A Rise Support Integrated in a Service Robot for Older People

Germund Larsson
Machine Design, Department of Design Sciences LTH
Lund University
P.O. Box 118
SE-221 00 Lund, Sweden

Abstract

The purpose with this Master Thesis work was to find an aid for a safe sit-to-stand movement integrated in a service robot.

Mainly, the design methodology described by Jan Landqvist has been followed in the project. The development process has been user-centred to understand the users' needs/problems in the sit-to-stand movements.

The idea, to solve safe support in a sit-to-stand movement, is to stabilize the lower part of one leg at the same time as the person is using a natural body movement.

Introduction

The most common accidents at home are falling accidents. Every third person over 65 years of age falls at least once a year and every second person over 80 years of age falls at least once a year [1]. The direct cost of severe and mild injuries in 2006 was 5 billion Swedish crowns. If no prevention of fall injuries is done direct cost will increase to 8.2 billion Swedish crowns in year 2035 with the development of today. The total cost of fall injuries is calculated to increase to 22 billion in year 2050 if nothing is done to decrease the number of fall injuries [2].

In earlier studies of the sit-to-stand movement, the aims were to study the movements of older people; how they performed in speed, with safety, ergonomically etc [3][4].

On behalf of Certec, Division of Rehabilitation Engineering Research, Department of Design Sciences at Lund University, the task for this Master Thesis work was to find a solution, integrated in the design of the robot HOBBIT, of support to the sit-to-stand movement for older people. HOBBIT is a project supported by the European Commission [5].

Methods

Mainly, the design methodology described by Jan Landqvist has been followed in the project [6]. The development process has been user-centred to understand the users' needs/problems in the sit-to-stand movements.

First, a literature study was done to find previous work about sit-to stand movements with older people. Also, a study how the human body changes at increasing age was done to learn about the limitations for older people performing a sit-to-stand movement.

Observations were made to understand the target group and get more knowledge how people perform a sit-to-stand movement. Observations were first made at a practical lesson in movement techniques for physiotherapists, and then in the waiting hall at the entrance of the University Hospital in Lund. Observations at the hospital were made at two different occasions. The latter observation was done when more knowledge about the topic was collected. At the hospital only persons who looked older, about 70+ years, were observed.

Discussions with experts were made to get more information and knowledge about performing a sit-to-stand movement.

After collecting information of the target group and how to perform a sit-to-stand movement, sketches and prototypes were made. Two different prototypes were build; the second one after experience from the first user-test and the first demonstration.

User tests of the prototypes were carried out to get feedback. Two male persons, 72 and 78 years old, were recruited from the target-group. Both prototypes were tested by each test person to get good feedback.

Demonstrations of the two prototypes were done to get feedback of the design. Demonstrations were performed to a physiotherapist working with older people.

Calculations of forces, distances and mass were done to get an understanding where the centre of mass of the robot HOBBIT would be placed to avoid the risk of the robot to overturn when the user performs the sit-to-stand movement.

Finally, sketches of the proposed solution integrated in the design of the robot HOBBIT were made.

Results

Literature Study

The human body changes with increasing age. The locomotor system, where skeleton, joints and muscles are included, is affected with increased age where muscles are the most affected parts [7, pp. 134-141]. A result of the literature study is that an older person performing a sit-to-stand movement does it more ergonomically to decrease the use of muscles.

Observations

Older people performing a sit-to-stand movement do it with calm and stability. They bend the upper body forward to decrease the distance from the centre of mass to the support area of the feet to easily rise from a sitting position. Some of the observed persons put one leg behind the other when performing a sit-to-stand movement to get a more stable movement but also a greater support area when standing.

Discussions with Experts

One result from the discussions with experts in sit-to-stand movements was that the older person should use a natural body movement. A natural body movement can be hidden in a person but can be evoked with stimulation. Stimulation can for example be a voice telling what to do or a human touch. In this work the stimulation comes from reaching for a handle. By reaching for a handle with your hand the upper body will follow and the distance from the centre of mass to the support area of the feet will decrease.

Another result from the discussions with experts was that one of the lower legs should be stabilized when helping a person from sitting to standing. The contact points of the stabilisation should be at the sides of the lower leg approximately two fingers in width below the kneecap.

The Idea

The idea, to solve a safe support in a sit-to-stand movement, is to stabilize one of the lower legs at the same time as the person is using a natural body movement.

The First Prototype

A first prototype was made to investigate if a feeling of stability could be achieved with a knee support.

The prototype is a wooden box with a knee support adjustable in height, see Figure 1. The knee support is designed as a wedge to get the contact forces at the sides of the leg, see Figure 2. The person performing the sit-to-stand movement stabilizes the prototype by his/her own mass on a foot plate.

Figure 1. The first prototype with knee support adjustable in height

Figure 2. The wedge

The First User Tests

The first user tests were performed with the first prototype, see Figure 3. The test persons are both male, 72 and 78 years of age. They did not feel difficulties in performing a sit-to-stand movement but were interested to evaluate the prototype.

Both test persons felt greater stability when using the knee support. To get a better connection with the lower leg the knee support could be rotatable.

