Visualisation Techniques for Collaborative GIS Browsers

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Abstract

Visual information overload is a serious problem for users of geographical information systems (GIS), or other applications with complex displays, where the requirements of access to both local detail and wider context conflict. This problem is compounded for users of real-time groupware applications by the need to maintain awareness information about other users and their actions. In this paper, we describe our use of fisheye views to assist with visual information overload management in GROUP*ARC*, a lightweight real-time groupware application for browsing and annotating GIS data.

1 Introduction

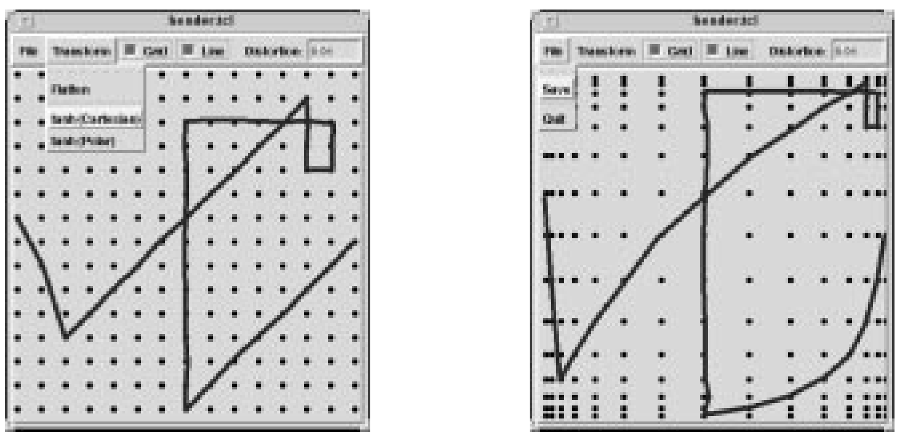
Our capacity for assimilating complex visual displays, such as GIS data, is limited. The phenomenon of visual information overload occurs when this capacity is exceeded, typically resulting in confusion, oversight and errors of interpretation.

The ability to focus on regions of interest in detail, while retaining awareness of context, is necessary if users are to visualise and comprehend complex graphical information effectively. It is important for users of GIS to be able to examine not only local feature detail (e.g. utility access points on some land parcels) but also to be aware of related but spatially separated features (e.g. high voltage network).

Conventional approaches to this problem include scrolling, zooming and split windows. However, each has its faults (see e.g. Churcher 1995*a*) both in terms of cognitive load for the user and clutter of the precious display real estate.

The terms "fisheye view", "distortion-oriented presentation" and "non-linear magnification" are among those used to describe visualisation techniques where the displayed image is transformed in some non-uniform manner. Since Furnas's (1986) introduction of the concept, there has been much interest in these techniques as a means of improving the usability of complex graphical displays (for a bibliography see Keahey 1997). While cartographers have made effective use of exotic projections for some time, the extension to dynamic interactive interfaces is more recent (Sarkar & Brown 1992, Sarkar & Brown 1994, Churcher 1995*b*).

The central idea is to emphasize "relevant" regions of the display, and de-emphasize less relevant areas, without loss of context. This is achieved by transformations which distort the distances between features while preserving connectivity and topological relationships. Figures 1 and 2 show some examples produced from a teaching tool we have developed. An important concept is the focus—a region where interest is concentrated—and distance from the focus is part of the measure of relevance or importance. Fisheye transformations are discussed further in section 2.



(a) No transformation (flat) (b) Transformed (equation 2)

Figure 1: Experimenting with fisheye transformations

The problem of visual information overload is particularly important for Computer Supported Collaborative Work (CSCW) applications—also referred to as "groupware". Baecker (1993) provides a good overview of groupware. Simple examples such as drawing tools are becoming commonplace in the commercial environment but there are many challenges associated with extending the concept to include "serious" applications such as GIS.

