Chapter 3
Impedance Control of a Spherical Parallel Platform

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ABSTRACT

This article describes the impedance control of an in-parallel actuated orientation platform. The algorithm is based on a representation of platform orientation which exploits the equivalent axis of rotation: this approach is more intuitive and easier to visualize than conventional methods based on Cardan or Euler angles. Moreover, since for small angular displacements the Mozzi’s axis lies very close to angular velocity, impedance control algorithms based on such representation provides better performances and smoother motions. Results of numerical simulations and experimental tests are shown and commented with reference to the spherical parallel machine.

INTRODUCTION

Parallel kinematics machines, PKMs, are now used in many different application fields, both in industrial environments and in advanced robotics developments. Such machines are given by a moving platform that is actuated in-parallel by several limbs, each one driven by actuators that are fixed with the ground.

On the other hand, due to the complex kinematics of 6-dof full mobility PKMs, research community is addressing the studies towards simpler
mechanisms that are able to perform elementary motions, like pure translations, pure rotations or even planar displacements. In fact some important applications may well be accomplished by these kinds of reduced mobility PKMs, while in other cases hybrid machines can be designed (e.g., a conventional “serial” wrist on top of a parallel shoulder) or mini-maxi architectures can be experimented.

Alternatively, a full-mobility task may be decomposed into elemental sub-tasks, to be performed by separate minor mobility machines, as already done in conventional machining operations (Callegari & Suardi, 2004). In this case a proper mechatronic design allows exploiting, at least partially, the advantages of both architectures, while the disadvantages can be minimized. In this way it is possible to realize hybrid cooperative systems with many degrees of freedom, leading to a modular and reconfigurable system architecture.

This is the case of the research being developed at the Department of Mechanics of the Polytechnic University of Marche, which aims at assessing the feasibility of complex assembly tasks (e.g., 6 axes operations) by means of two cooperating parallel robots, both characterized by a simple mechanical and control architecture. The two machines are based on the same 3-CPU kinematic topology but are capable of pure translation and pure rotation motions respectively. The control systems of the two machines will be equipped with an impedance controller, so that the relative stiffness of the system can be varied during parts’ mating to allow an effective accomplishment of the task; on the other hand, the complexity of the hybrid position/force algorithms (needing proper force sensors and the availability of real time robots’ inverse dynamics models) is avoided.

The present article describes the studies performed at the University of Genova and at the Polytechnic University of Marche in order to develop a well performing impedance control for the orientation platform: it is anticipated that few realizations are reported in scientific literature about the control of the stiffness for machines of pure rotation, let alone applied to parallel robots. This is the reason that addressed Bruzzone and Molfino (2006) to introduce the application of the natural invariants of the rotation matrix to the impedance control of PKM’s. Bruzzone and Callegari (2010) studied the control of the present robot by computer simulation; the present article presents the experimental results that are now available after its implementation on the prototype (see Figure 1).

**REPRESENTATION OF ORIENTATION**

There are many methods to describe the orientation of a rigid body, each of them having pros and cons that are well known to the research community since a long time (Tandirci et al., 1992; Bonev & Ryu, 2001; Bonev et al., 2002; Selig, 2005).

The most commonly used method in robotics is making reference to three rotations around the axes of the fixed or mobile frame: the order of

**Figure 1. The spherical parallel machine used in the experiments**