

Cooperative Research Projects of University of Naples in the ERNET Framework

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Summary

This note is intended to report on three undergoing research projects in the European Robotics NETWORK (ERNET) framework in which our group is involved; namely, a project on cooperative manipulator systems at DIS, Università di Napoli Federico II, a project on adaptive control for force and position tasks at LAG, INP-Grenoble, and a project on force/position control of a redundant manipulator at LIRMM, Université Montpellier II.

Project on Cooperative Manipulator Systems

Our group started doing research on cooperative arm systems in 1988. Below is a description of the theoretical work developed since then.

Manipulability kineto-static and dynamic ellipsoids have been defined to perform task space analysis of multiarm systems. A dexterous reconfiguration scheme based on the use of the above ellipsoids has been proposed. A nonlinear dynamic decoupling technique has been developed which achieves control of absolute object motion and of internal forces between pairs of end effectors. A simpler control strategy has also been proposed that assigns an impedance behavior to the controlled variables. A new task-oriented formulation which allows an effective description of coordinated motion tasks in terms of absolute and relative variables. Kinematic control of a two-arm (redundant) system has been developed, also in the case of rolling or sliding contact between the end effectors and a commonly held object.

In order to perform experimental work, a cooperative manipulator system setup has recently been established (Fig. 1). This consists of two 6-axis Comau SMART-3 S industrial robots (Castor and Pollux), both equipped with the open version of the C3G-9000 controller (Fig. 2). One robot is mounted on a sliding track which provides an additional degree of mobility, i.e. redundancy of both the single manipulator and the cooperative system.

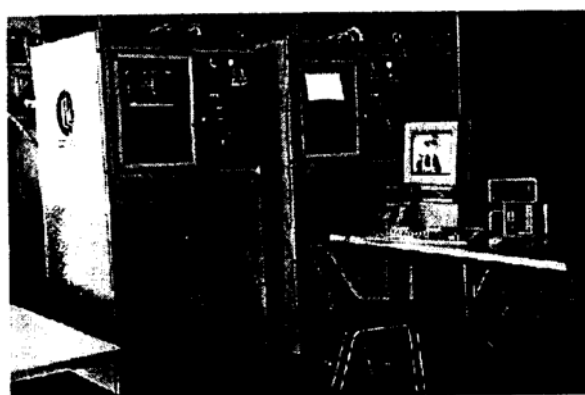


Fig. 2. The two C3G-9000 robot controllers.

Robot axes are actuated by brushless synchronous motors via gear trains with absolute resolvers. Maximum stroke of each manipulator is 1.4 m; the track enlarges the workspace of one manipulator and thus allows execution of more complex tasks. A 6-axis force/torque sensor ATI FT30-100 with force range of ± 130 N and torque range of ± 10 Nm can be mounted at each end effector (Fig. 3).

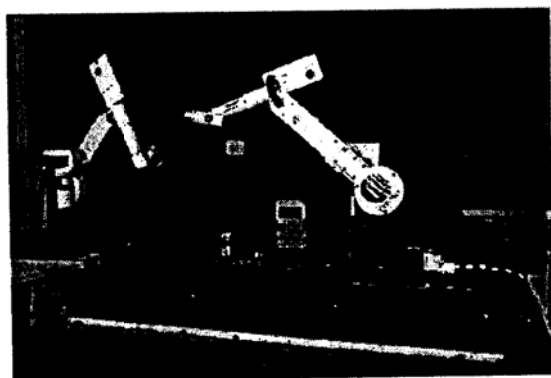


Fig. 1. The cooperative robot manipulator setup. The robot on the right is mounted on a sliding track.

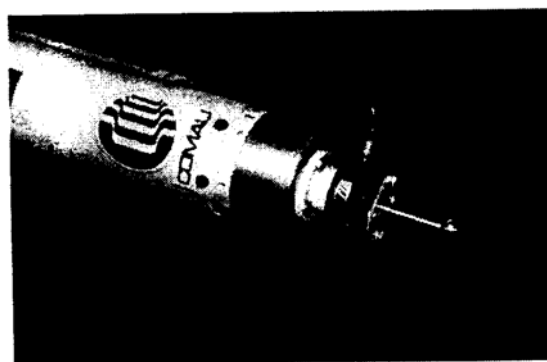


Fig. 3. Force/torque sensor at manipulator's end effector.

