

## Robotic Home Assistant Care-O-bot: Past – Present – Future

M. Hans, B. Graf, R.D. Schraft

Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)

Nobelstr. 12, Stuttgart, Germany

E-mail: hans, birgit.graf, schraft @ipa.fhg.de

### Abstract

*Technical aids allow elderly and handicapped people to live independently in their private homes as long as they wish. As a contribution to these required technological solutions, a demonstrator platform for a mobile home care system – called Care-O-bot – was designed and implemented by Fraunhofer IPA, Stuttgart. Care-O-bot is a mobile service robot which has the capability to perform fetch and carry and various other supporting tasks in home environments. This paper gives an overview about Care-O-bot's functionalities and first practical tests.*

**Keywords:** Robotic Home Assistant, Service Robot, Care-O-bot, Household Tasks, Intelligent Mobility Aid.

### 1 Motivation

To improve and to ensure the quality of life for the elderly and disabled constitutes an essential task of our society. According to numbers of the Federal Statistical Office, out of 82 million people living in Germany today, around 22 percent are seniors above 60 years. With the demographic development continuing, in ten years the number of people above 60 years old will reach one quarter, in the year 2040 even 36 percent of Germany's population [9]. In an equivalent way, the number of people impaired by diseases or handicaps will rise.

Technical aids enable people in need for support and care to live independently in their accustomed home environments for a longer time. This not only fulfils their desire for independence and autonomy, it also helps to avoid the high costs for the individual treatment in nursing homes that might otherwise be necessary. This, in turn, results in immense savings for the government as well as for each individual.

### 2 Functionalities of a Robotic Home Assistant

Technical aids provide support and instructional help in a person's daily life and also promote self-initiative. Therefore, a robotic home assistant would need to perform the following tasks:

#### 2.1 Household Tasks

Fetch and carry objects as e.g. books, medicine.  
Support in grasping, holding, and lifting objects.

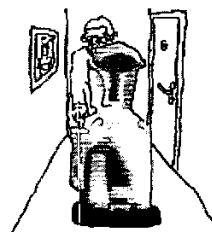


**Figure 1.** Care-O-bot serving a bottle of water to the bedridden user.

Execute everyday jobs such as serving drinks (Figure 1), setting the table, operating the microwave, simple cleaning tasks.

Control of the technical home infrastructure as e.g. heating system, air conditioning, lights, windows, doors, alarm system, etc.

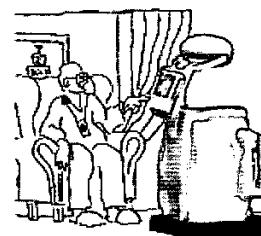
#### 2.2 Mobility Aid



**Figure 2.** Care-O-bot being used as an intelligent walking aid.

Support for getting up from the bed or a chair.  
Intelligent walking aid (Figure 2).

#### 2.3 Communication and Social Integration



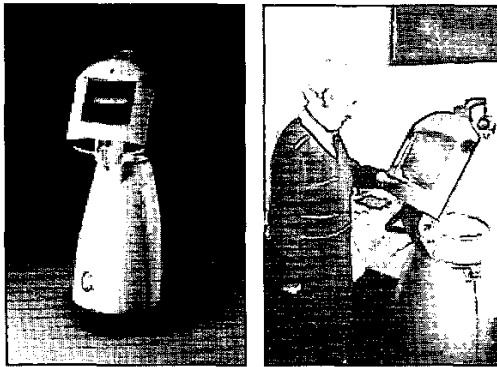
**Figure 3.** Communication Platform Care-O-bot.

Media management (Videophone, TV, stereo, etc.) (Figure 3).

Day-Time-Manager (time for medicine etc.).

