

Health Alert Dashboard

Gustavo Afonso Teixeira Albuquerque Passos
gustavo.passos@tecnico.ulisboa.pt

Instituto Superior Técnico, Lisboa, Portugal

May 2018

Abstract

Medical records have long been vital tools in patient care, and current technologies are bringing medical records into the 21st century through innovative software and hardware computer programs. Nowadays, those medical records are dispersed between paper and digital format making its analysis very exhausting and problematic. Through time many research of medical data visualization was made and we will discuss some of the existing software and applications so we can understand what was already done. The main goals of these research, based on information visualization, is to innovate and make the data more user friendly so health care experts make better use of the data. Also, based on the potential of information visualization, we created a web application, a interactive dashboard, to make easier the information access to health care experts like doctors, nurses allowing the analyzing it as a whole. Users tests show that with the dashboard, information retrieved is faster than the current softwares and data structure.

This document also contains our main goals regarding this project, the solution where we see what the solution consists including its architecture and our approach to it. Finally have our conclusions and future work.

Keywords: Data Visualization; Innovate; Web Application; Dashboard;

1. Introduction

Medical data are often large, complex, disorganized, and may reside in separate databases or in data warehouses. Medical data are also messy, incomplete, and may contain systematic errors that prevent analysis. These characteristics make medical information difficult to integrate and analyze. However, critical analysis of medical data can improve health care and have a positive impact on lives. Information visualization is one way to improve understanding complex data and consequently increase the value of electronically available medical data so effective information visualization techniques can both reduce the problems medical analysts face and ease their analysis tasks[7].

“Computer-based visualization systems” can be defined as “visual representations of datasets intended to help people carry out some task more effectively”[12]. Information visualization techniques focus on datasets with non spatial data attributes and discrete observations. Scientific visualization, on the other hand, concentrates on visualizing real objects with spatial dimensions typically three-dimensional (3D), for example, tumor nodes or blood vessels. With proper visualization we are able to map abstract data to compact repre-

sentation to convey meaningful information quickly. Furthermore, interactive information visualization is one way to enable exploratory analysis, an important aid to statistical confirmatory analysis.

Analyzing a single patient and analyzing multiple patients are different goals. The difference creates a dichotomy in the visualization systems. All systems in this survey either support tasks for analyzing a single patient, or those for analyzing multiple patients. Tasks that involve both, such as comparing a single patient with multiple patients with a similar history, are not extensively explored. Likewise, changing from multiple patient analysis to single patient analysis and vice-versa is not widely studied.

The main goal of this research is to study ways to visualize medical data in order to make relevant information available to the user while allowing pattern discovery.

- Study approaches to information visualization in health care.
- Learn the technologies behind the development of a dashboard with multiple visualizations.
- Create a dashboard with multiple visualization

in order to help health care professionals, dentists, to prescribe medications better, to plan treatments more effectively and improve patients health conditions.

To do so, several user tests were made. Specific tasks and questions were created to help stay focused on users requirements. The data was provided by the research work from an other colleague[8]. With data cleaning tools data will be analyzed and processed to make better visualizations. The goal of all the tasks and processed data is to get the best prototypes (low fidelity and functional) to finally get the desired visualization.

2. Background

2.1. Population level disease Control

Disease Data Correlator[11], is a visualization with different idioms that will help to have better comparisons.

Health is a common subject for all. So a tool that allows people to search and discover should provide different views depending on user's objectives. Some of these representations can some times prevent epidemic events.

The map view is a Choropleth map. The map in figure 1 shows the amount of people having a particular disease encoded a six color sequential color map in which darker represent a high percentages of people infected and lighter colors represents lower percentage. The detail view is dynamically loaded when a user selects a region on the Choropleth map.

