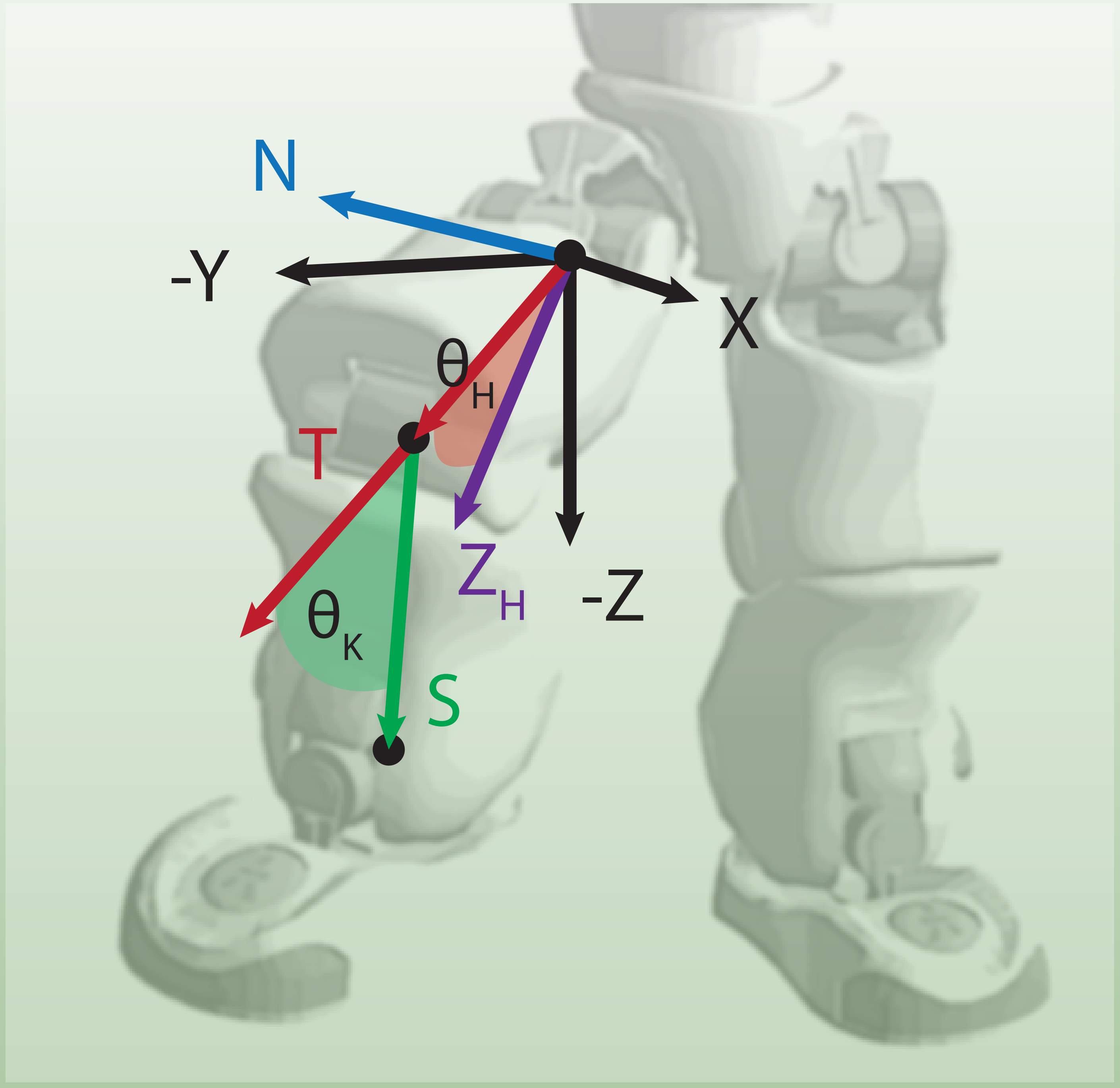
$$\mathbf{N} = \frac{\mathbf{S} \times \mathbf{T}}{|\mathbf{S} \times \mathbf{T}|}$$

