Planning with the Center-of-Mass rather than Stances for Humanoids walking on Uneven Terrains

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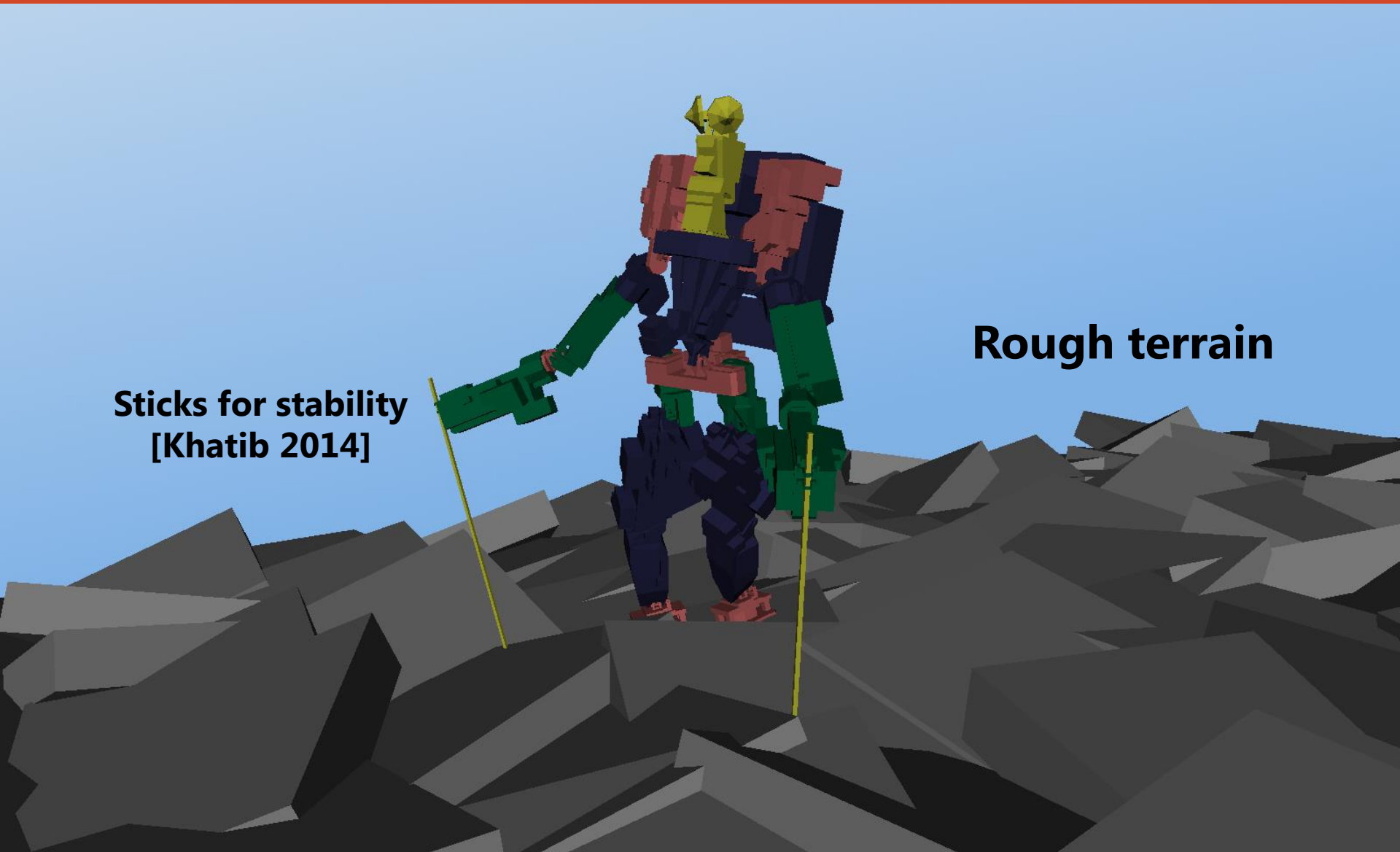
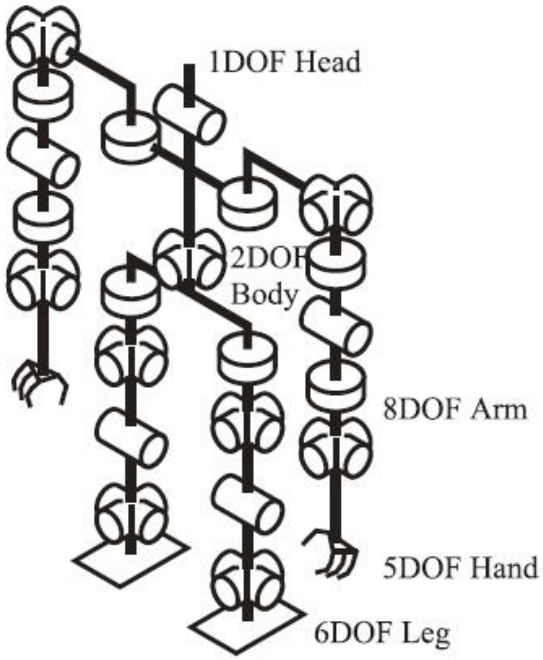
Setting



