I.AM.

IMPACT-AWARE MANIPULATION FOR LOGISTIC ENVIRONMENTS

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TU/e EPFL TUM cnrs Algoryx FRANKA EMIKA SMART ROBOTICS MASTERS IN FLEXIBLE AUTOMATION VANDERLANDE

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About me

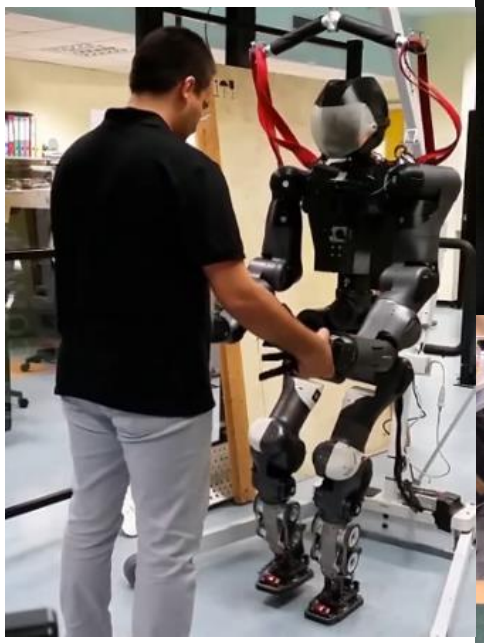
Postdoc at CNRS-LIRMM in Montpellier, France

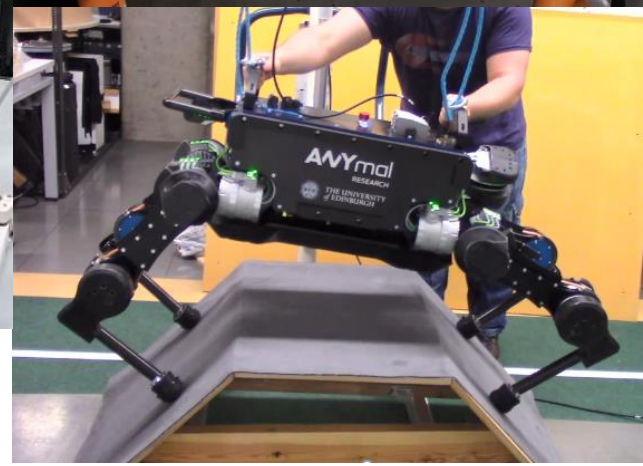
Research Interests

- Model-based Whole-Body Control
- Interaction through Forces
- Redundant Robots & Multi-Robot Systems

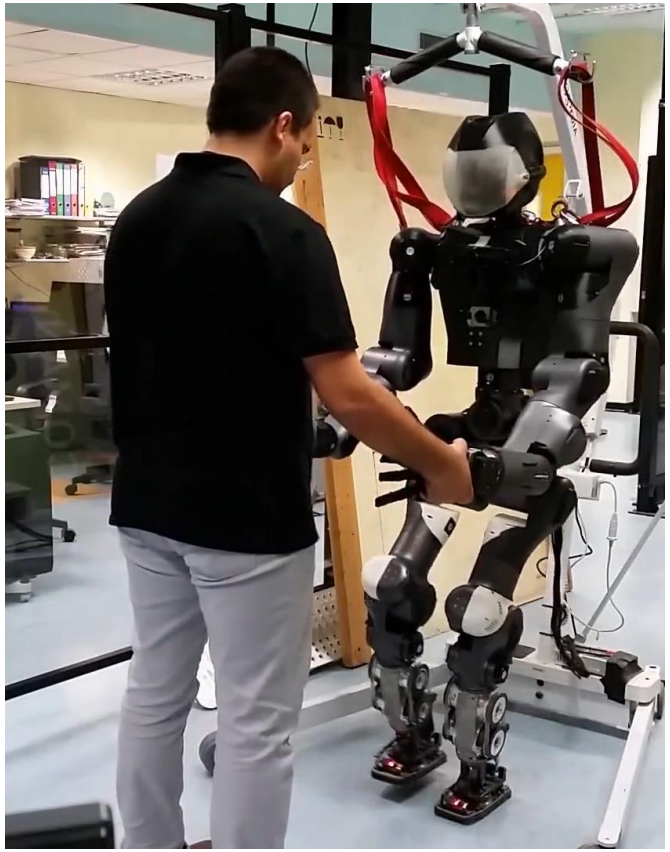
ROBOTS WITH A SENSE OF TOUCH

- Admittance/Impedance-control for human-robot interaction
- Exploiting contact forces for intention detection & adaptive control
- Torque-controlled robots enable impact / collision detection
- Next step: How to exploit impacts with existing robots?



