3D VISUALIZATION AND VIRTUAL REALITY FOR VISUAL DATA MINING
A Survey

Zohra Ben Said, Fabrice Guillet
LINA, UMR 6241 CNRS, University of Nantes, Nantes, France

Paul Richard
LISA, EA 4094, University of Angers, Angers, France

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Abstract: Visual Data Mining (VDM) aims at an easier interpretation of data mining algorithm results through the use of visualization techniques. During the last decade, many techniques of information visualization have been proposed, allowing visualization of multidimensional data. Previously, ((Chi, 2000), (Herman et al., 2000)) attempted to classify VDM techniques . However, these taxonomies do not take into account some innovative techniques based on 3D visualization and virtual environments (VEs). In this paper, we propose an exhaustive survey of recent techniques for VDM. These different techniques are detailed, classified and compared according to the following criteria : graphical encoding, interaction techniques and applications. Moreover, they are presented in tables together with graphical illustrations.

1 INTRODUCTION

Since the emergence of databases in the 60s, the volume of stored information grows exponentially each year. In the 90s, this accumulation of information in databases has motivated the development of a new field of research : Data Mining (DM) (Fayyad et al., 1996). In many applications, such as network management (Tee et al., 2004), finance (Schreck et al., 2007), seismic (Marroqun et al., 2008), users need to explore relations in the data. These data sets are often large and dynamic. In addition, understanding data and tendencies is essential for users to make correct decisions. The extraction of useful tendencies in data for the user (domain expert) constitutes the main challenge of this research. The use of visualization techniques proposed by VDM can improve the readability of the results and offers significant potential for interaction and exploration of large databases. Given the number and variety of available visualization techniques, it is a challenging activity for information designers to find out the methods, techniques and corresponding tools available to visualize a particular type of information. The comparison of visualization techniques across different criteria is not a trivial problem. Previously, ((Chi, 2000), (Herman et al., 2000)) attempted to classify VDM techniques . However, these taxonomies do not take into account the latest approaches based on 3D and virtual reality techniques. Visual Data Mining (VDM) is an approach to explorate data analysis and knowledge discovery that is built on the extensive use of visual computing. The basic goal is that large and incomprehensible amounts of data can be reduced to an easy representation. This visual reprsentation can be easily understood and interpreted by a human. According to (Card et al., 1999), information visualization allows the user to learn about data and relationships among these data. The popularity of digital terrain models (Simoff, 2001), based on the geographical framework and CAD-based architectural models of cities has demonstrated that multi-dimensional visualization can provide a more efficient way of exploring large data sets. Some recent developments are extending VDM with algorithmic animation techniques, multimedia support and virtual reality (VR) immersive representations, aiming at involving decision-makers in the mining and discovery process (Visual Analytics). Decision-makers should be able to examine this massive, multi-dimensional, multi-source and

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time-varying information stream to make effective decisions in time-critical situations (Keim et al., 2008). Therefore, the success of VDM methods depend on the development of adequate interaction and visualization techniques.

Main Contributions. In this paper we purpose

- A recent review of 18 visualization techniques accompanied with graphic illustrations.
- A classification of these techniques across 5 groups : Focus + context, 3D tree, virtual world, 3D scatterplot and dynamic graph.
- A comparaison of each group of techniques across 5 criteria : application, graphical encoding, interaction technique, advantages and drawbacks.

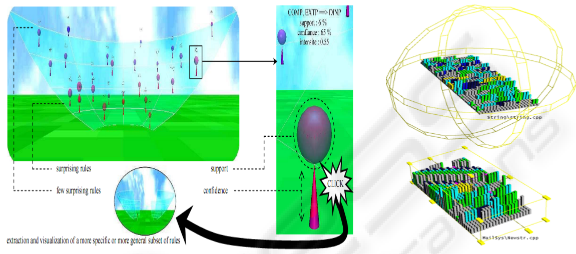
This paper is organized as follows. In section 2, we describe focus + context visualization techniques. In section 3 we present visualization techniques based on 3D virtual worlds. The paper ends with a conclusion.

2 FOCUS + CONTEXT VISUALIZATION TECHNIQUES

Originally, the method of focus + context visualization (F + C), aimed to wider detailds description of cetain parts of data (the point of interest, focus, etc), while the rest of the data is reduced in size in order to provide a guidance to the users. The best techniques F + C known, are the techniques of distortion: *fisheye* proposed by (Furnas, 1986). In the technique bending backwards, another variant of the F + C technique, the overview of different objects is not readable, but, miniature views of objects are index in order to help the user to move directly to the information sought. However, there are other methods that the distortion of space. The viewing volume for example, proposes to vary the opacity (Mroz and Hauser, 2001), *(*color shades) and frequency to achieve F + C visualization of 3D data. A detailed comparison of these techniques is presented in Table 1.

