Analysis of Information Visualization Techniques for Abstract data on Mobile Devices

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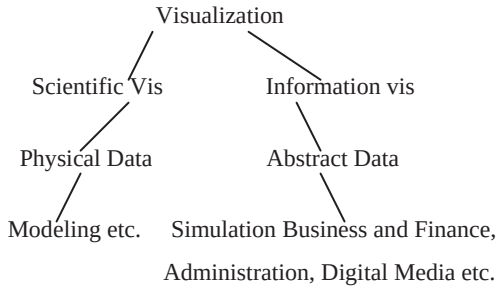
ABSTRACT
To perform visualization on mobile devices different types of data may use like text, picture, maps, physical objects, abstract data etc. According to data visualization is categorized in two areas of visualization that is, scientific visualization and information visualization. Scientific visualization refers to some specific type of data like physical data and it is used for computer modeling and simulation. Information visualization refers to abstract data and used in business and finance, administration, digital media and other abstract concepts. The physical and abstract data is only one classification but there are others classification like static and dynamic data, structured and unstructured data, or hierarchical and non-hierarchical data classification. This paper is focus on information visualization of abstract data on mobile devices.
Keywords: Information visualization, abstract data, mobile devices.

1 INTRODUCTION
As per known information, mobile devices have so many limitations as compared to desktop computers like displays are very limited, the width/height ratio is very different from the usual, the on-board hardware is much less powerful; the input peripherals are often insufficient for complex tasks, the input techniques are different, connectivity is slower, affecting the interactivity of applications when a significant quantity of data is stored on remote databases, there is a lack of powerful, high-level graphics libraries. But Recent mobile are more powerful having high resolution, more colors, large screen, fast connectivity, various tools than old one, but still visualization on mobile devices has remained a challenging task [1].

Various types of visualization on mobile devices refer to various types of data. Information visualization is one of the visualization types that refer to abstract data. Abstract data is generally used in business and finance, administration, digital media and other abstract concepts. As the information is increasing day to day but mobile devices reduces in size. So visualizing large data on mobile is one of the challenges. [2].

2 INFORMATION VISUALIZATION AND ABSTRACT DATA
I. Information visualization is defined as the use of computer-supported, interactive, visual representations of abstract data to increase cognition. Information visualization is thus a tool that helps the human in gaining insight into data. The purposes of this insight are discovery, decision-making or explanation. Information visualization may involve selecting, transforming and representing of abstract data in a form that facilitates human interaction for exploration and understanding. A related activity to information visualization is scientific visualization, which is typically used to gain insight into scientific, usually physical data [3].



II. Abstract data can be
1. Temporal data.
2. Spatial data.
3. Other types of data.

Temporal data, such as the voltage range, a stock's share price, and time series are examples of temporal data etc. Spatial data may be geographic data. [1].

3 APPLICATIONS
To display hierarchical information, researchers have proposed many algorithms for desktop screen visualization. Such algorithms are generally divided into connection and enclosure. Connection approach is explicit and displays hierarchy with a clear structure but utilize display area. Enclosure can maximally utilize the screen space but the layout is essentially implicit. Considering the limitations of mobile devices authors [4] presents new approach for hierarchical information visualization that is RELT (Radial Edgeless Tree).

The technological advances of mobile devices offer new opportunities to areas where geographic data has an important role. PDA, mobile phones and other portable devices are increasingly beginning to have location awareness via GPS devices. There are already several geo-referenced information visualization tools for desktop computers, such as MetaCarta, Google Maps and Google Earth [5].

Time series visualization used time dependant data. This type of data may used in business/finance, administration/management etc. As the mobile device has so small screen so it is difficult to visualize stock data on mobile. Two visualizations have been designed to represent stock values. The first one is devoted to

visualization of different values at a given time; the second one is devoted to visualization of the evolution of such values with time. If the values are too numerous, then a clustering can be used to summarize them like a K-Means clustering to merge 40 stocks in 7 clusters [6].

Temporal data is the time related data might use in in-field law enforcement operations. Some in-field operations are tracking (people, objects), patrolling, evidence and data collection, situation monitoring and investigative analysis performed by law enforcement officers that can benefit from using a mobile device for making rapid decisions. All these fields operations are time related so it is necessary to capture all things while visualizing [7].

Visualization of patient record is also possible on mobile devices like PDA. Information visualization technique have been used to present patient data in visual form with more intuitive navigate ways so that user can analyze and manage patient data easily [8].

