Ed-Ro – Educational and Research Robot

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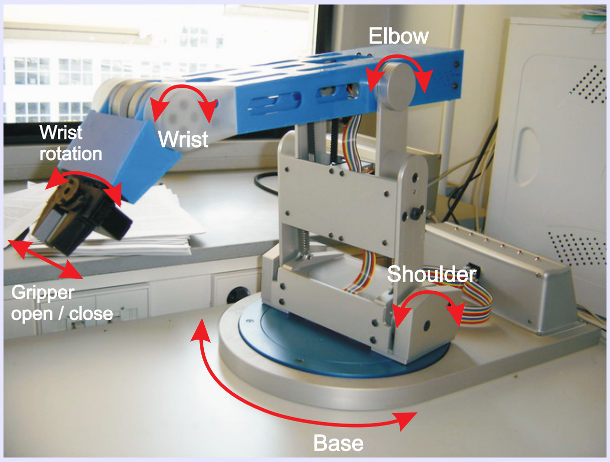
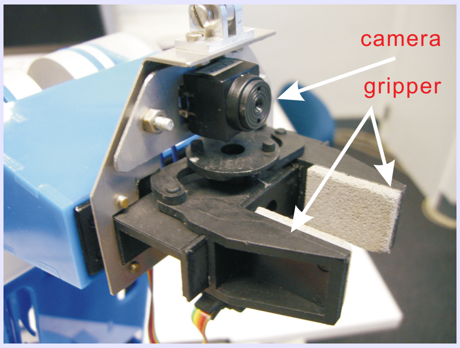
The Robot

Ed-Ro is a lightweight, low-cost robotic manipulator developed at the Delft Center for Systems and Control. It has five revolute joints and a two-fingered gripper, all actuated by DC servo-motors. Two internal springs, located at the shoulder joint, compensate for gravitational forces such that the manipulator maintains posture without actuation. The joint angles are measured by potentiometers. An additional current sensor in the gripper actuator provides information on the clamping force.



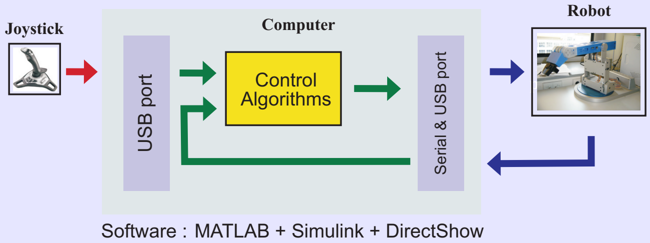
Gripper-Mounted Camera

A miniature camera is mounted above the robot's end-effector. This so-called eye-in-hand configuration is suitable for acquiring images from the robot's immediate environment and controlling the arm motion by means of visual servoing. The camera can capture gray scale images with the resolutions up to 320x240 pixels at a rate of 25Hz.



Control System

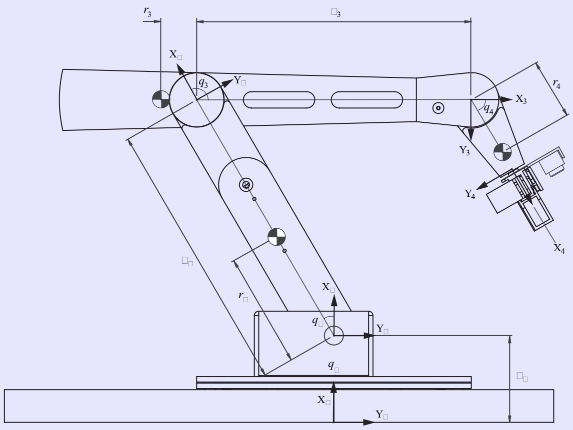
The manipulator is controlled by a computer via an RS232 serial port interface. A joystick connected to the computer allows the manipulator to be manually controlled by using position or velocity-based input. The camera images are passed to a low-cost USB frame-grabber where they are digitized.



Range of Experiments With Ed-Ro

The Ed-Ro robot can be used to demonstrate and teach a range of control principles both in courses as well as in graduation and other research projects. Examples are mechanistic modeling, system identification, joint control, kinematics and vision-based control.

- **Robot kinematic and dynamic modeling** includes on the one hand the basic kinematic and dynamic modeling aspects and on the other hand more advanced concepts like the modeling of friction, stiction and dynamic coupling.



