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REMOTE REHABILITATION ASSISTANCE WITH THE COMPLIANT ROBOT ARM BIOROB

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ABSTRACT

Within the scope of network based and individualized apartment and building service engineering, a standardized solution becomes more and more important for the multitude of integrable devices. Each of such services and devices came with a particular communication, protocol and analysis, requiring particular process reactions and parallel investments additional to further devices. The approach of the Smart-Home-Services project is to merge the communication of each single service to a standardized system. In a special application for this service system the compliant robot arm BioRob will be used for a remote rehabilitation assistance service. The new biologically inspired, lightweight and elastic robot arm offers a very high safety for patients in a similar way to a human arm. This paper shows the requirements and abilities of the compliant robot arm in rehabilitation assistance service applications which offer patients to practice relearning their own arm movements while their therapist controls and supervises this procedure by distance.

Index Terms— human-robot interaction, compliant robot, collision detection, rehabilitation assistance, home services

1. INTRODUCTION

In the last years home automation becomes more and more important in the field of residential construction. Single solutions are getting connected in novel global infrastructures. This reduces prices and expands fields of application. In actual home automation networks it is already imaginable to install complex assistance robot systems.

In the field of robotics safe human robot interaction is a major subject since many years. Safe robot interaction is an essential prerequisite for use in the medical-therapeutic field. This paper shows exemplary this scenario with the BioRob robot arm installed in the Smart Home Services home automation network.

2. SHS - SMART HOME SERVICES

The housing business - the provider of living room - stands at a boarder of social, technical and political changing, what results in a high adaption pressure for designing novel apartments. Individualized living worlds, new technology for network communication and process automation, new political determining factors bring providers of living room to search for novel solution concepts. The individualized apartment, which fits for people of all ages, which also has a low energy consumption and which is connected to the world is already today the challenge for a branch which measures capital investment in decades. [1]

Most of the already today existing realized solutions are separate and proprietary systems without an independent shared technical infrastructure. This are for example intercommunication systems, locking systems, fire alarm system, where each of this systems uses a own communication channel, a own communication protocol and a own process (see Figure 1, left). [1]

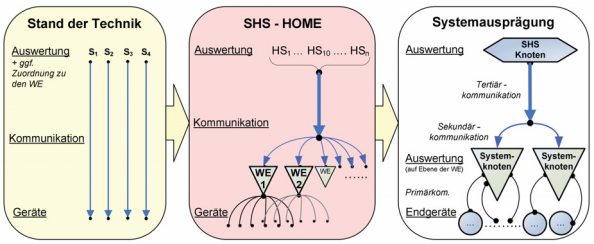

Fig. 1. Target of the SHS project

The main idea of the SHS concept is to use only one communication channel and protocol (see Figure 1, middle and right). That provides a new quality for a new, stable, easy and consistent technical solution in future-proof apartments and for new realizable electronic supported services. The final resolution offers a commercialization, which reduces complexity and cost

at one side and which offers a completely novel level of technical capabilities and economical efficiency.

The essential barrier for the realization of such a intelligent living is the existing investor benefit dilemma. That means the investor carries the investment for a solution which is offered to the renter of an apartment. A direct transfer to the rent is often not possible.

The solution of the SHS concept solves this problem in a way that both, the investor and the renter, have a benefit by the investments. The advantage for the investor is a cost optimized overall solution and the support for further expansions of the future proof system. Services for the housing business like facility services (for example network based heating and water measurement) and individual services for renters (living assistance, communication assistance, energy assistance, security assistance, handicap assistance, home automation assistance) are combined in one infrastructure.

Fig. 2. Userinterface ViciOne [2]

The usability is another important fact, which decides if a solution gets accepted by a user. So a graphical easy-to-use user interface for each apartment is intended. [1]

3. CHARACTERISTICS OF THE ROBOT ARM BIOROB

BioRob is the name of a biologically inspired compliant robot arm, which has human-like capabilities such as handling, collision detection and estimating forces. The robot arm consists of an aluminum basic structure and antagonistically coupled compliant elements, such as wires, linear and radial springs, which transmits motion and forces. These elastic elements provide a passive compliance to the robot arm, in a similar way to human muscles. First this makes the robot arm safe in cooperation to humans: collisions are measurable as unexpected position-difference-behavior between the robot arm joint and motor encoders, without the need of further sensors. Twice this makes the arm much lighter than using chains or gearboxes. This results in a very low energy consumption, what qualifies

Fig. 3. BioRob mounted at mobile unit

the arm for mobile applications. System parameters of the BioRob arm can be found in table 1.

	BioRob X4
Compliant joints	4
Total weight (including controller PC and power electronics)	4 kg
Arm length (shoulder to flange)	666 mm
Length of first link (base to shoulder)	276 mm
Payload (maximum)	2 kg
Payload (nominal)	0.5 kg
Energy consumption (w/o load)	nominal 15 W
Mounting position	arbitrary
Power supply	12 V, max. 40 W
Controller	compact PC

Table 1. BioRob X4 parameters [3]

The special lightweight construction in combination with non-self-locking motors offers a the possibility to take the robot by the hand and to move it passively around. So the easiest way to teach a trajectory is, to show the robot the desired movement in a hand guided teach in. The robot system records the shown movement and is able to play back the movement immediately.

