Hierarchical inverse-dynamics-based whole-body controller for bimanual mobile manipulation tasks

In order to perform mobile manipulation tasks it is necessary to control all parts of the humanoid robot including the mobile base, both arms and its head. This is not a trivial task as joint limits and collisions must be avoided, task goals must be achieved while maintaining a proper posture. There exist two strategies to combine these goals: (1) soft and (2) hard hierarchies. In the latter, a strict priority ensures that the robot can be operated collision-free while trying to achieve the desired goal.

This then allows to e.g. perform challenging tasks such as grasping an object while moving the platform or performing a handover task where the robot receives a toolbox from a human that it must grasp with both hands.

Fig. 1: ARMAR-3 demonstrating a mobile manipulation task [2]

As part of the ArmarX cognitive architecture, a memory is used as a mediator between high-level planning and low-level control. The whole-body controller developed in this project should be part of the lower level. As such, it should be possible to store controller parameters and desired targets for the body parts within the memory.

In this work, you will investigate how to design and implement a hierarchical whole-body controller that is able to fulfill the demanded real-time capabilities. You will also be able to test and evaluate your approach in simulation as well as on the humanoid robot ARMAR-6.

Relevant research questions include:

- How can mobile base and end-effector motions be coupled by a whole-body controller to achieve complex mobile manipulation tasks?
- How can the scene be encoded to enable real-time capable collision checking?

This work will be implemented as a unified real-time controller in the ArmarX framework and tested on the humanoid robot ARMAR-6: The following software is required:

- ArmarX (C++): armarx.humanoids.kit.edu

Contact:
Fabian Reister (fabian.reister@kit.edu), Jianfeng Gao (jianfeng.gao@kit.edu)
Byungchul An (byungchul.an@kit.edu)

[1] Dietrich, Alexander, Kristin Bussmann, Florian Petit, Paul Kotyczka, Christian Ott, Boris Lohmann, und Alin Albu-Schäffer. „Whole-Body Impedance Control of Wheeled Mobile Manipulators: Stability Analysis and Experiments on the Humanoid Robot Rollin' Justin". *Autonomous Robots* 40, Nr. 3 (März 2016): 505–17. https://doi.org/10.1007/s10514-015-9438-z.

[2] Grotz, Markus, Peter Kaiser, Eren Erdal Aksoy, Fabian Paus, und Tamim Asfour. „Graph-Based Visual Semantic Perception for Humanoid Robots". In *2017 IEEE-RAS 17th International Conference on Humanoid Robotics (Humanoids)*, 869–75. Birmingham: IEEE, 2017. https://doi.org/10.1109/HUMANOIDS.2017.8246974.