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Smart Home Applications for disabled Persons - Experiences and Perspectives

Paul Panek, Wolfgang L. Zagler, Christian Beck, Gottfried Seisenbacher
fortec – Research Group on Rehabilitation Technology,
Institut für Industrielle Elektronik und Materialwissenschaften,
Vienna University of Technology, A-1040 Wien, Favoritenstrasse 11/366-1B,
tel: + 43 1 58801-76613, fax: + 43 1 58801-36697
email: pp|chb|gs|zw@fortec.tuwien.ac.at   http://www.fortec.tuwien.ac.at

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Abstract. Alternative and Augmentative Communication (AAC) devices in combination with Environmental Control Systems (ECS) offer remarkable benefits for severely and multiple impaired persons. The authors have developed such a combined ECS and AAC system called AUTONOMY. This system was set up at two validation sites based on EIB Twisted Pair and EIB Power Line installations. An intensive evaluation took place in co-operation with therapists, teachers and disabled persons. Additionally, the prototype system was extended with a tele-support module using a protocol defined by the EU funded DE-4208 RESORT project. Experimental service centres provided technical support for the disabled users and the carers. Remote configuration, Tele-Help, Tele-Training and support of disabled users including single switch and head-stick users and care persons have benn tested quite successfully.

1. Introduction and Aim

One of the main reasons for severe motor- and multiple impairments is cerebral palsy. Here different brain regions can be affected resulting in random combinations of disabilities (motor, cognitive, communication, intellectual etc.). For severely motor impaired persons the implementation of so called Environmental Control Systems (ECS) can mean all the difference between inability and independent living. The ECS establishes a custom tailored interface between the user’s residual abilities and his or her physical environment by providing the possibility to operate electrical appliances, communications devices, doors and windows and a host of other things by remote control. The goal of communication aids (Augmentative and Alternative Communication = AAC) is to facilitate inter-personal- and tele-communications for persons who are not able to communicate in the usual manner.

The aim of this R&D project has been to implement an innovative technical system enabling severely motor and multiple impaired persons and their carers to benefit from up-to-date smart home technology as EIB and to demonstrate this potential to the public.

2. Technical Assistance System “AUTONOMY”

For several years now, our research group has been active in the development and field-testing of a combined ECS and AAC system we named AUTONOMY [5,6,7]. It is based on a PC hardware platform (notebook or a handheld computer) and on the MS-Windows operation system. The input/output hardware can be chosen from a wide range of standard and special devices to meet the specific needs of the disabled user. A set of peripheral hardware components links the system to the physical environment.

AUTONOMY was implemented into a smart-room at a support centre for severely and multiple impaired children at Axams (Tyrol, Austria) and at a public school in the south of Vienna. By using the EIB (European Installation Bus) for the electric wiring and infra-red remote control technology, nearly all appliances in the room can be remote-controlled via the system. When operating AUTONOMY as an ECS the teacher or therapist will create a dedicated system-configuration. The icons on the user's screen directly correspond to environmental commands (switching on the lamps, starting the CD-player, get the toy-train running, switch off everything). For AAC purposes configurations showing communication symbols on the screen can be created. Activating an icon by direct selection or scanning will result in a spoken or printed message.

As a main innovation AUTONOMY offers three different user-interfaces for the three distinctive user groups [7] working with the system (Fig.1):

- The disabled end-user (the person with special needs, who is using the assistance system).
- The facilitator / care person (e.g. a therapist, pedagogue or family member) responsible for the configuration and adaptation of the user-interface.
- The integrator / administrator carrying out the technical set-up of the system.

