# A Tele-Operation Tool for Humanoid Robots: On the Pilot Interface Design and Functionality

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## Introduction

Recent man-made or physical disasters, such as the Deepwater Horizon oil spill and the Fukushima Dai-ichi nuclear crisis, have highlighted the enormous potential of robots capable to perform hazardous activities during disaster response operations[1], resulting in a growing interest in Urban Search And Rescue (USAR) robotic research worldwide. In this context, initiatives such as the DARPA Robotics Challenge (DRC) introduced the scenario of using robots to manage disaster situations. Humanoid robots in particular can take advantage of the superior suitability of their body to deal with environments and tools designed for humans: traversing stairs and uneven terrains, and manipulating tools requiring both strength and dexterity.

Despite the increasing low-level capabilities of humanoid robots, tele-operation is still essential to exploit the human competence in terms of decision making, strategic thinking, perception capabilities and overall awareness of the task requirements and successful execution. Tele-operation is however an interim solution, with full autonomy being the ideal long term goal as telecommunication problems like intermittent availability, low-bandwidth and latency of the connection can occur in disaster scenarios and make the need for a certain degree of autonomy undeniable [1]. The mentioned remarks enforce the ever increasing trend towards a *semi-autonomous* or *supervisory* control.

In a disaster response scenario, the operator interface design and functionality in the master station has a strong effect in the situation awareness of a human operator, his strategical reasoning and also his stress levels during the execution of the remote task The peculiar challenges described above involve different robotics and control research areas, from Urban Search and Rescue (USAR) to Human-Robot Interaction (HRI), from tele-operation to Humanoid Robotics.

In this work we present our approach to to build a semi-autonomous framework for the control of a humanoid robot in disaster scenarios and describe features of our tele-operation Pilot Interface ([4]). Among the main desirable features, the ability of the human operator to issue symbolic commands to the robot, select the level of autonomy with which the robot performs each task and receive visual and status information feedback are of particular importance. In addition, the interface is designed to be modular and reconfigurable based on the peculiar needs for the task or the environment conditions and is thought to be general in order to be used by different kinds of robots performing in disaster scenarios. The interface has been tested on the COMAN humanoid robot [5] in simulation and in real experiments during demonstrations based on DRC tasks (Figure 1).

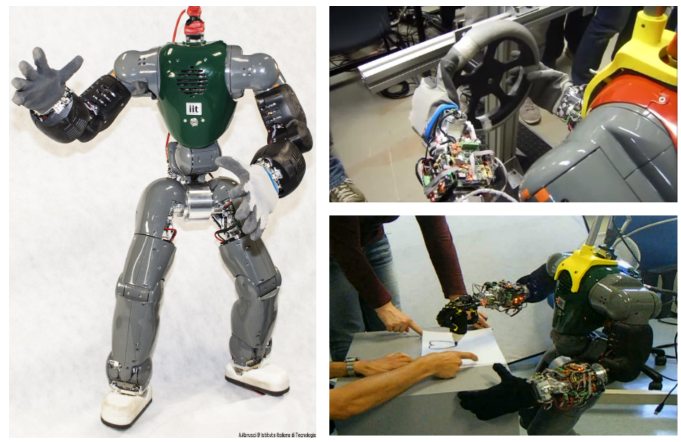

Fig. 1: COMAN is a humanoid bipedal robot equipped with series elastic actuators (SEA) and torque controlled joints. COMAN has 29 DOFs excluding the hands and head

## Pilot Interface

The pilot control interface (from now on PI) provides three different levels of possible controls. The high-level (*Traded*) control deals with the computation and execution of plans composed by primitives. the *Shared* control is constituted by a set of 3D Interactive Markers that represents body parts of the robot or objects of interest to be positioned in the Cartesian space. The operator can thus issue associated primitives or standalone primitives. Finally, we used *RobotMotorGui* (by YARP [2]) to access each joint in *Direct* control. At the lower control levels, the robot operates with minimum autonomy and relies mostly on the safe control of the human operator. It is reasonable that the operator could seamlessly switch between the levels of autonomy, depending on the task, on the environment and communication condition. In the proposed framework tele-operation control can be blended with autonomous motion controllers using tools that can guarantee safe trajectories considering self-collision and minimum effort.

