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Creating dynamic stand-up motions for bipedal robots using spline interpolation

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Technical Aspects of Multimodal Systems

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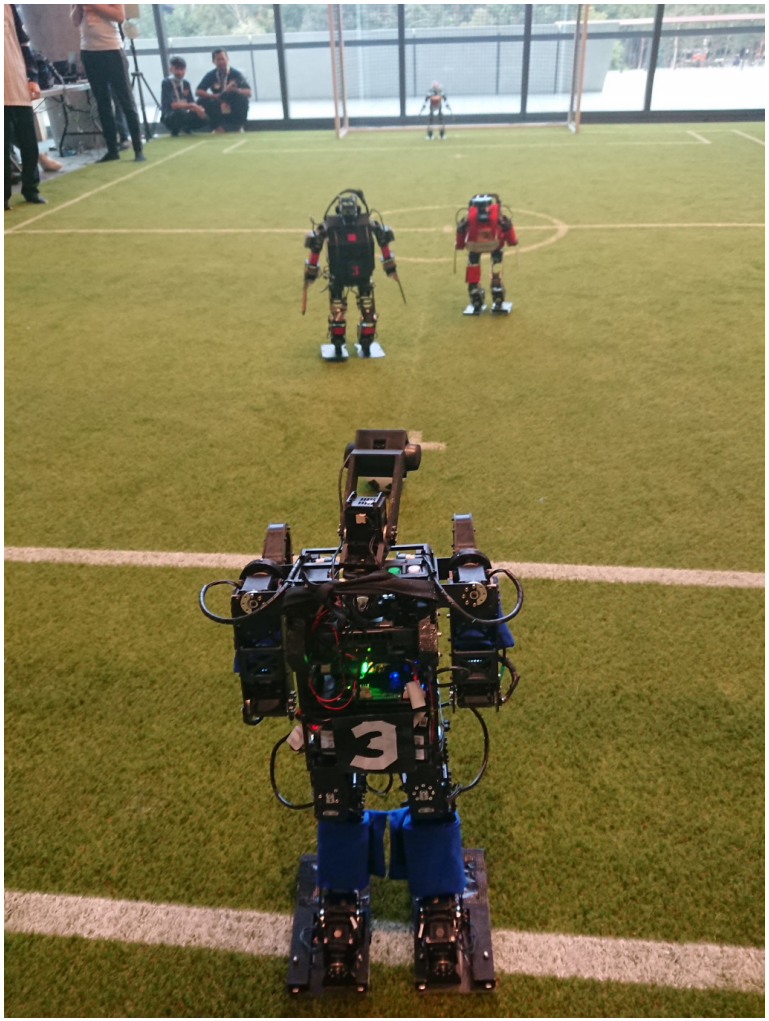
Outline

Outline

Motivation: Robocup



- Founded 1996
- Goal: beat human world champion by 2050
- Supports interdisciplinary research in artificial intelligence and intelligent adaptive systems
- 335 Teams, 40 Nations, 2200 Participants (WM 2019)

Motivation

- Bipedal robots tend to fall
- Current solution: Keyframe animations
  - Not very flexible
  - Prone to environmental disturbance
- Goal: Create feedback controlled motion

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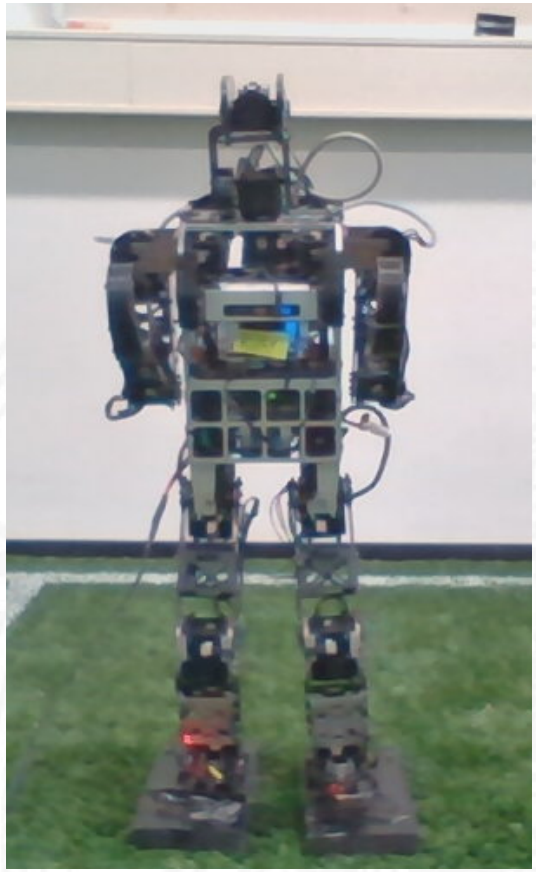
[1] Image courtesy of Judith Hartfill

Robot Platform

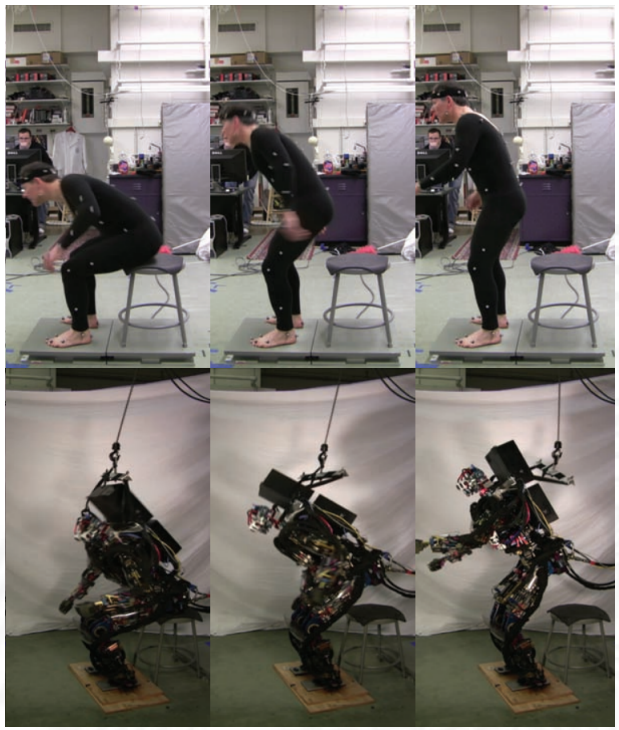
- Wolfgang OP
- 78 cm tall, ~8 kg heavy
- 20 DoFs
- Intel Nuc, Nvidia Jetson, Odroid
- Sensors: Industrial camera, IMU, load cells
- Series elastic actuators