$$\alpha_H = \text{from lookup(N)}$$

$$\varphi_H = \text{from lookup(N)}$$

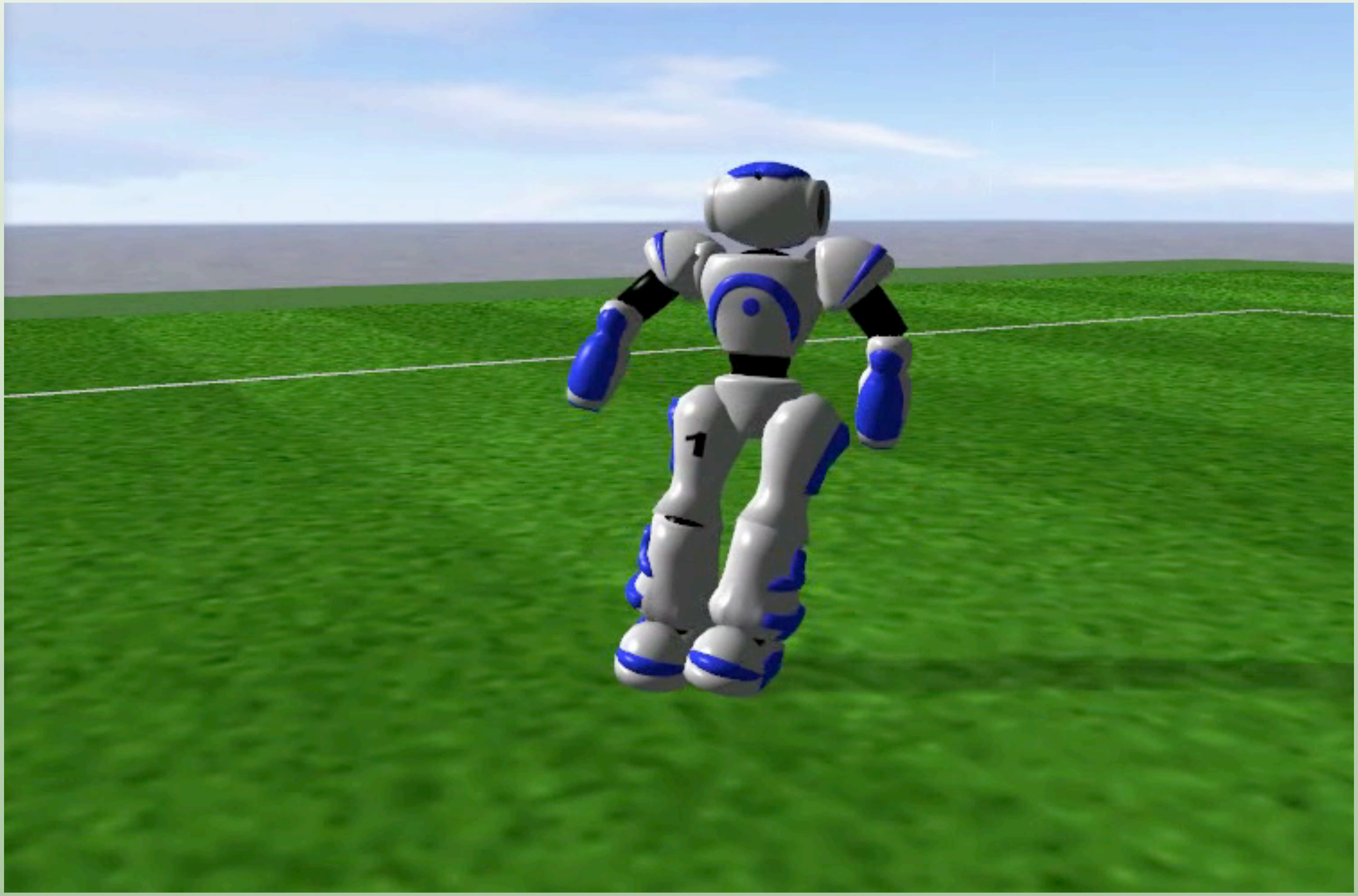
$$\theta_H = \angle(\mathbf{T}, \mathbf{Z_H}, \mathbf{N})$$

