Care-O-botÔ: The Concept of a System for Assisting Elderly or Disabled Persons in Home Environments

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***Abstract* – Medical expenses are increasing drastically all over the world. More than 30% of these expenses are related to elderly people. By the year 2030 the number of 60-year-old people will have doubled. Technical aids are required allowing people to live independent and supported 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-botÔ – was designed and implemented by Fraunhofer IPA, Stuttgart. The Care-O-botÔ is a mobile service robot, which has the capability to perform fetch & carry and various supporting tasks in home environments. Main emphasis is laid in communicational and social integrating tasks, like video telephone, automatic emergency calls and interactive communication. Focus of work performed so far is the mechanical design and realisation of the vehicle, the development of the control system architecture, the implementation and testing of navigation and motion algorithms. The integration of a sensor guided robotic arm is part of the next development phase.**

1. PRESENT SITUATION

Improving the quality of life for the elderly and disabled persons is becoming an essential task for society today. An important aspect for all people having the need to be supported in their daily-life-activities is to be still integrated into social life despite of their existing disabilities.

In Germany, the number of 60 year old people is expected to double, while the number of 90 year olds will triple by the year 2030. Accordingly, the number of people with illnesses and restricted capabilities is also expected to increase. Statistics reveal that the number of persons requiring home health care in the year 2040 will make up nearly 3.5 % of the population (today it is 2.1%).

The focus for the immediate future and the following decades is to realise the principle ”home care before facility care” as already stated in the existing care laws.

However, the financial strain on the country and the individual to provide this care is extreme, so the primary task for society will be to reduce the costs for care, while preserving and improving the quality of life for this group.

Significant savings occur when individuals that need support in daily-life-activities can continue to live at home, because the high costs incurred for individual treatment in Senior Citizen Centres and in Nursing Homes are eliminated. According to an economical study performed in the USA more than 3 billion US dollar could be saved per year, if all elderly US-citizen would stay just three more months at home before joining a senior citizen home.

Beside new decentralised services supporting elderly people at home, accompanying technological solutions are required helping people to facilitate life at home. Thus, after the successful performances of automated solutions in industrial production, it is now expected that the technological concepts of these solutions will be available also for application in common households in the near future.

Many factors promote the need for supporting technological solutions within the households of disabled and elderly people:

- The reduction in human mobilisation capabilities and the reluctance to perform daily tasks,
- The desire to be self-reliant, self-sufficient and self-responsible,
- Increase of single-person household, lost of relatives,
- Automation of household tasks provides more time for personal attention and care to nursing personnel,
- Increase in income due to benefit plans (ie. life insurance, savings, public and company health plans),
- Costs for mechanical and electronic devices are decreasing,
- Higher efficiency of sensors and control techniques,
- Innovative, automated solutions are available from industrial production and ready for immediate use.

In the next years there will be a successive development of total and partial systems in the area of home help aids. Assuming that these systems will be used in environments in which the user has little or no technical aptitude, these systems must have the ability to adapt to its environment independently and focus on its main function: to be a constant aid for the person in need.

2. REQUIREMENTS TO HOME CARE SYSTEMS

Technical systems can give support and instructional help and also promote self-initiative. Therefore, a mobile service robot would support the following functions in an optimal case:

Communication and Social Integration

- Communication with medical services and authorities (tele-medicine, doctors, government bureaux, etc.),
- Automatic emergency calls,
- Management of personal contacts,
- Management of home media (video telephone, TV, music, radio, interactive media etc.),
- Voice as natural and intuitive command interface,
- Multimedia touch-screen as additional interface.

Technical House Management (Infrastructure)

- Control of home infrastructure devices such as heating, air conditioning, lights, windows, front door, security / alarm systems etc.

Personal Supply

- Delivery and disposal of hot meals, food and drinks,
- Performance of simple household services - like cleaning or flower watering etc.

Handling Aid / Fetch and Carry Tasks

- Serving of hot and cold meals,
- Providing medicine and care products,
- Providing laundry and health care articles,
- Delivering books and remote control etc.,
- Support in grasping, lifting and holding of objects and devices – as e.g. during meal serving activities or holding a book etc.