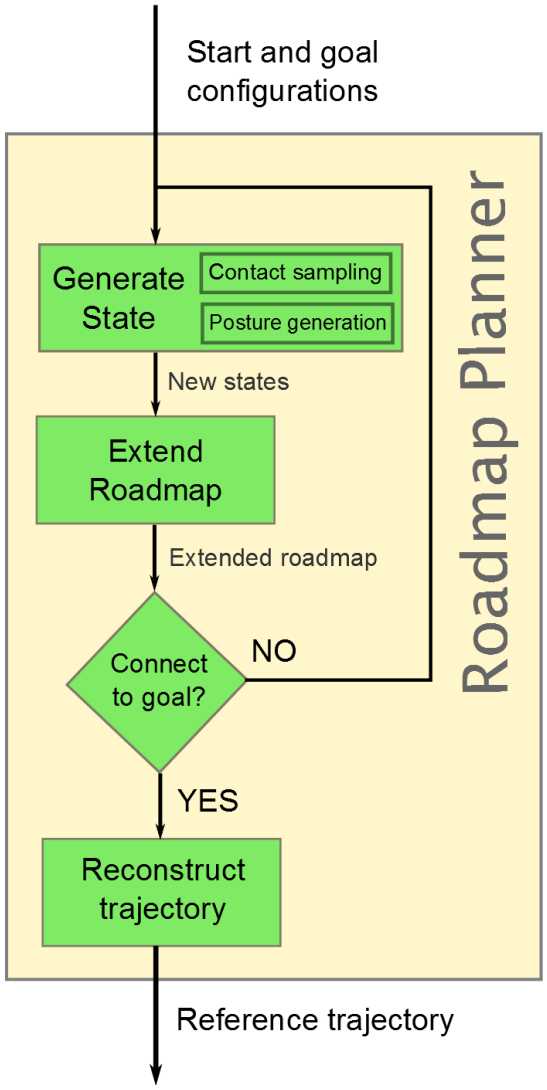
Hydra

- 41-DOF humanoid robot developed at Nakamura-Takano Laboratory
- All joints actuated by Electro-Hydraulic Actuation (EHA) [Kaminaga 2010]



