Multimedia Support for Complex Multidimensional Data Mining

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ABSTRACT

ISO-3D project aims to develop tools in order to analyse and represent business information from large collection of data. The designed tools are mainly representation tools using 3D graphics, sound and animation.

In this paper, we will present two of the graphic representation tools which use also sound and animated picture. We will explain why and how we use sound and animation with graphical representation in this data mining approach.

Keywords

Symbolic Objects, Visualisation, Sound, Animation.

1. INTRODUCTION

Economical data usually depend upon time but are also explained by an important number of heterogeneous variables. When recorded systematically, like in portfolio management (for banks) or audience monitoring (for TV), they constitute rapidly huge data bases. Managers need tools for extracting daily knowledge from these data.

Symbolic Analysis is a kind of data analysis which is able to deal with complex multidimensional heterogeneous data and to summarise information. It is broadly accepted that graphic representation facilitates interpretation of results.

Development of multimedia techniques allow now other representation means than visualisation by graphics; we think here to sound and animation. Moreover, in order to take quick decisions, it is necessary to work without delay on data which are often stocked on another site. It is why network technology is used.

ISO-3D project aims to develop tools in order to analyse and represent business information from large collection of data integrating also those new techniques. The prototype is running in a client/server architecture called Infobus, based on more recent network technology. The designed tools are mainly representation tools using 3D graphics as well as sound and animation.

In this paper, we will present two of the graphic representation tools which use also sound and animated picture. Before that, we will explain what is Symbolic Analysis in order to understand the data in input of our representation process for introduction of multimedia support and we will develop some arguments for the use of sound in data exploration.

2. COMPLEX OBJECTS CALLED SYMBOLIC OBJECTS

The standard methods of statistical data analysis accept as input, « individuals » by « variables » matrix. Each cell (i,j) of such an array contains the value taken by individual i for variable j. The value is said to be « atomic » in the sense that it is not a list or a set of values.

The Symbolic Data Analysis [BOCK&00] extends the input data structure to « individuals » by « variables » arrays where the value taken by an individual on a variable may be non-atomic, but possibly a set of values, intervals of values or a probability distribution.

For example this values can be

1. A set of quantitative values : [Age = {15, 22, 45, 47}].
   It means that the age of family members are 15, 22, 45 and 47.
2. A set of categorical values : [TV preference = {RAI1, R4}]

(notice that standard quantitative and categorical values are special cases of 1 and 2).

3. An interval : [Age = [15, 47]] which means that age in the family is between 15 and 47.
4. A set of weighted categorical values : [TV preference = {RAI1 (0.3), R4 (0.7)}] which means that 30 % of the family has daily preference for RAI1 channel and 70 % of the family has daily preference R4 channel.

We will give the name of Symbolic Object (SO) to a row of non atomic value.

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3. VISUAL REPRESENTATION

From user requirements in SODAS [NOIRHOMME&00] and ISO-3D projects, we know that users need to visualise a Symbolic Object (SO), a SO inside the reference population, various SOs in principal components space, SO during time and important changes, they also need to point out particular SOs on other graphs (like hierarchies, result of SO classification) and visualise them.

In ISO-3D, to meet these requirements, we have suggested the Temporal Star and the Simple Star graphical representation.

First, we will remember the principles of the Zoom Star [NOIRHOMME&00].

The **Zoom Star** representation is a radial graph where each axis corresponds to a variable .

We allow variables in intervals, multivaluate values, weighted values to be represented. We chose conventions for axes representation (colour, dots). A two dimensional and a three-dimensional representation have been designed.

In the 2D Zoom star, axes are linked according to each variable values (see figure 1 of Simple Star). Most weighted value of a categorical variable are linked as well as extremities of intervals. A surface is drowned by joining extremities of intervals or points of highest weight. This representation does not allow details about distributions associated to weighted categorical variables. However, the user can ask for the complete distribution to be displayed in another window by selecting the axis.

On the 3D Zoom Star representation, distributions corresponding to each weighted values are shown directly on the axis. We provide the user with the opportunity to animate the graphic by turning the picture around a vertical and an horizontal axis in order to make easier the retrieval of pertinent information. On the 3D representation, axes are not linked because the image is continuously changing due to animation feature. The iconic representation is then meaningless in that case.

Let us note that evaluation of the Zoom Star has been made in the past with students [NOIRHOMME& 98] and that validation has been made by many users of SODAS project [Bisdorff99] and by researchers[MENNESSIER&98].

Whereas users had no preliminary experiment with this kind of representation, it appeared that the Star was user friendly and answered user problems.

3.1 Simple Star

The Simple Star will be mostly used to show the detail of a Symbolic Object represented on a preliminary graphic (like Temporal Star or classification representation).