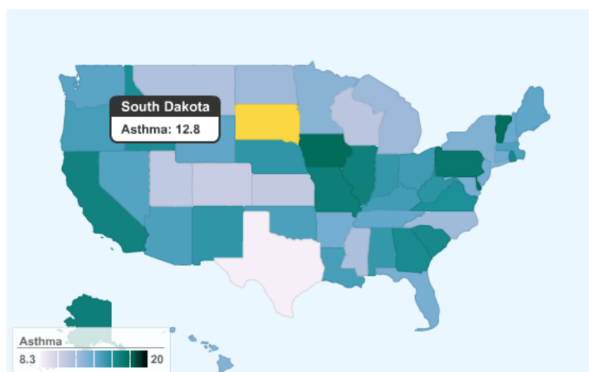


Figure 1: The Choropleth map in the Map View showing the state-wise distribution of the Asthma population of US[11].

With the data available several charts are created. For Race-wise prevalence and gender-wise prevalence, a 3D bar chart is used. According to Visualization Analysis and Design[7], a 3D bar chart is not the best way to represent data. It introduces unnecessary errors compared to 2D bar charts. The other are line charts that seems to have the correct use.

The figure 2 shows the correlated view of the demographic data to all the states in a single chart. A problem of this representation is that to show a clear picture of the state wise prevalence data the charts need to have a longer range along the X axis to plot all the states along the axis.

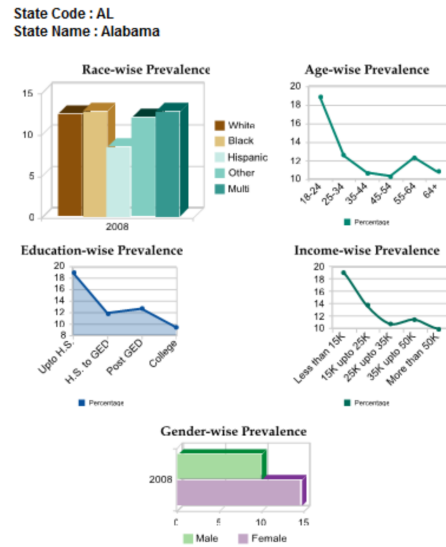


Figure 2: Details view window loaded with the demographic group-based data for the selected state[11].

2.2. Single Patient

LifeLines[9] is an important paradigm, having inspired other research. LifeLines[9], as we can see on figure 3 supports the visualization of many medical variables on the same screen and displays the medical record, summarized as a set of lines and events on a zoom-able timeline. Aspects of the record are grouped by problems, allergies, diagnose, etc. When a problem or other condition becomes inactive the line stops. Color can be used to indicate severity or type.

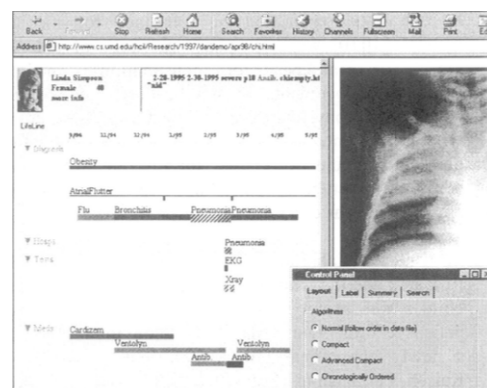


Figure 3: Example of patient health record in LifeLines[9]

The user can do the following when visualizing a patient record:

Details on demand - All events visible on the display form a menu giving rapid access to de-

tailed information (triggered by a double click on the event.) The detailed information appears in a separate page covering part of the display or optimally in tiled windows on the side.

Zooming - Zooming in and out can be done either by using the zoom-and-pan slider at the bottom of the display, or by clicking on the background of the image near the events that should end-up in the center of the zoomed image. A right button click on the background zooms out again. Zooming in and out reveals different levels of detail.

Highlighting relationships - In addition to the implicit vertical and horizontal relationships, searches can be performed on the entire record, highlighting all parts of the record that match with the selected region.