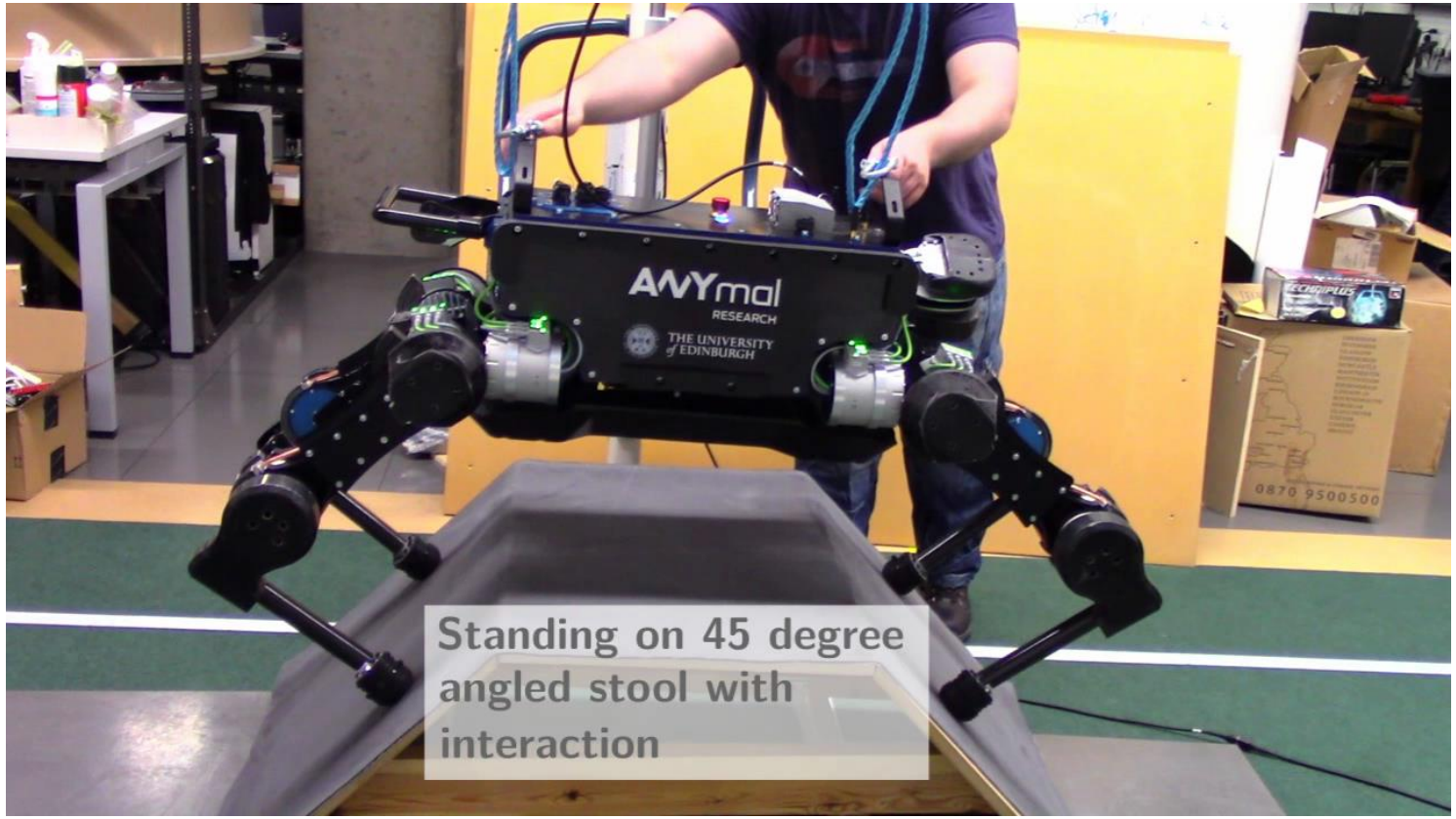


EXAMPLE: HUMAN-GUIDED ROBOT WALK



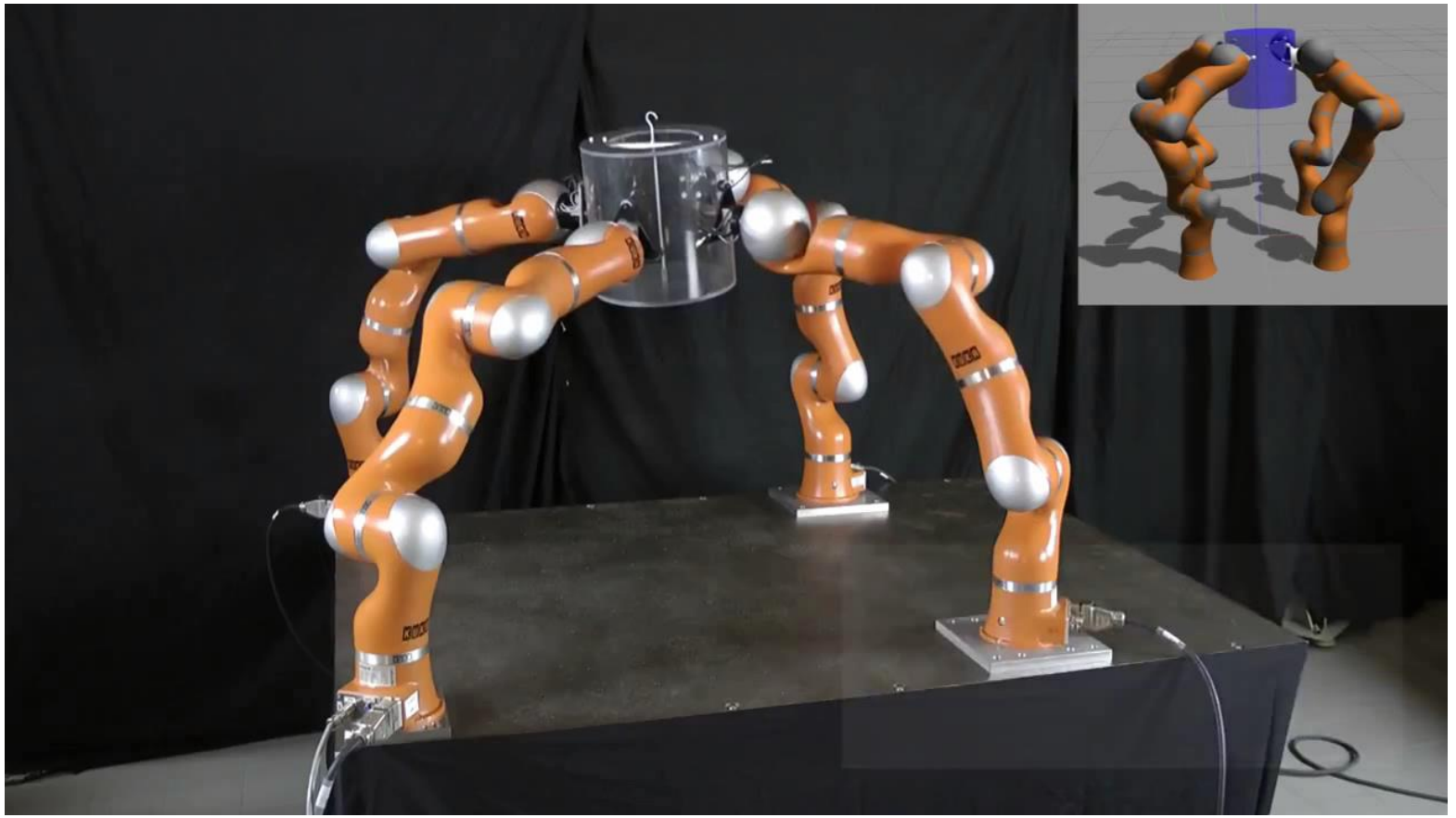
P. Mohammadi et al (RAM, 2019) „Compliant Humanoids Moving Toward Rehabilitation Applications“.
Video: https://youtu.be/v2zFpngoe_Q