To visualize data in 3D form, a well-known ghost view illustrative technique has been used. Ghost-views apply to 3D information a visualization technique, which ensures the visibility of selected items by view-dependently manipulating the transparency of unselected data [9].

Data access from Internet is huge amount of data or information so it is difficult to visualized web data on mobile devices due to small screen size. Therefore various layout methods and visualization algorithm have been developed to effectively delivery various types of information [10].

There is a problem with magic eye view visualization for hierarchy because it displays lot of unused space on mobile screen and the node labels gives the parts of the presentation. Therefore magic eye technique has been improved which specify half ellipsoid or half spheroid with different coordinates. [11]. Author [17] discus the different interface approaches for focus and contextual view i.e. overview-details, zooming, focus-context for desktop applications.

To perform vehicle navigation on mobile devices different techniques has been used that are spatial information filtering, modeling the context and also use one adaptive visualization method. It perform various task i.e. navigation, search etc. Adoptive visualization is one of the new approaches, which consider context and influence aspects [12].

Information visualization technique having insightful design principles and effective visualization prototype can also be used to visualize semantic structure of classical music and get insight into musical structure [13]. This can also be used by musical teachers, students and others for teaching and learning different piece of music and styles, as well as presenting interesting visual signs for musical features without the visual aid.

Visualization of places and areas where the user's data is tagged using placegram which is diagrammatic map representation on the basis of cognitive map theories is present in [14]. It also provides efficient browsing and visualization on mobile devices using 4D keys and compact layout.

Authors [15] present existing visualization techniques that hold multi resolution functionality and describe the visual hierarchical aggregation methods for massive data abstraction. Also presents interaction technique appropriate for multi scale visualization navigation.

For the visualization of multi dimensional data there is use of cross filter visualization technique and also represents design plan for corresponding multiple view interface using cross filter [16].

Interactive Weather Information System or IWIS is developed using unique design-oriented visual images to represent a select group of weather information for the learners [18].

Glaze is one of the visualization structure based on GPS on mobile devices to see the structure and orientation of surrounding and navigates in environment [28].

To improve emergency response and situational awareness [32] developed a mobile visual analytics tool. This mobile visual analytics tool consists of a 2D/3D visualization module, which shows personnel-related information, situational and static scene-related information, integrated multi media playback functionality for personnel outfitted with cameras, and fast-forward/rewind capabilities for reviewing events.

MobiVis, a visual analytics tool have been created, which integrates the idea of presenting social and spatial information in one heterogeneous network [33]. This system is used to visualize complex data since it contains social, spatial and temporal information.

Another application of information visualization is for mobile learning in which authors [35] compare visualized and non-visualized learning content on web and mobile.

4 INFORMATION VISUALIZATION TECHNIQUES FOR ABSTRACT DATA ON MOBILE DEVICES

4.1 Hierarchical information visualization i.e. RELT (Radial Edgeless Tree)

Hierarchical information visualization that is RELT (Radial Edgeless Tree), combines the features of both connection, and enclosure approach. RELT is one of the methods, which overcomes the drawback of connection and enclosure approaches. RELT uses adjacency and direction to represent relationships between nodes and visualized information in a radial layout [4].

The current music classification and selection is one of the applications of RELT. Representation of music files in 2D form which Cascade menus across multiple screens. The 3D type is simply a simulated 3D view with realistic looking albums. RELT allows the user to define the number of levels to be viewed.

Fig 1: A RELT arrangement of the example music collection .

4.2 Filtering mechanisms based on semantic criteria

There are already several geo-referenced information visualization tools for desktop computers, such as MetaCarta, Google Maps and Google Earth [5, 19].

Although this continuous improvement occurs, mobile devices have several limitations when compared to desktop computers and as a consequence visualization applications developed for the desktop cannot be easily ported to mobile environments.

A new application that was released recently is the mobile version of Google Maps. This application also has some limitations because there is no way for the user to further purify his search when there are a lot of results and some of them overlap others.

So the authors [5] describe an ongoing research that aims to design solutions for the visualization of geographic data on mobile devices. It intends to integrate and to use multiple representations with different levels of detail to express the user's preferences.

Another method is cross filter visualization for multidimensional data which uses interaction to show relation between different values like people, place, time etc. [16]. There are three main elements, views to display unique value, brushes to select subset of value, and switches toggles the filtering between pair of views. To connect these elements cross filter visualization built upon data transformation i.e. grouping, filtering, projection and selection. For the design of various data attributes and auxiliary views there is visual abstraction for individual brash able representation of data attributes and auxiliary view maps value into graphical attribute using time series plots, scatter plots, heat maps and histogram visual techniques.

