Application of Information Visualization Techniques in Representing Patients' Temporal Personal History Data

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Abstract. The anthropometries and nutrients records of patients are usually vast in quantity, complex and exhibit temporal features. Therefore, the information acceptance among users will become blur and give cognitive burden if such data is not displayed using effective techniques. The aim of this study is to apply, use and evaluate Information Visualization (IV) techniques for displaying the Personal History Data (PHD) of patients for dietitians during counseling sessions. Since PHD values change consistently with the counseling session, our implementation mainly focused on quantitative temporal data such as Body Mass Index (BMI), blood pressure and blood glucose readings. This data is mapped into orientation circle type of visual representation, whereas data about medicinal and supplement intake are mapped into timeline segment which is based on the thickness of lines as well as the colors. A usability testing has been conducted among dietitians at Faculty of Allied Health Sciences, UKM. The result of the testing has shown that the use of visual representations capable of summarising complex data which ease the dietitian task of checking the PHD.

Keywords: information visualization, health information system, temporal data.

1 Introduction

The anthropometries and nutrients records of patients are usually vast in quality, complex and exhibit temporal features. Therefore the information acceptance among users can become vague and give cognitive burden if such data is not displayed using effective techniques. As a result the needs to understand and extract knowledge from stored data are increasingly becoming important [1]. In this sense, the properties of visual representation should be manipulated accordingly in order to leverage the problems of data overload and complexity. Visualization is seen as one of the best alternatives to represent data that was dominantly represented with text and numeric. The Information Visualization (IV) discipline is therefore been actively researched as early as 1996. IV produces (interactive) visual representations of abstract data to reinforce human cognition; thus enabling the viewer to gain knowledge about the internal structure of the data and causal relationships in it. Plaisant [2] stated that the

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application of IV capable of giving meaning to data, reduced information loss, point to styles and patterns of data and visualize relations among data.

Suggesting and planning healthy dietary menus for patients is an important but complicated tasks which mainly performed by dietitians through consultation with patients. During the consultation session, the dietitian needs to go through the overall patient's Personal History Data (PHD) in order to obtain summaries of the patient's background and conditions. In certain situation, the dietitian needs to obtain detail information of certain information before any menu suggestions can be put forward. A number of information system to assist dietitians has been proposed. DietPal [3] is one of these which was developed at the Universiti Kebangsaan Malaysia (UKM) and tested at the Hospital of UKM. Although, DietPal has the capacity of assisting dietitians in managing and suggesting suitable dietary menus for patients based on standard procedures, dietitians are still struggling to view effectively required information which requires opening different menus and windows to make such information visible. According to Moore [4], the huge number of interfaces is one of the main problem in health information system. This paper proposed to apply, use and evaluate IV mechanisms for displaying the anthropometry and nutrients intakes in PHD, in such a way that the problem of information overload and cognitive burden can be reduced.

2 Background and Related Research

IV is about visual representations of the semantics, or meaning, of information. The main of IV is to reduce the complexity of understanding among users on some complex data [5]. It can be considered as the process of transforming data, information and knowledge into visual by making use of humans' natural capabilities [6]. The applications of IV are numerous and cross many disciplines. For temporal data a number of systems have been implemented such as Lifelines, PRIMA MMVIS, and LifeStream.

Temporal data has been used in many domains particularly in the domains of healthcare, marketing and flight management and scheduling. Lifelines use the timeline visual representation that is dynamic and interactive. Its dynamic feature enable immediate changes based on the changes of data and its interactive feature allow users to acquire further details of certain information. LifeStreams [7] represents data as time orientation file flows. Documents are sorted sequentially according to time series which eventually creating a flow of records. As a result the selection of documents will be much easier. PRIMA [8] on the other hand uses aggregation technique. Information containing similar chronology will be placed under the same cluster and each cluster is represented dynamic horizontal line. From our review, *timeline* is favored by many researchers working with temporal data.