Problem

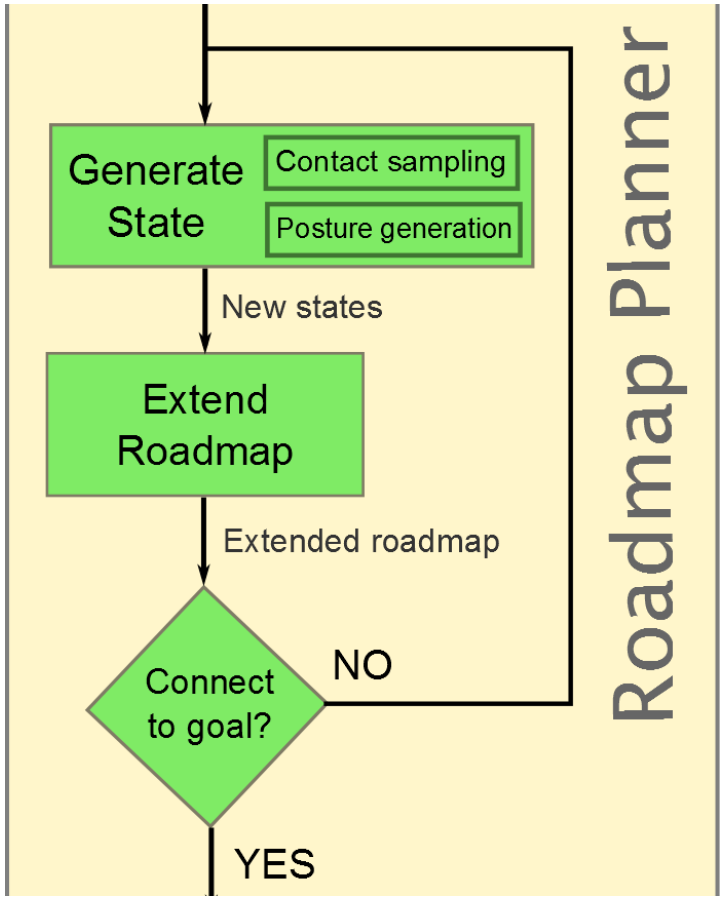
- **Motion Planning:**
  generate a reference trajectory connecting start and goal configurations
- **State-of-the-art:**
  contact planner with a posture generation step
- **Bottleneck:**
  posture generation (PG) is slow
- **Contribution:**
  reduce calls to PG by considering the desired direction of motion



Posture Generation

- **Contribution:**
  reduce calls to PG by considering the desired direction of motion

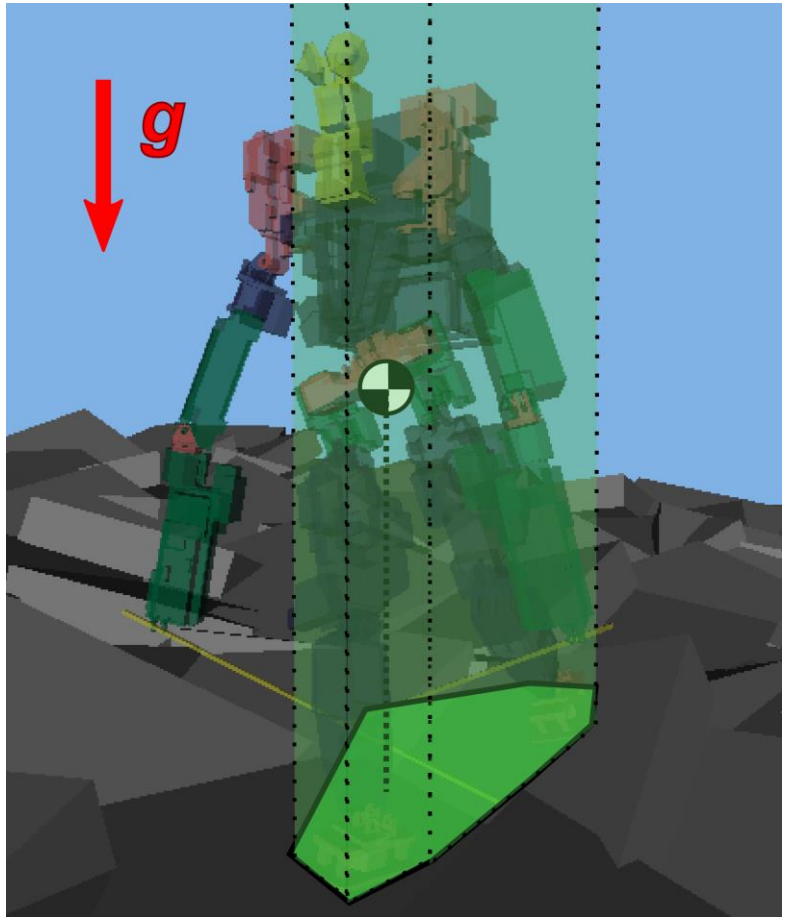
- We focus on the *posture generation* loop of the roadmap planner



Static Stability

- **Static stability condition:** the CoM lies in a right cylinder parallel to gravity [Bretl 2008]