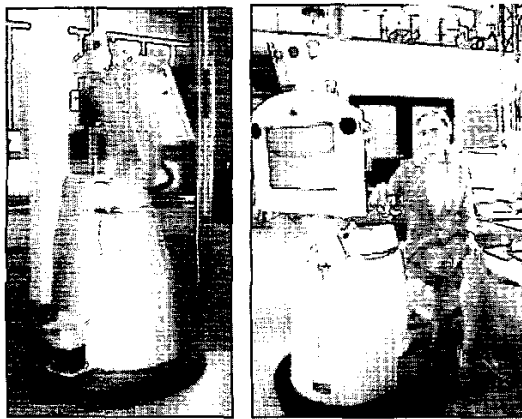
Communication with medial and public facilities  
(physician, authorities, etc.).  
Supervision of vital signs and emergency call.

### 3 Care-O-bot I and Museum Robots - Past



**Figure 4.** Robotic Home Assistant Care-O-bot

Care-O-bot is a mobile service robot designed by Fraunhofer IPA to perform the tasks mentioned above. The first Care-O-bot prototype was built in 1998 [7] (Figure 4).



**Figure 5.** Care-O-bot as an exposition guide (left) and as robot "JJ" in the TV series Jenny Co. (right).

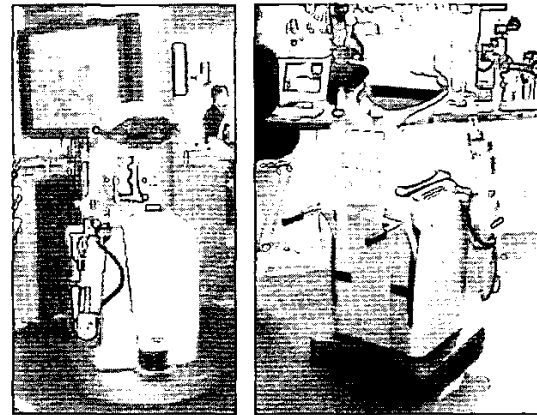
Care-O-bot has already proven its ability to operate safely and reliably in public environments. The robot has been an actor in the TV series "Jenny Co." and on several occasions operated as a trade fair and exhibition guide (Figure 5).

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 [8] (Figure 6).



**Figure 6.** Museum Robots  
Museum für Kommunikation Berlin

### 4 Care-O-bot II – Present



**Figure 7.** Care-O-bot II at  
HANNOVER MESSE 2002

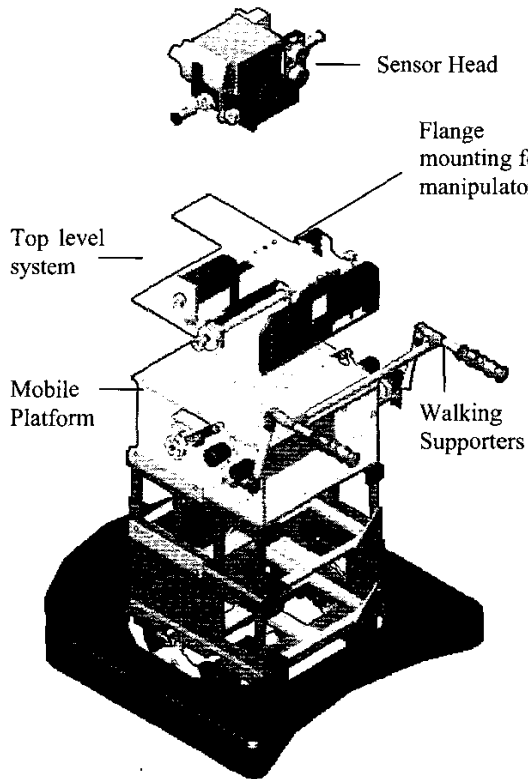
The next generation of Care-O-bot was built in 2001 and first presented at HANNOVER MESSE 2002 (Figure 7) and at Autom@tion Fair, Stuttgart. Care-O-bot II is equipped with a 6 DOF manipulator arm, adjustable walking supporters, a tilting sensor head, and a hand-held control panel.

