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A Framework for Improving Adaptive Data Visualization in Decision Support Systems

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by

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Abstract

Adaptive approaches are used to improve user experience and satisfaction for web browsing, based on profiling information gathered from user interactions. In decision support systems, the need for personalization adaptation has increased in order to provide more immediate and relevant information to decision makers, using web based access to data. Using visualizations for rendering complex query results, in real-time is of particular importance in many application domains.

In this thesis we propose an approach, and a framework, for measuring history, experiences and satisfaction of users of a healthcare decision support system. The focus is on user selections of visualizations, based on the nature of queries generated.

The aim of this framework is intended to provide collection of individual user experiences and satisfaction, in order to obtain a user population profile for later studies. The model used is a weighting scheme, but is designed to support later extensions and enhancements using 'AI reasoning techniques'. This model was implemented and a usability study was conducted to validate improvements compared to non adaptive data visualization systems. The outcome of this research may lead to increased accuracy and reduced time of selection of visualization, over repeated usage, and is therefore important as a productivity enhancement approach.

DEDICATION

To my beloved parents for their unconditional love and support

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The Web is steadily growing environment. Information systems are providing an escalating amount of processed data, both to professional users and also to large number of ordinary users across the globe. Earlier, websites and information systems were providing very slow and static data to the users, but nowadays, web applications are becoming more and more complex, thus providing users with a reliable and dynamic data. Easy to use interface and query languages are being developed, which form the part of the information systems and deliver and map the data into visualization to understand the data nature [1] which is defined as the nature of data sets like real valued data sets, Boolean data sets, integer data sets etc. Data is available to users in various complex forms which relate to fact, event and transaction in unprocessed form when this data is processed in such a way as to be meaningful to the person who receives it becomes information. Studies have found that there are massive amount of data available but it is not always used to deliver the exact and required information. Various architectures are introduced to deliver the efficient and intelligent deliveries of data. Data delivered after number of queries is of no use if the users who analyze the data are unable to analyze the data in the proper way. To overcome this, various frameworks are used to deliver the processed query data in the form of visualization. One part of these types of approaches is the "Personalization of information" delivered. By referring to Personalization of information here, we mean to deliver the personalized data to end users according to requirements and specific needs and roles of data. These types of information are intelligently delivered to the users, who are unaware of the various architectural and behavioral aspects of the components.

In the advancement of “personalization of information” approach the “Affective Computing” or “Adaptive Web” is the one area, which aims at bridging the gap between the human emotions and computational technology. Adaptive web applications are the intelligent applications, which deliver the right content to users at the right time while taking into account their preferences. Each user has different ways of looking at same point. Adaptive web techniques once start at the same level and as the users interact with the applications it keeps tracking their emotions, their likes-dislikes, their preferences, their ratings and also their approximations. Numerous numbers of techniques for adaptation have been introduced conceptually and practically. We propose an approach and a framework, for measuring history, experiences and satisfaction of individual users of a healthcare decision support system. The focus is on user selections of visualizations, based on the nature of queries generated. The framework aims at a collection of individual user experiences and satisfaction in order to obtain a user population profile for later studies. The model used is a weighting scheme, but is designed to support later extensions and enhancements using AI reasoning techniques. The system supports increased accuracy and reduced time of selection of visualization over repeated usage and is therefore important as a productivity enhancement approach.

1.2 Problem Statement

To outline the objective decision support elements in data visualization frameworks- specifically in context of adaptability, a range of Data Visualization, multiple platform deployment and automated selection of visualization. Furthermore these adaptive approaches to visualization selection and satisfaction will improve productivity, accuracy and timeliness of decision making when visualization is an essential part of the process.

1.3 Motivation

As the Internet is evolving, perspectives on the nature of web applications are changing rapidly. By observing user's interaction with the application, it can be found that what features are best served and most required by him. To address the personalization and adaptation nature of each user, Adaptive Web has emerged as the new research area. Capturing human behaviors in adaptive visualization system is a challenging task. In these visualization systems, there are myriad factors that account behind an individual's selection [2]. It gets typical when different users may have different perspective on same data visualization. We may consider different visualization of same data sets to understand it correctly but when visualization is critical factor in the decision support system, we need best served visualization of that query and data respectively. To build a kind of adaptive visualization framework, we fore mostly need to develop such a framework, which is able to read a raw data (sorted in nature) and also capable in visualizing those data sets. These visualization frameworks should have the ability to visualize data sets into various multi-color visualizations, multi-platform deployment and by using such an approach we should be able to make a framework, which can provide large visualizations to end user to select best suited visualization for given query and contributes in the adaptability factor. Adopting such an approach should enable us to develop more realistic adaptive data visualization frameworks.

1.4 Thesis Statement

Extend Data Visualization to include adaptability ingredients and to create a framework for improving adaptive data visualization in Decision Support System for Health Care society.

Health care system is highly dynamic and time constraining environment, which includes various key factors that are part of almost every social system.

1.5 Thesis Objective

The aim of this study is to outline the objective decision support elements in data visualization frameworks, specifically in context of adaptability, a range of Data Visualization, Multiple platform deployment, automated selection of visualizations and critically examine the influences of the factors that contribute to certain decisions in DSS.

First objective is to make an attempt to form a model data into visualization form. Data exists in various forms. It is only usable if we can figure out any important facts from the raw data available. Various query languages have already been generated to run various queries on these raw data sets and to get certain amount of required results. Results obtained are also in the form of data sets but in some sorted form. These sorted forms of data sets are still complex to understand. Here visualization plays an important role as it helps to visualize these complex forms of data into colorful, multidimensional graphs charts etc. that can be easily understood by humans. Second objective is making this visualization framework adaptive in nature. Adaptability delivers right content to users as per their requirement of certain query, at right time, with right information. E.g. If health care workers run a query about the new cases of cancer for last 10 years, then they would get data for the last 10 years in numerical forms but in adaptive visualization form they might get a visualization chosen by another users which effectively demonstrate the data values in graphical form. Third objective is to present an adaptive data visualization framework as a tool for decision support and create a bridge to other disciplines that can benefit from such a tool.

The outcome of this research may offer important evidence for creating supportive systems for adaptation in data visualization that maximizes their performance. For instance, in health care systems, where time-critical events require certain decisions, best served visualizations for given queries provide a stronger basis for beliefs, where visualization is important factor of system. Also, this framework is intended to provide for collection of individual user experiences and satisfaction, in order to obtain a user population profile for later studies. These studies can be of any type to get results about certain decisions and beliefs of particular society of people on certain data sets. These findings can allow allocating the settings that can maximize the quality of adaptability in visualization systems.

1.6 Contribution

In this research, an Adaptive Data Visualization system was designed, we analyzed the architecture and life cycle of existing adaptation middleware and proposed the design of a visualization framework that adapts and delivers the visualization, which is best served in its categories. The proposed framework uses the visualization libraries to deliver the data sets in graphical form, and also is adaptive in nature, so that it adapts the optimized path. In fact, the proposed framework can be considered as an early attempt of adaptation in visualization form, as the adaptation framework has already been experimented and implemented in wide areas that require systems for adaptive framework. The proposed framework in this thesis is adaptive in nature, which can be used independently of any another block to increase the user experience, and also contributes in the field of decision making by providing direct evidence suitable for validating strategies for further, intelligence based, prediction and automation of user intention.

1.7 Thesis Organization

The remainder of the thesis is organized as follows; Chapter 2 provides a literature review and background survey, which describes adaptation and decision support systems, numerous components involved in adaptation and various other adaptation frameworks available. Chapter 3 describes data visualization and analysis of data visualization techniques available. Chapter 4 describes brief overview of proposed adapted data visualization systems by discussing algorithm and several components involved in architecture designs. Chapter 5 is about implementation and designing of system and also about usability of system. Chapter 6 describes the results captured in usability testing and satisfaction of users. Chapter 7 concludes the thesis and proposes some avenues of future work in adaptive visualization frameworks.

CHAPTER 2

ADAPTATION AND DECISSION SUPPORT SYSTEMS

2.1 Introduction

In this chapter, a number of components of the adaptability have been discussed, which plays an important role in adaptive data visualization. Adaptability modeling has been discussed and role of its key elements e.g. adaptability in various systems, influence on the system has been described. Adaptive Data visualization could further be used as a decision support system, which could be a useful tool for organizations in decision making activities.

2.2 Adaptation Frameworks

2.2.1 The Web Behavior Model (WBM)

WBM model is timed state-transition automaton for representing classes of user behaviors on the web [3]. Graphically, WBM models are expressed by labeled graphs, allowing for an easily comprehensible syntax. Basically, there are different types of states, which are loaded in web browsers and special scripts i.e. WBM script. This script is run to know about the current state and as the state changes; it is accepted by another state. So there is at least one initial state and also one accepting state. This model doesn't cover all the alternative navigations.

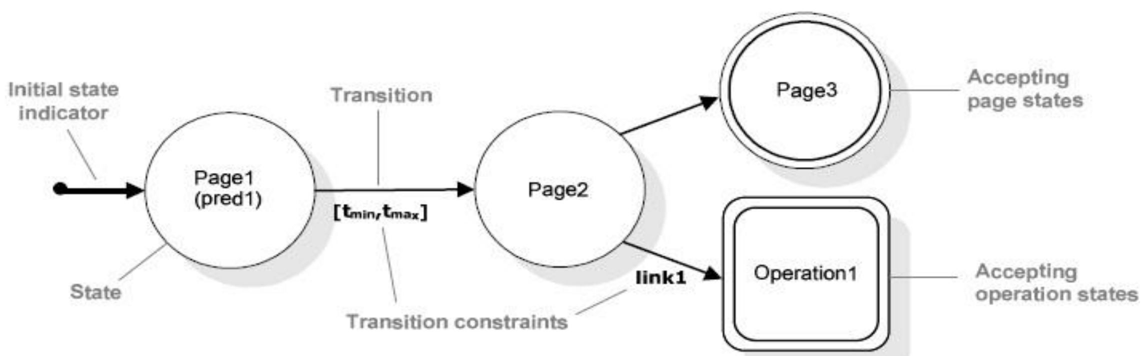

Figure 2.1 Transition States of WBM model.

Figure 2.1 describes the transition states defined in WBM with different transitions. State constraints - Entering a state may be subject to the evaluation of a state constraint, expressing a predicate over properties of the pages being accessed or operation being fired [3]. Such predicate may refer to contents displayed within pages or to operation parameters. The state is accessed only if the predicate evaluation yields to true [3].

Link constraints - Each transition may be labeled with the name of a link entering the page or enabling the operation. The state is accessed only if the specified link is navigated. Time constraints - Each transition from a source to a target state may be labeled with a pair [tmin, tmax] expressing a time interval within which the transition can occur. Either tmin or tmax may be missing, indicating open interval boundaries. If a transition does not fire within tmax time units, it can no longer occur; on the other hand, navigation actions that occur before tmin are lost [3]. The use of suitable time constraints may thus cause the invalidation of running scripts. One important aspect of WBM models is that not all navigation alternatives must be covered. As the aim of WBM is to capture a concise set of user interactions, describing particular navigation goals and respective “milestones”; only a subset of all possible navigation alternatives is relevant. E-commerce Web sites, for an example, make heavy use of so-called access-pages that only serve the purpose of providing users with browse able categories for retrieving the actual products offered [3]. Furthermore, Websites usually provide several different access paths towards their core contents. Therefore, by concentrating only on the interactions that really express the navigation goals, WBM allows both abstracting from unnecessary details and defining small and easily comprehensible specifications. Only performing specified target interactions – in the modeled order –may thus cause WBM state changes.

2.2.2 Limitation of WBM model

WBM is a timed state-transition automaton for representing classes of user behaviors on the Web. Limitation in WBM model is that adaptation patterns are already designed at designing stage without requiring a profound knowledge of the actual application structure. For complex system adaptation patterns there is no way to design adaptation factor at designing stage so this motivate us to make adaptive model in which no fixed rules are defined at designing stage and which can change adaptive factor according to users input.

2.2.3 ECA Rule Model (ECA)

In the advancement of upper model, a new ECA rule model is introduced that combines WBM scripts and Webml Adaptation system. In this model, rule engine is introduced containing certain set of rules and as a state changes, a new rule is defined and new script is generated, navigating from one URL to another. Rule engine shares the data and storing the data of completed states with the user profiles. Rule engine is not bounded to technology used web application and it can handle various web applications also. In case of crash of rule engine, web applications are operational and rule engine can be recovered independently [3]. So rule engine captures the transition records and saves them for making new rules.

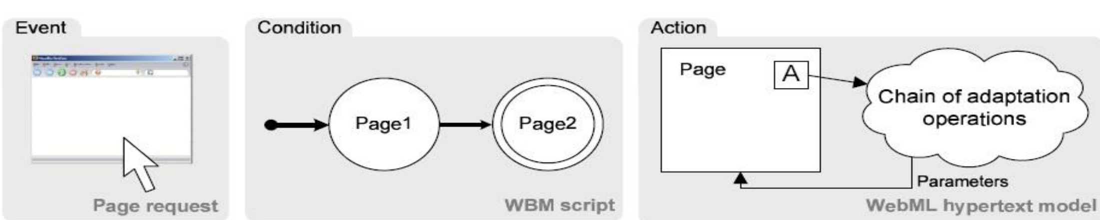

Figure 2.2 ECA rule model.

Figure 2.2 shows the ECA rule model acting in response to a user's visit to Page1 followed by a visit to Page2. Thus, the expressed condition only stands true, when the script gets to the accepting state Page2. Once the accepting state is reached, the actions (expressed as cloud in Figure 2.2) are executed and, after a re-computation of page parameters, possible adaptations may be performe**d.**

2.2.4 Limitation of ECA rule model

ECA rule model was introduced with adaptation rule engine which captures behavior and later these can be used in defining adaptive factor. But it only works at "on and if" conditions. If specific event occurs then only adaptive results will be shown. Also this adaptive rule is strict to specific page that user explore. So we need an adaptation rule engine in which all events will be captured and which later can be used to provide adaptive results when certain event occurs. The adaptation rule engine can also be used to capture all behaviors and later these results can be used to increase efficiency of system.

2.2.5 Adaptation model for visually impaired people

It is a framework to enable visually impaired people to gain access to graphics on internet. It is limited to specific type of users and hardware but now new framework has been introduced, which works adaptively considering different user profiles [4].

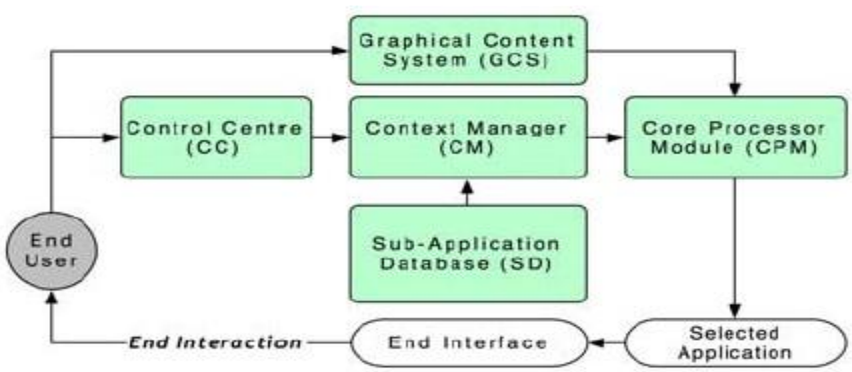

Figure 2.3 Components of visually impaired people adaptation framework.

The main components of the system include:

(a) Sub-Application Database (SD):- It is a standalone application that is capable of either extracting information of a vector graphic or rendering a bitmapped graphic. It processes the gathered data about the graphic and converts it into an accessible hepatic, tactile, audio (or a combination of any) interface [4]. There are a few reasons these functions are incorporated into different independent sub applications.

(b) Graphical Content System (GCS):- GCS provides the launching interface to application with perceiving information about graphical content selected by the end user. It also defines the type and format of the graphic, after the trigger action is performed by the user. Also GCS is responsible for sending information to CPM to carry out adaptation of content.