2.1 Applications of IV in Health Information System

Health Information System (HIS) deals with the resources, devices, and methods required to optimize the acquisition, storage, retrieval, and use of information in health and biomedicine. IV, by providing interactive visual representations of data and information aims to deepen exploration of the "information space", support optimal use of data and information - and help avoid overload. Chittaro [9] summarizes some of the goals of IV technologies for healthcare which includes:

- To allow "users to explore available data at various levels of abstraction"
- To give "users a greater sense of engagement with data"
- To give "users a deeper understanding of data"
- To encourage "the discovery of details and relations which would be difficult to notice otherwise"
- To support "the recognition of relevant patterns by exploiting the visual recognition capabilities of users."

One example the use IV technique in healthcare is LifeLines [2]. LifeLines provides a general visualization environment for personal histories. A one screen overview of the record using timelines provides direct access to the data. For a patient record, medical problems, hospitalization and medications can be represented as horizontal lines, while icons represent discrete events such as physician consultations, progress notes or tests. Line color and thickness can illustrate relationships or significance. Rescaling tools and filters allow users to focus on part of the information, revealing more details. Timelines, icons and lines are three techniques for visualizing health data in LifeLines.

2.2 Dietary Menu Planning System

Dietary menu planning is a complicated and tedious process that researchers have tried to automate since 1960s. A number of systems have been developed of which the focus is mainly to assist healthy individuals calculate their calorie intake and to help monitor the selection of menus based upon a prespecified calorie value. Although these prove to be helpful in some ways, they are not suitable for monitoring, planning, and managing patients' dietary needs and requirements. DietPal [3] is one of the systems meant to fill the gap by providing assistance for dietitian in planning and managing healthy dietary menu for patients. DietPal, however, has its limitation particularly in terms of too many information need to accessed from different interfaces and traditional representations of data. As mentioned earlier, dietitians need to view a number of information during the consultation session and a single visual representation of such information could reduce the cognitive burden among dietitians. Fig. 1 shows the interface for accessing different data of each patient in the web-version of DietPal.

To our knowledge, research or applications focusing on visualizing information for assisting in dietary menu planning and suggestion is currently not in existence. In this paper, we therefore embark on the suitability of using IV techniques in visualizing information related to this activity. We used the DietPal system as our reference of requirement specification among dietitians. The following section will provide discussion on the visual design process and then follows by a brief overview of the implemented system. We then conclude with conclusions and future research work.

Fig. 1. Interface of DietPal

3 Visual Design Process

The visual design process includes five important phases: visual mapping; representation for information structure; overall overview strategy; navigational strategy; and interaction strategy.

3.1 Visual Mapping and Representation for Information Structure

The visual mapping is the process of transforming PHD to visual representation. It is part of the visual pipeline proposed by Card et al. [10] as illustrated in Fig. 2, that is a computational process for transforming information into visual representation that can interact with users.

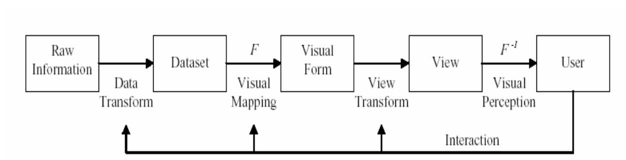

Fig. 2. Visualization pipeline

In the case of our study, we have identified the information used by dietitians during consultations process which are patient's personal data, medical history; biochemical data, dietary history and anthropometry data. It is, however beyond the scope of this work to visualize all the data. We therefore limit the data to be included as illustrated in Table 1 together with its corresponding visual mapping.

All the PHD proposed to be visualized in Table 1 will be examined in detail in order to identify the suitable visual features. The selection of which attributes to be visualized is based upon consultation with dietitians. Therefore, the quality of each attributes will first be identified either as quantitative, ordinal or nominal. Then the visual feature is chosen for each attributes based on its effectiveness and preciseness in representing the data quality. These are shown in Table 2.