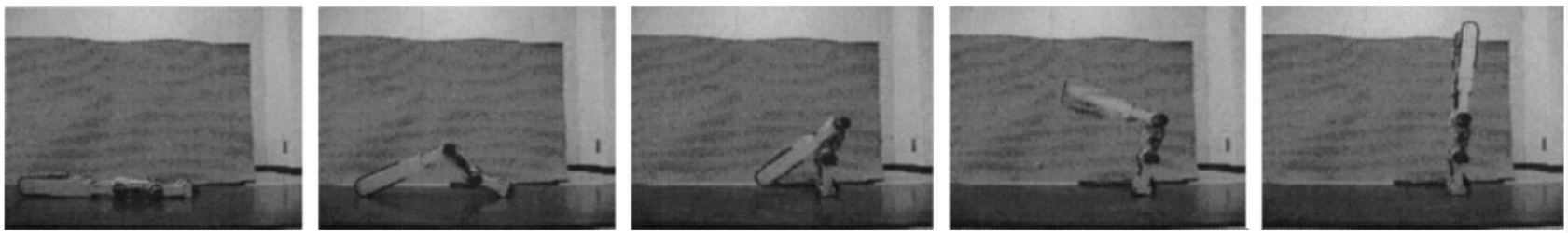
Outline

Related Work

- Keyframe animations
- Reinforcement learning
- Motion tracking
- Various uses of splines and pid for motion planning



[2]



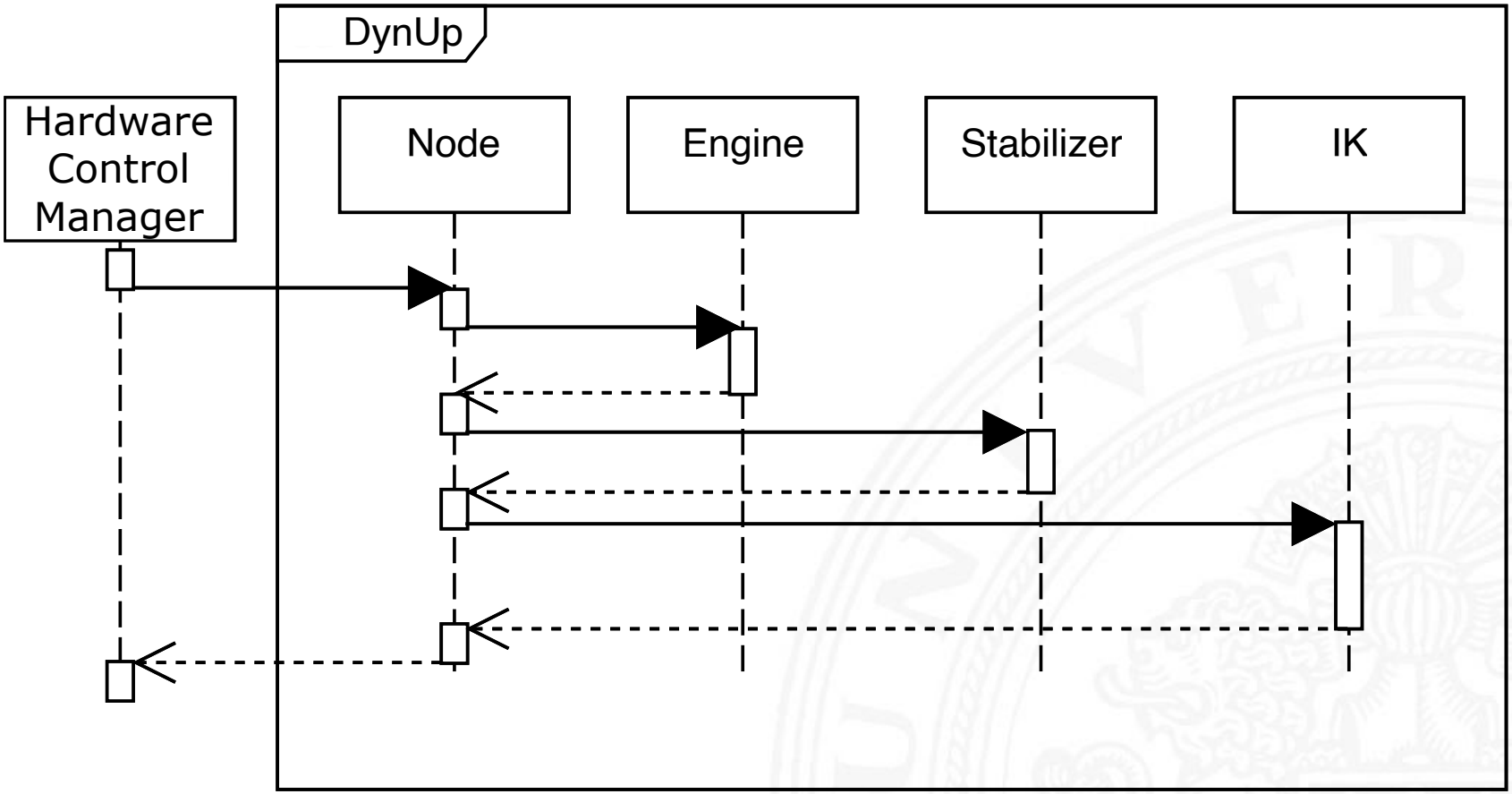
[3]

Outline

Node

- Communication between components and to HCM
- Handles robot model, requests and dynamic reconfigure
- On request:
  - Reset
  - Generate initial poses
  - Loop:
    - Get update from Engine
    - Propagate through components

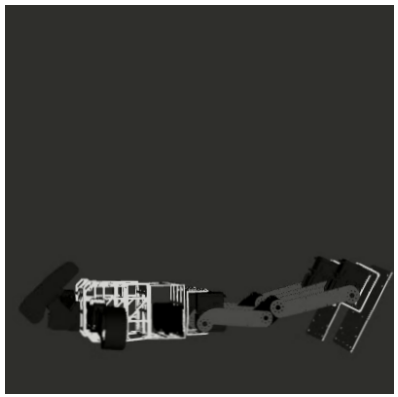
Schematics

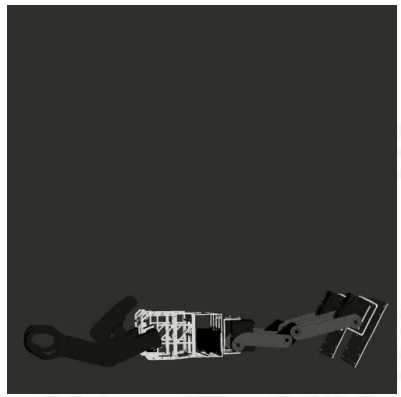


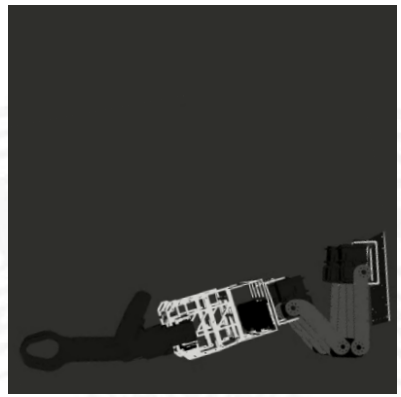
Engine I

- Create splines for motion
- Return transforms of each spline at each timepoint


(a)