The collaborative GIS browser GROUP*ARC* (Churcher & Churcher 1996*b*, Churcher & Churcher 1996*a*) is an example of a GIS groupware application. It is a flexible lightweight tool enabling users located anywhere on the internet to share, examine, discuss, annotate and visualise GIS data in real time using using a What You See Is What I See (WYSIWIS) model. It might be used in situations as diverse as a classroom exercise or a geographer in the field debating planning options with colleagues in another country.

Users of CSCW GIS applications must not only contend with the problems discussed above but also with the processing of additional information associated with awareness of other participants in the conference. Maintaining each participant's awareness of the presence, location, intentions and actions of others is an essential element of successful groupware and innovative techniques are being developed to address the issue (e.g. Greenberg, Gutwin & Cockburn 1996). GROUP*ARC*'s approach is discussed in detail elsewhere (Churcher & Churcher 1996*b*, Churcher & Churcher 1996*a*) and in subsequent sections.

There is currently much interest in developing CSCW GIS applications (Armstrong 1993, Armstrong 1994, Faber et al. 1994, NCG 1995, Jones et al. 1997). We envisage the gradual introduction of both CSCW capabilities and distortion-oriented presentation techniques into mainstream commercial GIS products over the next few years. Each is important in its own right.

Our current research concentrates on lightweight browsers rather than fully-featured GIS systems. There are a number of specific differences. Firstly, GROUP*ARC* allows users to work with GIS data without requiring them to have the same GIS software—or any GIS at all! Consequently lightweight tools such as GROUP*ARC* offer an alternative to simply waiting for vendors to embrace standards. It is envisaged that users will still turn to a fully-featured GIS for resource intensive tasks such as complex spatial queries and topological analysis. Lightweight tools offer extensive opportunities for extension and customisation in order to find the most appropriate solution (e.g. choice of transformation function) for each problem. Finally, portability across platforms (hardware, communications and operating system) is straightforward.

The remainder of the paper is structured as follows. In the next section we discuss fisheye views further and introduce the particular forms of fisheye view that we have incorporated into our latest version of GROUP*ARC*. Section 3 contains a brief summary of GROUP*ARC*'s GIS and CSCW features and indicates how fisheye techniques have been incorporated naturally. In section 4 we discuss some of the approaches we have explored, present results showing some of the techniques we have implemented, and comment on the relative suitability of each for GIS applications. Finally, some conclusions and indications of the future directions of our research are presented in section 5.

2 Fisheye views

An essential ingredient in any fisheye interface is a spatial transformation function, G, which maps a "flat" coordinate value, x, onto the corresponding transformed value, x'. The derivative G' is the corresponding magnification function. The main transformation function used in our current work is based on the tanh function (Keahey & Robertson 1996) which has the general form shown in equation 1 for one dimensional coordinates.

$$x' = \tanh(\beta x) \tag{1}$$

where β is a scalar parameter.

The tanh transformation maps coordinate values x in the range $[-\infty, \infty]$ onto corresponding values x' in the range $[-1, 1]$. It is very similar in its effect to that of the function $G(\hat{x}) = \frac{(d+1)\hat{x}}{d\hat{x}+1}$ made popular by Sarkar & Brown(1992, 1994) but is easier to work with in practice.

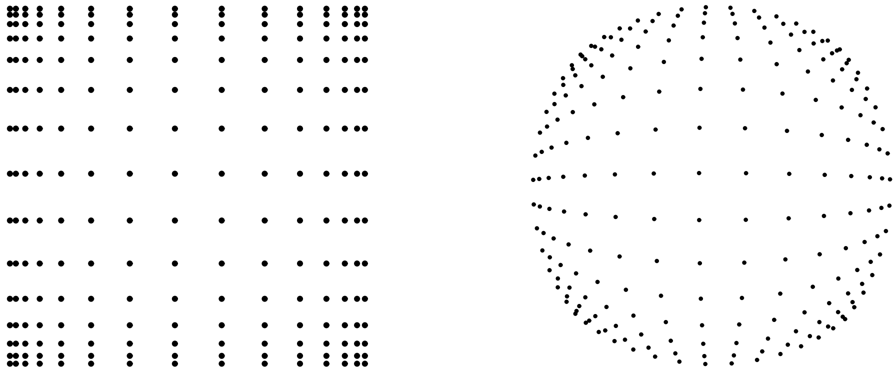
For GIS, we require the transformation to map the flat display region onto itself, in order to minimise jarring visual effects. In particular, the focal point, and points on the boundary, should be invariant while other points should all move away from the focus towards the boundary.

