KARLSRUHE ICRA 2013 IEEE International Conference on Robotics and Automation

Workshop
Whole-body Compliant Dynamical Contacts for Humanoid Robotics

Organizers: S. Ivaldi, T. Petric, J. Babic, M. Mistry

http://www.codyco.eu/index.php/workshop-icra2013

Objectives

For complex systems, such as humanoid robots, to persist and act in natural environments like humans do, contact and physical interaction become necessary and unavoidable. Robots may exploit predictable contacts to aid in goal achievement, as well as learn dynamics of contact in order to generalize over novel tasks and domains. Critically, robots should also be robust enough to cope with unpredictable contacts, via safe control mechanisms and compliance.
The aim of this full-day workshop is to advance the current control approaches and understanding about robust, goal-directed whole-body motion interaction through multiple contacts. The goal is to get an accurate picture of the state of the art in whole-body control of dynamic tasks with contacts, the latest advances in this topic, and the challenges of the current research due to the limitations of the available humanoid platforms.
The workshop will bring together researchers in humanoid robotics, motion control, machine learning and safety in human-robot and robot-environment interaction.

Topics of interest

- Contacts planning and control
- Whole-body task control
- Compliant whole-body movements
- Dynamics in humanoid robots
- Machine learning and optimization methods for contact planning and control

Invited Speakers:

- Oussama Khatib (Stanford University, USA)
- Abderrhamane Kheddar (CNRS-AIST, Japan)
- Christian Ott (DLR, Germany)
- Jan Peters (Technische Universitaet Darmstadt, Germany)
- Ludovic Righetti (University of Southern California, USA & Max Planck Institute, Germany)
- Vincent Padois (ISIR, CNRS UMR 7222 & University Pierre et Marie Curie, Paris, France)
- Francesco Nori (Istituto Italiano di Tecnologia, Genova, Italy)
- Jaeheung Park (Seoul National University, Korea)

- Nicolas Mansard (LAAS/CNRS, France)
- Sang-Ho Hyon (Ritsumeikan University & ATR Computational Neuroscience Labs, Japan)

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Organizers

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Program

Time	Talk
8:45- 9:00	Introduction Serena Ivaldi, Tadej Petric, Jan Babic, Mike Mistry
9:00 – 9:30	**Whole-body motion with the iCub** Francesco Nori
9:30 - 10:00	**Unified preview control for humanoid postural stability and upper-limbs interaction adaptation** Vincent Padois
10:00 - 10:30	Coffee Break
10:30 – 11:00	**Hybrid Drive for Torque-Controlled Exoskeleton and Humanoid robots** Sang-Ho Hyon
11:00 – 11:30	**Machine Learning for Robotics** Jan Peters
11:30 - 12:00	**Active sensing strategies for contact with compliant whole-body control framework** Jaeheung Park
12:00 - 14:30	Lunch Break
14:30 – 15:00	**Multi-contact non-gaited planning: from contact points to motion** Abderrhamane Kheddar
15:00 - 15:30	**Exploiting and controlling contact interactions for locomotion and manipulation tasks** Ludovic Righetti
15:30 - 16:00	Coffee Break
16:00 – 16:30	**Constraint-Consistent Whole-Body Robot Formulation** Oussama Khatib
16:30 – 17:00	**Hierarchical Inverse Dynamics** Nicolas Mansard
17:00 – 17:30	**Extending nullspace compliance control to multiple hierarchical subtasks** Christian Ott
17:30 – 17:45	Discussion & conclusion Serena Ivaldi, Tadej Petric, Jan Babic, Mike Mistry
17 :45	End

Program details

Time	Talk
8:45- 9:00	**Introduction** Serena Ivaldi, Tadej Petric, Jan Babic, Mike Mistry
9:00 – 9:30	**Whole-body motion with the iCub** Francesco Nori *Recently the iCub humanoid has been equipped with legs derived from COMAN (Tsagarakis et al., 2011). Thanks to this improvement the iCub is able to stand while executing goal directed actions (e.g. reaching). This talk will discuss how this capabilities have been implemented in the iCub. First, we will formulate a graph version of the recursive Newton-Euler algorithm for computing whole-body dynamics in presence of whole-body distributed tactile and force/torque. Second, we will investigate how to improve the whole-body dynamics computations via parameter identification. Finally, we will discuss some recent experiments on whole-body motion and force control in presence of multiple contacts.*
9:30 - 10:00	**Unified preview control for humanoid postural stability and upper-limbs interaction adaptation** Vincent Padois *This work proposes a robust whole-body control formulation for biped balance in disturbed conditions by manipulation tasks. In order to include the effects of the interaction of the robot with its environment, required by the manipulation task in the balance control, we introduce a distributed preview control which captures both balance and manipulation behaviors and enables the regulation of the interaction impedance. The initial ZMP preview control is extended to take into account the disturbance resulting from the manipulation task and the preview control of adaptive impedances used to drive the upper-limbs. The resulting behavior is illustrated in a simple scenario. Its aptitude to dynamically extract an optimal control strategy improving tracking performances of both manipulation and balance tasks is also assessed when complex perturbations have to be compensated for.*
10:00 - 10:30	Coffee Break
10:30 – 11:00	**Hybrid Drive for Torque-Controlled Exoskeleton and Humanoid robots** Sang-Ho Hyon *Torque control is the key technology for both humanoid robots and exoskeleton robots because it allows human-friendly assist control and natural interaction with environment. However, selection of torque-controlled actuator is not easy because lightweight, high load capacity and high response are usually difficult to obtain at the same time. We propose to combine pneumatic rubber muscles with small servomotors to meet these demands simultaneously. We present its high potential by presenting contact force control experiments on our first and second prototype of hybrid-drive exoskeleton robots.*
11:00 – 11:30	**Machine Learning for Robotics** Jan Peters
11:30 - 12:00	**Active sensing strategies for contact with compliant whole-body control framework** Jaeheung Park