3 VIRTUAL WORLDS VISUALIZATION TECHNIQUES

The *virtual worlds* (sometimes called *cyber-spaces*) are another important trend in 3D information visualization. Virtual worlds for VDM are generally based either on the *information galaxy* metaphor (Krohn, 1996) or the *information landscape* metaphor (Robertson et al., 1998). The difference between the two metaphors is that in *information landscape*, elevation of objects is not used to represent information (objects are placed on a horizontal floor). The specificity of *virtual worlds* is that they provide to the user some real-time 3D intuitive interaction and/or navigation techniques (control of the view point). A detailed comparison of these approaches is presented in Table 2.



(a): ARVis (b): sv3d

Figure 1: Illustrations of virtual worlds visualization techniques.

3.1 3D Trees Visualization Techniques

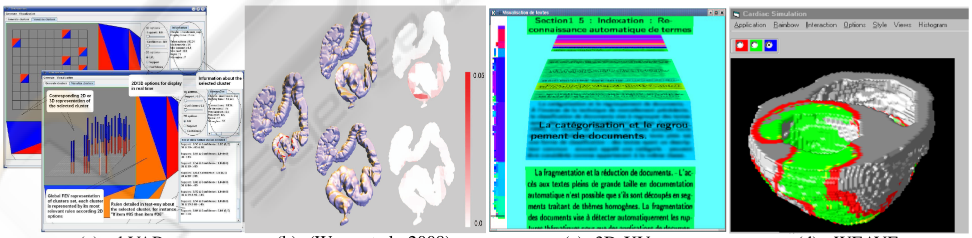
Trees are information visualization techniques based on hierarchical organization of the data. This approach finds many applications in graph visualization. Indeed, 3D tree was designed to display a larger number of nodes than those in 2D representations (TreeMap (Johnson and Shneiderman, 1991)). The *conical trees* are one of the best examples of this approach. They were introduced by (Robertson et al., 1991) for visualizing large hierarchical structures in a more intuitive way. 3D trees may be displayed vertically (ConeTrees) or horizontally (CamTrees). Some botanical approaches were proposed by (Ham and Wijk, 2003) and (van de Wetering Kleiberg and van Wijk, 2001).

3.2 3D Scatterplots

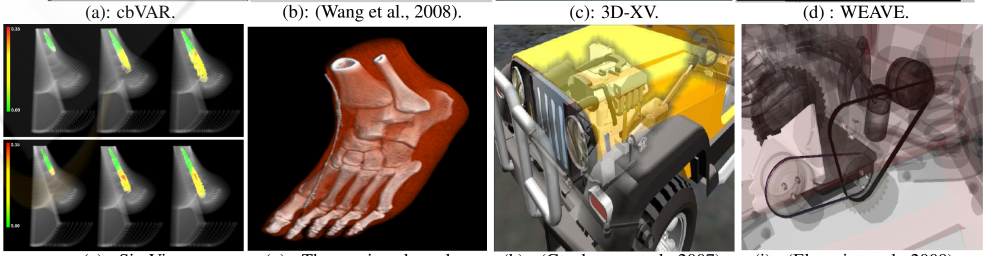
The 3D scatterplot visualization technique is one of the most common representations in 3D scientific information visualization. It is based on the *information galaxy* metaphor. The main innovation compared to 2D visualization techniques is the use of volume rendering that is a conventional technique in scientific visualization (especially medical imaging). The 3D rendering techniques use voxels (instead of pixels) to represent a certain density of the data. This technique has been adapted by (Becker, 1997), making the opacity of each voxel a function of the density of points.

Table 1: Comparison of Focus + Context Techniques.

Visualization system	Applications	Graphical encoding	Interaction technique	Advantages	Drawbacks
Visualization Fish-eye					
-CbVAR (Couturier et al., 2007) Figure 2(a)	-Visualization of association rules	-2D : context -3D : focus	-Selection -Zoom	-The display context help orientation -Displaying data in a cluster -Dynamic Tuning	-Few parameters displayed
- (Wang et al., 2008) Figure 2(b)	-3D shape	-Enlarge the focal region	-Selection -Zoom	-Deforming the non focal region without perceivable distortion	-Constraints in the case where there is not enough space
Bending backwards -3D-XV (Jacquemin and Jardino, 2002) Figure 2(c)	-Linear structures	-Focus area in the center of the screen and near data on the sides	-Navigation -Selection	-Different modes for information accessibility	-Visualization of sub-parts of data at one time
Linking and brushing **-Color** -WEAVE (Gresh et al., 2000) Figure 2(d) -SimVis (Doleisch et al., 2005) Figure 2(e) **-Opacite** -RTVR (Mroz and Hauser, 2001) Figure 2(f) -The Magic Volume Lens (Wang et al., 2005) Figure 2(g) -(Gtzelmann et al., 2007)Figure 2(h) **-Frequence** (Elmqvist et al., 2009)Figure 2(i)	-Medical data, scientific and industrial	-Utilization of colors (SimVis, WEAVE) , opacity (RTVR) and frequency to emphasize the focussed data parts	-Selection -Feedback (changing of colors, etc.)	-Multiple linked views -Immediate feedback -Fast detection of dependencies and correlations	-No semantic zoom



(a): cbVAR. (b): (Wang et al., 2008). (c): 3D-XV. (d) : WEAVE.

