Intelligent Sweet Home for Assisting the Elderly and the Handicapped

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Abstract. In this paper, we present some aspects of the project "Intelligent Sweet Home" that is focused on development of human-machine interaction in the smart house for assisting the elderly and the handicapped. In this study, we propose a conception and a strategy to give active services for a convenient daily life and to control the robot and home appliances human-friendly.

1. Introduction

Future society must be utopia in which every constituent can share equal welfare. In particular, it should be a society where the elderly and the physically handicapped can lead their lives happily along with the normal people. It is instructive to note that the number of the elderly is drastically increasing along with the number of the handicapped caused by a variety of accidents in the complicated and diversified society [1]. In order to realize a welfare-driven society, it is essential to build an infrastructure with a variety of facilities based on advanced technology or devices and systems that are human-friendly.

The importance of smart house for the elderly and the handicapped may be well understood from the various existing studies such as AID project [2], Smart House project at University of Sussex, HS-ADEPT [3], HERMES, the Smart Home project at Brandenburg Technical University, the Gloucester Smart House, the SmartBO project [4], the smart house at the Colorado University [5], Welfare Techno Houses in Japan, Robotic Room at the University of Tokyo [6], etc.

In this paper, we comment some of the conceptions that were implemented in our Sweet-home project. Proposed organization of the smart house considers some recent technology innovations as well as some specifics in the lifestyle and traditions in Korea. Since R&D of intelligent human-friendly residential system is urgently in demand to comply with the

needs of human being to lead more convenient and safe lives and to deal with the increase in the number of the elderly and the handicapped, Intelligent Sweet Home for assisting of the elderly and the handicapped, developed at the Human-friendly Welfare Robot System Engineering Research Center in KAIST, aims at development and testing of new ideas for the future smart houses and their control. Our work was based on the idea that the technologies and solutions for such smart house should be human friendly, i.e. smart houses should possess high level of intelligence in their control, actions and interactions with the users, offering them high level of comfort and functionality.

The Intelligent Sweet Home consists of three main parts: intelligent bed robot system, soft remocon, and network. Overall view of the current scenario of the Intelligent Sweet Home is shown in Figure 1. An intelligent bed robot system is designed for the active service for the people with movement limitations, and soft remocon system is developed as a human-friendly interface conrolling home appliances. The network performs information exchange between subsystems such as robotics arm, position sensor device, camera system, and hand gesture recognition system.

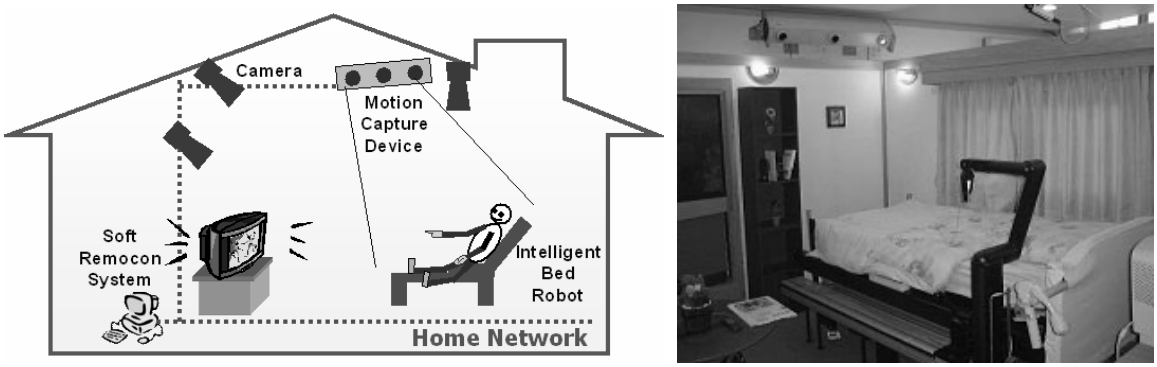


Figure 1 Overall System of Intelligent Sweet Home

2. Intelligent Bed Robot System

Intelligent Bed Robot system was developed as an active service agent to assist the elderly and the handicapped to live a convenient daily life since they usually spend much time in their beds and suffer great inconvenience even for a little movement. As shown in Figure 2, “Bed” + “Robotic Arm” is our motivation and concept to give effective service to the elderly and the handicapped. “Bed” is a suitable place for a long time service and “Robotic Arm” is proper as an active agent.

Figure 1 shows the prototype of the system consisting of three parts – automatic bed, robotic arm and motion capture device. The bed is designed in consideration of human body and can change its pose in various ways. MANUS arm is attached to the side of the bed and is utilized to serve four kinds of fundamental tasks: pulling a book and put it back on the bookshelf, transporting a newspaper, giving a massage, and pulling a quilt over and

putting away it. To this end, the robotic arm needs the on-line position information of objects with high accuracy and the motion capture device is utilized to supply the position information in real time. Motion capture system is also used to make human-friendly motion trajectories of the robotic arm. The fundamental tasks can be extended by adjusting the motion trajectories of the robotic arm by applying effective position sensors.

