Visualization Flows and Outcomes

Mary J. McDerby and Martin J. Turner[1]: Research Computing, University of Manchester

We present here, in this short paper, two of the most famous abstract data-flow models used within scientific and information visualization, and then give a brief set of examples of "variations on a theme" for the same data set. The models are the Haber and McNabb [1] Dataflow Reference Model for Scientific Visualization and Spence's Navigation Framework for Information Visualization [2].

1 Haber and McNabb – Dataflow Reference Model

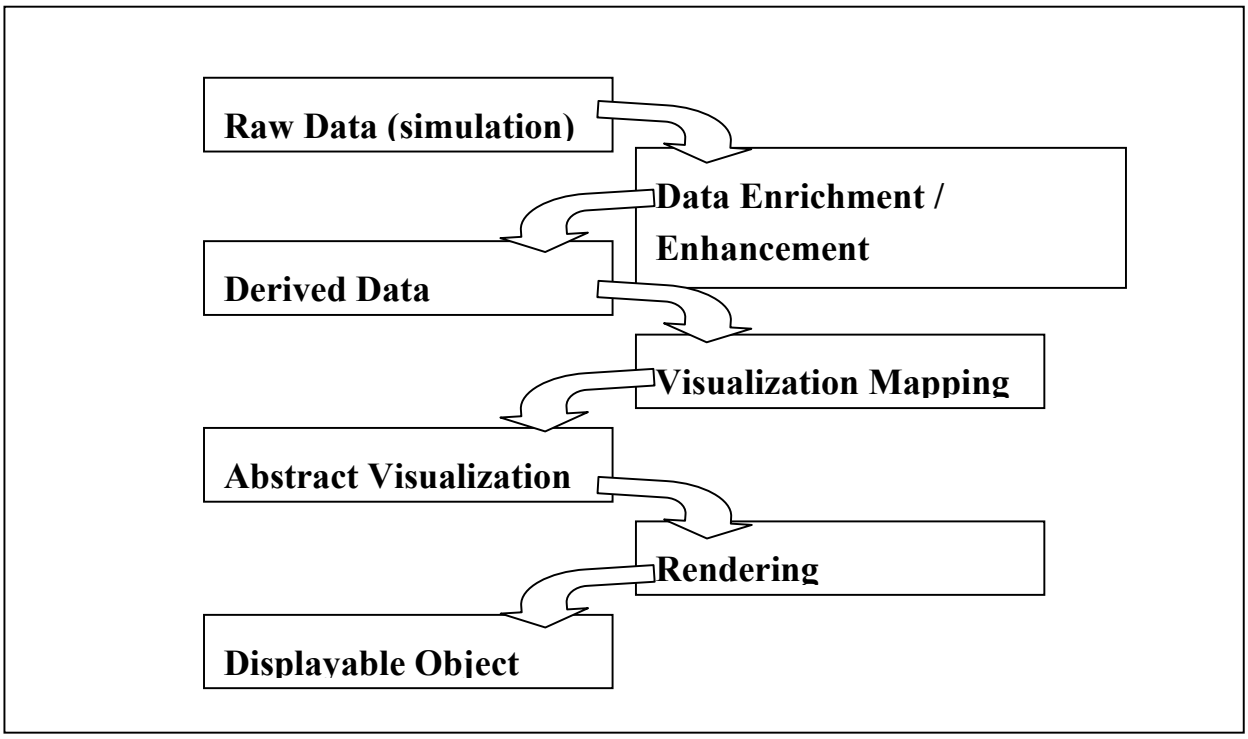


Figure 1: Haber and McNabb Reference Model, adapted from [1]

The authors of this Dataflow Reference Model take the view that visualization is a series of transformations that convert raw data into a displayable image. The goal of these transformations is to convert the information to a format that is understandable by the human perceptual system while maintaining the integrity of the information. Within the Haber and McNabb Reference three major transformations occur:

[1] Mary.McDerby@manchester.ac.uk, Martin.Turner@manchester.ac.uk

1.1 Data Enrichment/Enhancement

This is the first transformation and operates on the raw data obtained from the simulation or data capture phase. Operations such as interpolation, filtering or smoothing that are designed to reduce noise or increase the quality of the data are commonly performed at this stage to create the derived data.

