Original Article

THE FUTURE OF HEALTH INFORMATICS: VISUAL ENHANCEMENTS IN ELECTRONIC HEALTH RECORDS

Alexander Paul Mercer, Ph.D. and Elizabeth Anne McCarthy, MSc

Memorial University of Newfoundland, Canada

Abstract: The evolution of e-health systems, including electronic health records (EHR) and personal health records (PHR), has the potential to revolutionize the healthcare sector. The implementation of computerized record systems holds the promise of saving lives, preventing medication errors, and yielding substantial cost savings, as demonstrated by estimates suggesting 60,000 lives saved, 500,000 medication errors prevented, and $9.7 billion saved annually (Leapfrog, 2004). The World Health Organization defines e-health as the cost-effective and secure utilization of information and communication technologies across health-related fields, encompassing healthcare services, health surveillance, health education, and research.

E-Health encompasses various application domains, including electronic medical records, telemedicine, telecare services, consumer health informatics, and Internet-based technologies. The transformative potential of information technology in reshaping industries and creating value for stakeholders is widely recognized, particularly in information-intensive sectors like airlines, financial services, and retailing.

In the context of healthcare, the growing population and increasing prevalence of diseases have generated vast amounts of data. E-health systems are gaining prominence due to technological advancements, addressing the data management challenges posed by expanding patient populations and healthcare demands. This paper explores the transformative potential of e-health systems, emphasizing their role in enhancing healthcare delivery, data management, and patient outcomes.

Keywords: E-health systems, electronic health records, telemedicine, healthcare transformation, data management.

Original Article

1. Introduction

Advances in the e-health systems including electronic health records (EHR) and personal health records (PHR) may have a significant impact on the health sector. ―Implementing a computerized record system . . . could save 60,000 lives, prevent 500,000 serious medication errors, and save $9.7 billion each year.‖ (Leapfrog, 2004). The World Health Organization defines e-health as: ―The cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research". Key application areas of e-Health include electronic medical records, telemedicine and telecare services, consumer health informatics, and Internetbased technologies and services.

The transformational power of information technology in altering the nature of competition in an industry and creating value for both firms and consumers has long been acknowledged in diverse industry sectors such as airlines, financial services, and retailing. The common characteristic among industries that have experienced such transformations is that they are information intensive—that is, a significant proportion of their value-creation activities occur through the storage, processing, and analysis of data. Nowadays e-Health systems gain popularity because of the technological advances. By increasing the population growth, the number of patients and diseases are increasing as well which involved a huge amount of data.

Recent development in Electronic Health Record (HER) systems has resulted in producing data at an unprecedented rate. The complex, growing, and high-dimensional big data available in EHRs represent great opportunities and challenges for researchers and practitioners in the healthcare section (Abdullah, Rostamzadeh, Sedig, et al, 2020). Sometimes it might be required to analyze heuristic information for doctors or medical students which can improve their learning and decision quality (Abdullah, Rostamzadeh, Sedig, et al, 2020). For example, medical students may need to learn from previous cases about how to treat a disease; doctors or medical students may need to do some comparative analysis to diagnose a disease or research on new medicine to treat a disease. In these cases, they need to view historical data.

Dealing with these huge amounts of data is a real challenge. In the past doctors and medical students can retrieve information by using traditional queries. The information (e.g. blood test results) is normally presented in tabular format. However, if the retrieved result shows too much information then deal with the tabular representation is tough. Because in that case, we have to see the whole table by using scrolling up and down, and then have to compare results with other tables which is a time-consuming task and it will also have an odd effect on the human perceptual process.

To overcome this problem we can take advantage of the advanced data visualization technologies. Some researchers have tried to apply data visualization technologies to HER or PHR systems (e.g. Stirling, Tubb, Reiff et al. 2020; Abdullah, Rostamzadeh, Sedig, et al, 2020). In this study, we have proposed a system whose purpose is to deal with the medical data using various visualization techniques which will overcome the problem of traditional systemsand also improve the performance of decision making of the doctors or medical students. The main contribution of this paper is the design of a system that will work as a decision support system in which doctors or medical students will be able to visualize different medical information of the patients based on different parameters which will improve the performance of the decision quality.