For our purposes it is also important to be able to move the focus to any point within the display to enable users to see most clearly the portion of the display under most active discussion. In practice, users will move the focus precisely to attract attention to a specific area. If we consider values of x in the range $[0, x_{max}]$ with the focus, x_f in the same range then we should replace the transformation of equation 1 with

$$x' = \begin{cases} \tanh(\beta(x - x_f))(x_{max} - x_f) + x_f & (x > x_f) \\ \tanh(\beta(x - x_f))x_f + x_f & (x \leq x_f) \end{cases} . \tag{2}$$

Extension to 2-dimensions, essential for any GIS application, is generally achieved using an orthogonal (Cartesian) or a polar (radial) approach. Further description of these and other approaches is available elsewhere (Keahey & Robertson 1996, Keahey 1997, Leung & Apperley 1994). Figure 1 shows a simple application we have developed to experiment with the effects of varying the parameters and functional form of G and some sample output appears in figure 2.

In the Cartesian form, the 1-dimensional transformation of equation 2 is applied independently to the x and y coordinates. The effect of this transformation is visible in figure 2(a). Under this transformation horizontal/vertical lines remain horizontal/vertical but, in general,



(a) Cartesian ($\beta = 0.01$) (b) Polar ($\beta = 0.01$)

Figure 2: Comparison of Cartesian and polar tanh transformations (focus at centre of display).

angles are not preserved (as can be seen in figure 1). It is possible to apply transformations of different powers to each dimension (i.e. $\beta_x \neq \beta_y$) though we have not found it useful to do so.

In the polar form, the distances involved are not along the x or y coordinate axes but rather along the vector $\hat{\mathbf{p}} = \mathbf{p} - \mathbf{f}$ from the point $\mathbf{p} \equiv (x, y)$ to the focus $\mathbf{p_f} \equiv (x_f, y_f)$. The radial component of $\hat{\mathbf{p}}$ is then given by $r = \sqrt{\hat{p}_x^2 + \hat{p}_y^2}$ and the polar counterpart to equation 2 is

$$\mathbf{p}' = \frac{\tanh(\beta r)}{r}\hat{\mathbf{p}} + \mathbf{f} \tag{3}$$

Figure 2(b) shows the polar transformation of equation 3. The effect is familiar as it resembles that of the ultra-wide angle “fisheye” lens used in photography. Although this transformation bends horizontal and vertical lines it does preserve angles more closely. Though we have yet to perform controlled user studies, our experience to date supports Sarkar & Brown’s (1992) observation that users preferred the polar version of their transformation for geographical data.

3 GROUP*ARC*

GROUP*ARC* was initially developed to explore the potential of lightweight CSCW browsers for GIS applications. It is written in Tcl (Ousterhout 1994), runs on Unix, Macintosh and Windows platforms and uses GroupKit (Roseman & Greenberg 1992, Roseman & Greenberg 1996), a toolkit for building real-time groupware applications (called *conferences*). When GROUP*ARC* is running, GroupKit manages the registration of conference participants (who may enter or leave at any time) and communication between the GROUP*ARC* replicas on individual participant’s