1.2 Visualization Mapping

The result of this transformation is an imaginary object called an "Abstract Visualization Object" or AVO that is constructed from the derived data. Visualization Mapping involves mapping the data into attribute fields that describe the AVO. The attribute fields may include: geometry, time, colour, transparency, luminosity, reflectance or surface texture. Transfer functions are used to define mappings to the AVO fields. Some examples of transfer functions include; the extraction of an isopotential surface from a three-dimensional field representation (surface contouring), the cropping and selection of areas, as well as the use of linear or non-linear functions to highlight features As there are many different transfer functions available, an interactive system is often used to allow for real-time modification and enable dataset exploration.

1.3 Rendering

The rendering transformation operates on the AVO to produce a displayable image. This final transformation involves the use of familiar operations from computer graphics and image processing. Typical rendering operations include different view transformations i.e., rotation, translation, and scaling, perspective mapping and clipping, as well as alternative optical effects including, hidden surface removal, shading, shadowing, and optical transfer functions used within volumetric rendering.

A visualization idiom is defined as any specific sequence of data enrichment and enhancement transformations, visualization mappings, and rendering transformations that produce an abstract display of a specific data set.

2 Information Visualization – Spence Navigation Framework

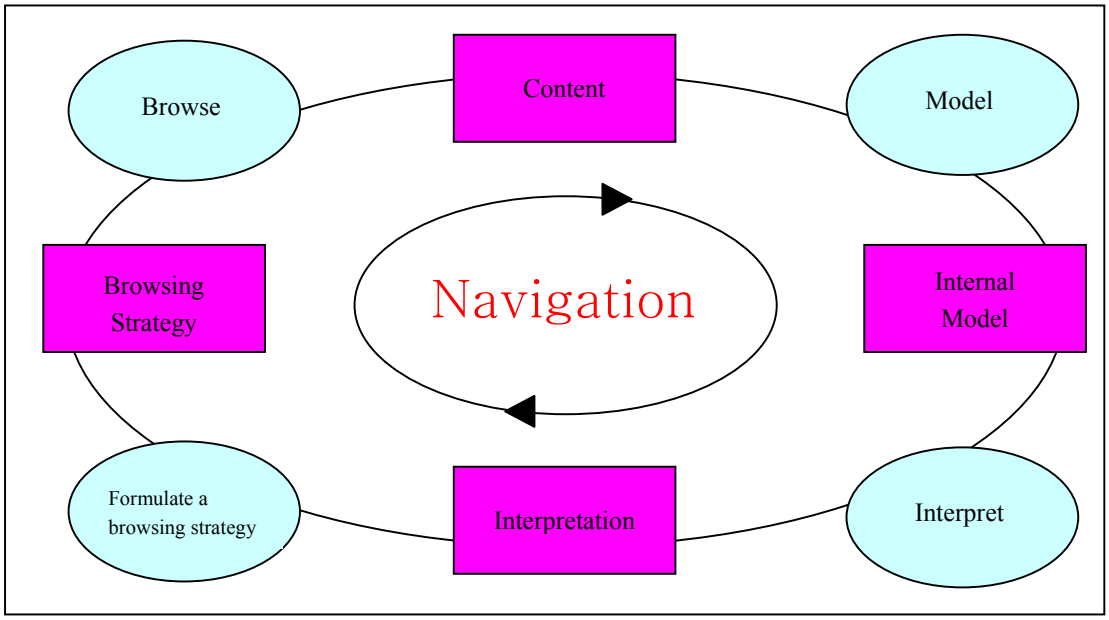


Figure 2: Robert Spence's Navigation Framework adapted from [2]

The navigation framework proposed and described by Spence [2] serves to describe the process of navigation of an information space, where navigation is defined as the creation and interpretation of an internal mental model. It takes into account interactive exploration, and describes investigatory modes including global view and zooming in to detail as well as progressive scanning. Whereas the dataflow reference module, previously described, only shows how data can be modified from source to visualization.

