Human Computer Interaction in Medical devices

CS5760: Assignment 2: Topic Paper

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Abstract:

This paper works on the applications of Human Computer Interaction (HCI) in the field of Medical devices, specifically the hospital beds and the infusion pumps. Even though HCI is widely used in medical devices, it's application does not completely ensure patient's safety. The paper demonstrates a case study on hospital beds and infusion pumps, and critically evaluates the shortcomings of the conventional design approach. Voice commands or speech recognition in HCI has been researched over the last decade. Integration of voice recognition with the available technology will help in improving the use of medical beds for patients. The paper also provides a speech recognition algorithm that would help in interpreting the voice commands by the patients. False alarms and human errors have significant effect on the usage of infusion pumps. The challenge is to reduce the errors and improve patient safety. The paper recognizes the challenges and provides a potential solution to alleviate the errors. Additionally, a heuristic evaluation was performed to help understand the voice recognition system and user interface for the medical beds.

1. Introduction:

HCI in Healthcare covers a very broad range of important topics that improve the safety, ease of use and user satisfaction of medical devices. HCI helps in optimizing a system, for example, it is essential to make a system secure, but the level of security needs to be governed as per the usability of users. Like security, other patient related aspects affect the usability of the devices. These causes can be minimized if we integrate the applications of HCI and use the heuristic evaluation for the patients' safety.

2. Background:

Research shows that, there is a connection between usability problems and human errors. Errors in using the medical devices has proved to be a common source of injuries and deaths in patients. Some of the cases show that this is due to the poorly designed interfaces and the difficulty in using the devices. This results in variety of human errors due to poor understanding from the users. The USA Food and Drug Administration (FDA) recognizes that poorly designed interface can introduce errors even though the user is efficient and skilled. In response, FDA has revised its Good manufacturing practice regulations to include specific requirements for the product usability. The usability engineering is modified to form the heuristic evaluation of the usability problems in medical devices. This technique will help in finding the cause and the location of the medical errors.

According to Acharya et al. 2010, the FDA (USA food and drug administration) formed a bed safety workgroup to improve the safety of beds in hospitals. This was in response of the many accidents such as patients got caught, trapped and entangled in the bed which resulted in deaths or serious injuries. This was the due to confusion or improper understanding of the functionalities and the poorly designed malfunctioning of the beds.

According to Johnson et al., primarily the problems are due to device usage errors instead of device failures. Developing a predictive design is the key for every designer to avoid human errors. Human errors evolve with design and there is no way of predicting the next phase of errors. Hence, it is critical for the designers to understand the usability of the device and design accordingly.

As per the FDA records, approximately 56,000 reports of adverse events associated with the use of infusion pumps, including numerous injuries and deaths were submitted. Between the years 2005 to 2009, the manufacturers recalled 87 infusion pumps to resolve identified safety concerns. Majority of the reported errors were contributed by defective engineering and design. The flawed devices additionally contribute to user errors.

3. Medical Beds:

The case study is based on the modern beds in hospitals. The beds have three control panels which include the Patient, Nurse and the attendant panel. Each panel has different buttons with different functionality from the perspective of the patients, nurse and the attendants. The buttons include the functionality to change the position of bed that also changes the posture of the patient. Below are the functionalities of some of the buttons on the control panel, Fig.1 and 2 show the pictorial representation of the same:

1. Up: This button is used to change the position of backrest and move it upwards in steps of five degrees from zero to sixty degrees.
2. Down: This button is used to change the position of backrest and move it downwards in steps of five degrees from zero to sixty degrees.
3. Lift: This button is used to move the bed Up or lower the bed position.
4. Tilt: This button is used to tilt the bed. Tilt moves the bed in the steps of one degree from zero to ten degrees.
5. Knee: To change the position of legs only below knees.
6. Thigh: To change the position of thighs.
7. Backrest: To change the position of back.
8. BTK: To change the backrest, thigh and knee position at the same time.
9. Lock: To lock the current position of the bed.
10. Battery: This button shows the indication of the battery level of the panels.

These beds are usually used in general wards, intensive care units and pediatrics.

Using these various buttons for operation of bed will not be useful for:

1. Senior patients with age range of 70 onwards
2. Patients with no or low visibility or need glasses for reading
3. Children
4. Patients having hand injury/hand fracture
5. Patients who are not comfortable using the keys

To overcome these problems new system can be integrated with the existing automated modern beds so that it is more convenient to operate.