The remainder of this paper is organized as follows: in section 2, a literature review is briefly described. In Section 3 the research model is proposed. In Section 4, a system with advanced data visualization techniques is designed. Finally, the conclusion and work are presented.

2. Literature Review

The term E-Health has been in use since the year 2000. This area is full of research opportunities. Some works have been done in this field. Electronic health records (EHRs) contain a wealth of information. Categorical event data such as complaints, diagnoses, treatments, etc., are important, and play important roles in health providers 'decision making. However, past research efforts have been focused on numerical data and single-record visualization techniques. Discovering patterns of categorical events across multiple records is supported in limited ways in (Shneiderman, 2010).

Augmented and Mixed Reality technology provides to the medical field the possibility for seamless visualization of text-based physiological data and various graphical 3D data onto the patient 's body. This allows improvements in the diagnosis and treatment of patients. Key issues in developing such applications are the tracking methodology, the display technology, and most of all ensuring good usability. There have been several research groups who extended the state of the art in employing these technologies in the medical domain and addressing issues of human-computer interaction, interaction design, and usability engineering (Reinhold, Johannes, and Steve, 2007). Most of the works have been done in personal health record (PHR). The implementation challenges of PHR and

PHR infrastructure are reviewed (Piras, Cabitza, Lewkowicz, and Bannon, 2019; Halamka, Mandl and Tang, 2008). Particular evaluation of PHR functions, adoption and attitudes of healthcare providers and patients towards PHRs, PHR related privacy and security, and PHR architecture are discussed (Niazkhani, Toni, Cheshmekaboodi et al, 2020; Kaelber, Jha, and Bates, 2008).

3. The Research Model

Our research model draws its theoretical foundation from cognitive fit theory (Vessey 1991) which has been widely used by many research domains for problem-solving and it could be applied to many dimensions of fit. Cost benefit theory is the overall framework for the cognitive fit theory. According to cost-benefit theory, decision-makers 'trade-off the effort required to decide vis-à-vis the accuracy of the outcome. The error and effort required to make a decision and may therefore induce decision-makers to change strategy is influenced by the factors: (1) task and (2) context. According to Payne (1982), task variables are those ―associated with the general structural characteristics of the decision problem‖. Context variables are those related to the actual values of the objects under consideration. Task variables have been shown to influence effort. Context variables influence accuracy. To apply cost-benefit theory to decision making using graphs and tables, we first need to determine the characteristics of both the problem representations and the tasks they support. We view problem representation and decision-making tasks as independent.

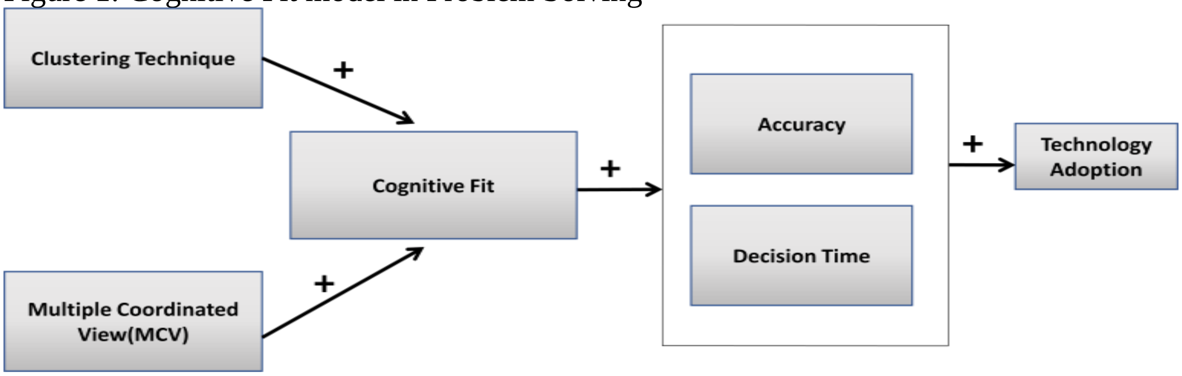
Let us assume we are considering graphs and tables derived from equivalent data, so that all information in one is inferable from the other, with a different type of information predominating in each. Graphs are spatial problem representations because they present spatially related information; that is, they emphasize relationships in the data. They do not present discrete data values directly.

