Open Source Whole-Body Control Framework for Human-Friendly Robots

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***Abstract*— Whole-body operational space control is a powerful compliant control approach for robots that physically interact with their environment. The underlying mathematical and algorithmic principles have been laid in a large body of published work, and novel research keeps advancing its formulation and variations. However, the lack of a reusable and robust shared implementation has hindered its widespread adoption.**

To fill this gap, we present an open-source implementation of whole-body operational space control that provides runtime configurability, ease of reuse and extension, and independence from specific middlewares or operating systems. Our libraries are highly portable. Decoupling from specific runtime platforms (such as RTAI or ROS) is achieved by containing application code in a thin adaptation layer.

In this paper, we briefly survey the foundations of whole-body control for mobile manipulation, describe the structure of our software, very briefly present experiments on two quite different robots, and then delve into the bundled tutorials to help prospective new users.

EXTENDED ABSTRACT FOR SUBMISSION

Robot control foundations for physical interaction with objects and persons in everyday settings have been investigated for approximately three decades ([1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18]). In addition to advances in mechatronics (e.g. backdriveable actuation, effectively controllable torques), we now have mathematical and algorithmic foundations for creating human-like robotic motion skills (e.g. coordination, stiffness regulation, contact control).

The `stanford-wbc.sourceforge.net` project is based on the whole-body operational-space from the Stanford Robotics and AI Lab. It was released under the LGPLv3 open-source license to foster the use of these techniques in new applications. It relies on the adaptive hierarchical arrangement of operational space *tasks* into sensorimotor whole-body *skills*. A prioritized control structure provides dynamical decoupling: tasks are accumulated via null space projections to avoid interference. This control structure thus provides two orthogonal ways of influencing behavior, inside tasks or through hierarchy changes in the skill.

Fig. 1 depicts the main components of our framework. It separates mathematical foundations from runtime configurability in a platform-independent way. We support two types of end-users (control integrators and researchers) and provide data logging, parameter reflection, and online configuration. In an earlier paper [20] we have experimentally demonstrated that the software is mature enough for building a community of users and developers who can work on extensions and applications. In this paper, we focus on learning to use and extend the `stanford-wbc` software. Apart form more detailed descriptions of the class and object structures, we present the tutorials included in our software (e.g. Fig. 2).

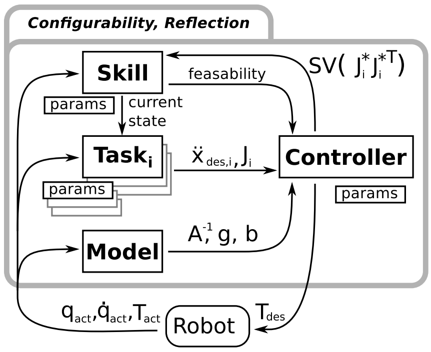

Fig. 1. Architectural overview of the Whole-Body Control software. SV stands for *singular values*, T_{des} is the desired joint-torque vector, and $\{q_{\text{act}}, \dot{q}_{\text{act}}, T_{\text{act}}\}$ are the actual joint positions, velocities, and torques. The rest of the notation is the same as in Algorithm **??**.

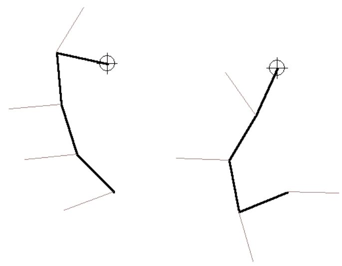

Fig. 2. Screenshots from the tutorials. The thick line is a planar robot arm, and the crosshair is the end-effetor. The thin lines indicate desired "posture" positions for each joint. Here, the posture is projected into the nullspace of an end-effector position task.

Robots that physically and safely interact with people and objects in everyday environments require mechatronics and control approaches that properly deal with forces and dynamics. The principles are understood, and current mobile manipulators demonstrate the technological feasibility. We believe that the remaining hurdle now lies in the complexity of the required models and the difficulty of producing reusable extensible software frameworks that provide advanced control methodologies. In combination with the `utaustin-wbc` operational-space extensions from UT Austin, our software is also embedded in the ROS `whole_body_control` stack. This makes our implementation readily available to a large community of roboticists for testing, use, and modification.

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