Visual Features Comparison of Smartphone and Tablet in Visual Mobile Data Mining Framework

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Summary
The emergence of mobile and telecommunication technologies and the demand of data analytics lead the importance of mobile data mining in the last decade while the limitations of mobile devices great challenge in the reciprocated integration of these disciplines. Mobile devices are improving from the digital calendar to high capabilities computing devices that encourage the researchers to work in the mobile data mining environment continuously. In this paper, we discussed a Visual Mobile Data Mining (VMDM) framework, which incorporates both these emerging technologies to facilitate nomadic user for information. The study defined ten features that ensure information visualization features, i.e., functionality, effectiveness, efficiency, usability, and usefulness for interactive visualization techniques on mobile devices. The results are analyzed for the defined features and proposed interactive techniques used for descriptive data mining data, and compared which showed promising results for both smartphone and tablet, three of the features are weak for the smartphone as compared to the tablet. The VMDM framework is potentially incorporate different dimension in interdisciplinary research work especially, to other visualization techniques and web services to facilitate a wide range of mobile device users.

Key words:
Visual Mobile Data Mining framework, Data mining result's interactivity, Drill down interactive visualization technique, Legend navigation interaction, Mobile device visualization interactivity

1. Introduction

The mobile and telecommunication technologies are rapidly improving, and the cost is decreasing, which encourages the researchers to use these battery-operated devices for information search using the World Wide Web (WWW) besides social interaction. The researchers are inspired to work for efficient mobile interfaces that should effectively display information on small screen devices and efficiently utilize unreliable low bandwidth connections. Despite the revolutionary enhancement in the resources of mobile devices (especially, computation, storage, and connectivities), mobility and scale-down technologies lead to some limitations [17]. Mobile devices are used to facilitate the nomadic users to access information quickly, easily, and almost at no cost. Smartphones and tablets are widely used mobile devices, for information access and search, news, social interaction, eBooks, articles and entertainment, etc., via Internet [9]. Mobile devices gained more popularity because of the features like computation, memory, connectivity, etc., the researchers have been encouraging to adopt services from desktop systems or laptop computer systems to mobile devices.

On the other hand, the business tycoons are looking for tools and techniques which help them to extract information from massive data, useful for them. Hence, data mining in the present era is attracting the attention of persons related to the information industry, marketing or business, investors, etc., even society as a whole. For example, to track the stocks in the stock market, to find market trends about a product, to find out the best book based on some criterion using the Amazon book record repository to guide a user to take the decision and buy the book, etc. Mobile data mining is an integrated environment that mainly consists of data analysis techniques in the mobile computing environment. The market needs to adopt mobile data mining to facilitate a wide range of mobile device users with useful, potential innovative information extracted with advanced data mining techniques. For ubiquitous use of data mining techniques and rapid development in mobile technology, encourages researchers to introduce methods that utilize these emerging technologies [4]. However, comprising these emerging technologies is not that simple and straightforward, hence facing several challenges.

- Massive Dataset: Normally, data mining is applied to a massively large dataset, which requires high storage capacities, both primary storage and secondary storage.
- High Computation Process: The data mining tasks, processes, algorithms and operators are computationally costly, requiring high computing capabilities, i.e., high processor speed.

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While mobile devices carry many constraints. To bring data mining tasks to the mobile devices are not feasible due to mobile device's limitations;

- Unreliable & Low bandwidth: to transfer massive data on unreliable and low bandwidth is not reasonable.
- Storage capacity: the limited storage capacity, not allowing to bring all the data to the mobile device, leads to inefficient data manipulation, i.e., data cleaning, filtration etc.
- Power consumption: The long computation process needs more time to complete and requires a long battery life.
- Limited processing capabilities: mobile devices' processing abilities do not allow the entirety computations of data mining processes.

