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Visual Designers Perspective for use of Information Visualization in Electronic Health Records

Muhammad Sheraz Arshad Malik[1], Suziah Sulaiman[2]
Department of Computer & Information Sciences
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750, Tronoh, Perak, Malaysia
sheraz_g02070@utp.edu.my[1], suziah@petronas.com.my[2]

ABSTRACT

Visual Designers are one of the core functional stakeholders involved in designing of Information Visualization (IV) tools to facilitate the understanding of Electronic Health Records (EHR). Interface design, icons selection, color adjustment to complex data representation in numerical to graphic metaphoric formats are main areas of Visual Designers efforts to make an IV application more viable for its use by other stakeholders such as Doctors and Database Administrators (DBA). Current IV applications lack the simplicity and completeness in interface understanding point of view due to complex designs and incomplete patient information representation. This is resulting lesser interactional input of Visual Designers in the development of IV applications for EHR. Complex and non-aligned IV designs formulate a difficult representation of EHR that cause difficult understanding, complexity of information flow and poor user interaction. Less knowledge about IV design, poor functional interpretation of visualization and incomplete representation lead to weaker and non-implementation phase of IV in EHR. The key features with Visual designers are understanding user requirements, VAS limitations knowledge, and future improvement perspective from design point of view. This paper presents the outcome of a survey based questionnaire study conducted on Visual designers working in public hospitals and temporal data formats. This research provides an outline of Visual designer's knowledge factors identification affecting overall performance of IV applications.

Keywords: *Visualization and EHR, information visualization Model, Visual Designers, visualization occlusion areas, CARE 1.0, IV and EHR*

1. INTRODUCTION

Visual Designers support in providing simple, user friendly and interactive IV application designs for EHR that intricatingly represent different patient history facts and comparative analysis.[1-3]. Perceptive sensory organs utilizing human eyes tend to perceive information with colors, lines and texts in more distinctive way as compared to black and white images [4]. Doctors, DBAs and Visual Designers are three stake holders that are directly and indirectly involved in information visualization (IV) for EHR systems.

Although doctors hold the primary stake holder's position to stand as direct beneficiary for IV applications in EHR yet depends upon other two stake holders to execute such tools. IV applications are using different color codes, graphic combination formats, layout styles and integration of various data types such as numbers, figures, texts and combination of any of them [5-7]. Temporal query results are usually represented in different categories against different data fields using legends, graphs and compounded border shades to identify the importance and value of information. But these combinations quite often create problem in understanding the basic concept of information based on not only human eye perception but also due to the missing importance value of represented information [4][8]. A few examples of common visualization errors reported are non-color differentiation in various auction websites to live game display boards where often same screen is sharing mixed information with the advertisement banners on side that hinders the end user interaction level [5][8-9].

Different available visualization forms such as graphs, colored lines and distinguishing pictures of data facilitate in understanding of analytical information for end users in EHR. Doctors place a query as a requirement and DBAs extract information based on that query while designers design the format of visualization in simple and easy format. IV for EHR data is quite complex area of information exploration as visual designer and DBAs both are not medical professionals and do not understand the complete requirement of doctors. This results in an information gap for presentation of temporal data and important aspects of EHR [4-8,10]. This can be addressed in better way for solution by interacting the requirements flow between all stake holders [11-13],

Visual Designers play a vital role in development of discrete and unified interfaces of IV applications in single or multiple patients EHR based on human perception and feasibility of ease in reception for end users. Current IV applications more focus on information retrieval, data gathering and displaying the results rather than focusing on the configuration of its means with respect to doctors that find it more difficult in understanding [10-11]. Merely based on doctor's requirements, IV applications cannot provide enough information related to single or multiple patient's record. The role of Visual Designer is to intervene in this gap and

provide a viable solution for best pattern understanding for human neurons. Still not a single pattern defined or discovered where human perception can be said more responsive so researchers used trial and error method [2]. EHR query results can be represented either in tabular form or in textual context but will not able to help end users to clarify the identification about significance of interesting and required information highlights [18].

Minimum IT resources both in human and machines are one of the major contributing factor in controlling the information flow at public sector health units. Different past IV applications such as TimeLine [13], SOAP [8], Problem Oriented Medical Record (POMR) [9], Event Flow [10], LifeFlow [30] and using extended form of Delone and Mclean Model[1] are significant work in similar domain but still they are less in addressing the input from core stake holders areas of interest for improving the overall EHR visualization. There are few significant resaons such as shortage of IT professionals related to IV, time limitation to per patient interaction, difficult EHR visualization tools operating mechanisms and lesser interaction with other stake holders about technology knowledge flow [12-15]. A better solution to address this area is giving opportunity to all stake holder in IV applications i.e doctors, DBA and IV to input their requirements, evaluation and knowledge gaps improvement areas identification for further enhancement in EHR visualization domain.

