

Anthropomorphic Robot Assistants – Giving the Human a Helping Hand

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Abstract

Robot assistants, which are employed outside traditional manufacturing applications, can support flexibility by solving diverse tasks in cooperation with human operators. Two mobile robot assistants, Care-O-bot and rob@work have been built and installed at Fraunhofer IPA in order to assist human users in home and production environments. Intuitive and dependable operation is a major prerequisite for being able to apply the systems safely and successfully in unmodified natural environments inhabited by humans.

1. Introduction

Today, technical assistant systems are mainly used as specialists in clearly defined industrial applications. Industrial robots do not interact with human operators, in the contrary they are usually separated from the human user for safety reasons. In the near future, service robots equipped with mechanisms for communication, interaction and behaviours will be employed outside traditional

manufacturing applications [6]. Based on the human's instructions and control, the assistive systems will be able to cooperate with and assist their human operator. Operating robots in unmodified natural environments imposes requirements on the robots, which are incomparably higher than demands made on the capabilities of industrial robots [12]. These requirements concern the robots' sensory perception capabilities, their mobility and dexterity, as well as their task planning, reasoning and decision making capabilities.

Adequate sensory and control systems support the operating robustness and physical safety of the user, which is a major prerequisite for the acceptance of service robots in our everyday life [7]. The technology available today meets these demands only on a very limited extend. Cooperating closely with a human is only possible if the robot assistant is enable to communicate, interact, and collaborate with human users in a natural and intuitive way. Human friendly interfaces involving all human senses and communication channels are essential for efficiently programming and instructing the robot, which is in turn the basic requirement for an effective and flexible use of robot assistants.

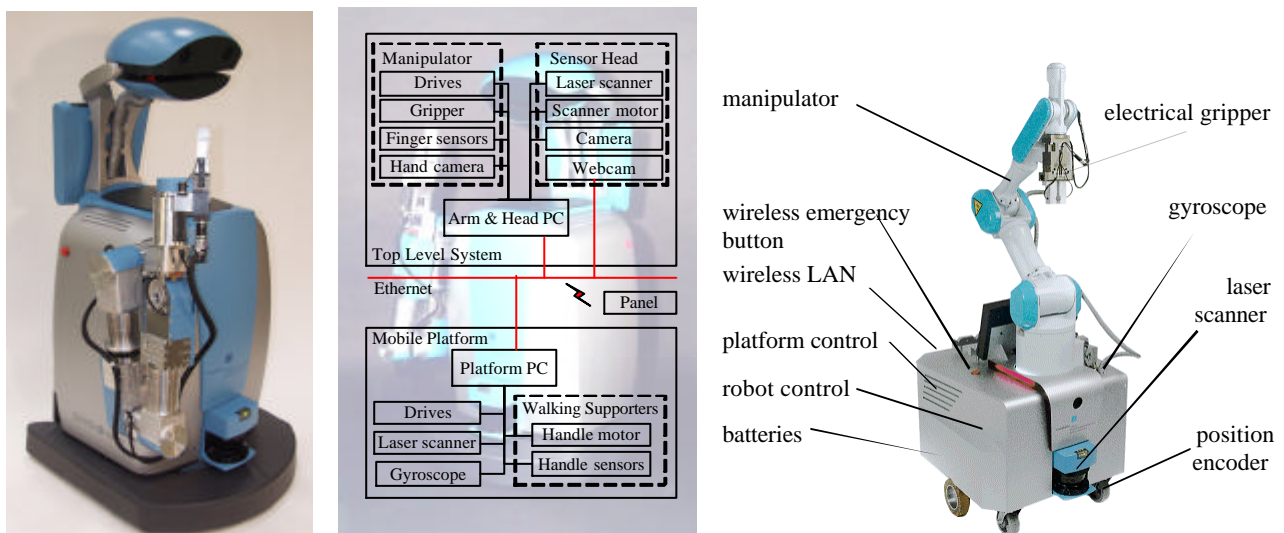


Fig. 1. Home care system Care-O-bot II and production assistant rob@work.