Thus, it is not feasible to bring data mining tasks to mobile devices having limited resources. A study comprehensively discussed possible scenarios, where we can incorporate data mining techniques in mobile devices and the best architecture in the environment with current resources [13]. The motivation is to provide beneficial data mining results (required extracted information) in such a way that they are more useful to the end-user and according to their cognitive capabilities. The client-server architectures allow mobile devices to invoke, execute data mining tasks on the remote server from the mobile client and visualize or demonstrate significant results to the nomadic users. Keeping in view the importance of data mining, the use and limitations of mobile devices, the demand is to effectively visualize results (information) on a small screen of a mobile device. The information should be visualized in such a way that it provides the inside in a glance, easy to understand with less cognitive resources and less distraction of the user from their current task [5]. The human cognitive capabilities enable the user to work on several tasks at a time or in parallel and demand fast information retrieval and processing, effective and easy to complete. For this purpose, we introduced the Visual Mobile Data Mining (VMDM) Framework and designed research statement of the study "Interactive and usable visualization techniques for data mining results on mobile devices can easily and effectively interpret the inside of data".

The paper is arranged as; in the first section, we explained the background for the readers. In section II, we described the VMDM framework with a brief discussion on interactive techniques and visualization features studied in this paper. In section III, we discussed feasible application scenario, adopted research design and evaluation techniques, participants considered for the study, dataset, survey design and analysis procedure. In the last section IV, we analyzed the results for smartphone and tablet, and compared the user's sanctification about the defined features and conclude the findings.

2. VMDM Framework

Information presentation is always a challenging task on small touch screens because of the limited space available. As compared to the standard display screens and in the absence of standard input devices, it becomes more challenging to visualize and manipulate the information effectively [1]. To effectively utilize the small screens of mobile devices need to focus and deal with the information as follow;

- Information selection: It is essential to use small screens of mobile devices wisely and select information, which is of utmost importance for the users.
- Information Presentation: To display information on small screen offers more challenges with mobile devices and become the most critical problem to handle, and the selected information presentation or visualization that best suited to the data and its nature.
- Interface Interactivity: To manage information on the available small screen, need efficient and effective interactive mechanisms to manipulate data for the users effectively.
- Visualization Features: To produce effective information visualization that ensures the visualization features such as functionality, usability, effectiveness, efficiency, and usefulness.

We introduce a layered framework, namely Visual Mobile Data Mining (VMDM), as shown in Fig. 1. The enhanced framework combines both the information extraction model and the information visualization model with a brief description [13] [8]. The VMDM presents the main components and their interconnection involved in the mobile data mining environment scenarios, functions performed by different components and its sequence.

The VMDM framework is designed to introduce end-user's interactive mechanisms for exploring the inside information quickly and easily over mobile devices of all types, especially smartphones and tablets. The Amazon dataset is used to study the inside information extracted using data mining technique and help the end-user to decide about the best book based on different criteria by extracting related information.

2.1 Interactive Techniques

We introduced two interactive techniques Drill-down approach and Legend-navigation approach and one hybrid approach by combining both DDA and LNA for the bar charts and in column charts, as discussed below;

Drill-Down Approach is used to access low-level details of the data from a higher level or drill down means to move from abstract or aggregated information to detailed information extracted via data mining tasks in the mobile data mining environment, as shown in Fig. 2 [10].

Legend Navigation Approach is a best-suited mechanism for data discrimination, i.e., to compare the comparative target class (es) [11]. Initially, we use the maximum of four classes, which can be further specified as the best feasible count or maximum comparative classes for smartphones and tablets, as shown in Fig. 3.

Drill down and Legend Navigation Approach is used to get comprehensive details about target classes and explore required information by both dimensions, i.e., exploring one graphical information representation from a higher level to the low level and comparing it with other comparative classes, simultaneously [12].