$$\theta_K = \angle(\mathbf{S}, \mathbf{T}, \mathbf{N})$$



MOTION OPTIMIZATION

Original Motion (directly using MoCap angles)



MOTION OPTIMIZATION

- MoCap provides 16 joint control angles at 50 Hz. Model has 22 DOF.
- Model:

$$y(\mathbf{x}, \boldsymbol{\theta}) = \sum_{j=0}^{N-1} \theta_j \phi_j(\mathbf{x}) = \boldsymbol{\theta}^{\mathrm{T}} \Phi(\mathbf{x})$$

- Basis functions:

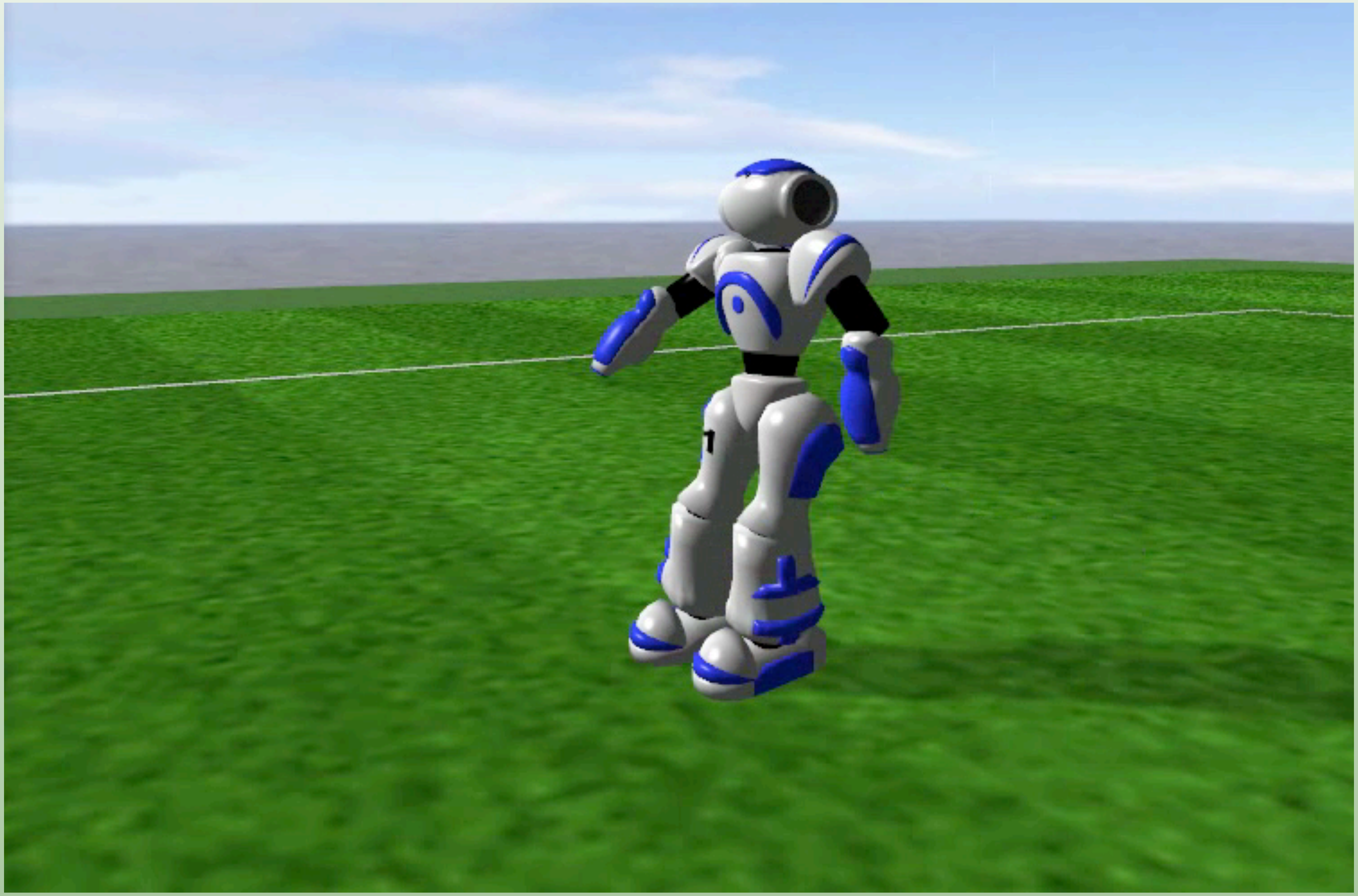
$$\phi_j(x) = x^j \qquad \phi_j(x) = \sigma\left(\frac{x - \mu_j}{s}\right)$$