Coding attributes - Control panels are available to setup the mapping of the main display attributes (label, color and line thickness) to the data attributes.

Summarizing - Another way to deal with large records is to allow summarization of the events. The architecture allows a set of events to be recursively aggregated and replaced with summary events.

A different method to gather medical data is via tele-medicine, the use of telecommunication and information technology to provide clinical health care at distance. We have Caregiver[2] to visualize that kind of data.

One of the key concepts of information visualization is focus and context, the idea of embedding different scales in a single view in order to maintain context while navigating and examining details. Caregiver[2] presents focus and context techniques in two ways. Horizontally, selected areas can be enlarged in time by sliding a “magnifying lens” along the time axis. The region inside the lens is enlarged, while the two regions on the outside are compressed accordingly. This provides a very efficient and intuitive mechanism to navigate and find details on a large time-scale, without losing the orientation or overview. Vertically, patient details can be enlarged by double-clicking on a patient timeline in the overview. The chosen time line expands dynamically to reveal full details about selected attributes. The other timelines are compressed accordingly to make space for the expanded panel, but remain visible at all times.

In figure 4, for example, on the left side there are two views that show the data as timelines. The goal of these views is to present a single overview of the whole data in a graphical way, while allowing quick access to details of interest. Timelines are an intuitive way to show the data for the current state of the patients related to past developments and

the interventions that were administered.

The upper view shows the duration and size (number of patients mapped to thickness of the line) of the patient peer groups formed for the purpose of common interventions. Clicking on one of the groups highlights the participating patients in the lower view, and vice versa. The lower view shows one timeline for each patient in the program. One of the attributes can be chosen to be shown in this overview.

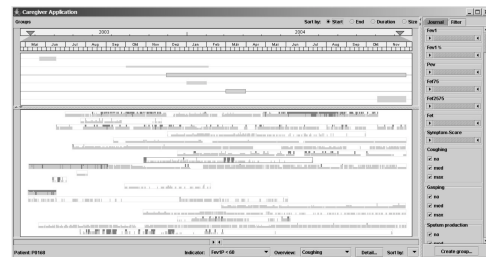


Figure 4: Example of Caregiver[2] interface

With different user interaction we have Midgaard[1]. The goal of the Midgaard project is to present different interactive visualization techniques that enable users to reveal the data at several levels of detail and abstraction, ranging from a broad overview to the fine structure and introduce a time visualization and navigation technique that connects overview+detail, pan+zoom, and focus+context features to one powerful time-browser. Midgaard can also be used to visualize patient data in combination with treatment plans (indicated by gray areas in the background of the patient data, as we can see in figure 5) and it provides different views for physicians, nursing staff, and patients. About interaction it is possible to do a semantic zoom, browsing through different visualization techniques and data abstraction levels from a broad overview to a fine structure.

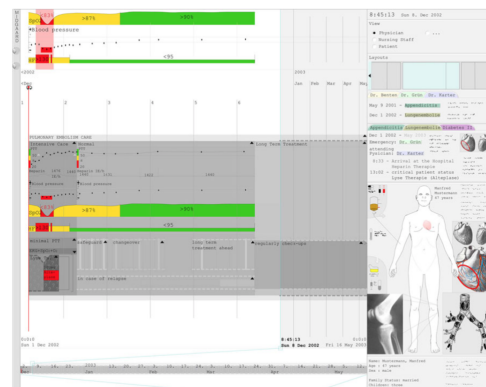


Figure 5: Example of Midgaard[1] interface with control panel and data visualizations.

