

Towards Robotic Assisted Hygienic Services: Concept for Assisting and Automating Daily Activities in the Bathroom

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Purpose Elderly people use competencies necessary to perform Activities of Daily Living¹ in the following sequence: 1. Bathing, 2. Dressing, 3. Toileting, 4. Transferring, 5. Continence, 6. Feeding. Although bathing is a basic ADL, only a few approaches have tried to establish advanced assistive technology for this field. In the proposed research a basis for introducing automation and robotics for bathing activities was developed. **Method** Bathing can be divided into a multitude of subactivities which have various relations to each other². In our research we have identified those subactivities as well as usual course of activity (activity chains). In order to identify sub-activities which can or should be automated the bathing activity was analyzed (course of activity, time needed to perform sub-activities, problems etc.) of several persons of different ages. Based on this research concepts for partially and fully automated bath environments were explored. This exploration design was performed systemically as follows: i) research and identification of needs, ii) definition of requirements, iii) identification of technologies and processes, iv) initial concept, v) experiment in real environment, vi) final concept and further development roadmap. **Results & Discussion** The concepts developed for configuring a robotic bath show that, it is basically possible to automate a sequence of subactivities in the bathroom. However, there remain many open questions: What degree of automation is suitable for which kind of person? Can safety issues, especially in the bathroom, be met by an automated bath? Can the system be modularized in order to meet the requirements of different room layouts?

Keywords: ambient integrated robotics, daily living activities, demographic change design

INTRODUCTION

Caring for elderly people is becoming increasingly important. Originally, children took care of the older generation, but this changed especially in industrial countries. In China and Japan children used to care their parents as they entered old age. Nowadays, this practice often is no longer followed. Additionally, the care system in many countries varies, contributing more or less to the ageing society. For example in China, there is no global state care system establishment. Only 1% of the 80+ generation is found in private health care facilities. The ageing society is required to cover its own caring expenses in private facilities.

Nowadays, the majority of the population worldwide focuses more on their professional career, rather than to the family^{3,4}. That means not only that people increasingly pass on the responsibility of caring the elderly, but also a lower birth rate is recorded. Since the young generation is gradually decreasing, demographic change⁵ is increasing at a rapid rate, and therefore the definition of a strategic approach efficiently dealing with this problem becomes even more essential. A demographic change measure within the past century and an estimated growth in the next 20 years in Europe is presented in Figure 1.

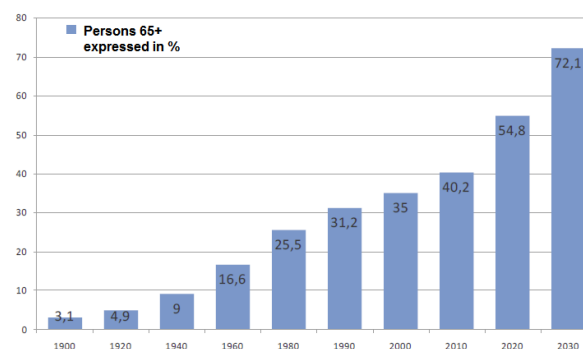


Fig. 1. Projected demographic change in Europe

RESEARCH AND SURVEY

Activities of Daily Living (ADLs)⁶ represent the everyday tasks people usually need to be able to independently accomplish. ADLs can be grouped in two main categories: a) Basic ADLs (BADLs) and b) Instrumental ADLs (IADLs). BADLs⁷ consist of self-care tasks, including: personal hygiene, grooming, dressing and undressing, self-feeding, functional transfers (getting into and out of bed or wheelchair, getting onto or off toilet, etc.), and mobility (walking without using an assistive device such as walker,

cane, crutches, or wheelchair). More complex skills are defined as IADLs. IADLs are not necessary for fundamental functioning, but they let an individual live independently in the community⁸. IADLs include housework, taking prescribed medications, managing money, shopping for groceries or clothing, use of the telephone or other form of communication, using technology (as applicable), and transportation within the community.