A specific example activity described through Figure 2 could be browsing a road map on the AA website in order to find a pattern such as a route to a location. The modelling of that pattern results in an internal model (or 'cognitive map'). Interpretation of that model is the next step – this could be identifying a shorter route. Next, based on the interpretation, the user formulates a new browsing strategy – this could be the decision to display two maps together to see, again by browsing, if the shorter route is indeed the best (e.g., any traffic hotspots at the time of travelling could be identified). According to Spence [3] the entire framework is that of navigation, in the sense that the internal model is being created and explored. The overall intention or goal is the general desire to gain insight (via visualization) into the origin (in our case how to get from A to B).

The framework described in Figure 2 refers to internal (mental) processes – it can be extended to include external features such as the externalization of the data the user is browsing (Figure 3). This is in order to reflect the fact that the execution of any task involving information visualization will be motivated by the user's intention and influenced by many factors. One of these is the user's internal model. Another is the visible externalization of some data. A decision as to how – as well as whether – to proceed will depend upon an interpretation of these sources of information. Figures 3 and 4 shows the externalization of data and how it fits into the navigation model with regards to interpretation.

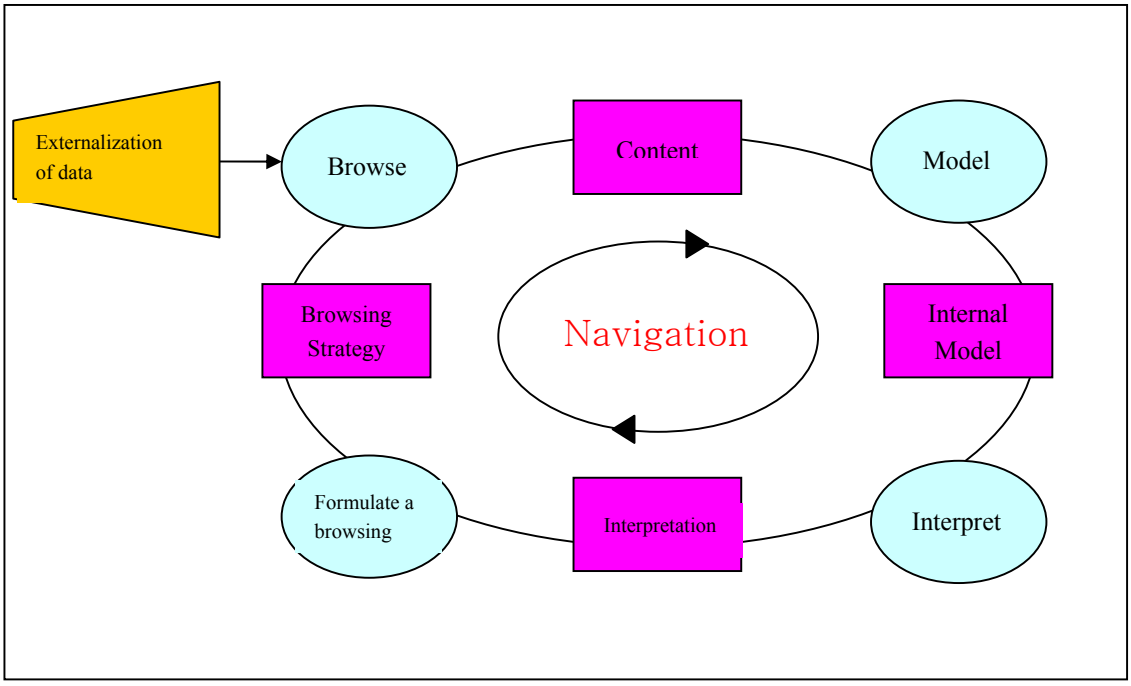


Figure 3: Browsing of Externalized Data Leads to an Internal Model

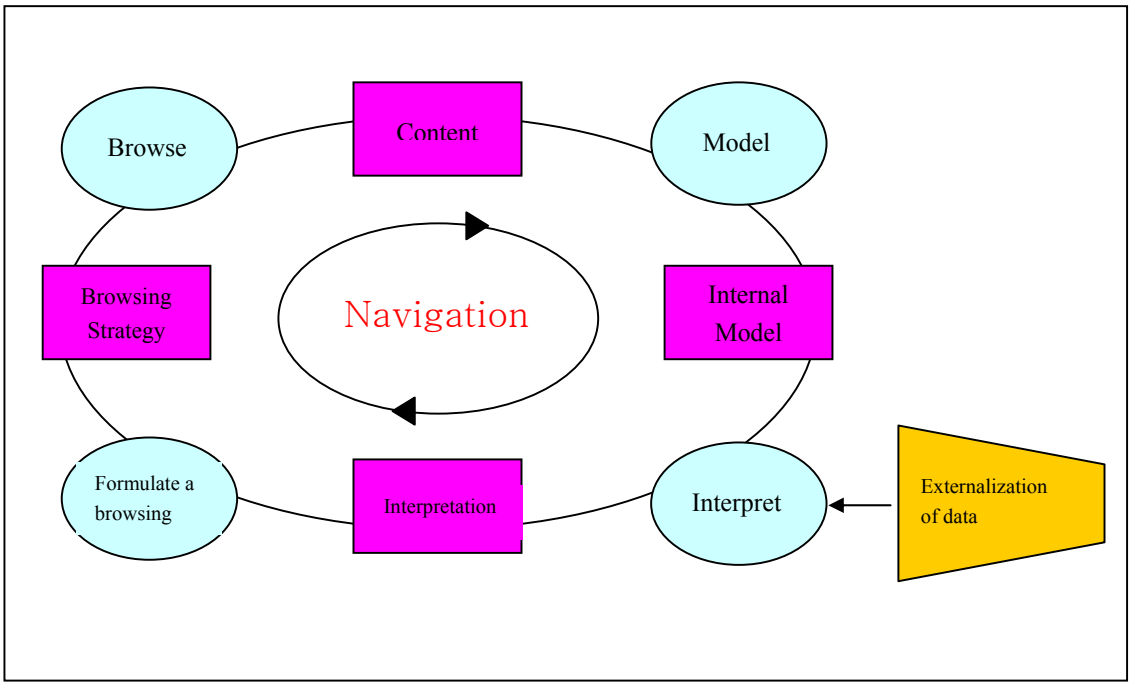


Figure 4: Interpretation of the Internal Model and Externalized Data

Similarities exist in the Haber and McNabb Visualization Reference Model, and the Spence Navigation Framework and include:

- There is an iterative activity resulting in data being refined, and the visualization model being continually re-defined.
- The Browsing Strategy in the Spence model can be compared to Raw Data in the Haber and McNabb model. With Browse being implemented within the Data Enrichment phase – whereby a user can refine their browsing strategy that will add information to the model.
- Content in the Spence model can be compared to Derived Data in the Haber and McNabb model. The Content can be reviewed over and over again or even added to – building up the Model (or Visualization Mapping in Haber and McNabb) leads to an Internal Model (Abstract Visualization).
- The Interpret part in Spence's model is equivalent to Rendering in Haber and McNabb with the Displayable Object forming via the Interpretation (Spence).