Multiple visualization formats adapted in IV tools for single and multiple patient records is one of the biggest challenge. This results in different patterns of same information that creates confusion and difficulty for doctors and other users. As designers associated with different organizations and tools development tend to provide a tool based on their perceptual judgment at varied level of knowledge to their end user result in differentiation and challenging scenario of disuniformity in information means [9-11]. Visual designers can provide a best mean of unifying the same application Graphical User Interface (GUI) format that can be in different language but similar in design and color pattern will result an ease of understanding for medical professionals. For example Microsoft Windows adapted either in different countries, languages and devices do not lose the basic means of user interaction behavior. In EHR visualization tools can only be given a standardized uniformity only if proper evaluation of Visual Designer's requirements, professional knowledge capabilities and scope of future perspectives can be determined for such tools with their reference.

The research study follows a similar pattern of Delone and Mclean Information System Model as in figure 1.

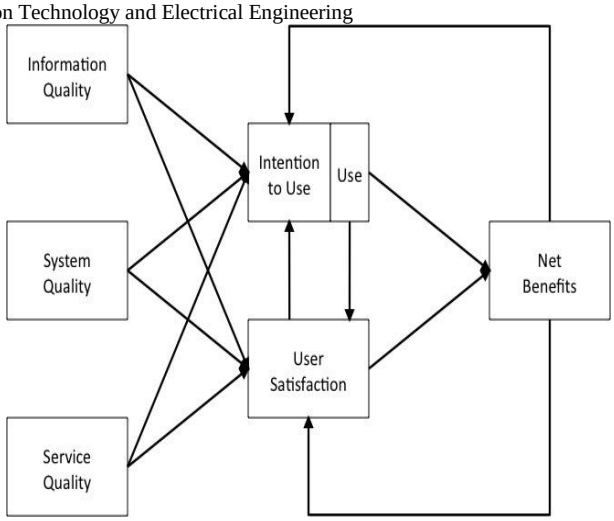

Figure 1: Updated Delone and Mclean IS Model (*C.Bossen et.al 2013*)

This model is comprised of three areas of quality such as service, information and system that are used as feedback for intention of use and user satisfaction mode. Thus benefits from both perspectives are inter linked and connected with each other with respect to the end user of system. Based on previous work, studies, applications and tools in similar domain, there are 31 knowledge, skills, use and future perspective area factors collected in relation to Visual Designer towards the overall EHR system. Similar approach is adapted in CARE 1.0 i.e is a proposed model and simplified EHR visualization tool to address primary and secondary stake holders i.e doctors, DBAs and Visual designers requirements respectively [13][14][15].

This paper is organized as follows: Section II presents the relevant work and EHR visualization problems with reference to Visual designers and gaps previously identified by researchers in the similar domain. Section III presents the details of the study and its different areas, factors and outcome in the form of results in graphical format. Section IV describes the conclusion and results while section V highlights the future work areas.

2. RELATED WORK FOR EHR VISUALIZATION

EHR visualizations represent past patient records that are including their demographical details such as names, birthdate, location, past hospital visits, symptoms or disease identification, test reports and doctor's recommendations about medicines, treatment and operational details. These visualizations are normally developed and characterized based on the selected data field sets based on the end user requirements with the help of single or multiple patient records and retrieved from one or many data pools [16-18][26]. Representation of single patient record is normally with the personal information along with disease or problem details along with medicine and test recommendation, outcome of tests and medicine and later discharge date or release date from the hospital with life status healthy, dead or transfer to

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other unit as in LifeLine1, LifeLine2 and TimeLine [7][10][13][30].Researchers for these solutions reported to work on knowledge improvement, records visualization granularities enhancement and information sharing between stake holders as leading gaps and future work.

Another approach addressed in developing such application solutions by using the same IS model as mentioned in figure 1 were previously proposed. Prefuse and ProtoViz are one of the few tools tried to represent the graphical form of patient related information in categorical and classified format [7][24] lesser addressing towards the error handling and data perception difficulties for stakeholders. More work is also performed in making the applications more analytical and information oriented that really turned the overall meaning of simplicity in operation as in VisualDecisionLinc using comparative effectiveness research [23] but resulting in difficult GUI with multiple links.

