AUTOMATION AND TELEMATICS FOR ASSISTING PEOPLE LIVING AT HOME

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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 to outside home 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 is built in a model home, which is open to the public.

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

1 INTRODUCTION

The average age of people 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 institutions. This is also more cost effective.

Currently there are plenty of research about smart homes and technology for elderly to live longer at home. Review of these is done by (Stefanov et al. 2004). Usually research is concentrated around one or few technologies, for example around networked cameras observing and measuring events at home (Morioka et al. 2004), (Irie et al. 2004) or around home robot control (Graf et al. 2002). Same tendency is in more commercial solutions, where one company presents its products (FEMINITY, 2004), even using own smart show house. Other approach is houses or apartments where independent gadgets and architectural solutions, that help life of disabled and elderly people, are displayed like (TOIMIVAKOTI, 2004) before. In our approach we integrate many technologies trying to evaluate co-operation of technologies and problems raised from that. We also try to find users' opinions and needs, witch are often neglected or assumed to be well known.

The aim of this study is to develop modern technology solutions, particularly 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 were implemented in a demonstration system.

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

Social Services Department of City of Helsinki has two model apartments called "Functional home" (FH) (TOIMIVAKOTI, 2004) for exhibiting living solutions for elderly and disabled people. The place is open to public. There are three fulltime professional employees to guide the visitors. The apartments are equipped with assistive devices in a cosy atmosphere with appealing furniture and design. In addition to showing the assistive solutions in real environment four larger show rooms are stacked with assistive devices.

Visitors to FH consist of social sector students and workers, building professionals, elderly and disabled people and their relatives and friends, and of 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 a user interfaces to an automation system or as a moving communications platforms. Some 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. In some sense, a small robot could replace a pet in some circumstances. For allergic people or in environments like some nursing homes where it is not allowed to bring pets, a mechanical pet might be a welcomed substitute.

Indoors robots can best be 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 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 one technical solution has been universally accepted. On one hand the multitude and on the other the lack of standards is hindering the growth. The home server and gateway technologies are important, because home robots will communicate with the outside world through these gateways.

2 OBJECTIVES

The objective is to research different aspects of a remote assistive system for elderly and disabled. The general scenario is: In need a person at home asks for outside help using telecommunication. In return he gets help via the Internet as personal communication or as remote operation of some home device, e.g. a home robot. Local automation helps the person without the need of a remote helper.

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:

- Various user interfaces: mobile robot, mobile phone, indicator lamps and alarms
- Mobile robot looks for a person, displays a message, and waits for a acknowledgement
- Monitoring the kitchen stove
- Informing of incoming 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
- Communication between home and outside

The main features of the system are:

- Two-way communications system between people and equipment at two distant locations over Internet
- Video and voice communications
- Augmented reality user interface
- Use of virtual models in navigation and path planning
- 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

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

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

3 EQUIPMENT

3.1 *Overview*

The physical setup of the demonstration system consists of several parts:

- Home server
- Home robot
- Home automation system
- Internet connection
- Local area network (LAN)
- A number of dedicated devices

The home server is the heart of the system. All the messages in the system go through it and it also takes care of processing the incoming data and taking appropriate action. The robot, the spherical Rollo or the wheeled Rolloottori, acts as a mobile user interface and a platform for one of the cameras. A sketch of the system setup is shown in Figure 1.

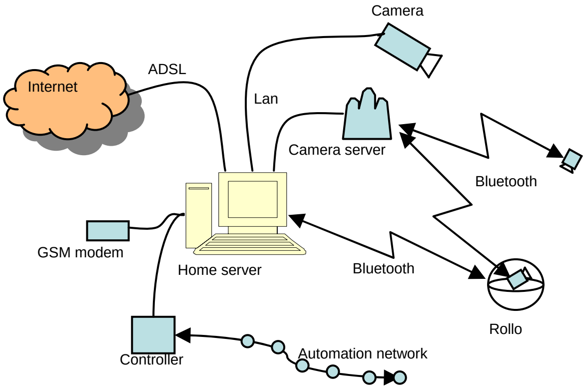

Fig. 1. General system structure

3.2 Ball shaped robot – Rollo

Fig. 2. Rollo

Rollo has a spherical transparent cover (Fig.2). It moves forward and backward by moving its internal drive unit (IDU), displacing its center of gravity. When the rim that attaches the cover halves to the IDU is horizontal, it can change its direction. When the rim is in vertical position, it can move sideways. The energy source is a NiCd battery, which provides power for up to a couple of hours, depending on the use of its electrical drive motors, screen, camera and radio devices.