- Initial objective function:

$$\min \sum_{i=1}^{M} (t_i - \boldsymbol{\theta}^{\mathrm{T}} \Phi(\mathbf{x}))^2$$

MOTION OPTIMIZATION

Curve-Fit Motion



MOTION OPTIMIZATION

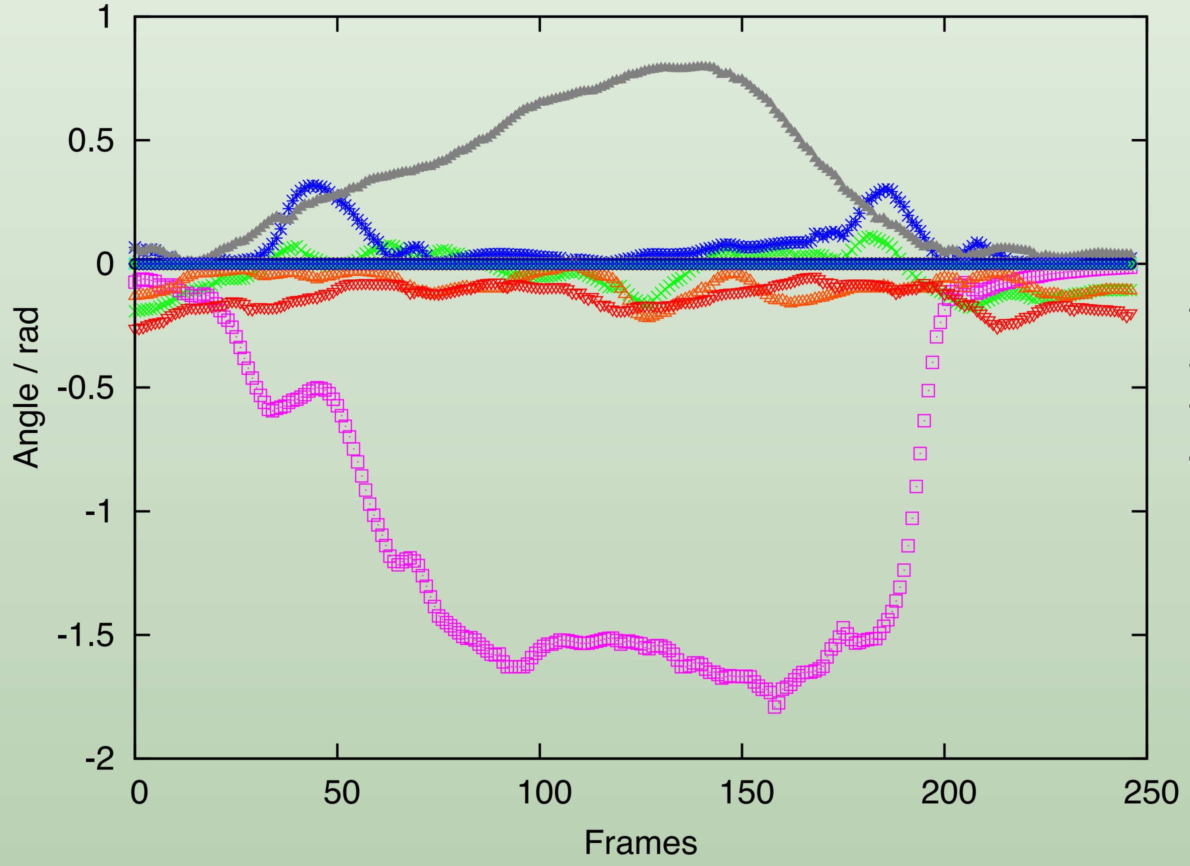
- Initial optimization of the model parameters is used as a seed for the optimization of the motion for stability on the robot.
- Task is optimization problem with two conflicting objectives.
- Following exactly joint angles provided by the MoCap does not guarantee the outcome to be correct.
- Also, the changes in the angles have to be small to ensure the final result to be close to the captured motion.
- Objective functions:

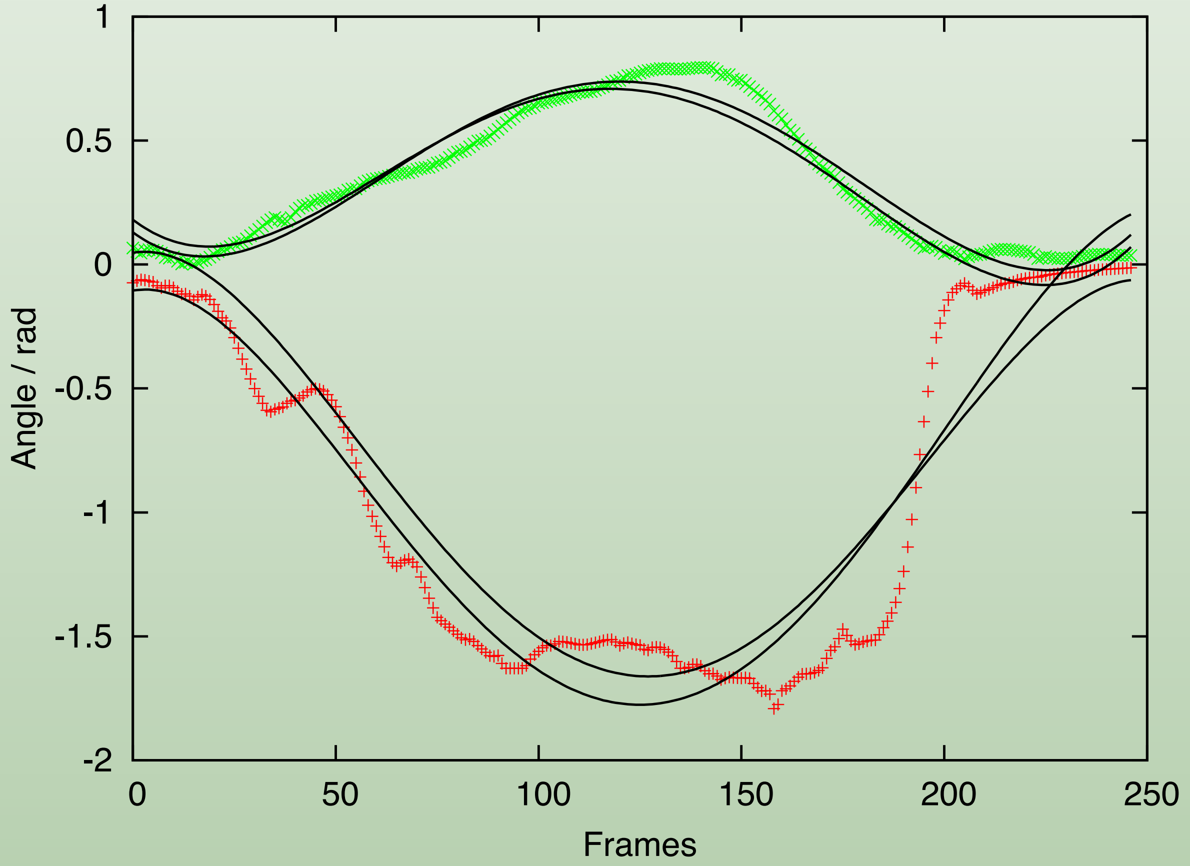
$$\sum_t \max_{i \in \{\text{fwd,up,side}\}} (\angle(\text{MoCapTO}_{t,i}, \text{ObsTO}_{t,i}))^2$$