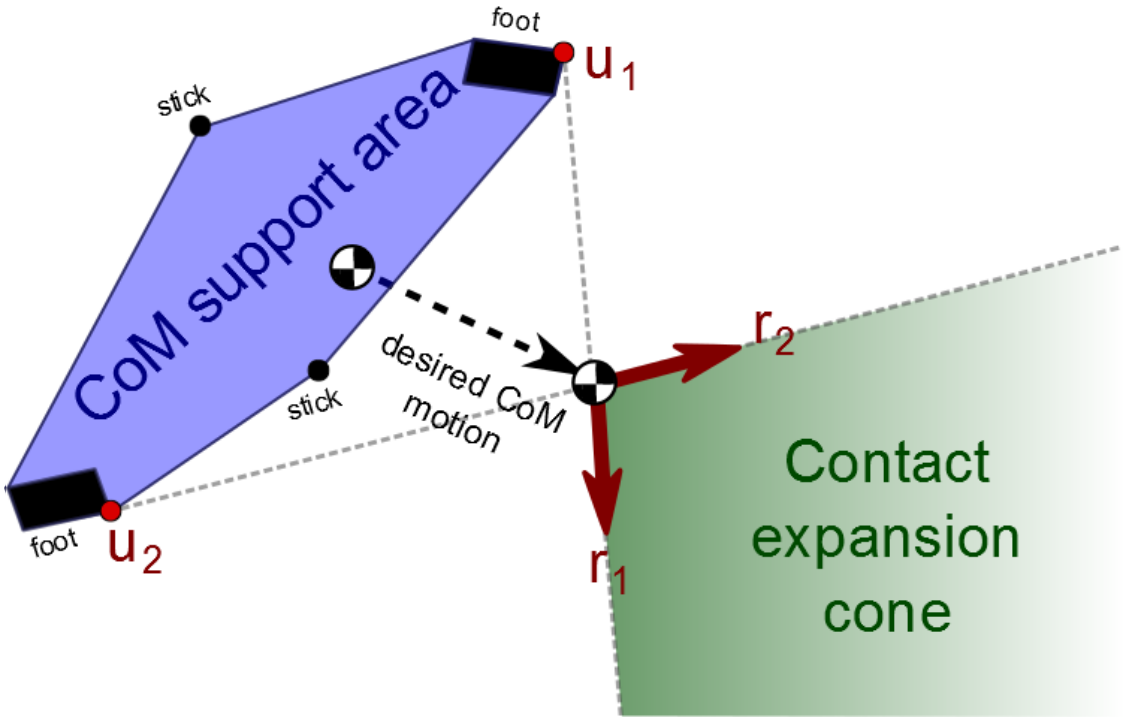
- **Computing this cylinder:**
  - Recursive Polytope Projection [Bretl 2008]
  - Double description method [this paper]