BADLs such as bathing, dressing and eating, can be used as a basis for assessing the independence of the ageing society. Older people tend to require even more assistance in performing BADLs, requiring thus the constant presence of an extra caretaker, i.e. they are care dependent. A representation of the required assistance in BADLs according to different age groups can be seen in Figure 2. Considering the demographic change projection depicted in Figure 1, it can be easily noted that this assistive service reflects to a very small fraction of available population age groups, which gradually becomes even more negligible, due to the evolving demographic change.

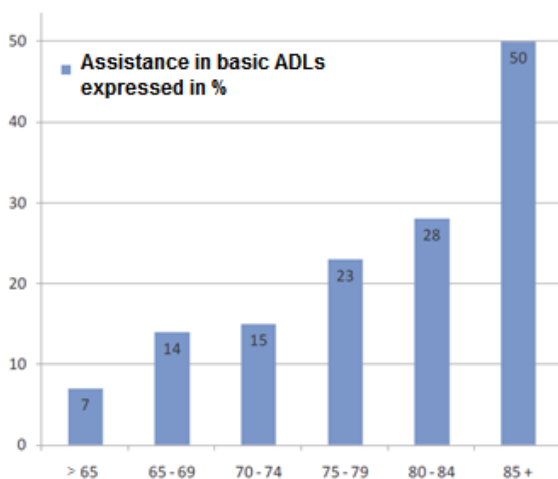


Fig.2. Care dependency vs. age groups

The daily routine of elderly people is often accompanied by functional challenges. Even, simple tasks sometimes require human assistance. In order to enhance the independence of elderly people numerous assistive devices and technical aids have been developed. Designers often focus on simplifying hygiene tasks, because the sense of shame is very high in these situations. For example, to adapt the height of the toilet seat an add-on riser can simply support older people to stand up from a sitting posture. Similarly, the shower ought to be designed barrier-free in order to easily adapt in various situations. Problems addressed during showering include severe injury risks from slipping and fatigue induced by prolonged standing. Additionally, a wide range of various waterproof chairs exist in the market. These are often foldable and have additional features to

enable a comfortable bathing process. Figure 3 depicts some of the aforementioned aiding devices.



Fig.3. Existing aids in personal hygiene BADLs

An extended problem is the bathing process. The arrangement of a standard bathtub, introduces a series of difficulties to elderly people. Its heightened side edge is often a challenge for elderly people. They do not have the physical strength to independently enter, sit down and stand up in a bathtub. To overcome these limitations designers created “walk in tubes” or developed chairs with an electric lift function to compensate the height difference (Figure 4).



Fig.4. Bathing assistive solutions

The disadvantages of the aforementioned approaches and solutions presented in Figures 3 and 4, concern the fact that in many cases the presence of an assistance is required, either to supervise the whole procedure or to assist on the deployment and operation of the assistive device. Their contribution in increasing independence for the ageing society in BADLs is clear, but the proposed research aims to optimize and enhance even further this independence factor, by configuring the environment of the individual in order for the functions and services to come to the user, than the other way around.

EXPERIMENTS

To optimize the bathing environment and identify needs and difficulties of hygienic processes, a behavioral analysis was followed. Eight individuals of

different ages were evaluated and the required time fulfilling the bathing process was recorded. Table 1 presents the corresponding evaluation results.

Table 1. Bathing time requirement evaluation results

Person	Age	Sex	Bathing time (minutes)
1	23	Female	6.3
2	25	Male	4.7
3	26	Female	9.5
4	51	Female	12.3
5	56	Male	5.4
6	79	Female	15.2
7	83	Female	13.3
8	85	Male	14.2

Additional tasks were evaluated by the 8 individuals during the experiment. According to the person sex, the following tasks were performed.