$$\sum_t (\sum_j (\text{MoCapAngle}_j - \text{ObsJointAngle}_j)^2)$$

- ES/PSO algorithms are used again to optimize the model parameters.
- Optimize only the traces of the agent's legs (12 traces for each motion), N × 12 parameters (e.g., with eight parameters, we optimize 96 parameters).

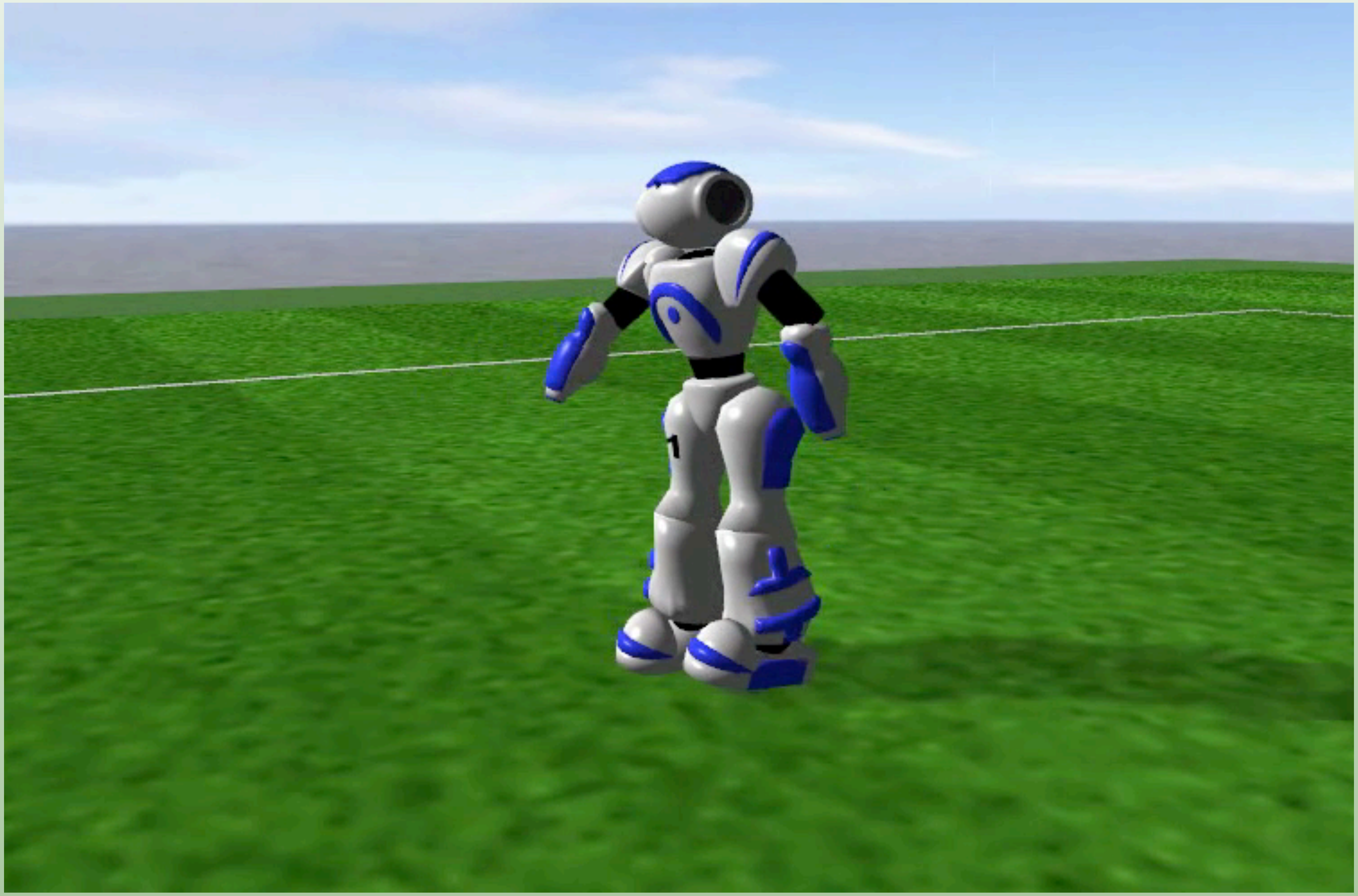
EXPERIMENTAL SETUP





MOTION OPTIMIZATION

Optimized Motion



MOTION CAPTURE AND OPTIMIZATION

Seekircher, A., Stoecker, J., Abeyruwan, S., & Visser, U. (2014). Fast, robust, and low-cost method to create complex whole body motions on biped robots. *Artificial Intelligence Journal,* under review.

CONCLUSION

- Hypothesis verified: robust motions for a biped soccer robot can be quickly generated with inexpensive MoCap techniques and optimization.
- Kinect sensor provides enough information to map complex and initially unstable poses, such as the balancing motions.
- We have found a process that can be used to produce a number of motions needed for humanoid soccer robots.
- No claim that our approach will hold for all possible motions.
- Motions were mostly stable after ~30 min.
- Making use of parallel processing on a cluster of computers can bring the entire processing time down to 10-30 min per motion, including the MoCap.
