Collaborative Information Visualization Using a Multi-projection System and Mobile Devices

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***Abstract*—The wide availability of database systems and low cost of hardware allow enterprises and researchers the opportunity to store large data collections. The challenge then became the understanding of these data. To overcome this problem Information Visualization (IV) techniques have been employed to amplify the human cognitive ability through graphical data representations, that show properties and relationships from these data. This work presents an approach to overcome the visual scalability by using a Multi-projection system, allowing the exploration of large datasets. Additionally, this approach allows collaborative interaction and exploration by using mobile devices like tablets and smartphones.**

***Keywords*-collaborative; information visualization; multi-projection; mobile devices.**

I. Introduction

The low cost of hardware and the wide availability of database systems, as well as other storage ways, increased the amount and size of datasets. Therefore, the great challenge became the understanding of these data because most tasks are practically infeasible, such as identification of clustering, patterns, trends and outliers.

To overcome this problem, some efforts have been made on the field of Information Visualizations (IV) to create visual representations from datasets properties and relationships. So, the human visual system can be used to aid in the identification of patterns, trends and outliers, allowing a better data comprehension and the discovery of new informations and knowledge.

However, when data volume increases the visual representations are impaired. Thus, multi-projection environments, commonly used in Virtual Reality (VR) systems, can be employed to enlarge the projection plane and to allow more natural interactions to the users, making the exploratory process easier.

In this way, this work presents a visualization system that enables the exploration of large datasets in a collaborative way, by using a multi-projection system and mobile devices to interact with visual representations. So, users can have an overview in the VR environment and use a mobile device to focus in some areas without losing the overview context. Additionally, is presented an augmented visualization approach using mobile devices to retrieve details on demand from exploration performed in the virtual environment.

The paper is structured as follow: An introduction to the main concept followed by description of visualization system and its features; finally, a comparison study with other applications and final considerations is presented.

II. Main Concepts

A. Virtual Reality and Multi-projection Systems

In order to make the interaction between human and computer more intuitive and natural, Virtual Reality can be defined as an "advanced user interface" to access computer applications allowing visualization, movementation and interaction in real time tri-dimensional environments created by computer. These environments are primarily visual experiences, although other senses can be used to enrich the user experience [1]. VR systems are used to several purposes: simulation, games, visualization, collaborative environments, education, modeling, and others [1]–[7].

Widely used in VR applications, multi-projection systems are composed by multiple screens, providing distinct points of view of the environment and, usually, enabling stereoscopic vision. Thus, it is possible to create an experience with high immersion power, one of the VR systems main characteristics [2], [8].

These multi-projection systems have several advantages when compared to other VR approaches, such as: less user fatigue, large visual space and possibility of collaborative use [9].

B. MiniCAVE

The MiniCAVE [10] is a low cost multi-projection system and its structure is composed by a graphic cluster responsible for real time generation and rendering of 2D or 3D images, high-bright screens and high definition projectors with polarized lens, which can allow stereoscopic vision.

Figure 1 shows the floorplan with the arrangement of MiniCAVE elements and the Figure 2 presents a molecules visualization application using the MiniCAVE.

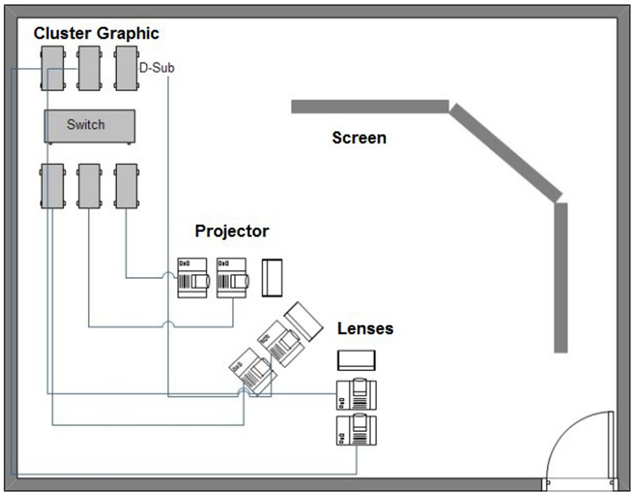


Figure 1. MiniCAVE structure showing three pairs of high definition projectors aligned with the three high-bright screens [10]

