Chapter 27
Portable Haptic Arm Exoskeleton

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ABSTRACT

This chapter describes a seven degree of freedom force-reflective device able to produce haptic rendering on the human arm, either as master for teleoperation of a slave robot, or in interaction with a virtual reality. This project was conducted on behalf of the European Space Agency (ESA) as a prototype of the master device used for teleoperation of future anthropomorphic space robotic arms on the International Space Station (ISS). The motivation is to decrease the number of extravehicular activities of the astronauts, even for complex situations. The structure of portable anthropomorphic exoskeleton of 7 degrees of freedom has been selected by ESA because it allows a more intuitive control of anthropomorphic slave arms; it also allows multiple contact points, offers a larger workspace (comparable to the human arm). Besides, being attached on the astronaut, the system involves only internal forces (it is self-equilibrated) and can be used in zero-gravity.

INTRODUCTION

Manned Extra-Vehicular Activities (EVA) have been a core part of the space exploration either in Earth orbit (space stations, satellites servicing) and planetary exploration. Due to the complex nature, the risks and the costs associated with such tasks, Space Agencies have implemented a number of robotic devices to support or even perform EVAs. The motivation is to decrease the number of spacewalks for astronauts. The ERA and the Canadarm 2 are examples of large robotic arms currently in use on the International Space Station (ISS) to support handling of heavy payloads and modules. Recently, new interest has grown in the development of humanoid robots with advanced dexterous manipulation capabilities. Eurobot (ESA) and Robonaut (NASA), launched

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on-board the ISS in 2011 for preliminary testing, are examples of on-going research developments. They are equipped with anthropomorphic arms, kinematically equivalent to the human arm. These robots will either be controlled autonomously or through manual teleoperation by an astronaut staying inside the space station.

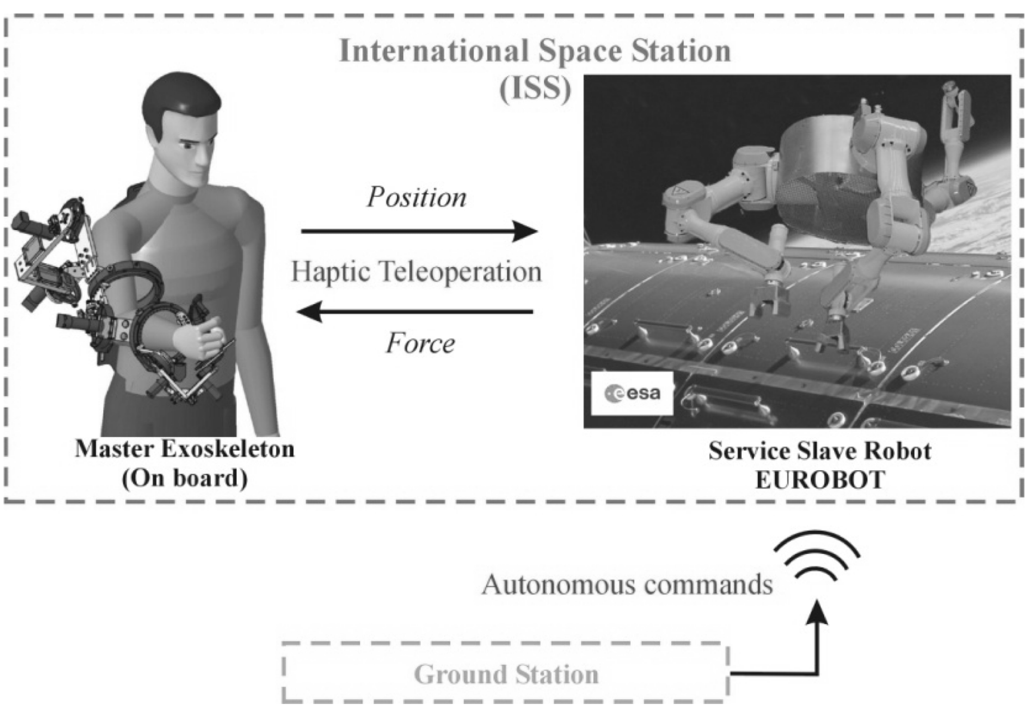
The device presented in this chapter was designed at the initiative of the European Space Agency as a prototype of the master device used for teleoperation of these future anthropomorphic space robotic arms on the ISS (Figure 1). Called "SAM", for *Sensoric Arm Master*, it consists of a seven degrees of freedom force-reflective interface, able to produce haptic rendering on the human arm, either as a master for teleoperation of a slave robot, or in interaction with a virtual reality. Compared to simple joysticks controllers, the structure of a portable anthropomorphic exoskeleton with seven degrees of freedom has been selected because it allows a more intuitive control of this family of slave robots with a larger workspace (comparable to the human arm). Furthermore, the addition of force information to the operator, with multi-point contacts capabilities, improves the immersion and the quality of the manipulation. Besides, being attached on the astronaut, the system involves only internal forces (self-equilibrated) and can be used in zero-gravity.

After a short review of the principle of force-feedback and the concept of exoskeleton, this chapter discusses the various steps of the design of the SAM project: kinematics, mechatronics and control.

Introduction to Teleoperation Haptic Feedback

Force-feedback (or kinesthetic) haptic interfaces are used to increase the user's performances during tasks. They can produce realistic haptic feedback and improve the sensation of immersion of the user. Historically, their developments started in the 1950's in the context of master/slave manipu-

Figure 1. Concept of teleoperation on-board the ISS



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