(**c) Control Centre (CC):-** Control centre allows users to read and modify their profile and preferences, system configurations and sub-application settings. Though user profiles are created during the system installation process, user still can change their preferences manually later. It also provides import and export function.

(d) Context Manager (CM):- It stores and manages the context information i.e. information required for adaptation that includes information about (a) graphical contents, (b) system configuration and hardware/software components of assistive technologies, (c) requirements (e.g., system configuration) and feedback provided by each sub application (both information is specified by the sub application developers), and (d) user's profile and preferences [4].

(e) Core Processor Module (CPM):- CPM performs adaptive logic by gathering input provided by both GCS and CM. The CPM performs the adaptation to locate the most adequate end interface for its users [4]. It also communicates with the available assistive technologies.

2.2.6 Limitation of adaptive impaired model

This model is designed specifically for visually impaired people. This model requires different kind of visualizations and hardware for actual system to work. Main limitation of this model is that people needs to change hardware so that actual system got adapted. But same time in as in adaptive model introduced here give users different kind of visualization and users have to choose best suited visualization so that they can understand and gain access to rest of visualizations.

2.3 Decision Support Systems

Making decisions concerning complex systems (e.g., the management of organizational operations, industrial processes, or investment portfolios, the command and control of military units; or the control of nuclear power plants) often strains our cognitive capabilities [6]. Even though individual interactions among a system's variables may be well understood, predicting how the system will react to an external manipulation such as a policy decision is often difficult. There is a substantial amount of empirical evidence that human intuitive judgment and decision making can be far from optimal, and it deteriorates even further with complexity and stress. Because in many situations, the quality of decisions is important, aiding the deficiencies of human judgment and decision making has been a major focus of science throughout history [7]. Disciplines such as statistics, economics, and operations research developed various methods for making rational choices. These methods, often enhanced by a variety of techniques originating from information science, cognitive psychology, and artificial intelligence, have been implemented in the form of computer programs, either as stand-alone tools or as integrated computing environments for complex decision making. Such environments are often given the common name of decision support systems (DSSs).

Decision support systems have become popular primarily because of their capability to fill the need of decision making by given information. A Decision Support System is a class of information systems that supports business and organizational decision making activities. DSS couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions [7]. It is a computer-based support for management decision makers, who deal with semi-structured problems. A properly designed DSS is an interactive software-based system, intended to help decision makers compile useful information from a combination of raw data, documents, personal knowledge, or business models to identify and solve problems and make decisions. Decision Support System is a general term for any computer application that enhances a person's or a group's ability to make decisions. It can also be used as a tool in which user inputs the data and the software component process the data and decisions are made on the basis of the information given. In order to make the decision making tool, all the major components of the system should be considered in the system to get the optimal results.

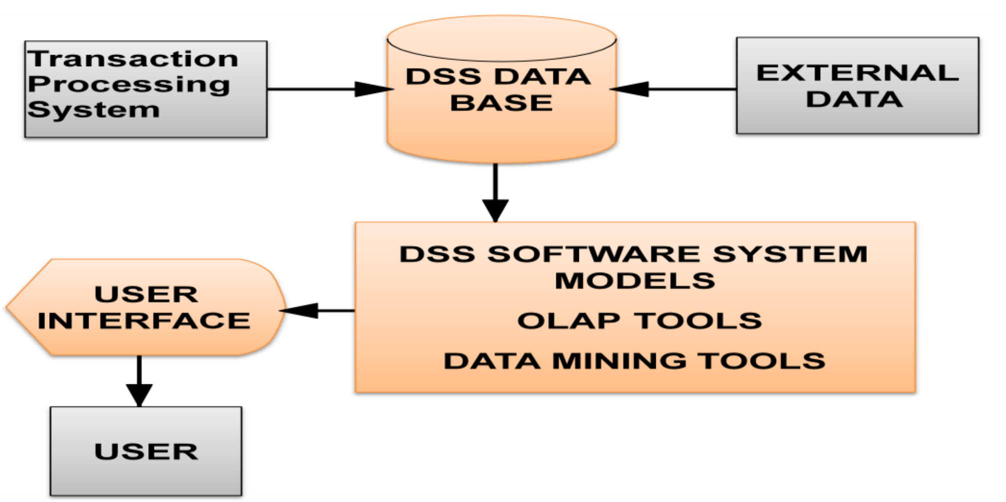

Figure 2.4 Decision Support System flow.

Consider an example: A national on-line book seller wants to begin selling its products internationally but first needs to determine if that will be a wise business decision. The vendor can use a DSS to gather information from its own resources (using a tool such as OLAP) to determine if the company has the ability or potential ability to expand its business and also from external resources, such as industry data, to determine if there is indeed a demand to meet. The DSS will collect and analyze the data and then present it in a way that can be interpreted by humans. Some decision support systems come very close to acting as artificial intelligence agents. DSS applications are not single information resources, such as a database or a program that graphically represents sales figures, but the combination of integrated resources working together.

Decision Support Systems are valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker and in which precision and optimality are of importance [8]. Decision support systems can aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, and aiding the process of structuring decisions. They can also support choice among well-defined alternatives and build on formal approaches, such as the methods of engineering economics, operations research, statistics, and decision theory. They can also employ artificial intelligence methods to address heuristically problems that are intractable by formal techniques. Proper application of decision-making tools increases productivity, efficiency, and effectiveness and gives many businesses a comparative advantage over their competitors, allowing them to make optimal choices for technological processes and their parameters, planning business operations, logistics, or investments.

Decision making is a fundamental managerial activity. It may be conceptualized as consisting of four stages: intelligence, design, choice and implementation.

2.3.1 Important aspects of the Decision Support System

Below we list those aspects that are considered important to decision support systems.

1) The most important consideration is the Decision Support System's ease of use - its ability to allow non -technical people to deal with it directly. The single greatest and most enduring problem with computers has been their inflexibility, their inability to let the person, who actually needs the data, to deal directly with the computer.

2) The ability to access information should not be restricted to only the part of an organization or to only certain managerial or professional groups. Instead, the resource should be distributed to all the people and part of an organization needing it, without widespread access; the power of advanced Distributed Processing System will go untapped as they typically have in the past.

3) The ideal Decision Support System, in sharp contrast to previous method of designing applications, should not be a 'system' in the strict sense of the term. Rather, it should be a highly adaptive decision support generator that can easily be used by professionals to quickly design data support prototypes suited to each specific decision-making task. This adaptive tool must allow quick design changes, if the original design does not closely match a person's information gathering style or needs.

4) To adequately support the human element, this highly adaptive support capability must be able to provide access to operational data and as well as to summary data that has already been processed by the application programs designed for other specific operational tasks. Equally

important, this tool must provide the professional with access to an organization's raw data and it must also allow the access to be accomplished in one step using a single uncomplicated procedure or command and without having to re-key non summary data.

5) The organizations need to access original data sometimes because efficiency is related to how well the original data is organized in the system; so the Decision Support Generator should be able to interface with the true DBMS. It should also be able to access standard 'flat' files indirectly, using the power of the host computer to facilitate both the user interface and data access without changing existing files.

6) The management or professional information workstation would incorporate a keyboard, display screen and an interface to a printer which could print everything from straight text to graphics like pie charts, bar charts and line charts.

7) The support tool must interface with several different systems and capabilities, it must be compatible with all of them, the tool must provide users with a single easily used language to access manipulate and present data in a way that will best support the end-user.

2.4.2 Capabilities offered by DSS:

1) Support decision making in ill-structured situations- in which, precisely owing to the lack of structure, problem do not lend themselves to full computerization, and yet require computer assistance for access to and processing of voluminous amount of data.

2) Help to rapidly obtain quantities results needed to reach the decision.
3) Support various stages of the decision making process.

4) Foster high-quality decision making by encouraging decisions based on the integration of available information and human judgment.

5) Offer flexibility as opposed to a preordained pattern of use - making it easy to accommodate the particular decision making style of an individuals.

6) Facilitate the implementation of the decisions which frequently cut across department boundaries.

7) Support group decision making particularly through group DSS (GDSS).

8) Give organization the opportunity to gain a better understanding for their business by developing and working with models.

Decision support systems are used in various domains from military, education industry and any other industry. DSS tools are being used to improve the effectiveness of the system rather than the efficiency of the systems. These tools are potential measuring tools, which are used for management purposes. In DSS, the decisions are largely dependent on the quality of information. While concluding any decisions, best case scenarios are always considered with no faults in a system. Problems arise when the quantities of available information are huge and non uniform and their quality could not be stated in advance. Decision support systems for observing a complex system is a challenging task to build. Complex systems are highly dynamic in nature, which consist of various parameters that have specific effect on the system. Once we have all the important parameters of the complex system in the DSS, it is easy to conclude the decisions but it is hard to decide that which parameter has more influence on system than other.

2.3.3 Summary

In section 2.2.1, we analyzed the WBM adaptation rule model which defines the adaptation rules by using which adapted systems can be built to provide users adapted results it has limitations that adaptation rules are already designed in the system. Based on our further analysis in Section 2.2.3 we have found that advancement of adaptation is to make rule engine in which certain rules are defined and these rules can be used for further adaptive factors main limitation is that it works only with “on and if” conditions. If these conditions can be removed than this rule engine can be further used for providing actual adaptive factors. Then we have studied about adaptive engine used for visually impaired people to provide them real access to visualizations but limitation is to change hardware so that they got access and can see visualization but from this study we analyzed that rather than changing hardware if we change our software to produce different kind of visualizations for normal users it can be beneficial to understand it and make it adaptive according to their specific needs.

Later we have studied decision support system and their capabilities which provide us brief description of architecture and their real time evolvement in various domains. Our next objective is to make adaptive engine which capture users behavior, their likes dislikes on previous selections and provide results according to their requirements. In decision support system such type of adaptive framework is lacking later in this visualization framework will be introduced which provides adapted results of data visualizations in decision support system.

2.3.4 Statement of Research Objectives:

The objective of our work is to demonstrate that the adaptive web approach, and its entire set of supportive mechanisms provided by WEBML, ECA rule and another frameworks, can be integrated into the data visualization platform, through enhancing the capability of decision support systems in which visualization is important part of DSS.

In this thesis research, our practical goal is to construct adaptive data visualization system which proves to be productivity enhancing tool in decision support system where visualization is essential part of decision, while also serving as foundation platform for future research. We focused on solving limitations in previous adaptation frameworks, namely predefined adaptation patterns, on and if conditions and hardware alteration. Another goal is to built a data visualization framework which has capabilities of rendering complex forms of binary data sets, across platform deployability and provides direct evidence with enhanced options for user choice and multicolor visualization to data set users.

2.4 Related Work

2.4.1 In the domain of adaptation in e-learning

Related work can be seen in the WEBML system [3] in which the platform, which is adaptive in nature and independent of any language, is made and it runs. This is open framework and can be used with any system. This was first implemented in the e-learning systems which are largely becoming adaptive by user choices. The user first logins in the system of e-learning to see the various courses offered. If the user is not interested in any or some courses, the system captures this user behavior. This is done purely in the navigation from one type of course page to another.

When user logins again in the system, only those courses are offered, in which the user shows interest. This is implemented in e-learning as this is the basic in nature of adaptation.

Advancement is done based on this architecture. Link and time constraints are fully implemented and rule engine is introduced in which all the rules are captured and further, the application works on these rules.

2.3.2 In the domain of adaptation in Agent system

Another related work is the JADE (Java Agent Development Framework) [5]. The proposed agent platform employs agent containers, so that the agents can handle self-creation, self-management, and self-destruction operation based on the context-aware services with the filtered and compounded context information of the context monitor [5]. It also employs the reconfiguration manager, which dynamically reconfigures the platform by looking up the agents and services through the discovery operation.

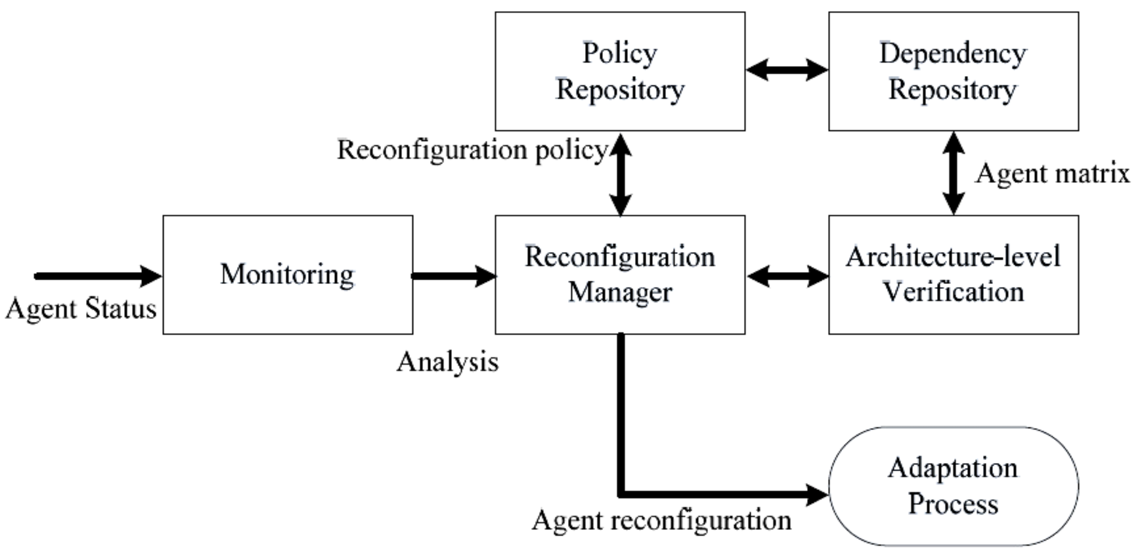

Figure 2.5 JADE architecture diagrams.

The run time adaptation approach takes advantage of architecture modeling and multi-agents. It uses matrix-based dependence analysis model to guarantee the required performance after the reconfiguration, which was adopted by the multi-agent system to automate the adaptation process [5]. The agent adaptation manager consists of analysis, reconfiguration, and architecture-level verification component for processing agent reconfiguration at runtime. The agent itself uses the fd matrix to verify the performance prerequisites at run time. The reconfiguration manager is one of the abstract components of the platform manager. The monitoring component uses an agent thread in the agent container to observe the status of the agent. It analyzes the runtime throughout, with regards to the performance constraints. The policy repository manages the adaptation strategy using the dependence matrix. The reconfiguration manager checks the information extracted from the monitored data, and then decides appropriate adaptation strategy. For this, there is a predefine adaptation and decision policy. Following this, it starts the reconfiguration process by transforming the matrix. The dependence repository keeps the matrix representation used in remote agents, which is handled with agent repository for providing detail information of implementation [5]. After the policy is determined, the architecture-level verification checks the validity of the reconfiguration.

2.4 Summary

In Table 1, we compare the related works with the current proposed framework, we state once again that our goal is to make adapted visualization framework which is optimized to produce data visualizations from data sets, with enhanced motion based visualization, decision making tool with multiplatform deployment. The features listed under the proposed adaptation visualization framework column can be viewed as a wish list that needs to be implemented in our work.

	NON Adaptive Visualization Frame Work	ECA rule Model	WEBML Frame Work	Proposed Adaptability Visualization Frame Work
Adaptability Behavior Dependency	Not Found	Fixed Rules	Fixed Rules	User Behavior
Adaptation Age	Not Found	Changes Manually	Changes Manually	Changes Automatically
Display of information on mouse rollover	Yes	No	No	Yes
Automated SQL query	No	No	No	Yes

Table 2.1 Comparison of various models

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CHAPTER 3

DATA VISUALIZAION

3.1 Data Visualization

Data visualization means providing the image of existing software using visual objects. Data visualization might visualize different aspects of the data, such as data structure, comparison, flow and even the certain behavior of the data trends. It is proven that appropriate visualization can significantly reduce the effort spent on different phases of data comparisons and development of various decisions based on the data types. By means of visualization, data analysts and stakeholders can obtain an overall point of view of the data structure, data logic or explain and communicate with the decision support process [10]. Generally, data visualization is used for data behavior exhibition, so that complex data can be viewed and compared with simple visualization. A numerous data is available to study and compare these types of data to reach certain decisions in less time. Data Visualization is considered as the best technique logically and practically. By providing a good graphical representation in order to visualize the data, a better user understanding of the system can be more promising than textual representation of the data [9].