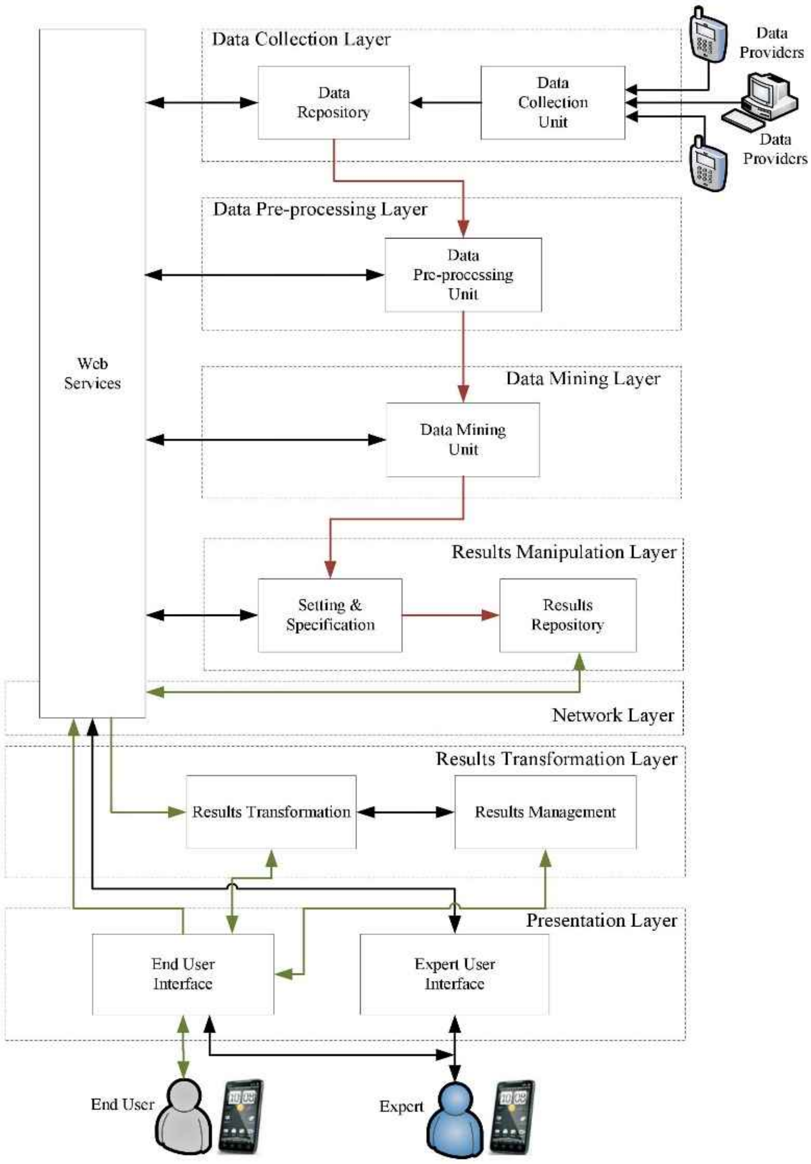

Fig. 1 Visual mobile data mining framework

2.2 Visualization Features

The quality of mobile device interfaces depends on the quality of the user's experience while performing a task in all types of mobile application interfaces. Nowadays, mobile users expect more because of the use and the services provided by using mobile devices, e.g., according to a study, on average, US users spend five hours on mobile devices every day [2]. They demand more features that make them happy to use mobile, e.g., fast loading time, easy to use and delight during the interaction, etc. Mobile users usually are searching for specific information they required. There are some important features of mobile devices that help to find the required information easily and quickly. The intended objectives of this study are to achieve the features (discussed subsequently) by developing a functional prototype to validate, evaluate, and analyze the user's experience, which facilitates mobile device users with interactive, useful and informative information [13]. The study focuses on the following features;