Interactive differences also exist and include:

- Spence takes a form of soft system's methodology in his Framework – analysing the user's mental model and environment to understand how the visualization may progress through interactivity. For instance, taking the simple roadmap example described above, the 'Interpretation of data' (Figure 4) may be affected by the siting of a known landmark leading to an understanding of where he/she is in respects to the roadmap visualization being used ('Insight into data').
- Interactivity in the Haber and McNabb model is a 'taken fact' that the scientist will look at the visualization and decide to modify it based on what he/she can see e.g., visualization of a piece of graphite after bromination, the scientist may want to analyze the air pockets between the particles rather than particle clustering, in which case the first step would be to visualize the molecules – understand – then do an inverse visualization of the data to understand the air gaps. Hence, forming a mental picture (and visualization) of the experimental process.

3 Example uses of these structures for flow visualization.

Vortices are an important feature in all types of flow research. Vortices are the result of an obstruction in a downstream fluid flow as shown in Figure 5. Informally a vortex is defined as a swirling flow pattern which often behaves as a coherent structure in time dependent flows.

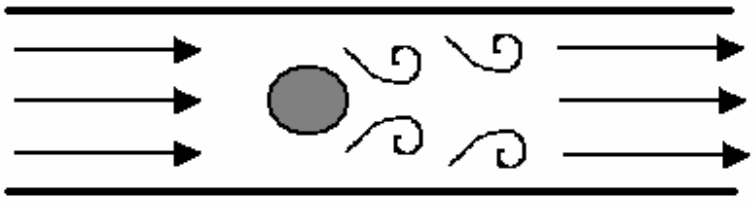


Figure 5: Vortices as the Result of an Obstruction

Vortex visualization is very important within the field of engineering and depending on their effects the presence of vortices (e.g. machinery or hydraulics) must be either prevented or promoted. We want to consider a small section of the possible choices a user has in constructing a dataflow model – and will take

for example of simple 3D fluid flow volume. The following is how that example fits into the Haber & McNabb model for a specific data file.

- *Simulation* The primary output of the simulation is the single data file containing the x- y- and z-direction vectors. The data are float values uniformly spaced on a grid of $25 \times 25 \times 40$.
- *Data Enrichment/Enhancement* By combining vector components the flow direction can be easily extracted.
- *Derived Data* The derived data is now the flow direction of the vortex.
- *Visualization Mapping* The magnitude of the flow can be shown via various geometric objects for example streamlines that follow the flow, or glyphs indicating direction and magnitude to produce the Abstract Visualization Object. This can now be rendered as a displayable image.

Figures 6-10 show four examples of interactive data flow specification. These show both the abstract layout required for the specific incarnation of the data flow network (using the AVS Express product), along with one view of the resulting visualization.

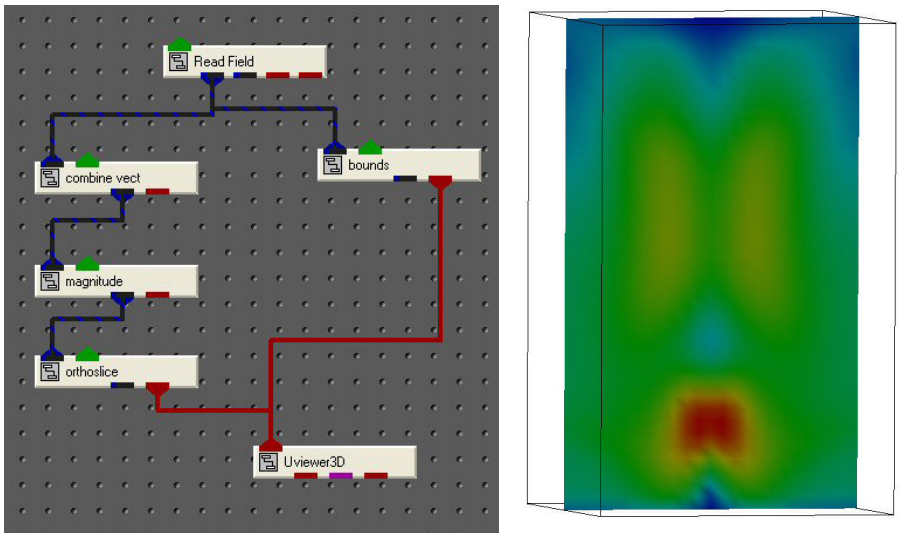


Figure 6: AVS/Express network (for details of further example see [5]) and visualization showing the original simulation data being read in and visualized as an orthoslice with bounds

