Conceptual Design of a Mechatronic System for Supporting Basic Quality of Life of Bedridden Elderly People

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Abstract. Ambient Assisted Living is an important subject to be explored and developed, especially in developed countries, due to the increasing number of aged people. In this context the development of mechatronic support systems for bedridden elderly people (BEP) living in their homes is essential in order to support independence, autonomy and improve their quality of life. Some basic tasks as eating, taking a bath and/or hygiene cares become difficult to execute, regarding that often the main caregiver is the other element of the aged couple (husband or wife). This paper presents the conceptual design of a mechanical system especially devoted to assist the caregiver in the handling and repositioning of the BEP. Issues as reducing the number of caregivers, to only one, and reducing the system's handling complexity (because most of the time it will be used by an aged person) are considered. The expertise obtained from the visits to rehabilitation centers and hospitals, and from working meetings, are considered in the development of the proposed mechatronic system.

Introduction

The increase of life expectancy in developed countries, implies the issue of elderly people that no longer have the autonomy of movement and ability to take care of themselves. The European Commission Directorate General Health & Consumers states that by 2025 the age of more than 20% of Europeans will be equal or above 65 (Fig. 1). With the increasing life expectancy in Europe it is predicted a particularly rapid increase in the number of people over 80 years [1].

The solution that many families adopt is to commit the bedridden individual to an institution specialized in geriatric medicine; institution such as nursing homes, hospitals, adult daycare centers, hospices and others. The problem is that these facilities are costly and are being overflowing with admission requests. The ratio of elderly people vs. trained and certified geriatric nurses has risen. There are simply not enough trained professionals to take proper care of the increasing elderly population. As such the incumbency of taking care of the elderly falls on the family and it is provided in their residence. In several cases the one providing care to the bedridden elderly people (BEP) is his/her life partner. With almost the same age these caregivers have not, commonly, the strength to properly handle the bedridden individual. When this situation occurs it is observed a decay of physical and psychological health of both parties [3, 4].
There is a lack of equipment specifically designed for home setting. Home equipment presently available is, in most cases, a strip down and less costly (but still very costly) version of the hospital option. But these are not explicitly intended for the average home and untrained user which implies that the equipment will not operate as well as it should [5]. Presently, the available option to move and reposition the bedridden individual that are intended for average home setting do not, in most cases, prevent the need for the caregiver to apply force. Also many of these applications only help in certain situations. The lift chair or the lift cushion, for example, are devices that apply a lifting mechanism that helps change from a sitting down position to an almost standing stance. This option is only viable when the individual is already sit down. Bed Rail are another example of devices that help with the BEP repositioning. They provide a steady structure on which both the BEP and caregiver can rely for support. There are also crane-like structures known as patient lifts that assist the BEP transportation and movement. There are three main types: ceiling lifts, portable lifts and slings. For safety issues these devices ideally involve two caregivers and they require caution when moving the BEP because any mistake can cause severe damages to the individual [6]. Some approaches to this topic have been made but further development is needed [7-10].

The main focus of the solution proposed, in this paper, is to create a mechatronic system that will facilitate the movement and repositioning of the BEP. This can be to reposition the individual in a more comfortable position or handle his/her daily hygiene routine thus reducing the amount of work and effort that the caregiver must dispense and minimize the strain on both individuals. The final goal is to aid comfort and mobility and also promote independence and autonomy.

The paper structure is as follows: first, the Introduction of the thematic, followed by the presentation of the system goals; further, there are described the system constrains, followed by some explanations about the considered approach for this work; the proposed approach and the concept steps are then considered and the main purpose of the paper (transforming bed concept) is also presented. Finally there are presented the main conclusions and possible future work.

**System goals**

The main goal of this mechatronic system is to facilitate the movement and repositioning of the bedridden individual. As the individual is lying down, the system must be able to move him/her around providing comfort and reducing the caregiver’s effort when handling the BEP daily hygiene routine.
The development of a multipurpose solution that not only would provide the movement mentioned above but also provide movement inside the home is desirable. Since the transfer of the bedridden individual between his/her bed and other solution that provides motion around the home (ex: wheel chair, standing frame) is also a difficult task. It would be ideal if the same solution that facilitates the movement would assist in the transfer between bed and other motion solution.

Another difficult issue that the bedridden individuals face is the arduous hygiene task. Taking a bath now means transferring from the bed to the bath facilities implying multiple types of movements and several transfers.

**Constraints**

The constraints when handling elderly individuals are numerous:

- **Velocity of movement.** The movement of the body must be done in a relative low velocity to prevent discomfort or injuries. Many of these individuals suffer from joint pains and rapid or unusual movements may cause irreparable damages.

- **Skin contact surfaces.** The surface in contact with the body must not cause any friction that would cause discomfort or scaring the skin. Skin lesion is an unavoidable subject when dealing with bedridden individuals. Also the prolonged contact between the skin and a surface may cause ulcers [11, 12].

- **Location.** Some solutions prove themselves inadequate, when placed in the average household, due to their size or weight. The ways some houses are architecturally planned leave very little room for large movements, thus limiting the allowed space for the device motion. Some solutions, like ceiling lifts, are not viable in some houses due to the building structure [13].

- **Anatomical constraints.** The movement produced by the system should not exceed the anatomical constraints of the human body. If this constraint is not considered it is observed compression or overextension of limbs and joints. Another issue that may occur is if two parts of the mechatronic system are moving adjacently they can act as “scissors” and harm the patient. The system must be mechanically limited in order to physically assure that these types of movements cannot occur.