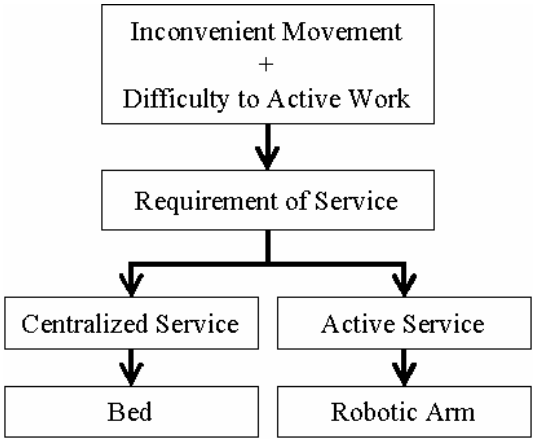
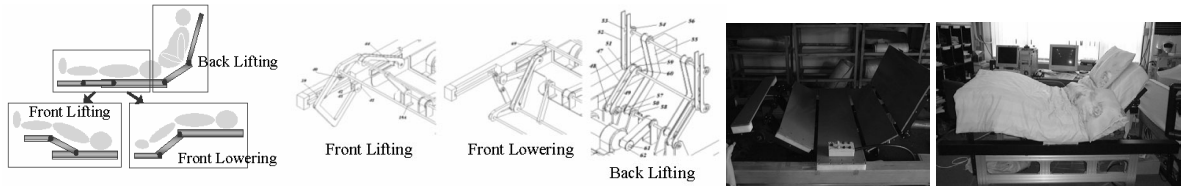


Figure 2 Motivation of Intelligent Bed Robot System

2.1 Bed Mechanism Design

As the concept of the bed is changed as life space, the user should keep his pose comfortably for a long time on the bed or be able to change his pose at any time that he wants to do for the prevention of some diseases like a bedsore or a skin disease. An articulation of human body is various. A dominant movement of human body is, however, determined by three joints, a knee joint, a pelvis joint and spine joints when he is on the bed.



(a) (b) (c) (d)

Figure 4 Flow of Bed Mechanism Design

Figure 4 a) shows various poses of human body using the above joints. As shown in Figure 4 b), the mechanism is divided by two parts, upper and lower. The upper part can be folded from 0 to 90 degrees and the folded curve is similarly formed as the curve from pelvis to waist of human body by adopting four-bar linkage mechanism. The lower part is folded from –70 to 70 degrees for the user to keep a comfortable pose like a folded sofa by adopting parallel mechanism and slide crank mechanism.

2.2 Robotic Arm and Motion Capture Device

Figure 1 shows robotic arm attached at the side of the bed for manipulation. A linear guide (1.5m) is actuated for large work range. As shown in Figure 5, the robotic arm has the large work range including a table, a bookshelf and a massage-hanger around the bed. The robotic arm can manipulate with pre-programmed path for service delivering a newspaper or a book by assuming that the position of these was fixed. The motion capture device can be used to feedback the position data of markers attached on the edge of a quilt in real time.

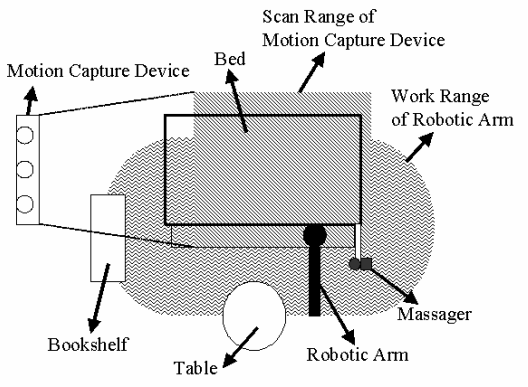


Figure 5 Workspaces of Robotic Arm and Motion Capture Device

Two markers are used to find the direction and the position for gripping a quilt as shown in Figure 6. The position of marker by motion capture system is translated to the position by the end effecter of robotic arm using coordinate transformation. Since the scan range of motion capture system includes all ranges of the bed, we can obtain position information of anything on the bed, a pillow, a movement of the user, etc.