Figure 1. Control panel for nurses on the medical bed [1]

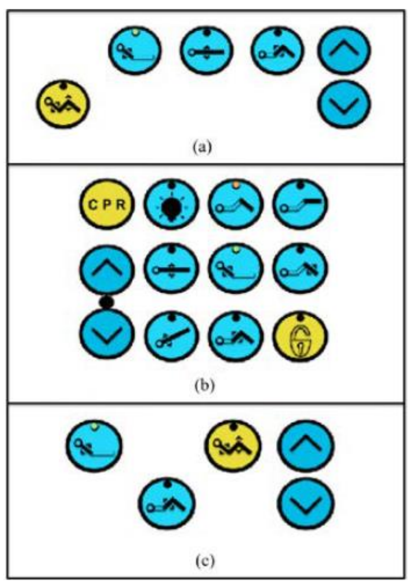

Figure 2. List of functionality buttons for (a) patients (b) nurses and (c) attendants [1]

3.1. Proposed solution for the Case study:

Using the modern beds for controlling its position is an important development in the field of medical devices. But in certain scenarios it may prove ineffective. Let us consider a case where a patient is alone in the room and has a hand fracture and he wants to seek help immediately; and if the control panel is inaccessible. Fig. 3 shows an existing medical bed Narang Medical Bed Ltd. which is in market by with two control panels (to the left and to the right side of the bed) can be useful for patients with arm fractures, however in case both the arms are constrained the panels are not useful. The control panel needs to be accessible for the patients of any medical conditions. Instructions regarding the usage of the panel must be easy to understand and readily available to the patients along with the awareness of the functionalities. This seems a bit difficult if the patient is very old or even a small kid. The patients having visibility issues may also be hesitant to use these features.

Figure 3. HF1048 - Comfy I.C.U. Bed, Electric, Five Function With Two Controls.
Retrieved from: https://www.narang.com/hospital-medical-furniture/hospital-beds-icu/HF1048.php

Control panel instructions will require a detailed study of the panel and its functionalities. Every patient may not cope up with the instruction making the system less efficient. To overcome the drawbacks of such system, voice recognition can be integrated with the bed panel. Voice recognition not only eliminates the complexity of the panel with multiple buttons to operate but also make it easy for the users to use the device with less information of the system.

Human computer interaction can be used in Voice recognition. This deals with the information required by different audio signals. Voice recognition feature can decode the human voice. HCI systems using speech recognition require a human to explicitly indicate one's intent to speak by turning on microphone.

Figure 4. Voice recognition representation, Retrieved from: google.com

A simple algorithm for speech processing can be used in following steps:

1. Signal generation: The process of speaking from a human mouth
2. Signal capturing and pre-condition: Digitalization of voice and application of filters to reduce noise and improve clarity.
3. Feature extraction: Process the captured signal by extracting information that is of interest to the system one at a time.
4. Pattern Matching: Determine what word or phrase the extracted feature belongs to and concludes on the system output.

Availability of voice recognition will allow the patients to give vocal commands for the functionalities provided by the bed. They can change the posture of their body even if there is no one around in the room. This feature can be implemented in general wards where attendants or nurses may not be available 24*7. Maintaining the conventional control panel, addition of this feature can be an influential feature to help the patients. Patient's reliance on nurses will also be slightly reduced.

The detailed algorithm for voice commands to change the position of the bed:

Step 1: Record the sound using a microphone for the desired time. The patient will give the voice command to change his posture.

Step 2: Save the recorded sound.

Step 3: During speech recognition, real time speech is recorded; and is checked with the already recorded sound. This will include the sounds for all the functionalities of buttons such as Up, down, tilt, backrest, knee, lock etc.

Step 4: As soon as sound is matched with the pre-recorded sound, the work allotted to that sound is done. Thus, the position of the patient can be changed as instructed.