2. Care-O-bot and Rob@work

Care-O-bot is a mobile service robot designed to enable elderly and handicapped people to live independently and supported in their private homes for a longer time. The first Care-O-bot prototype was built in 1998 [15]. Care-O-bot has already proven its ability to operate safely and reliably in public environments. Three robots based on the same hardware platform and control software have been installed in March 2000 for constant operation in the “Museum für Kommunikation Berlin” where they autonomously move among the visitors, communicate to and interact with them [14]. Care-O-bot II (Fig. 1, left and middle) is equipped with a manipulator arm, adjustable walking supporters, a tilting sensor head, and a hand-held control panel. The manipulator arm, developed specifically for mobile service robots [9], provides the possibility of handling typical objects in the home environment. The flexible gripper attached to the manipulator is suitable for grasping objects found typically in a household as e.g. mugs, plates, and bottles. The hand held control panel can be used for flexible instruction and supervision of the assistant at all times.

Rob@work (Fig. 1, right) is the prototype of an intelligent assistant in production environments [4]. It consists of a mobile platform, able to navigate and localise itself autonomously, a commercial manipulating arm, and an adequate supervision system for the robot and human workspace. It can support the human operator in fetch and carry, assembly and tool handling tasks and thereby help to reduce costs and enhance the quality of a product. The human operator is responsible for command, supervisory, and instructional functions, while rob@work will carry out boring, repetitive, and strenuous operations.

3. Care-O-bot II Trade Fair Presentations



Fig. 2. Care-O-bot II at HANNOVER MESSE 2002.

Care-O-bot II was first presented at HANNOVER MESSE 2002 and at Autom@tion Trade Fair in Stuttgart

where it handed over business cards to the visitors (Fig. 2). Visitors were detected and approached automatically, using the laser scanner of the mobile platform. Once a visitor had been reached, the robot activated its arm to grasp one of its own business cards from a special tray on top of the platform and presented it to the visitor. The motion of the arm was combined with speech output and corresponding information on the screen to enhance intuitive man machine interaction. The visitor could then take the card. The gripper being equipped with an optical sensing system would detect the movement of the card and open up. In a second step the robot requested the business card of the visitor. The same optical systems was used to detect the card being put in the “hand” of the robot which the closed to hold the card.

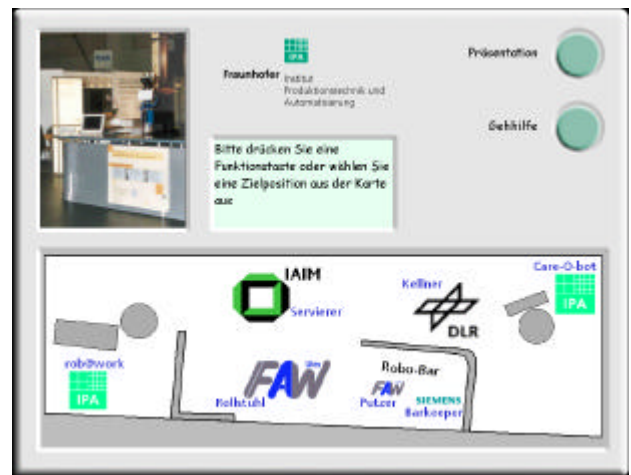


Fig. 3. Care-O-bot II user interface for HANNOVER MESSE 2002 .

After the business card exchange, further services were offered by the robot. The user could request additional information on Care-O-bot or Fraunhofer IPA, let the assistant guide him to a specific exposition area, or test the intelligent walking aid. The robot would turn on the spot by 180 degrees and thereby present its touch screen to the user. Fig. 3 displays the different service options, including a schematic map of possible targets the user could be guided to. In the upper left the current view of one of the robot’s cameras is displayed.

4. Rob@Work Application Scenarios

Flexible and situational task sharing between human worker and robot is a vital element of “human centred automation”. The robot assistant rob@work stands for a vision of an easy to use intelligent helper for manual work places. Through the combination of a mobile and automatic navigating platform with a manipulator, rob@work is able to fetch and carry objects, support in grasping, holding and lifting objects, and assists in complex production processes like welding or bonding.