Table 1. Personal History Data

Personal History Data (PHD) Types	Attributes	Proposed Representations
Personal Data	Name	Text
	Age	Text
	Race	Text
	Gender	Text
	Employment	Text
	Address	Text
	Telephone Number	Text
	Income	Text
	Marital Status	Text
	Spouse Occupation	Text
	Spouse Income	Text
	Number of Children	Text
	Living with who	Text
Anthorpometry Data	BMI Values	Visual
	Height	Text
	Weight	Text
	BMI Classification	Visual
Glucose Test	RBS Reading	Text
	FBS Reading	Text
	Glucose Level Classification	Visual
Full Blood Picture	Pressure Reading	Text
	Pressure Level Classification	Visual
Blood Pressure	Sistol/Diastol Readings	Text
	Blood Pressure Classification	Visual
Medicinal Intake Record	Type of Medicine	Text
	Amount of Intake	Visual
Supplement Intake Record	Type of Supplement Taken	Text
	Amount of Supplement Taken	Visual
Dietary Record	All dietary record	Visual and text

Once the visual representation has been achieved, the next process it the allocation of visual representation into space and vertical time of users' view. There are four types of information structure to be considered: tabular; space and temporal; trees and network; and text and documentations. In this study, the space and temporal structure will be the focused. Temporal data is divided into two: temporal dimension and temporal structure. Temporal dimension is the space or locations for the overall process of visual coding whereas temporal structure is the date values under study and mapped into visual presentation. The visual presentation produced from the temporal

Table 2. Visual features for PHD

Personal History Data (PHD) Types	Attributes	Data Quality	Visual Feature
Anthorpometry Data	BMI Values	Quantitative	Label - text
	Height	Quantitative	Label - text
	Weight	Quantitative	Label - text
	BMI Classification	Nominal	Orientation-Angle / Size-Sector
Glucose Test	RBS Reading	Quantitative	Label - text
	FBS Reading	Quantitative	Label - text
	Glucose Level Classification	Nominal	Orientation-Angle / Size-Sector
Full Blood Picture	Pressure Reading	Quantitative	Label - text
	Pressure Level Classification	Nominal	Orientation-Angle / Size-Sector
Blood Pressure	Sistol/Diastol Readings	Quantitative	Label - text
	Blood Pressure Classification	Nominal	Orientation-Angle / Size-Sector
Medicinal Intake Record	Type of Medicine	Nominal	Line-Segment
	Amount of Intake	Quantitative	Size-Thickness
	Level of Intake	Quantitative	Colour
Supplement Intake Record	Type of Supplement Taken	Nominal	Line-Segment
	Amount of Supplement Taken	Quantitative	Size-Thickness
	Level of Intake	Quantitative	Colour
Dietary Record	All dietary record	Nominal and Quantitative	Dot – Simple Representation

structure will be allocated in the temporal dimension. In this study the specific temporal visualization process is based from the work of Daasi et al. [11] as illustrated in Fig. 3. The first step involves identifying temporal values to be visualized and then transforming the values into analytical abstractions.

In the case of our study the circle orientation, timeline and simple icon used to represent PHD will be placed in the temporal space. Temporal value identified is time and PHD is divided into two time categories: linear and periodic. The linear category involves data such as anthropometry, blood pressure, glucose level, biochemical and dietary records. Each data values will be assigned a single timestamped such as '*01/05/2009*'. The periodic category involves data such as intake of medicine and