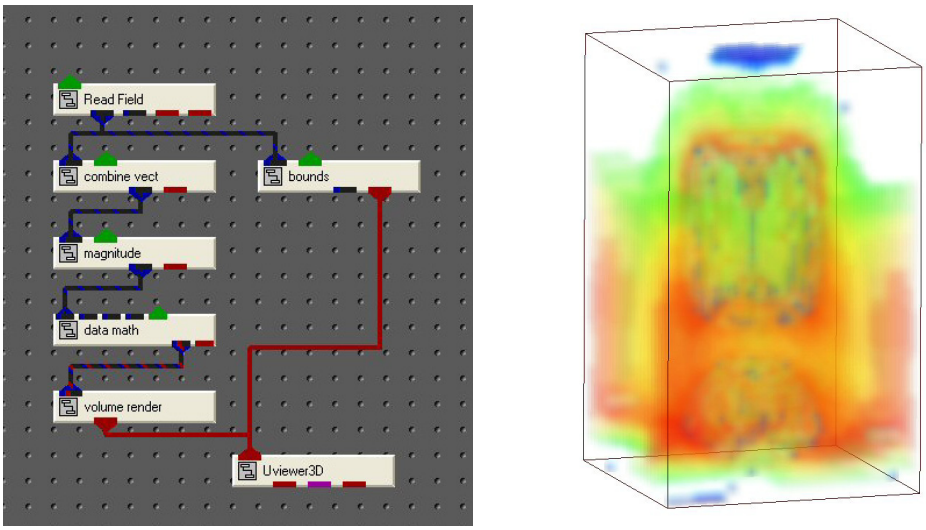


Figure 7: AVS/Express network visualization which results in a Volume Render of the Vortex Data