The test persons were missing a handle when performing the test. A handle should be at a height of 55-45 cm, i.e. lower than a chair handle approximately 65 cm [8].

Figure 3. The first user test

The Second Prototype

The second prototype uses the same method to stabilize one of the lower legs with the wedge but is equipped with a handle adjustable in height; 55, 50, 45 cm. The horizontal distance between the knee support and the handle is 40 cm, see Figure 4. The knee support is rotatable around its horizontal axis to get a better connection with the leg, see Figure 4. The second prototype does not have a foot plate, so the person is no longer stabilizing the construction. This simulates the scenario with the robot in a more realistic way.

The purpose with the second prototype was to investigate the height and distance of the handle in relation to the knee support.

Figure 3. The second prototype

Figure 4. The knee support rotatable around its horizontal axis

The Second User Tests

The second user tests were performed with the same test persons to get good feedback from users who had experience from the first prototype, see Figure 5.

The handle should be at a low height, 45 cm, to make it easy to perform a sit-to-stand movement. The handle should also be in the same direction as the knee support to minimize a sideway rotation of the robot. The horizontal distance between the knee support and the handle should be adjustable to satisfy a greater group of people.

Figure 5. The second user test

Demonstrations

Demonstrations of the prototypes were made to a physiotherapist working with older people.

Often older people have one leg weaker than the other. A result of the demonstrations was to stabilize the stronger leg to get a stronger and more stable movement when performing a sit-to-stand movement.

Another result is to have a handle at a lower height than handles of chairs to get the upper body further forward to decrease the distance from the centre of mass to the support area, which makes the movement easy to perform. However, the handle should not be too low because that could lead to difficulties to stretch out from the bent position. The handle should be at a height of 55 cm.

Calculation

Calculations of forces, distances and mass were done.

With data from user tests the centre of mass should be placed between 273 and 350 mm from the front of the robot so the robot does not overturn when the user is performing the sit-to-stand movement. This distance was calculated for a 70 kg person and a 70 kg robot.

Proposed Integrated Solution

Conclusions of the proposed solution were made from the literature study, discussions with experts, observations and user tests.

The handle is placed at a height of 55 cm and 40 cm from the knee support. The knee support is placed at an adjustable height of 35-45 cm to satisfy a greater group of people, se Figure 6. The knee support is integrated in the design of HOBBIT and can be folded out to the user when needed.

When performing the sit-to-stand movement with the proposed solution the person is using a natural body movement. By using natural movements the risk of the robot to overturn decreases. Furthermore, the proposed solution reduces the sideway pulling force and uses a larger pushing down force, see Figure 7.

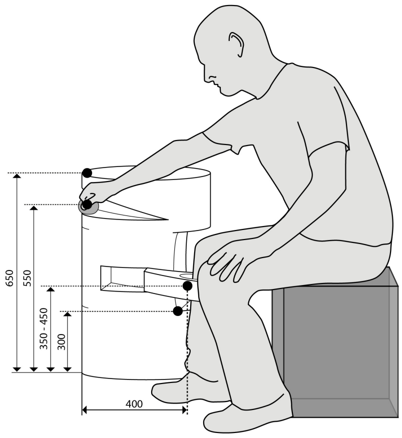

Figure 6. Distances of the proposed solution

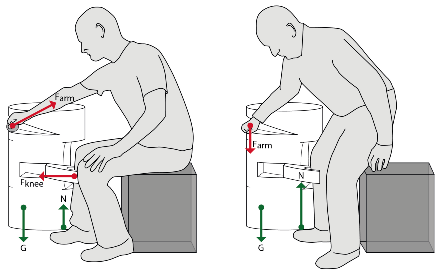

Figure 7. Forces when performing a sit-to-stand movement

Discussion

The development process has been user-centred to understand the users' needs/problems in the sit-to-stand movements. User tests has been performed with the target group, though the result of the user-tests could have been more satisfying if the test persons have had difficulties in performing a sit-to-stand movement. However one of the test persons did comment that it was easier to perform a sit-to-stand movement at a higher sitting height [8]. It was important to test the two prototypes with the same test persons to get good feedback.

The proposed solution is working with a natural body movement. It is important to stimulate a person to perform a sit-to-stand movement using a natural body movement to decrease the use of the muscles.

The proposed final solution, which has been developed in this Master Thesis work, is an aid for performing a sit-to-stand movement. A literature study and discussions with experts showed that an aid for performing a safe sit-to-stand movement exists, but not for self-help. The idea of the proposed solution is not limited to a robot but can also be developed into an independent aid or an accessory to a chair or a bed. A continued development of the wheeled walker is not excluded.

Conclusions

The proposed solution is working with a natural body movement at the same time as one of the lower legs is stabilized. By using a natural movement the use of muscles in the legs will decrease because the upper body will move further forward and the distance between the centre of mass and the support area of the feet will decrease. Also, the risk of HOBBIT to overturn will decrease when using a natural movement when performing a sit-to-stand movement due to the reduction of necessary pulling force from the user. The stabilization of the lower leg makes the performance of the movement feel more safe and stable.

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