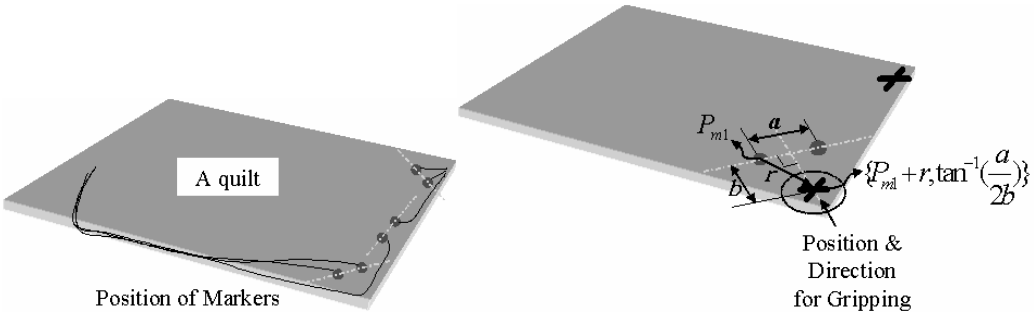


Figure 6 Position and Direction of End-effecter to grip a quilt

2.3 Experimental Results

In human machine interfaces, distance between human and robot is very important factor. So, we first divided distance by four ways: FAR, MIDDLE, NEAR, and CLOSE, and

selected proper service jobs for each term as shown in Table 1. Four jobs are related to a basic or cultural modern life of human being. The job of robotic arm is given by pre-programmed path and motion capture feedback data is sent to the system per 100ms with 1mm resolution.

Table 1 Classification of service job

Distance	Job
FAR	Delivering Drink from Special Box
MIDDLE	Delivering the Book/Newspaper
NEAR	Covering a quilt over
CLOSE	Massage

Since Intelligent Bed Robot system is developed to be able to cover the centralized service area, the service range is confined by its structural configuration and mobility for the service job with FAR-Distance. Actually the user wants to extend his field of activity, for instance, he may want to drink a coke in his refrigerator which is more far placed. To resolve this requirement (FAR-Distance), we propose the cooperation with our system and another agent such as mobile robot, and introduce the possibility of active service for the user through the cooperation job of multi-agents. Mobile agent is able to localize its posture using our vision system. The work of mobile agent is to deliver the drink in the box as shown in Figure 7. To do this work for itself without help from the user, we have designed a particular box using simple mechanism. For cooperation with Intelligent Bed Robot System, the mobile robot delivers the drink in the work range of robotic arm so that the robot arm can grip it.

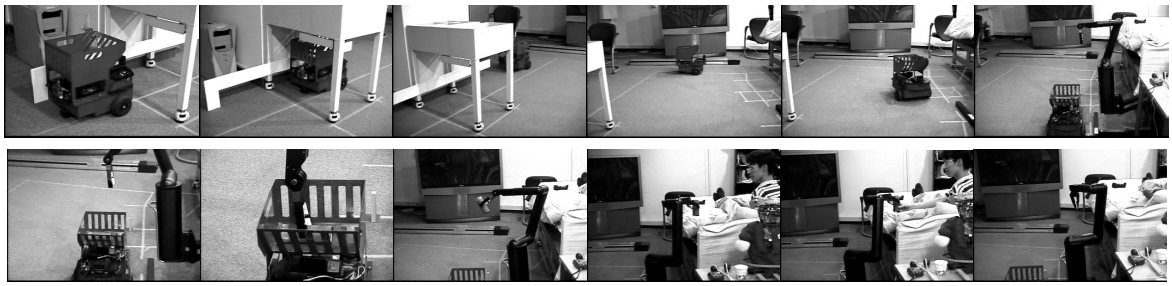


Figure 7 Delivering Drink Service using Cooperation Job

3. Soft Remocon

Significant part of Intelligent Sweet Home is devoted to development of innovative solutions for more natural human-oriented interface for control of home-installed devices. Our understanding is that frail disabled would feel much comfortable if the applied HMI does not require any sensor attachments to the user. In our study we propose a conception for control of the robot and home appliances by predefined hand gestures remotely sensed

by ceiling-mounted CCD cameras. There are two modes of control of the home environment:

A. Simple mode – User selects the home appliances by pointing to them. Dwelling or voice is used for confirmation of the selection and activation of the selected device. Next pointing to the same device turned it off. The mode was applied to “on-off” control of the TV, lamps, curtains opening/closing, etc.

B. Extended mode – Using a hand gesture, the user first activates a mode where a list of tasks and services appear on the TV screen. Then, pointing to the TV and moving his/her hand, the operator selects from the menu a command that should be executed. Last, taking certain hand posture or using voice commands, user confirms selected command and initiates its execution. Such mode can be used for changing of the TV channels; setting of home environmental parameters such as indoor temperature, light intensity, sound loudness of audio devices, as well as for selection of pre-programmed tasks that will be automatically executed by the robot or other home- installed devices.

