Remotely Controlled Communication and Control System for Limited Mobility Individuals

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***Abstract*—Design improvements to a remotely controlled system for patients with limited mobility are described. This system provides communication and control of the room environment with mouse control that can be adapted to the functional need of the user. Analysis is provided on the selection and integration of components within the system as well as an overview of the simulated access times for several key components. Transition to an open source Android operating system is discussed for long-term use in the home environment. Prototype configurations for use in the hospital and home environment are introduced.**

Keywords-assistive technology; limited mobility; Android mobile devices

I. INTRODUCTION

There is a great deal of interest in furthering the capabilities of smart homes and intelligent environments [1][2][3][4]. Our contribution to this research field is to create a system for use by individuals that may have temporary or permanent limitations in their mobility while they are recovering in the hospital as well as discuss open source options for a home version of the system for remote control of the environment as well as social interaction. There are several solutions available for the control of devices [5][6]. However, limited head motion and vocal quality can prevent successful usage and these limitations are highly prevalent during the initial traumatic or acute medical treatment phase. Solutions that interfere with eating or require a dental device also pose complications during the first few months of treatment [7][8] which would not lead to wide spread adoption by care providers or patients. Still other solutions utilizing high end robotic systems are beyond the financial means of many facilities to adopt for each patient [9][10].

Our approach is to start with off-the-shelf components that integrate necessary functions for use in the hospital room to lower the barriers for adoption and access. This approach is highlighted in the first half of the paper for individuals with severe hand use limitations such as quadriplegia, peripheral nerve injury or amputations. Primary needs within the hospital room are identified by the team through a series of interviews with nursing staff, doctors, and patients at the Denver Health Medical Center. A prototype system is designed and described in the abstract listed in [11]. This paper will provide detailed discussion of the system components and provide additional information on the necessary transition in care from the hospital to the home environment. Our approach for this phase of the care cycle is to adopt the open source platform of the Android devices. Current progress on this development is highlighted along with future plans to integrate the Android platform into the hospital room solution as well as expand the user interface options for a wider audience of individuals undergoing significant medical or surgical care.

II. STANDARD HOSPITAL ROOM

Through a series of discussions between the rehabilitation department at Denver Health, engineering students and faculty as well as a tour of the facility, it was determined that the standard hospital room interface for control of room devices does not provide needed access for patients with significant mobility limitations. Thus, the patient must resort to constantly calling the nurses' station for assistance and support. Items that are of major concern are control of the lights, fan, television, phone, and access to the internet. These devices are generally controlled with a hand held mechanical switch that requires significant body position changes, ambulation, and the ability to hold a receiver for communication. This makes it very difficult for someone who is restricted in movement while recovering from a polytrauma to maintain communication and control of the room environment. The use of the current call button to ask for nursing assistance is also a source of anxiety for many patients since the standard hospital room interface required the ability to speak which may be limited in the first few months of treatment if the vocal cords are damaged or if the airway is compromised. Another obstacle is the language barrier that can impact communication and the care needs.

A system with an adaptable user input device that accommodates the limitations of an individualized patient is necessary to assist regaining the ability to communicate and control the hospital room environment. This new system known as the smart room provides greater freedom that should improve satisfaction with care during the acute treatment phase in the hospital.

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III. SMART HOSPITAL ROOM DESIGN

The goal of this initial project is to design a system that enables the patient to call the nurses' station in the hospital and to have some control over his/her environment when mobility is limited and no hand use is available. Standard hospital room interfaces are used for control of the television and reading lights since the connections are already made within the room. The control of a fan is performed through a wireless interface and additional lighting may be provided as well for patient comfort. A handheld phone is replaced with a virtual phone interface through a browser. For the adaptable user interface, it is assumed that only neck motion is allowed and that vocal cords may be damaged. To accommodate this need, an adaptable mouse is selected for control of the user interface. Patients select a component on the user interface by moving an arm, shoulder, head, etc. and holding it over a spot to simulate a mouse click. Messages are sent to the nursing station in the form of scripts and standard requests are part of the system implementation. The device is mounted on a bed stand that is adjusted to a comfortable height by the nursing staff so that the patient can see the screen as shown in the center of fig. 1 while moving the mouse to select the specific devices to control. A sleep function is also available so that the patient is not constantly forced to stare at the screen.

A. User Input Function

The user input function is focused on head motion and commercially available solutions are utilized for implementation. Three main types of interface are analyzed that included a head tracking, eye tracking, or manual manipulation. A head tracker utilizes infrared light and an infrared camera. Light is emitted on the users face and reflects back to the camera via a small reflector placed on the user's forehead. The head tracker processes the movement of the incoming light and converts the information into a language usable by a standard mouse driver. An eye tracker allows the user to place the mouse pointer anywhere on the screen simply by looking at the desired location. It is a camera mounted on a computer monitor and is focused on one eye. Manual manipulation devices are essentially joy sticks that are operated by the user via the cheek, chin, hand, elbow, or any body part with well controlled movement. Some devices use puffing and sucking to trigger a click or any other pre-defined operation.