The Simple Star is analogue to the Zoom Star in 2D but the functionality are slightly different.

To be consistent with Temporal Star, some conventions of colour and colour shade are used.

Several stars representing different objects can be superposed (figure 1).

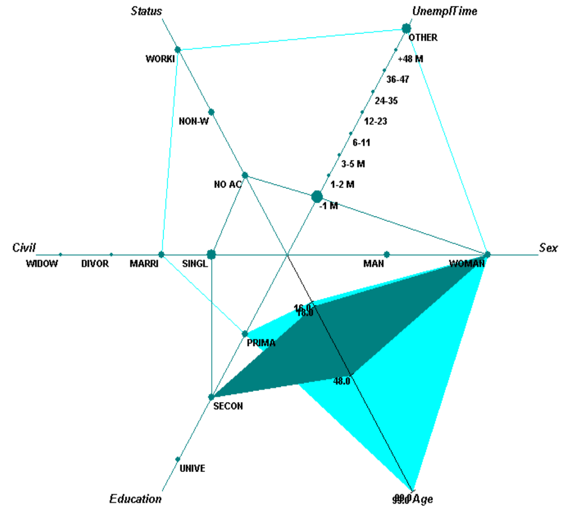

Figure 1. Two Superposed Simple Star.

3.2 Temporal Star

The aim of the Temporal Star is to represent a Symbolic Object at different epochs.

A star in perspective represents the symbolic object at a given epoch (like in the 3D Zoom Star).

The stars at different epochs are thread on one axis representing time (figure 2). This figure can be moved and zoomed. Different colours can be chosen for the different axes. On each axis, representing a categorical variable, the histogram can be shaded, coloured. To emphasise the evolution from one epoch to another, when the axis represents a quantitative variable (mean or intervals), the extremities of the intervals (min, max) or means can be joined. and a transparent veil will be added to the stars (on demand).

It must be also possible to select a particular star on the thread and to display it on the form « Simple Star » (see figure 2).

4. USE OF SOUND IN GRAPHICAL DISPLAY

Most modern graphical displays are highly visually demanding because all information is graphically presented. Our visual sense on the other hand has a rather small area of high focus. A problem arises when a user must concentrate on the visual feedback from one part of the display, so that feedback from another part of the display may be missed as it is outside the area of visual focus. As the amount of information contained by the visual display increases, it may arise that the user become overloaded and the display ineffective. This problem has been extensively documented in recent research, for example by S.A. Brewster who studied auditory enhancements to tool palettes [BREWSTER98a], graphical buttons [BREWSTER&95], etc.

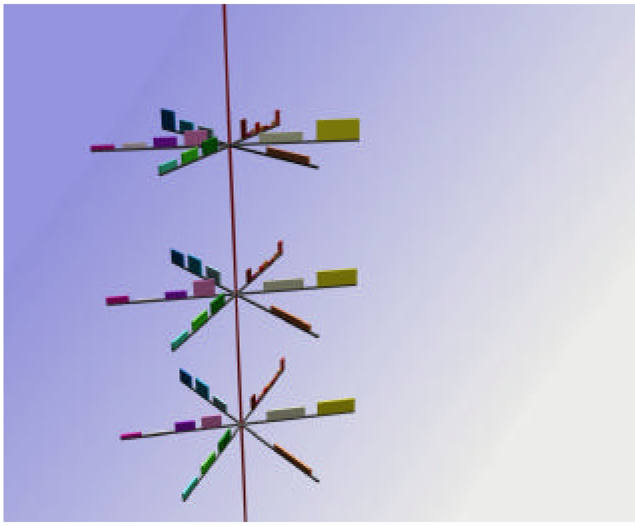

Figure 2. Temporal Star

Another problem arises when representing multi-modal information. In real life, a person is interacting with more then only visual sensations. Most Human-Computer Interfaces represent however only one mode, namely the visual mode. Since it is impossible to convey all the information received by all modes using only visual representation, the user would benefit from a multi-modal interface, because of an increased amount of information and a more natural way of representing it. [ANRIJS99]

How sound can improve the graphical interface?

In [KRAMER94], G.Kramer distinguishes several advantages that result from combining the graphical interface with sound.

The main advantage is that sound can be integrated without interfering with the visual display. Sound is eyes-free. This *nonintrusive enhancement* offered by sound ensures that the user does not become overloaded. It even decreases the overload because sound can replace insufficient or inappropriate visual cues

When representing data, sound offers high dimensionality of up to seven dimensions [CONVERSY&95] and, compared to the visual display, offers *a superior temporal resolution* and *complementary pattern recognition abilities*. The human ear is more sensitive to changes than human vision and perceives the same information in a completely different way, thus providing new and complementary ways to detect occurring trends and relationships in datasets. Moreover, this complementary information leads to *intermodal correlations* where patterns detected by one sensory display are confirmed and verified by the other sensory display.

