AUTOMATION AND TELEMATICS FOR ASSISTING PEOPLE LIVING AT HOME

Panu Harmo, Jere Knuuttila, Tapio Taipalus, Jose Vallet, Aarne Halme

Automation Technology Laboratory, Helsinki University of Technology (TKK), Konemiehentie 2, 02150 Espoo, Finland. Tel. +358 (0)9 4513313, fax +358 (0)9 4513308, e-mail: Panu.Harmo@hut.fi, http://www.automation.hut.fi/AA/

Abstract: This paper describes a robotic and automation system presently under development for studying home automation and indoor robotic technologies as well as new service scenarios based on these technologies. The system consists of remote users, a home automation server, home automation equipment and home robots. Alarms and data are sent outside the home to helpers and caretakers. A remote user connects to the home server from the Internet to interact with the home and the people residing there. A demonstration system, that is open to the public, has been built in a model home.

Keywords: telematics, telecommunication, robotics, multimedia, remote control, virtual reality

1. INTRODUCTION

The average age is rising in most western countries. In the future, there will be proportionally more elderly people than there is now. Greater effort is needed to take care of these persons. Many aged people prefer to live at home rather than to move to an institution. Living at home is also more cost effective.

Smart homes and technology for elderly to live longer at home has been researched in numerous projects. Review of these has been done by (Stefanov et al. 2004). Usually research is concentrated on one or few technologies, such as networked cameras observing and measuring events at home (Morioka et al. 2004), (Irie et al. 2004) or home robot control (Graf et al. 2002). This is also common in commercial solutions, where one company presents its products (FEMINITY, 2004) often using its own smart show house. Another approach is to use show houses or apartments where independent devices and architectural solutions that aid the life of disabled and elderly people are displayed (TOIMIVAKOTI, 2004). We integrate many technologies and try to evaluate compatibility and interoperability issues. We also try to find users' opinions and needs, which are often neglected or assumed to be well known.

The aim of this study is to develop modern telematics, home automation and home robotics solutions to assist elderly and disabled persons to live safer and better in their homes. Some of the findings and ideas are implemented in a demonstration system.

The demonstration system consists of an Internet connection, home automation devices and networks, home robots and user interface devices. The system is built in a home-like environment to get most realistic results from tests. For the development work it is also important to get user feedback.

Social services department of City of Helsinki has a long-term exhibition called "Functional home" (FH) (TOIMIVAKOTI, 2004) containing two model apartments for exhibiting living solutions for elderly and disabled people. It is open to the public. There are three full-time professional employees to guide the visitors. The apartments are equipped with assistive devices in a home-like atmosphere with appealing furniture and design. In addition to showing the assistive solutions in real environment, four larger show rooms are full of assistive devices.

Visitors to FH consist of social care students and employees, building professionals, elderly and disabled people,their relatives and friends and ordinary citizens. Cooperation between the engineering and social sector people can bring about fresh new ideas for new assistive schemes.

Mobile robots can be useful in many ways in homes and offices. For example they can be used for monitoring and measuring the environment, they can act as user interfaces to home automation systems or as moving communications platforms. Some mobile home robots are already in the market. These existing robots are mainly for entertainment such as the Aibo from Sony, for mowing the lawn such as the Auto Mower from Husqvarna, for vacuuming such as the Trilobite from Electrolux. Robots can replace pets in some cases. For allergic people or in environments like some nursing homes where pets are not allowed, a mechanical pet might be a welcomed substitute.

Indoor robots can be best utilized in an intelligent environment, which comprises of home automation networks, connected sensors, actuators and other devices. Indoor service robots use the local network to exchange information and controls with the other connected devices. A remote user can connect to the local network to retrieve data and to control the robot and other devices in the network. In this type of environment, effective remote interaction with the service robot can be implemented by utilizing virtual models and augmented reality.

The developments in home automation are paving the way to home robotics. During the last few years the market for commercial home automation networks and home network gateways has grown, but no single technical solution has gained a clear edge over the others. On one hand the multitude and on the other the lack of standards is hindering the growth. Home server and gateway technologies are important, because home robots will communicate with the outside world through these gateways.