The data in a graph are accessed using perceptual processes. On the other hand, tables are symbolic problem representations because they present symbolic information; that is, they emphasize discrete data values. The data in a table are accessed using analytical processes. As we already know that, the theory of cognitive fit applies cost-benefit theory to decision making using graphs and tables in two ways. First, the simple form of the theory, which addresses information acquisition and well-defined evaluation, is a special case of cost-benefit theory. Second, the more traditional view of cost-benefit theory involving strategy shift applies to decision making on more complex tasks where several appropriate strategies may be available.

When the types of information emphasized in the decision-making elements (problem representation and problem-solving task) match, the problem solver can use processes (and therefore formulate a mental representation) that also emphasize the same type of information. Consequently, the processes the problem solver uses to act both on the problem representation and the task will match. The resultant, consistent mental representation will facilitate the decision-making process. Hence, cognitive fit leads to an effective (i.e., accurate or precise) and efficient (i.e., fast) problem solution.

Using the cognitive fit theory and cost-benefit theory, our research model describes that matching the problem representation directly to the task has significant effects on problem-solving performance.

Figure 1: Cognitive Fit model in Problem Solving



In our research model, we have used the clustering technique and multiple coordinated views (MCVs) as the independent variable. From the theoretical foundation,it is clear that perceptual processes require less effort than analytical processes which will make the decision time faster. Perceptual processes involve graphical representation. Again, analytical processes involve symbolic representation. Tables are symbolic problem representations that will improve the accuracy of the information. When problem representation and problem-solving tasks are defined properly then it will positively affect the mental representation for task solution, which will lead to problem-solving performance. Therefore, in this study, we proposed our system in such a way so that it will take both the advantage of graphical representation and tabular representation which will improve the performance in terms of decision time and accuracy.

4. System Design

Base on the theoretical foundation and research model we can generate some hypotheses which will discover whether these hypotheses are true and assess the usefulness of the proposed system.

Using the proposed visualization-based system, we are thinking that a user will be able to complete the specified task faster than with a traditional general system. Because when the processes the problem solver uses to act both on the problem representation and the task will match. The resultant, consistent mental representation will facilitate the decision-making process. In our proposed research model, we are using the clustering technique and multiple coordinated views (MCVs) for problem representation and task completion. Therefore, the resultant mental representation will facilitate the decision-making process.

4.1 Data Collection

We have proposed a visualization-based decision support system in this study. The purpose of designing this system is to see what the value is of providing various visualization techniques such as multiple coordinated views (MCV), zooming, focusing, details-on-demand etc.

Various usability issues were examined when designing this application. The first concern was how we could display the result of the searched attribute. In this study, we used the clustering concept. When the user will give keywords to the system then the corresponding cluster of that particular attribute will be displayed on a 2D surface.

The second concern was of color. In this study, we used white shaded color as the application background color. Consequently, according to the opponent-process theory of color, there were five colors left that were available for use: red, green, yellow, blue, and black. For representing complex, medium, and normal medical conditions we will use red, yellow, and green colors. As a result, blue and black were reserved for another purpose.

The final consideration was how a user will interact with the system. To ensure user-friendly interaction we will add different interaction techniques like zooming, focusing, and multiple coordinated views, and so on.