To view the information and related maps on mobile devices there is use of tree map technique. It displays information in table and in the form of maps. The related information is point out on maps with the help of brushing and dispersion or scattering technique. Dynamic filter mechanism is also useful to focus on minor group of data from continues downloaded data. These techniques help the tourist to find out related information on mobile devices [20].

Filter mechanism is also used to generate zooming of biomechanical 3D motion data on screen [25].

Semantic and temporal filtering techniques are used for the visualization of ontology graphs and temporal information respectively on mobile. Semantic allows the visualization on small screen and temporal provides interaction of time varying data [33].

4.3 K-Means clustering:

Two forms of visualization have been designed to represent stock values. The first one is devoted to visualization of different values at a given time; the second one is devoted to visualization of the evolution of such values with time. If the values are too numerous, then a clustering can be used to summarize them like a K-Means clustering to merge 40 stocks in 7 clusters.

Clustering may be used to represent the variations in stock values in the form of bar chart. In which positive value are represented from bottom to top on the bottom line and negative value from top to bottom on the upper line.

Pixel bar chart may used to visualize the advancement of values during a period for different clusters (or stocks).

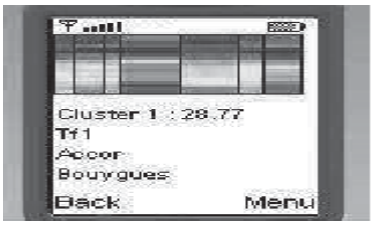


Fig. 2. Pixel Bar Chart.

Each column present to a cluster and the number of stocks in the cluster relates to its width. Each daily value is mapped on a color scale. The different days of the period are represented from bottom to top [6].

Cluster visualization is given for the time series data in which clusters are used on calendars which combines with patterns shown as graph [29]. Along with cluster there is interaction for better investigation of time data.

Clustering is also used to show the relation between interview and survey on mobile device in project management [30].

4.4 Ghost technique with push based mechanism:

Real-time data is obtained from sensors such as GPS (Geographical Positioning System) and cameras that reorganized in few seconds. Recent updates of information correspond to their background information of past, so that in-field responders can follow changes over time. As the mobile devices have less memory so it is necessary to balance history store with actual memory. To visualize such data, ghost technique is used. Push based mechanism is also effective for the visualization of temporal and spatial historical data [7]. It uses a focus plus context exploration lens that also doubles up as a spatial filter for geo-tagged data.

4.5 Information visualization technique with intuitive navigate:

The visualization of patient data at temporal granularity shares some common interface features like time line, temporal scroll bar and zoom buttons. This technique helps the visualization on mobile devices with intuitive navigation [8].

4.6 Ghost view illustrative technique:

Ghost view can be used for volume visualization or 3D multimedia data. Firstly tree cube structure visualization technique is used for the management of 3D multimedia data. Tree cube is generally hierarchical visualization technique, which is also known as tree map. Tree cube holds the 3D multimedia data like 3D geometry model. One of the objects of this model may be one model. And the relationship between these objects is referees as hierarchical which allows fast navigation. For the tree cube visualization small phylogenetic data and sub tree has been used.

Like ghost view spring model is another technique, which generally used to see the division of the whole information space according to its attributes or the expansion of information objects. It also allows comparison between single objects and volume. So this technique is generally useful for multivariate data sets.

Author [9] used this technique for health data visualization in which ten different attributes recorded by a health insurance have been used. This includes the number of influenza cases, the cases

of gastro-intestinal diseases, cases of arthropathy and more, which may use to place the visual representatives of the districts.

Effective browser and effective information retrieval technique is also useful for the visualization of multimedia data on mobile devices [27].

4.7 Fisheye view with focus and context method:

Focus and context visualization technique is more useful commonly used technique for information [21]. Fisheye visualization algorithm may apply to both sequential and hierarchical layout according to the types of information for the effective visualization [10].

Magic eye view is generally modified for hierarchies on hemisphere. Every node in the hierarchy are mapped on the two dimensional Cartesian plane with two angles.

$\varphi = 2 \prod * x/maxx$, $\theta = 2 \prod * y/maxy$.

