# SAPHARI

SAFE AND AUTONOMOUS PHYSICAL HUMAN-AWARE ROBOT INTERACTION

SEVENTH FRAMEWORK PROGRAMME

COGNITIVE SYSTEMS & ROBOTICS

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## Deliverable 2.4.1

# *Prototypes of safe and interactive tools and hardware safety concept of workspace*

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| R = Report<br>P = Prototype<br>D = Demonstrator<br>O = Other | PU = Public<br>PP = Restricted to other programme participants (including the Commission Services)<br>RE = Restricted to a group specified by the consortium (including the Commission Services)<br>CO = Confidential, only for members of the consortium (including the Commission Services) |

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# Safe Gripper Design

## Previous Work

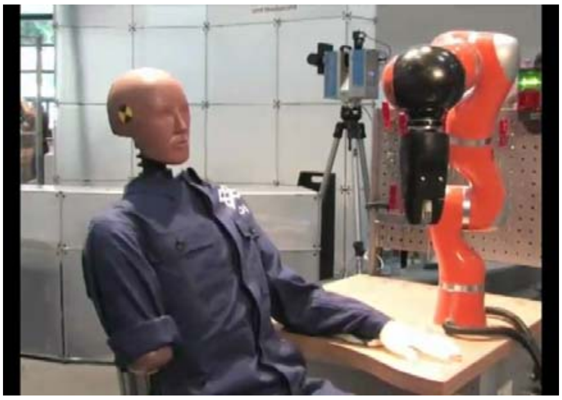

Figure 1: First safe gripper design, originating from the SME-Robot project.

The first prototype of a safe gripper design originates from the SME-Robot project, in which safety tests have been performed using a modified crash test dummy and a light-weight robot, focusing on blunt impacts and usage of sharp tools. Since the SCHUNK commercial gripper available at that time had several sharp edges and turned out to pose substantial safety risks to the users manually interacting with the robot, a rubber cover has been designed. In this way, a consistent safety level was achieved for the arm and the gripper. However, it quickly turned out that a major drawback for interaction still was the fact that the user had to release the robot during teaching tasks in order to trigger simple actions on a keyboard, such as storing individual robot configurations, starting and stopping trajectory recording or switching between control modes.

## First Design Study

Figure 2: Designer model of gripper for human-robot interaction with touch display

Based on the results of the design study reported in Milestone 28, further investigations towards a safe gripper for safe human robot interaction have been performed. The goal of these activities is to develop versatile yet simple grippers that are safe, easy to operate and enable close collaboration of human worker at the beginning of SAPHARI and robot by providing easy to use interfaces.

In order to address the above mentioned interaction requirements, a design model had been developed, see Figure 2. A main focus of the study was on the ergonomic shape avoiding sharp edges and clamping possibilities. Secondly, a touch display was integrated into the model in order to allow the visualization of the robot state and of the available interaction options in every program state. Using the touch interface, the user should be enabled to do comfortable hands-on programming and cooperative work with the robot without the need of additional input devices in the nominal case.

**Figure 3: Gripper design used for the SAPHARI human robot interaction experiments. The gripper is based on a Weiss Robotics WSG25 gripper and a Smartphone. This gripper was presented in Milestone 28.**

## *Preliminary Experiments Gripper*

For the experiments in the first two years of the project, i.e. for the Brio and the Medical Scenario, the gripper from Figure 3 was developed and used.

In Task 2.4 Milestone M28, a commercially available gripper (Weiss Robotics WSG50) has been modified to fit the specific needs of the project. In addition, a smartphone has been added to the gripper as a touch interface (Figure 3). This gripper has been a good basis for the experimental evaluation of the pHRI concepts but does not fit the needs of a commercial gripper for industrial use. This concerns both safety and ergonomics aspects.

Hence, in WP2.4 an in depth design study of a fully integrated gripper has been performed in addition. The results will be presented in the following focusing on four key aspects of the design:

- Grasping versatility and dexterity
- Safety
- Low cost production
- Easy to use and intuitive human machine interface

## *Finger Based Gripper Design*

### *Grasping Performance*

The gripper used in M28 showed to be well performing in particular grasping cylindrical objects or objects with an "extruded" shape (constant cross section - at least partially - along the direction perpendicular to the plane spanned by the grippers). Due to its planar two finger setup this kind of gripper is not suitable for grasping spherical objects in a stable configuration. Hence, the proposed SAPHARI- Gripper was a three fingered, reconfigurable gripper (Figure 4). To grasp extruded objects the gripper is used with two fingers in parallel opposing the thumb, whereas it is used in a classical three finger setup to grasp roughly sphere shaped objects.