Three ceiling-mounted CCD colour cameras with pan/tilt motions are used to acquire the image of the room. For the simple identification of the commanding hand in the complex background, it is assumed that the user should wear a colour (red & blue) hand band. The colour hand band is tracked by means of the condensation algorithm [7]. Then, image segmentation is applied to extract the hand colour region from the neighborhood of the colour hand band region. For representation of raw data, a feature extraction procedure is also included. It is followed by pointing recognition procedure that recognizes the pointing gesture and calculates the orientation angle and pointing direction of the hand. The control procedures end with sending appropriate IR signal for controlling home appliances.

3.1 Detection of the Pointing Hand in the Complex Background

A 640x480 image from each camera is reduced to a 320x240 image using a bilinear method for fast computation. In order to reduce the effect of the luminance and shadows, we applied a normalization *rgb* transformation. Since the colour hand band marker has a big value of red colour and a big value of blue one, to extract it from complex background, we apply proper threshold to the normalized *r* and *b* images separately. In the tracking of the colour hand band, we use the condensation algorithm that is a sampling-based tracking method. Then, the commanding hand area should be extracted by thresholding normalized *r*, *g* and *b* images and applying logical AND operation from the neighborhood of the colour hand band region. After removing the remaining small noise using the open/close operation, we get the hand colour region as shown in the lower image of Figure 8.

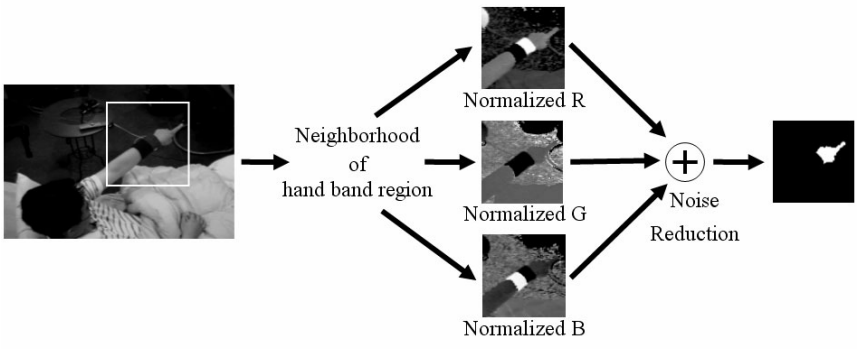


Figure 8 Detection of Hand Region

3.2 Detection of the Hand Orientation and the Pointing Direction

In order to calculate the 3D position of the hand, we use the images from two cameras as shown in Figure 9. We find the space orientation of the lines that connect the center point of each camera with both end points of the hand region of the sensed image. Then, we can calculate the global coordinates of the intersection points A and B. The hand orientation vector can be obtained from the direction of the line AB.

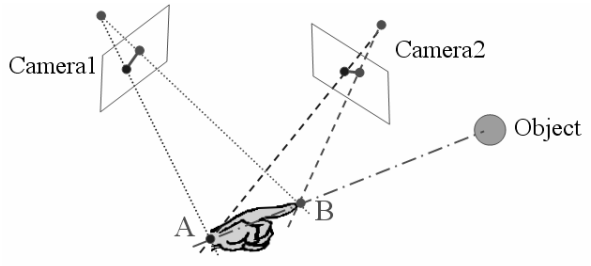


Figure 9 Hand Orientation Vector in Global Coordinates

3.3. Experimental Results

The soft remote control system was tested in the Intelligent Sweet Home for control of TV, automatic curtain, lamp and personal robot. Figure 10 shows some tests with the soft remote control system. Experiments show that the average recognition rate during the experiments for recognition of pointed objects was 95%. In extended mode, the desired item from the menu tree was successfully selected.

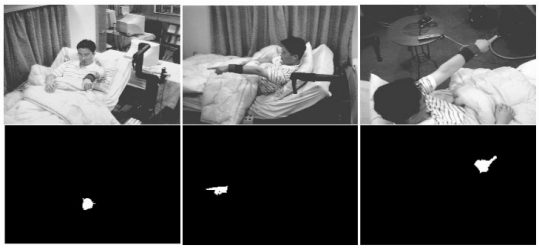


Figure 10 Three Images from Each Camera and Detected Hand Region

4. Concluding Remark

In this priliminary result of developing Intelligent Sweet Home, we have suggested and have implemented several components which help the elderly and the handicapped have independent daily living. Further, according to evaluation by the handicapped, we have collected feedbacks which will be seriously considered for desiging the next version of the systems. We believe that one of the biggest reforms to occur in residential space is to adopt various service robots to help the habitants in many ways. The idea of Intelligent Sweet Home is treated at present not as a science fiction but as important goal with strong social and economics aspect. Its realization will give a solution of many existing problems of the welfare society and will make the handicapped/elderly's lives as well as human life much pleasant and easier.

Acknowledgement

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