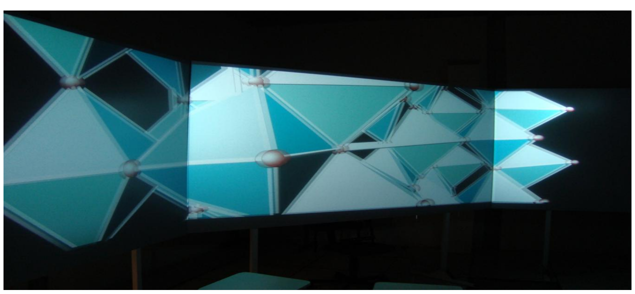


Figure 2. VR application for molecules visualization in the MiniCAVE using stereoscopic vision [3]

C. Augmented Visualization

Augmented Visualization (AV) is the process through which the analyst forms hypothesis about the data and also refines them, in an interactive environment that allows data manipulation, exploration and navigation [11]. A good visualization environment must allow users to drill down and get more data about any element that seems important. In a computer application, this can be translated to an interface that allows dataset overview, filters, zoom and details on demand [11], [12].

Another definition of Augmented Visualization uses the term “augmented” as a reference to techniques of Augmented Reality (AR). In this case, as illustrated in Figure 3, AV is treated as an interaction method that uses mobile devices to allow user navigation and to display additional

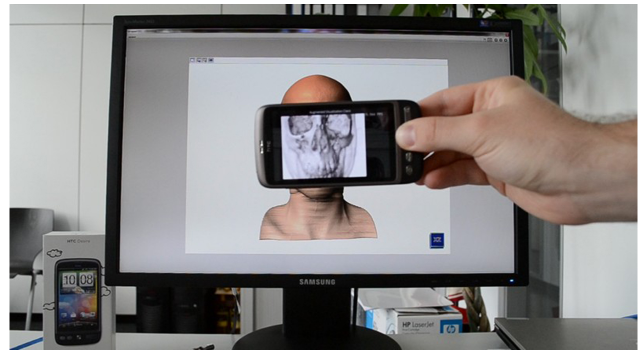


Figure 3. AV application employing a smartphone to allow x-ray vision on models displayed in the computer [13]

information based on recognition of fiducial markers or natural environment features [13].

In this paper, the Augmented Visualization term will be used to define a system in which mobile devices are employed to allow interaction, exploration and exhibition of additional information to users, but without necessarily using fiducial markers or pattern recognition techniques, commonly employed in AR systems; the term “augmented” is used in the sense of the visualization system enhancement, showing additional information not displayed in projections or monitors.

III. A System for Collaborative Information Visualization using Multi-projection and Mobile Devices

This section describes the application that enables data visualization and exploration by using Virtual Reality techniques and mobile devices to create a better user interaction.

The combination of the multi-projection technique, providing a platform with capacity to display large amount of data, with the use of mobile devices, allowing more intuitive interactions and to display additional information, increases the user cognitive power and creates an Augmented Visualization environment.

Mobile devices also provide to users an individual workspace in which is possible to analyze details and share information with others users, increasing the collaborative capacity of this environment.

A. Overview

The developed application can perform all common steps of an Information Visualization application, from data processing and transformation to manipulation and exploration of the visual representation.

Following guidelines proposed in literature and organized in [14], the configuration and features are categorized in Hardware and System Setup, Information Visualization

Features and Collaborative Features. They are detailed as follows.