EXAMPLE: BALANCING WITH A QUADRUPED



N. Dehio et al (ICRA, 2018) „Modeling and Control of Multi-Arm and Multi-Leg Robots: Compensating for Object Dynamics during Grasping". Video: https://youtu.be/Ao-0W9chAd4

EXAMPLE: COLLABORATIVE OBJECT HANDLING



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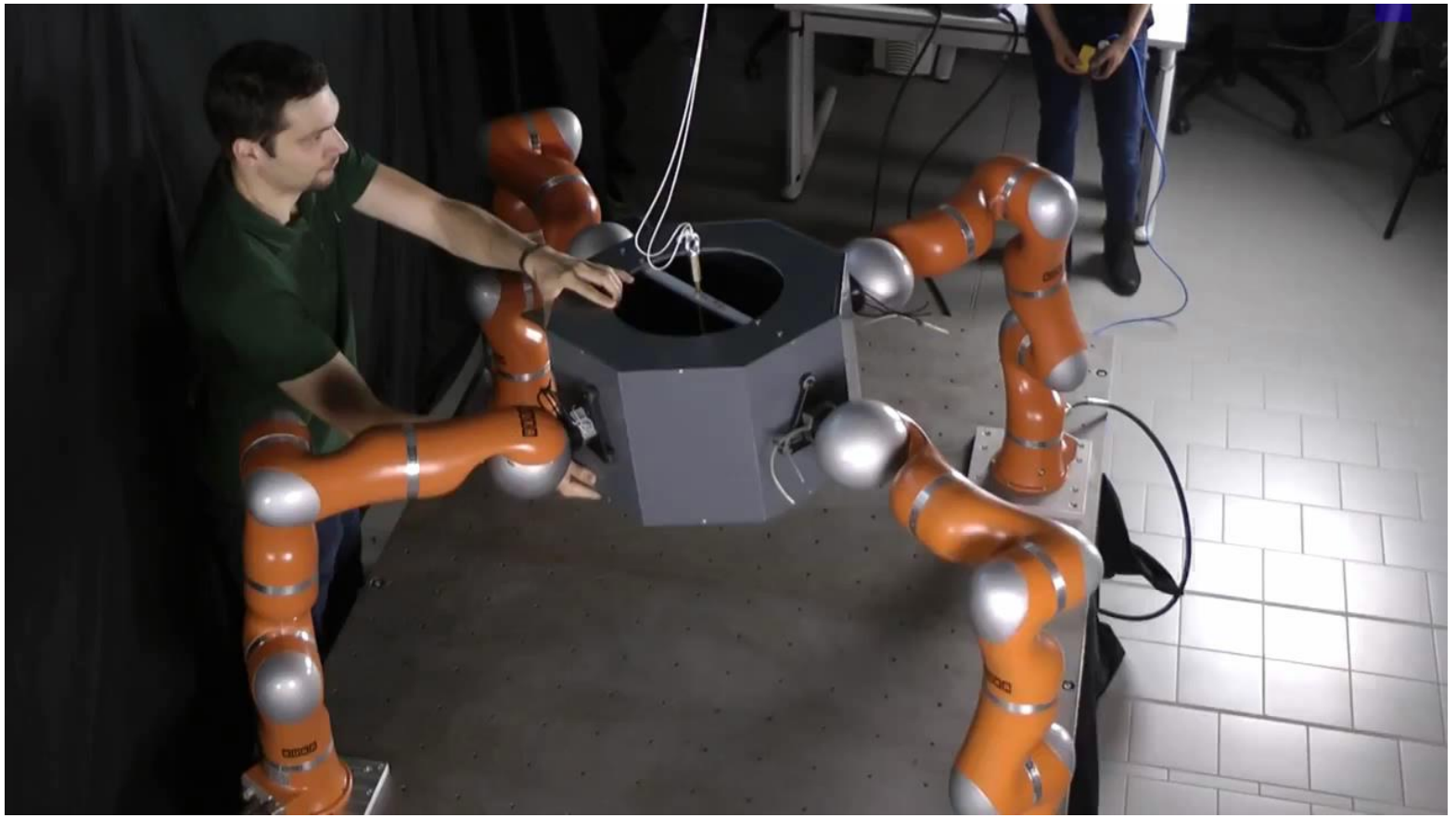