	During the operation of humanoid robots in various situations, it requires to perform tasks under multiple contacts. In such situations, it is important not only to have robot control strategies under multiple contacts but also to have the precise knowledge about the contact. In this talk, first, it will be briefly introduced the whole body control framework that utilizes contact forces. Then, active contact sensing strategies will be presented, which use kinematic constraints and compliant motion control. During active sensing, the robots in fact interact with unknown environment. Therefore, compliant motion control is applied not to lose the contacts without damaging the robot or the environment. Then, kinematic constraints are exploited to reason about the environment. The examples of the implementation of active contact sensing algorithms will also be presented.
12:00 - 14:30	Lunch Break
14:30 – 15:00	**Multi-contact non-gaited planning: from contact points to motion** Abderrhamane Kheddar *This talk sums up our main achievements together with limitations in planning multi-contact non-gaited motion with humanoid robots and their dynamic motion achievement without model reduction; that is to say, considering all the degrees of freedom with limitations, constraints, together with multi-contact non-gaited transitions. We describe recent results in the way we resolve multi-contact locomotion and manipulation tasks under a single planning framework, illustrating the obtained results with simulation examples involving humanoid robots and some tasks borrowed from the DARPA challenge. On-going and future works related to this issue are also discussed.*
15:00 - 15:30	**Exploiting and controlling contact interactions for locomotion and manipulation tasks** Ludovic Righetti *We expect robots to be able to perform complex tasks that involve at the same time locomotion and manipulation skills (it might be necessary to grasp parts of the environment to cross a difficult terrain and to maintain balance on the tip-toes while reaching for an object of interest). In all these scenarios, robots will have to perform tasks in constant interaction with an uncertain and changing environment. In this presentation, I will show our recent results towards exploiting and controlling contact interaction in both locomotion and manipulation tasks. We designed model-based motion controllers that are able to exploit torque redundancy to optimally distribute forces among multiple contact points. Such approaches can be exploited to build robust balance and locomotion controllers as can be seen in our experimental results. Finally, I will present some of our latest results on compliant manipulation, where we exploit contact interactions to simplify and improve dexterous manipulation tasks.*
15:30 - 16:00	Coffee Break
16:00 – 16:30	**Constraint-Consistent Whole-Body Robot Formulation** Oussama Khatib
16:30 – 17:00	**Hierarchical Inverse Dynamics** Nicolas Mansard *The operational-space inverse dynamics can be written as a linear optimisation program and solved by off-the-shelf solver. On the other hand, when several constraints and motion objectives have to be accomplished simultaneously, a way to handle conflicts in the multi-objective problem is*

	to rely on a hierarchy. Both methods have their advantages and drawbacks. We have proposed a hierarchical optimisation solver that enables the resolution of linear programs within a hierarchical order. In particular, it is possible to take into account directly in the solver inequality constraints on the joint position, velocity, acceleration or torques, or constraints on the contact forces. This inverse-dynamics scheme has been used in several demonstrations that will be presented and discuss. The presentation will open the discussion on the on-going implementation of this scheme on the humanoid robot HRP-2.
17:00 – 17:30	**Extending nullspace compliance control to multiple hierarchical subtasks** Christian Ott *The control of humanoid robots involves the coordination of a large number of degrees of freedom. Often it is of interest to simultaneously handle several tasks (like manipulation, balancing, collision avoidance, etc...) with different priority. While general control approaches for physical interaction require the measurement of external forces acting on the robot, it is well known that in compliance control without inertia shaping the measurement of external forces can be avoided. It has been shown that by choosing a proper set of dynamically consistent null space velocities, one can still achieve a partial decoupling of a main task and its null space dynamics. This can be utilized in the design of feedback controllers. In this talk we will present some recent results, which allow to extend this idea to compliance control of multiple hierarchical subtasks. An appropriate dynamics formulation will be presented, which incorporates a partial decoupling of the energetic behavior at the different task hierarchy levels. Based on this dynamics formulation, prioritized null space compliance controllers can be implemented, which allow a formal proof of the closed loop stability.*
17:30 – 17:45	**Discussion & conclusion** Serena Ivaldi, Tadej Petric, Jan Babic, Mike Mistry