2.3. Multiple Patients

LifeLines2[14] introduces new ways to visualize information and is an extension to Lifelines[9] that

was designed to summarize the entirety of a single personal history record (e.g. a medical record). In contrast, LifeLines2[14] displays selected subsets of the records from multiple patients. It consists of a visualization of records for temporal categorical data. For example figure 6 (a) shows individual records, and (b) shows the aggregation of events over time. (c) Contains controls to the basic operators: align, rank, and filter. (d) Shows controls for event distribution and grouping each triangle represents an event. The data is presented chronologically, and the records are ranked by the number of disease events. For instance, in Figure 6 it is easy to see the co-occurrence of pneumonia, influenza and asthma. However, in pneumonia and influenza incidences it is not clear, whether asthma occurred before or after. Users are forced to zoom in to each first occurrence of pneumonia and influenza for details, but each zoom can only reveal the details of a particular pneumonia and influenza event.

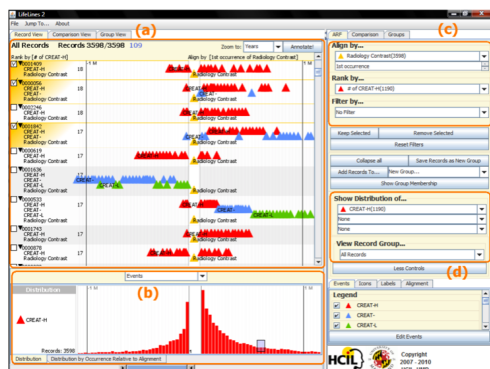


Figure 6: Example of LifeLines2[14] interface.

The distinguishing interaction technique of LifeLines2[14] from the first LifeLines[9] is alignment. Users can align all records by a specific event type (for example, heart attacks). Every record's first heart attack event will then be aligned vertically. Records without heart attacks are filtered out. When the records are aligned, the timeline switches from an absolute calendar scale showing the current date of the events to a relative scale showing the amount of time before or after the date of the event used for alignment (i.e., one, two, or three days before/after). This allows users to spot trends in the timing of other events relative to the alignment event, in a group of patients. Users can also align by the *n*th occurrence of the event (e.g., the second heart attack), or they can align by all occurrences. In that case, the display of a record is duplicated for each occurrence of the event and each duplicate is aligned by one occurrence.

Focusing in the time variable we have VISITORS, VISualization of Time-Oriented Records[6], which combines intelligent temporal reasoning

computational mechanisms with information visualization methods for display and exploration of time-oriented records of multiple patients. As depicted on figure 7 the two top panels display patients lists (denoted by A) and lists of time intervals (denoted by B), retrieved by computing the previous population-expressions that enables users to interactively specify temporal and knowledge-based constraints, through a graphical expression-specification module, which enables users to define the patient subsets selected for exploration. The graphs (denoted by C) show the data for a group of 58 patients with scatter plot combined with a line chart (graph 1) and for graph 2 and 3 are a multiple bar chart visualization.

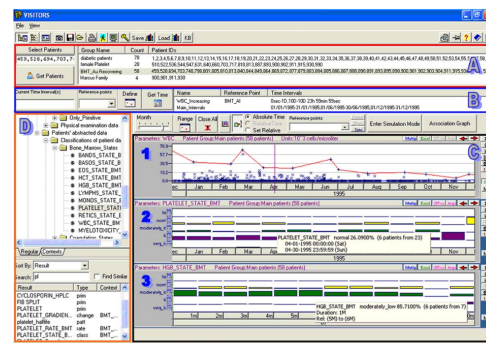


Figure 7: The VISITORS[6] main interface.

In figure 8 the individual raw data is represented at a resolution level of seconds with respect to time granularity, but the population statistics are aggregated at a granularity of months, according to the user's current request. All laboratory test results for the specific cell count for patients treated during this period are displayed as (blue) X's (denoted by region 1). Through the density of the points, the user can judge the number of data instances belonging to each value or time period range. The top (red) line (denoted by 2) represents the monthly maximal value of the whole group. The tooltip provides detailed information about the maximal value), the ID of the patient with that value, and the observation time. The bottom (blue) line (denoted by 4) and the middle (green) line (denoted by 3) represent the monthly minimal and mean values, respectively. On the left-hand side (denoted by 5) are displayed statistics for the whole time period. The three dotted lines drawn inside the panel indicate the mean value standard deviation for this period.