These tools were developed based on Questionnaire based studies, focus group and interview based case study approach as used in Delone & Mclean IS model [1][33] for evaluation of system, information and its impact of quality on its users directly. But results still show a gap in end user satisfaction based on the in-depth knowledge about patient data updation, management and interesting facts segregation. This is impossible in most of the approaches as using mixed triangulation methods for complex EHR solutions as they have both pre and post implementation affects based on user adaptations, use mechanism of system and nuanced change.

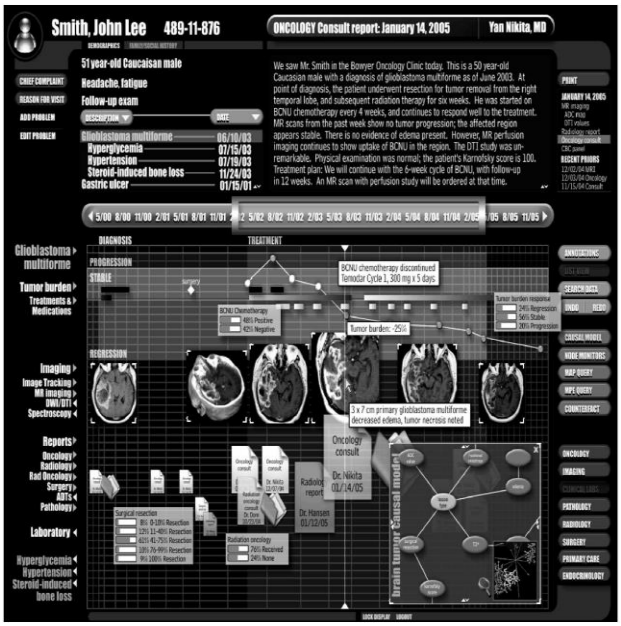

Figure2: Snapshot of TimeLine (A.A.Bui et.al)

Visualization of temporal query results and event classification based on similar sequences is normally represented in the form of legends, colored graphs and circles to facilitate information understanding [19-21]. Significant limitation for such visualization tools is complex visualization, difficult to develop and arrange data as per user requirement and error handling. As mentioned TimeLine in Figure 2, design is good with information display wise but difficult to understand the information in simple way. This depicts more absence of a designer perception sense with reference to understand DBA and Doctor requirements [3][21-24][30].

Hungarian Algorithm is a match and mismatch option provision solution proposed later to address data handling [31]. It has limitation in addressing the interaction of end user particularly designers to give a choice for handling larger data representation. A few other solutions tried to represent data by aligning, filtering, grouping on basis of interest columns and regrouping, zooming of single or multiple patient records. But these tools fail to facilitate in bringing granularity and provide a schematized exploration of information level to the end user but often result in lack of interest due to mismatched requirements of stake holders [10-12][16-19]. Terminologies appearance and heterogeneous format representation of non-uniform EHR data results in miscellaneous forms of visualization. This results in poor and incomplete IV that could not provide required information to end user due to occlusion of different metaphor objects.

To better address the naming convention of International Disease Code (ICD) 9 and ICD 10 against an event and incident , a five w's based approach including of what, when, where, why and how implemented in a circular graphic tool [30-31]. This tool also lacks the addressing issues towards the designer's knowledge and skills based gaps rather more on doctor's gaps covered. More work for single patient data record and multiple patients less addressed and result in complex visualization. National Health Services (NHS) UK also tried to focus on identifying the gap needs in knowledge, skills and future needs of EHR visualization demands with adjunct interaction of its all participating stakeholders [22-23].

In this paper, the authors adapted a similar ICT procedures similar to those in previous tools and development process based on survey and close questionnaire based study with Visual designer of different government hospitals and public organization [3][9][20-25]. Visual Designers are secondary stake holders in IV tools and their feedback is gathered based on their knowledge, daily IV interaction abilities, difficulties and future expectations. Visual Designer's role is minimum in relation to information use but very much vital with reference to perception provision to other EHR stake holders such as doctors.

3. MOTIVATION FOR THE STUDY

This research work is an outcome of third phase of an ongoing project, CARE1.0 and following the Delone and Mclean model as mentioned in figure 1. All three stake holders i.e Doctors, DBA and Visual Designers interact with EHR visualization but its practical implementation is majority hindered by poor color contouring, complicated

spatial layout in design pattern and difficult data perception [13][16][32-34].

