THE APPLICATION OF 2, 3 AND 4D COLOUR GRAPHICS DISPLAY TECHNIQUES IN THE INTERPRETATION OF COMPLEX MULTI-LAYER DATA MODELS

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1. INTRODUCTION

Computer graphics display applications can be divided into three sub divisions:-

1) The representation of physical objects.

2) The representation of the interaction of related data sets.

3) The creation of pictures which have neither direct physical nor data relationships.

This paper deals only with the second application area and the advances in device independent graphics software techniques which allow increasingly complex data relationships to be visualized.

The paper argues that although historically the usage of vector graphics software and hardware systems was deemed sufficient to display data models, today a combination of both raster and vector based systems is necessary to address the application needs of the modern user.

Examples are shown from a wide range of data interpretation applications areas ranging from 2D through 3D to 4D displays demonstrating the results achievable using today's 2D display hardware.

The argument is then extended to applying similar techniques in a 3D hardware environment and the benefits to be gained.

2. 2D REPRESENTATION

The various options for 2D representation of data in XY graphs are familiar to most computer users:-

- Scatter graphs
- Line graphs
- Bar graphs
- Pie charts

These display techniques will continue to be utilised in applications where the visualization of the interaction of only 2 variables (often with multiple data sets) is all that is required. There are many variations on the main themes, with most work recently concentrating on presentation quality and style to meet the increasing demand for business graphics usage. This is most prevalent at the PC level where the display technique is quite sufficient for the majority of applications needs with limited data volumes and complexity.

The display of 3 variable interactions has been feasible for quite some time via 2D contour line maps. This technique has been traditionally utilised for geo-related applications, e.g. topographic maps and some technical data analysis where 3 variables are involved. The limitation of this technique is that once a certain value of data is reached (perhaps 1,000 intersections) the maps become extremely complex to read - highs and lows are easily confused and visualization of the total data model is impossible.

A far more effective way to deal with these 3 variable applications is to utilise accurate colour shading between the chosen contour intervals to emphasise the models' form. This technique five years ago was limited to those who could afford the very expensive colour raster terminals and colour raster hardcopy devices needed to produce the pictures. Today these devices are within the reach of most users.

Colour shaded contouring allows very large (many millions of data intersections) 3 variable data sets to be accurately interpreted enabling complex data modelling, not just in geo-related applications but also in many branches of research and engineering. Incorporation of discontinuities, barriers or, in geological terms, faults, is quite feasible and in many cases critical to enable correct analysis.

An extension of the 3 variable colour shaded contour display is to use multiple 2D planes to visualize multi-layer data models. Such models may represent changing data relationships through time, physical depth in a subsystem, certain temperature or pressure regimes, or other constants for the 3 variable interaction.

The 2D colour shaded contouring technique can be applied to certain specialised application areas with dramatic results. Its contribution to the interpretation of seismic data has provided oil exploration researchers with a powerful user tool.

The natural progression from these 2D shaded colour contour techniques is to extend the methodology into 3D representations.

3. 3D REPRESENTATION

In this section I deal with 3D representation on 2D devices using 2D fundamental software techniques.

3D representation of 3 variable interactions has been available as wireframe diagrams for some time.

3D representation has also been used in business graphics with bar charts and pie charts.

The 3D wireframe as a data modelling tool can only provide the broadest overview of the data relationships involved. The interpreter is unable to see data range values within the model and is only able to use the display for rather crude comparison work. The addition of accurate colour shaded contouring to the 3D wireframe changes the picture somewhat.

Colour contouring picks out the value ranges so that the interpreter can accurately read the intersection value at any point on the model down to individual values if he sets his contour intervals freely enough. A far more accurate analysis of the 3 variable interactions is therefore possible.

In many cases an interpreter wishes to visualize a 3 variable display in both 2D and 3D representation simultaneously. This is quite feasible and allows viewing "behind the peaks" whilst giving the advantages of 3D visualization.

As with the 2D colour shaded contour models, visualization of multiple 3D models can be very useful in complex data environments where a constant variance can be displayed in relationship to the 3 variable data.

4. 4D REPRESENTATION

The colour shaded contouring techniques developed by UNIRAS were quickly utilised by major oil companies in the early 1980's. These companies also wished to display rock types (geology) and the techniques were expanded to include these requests. This display of a 4th variable in a 3D representation in a 3D representation is termed 4D representation.

4D representation is now utilised in many data analysis applications where the inclusion of the interaction of a 4th factor can dramatically enhance the interpreter's efficiency.

4D can also be used to demonstrate the validity of models by demonstrating the accuracy of interpolation techniques. Kriging is a geostatistical methodology which can greatly enhance an interpreter's data model analysis in 3D by colour contouring the validity of his model in relation to actual data intersections prior to interpolation.

4D is also very useful in relating a 4th variable to a 3D model constructed by CAD systems. Examples are air pressure on a car body or temperature on an aero engine.

The principles of 4D representation already show considerable promise in a large number of complex data analysis applications. The integration of 4D representation with true 3D hardware systems will provide even further depth of analysis opportunities.

5. INTEGRATING MULTI DIMENSIONAL REPRESENTATION WITH GRAPHICS STANDARDS

An important consideration for any graphics software technique today is its application within the graphics standards environment.

The techniques described in this paper address functionality not catered for in the GKS or PHIGS standards but required by users who also wish to comply with such standards as far as possible.

It is in the interests of a software vendor to create standards-based applications to take advantage of the standards' functionality which is being increasingly incorporated in device firmware by hardware manufacturers.

UNIRAS has developed a strategy which enables the techniques described to operate within GKS 2D environments today and cater for GKS 3D and PHIGS environments as their usgae becomes more widespread.

A description of this "standards independent" approach is outside the scope of this paper but is described in Dr. Mikael Jern's paper as part of the proceedings of the Eurographics 1987 Conference. "The need for more intelligent facilities in graphics standards.

6. MULTI DIMENSIONAL REPRESENTATION UTILISING 3D HARDWARE DISPLAYS

The pressure to compete in product innovation, efficiency and reliability in all areas of research and development will increase over the next 2 years as the price performance ratio on 3D display hardware will change in favour of the interpreter.

The ability to analyse greater multiples than 4 data sets will therefore become feasible and necessary within this period.

The display techniques generated for today's 2D graphics devices are extensible into this true 3D environment and will enable the interpreter a far greater scope of analysis.

In a true 3D model of a cube, 6 independent variables will be modelled interacting throughout the volume of the cubic form. Sections can be cut at any angle to view surfaces within the model, ranges of 3D interaction can be cut out and analysed volumetrically, 3D barriers and discontinuities will be taken into account and even travel-through passes will be possible with visibility ranges set to control translucence for viewing.

Multi-faceted 3D models will be feasible to show greater ranges of variable interactions with intelligent display management software selecting for the interpreter the most relevant viewing options.

Obviously, the advancement of accurate display techniques for these multi-variable, multi-layer models depends also on the accuracy of the many statistical methods utilised to interpolate data in a 3D environment. The two technologies must advance hand in hand to ensure the efficiency of interprative tools.

At UNIRAS our mission is to ensure that as 3D hardware becomes affordable enough to be used in increasingly complex data interpretation applications, our device independent graphics software tools will be in place with the standards' compatability and performance levels necessary to take advantage of it.