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Towards an anthropomorphic manipulator for an assistant humanoid robot

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***Abstract*— This paper describes ongoing effort in developing an anthropomorphic arm/hand manipulation system as part of the German Humanoid Research Project SFB588. This project aims at building a humanoid robot that assists humans in everyday service tasks. The manipulation part of this project has to deal with a service environment and to cope with the wide variety of objects and activities encountered in dynamic unstructured environments. Here, we describe several research lines aimed to fulfill these requirements. They consist in building anthropomorphic robotic hands and arms that integrate sensorial capabilities, developing manipulation algorithms that make use of such capabilities, and developing an architecture able to integrate the control of this subpart in the whole humanoid control system.**

Fig. 1. The humanoid robot ARMAR in the kitchen.

I. Introduction

The work presented here is a part of the longterm humanoid robot project SFB588, which aims at developing a humanoid robot that can assists humans in everyday service tasks [1]. It should be able to adapt to an unstructured environment, to have the necessary skills to help humans, and to communicate with them in a friendly and intelligent manner. This project represents a large effort that implies developments in many fields: mobile robotics, human-machine interaction, machine learning, vision, cognitive reasoning, robotic manipulation, etc.

Manipulation component, as a part of this system, has to meet these goals, too. It has to help humans in manipulation tasks, and particularly, be able to manipulate objects that appear in the environment. This implies not only to have the necessary computational skills, but also the appropriate hardware tools, i.e. hand, arm and sensory system.

The half-term goals of the project in the aspect of manipulation are these:

- To carry out a **study of the requirements** for the manipulation system according to its environment and tasks.
- To develop control and algorithmic strategies that make **use of sensorial information**. Initially this will be focused on tactile and force information, but later it will also include visual information.
- To endow the robot with an **action repertoire** for the execution of manipulation tasks in human-like way.
- To develop a control system that integrates the control of the hand within the humanoid control architecture.

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In the next sections we give a glimpse of how these goals can be achieved.

II. Analysis of the requirements of an anthropomorphic manipulator

For a useful design of the hand is necessary to understand the tasks to be performed by the robot and the objects and the environment where these will be executed. In the project SFB855 the designated environment is human homes. In particular, and in the current stage of the project, the main focus lies on a kitchen environment. A real kitchen has been build as a testbed for the humanoid.

Within that experimental environment the humanoid has to deal with all kind of objects and to perform some basic manipulations tasks. Despite this apparent simplicity, complex requirements lie behind. First of all objects of all shapes and sizes appear in this environment: bottles, glasses, cups, plates, cutlery, trays, door handles, switches, buttons. Moreover different manipulation actions might be required on these objects: transporting, pulling, pushing, pouring/filling, pressing and switching buttons, and giving to/receiving from humans. Notice that most of these tasks do not require very precise or dexterous manipulation, but a large flexibility in the skills of the hand.

Since the robot has to work in an environment mostly designed for humans, the approach followed in this project is to build a anthropomorphic arm/hand system that allows to imitate the way humans perform these activities.

To make an anthropomorphic hand appear natural the movements and grasp types have to resemble those of the human

TABLE I

OBJECTS, TASKS AND GRASP PATTERNS

Object	Task	Grasp pattern
Bottles, Glasses and Cups	Transporting	Power, cylindrical (from the side or from above)
	Pouring/filling	Power, cylindrical (from the side)
Cups (using han– dle)	Pouring/filling	Power,lateral/Precision, Pinch
Plates/trays	Transporting	Power,Lateral/Precision, Pinch
	Receiving from human	Non-prehensile, planar hand
Pens/cutlery	Transporting	Precision, Prismatic
Door handles	Closing	Power, cylindrical
	Opening	Power, cylindrical/Non-prehensile, hook
Small objects	Transporting	Precision, Circular (Tripod)
Switches, buttons	Pushing	Non-prehensile, Pointing
Rotary switches, bottle taps	Rotating	Power, Lateral / Precision, Tripod

hand. In this sense many taxonomies of the human hand grasping postures have been studied from the physiological point of view [2] and its translation to robotics hands [3]. Table II describes the range of manipulations activities in which the hand is going to be involved in relation with the grasp patterns necessary to execute them [4].

At the *Institute for Applied Computer Science of Forschungszentrum Karlsruhe (FZK)* several hands has been designed in the past trying to fulfill these requirement [5]. On one hand, a 10 d.o.f. hand controlled through pneumatic actuators, and a 8 d.o.f using fluidic actuators. In these first versions of the hand the purpose was to study the usefulness of the different actuators. They have shown severe limitations for being used for the required tasks. An immediate goal of the project is to develop a hand able to meet the task requirements described above.

Fig. 2. A prototype of a human-like hand.

III. USE OF SENSORIAL INFORMATION

The use of sensorial information is a necessity when working in an unstructured environment, as is the kitchen considered in this project. Two main kinds of sensorial inputs are considered in this project: tactile and vision.

Tactile sensing is necessary to detect mechanical contacts of the hand/arm with its environment. This is crucial for grasping control and because of security reasons. A tactile sensor has been developed [6]. It consist of an array of electrodes printed on flexible circuit board which is covered by a conductive foam. Under pressure, the resistance between the foam and the electrodes changes and is measured via the electrodes on the circuit board. A controller digitalizes the signal and sends an array of values to a computer. Our plans consists in covering the parts of the hands that make contact during the grasping activities (fingertips, inner side of phalanxes and palm) with customized versions of these arrays.