Amalga [3], Prefuse [6] and RAVEL [19] focus on texture gradients and linear perspective of EHR missing the interaction depth, degree of contrast and stereoscopic depth of design. Previous tools tried to more work on satisfying the needs of one stake holders but missing the input and weaker knowledge side from the other participating stake holders that can lead to provide more simpler and affordance in visualization [26-29][33].

The primary objective of this paper is to identify the areas in knowledge, skills, visualization handling and future expectations of Visual designers. This will help to measure the limitation areas and develop a model for future IV applications in EHR.

4. VISUAL DESIGNERS CASE STUDY DETAILS

In this study, survey based questionnaire approach is used in a stratified sample of participants randomly. Visual designer is a strategic focus group and similar technique is used in previous EHR applications [10][13][22][24][29]. 100 Visual designers participated in this study, having an average experience of 3 years with work background of handling temporal data visualization from different domain with similar scope of use. The gaps and areas of issues are same as used for doctors and DBAs in their case studies using literature review and expert's opinion of EHR visualization domain

31 factors as mentioned in table 2 are selected based on questionnaire mentioned in table 1. Likert scale from 1-5, where 1 is representing poor or no understanding while 5 is for the expert level in that area of factor. The outcome of the survey based data is represented in the comparative analytical form in figure 3.

Table 1. Sample Qustionaire for Visual Designer

Statement	Rating				
	5	4	3	2	1
Section : Basic knowledge about Information Visualization (IV) and tools					
How much do you know about IV tools and applications?					
How much expert are you in any existing IV tool(s) use in health care or any other similar domain?					
How much do you know about representation of data of any type in an IV tool or application?					

Table 2. Factors related to Visual Designers

- IV tools knowledge
- Existing IV tool
- Data transformation IV tool
- IV data handling tecniques
- Non-temporal data visualization
- Single patient record visualization
- Multiple patients data visualization
- Color mapping
- Fields visualization
- Visualization architecture
- IV creation
- IV updation
- EHR Representation
- Errors identification
- IV Amendment
- Temporal data Representation
- Color and pattern Understanding
- Missing Information
- Efficiency Measurement
- Point of interest
- Visualization Design
- Layout weakness
- Poor data extraction
- Functionality metrics
- Complete solution
- Ease in understanding
- Level of extensive info
- Simplification in operation
- Information sharing
- User friendly GUI
- Multiple Data flow

In Figure 3, factors are represented on X-axis and number of participants on Y-Axis. Five different colors are used against each likert scale category. IV tools knowledge, Existing IV tool, Data transformation in IV, Single patient record visualization, color mapping, IV creation, Errors identification, EHR representation, Layout weakness, Poor data extraction, Functionality metrics and Information sharing are the key factors where more than 60 percent of Visual designers feel comfortability.

Some factors such as IV data handling techniques, non-temporal data visualization, multiple patients data visualization, Fields visualization, Visualization architecture, IV creation, IV updation, IV amendments, temporal data representation, Color and pattern understanding, Missing Information , Efficiency

Measurement, Point of interest , Visualization design , Complete solution, Ease in understanding, Level of extensive information,

Simplification in operation and User friendly GUI represent less than 45% of Visual designers expertise. These factors were also reported in past work in different tools and models to be addressed in oncoming applications either in single set or with combination of two or more by researchers [4][9][11][19-20][24][30-34]. Highlighting these areas will help in working on the improvement in design, functionality and interface of such applications to self-heal these gaps [23-26].

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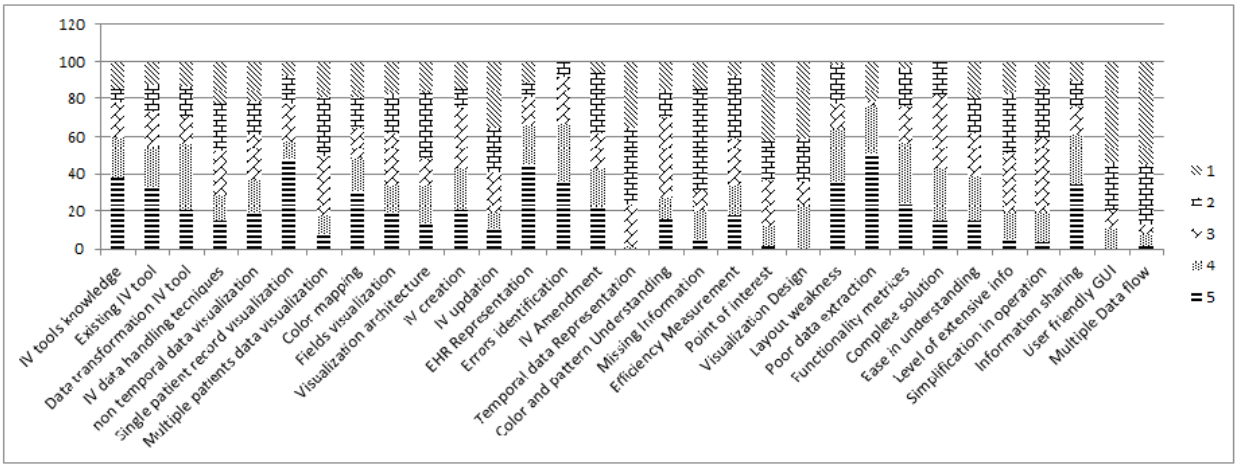

