SEALE: Stability Enhanced Assistive Lift for the Elderly

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Abstract - **This paper describes a assistive robotic student project known as the Stability Enhanced Assistive Lift for the Elderly (SEALE), intended to help elderly and disabled individuals who need assistance in standing up from a seated position. The user could be on the ground following a fall or seated in a chair. The device consists of a foldable walker equipped with two battery powered motors that winch a lifting harness which is instrumented to measure pressure and load. These are necessary to determine the posture and location of the patient and thus allow for sophisticated controls in order to help the user maintain his/her vertical stability and prevent falling or tipping. As the user attempts to lift him/herself, the robot senses a drop in the harness tension and/or the contact pressure and based on a predetermined algorithm, engages the motors to wind-up the harness. The salient feature of this approach is that it allows the user to expand most of his/her diminished strength to stabilize him/herself while the lift system provides a large portion of the lifting force. The educational outcomes as well as the technical specifics are presented and discussed from the perspectives of the student authors.**

Index Terms – Assistive technology, Student projects, Mechatronics design.

INTRODUCTION

There is nothing more precious to senior citizens than the ability to live independently in their own homes. A 2007 study "Aging in Place in America" commissioned by Clarity and the EAR Foundation [1] found that "senior citizens fear moving into nursing home and losing their independence more than death." According to the study, 39% of senior citizens rated 'loss of independence' and 'moving out of home and into a nursing home' as their greatest fears, while only 3% rated death as their greatest fear. In all, 89% of all senior citizens surveyed expressed a desire to age in place, or grow older without having to move from their homes.

With a significant number of senior citizens fearing loss of independence more than the finality of death itself, a technologically advanced and wealthy society owes it to these men and women to devise the means of maintaining their independence. According to the Clarity and EAR Foundation study [1], 54% of seniors are more open to new technologies such as ambient sensors that enable an independent life through the monitoring of their health and safety.

The need to devise solutions to help the elderly remain independent is not only a societal and moral imperative but is quickly becoming an economic necessity with the burgeoning population of senior citizens. According to a fact list from LifeAlert® [2], 26 states in the U.S. are projected to double their elderly living (65+ & older) populations between 2000 and 2030. Among the population of elderly people living alone, falling is a leading cause of death and injury. This study claims that nearly a third of the current 35 million Americans over the age of 65 will fall in a given year.

On the market today, there are numerous products and services that have been developed to solve the problem of getting senior and disabled citizens the help they need in getting back up after a fall as quickly as possible. On the services side, there are a number of entities like the LifeAlert® with its famous slogan "Help, I've fallen and I can't get up" which takes a signal from a bracelet and pendant and contacts relatives or emergency services. There are also many products that help elderly people transition between postures, mainly between sitting and standing. A sampling of these devices is shown in Figure 1.

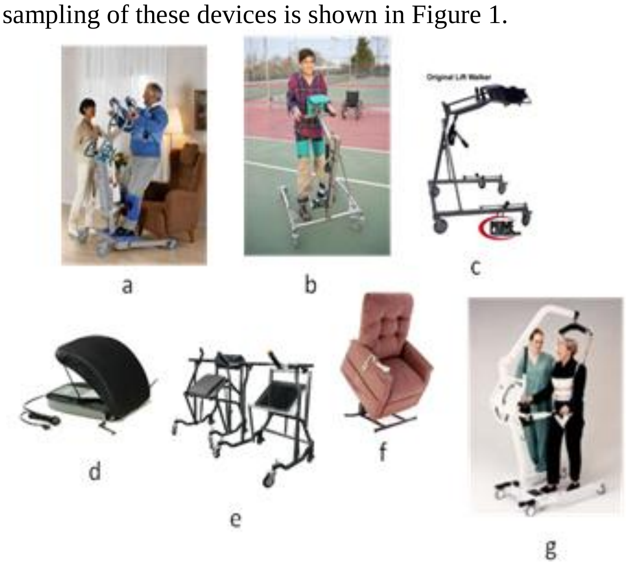

FIGURE 1
VARIOUS PATIENT LIFT ASSIST SERVICES AND WALKER DEVICES (A)ARJOHUNTLEIGH'S SARA 3000 [6], (B)NEW LIFT WALKER [3], (C) THE ORIGINAL LIFT WALKER [3], (D) UPLIFT SEAT ASSIST, (E) MDL LIFT ASSISTED WALKER TEAM FROM RENSSELAER [8], (F) THE LIFT SEAT [7] AND (G) MEDFIT SYSTEM [4], LIFE ALERT®

The devices shown in Figure 1 are highly specialized and are meant to perform one or two main functions at most, which are either walking assistance or assistance in getting up from a seated position. Most of the devices are also bulky and not portable, thereby limiting their range of use. Also, they are passive devices that require the user to adapt to them. In other words, a user will have to learn how to work with the device. Current existing technology can be used to develop smart devices that learn to work with the patient. The subject of this paper is one such technology named the Stability Enhanced Assistive Lift of the Elderly and known by the acronym SEALE.