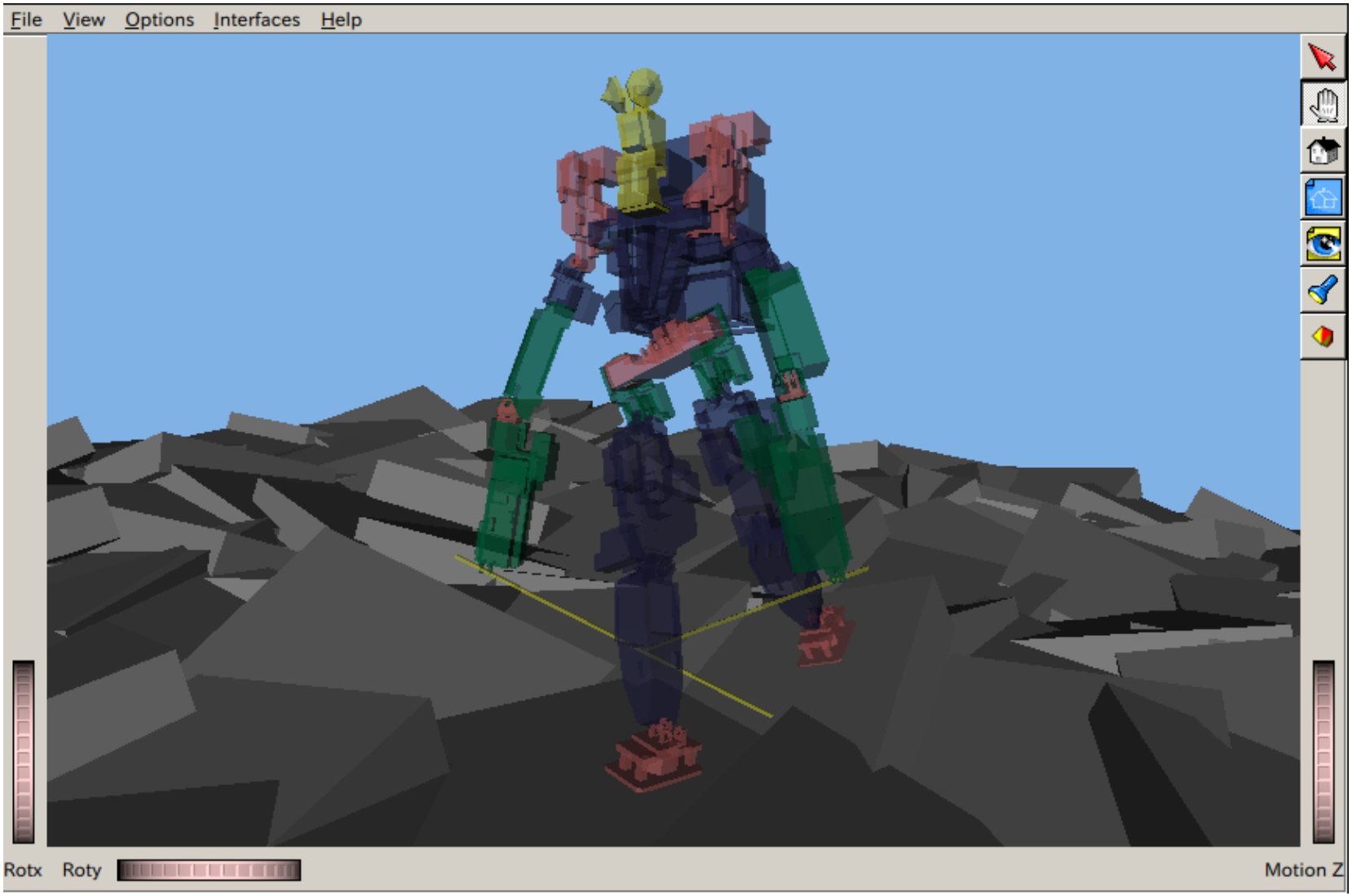
CoM-based steering

When moving a contact (foot or stick):