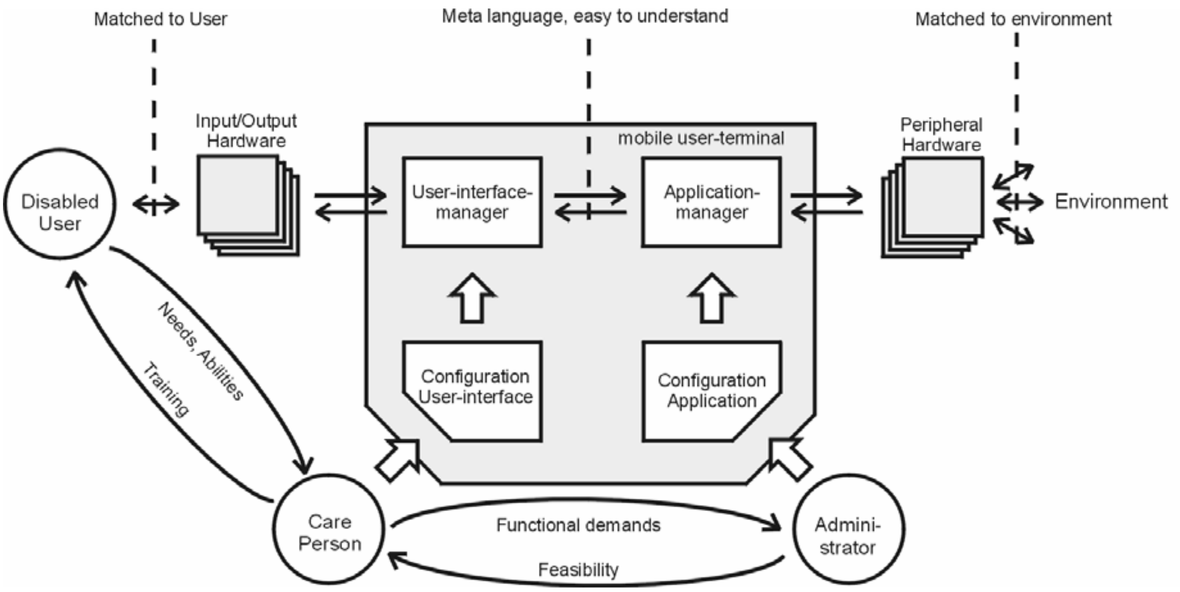

Figure 1: Block diagram of the AUTONOMY system showing interaction between system components and user groups [5,6,7].

The co-operation between these three groups of users is essential for optimisation and successful use of the system. The three interfaces/tools (user-interface, configuration tool and setup/test tool) are tailored to the very specific needs and abilities of the three different user groups according to the specific roles they play in setting up, configuring and operating the entire system.

Figure 1 shows the interaction between the system components and how the different user groups utilise dedicated user-interfaces. The user-interface-manager and the application-manager are internally linked with one another by an easy to understand meta language. This ensures that after the integrator (= system administrator) has set up the application configuration and the peripheral hardware the facilitator (= care person) can refer to non-cryptic (non-technical) terms when configuring the user-interface.

The task of the facilitator is to enable the impaired person to discover and exploit new areas of self-determination and independence. He/she will need a versatile and easy-to-use tool which enables him/her to create not only various user interfaces but also creative procedures for working with the communication and environmental control functions in a didactic and therapeutic manner.

Up from a certain degree of impairment motor- and multiple disabled persons rarely are able to use conventional environmental control and augmentative communication systems. To attain this ability, in many cases customer tailored user-interfaces plus a long-time training process is necessary. Even learning the relation between reason and effect and experiencing self-effectiveness (being able to make something happen in the environment) is the first big challenge and often an entire new experience.

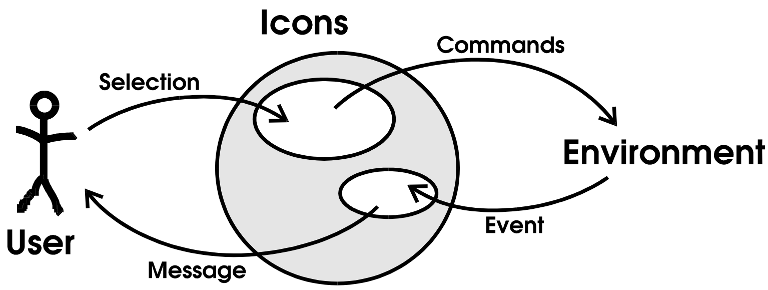

Figure 2: Concept of interactive, bi-directional icons used in the AUTONOMY system [7].

Hence, a technical system capable to meet the needs of these users has to fulfil three criteria: (1) give optimal support to the training-process; (2) support the facilitators with a tool to easily adapt the system to the rapidly changing user needs; (3) be capable to grow from first experiencing self-effectiveness up to a multi-functional multi-purpose technical aid.

3. Methods

Two smart training rooms in Austria have been equipped with AUTONOMY and EIB:

- Mobile platform for running the AUTONOMY user interface for the disabled person
- EIB (TP, PL) for lighting, blinds, fan, door opener, emergency call, etc.
- Infra-red transmission for consumer electronic (VCR, TV, CD-Player, Tuner, ...)
- Emulation of keyboard and mouse for controlling a standard PC
- General input / output facilities for controlling electric toys
- Video door control
- Telephone and internet connectivity

The first room, located at Elisabethinum, a support centre for disabled children in Axams near Innsbruck, was operational in 1995 using EIB Twisted Pair (TP) technology, the second, located in a public school in the south of Vienna, was operational in 1998 using Power Line (PL) as transmission medium.

