THE DEVELOPMENT OF REHABILITATION ROBOT

Ing. Lucia Koukolová, PhD.
Technická univerzita v Košiciach, Strojnícka fakulta, Katedra výrobné techniky a robotiky
B. Nemcovéj 32, 042 00 Košice
e-mail: lucia.koukolova@tuke.sk

Abstract

The paper presents expected development of robots for assistance to old and handicapped people because of changes in the age structure of the population. The first part of the paper describes current situation in the field of personal service robots and its utilization in the area of rehabilitation. The second part of the paper describes the proposed procedure of rehabilitation robot development.

Key words: robotic rehabilitation, personal service robot

INTRODUCTION

During the initial period of robotics development the efforts of the research teams were focused most of all on industrial uses of the robots. Just like were the first applications. Only in the 80. realization of the concepts, to involve robots in human environment, became workable. It was connected mainly with development of the mobile systems, which have made it possible for robots to relocate.

From among non-industrial robot applications, regarding size of the market in categories amount of sold units and turnover, robots worked closely to people make the most promised group. The term “Personal Robot” (PR) more and more come out in the scientific publications and advertising aids, presented by manufacturers of robots. In the ISO-standard refer the terminology [2], service robots are divided into 2 groups:

- personal service robot (service robot for personal use) – service robot used for a non-commercial task, usually by lay persons, e.g. domestic servant robot, automated wheelchair, personal mobility assist robot, and pet exercising robot.
- professional service robot (service robot for professional use) – service robot used for a commercial task, usually operated by a properly trained operator, e.g. cleaning robot for public places, delivery robot in offices or hospitals, fire-fighting robot, rehabilitation robot and surgery robot in hospitals.

One of the main jobs of these devices in the near future will be care of aged and physically handicapped people. In this group the rehabilitation robots have a special place. These devices are today used primarily by hospitals and treatment centres that provide services to the population and they are classified as professional service robots. The work with rehabilitation robots is organized always in the individual mode: one patient - one robot. Main task of operator (physiotherapist) is teaching of the new exercises. Then his role is often limited to the initiation of the rehabilitation session, supervision and analysing of the results, progress. In many cases, the patient could practice independently, also in their own home, if he possessed such a robot. As an one of the most serious barriers in the widespread of such a devices as personal robots, the problem of communication can be indicated. They must be easy to use in operation and user-friendly, especially for the above mentioned groups of elderly and handicapped people. It can be supposed, that equipment of robots with effective, and in the same time simple communication systems, will decide considerably about acceptance of these devices by future users.

CHANGES IN THE DEMOGRAPHIC STRUCTURE OF SOCIETY

With the increasing performance level of medical interventions and of daily comfort, the population’s life expectancy is increasing, too. It is estimated that, in the EU member states, the proportion of the population aged more than 65 years will grow, from 17.4% in 2010, to 30% in 2060. Europe is facing the ageing of the all population. The number of those aged of 80 years or more will triple from 2010 to 2060, while the general population will have a decreasing trend in numbers [4]. Unfortunately, this means, on one hand, the increasing proportion of neurological, locomotor, heart and lung chronically affected persons and individuals with disabilities of different degrees. Heart disease and stroke will become the leading cause for disability worldwide in the next 10 years. The World Health Organization asserts that we have 15 millions new strokes per year, 5 million of the stroke survivors live with a permanent disability, many of them failing to regain any degree of functionality of their upper limbs [5]. Disabling pathological conditions and trauma may occur no matter the age. And disability means decreased quality of life, in all aspects. Disabilities affect 15% of the European population. That means one of four Europeans has a family member with a disability. 75% of people with severe disabilities don’t work. 38% of disabled people with ages from 16 to 34 years have medium revenue comparable
with 64% of the revenue of those without disabilities. The bigger the number of those disabled, the bigger is the social force oriented to caring activities. This brings bigger health care costs, thus having a negative impact on the European economy. It becomes imperative to find solutions to provide quality health service and care for those in need, without blocking an important working force in the assistive sector.