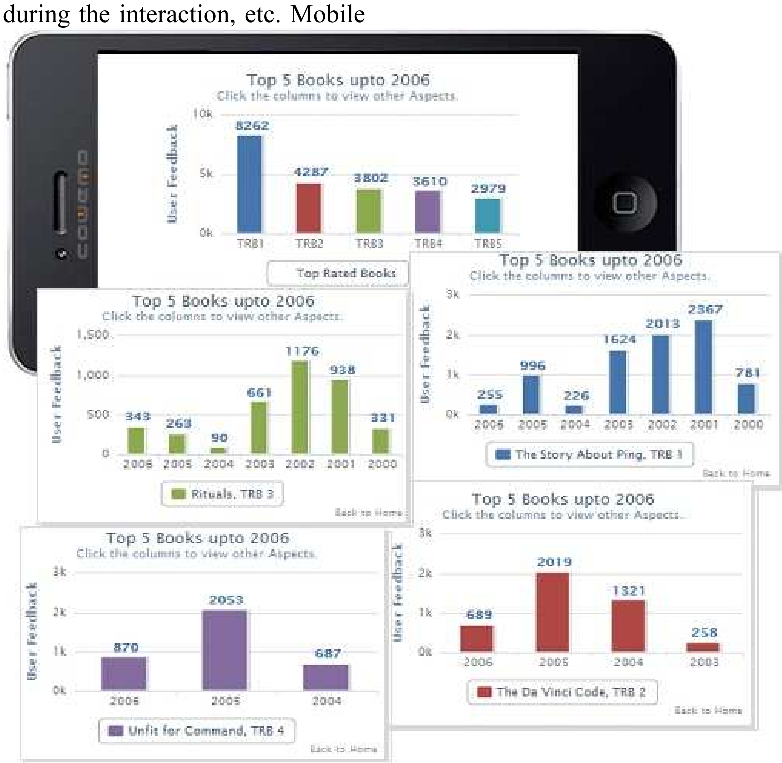

Fig. 2 Drill-down approach

1. Dynamic and Scalable Layout The layouts of the functional prototype dynamically transform the visual layout, or information visualization regarded mobile device screen size. The scalability of visualization techniques makes it more feasible for small size screen, the zooming (zoom in or zoom out) should not distort the graphics and provide a sharp and clear visual graphics display on mobile devices. Scalability and dynamism both are technological issues; these features can be achieved with the help of advanced technologies, by considering best-suited programming languages and techniques after analyzing the implementation environment, as shown in Fig. 4.

2. Multi-brand Smartphones and Tablets The functional prototype supports different brands of smartphones and tablets regardless of their underlying architecture. The web browser is used for interactive visualization techniques presentation as data mining results become available to a wide range of mobile device users. For evaluation, different brands of smartphones and tablets are employed during experiments to rectify technical issues in the information presented.

3. Serving Tasks The main question of any UI is "does the UI serve the user well and get the information for which the user is looking for?" or in other words, is it according to the user's requirements? The purpose of the tasks depends on the situation. Here, the main goal is to find out the best book and enable the user to decide.

4. Appearance The overall layout of the interactive mechanism is crucial because the extraction and understanding of information over smartphone and tablet as both the devices have different screen dimensions.

5. Data Fetching & Manipulation The smartphone and tablets have different computing ability and hence the fetching (fast access or response) and manipulation of information have different user's experience.

Fig. 3 Legend navigation approach

6. Zooming The limited size of the screen of the mobile devices, the users need to zoom in or zoom out the visual information during exploring and navigate through the data.

7. Attractiveness The overall attractiveness and joy being using the proposed interactive techniques on both mobile devices, i.e., smartphones and tablets.

Fig. 4 DDA interaction visual display on smartphone and tablet

8. Focus & Attention The mobile devices normally use on the go, i.e., performing other tasks in parallel. The purpose of this feature is to keep the focus on parallel tasks and find out the required information easily.
9. Interaction One of the important features for limited screens is the interactivity of users. In this feature, the overall interaction of the information visualization and its information exploration is assessed.
10. Content Visibility & Usability Mobile devices are used to in different light condition, which increases the importance of different feature which make the contents visible, i.e., colour combination, general labels and axes labels.

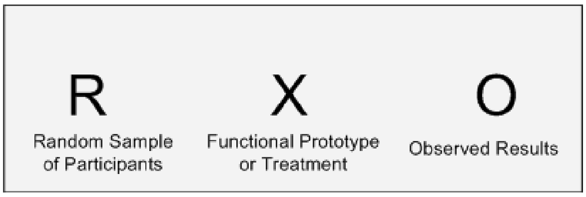

Fig. 5 Posttest-only randomized experimental research design

3. Results Analysis & Discussion

Evaluation is an essential part of the research process. It is a systematic approach to analyze the worth, quality, reliability and assess the significance of the research study by analyzing the data. In user-centric studies evaluation is to validate the posted research statement by using statistical measures.