Another advantage (not mentioned by Kramer) is that short-term memory processes (and therefore remembers) auditory and visual data in a different way. Auditory data has been shown to be remembered longer than visual data.

A sonic interface has one important disadvantage, namely that, unlike the human eye, which can ignore visual stimuli by moving its focus or simply closing its eyelid, a human ear cannot ignore auditory stimuli. In an office environment, this can cause severe problems as users are disturbed by sounds coming from other users.

The most obvious solution is the use of headphones, but this isolates the user from events and communication in the office and is thus undesirable. A method using only one earphone has been proposed and tested with satisfactory results. With this method the right ear has an earphone and captures information coming from the computer, while the left ear is free to capture information from the office.

5. USE OF MUSIC IN GRAPHICAL DISPLAY

The potential of music as an output medium has hardly been examined. However music is the most sophisticated medium of the auditory media. The information is highly organised into complex structures and sub-structures. It can then be used to transmit complex information to a user. As emphasised by James L. Alty [ALTY95], music has some advantages on other media :

« - music is all-pervasive in life. It is very memorable and durable. Most people are reasonably familiar with the language of music in their own culture. Once learned, tunes are difficult to forget ».

« - music involves the simultaneous transmission of complex ideas related over time, within an established semantic framework ».

Let us add two other related arguments:

- Music is often used to transmit information, even if we are not as conscious of that phenomenon as for video channel. We think here about the use of music and sound in movies.

- Western music is organised mathematically with ratios, equal frequency differences between sounds, predefined duration (note value, silence value). It is then not surprising that mathematical structure, and numerical data can be transmitted through music.

Music has a large variety of parameters. Besides characteristics for elementary sounds like pitch, timbre, loudness, duration, reverberation and location, music uses chords (harmony), rhythm and polyphony. This one is very helpful because it can be used to transmit several information simultaneously.

We could think that only musicians are able to perceive musical sound with accuracy.

In [ALTY95], J. Alty describes experiments about perception of tones. Of course, he observes differences between individuals but he can conclude the following :

- Human beings can perceive numerical difference between two tones, usually to about ±1 tone within the octave though the accuracy decreases away from their reference point (large or small intervals are better perceived than middle ones).
- Subjects seem to be able to follow and remember the general pattern of a tune, but the magnitude of variation vary considerably from one to another.
- Rhythm appear as a candidate for improving intelligibility. More rapid presentation of the sequence could help. Not surprisingly, response is more accurate when the notes are organised into a tuneful sequence than when they are sorted.

6. USE OF SOUND IN ISO3D

We have seen the interest of using sound in Human-Computer Interface. The problem is now to decide when choosing graphic or audio. Audio can replace graphic in special cases : when the user is concentrated on a task which does not allow him any distraction by a screen, when the user is blind or is not able to see, for any kind of reason (for example, lack of light).

In ISO 3D, these reasons have not been identified in the user requirements, (but it could happen that some users are partially-sighted). It is thus not appropriate to use audio alone. We have decided to use audio in complement to graphic representation. Graphic representation is the normal way to summarise data. Sound is not usual at all for statisticians. We think that users will be less disturbed if we use sound as a complement to graphic representation.

Let us add that in a previous survey for SODAS project we have asked to statistical users if they were ready to use 3D, colour, sound. The answer was positive for 3D and colour but negative for sound. We have then to take into account a certain negative a priori against sound. Perhaps, that if we ask the same question to younger users, from video game generation, the answer would be different, but at the present moment, with present users, we have to introduce sound carefully. For example, sound cannot be imposed but can be chosen at the beginning of the session.

We have tried, in absence of sound user requirement, to imagine for what kind of information sound could be used. In systems supervision or process control, sound is often used to attract attention on particular problems.

In complex multidimensional data representation, situation is different. The more accurate problem is to represent a large amount of information : large amount of variables of different types, given generally not by single value but by an interval or a distribution. It is then difficult to give all the information at once. In graphic interface, we choose an interactive approach but sound can help to give some kind of information on demand. We have chosen characteristics which seemed hard to be given visually.

6.1 The type of axes

The variable can be numerical, given by an interval of value, categorical, given by a distribution and non applicable, when the axis is represented but is not used for the present object.

A warning can be given on the axes type, when selecting an axis. This warning will be given in the form of a musical earcon. Different sounds have then to be designed for each type and must be very distinct. Rhythm chord and timbre will be important elements to improve the disambiguation between sounds

6.2 Dissimilarity between two symbolic objects

When the symbolic objects are represented on a Temporal Star, linked by a central thread representing time or in different windows, like in the Simple Star way, user can be interested to know in which amount the objects differ from each other.