- Observation: CMA-ES and xNES are similar in performance, PSO shows partly smaller errors with a larger variance and it takes longer to learn.
- Models with sigmoidal basis functions yields good results for all three algorithms.

EXPERIMENTAL SETUP

- SimSpark [ORR04],the simulated robot is a humanoid robot similar to the Nao (21 DOF, sensor cycle 50 Hz).
- 4 motions in the experiments: 1) lift right leg, 2) simple kick, 3) forward lean with balancing on one leg while stretching the other leg back, and 4) leans torso to the side.
- Joint motions modeled using polynomials and linear weighted sigmoidal basis functions.
- Models are initialized by minimizing the least squared error to the input angles.
- Using the initial parameters as a seed, 12 leg joints are optimized by CMA-ES, xNES, and PSO using the fitness function based on the joint and the torso error.
- Population size is 50 for all optimization methods.

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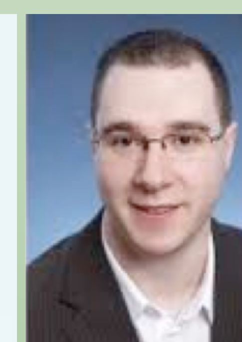

FINAL KIDSIZE ROBOCUP 2013

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FINAL ADULTSIZE ROBOCUP 2013