The objective is to research different aspects of a remote assistive system for elderly and disabled. This is done by assembling an experimental demonstration system to FH. Evaluation is done from experiences gathered from tests and by questionnaires to the visitors of FH. This paper first discusses the used technologies and equipment. The system functions are described in chapter 3. Experimental methods and results are presented in chapters 4 and 5 followed by discussion and conclusions in chapter 6.

2. EQUIPMENT

2.1. Overview

The general scenario is this: a person at home asks for outside help using telecommunication. He gets help via the Internet in the form of personal communication or remote operation of some device, such as a home robot. Also local automation helps the person without the need of remote operations.

To build such a system various technologies needed to be investigated. The demonstration system was to be built using wired and wireless home networks, mobile robots and a home server computer with an Internet connection. The functions of the system are:

- User interfaces enabling controlling of home devices and informing the users of the equipment states.
- A mobile robot used as a messenger: it looks for a person, displays a message, and waits for a acknowledgement
- Monitoring the kitchen stove
- Informing of incoming traditional mail
- Reminding to take keys when leaving the house
- Measuring of the activity level of the inhabitant using multiple IR motion detectors in every room
- Communicating to home through Internet, cellular network and other networks.

The main features of the system in order to have functions above are:

- Video, audio and data communications over TPC/IP
- Teleoperation of cameras, robots and other devices over networks
- Access and sharing of documents and data
- Data collection, storage, management and distribution of the measured data
- Use of virtual models in navigation and path planning
- Augmented reality user interface

The central technologies needed to develop the features are the following:

- Home automation and home automation networks
- Home gateways
- Mobile home robots
- Positioning system for robots, people and equipment
- Video conferencing
- Virtual models and augmented reality

The most significant part of the system is the home server. All messages and controls go through it. The server also takes care of processing the incoming data and taking appropriate action. The robots, the spherical Rollo (Fig. 2.) or the wheeled Rolloottori

(Fig. 3.), act as mobile user interfaces and platforms for cameras. A sketch of the system setup is shown in Figure 1.

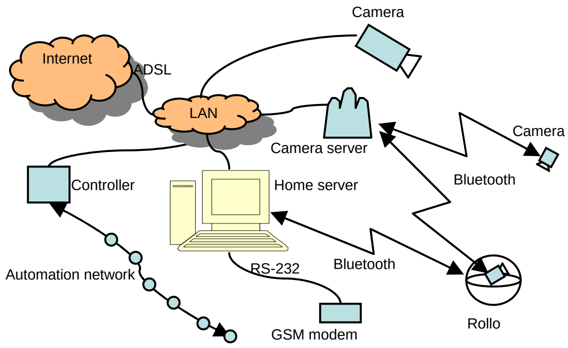

Fig. 1. General system structure

Next, the main parts of the demonstration system are presented:

- Home server
- Home robot
- Home automation network
- User interface of the system

2.2. Home Server

The server is a PC running Windows 2000 operating system. It provides the external user with access to the robot, its devices and external camera. It relays video from robot and other cameras. The server is used for downloading the user interface program to the user stations as well. The home automation network is connected to the server through a local area network. The server makes decisions based on the incoming sensor data and controls the outputs of some devices. It relays messages between different sub-systems and can receive and send messages to the different mobile interfaces such as PDAs, mobile phones and the robots

Some robot functions such as localization are computationally so heavy that they have to be performed in the server instead of the robot. Localization relies on landmarks, specially designed images placed on the ceiling. The landmarks include identification and orientation information. By analyzing the robot camera images and using stored image position information, the position and orientation of the robot can be calculated.

There is also a GSM modem connected to the server. The modem is used for sending messages about the state of the system. The user can also inquire the state of the system and control the devices of the system using this connection.

2.3. Ball shaped robot – Rollo

Rollo has a spherical transparent cover (Fig.2). It moves forward and backward by displacing its center of gravity by moving its internal drive unit (IDU). When the rim attaching the cover halves to the IDU is horizontal, the ball can turn around. When the rim is in vertical position, the ball can move sideways.