This paper discusses the development of the SEALE technology. This includes a description of the actual functions of the device and how it interfaces and aids a patient. A detailed description of the device follows which focuses on the various components and subsystems. The paper follows with a description of the market potential for this technology as well as its various possible assistive technology applications. The educational experience of the authors as well as the rest of the team is presented. The paper concludes with a short description of the future plans and a conclusion.

FIGURE 2
INITIAL AND PROTOTYPICAL STAGES OF SEALE

The SEALE; shown in its initial and final stages in Figure 2, is an intelligent lifting device which will include the main final functionality of being able to:

- Intelligently assist and lift an elderly or disabled person from the ground after a fall.
- Intelligently assist and lift an elderly or disabled person from a seated position.
- Be usable in its originally intended capacity as a bariatric walker.

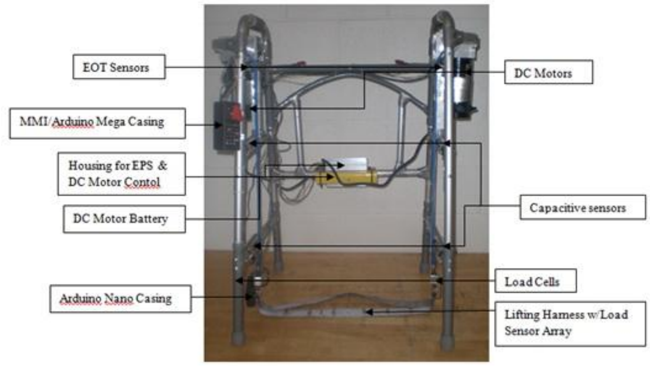

FIGURE 3
SEALE WITH LABELED COMPONENTS

THE SEALE DEVICE

The SEALE, shown in Figure 3, is designed to be interactive and to take the cues from the user. The user first slides into the lifting harness at which point the load sensors register and record the weight distribution of the user on the harness to determine whether the user is in a safe upright position (displayed by a row of LEDs on the Man-Machine Interface MMI). Once the user is in a safe upright position, s/he places hands and pushes down on the capacitive sensors located on both sides of the SEALE. The robot senses that the user intends to be lifted by sensing the reduction in weight registered by the load sensors. The DC motors then begin the lifting process to reestablish the weight that was initially recorded. Basically, the motors keep winching up as long as the patient keep pushing down and will immediately stop as soon as the patient stops. Meanwhile, the weight distribution is continually monitored by the load sensor array and the load cells on either side of the harness. Based on the weight distribution and difference registered by the load sensor array and load cells respectively, the DC motors increase or decrease power in order to keep the user safely upright throughout the lifting process. An additional failsafe has also been put in place in the form of stopping the DC motors when the user lets go of the capacitive sensors on the lower row until they place their hands on the sensors on the upper row in order to continue the lifting process. The purpose of the failsafe is to allow the user some time to rest if needed. When the user reaches the height intended, they can let go of the capacitive sensor, or when they reach the maximum height, the end of travel sensors will automatically stop the DC motors. (Legend of labeled parts in Figure 3 can be found in Appendix I.)

THE SEALE TECHNOLOGY

As described in the research from reference [2], the amount of time it takes for a patient who has fallen greatly determines whether he/she would be able to retain their independence. With this in mind, the team resolved to ensure that the time it would take for a patient to get back to a standing position through the assistance of the SEALE would be dramatically shorter than the time it would take for emergency services to arrive on the scene. The most effective way to fully appreciate the functionality of the SEALE would be to imagine it from the perspective of the user.

The inspiration and impetus for building the SEALE was due to the needs of a client who is an elderly disabled woman currently living alone and wanting to maintain her independence. Her disability is due to both of her rotator cuffs being torn, thereby resulting in her experiencing difficulty getting up from a fallen position. Due to her independent nature, she is less inclined to ask for help from others when she falls, and she wants to be able to keep this sense of independence.

