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Visualizing the Cascade Effect of Redesigning Features in an EMR System

Samar HELOU[a,1], Victoria ABOU-KHALIL[b], Goshiro YAMAMOTO[c], Osamu SUGIYAMA[d] and Tomohiro KURODA[b,c]
[a] *Global Center for Advanced Medical Engineering and Informatics, Osaka University*
[b] *Department of Social Informatics, Graduate School of Informatics, Kyoto University*
[c] *Division of Medical IT & Administration Planning, Kyoto University Hospital*
[d] *Preemptive Medicine and Lifestyle Related Diseases Research Center, Kyoto University*

Abstract. Electronic Medical Record (EMR) systems are complex systems with interdependent features. Redesigning one feature of the system can create a cascade effect affecting the other features. By calculating the cascade effect, the designers can understand how each individual feature could be affected. This understanding allows them to maximize the positive effects and avoid negative consequences of their redesign activities. To understand the cascade effect, the designers can look at their computations' results; a task that becomes more difficult when the number of features grows. To reduce their task load, we propose a tool for visualizing the cascade effect of redesigning features in an EMR system. Our preliminary evaluation with six graduate students shows that visualizing the cascade effect reduces the task load and slightly improves their performance when analyzing the cascade effect. Ways for improving the tool include (i) showing the computation results within the visualization, and (ii) allowing the designers to compare the cascade effect generated by redesigning different features.

Keywords. Design, EMR System, Visualization

1. Introduction

The designers of Electronic Medical Record (EMR) systems need to continuously redesign the systems to fulfill the emerging needs of their users [1,2]. It is common for the designers to be faced with multiple EMR features to redesign. Each EMR feature represents a distinctive aspect or attribute of the EMR system. For example, one EMR feature could be its usability, while another EMR feature could be its integration with the used medical devices. Since the designers have limited resources, they need to choose which feature to redesign. This choice is difficult because EMR systems are complex socio-technical systems where the systems' features are interdependent i.e., redesigning one feature will affect the other features of the system. For example, integrating the EMR system with the used medical devices would increase its usability. As another example, automatically generating EMR summaries from the EMR notes would facilitate the exchange of EMRs between healthcare providers which would consequently reduce the preparation time for the consultations [3].

[1] Corresponding Author: Samar Helou, E-mail: helou.samar@gmail.com.

Previous work showed that considering the interdependency of the features is needed to know which features are the most important to (re)design [3]. By calculating the cascade effect generated by (re)designing each feature, the designers can assess the overall effect that redesigning each feature will have on the system as a whole. Accordingly, the designers can optimize their design strategies by choosing to work on the features that generate the largest positive effect on the system.

To understand the cascade effect of redesigning each feature, the designers need to understand how each individual feature in the system is affected. To do so, the designers can check the details of the computations. However, when multiple features are considered, looking at the computations' outputs requires a high mental demand and could result in an incomplete understanding. In this case, visualizing the cascade effect can reduce the required mental workload by offloading work to the perceptual system [4].

The aim of this work is to support EMR designers in understanding the cascade effect of their redesign activities. To this end, we propose a tool for visualizing the cascade effect generated by redesigning features in an EMR system.

2. Methods

Previous work described a method for calculating the cascade effect of redesigning features in an EMR system [3]. First, the designers have to analyze the relationships between the features and then compute the overall effect of modifying each feature.

2.1. Analyzing the Relationships between the EMR Features

First, the designers have to analyze and quantify the influence that each feature has on all the other features. For every two features f_i and f_j, the designers have to answer the following question: "If we redesign feature f_i, how will that influence feature f_j?"

To answer this question, the designers assume that feature f_i has a positive influence on feature f_j when an improvement of f_i leads to an improvement of f_j. Similarly, feature f_i has a negative influence on feature f_j when an improvement of f_i leads to a deterioration of f_j. To quantify the influence, the designers can employ a linear scale ranging from "-0.9: very strong negative influence" to "0.9: very strong positive influence" with the middle point being "0: no influence".

