Design and Validation of Force Control Loops for a Parallel Manipulator

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ABSTRACT

This paper addresses problems for design and validation of force control loops for a 3-DOF parallel manipulator in drilling applications. In particular, the control design has been investigated for a built prototype of CaPaMan2bis at LARM (Laboratory of Robotics and Mechatronics of Cassino). Two control loops have been developed, each one with two types of controllers. The first one is a Constrained Control Loop, which limits the force that is applied to an object to stay below a given value. The second one is a Standard Control Loop with external force feedback, which keeps the force at a given value. The control loops have been implemented on CaPaMan2bis by a Virtual Instrument in LABVIEW Software. CaPaMan2bis has been attached to a serial robot to make dynamic tests. The results of the experimental tests show the effectiveness and quick response of both algorithms after a careful calibration process.

1. INTRODUCTION

Parallel manipulators have been used for many applications because of their better characteristics with respect to those of serial manipulators, such as high stiffness, high payload, high precision and high velocity and acceleration (Merlet, 2006). For these reasons parallel manipulators are suitable for applications such as manipulation, packing, assembly and disassembly processes, motion simulation and milling machines. Some examples are Delta Robot, Orthoglide, Stewart Platform, Tricept and...
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At LARM: Laboratory of Robotics and Mechatronics, a three D.O.F (degrees of freedom) spatial parallel manipulator named as CaPaMan has been built and studied (Ceccarelli, 1997). For a first version several analysis and tests have been studied and reported (Ceccarelli, 1997, 1998; Ceccarelli & Decio, 1999; Mendes & Ceccarelli, 2001; Ottaviano & Ceccarelli, 2002; Ceccarelli, Decio, & Jimenez, 2002; Wolf, Ottaviano, Sho-ham, M., & Ceccarelli, 2004; Ottaviano & Ceccarelli, 2006). Later two prototypes have been built named CaPaMan2 and CaPaMan2bis which also have been studied and reported (Aguirre, Acevedo, Carbone, & Ottaviano, 2003; Carbone, Ceccarelli, Ottaviano, Checacci, Frisoli, Avizzano, & Bergamasco, 2003; Carbone & Ceccarelli, 2005a, 2005b; Hernández-Martínez, Ceccarelli, Carbone, & López-Cajún, 2008). In addition CaPaMan2bis has been implemented as a part of a hybrid robotic architecture for surgical tasks (Carbone & Ceccarelli, 2005b) as a trunk module in a humanoid robot design that has been named as CALUMA (CAssino Low-cost hUMAnoid robot) (Nava, Carbone, & Ceccarelli, 2006) and as an intelligent wrist for milling applications (Briones-Leon, Carbone, & Ceccarelli, 2009).

This paper proposes a further development for a force control for the manipulator robot CaPaMan2bis as a terminal tool for a serial parallel robotic architecture for drilling applications. A force-feedback control for parallel manipulators is discussed in Merlet (1988), two other reference methods of force control are presented in Erlbacher (2000), another one has been applied for the LARM Hand III in Iannone, Carbone, and Ceccarelli (2008) and several methods are explained in Yiu (2002).

Two force control loops has been developed specifically for CaPaMan2bis and its application in drilling operations. The first one is a constrained control loop that actuates when the force is higher than the desired and the second is a Standard control loop that actuates at all times taking the force to the desired level. For each control loop PD and PID controllers have been implemented and experimentally tested.

2. A SERIAL-PARALLEL MANIPULATOR AT LARM

The experimental setup at LARM is composed by the serial robot SCARA Adept Cobra and the parallel robot CaPaMan2bis as shown in Figure 1. The serial robot is a SCARA Adept Cobra