During the initial design phase of our project, the team met with the client to see what she would need in a medical device. It was at this point that she explained how she gets up on her own. She described that when she falls she would crawl to her basement stairs, swing into a seated position with her feet over the first couple of steps. After this she would get to a standing position by pulling up on the handrail. The team was shocked to hear this because a misstep would cause her to fall down the stairs. A solution had to be found quickly.

In order to use the SEALE, it was proposed that since the patient was capable, she would move herself over to the device, after which she would position herself in the lifting harness. This being done, she would turn on the SEALE, which would in turn go through the starting process of registering her weight through the load sensor array attached to the lifting harness. With the weight distribution registered, the client would then push down on the capacitive sensors located on either side of the SEALE at which the SEALE, sensing the pressure on the sensors, and also the slight loss of weight caused, will move in order to regain the previously recorded weight and weight distribution. The SEALE will keep lifting until the client takes her hands off the capacitive sensors, signaling that she needs to rest, or she is moving her hands up to the next row of capacitive sensors at which the SEALE stops the lifting process until she places her hands on the next row, signaling that she is ready to continue. With her hands on the capacitive sensors, the SEALE continues the lifting process until she takes her hands off again or when the harness reaches its maximum height, at which the SEALE will stop moving and the patient will proceed to stand up. The entire process will be completed in less than 6 minutes.

INNOVATION

The medical devices shown in Figure 1 in addition to being highly specialized, are passive; they are not capable of registering or reacting to the needs of the user. This lack of interaction forces the user to adapt and adjust to working with these devices. The SEALE is designed to interact with its user in that it registers changes before and during the lifting process and adjusts itself accordingly in order to ensure the safety and satisfaction of the user.

The design of the system was inspired by the knowledge that humans are sophisticated robotic systems consisting of three subsystems:

- Sensory subsystem (sensory inputs plus the balance sensation)
- Intelligence subsystem(Brain & Nervous system)
- Actuator subsystem (muscles)

In the event of old age or many disabilities, the actuator subsystem deteriorates. The SEALE is designed to subsidize and compensate for the loss of strength. Furthermore, in its dual capacity as a lift and a walker helps solve part of the loss of the *actuator subsystem*.

Another benefit of a device like the SEALE is its potential for myriad uses in the handicapped segment of the consumer market. The device could potentially be adapted for physical therapy by gradually limiting the amount of lifting help a user can access over time. It can also serve as a more portable option for lifting patients from beds in hospitals. In other words, there is no reason why this device should be limited to one segment of the consumer market. Figure 4 shows a computer-aided design model of the SEALE which was used to conduct stress tests based on a maximum weight (300lbs) and also to determine the ergonomic positioning of man-machine interface (MMI) sensors.

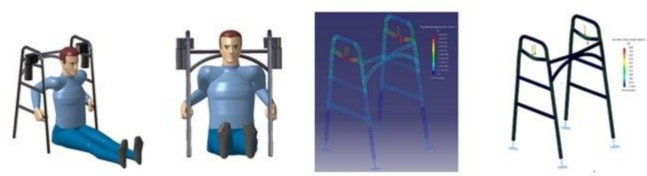

FIGURE 4
CAD MODELING, DESIGN & TESTING

THE MARKET POTENTIAL

The target demographic for the SEALE device consists of elderly and/or disabled persons who seek to live independently but need assistance in basic personal mobility. According to a report by the Center for Disease Control, a 65-year-old senior citizen can expect to live on average till the age of 84. A release from the U.S. Census Bureau [3] states that by the year 2015, the U.S. senior citizen population is projected to increase by 40% from their 2008 number of 36.5 million. The release also states that by the year 2050, the 65 and older population of the U.S. will more than double to 89 million.

Also, according to a U.S. Census Bureau Facts for Features release, 25.8 million persons in the US have a form of physical disability. Of the population between the ages of 16 & 64, 12% are living with a disability. This proportion increases to 41% for the 65 and older population. “There are 3.3 million people 15 years and older who use a wheelchair, and another 10.2 million people who use an ambulatory aid such as a cane, crutches or walker [2].”

Market Growth Prospect

Based on the above information, the market for the SEALE technology is set to grow moderately over the next 5 years, and exponentially over the next 40. Even though there is still a gap in the income between working adults and the elderly and between the disabled and able bodied individuals, that gap has been narrowed with the signing of the Americans with Disabilities Act. In the US, the elderly and the disabled have significant incomes. The purchasing power is further subsidized by health insurance and various social programs. As of 2008, 36.5 million (disabled and able-bodied) people in the U.S. age 65 and older, had a yearly median and mean income of $18,337 and $29,195 respectively, giving them a total income of $1 trillion. The U.S. Census Bureau states that the median monthly earnings for people age 21-64 with non-severe disabilities is $2,250, compared to $2,539 for those without disabilities. The income gap is much higher for those with severe disabilities ($1,458).