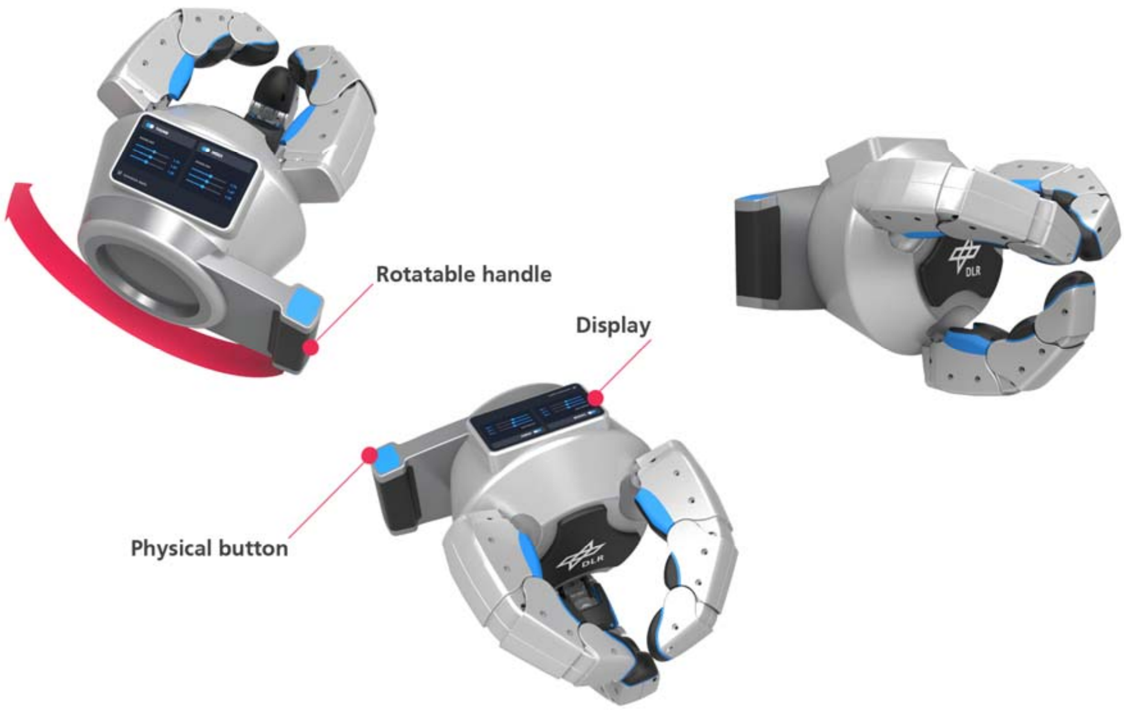


**Figure 4: The SAPHARI Gripper Study: The gripper provides re-orientable fingers modular fingers, a rotatable handle and a touch display for human robot interaction. The modular design of the (identical) fingers is based on commercially available gears and drives. The rotatable handle allows the user direct interaction with the torque controlled robot without getting in contact to the fingers on one hand. On the other hand, by being rotatable, it allows the user to reconfigure the position of the handle relative to the robot position for ergonomic and effortless use during interaction. The physical button on the handle releases the handle for repositioning of the handle. The touch display located on the hand basis allows the user to seamlessly interact with the robot in an intuitive and easy to use manner.**

### *Safety*

The gripper is intended to be used in close collaboration with human beings. Hence, the suggested design uses round edges and soft surfaces to reduce the risk of injury in case of collision. Additionally, the finger design avoids gaps between housings to reduce the risk of pinching of e.g. unintentionally inserted fingers or objects.

### *Low Cost Production*

The SAPHARI Gripper Study is intended for industrial use. Hence, production cost and simplicity is of major importance. Consequently, fully modular fingers are used for the design to reduce the amount of needed parts and to maximize lot sizes. The fingers use commercially available drives and gears for the same reasons.

### *Man Machine Interface*

As illustrated in Milestone 28 the gripper should provide an intuitive and easy to use interface for human robot interaction. During the preliminary experiments performed the concept of using a touch display appeared to be both, intuitive and easy to use. To reduce the cost of the gripper a standard sized smartphone display was used for the design of the gripper. Since the SAPHARI concept makes extensive use of the compliance control and torque control to interact with the human, a rotatable handle is integrated into the gripper. It allows for interaction between the robot and the human without touching the gripper itself on one hand. On the other hand, the handle can be repositioned by using the blue button on the side of the gripper for ergonomic and effortless interaction between the robot and the user regardless of the position of the robots $7^{th}$ axis. Additionally, the repositioning feature reduces the overlap of the workspaces of the human being and the robot and, by this, reduces the risk of collision between human being and the robot.

While this study was performed within the SAPHARI project, the hardware realization of this gripper is not part of the project, since the required resources would considerably exceed the 6PM dedicated by DLR to this task. The prototyping of this kind of grippers was a topic of a separate, bilateral cooperation between DLR and KUKA the prototype and was supposed to be usable as an in kind contribution in SAPHARI. Due to delays in the legal negotiation of the follow-up cooperation, this gripper is not available yet for the project and its realizability until the end of the project is questionable. The alternative will be a simpler gripper still satisfying the safety constraints together with the reworked interaction device included in the tool changer, as presented in next section. This makes the interaction aspects independent of the gripper choice, while the gripper will be easily exchangeable.