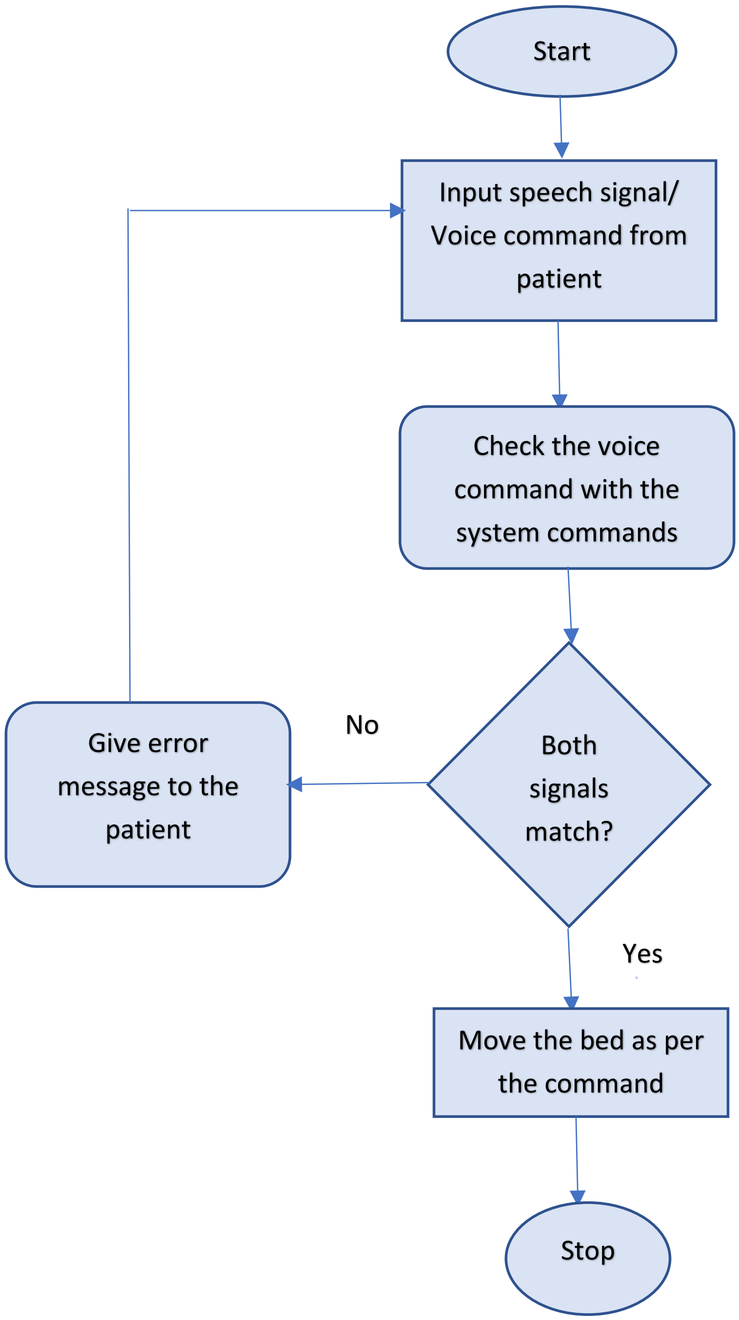

Figure 5. Flowchart for integration of voice recognition

3.2. Heuristic evaluation:

1. Aesthetic design: The design should be simple. The patient should easily understand what is to be done to give the voice commands.
2. Informative feedback: The patients should get the feedback if the Voice commands are not recognized by the system. The feedback should be concrete and specific so that patient will do the commands correctly if something goes wrong. The feedback should be a voice command to give the command again to the system.

3. Recognition rather than recall: It is used to minimize the user's memory load. The design should be such that patient may not need to remember much operations. It should be easy to use and understand.
4. Flexibility and efficiency: The system should integrate the existing functionality of the control panel with the additional feature of voice commands. This will enable the reuse of the existing system efficiently and provides option for patients to use the buttons or to give the voice commands.
5. Using user's language: As the system is based on voice commands and speech recognition techniques in HCI, the commands embedded in the system should be in user's language. It will help in matching the command by patient with the system easily which would result in the proper execution of work by the system.
6. Providing good error messages: If the patient is wrong in providing commands it should be prompted in understandable language and using beeps to indicate the incorrect command.
7. Reversible actions: Even though the system is based on voice commands, user should be able to reverse the action done. It should provide the option of Undo to be in the original position.

3.3. Challenges for case study:

1. Execution time: If the patient does not understand the system clearly or if in panic then he might give several instructions in the hesitation. This must be treated carefully to allow only one command to process at a time and not miss the other commands.
2. Wait time: Wait time in between commands needs to be optimized for fluidic operation of the system.
3. Clarity and Noise: The system should be designed in a way that it should interpret the voice commands even if they are not clearly audible.
4. Language: If the patients of the system do not understand the language the system is implemented in, then he must use the existing control panel to give instructions. Therefore, this development will make the voice recognition useless for that particular user. Adding language options is a good option to overcome this issue, however it adds another complexity to the problem.