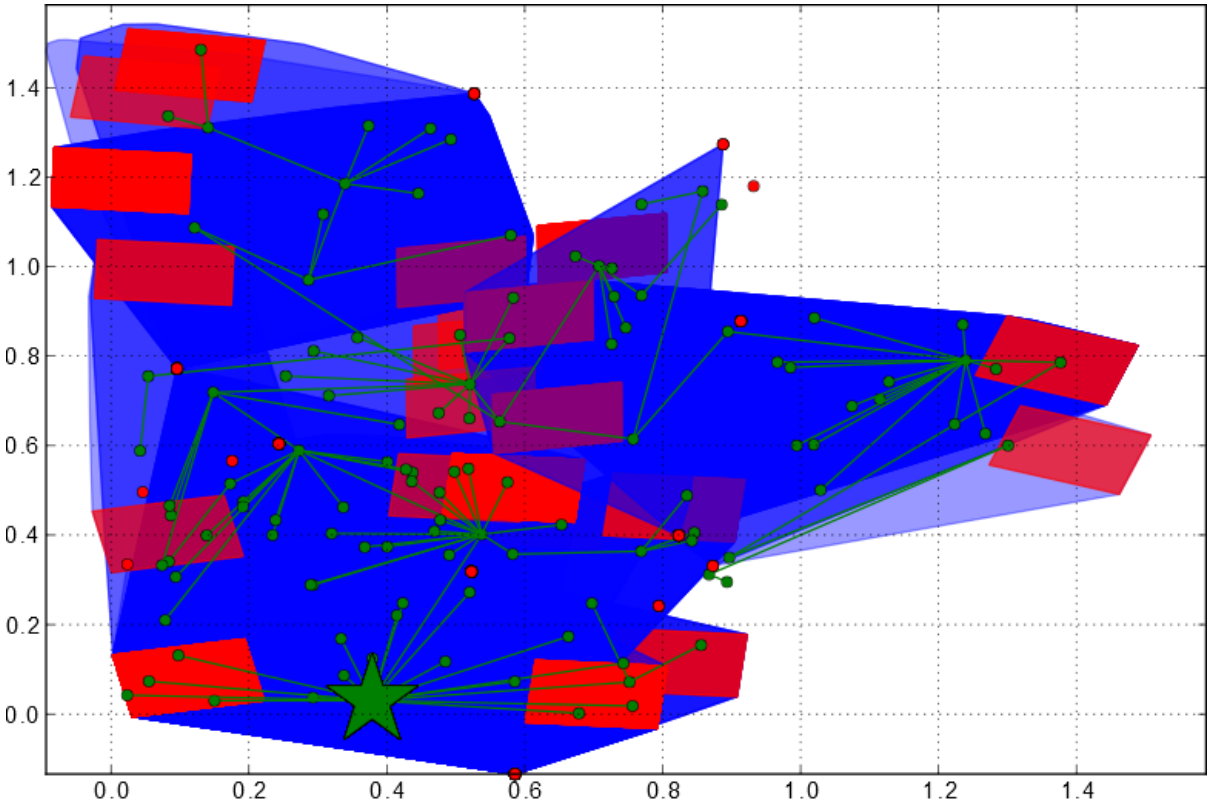
- **Previous:** sample next contact positions at random
- **This work:** select contact position based on desired CoM



Generated Postures (samples)

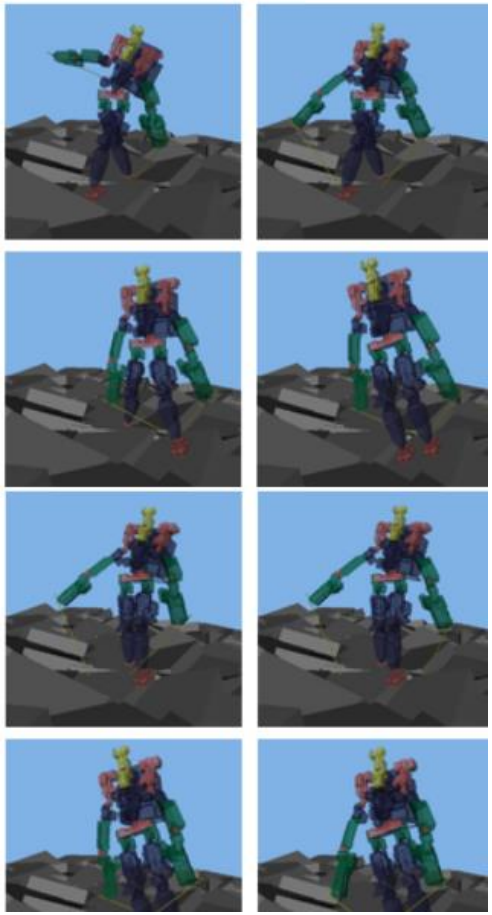


Roadmap with Stability Polygons



Conclusion

- **Roadmap planners** for humanoids usually require many calls to the posture generator; we filter these calls by considering **desired CoM motions**
- **Contribution** to motion planning: plan in reduced CoM state space, link with contact
- Validation: posture generation for Hydra on rough terrain



Thank you for your attention.

References

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Bretl, Timothy, and Sanjay Lall. "Testing static equilibrium for legged robots." *IEEE Transactions on Robotics,* 24.4 (2008): 794-807.

[Kaminaga 2010]

Kaminaga, Hiroshi, et al. "Backdrivability analysis of Electro-Hydrostatic Actuator and series dissipative actuation model." *2010 IEEE International Conference on Robotics and Automation (ICRA)*.

[Khatib 2014]

Khatib, Oussama, and Shu-Yun Chung. "SupraPeds: humanoid contact-supported locomotion for 3D unstructured environments." *2014 IEEE International Conference on Robotics and Automation (ICRA)*.