At HANNOVER MESSE and Autom@tion Fair 2002 Care-O-bot II exchanged business cards with visitors. Visitors were detected and approached automatically, using environmental information provided by the laser scanner of the mobile platform. Once a visitor had been detected and approached, the robot activated its arm to grasp one of its own business cards stored on a special tray on top of the platform and presented it to the visitor. The motion of the arm was combined with corresponding speech output and graphical 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 detected the movement of the card being pulled away by the user and open up.

In a second step the robot requested the business card of the visitor nodding to him with his head. The same optical system was used to detect the card being put in the "hand" of the robot which then closed to hold the card. Care-O-bot then put the card of the visitor to its tray.

#### 4.1 Mechanics



**Figure 8.** Mechanics of Care-O-bot II

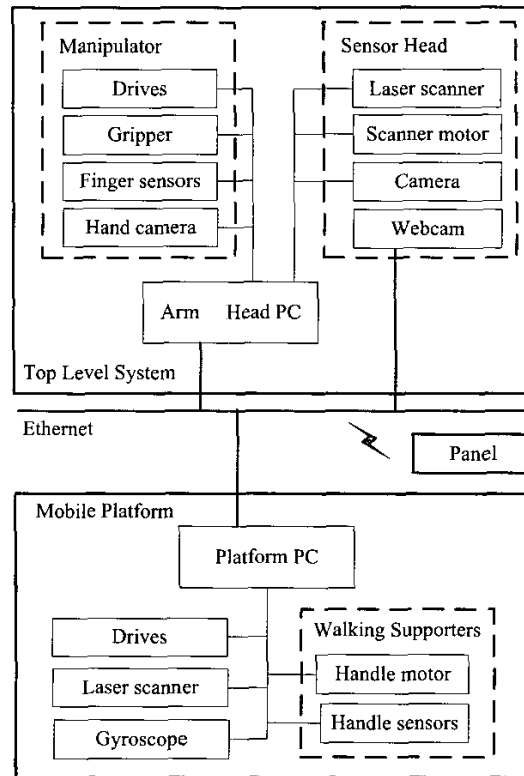
Figure 8 shows the mechanical components of Care-O-bot II. The robot consists of two autonomous systems: the mobile platform with the walking supporters and the top level with the manipulator arm and sensor head.

Both systems can be disconnected easily. They both work independently with their own PC, power supply, and emergency control circuit. This is a great advantage for development, because two developer teams can work on the robot simultaneously. If the two subsystems of the robot are connected, they work as one system and any emergency button triggers both emergency control circuits.

#### 4.2 Hardware-Architecture

The hardware-architecture of Care-O-bot II is shown in Figure 9. It is a mirror of the mechanics, consisting of

two independent control systems each based on an industrial PC. Platform and arm/head PC are connected directly by an Ethernet link.



**Figure 9.** Hardware-Architecture of Care-O-bot II

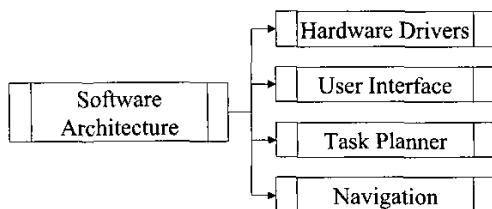
The PC of the top level system controls the drives of the manipulator arm and the sensor head and activates the gripper. Furthermore, it processes the sensor data of the cameras and laser scanner. The PC of the mobile platform controls the autonomous movement of the robot and adjusts the walking supporters. Care-O-bot is additionally equipped with a hand-held control panel which can be attached to the back of the platform. It provides the user interface (PC with a touch screen) and is connected to the other control computers by wireless LAN.

All drives, the finger and the handle sensors of the walking supporters are connected via CAN-bus to their corresponding PC. Communication between the PCs is based on Ethernet. The other components are connected through serial ports.