3.1 Application Scenario

We comprehensively discussed six different application scenarios in our previous studies [9]. Where we explain how we can assimilate data mining in mobile devices environment based on the role of a mobile device. As discussed, the limitations of the mobile device, the most prominent role is to use mobile as an information client or a data provider. For example, the [16] discusses the role of the mobile device as a data collector from citizen's mobile communication and use for intelligent transportation management for city planners. Similarly, the VisTiles framework presents a mobile device as a tool to explore visual data by coordinating and combining co-located mobile devices [14]. Keeping in mind the mobile device restraints, massive datasets, and high computing data mining techniques or processes, 1st and 3rd scenarios are best to employ. In both situations, the mobile device acts as a client to view mining results and facilitate the nomadic user providing interactive visualization techniques.

3.2 Research Design

Similarly, a research design is also one of the essential parts of any research study and used to carefully and efficiently investigate the outcome. Without proper research design, the study methods conclude weak results and even fail to answer the questions raised in the framework. "Research design in the plan, structure, and strategy of investigation conceived to obtain answers to research questions and to control variance" [9]. Many research designs are discussed in different studies [13]. For this study, we choose the Posttest-Only Randomized Experimental research design (Fig. 5) because we do not have any special interactive visualization techniques or studies for mobile devices to which can be used for comparisons.

3.3 Evaluation Techniques

The worth, reliability and significance of a research study can be analyzed by choosing a suitable evaluation procedure based on some criteria. Evaluation is one of the substantial steps of the research process [15] [7]. The selection of evaluation technique depends on the nature of the research study. The study evaluates the effectiveness of the interactive technique in information visualization by considering visualization features described in section II-B. This study is assessed by using a questionnaire-based control experiment, in which, the participants were asked to execute several task-based experiments using functional prototype and fill the feature-based questionnaire and conduct individual interviews.

Table 1: Participant's demographics on the bases of age and education

Age-wise Distribution				
Age Rage	Male (73%)	Female (27%)	Smartphone Usage	Tablet Usage
21-25	19%	14%	100%	40%
26-30	41%	10%	100%	51%
31-35	13%	03%	100%	90%
Education-wise Distribution				
Education Degree	Male (73%)	Female (27%)	Smartphone Usage	Tablet Usage
BS	12%	05%	100%	30%
MS	41%	15%	100%	69%
PhD	20%	07%	100%	98%

3.4 Participants

Target Population: The individuals who have experienced the Amazon online retailer, observed the best book and have used or are using a mobile device(s) like Smartphone and Tablet, make up our target population. Accessible Population: The students from different educational institutions around the capital and Khyber Pakhtunkhwa are considered, which have to experience the Amazon online retailer, the best book and have used or are using a mobile device(s), make up our accessible population. Sampling: The study considered the simple random sampling technique, where each individual from the population has an equal chance of being selected as a sample. The proposed interactive techniques and the related features are tested with real users using the functional prototype. The study is conducted with 41 volunteer participants in the experimental trials. The participant's demographics are summarized on the bases of age and education, as follows;

The participants were selected for experiments based on two demographic parameters, i.e., age and education, using the mobile device. The knowledge of the selected participant is more important than all other demographic characteristics because the selected dataset is an Amazon book dataset where education is more important than other demographics. The participants must also observe Amazon books shopping and having experience of using mobile devices.