Figure 3: Comparison of all factors for Visual Designers in HER

5. RESULTS AND DISCUSSION

Visual designers and visualization tools play a vital role in developing an interactive decision support visual analytic system using IV. Designers work on providing GUI, format of resulting visualization and color pattern negating this cliché " a picture is worth of thousand words" by using number, texts and other formats for data [2]. Above results show multi chunk queries will result in more complex visualization. This can be solved by utilizing a visual query into series of subqueries and only to the point information can be selected or the closest dealing data facts can be aggregated avoiding information burden on GUI. Results are highlighting the facts that majority of designers are poor in IV creation, updation, comparing multiple patients records, analysis of important facts provision and user friendly GUI. Reasons for such gaps are poor data transformation techniques, less interaction flow between stake holders, poor visualization architecture understanding, decrease color contouring and absence of extensive patient information.

The primary objective of this paper is to identify the deficiency areas in relation to IV knowledge, tools handing skills, scope of use and future perspective in next generation multiple EHR applications. Although designers feel more good in color coding, identification of data metrics with different patterns, shaping the events of interest in pictorial objects such as disease and date of treatment with dosage in few past tools but fails to address same in multiple patients records due to lesser domain knowledge. Occlusion is often used a method and a metaphor for ranking the important information with lesser important information.

Based on comparison of results, both knowledge and skill oriented factors related to designers represent lower scale in more than 50% population. These factors are directly related to IV data handling techniques, non-temporal data visualization, multiple patients data comparison, highlighting important information with respect to end user, missing information identification, non-friendly GUI and multiple data flows in IV tools. It is observed in health units that due to poor meaningful GUI, lesser availability of desired temporal data facility and excessive use of colored metaphor details result in lesser adaptation by doctors and other stake holders. These seven above important factors related to Visual designers need more attention in future IV tools.

Visual designers feel more comfortable and have satisfactory level of desired skills in areas of different IV tools general operating knowledge, information errors identification, single patient record visualization and EHR schematic representations but fail to handle complex and multiple visual queries. Significant reasons behind are lesser knowledge about EHR data base, interactivity challenges for other stake holders and system limitations understanding.

These can be covered by using interactive feedback, occlusion of higher pictorial depth cue in GUI and active interaction of all stake holders together for an effective IV tool development. Based on studies conducted in similar pattern for doctors and DBAs within the same fashion, it is observed that a knowledge pool should be used to aggregate the requirements of different stake holders with their scope level to EHR database and a uniform agreed format of GUI to facilitate understanding for lower skill to medium skill level stake holder with auto help mode in tool.

6. FUTURE WORK EXPLORATION

IV facilitate in multiple EHR visualization by single or multi chunk queries based on end user requirements. Interesting facts often occlude by non-relevant data facts due to affect in size constancy and color patterns. Depth cues determine the size of important information facts based on pictorial and non-pictorial representations of more important facts. Occluding the lower demand value objects based on higher value will help in better perception to stakeholders such as doctors. Although in this paper, problems areas are identified with reference to visualization and designer's perspective but still fine granularities with human perception is missing in terms of information cast shadows, height and dimension of objects and depth of focus using shading. More parameters can be addressed in future work to integrate the perception of all stakeholders for IV implementation.

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AUTHOR PROFILES

Sheraz is currently pursuing his PhD in domain of Human Computer Interaction at Department of Computer and Information Science at Universiti Teknologi PETRONAS Malaysia. His area of research work is Information Visualization in temporal data for multiple Electronic Health Records.

Suziah Sulaiman obtained her PhD from University College London, United Kingdom. She is currently teaching at Universiti Teknologi PETRONAS, Malaysia. Her research interest includes human computer interactions, user haptic experience, virtual environment, and health informatics.