Promotion

The commercial competitiveness of the SEALE is premised on reaching the target demographic and on articulating a compelling value proposition. Ways of achieving the former are advertising, word of mouth, awareness seminars and a partnership with senior citizen and disability organizations such as the AARP and the DAV (Disabled American Veterans). As is the case with most medical devices, the target of any promotional plan should be the care providers and the third parties that actually pay for or subsidize the purchase (insurance companies, federal and state governments). The value proposition for these entities is simple. The SEALE robot will allow our target demographic to live independently or will allow aging spouses to care for each other. The alternative is expensive assisted living or frequent emergency calls.

THE EDUCATIONAL EXPERIENCE

The original team consisted of two mechanical engineering (Design & Build) and three electrical engineering (Electrical & Algorithmic development) graduate students. It was assembled on the 8th of September 2009 as part of a Sensors and Actuators class. The purpose was to enter the Robotics Innovations Competition and Conference (RICC) by finding a way to improve the quality of life through the use of robotics. From the onset, the team had many advisors who were interested in the SEALE project due to its novel nature and potential educational benefit. The SEALE, in addition to being built for the RICC, also doubled as a semester project for all the team members. Since the RICC was to be held roughly 2 months from the date of the creation of the team, time management and leadership skills became of paramount importance to all the members in order to meet the various deadlines that had been set by the RICC administrators. Making matters difficult, there were new concepts and knowledge being divulged in the class, scheduling conflicts that kept occurring, new software that had to be mastered, unfamiliar machines and tools that had to be used in the creation of the device. However, due to the guidance and help of the advisors, the team pulled through most of the obstacles and ended up finishing in 2nd place at the competition.

When designing and building the SEALE for the client, and in readiness for the RICC competition, the team tried to avoid over customizing and specializing the robot by keeping the interests of a target market in mind as opposed to one individual. This mindset helped the audience and judges appreciate the uses of the SEALE all the more. Market research was also conducted in accordance with RICC rules, and more importantly to add another dimension to the design and educational benefit to the team as a whole. In other words, by using marketing as a parameter, the team was able to resist the temptation as engineers to overdesign the SEALE. The competition forced the team to see the SEALE more as a product being developed than as a project being undertaken.

Based on that desire and the widely varying level of technological savvy within our major target demographic; Safety, Ease of Use and Comfort also became goals that had to be attained in order for our product to be a success in the targeted market. Safety was the most important to the team, hence the focus on user balance assistance while the lift is in operation, an emergency-stop switch in the event of some unforeseen circumstance, and the use of self locking worm-gear DC motors as the lifting apparatus to ensure the user doesn’t fall in case of a power failure. The teams’ attention to Ease of Use is intended to make the device more appealing to potential users of the product, and a focus on the Comfort of the user while the device is in operation is to ensure the device will be the first thing that comes to mind in an emergency situation.

CONCLUSIONS

A robotic assistive technology was developed by a team of five students in a graduate mechatronics course. The Stability Enhanced Assistive Lift for the Elderly (SEALE) is a device that is intended to complement an elderly person’s diminished strength by providing a lifting force through an instrumented harness. The lifting force is only a fraction of the weight of the user and is provided as a supplement to the user’s own strength. The work provided a good educational experience, reinforcing skills such as teamwork, communication, marketing and technology.

ACKNOWLEDGMENT

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APPENDIX I

Legend

PART	PURPOSE
DC Motors:	Self-locking worm gear DC motors to provide lifting power.
Capacitive Sensors:	Act as a failsafe (user needs to apply pressure in order to start the lifting process).
Load Cells:	Calculate and register weight difference.
Lifting Harness w/ Load Sensor Array:	User sits in the harness, while array calculates weight distribution.
Arduino Nano:	Gathers weight differential and distribution, and capacitive information and relays it to Arduino Mega.
Arduino Mega:	Collects information from Arduino Nano, processes and uses the information to relay commands to the DC motor control board.
DC Motor Battery:	Powers DC motors.
Housing for EPS & DC motor Control:	Houses Power Supply for Electronics and DC motor control board which controls the DC motors.
MMI:	Man-Machine Interface: Used to display SEALE status, increase or decrease power used (for more or less assistance from SEALE), activate emergency stop.
EOT Sensors:	Used to determine when the lifting harness has reached the maximum height and proceeds to stop the DC motors.