Analysis on Human-Computer Interaction

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Abstract - *Time spent by humans, interacting with computer systems to perform day today activities increase with the development of the world. Hence it is useful and important to identify and analyze the factors that affect Human Computer Interaction (HCI). These factors are categorized under three topics Human–computer interaction methodology based factors, interface design based factors and human factors for the convenience of analysis. Factors from all three categories are analyzed to gain a broader knowledge in each area. After the analysis of factors from all three categories, a discussion is provided which identifies various ways to improve HCI based on analyzed factors.*

Index Terms – HCI, Human computer interaction, user interface design

I. Introduction

Human–computer Interaction (HCI) involves the study, planning, and design of the interaction between users and computers. Therefore several factors from both user and computer side effects the HCI. In this paper factors affecting the HCI are identified, discussed & analyzed to get an idea about How the HCI is influenced by these factors. To ease the analysis of the identified factors, they are categorized under three main topics,

- Interaction methodology based factors
- Factors based on the interface design
- Human factors

Interaction methodology based factors cover the factors emerged due to the currently implemented methodologies for interacting with computers (mouse, gesture based interaction methods, touch based methods, etc.) affect the HCI. According to a research conducted to check the usability of Direct Pen Interaction with a Conventional Graphical User Interface [1] and various interaction methodologies based on capacitive facial movement detection [2], Combining Eye Gaze Input with a Brain-Computer Interface [3] & Vision-Based Hand Gesture Applications [4] it is evident that interaction methodology can be considered as an important field of study when considering factors affecting HCI.

When considering the factors affecting the HCI, factors emerge by the design of the user interface where user and computer system interact, plays an important role. Second category covers these factors. It is inevitable that the interface design depends on both interaction methodology used and the human factors of the targeted users. Furthermore Good interface design requires diverse knowledge of systems design processes and user characteristics, including Speed and efficiency needs, Reliability issues, Security concerns, Level of usability and functionality required Users' past experience with same or similar product, etc.

Considering about Human factors such as Age, limited short term memory, different interaction preferences, cognitive capabilities, etc. are critical for the successful HCI implementation. Unless human characteristics are considered when designing systems, the results can be loss of productivity and resources. Referenced research papers such as How Age Affects Pointing with Mouse and Touchpad [5] discusses the importance of considering human factors in the study of the factors affecting the HCI. Researchers point out that "Effects of age on pointing performance have become increasingly important as computers have become extensively used by still larger parts of the population" By investigating performance of users at various ages when pointing with mouse and touchpad.

II. HCI methodology based factors

There are various methods and equipment used to communicate between the two parties, humans and computers. From mouse and keyboard, it has made the way up to much more complex devices but easier and user friendly. Basically theses methodologies can be categorized into two distinctive groups.

- Touch based
- Touch-less

In touch bases mechanisms user has a direct physical contact with hardware of the computer. Traditional devices such as keyboard and mouse belong to this category. In order to type, user has to press a key of the keyboard. To select an item, user has to move the mouse and click on it.

As the name suggests touch-less mechanism do not involve any direct contact between user and the computer. Some of the touch-less methods is speech recognition, gesture recognition and facial movement recognition. Some of these are still in experimental level. One huge benefit of touch-less mechanism is that it makes easier for disable people to interact with computers. Therefore experiments are carried out to come up with more techniques which allow every human to interact with computers easily despite of their disabilities and differences.

Every interaction methodology has weaknesses no matter what the category it belongs to. Some are not very accurate while some are accurate but not very user friendly. Impact of these weaknesses to a particular context depends on the environment it is being used, users etc. If we consider all the computer users, they are of different age limits, different

capabilities and different preferences.

In the modern world computers are used for different purposes. They are used in simple day to day activities as well as in complex tasks such as performing complex scientific calculations. In some cases most important factor of interaction may be usability while in another accuracy may be more important.

In order to clarify the best suited human computer interaction methodology for a particular context, there should be a method to identify critical factors and requirements of the operational context as well as to measure to what extent that each methodology can satisfy those requirements. Best method can be selected only after then. Hence it is essential to assess how well that each methodology can deal with the factors which affects human computer interaction.