Fig. 1 Care-O-bot™ serving a hot meal to a person laying in bed

Fig. 2 Care-O-bot™ giving a helping hand as mobile walking aid

Mobility Support

- Support and guidance assistance,
- Seating and stand-up assistance,
- Support for getting up from chair or bed, support as a intelligent standing and walking aid, giving a helping hand on the way to the bathroom.

Personal Management

- Day-time-management (daily routine, medications, reminder to birthdays, fixed dates and events, activity motivation etc.).

Household Tasks

- Meal preparation and serving (e.g. micro wave, stove),
- Pouring out drinks,
- Simple cleaning tasks etc.

Personal Security

- Monitoring of personal safety,
- Monitoring of vital parameters (pulse, respiration, blood pressure, temperature, etc.),
- Monitoring of mental parameters (behaviour, activities, responsiveness, etc.),
- Health management (information, advice, motivation),
- Recognition of missing / critical life signals or abnormal daily routines,
- Alarm functions in terms of automatic call contact to neighbours, local services and / or authorities in case of emergency (tests, wake-up calls, emergency calls),
- Control of safety threats (smoke, water, gas, burglary).

Fig. 3 Care-O-botÔ acting as central communication platform

The resulting advances and benefits for elderly and disabled people applying technological aids – like Care-O-bot™ – are the following:

- Increase of personal independence,
- Improvement of quality of life,
- Strengthening and supporting personal mobility,
- Active aid during absence of care personnel and nurses,
- Increase of individual security,
- Unified and easy handling and operation of home infrastructure through natural speech,
- Better social integration via video-phone,
- Reduction of medical costs for in-house care.

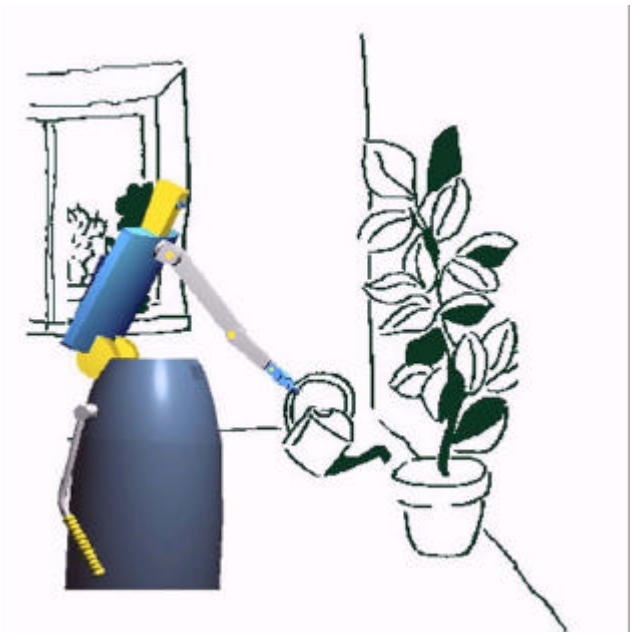

Fig. 4 Care-O-botÔ performing useful household tasks

3. SPECIFICATION OF TECHNICAL SOLUTIONS OF A MOBILE HOME CARE ASSISTANT

Taking the given requirements into account, the following technological concept was developed by Fraunhofer IPA:

Mechanical Concept

- Mobile platform suited for home environments – with limitation to a flat floor level – optional: elevator rides,
- Integration of a manipulating arm able to perform simple handling tasks like fetch and carry,
- Flexible hand suited for grasping, holding, serving etc.,
- Walking aid and standing up aid for disabled people,
- Integration of all electrical components.

Electrical Concept

- Independent, battery based energy management and supply,
- Automatic battery recharging,
- Interfaces for external instruction (remote control),
- Interfaces to home infrastructure.

Control System Hardware

- Modular and extendable control system hardware,
- Unified and standardised interfaces to various types of control components and sensors,
- Design to low-cost architecture,
- Sufficient hardware capacity for multimedia purposes and speech recognition.