3.1 The Smart Room

A single room apartment at the support centre Elisabethinum was completely re-furnished (Fig.3). It consists of four dedicated areas: one area for living, an area for TV/HiFi, a working area with PC, Modem, FAX and an area for playing with electric toys. An EIB system was installed for controlling lamps, window-opener and blinds.

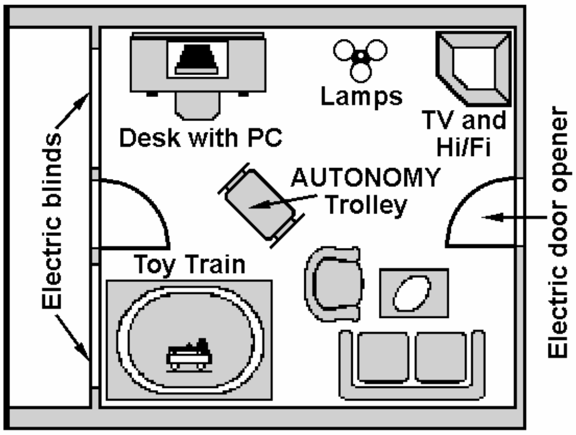

Figure 3: Smart Room at support centre Elisabethinum in Axams near Innsbruck. Equipped with EIB Twisted Pair and the AUTONOMY system in 1995.

The prototype of the assistive system was installed in October 1995. It consists of a mobile user-terminal (Fig.4a) and several stationary peripheral hardware modules (Fig.4b). The user-terminal serves as platform for running the dedicated software tools for all three user-groups (end-user, facilitator, system-administrator). It uses MS-Windows 3.11 (later upgraded to Windows 98 SE) as operating system and offers a multi-user environment. For each user of the system an individual set of configuration properties can be stored. The peripheral hardware covers modules for generating infrared codes, for controlling the EIB and for general input/output facilities.

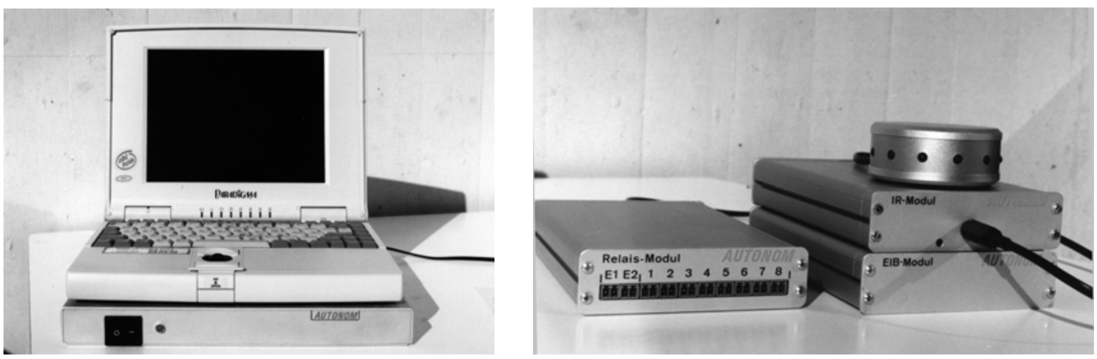

Figure 4: Autonomy user interface implemented on MS Windows based laptop, below Busmaster of Autonomy fieldbus system (left picture). Three peripheral modules for input/output, infrared and EIB-Link (right picture).

3.2 The Field Study

An interdisciplinary team of teachers, therapists, carers and researches was set up to carry out a field study (1996-1997). The general strategy has been to introduce the system as a new flexible tool to implement the therapist's own ideas in a creative way.

