The Knowledge Engineering Review, Vol. 18:2, 175–181. © 2003, Cambridge University Press
DOI: 10.1017/S0269888903000584 Printed in the United Kingdom

Advanced visual interfaces: the focus is on the user*

TANIA DI MASCIO[1] and LAURA TARANTINO[2]

[1] *Dip. di Informatica e Sistemistica, Università di Roma "La Sapienza", Rome, Italy; e-mail: tania@ing.univaq.it*
[2] *Dip. di Ingegneria Elettrica, Università dell'Aquila, L'Aquila, Italy; e-mail: laura@ing.univaq.it*

Abstract

The current trend in the production of information appliances is the human-centred, customer-centred approach, where technology serves human needs invisibly, unobtrusively. The emphasis shifts from the application programs to the users, their tasks and their workplaces, making computation often move off the desktop to become embedded in the world around us. In this scenario the role of the visual interface becomes crucial since, as far as the customer is concerned, the interface is the product. In this paper we briefly survey the most recent results in the field of advanced visual interfaces, with focus on users' needs and ways to serve them.

1 Introduction

> Invisible Computer . . . is the end result, hiding the computer, hiding the technology so that it disappears from sight, disappears from consciousness, letting us concentrate upon our activities, upon learning, doing our jobs, and enjoying ourselves.
>
> Donald Norman, *The Invisible Computer*

As pointed out by Norman, the current goal in the production of information appliances is to move from the current situation of complexity and frustration to one where technology serves human needs invisibly, unobtrusively: the human-centred, customer-centred way (Norman, 1998). The role of the User Interface (UI) is hence increasing to the extent that, according to Raskin (2000), its design should start once the product's task is known, while the rest of the system should be implemented to the interface design (thus reversing the customary order of design and implementation phases as suggested by traditional project management (Eriksson & Magnus, 1998)). In other words, the emphasis shifts from the application program to the user, who does not care about what is inside the box: as far as the customer is concerned, the interface is the product.

Furthermore, not only is the UI changing its role in the system, but it is also changing in nature. While the interface between people and computation has traditionally been based on conventional input and output devices (such as screens, keyboards and mice), nowadays computation is increasingly moving off the desktop and becoming embedded in the world around us. This trend can be traced back to a seminal article by Weiser (1991), presenting a vision of "ubiquitous computing", in which the traditional desktop computer is no longer the focus of computational interaction.

This recent evolution in the field of human-computer interaction is reflected by the works presented at the sixth edition of the International Conference on Advanced Visual Interfaces, AVI 2002 (De Marsico *et al.*, 2002), which we briefly survey here. We start the discussion by overviewing

* Partially supported by the University of l'Aquila under the Representation and Interaction Techniques for Spatial Data project.

information tools supporting personal work tasks or relationship, group-oriented tasks. Not surprisingly, many of them are devised to help users organise, filter and monitor "peripheral information", i.e. information that people want to intermittently examine throughout the day (like weather forecast, financial statements and so on); the amount of peripheral information continues to increase, thus becoming distracting and disruptive to other important tasks. We then review contributions on a more general and methodological level of abstraction, again facing the problem of visualising and interacting with huge quantities of information. There follows a discussion on users' studies aimed at devising design principles and guidelines in different application frameworks. Finally, we see how users and their workplaces can be supported by designers of UIs.

2 Serving users' tasks

Though some cultural relativism is necessary, undoubtedly people develop cultural biases based on their exposure as children. A user-centred approach to the design of information products cannot leave cultural analysis out of consideration, to achieve acceptable global solutions, or to devise localised, customised designs.

Cultural issues are the main concern of Aaron Marcus's invited paper (2002), which introduces the cultural anthropologist Hofstede's (1997) cultural dimensions and considers how they might affect user interface components (metaphors, mental models, navigation, interaction and appearance). Marcus forecasts a future scenario in which UI development tools will enable designers to semi-automatically adjust user interface designs per cultural dimension and, ultimately, per culture. The challenging issue is hence to develop tools to support multicultural UI design so as to make it feasible to develop multiple versions of products in a cost-effective manner.

Among Hofstede's cultural dimensions we recall here the orientation to individual or group achievement (individualism versus collectivism), according to which some of the papers presented at AVI 2002 may be classified, depending on whether they support personal work or relationship, group-oriented tasks.