In recent years, visualization methods have been developed to support both, the logical structure and the time-oriented aspects of computer-executable clinical treatment plans. However, visualizing the effects of applying treatment plans as well as supporting the exploration of effects on patients' conditions are still largely unresolved tasks.

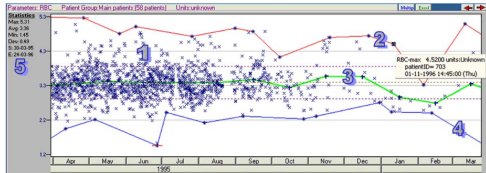


Figure 8: Data visualization for a specific cell count, in a raw concept, for a group of 58 patients[6].

To fill this gap, CareCruiser[4] was developed to enhance known visualization methods to communicate the processes of treatment plan application together with their effects on a patient condition in an easily understandable way. To better understand, in figure 9 the logical view (a) communicates the logical structure of treatment plan execution by means of a flowchart-like representation. The lower left part (b) displays a tree graph to visualize the hierarchical structure of treatment plans and sub-plans; the time-oriented view (c) focuses on the temporal-qualities of applied treatment plans, clinical actions, and patient parameters. The time-oriented view is extended with step-wise interactive means to explore the effects of applied treatment plans on the patient's condition. This screen shot shows one treatment plan that has been applied on three different patients (aligned vertically for comparison). The charts and treatment plans are colored according to the color scheme of the parameter values' distance to the intended value. Selecting ranges with big distance to the intended value with the range slider draws attention to critical cases and brings out the differences between the conditions of the three patients.

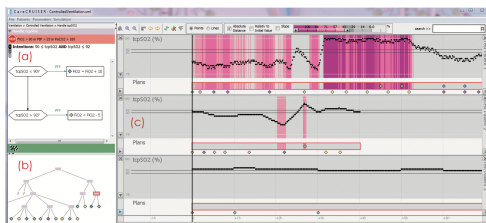


Figure 9: Example of CareCruiser[4] interface.

VIE-VISU[5] is a graphic visualization system which uses metaphor graphics to represent a patient's status in neonatal intensive care. Graphics representation offers a wide variety of methods to support humans in the integration of data. VIE-VISU encodes categorical variables with geometrical shapes and their color, and encodes numerical variables by the size of glyph elements. The VIE-VISU display is a client-server application. It is embedded into the standard network of bedside and nursing workstations. The client offers a set of buttons for display management: it is possible to change the display between metaphor graphics and data values, moving around on time axis, changing time scales and select different patients to view. The value of a parameter is either depicted by the size of an object or by its color. The larger the value the larger the object, or darker the color. (Different visualizations, i.e types of ventilation, for the same patient).

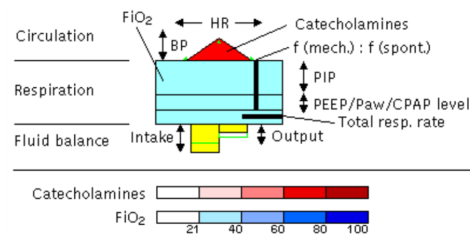


Figure 10: Example of VIE-VISU[5] geometrical shape.

3. Methodology

The final Solution is a visualization dashboard, that presents the patient history data, allowing users to find relevant patterns and timely alerts of problematic situations so doctors can act fast and adequately. It consist of a web application, running in any browser. Patient data were provided by by a research work from an other colleague[8].

To begin the implementation we started by determining some important concepts that will help get a better interface and interaction. There is a high number of people interested in the development of a system which can be affected positively or negatively by its introduction. So with the process below we will known who are they and what can we do.