Table 2: Statistical measures of participant's response for all features

Devices	Mean	Standard Deviation	Standard Error (95%)	Confidence Interval
Q1. Serving the overall purpose				
Smartphones	4.55	0.62	0.220	4.66 – 4.44
Tablets	4.75	0.44	0.157	4.83 – 4.67
Q2. Appearance of the overall layout				
Smartphones	4.23	0.56	0.197	4.32 – 4.13
Tablets	4.71	0.53	0.186	4.80 – 4.62
Q3. Time to fetch data and populate charts				
Smartphones	4.65	0.49	0.171	4.73 – 4.56
Tablets	4.71	0.46	0.162	4.79 – 4.63
Q4. Zooming effects (i.e. Zoom-in and zoom-out)				
Smartphones	4.58	0.56	0.199	4.68 – 4.48
Tablets	4.29	0.53	0.186	4.38 – 4.20
Q5. Attractiveness of overall layout				
Smartphones	4.45	0.57	0.200	4.55 – 4.35
Tablets	4.48	0.51	0.179	4.57 – 4.39
Q6. User's focus and attention during use				
Smartphones	4.35	0.55	0.194	4.45 – 4.26
Tablets	4.48	0.51	0.179	4.57 – 4.39
Q7. User's satisfaction about overall interactivity				
Smartphones	4.65	0.49	0.171	4.73 – 4.56
Tablets	4.71	0.46	0.162	4.79 – 4.63
Q8. User's experience about the colour combination				
Smartphones	4.26	0.63	0.222	4.37 – 4.15
Tablets	4.58	0.50	0.177	4.67 – 4.49
Q9. Chart's labels				
Smartphones	3.52	0.72	0.255	3.64 – 3.39
Tablets	4.35	0.49	0.171	4.44 – 4.27
Q10. Axes labels				
Smartphones	3.87	0.67	0.236	3.99 – 3.75
Tablets	4.48	0.51	0.179	4.57 – 4.39

3.5 Dataset

In the study, the data mining techniques are applied to the Amazon Books dataset published in 2008 [7]. The dataset has seven years of data from the year 2000 to the year 2006, the size of the dataset is 8.3 GB, contains user's feedback or reviews, helpful feedback, book ratings, user's ranking, etc. The tasks have been designed to find out the best book on the bases of some specified criterion.

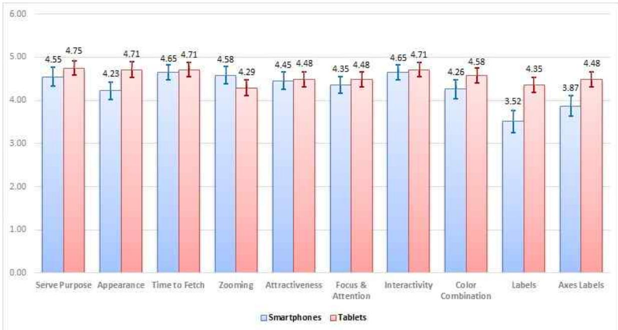

Fig. 6 Comparison: visualization techniques features on mobile devices

3.6 Survey Design

We choose the control experiment evaluation technique based on a survey or questionnaire. Quantitative research methods are useful for identify relationships among variables, measure and analyze using statistical techniques. After studying numerous systems, it is concluded that 78% of the evaluation is based on surveys [18]. In surveys, a questionnaire is used to collect the data using a functional prototype over a sample of real users selected from the population and generalize the results to the whole population [3]. The questionnaire used for the evaluation contained five features, visualization techniques, and interactive mechanisms using a five-point Likert scale which is commonly used in questionnaires and is the most widely used scale in survey research [6].

3.7 Analysis Procedure

The evaluation of visualization techniques and defined visualization features on mobile devices provided via a functional prototype to the participants. The survey is conducted through a questionnaire from the participants to analyze visualization techniques with different related features on mobile devices. The participants were asked to perform tasks on the smartphone and tablet. After the completion of tasks, the conducting survey is accomplished by filling the given questionnaire, the main points according to [9] are; A group, sample, representing the population, are studied for their characteristics (such as abilities, opinions, attitudes, beliefs, and/or knowledge) to extract information.

- Data is collected from the individuals by mainly asking questions using feedback forms, i.e., questionnaire.
- The sample's participants were asked questions rather than going through all the members of the population.