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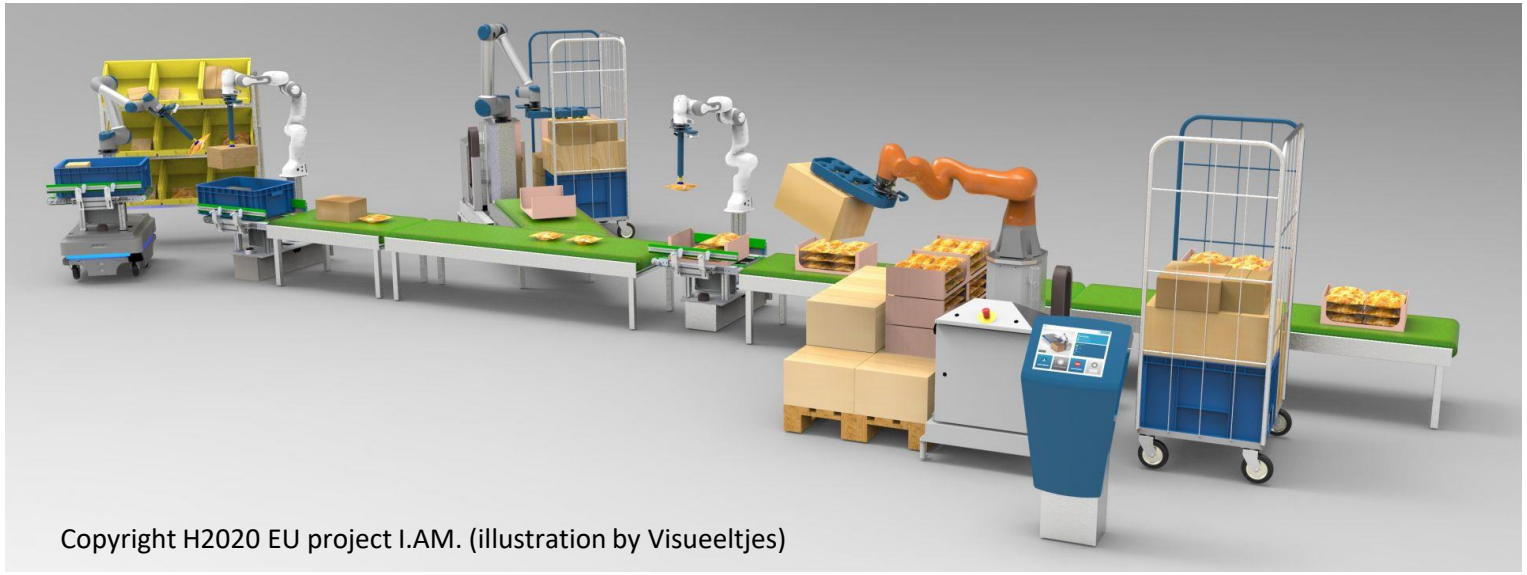
MOTIVATION

Providers of process automation for logistics are seeking for new technologies to reduce the cycle time of take-and-put operations using robots.



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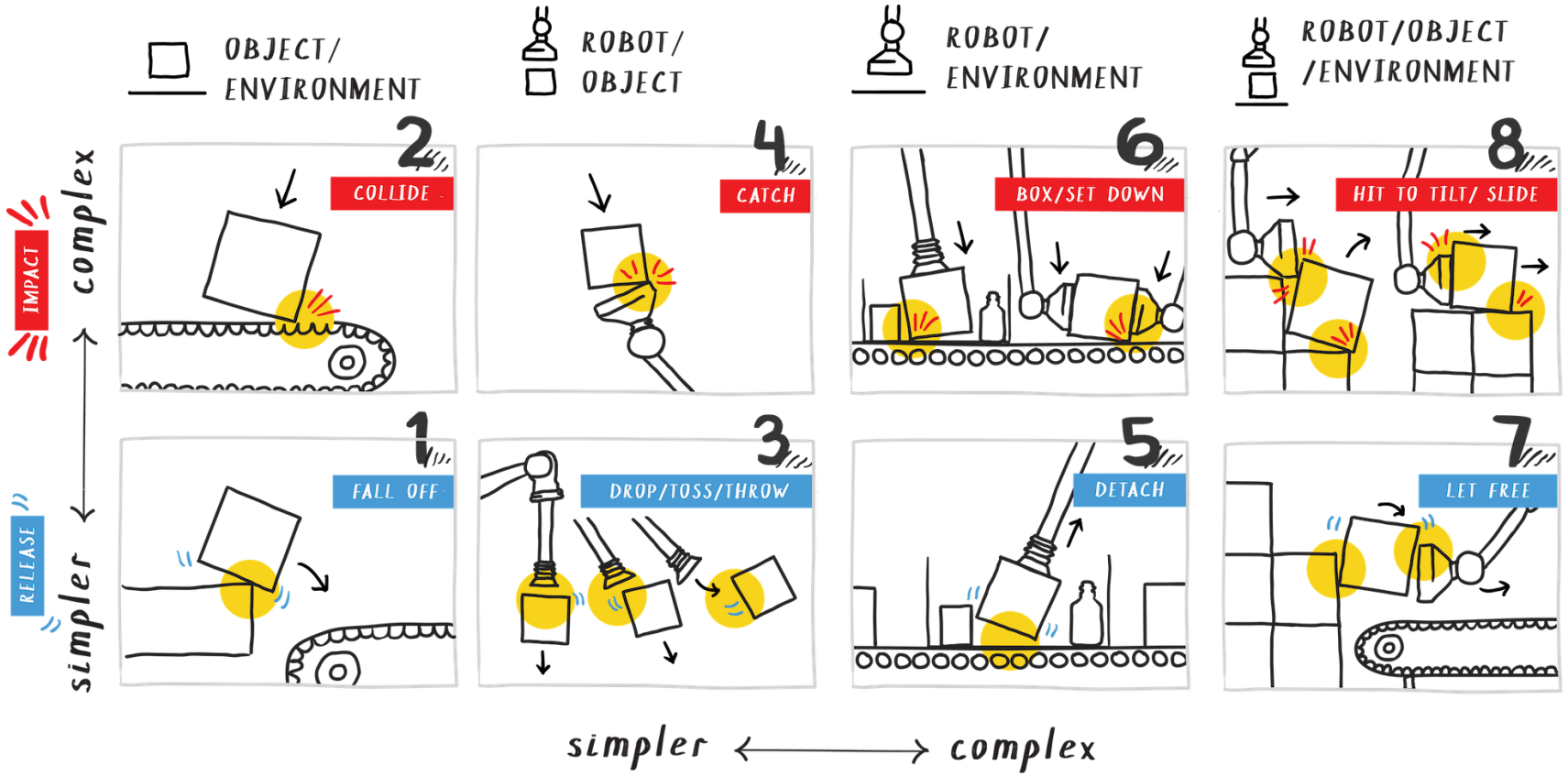
IMPACTS IN LOGISTIC ENVIRONMENTS