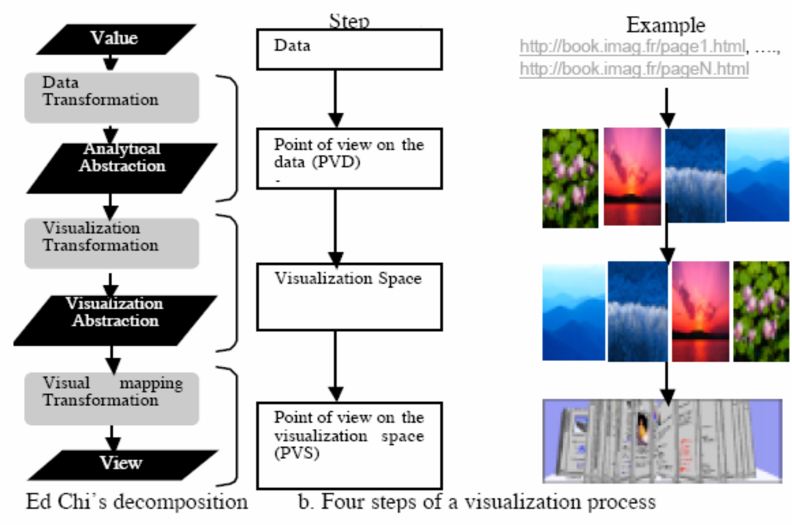

Fig. 3. Information visualization data state reference model.

supplement intake, and each values will be assigned a periodic timestamped such as '*05/05/2009 to 08/07/2009*'. The analytical abstraction will then divided the time unit into smaller units. In our case, time is divided into granular and multi-granular whereby granular is in year unit and multi-granular is decomposed into semester and month. Fig. 4 illustrates an example of analytical abstraction.

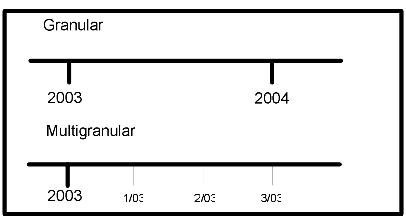

Fig. 4. Decomposition of temporal values in analytical abstraction

These analytical abstractions are then transformed into visualization abstracts. The process will result in the creation of temporal space and dimensions. We represent time as a single temporal space with one dimension. All the related PHD are uploaded into the temporal space. The granular and multi-granular are located at *x*-axis whereas data values are located at *y*-axis as illustrated in Fig. 5.

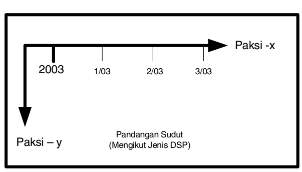

Fig. 5. The *x* and *y* axis of temporal space

The last step is to place the analytical abstractions into the temporal space for user's presentation. Timeline is chosen in this study because it is the best method to represent temporal information. Fig. 6 shows an example timeline representation for anthropometry data.

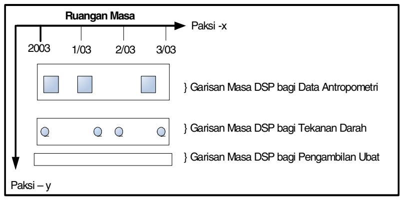

Fig. 6. Timelines for anthropometry data

3.2 Overview Strategy

Overview strategy is one of the interactive mechanism in IV for summarizing the PHD of each patient. In our implementation, all the PHD can be viewed into one screen and the data is represented in a compact visual representation. We used the tabular fisheye view technique for arranging all the interfaces into one canvas and the canvas can be distributed into columns and rows. Fig. 7 shows the implementation of the overview strategy.