First, we defined our users according to Eason[3], there are 3 types of users: **primary**, **secondary** and **tertiary**. Primary are those that interact directly with the system. Those who seldom interact with the system or interact with the system through other people. Finally everyone else that is affected by the system. For our dashboard, primary users are dentist and dentist assistants, secondary users are patients and tertiary users are patients family and the hospital CEO. We used this

approach because this method, with those three layers of user interaction with the system, allow us to classify quickly and accurately our users.

After we defined the stakeholders using Sharp and colleagues[13] process. It focus on stakeholders interaction: Baseline, Satellite, Suppliers, and Clients. Involving stakeholders can build trust, which can ultimately lead to increased consensus for your project or final decision. It can also increase transparency and lead to better decision making. With this approach, the interaction of our users are well defined making easier to understand the requirements of our solution and their priorities.

So we have three users profiles. Firstly we have a experienced dentist with more than five years of experience.

Profession: Dentists;
Experience: More than 5 years;
Personality: Impatient and persistent;

Secondly we have a young health care professional with less than five years of experience.

Profession: Cardiologist;
Experience: Less than 5 years;
Personality: Extrovert and sportive;

Lastly we have a young health care professional with less than five years of experience.

Profession: Oncologist;
Experience: Less than 5 years;
Personality: Active and generous;

Our focus group are health care professionals with active practice that like technology and want to be a part of a group that want to make a change in the way health care and technology interact with each other.

Also related to user research we had to create personas and scenarios. Personas communicate context in which the product will be used, behaviors and attitudes of users wants, needs or expectations from the product we are designing. They also show difficulties users want to overcome and goals that users may have. Personas will help better connection with users needs, as source of inspiration and keep things grounded in user research. In decision-making by validating decisions. Scenarios are short stories that will answer to several questions to set a context of the scenario: "Where is the persona?", "When does it happen?" and "Who else is around?". Then we need a motivation for what happens and user goal. With a motive, the user will act accordingly with the actual situation: "What happens?" "How/why does it happen?". Finally the consequences of those actions: "What is the result?" "Was the goal accom-

plished?".

For the implementation, to develop the dashboard, we searched for multiple technologies and after a extended research the most appropriate was the combination of D3.js¹ and React.js². To use both, we had to make some adaptations in the source code of the visualization in D3. Those modifications allowed React to recognize all parameters and data that the D3 files have.

4. Results & discussion

From the user research we concluded that diseases and medication can be at completely different groups but also can be clustered in groups with common properties like rarity of diagnosing / prescribing and probabilities of coming and be used together. We also learned that low number of simultaneous visualizations in the dashboard is preferred. This is interesting to see that there isn't a one way to do the dashboard interface but is also negative because it shows that users don't have the same vision of the final product but have the similar needs, which can be confusing to the development process. About our users we gathered user expectations. The users showed that they are reluctant about abandoning their actual for searching this kind of patient information and some are not very confident of the accuracy of the data and if it can be generalized. In the other hand for they are optimistic about the preventiveness of the solution, retrieving information very quickly, easy to understand and for recent graduate can be very helpful like a mentor. Finally it was mentioned a problem that what will happen if the dataset fields changes, who is responsible for the information that is represented and its consequences if applied to a patients. For the green hat we had just a suggestion, mobile version, to use in tablets in appointments.

5. Conclusions

Trough the years different algorithms and visualizations were created to help transforming big quantity of health data into information useful for experts in different fields (i.e LifeLines[9] for doctors in hospitals and RODS[10] for epidemic control).

Some of the solutions we have seen are in some way incomplete or have gaps and based on those works with the development of this dissertation we will study ways in which an effective visualization can fix some of those gaps providing an interactive dashboard to provide health care experts with relevant information at the right time in the right way.