4.2 Visualization Based System

This section describes the main characteristics and functionalities of the proposed decision support system.

4.2.1 Visualization Techniques

In the proposed visualization system, there will be an option where users will give the search keyword based on their need. After giving the search keyword, the retrieved result will be displayed on the screen (see Figure 2). For example, a user wants to see that what the treatment for a particular disease like ―Migraine‖ was. Each table contains multiple attributes. Here Medication Table contains the disease name, treatment, condition, important findings, and symptoms. The personal information table, family history table, allergies table also contains multiple attributes. When a keyword is given for a particular attribute then the corresponding information will be displayed for the corresponding table in multiple coordinated views (MCVs) (see Figure 2). Then the user will be able to analyze data simultaneously in all views. Here each point on the medication table represents the search result for ―Migraine‖. Where red points indicate severe condition, yellow points indicate medium condition and green points indicate normal condition of the diseases. Therefore, when any keyword is given to the system then based on that keyword corresponding result will be displayed as points and other tables will display results based on the first attribute of each table.

Figure 2: Searched result in multiple coordinated views (MCVs)

4.2.2 Coordination

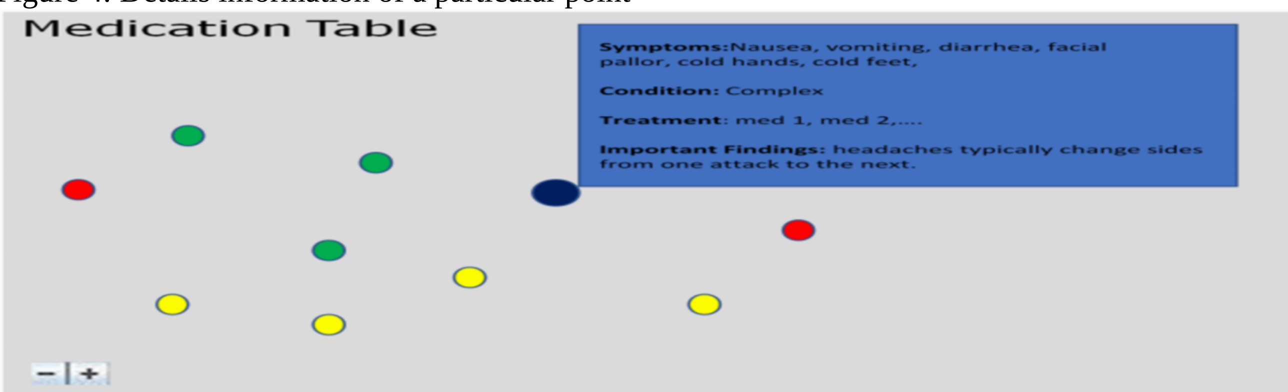
One thing is important in this system. We have used three colors for three conditions of diseases. In this case how a user will be able to know that which point corresponds to which other points in different table. To identify this thing another level of interaction is needed and that is hovering the mouse. When users hover the mouse on any points then that point will be highlighted as blue and the shape will become a bit larger. By which users will be able to pre-attentively identify all the related values in the multiple coordinated views which also will lead faster perception process (see Figure 3).

Figure 3: Coordination technique for a particular point

Original Article

Details-on-demand are set for all visualization techniques. The user selects the attributes that will be presented as additional information about each data item using the tabular box (see Figure 4). In this case user needs another level of interaction. For viewing the detailed result of any point, users have to click on that particular point, and then details information will be displayed in a tabular box.

Figure 4: Details information of a particular point



4.2.3 Zooming

When any keyword is given to the system for searching the result then based on that keyword corresponding result will be displayed as points. If the searched result contains many points in that case it looks messy. That‟s why we add the zooming technique in this system. When the user will zooming in to the system (clicking on the _+‟sign) then it will reduce messiness and then the points will be looking clearer. If a user wants to zoom out from the system, then he has to click on the _-_ sign (see Figure 4).