- Remove clothes
- Using toilet
- Brush teeth
- Shower
- Hair washing
- Shave
- Hands washing
- Dry off
- Hair styling
- Blow drying
- Cleaning ears
- Dressing
- Facial wash
- Putting Lotion
- Make up
- Wash with washcloth

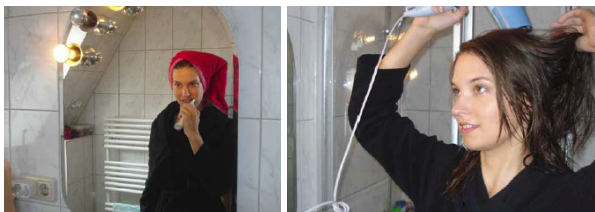


Fig. 5. Evaluation tests

RESULTS

The evaluation experiment confirmed that elderly persons require much longer time to perform most subjected tasks, Figure 6. Although the combinations of the tasks differ for each person, some tasks are performed by all and the order of them is the same, i.e., taking clothes off, showering, drying off and dressing. It is noticeable that the oldest person needs a shorter time to accomplish the series of given tasks than the average does. This is because in that case the person is not independent and another person was required to wash the older person with a washcloth, requiring therefore less time than an independent test person.

The results can be summarized in three main identified points:

- Usage vs. layout: scattered processes and long distances between every “station”
- Agility: physical agility decreases in old age and complicates the daily routine

- Mobility: Confined spaces affect domestic mobility

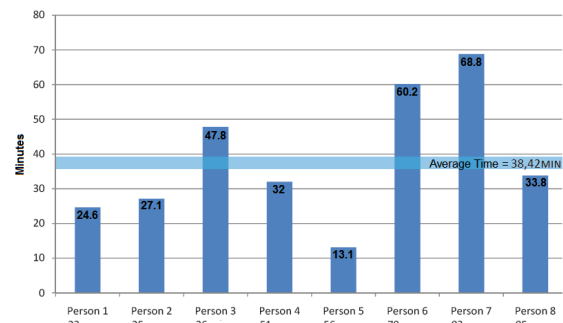


Fig. 6. Overall time required to accomplish all subjected tasks

CONCEPT

After defining the processes existing in the personal hygiene and grooming, it is possible to define a concept for an optimized bathroom environment. Emphasis is given to efficiently address mobility issues in confined spaces. Nowadays, space within the home environment is a luxury only for a very small fraction of population groups. The layout of the average family houses in Europe⁹ ranges around 60 m². Thus, the free space must be exploited to its limits in order to allow enough space for mobility. The future bathroom should be compact and user-friendly.

The proposed concept combines the functions in order to enable a novel process flow adjustment. The main idea is to fuse various technologies and robotic elements, in order to enable a novel scheme of processes flow, while performing BADLs. The term ‘process flow adjustment’ refers to the proposed automated bathroom environment, which adjusts in a novel manner the process flow, while performing BADLs. The processes flow of BADLs, in case they are performed in a regular residential environment, significantly differs from the processes flow offered by the proposed automated environment, due to the fact that the processes are fused in a single cell, allowing the BADLs to be efficiently performed.

In Figure 7, a process combination scheme is depicted. An automatic “bathing machine” for people can offer the ability of automate the bathing process reducing the time and the effort needed. An arrangement of a drivable toilet, allows an accordingly customized mobility assistive device such as a wheelchair, to dock to the toilet and allow a straightforward transfer, without requiring excessive physical strength. An embedded cabinet system, attached to the outer wall of the shower cabin, serves as a discrete storage space, in accordance to reduced space demands. A functional wall embedded behind the mirror of the bathroom, offers services such as measuring and display terminal of user’s vital signs, tele-care and tele-consulting, communication medium, etc. A mobility assistive wheelchair, specifically

designed to adapt to the various function of the bathroom environment, offers conformity, ease of use, contributing in enhancing the independence of elderly people in performing ADLs.



Fig. 7. Process combination scheme

The concept addresses the general configuration of the apartment. The layout must be flexible, as well as individual. The bathroom concept and the kitchen with its appliances should be the only fixed functions in the room and all interior walls should be eliminated. This enables a barrier-free arrangement of the apartment.

