Physical human-robot interaction with the OpenPHRI library

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OpenPHRI is a C++/Python software with several built-in safety measures, designed to ease robot programming for physical human-robot interaction (pHRI) and collaboration (pHRC). Aside from providing common functionalities, the library can be easily customized and enhanced, thanks to the project's open source nature. The library is distributed online[1] free of charge under the GNU LGPLv3 license[2]. OpenPHRI is written in C++ to maximize efficiency in terms of computation and memory footprint and to easily embed it in existing projects. Python bindings are also provided, since this language is largely used in the robotics community. An interface with the robotics simulator V-REP[3] is also provided.

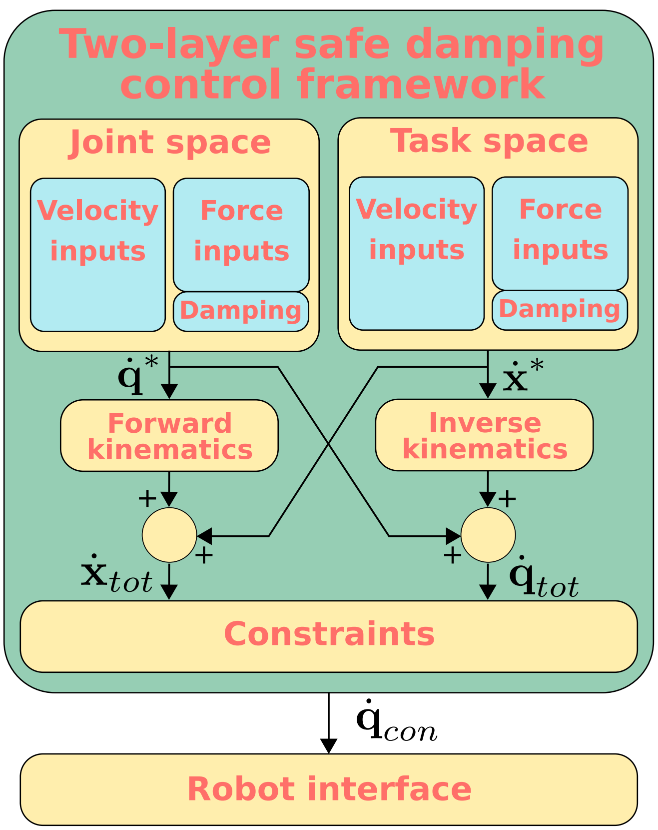

Fig. 1: Overview of the OpenPHRI framework. Its core components are: *force inputs*, *velocity inputs*, and *constraints*.

[1]https://github.com/BenjaminNavarro/OpenPHRI
[2]https://www.gnu.org/licenses/lgpl-3.0.en.html
[3]http://www.coppeliarobotics.com

The framework consists in a two-layer damping controller depicted in figure 1. Damping control is a particular case of impedance control [1], which makes the robot act as a mass-spring-damper system. Although impedance control proved useful for complying with interaction forces while following a predefined trajectory, it can be extended to fit many more scenarios. We design a more generic controller that includes real or virtual *force inputs* and *velocity inputs*. In this work, the focus has been on :

- real forces exchanged with the human or environment,
- virtual mass and stiffness forces (generating inertial and elastic effects),
- virtual forces repelling away from obstacles,
- velocities generated by a trajectory generator,
- velocities output by a force controller.

To reduce the velocity in unsafe situations, we add constraints, that determine the value of a *velocity scaling factor*. If multiple constraints are active at the same time, the most restrictive one, i.e. the one leading to the lowest velocity, will be chosen. This makes sure that all the constraints are satisfied at any given time.

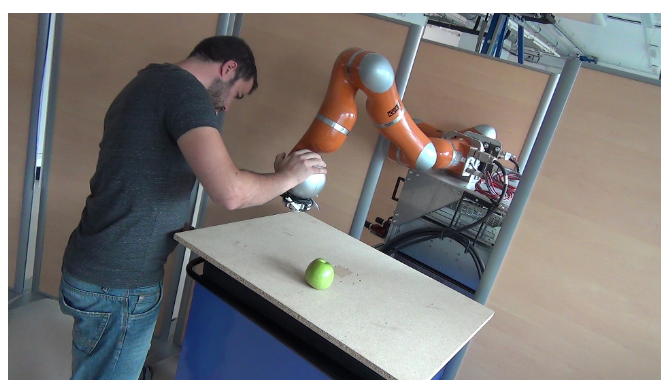

Fig. 2: Setup for the experiment.

In less than 35 lines of code one can set up a V-REP scenario where a serial manipulator robot Kuka LWR4+ is moved with an external force applied, while limiting its velocity, reading sensory input, and sending joint commands to the simulator. See Fig. 2 and video available at: http://bit.do/openphrivideo

For further details on OpenPHRI, the reader should refer to [2].

How the Proposed Work Addresses the Workshop's Research Questions

1) How can a robot understand operator's actions, intentions and eventually her/his physical and mental status?
   In this work, we mainly use force sensing to transmit the operator intentions to the robot. In other works from our group, we have used vision, tact, and muscular (EEG) as well as brain (BCI) activity.
2) What should a robot do to make its behaviour understandable by the operator, therefore enforcing a sense of trust?
   The robot motion should be smooth and predictable. For this, OpenPHRI also relies on a trajectory generator, detailed in [2].
3) How much information should the robot provide to the operator? What means of communication should the robot use?
   For now, only motion and stiffness are used in OpenPHRI. In our opinion, audio also provides an interesting means of communication, although it has been seldom studied in the pHRI literature.
4) How much information does the robot need from the operator? What are the best ways to represent such knowledge?
   See reply to 1.
5) How can a non-expert operator communicate with the robot in a natural manner?
   Audio, vision and touch appear as the most promising means for intuitive human-robot communication.

Acknowledgments

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References

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[2] B. Navarro, A. Fonte, P. Fraisse, G. Poisson, A. Cherubini, "OpenPHRI: an open-source library for safe physical human-robot interaction", *IEEE RAS Robotics and Automation Magazine, Special Issue on Human-robot collaboration for production environments*,2018 (to appear).