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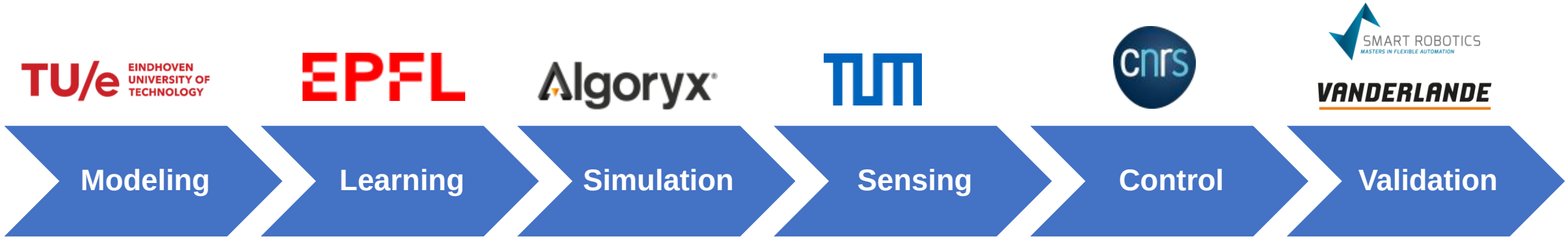
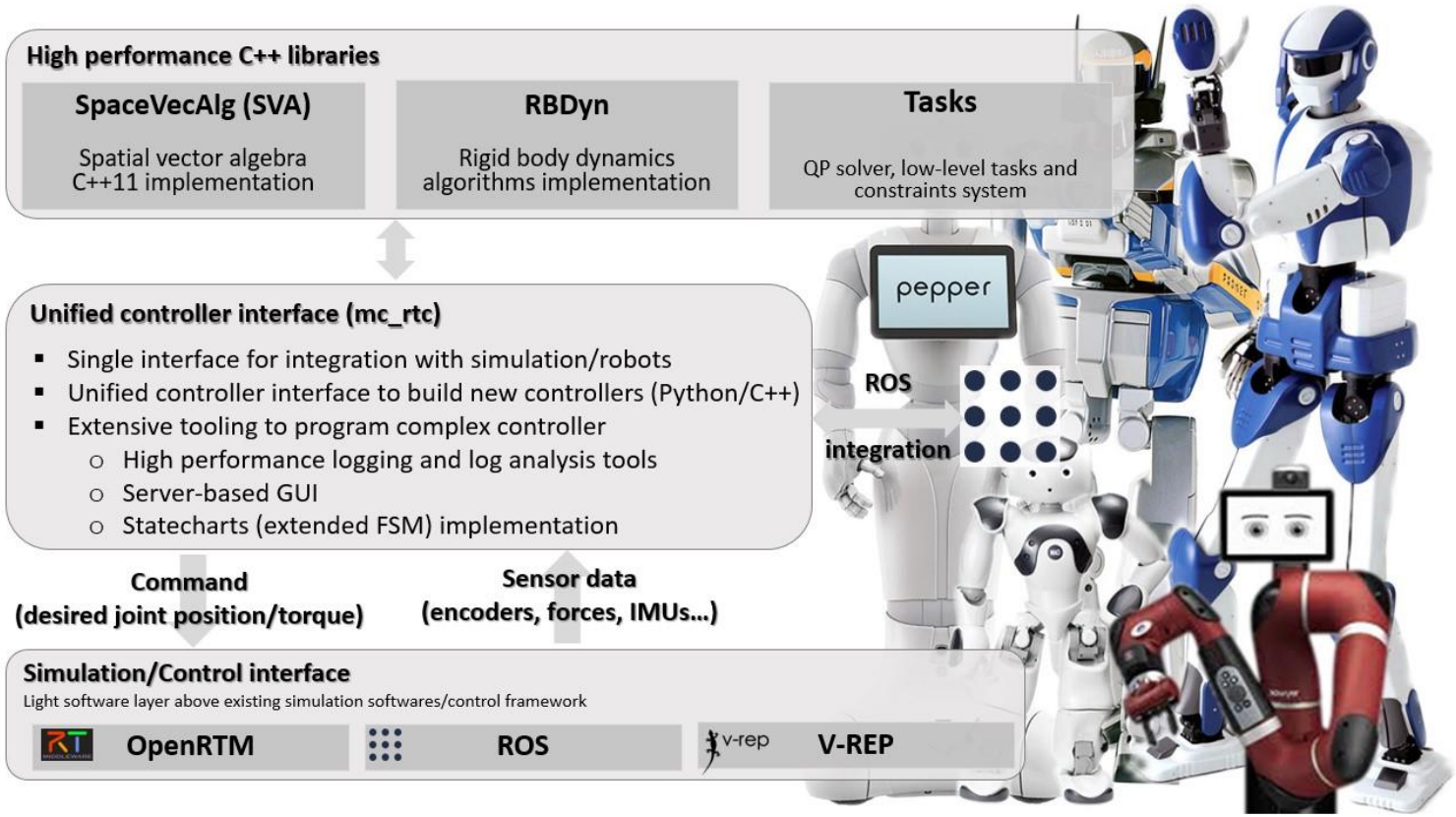
WHAT IS IMPACT-AWARE MANIPULATION?