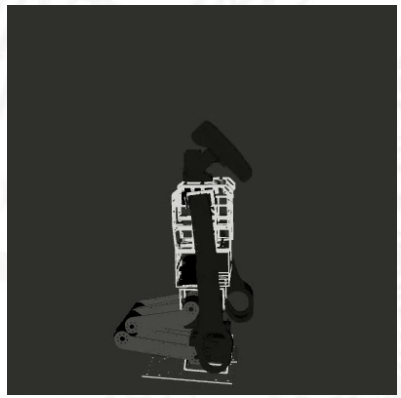

(b)

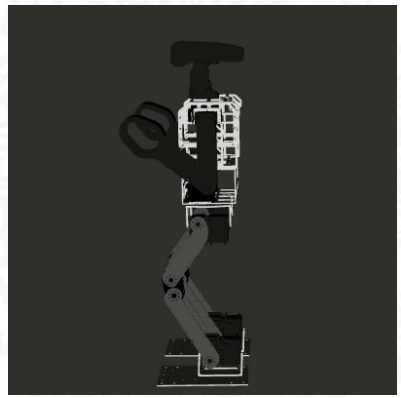

(c)


(d)

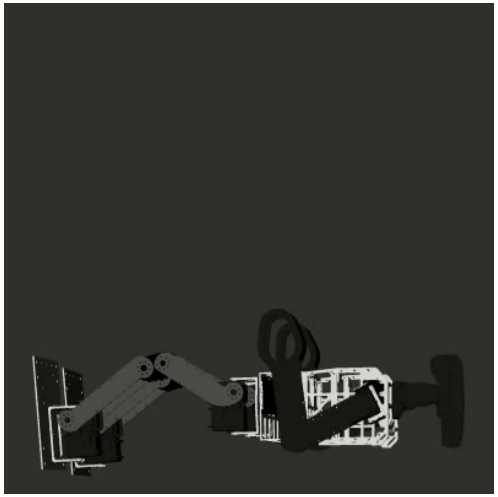

(e)


(f)

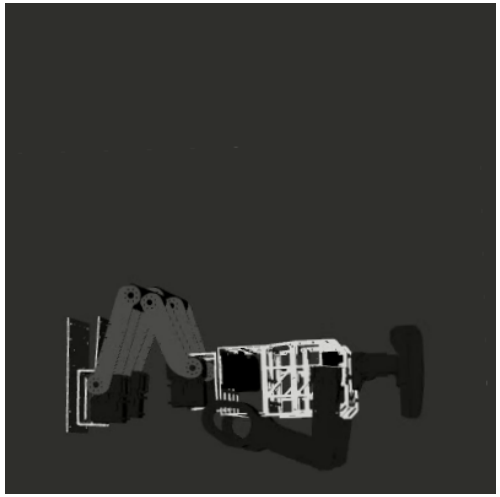

(g)


(h)

Engine II



(a)

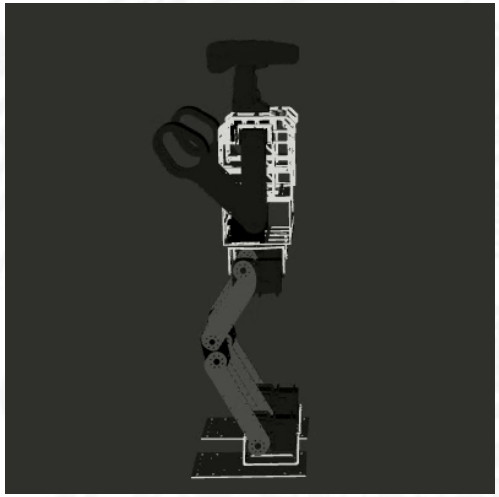


(b)

(c)

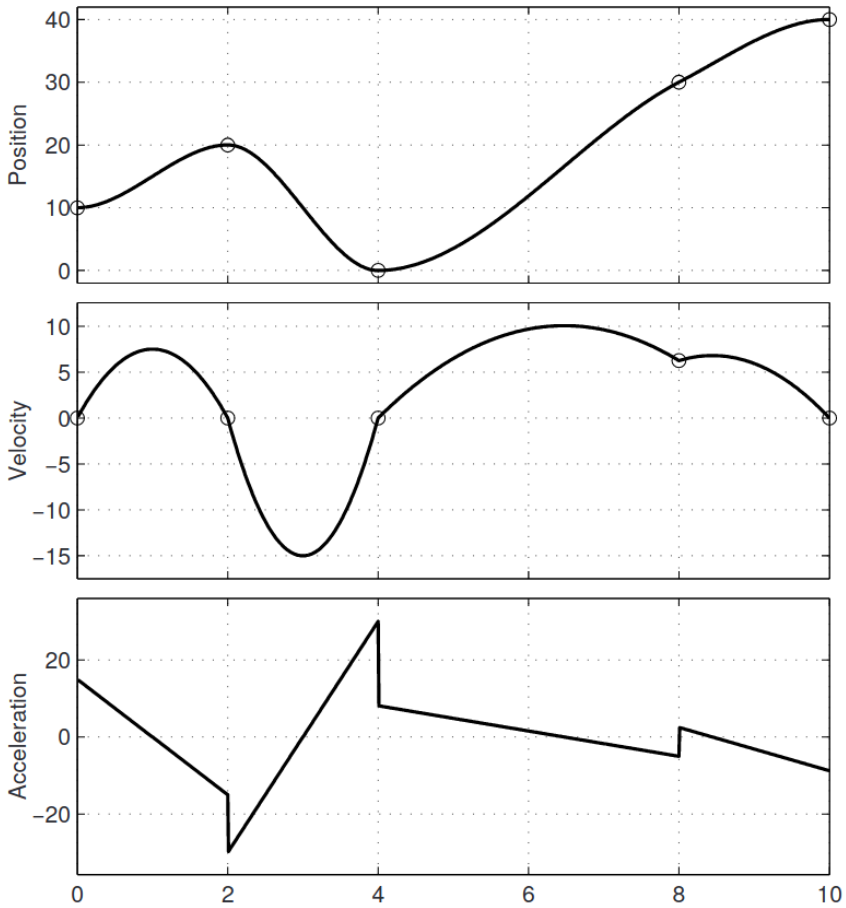
(d)

(e)