The C3G-9000 robot controller has a VME-based architecture with 2 processing boards; namely, the Robot CPU (RBC) and the Servo CPU (SCC), both based on a Motorola 68020/68882 CPU. Tasks running on the RBC board accomplish user interface functions and interpretation of user programs. The SCC board has an additional DSP and takes care of trajectory generation, inverse kinematics, and joint position servo control. Manipulators can be programmed in PDL2, a PASCAL-like proprietary language by Comau which features additional instructions to handle typical robotic tasks.

Connection of the two VME buses to the AT bus of a PC is made possible thanks to bus adapter boards by Bit 3 Computer Co. The PC and the C3G controllers communicate via the shared memory available on the RBC board. Time synchronization is accomplished by interrupt signals from the C3G to the PC, and variables can be exchanged at 1 ms sampling time. A set of C routines are available to drive the bus adapter boards so that the user can easily access relevant variables. Options are provided that permit:

- Operation of the robotic cell constituted by the two manipulators controlled by their native C3G's as stand-alone units (the PC is excluded).
- Operation of the robotic cell where each manipulator is controlled by a PC as a stand-alone controller.
- Operation of the robotic cell with a single PC which coordinates and controls the two manipulators.

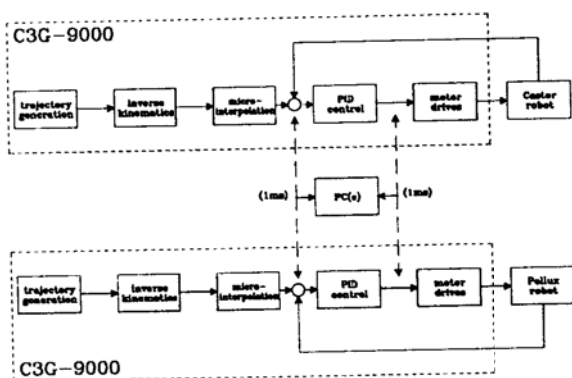


Fig. 4. Functional scheme of the control architecture for the cooperative manipulator setup.

Fig. 4 depicts the functional scheme of the control architecture for the cooperative manipulator setup.

On April 10, 1995, Mr. Jérôme Szewczyk from Laboratoire de Robotique de Paris, Université Paris 6, Vélizy, France has come to our lab for a five-month stay under ERNET to pursue experimental work on:

1. PD-type control schemes based on kineto-static filtering of joint error components causing internal forces,
2. impedance programming and adaptation for a single manipulator, when the other performs as a dynamically changing environment.

Project on Adaptive Control for Force and Position Tasks

The group at LAG, INP-Grenoble, lead by Dr. Carlos Canudas de Wit, has been lately concerned with development of new techniques for position and force control based on the idea of performing adaptive feedforward compensation of a desired impedance. The case of joint flexibility has been also considered. Special concern has been given to analyzing stability issues in the transition of the manipulator's end effector from non-contact into contact with environment.

Experimental work is currently in progress on a 2-axis arm (CAPRI), equipped with end-point and lateral force sensors is available. A real-time dSPACE control architecture is available with the possibility of downloading SIMULINK block diagrams.

On June 1, 1995, Mr. Luigi Villani from our group has gone to LAG for a five-month stay under ERNET to pursue work on:

1. development of passivity-based adaptive control techniques for force regulation and motion tracking control,
2. inclusion of time delays and stability analysis of contact with a compliant environment.

Project on Force/Position Control of a Redundant Manipulator

The group at LIRMM, Université Montpellier II, lead by Dr. Pierre Dauchez, has been working on hybrid force/position control both of open-chain and closed-chain manipulator systems since 1988. Control schemes have been developed both for a system of two cooperative PUMA manipulators as well as for the DELTA and HEXA parallel manipulators. Some recent extensions regard the use of fuzzy control schemes for parallel manipulators which provide robustness for operation in different locations of the workspace. Besides parallel manipulators, a Mitsubishi PA10 7-axis manipulator is available, which is equipped with force sensor and can be controlled by a Pentium under QNX operating system.

On June 1, 1995, Dr. Pasquale Chiacchio from our group has gone to LIRMM for a four-month stay under ERNET to pursue work on:

1. development of force/position control schemes for redundant manipulators with regard to medical applications,
2. control of end-effector forces with stabilization of internal motion.

Conclusions

It is wished that all the above research projects come to fruition, for the mutual benefit of the researchers exchanged and overall of the four groups involved. It is planned to present the outcoming results at the final Workshop of ERNET.