Tab. 1 Population of Slovakia - projection by biological age groups [6, 7]

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>5435</td>
<td>5416</td>
<td>5416</td>
<td>5396</td>
<td>5340</td>
<td>5250</td>
</tr>
<tr>
<td>65+</td>
<td>672</td>
<td>789</td>
<td>935</td>
<td>1062</td>
<td>1153</td>
<td>1201</td>
</tr>
<tr>
<td>65+ [%]</td>
<td>12.3%</td>
<td>14.5%</td>
<td>17.3%</td>
<td>19.7%</td>
<td>21.6%</td>
<td>22.9%</td>
</tr>
</tbody>
</table>

Situation in the most developed countries is even more serious.

Tab. 2 Population in other countries – projection by biological age groups

<table>
<thead>
<tr>
<th>Country</th>
<th>2010</th>
<th>2050 (projection)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-14</td>
<td>15-64</td>
</tr>
<tr>
<td>Japan</td>
<td>13.2</td>
<td>63.7</td>
</tr>
<tr>
<td>South Korea</td>
<td>16.4</td>
<td>72.4</td>
</tr>
<tr>
<td>Italy</td>
<td>14.1</td>
<td>65.6</td>
</tr>
<tr>
<td>Germany</td>
<td>13.5</td>
<td>66.1</td>
</tr>
<tr>
<td>China</td>
<td>19.5</td>
<td>72.4</td>
</tr>
<tr>
<td>France</td>
<td>18.4</td>
<td>64.8</td>
</tr>
<tr>
<td>Canada</td>
<td>16.4</td>
<td>69.5</td>
</tr>
<tr>
<td>Sweden</td>
<td>16.5</td>
<td>65.2</td>
</tr>
<tr>
<td>UK</td>
<td>17.4</td>
<td>66</td>
</tr>
</tbody>
</table>

**ROBOTIC SYSTEMS USED IN HEALTH SERVICE AND CARE OF OLDER PEOPLE**

Because of the ageing of our population, there is a growing necessity for new technologies that can assist the elderly in their daily living. There are two main arguments for this. First, it is expected that countries will face a tremendous shortage on staff and qualified healthcare personnel in the near future. Second, people prefer more and more to live in their own homes as long as possible instead of being institutionalized in sheltered homes, or nursery homes when problems related to ageing appear. To address these issues, we not only need sufficient health care personnel, but also the presence and appliance of high-tech devices. ICT technology and robotics are developing quickly nowadays, resulting in products that have the potential to play an important role in assisting the elderly. In order to use new technology in an effective and efficient way, robust information with respect to their effects is needed, especially when used in healthcare.

Fig. 1 Categorization of assistive robots for elderly people

Robot research in elder care concerns assistive robots that can be both rehabilitation robots and social robots (Figure 1). The first type of research features physical assistive technology that is not primarily communicative and is not meant to be perceived as a social entity. Examples are smart wheelchairs, artificial limbs and exoskeletons. The field of social robotics concerns systems that can be perceived as social entities that communicate with the user. Of course there are also projects with social robots aimed at rehabilitation and vice versa. Studies on social robots in eldercare feature different robot types. First, there are robots that are used as assistive devices which we will refer to as service type robots. Functionalities are related to the support of independent living by supporting basic activities (eating, bathing, toileting and getting dressed) and mobility (including navigation), providing household maintenance, monitoring of those who need continuous attention and maintaining safety. Examples of these robots are ‘nursebot’ Pearl, the Dutch iCat (although not especially developed for eldercare) and the German Care-o-bot. Also categorized as such could be the Italian Robocare project, in which a robot is developed as part of an intelligent assistive environment for elderly people. The social functions of such service type robots exist primarily to facilitate interfacing with the robot. Studies typically investigate what different social functions can bring to the acceptance of the device in the
living environment of the elder, as well as how social functions can facilitate actual usage of the device.

Second, there are studies that focus on the pet-like companionship a robot might provide. The main function of these robots is to enhance health and psychological wellbeing of elderly users by providing companionship. We will refer to these robots as companion type robots. Examples are the Japanese seal-shaped robot Paro, the Huggable (both specifically developed for experiments in eldercare) and Aibo (a robot dog by Sony). Social functions implemented in companion robots are primarily aimed at increasing health and psychological wellbeing. For example, studies investigate whether companion robots can increase positive mood in elderly living in nursery homes.