Once the relationships between the features are quantified, the designers can create the feature dependency matrix $D = [d_{ij}]$ where all principal diagonal elements are equal to zero and d_{ij} represents the degree to which feature f_i has an influence on feature f_j .

2.2. Computing the Cascade Effect

$A = [a_{ij}]$ is the direct effect matrix where a_{ij} represents the direct effect of modifying feature f_i on feature f_j. Matrix A is an identity matrix. The cascade effect of modifying each EMR feature is computed using the following equation:

$$C = A \times D + A \times D^2 + \ldots + A \times D^h,\ h \rightarrow \infty$$

$C = [c_{ij}]$ where c_{ij} is the cascade effect that modifying feature f_i has on feature f_j.

2.3. Visualizing the Cascade Effect

The purpose of the visualization tool was to support the designers in understanding the effects of redesigning a feature. Therefore, for every feature, we needed to visualize the cascade effect that redesigning this feature will induce on all the other individual features. To build a prototype of the visualization tool, we worked with a case study of redesigning an antenatal care EMR system. We used the list of features and the dependency map presented in that study [3]. To compute the cascade effect of redesigning each feature, we used python and followed the calculation steps described in section 2.2.

We built the prototype of the visualization tool using HTML, CSS, and JavaScript. The prototype's interface is shown in Figure 1. The green bars represent the baseline, i.e., the initial state of the EMR system before any redesign activity. By pressing on a "Redesign" button, the users can see the direct effect in blue and the indirect effects in yellow. The figure shows, as an example, the cascade effect of redesigning the EMR system to automatically generate summaries from the EMR notes. The working prototype is accessible via: casceffect.netlify.com.

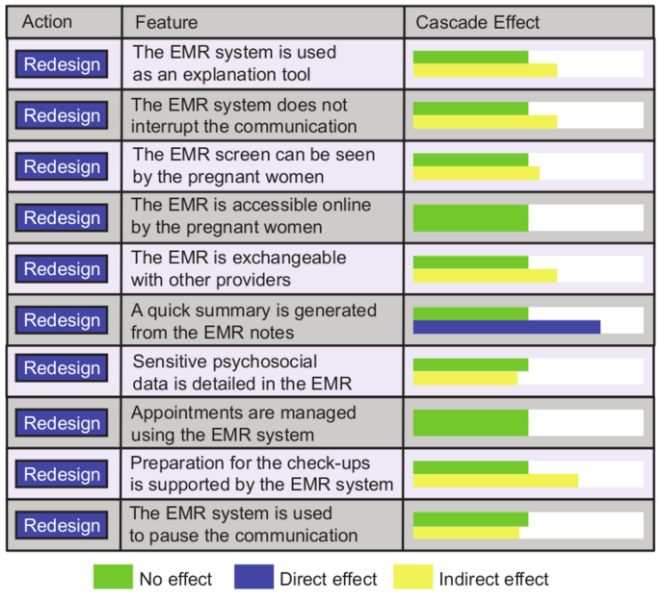

Figure 1. The interface of the visualization tool.

2.4. Evaluating the Prototype of the Visualization Tool

We conducted a preliminary evaluation of the visualization tool with six graduate students. We indicated to the participants the three features that have the largest overall effect on the system. Then, we asked them to conclude why these three features had the largest overall effect by using the results of the computations shown in Figure 2, and by using the visualization tool. Half the participants used the results of the computations first and the other half used the visualization tool first. After using each method, the participants answered a NASA-TLX questionnaire. NASA-TLX is a multi-dimensional scale used to measure the workload estimates of a task [5].