CHALLENGES

- Avoiding hardware damage
- Nonsmooth dynamics, discontinuities
- Impact propagation on robot structure (including floating-base)
- Integration of shock-absorbing, deformable materials
- …

OPEN SOURCE SOFTWARE FRAMEWORK MC_RTC



Available: https://jrl-umi3218.github.io/mc_rtc

OPEN SOURCE SOFTWARE FRAMEWORK MC_RTC

- Single interface to write a controller
- Even more extensible by plugins
- High-level tasks (e.g. force control, visual servoing, whole-body stabilization)
- Controller logging facilities
- GUI for interactive control and monitoring
- Extensible state-charts facilities

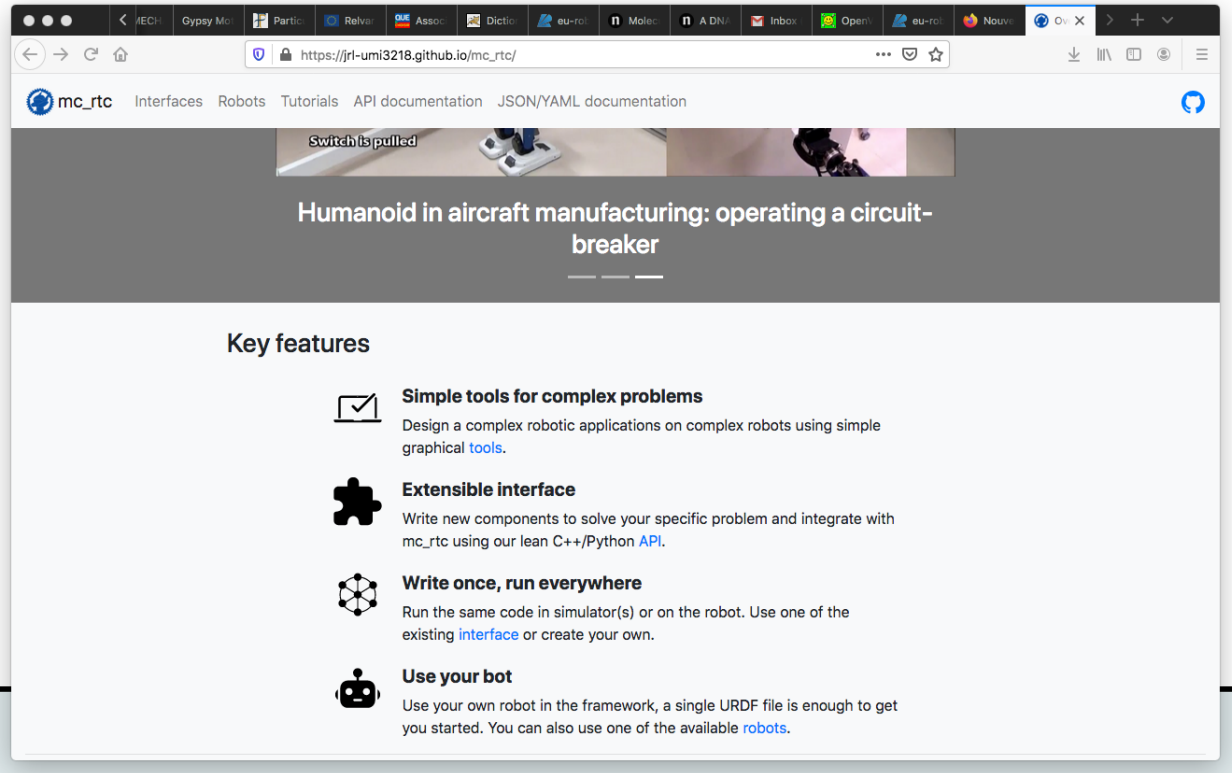
Available: https://jrl-umi3218.github.io/mc_rtc

OPEN SOURCE SOFTWARE FRAMEWORK MC_RTC

Everything available at: https://github.com/jrl-umi3218/mc_rtc

Operating systems

- Linux
- MacOS
- Windows



IMPACT-AWARE QP-CONTROL

At impact, a QP can become unfeasible at the next iteration because of state jumps