The PI is designed to provide both visual feedback to the operator for validation purposes (or confirmation if needed) in

[1]http://spectrum.ieee.org/automaton/robotics/industrial-robots/fukushima-robot-operator-diaries

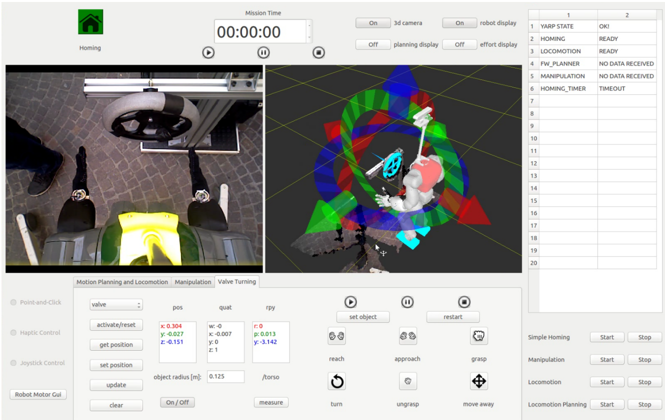

Fig. 2: A possible configuration for the PI. In this particular example the PI is used in a turn-valve task

a high level of autonomy, e.g. the planner shows the planned path before execution, and as a display control apparatus in the middle level, e.g. the operator can adjust the position of a 3d model of an object superimposing it onto a point cloud. Modularity in complex software systems is obvious necessary to provide robustness and permit reconfiguration and expandability. In our architecture many control modules have been developed using *YARP* and *ROS* [3] as a middle wares. These modules perform manipulation, locomotion, planning, perception and whole-body loco-manipulation tasks. Each module is a standalone process that runs on the robot and interacts through messages with the Pilot Interface, from which it can receive a start/stop message and custom commands (Figure 2). Due to the large number of different tasks that a *USAR* robot might perform, a modular and reconfigurable Pilot Interface is also needed. Since each robot control module is an independent process, we want its respective operator widget to be an independent UI as well. With the proposed approach each individual control module widget can be executed as a standalone GUI, so that it can be tested or used without starting the whole PI. Therefore the PI is completely configurable trough an XML file that allow expandability and reconfiguration according to the modules installed in the robot.

The PI was used to control IIT's *COmpliant huMANoid* (COMAN), which is a torque controlled robot with 31-DOFs equipped with two Pisa/IIT - SoftHands[2]. The robot will have a Carnegie Robotics MultiSense S7 sensor[3] mounted as a head, but we are currently using a RGB-D camera (Asus Xtion Pro Live) mounted above the torso. We used ROS 3D interactive markers to manipulate the end effectors of the robot within their work space while a Stack of Tasks optimization routine control these position maintaining the center of mass in the convex hull of the current support polygon.

We validated our framework in manipulation tasks such as the valve turning and the door opening tasks which were performed by an operator through the pilot interface. In both the tasks manipulation primitives parametrized with respect to the object position and orientation have been used in sequence to execute the tasks. The execution of the Primitives can be started standalone by the operator or it could be driven in a sequence by using a state machine. Another important aim of the PI is to feedback intuitively the status of the robot to the operator. This is implemented by the support interface which visualize the state of the control boards of the robot, displaying their status in a intuitive way, together with a tool to monitor the network state (Fig. 3) which is also important due to the bad communication conditions that may exist in a disaster scenario.

Fig. 3: Control Boards Status widget (left) and Network Status widget (right)

Using the network monitor tool the operator can customize the data sent through the network, allowing him also to select different modes of data transmission e.g. compressed if communication conditions degrade.


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[2]http://softhands.eu

[3]http://carnegierobotics.com/multisense-s7/