The robot is controlled by a microcontroller (Phytec MiniModul-167 using Siemens SAB C167 CR-LM micro controller). For visual and audio perception the robot is equipped with a camera and a microphone and a video link. The camera can be tilted +-100 deg. When it points upwards it is used for detecting visual landmarks in 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 is 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.

3.3 Rolloottori

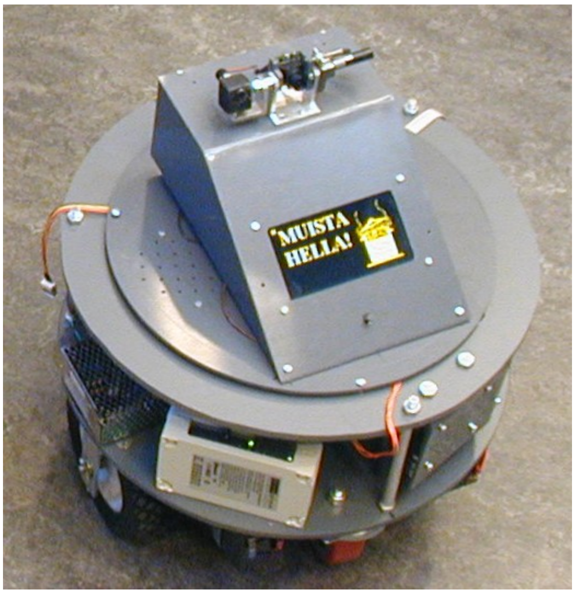

Fig. 3. Rolloottori has the same functionality as Rollo, but uses wheels for moving. It also has a touch screen which can be used as an input device.

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

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

3.4 Home Server

The server is a PC running Windows 2000 operating system. It provides the user with access to the robot, its devices and external camera. It relays video data 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 software running in the server can then make decisions based on the incoming sensor data and control the outputs of some devices. The server also relays messages between different systems. It can receive and send messages through the local network or via Internet, locally to the robot and locally or remotely to different mobile interfaces such as PDAs or mobile phones.

Some 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 so that by looking at the image from the robot camera and using stored information about their position, 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 and control devices in the system.

3.5 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 there are magnetic switches on doors, movement sensors, presence-sensing floor and bed sensor, connection to the stove and some 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.

3.6 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. Assister user interface program, the main interface to the system, can be run on any PC machine that can connect to the home gateway.

The assister connects to the server and can control the robot, the home automation system and other devices. The assister also receives video data from selected camera. It also contains virtual model of the remote environment. Video and virtual model can be overlaid to produce an augmented reality view.

In addition, several other user interfaces can be used. The robots can be operated locally using a TV remote controller. The robots can interpret the infrared signals and act accordingly. Also, they can be taught to play back these signals and in turn control televisions or other IR-operated devices.

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

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

Fig. 5. Virtual model of the kitchen

4 SERVICES

The system provides functionality for some selected use cases. These have been used as examples of what the system can be used for.

4.1 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 system. 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 screen and a sound.

4.2 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 a SMS message.

4.3 *Activity Alert*

Multiple IR motion sensors generate signals when people are moving about in the apartment. Simplest way to use this signal is to determine person's position by detecting where he has last moved. This data can also be used to determine the activity level of the person or persons living in the apartment. Alarms can be generated, if the activity is abnormal.

4.4 *Detailed description of Stove Alert*

Here is explained stove-alarm in more detail as an example of system functionality. First user sets stove on, in order to cook something. This is recognized by system via Linet (LINET, 2004) and using current sensor around power cable of stove. Time and nature of action is stored in database. Other functional part is infrared-(IR-) motion detector, observing kitchen. Both these sensor detections are also stored in database and transmitted via Linet to server computer. Program called "Home Alert" is following these events stored in database and has logics based on system. If now movement is not detected in ten minutes around kitchen while stove is on, alarm is set. Actions following this alarm can be configured by administrator, and in our case robot tries to remind user first. Location of user can be found from database as last event from motion detector, door sensor, floor sensor or bed/seat sensor. Robot is driven to user and it is signalling alarm by message on display, sound and motion.