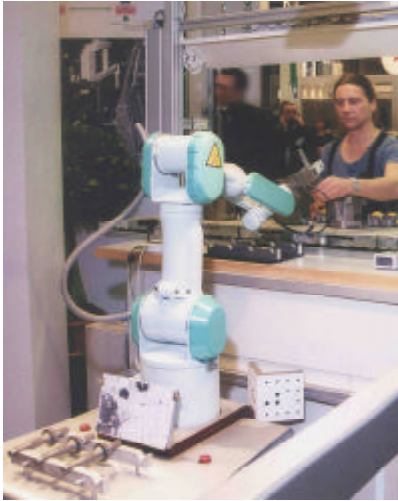


Fig. 4. Rob@work at HANNOVER MESSE 2001

Two applications involving direct man-robot interaction have been implemented and tested on the mobile robot assistant rob@work: an exemplary pick and place action where the robot carries shafts from a conveyor belt to a manual workplace (assembly of hydraulic pumps, Fig. 4) and the shared welding of manual gas metal arc.

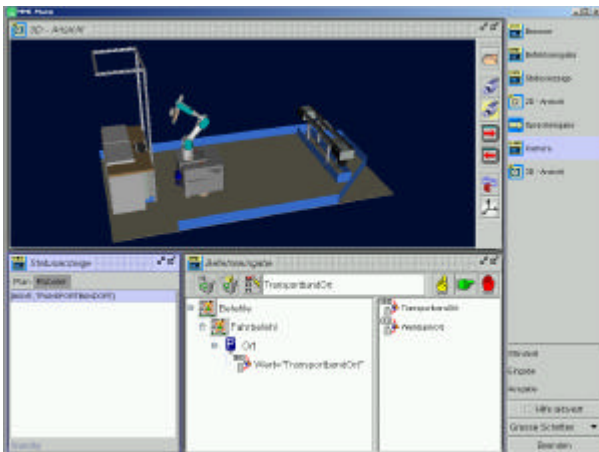


Fig. 5. User interface for pick and place action

An important module of the robot assistant is the man-machine-interface (Fig. 5). This component has to combine several different input types (speech, gestures, command selection, etc.) and output mechanisms (3D world model, sensor information, planned action, etc.). A special desktop-like user interface presents different possibilities to load different input- and output modules.

A common command in the pick and place scenario is “Get 20 shafts of type xyz”. The vocal user input is given to the voice processing of the MMI which analyses the request and generates an appropriate action plan. All information (user input, generated action plan) is displayed on the user interface for supervision and – if necessary –

modifications by the user. After an action plan has been approved by the robot operator, the execution of the plan can immediately be started by pressing the “Start” button on the user interface.

5. Object Manipulation

5.1. Path Planning

For a robot assistant interacting with humans, moving its manipulator along preplanned trajectories is not sufficient. For secure and dependable operation, environmental data must be acquired and considered throughout the whole manipulation process. For supervising the manipulation process, Care-O-bot II has been equipped with a tilting sensor head containing a laser scanner and two cameras [13].

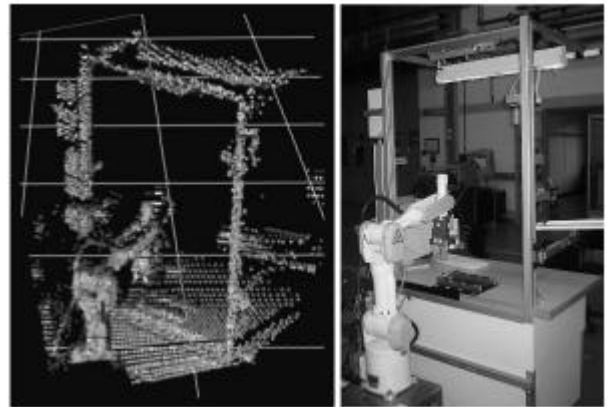


Fig. 6. Environmental model acquired with the 3D laser scanner.