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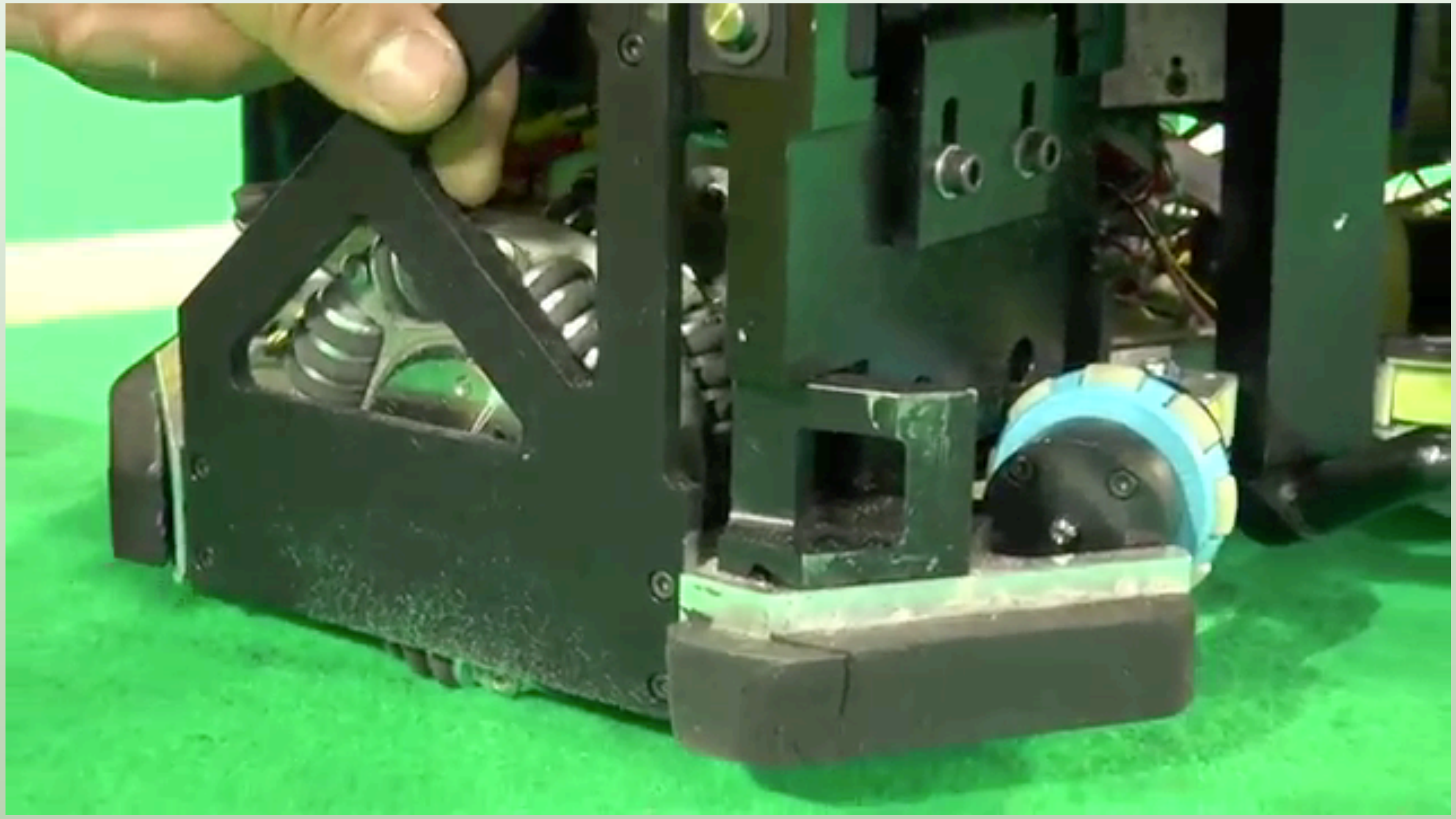
MIDSIZE LEAGUE INTRODUCTION



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FINAL 3D SOCCER SIMULATION ROBOCUP 2013

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FINAL SMALL SIZE LEAGUE ROBOCUP 2013

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FINAL STANDARD PLATFORM LEAGUE ROBOCUP 2013

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