Multi-contact Locomotion and Perception on the Humanoid Robot HRP-2

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Presentation overview

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Humanoids in Factory like environment

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Humanoid robot HRP-2 evolving on stairs

[Kudruss, Humanoids 2015]
[Carpentier, ICRA 2016 submitted]

Previous work
[Luo, ICRA 2014]
[Vaillant, Humanoids 2014]
[Noda, ICRA 2014]

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Humanoid robot HRP-2 stepping down

[Cuong, IEEE Trans. on Mechatronics 2014]

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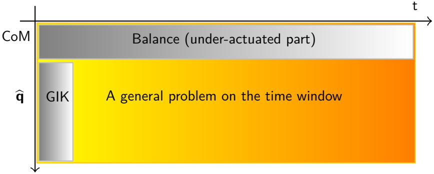
Motion generation: the general problem

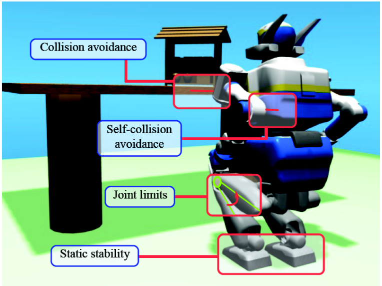
$$\begin{cases} \min f(\mathbf{u}(t), \mathbf{v}(t)) \\ \mathbf{g}(\mathbf{u}(t), \mathbf{v}(t)) < 0 \\ \mathbf{h}(\mathbf{u}(t), \mathbf{v}(t)) = 0 \end{cases}$$



with $\mathbf{u}(t)$ the control and

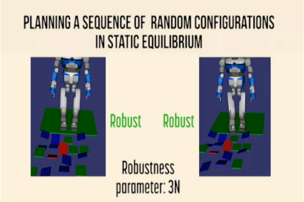
$\mathbf{v}(t)$ the environment model

Which $\mathbf{v}(t)$ for multi-contact control ?



Planning complex contact sequences

- Fast conctact planner from environment CAD (near real-time) [Tonneau, ISRR2015]
- Evident need of dense mapping as input
- Preparing force control using robust balance

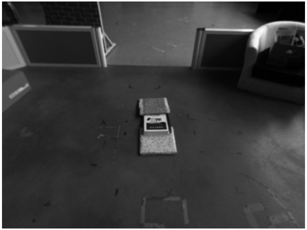
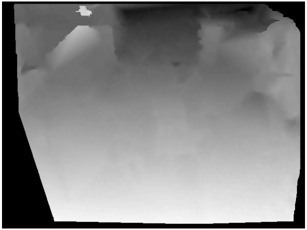
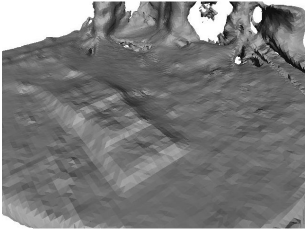


[Del Prete, ICRA 2016 Submitted]

Problems with the environment model

Noise in the contact surfaces —Solution→ Torque control

Online adaptation to unknown terrain

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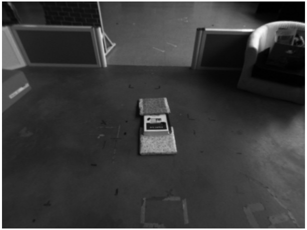

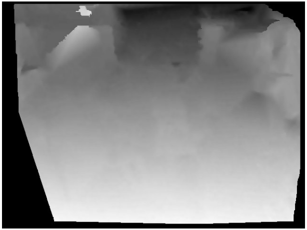

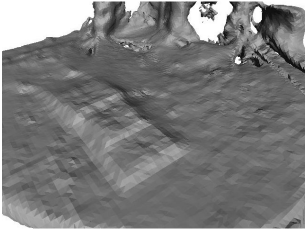

Torque control for some humanoid robots (HRP-2) is difficult to achieve

Torque control

- Torque control on a stiff-actuation robot
- Using end-effector force-torque sensors + IMU + encoders
- Efficient reconstruction of the motor torques
- Feedforward on the reconstructed torques (= friction compensation)
- Feedback on the force sensors (= perfect contact tracking)

[Del Prete, IJHR 2015]

Problems with the environment model

Noise in the localization

- Rigid robot are good to localize *locally*
- SLAM in large environment and use for planning is a challenge
- In general geometric environment are simple for planning
- Direct use of geometric models is sometimes preferable
- Noise due to foot landing and robot
- Replanning and fast control are necessary

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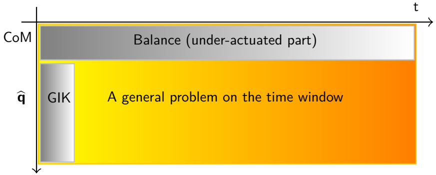
Contact and underactuation

$$\begin{cases} m(\ddot{\mathbf{c}} - \mathbf{g}) = \sum_{i=1}^{N_c} \mathbf{f}_i \\ m\mathbf{c}_\times(\ddot{\mathbf{c}} - \mathbf{g}) = \sum_{i=1}^{N_c} \mathbf{p}_{i\times}\mathbf{f}_i \end{cases}$$



Challenges in Multi-contacts locomotion

- The general template model includes Quadratic Constraint which can be concave
- The problem is NP-Hard with $\mathbf{c}$ or $\mathbf{f}$ as free variables
- Are the real problems that hard ?
- Open problem : real-time computation with $\mathbf{p}_i$ also free variables ?

Model-predictive control for 3D locomotion

- Fast optimal control for central-dynamics pattern generation
- Near real-time (80ms per cycle), ready for MPC
- Optimize the COM trajectory while keeping the angular momentum low
- On-going connection with the IMU+force sensor
- Submitted to ICRA 2016

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Conclusions and Perspectives

- Conclusions
  - Human environments are still very challenging due to symmetries, lack of textures, occlusion.
  - Including a-priori knowledge helps.
  - Real-time multi-contact based motion generation is difficult
  - Choosing from scratch new contact might be difficult unless candidates are already known.
- Perspectives
  - Efficient formulation might be found
  - Stochastique approach of control