Fig. 2. Rollo, the ball shaped home robot

The energy source is NiMh batteries, which provide power up to two hours, depending on the usage of the motors, screen, camera, and radio communications. The robot is controlled by a microcontroller (Phytec MiniModul-167 using Siemens SAB C167 CR-LM microcontroller). For visual and audio perception the robot is equipped with a camera, a microphone and a video link. The camera can be tilted +-100 deg. When it points upwards, it is used for detecting visual landmarks on the ceiling. For communication with the server a Bluetooth chip is used. The robot has sensors for temperature, pan, tilt and heading of the inner mechanics, and pulse encoders in the drive motor. The software has been written in C language.

Rollo can be controlled by either sending commands through the Bluetooth radio or by using an infrared remote controller. The commands include turning for a certain number of degrees, running for a certain distance, using the auxiliary devices and displaying messages and graphics on the screen.

2.4. Rolloottori

Rolloottori has been used to test different ideas and technical solutions. The spherical shape limits the space and weight of devices that can be integrated in the robot, so a more flexible platform was needed in the development phase. Also, since the control of the spherical shape has not been thoroughly mastered yet, Rolloottori provides a platform that can be used to test tasks that require more deterministic movement.

Rollo and Rolloottori have the same electronics, also designed at the TKK Automation Laboratory. With Rolloottori, testing a touch screen user interface was possible.

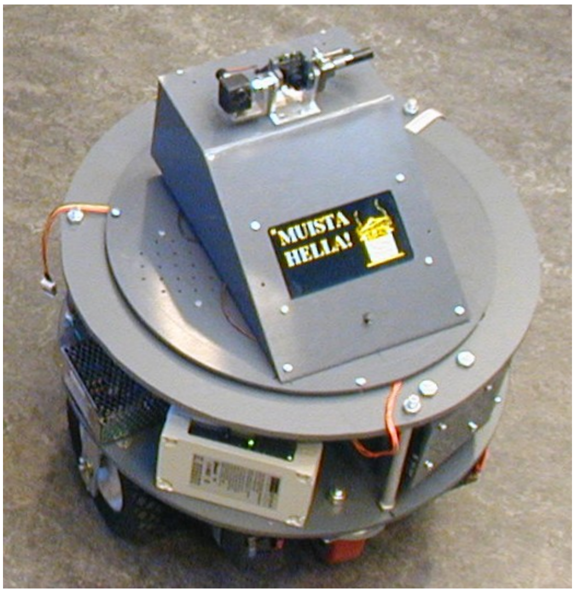

Fig. 3. Rolloottori has the same functionality as Rollo, but uses wheels for moving. It also has a touch screen which can be used as an input device.

2.5. Home automation network

The server is connected to a Linet network (LINET, 2004). Linet (Light network) is a single pair automation network that allows up to 200 devices connected to it with free topology. Currently the network comprises of magnetic switches on doors, movement sensors, a presence-sensing floor and a bed sensor, a connection to the stove and to some other electrical devices. The network has its own controller board that has some basic programmable features, but more complex functions have to be performed on the server. The server reads the network state through the LAN and if needed, will send control commands back to the Linet controller.

2.6. User interfaces to the system

There are a number of user interfaces that can be used to control the robot or devices in the automation network. User interface program Assister, the main user interface to the system, can be run on any PC computer that can connect via internet to the home server.

The Assister program connects to the server and can control the home automation system, including the robots. The Assister also receives video from the cameras. It also contains virtual model of the remote environment. Video (Fig. 4.) and virtual model (Fig. 5.) can be overlaid to produce an augmented view. In this view states of the devices can be visualized. The augmented reality view acts as an intuitive interface to a database containing information about the home. Information about an object can be obtained by pointing at it.

The system also has other user interfaces. The robots can be operated locally using a TV remote controller. The robots interpret the infrared signals and act accordingly. They can also be taught to play back these signals and thus control televisions and other IR-operated devices.

Wireless application protocol (WAP) user interface has also been developed for controlling the system using a mobile phone or a personal digital assistant (PDA). Locally these interfaces can connect via Bluetooth connection and over a longer distance general packet radio system (GPRS) can be used.

Fig. 4. Video image of the kitchen in Toimiva koti

Fig. 5. Virtual model of the kitchen

3. SERVICES

The system provides functionality for some selected use cases. These have been used as examples of what the system could be used for. They have been implemented with Java program running in the home server.