By graphical presentation of data, the capabilities of the user's data processing would be utilized much more effectively than other presentation methods. If a suitable graphical representation tool is chosen properly, there would be less need for perceptual and mental information recording and it would reduce the memory loads. By providing graphical interfaces, there would be a faster information transfer between computer and people because it has been proven that symbols can be recognized and classified faster and more precise than text by users.

Also, because of its simplicity, graphics will remain in casual users' minds a lot easier. It also gives a better feeling of control to users when they can see objects on the screen. Overall, graphical visualization can provide many other benefits such as faster learning, faster use and problem solving etc.

There are several data visualization tools and techniques available. Visualization techniques consist of collection of elements, such as points, lines, shapes, texts and textures which each of these elements illustrates as an entity or an attribute from a dataset, which is going to be visualized. In some cases, more than one visualization technique can be applied for a system. Data visualization techniques can be categorized into two groups of static visualization and dynamic visualization of data. An example of static visualization of data is visualization formed by certain data sets in static forms, which forms just like charts and also represent static value. On the other hand, dynamic is one in which chart value changes with certain time frames. Here we define time frame that can be time span of certain years or it can represent the same time. There is difference between values of two columns, which can be later overcome or kept same.

With regard to dimension, visualization can have either two or three dimensions. Two-dimensional visualizations tools mainly involve graph or treelike representations, which may contain many nodes and arcs [11]. For some systems, which have too much information to be visualized, using two-dimensional technique may cause confusion. Therefore, in some papers, the need of extra spatial dimension is suggested, which may make it more possible for the designer to describe more aspects of the system [11].

To choose the best visualization technique for the existing data, first of all, the reason and goal of the visualization should be clear. Then the group of users and their level of knowledge and experience with computer systems should be defined. Also, all the existing data sets and elements in the datasets and all the relationships between them should be detected and the aspects of the data, which are going to be presented, should also be decided. The usages and limitations of the existing system, which is going to be visualized, should also be investigated [12]. On the other hand, the current data visualization techniques need to be evaluated. At the end, the technique that displays the best visualization of data sets and meets the requirements of the system should be chosen and implemented.

3.2. Data Visualization Techniques Analysis

The main reason for this visualization is to make the text-based system comprehensible for users. In this case, users would spend less time to have a more clear and precise point of view of the system. It will happen in this way that instead of reading the data and memorizing the structure of the datasets, users will see the flow of the data dynamically while working with the text-based system and have an overview of the all datasets in a big scale in front of them.

The decision-makers always use data to identify opportunities, trends, and areas of concern in their respective businesses. Most data reaches to them is in the form of tabular reports, and they find it challenging to quickly and effectively absorb the information, spot patterns, identify aberrations, and see hidden relationships. Fortunately, though the volume of data that they deal with is ever expanding, data-visualization tools have been evolving to the point that they can now transform large quantities of complex data into meaningful visual representations that incorporate the science behind human perception and cognition.

Basic Charting is the most common and basic form of data visualization. Basic charting involves Pie, bar, and line charts that help the audience in quickly identifying general upward and downward trends as well as groups within the data that are performing differently than other groups. These basic charts are typically used to display the relative performance of key business dimensions, such as market segments, product groups, geographic regions, and business units. Instead of looking at a tabular list of numbers, the audience can literally see how data relates to other data. By effectively highlighting exceptions, these charts allow the audience to spend more time pursuing an opportunity or resolving a problem and less time trying to discover or define it. Most online query and reporting tools generate these charts automatically, thereby reducing the time that end users spend manually creating charts in offline tools such as spreadsheets [13].

Graphical Indicators involve Graphical icons, colored symbols, stoplights, gauges, and other performance meters that are being used to provide audiences with a rapid visual overview that shifts focus to the information of greatest interest and reduces the time otherwise spent studying an entire screen of information [13]. This has been particularly useful in enhancing scorecard reporting systems that once simply presented an at-a-glance view of a tabular list of key metrics.

Scorecards and dashboards increasingly incorporate basic charts to display summary information and as a way to present additional information once the user selects a particular metric. For an example, confronted with a summary metric indicating that revenues are flat year-to-year, a supporting bar chart can quickly communicate which regions are growing, declining, or flat.

Advanced data-visualization applications provide sophisticated graphical representations. Whereas a bar or pie chart represents a simple series of data points. Advanced visualization applications can display more than a half-dozen dimensions per graph object. These graphical representations extend beyond traditional pie, bar, and line charts to include multidimensional charts, histograms, scatter plots, constellation graphs, geographic maps, floor plans, spatial images, statistical control charts, and heat maps among other graphical images. Since companies are no longer encumbered by tools such as basic query report writers and pivot tables (which can be challenging and inefficient to use when many data attributes are involved), they are unlocking valuable information about customers, products, markets, sales reps, employees, and financial performance [13].

Animation adds another easily consumed aspect to visualizations. Watching data change over time gives both a velocity and direction to the values it represents. Knowing your current sales and expenses is a good thing. Knowing whether they are increasing or decreasing and at what rate can be critical to the business.

Immersive data-visualization solutions place the audience in a virtual environment containing three dimensional representations of complex data.

The environments range from desk-size to wall-size to room-size systems and combine visualization, computational, data management, and projection technologies. Immersive data visualization is being used extensively in the areas of research and product development, where users benefit from hands-on interactivity with virtual models, prototypes, and data sheets. Imagine flying through multidimensional sales or cost data sets to identify trends, patterns, and outliers [13]. The business analyst's desk job may never be the same.

Interactive Capabilities Interaction is the key to provide a full information experience. While the traditional reporting environments presents a static pie and bar charts, interactive visualization applications allow the user to directly interact with the chart or image to study the underlying data and discover new information. Charts or images can be rotated to reveal the most insightful view of information. Portions of an image can be brushed over with a mouse to reveal context-specific information about a data point, including the data value and various dimensional attributes such as geographic location, demographic group, organizational entity, etc. Scroll bars can be used to move left, right, up, and down to view data points that would otherwise be off the screen due to the limitations of traditional bar and line charting tools.

Filter planes allow the user to isolate data points above a threshold value, much like mountain peaks rising above low level clouds [13]. This draws the audience's attention to the values of greatest interest. These capabilities are analogous to a visual query where users can select subsets of the data, zoom in to detail, filter unwanted values, and drill down into areas of interest, much as they would with a programmed query but without the need to decide in advance which dimensions of the data to focus on. This direct interaction with the visualization allows the user to shift focus from query writing, report formatting, and user interfaces to information discovery and analysis [13].

The linkage of information across display elements through color-coding and synchronized context represents one of the most powerful advanced interactive capabilities. This presents a richer comparative context, making it easier to consume information and relate back and forth between images as the user makes various analytical choices.

3.3 Summary

In this chapter we studies and analyse the various techniques of data visualization. As data visualization is a vast field so before starting our framework it is mandatory to understand visualization theory. How actually visualization helps real users to demonstrate various facts of collective data. This chapter here analyse the various aspects involved in the study of visualization by providing information and capabilities offered by data visualization techniques. These techniques are further implemented in our work on real visualization framework. From these techniques we are implementing in our framework so that this adaptive framework actually works and provide results to real time users. Further these visualizations are analysed and only those visualizations are added which actually interpret and actual meaning of data sets and which are understandable by human being as these visualization may play important part in decision support system.

CHAPTER 4

PROPOSED ADAPTIVE BASED DATA VISUALIZATION FRAMEWORK

4.1. Introduction

Previously developed visualizations frameworks are capable of producing various data visualizations. These frameworks are designed to produce certain type of charts and visualization, which are able to render data sets into graphical forms. They manage the data sets and are able to visualize them according to the graphs requested or designed by the users to show the end results. As the data sets change, the form of visualization changes as well. Users are able to view only the graphs which are designed to show the results. Later users can switch from one type of visualizations to another type.

An improvement that can be applied to data visualization framework is the behaviour of the system. Adaptive based data visualization is presented in this thesis, which visualizes the data sets and produces the end results which are best served in its class. It is used in the decision support systems, where time critical events are required to view the best results of given data sets, which is best served and chosen by users and adaptively produced. It has already been mentioned in previous chapter that visualization techniques are considered as best way to get results of large number of data sets. Also, this framework is independent component, which can be applied and can be used on numerous systems and is free of specific language requirements.

For this reason, this visualization method shows the adaptivenes and cross platform deployability. Visualization is done on the service layer and top of them. Various questions are asked from users to gather user information and also to gather log of user's time spent on screens. Later these logs are used to produce adaptivenes in the system. There are various approaches and factors which also contribute in adaptivenes of the system. Two dimensional charts are used now to produce visualization but to visualize data sets it can be infinite data sets, which can be visualized on framework rather than doing queries on database. Also all charts are motion charts, which change with time spam. So these charts can also be used as one another dimension i.e. time. The goal of this adaptive data visualization framework is to give the user, which is mainly a decision maker, a better understanding of the data sets, and helps in quick decision making where time critical events are major part of the system.

4.2 Architecture of the Adaptive Data Visualization framework

The deliberations conversed in the previous section let us see the system architecture with the following features:-

- The graph based data visualization platform for representing data bases. This platform is suitable for representing multiple data sets in the graphical form to visualize the data from number sets to certain figures. This platform is independent of backend technology and can be implemented in any system.
- The user adaptation engine is introduced, which is used to deliver the visualization of data sets intelligently, which is best served in its category. This adaptation system is capable of adapting the environment and changes automatically to deliver the user preferred visualization for certain type of data sets.
- There is culture leader’s approach, which enables the system to work independently and intelligently from another sub category of visualization and also this influences the adaptation, according to their culture and behavior.

- This defines two algorithms – One is for adaptation and another is to represent the different visualization of the same data sets to two different users.
- The construction and the management of an effective user model, which allows the system to provide the user with the most appropriate visual representation according to his or her skill and needs.

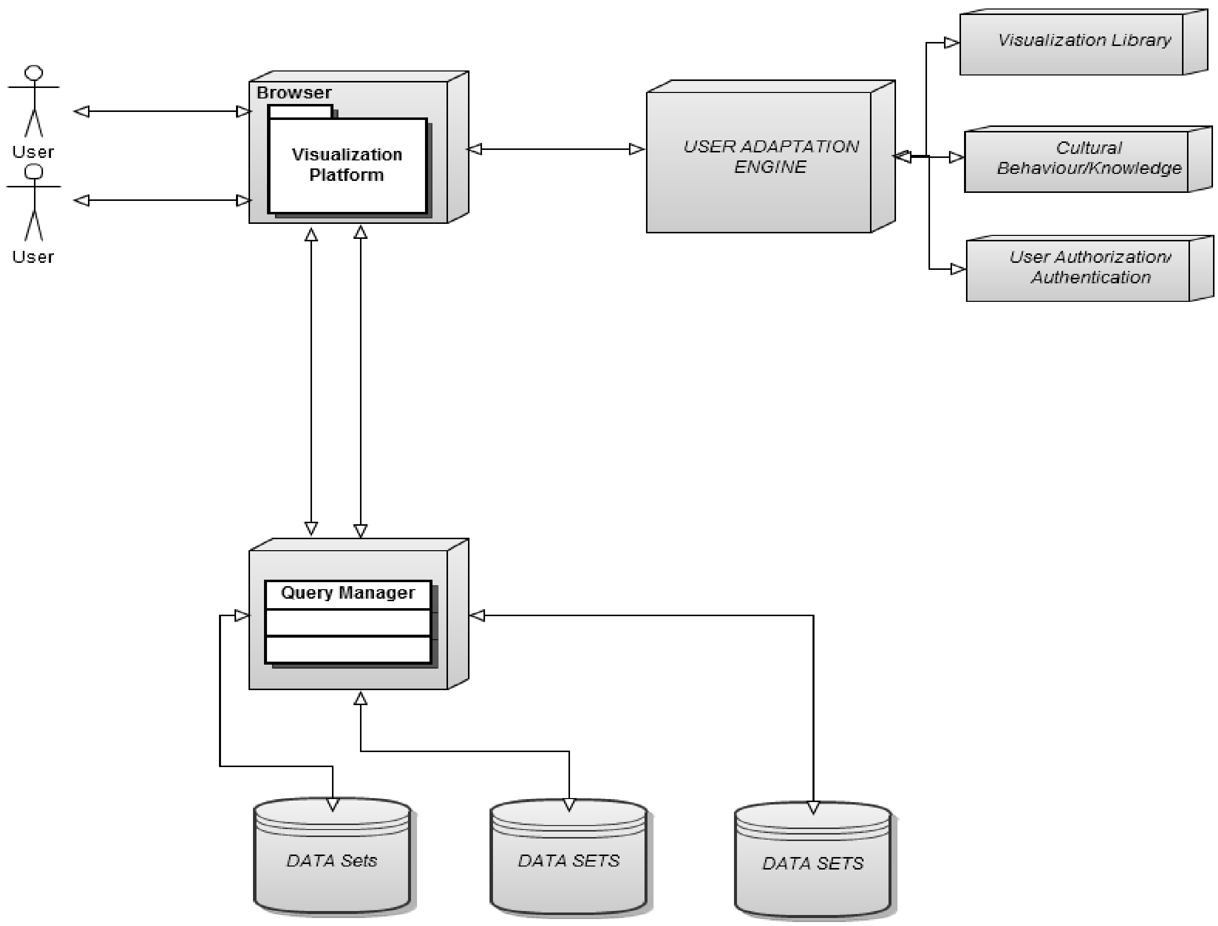


Figure 4.1 Architecture diagram of framework.

4.3 Architecture of system

In Figure 4.1 the architecture of the system is shown, which incorporates Visualization Platform, User Adaptation Engine which incorporates the visualization library, Cultural Behavior/knowledge, User Authorization/Authentication. Also there is a query manager, which is connected to Data sets to retrieve the required information from the data base by running certain queries. User Adaptation Engine is responsible for adapting the user preferences path, as user interacts with the system and updates the adaptive path and serves the best path to other users according to their queries. User Adaptation is intelligent enough to provide the best served visualization to users adapted by users. User adaptation engine uses artificial intelligence by only displaying visualizations according to quality of data, by quality of data means that there is numerous numbers of data sets available, but all of them can't be used in same visualizations so for this user adaptation engine checks which visualizations are best served for given quality of data. Also, User adaptation engine is responsible for recommending users the visualization chosen by expert users or we can say expert users are influence people which can change the adaptation pattern and influence other users by using their intelligence on given queries.

4.4 User Role

Adaptive data visualization framework is designed to work in different organizations of different area of work. Each organization has data integrity policies for different level of users for this user role module is designed in framework. Each level of users has access to visualization according to their role specific needs. Only users with specific permission of visualizations are able to get access to all kind of visualization libraries. Thus it purely works on the role based model, which works as an example for Chart Sets-

All Chart= {A}, Line Chart= {L}, Column Chart= {C}, Bubble Chart= {B}

User X = $\{C\} \cup \{B\}$, User Y= $\{A\} \cap \{C\}$

By introducing user role to our framework, we can easily manage user profile and each user can has special permissions to the visualization as for some user role, they just need single chart type.

Also in our data visualization system each user has different role and user adaptation engine is intelligent enough to capture user personal behavior on same data or can say remember user choices on same kind of data so when query is done on data base, user adaptation engine check about choices of visualizations used by users in previous selections on same kind of data sets and give users that visualizations.

4.5 Data Labeling

Data labeling is defined as labeling of data sets, so that when the data sets are viewed by the end users, they provide the information of data sets in its end value. In the visualization, data is represented in bar, pie charts, bubble charts etc. When end user views the result of end query, data is represented in the form of charts and each user interprets the data in different way. So data labeling is must in the visualization form. In our framework, when user roles over the mouse on the visualization, values of the data is represented with maximum information, which can be delivered to the end user. So data labeling provides all relevant information with other information at the side.