#### 4.3 Control Software

The control software for both, the mobile and arm/head control platform of Care-O-bot II is based on the "Robotics Toolbox", an extensive software library, which in several independent packages contains modules for implementing all necessary mobile robot

control functions, as e.g. autonomous navigation, obstacle avoidance, sensor and actuator drivers etc.

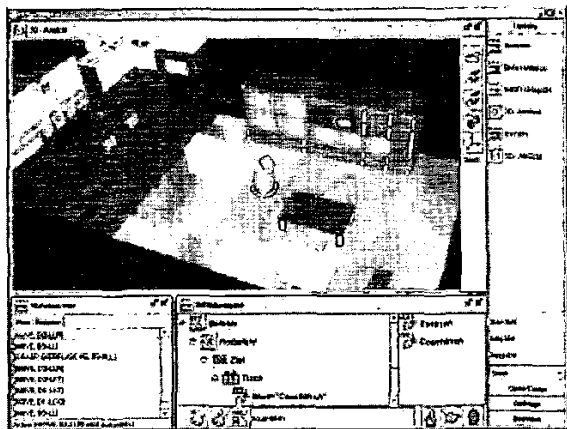


**Figure 10.** Some Robotics Toolbox components

This software library, developed by Fraunhofer IPA (Figure 10), not only enables the development of complex robot control programs in short time, it also facilitates the transfer of an existing programs to different hardware platforms and operating systems [10].

#### 4.3.1 Multimodal User Interface

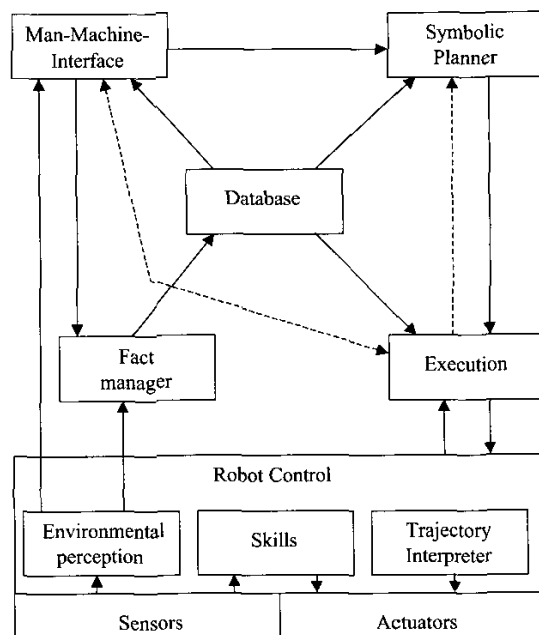
Even users without any prior technical knowledge should be able to operate and use Care-O-bot without difficulties [1]. For simple man-machine communication without misunderstandings, multiple sensing channels (speech, haptics, gestures) should be addressed. Commanding the robot, for example, is done by speech input and by using the integrated touch screen. The necessary feedback about the robot system state is given by speech output and graphical presentations on the monitor. The user interface is implemented on a hand-held, lightweight control panel, which the user can retain even while the robot moves around. The panel is radio-connected to the robot platform PC, so that the user is able at all times to supervise or modify the current behaviour of the robot or e.g. call it to a certain position. The current camera view of the robot can additionally be displayed on the mobile control panel. Figure 11 shows an example, a 3-D map of the robot assistant in a home environment.



**Figure 11.** Graphical user interface output of Care-O-bot

#### 4.3.2 Interactive Task Planner

Care-O-bot is equipped with a hybrid system architecture, containing deliberative and reactive components [4]. The basic modules are shown in Figure 12. Regular arrows represent data flow, dashed arrows represent control flow.