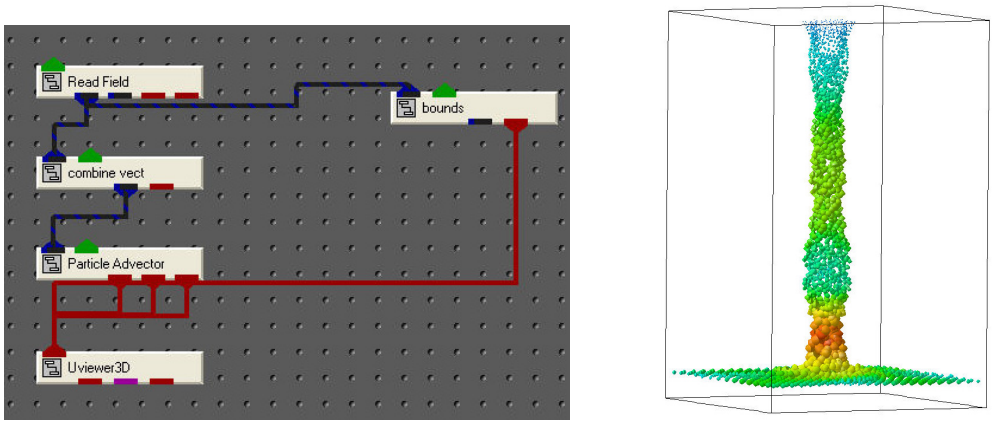


Figure 8: Particle Advection Network and Visualization

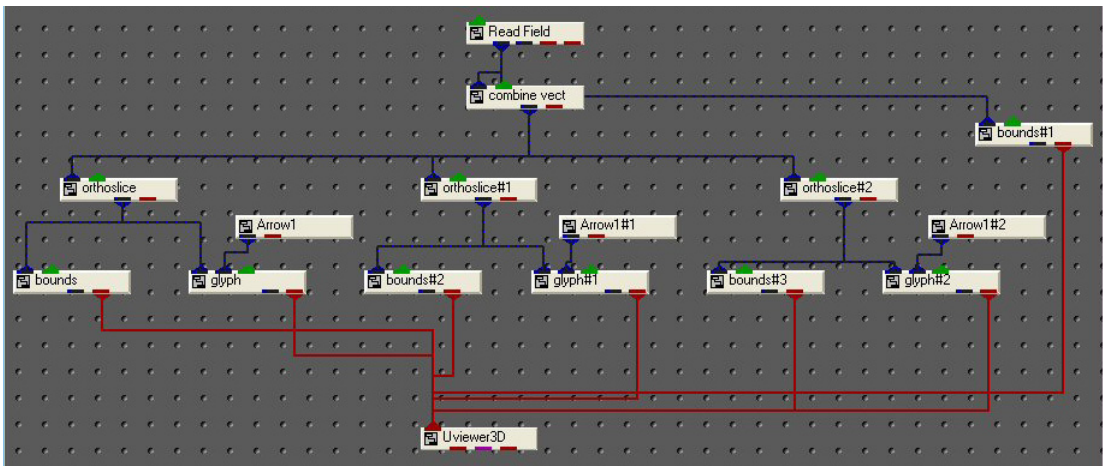


Figure 9: AVS/Express network for the Three-Plane Glyph Visualization

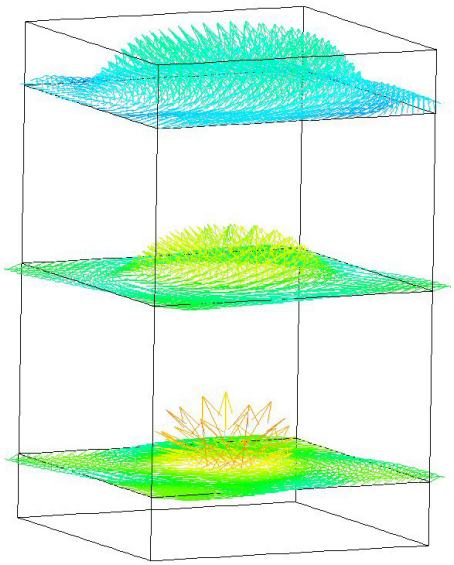


Figure 10: A more complex three-Plane Glyph Visualization of the same data

4 Interaction and control of data from source to screen

Each of these visualizations can of course be dynamically interacted with. This involves importantly modifying, both the rendering stage and also the data flow model itself as the user requires. The key concept of visualization interaction is to present choices to the user, as there are many ways of applying different operations and it should not be imposed on the user to see just one view – but to investigate.

It is proposed for further discussion that this separation of the data flow stages allows repeatability and extends itself to many other non-scientific themes.

References

[1] R.B. Haber, and D.A. McNabb, Visualization Idioms: A Conceptual Model for Scientific Visualization Systems *Visualization in Scientific Computing*, IEEE, 1990, pp. 74-93