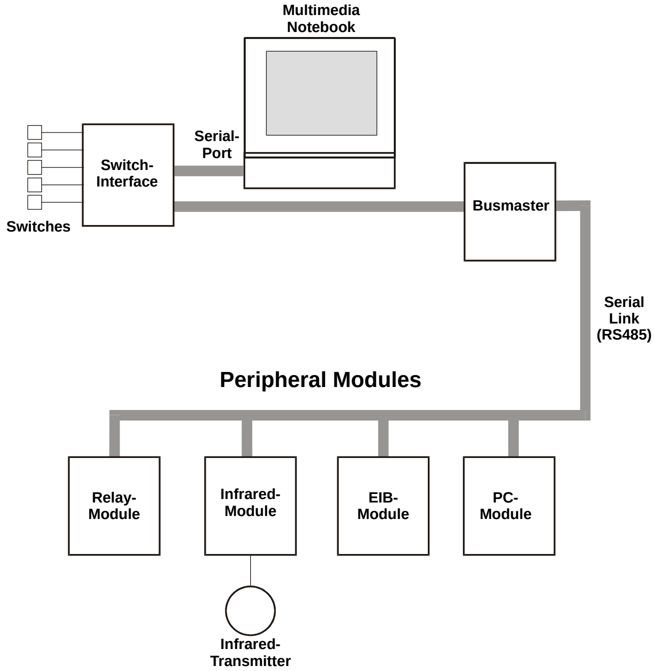

Figure 5: Structure of Autonomy prototype system used at smart room at Elisabethinum. Twisted Pair EIB is connected via RS-232 link to EIB-Module which itself is part of a RS-485 based Autonomy field bus system.

Several case studies were carried out. Three pairs of facilitator and end-user were asked to document each session they had with the system. A diary was written by the therapists to document achieved improvements but also to give feedback about the system itself. The configuration files of the individual user-interfaces were copied every week to retrieve information concerning the alterations of the different configurations. The logfile of the system contains general information concerning the usage of the system and the different configuration files used. (In the following case studies all names of persons were changed).

3.3 Case Study Martin

Martin is an 8 years old boy who is severely retarded in his psycho-motor development, has spastic tretraplegia. Martin's facilitator configured the system to provide a user-interface suitable for Martin. Two switches were used as input device, the desktop offers four objects (TV, music, light, toy train) which can be switched on and off. Because of Martin's severe impairment, the first steps of using the system were done in close co-operation with his therapist. Martin is only controlling the Select-key via head-turning, his facilitator is pressing the Arrow-key and asks Martin if he wants to do anything with the marked object. In the first phase of the case study the system was used to find out if Martin actually can differentiate between "yes" and "no" while using the system. This became possible since it is known that he likes to watch TV. Using the system enables him to switch on TV by his own.

3.4 Case Study Irene

Irene is a young girl, aged 11. She has a good understanding of speech, symbol and text. She is unable to speak. As input device she is using a proximity sensor. Her configuration is rather complex: Consisting of 7 menus it can control nearly all of the peripheral devices (lamps, TV, CD, toy train etc.) and is also configured to offer some AAC functions. As her facilitator states, Irene enjoys working with the system a lot, as it empowers her to decide herself what shall happen (feeling herself self-effective). During her leisure time she often decides to go up to the smart room to use the system just for fun.

3.5 Case Study Caroline

Caroline is 11 years old and has a tetraplegic athetosis. She is trained to use the system in a special way because of her very restricted perception. Her facilitator has constructed a felt board with big symbols to simulate the user-interface of the system. Thus, Caroline is controlling a mediated user-interface as she is observing the felt board while her facilitator is operating the real system. According to Caroline's decisions the system responds with sound, speech and activities of peripheral devices.

4. Results

The technical system proved its usefulness in therapy and training. The acceptance of the system by disabled persons and their carers was quite high. EIB as smart home technology has demonstrated its flexibility and benefit for persons with special needs.

4.1 Acceptance by the Rehabilitation Team

It is evident, that the success of the introduced technical concept is fully depending on the acceptance by the rehabilitation team. Thus, it is evident that the easy to use facilitator’s tool seemed to be one of the most critical part during the introduction phase of the assistive system. One of the main goals of developing AUTONOMY was to provide a configuration interface which enables even complete computer illiterate persons to create client tailored user interfaces and application. The concept received perfect acceptance from teachers and therapists and meanwhile several hundred different configurations were set-up at the test site [24].

4.2 Usability by the End-Users

One of the key-points of the introduced concept is the high grade of adaptability and the possibility to create multi-modal interfaces. It has been proven, that this concept allows persons with multiple impairments to use the assistive system. Especially for persons with a high grade impairment this concept brought a decisive improvement in usability.

4.3 Consequences on the Rehabilitation-Process

The assistive system has been used in co-operation with therapists and teachers working with the disabled person. Therefore, it had become an integrated part of the rehabilitation program. It has shown, that the application of the technical assistance system can accelerate the rehabilitation-progress, not only in the areas of independence, self-determination and responsibility, but also in training of dedicated functional abilities.