A goal related with the use of tactile sensor is the development of a grasping control algorithm that uses the tactile information as guidance for reaching a firm grasp through a sequence of grasping/regrasping actions. This algorithm could be trained and enhanced by the use of demonstration data provided by a dataglove enhanced with Force Sensing Resistors (FSR) [7].

Vision is the most powerful mean to obtain information about the environment. In the case of manipulation tasks it might have many applications: location and identification of objects, obtention of information about objects like shape, material, movement, etc, feedback for reaching and grasping actions, interaction with humans, and many others. Initially we plan to use vision for the generation of grasp patterns of unknown objects from its shape, in a similar way as it is done in [8]. In further steps we aimed at using vision as feedback for the execution of grasps and other manipulations.

IV. GENERATING OF MANIPULATION TRAJECTORIES

To cooperate with human beings, humanoid robots not only have to feature human-like form and structure but, more importantly, they must possess human-like motion characteristics in the execution of manipulation tasks. Since most manipulation tasks are specified in terms of object trajectories, we use algorithms for solving the inverse kinematics problem associated with redundant arms and generating of human-like robot arm motions as it is done in [9]. Furthermore, human motion capture will be used for the generating motion trajectories from the marker data captured by an optical tracking device.

A given manipulation task is decomposed into several subtasks, representing the sequence of actions the hand/arm manipulation system must carry out to accomplish the task goal. The coordinated execution of a manipulation task requires the scheduling of the subtasks, their synchronization with logical conditions, external and internal events, and a deterministic switch between sequential/parallel actions. Therefore, a framework for coordinated execution of tasks using condition/event Petri nets is used [10].

V. INTEGRATION WITHIN THE ROBOT CONTROL SYSTEM

Control Architecture

The control architecture is divided into three levels [10]:

- The task planning level specifies the subtasks for the arm and hand. Those could be derived from the task

description autonomously or interactively by a human operator.
- The task coordination level generates sequential/parallel primitive actions for the execution level in order to achieve the given task goal.
- The task execution level is characterized by control theory to execute specified sensory-motor control commands. This level uses task specific local models of the environment and objects, which represent the active scene.

Implementation Framework

For the implementation of the control architecture we have used as framework the modular controller architecture (MCA2)[2]. It provides a standardized module framework with unified interfaces. The modules can be easily connected into groups to form more complex functionality. These modules and groups can be executed under linux, RTAI-Linux and Windows and communicate beyond operating system borders. Moreover, the graphical debugging tool MCAadmin/MCAbrowser which can be connected via TCP/IP to the MCA processes visualizes the connection structure of the modules and groups and provides access to the interfaces at runtime. The MCAGUI provides a graphical user interface with various input and output entities.

VI. Conclusion

In this paper we presented several research lines aimed to fulfill manipulation requirements in human-centered everyday environment. We propose manipulation algorithms that make use of sensorial capabilities and an architecture able to coordinate the task execution of the hand/arm system and its integration into the the whole humanoid control system.

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References

[1] R. Becher, P. Steinhaus, and R. Dillmann. Armar ii: A learning and cooperative multimodal humanoid robot system. *International Journal on Humanoid Robotics*, 1(2):142–156, 2004.

[2] Chirtine L. Mackenzie and The Iberall. *The Grasping Hand*. Number 104 in Advances in Psychology. North-Holland, 1994. ISBN: 0-444-81746-8.

[3] M.R. Cutkosky. On grasp choice, grasp models and the design of hands for manufacturing tasks. *IEEE Transacations on Robotics and Automation*, 5(3):269–279, 1989.

[4] D. Osswald, J. Martin, C. Burghart, R. Mikut, H. Wörn, and G. Bretthauer. Integrating a flexible antropomorphic robot hand into the control system of a humanoid robot. In *International Conference on Humanoid Robots*, page 12, Karlsruhe, Germany, October 2003. On CD-ROM.

[5] S. Schulz, Ch. Pylatiuk, A. Kargov, R. Oberle, and G. Bretthauer. Progress in the development of anthropomorphic fluidic hands for a humanoid robot. In *The International Conference on Humanoid Robots*, Los Angeles, Nov 2004.

[6] O. kerpa, K. Weiss, and H Wörn. Development of a flexible tactile sensor for a humanid robot. In *IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems*, pages 1–6, Las Vegas, Nevada, October 2003.

[2] `http://mca2.sourceforge.net/`

[7] R. Zöllner, O. Rogalla, and R. Dillmann. Integration of tactile sensors in a programming by demonstration system. In *IEEE Intl. Conf. on Robotics and Automation*, pages 2578–2583, Seoul, Korea, May 2001.

[8] A. Morales, P.J. Sanz, A.P del Pobil, and A.H. Fagg. An experiment in constraining vision-based finger contact selection with gripper geometry. In *IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems*, pages 1711–1716, Lausanne, Switzerland, October 2002.

[9] T. Asfour and R. Dillmann. Human-like Motion of a Humanoid Robot Arm Based on Closed-Form Solution of the Inverse Kinematics Problem. In *IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems*, Las Vegas, USA, 27-31 Octorber 2003.

[10] T. Asfour, D.N. Ly, K. Regenstein, and R. Dillmann. Coordinated task execution for humanoid robots. In *International Symposium on Experimental Robotics*, Singapore, June 2004.