A. Facial movement recognition

Facial movement recognition is a touch-less mechanism. Most common facial movements used to interact with computer are related to eyes. Research has been carried out to use frowning, eyebrow lifting, winking, blinking and eye gaze as input to perform actions. [2]

Typically facial movement recognition methodology is used to perform actions which are usually done with mouse. Pointing can performed by tracking the eye gaze. Clicking can be implemented using several techniques which are called as "screen button" and "dwell time". In screen button method, user has to look at the target and he has to subsequently look at the target area, to select and click the target. In dwell time, target will be selected when the user's gaze has dwelled on the target for a specific time period which is predetermined. Blinking and winking eyes can also be used to implement clicking. [2]

All the above mentioned methods deal with factors affecting HCI, in different levels. In dwell time based solutions, there is a tradeoff between accuracy and speed. Although it provides faster interaction between humans and computers, there is a slight problem about its accuracy. If a user is trying to understand the functionality or read the description of a button, he or she may have to look at it for a considerable amount of time. Since the system does not have the ability to understand user intentions, it may mistakenly perform a clicking action although user's intention is different. [4] For a typical computer user who users computers for simple activities, speed will not be a huge issue. They don't need high speed interaction methods. But they won't like the idea of computer mistakenly perform actions which user doesn't want. This thinking pattern differs from one context to another. For a scientific project where the accuracy is most important, dwell time based solution may be taken as the most suitable option. Hence it is obvious that when choosing the suitable interaction method, user's intentions and preferences play a big role.

Results of an experiment which was carried out to evaluate the feasibility of frowning and eyebrow lifting recognition method, shows that different relationships exist between that particular interaction method and the user with respect to the user's gender and familiarity of the method. According to the results, eyebrow lifts of users' were detected quite efficiently and consistently but most of the time frowns were not correctly detected. Results also suggest that the performance of the method is better with experienced users than inexperienced ones. [2] Therefore we can assume that this method is not good for a system which a person is not using often. If we take an ATM machine users interact with it for a very short period of time. For such systems this method won't be appropriate. Other interesting fact that was found about the results of the experiment was that the detection of frowns was more problematic with females. [2] This proves that the gender also has an effect on HCI.

Usability of the method is another important fact which affects HCI. Even though the detection of frowning and eyebrow lifting is complex, still the device used for detection should be small, wearable, and easily adopted into use. [2] If not there is no use of the method simply because no one would want to use it. Implementation of the method on the frames of glasses was identified as user friendly. According to the research measurements, highest sensitivity of the measurement to frowning and eyebrow lifting can be achieved by placing electrodes on the frames above an eye, directly in front of an eyebrow. But it cannot be ensured that electrodes will always place properly since frame is not fixed. [2] These facts have to be considered in selecting this method for HCI.

B. Hand-Gesture

Hand gesture based interaction methods is another research area of touchless HCI. This methodology also has its own strengths and weaknesses. Impact of these characteristics varies with the operational context that it is being used. For example accuracy is not an essential requirement for an entertainment system based on hand gesturing, but for a life critical system accuracy is a critical fact. [3] Likewise characteristics of hand gesture methods may vary from one context to another. So requirements of the system have to be analyzed before deciding the interaction method.

Hand gestures can be detected by variety of sensors. "Data gloves" is one of those sensors. [3] This is where usability comes in to play. Some users may not like the idea of wearing gloves. It may be uncomfortable for them. So this is one factor that has to be considered. Other aspect is that it will take time to wear the data gloves. This causes increase in setup time. [3] For some applications, interaction has to be very quick and accurate. For such systems, method with high setup time may not become handy. Similar to other methods this also has a tradeoff between number of gestures to be recognized by the system and its accuracy. [3] If the system can recognize considerable amount of gestures it degrades the accuracy. So users of the system have to decide the most important factor, accuracy or number of gestures. This is an example of how the various factors impact on choosing a most appropriate interaction method.

C. Direct Pen Interaction

Tablet PC is on device in which direct pen is used for interaction. Just because everyone is familiar and comfortable in using pens we cannot come to the conclusion, that it will be natural an efficient to use pen as a way of HCI. There are few facts and results of some studies carried out to observe the users' preference to use direct pen interaction.[1] These can be used to come to a more reliable and truthful conclusion.

Accuracy is one important factor that has to be considered when assessing an interaction methodology. Crossing and tapping are two pen interaction paradigms. [1] According to a study that has been carried out, they have found using crossing for selection of a target is faster than tapping. Age factor also affects these two paradigms. Experiments has showed that older users make less errors in crossing than tapping while there is no significant difference for younger users.[1]

If the pen is used instead of mouse, it should have features to emulate mouse clicks. In Tablet PC's dwell time is used to perform right click action of the mouse. But it is found that dwell time is slower, more error prone and most users are not very keen on using dwell time for mode selection. [1] All these factors including age limits of user, user preference and interaction paradigm to be used have to be considered when using pen interaction method in any context.

III. Richness of the Interface Design

Interaction between users and computers occurs at the user interface, which includes both software and hardware. According to Wikipedia,

"The user interface, in the industrial design field of human–machine interaction, is the space where interaction between humans and machines occurs. The goal of interaction between a human and a machine at the user interface is effective operation and control of the machine, and feedback from the machine which aids the operator in making operational decisions. The design considerations applicable when creating user interfaces are related to or involve such disciplines as ergonomics and psychology."

