# Towards a Third Hand

Rudolf Lioutikov, Oliver Kroemer, Guilherme Maeda and Jan Peters

Technische Universitaet Darmstadt, Intelligent Autonomous Systems
Hochschulstr. 10, 64289 Darmstadt, Germany
{lioutikov, kroemer, maeda, peters}@ias.tu-darmstadt.de

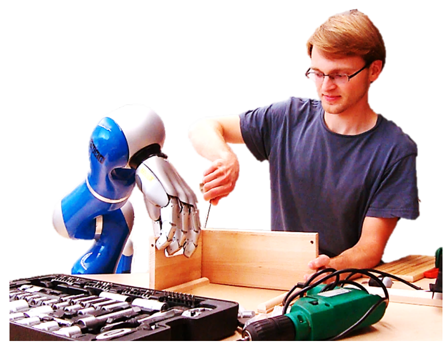

**Fig. 1.** Illustration of a human-robot collaboration. The robot assists the human in an assembly task and acts as a "3rd Hand".

Robots in industrial manufacturing are usually programmed to repeatedly perform a fixed set of movements in an identical manner. However, rapidly changing product lines and the need for fast development and prototyping of new products combined with the expensive re-programming of such robots, demand a paradigm shift in industrial robotics. Robots in modern industry have to perform multiple tasks and must adapt to dynamic environments and changes in the executed task. In addition robots should be able to learn from human demonstrations in order to eliminate the costs of re-programming. Ideally the instructor should be allowed to teach the robot similarly to a novice co-worker. By teaching the robot personally, the robot adapts to the specific work flow of the worker and actively increases the productivity, thus the robot would act as a personalized assistant.

In order to achieve such a behavior, novel algorithms and frameworks in areas such as computer vision, relational reinforcement learning, human-robot interaction and motor skill learning are needed. A project combining those areas and aiming to make significant advances towards semi-autonomous human-robot interaction tasks is the 3rd Hand project. The project consists of researchers from the University of Innsbruck, Inria Bordeaux, the University of Stuttgart and the Technical University of Darmstadt.

The goal of creating a framework for a semi-autonomous robot platform, will lead to a new type of manufacturing where human workers are not replaced, but instead empowered by robots. The human-robot interaction allows the worker to train the robot such that the worker can use the robot as a 3rd-Hand in order to increase their own productivity, as illustrated in Figure 1.

This human-robot collaboration represents a new robotics paradigm, opening the door for robots, that can be programmed and commanded by interactions and instructions. They are capable of skill self-assessment, which allows them to determine how certain they are about applying a skill and request additional demonstrations when necessary. Additionally an explicit model of the team behavior enables them to select a skill depending on the action of the worker.

Under those principles the robot platform is expected to learn hierarchical and cooperative tasks from demonstrations, learn from instruction as opposed to traditional programming methods, and find relevant connections between different situations to transfer knowledge between tasks and environments.

The newly developed methods will enable robots to extend their repertoire of interaction skills, without extensive effort for the worker. The robot will learn when and how to assist its interaction partner in their task.

In order to demonstrate the efficiency and the potential of such a robot-platform we will evaluate it on a collaborative assembly task of an IKEA-like shelf, where the robot acts as a semi-autonomous 3rd hand.

As a first step in the project we introduced the SL_robcom framework and showed the potential of sequencing dynamical movement primitives in order to achieve complex tasks [1].

The collaboration and integration of the individual groups will be mostly implemented by using the widespread robot operating system (ROS). At the same time the robot should guarantee reliable real time behavior. A system which has proven itself numerous times under the strict real-time constraints, is the Simulation Laboratory (SL). In order to combine these two systems we introduce the SL_robcom framework which extends SL and offers client APIs, which are also implemented in ROS. A simple Illustration of SL_robcom is given in Figure 2.