Especially cognitive and motor impaired children encounter severe problems in experiencing the principle of reason and effect. As their possibilities to handle objects by themselves and to perceive what will happen ("...will it drop to the floor and crash when I release it?") are restricted they encounter a deficit along these lines. The smart-room can help to teach these basic principles. Properly configured, accessing an icon by hitting a switch can cause to start a firework of sound and light. It occurred that children needed such experiences to conceive the concept of reason and effect for their first time.

5. Discussion

The experiences collected until now are very positive. The structure of the AUTONOMY system meets the requirements of the different user-groups very well and, therefore, has found a high level of acceptance. The close multidisciplinary co-operation between the support centre and fortec has created a fertile atmosphere of teamwork between developers, care-persons and end-users.

At the support centre it is necessary to take a lot of small steps in training the severely impaired end-users to handle the system. Nevertheless, the goal for the future is to allow for a more independent way of living by using the functionality of the technical assistance system. In parallel to the two smart rooms running AUTONOMY systems based on EIB, a low cost version of the AUTONOMY system [3] was introduced to the market and is being sold by a Viennese company since 1999.

EIB based on Radio Frequency is planned to be introduced in addition to existing Power Line (PL) and Twisted Pair (TP) media in order to increase mobility of AUTONOMY user terminal, which currently is based on TP/PL and, therefore, wire bound. The currently still high costs of EIB installations are expected to be reduced significantly in future. In this way smart home systems will contribute to a society of equal opportunities [15,16].

6. Perspectives – Tele-Help Services over IP Networks

The response from the field tests on the one hand led to the development of a low-cost version of AUTONOMY [3] which is also suitable for private applications. On the other hand it motivated the launch of the EU-supported R&D project RESORT [12,22].

RESORT stands for “Remote Service of Rehabilitation Technology” (RT). The objective of this project was to develop a telematic link (Fig.6) between the user or the care person on one side and a service provider (technician, therapist, other experts) on the other side. The link not only provides video-telephony capabilities but also remote supporting the user's PC. Problems with the system, updating of software or changing configurations can be handled in this way. Following the AUTONOMY philosophy the telematic linking will be as easy as clicking on an icon.

The RESORT system provides the following functionality: (a) RCI (Remote Control Interface) for "real time synchronisation" of RT systems (b) easy-to-use scaleable User Interface (c) real time communication and interaction: audio and video, H.323 compliant (d) database access (e) file transfer (f) synchronisation of file systems (g) text communication (h) platform in-dependency (i) security. It offers three different modes of operation:

- In the communication mode RESORT provides hands free communication between user and service provider. If the bandwidth is large enough an additional video link can be established.
- In the student-teacher mode an additional data-link is established. The service provider will load exactly the same RT application as the user is running. The two applications - at the user’s site and at the provider’s site - will be synchronised via the data link.
- In the tele-service-mode the service provider has the possibility to down- and upload files from and to the user’s PC, modify configurations and test the changes he/she has made.

At the end of year 2000 the prototype of the RESORT system was released, additionally the AUTONOMY system was equipped with a RESORT compliant interface. The core of RESORT was implemented in Sun Java 1.3. The system exploits existing technologies for tasks like video / audio transmission according to H.323 specification and desktop/application sharing according to T.120. The user interface of the Resort controller can be tailored according to the needs of the users. Although the full functionality is always available, the degree of complexity of functions and information shown to the individual user can be varied within a wide range.

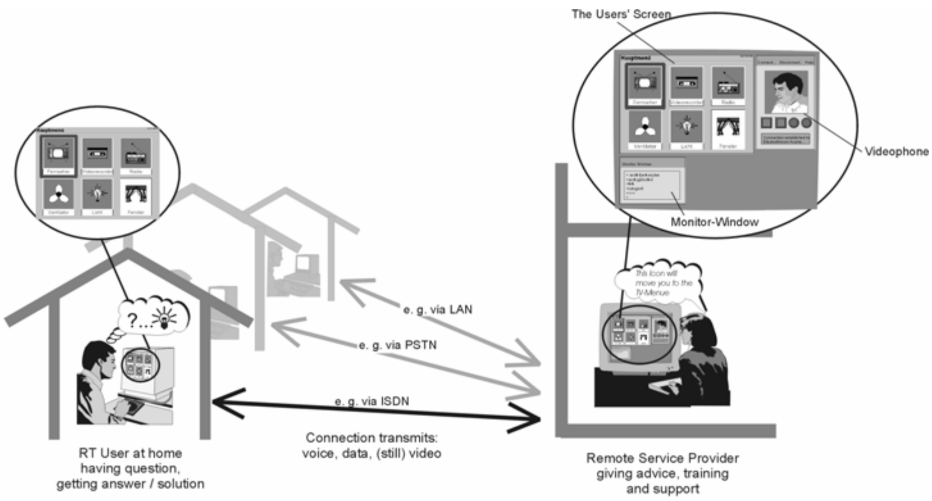

Figure 6: Remote service provision for PC based RT systems designed by EU funded RESORT project.