During this work we learned about some of the research that have been made around information visualization and health care. With that knowledge, the challenge to create a dashboard were a very in-

¹<https://d3js.org/>

²<https://reactjs.org/>

interesting one. We searched for similar approaches and started to build our own. We started with user research defining user types, personas and our focus group. From the workshop done, Six Thinking hats, Pictive and Card Sorting, we could conclude that users are still averse to change. They are already too familiar with their tools and don't want to learn everything from scratch again. In the other hand the dashboard does in fact give the user any information he/she wants, with the given data, very quickly and in a orderly way. The thing they most liked was that all the information is centralized in one single place. In the moment of creating the dashboard, we made the charts and the dashboard in different technologies. The toughest part was the integration of the D3.js charts into the React.js dashboard because of the many differences of handling the DOM.

The solution now it's in a initial state. In the future it can be upgraded with many features regarding new filters, to allow users to have a better and more focused view, more communication between charts to make the system more interactive and add new charts for more diverse and complete information. Interactivity is very important to user interaction, so it should be refined and perfect the best we can. Filtering by disease or by medication will be possible. A set of check boxes will be provided and when a disease or medication is selected, it will to switch its visibility on the active charts. Users are already able to choose the visualization they want to see. It requires about 3 step to do so. We can reduce the number of step by creating a interactive menu that with 1 step we can filter everything we want. Between visualizations, same concepts will be highlighted simultaneously. All these new features will increase significantly the quality of our Dashboard Alert.

References

- [1] R. Bade, S. Schlechtweg, and S. Miksch. Connecting time-oriented data and information to a coherent interactive visualization. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2004.
- [2] D. Brodbeck, R. Gasser, M. Degen, S. Reichlin, and J. Luthiger. Enabling large-scale telemedical disease management through interactive visualization. *European Notes in Medical Informatics*, 2005.
- [3] K. D. Eason. User-centred design: for users or by users? *Ergonomics*, 38(8):1667–1673, 1995.
- [4] T. Gschwandtner, W. Aigner, K. Kaiser, S. Miksch, and A. Seyfang. Carecruiser: exploring and visualizing plans, events, and effects interactively. *2011 IEEE Pacific Visualization Symposium*, 2011.
- [5] W. Horn, C. Popow, and L. Unterasinger. Metaphor graphics to visualize icu data over time. *Intelligent Data Analysis in Medicine and Pharmacology (IDAMAP-98)*, 1998.
- [6] D. Klimov, Y. Shahar, and M. Taieb-Maimon. Intelligent visualization and exploration of time-oriented data of multiple patients. *Artificial intelligence in medicine*, 2010.
- [7] T. Munzner. *Visualization Analysis and Design*. CRC Press, 2014.
- [8] F. M. C. N. M. Nunes. Multiviz: Data visualization of patient records. 2017.
- [9] C. Plaisant, R. Mushlin, A. Snyder, J. Li, D. Heller, and B. Shneiderman. Lifelines: using visualization to enhance navigation and analysis of patient records. *Proceedings of the AMIA Symposium*, 1998.
- [10] S. Purushe. Evaluation of user interfaces for medical data visualization: a critical study of ui of emergency medical infovis. 2010.
- [11] S. Rashid. Disease data correlator. 2008.
- [12] A. Rind, T. D. Wang, W. Aigner, S. Miksch, K. Wongsuphasawat, C. Plaisant, and B. Shneiderman. Interactive information visualization to explore and query electronic health records. *Foundations and Trends in Human-Computer Interaction*, 5(3):207–298, 2011.
- [13] C. B. Stetler, M. W. Legro, C. M. Wallace, C. Bowman, M. Guihan, H. Hagedorn, B. Kimmel, N. D. Sharp, and J. L. Smith. The role of formative evaluation in implementation research and the queri experience. *Journal of General Internal Medicine*, 21(S2), 2006.
- [14] T. D. Wang, C. Plaisant, A. J. Quinn, R. Stan-chak, S. Murphy, and B. Shneiderman. Aligning temporal data by sentinel events: discovering patterns in electronic health records. *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2008.