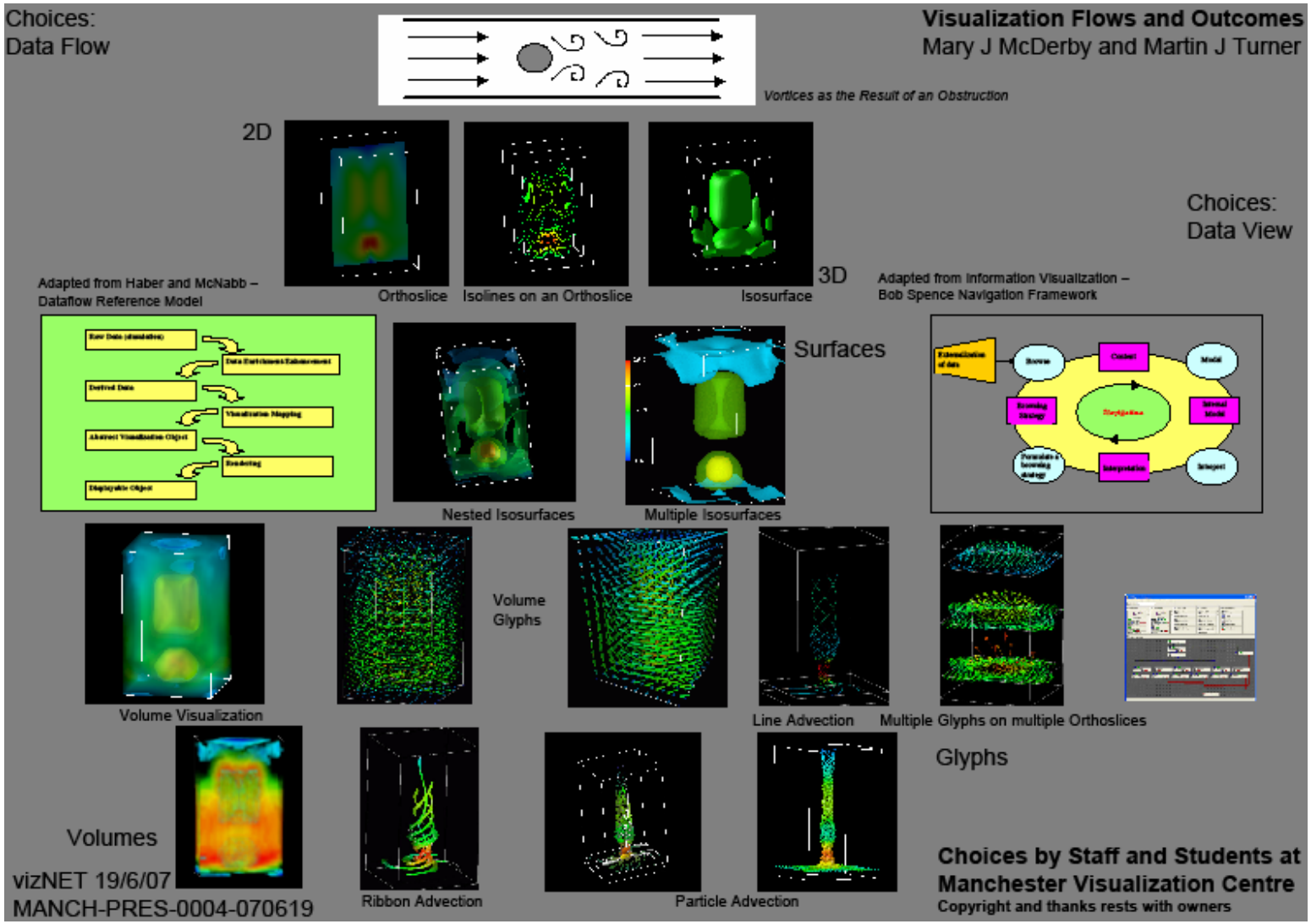
[2] R. Spence, A Framework for Navigation *International Journal of Human-Computer Studies*, **51**, 5, 1999, pp. 919-945

[3] R. Spence, *Information Visualization*. Addison Wesley 2000

[4] R. Spence, *Information Visualization: Design for Interaction* 2006 Prentice Hall 2nd Edition

[5] W.T. Hewitt, M. Cooper, N.W. John, Y. Kwok, G.W. Leaver, J.M. Leng, P.G. Lever, M.J. McDerby, J.P. Perrin, M. Riding, I.A. Sadarjoen, T.M. Schiebeck, and C.C. Venters, 2005, Chapter 35: Visualization with AVS in Johnson C. and Hansen C., (eds), *Visualization Handbook* Elsevier

vizNET document reference MANCH-WORK-0003-230807



Appendix A: Poster submitted to display a range of selection and data visualization options.