Problem

- Impact location is difficult to plan
- Impact timing is difficult to plan

J. Wang et al (2020) "Impact-Aware Task-Space Quadratic-Programming Control"

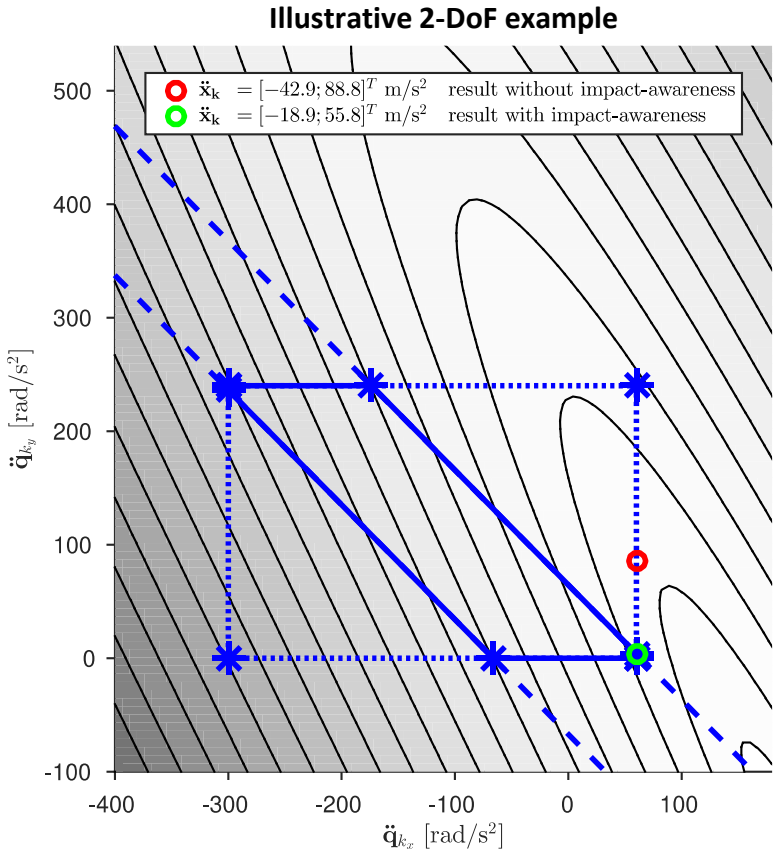
IMPACT-AWARE QP-CONTROL

At impact, a QP can become unfeasible at the next iteration because of state jumps

Approach

- Always assume impact in the next iteration
- Use impact model to predict state jumps
- Formulate constraints for post-impact states
- Let the QP determine the maximum velocity for desired impacts

-> Can be seen as a 1-iteration MPC



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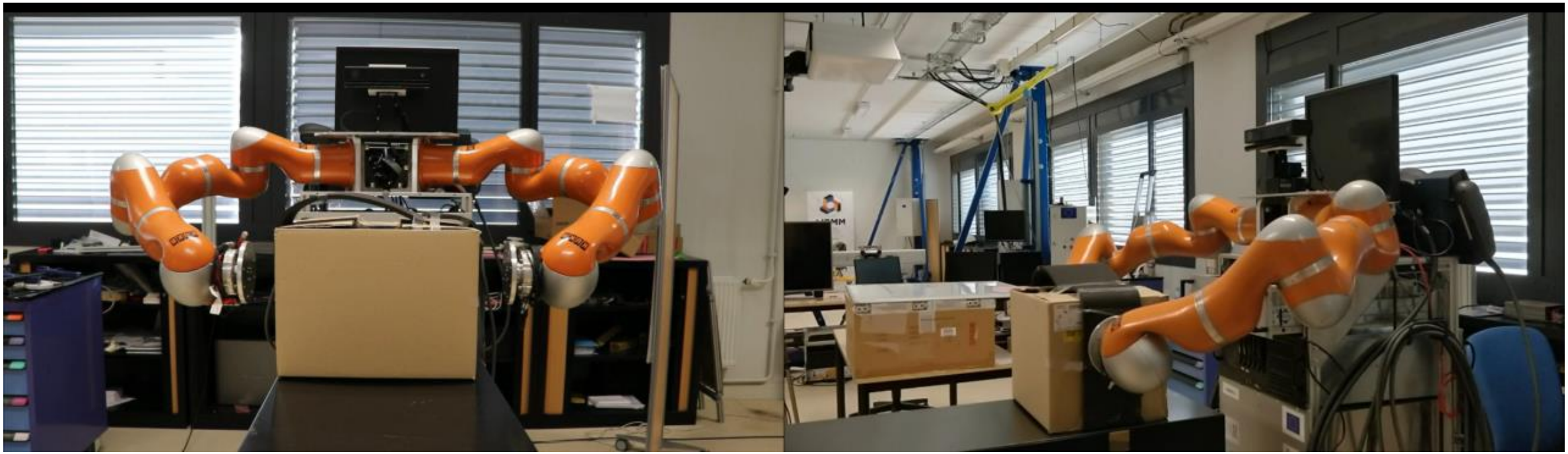
IMPACT-AWARE QP-CONTROL