- Hardware and System Setup
  - Size: to show large datasets the system uses a multi-projection environment composed by three screens with 2.5 meters of width and 1.5 meters of height. Each screen has high definition resolution (1920x1080 pixels) generated by BenQ W1000 projectors. The environment also has space for 10 to 15 persons, enabling co-located collaborative use;
  - Configuration: the multi-projection environment is used as overview. The individual workspace for focus and details on demand is held on mobile devices;
  - Input: users inputs are done through mobile devices. These have touch screen and allow the input of texts and drawings, in addition to interactions with the visualization. Furthermore, the system can identify from which user the input is given;
  - Resolution: the overview and mobile devices have high definition output resolution. Specific pens can be used to improve the precision on interaction and input;
  - Interactive response: to improve the response during user interaction, part of the processing can be directly done by the mobile devices. Additionally, only the data related to the view of each user are sent in the communication with the visualization server.
- Information Visualization Features
  - Supporting Mental Models: the individual representations created by the users can be organized in their own way;
  - Representation Changes: users can create, in their mobile device workspace, additional representations and alternative graphic formats to explore other characteristics of the entities of interest;
  - Task History: users can include annotations in the visual representations to aid other collaborators to understand the logic that led to the task resolution;
  - Perception: the positioning of the screens in the multi-projection environment allows users to be close to the 3 screens avoiding distortions.
- Collaborative Features
  - Workspace organization: the system enables a shared workspace which is the overview gotten from the visualization server and it also enables individual workspaces on mobile devices;
  - Fluid Interaction: after generating the initial view, most of the interactions are performed by the mobile devices touch screen;
  - Information Access: all users can see the content generated by the others, as well as data that are not displayed in overview;
  - Collaboration Style: it allows users to work in a part of the problem in their own mobile device and share it later;
  - Communication: in addition to the the annotations and graphical representations that can be shared, the collaborative environment allows natural verbal communications, because the users are co-located. The system can also be used by remote exploration, even though the overview benefit is lost.

The application is divided in two parts, the first is a desktop module responsible for data selection, visual attributes mapping and visual representation generation. The second is responsible for user interactions and exhibition of additional informations and uses mobile devices like smartphones and tablets.

B. Desktop Application

This module is responsible for fetching the data through SQL commands executed by the user over a relational database connection or by importing tabular files such as CSV ones and, based on the resulting dataset, allows the mapping of columns to visual attributes like size, colors and shapes. It also allows the user to choose between graphical layouts and select the one that is more useful for the type of information to be investigated.

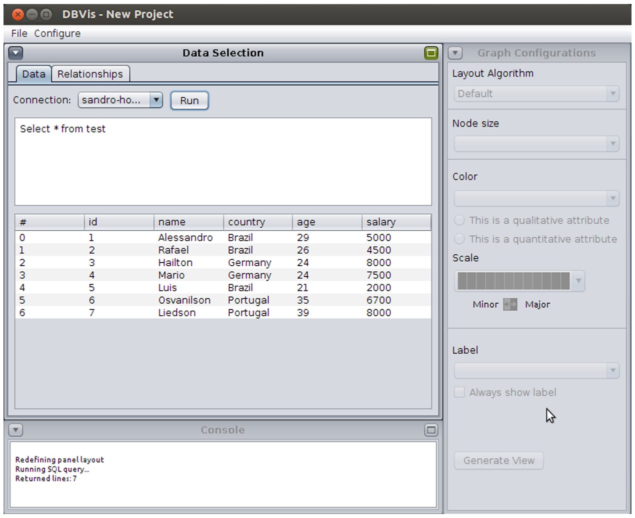
This module is developed in Java which is multi-platform, supports connectivity to many relational databases systems through Java Database Connectivity (JDBC) specification and provides some Information Visualization libraries such as JUNG [15] and Prefuse [16].

Figures 4 and 5 show the creation of a graph representation computation from a dataset selected through a SQL command.

After mapping columns to visual attributes and choosing the graph style, the visual representation is generated and displayed using the MiniCAVE multi-projection system (Fig. 6).