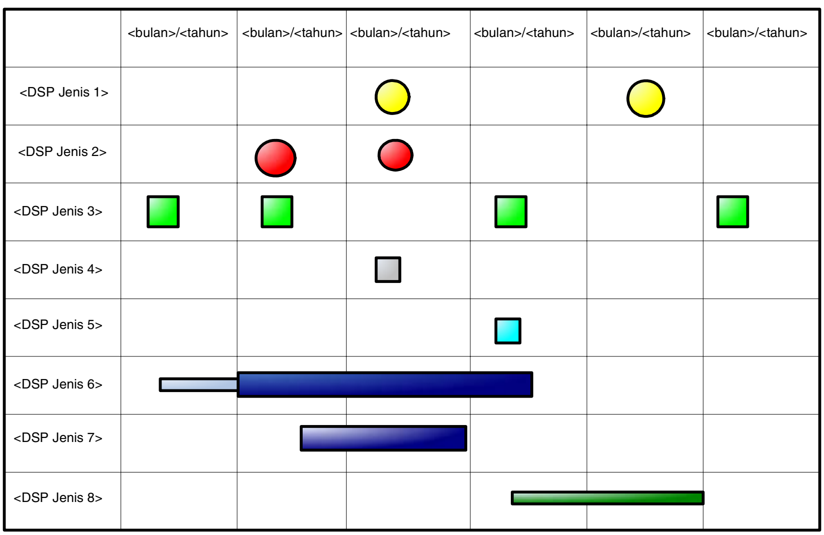

Fig. 7. Allocation of all PHD in one interface for the overall overview strategy

3.3 Navigational and Interaction Strategy

Navigational strategy is meant to support navigation of the overall overview strategy for viewing the details of the required item. There are quite a number of method available such as *zoom and pan*, *overview and details*, and *focus and context*. In our implementation the *zooming* technique is used which allow users to *zoom in* or *zoom our* with a single mouse click with a scale of 0.25 to 1.00.

4 DietVis

The implementation of the aforementioned design is called DietVis. As mentioned earlier DietVis is meant for dietitians during consultation with patients. DietVis is integrated with the existing DietPal system which is a system for managing and planning healthy dietary menu for patients. DietVis was developed using Java and utilized the packages provided by Piccolo [12]. The main interface of DietVis is as illustrated in Fig. 8. As can be seen the interface is divided into three main spaces: personal data space, caption space and PHD space. For significant reason, we focused our discussion on the PHD space only.

The PHD space is clearly the most important space it occupies the majority of the DietVis interface. This is where all the health and dietary records of a specific patient is visually mapped. As can be seen in Fig. 8 the space is divided into column and row where the time and PHD data are represented respectively. The circle orientation, icons and timelines are the three visual representations occupying this space. The circle representation is meant to visually indicate the various category of nominal values such as the glucose level and BMI classification. Each colored and occupying sector indicate different classification from low to high risk factor. For example the Fig. 9 shows different classifications of BMI: slim, ideal, pre-obesity and obesity.