Hemispheres are then used to calculate the Cartesian coordinates:

$x = r * \sin(\varphi) * \sin(\theta)$,

$y = r * \cos(\varphi) * \sin(\theta)$, $z = r * \cos(\theta)$

But there is a problem with magic eye view visualization for hierarchy because it displays lot of unused space on mobile screen and the node labels gives the parts of the presentation. Therefore magic eye technique has been improved which specify half ellipsoid or half spheroid with different coordinates. A spheroid is expressed by the formula: $x^2/a^2 + y^2/b^2 + z^2/b^2 = 1$

Calculate the coordinates:

$x = a * \sin(\varphi) * \sin(\theta)$, $y = b * \cos(\varphi) * \sin(\theta)$, $z = b * \cos(\theta)$. Then it solves the formula with respect to x and y coordinates only. This improves magic eye view technique visualized data on whole screen of mobile devices [11].

Rectilinear focus plus context techniques is used by [31] that provides navigation by dynamic linking of side views of quad tree. Develop new tool with the help of techniques like similarity measures for structural comparison and guaranteed visibility.

4.8 Adoptive visualization:

Adoptive visualization is one of the new approaches, which consider context and influence aspects. Therefore it obtain different context like user location, time, environment, system information etc. After obtaining context on mobile devices then it sends to the server for additional processing. After that context classifying and dividing their properties on the basis of ontology have created database. This process is known as context modeling. Mapping tables has been created between context and GR (Geographic Relevance), which is a relation between a geographic information need and the spatio-temporal expression. Now on the basis of GR rules spatial information has been filter to find useful user-related information. Appropriate adoptive visualization technique has been used to find visualization-based context. And at the last visualized context has been present on mobile device [12].

Adoptive method is also used for the cryptographic visualization of geographic information on mobile devices [26].

4.9 Layer braid and theme fabric visualization prototype:

Musical structure data contains different layers and themes those are getting back from descriptive essay. For the visualization of semantic structure of music data there are consistent, intuitive, effective and aesthetic design principles for visual representation. To represents layers in visualization there is use of different color plan. Prototype visualization those are layer braid and theme fabric provides micro level layer relationship and theme disparity and also provides interaction between layers and theme [13].

4.10 Diagrammatic map based visualization:

Placegram is one of the diagrammatic map based visualization technique which includes preprocessing, place layout, connecting and weighting places or area clustering and label layout. Preprocessing is for input data (place) to merge them together for next steps. Here is use of place alignment algorithm to compress layout horizontally and vertically and in grid alignment places are break to brows using 4D keys and to get easy visual layout on mobile devices than normal mode. These places are link together by constructing minimum spanning tree and the corners of tree are flattening diagonally. Every place has almost one connection to any 4 sides. Place having more data and frequent visits are shown with large size [14].

4.11 Hierarchical Aggregation Visualization:

In hierarchical aggregation it is needed to differ between overlapping and space filling visualization techniques that is overlapping never restrict on visual items layout while the space filling restrict on layout to avoid overlapping. These techniques provide visual representation of actual as well as aggregate data items. Hierarchical visual aggregation of scatter plot uses overlapping technique so there is occurrence of occlusion.

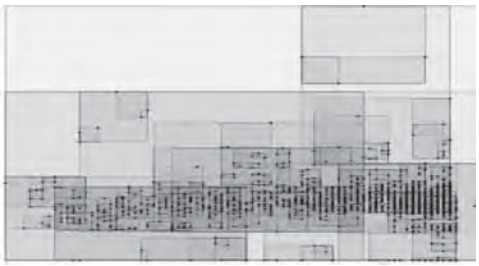


Fig.3: 2D building box aggregation of scatter plot visualization.

There are above, below, level and range rendering traversals to travel visual hierarchical aggregation. For navigation and manipulation there are zoom and pan, drill-down and roll-up, local aggregation, flipping, coupled zooming and drilling interaction techniques. Like scatter plot there is also the visualization of parallel coordinates, star glyphs, tree maps, node link diagrams etc [15].

For the hierarchical visualization and interaction of social photos [23] provides Hasse Diagram (Lattice) algorithm and also uses indexing for the more indexation of new photos through propagation.

4.12 Radial Visualization:

Radial visualization technique is useful for the description of interactive system who arranges the data in elliptical form. Some visualization techniques like pie charts, star plot, and radar plot are generally used in business and media to communicate numeric

data but radial visualization technique is use to comprise the interactive management of data. Various applications are based on radial visualization i.e. hierarchical structure, relationship among disparate entities, ranking of search result and serial periodic data. Seven high level design patterns have been proposed to describe radial visualization systems. Tree pattern visualized hierarchical data, star and ring based views the relations among unlike entities. Concentric and Euler pattern is the combination of both tree and star, spiral views time based data. Authors [22] also focus on some design dimensions like 3D visualization, centroid, interactivity, access permission etc.