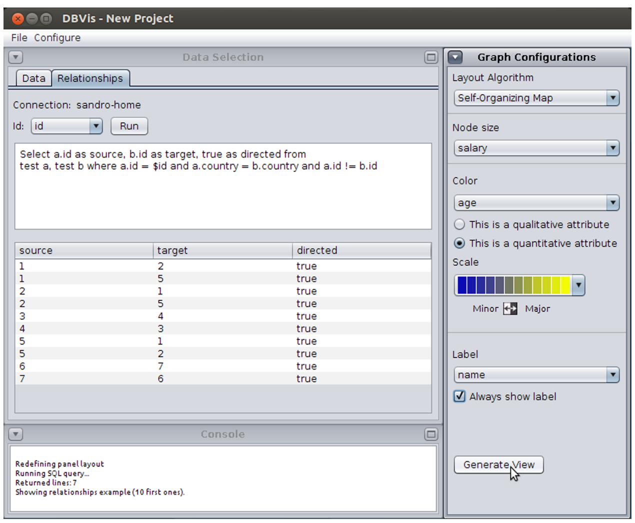
When the projection starts, an embedded web server is also started and provides a communication layer using REST technique [17]. This layer enables communication with external devices such as tablets and smartphones. This technique does not have a specific target platform and allows all devices that can do Hypertext Transfer Protocol (HTTP) requests to interact with the visualization.

Besides, this communication layer can be exposed through internet, allowing remote users to view and to interact with the representation, sharing information with users located in the MiniCAVE. The environment configuration is shown in Fig. 7.



#	id	name	country	age	salary
0	1	Alessandro	Brazil	29	5000
1	2	Rafael	Brazil	26	4500
2	3	Hailton	Germany	24	8000
3	4	Mario	Germany	24	7500
4	5	Luis	Brazil	21	2000
5	6	Osvanilson	Portugal	35	6700
6	7	Liedson	Portugal	39	8000

Figure 4. Selection of entities using a SQL command



source	target	directed
1	2	true
1	5	true
2	1	true
2	5	true
3	4	true
4	3	true
5	1	true
5	2	true
6	7	true
7	6	true

Figure 5. Selection of entities relationships and visual mapping

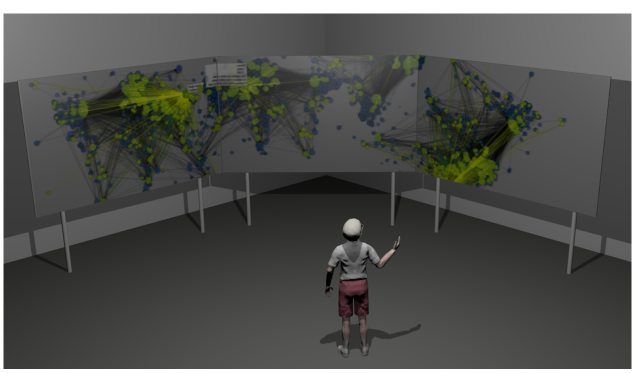


Figure 6. Graph visualization using the MiniCAVE

C. Mobile Application

The user interaction is done using mobile devices like tablets and smartphones. Compared with devices used in VR

