mVisualizer: Easily Accessible Data Exploration for Clinicians

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Abstract:

In medical research and clinical work, having direct access to a large knowledge base of information about patients is very useful. Software for information visualisation can help the user browse, analyse and learn from such knowledge, thus providing new insights and accelerating research. However, when introducing new software to clinicians, who may have limited computer knowledge, adoption can be hindered by the complexity of the applications and the time investments necessary to learn them. By involving clinicians directly in the design process, we have developed mVisualizer, an application that provides a hands-on workspace to visualise and explore patient data. mVisualizer was designed for accessibility and simplicity, and to encourage users to explore the data in order to make discoveries and pose new questions relevant for knowledge gathering and research. The user-centered approach helped ensure that mVisualizer is understandable and easy to learn for clinicians. The application is in use by clinicians today, and its use has led to new discoveries and theories that will be the subject of future medical research. This leads to the conclusion that information visualisation software for exploring patient data can help clinicians and researchers by making the data more accessible, which stimulates research and learning.

Keywords:
Access to Information; Data Display; Dental Informatics; Information Retrieval; Medical Informatics; Oral Medicine; Software Design; User-Computer Interface

1. Introduction

Since 1995, clinicians at the Clinic of Oral Medicine and Department of Endodontology/Oral Diagnosis at the Sahlgrenska Academy in Gothenburg have been using computer software to collect formal data about patients during examinations as part of the MedView project [1]. The data for each examination uses a protocol where values for observations are selected from a standardised set of values based on a formal model [2].

The purpose of collecting this data is to use it for learning and clinical research. Once data has been collected, clinicians need a way to access it. Traditional access methods such as browsing medical records, querying databases or generating reports, have the disadvantage of requiring a clearly defined question from the outset. If it is later discovered that additional information is needed, or that the question needs to be modified, the process must be restarted. This results in a high turn-around time when asking questions.

These problems can be solved by introducing interactive software for analytical viewing of the patient data, i.e. the activity of visually exploring the entire database to find patterns...
and relations that may warrant further investigation. To this end information visualisation is used, which can be defined as visualising and navigating abstract data and structures [3, 4].

Such software gives clinicians direct access to the patient information, which reduces the delay between asking a question and getting an answer. Another advantage is that questions can be formulated iteratively and on-the-fly during data exploration.

For these reasons, an application for exploring the collected patient data was developed. This paper details the design process, and the results of clinicians using the application in their daily work.

2. Design considerations

From analysing the problem, three major design goals were established to maximize the usefulness of the application to clinicians and researchers.

2.1. Goal 1: Simplicity

When introducing new software, adoption can be hindered by the time investment required to learn how to use the software. Clinicians are busy people and generally have limited computer knowledge. Because of this, they can be impatient and reluctant to invest the time necessary to learn new applications, especially complicated ones that demand a lot of the user. Previous attempts to create applications for visualisation of MedView data [5] have been made, but these have focused on creating new types of visualisation and have not been widely adopted by the clinicians due to being too complex or abstract. This reluctance to adopt complex applications highlights the need to keep new software for clinicians simple and easy to learn.

2.2. Goal 2: Accessibility

If a clinician gets a hunch or an idea which prompts a question, for example during a coffee break, it should be easy to walk over to a computer and follow up on the question immediately. If accessing the patient data is regarded as complex or time-consuming, the idea might be shelved until later, and in the worst case forgotten. In other words, having software that provides a simple and time-efficient way to access the patient data can stimulate research, as questions and ideas can be acted on immediately when they appear.

2.3. Goal 3: Exploration

The purpose of examining the collected data is not only to find the answers to questions, but also to discover new questions that may not have been asked before. Clinicians state that “The key to medical research is asking the right question”. Thus the application should not only help in answering questions, but also help refine them and discover new ones. This can be achieved by encouraging the user to explore the patient data, creating visualisations to follow a train of thought and hopefully make new discoveries about the patient information. In other words, what is needed is not an application that provides answers, but a workspace that helps the user explore the data interactively. The users should feel that they are using the application as a supporting tool for exploring the data, not a device that automatically provides answers to given questions. To encourage such exploration, the interface should encourage the users to interact with the data and explore it, to feel empowered and realize that they are the ones doing the actual work.
3. Method

When developing the application, a user-centered design method [6] was used, based on short (1-2 weeks) iterations of developing ideas, prototyping them and later implementing them. This method was chosen as a response to the difficulties involved in getting the clinicians to adopt new software. By meeting regularly with the users to discuss their needs and evaluate the latest progress, development could be kept on track with respect to the established goals, and ideas and concepts that proved too complex or simply not useful could quickly be discarded or taken back to the drawing board.

4. Solution: mVisualizer

The result of the development is mVisualizer, an application which provides a visual workspace for exploring patient data (Figure 1). mVisualizer uses multiple views and an interaction method based on graphical selections and drag-and-drop operations. This type of interaction was inspired by Visage [7] by the SAGE Visualization group1.