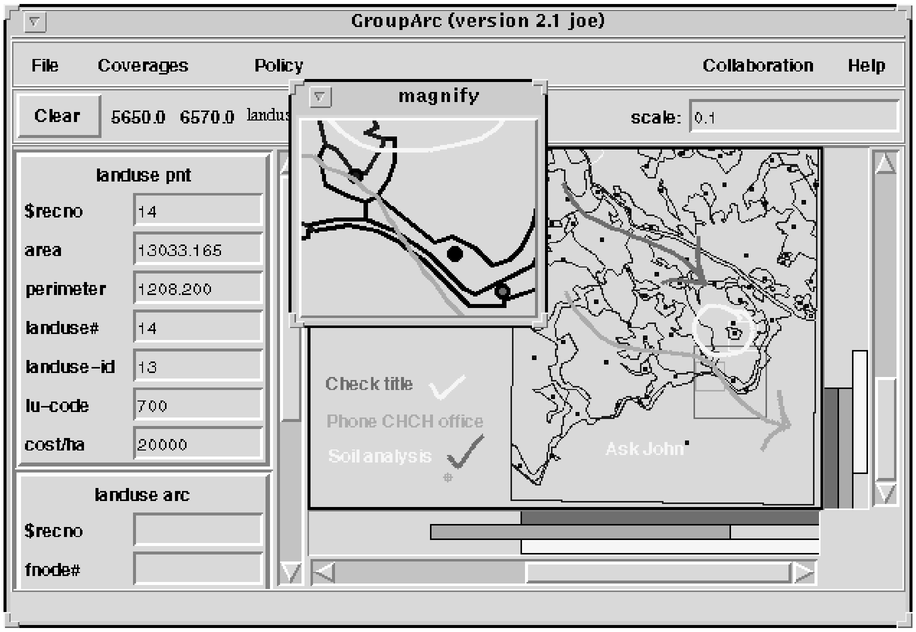


Figure 3: Typical GROUP*ARC* session.

workstations. Typically, users will be participating in several additional conferences—such as editors and drawing tools.

GROUP*ARC* users load one or more coverages (thematic layers) and then explore and annotate them with text and sketches during the course of a discussion. The coverage stacking order is reflected by shading and may be modified by users to handle co-located features.

These figures show several aspects of typical GROUP*ARC* use scenarios. User-selected characteristic colours are used to distinguish individuals. Multi-user scrollbars, consisting of an ordinary scrollbar plus an indicator showing the relative positions of other users, are visible and show that there are currently three participants whose viewing regions may overlap (figure 3) or diverge(figure 4(a)). Telepointers, which show remote users' cursors as blobs of their characteristic colours, are a further awareness indicator. A telepointer is visible in figure 3 near the check mark beside the text "Soil analysis".

Figures 4(a)–5(d) show a single coverage of data about roads in part of Christchurch. The GROUP*ARC* image window (figure 4(a)) shows a GIF image which has been annotated as the three conference participants acquaint themselves with the location of the region to be discussed.

A particular arc has been selected (thick line) as the response to a query ("which arc has $recno = 613?"). The arc immediately to the right has been highlighted, as the user's cursor (not shown) is currently over it, and the corresponding attribute data are shown. The text annotation "My house" and the sketched circle have been added by other users.

4 Implementation & experience

Experience with GROUP*ARC* has indicated clearly that loss of context is a problem as users focus on local detail. In this section we illustrate some of our approaches to date.

The simplest solution we implemented (figure 3) provides each participant with a floating window containing a uniformly magnified view of part of the main display. The main GROUP*ARC* window contains rectangles (coloured to represent the corresponding users) which show the regions each user sees in the magnified window. These may be dragged around—typically to enable users to align their high-detail regions.

This technique is similar to that of the offset lens (Greenberg et al. 1996) and is particularly effective where the data is relatively uniformly detailed. In such cases fisheye transformations move many peripheral features to nearly identical locations leading to densely cluttered regions.