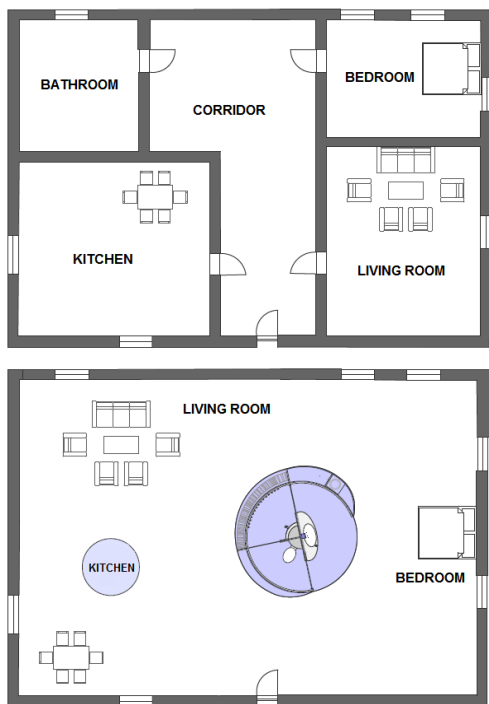


Fig. 8. Apartment transformation to barrier-free arrangement

SOLUTION APPROACH

The idea for the futuristic bathroom is to divide it into three sections: the shower room, the toilet and a

functional wall with washbasin. The shower room comprises a “bathing machine” that has water nozzles attached to the sides, which spray water as well as shower gel. Integrated blowers dry the user with hot air after showering. The washbasin is height-adjustable like the storage cabinets and shelves attached to the outer wall.

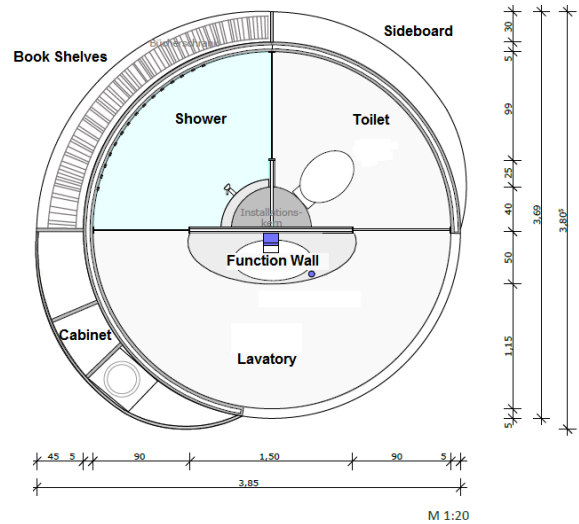


Fig. 9. Proposed bathroom environment

Additionally the electrically driven wheelchair provides mobility to each station of the proposed bathroom environment. The wheelchair was specifically designed to be compatible and adaptive in order to dock with the toilet. The wheelchair seat can be raised to various elevation levels according to functional requirements. The proposed wheelchair aims to allow the user to move easily into all possible areas of the bathroom environment, and at the same time be used in most of the performed activities without requiring the user to repeatedly transfer to different locations.