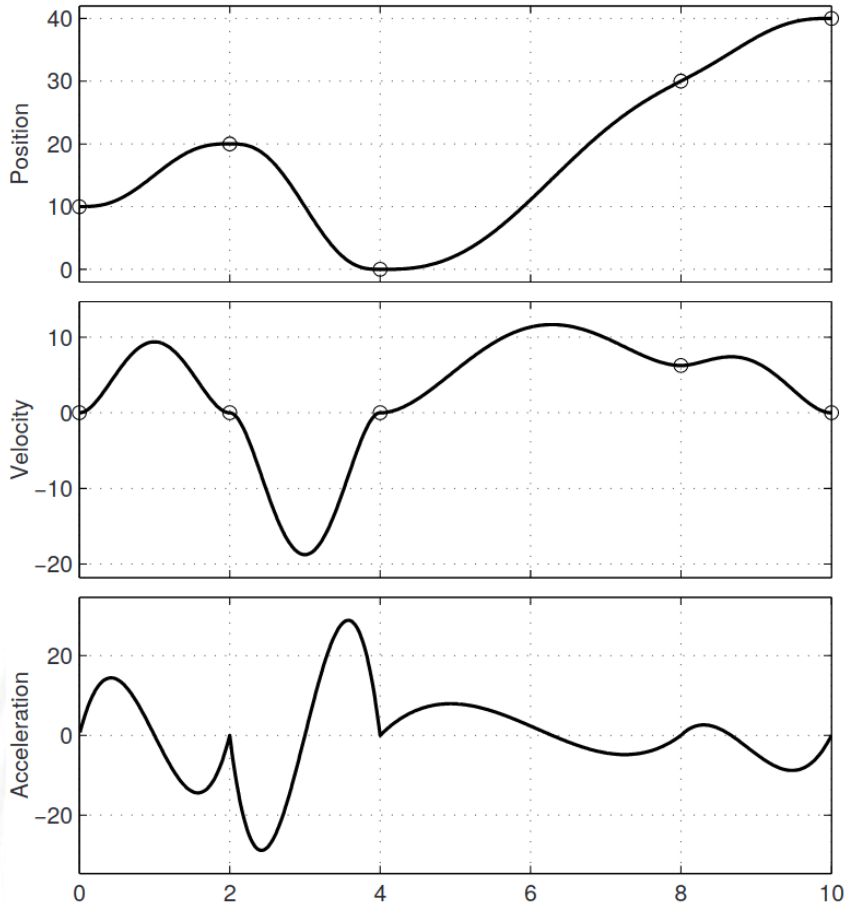


(f)

Engine III: Quintic Splines

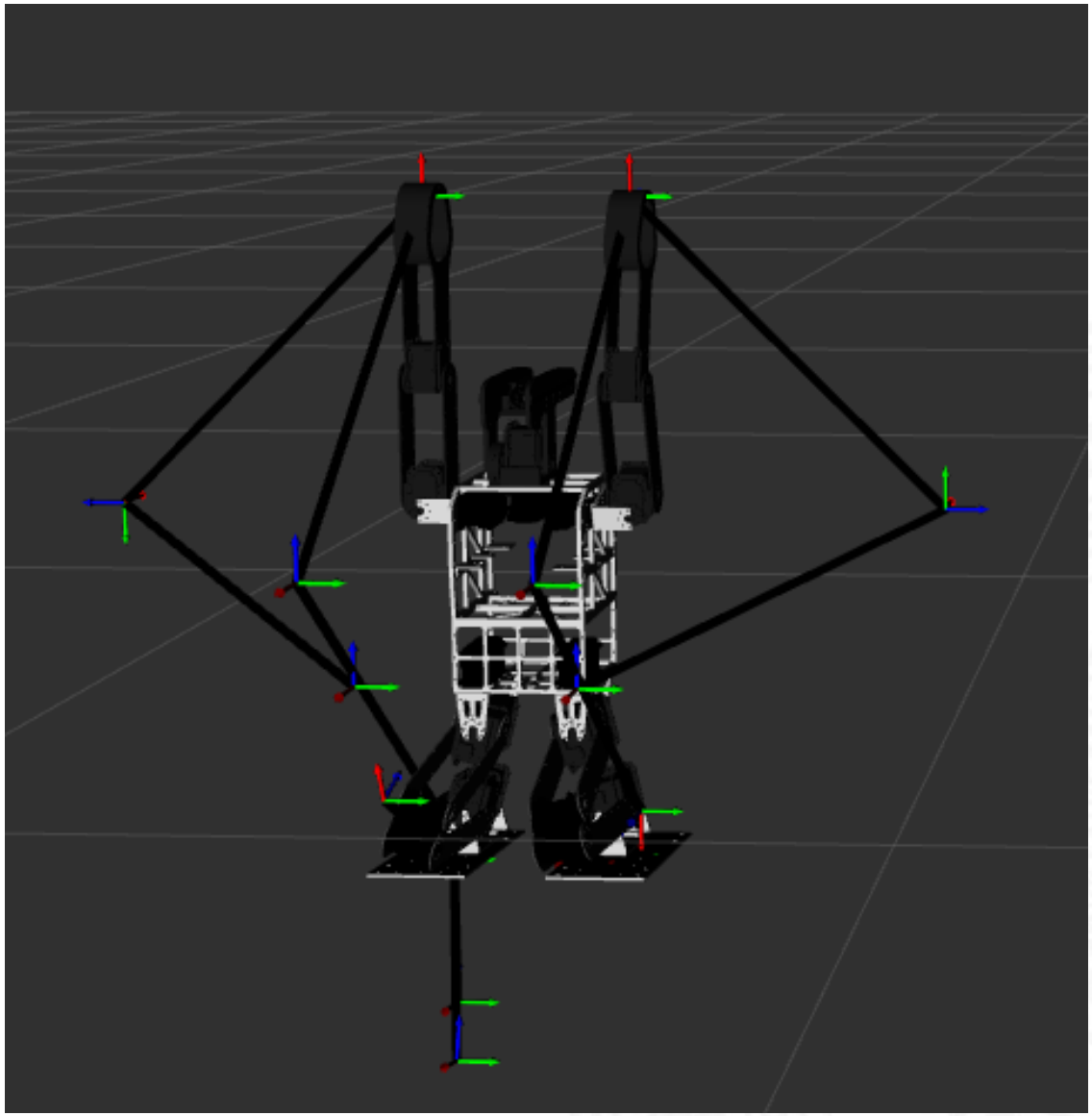


Cubic spline [1]