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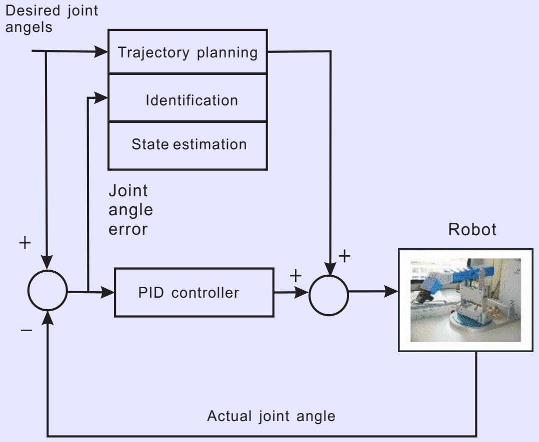
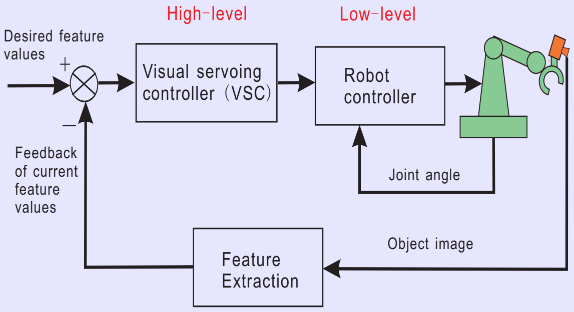
- **Parameter identification and learning control** experiments range from basic step response tests for the individual joints, to advanced multivariable learning control. An optimization-based scheme for multivariable decoupling feedforward control has been developed.

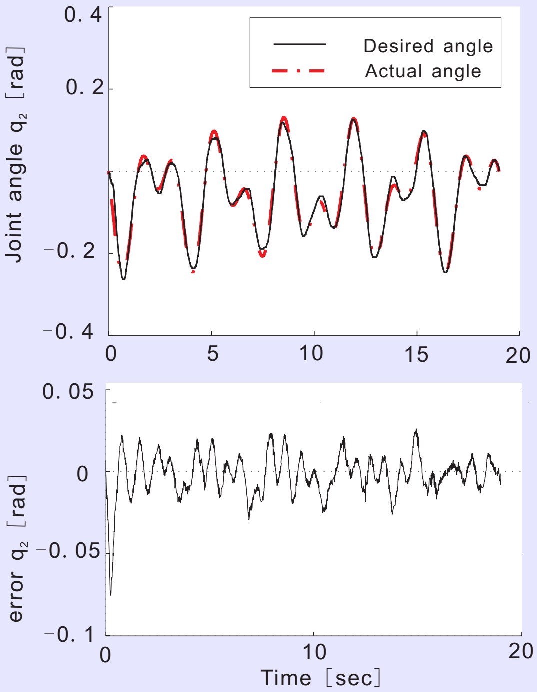


Learning Feedforward Control

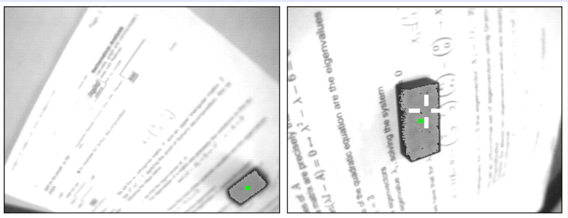
- **Control system design** includes the two main hierarchical levels: low-level joint control and high-level vision-based control.



Joint controller design typically includes performance requirements on a sufficiently high bandwidth and good stability margins for fast transients as well as low speeds of operation which are typical for visual servoing. The joint controllers consider effects such as friction and stiction in the joints as well as dynamic coupling of the robot links. The following figure shows an example of a reference-tracking result for the shoulder joint after automatic tuning of the controller's parameters.



Vision-based control design is an active area of research with a large number of potential applications in the future. A typical visual servoing task involves guiding the robot's end-effector to a desired pose with respect to a given object in the workspace of the robot. The figure below shows an example of an initial pose on the left and a final one on the right. The final pose was attained through visual servoing.



The feedback control law is based on image features extracted in real time from the camera images. Several feature-tracking algorithms have been implemented in the robot control software and their performance has been compared.