4.13 Relational entity resolution with novel network visualization:

For the interactive entity resolution in relational data authors [24] presents D-dupe which combines relational entity resolution with novel network visualization. Entity resolution is for two task, duplications and data integration. Searching is used to find similarity and duplications and dupe is used to increase search performance. D-dupe is used to visualize relational context and cluster wise context to show relation between duplicates clusters.

4.14 Visual analytic method:

A visual analytic method has been developed on mobile devices to get crisis response of sensor and other types of data. [32] Uses client server approach, server for the conversion of sensor and other types of data, client for 2D/3D visualization and interaction. Client also uses circular queue for the organization of different types of data. To visualize data on mobile various types of categories are used i.e static, dynamic temporal, spatial, aggregation etc.

Using interactive visual presentation of information a faster and better insight from data is possible. Avin Pattath and group [34] have shown the potential for mobile visual analytic method in a wide range of applications, including both time-critical analysis and more detailed, investigative analysis. They have also presented a number of issues that must be addressed in developing this method so that they can become effective tools for actionable decision-making.

4.15 Structured information visualization:

Author [35] discuss two contents i.e. non-visualized and visualized content via graphic, animation, and image to compare and finds the result that structured information visualization is more effective for mobile learning.

5 USE OF INFORMATION VISUALIZATION

As compare to the desktop, mobile devices have many limitations but two main limitations are small screen and less memory. Due to the small screen size effective information display is difficult. So many information visualization algorithms and techniques of desktop like clustering, filter, focus and context etc may apply on mobile devices to solve mobile limitation. Information visualization allows effective visualization of large information on mobile devices.

As the mobile devices have less memory, sometime it may takes the use of remote server for information storage. Therefore some information visualization techniques are used at server side and some at client i.e. mobile side. Client server approach is more convenient for the visualization of large amount of information from remote side on mobile devices.

6 ANALYSIS AND DISCUSSION

Here the various types of abstract data and their related visualization techniques have been arrange in tabular form.

Abstract data types	**Information visualization techniques**	**Comparing mobile visualization techniques with desktop techniques.**
Music data	Hierarchical information visualization i.e. RELT (Radial Edgeless Tree)	RELT is best as compare to other hierarchical technique of PCs. RELT display data in tree form effectively on small screen.
Geographic data	Filtering mechanisms based on semantic criteria	Present intelligible information to the user and allows the visualization of geo-referenced information on mobile devices.
Stock market data	K-Means clustering	Desktop techniques displays too detail graphs while K-means clustering use contrast boundary instead of line boundary to the graph and give information on demand, interactively.
Temporal data for in-field law enforcement	Ghost technique with push based mechanism	Ghost technique may used for desktop but as mobile has less memory so Push based mechanism is used with ghost technique for the visualization of temporal and spatial historical data.
Patient data	Information visualization technique with intuitive navigate	To display patient data on small screen as compare to desktop it is necessary to use intuitive navigation visualization rather than desktop.
3D multi media data	Ghost view illustrative technique	Tree cube structure technique is used for the management of 3D multimedia data. Which is hierarchical visualization allows fast navigation and spring model is another technique

Abstract data types	Information visualization techniques	Comparing mobile visualization techniques with desktop techniques.
		useful for multivariate data sets.
Web data	Fisheye view with focus plus context method.	There are different visualization methods for desktop to display web data like scroll, which is not applicable for mobile due to small screen size.
Spatio-temporal data	Adoptive visualization	This technique is used to display user context and geographical relevance on mobile devices to perform navigation and searching.
Place data i.e area, city, country etc.	Placegram i.e a diagrammatic map based visualization.	Normal mode of place gram is useful for both PC's and mobile while the keypad mode is useful for mobile devices.
Aggregate massive data	Hierarchical aggregation visualization based on overlapping and space filling.	Both are useful for small screen due to rendering traverse and interaction techniques i.e. zooming, drilling etc.
Relational data	D-dupe with novel network	Desktop technique D-dupe combines relational entity resolution with novel network visualization. Cluster mechanism may used for visualization on mobile.

7 CONCLUSIONS

This paper discusses the different information visualization techniques for different types of abstract data on mobile devices as compare to desktop. It also gives focus on the use of information visualization on mobile devices and desktop screen.

Many of the desktop information visualization techniques can be used for the visualization on mobile. It has been found that mostly filter, cluster, focus and context, zooming mechanisms are more useful for the visualization of abstract data on mobile devices.

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