Control System Software

- Environment recognition,
- Map building,
- Task, action and execution planning,
- Dynamic path planning,
- Collision avoidance,
- Obstacle surrounding,
- Reactive navigation,
- Dead reckoning,
- Force feedback control in walking aid mode.

Operator's Interface

- Instruction of Care-O-bot™ with natural speech,
- Answers, announcements and provision of information by Care-O-bot™ in natural speech,
- Alternative instruction and provision of visual information on touch screen,
- Video-telephone connection.

4. MECHANICAL DESIGN, CONSTRUCTION AND IMPLEMENTATION

For such a complex mobile robot like the Care-O-bot™ an application specific mechanical design and construction was necessary and has been performed by Fraunhofer IPA in Stuttgart. First all the details of mechanical requirements have been collected and analysed in detail. In short the following extract is given of some of the important aspects:

Requirements to Care-O-bot's™ Mechanics

- Manoeuvrability in narrow home environments – as e.g. turning on the spot, backwards driving, reactive navigation,
- Compact design fitting for standard home environments – e.g. widths of doors, bathrooms, kitchens etc.,
- Highly integrated mechanics to fit the given environmental requirements,
- Design for minimal weight,
- Low centre of gravity for maximum stability as walking aid,
- Integration of fast cycle rechargeable battery cells to guarantee a 24 hour readiness for duty,
- Integration of multipurpose manipulating arm with a multipurpose gripping device,
- Multimedia touch screen in optimal position,
- Design for both: maximum functionality and user acceptance,
- Consideration of modern safety and EMC restrictions,
- Ergonomically useable walking aid for handicapped people.

Mechanical Solutions and Modules of Care-O-bot™

- Two differentially driven wheels in combination with four independent supporting wheels,
- Symmetrical circular form of main body resulting in minimal collision dangers,
- Highly integrated mechanical body structure with a maximum diameter of 0.6 m,
- CAD-optimised body frame construction realised in alloy resulting in a low total weight of 120-150 kg,
- Centre of gravity at lowest possible level due to lowest possible integration of heavy components – like batteries, drives etc.,
- Use of NiCd-batteries in combination with an active contact finger for recharging,
- Mechanical synergy of first arm axis and monitor holder – allowing to easily change position and orientation of touch screen,
- Degrees of freedom of manipulating arm extended through two additional rotational axes in vehicle body,
- Mechanical layout, cover and user interfaces developed by professional designers,
- Limitation of the torque from the main drives, integration of a position detecting and force sensitive bumper, emergency stop buttons and programming of safety fields in the certified laser scanner,
- Integration of a flexible and ergonomic walking aid with an easy to learn manoeuvring interface.