Support for collaborative tasks is the main goal of Vernier *et al.* (2002), presenting *circular tabletop interfaces*, studied within the framework of a a *beyond-the-desktop* project whose overall goal is to investigate ways to effectively and intuitively organise, navigate, browse, present and visualise digital data in an interactive multiperson conversational setting (Shen *et al.*, 2001). The paper discusses a layout mechanism for circular interfaces based on a polar coordinate system, presents two fish-eye view deformations to support different types of user activity, and illustrates a hierarchical representation of data that avoids display cluttering.

Oriented to collectivism is also "What's Happening" (WH), a set of two tools designed to help promote awareness of information and activities in a local community (Zhao & Stasko, 2002). The first tool is the WH communication bar, a small corner-of-the-display interface that cycles through local community and general interest information blurbs that it has gathered. The second tool is the WH screen saver, showing graphics and text excerpts from pages on websites in the community. Differently from Computer-Supported Cooperative Work (CSCW) systems, which demand a substantial amount of attention and participation from the user, the WH system supports the community in an unobtrusive, peripheral manner, according to principles of *calm technologies* (Weiser & Brown, 1996): interfaces stay in the user's periphery of attention, while still providing some value to the user, and shift smoothly into focus when necessary.

Also based on calm technology, but oriented to individualism, is InfoCanvas (Miller & Stasko, 2002), a pictorial representation of peripheral information. Through a Web-based interface, people identify information of interest, associate a pictorial representation with it and place the representation on a virtual canvas, presented on a second display, on a desk like a picture frame, or hung on a wall like a painting.

A departure from the desktop is exhibited also by Lola, displaying entries in a music database for exploration and selection (Amant *et al.*, 2002). Lola is designed for deployment in situations in which the user's attention is a tightly limited resource (like while driving a car). The paper describes a cognitive modelling framework and the multidimensional visualisation technique adopted by the system, based on pre-attentive visual features (hue, luminance, size, density and regularity). Cognitive tasks, such as filtering, reading and selecting musical tracks, are hence transformed into perceptual tasks, such as identifying properties of tracks and sets of tracks by visual means.

Like InfoCanvas and Lola, the Scope tool (van Dantzich *et al.*, 2002) serves individualistic tasks, again related to peripheral awareness. The aim here is to collect notifications coming from multiple applications into a unified interface, offering discoverability, scalability and easy identification of multiple items. These guidelines led to the use of abstract visual elements (such as basic geometric shapes), which proved to be more effective than less abstract icons that do not resize gracefully, often ending up in a cluttered display. Scope is a circular display borrowing its metaphor from a traditional radar view, thus using spatial location to code attributes, an unconventional choice that makes the tool not immediately intuititive to grasp. On the other hand, usability studies show that Scope is learned and appreciated within a single session of trained interaction.

3 Interacting with large datasets

Besides ad hoc solutions to specific tasks, it is worth discussing some significant contributions to the field coming from researchers working on a more general and methodological level of abstraction. In this section we discuss two proposals from the collection of AVI 2002 papers, undoubtedly deserving space due their originality and efficacy. Again, key issues are the visualisation of and the interaction with huge quantities of information, which force designers to devise presentation schemes departing from conventional ones, to overcome both visual and computational limits. Traditional node-link diagrams, for example, while adequate for visualising small, compact graphs, fail to effectively scale to large graphs; when the number of points or lines being plotted becomes large compared to the number of pixels on the display the screen becomes a solid mass of colour, making the visualisation unintelligible.

3.1 Interacting with large hierarchies

Apart from Lola, the tools discussed in the previous section deal with mostly unstructured information. Different in nature is hence the aim of Degree-Of-Interest (DOI) trees (Card & Nation, 2002), in use at PARC for interacting with organization charts, and adequate for displaying hierarchical information. Hierarchical structures are increasingly common as a means for organising large amounts of information (even websites are often approximately hierarchical). Hierarchies are becoming ever larger, and provision of explorable, visual representations is essential to make them accessible.

Traditional node-link diagrams or outline methods (such as the Apple Hierarchical Filing System) fail to scale to even moderately large trees, and appropriate techniques (such as distortion and the use of the third dimension) have to be adopted to ovecome the inefficacies. Advanced techniques for visualising hierarchies may be classified in two main groups, depending on whether the class-subclass relationship is represented by means of enclosure in 2D spaces (TreeMaps (Johnson & Shneiderman, 1991) are the most notable example), by visualising connections using the third dimension (such as in ConeTrees (Robertson *et al.*, 1991)), or by a combination of the two. Many dynamic tree layouts are based on a focus + context approach, to decide which portions of the tree to show at any instant, according to the user's computed degree of interest.