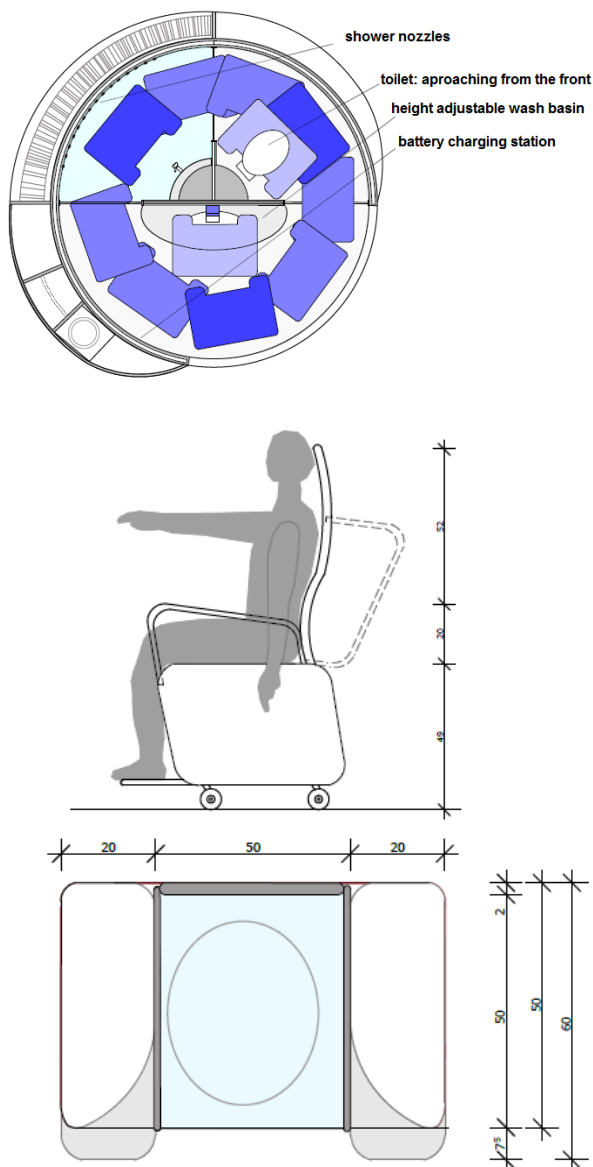


Fig.10. Proposed wheelchair design

CONCLUSIONS

An approach towards robotic hygienic assisted services focusing on the global demographic change problem is addressed in the proposed research. Elderly people tend to require assistance in performing basic ADLs. The demographic change prediction though, reveals a disparity in having younger people to continue to contribute in assisting elderly people, while the younger generation is diminishing in numbers over the recent years. Eventually, a great number of elderly people are going to face the consequences of this demographic transformation in their everyday living.

It is therefore important to try and increase the independence of elderly people in ADL performance. The functions and procedures need to be automated in order to allow their unattended accomplishment. Technologies need to be combined with architectural approaches, in order to provide fully optimized and

modular solutions, efficiently addressing the various tasks.

The proposed approach dealt with identifying the needs and requirements by conducting a survey among various age groups and identifying the main bottlenecks and limitations. A design procedure was then proposed in order to provide an efficient solution in optimizing hygienic services in the home environment while increasing the independence of elderly people in the corresponding ADLs.

The proposed concept comprises the combination of robotic and architectural elements, aiming at the realization of a novel robotic bathroom, which in combination with a specifically designed compatible robotic wheelchair can efficiently address mobility issues elderly people face, simplifying hygienic services and minimizing the existent injury risks that commonly occur in such situations.

References

1. Frederick, C., *The New Housekeeping, Efficiency Studies in Home Management*, New York: Doubleday, Page & Company, 1913.
2. Warrell, D.A., Cox, T.M., Firth, J.D., Benz, E.J., *Oxford Textbook of Medicine*, 4th edition, Oxford: Oxford University Press, 2003.
3. Lu, L., Kao, S., Cooper, C.L., Allen, T.D., Lapierre, L.M., O'Driscoll, M., Poelmans, S.Y., Sanchez, J., Spector, P., "Work resources, work-to-family conflict, and its consequences: A Taiwanese-British cross-cultural comparison", *International Journal of Stress Management*, Vol. 16, pp. 25-44, 2009.
4. Frone, M.R., *Work-family balance*. In Quick, J.C., and Tetrick, L.E. (editors), *Handbook of occupational health psychology*, Washington, DC: American Psychological Association, pp. 143-162, 2003.
5. Krueger, D., Ludwig, A., "On the Consequences of Demographic Change for Rates of Returns to Capital, and the Distribution of Wealth and Welfare", *Journal of Monetary Economics*, Vol. 54(1), pp. 49-87, 2007.
6. Wiener, J.M., Hanley, R.J., Clark, R., Nostra, J.F. van, "Measuring the Activities of Daily Living: Comparisons Across National Surveys", *Journal of Gerontology*, Vol. 45(6), pp. 229-237, 1990.
7. McDowell, I., Newell, C., *Measuring Health: A Guide to Rating Scales and Questionnaires*, 2nd edition, New York: Oxford University Press, 1996.
8. Bookman, A., Harrington, M., Pass, L., Reisner, E., *Family Caregiver Handbook*, Cambridge, MA: Massachusetts Institute of Technology, 2007.
9. United Nations Publication, *Trends in Europe and North America: The Statistical Yearbook of the Economic Commission for Europe (Trends in Europe & North America)*, 2001.