4.6 Query

In the framework, Query builder works with the framework. By running a single query, user can interact with the multiple visualizations. By running a single query that ends up to output as data values, user can see the visualization of a single data set in multiple ways. User need not to run the queries at each time to see the different visualizations.

4.7 Chart Types

There are different types of charts available in the framework. To display the data in multiple forms, different chart types are required. As per the user requirements, Chart types and authentication is provided to the end user. These chart types can be latterly added in the system. Various available chart types, which can be implemented in the system are –Area Charts, Line Charts, Bar Charts, Column Charts, Pie Charts, Bubble Charts, Candle Stick, Multiple Series, Plot Charts, Cascading Column, Multiple Data and HLOC Charts.

4.8 Multi Language Deployments

This Visualization framework can be deployed on multi language frameworks, since this system can be used in number of multi-language computer systems. Proposed system can be enabled to work with java, C++, vb.net etc. as this framework is designed to work cross platform to give visualization without changing any language. Any language can send request to display visualization.

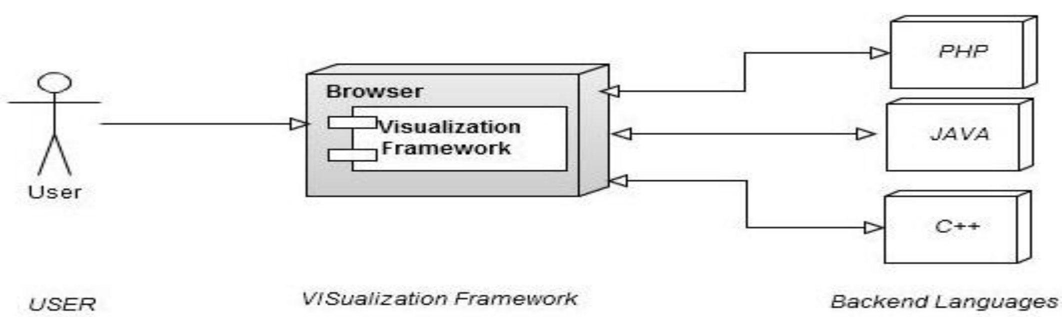


Figure 4.2 Multi language deployment diagram of system.

4.9 A.I. approach

User adaptation engine is responsible for providing adapted results by using artificial intelligence approach. User Adaptation engine capture user's behavior about choices chosen by users on data sets. It capture's and displays same choices of visualization when same kind of data sets are selected. Moreover intelligently it recommends another user's about choices chosen by expert user. Expert users are user's which influence other users; results chosen by those expert users have strong impact in creating some influencing results. Quality of data is also checked and system is optimized to produce only those visualizations which can be best served for given data.

4.10 Proposed Algorithm

```
For Each Query Q is done
Display Results in table T
IF V is essential part of the query
 Call displaychart with V
    t = display V
 Check user Authorization
    t=check user group
 Show All visualizations
 else show authorized visualizations
Check Query name
       t= compare query name in database
IF exists check adaptivenes factor A
Display result with max A
ELSE Check Table name elements
      t= check table name elements in query table
 IF exists check adaptivenes factor A
Display result with max A
      t=display result with maximum adaptivenes factor
ELSE  Check user recent charts
Display result with max viewed
Else Display default
LOG user data
       t=createlogs of user session
with time t max(t) and min (t)
with selection of chart for given query Q
Update Adaptivenes factor A for given query Q
```

Figure 4.3 Algorithm of working of framework

4.11 Explanation of Algorithm

Below is the explanation of the above algorithmic steps. The following cases may happen in the system.

a. For every query, Q done on the database system with certain attributes
b. Query display results in tables T with row and columns.
c. If there is need to visualize the query results where it is essential part of the query, then call function display chart. Task is to display result in visualization form.
d. Now check authorization if user is authorized to view all charts or certain specific charts. Call function to check user group.
e. Now check Query Name if same name appears in data base system
f. If there is same name, then check for adaptivenes factor
g. For Maximum adaptivenes factor, display chart type, which has maximum adaptivenes
h. If there is no adaptivenes factor, then program logic checks for recent charts viewed by users and its intelligence factor checks what kind of charts user like.
i. If there is no previous history, then it displays default chart.
j. Now logging is done, which records users time, choices and update adaptivenes factor.

4.12 Summary

In this chapter our proposed system is introduced. Our first goal is to make architecture of system, as we had earlier studied about various adaptive frameworks and visualization of data sets. Now our primary goal is to make a framework primarily for decision support system which is able to deliver data visualization by using adaptive technologies. Architecture of proposed framework is introduced which has capability of producing different types of chart for different role in system with enhanced options of inbuilt query module and data labelling also which works with Artificial Intelligence and can be deployed on multiple platform to produce adaptive results of data visualization. Later algorithm for this is introduced in chapter which explains step by step details of working. This chapter explains the technical details and design of architecture further based on this actual implementation is done which is explained in next chapter along with details of usability testing.

CHAPTER 5

IMPLEMENTATION AND USABILITY STUDY

5.1. Implementation

In this thesis for development, 'Eclipse editor' was used for design and development of chart component. All chart components uses Flex engine which is open source software. Script used was Macromedia Flex Markup Language also known as MXML and Action Script 3 for User Interface and chart logic. All Data visualization charts including Line, Bar, Pie, Bubble and Plot were custom developed using Action Script 3 and MXML and no third party API was used. Project source code can be opened and debug, using Adobe Flex Builder or Eclipse Editor. Mainly two types of source files exist in flex project (1) MXML (2) AS and compiled file is flash SWF which runs on flash player plug in installed on web browser or machine. As this is language free framework, it means it can be used anywhere with any backend language. Thus it has its own Data base and adaptation components which are independent in nature. So to start working of this component, xml data structure is required, which feeds chart components, following which it starts working on its own.

Chart component starts with loading an XML feed using action script. On the completion of XML loading, XML parsing is done for storing XML data into action script objects/collections, which serves as data provider for all the charts. Animation effects are implemented on loading data into the charts for chart's smooth drawing. On right side of the chart area, a list of category is displayed with corresponding chart category color. A collection of options is displayed on both the axes for selecting different data axis/parameter for charts. When chart display is done, user is asked randomly for the input on certain query visualization, which is then saved and it logs data for adaptation purposes. Initially, adaptation for all charts and system is zero but as the user interacts with system, adaptation starts logging data which is saved in data base files. Later these data base files are used for Artificial Intelligence purposes to display the best served charts for given queries.

Main starting file is: DevChartComp.mxml and it starts with <application> tag. This is first tag or file which gets executed as visualization start point. On initialization of Application, "initialize" event gets fired and we call an action script function ('appInit()') on this event to load the XML feed. As this event is initialized, it starts loading all sorted data from XML files. On XML loading, complete application calls a function "loadDataComplete". At this point, application is done with data loading followed by XML parsing to store data into action script objects using function "mXMLToObject". Once application is done with UI design components rendering a creation, complete event gets fired and app calls another function "mInit". Basic styling of components is done in this function, and this function ensures all the UI components rendering and data assignment to them, no more loading is pending by this stage.

In MXML code, we have used a Tab Navigator control to create the Tabs view of different charts

The first component i.e Line charts, gets displayed by default. Every chart has a property "dataSet", which serves as data provider to that chart and is bounded to the data source i.e. "valueObj".

On both sides of the chart axis, we have used a combo box control, which provides the option to switch the data category for that axis. Whenever user makes any selection in combo box, the "change" event of that combo box gets triggered and we call custom functions "updateXAxis()" and "updateYAxis()" for respective combo box controls. These corresponding functions are used to refresh the chart components for new data set. Every chart component has a function “onCreationComplete()”; this is used to create the corresponding custom chart and data assignment. On the right side of the chart component, we have a Legend control used to display the List of categories. To control the animation effect speed of charts, we have a horizontal slider, where user can set the animation speed from 1 to 10 seconds.

All the charts are custom dynamic charts, created using Action Script 3 based on data coming from XML. Every chart is having a custom tool tip box to accommodate the additional information related to any data point of the chart.

All these charts are extended controls of basic chart controls provided by Adobe flex SDK, which are customized using action script as per requirements.

Now comes the adaptation part, in which, user is asked randomly to give views and ranking for each chart, when each one of them is being displayed. Also time spent on each chart is being logged. In this way, we get data and save data in db file for each chart. Later when same type of queries is done, our program logic checks which chart has largest adaptive values. If it finds it, then that chart is displayed first but if not, it logically checks various factors such as the user’s preferences for last time, what type of charts the user likes the most and also the other elements in charts tables to ensure chart display according to data quality.

5.2. Usability Study

Usability is a quality characteristic, which evaluates some main attributes during software development process. It is believed that usability attributes are some accurate and measureable components of an abstract concept, which is usability [14]. These attributes are:

- Learn ability - How quickly and easily users can perform a productive work with a new system and how easily they can remember the way the system operates after not using the system for a while.

- Efficiency – The number of tasks which can be done by the user in a specific time interval.
- Reliability – The error rate using the system and time it takes to recover from the errors.
- Satisfaction – The level of user satisfaction after working with the system.

The way these attributes can be measured is by observing the users, while they are working with the system and have an interview with them after they accomplish a task with the system [14].

In issues that human interacts with technology, the analytical research paradigm is not sufficient. Therefore, empirical studies in software engineering are getting more acceptable continuously [15]. Usability is about how the system interacts with the user [16]. Usability engineering defines the final usability level and ensures that the software under usability testing reaches that level [16].

Usability study can be done by different methods. These methods are divided in two general groups as empirical and analytical methods. In the projects in which human interacts with machines, empirical studies are very useful [15]. On the other hand, analytical studies can give early feedback about the design of the interactive system to software testers. Analytic method consists of two classes of methods, which are usability inspection and cognitive walkthroughs. Usability inspection, involves systematic inspection of the design by means of some factors for a practical, good design.

One example of usability inspection method is heuristic evaluation, which is an informal usability testing method. In this method, based on general-purpose design guidelines, the evaluator inspects the proposed design in order to check whether the usability principals have been followed in the design [17].

In [17] nine heuristics are proposed: simple and natural dialogue, speak the user's language, minimise user memory load, be consistent; provide feedback; provide clearly marked exits; provide short cuts; good error messages, and prevent errors.

The other method, which is the cognitive walkthroughs, uses more explicit, detailed procedure and conducts a more work-based usability analysis by testing real users when faced with the system. It analyzes the quality of the interface in directing the user to accomplish a task by asking three simple questions: Will the correct action be made sufficiently evident to users?, Will users connect the correct action's description with what they are trying to achieve?; Will users interpret the system's response to the chosen action correctly?. Whenever there is a "no" answer to any of these questions, problems may occur [17].

There is a usability engineering model presented by 'Gould and Lewis' and is called "famous rules". The rules included in it are: early focus on users, user participation in the design, coordination of the different parts of the interface, empirical user testing and iterative revision of designs based on the test results [18].

For usability engineering, there is a term called usability engineering life cycle, which not only means how the current interface design is satisfying but also whether it is modifiable for future interface. This life cycle has three stages as follows:

5.2.1 Predesigned Stage

The main goal of this step is to know about the target user and the task he is going to accomplish. The more it is done in this stage; it would be more cost effective for the whole testing because most probably the number of changes that should be done in the future will be reduced.

1. Early focus on the user: The first step in usability testing is to know about the user and their exact needs from the system. For an example, knowing about user's work experience, educational level, age, level of computer experience will help to anticipate user's problems and consequently will help to design a better interface with considering user's learning difficulties. Also, the weaknesses of the current system should be discovered. It should be clear that in the current system, what obstacles the user has on his way to achieve his goals, or what is making the user to spend lots of time or makes the user uncomfortable with the system.
2. Setting usability goals: In usability testing, the four usability characteristics should be met. Obviously for each system, the priority of each characteristic would be different. But on the whole because all of them are related, getting a good result in any of them can be satisfying.

5.2.2 Design Stage

The main goal of this phase is to reach a useable implementation that is suitable to be released. For this reason first, based on the usability principles, we have to provide a prototype of the final system and then test the prototype system with real users to make sure the design will meet our goal.

1. User participation in the design.
2. Coordination of the different parts of the interface

3. Empirical user testing: This step is very beneficial and it has two basic forms. The first one, which is mostly quantitative, will check if the usability goal has been achieved or not and the second one, which is more qualitative, will seek the reason of the parts of the interface, which are wrong and the amount of their wrongness will be figured out. Different testing methods can be used in this step, like user observation while working with the system and asking questions from the user about his experience with the system.
4. Iterative revision of design based on the test results: Based on the empirical testing stage, we can redesign the interface and again do the testing on the new interface.

5.2.3 Post design Stage

This stage is the follow up study of product used in the field. The same task, which is done in design stage, which was revising the design and retesting it repeatedly, can be done with the final product with considering the final product as a prototype of future products [19].

5.3. Proposed Usability Testing Method

Based on what is discussed in usability section of this research, survey was provided to users. In which, both analytical and empirical testing was conducted in this thesis. For analytical testing, a combination of usability inspection and cognitive walkthroughs methods were used along with famous rules, as much as it was applicable and practicable with the available feasibilities, in different phases of designing the system. The main focus was on meeting usability attributes, as much as possible, in the visualization framework.

The data visualization system modified by applying relevant queries of data sets. These Queries already done on data sets and final results of data sets then visualized in our framework. User in the system could view query and results. All results are then visualized, from which user can select the various available visualizations. As users view the results, they are able to give there feedbacks from which adaptation part starts. Next time, result based on that query is shown to the users, which are previously selected as best by the users. To inspect, all data is logged in the system and this data is then used to gather results in different forms. Around 10 queries are done on different forms of data sets. These queries first display results in the form of line charts as a default and after system get adapted, we are able to see different chart for different queries as a default chart. Logged data is then used to get the results as at certain time interval, users like the same result of the particular query. Users' comments are logged to get more outputs. This study gathers the facts about user to reach certain decision in decision support system by just seeing our visualization framework. By seeing certain output of visualizations, which is best served in for given query user can reach certain decisions which are involved in the time critical events.

For the empirical testing, both systems were tested by users from both, computer science and business departments. A questionnaire was provided to the users for asking their idea about the system for both improving the user interface usability and comparing the visualization system with the simple data result system. Also, in some special cases the idea of some of the users with high experience in software development were asked and applied to the system as much as applicable.

CHAPTER 6

RESULTS

Our Data Visualization system was subjected to usability evaluation by two groups of users with varying levels of data analysis and computer expertise. The first group included 20 students with very little experience in using decision support systems but good in data evaluation skills from business department. The second group consisted of 50 computer science students. It was assumed that in general, computer science students will have a higher experience in using data visualization software/tools than business students, who are not expected to have any, or very little, experience with this field.

	Computer Students	Business Students
	Visualized system	Visualized system
Undergrad (1st yr)	3	1
Undergrad (2nd yr)	9	2
Undergrad (3rd yr)	4	6
Undergrad (4th yr)	4	10
Master's	24	1
PhD	6	0

Table 6.1 – Distribution of participants in the test according to their academic level

6.1. Description of framework to users

The order of the tasks that participants were asked to do is as follows. First, they were asked to go through a brief description of adaptive data visualization system. Participant can understand visualization framework. They were given brief introduction of adaptive part as to how system gets adaptive when users use the system Also they were given survey detail about how the survey is designed for measuring history, experiences and satisfaction of users in decision support system. There were around 10 queries of different data sets which were almost done on around different unique data bases and mostly were from the data sets of Canada statistics [20]. These query results were then visualized using our adaptive data visualization tool. Adaptive data visualization tool visualized all query results in different kinds of charts. User could explore different types of charts and could choose the best result, give like and dislike. Also time spent on each chart was logged. In each query, brief introduction about query was given and also to log data, questions were asked so that user could read data sets and could think and answer on same questions asked. The answers provided were also logged. Survey was done after one question and another and all data was logged and saved. At starting level of survey, all charts were set to simple line charts. As users used system and gave their feedbacks, system got adaptive and displayed result chosen by users and which served best in their class. Because decision support systems can be used in different domain and in different level of expertise area these system has different results in different studies and surveys.