It emphasizes the importance of applying the HCI principles such as psychological concepts whenever designing an effective user interface. When we deal with the technology we have to fit the technology to person not the person to the technology. In most cases designers are not the people who get the benefit of it. Then technology is likely to fail. Therefore a designer who implements a rich user interface would consider about several Human factors. People mainly expect the convenience while interaction. Designer has to make convenient the user while preventing and reducing errors. Increased productivity and effectiveness may be helpful in achieving user satisfaction as well. Human factors may also decides the system design where it would adhere HCI principles more and more rather than following basic UI designing techniques. First and foremost, time to learn something and retention over time of a user has to be taken in to consideration. Speed of performance may be a critical factor in highly interactive system. Meanwhile keeping track of user errors and the rate of errors will enhance the quality of the system while providing more convenience to the user. Ultimately the user satisfaction might be the critical factor which talks about the success of the effort done by the designer. [6]

The general review of a main research done about User friendliness and human-computer interaction in online library catalogues by Micheline Hancock-Beaulieu reveals us clearly how the notion of user friendliness is discussed in terms of the relationship between interface design and the nature of human-computer interaction in OPACs. This paper also illustrates that user friendly interfaces cannot be developed independently without developments in the functionality of the search software and enhancements of the raw database. The researchers suggest WIMP environments, probabilistic retrieval and knowledge base structures as a combined strategy to improve the quality of interaction in online catalogues at the bottom line. This research focused on online library catalogues which are probably the most established of 'end user' information retrieval systems. This system would be an example to examine user friendliness since it is easy to learn and easy to use, particularly for the naive or novice computer user.

This paper will explore the notion of user friendliness in terms of the relationship between interface design in online catalogues and the nature of human-computer interaction in retrieval. [7]

A. Levels of interaction

Four major levels can be identified according to the command language grammar for interface design. They are

- Global level
- Semantic Level
- Syntactic Level
- Communication Level

The highest level, the global level deals with the task itself which is involved with both user and the machine. Semantic level determines how the objects for the task are defined and represented. (I.e. Bibliographic records).Syntactic Level takes care of the operations to accomplish a certain task.(i.e. search strategies and tactics). The lowest level or the communication level displays the ultimate result for the operation initiated by the user. [7]

B. Criteria for interaction

Improvements in human-computer interaction in online catalogues would seem to require the following criteria:

- greater flexibility in input/output facilities;
- improved capability of the search mechanisms;
- Better representations of the knowledge base.

Finally the research paper [7], comes to the conclusion by conveying the idea,

"It would seem that to date designers of online library catalogues have not adopted a user-centered approach. Human-computer interaction issues such as usability,

flexibility, effectiveness and user satisfaction have had little impact[1]. Information retrieval in its very essence is an interactive task. Although some enhancements could be introduced in existing interfaces to make them more 'user friendly', improvement in the overall quality of interaction would require a more integrated strategy."

C. Optimal menu for ATM

According to the research paper about investigating the human computer interaction problems with automated teller machine navigation menus by Kevin Curran and David King addresses the problem of whether ATM menus are designed in an optimal manner. During the research the design of each banks menu system was recreated in a laboratory environment and user evaluation observations were made. An optimal ATM navigation menu was designed, which ultimately reduces transaction times.

D. Interacting with ATMs

Even though ATM machines provide very valuable service to the banks customers they are confused in using this. Therefore good user interface design is imperative for high-usability levels. We can recognize some inconveniences faced by users while involved in ATM operations. According to the paper they are as follows,

- Waiting in the queue to use the ATM.
- Inability to see the ATM screen well.
- Wrongly inserting the ATM card.
- Getting the required amount of money.
- Understanding how to perform operations.

Preece (1994) states it that "the best user interface design guidelines are guidelines in a true sense". The following principles can be applied widely,

- Know the user
- Reduce cognitive load
- Engineer for errors
- Maintain consistency and clarity.

The paper concludes by reminding its main objective which was to design a "best-of-breed" ATM menu system. This was achieved in the form of the OptiATM. It provides more efficient and usable system than the previous one with rich user interfaces. Nevertheless finally it says,

"However, as the services offered grow, the ATM menu designs will become more complicated. This may lead to the systems becoming even more confusing for users and harder to choose. It is recommended that ATM designers consult extensively with ATM users to help them design and create easy-to-use and efficient ATM systems." [8]

It is essential to adhere to the Human computer Interaction Principals to create a rich user interface design with effectiveness, productivity and user friendliness.

IV. Human Factors

In human computer interaction, the most desired requirement is to make the application more human understandable. Humans are the most important objects in application development. Because of a single mistake in application development in the context of interaction it may cost billions of money of a valuable human life. As examples consider a large scale business, if the operational software of the company are changed and if the interfaces of those software are completely strange to the employees the will be a performance decrease in the company. performance decrease will cost millions to the company. Consider software that interacts with doctors and nurses to manage the dosages given to patients. a little mistake in design of the interface can cause a death.