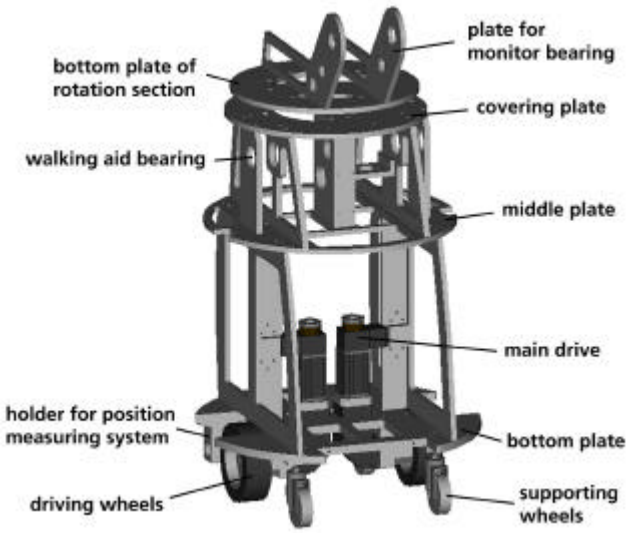

Fig. 5 Mechanical construction plan of Care-O-bot Ô

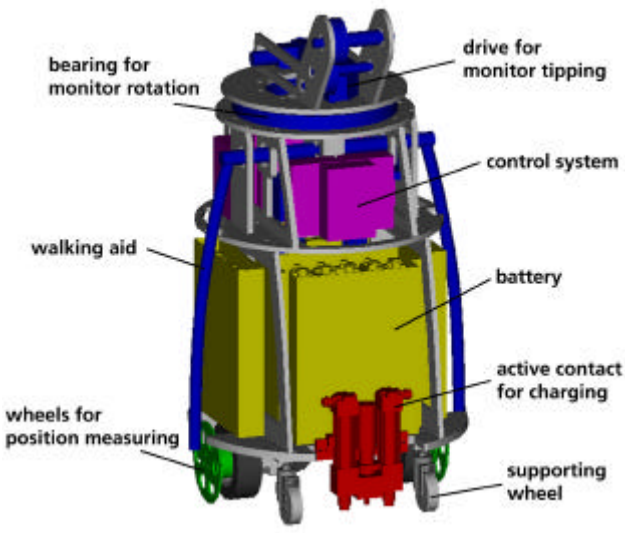

Fig. 6 Functional modules and its placement within Care-O-bot Ô

5. CONTROL SYSTEM ARCHITECTURE

To fulfil and perform all required functionalities of Care-O-bot™ a sophisticated control system is necessary. While designing such a suited control system architecture the following functional aspects and technological needs have been taken into account by Fraunhofer IPA:

Technological Needs of Control System:

- Manual remote control of Care-O-bot™ (optional),
- Central disposition of several Care-O-bot™ acting in parallel – e.g. in a nursing home (optional),
- Natural speech control interface and visual touch screen commanding for elderly and disabled people,
- Multimedia touch screen for information visualisation and manual instruction,
- Video-telephone connection on touch screen,
- Sensors for environment recognition, map building, collision avoidance and navigation purposes,
- Drive control of motion axes,
- Drive control of rotational body axes,
- Drive control of manipulating arm,
- Modular architecture for future extensions,
- Control of supporting electrical devices – like mechanical bumpers, signal lights, battery charger etc.

The resulting control system architecture has the following technical characteristics:

Resulting Control System Architecture:

- Master PC for vehicle control with RT kernel Vx-Works for instructing all device and drive control modules,
- Modular field bus network based on CAN-bus allowing to easily connect various types of decentralised control modules – e.g. for axis control, sensor data evaluation etc.,
- Various types of operation modes driving the Care-O-bot™ according to the needs of its usage – as e.g. automatic, manual and reactive mode,
- Connected sensors for navigation are: CCD-camera, high-resolution 2D-laser scanner, segmented mechanical bumper and position measuring wheels,
- Secondary PC, connected via Ethernet, running under Windows NT/95, being responsible for the control of all communicational tasks – like speech control, multimedia touch screen, video-telephone, external instruction and linking via wireless Ethernet connection.