When mVisualizer is started, the user loads patient data into one or more initial Data Groups. This data can then be dragged to one or more Views for exploration (Figure 2). Several types of Views exist: Bar charts, Scatter plots, Frequency reports and Tables, and also some MedView-specific views such as the Photo View, which allows browsing of images taken during examinations, and the Summary View, which contains a computer-generated summary of the examination, similar to what a medical record may contain.

![Figure 1: The mVisualizer application, shown here with three types of Views (Bar chart, Photos and Patient Summary), the Query Tool and the Data Group window.](http://www-2.cs.cmu.edu/~sage/)
By using multiple views in parallel, relationships that are not apparent from a single visualisation may be discovered [8]. Views are linked by visual cues such as brushing (elements selected in one view are marked in others) and colouring, which helps the user to keep track of which examinations correspond to each other in different Views.

Figure 2: Example of how sets of examinations can be “drilled down” by selections and subsequent drag-and-drop operations between Views.

The basic way of working with mVisualizer is using Views of the patient data to select subsets of examinations that share some kind of relationship or common properties. Such subsets can then be dragged to other Views for new insights, or tagged as members of one or more Data Groups. Since elements in a View are rendered colour-coded by the Data Group they belong to, this is an effective way to compare how different sets of data are distributed in a View. If a detailed look at an examination is desired, the user can double-click on an examination at any moment to view the Summary of the examination and its associated images.

mVisualizer provides several different ways to ask questions or isolate sets of examinations. In addition to using selection and drag-and-drop operations to find interesting sets of data (Figure 2), the user can make formal queries by using the Query tool (see Figure 1), or use text search to single out examinations containing specific data. The advantage of having multiple ways of working is twofold: First, different kinds of questions (in the mind of the user) may lend themselves better to different ways of interacting with the data. Second, different users may choose to approach a question in different ways.

A problem when working with large and detailed sets of clinical data is that the value domain can become hard to survey, and/or may have a level of detail that is not relevant from the researchers' point of view. Some topics generate hundreds of possible values.
From the aspect of analysis, it would be extremely difficult to analyse the database if individual values could not be assembled into larger groups. For this purpose, Aggregations can be created to cluster input data into categories. One example where this is useful is to put individual drugs into larger categories such as “diuretics”, “NSAIDs” or “steroids”. The clustering can then be used as an analytical tool to detect patients with established criteria.

Figure 3: A bar chart View of allergies before and after aggregation. Note how the value domain and the amount of examinations per value have changed.

Aggregations can therefore also be applied in order to sample patients with similar professions, similar diagnoses, or in any situation where a clustering of parameters is regarded essential for the analysis.

In mVisualizer, Aggregations can be applied to any View at any time to unify the value domain (Figure 3). When the views thus become less scattered, common denominators or relationships that were not noticeable before may stand out. Aggregations are created by clinicians themselves, and can be re-used and shared with other users.

When discoveries have been made in mVisualizer and further, more formal research, is desired, data can be exported (to Excel or text format), which enables the user to continue working with the data in other applications such as spreadsheets or statistical tools.

5. Evaluation and practical use

The research use of mVisualizer at the Clinic for Oral Medicine proved itself early on, as correlations between estrogen levels and changes in the mucous membranes of patients diagnosed with Oral Lichen Planus were found using an early version of mVisualizer before development was finished. This indicated that the user-centered approach was working, and that we were on the right track.

When the development process was finished, mVisualizer was deployed at the Clinic for use by the clinicians. Giving a short demonstration of about 15 minutes is usually enough to get users started, and enthusiastic users tend to help other clinicians to learn the application. As of today, it is being used daily and its group of users is growing.

Recently, mVisualizer was used to examine a group of patients that shared a “burning sensation” in the mouth, which was caused by a kind of lesion. When surveying these
patients in mVisualizer, originally looking at factors such as medication, smoking and allergies, it was discovered that the patients all shared certain characteristics: accumulations of calculus and decreased levels of saliva. This combination can cause increased amounts of bacterial plaque in the mouth. The conclusion drawn was that such conditions might be the cause of the lesions. The examination data that was used was exported for sharing with other clinics, and will be the subject of research in the near future.

6. Conclusions and future work

Through careful user-centered design, we have developed an application that gives clinicians easy access to the patient data for research and daily work at the clinic. Users state that “mVisualizer provides us with new possibilities of getting insight into the patient data that we did not have before”. The accessibility of the data enables them to quickly check out hypotheses, and the focus on exploration encourages finding new insights and relations between different aspects of the patient data. The application is now in daily use at the clinic, and has yielded several practical results in the form of new questions and discoveries about the patient data.

This leads to the conclusion that interactive information visualisation software that helps explore patient data can be very helpful to clinicians and researchers. When the patient data is made accessible to clinicians, learning from the patient information is made easier and research is stimulated.

Future development of mVisualizer will focus on providing additional types of visualisation and new perspectives. One such area is that clinicians want to be able to view overall trends in a larger time perspective, such as the effect of treatments over a longer time.

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8. References


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