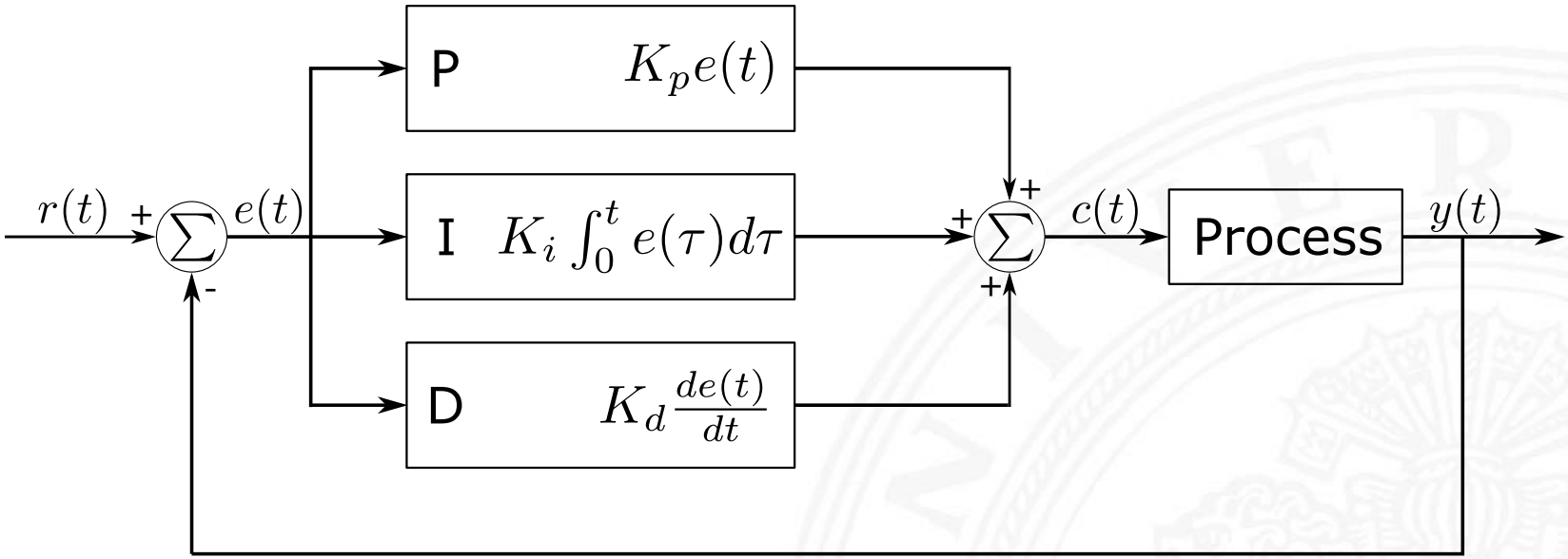


Quintic spline [1]

Engine IV: Visualizer

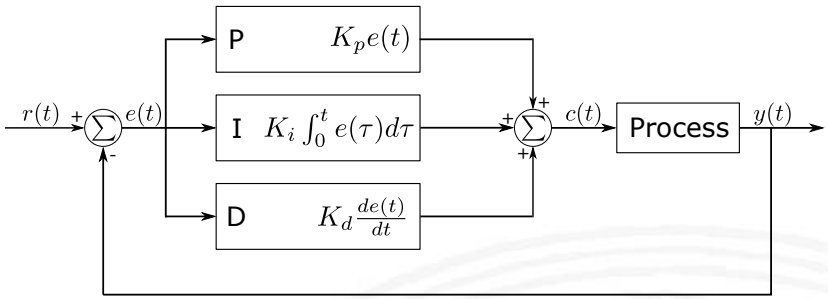


Stabilizer I



Stabilizer II

- Two pid controllers
  - Trunk pitch
  - Trunk roll
- control_toolbox package
- Tuned with Ziegler-Nichols method, manually adjusted

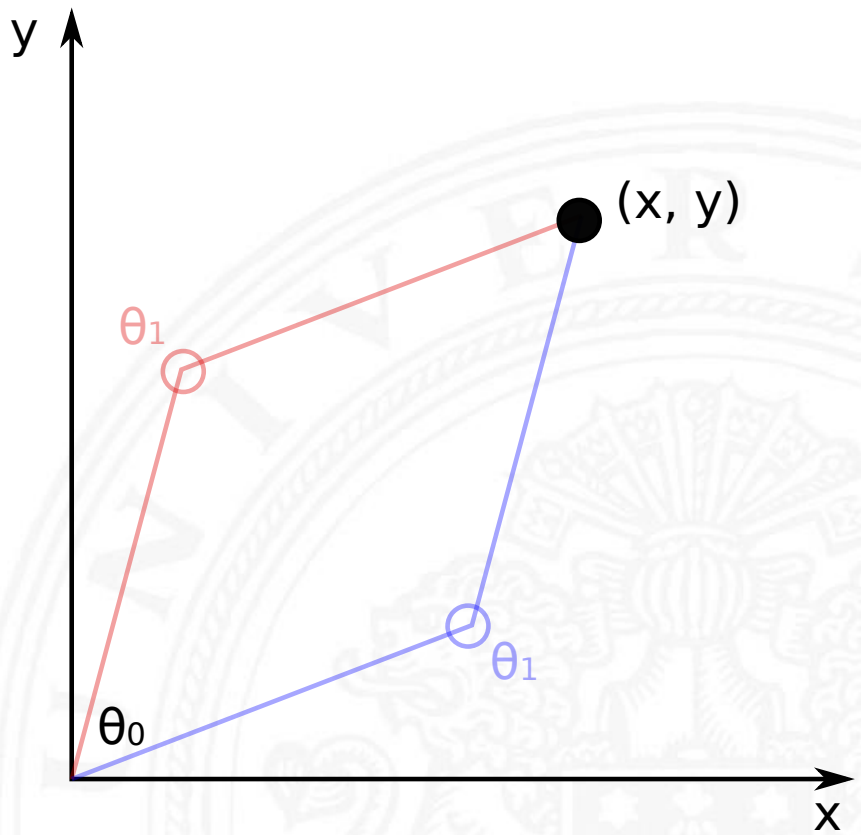


	trunk_pitch			trunk_roll		
	K_P	K_I	K_D	K_P	K_I	K_D
calculated	0.42	1.68	0.026	0.76	4.88	0.030
modified	0.42	1.68	0.026	0.76	2.00	0.030