It has to be observed that much of the literature on tree layouts does not consider trees in which the nodes themselves contain significant information, and furthermore layouts are not bounded in space, thus making it difficult to use them as modular components of information displays.

The DOI trees developed by Card and Nation make a step beyond existing focus + context trees, overcoming existing limitations by combining all focus + context techniques with a method that makes tree layouts bounded in space. DOI trees combine (a) an expanded computation of users' DOI estimates with (b) logical filtering to elide nodes of low DOI, (c) geometric scaling of node size according to DOI so as to be able to hold different levels of information, (d) semantic scaling of the contents of the nodes with node size, (e) clustered representation of large unexpanded branches of the tree and (f) animated transitions, designed to speed the user's rapid understanding of changes in the tree. Nodes of most interest are filtered for visualisation, geometrically enlarged, semantically zoomed and shown in tree context of relevantly selected other nodes. Nodes predicted to be distant from the user's interest are shrunk, aggregated or elided.

3.2 Randomness in information visualisation

An unconventional proposal to the problem of interacting with extremely large datasets is provided by Dix and Ellis (2002), as usual provoking and stimulating interesting discussion. Their work stems fron the observation that the use of random algorithms in many areas of computer science has enabled the solution of otherwise intractable problems (this is the case of, e.g., neural networks and genetic algorithms, basically non-deteministic and aimed at finding "a" solution rather than "the best" solution). They furthermore observe that the dataset is often a sample from the real world as the underlying data is intrinsically continuous or otherwise vast. Deliberately introducing further random sampling can improve visualisation when details are only required for some data items, there are many data points to show and/or when calculations lose some information anyway (e.g. average, representative histograms).

The paper suggests ways of using randomness to enhance or enable different forms of visualisation and interaction, both in existing, non-random systems, and in the novel Astral Visualiser, based on the metaphor of a stargazer's telescope. Two attributes or derived values are chosen for the x, y coordinates and a small set of a few hundred sampled records are originally chosen and plotted. After the user has selected an area of interest, Astral zooms in and samples more records in that area. The Astral Visualiser can work with 2D views of arbitrarily large datasets, allowing both the overall structure of the data to be seen and also the ability to zoom into individual data items. Besides the visualiser, the paper also discusses some of the general issues sampling raises for interaction (e.g. how to make the user aware of the approximation) and how to choose correct sampling levels, taking into account human perception and understanding.

The efficacy of random sampling definitely needs more experiments, comparison with conventional deterministic techniques and usability study to analyse the user reaction to approximate searches, but certainly Dix and Ellis put in new light the use of randomness in information visualisation, limited so far to a few cases (such as the Influence Explorer (Tweedie *et al.*, 2002)).

4 Studying the user

In order to be user-centred, the development of any interactive system should include the identification of the users and their needs, along with the usability evaluation and validation tests of the system. Notwithstanding the crucial role that usability plays in the acceptance of a product by customers, even widespread applications still exhibit major usability problems. For example, it has been estimated that 65% of virtual shopping trips on the World Wide Web end in failure and 40% of users do not return because of problems in website design (Pirollo *et al.*, 2002).

Despite of a decade of widespread use, there has been limited progress towards a deep scientific understanding of the psychology of human interaction with the World Wide Web. A proposal in this direction comes from Pirolli *et al.* (2002), who developed a methodology for studying and analysing the psychology of users performing "ecologically valid" WWW tasks (that is, tasks that resemble what people do in real, culturally significant situations (Neisser, 1976)). Controlled laboratory experiments have then been conducted on tasks of this type, to collect "user traces", i.e. records of all significant states and events in the user-WWW interaction, based on eye-tracking data, application-level logs and think-aloud protocols. A *user tracing architecture* is presented, which enables the development of computational models of users that can be tested against datasets of user traces. The architecture is used for developing and testing cognitive-perceptual simulation models by matching the output of the model against the traces.