The most important issue in the analysis is the ease of use for the patient. Cursor control, mouse click control and wearable parts are of higher importance compared to other criteria like price, sensitivity, weight, size, distance between user and device and system requirements. Based on analysis of these alternatives, the SmartNav 4:AT by Natural Point, a head tracker that uses a high resolution infrared camera was selected. The initial prototype of this device is shown in fig. 1.

As the project moves forward into the Android tablet interface, the opportunity to track head or limb motion with a front facing camera is possible. This will reduce the overall complexity of the system configuration and enhance the portability of the system from the hospital room to the home environment. Additional options that can read brain signals from an EEG monitor are also possible for individuals who don't have head motion but are cognitively intact. The following sections outline the evaluation of the user functions and describe how the initial prototype is created. Discussion is also performed on the update of the system to the Android platform. The new Android system will also provide portability so the system can be used on a wheelchair.

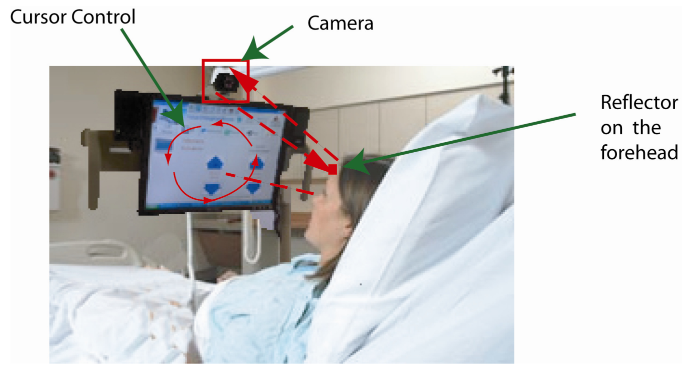

Figure 1: Hospital Stand Prototype

B. Nursing Station Communication

Communication with care providers is a high priority for patients. Typically a panic button and speaker are used for this function. Since the patient might not be able to speak, scripts are used for standard requests and a keyboard is available for custom requests. A computer with instant messaging (IM) software is placed at the nurses' station to interface with the patient and respond to their requests. Wireless communications through the hospital intranet is used for this piece of the system. The patient is able to choose from a list of pre-programmed requests and responses and also be able to type custom message via an on-screen keyboard. The language challenge is also alleviated since the software is programmed to display various languages or images representing the desired request. The language most suitable for hospital staff is sent, however, custom messages are sent as is.

C. Telephone Function

This function is constrained by the cost associated with additional service charges, and need for additional hardware. One option is to use the existing landline is used to make and receive phone calls. This would require a modem, a sound card, and a slot support for a landline cord. Additional service charges are not required. However, the extra hardware required does not lend itself to our future goals of using the Android tablet for the home based interface. Additionally, the software development would be complex. Another alternative is to use the internet and VOIP technology to make and receive phone calls. Various software exist that can easily accomplish this functions. The extra service charges are minimal and can be covered by either the patient or the hospital. This alternative saves time in the design process because the only additional requirement is a microphone and a speaker which is integrated into tablet devices. For the first generation prototype, Skype was selected for use in the GUI environment. The original version in Visual Basic 2005 required a separate launch of the interface which increased access time and complexity of the system. A newer version of the system was created in .NET and the Skype interface was incorporated directly into the GUI. This enhanced the access time and made the system simpler to control. An overview of the phone function layout is shown in fig. 2.

Figure 2: Virtual Phone Interface Layout

D. *Internet Connection*

Social isolation can have a significant impact on recovery following major polytrauma or medical illness. Losing the ability to perform simple, everyday tasks such as reading the newspaper, writing a letter and keeping in touch with friends over a multi-month recovery time is common. The ability to communicate with friends and family over the internet provides access to these capabilities. With the internet, the patient can access audio books, keep in contact with loved ones via email, and perform other activities that will help improve their quality of life. Diversional and educational resources can be made to be easily available.

There are several options for the implementation of the internet capability. Ethernet can be used to provide the system with internet connection. This method needs many hardware requirements, such as a 233MHz processor or higher, a NIC card (i.e. network interface card, Ethernet card), internet cable plug in, and a broadband modem. The type of modem needed depends on the type of broadband services that is used. This approach is restrictive like the hardware solution to the telephone connection. Another option that is already available in many hospitals is wireless internet. The computer platform would need a wireless adaptor if Wi-fi is not available which is generally possible through a USB interface. This approach for the internet access is also very portable to the home based Android platform as shown in the overview in fig. 3.

E. *Television and Room Light Interface*

In order to control the television and room lights, access to the room interface is required. The parallel output of the computer connects to the hospital room bed interface unit through the Hill-Rom SideComm connector.. This connector is a 37 pin receptacle. In manual mode, the devices are activated when the buttons are pushed which triggers the contact between specific pins in the connector. For the computer interface, a contact switch is mimicked by using 5V reed relays appropriate for activation with TTL logic. Diodes are used to protect the parallel port from feedback signals. A logic one signal is sent through the parallel port for one second. This signal causes contact between the SideComm pins and enables the control of the device. For the home based system, alternative approaches for interface to the television unit are required. One option is to control the television with a Bluetooth interface.