The RCI (Remote Control Interface) and the RESORT protocol allow synchronisation in real time. This is possible as only small data messages are transferred instead of changed screen contents. This method dramatically reduces the required bandwidth [2] and enables the RESORT system to provide real time monitoring of single switch users. The Resort controller module (RC) is linked to (a) communication modules for video, audio and chat, (b) to the database, (c) to the RT system and (d) via network interface to the remote RC. As network protocol IP is used. TCP/IP for control messages, UDP mainly for audio and video. In order to test and demonstrate the benefits of the system 2 existing RT systems [3,18] have been equipped with a Resort interface.

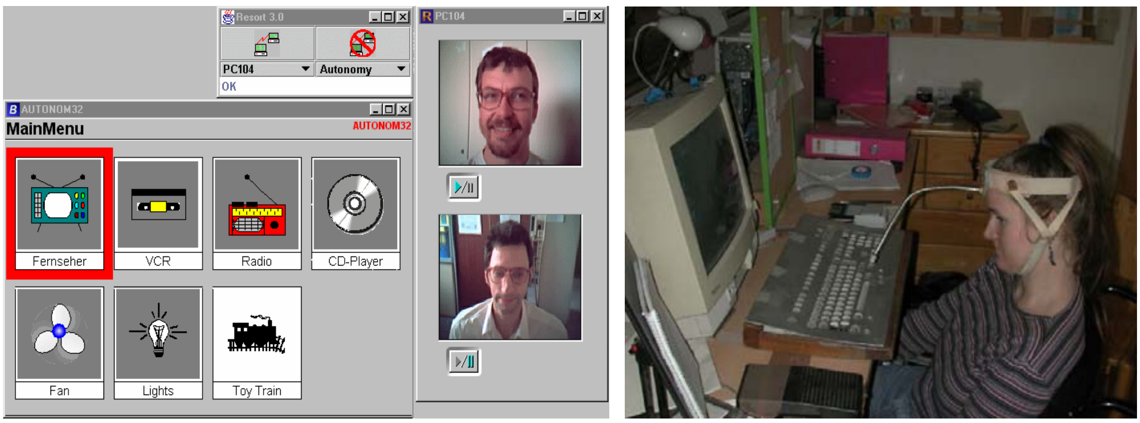

Figure 7: Screen Shot of client’s screen during a RESORT Tele-Help session (left picture).
Non speaking head stick user behind her PC running commercial version of AUTONOMY for communication in synthetic speech and for environmental control equipped with RESORT tele-help module.

In order to ensure a high level of flexibility several internal interfaces were introduced. The out-come is a highly modular system which allows to exchange specific parts without the need of adapting other parts. This increases the independence from 3rd party products for audio, video, application sharing, desktop sharing, etc.

The prototype system was demonstrated in 15 workshops organised for care persons, disabled users, manufacturers and service providers in Austria, Germany, The Netherlands and Scotland. Additionally real life tests have been carried out [22]. The results from the real life tests showed that the system was usable by disabled people and their primary carers. Furthermore, both primary and secondary carers consider the system a viable tool for the delivery of support for users of RT systems.

Additionally to the RESORT prototype software, the RESORT protocol has been developed and documented. This allows other manufacturers to adopt the RESORT protocol for their products in order to strengthen their position in the RT market. The RESORT Software Development Kit (SDK) provides material needed by a 3rd party manufacturer of RT applications in order to make their own RT systems RESORT compliant. This kit currently consists of a documentation of current RCI specification v3.21, a manual explaining how to develop a RESORT compliant RT application out of a conventional one, the API, and sample software including source code [12].

7. RESORT Interest Group

In order to ensure ongoing research and development the RESORT Interest Group (RIG) was set up in early 2001. The RIG is providing a framework for disabled users, care persons, manufacturers, service providers, and researchers to continue the engagement in the area of remote service provision. Interested parties are invited to watch and to join the activities of RIG by visiting the RESORT home page [12]. Currently, pilot service centres are being established and new RESORT compliant applications are being developed taking into account also non PC based RT as robots, prostheses [1,8,19] and wheelchairs.

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