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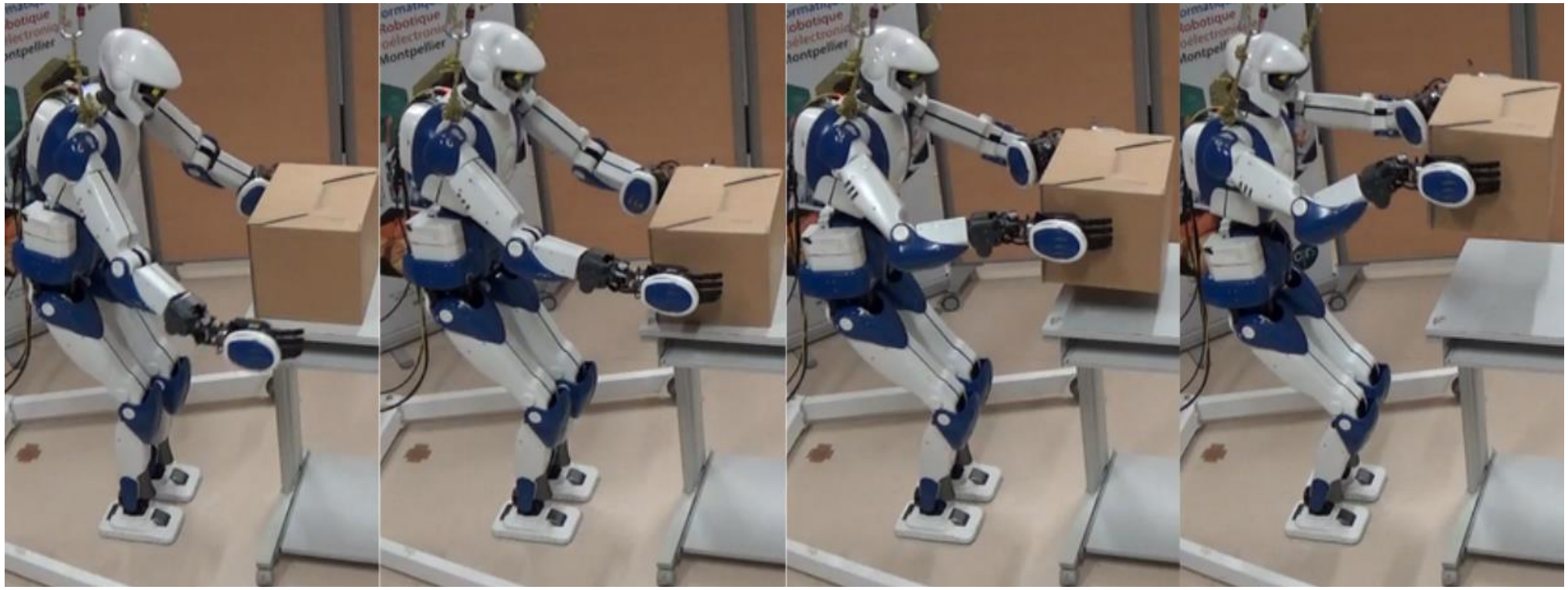

J. Wang et al (2020) “Impact-Aware Task-Space Quadratic-Programming Control”.
Video: https://youtu.be/v1Jfy8-jiwE

IMPACT-AWARE QP-CONTROL

No knowledge needed for…

- Exact contact localization
- Exact impact timing
- No need of reset map

-> Approach applies to existing, rigid robots

J. Wang et al (2020) "Impact-Aware Task-Space Quadratic-Programming Control"

https://arxiv.org/abs/2006.01987

Impact-Aware Task-Space Quadratic-Programming Control

Yuquan Wang, Niels Dehio, Arnaud Tanguy, and Abderrahmane Kheddar

SAGE

Abstract

Generating on-purpose impacts with rigid robots is challenging as they may lead to severe hardware failures due to abrupt changes in the velocities and torques. Without dedicated hardware and controllers, robots typically operate at a near-zero velocity in the vicinity of contacts. We assume knowing how much of impact the hardware can absorb and focus solely on the controller aspects. Hybrid controllers with reset maps provided elegant solutions for given impact tasks. The novelty of our approach is twofold: (i) it uses the task-space inverse dynamics formalism that we extend by seamlessly integrating impact tasks; (ii) it does not require separate models with switches or a reset map to operate the robot undergoing impact tasks. Our main idea lies in integrating post-impact states prediction and impact-aware inequality constraints as part of our existing general-purpose whole-body controller. To achieve such prediction, we formulate task-space impacts and its spreading along the kinematic and potentially arborescent, structure of a floating-base robot with subsequent joint velocity and torque jumps. As a result, the feasible solution set accounts for various constraints due to expected impacts. In a multi-contact situation of under-actuated legged robots subject to multiple impacts, we also enforce the dynamic equilibrium margins. By design, our controller does not require precise knowledge of impact location and timing. We assessed our formalism with the humanoid robot HRP-4, generating maximum contact velocities, neither breaking established contacts nor damaging the hardware.

Keywords

Task-space control, quadratic optimization control, humanoids, impact tasks.

1 Introduction

In robotics, instantaneous impacts occur when robots make contact – intentionally or accidentally – at relatively high velocities (cf. Fig. 1). Impacts may cause high impulsive forces and velocity jumps at the contacting surfaces. Impact energy and jumps propagate through the robot's links in the joints, which might cause severe mechanical damage. Abrupt changes in velocity or torque mean discontinuities that may destabilize closed-loop controllers. Floating-base robots can also witness sudden breaks of pre-existing unilateral contacts resulting in a sudden loss of balance.

When possible, a simple solution is to plan and control new contacts carefully with near-zero contact admissible velocities. Otherwise, new contacts are made with relatively high velocities, e.g., walking or jumping humanoids. In this case, the robot continuous dynamic equations of motions are not a good match for the induced physics, and another set of equations must be considered together with a transition policy (called reset maps), see a review in Sec. 2. Such a transition policy requires knowledge of additional parameters that depend on the environment (and robot) stiffness, the impact model, the impact localization on the robot (and the environment), the contact normal, the exact impact time, and even more. Acquiring *in-situ*, instantaneously, and reliably these parameters are not always possible in practice.

In fact, a large part of handling properly robotic impacts must be tackled first from a hardware design perspective, see the introductory part of Sec. 2. It is t

Figure 1. In this schematic sketch, a humanoid robot is impacting a wooden piece as we can commonly find in karate. In stance (a), there are $m_1 = 2$ established contacts (red), $m_2 = 0$ impacting end-effectors (green), and $m_3 = 2$ free limbs (yellow). Stance (b) is represented by $m_1 = 2, m_2 = 1, m_3 = 1$ and stance (c) by $m_1 = 3, m_2 = 0, m_3 = 1$.

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Y. Wang and A. Kheddar are in part with the Beijing Institute of Technology, Beijing, China.

arXiv:2006.01987v1 [cs.RO] 3 Jun 2020

IMPACT DATA COLLECTION

Which data are you interested in?

- Joint encoders
- Force plates
- IMUs
- Motion capture
- High-speed camera
- …

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