A. Cognitive capabilities

When designing software which has human computer interactions, human cognitive capabilities should be considered.

- Iconic memory: This very short term memory includes images left in memory when a user closes their eyes.
- Short-term memory: A temporary memory store where information decays over time.
- Working memory: A temporary memory store that includes refreshing or reusing the information.
- Long-term memory: A memory that is permanently encoded with longer more permanent memories.

In addition, memory can be classified as declarative memories that include facts or statements about the world and procedural memories that are used to perform procedures. More specifically, implicit memories are not reportable and explicit memories can be reported. Human factors workers must also consider human learning abilities and how to design information technologies to support different learning styles. [9].

Each of the fact described above affect the usability of the human interaction application directly. The facts like humans forget things easily and they and they do mistakes should consider in advance. Considering all those cognitive facts what the software designers do is they should design the software interface which lies between the program and human in a way that minimize critical mistakes. There are examples of how fault designs lead to disasters like Aircraft accidents.

B. Age

Another major concern for human computer interaction is the age differences, because human abilities and preferences changes from age to age. Children like more colorful interfaces having basic shapes so that they can understand them well. Children prefer big fonts and also the way they interact with the interface is different compared to other age categories. There are people who belong to youth category who like more radical designs of interfaces, more informatics interfaces and youth category like more professional types of interfaces which is completely different from child category. Another

important age group is the old age group. They have different preferences compared to other groups. Some requirements relate with their physical disabilities like lack of hearing, lack of seeing and so on. The challenge in human computer interaction interface designing is that designing interfaces which suits to all kind of age groups. There are existing interfaces which were designed to targeted age groups. As an example ATM machine, used by youth and old people, by outer inspection we can see the interface which is optimized for both age categories using Descriptive graphics, Text, Voice and button (touch or push).

C. *Disabilities*

In human population, not all the humans have same abilities, there are people who are disabled as well. Some people may be born with disabilities while some may be disabled because of accidents. When designing human computer interaction interfaces we need to consider about them too, the populations who have disabilities. Interface which is designed should not be optimized to a specific person, it should be optimized to a general population. Then only people will get familiar with the application which has that interface.

D. *Language capabilities*

Another way of interacting computers with humans is that using text messages. But in that scenario also there are issues, those are, not all the humans have the same degree of language capabilities. Some may speak different languages. Therefore when designing human computer interacting interfaces, whatever the language used it should be the basic of that language. Then an average human will be able to understand it. As mentioned above, the cost of the mistakes done because of errors in interface design is high. Therefore mistakes should be prevented by taking all the required actions.

V. Conclusion

From the above analysis it is observed that each methodology used for interaction has its own set of pros and cons. In the research paper Direct Pen Interaction with a Conventional Graphical User Interface [1] researchers express that, "Our findings reveal five overarching issues when using direct pen input with a conventional GUI: lack of precision, hand occlusion, ergonomics when reaching, cognitive differences, and limited input." But it is inevitable that touch based technologies for input has a higher potential in mobile devices because it reduces the additional hard ware needs like a need of a separate pointing device & reduces the need of special conditions like a need of a flat surface. If we consider the applications that use Eye Gaze Input with a Brain-Computer Interface [3] & Vision-Based Hand Gesture HCI Applications [4] it is observed that these methods are comparatively expensive and requires a considerably large physical area to use. On the other hand these technologies have a higher usability factor because these technologies can be used even by differently abled users.

From our study in this area it is observed that richness of the interface design affects HCI the most. Richness of the interface design directly affects accuracy, usability, efficiency, and effectiveness of the HCI. Not using a suitably designed user interface can lead to error prone & inefficient usage of the system, moreover it could result user frustration which may eventually lead to user rejection of the computer system. But by improving the interface design efficiency of interaction can be dramatically increased which may eventually results in higher level of user satisfaction.

As explained in earlier parts human factors naturally affects HCI as the computers have become extensively used by large parts of the population who has dramatically varying physical characteristics. Human factors shall be taken into the consideration when designing both interfaces and hard ware methodologies for interaction. Unless human characteristics are considered when designing systems, the results can be loss of productivity and resources due to the usability issues of the system created.

Due to the lack of detailed data it is hard to come up with highly accurate effectiveness measurements on HCI by each factor. But it is noted that selecting a HCI methodology directly depends on the context of the expected work space and the type of the work. And By improving and adapting existing widgets for new interaction methodologies HCI can move into a new era of development while maintaining the consistency of the legacy designs of interfaces. It will help users with many physical differences to work in a consistent environment of HCI with considerable level of user satisfaction.

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