4. Infusion Pumps:

Infusion pumps are used in hospitals, nursing homes etc. Infusion pump is a device that is used for delivering the fluids into a patient's body. The fluids can be the nutrients such as hormones, antibiotics, chemotherapy drugs, and pain relivers. The fluid to be inserted into the body is in measurable and required amounts. The operation of the infusion pumps depends on a software which is based on the programming of the rate and duration of fluid delivery. These pumps have the capacity to deliver the liquids in smaller amount which makes it advantageous. Types of infusion pumps are large volume, patient-controlled analgesia (PCA), elastomeric, syringe, enteral and insulin pumps. They are used either as stationary or portable.

Figure 6. Smart infusion pump [11]

To safeguard patient safety, it is essential to monitor pump failures. The infusion pumps have, in general, a high frequency of usage since they govern the dosage of critical liquids. Infusion pumps have the safety features of alarms or the alerts which is used to indicate the blockage in the tube of air or another. Smart versions of infusion pumps give the alert if there is risk of an adverse drug interaction or the pump's parameters are not within the safety limits.

Problems in the infusion pumps:

1. Audibility of alarms
2. No centralized alarming system
3. Same alarms for different problems

Alarms are classified into technically correct/technically false and clinically relevant/clinically not relevant. Alarms, technically correct, are based upon a technically correct measurement. Technically false alarms are not based on a technically correct measurement. Because not all technically correct alarms are clinically relevant, they can be further differentiated into clinically relevant or not relevant. Research shows that about 72% to 99% of alerts are false.

4.1. Proposed solution:

The problem with the false alarm in the infusion pumps can be improved by using the centralized alarming system. Regular testing of the device may end up producing some alarms. These alarms, during the testing, can be confusing for the patients and can cause fear in them. Also, the alarms tend to be of different sounds based on the criticality of the cause. Light sounding alarms are proposed for non-critical reasons. The people always rush in the direction of the doctors in an event of unexplained alarm. All the general ward rooms are monitored by a centralized data logging room. Thus, every activity from all the rooms is monitored from outside the room 24*7. In this situation, the alarming system can be made centralized so that only the person monitoring the rooms will hear the alarm from any room. This will not make the patient or the members in the room to panic. And the situation can be handled by a doctor if necessary.

4.2. Heuristic evaluation:

1. Visibility: The information should be properly displayed on screen. The indication of the nutrients should be displayed on the screen and the quantity delivered. The screen should also provide the feedback if there is wrong in the working of the pump.
2. Undo: Users should be able to perform actions and reverse the actions. The users should be able to modify the data and if the representation of data is not correct then he should be able to go back to the previous configuration.
3. Language: As the pumps include text interface, the intended users should have the same language of the system.
4. Error: The errors can be indicated on the screens and should use alarming system on the centralized machine.
5. Flexibility: The system should be flexible enough to produce the alarms based on the criticality of the issue.
6. Feedback: Users should be given right and informative feedback. The feedback should be concrete and understandable so that it would be easy for nurses or the attendants to carry the necessary action on patient immediately.

4.3. Challenges:

1. Software Problems: A software error message is displayed, stating that the pump is inoperable. This occurs in the absence of an identifiable problem.

2. Human factors: The design of the infusion pump monitor can be confusing to the users. The commonly used infusion pumps provide ambiguous instructions on which units of measurement the user is expected to enter. Pump labels or components become damaged under routine use and are susceptible to improper treatment. Late and missed responses are a result of improperly designed functions. False alarms will end up reducing users' sensitivity to all alarms. Confusing and cluttered display will end up delaying therapy.

3. Broken/damaged components: Mishandling of the device may result in fracture or damage of the components. Malfunctioning components must be detected as soon as possible. Purging of the electrical components due to voltage surges may also end up damaging the operation of the device.

4. Battery failures: Premature battery failure is unexpected and very harmful for the smooth operation of the device.

5. Conclusion:

Human Computer interaction has many applications. One such application is in the field of Medicine. Many of the applications can be integrated together to provide the easy to use system for a user. Building the system based on HCI principles ensures economical system. If the device manufacturers, consider these principles before building an application they will also ensure patient's safety.

Voice recognition will help solve multiple issues related to the operation of medical devices like the bed. It would not only relieve work load from the hospital staff but also help patients get some control of their comfort. Although there are critical challenges towards designing an efficient voice recognition system, the benefit of its installation will improve patient's safety. Addition to the voice recognition can be the gesture recognition which has proven to be more useful for all the handicap persons.

The introduction of smart pumps will help resolve most of the errors related to the infusion pumps. Human errors cannot be totally eradicated but limiting them can be achieved by overcoming the aforementioned challenges. Classifying the emergency alarms would relieve anxiety in patients and centralized system will additionally ease the workload of the hospital staff. More research on this technology will resolve additional issues with smart medical devices.

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