The environmental model acquired with the 3D laser scanner consists of a large number of distance values (Fig. 6), which can be evaluated to detect obstacles close to the robot arm. In order to identify potential points of collision, the environmental data must be saved and provided in a data structure which enables simple access and the possibility to quickly calculate the minimal distance to each scan point. Therefore, a UB-tree representation has been selected.



Fig. 7. Random and smoothed path for grasping over a wall

A collision free trajectory for the robot manipulator is generated by using a Rapidly-Exploring Random tree (RRT). The method described in [5] has been modified in order to find a fairly accurate trajectory as fast as possible. Based on this trajectory an optimised and smoothened trajectory considering local data is generated. First simulation results have verified the great flexibility and variety of the method. The task of grasping over a wall could already be solved. Fig. 7. shows the randomly generated and smoothened path of the robot endeffector, as well as the initial and target configuration of the robot arm. Calculating a trajectory using the modifies RRT method was solved in most cases within the tenth of a second. Smoothening and optimising the trajectory, however, lasted up to one minute which is not sufficient and will be optimised in the future. First experiments on a real mobile platform a also planned.

5.2. Workspace Supervision

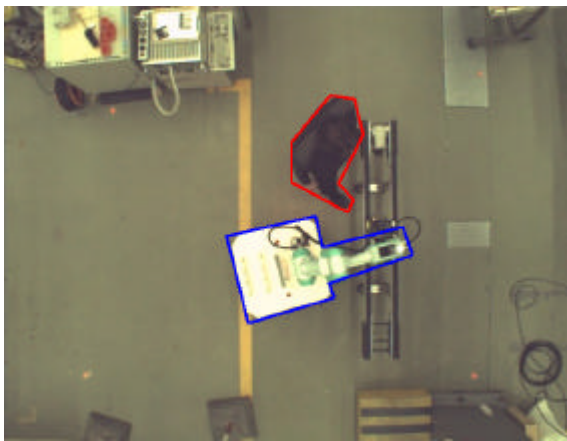


Fig. 8. Overhead camera supervising the workspace of rob@work

For supervising the workspace joined by both, human and robot operator, several specific locations within the working area of rob@work are covered by overhead cameras. In case a person has been detected in this area, the operating speed of the manipulator arm will be reduced in order to avoid collisions between robot and human.

6. Intelligent Walking Aid

The functionality of Care-O-bot II as an intelligent walking aid provides an enormous enhancement in safety and comfort compared with conventional walking supporters [2]. In a similar way as with conventional walking support systems (“rollators”), the robot moves depending on the forward or backward pressure applied to the supporting handles. If an obstacle has been detected in the assigned moving direction of the robot, however, the robot will take over control and lead the user to his target along a collision free path.

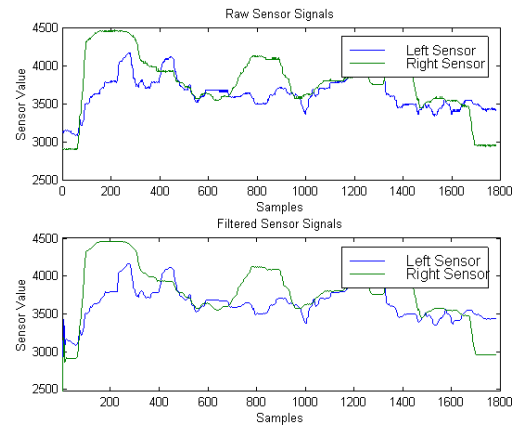


Fig. 9. Raw and filtered sensor signals

The pressure applied by the user is measured by sensors inside the handles of the walking supporters. Due to fluctuations of the applied pressure, values read from the sensors need to be filtered. At first the sensor signals are subjected to a second order IIR (Infinite Impulse Response) low pass butter worth digital filter (Fig. 9) [10]. The selected filter eliminates high frequency noise signals arising due to the movement of the robot and other artefacts.