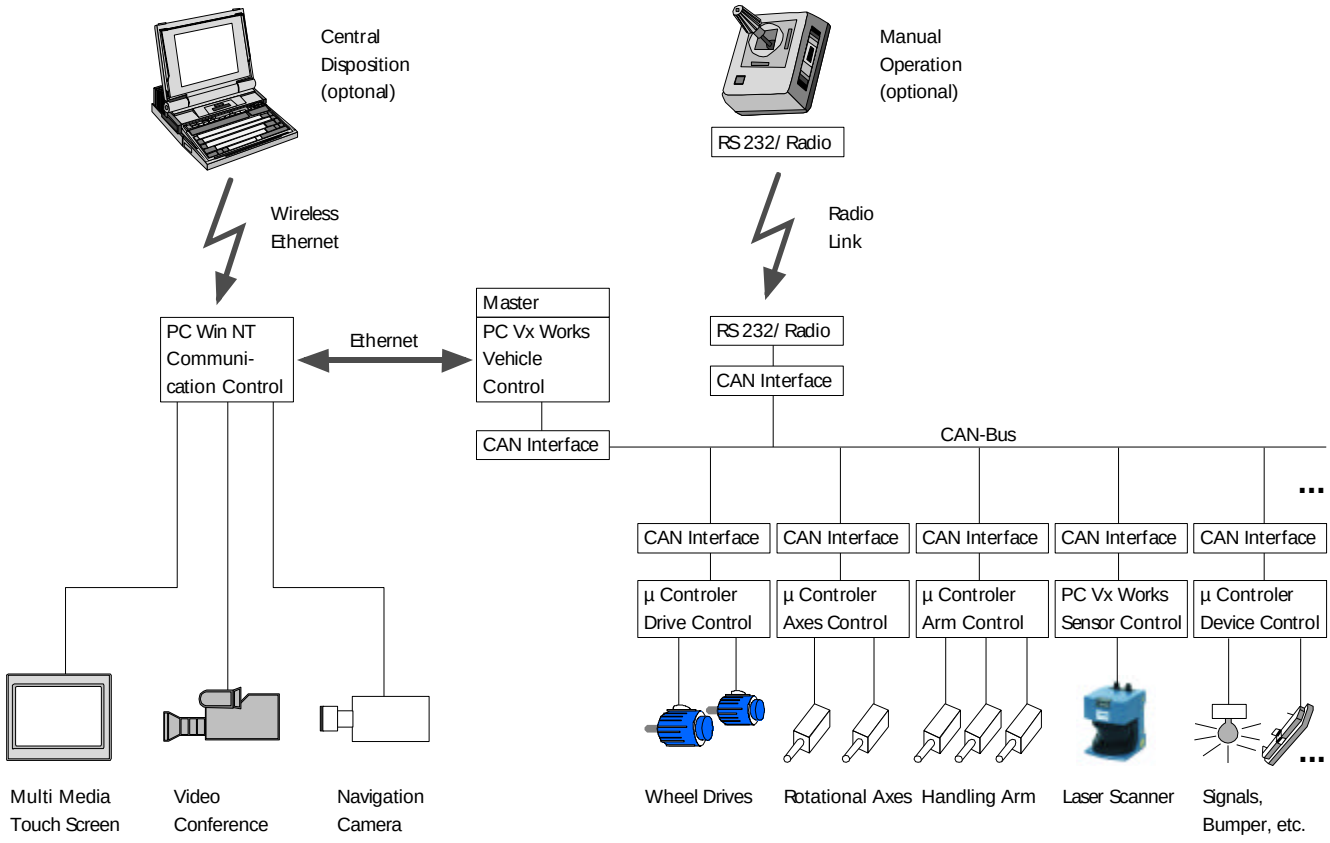

Fig. 7 Care-O-bot'sÔ decentralised control system architecture

6. PROTOTYPE REALISATION

The prototype system of Care-O-bot™ – as shown in figure 8 – was integrated, tested and optimised by Fraunhofer IPA in Stuttgart. It was successfully presented the first time to the public at the Hannover Fair, in April 1998. On basis of the very promising demonstration results and the given feedback from both customer and supplier side, the technological concept of Care-O-bot™ will be further developed and integrated at Fraunhofer IPA in close cooperation with related industrial partners and professional care service organisations. The next step in technological development at Fraunhofer IPA will be the implementation and integration of a supporting manipulating arm into the mobile platform. The first simulation tests with various arm types have been performed yet – with encouraging results.

Although Fraunhofer IPA is in discussion about the long-term industrial exploitation of Care-O-bot™ nothing is decided yet and all the rights of the Care-O-bot™ concept are still in the hands of Fraunhofer IPA.

Fig. 8 Integrated Care-O-bot™, ready to operate

7. CONCLUSION AND OUTLOOK

Due to the given demographic trends and developments within the industrial societies all over the world practical solutions are required that help to dam exploding medical costs. Besides new decentralised supporting services for elderly and disabled people living longer at home, new technological solutions are required to facilitate their daily life.
With the developed concept of an intelligent Care-O-bot™ an interesting solution is available that allows to further facilitate and enable the secure living of elderly people at their private homes under safe conditions – according to their own wishes. Nevertheless the underlying technological concept of Care-O-bot™ is not limited to applications in health care. Further possible applications of the Care-O-bot™ concept are:

- ”Personal robot” in private homes (”robotic butler”),
- Mobile information desk in public areas,
- Robot valet,
- Safety guard,
- Robot receptionist in office buildings,
- Guided robot tours in museums,

Etc.

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