Now robot motion is described in more detail as a more detailed example. Control hierarchy in this case is presented in figure 6.

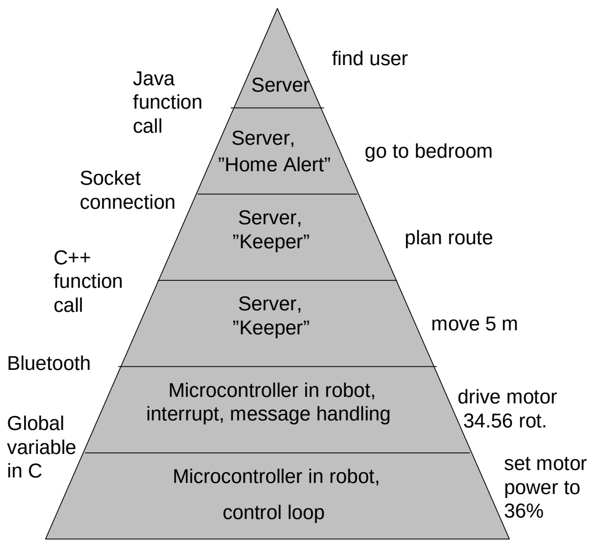

Fig. 6. Control hierarchy for moving robot in stove-alarm case

Home Alert triggers user search and user located to bedroom. Then command to find route to bedroom from current position of robot is calculated and robot command is generated based on that. Command is then sent to robot from serve and "Keeper" program and calculated to desired motor encoder readings based on motor power control signal.

If user is not found or he is gone outdoors, when he would have been warned about stove already, stove is set off. After shutting of the stove email message is sent to care control central, SMS is sent to user's and his relative's mobile phones and robot shows message on display about event. On the other hand, if user acknowledges alarm from robot or goes to kitchen, alarm is set off and system keeps running as nothing would have happened. Although all events would be stored on database and used to normal behaviour analyses to recognize abnormal behaviour in future.

5 USER FEEDBACK

To obtain user information of the demonstration system and peoples attitudes towards home automation and home robotics in general, web based information pages and questionnaires were built.

All the above mentioned services were described using video movies, slide shows and textual descriptions. The technologies used were explained in their own documents. After being exposed to the pages or after visiting the FH the people were asked to answer questions on the topic.

General questions were divided to five categories:

- assistive technologies in general
- home services
- home automation applications
- home robotics applications
- application specific questions

6 RESULTS

People are much divided on their opinions about home technology. General trend seems to be, however, that 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 on dangerous situations was seen much more desirable than a robotic companion or a pet.

The initial plan was to build a pure telematic assistance system. In discussions and demonstrations we found out that people preferred to have an automation system and a robot under their own command. Only, if the local system did not solve the problem, then the outside help was welcomed.

A demonstration system for testing the system functions is operating at FH.

Internet- and local area networks produce unpredictable communications delays in receiving the video and in sending the commands. However, the virtual model will react to the camera control commands immediately. This way the user can interact with the model. A after a time delay he will see the effects of his commands on video as well. The wait and see mode of teleoperation work well, but it makes the system controlling very slow.

7 DISCUSSION

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

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

Virtual model is a good interface to data and documents. Using a completely transparent model plain video image can be an interface to machine data and documents.

Integrating the video image with a virtual model of the home has been tested. Aligning the two is often a problem. During the project it has been found out that the best method is to either keep the virtual model completely transparent or have it in a separate window. Either way, it offers information to the user but does not degrade the image quality of the video image.

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.

The presented system utilizing home robots for developing home services is a well functioning concept that is worth developing more. There are several growing technologies that support the development of indoor service robotics:

- Home servers
- Home automation networks
- Wireless communication
- Faster communication lines to homes

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.

8 CONCLUSIONS

The technologies to build robotic home assistance systems are now becoming available. Pressures to assist home living of the rapidly aging society are high and users are ready to accept new technologies to their homes.

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