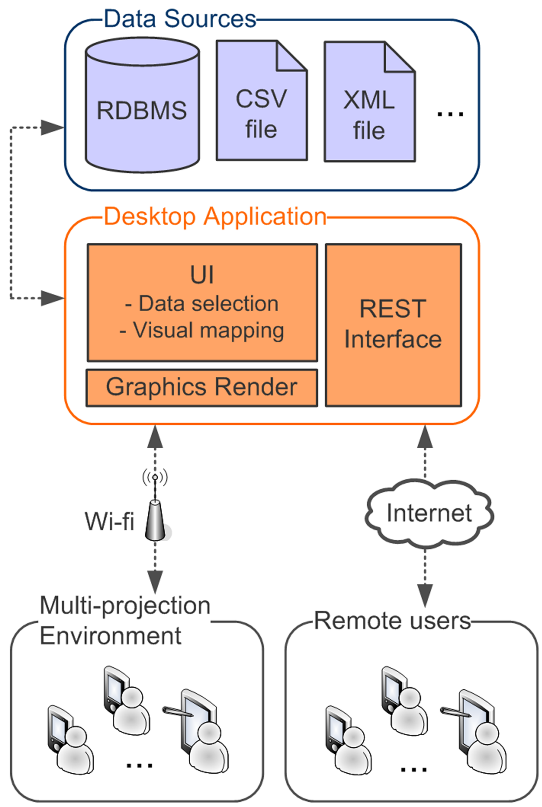


Figure 7. Environment Configuration. The system can connect to external databases or load files, and exposes an REST interface to allow users interaction using internet and wi-fi network.

multi-projection environments (e.g., data gloves and specific sensory devices), mobile devices have a lower cost and provide many useful features, such as accelerometers, gyroscopes, high definition cameras and even high processing power in some cases.

Furthermore, it's possible to use the screen to display additional information and the mobile device processing power to perform some tasks, reducing the amount of data transferred between the mobile and the desktop applications. This also reduces the processing done in the server, improving the system scalability.

The mobile application is designed to run over Android operational system, due to the possibility of using open source software as development platform and the wide range of available devices. The connection with the desktop application, also called as visualization server, uses a local wireless network or internet (remote users).

These are the features included in the mobile application: navigation and zoom, additional information, selection, textual notes and graphs creation.

1) Navigation and Zoom: This is the initial mode when the application connects to the visualization server, and allows the users to navigate in the representation using mobile device to view regions of interest and perform zoom operations if necessary (Fig. 8). This interaction is coordinated with the overview, where a rectangle with the user name appears, showing the area that is being explored (Fig. 11).

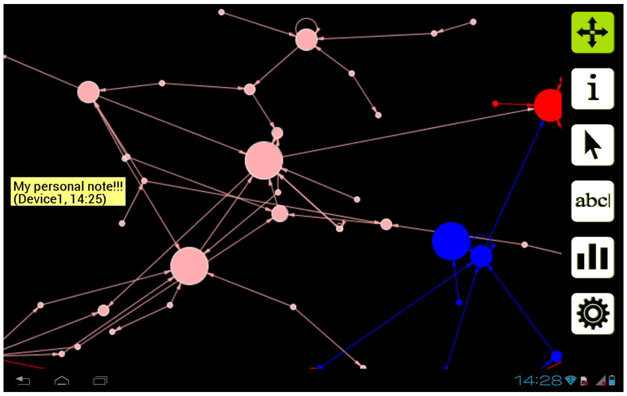


Figure 8. Detailed view with zoom into a region of interest using a tablet with 8.2 inches and 1280x800 pixels of resolution

2) Additional Information: Sometimes, some of the data attributes can't be mapped to visual properties in the overview, but these can be viewed in text format by touching a node displayed on the screen.

3) Node/Entity Selection: When using a graph representation, users can select an entity or region on the mobile device and these interactions are coordinated with the overview, so the selected nodes are highlighted on the multi-projection display, as well as their relationships and direct neighbors in order to provide a better understanding of their relationships (Fig. 9).

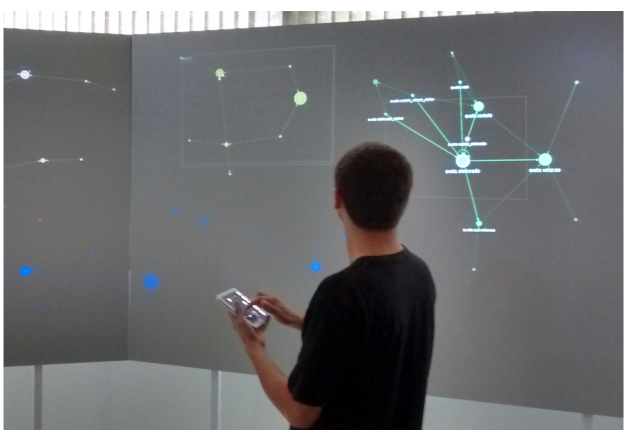


Figure 9. User selected entities are highlighted to provide a better understanding of their relationships

4) Text Notes: Users can share their findings using text notes, allowing other collaborators to understand the logic used to complete the tasks.