3.1. Mail Alert

The mailbox outside the demonstration apartment is fitted with a pair of optical proximity sensors that can sense any mail put in the box. The sensors are connected to the automation network. When new mail arrives, the Mail Alert checks where the user was detected last and sends the robot there. The robot will inform the user of the mail with a message on the screen and a sound.

3.2. Key Alert

Key Alert uses a magnetic switch on the front door, a movement sensor, a switch for a key ring and a buzzer. It uses simple logic to reason when the user is coming home or going out. Key Alert appropriately reminds about placing the key in its place when coming home or taking it when going out. The user can be reminded with a buzzer sound and a light by the front door, with the home robot and an SMS message.

3.3. Activity Alert

Multiple IR motion detectors generate signals when people are moving in the apartment. Additionally, door sensors, floor sensors and bed/seat sensors can be used. These make simple localization possible; the user is expected to be found where movement or action was last detected. Also, the system could be made to learn a statistical profile for the activity level of the apartment. Then any statistically significant changes in daily activities could be detected and alarm could be sent, if the change is of concern.

3.4. Detailed description of Stove Alert

The following describes a detailed example of a service. The stove power consumption is monitored with a current sensor connected to the Linet network. IR movement sensor is used to detect movement in the kitchen. The sensor data is collected, processed and stored in a database by Activity Alert.

The user turns on the stove and leaves the kitchen. If no movement is detected in ten minutes an alarm is set. The response to the alarm can be configured in the program. In our example the home robot tries to find the user and remind him. Stove Alert uses the Activity Alert block to locate the user. Let us assume that the user has been detected in the bedroom. Stove Alert sends a request to the home server to drive the robot to the bedroom.

The home server then finds a path from the current robot position to the bedroom, calculates necessary movement commands to follow it, and starts sending the commands to the robot. The robot control hierarchy can be seen in Figure 6.

The robot receives movement commands and translates them into desired motor encoder readings. Motors are driven to desired position using cascade controller. The speed is controlled by encoder readings (position of the robot) with a P-controller and the power fed to the motor is controlled by speed utilizing a PID-controller.

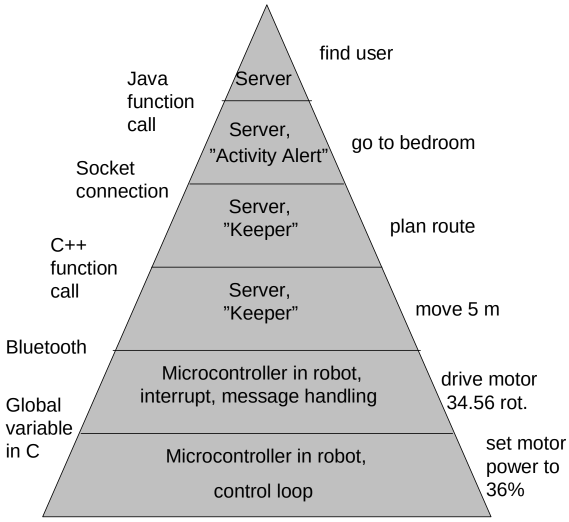

Fig. 6. Control hierarchy for moving the robot in Stove Alert case. The cone depicts the corresponding hardware and software giving the commands. The commands are presented on the right of the cone and communication medium on the left.

Robot comes to the user, reminding about the stove alarm with a message on the display by sound and motion. If the user goes to kitchen or acknowledges the alarm by pushing a button on the robot, the alarm is cancelled and the stove continues heating.

If the user cannot be found, the stove is automatically turned off. In that case an email message is sent to a care call centre, an SMS is sent to a helper or a relative and the robot shows a message on the display about the event.

4. EXPERIMENTAL METHODS

To obtain user information of the demonstration system and people's attitudes towards home automation and home robotics in general, questionnaires and web based information pages were made.