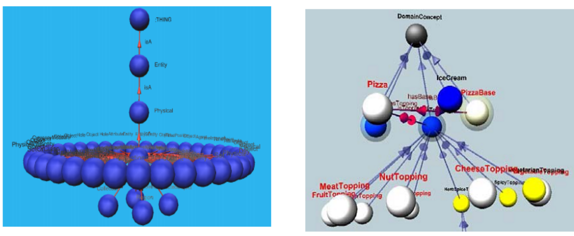


(e) : SimVis. (g) : The magic volume lens. (h) : (Gtzelmann et al., 2007). (i) : (Elmqvist et al., 2009).

Figure 2: Illustrations of Focus + contexte Visualization Techniques.

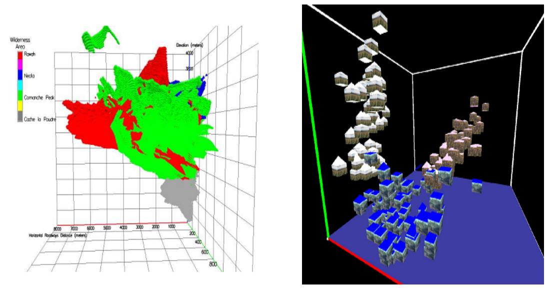
Table 2: Comparison of virtual worlds approaches.

Visualization system	**Applications**	**Graphical encoding**	**Interaction techniques**	**Advantages**	**Drawbacks**
Virtual worlds					
-ARVis (Blanchard et al., 2007) Figure 1(a)	-Visualization of association rules	-Size of a cone, of a sphere, their colors, position of objects on the arena	-Navigation -Selection -Zoom	-Order by set of rules -Navigation according to neighbor relation	-No hierarchical representation
-Source Viewer 3D (sv3D)(Maletic et al., 2003) Figure 1(b)	-Visualization of file structures	-Each code file is represented by a container. -Color : type of the control structure	-Navigation -Zoom -Selection -Filtering	-History -Screen shots -Free	-The cylinder position in the container does not represent any variable -No relations between classes or files -No hierarchical representation
3D trees					
-SUMO (Buntain, 2008) Figure 3(a) -OntoSphere3D (Bosca et al., 2007) Figure 3(b)	-Visualization of ontologies	-Atom : concept -Size of atom : number of documents associated to the concept -A cluster : concepts having shared documents	-Zoom -Navigation	-Easily interpretable	-One hand interaction
3D Scatterplots					
-3D Scatter Plot (VR) (Bovbjerg et al., 2003) Figure 4(a)	-Visualization of large data sets	-Different colors/textures to distinguish objects and clusters -The graphical variables are : position, shape, size, color, sound and texture	-Navigation -Selection -Zoom	-Use of sounds	-Limited number of graphical variables -Not very efficient
-VRMiner(VR) (Azzag et al., 2005) Figure 4(b)	- Visualization of multimedia data	-Color, texture, position, shape and sound	-Zoom -Navigation -Selection -Synthetic audio	-Use of VR techniques -Visualzation of large images -Low cost	-Limited number of graphical variables
Dynamical graphs					
-PEx (Paulovich et al., 2007) Figure 5	-Visualization of multidimensional data	-3D projection of multidimensional data -Color coding of apparition frequency	-Research -Selection -Personalization -Filtering	-Free -Visualization of both structured and non structured data	-No detail on demand



(a): SUMO. (b): OntoSphere3D.

Figure 3: 3D trees visualization techniques.

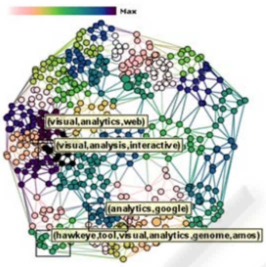


(a): 3DVDM. (b): VRMiner.

Figure 4: Examples of 3D Scatterplots.

3.3 Dynamic Graphs

Another technique based on the *information galaxy* metaphor make use of dynamic graphs. Dynamic graphs enable self organization data sets in the visualization area. This approach is mainly used for the visualization of hypertext or social networks. In this context, a better approach is to apply a force system to the nodes and links in order to find a minimum energy state of the system (or steady state) and determine the position of the nodes.



PEx :(Paulovich et al., 2007).

Figure 5: Example of Dynamic graphs.

4 CONCLUSIONS

VDM aims at an easier interpretation of data mining algorithm results through the use of intuitive and interactive visualization techniques. In this paper we proposed a recent review of 18 visualization techniques accompanied with graphical illustrations. This techniques are compared across 5 critera : application, graphical encoding, interaction techniques, advantages and drawbacks. Even if, the main result is that information visualization is indeed in great part of application fields , this study shows that there is a lack of interaction techniques. The main techniques proposed, by most visualization techniques, are basic techniques like : zoom, selection, navigation. The only system that offer a navigation through neighborhood relations between data is ARvis. For an efficient data mining process, the user must be more involved in the data mining process. Consequently, more sophisticated interaction techniques should be implemented.

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