6.2. Requested Task

After description of framework, users started their survey. They were given a survey tool, which consisted of different queries in different fields. Users started using survey and answered one query after another. There was only one query in one page. User, who was testing data visualization tool, was provided with the details of all data sets already. In some queries, users were asked to choose which visualization provides best view of data sets according to comparison of two data in same visualization. And in some, users provided their opinion on alarming factors on all of the query sets. As in considering decision support system queries are served like to reach certain decisions by just viewing visualization. User was supposed to give their opinion on different visualization for same query in ratings. All ratings were done in providing stars from 1 star to 5 stars. Also there were likes and dislike buttons to provide user opinions. All users were also provided to give their special opinion on queries like in comments forms. As users logged in the system, their time was also logged apart from how much time user spent on each query to reach certain decisions? These logged data can further be used to study purpose.

Each query displays different results. These results, which were automated in graphical form, provided users a clear view of data sets as to what is required to reach certain decisions. There were tasks which required user to explore different visualization and choose the best served visualization for the given query, which was already done on the datasets. Users could also provide their comments and notes if their satisfaction level was not achieved.

The start time was recorded for each user, once he/she started to work with the system and the end time was noted as soon as the user was done with choosing all the requested requirements and dropping the rest of the variable requirements. The duration of the time the user spent to finish the tasks with the system was calculated in order to investigate, on average, how long it takes for the users to finish the task. This time will be needed to compute the efficiency of the system, which is about the number of the tasks that can be done by the user in a time interval at starting and how the time interval increases or decreases as the system gets adapted and it is one of the main factors in usability testing.

By having the adaptive and other results of the study for adaptive data visualization, these two systems, one with adapted path and other without adaptive, could be compared from efficiency and error-rate perspectives. In order to calculate other factors in usability study, such as learning ability, efficiency and user satisfaction, the participants were asked to fill up a questionnaire and according to their answers, other usability factors were analysed.

6.3 Time

A study on what users have done on the start of survey to end of survey was conducted for the measured time of the adapted data visualization framework to normal data visualization framework group.

For the two different groups, one for computer science and another one for business students, data were logged, in order to record time taken by users to complete the requested survey. At starting, the system adaptation level was zero and by default it showed same charts for all queries. User took time to choose best results for query but, as we saw, after interval of time as system showed adaptation results as it got adapted, it displayed the best result for given query, so the time taken to solve query got less.

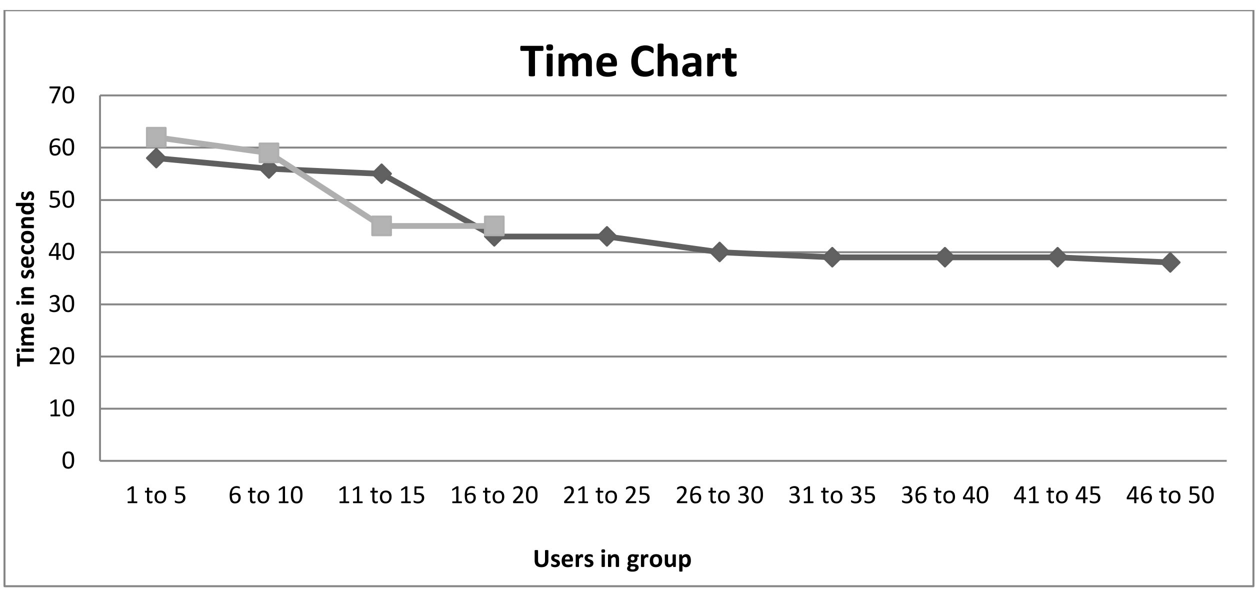


Figure 6.1 Average times taken to complete a query

Here in figure 6.1, average time taken to complete a query by two groups i.e. business and computer science is plotted. In X axis, there is query groups. We divide query groups in range of 1-5 and their mean time is plotted, whereas Y axis describes time in interval of seconds. So for choosing best visualization, first user group from computer science i.e. 1-5 has taken 58 seconds i.e. mean time for all 5 users and second group i.e. business students have taken 62 seconds. All graphs are plotted by mean time of each group against the each group.

As we analyze graph, we see that at starting, computer science students take more than 50 seconds but as the system gets adapted and it shows results of adapted path, the user can see best results of given query time limit decreases from range of 50 seconds to 40 seconds and after certain queries, it remains same in between the range of 35-40 seconds. While in business students, it starts from 62 seconds and decreases to range of 45 seconds, however it takes less time to come in this range. As in this group, there are only 15 students and business students are better in statistical analysis as compared to computer science students

So above results predicts that adapted data visualization framework is considered as important tool in decision making. As we have seen that with passage of time, system becomes more adapted and decreases time to solve certain queries.

6.4 Adaptation

Adaptation is defined as the adapted path by system. With the passage of time, we can see all systems got adapted. In usability testing, it is important to get results of adapted system as starting system is neutral state but with a passage of time, when the user interacts with system, the system itself captures certain behaviours and also users provide their input to system. All behaviours are captured in adaptation engine. We can see that in given chart at starting adaptation level is 0. Each user interacts with system and provides its feedback. Bubble chart is ranked on top as most of users choose bubble chart visualization best for that query. Also second chart i.e. is best suited for this query is bar chart. Adaptation factor for bubble chart is around 20 and for bar chart is 13 and for both pie and line chart is 9. When adaptive results of one query are compared with same type of queries, we see that user's preferences get certain path and as system gets adapted, this path is followed.

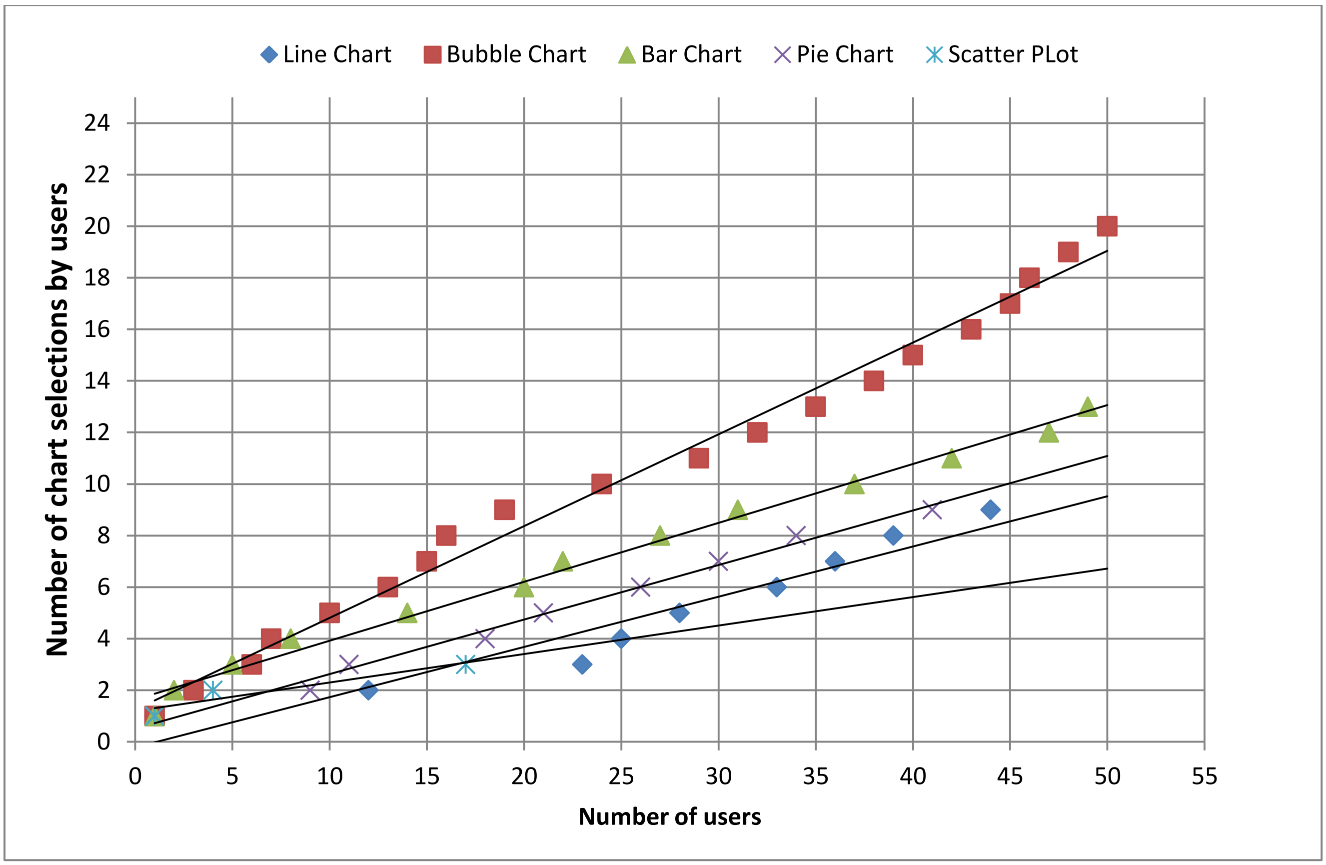


Figure 6.2 Adaptability factor of query

This usability provides a path for future adaptive system developments. As all the data are logged, these results are further used to demonstrate and reuse these results to provide users best suited visualization of specific domain in visualization systems.

6.5. Questionnaire

The questions of the questionnaire were designed to address the main factors of usability, which were learning ability, efficiency, error rate and satisfaction. In this part of the thesis, each question and the purpose of designing them for evaluating each factor was discussed and all the results gained from the users' opinions were evaluated.

6.5.1. Learning ability

The first two questions were aimed to evaluate learning ability of the systems. As it was mentioned before, learning ability is about how fast and easy users can work with a new system for the first time. This factor can address easiness of the system based on user's opinion as well as the user's opinion about his/her understanding of the system.

6.5.1.1. Easiness

In the first question, users were asked to rank the level of easiness of working with the system based on their experience. The answer of the users to this question represented their personal impression about their experience of working with the system. In figure 6.3 it can be seen that average easiness point for first computer science group, which we categorised as first 25 participants, which is 5.9 out of 10, is lower than average point for the second group i.e. 26-50 participants, which is 7.8. This is also confirmed by the higher average score acquired from second business group that is 6.72 and is 0.89 higher than the average for first group 5.83. This confirms that as system got adapted, easiness increased and the user found adapted system easier.

In Figure 6.3, average easiness points have been categorized for the business students and computer science students groups. On the whole, on average easiness score given by group B for both computers and business students were higher than the score and the suggested easiness rank by all the users from group A. However, in Group A, although the average score attained from computer science group, which is 5.9, is higher than business students group's score, which is 5.83, the business students gave a lower easiness point than computer science students. This difference can either be related to the unequal number of participants from each field or it can be because of difference in educational background of participants that can give them various standards for defining easiness.

In case of graphical interface group, both the average score and average easiness point for computer science student is higher than business students.

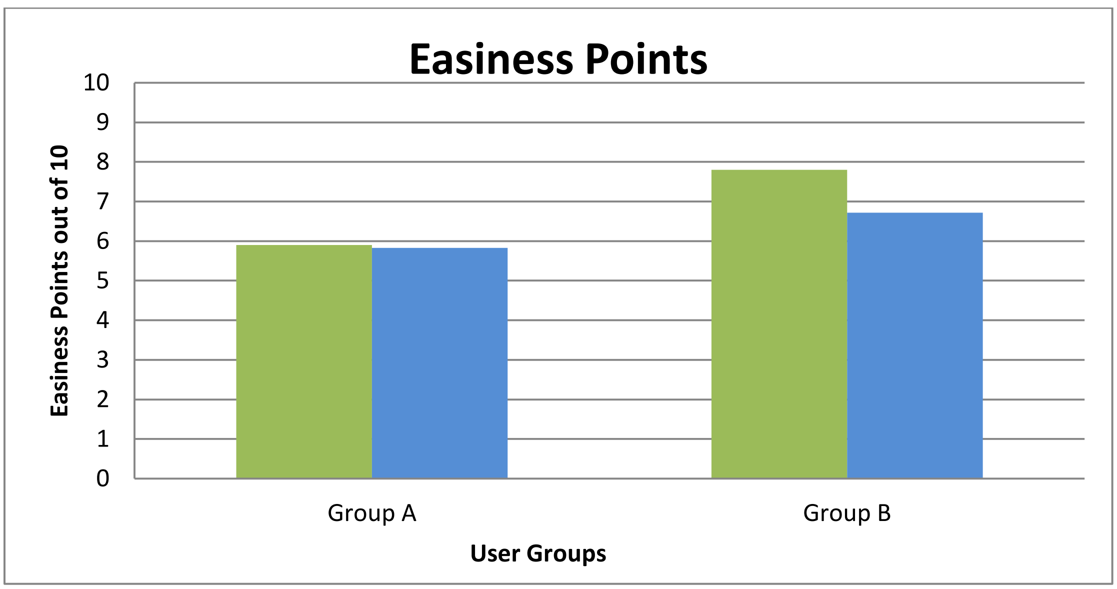


Figure 6.3 - Comparison of average Easiness point of different groups

6.5.1.2 Understandability

Understandability is another factor that was evaluated in this study. Users were asked to rank their understanding of the system from 1 to 10. Since this point was given to the users by their own, we needed to modify this rank based on how successful they did the tasks and how fast they finished the tasks. Therefore, the following formula (1), which satisfies these needs, was suggested by Han X. Lin [21].

$$\text{Understanding(U)} = \frac{\text{User\_rank} \times \text{Score}}{\text{Time}} \qquad \text{Formula (1)}$$

In this formula, score represents how successful users were in performing the tasks. Therefore a high score shows the subject who had better performance (picked and abandoned correct requirements in less time) and understood the systems better and therefore his suggested score for his understanding is more valid and would have a higher weight and vice versa.

In Figure 6.4 a comparison between Understandability and easiness values has been made. It can be seen that Understandability value, in Group B is higher than in Group A for both user groups from computer department and business department.