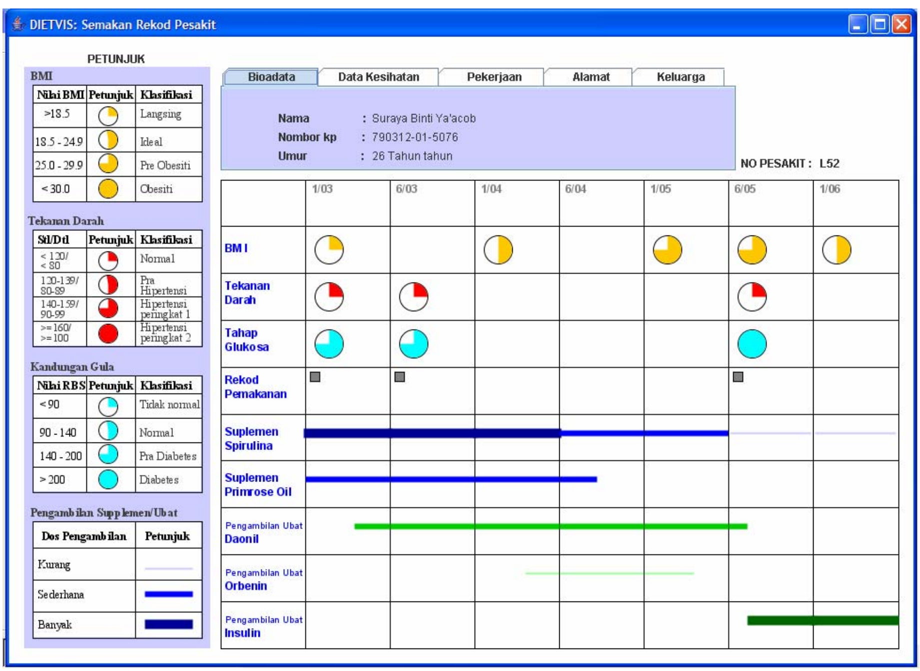

Fig. 8. Main interface of DietVis

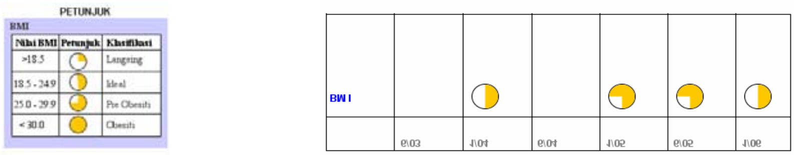

Fig. 9. Different classification of BMI based on the circle orientation

Before zoom-in After zoom-in

Fig. 10. Example of zoom-in feature for glucose level data

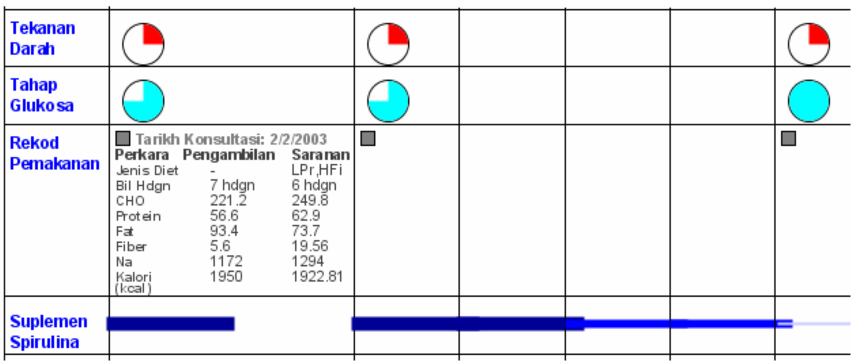

Fig. 11. Icon representation for patient's dietary record

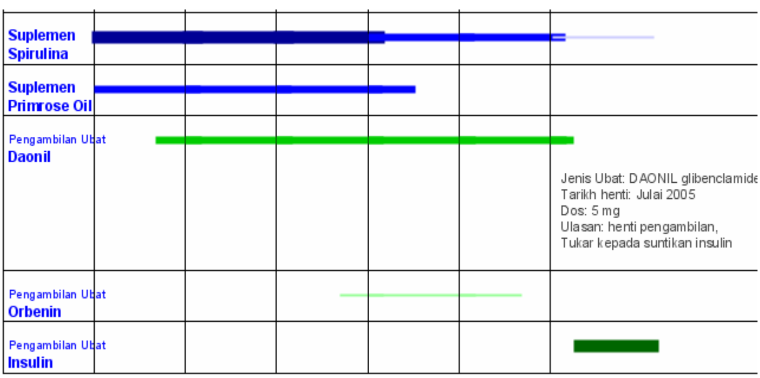

Fig. 12. Timeline representation for medicine and supplement intake

From one glance, a dietitian will be able to know the BMI classification of each patient from the occupying space of the circle.

It is beyond the scope of this paper to discuss DietVis in great detail. However some of the important features of DietVis is briefly illustrated. Fig. 10 shows the *zoom in* and *zoom out* features of DietVis. Fig. 11 and 12 on the other hand show the visual representation of the patient's dietary record and timeline for medicine and supplement intake.

5 Conclusion

This paper described the application of IV in dietary menu planning and management. We have conducted a usability testing among dietitians using the framework proposed by [13] consisting of five elements: limitations, cognitive complexity, spatial organization, information coding and state transition. The usability testing has been conducted among eight dietitians and an average score of more than 80% for all criteria except spatial organization. The low score for spatial organization is due to the limitation of the system to provide instant actual date for each data.

Our on-going research work among others is to improve the spatial organization of the system in terms object location and spatial orientation. Spatial organization is related to the overall layout of a visual representation, which comprises analyzing how easy it is to locate an information element in the display and to be aware of the overall distribution of information elements in the representation. Locating an information element can be hard if some objects are occluded by others, and if the layout does not follow a "logical" organization depending on some characteristics of the data elements. So, degree of object occlusion and logical order are characteristics to be measured in the visual representation. The spatial orientation, which contributes for the user being aware of the distribution of information elements, is dependent on the display of the reference context while showing a specific element in detail.

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