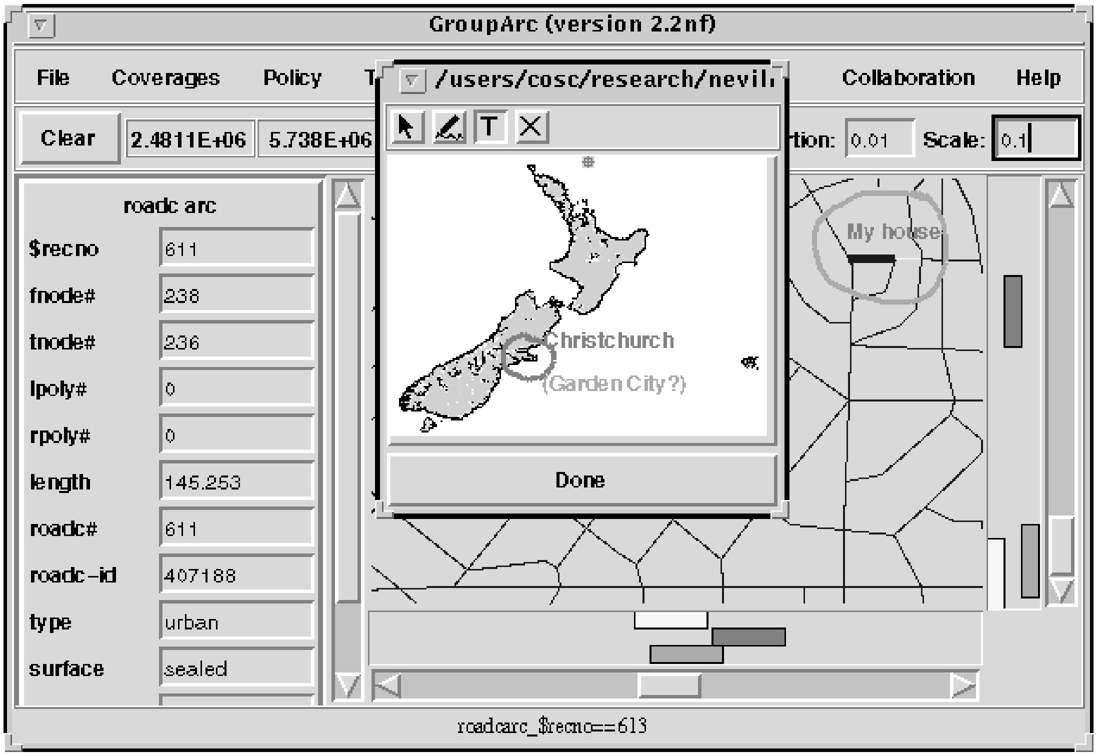
Figure 4(b) shows the entire coverage fitted into a window ready for transformation. The position of the focus is indicated by the magnifying glass at the centre of the figure.

Figure 5(a) shows the effect of the transformation of equation 2 with the focus remaining at the centre. All features have moves away from the focus, as expected from figures 1 and 2, and the arcs (including sketch annotations) have been distorted. The text annotations have also moved but, for clarity, their size has not been changed.