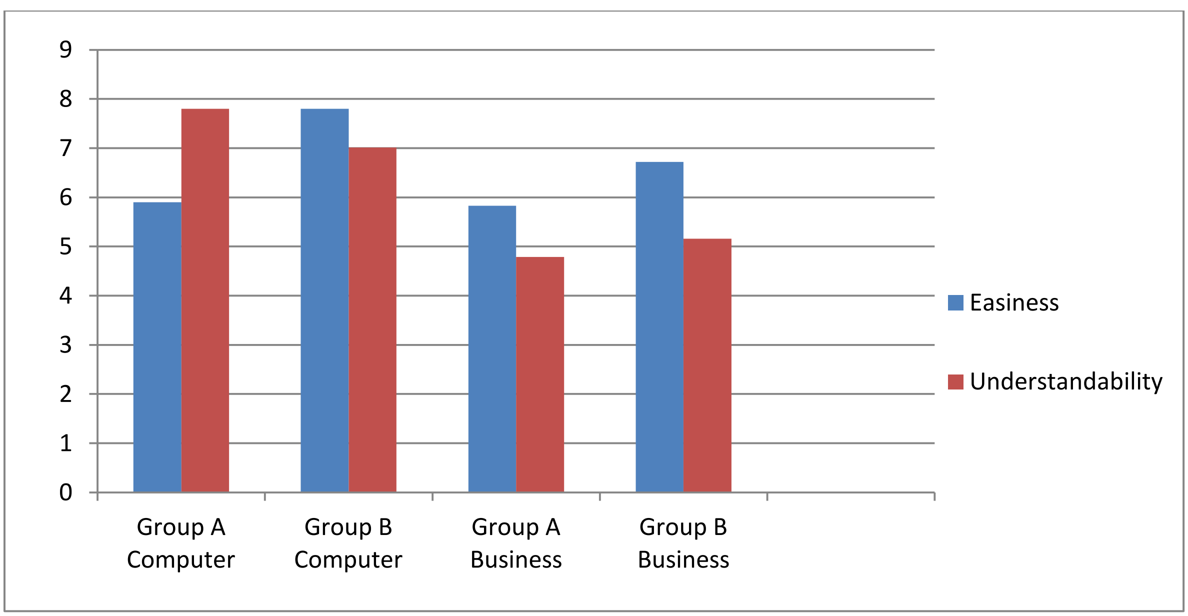


Figure 6.4 – Comparison of Easiness point to the estimated Understandability point

Also, as was mentioned before, the easiness factor for Group B was higher than Group A. Since both easiness and Understandability for Group B was higher than Group A, it can be concluded that learn ability of Group B is higher for both computer users and business users.

	Group A Computer	Group B Computer	Group A Business	Group B Business
Easiness	5.9/10	7.8/10	5.83/10	6.72/10
Understandability	3.85 U	7.01 U	4.79 U	5.16 U

Table 6.2 – Easiness and understanding points for different groups

6.5.2. Efficiency

As it is mentioned before, efficiency factor represents number of tasks that can be done by a user in a specific time unit. Thus efficiency can be calculated from dividing score by the time users need to complete the tasks. It should be noted that score is calculated based on number of tasks users have done successfully.

As it can be seen in Figure 6.5, average of efficiency in Group B is 0.78, whereas in Group A average is 0.54. In other words, efficiency in Group B is about 0.24 higher than efficiency in Group A, which means, in the same time unit, users can perform 40% more tasks correctly when users use adapted system then normal system.

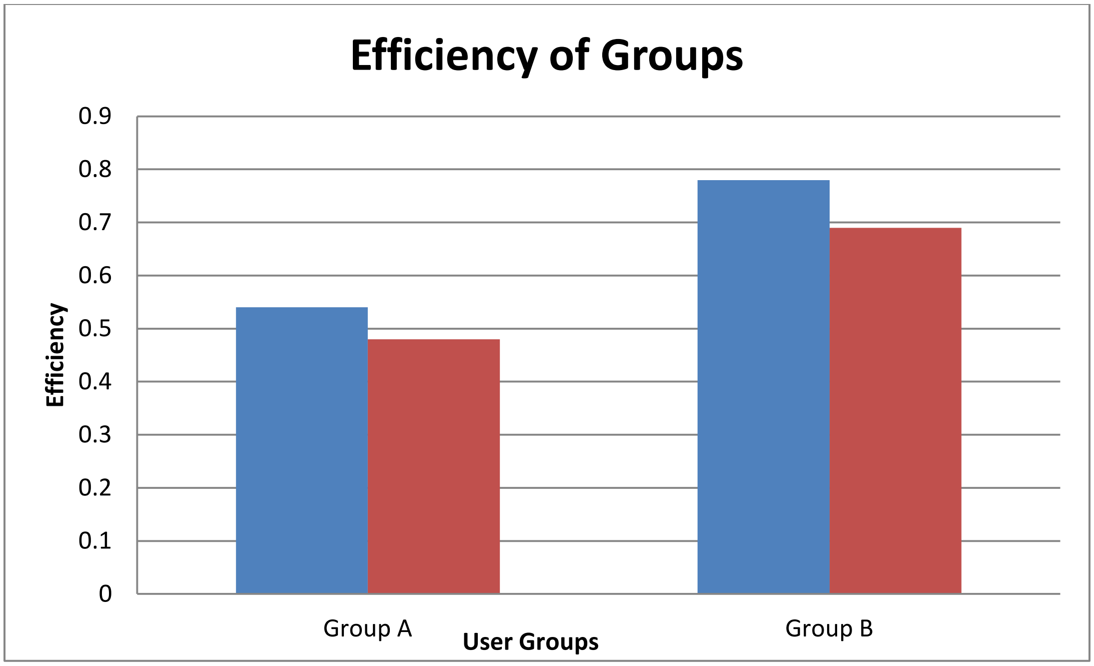


Figure 6.5 – Comparison of Efficiency between different groups

In Figure 6.5, efficiency for different users based on their level of expertise in computer issues, is categorized into four groups. By looking at the figure, it can be seen that efficiency of the users who used adapted system, no matter whether they were from computer department or business department, is higher than users who used normal interface. In particular, efficiency of computer students who used adapted system is higher than other users.

By looking at this factor, we can conclude that having an adapted data visualization framework helps users work with the system faster and more accurately.

6.5.3 User Satisfaction

The last usability factor, which was evaluated in the study, was user satisfaction. One of the questions in the questionnaires was designed to evaluate the overall satisfaction of the user of working with each system. In this question, all the participants were asked to score their overall satisfaction of the system out of 10. The results were as follows.

The average scores of the computer students' Group A was 6.35. This score increases to 8.2 for the business students who worked with the same system. For the system with Group B, computer students were 8.1 satisfied while business students' satisfaction level was 8.55. These statistics are illustrated in Figure 6.6. Overall, all users of Group A system gave the score of 7.27 to their satisfaction of the system and users of the Group B system determined their level of with the score 8.32 out of 10.

Figure 6.6 - User overall satisfaction of the system for different groups

In comparing the two systems, overall, the participants of the Group B i.e. Adapted Visualization system were more satisfied than the participants of Group A i.e. classic visualization system.

On average, the score of user satisfaction for business students who worked with the Adapted System was higher than the business students who worked with Non Adapted System.

In order to demonstrate the claim that the chosen adapted data visualization system enhances the interface of the simple visualization system in different ways, other than the questions about usability factors, some other questions were added in the questionnaires, such as users' opinions about what changes can be done in each system and the necessity of visualization for them etc. These questions are discussed as follows below.

6.6. Necessity

One of the important questions was "Do you think that Adapted Visualization is necessary for visualization framework?" This question was only asked of the students who worked with the adapted visualized system. Basically, this question can show whether users found the adapted system is useful and adaptability increase their efficiency. The answer options for this question were: necessary, no difference and not necessary. Overall, 77 percent of students think it is necessary and 13 percent of students think it makes no difference if it is adapted or not, and only 10 percent thinks that adaptation is not necessary.

So it is clear that more students feel the system should be necessary and adaptation overall increases their performance and understanding.

6.7 Problems

In the questionnaire there is a multiple-choice question for the students who worked with this system, which gives the users the option to add their opinion about the problems that the system has. The three options that were very noticeable, based on the usability standards for designing user interface, were given as options to the users and they were also asked to add their own opinion if they find more problems in the system. The options given to them were as follows:

(a) Need more data visualization techniques and attributes.

(b) Improper data visualization of given queries and is not understandable.

(c) System is not in adapted state.

(d) Trend view of data required.

Between these three choices, the percentage of Group A computer students who selected choice “a” was 30%. 20% agreed to choice “b” and 56% choice “c” and 38 %. Between business students, choice “a” was chosen by 24% of the participants, choice “b” by 20%, choice “c” by 48% and choice “d” by 48% of them.

For Group B, between these three choices, the percentage of Group B computer students who selected choice “a” was 32%. 19% agreed to choice “b” and 26% choice “c” and 32 %. Between business students, choice “a” was chosen by 22% of the participants, choice “b” by 23%, choice “c” by 34% and choice “d” by 43% of them.

Some participants added their own ideas about the system. Some of the added comments were as follows:

- Option for to display adapted result or not?
- Option to view more details of data.
- Confusion in some data values.
- Should have Audio option.
- Smooth visualization.

CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1. Conclusion

In this research, a study was carried out to conclude that when the adapted data visualization technique and further enhancements are applied on the simple data visualization system, it gives better understanding to users of the data sets and reduces the time and effort they need to spend on eliciting desired requirements. This research has been accomplished in a number of steps. Initially, the previous available adapted and visualization system were studied and based on basic concepts in design of that system, the most suitable adapted data visualization framework from both semantic and usability points of view were designed and implemented. Furthermore, a usability study was conducted on a group of students with different academic backgrounds to justify that the proposed design can positively improve the usability of the adapted data visualization system.

The results of the study show that overall users had a positive opinion about using adaptive data visualization framework. When certain parameters are evaluated we claim certain results based on usability testing of the framework which are:

1. We first proposed the concept of introducing adaptability approach to enrich the data visualization framework which can render a range of data visualizations best suited for given quality of data. Our framework is able to produce adaptive multi coloured visualizations results which is implemented and tested on LHIN.

2. The framework is capable to support multi language deployment and able to produce same quality results in all platforms.

3. We performed usability test of our framework and thereby provided a benchmark for comparison against future improvements.
4. The prototype framework itself can serve as a research platform to support future research. .

The detailed impact of work includes:

- **Time** Our adaptive data visualization framework increase productivity by displaying adaptive results of queries where data visualization is essential part of the query. In usability testing we have seen that there is decrease in average time to solve query when compared to non adaptive data visualization system. Hence this will become important decision making tool in time critical events.
- **Adaptivenes** From results it is concluded that by repeated use of our adaptive data visualization system it starts displaying adaptive path for queries done. Adaptivenes is important factor for future adaptive system developments. As all the data are logged, these results are further used to demonstrate and reuse these results to provide users best suited visualization of specific domain in visualization systems. In usability test we have seen as system got adapted there is certain trend for one type of visualization.
- **User Satisfaction** User satisfaction of our framework increases the efficiency of work by providing users more satisfaction when compared to simple visualization systems. In usability test we have seen that understandability of data interpreter increases efficiently and user find it easier to understand when compared to non adaptive visualization system.

Although our work is still preliminary, the prototype framework can be used to support and conduct further research, and provide benchmarks and new research hot spots. In the end, our work will impact the way applications are constructed to utilize adaptation technology, and provide data visualization application developers with more options to designing and manage their applications.

The proposed framework is adaptive in nature, which can be used independently of any another block to increase the user experience, and also contributes in the field of decision making by providing direct evidence suitable for validating strategies for further, intelligence based, prediction and automation of user intention.

7.2. Future Work

Despite the fact that the adapted data visualization improved the usability and quality of the data visualization systems, the results of the usability study show that there is still a lot of scope for improvement. In fact, the proposed framework can be considered as an early attempt of adaptation exclusively in the field of data visualization, future work will need to be fulfilled from the following aspects:

1. **Adaptation:** Currently adaptation is working using weighting scheme which intelligently capture previous selections and preferences but this can be replaced with Artificial Intelligence algorithms which captures personal behaviours and overall view and produce adapted results according to previous user behaviours. Also one another factor is the quality of data that can be considered to choose specific data visualization techniques, which can also be influenced by specific users and satisfaction of the users can be achieved. This may be expressed as Adaptation (A).

   $\mathbf{A = S + Q + I}$ where S=satisfaction, Q= quality of data, I=influence

2. **Visualizations:** Currently visualization platform only produces 5 types of visualizations, but this platform is designed to support multiple types of visualizations. As action script is used to design the entire platform so these actions can be used to produce variety type of visualizations just in one screen with more than 6 dimensions of data. Currently all visualizations are produced with smooth motions and these motions can be used as another dimension which is time.
3. **Handheld device integrations:** Our platform is tested on android platform and produce quality of visualizations but in some platforms where flash files are not permitted certain mobile apps can be designed with same action script.

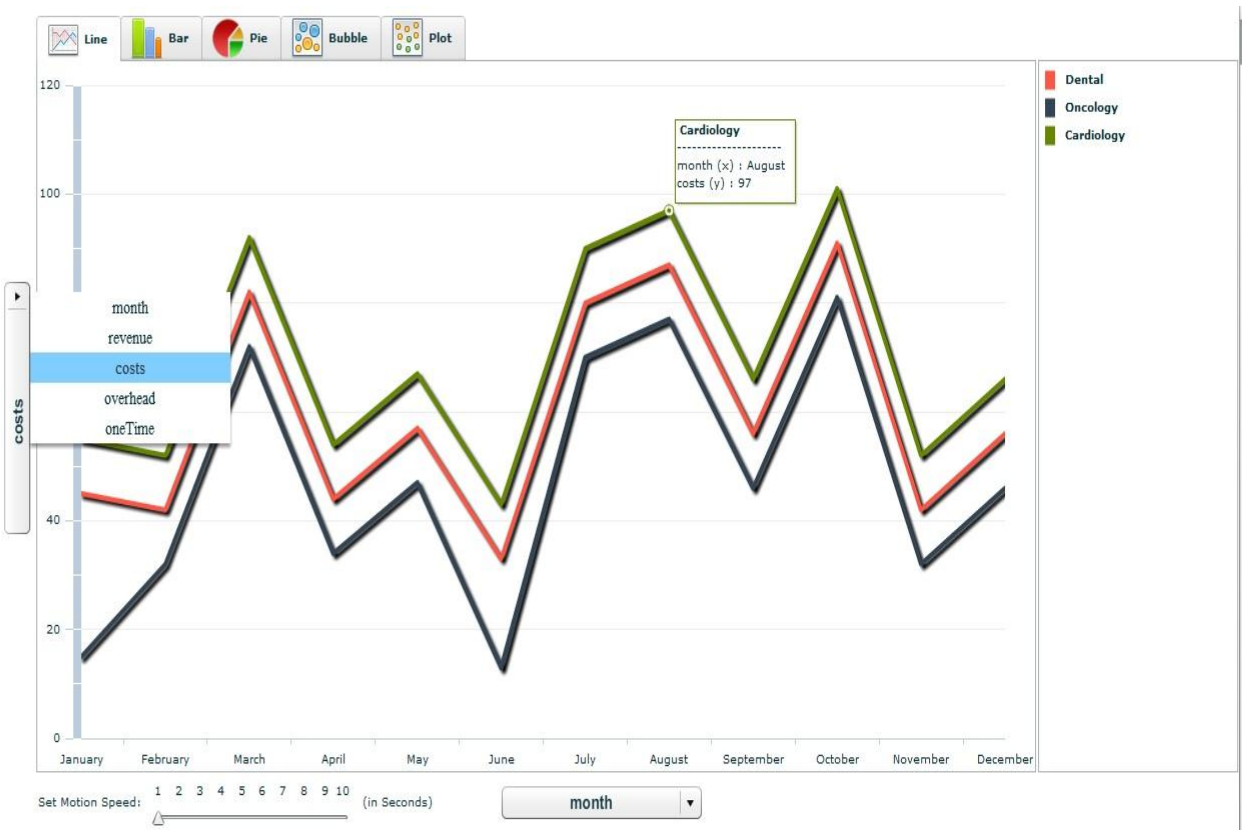
APPENDICES

Appendix A

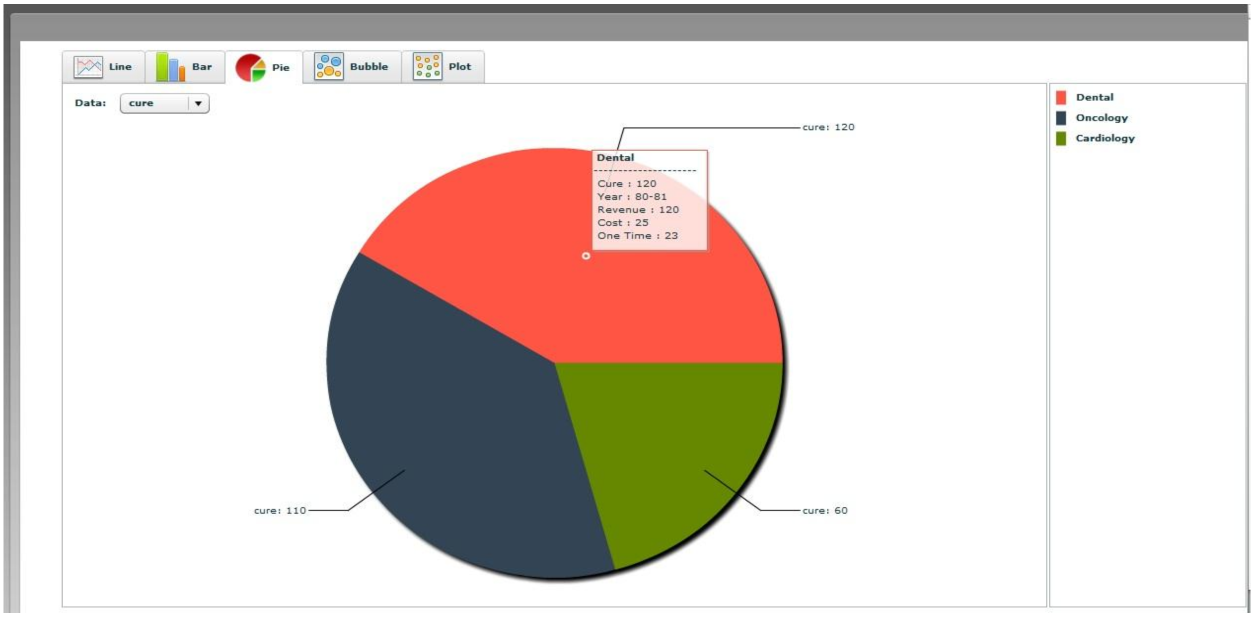
Data Visualization Framework

The following figures illustrate the data visualization framework, which were designed and tested before integration on query builder.