For using BioRob in mobile applications a movable rack mount was constructed. This rack can easily be moved to a desired place. Being mounted at this rack, the robot arm is adjustable in height and in distance to the rack arm. Inside the foot of the rack mount were placed the small controller computer, a battery pack and a wireless module. An application can be developed for different devices, which are connected to the

controller computer via ethernet or wifi. The application programming interface is implemented for personal computers running with Windows, Linux or Mac OS and for mobile iOS devices. Especially the mobile devices are important to offer easy-to-use user interfaces to the robot arm. Special tasks can be developed and provided in small mobile apps. These small programs keep graphical user interfaces as simple as possible to make a complex robot system applicable for home use.

4. THE ROBOT ARM AS REHABILITATION ASSISTANT

In the following considerations the key focus is not the medical obviousness. The rehabilitation assistance service shall be seen as a economic and effective addition to the personal contact to medical practitioners. The services described in the following are not proved by medical tests yet.

In relation to rehabilitation assistance, "med assistance" (medical assistance) stands for all medical services which a medical service provider (doctor, orthopedic specialist, psychologist, etc.) can provide. This services are activated, controlled and executed using telecommunication equipments. It is an exchange of confidential information and instructions. This requires a high standard of safety. The goal of med assistance is a improvement in quality of life of patients and a faster consultation with medical specialists what results in a faster introduction of therapies.

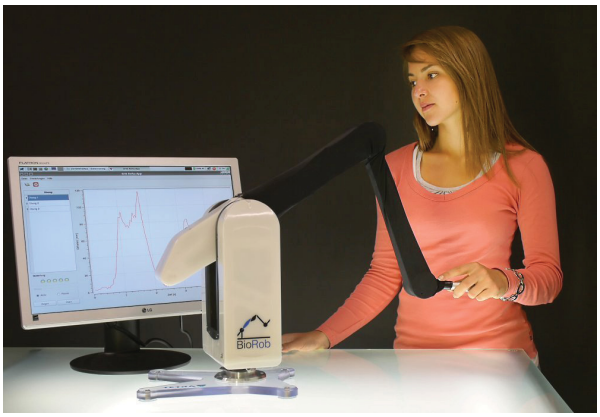

Fig. 4. BioRob Reha Assistant

An example for rehabilitation assistance is the movement relearning process after a stroke or a surgical intervention at a patients shoulder. The patient is already able to move his arm his self, but he needs a active movement training to rehabilitate for full mobility. The method of rehabilitation is to move the patients arm with a movement the therapist defined. Using a special robot different training methods can be performed.

Robots in the field of rehabilitation assistance are systems which generate mechanical movements to assist the rehabilitation process. This can be autonomous operating robot arms or active orthoses. The patients safety is at any time very important when cooperating with a robot.

Combining the characteristics of BioRob with the properties of the Smart Home Services network qualifies the system for novel applications like for rehabilitation or massage tasks.

Fig. 5. BioRob Head Message

For the realization process the first step and easier task was to use BioRob as massage assistant. For a special demonstration a head massage tool was mounted at the end effector of BioRob. The system only uses the wireless functionality between the robot and the user interface device in the SHS network. To offer the possibility to use a small touch screen device as user interface, the BioRob API was transformed to the mobile platform iOS. The trajectory was then planned by a special head massage app. The only manual operation which has to be done by the user in advance of the massage is to define the users head position. So the head message application got only two buttons and is very easy to use: one button to teach the users head position and one button to start and stop the massage movement.

In a second task the robot is used for movement relearning and rehabilitation assistance. For this application the SHS network plays a bigger role, because the therapist and the patient are standing in contact via network communication. So the therapist uses a robot arm to generate exercises and sends them via network to the communication node located in the flat of the patient. Using the user interface device the patient can load the exercises to his robot and execute them. This can be made with the iOS device again. First the robot shows the patient how the exercise looks. Then the patient has to practice this exercise together with the robot arm. After the exercise is finished the patient can read a status information on the display of the user interface about how good the movement has been done. This

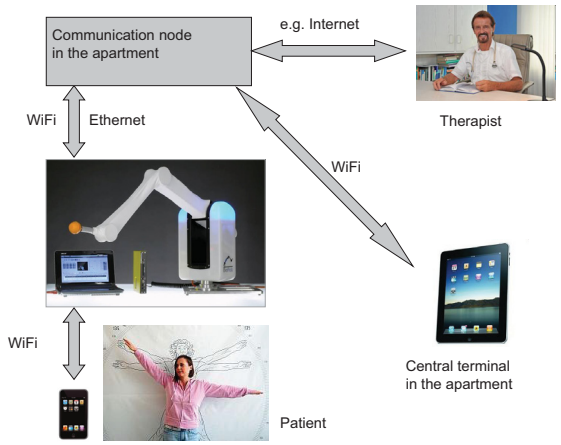

Fig. 6. Principle of the system

status information will also be stored on the communication node inside the flat. From this node the therapist downloads this information as feedback and can generate new exercises. In further stages another communication channel will be used for video communication between the therapist and the patient for advices, questions and supervision.

5. SUMMARY

For novel home automation services and assistance systems a standardized communication infrastructure is necessary. One solution was developed in the SHS project. The developed infrastructure offers the possibility to install complex sensor actor systems as needed for rehabilitation assistance. We presented the BioRob arm which is able to act in direct cooperation to humans and showed possibilities how to use the arm in novel living rooms as rehabilitation assistant.

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