**DEVELOPMENT OF THE PROFESSIONAL REHABILITATION ROBOTS**

The area of development of rehabilitation robots is now developing rapidly. It should be noted that commercial industrial robots are also used for rehabilitation. However, industrial robots are still generally designed for quick and very precise handling of larger workspace and higher lifting capacity and high accuracy. They also have a high versatility. This makes them expensive for use in rehabilitation but also because of the full-utilization of their opportunities which are not fully used in the field of rehabilitation. Therefore rehabilitation robots are now being developed as a new kind of robots that are assigned to service robots, respectively to robots for healthcare.

In general, the definition of a rehabilitation robot is based on the definition of an industrial robot and says that rehabilitation robot is a reprogrammable robotic manipulator designed for the rehabilitation handling of one or more of the human motion axis. Therefore its mechanical structure is alike an industrial robot and it has a base, arms, joints and (grippers).

Rehabilitation robots, like the industrial robots, are expected to handle in a three dimensional environment but many rehabilitation activities are carried out in the plane, respectively in one direction. The differences in requirements for rehabilitation robots from industrial robots are such as smaller workspace, lower speed, lower load capacity and accuracy.

The proposal of a rehabilitation robot, Fig. 2, is based on the requirements for rehabilitation. The therapist can define rehabilitation movements in space, their speed and strength necessary for their implementation. Based on these input parameters constructor sets motion trajectories in 3D space and determines the size of the rehabilitation area.

![Fig. 2 Proposal of rehabilitation robot](image)

The proposal of manipulator kinematics is done in the next step. This proposal should allow the implementation of rehabilitation in the range of most natural human movements. Final proposal must not restrict the movements necessary for rehabilitation. Subsequently, the method of fixation and the fixation points of human rehabilitation parts are designed (hand, foot, finger, ..).

In the next stage, there is a conceptual design of the rehabilitation robot in CAD. The design of rehabilitation robot is time-consuming phase, detailed construction solution including the selection of the drives, too. Specific activity is the selection of construction materials.

When designing a rehabilitation robot the requirement for safety becoming important because of the direct contact with human. In order to ensure high safety of rehabilitation robot this activity is often addressed in a separate step. From the perspective of the patient and therapist rehabilitation robot must be equipped with multiple...
and redundant safety features which can monitor for example max speed of motion which should be about 0.25 m/s (while industrial robots have speed about 3m/s). Rehabilitation robot must not manipulate with human forcibly, its control system based on the feedback from sensors must monitor the resistance of a human during rehabilitation movements. Exceeding the specified force effects of robot respectively torques in the joints, robot automatically stops or slows its movements. In case of collisions rehabilitation robot is equipped with buttons to stop its movements by both patient and therapist.

In the phase of designing the control segment there is attention paid to the blocking functions as well as the way of easy programming – most commonly by learning. The control system of each rehabilitation robot should allow to program individually for each patient:
- required motions, their speed, number of cycles
- possibility to change movements during rehabilitation cycle
- record the progress of rehabilitation
- allow determining the optimal rehabilitation program, its length and time of the cycles

The proposed solution of rehabilitation robots is verified by using virtual testing, where the collisions between robot-patient and robot-therapist are verified.

The development of rehabilitation robots is relatively new area where methodology of system approach is still being formed. That is why we are currently seeing the proposal of rehabilitation robots for more partial rehabilitation instead of complex rehabilitation. But also in this field can be expected the development to the higher functional and reconfigurable rehabilitation robots.

CONCLUSION

The development of rehabilitation robots is relatively new area where methodology of system approach is still being formed. That is why we are currently seeing the proposal of rehabilitation robots for more partial rehabilitation instead of complex rehabilitation. But also in this field can be expected the development to the higher functional and reconfigurable rehabilitation robots.

Reference

[7] Prognosis of the population of the Slovak Republic in 2050, INFOSTAT - Institute of Informatics and Statistics

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