The first step is to compute a dissimilarity measure between both objects and then to show dissimilarity on the form of a number.

Process can be lighten if dissimilarities are computed automatically, at the beginning of the session, and given to users, in audio way, on request, by a selection click on both objects. A musical sound will be played, with duration proportional to dissimilarity value.

In a first approach, we have divided the range of dissimilarity measure into five equal intervals and to map each of these intervals into a sound with proportional number of chords or notes. For example, if the dissimilarity has a value of 3 (in a scale between 1 to 5), three notes or chords are played successively.

Let us note that sounds for dissimilarity must be very distinct from earcons for axis type.

6.3 The weight of axes

When representing axes in a radial shape, there is no first axis, no last one and axes order is usually arbitrary. When variables are the result of a Principle Component Analysis, they are given with a weight corresponding to the percentage of information (or inertia) explained by each one. This element is important but is usually given in a table, annexed to the graphical representation.

It could be much more helpful using sound. When moving the cursor over an axis, a sound according to the importance of the axis will be played. The visual display will remain unchanged and the user will not have to shift his focus off the symbolic object.

Earcons or musical sounds are of different length/height according to the weight of the axis. A mapping between weight and pitch is tried.

7. ISO3D CHOICE TO GENERATE SOUND

Several decisions had to be taken in order to create sound inside ISO-3D software.

The first step was to make the choice of the type of sonic representation. We have chosen musical sound instead of speech, natural or virtual sound. In preceding paragraphs , we have explained most of the reasons for choosing music but we have to admit that it is also the result of a personal subjective choice.

The second step concerns the way to create musical sound: to copy sound in wave format and transform it into MP3 standard or to design our original sounds.

Copying sound to create musical earcons would be like copy parts of paintings to create icons. It would not be well appropriated, not sufficiently flexible, not easy to tune, not master. We then decided to create our own musical sound.

At the third step, we have to decide who will design the sound. An orchestra ? It is out of our budget ! A musician ? We know some very well.

The first possibility would be to record (in audio or wave format) and then digitalise and compress the result. This solution needs studio record material.

An alternative, and it is the solution that we have chosen, consists to use a synthesiser which transforms directly a large variety of sounds into MIDI format files. This solution allows a large range of timbres, tones, which cannot be obtained with a single instrument. It can also generate polyphony.

The last step concerns hardware/software synthesiser. For our musician, who is pianist, it is much more natural to use keyboard then to tune the sounds on a computer. Moreover, virtual or software synthesiser need still some improvement to have the same quality as hardware synthesiser. The advantage of external production on internal one is that these sounds are easy to integrate in the application and that they are hardware independent, meaning that, no matter the used soundcard is, the sounds produced are the same. The disadvantage is that only few parameters, like balance and loudness, can be modified while using the musical sounds in the application tool.

To design a more adaptable product, we have decided to offer a library of sounds, with a choice by default (like when you choose your bell ring on your portable telephone or the colour of screen).

8. ANIMATION

Animation of an object can help to understand his evolution along time.

We have used this technique to show the evolution of an object represented by a Simple Star. Considering, for example, the data of TV audience of a family recorded by minutes, if we superpose quickly the pictures of Simple Star for each minute, we obtain an animated picture which shows the evolution of family preference all along the day.

9. SOFTWARE DESIGN

A first version of the software has been developed using Java 2.0, Open Inventor, 3D-MasterSuite and Java Media Framework 2.0 (JMF). It runs in a client/server architecture on the web (InfoBus technology).

OpenInventor is a 3D graphic API using OpenGL standard. 3D-MasterSuite extends and includes Open Inventor and high level 3D graphic classes. We have used the Java version so that , when necessary, objects not available in 3D-MasterSuite can be programmed in Java.

The JMF is an application programming interface (API) for incorporating media data such as audio and video into Java applications and applets. It is specifically designed to take advantage of Java platform features and supports several audio and video formats. JavaSound has been incorporated into JMF (which has been lately incorporated into Java 1.3).

The JMF 2.0 API extends the framework by providing support for capturing and storing media data, controlling the type of processing that is performed during playback, and performing custom processing on media data streams. In addition, JMF 2.0 defines a plug-in API that enables advanced developers and technology providers in more easily customising and extending JMF functionality.

To implement the sound, we had to make a link between Open Inventor and JMF. A special sound object has been implemented. Its task is to:

- initialise the soundcard
- to load a sampled file (e.g. WAV) or a MIDI file
- to play that file

10. EVALUATION

Next step is to evaluate the prototype with the users who provided pilot applications. It will be done for November 2000. These applications are TV Audience in RAI (Italy) and portfolio management in ING (The Netherlands).

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Participants:

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Companies : Matra System & Information, TGS (France), CISIA (France).

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