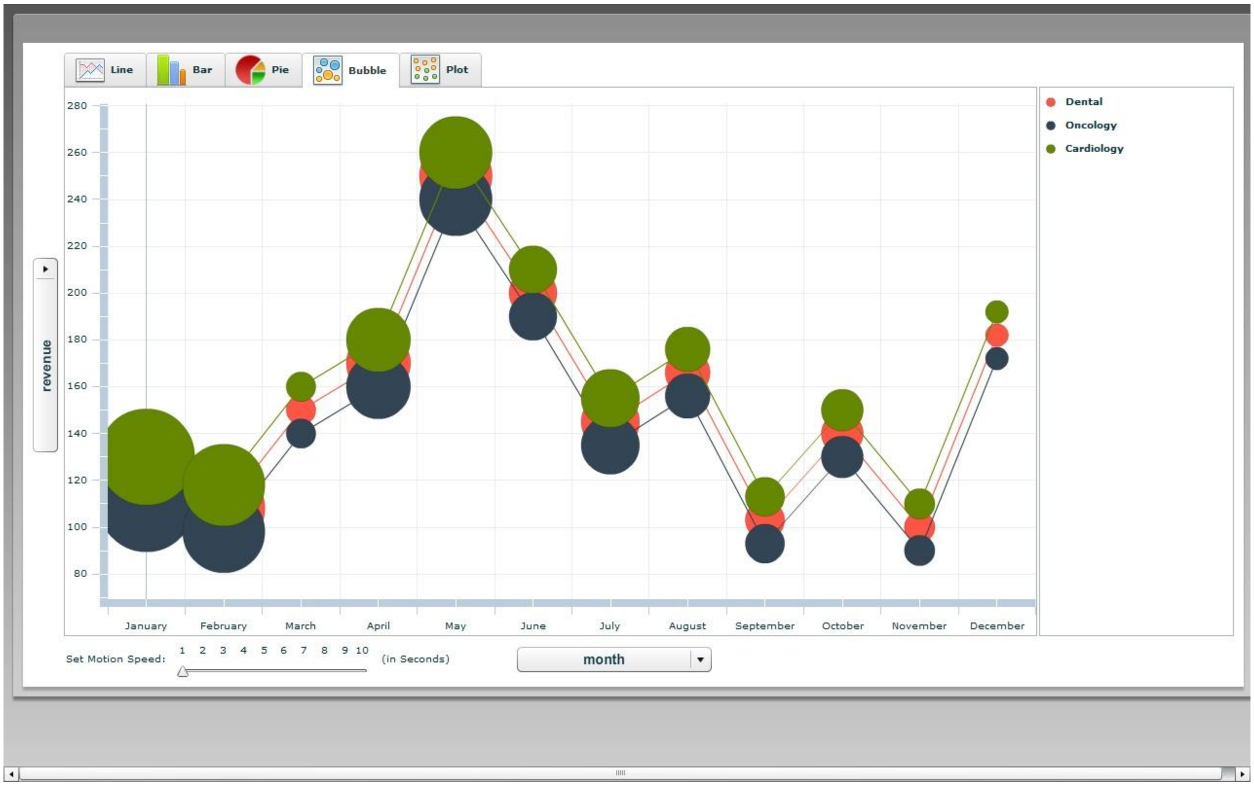
Line charts with drop down option to select different column



Bar Chart with mouse rollover display of data



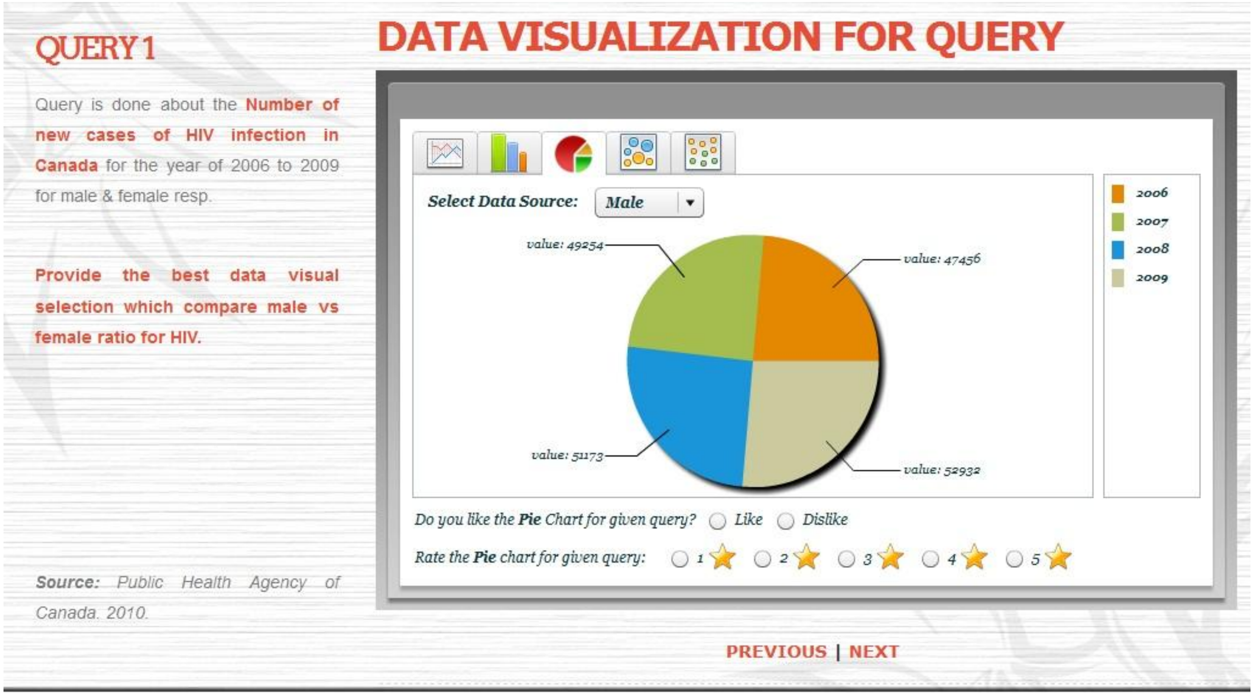
Motion Bubble charts

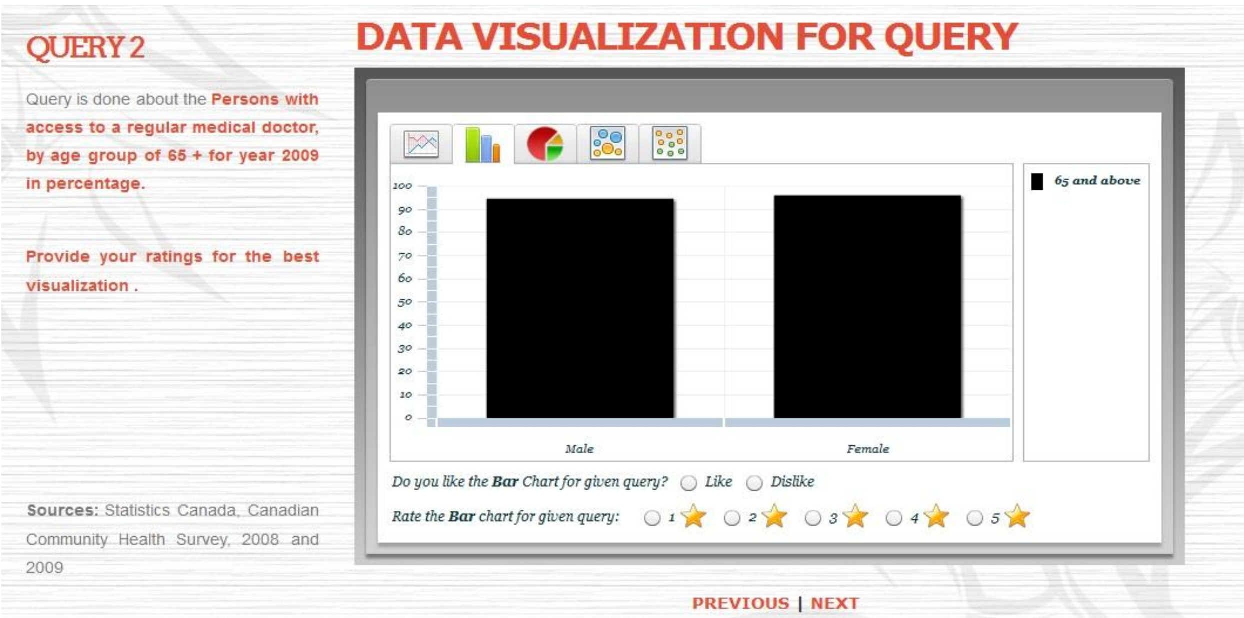


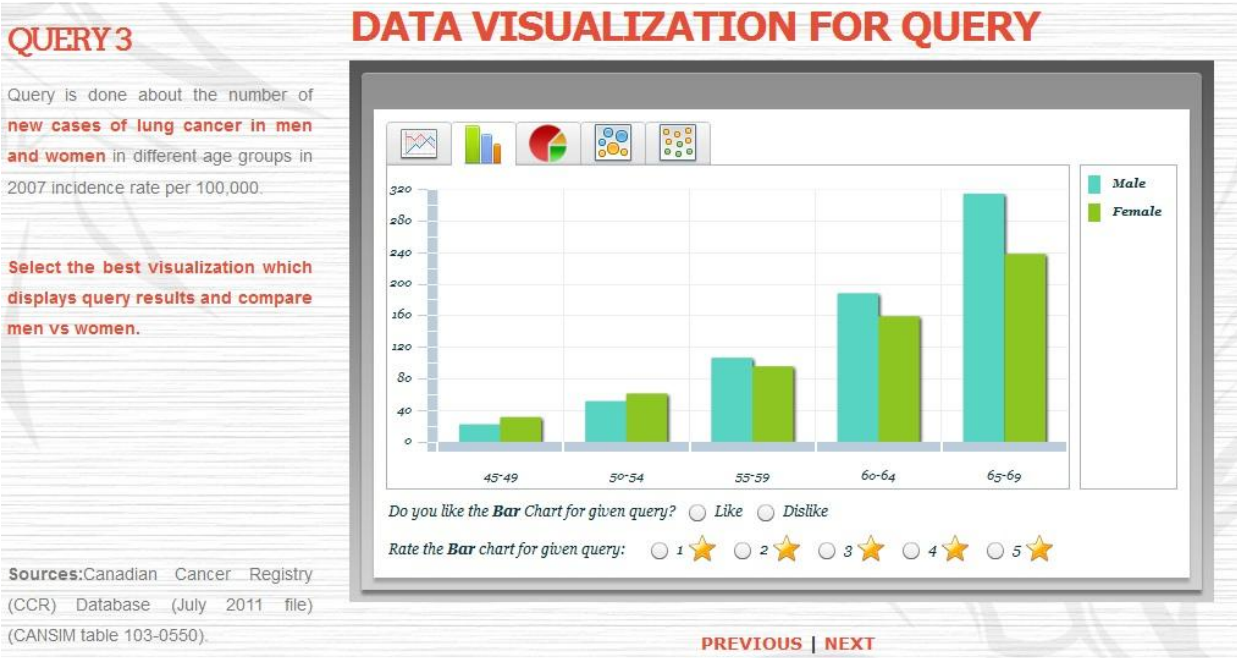
Appendix B

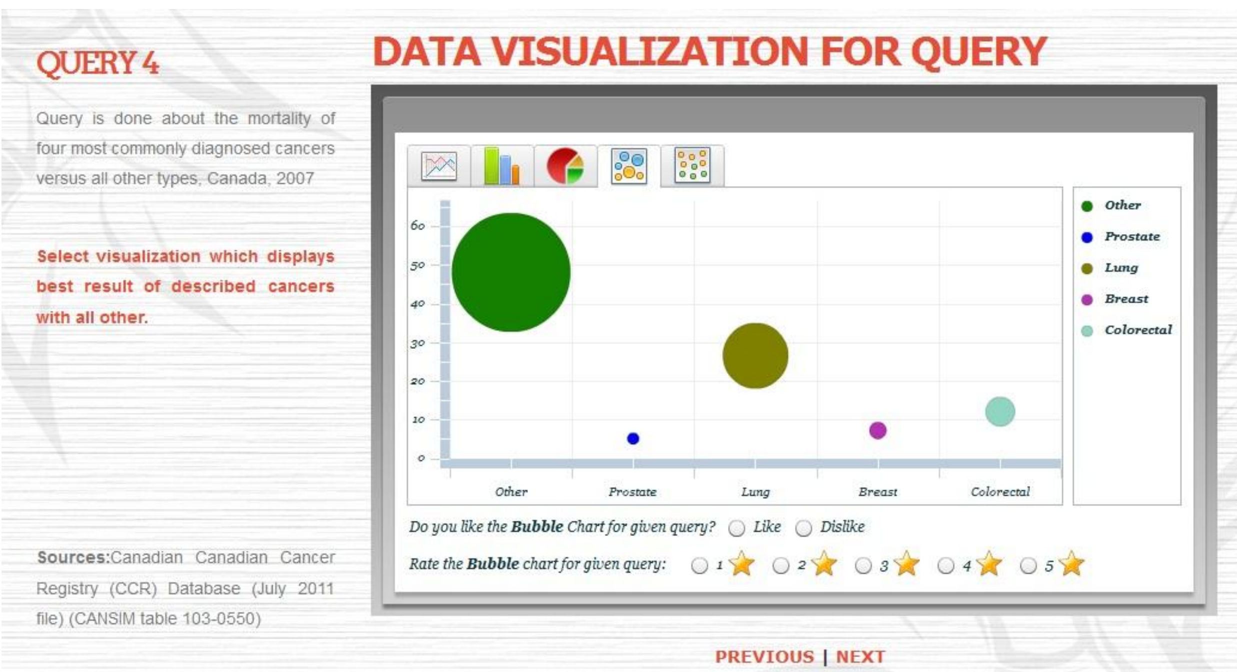
Usability Study Survey

The following figures illustrate the online survey, which were required to complete by participants for the purpose of usability investigation.