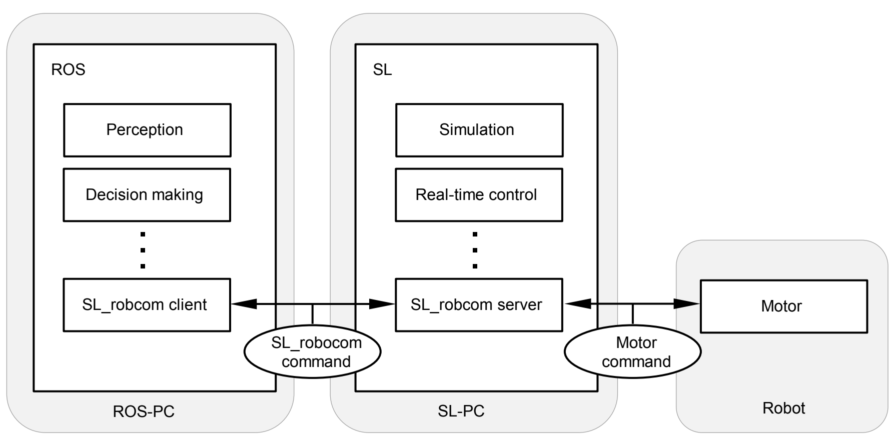


**Fig. 2.** Simplified illustration of the system architecture applied in this work.

Flexibility and adaptability are crucial properties for a semi-autonomous robot platform. These properties can be achieved by sequencing several small sub-tasks in order to achieve a complex task. Each of those sub-tasks can be represented by a movement primitive (MP). A widely applied choice for the encoding of movements are dynamical movement primitives (DMPs), see [2]. The sequencing of MPs is illustrated in Figure 3. One particular property of DMPs is the ability to easily generalize to different goal states. This allows them to modify a task, where each sub-task is slightly different from the original demonstration, while the overall task appears mostly similar. A single DMP trained for the entire task would not allow such flexibility. In previous work we successfully evaluated the capabilities of the sequencing of DMPs on a complex bi-manual cutting task [1].

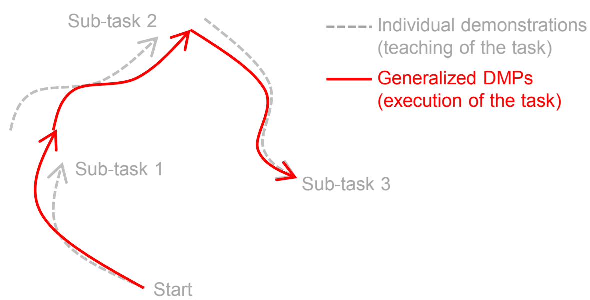


**Fig. 3.** Sequence of demonstrated steps where each step is encoded by a DMP.

However, the sequencing of movement primitives is not limited to DMPs. Different representations might offer characteristics which are even better suited for the interaction with humans. It is therefore important to identify beneficial and suitable properties of other representations with respect to human-robot collaborations, which might lead to the combination and the development of new primitives.

Independent of the actual choice of movement primitives a major issue with respect to sequencing MPs is the acquisition of the segments which represent the sub-tasks. So far the segments where defined manually, which appears reasonable but nevertheless increases the workload of the interaction partner. A semi-autonomous robot should be able to automatically segment an entirely demonstrated task. This is a non-trivial problem which has so far not been widely addressed. The automated segmentation can be used to identify similarities between different tasks, and therefore allow the robot to adapt during one task in a way it learned during a different task. The possibility to automatically detect and reuse segments from complex tasks allows to train and maintain a skill library which improves the adaptability and flexibility of the robot.

## References

1. Lioutikov, R., Kroemer, O., Peters, J., Maeda, G.J.: Learning manipulation by sequencing motor primitives with a two-armed robot. In: Proceedings of the 13th International Conference on Intelligent Autonomous Systems (IAS). (2014)
2. Ijspeert, A.J., Nakanishi, J., Hoffmann, H., Pastor, P., Schaal, S.: Dynamical movement primitives: learning attractor models for motor behaviors. Neural computation **25**(2) (2013) 328–373