Results of pid tuning

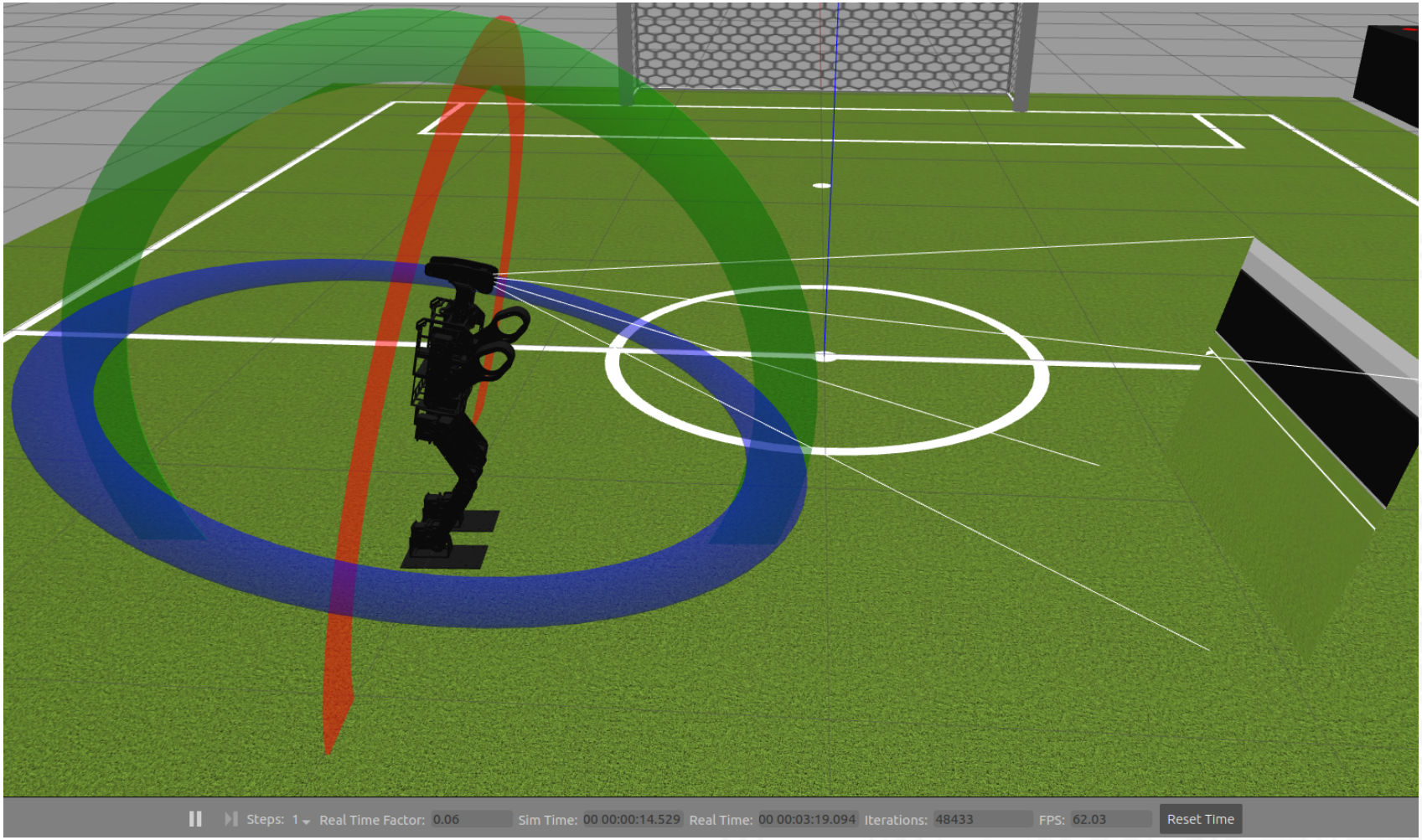
IK Solver

- Motor positions from endeffector pose
- Multiple solutions
- IK Solver
  - Bio IK
  - Memetic algorithm
- Approximate goals