The user's responses for each combination have noted based on directly and indirectly effective parameters or features of visualization techniques. For statistical analysis, we considered five measures to ensure accurate results about the population and follow the following procedure;

- Mean is computed to find out the average user's responses for each question about a feature for the overall user's perception.
- Median is computed to show the most selected option from the Likert scale and hence justifies the mean value.
- Standard Deviation (SD) is required to show the variation among users responses, and high standard deviation means a high difference in user's responses and hence less reliable results or vice versa.
- Standard Error (SE) is calculated to find out how close the sample mean to the population mean. SE shows the variation of the results for the population. A largest standard error would mean that there is a lot of variability in the population, so different samples would give you different mean values. A small standard error would mean that the population is more uniform, so your sample mean is likely to be close to the population mean.
- Confidence Interval (CI) represents the confidence level that contains the true value for the unknown population. There are three typical confidence intervals of 90%, 95% and 99%. A 95% means the probability that the population parameter lies / covers within the given range.

4. Smartphone and Tablet Comparison

In this section, we are analyzing directly and indirectly features, affect the visualization techniques such as functionality, effectiveness, efficiency, usability, and usability. The study defined ten questions specifically address the usefulness of the interactive visualization features on mobile devices in the mobile data mining environment. Each feature is statistically analyzed by considering the different statistical measure. We compared the user's response for both smartphones and tablets for the visualization techniques presented using the functional prototype. There are sixteen (16) questions addressing mobile devices related features. Q1 is about the satisfaction of users serving the task on both the devices, 85% of the participants are satisfied. Q2 is related to the overall appearance of the visualization techniques; more than 80% of results achieved; the tablet shows a bit better results. Q3 is about data fetching, manipulation, and navigation time. The participants showed an appreciable response and more than 90% of the selection agreed or strongly agreed. There is a difference in screen sizes of mobile devices, and scalability is one of the main issues. In Q4, the participants asked about the scalability of the visual presentation, shows 93% healthy user's response. Q5, Q6, Q7 questions address overall attractiveness, focus, attention, and interaction, respectively, which shows good user's response of approximately 90% for these features for both smartphone and tablet. Q8, Q9, Q10 questions deal with the colour combination, title or data or axes labels usability and visibility, respectively, tablet (88%) results are bit better than a smartphone (76%). The table II show all the statistical data about all the question, and the results are summarized in Fig. 6.

Table 3: Statistical measures of participant's response for all interactive techniques

Chart Type	Interactive Technique	Devices	Mean	Standard Deviation	Standard Error
Column Chart	Drill-Down Approach	Smartphones	3.65	0.61	0.21
		Tablets	3.97	0.66	0.23
	Legend Navigation Approach	Smartphones	3.52	0.72	0.25
		Tablets	3.74	0.51	0.18
	Hybrid Approach	Smartphones	3.87	0.62	0.22
		Tablets	4.42	0.56	0.20
Bar Chart	Drill-Down Approach	Smartphones	3.35	0.80	0.28
		Tablets	3.71	0.59	0.21
	Legend Navigation	Smartphones	3.10	0.75	0.26
		Tablets	3.61	0.62	0.22

	Approach				
	Hybrid	Smartphones	3.65	0.55	0.19
	Approach	Tablets	4.23	0.50	0.18

Fig. 6 compares the user's rating regarding all the features for mobile devices. The figure presents similar results for most of the features for both Smartphones and tablets. The outcome for overall appearance, colour combination and labels are relatively better for the tablet as compared to a smartphone. At the same time, the users appreciate the scalability of the visualization technique for Smartphones because it has a small size screen while usually not needed for a tablet screen.

The variability in mobile devices regarding software and hardware support is a challenge, the study considers two types of mobile devices, i.e. smartphone and table. To evaluate the proposed interactive techniques on mobile devices is of utmost importance to examine the utility of the visualization techniques. This section describes how the users rate the interactive techniques on the smartphone, tablet, comparison of both, visualization techniques, its comparison and features comparison.