The EMR system is used as an explanation tool	1.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00
The EMR system does not interrupt the communication	0.00	1.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00
The EMR screen can be seen by the pregnant women	0.00	0.00	1.11	0.22	0.11	0.03	-0.37	0.00	0.00	0.00
The EMR is accessible online by the pregnant women	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
The EMR is exchangeable with other providers	0.00	0.00	0.11	0.22	1.11	0.33	-0.37	0.00	0.00	0.00
A quick summary is generated from the EMR notes	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Sensitive psychosocial data is detailed in the EMR	0.00	0.00	-0.37	-0.73	-0.37	-0.11	1.22	0.00	0.00	0.00
Appointments are managed using the EMR system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Preparation for the check-ups is supported by the EMR system	0.00	0.00	0.03	0.07	0.33	0.70	-0.11	0.00	1.00	0.00
The EMR system is used to pause the communication	0.00	-0.30	-0.33	-0.07	-0.03	-0.10	0.11	0.00	0.00	1.00

Figure 2. The computations results.

3. Results

The results of the evaluation are shown in Figure 3. Each bar represents the distribution of the scores given by the six participants. By considering the mean and the median of the reported scores, we conclude that using the visualization tool tends to require less mental demand, temporal demand, and effort. Moreover, using the visualization tool may reduce the designers' frustration and slightly increase their perceived performance. However, the tool requires more physical demand due to its interactive nature.

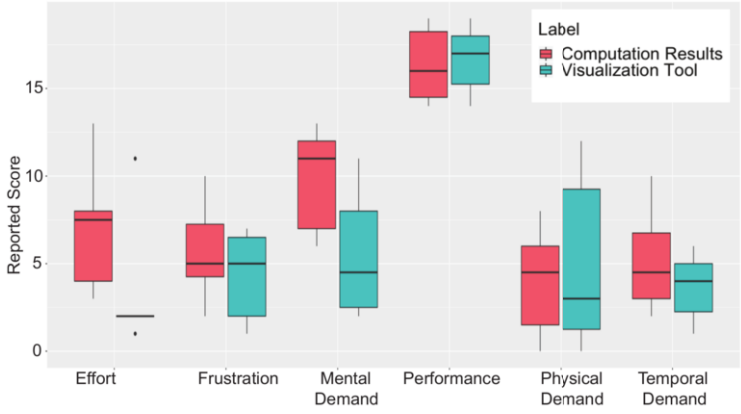

Figure 3. Using the computations' results versus using the visualization tool.

4. Discussion

All the participants agreed that using the visualization tool required less mental and temporal demand than the computations' results. However, two participants reported that the visualization tool was more physically demanding. One of these two participants further reported that using the tool required more effort and caused them more frustration. The effort required by the tool was attributed to the difficulty of

comparing the cascade effect of different features. The current prototype only allows the designers to visualize the cascade effect of one feature at a time. One way to address this issue is to allow the designers to choose multiple features and visually compare their cascade effects.

The participants also reported that they could not accurately quantify the cascade effect when they used the tool. Instead, they had to qualitatively and approximately assess it. This issue could be addressed by adding the quantitative data from the computations' results to the visualization. Moreover, in order to fully understand the cascade effect, it is important to know how the effect is propagating across the features' network. In other terms, the designers need to know the source of the effect on each feature. To this end, an animation tool showing how the cascade effect propagates along the system's features might prove fitter as these tools are usually used to represent dynamic systems [6].

Finally, it is important to note that the effect generated by a design change depends on the way the features are implemented and on the context in which the EMR system is used. Moreover, the calculated cascade effect depends on the subjective interpretations of the designers. Therefore, the prediction of the cascade effect may not accurately reflect the real world. The method's current merit lies in its ability to support the designers in finding a way of calculating, approximately, where a good course of redesign lies. Further research is needed to evaluate the method in work place settings.

5. Conclusion

Understanding the cascade effect of redesigning features in an EMR system allows designers to optimize their redesign strategies. To support the designers in their analysis, we proposed a tool to visualize the cascade effect of redesigning features of an EMR system. Our preliminary evaluation with six participants showed that the visualization tool could reduce the designers' mental and temporal demand and improve their performance when analyzing the cascade effect of redesigning the system's features. Further work is needed to reduce the physical demand required by the visualization tool and to allow designers to easily compare the cascade effect of redesigning different features.

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