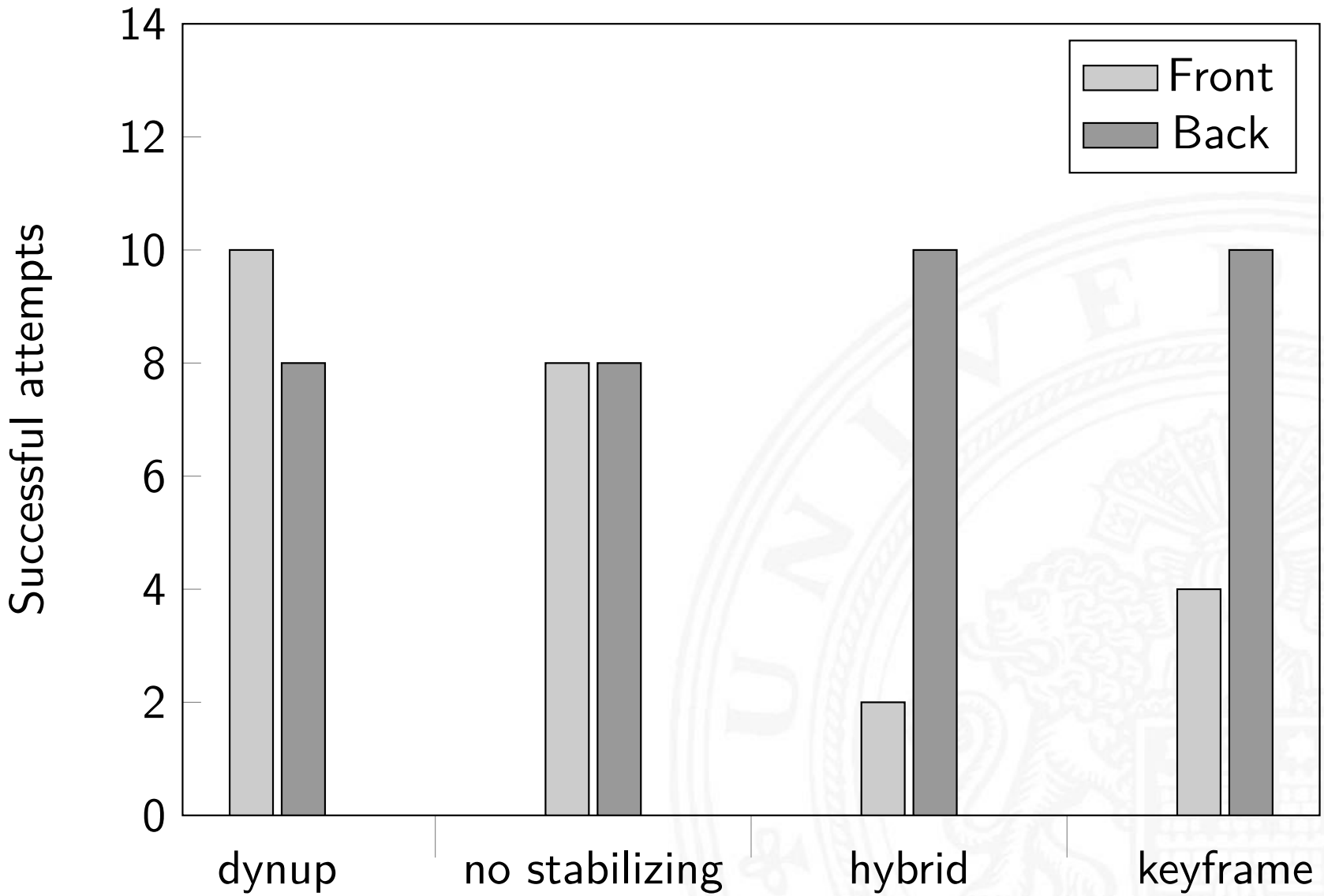


Outline

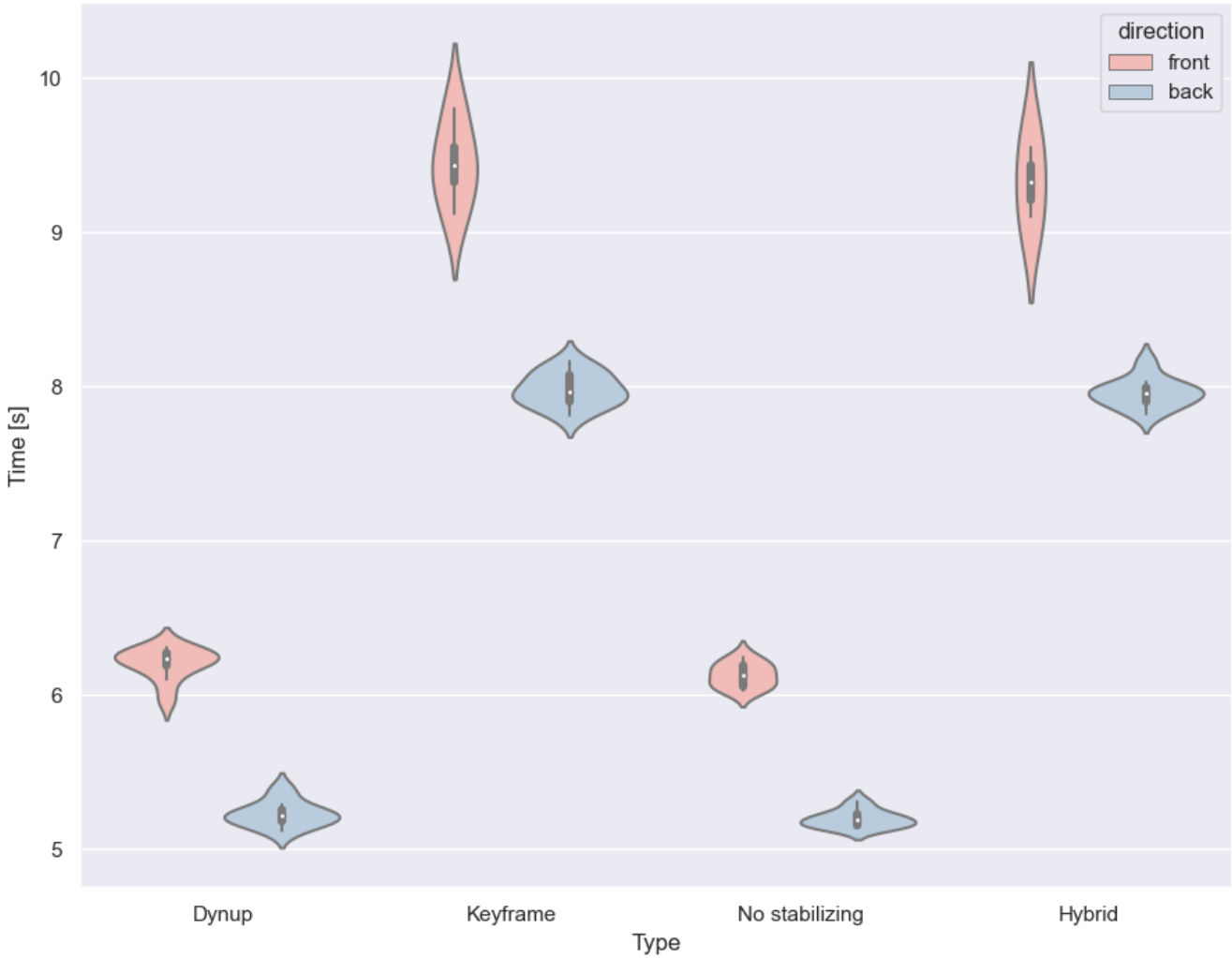
Setup


Steps: 1
Real Time Factor: 0.06
Sim Time: 00 00:00:14.529
Real Time: 00 00:03:19.094
Iterations: 48433
FPS: 62.03
Reset Time