Table III shows the user's rating regarding all interactive techniques for the smartphone. The LNA+BC (M=3.09, Median=3, SD=0.66) technique shows poor results, DDA+BC (M=3.35, Median=3, SD=0.8) shows weak results because of mobile device user mostly uses a smartphone as horizontally tilted. If the numbers of bars are large, then it looks close, difficult to manipulate and understand due to the height of the Smartphone screen. As the number of bars in LNA is more than the DDA thus, it produces poor results. On the other hand, the DDA+LNA+CC present more reliable results on the smartphone.

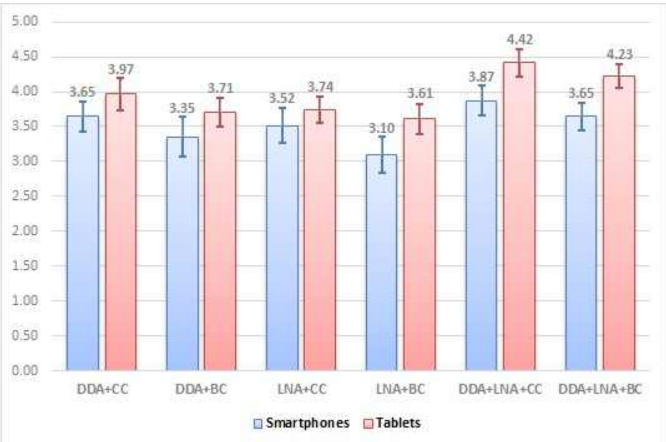

Fig. 7 Comparison: Interactive Visualization Techniques on Mobile Devices

Fig. 7 shows the user's rating regarding all interactive techniques which appear to be fair for all the techniques using a tablet. The DDA+LNA+CC and DDA+LNA+BC show the most encouraging results because both techniques provide two ways to explore the information. By DDA, one explores the information in more detail (two-level details), and by LNA, one explores the comparison with comparative classes, compare different features or characteristics. Other techniques present almost the same results due to a reasonably large screen. The mean values ranges between M=3.6 (Median=4, SD=0.62) to M=3.97 (Median=4, SD=0.66). The information provided by any given interactive visualization technique can be represented using four different charts with almost eight backward and forward navigations. On the other hand, the stated interactive technique reduces these navigations to two. It provides a comparison of all four features or detail information of the targeted class by legend navigation and drill-down interactive mechanisms.

5. Conclusion and Future work

Emerging technologies like mobile technology, telecommunication technology with advanced and complicated data analysis techniques can efficiently and effectively address the information need of a wide range of mobile device users. Despite many limitations of mobile devices and considering the recent resources, client-server architectures allow visualizing or showing the mining results in a significant way for nomadic users using less cognitive resources in visual mobile data mining (VMDM) framework. This study defined ten features for information visualization features for the proposed interactive techniques in the VMDM. In which three of the features, i.e., overall appearance, labels, and axes labels presented on the smartphone showed weak results as compared to tablets while the mobile device users inspired from zooming or scaling features on the smartphone. The drill-down approach for presenting information showed good results on both smartphones and a tablet as compared to the legend navigation approach. However, the hybrid approach showed excellent results on mobile devices.

The framework can be extended in the future to facilitate a large number of users with inexpensive and informative information, which enables them to enhance their knowledge,

- To introduce new visualization techniques and related interactivity for mobile devices, considering user's aspects as well as system aspects.

- The study uses one level details of the associated data, and it can be enhanced to two and three-level details and abstraction, depending on the data and user requirements.
- To specify the number of aspects or characteristics of data that can be best to represent and compare for the legend navigation approach, which does not affect the visualization feature and enhance the utility of the approach.
- To extend the study for other purposes or different domains or data sets.
- To map the proposed architecture with other well-known architectural models like SOA, RESTful, SOAP, etc, to further enhance the utilization of the VMDM framework.
- We can bring some data mining tasks and limited data sets to mobile devices, but to specify the type of operations and the size of the data set feasible for mobile devices.
- Find out the improvement by applying these interactive techniques, the de-Questionnaire column and bar graphs can be used for comparison to validate the improvement.

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