5) Additional Charts: Users can generate other charts using attributes from entities shown in the explored region (Fig. 10). These charts can be used to understand other properties of the dataset not contained in the overview and can be shared with other users.

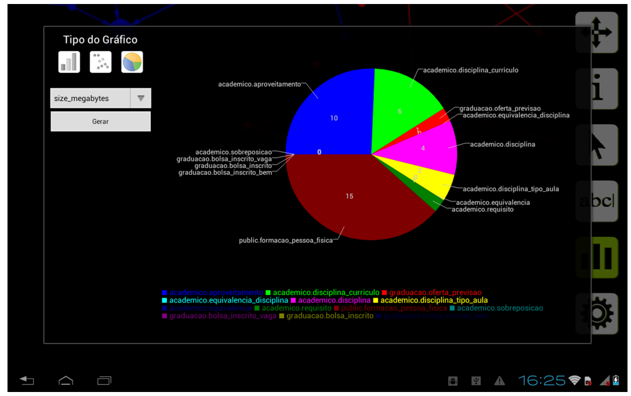


Figure 10. Round chart created using quantitative attributes of the entities shown in the individual user workspace

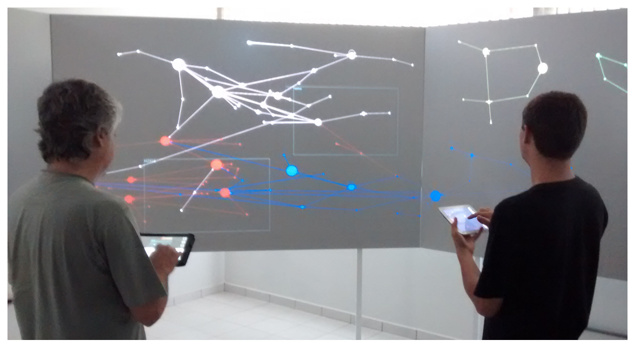


Figure 11. Users interacting in the MiniCAVE to analyse a relational database structure and couplings between tables of different systems using directed graphs representation. The rectangles in the projection are the region that users are exploring in their mobile devices

CONCLUSIONS

This work have presented two techniques: Augmented Visualization using mobile devices and Multi-projection. Combined, they can provide better user interactions in IV applications. These techniques have been applied in the creation of a collaborative system with large visual space, multiple simultaneous users support and good scalability.

Some considerations can be made compared to other existing tools (Table I). Our system has some advantages such as a large visual space with the capacity to display huge amounts of data, collaboration of co-located and remote users, identifiable user inputs, distributed processing, greater simultaneous users capacity and scalability.

The system is in the final stages of development and some preliminary user tests have been performed. The next steps are the improvement of some features and an extensive tests routine with users to evaluate system usability.

Table I
COMPARISON WITH OTHER INFORMATION VISUALIZATION TOOLS

System	Type	Large Visual Space	High Resolution	Distributed Processing	Collaborative Use	Simultaneous Users	Remote Access	Identifiable Input
Our System	Multi-projection	Yes	Yes	Yes	Yes	1 - 15	Yes	Yes
CaveDataView [18]	Multi-projection	Yes	Yes			1		
CAVE-SOM [19]	Multi-projection	Yes	Yes			1		
Analyst's Workspace [20]	Desktop	Yes	Yes			1		
InfoVis Toolkit [21]	Desktop		Yes			1		
Tulip [22]	Desktop		Yes			1		
Cambiera [23]	Tabletop Display		Yes		Yes	2		
Interactive Tree Comparison [14]	Tabletop Display	Yes	Yes		Yes	2		
Infotouch [24]	Tabletop Display					1		

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