- **Liquids.** Special considerations must be taken into account so that human physiological fluids do not cause hygiene problems to the patient nor to the mechatronic device.

- **Standards.** National and international safety and health standards prevent the implementation of certain solutions. In Europe hospitals the equipment must be certified by the International Organization for Standardization (ISO) Also, some countries have their own safety and standard legislation that define and regulate new devices.

**Approach**

The approach adopted for the development of the mechatronic solution follows the diagram on Fig. 2. It provides a methodology, based on several steps development, to serve as a guide to the overall process.
Starting with the concept step, the development passes to the dimensions analysis, dimensions from which the kinematics study is developed. The Dynamics study provides the stresses and strains values that are taken into account on the parts and motion mechanisms, the materials and actuators are chosen in accordance with those values. The control system(s) selection and sensors selection are interdependent steps. The general layout of the control system and attached components are shown in Fig. 3.

![Control System Diagram](image)

Fig. 3 Control System Diagram.

Known these devices and parameters (emergency cases, limits, velocities, lengths, weights) a set of control laws can be defined. After proper simulation, the final objective is the creation of a working prototype for testing the concept with trials.

**Conceptual step**

The conceptual step is one of the most time consuming stage of the development process. The mechatronic system is still in the conceptual step but the idea gets refined at each conceptual design that is discharged. Each conceptual design was run through 3D Computer Assisted Drawing (CAD) software and motion simulation software. This approach is less time-consuming and less costly than creating a prototype for every concept. The steps taken into consideration when conduction the analysis was, mainly: the parts design, motion mechanisms selection and location and collision detection.

**Parts design.** The parts were designed in accordance to the human measurements references and to the common houses’ configuration. This is so that the concept may prove viable for the average person and also that the complete solution works within the boundaries of the typical house[13, 14].

**Motion mechanisms.** The device motions can be either linear, rotation or a combination of both. Choosing which type of motion mechanisms to implement depends on the type of motion desired. Linear motions require devices as linear actuators, linear drives and slides. The main consideration with these devices is the stroke size; it must be well-defined in order to never exceed the allowed range of a movement. Rotation motion, on the other hand, requires devices as servo motors or stepper motors and torque is preferred over velocity since the movements must be done in low velocities but must handle heavy weights. All motion mechanisms must incorporate a mechanical brake for safety but nevertheless the system must be mechanically limited in order to never exceed the safety limits. Both the motion mechanism space and the workspace requirements can be checked with the 3D CAD software.

**Collision detection.** Motion simulation software offers an approach to solve collision issues computing which couples of polygons are interpenetrating. The software algorithm gives feedback in the form of a visual, glowing part, and audio, chime sound, when parts collide. After reviewing
the simulation results, the system can be iteratively improved. Some designs may be even considered impractical and/or may discharged due to financial restrictions.

**Transforming bed concepts**

The idea of a transforming structure considering three options is entirely new, contrasting with existing approaches that are generally limited to only interchange between two options. The concept introduced in this paper enables the interchange between three different structures: an adjustable bed, Fig. 4 (a), a standing frame, Fig. 4 (b), and a verticalization wheelchair, Fig. 4 (c) while providing other convenient functions [15].

![Fig. 4, “Transforming bed” concept ideas: a) Bed; b) Standing Frame; c) Wheel chair.](image)

One of these functions is a feature that assists in the repositioning of the BEP by removing the need for any type of physical effort from the individuals involved. This feature is referred to as the “roll over” feature. When the system is in the *bed mode*, one of the lateral parts that compose the bed will support the BEP by inserting itself under patient. The motion described by this part is a mix of rotation, Fig. 5, a) Rotation movement, and translation, Fig. 5, b) linear movement.

![Fig. 5, “Transforming bed” concept: a) Rotating movement; b) Linear movement; c) Bed sheet placing.](image)

This will enable the caregiver to take care of the BEP hygiene routine permitting to change sheets, Fig. 5, c) Bed sheet placing, change clothes, give a sponge bath or simply to turn the BEP into a more comfortable position.

The wheel chair mode of the “transforming bed” was projected taking into account the DIN 18100 and ISO/TC 162 standards that standardize the field of doors, doorsets and windows. This was done by designing the central section of the bed with the dimensions that would permit the wheel chair (and the standing frame) to pass through the standard home doorset. Since the bedridden individual is not transferred from the bed onto other devices, the risk of injuries is decreased.

**Inflatable bathtub.** Another part of the “Transforming bed” concept is the option to apply an inflatable bathtub. When a more thorough bath is needed the caregiver can use the “roll over” feature to spread an inflatable bathtub, in the same way he/she would apply a bed sheet, and inflate the device for its use.
Conclusions and future work

There is a need for further development of new devices and applications to provide a solution to the emerging problem of handling Bedridden Elderly People.

A brief presentation was made describing the current available options to move and reposition the BEP. The main constraints in this type of applications were identified and defined. Some design concepts were drawn using 3D CAD tools and were submitted to motion simulations software to determine their viability. The “transforming bed” concept introduced appears viable but further studies must be performed. A suitable concept determines the viability of the system by accommodating all the system constraints previously described. In the performed analysis, some concepts related with kinematics were already developed. After this completed study, the dynamics analysis will be performed in order to properly determine the movement’s velocities, accelerations, torques and forces values while performing material selection to match these values.

References