5. Conclusion

In this paper, we proposed a decision support system in which Doctors or medical students (more specifically medical students) will be able to visualize different medical information of the patients based on different parameters and which will improve the performance of the decision quality. From a theoretical foundation, we have known that graphical representation will make the decision time faster and tabular representations will improve the accuracy of the information. In our proposed system initially, we displayed the searched result as a cluster form in 2D surface which is correspondent with the graphical representation. Again for seeing the detailed information of any particular point we add an extra level of interaction to the corresponding point. So that when the user will click on a particular point then the detailed information will be displayed in tabular format. Therefore, in our proposed system both the decision time and accuracy will be achieved based on the well-known theoretical foundation.

In short, the traditional system for visualizing patient ‘s information is the history of progression, and the proposed visualization-based system using various visualization techniques is a step in the advancement of information technology.

6. Future Work

The scope of user interaction is currently lesser than it is expected in this proposed version. The future work will be to modify the proposed system to incorporate more interaction techniques such as filtering, panning, etc., so that the user can find their desired information in the easiest possible way. Again, we have a plan to collect real data from some reputed e-Health system provider. Then we will add various features to improve the system based on the customer needs. And we are also planning to run a user evaluation so that we can compare our proposed system with the traditional general system.

References

Abdullah, S., Rostamzadeh, N., Sedig, K., Garg, A. X., & McArthur, E. (2020), Visual Analytics for Dimension Reduction and Cluster Analysis of High Dimensional Electronic Health Records, Informatics-Basel, Vol. 7, No. 2, article No. 17.

Halamka, J. D., Mandl, K. D., & Tang, P. C. (2008). Early Experiences with Personal Health Records. Journal of the American Medical Informatics Association, Vol. 15, No. 1, pp. 1-7.

Kaelber, D. C., Jha A. K., & Bates, D. W. (2008). A Research Agenda for Personal Health Records (PHRs). Journal of the American Medical Informatics Association. Vol. 15, No. 6, pp. 729-736.

Niazkhani, Z., Toni, E., Cheshmekaboodi, M., Georgiou, A., &Pirnejad, H. (2020), Barriers to patient, provider, and caregiver adoption and use of electronic personal health records in chronic care: a systematic review, BMC Medical Informatics And Decision MakingVol. 20, No. 1, Article Number: 153.

Payne, J. (1982). Contingent decision behavior.Psychological Bulletin, Vol. 92, No. 2, pp. 382–402.

Piras, E. M., Cabitza, F., Lewkowicz, M., & Bannon, L. (2019), Personal Health Records and Patient-Oriented Infrastructures: Building Technology, Shaping (New) Patients, and Healthcare Practitioners, Computer Supported Cooperative Work-The Journal Of Collaborative Computing And Work Practices, Vol. 28, No. 6 , SI Pages: 1001-1009 .

Reinhold B., Johannes C., & Steve, W. (2007). Some Usability Issues of Augmented and Mixed Reality for e-Health Applications in the Medical Domain. In Proceedings of the 3rd Human-computer interaction, pp. 255–266.

Shneiderman, B. (2010). Electronic Health Records Search & Visualization. (available at http://www.cs.umd.edu/hcil/lifelines2/).

Stirling, A., Tubb, T., Reiff, E. S., Grotegut, C. A., Gagnon, J., Li, W. Y., Bradley, G., Poon, E. G., & Goldstein, B. A. (2020), Identified themes of interactive visualizations overlayed onto EHR data: an example of improving birth center operating room efficiency, Journal of The American Medical Informatics Association, Vol. 27, No. 5, Pages: 783-787.

Original Article

The Leapfrog Group Fact Sheet. (2004). (available at http://www.leapfroggroup.org/FactSheets/LF_FactSheet.pdf).

Vessey, I. (1991). Cognitive fit: a theory-based analysis of the graphs versus tables literature. Decision Sciences, Vol. 22, No. 2, page 219–240.