All the above mentioned services were presented using video movies, slide shows and textual descriptions. After being exposed to the pages or after visiting the FH, people were asked to answer questions on the topic. The categories were assistive technologies in general, home services, home automation applications, home robotics applications and application specific questions

The first part of the questionnaire study was done during fall 2003 when 83 persons responded. The questionnaire was anonymous, but some background information was requested. Majority of the participants were health or social care professionals. Only about half of them provided their age, but of those who did, were between 18 and 69 years, average being 45 years. A clear majority were women. Second part of the study will be done during spring 2005 when approximately additional 100 persons will participate.

Experiences from the system and the technology are evaluated with meetings, with internal reporting and in thesis works and other academic writings. Discussions with care professionals and other related persons together with demonstrations gave significant results.

5. RESULTS

People are much divided in their opinions about home technology, but existing or known applications appeal to people.

Most of the respondents were studying or working in social services field. They valued technologies and services for assisting the basic activities of daily living (BADL). Services for personal hygiene were more attractive than taking care of pet animals and visiting beauty parlour. Moving aids were more wanted than remote control of home devices. Most wanted automation solution was the Stove Alert and least wanted were speech control of equipment and the Mail Alert. A security robot that warns about dangerous situations was seen much more desirable than a robotic companion or a pet.

The initial idea of building a purely telematic assistive system was not found appealing. People, what ever age or condition, want to control their own lives. Possibility to get remote assistance was seen as a good safety feature, but it should be used only after personal intervention and local automation could not solve the problem. People want independence and autonomy, not so much control.

Integrating the video image with a virtual model of the home has been tested. Aligning the two geometrically is often a problem. Internet and local area networks produce unpredictable communi-cations delays in receiving the video while virtual model has immediate response. As a result, the image superposition is confusing. The best method is to either keep the virtual model in a separate window or completely transparent. Either way, it offers information to the user, but does not degrade the image quality of the video image. Virtual model serves as a good interface to documents and other data, such as status information.

The spherical Rollo has been found out to be significantly more appealing than the wheeled Rolloottori. Despite the technical difficulties with controlling a ball, it is worth continuing its development.

6. DISCUSSION AND CONCLUSIONS

Close cooperation with various users and professionals from the social services sector turned out to be essential to the project. This type of cooperation provides much needed feedback.

The presented system, utilizing home robots for home services, is a well functioning concept that is worth developing. Several technologies - such as home servers, home automation networks, wireless communication and fast Internet connections - supporting the development of indoor service robotics are becoming common.

Some commercial home robot models for vacuuming have already been introduced. However, many challenges still await to be tackled; low cost, low maintenance and easy to set up localization system being one of the most challenging.

The technologies for building robotic home assistance systems are now becoming available. Pressure to assist home living of the rapidly aging society is high and some users are ready to accept new technologies at their homes.

REFERENCES

Graf B., E. Helms, V. Lakshmana, B. Rohrmoser, R.D. Schraft, (2002). Anthropomorphic Robot Assistants - Giving the Human a Helping Hand. *IARP IEEE/RAS Joint Workshop on Technical Challenge for Dependable Robots in Human Environments*, Toulouse, pp 20-24.

Irie K., N. Wakamura, K. Umeda, (2004). Construction of an Intelligent Room Based on Gesture Recognition. *IROS '04*, Sendai, pp 193-198

Morioka K., H. Hashimoto, (2004). Appearance Based Object Identification for Distributed Vision Sensors in Intelligent Space. *IROS '04*, Sendai, pp 199-204.

Stefanov D.H., Z. Bien, W.-C. Bang, (2004). The Smart House for Older Persons and Persons With Physical Disabilities: Structure, Technology Arrangements, and Perspectives. *IEEE trans. On neural systems and rehabilitation engineering,* **Vol 12, No 2,** June, pp 228-250

AUTOMAATIO AVUKSI, User feedback gathering in research project "Automaatio Avuksi" to study technologies for helping elderly live longer at home, (2004). Helsinki, http://www.automaiton.hut.fi/AA/AAcases.html.

FEMINITY, Product family of intelligent home appliances by Toshiba, (2004). Tokyo, http://feminity.toshiba.co.jp/feminity/.

LINET, Commercial home network technology, (2004). http://www.linet.fi/

TOIMIVAKOTI, Show house and information center for help equipment for elderly, (2004). Helsinki, http://www.hel.fi/sosv/toimivakoti/.