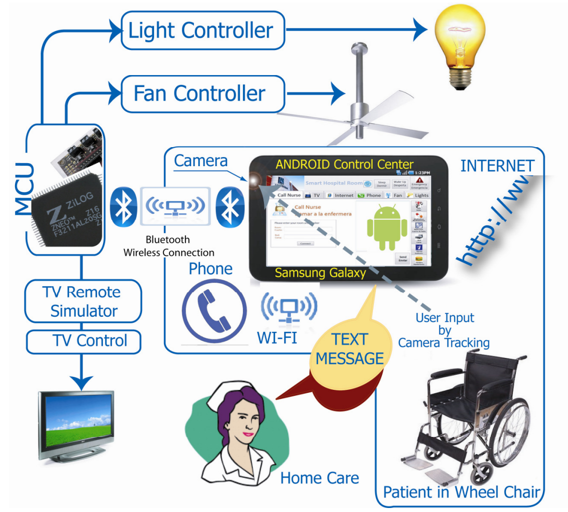

Figure 3: Android Based Interface System

The main concern for the portability of the television control from the hospital to the home environment is the variation in model types. A universal remote approach is required that can be programmed for the specific television in the patient's home. This part of the smart hospital room interface requires further analysis as the project moves forward.

F. *Fan Interface*

Many patients have difficulty regulating body temperature or find the institutions set temperature unpleasant. Since the standard hospital room does not have a fan as part of the control interface, the standard approach is to have a hospital staff member turn off and on the fan. This is a labor intensive process that can be improved through the smart hospital room interface.

For the initial design, students selected an off-the-shelf plug with remote interface capability. Wireless communication is performed through the Z-wave protocol which requires configuration and integration into the GUI. This interface will be improved with the new Android design. A Bluetooth interface to the wall plug is shown below to replace the Z-wave device and provide a more uniform system configuration as shown in fig. 4.

G. *Bluetooth Interface*

As shown previously in fig. 3, a Bluetooth interface is the next stage of the system configuration. It can be used by a desktop computer or with an Android device. The Android device is practical for transferring the system to the home environment since it can move with the patient on a wheel chair. Interfaces and communication components transfer from the control panel (Desktop in the hospital room or Smartphone/Tablet in the home environment) via Bluetooth with a predefined command set. A Zilog board (Z16MiniZNEO) receives the instructions and controls a solid state relay board to implement the instructions as shown in fig. 4. The system is flexible to include more controls in the room if necessary.

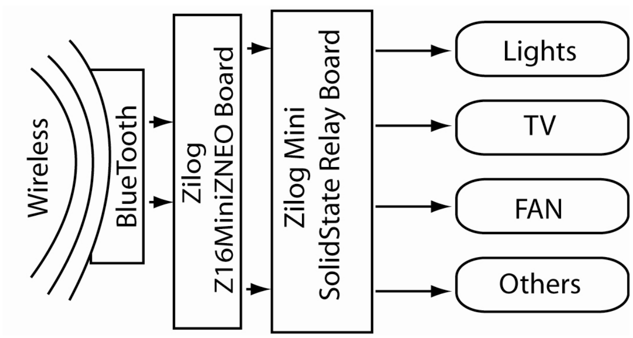

Figure 4: Bluetooth Microcontroller system

IV. SIMULATED HOSPITAL SYSTEM ACCESS TIMES

Observed execution times were recorded with a stopwatch and predicted execution times were also captured using the CogTool software [12]. The longest time for access was 9.33 seconds for TV control from the observed time but the predicted time was much smaller at 6.85 seconds. The second longest access time was 9.05 for nurse communication from the observed time but the predicted time was much smaller at 6.66 seconds. It stands to reason there is room for improvement in the user interface speeds for interaction that will be pursued in the home version of the system. Further study is required for the Bluetooth wall plug interface since the integration into the Android platform is still in development.

V. CONCLUSION AND FUTURE DIRECTIONS

A system for controlling a room's environment by a person with limited mobility and hand function is described with detailed analysis of design alternatives. The key attributes of the system are described along with a prototype solution to allow freedom for a disabled person and remote monitoring by the attending physician and/or staff.

Additional features and refinements to the embedded system are currently under way to further reduce the cost of the system and increase the ease of use. Incorporation of the Android operating system is the next major step. Android tablets with multi touch supported screens will provide very flexible user interface that can accommodate limited touch that does not limit screen usage like traditional GUI. Android also have three directional accelerometers that sense the motion of the device and can be used as an emergency connection interface.

The long-term goal is to reduce the anxiety of individuals with significant mobility limitations by providing them with communication and control capabilities. Patient satisfaction of the users of the smart room versus the standard hospital care setting will be evaluated. A prototype device for Bluetooth interface to a wall plug was created and will be further enhanced to provide more options for control of the room environment.

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