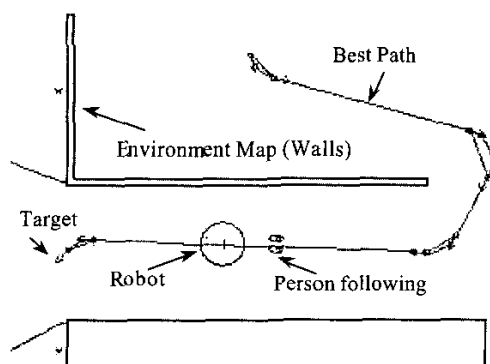
**Figure 12.** Basic modules of the system architecture of Care-O-bot

The assistant can be instructed interactively through the *man-machine-interface*. Each user command is transferred to the *symbolic planner* which then generates a list of possible actions necessary to fulfil the given task. The *execution module* picks a suitable action from the list and triggers the *robot control* to execute it. All modules need a previously learned world-model containing information about the environment, which is provided in a database. The assistant's knowledge about its environment is updated continuously based on sensor readings. Further, it displays the progress of task execution via the *man-machine-Interface*.

With the given system architecture, Care-O-bot is able to plan and execute complex tasks autonomously.

#### 4.3.3 Navigation

For navigation, Care-O-bot uses a flexible path planning method for nonholonomic mobile robots. An intelligent planner based on a static map of the robot's environment has been developed. The generated path is smoothened and eventually modified in reaction to dynamic obstacles or other external forces [3].



**Figure 13.** Collision free path planned for the robot while being used as an intelligent walking aid

The developed method comprises the possibility to set current robot properties and different motion restrictions on the fly. This is e.g. necessary in case a person follows the robot using the walking aid (Figure 13).

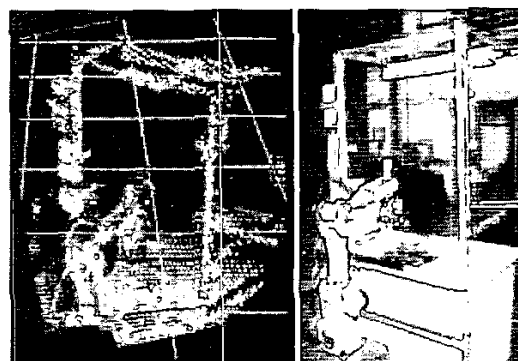
#### 4.4 Manipulation

One of the assistant's most important skills is the ability to manipulate objects in its environment (see section 2.1). A manipulator arm, developed specifically for mobile service robots, 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 gripper has sensors to detect objects being placed in the gripper, for additional information about the shape and kind of the object a camera is attached.

#### 4.5 Sensor Head

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.

The environmental model acquired with the 3-D laser scanner consists of a large number of distance values (Figure 14), which can be evaluated to detect obstacles close to the robot arm. A collision free trajectory for the robot manipulator can further be generated based on this data [6]. Some promising first simulation results could already be obtained.



**Figure 14.** Environmental model acquired with the 3-D laser scanner.

#### 4.6 Walking Aid



**Figure 15.** Care-O-bot being used as an intelligent walking aid at HANNOVER MESSE 2002

The functionality of Care-O-bot as an intelligent walking aid (Figure 15) provides an enormous enhancement in safety and comfort compared with conventional walking supporters. According to the user requirements, different autonomy levels of the mobile assistant can be selected [2]. In a similar way as with conventional walking support systems, the robot moves depending on the forward or backward pressure applied to the supporting handles. The applied pressure is measured by sensors inside the handles of the walking supporters.

Two basic operation modes have been implemented on the intelligent walking aid: "Direct Control Mode" enables the user to "push" the robot to a certain direction, whereas obstacles on the path are detected and surrounded. In "Target Mode" the user follows the assistant along a preplanned, optimal path to a previously specified target.

## 5 Outlook - Future

The second Care-O-bot prototype is a complex system with high potential for development of challenging tasks. In the near future, applications will be implemented, beginning with simple fetch-and-carry duties as a basic feature. The abilities of the robot assistant will be improved step by step with the goal to fulfil the requirements as mentioned in chapter 2. Autonomous grasping of multiple objects, methods to teach these objects to the robot, for example by showing them to the cameras, and autonomous grounding and anchoring are additional tasks that will be solved soon.