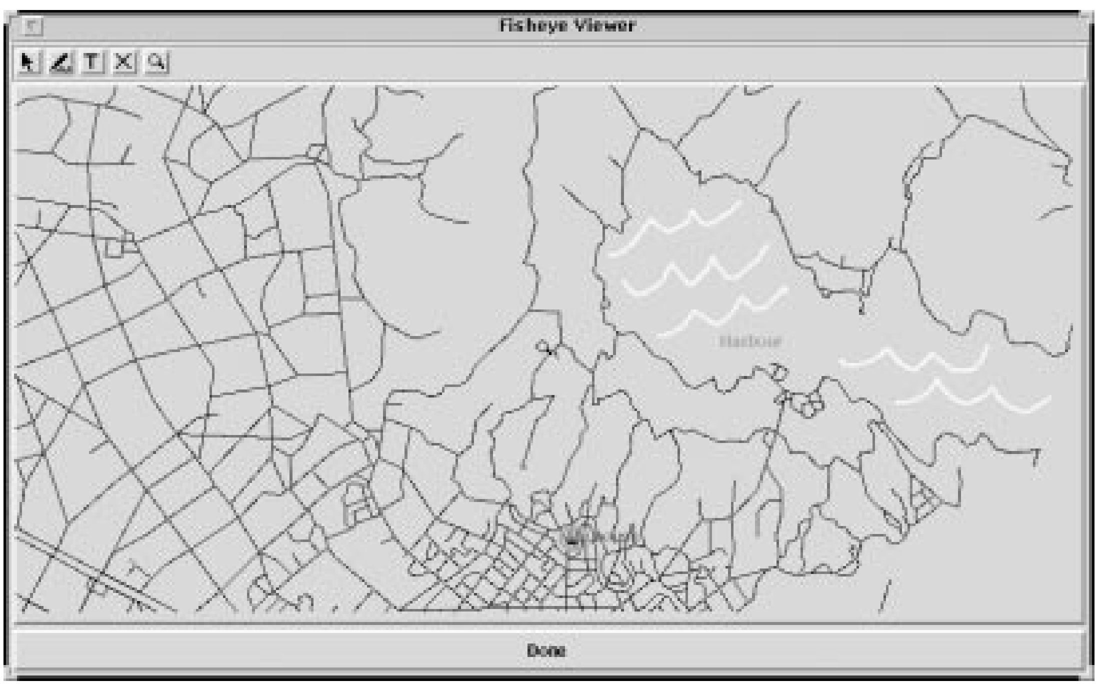
Figure 5(c) shows the effect of moving the focus close to "My house". Applying the transformation of equation 3 with the focus at the centre and "My house" produces the displays of figures 5(b) and 5(d) respectively.

We have not yet performed comprehensive user evaluations of our fisheye additions. However, anecdotal evidence from our colleagues and students suggests common themes. Firstly, the system has proved easy to learn and use and we believe a single user-controlled parameter is more natural than the 5 used in Sarkar & Brown's (1992) system. Polar transformations seem intuitively more appealing and users report greater difficulty judging distances and orientations in the Cartesian form. The addition of grid lines as a background cover might help. The polar transformation also seems to be preferred where the focus is near the edge of the display, where the Cartesian form tends to give a crush of features. The simple floating zoom window has proved surprisingly popular. It also avoids the perception that the space between features is being magnified.

Given that Tcl is an interpreted language, the efficiency of the transformation is satisfactory—typically 7 seconds for the roads cover on an 85MHz SPARCstation 5—and users have not