### *Tool Changing Device with 360° Display and Input Buttons.*

During intensive testing of an interactive gripper consisting of a Weiss WSG50 and a smartphone in collaborative tasks in the lab and during two industrial fairs, advantages and disadvantages of this setup became apparent. The motivation of equipping the gripper with a smart phone was to display information to the user and offer possibilities to command the robot by pressing buttons on the smartphone screen. This enables the human coworker to easily confirm needed information in a task, for instance teaching positions to the robot. In the Toy Assembly Task presented in year two of the project, a subtask of the robot was to pick objects out of a cupboard. During this motion, the smart phone screen pointed upwards and was not visible to the human coworker. Potentially important information, e.g. an emergency state, could therefore not be conveyed. Also during other motions and static poses of the robot, the problem of not being able to see the screen existed. Another disadvantage concerns the flexibility of the robotic setup. In many applications it is necessary to exchange the end effector. The mechanical design of other end effectors may not always allow the attachment of a smartphone. In this case, the robot can no longer display information to the user. As a result, we have decided to attach an omnidirectional screen to the last axis of the robot. Furthermore, an autonomous tool changing system is currently developed for improving the flexibility of the system.

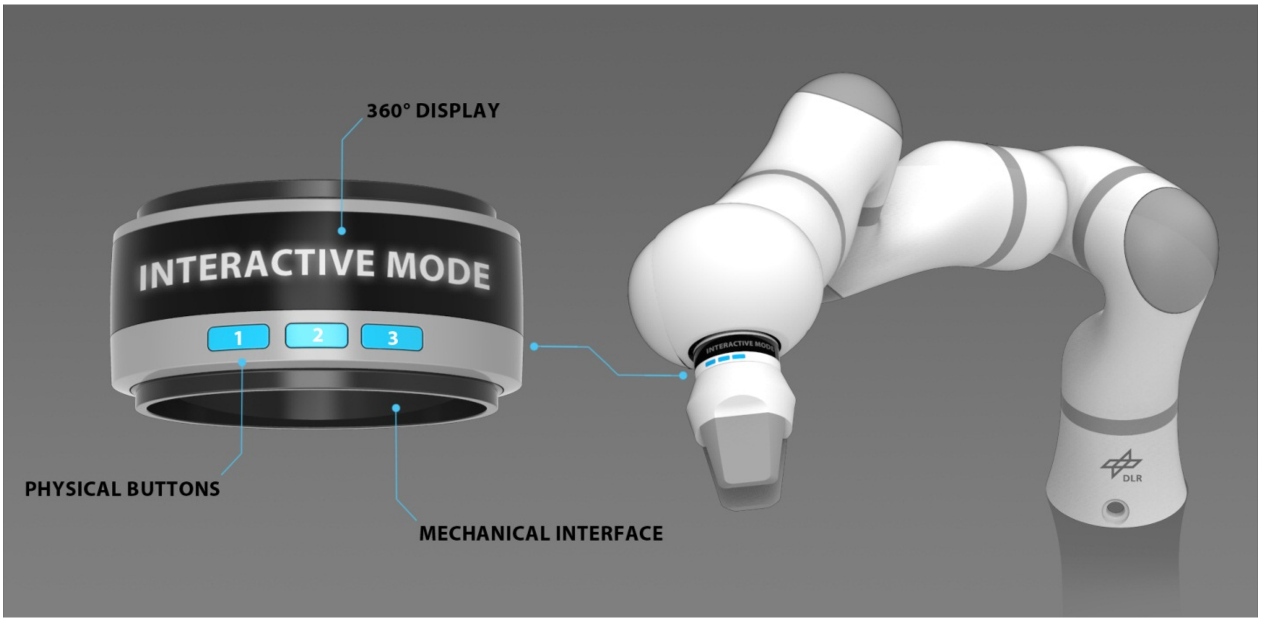


**Figure 5: Interactive tool changing system with a 360° touch display and one or more hardware buttons as input.**

As shown in Figure 5 the tool changing system is additionally equipped with three physical buttons. It turned out that it is favorable to have a physical input that the coworker can look at the object to be processed. These inputs can be for example closing the gripper, teaching a position or switching the robot control state, for example to a gravity free mode.

### *Conclusion*

The development of interactive devices took several iteration steps and involved various design and interaction studies. It turned out, however, that only extensive testing, including not only the researchers involved in the project, but also external partners and random visitors during Automatica and Interpack fairs can provide a real evaluation of the usability of the designs. This experience determined us to rethink the version of the interactive component for the SAPHARI project, leading to a new design which will be realized in the last year.

In summary, it can be stated that we have finally developed an interaction device with higher efficiency concerning the information transmission, which will increase the flexibility by implementing an autonomous tool changing system and will facilitate an easier handling of the robot by using physical buttons as inputs. This new device will be realized in year four, integrated with the robot and the gripper and demonstrated in the final medical scenario.