Chapter 12

Collaborative Visual-servoing of the MANUS Manipulator

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12.1 Introduction

The rehabilitation robot Manus (Verburg, 1996) is an assistive device for severely motor handicapped users. With it, users can perform daily tasks that would otherwise be impossible or would require the help of other persons. Manus has eight degrees of freedom (DOFs); three for positioning the gripper, three for rotating the gripper about three axes, one for opening the gripper and one external lift.

Because of its eight DOFs, Manus is a complex device, which is sometimes cumbersome to control for persons with very limited residual functionality. A challenge for the research community is to develop assisting technology for controlling complex devices like Manus in an intuitive way. Here, a method is proposed, which uses sensors (such as cameras, force torque sensors, and infrared distance sensors) to ease the control of the system. Manus must operate in a challenging unstructured environment and it is not our goal to make it fully autonomous. Our philosophy is that the user actively controls the device and retains supervision in all circumstances. The combination of direct user control and autonomous sensor control is known in literature as “collaborative control”.

This paper is organised as follows. The next paragraph describes the general architecture of the proposed controller. Next, a vision-based controller, which is the central part of the collaborative controller, is discussed in detail. Finally, the user interface is described followed by a description of the first user trials.
12.2 Collaborative Control

The main difference between a collaborative control system and a standard fully autonomous control system is that collaborative control requires a higher degree of involvement from the user in the control loop. The role of the user is not limited to issuing prescribed high-level commands. Instead, the user actively takes part in controlling the robot. Figure 12.2 shows the general architecture of our collaborative controller. The manipulator (Manus) has to interact with objects that exist in the environment (a cup on a table, a book on a shelf, a spoon in a cutlery tray, etc.). The user can see both the manipulator and the objects in the environment. Based on his/her observations he/she can issue commands to the manipulator through a user interface. Sensors are used for measuring different aspects of the manipulator or the environment. Examples are angle encoders that determine the pose of the robot, a force-torque sensor that measures the interaction force between object and robot, or a camera, which measures the pose of an object with respect to the camera. Note that sensors can be integrated in the manipulator as well as in the environment. The sensor outputs are fused in the sensor fusion block to obtain a more reliable representation of the world. The output of the sensor fusion block is fed to the control fusion block, which controls Manus.

The sensor fusion block applies Kalman filtering to the measurement of the camera and the distance sensor, which results in a more reliable estimation of the current state (e.g. pose of the object with respect to the manipulator) of the system. This block can also be used to fuse multiple cameras each with a different position and direction and select the best view of the environment. The outputs of the sensor fusion (Ng, 2003) block are various state variables, which each require a different type of controller. The control fusion block contains these controllers and combines their outputs to a consistent control input to the Manus. The fusion of the various control laws (controllers) takes care of two issues: distribution of the DOFs between the control laws and minimisation of the coupling between the control laws. For example, a camera is used to control the roll, pitch and yaw, a distance sensor is used to control the Z position and the user controls the X and Y position.