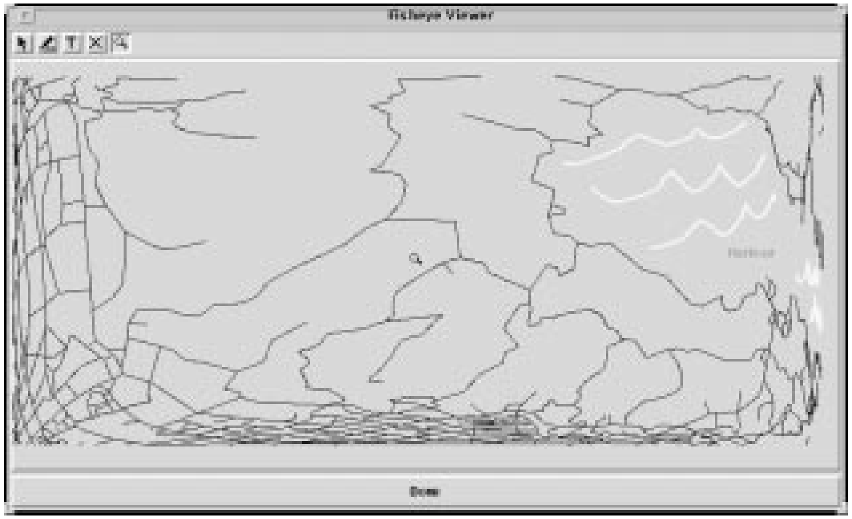


(a) Main GROUP*ARC* display

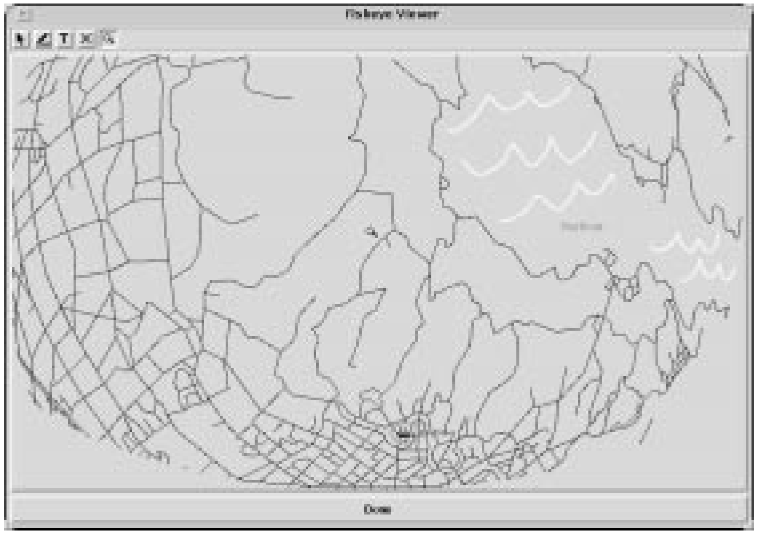


(b) Undistorted

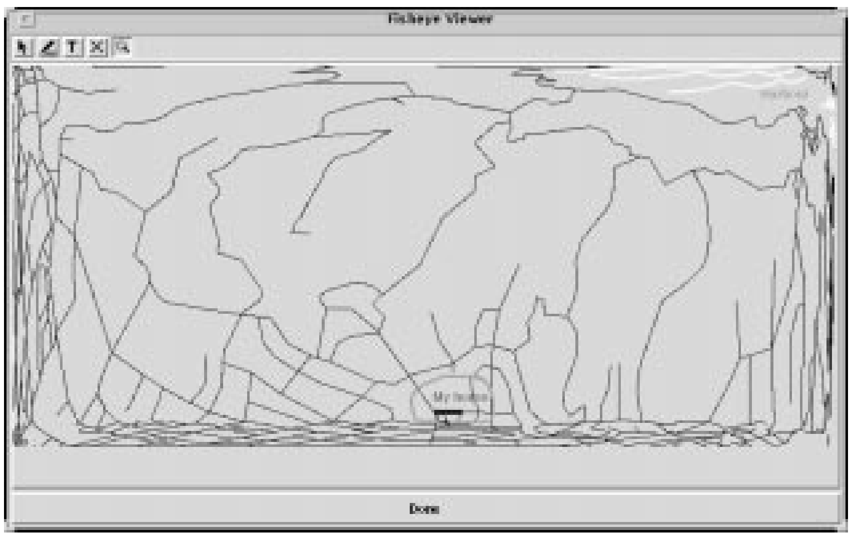
Figure 4: Christchurch roads coverage



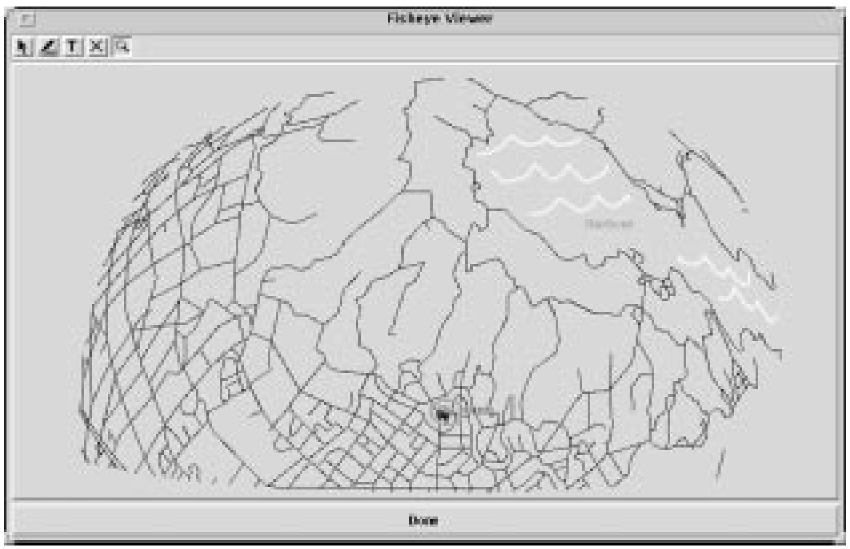
(a) Cartesian, central focus



(b) Polar, central focus



(c) Cartesian, focus at “my house”



(d) Polar, focus at “my house”

Figure 5: Fisheye views of the Christchurch roads coverage

commented adversely about response times. The roads cover consists of 791 arcs composed of 2390 points. Distortion is achieved by repositioning the points so the density of points used in digitising can affect the smoothness of the result. Our experience with other applications suggests that an order of magnitude improvement may be obtained by implementing critical functions in C.

We are currently exploring two major directions. Firstly, our experiences suggest that hybrid transformation functions are likely to be superior and we are currently developing these. Hybrid transformations uniformly magnify points within a specified region centred on the focus and non-linearly transform points outside this region with a smooth transition at the boundary. Some work on such functions has recently been reported by Keahey & Robertson (1996).

The second direction represents more of a step towards Furnas's (1986) original concept of transforming features according to their *degree of interest* (DOI), rather than purely spatial location. A feature's DOI includes contributions from its *a priori interest* (API) and its *distance* (D) and in the 1-dimensional case has the form

$$DOI(x|x_f) = API(x) - D(x, x_f). \tag{4}$$

Each feature's API depends primarily on its non-spatial attributes and is independent of the location of the focus. In the case of GIS applications, factors contributing to the API might include the coverage (e.g. "roads are more relevant than rivers"), attribute values (e.g. "sealed roads are more relevant than metalled roads") or coarse spatial properties (e.g. roads in our province are more relevant than those in neighbouring provinces).