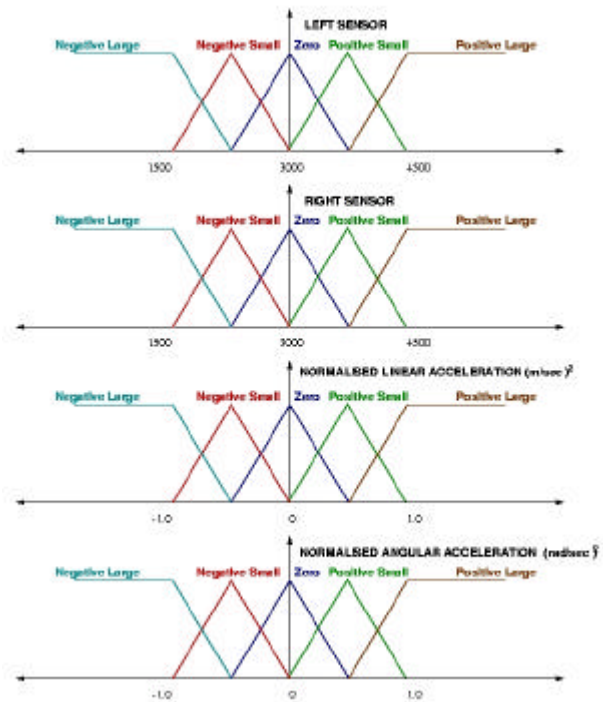


Fig. 10. Memberships functions for fuzzy controller.

The filtered sensor signals are used to control the movement of the robot. The user pushes the walking aid handles, which in turn controls the robot movement. This human heuristics knowledge about how to control a sys-

tem can easily be represented and manipulated in a Fuzzy controller. Thus, a Fuzzy controller [16] has been implemented with left and right filtered sensor values as the two fuzzy inputs and target linear and rotational acceleration as the fuzzy outputs (Fig. 10). In our implementation of the fuzzy controller twenty-five fuzzy logic rules map the sensor data into robot control outputs (desired linear and rotational acceleration). In fuzzy control [11] at first fuzzification of the Sensor values is done. Then rules are matched from the rule base to determine 'which rules to use'. From inference engine conclusions are determined. These fuzzy rules take the form as follows: *If Left Sensor is zero AND Right Sensor is zero then acceleration of the robot is zero.*

Finally the decisions are turned to be actions in the form of linear and rotational acceleration. Depending on the current speed of the robot, the new target linear and rotational speeds are set. This step is done in the defuzzification method. The method of "centre of gravity" (COG) method was used to get the final crisp values to drive the robot motor. If an obstacle has been detected in the assigned moving direction of the robot, the calculated velocity vector will be modified to lead the robot along a collision free path.

7. Summary and Outlook

The anthropomorphic robot assistants Care-O-bot II and rob@work have been presented. Both platforms are mobile and able to navigate autonomously in their operation environment. They are both equipped with a manipulator arm. Care-O-bot II is designed to operate in home environments and uses local sensing systems as a 3D laser scanner and vision to avoid collisions when manipulating objects. Rob@work operates in production areas and uses an overhead camera system to supervise areas which are used by both, robot and human workers.

Both robots are operated through the graphical user interface which is also a touch screen and give elaborate feedback about their activities. Care-O-bot II in addition uses speech output in order to communicate with its user.

A method to plan an optimal path for a mobile robot arm has been presented. First simulations show promising results. The next development steps will be the optimization and testing of the method on a real robot platform. In the future, autonomous grasping of multiple objects, for example objects usually detected in home environments will be implemented on Care-O-bot II. Methods to teach these objects to the robot, for example by showing them to the cameras will be implemented.

A sensor filtering and motion control system to intuitively operate an intelligent walking aid robot has further been presented. To set the speed of the robot according to user demands, a fuzzy control system has been implemented. Soon, this system will be extended to also determine and properly react to unusual situations as e.g. when the user

is about to fall and to adapt certain motion parameters as e.g. the speed of the robot to specific users.

8. Acknowledgments

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9. References

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