QUERY 3
DATA VISUALIZATION FOR QUERY
Query is done about the number of new cases of lung cancer in men and women in different age groups in 2007 incidence rate per 100,000.
Select the best visualization which displays query results and compare men vs women.
Sources:Canadian Cancer Registry (CCR) Database (July 2011 file) (CANSIM table 103-0550).
Male
Female
320
280
240
200
160
120
80
40
0
45-49
50-54
55-59
60-64
65-69
Do you like the Bar Chart for given query? Like Dislike
Rate the Bar chart for given query: 1 2 3 4 5
PREVIOUS | NEXT


QUERY 4
DATA VISUALIZATION FOR QUERY
Query is done about the mortality of four most commonly diagnosed cancers versus all other types, Canada, 2007
Select visualization which displays best result of described cancers with all other.
Sources:Canadian Canadian Cancer Registry (CCR) Database (July 2011 file) (CANSIM table 103-0550)
Other
Prostate
Lung
Breast
Colorectal
60
50
40
30
20
10
0
Other
Prostate
Lung
Breast
Colorectal
Do you like the Bubble Chart for given query? Like Dislike
Rate the Bubble chart for given query: 1 2 3 4 5
PREVIOUS | NEXT

QUERY 5

DATA VISUALIZATION FOR QUERY

Query visualize results-

What is the main source of stress for 6 to 10 highly stressed workers?

Select which visualization provides accurate information.

Sources: Canadian Canadian Cancer Registry (CCR) Database (July 2011 file) (CANSIM table 103-0550)

PREVIOUS | NEXT

QUERY 6

DATA VISUALIZATION FOR QUERY

Query is done to get data for the year 2009 and 2010 in percentage for **Police-reported hate crimes, by type of motivation in Canada.**

Provide your rankin for visual of data .

Sources: Canadian Centre for Justice Statistics, Incident-based Uniform Crime Reporting Survey.

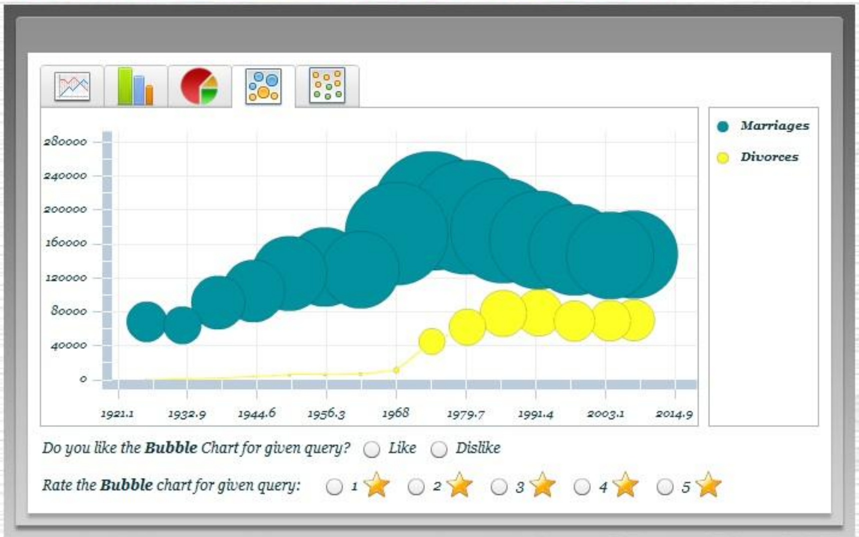
PREVIOUS | NEXT

QUERY 7

DATA VISUALIZATION FOR QUERY

Query is done to check **Number of marriages and divorces, Canada, 1926 to 2008**

Select visual which provide information for marriages vs divorces..



Sources: Statistics Canada, Health Statistics Division, Canadian Vital Statistics, Divorce Database and Marriage Database.

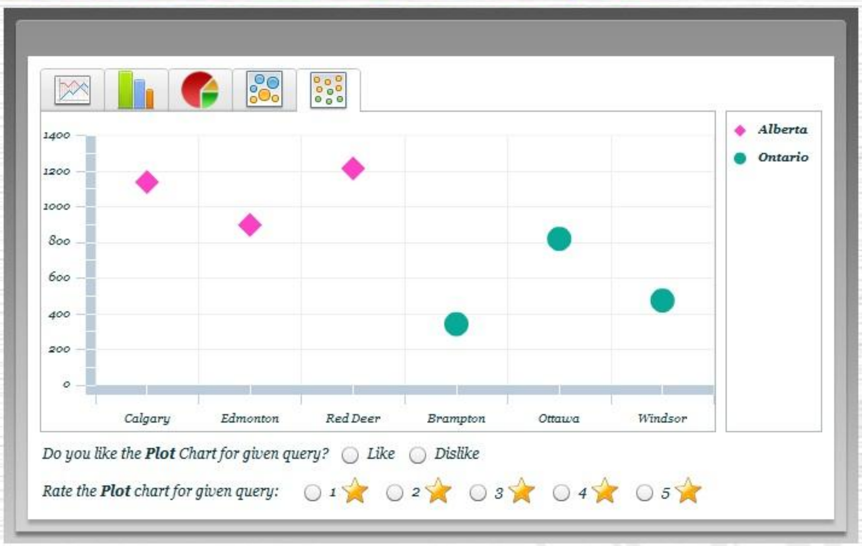
PREVIOUS | NEXT

QUERY 8

DATA VISUALIZATION FOR QUERY

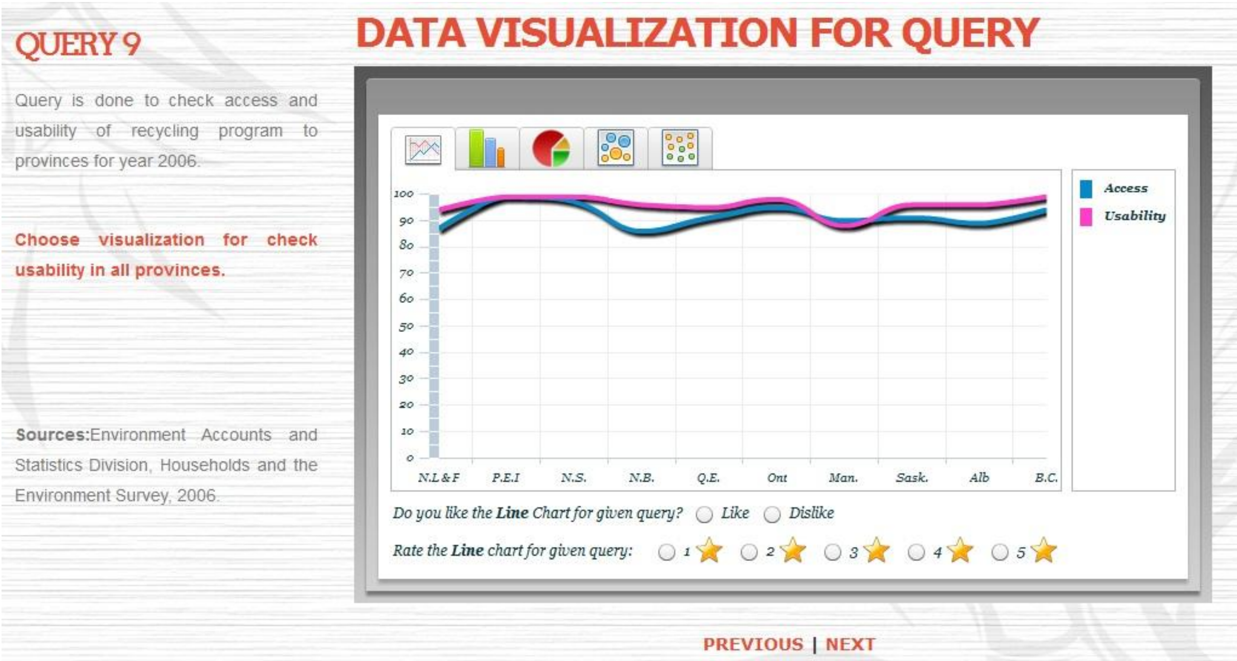
Query is done to check number of address available for postal code starting with (L7A, K1Y, T1Y) which results with province.

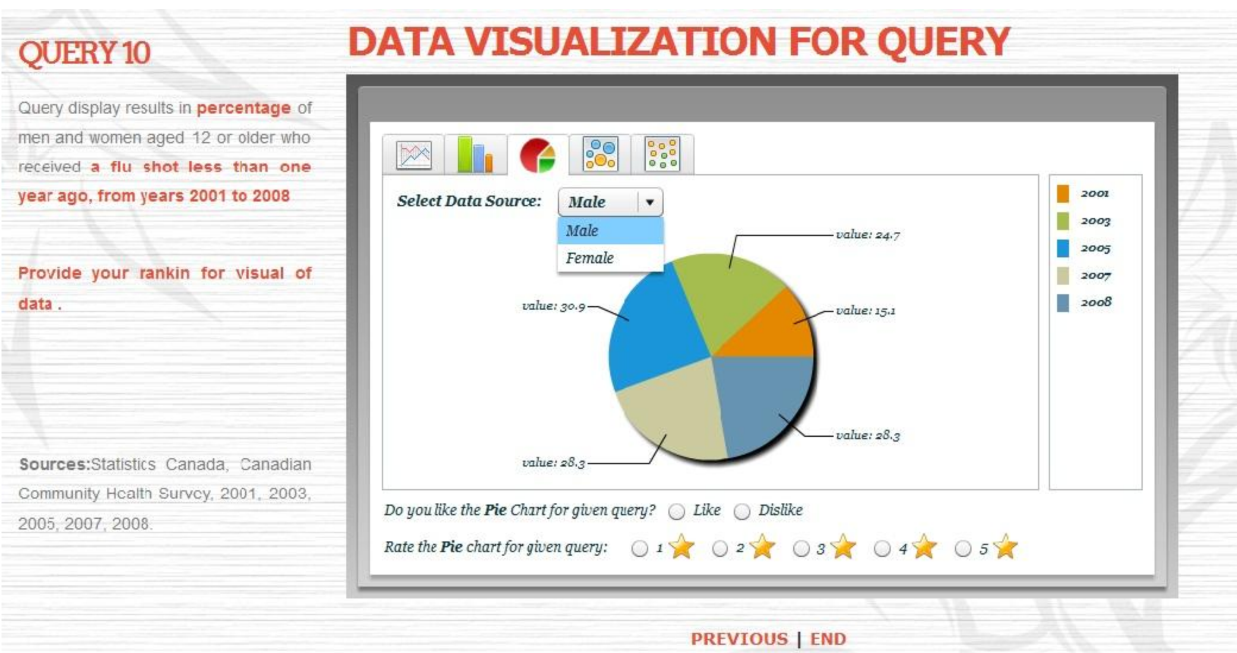
Select visualization which describes number of addresses available.

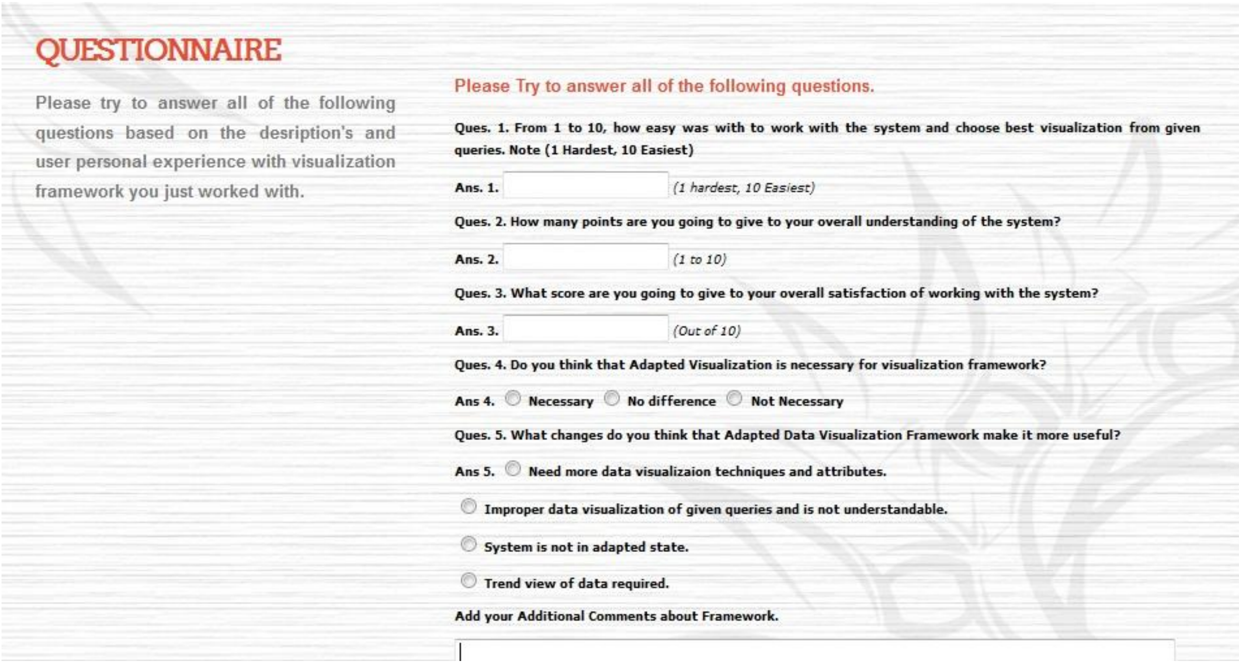


Sources: Statistics Canada, Health Statistics Division, Canadian Vital Statistics, Divorce Database and Marriage Database.

PREVIOUS | NEXT


QUERY 9
DATA VISUALIZATION FOR QUERY
Query is done to check access and usability of recycling program to provinces for year 2006.
Choose visualization for check usability in all provinces.
Sources:Environment Accounts and Statistics Division, Households and the Environment Survey, 2006.
100
90
80
70
60
50
40
30
20
10
0
N.L & F
P.E.I
N.S.
N.B.
Q.E.
Ont
Man.
Sask.
Alb
B.C.
Access
Usability
Do you like the Line Chart for given query? Like Dislike
Rate the Line chart for given query: 1 2 3 4 5
PREVIOUS | NEXT


QUERY 10
DATA VISUALIZATION FOR QUERY
Query display results in percentage of men and women aged 12 or older who received a flu shot less than one year ago, from years 2001 to 2008
Provide your rankin for visual of data .
Sources:Statistics Canada, Canadian Community Health Survey, 2001, 2003, 2005, 2007, 2008.
Select Data Source:
Male
Male
Female
value: 24.7
value: 30.9
value: 15.1
value: 28.3
value: 28.3
2001
2003
2005
2007
2008
Do you like the Pie Chart for given query? Like Dislike
Rate the Pie chart for given query: 1 2 3 4 5
PREVIOUS | END



QUESTIONNAIRE

Please try to answer all of the following questions based on the desription's and user personal experience with visualization framework you just worked with.

Please Try to answer all of the following questions.

Ques. 1. From 1 to 10, how easy was with to work with the system and choose best visualization from given queries. Note (1 Hardest, 10 Easiest)

Ans. 1. ________ *(1 hardest, 10 Easiest)*

Ques. 2. How many points are you going to give to your overall understanding of the system?

Ans. 2. ________ *(1 to 10)*

Ques. 3. What score are you going to give to your overall satisfaction of working with the system?

Ans. 3. ________ *(Out of 10)*

Ques. 4. Do you think that Adapted Visualization is necessary for visualization framework?

Ans 4. ○ **Necessary** ○ **No difference** ○ **Not Necessary**

Ques. 5. What changes do you think that Adapted Data Visualization Framework make it more useful?

Ans 5. ○ **Need more data visualizaion techniques and attributes.**

○ **Improper data visualization of given queries and is not understandable.**

○ **System is not in adapted state.**

○ **Trend view of data required.**

Add your Additional Comments about Framework.

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