The distance is measured from the feature to the focus and may include contributions from "conceptual distance" as well as pure spatial distance. For example, the distance between two urban locations may be the straight line distance between them weighted by the "Manhattan" distance between them and the number of traffic lights along the route. The (focus-independent) API and (focus dependent) distance can combine in such a way that the overall DOI for a "very interesting" feature far away is similar to that of a "less interesting" feature nearby.

The display is then presented in such a way that higher prominence is given to the most relevant (i.e. largest DOI) features at the expense of less relevant (lower DOI) ones.

This approach suggests a solution to the problem of dense regions produced by transformations. As its DOI decreases, a feature becomes progressively de-emphasized and ultimately omitted from the display when its DOI becomes less than a user-selected threshold value. For example, labels may cease to be displayed when their font size becomes too small to read, extended features may be represented by points and colour may be replaced by monochrome.

5 Conclusions

We are encouraged by the success of our addition of fisheye capabilities to GROUP*ARC*. They have proved useful in helping users visualise GIS data not only in GROUP*ARC* sessions with others but also in the single user case.

Our current efforts are directed towards adding hybrid transformation functions and developing an interface to support user-selected API functions and DOI thresholds. The API will be specified by selecting from the available coverages and placing constraints on attribute values using the existing query functionality. Users will then have a natural, problem-related means of achieving a high degree of control over the transformation details. We will then optimize for performance by implementing the transformation functions in C before proceeding with controlled user trials.

We also intend to investigate the potential uses of multiple focus points, one per conference participant, which allow several regions of interest to be examined in greater detail simultaneously.

6 Acknowledgements

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