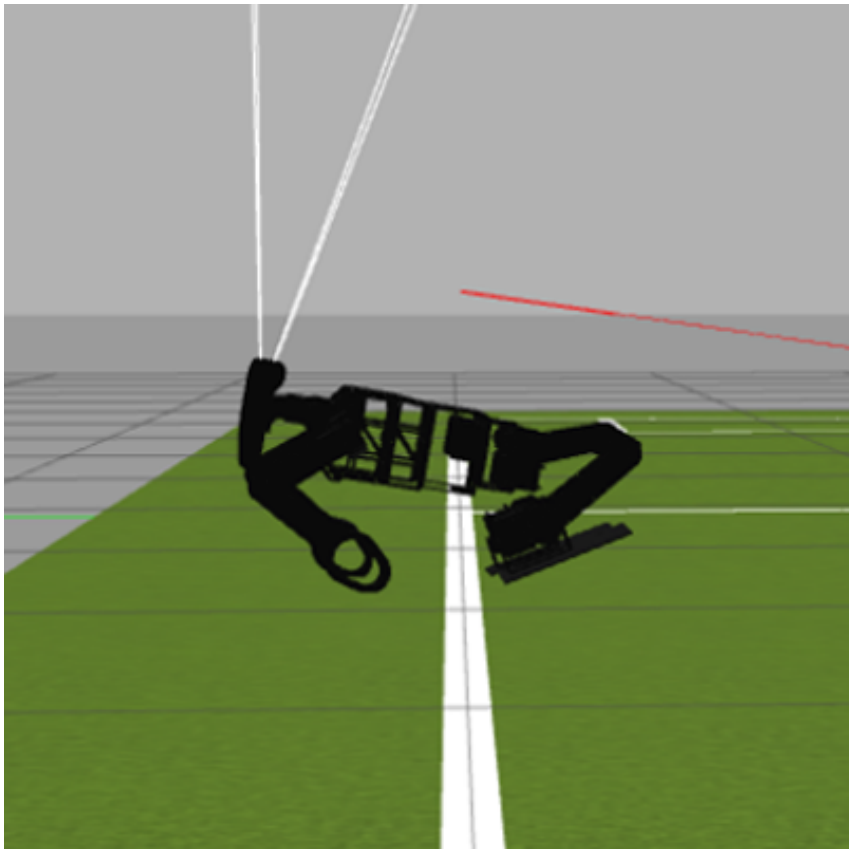
Evaluation I



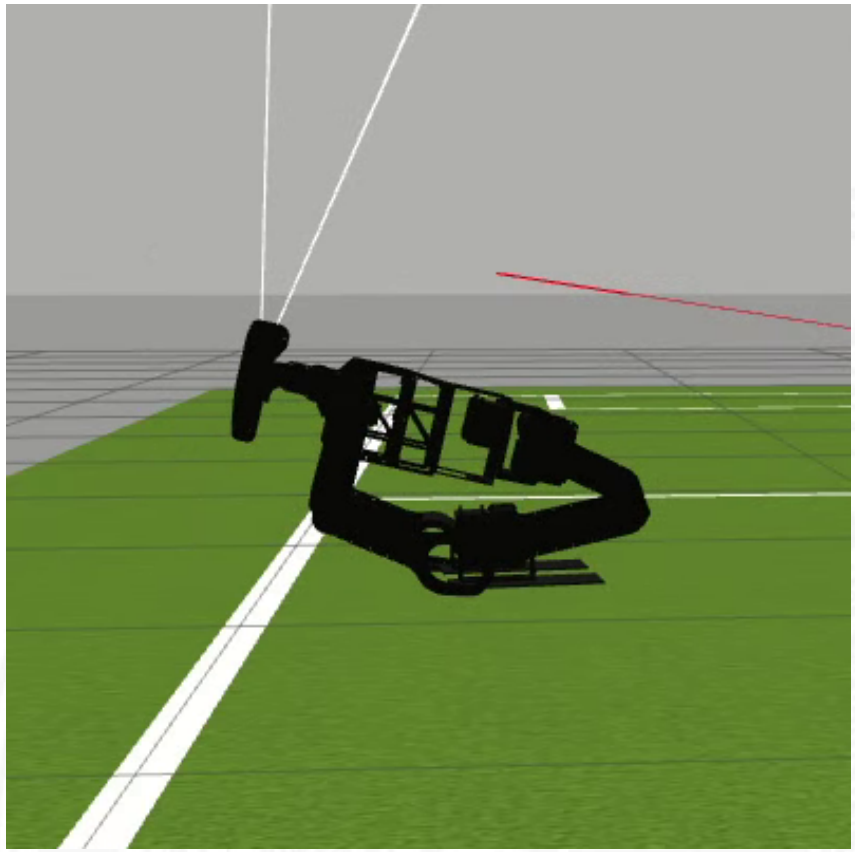
Evaluation II



Evaluation III



Keyframe Animation



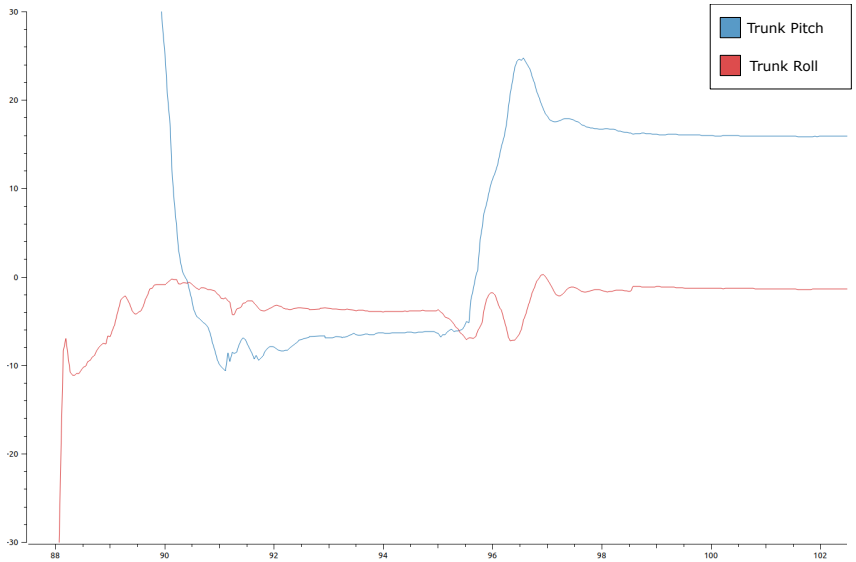
DynUp

Evaluation IV

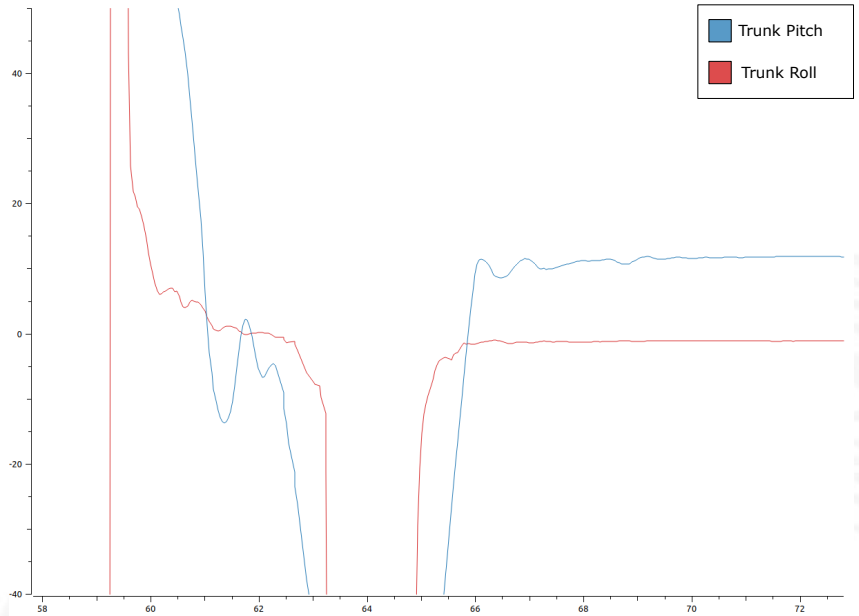
Video

Evaluation V

IMU tracking: front



DynUp



Keyframe

Effort measurement

- No major differences

Outline

1. Motivation
2. Related Work
3. Approach
4. Evaluation
5. Conclusion

Conclusion

- Closed loop stand up system
- Reliable against environmental influences
- Fast and stable
- Transferrable
- Open source on github

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[2] https://github.com/bit-bots/bitbots_motion/tree/feature/dynup-ba/bitbots_dynup

Future Work

- Compare IMU with foot pressure sensors
- Automatic parameter tuning
- Adapt to new robot model

References

[1] Luigi Biagiotti and Claudio Melchiorri. *Trajectory planning for automatic machines and robots*. Springer Science & Business Media, 2008.

[2] Michael Mistry et al. "Sit-to-stand task on a humanoid robot from human demonstration". In: *2010 10th IEEE-RAS International Conference on Humanoid Robots*. IEEE. 2010, pp. 218–223.

[3] Jun Morimoto and Kenji Doya. "Acquisition of stand-up behavior by a real robot using hierarchical reinforcement learning". In: *Robotics and Autonomous Systems* 36.1 (2001), pp. 37–51.

Thank you for your attention.
Do you have any questions?