Care-O-bot II has a tilting laser scanner to acquire 3-D information about its environment. A method to plan an optimal path for a mobile robot arm has been simulated and shows promising results. The next development steps will be the optimisation of the method and execution of first tests on the real robot platform.

A sensor filtering and motion control system to intuitively operate an intelligent walking aid robot is further in development. 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 the parameters of the robot to specific users.

## 6 Summary

An overview of the development of robotic home assistant Care-O-bot has been presented. First, the motivation and the required functionalities of a robotic home assistant have been presented. After giving a short retrospective view of the first prototype and the related museum robots, the Care-O-bot II platform and its components and abilities have been described:

The robot has a modular hardware-architecture and mechanics, which supports flexible development and reduces maintenance costs.

The control software is based on the "Robotics Toolbox", an extensive software library, which contains modules for implementing all necessary mobile robot control functions.

With its interactive task planner, Care-O-bot is able to execute complex tasks autonomously. A hybrid software-architecture enables deliberation and reactive behaviours.

For supervising the manipulation process, Care-O-bot II has been equipped with a tilting sensor head containing a laser scanner and two cameras. The robot is able to gather all important information about its environment which can in a next step be used for planning the movement of the manipulator arm.

Care-O-bot II can be used as an intelligent walking aid. Forces applied to the handles of the walking

supporters are measured and generate an adequate movement of the platform.

Last, an outlook of future goals has been shown. The given abilities of Care-O-bot II will be improved step by step, adding new applications, and integrating additional sensor data and processing methods to fulfil the requirements of performing household tasks, being a mobility aid and supporting communication and social integration of elderly people.

## 7 Acknowledgement

Part of this work has been supported by the MORPHA-project [5] funded by the German Ministry of Education and Research (bmb f) under grant 01IL902G9.

## 8 References

- [1] Graf, B., H gele, M.: "Dependable Interaction with an Intelligent Home Care Robot". In Proceedings of ICRA-Workshop on Technical Challenge for Dependable Robots in Human Environments, 2001, pp. IV-2.
- [2] Graf, B.: "Reactive Navigation of an Intelligent Robotic Walking Aid". In proceedings of ROMAN-2001, pp. 353-358.
- [3] Graf, B., Hostalet Wandosell, J. M.: "Flexible Path Planning for Nonholonomic Mobile Robots". In Proceedings of The fourth European workshop on advanced mobile robots (EUROBOT'01), September 19-21, 2001, Lund, Sweden, pp.199-206.
- [4] Hans, M.; Baum, W.: "Concept of a Hybrid Architecture for Care-O-bot". In proceedings of ROMAN-2001, pp. 407-411.
- [5] "MORPHA Interaction, Communication, and Cooperation between Humans and Robot Assistants", <http://www.morpha.de>, 2002.
- [6] Rohrmoser, B.; Parlitz, C.: "Implementation of a path-planning algorithm for a robot arm". In: VDI-Berichte 1679: Robotik 2002, S. 59-64, D sseldorf: VDI-Verlag GmbH, 2002.
- [7] Schraft, R. D.; Schaeffer, C.; May, T.: "The Concept of a System for Assisting Elderly or Disabled Persons in Home Environments", Proceedings of the 24th IEEE IECON, Vol. 4, Aachen (Germany), 1998.
- [8] Schraft, R. D.; Graf, B.; Traub, A.; John, D.: "A Mobile Robot Platform for Assistance and Entertainment". In Industrial Robot Journal, Vol. 28, 2001, pp. 29-34.
- [9] "Statistisches Bundesamt Deutschland", <http://www.destatis.de>, 2002.
- [10] Traub, A.; Schraft, R. D.: "An Object-Oriented Real-time Framework for Distributed Control Systems", in Proceedings of ICRA-99, pp. 3115-3121, 1999.