A study of user-WWW interaction is proposed also in WebQuilt, a Web usability logging and visualisation system that helps web design teams record and analyse usability tests (Waterson *et al.*, 2002). The logging portion of the system gathers clickstream data that get aggregated and presented as an interactive graph, having images of the pages visited as nodes, and transitions between pages as arcs. WebQuilt provides filtering capabilities and semantic zooming, allowing the designer to understand the test result at the gestalt view of the entire graph, and then drill down to sub-paths and single pages. The visualisation highlights relevant usability issues, such as, among others, pages where users spent more time, navigation patterns, exit pages, all within the context of a specific task.

Steering designers, even if in a different context, is the aim also of Plumlee and Ware (2002), who present a theoretical model of performance that contrasts the relative efficiencies of zooming and multiple windows (two techniques usually adopted to address the focus + context problem) when used by humans for completing a taks involving comparisons between widely separated group of objects. The model predicts that zooming should be better for navigating between a few distant locations when demands on visual memory are low, but that multiple windows are more efficient when demands on visual memory are higher, or there are several distant locations that must be investigated. The work could be helpful to interface designers in deciding when and how to employ various navigation techniques.

Guidelines for designers, in the field of secure systems, come from the work of De Angeli *et al.*, addressing knowledge-based authentication systems in self-service technology, and presenting the design and evaluation of the Visual Indentification Number (VIP). The basic idea behind it is to use pictures in place of numbers as a means for user authentication. The study and associated design exploration revealed important knowledge about users, their attitude towards and behaviour with novel visual authentication approaches. The usability study demonstrated the merit of the visual PIN idea but also stressed the need for further user-centred design to maximise the benefit of the concept.

5 Design issues

As the discussion so far conducted suggests, the job of the designers of visual interfaces becomes increasingly difficult. Complexity comes from, among other things, the shift from single to multiple users, and from the variety of workplace settings and user populations for which products are intended. An interdisciplinary view of the problem of developing complex software systems is essential to a human-centred rather than artifact-centred approach: software engineering, usability engineering, HCI, knowledge-based systems, computer-supported cooperative work, ethnographic methods and social and psychological theories, all can cooperate to create software systems that support end-users.

The contributions coming from the above-mentioned disciplines and their synergy are extensively and organically discussed by Redmiles (2002) in a paper presenting methods and tools aimed at supporting multiple end-users' views (including those of software developers, who are actually users of software tools). The paper is definitely an excellent and pragmatic survey of the work of many researchers in the field, and its rich bibliography constitutes an essential guide to designers and software developers.

Other works in the AVI 2002 collection of papers provide principles and guidelines necessary to steer designers in the choices related to dialogue techniques and visualisation techniques, crucial in the development of information artefacts.

Over the past decade, researchers have developed dialogue techniques that improve the original desktop metaphor and WIMP (Windows, Icons, Menus, Pointing) graphical UIs. Marking menus, floating palettes and toolglasses are examples of such post-WIMP techniques. Though the literature reports studies on the efficacy of these interaction techniques, commercial applications rarely use them, partly because they are not supported in standard interface toolkits.

The paper of Mackay (2002) aims at encouraging software designers to consider exploiting these unconventional techniques in new applications. Following previous work of the same author on post-WIMP interfaces, the paper discusses the use of marking menus, floating palettes and toolglasses in a Colored Petri Net editor, and describes a controlled experiment to identify the circumstances under which users prefer each technique. The result of the study suggests that (a) floating palettes are command-oriented and perform best when the user must repeatedly reissue the same command and that (b) marking menus are object-oriented and are most efficient when the user has to apply several commands on the same object on the screen, while (c) toolglasses are preferred when dialogue involves rapid switching between objects and commands. A good design strategy would then be based on the integration of the three dialogue techniques.

As to design choices related to visualisation techniques, an interesting discussion is provided by Janacek and Pu (2002). Their paper discusses the general concept of fish-eye view into a framework than can be used by the designers of interactive visualisation interfaces (and potentially by their users) to control and refine the visual and semantic richness of these techniques. The framework includes two components: a DOI function and a set of emphasis algorithms (the visual techniques used to emphasise or de-emphasise objects based on their DOI). The framework is validated through the implementation of a prototype applying fish-eye view to tabular displays.

6 Conclusions

In this paper we presented some recent achievements in the visual interface field presented at the AVI 2002 conference. The conference programme included 3 invited papers, 28 research papers, 12 system papers and 11 posters. Space limitations forced us to limit discussion to only part of the AVI 2002 collection of papers, covering only some of the topics of interest. Just to take one example, the discussion on unconventional dialogue techniques in Section 5 might be extended by including results related to the use of non-conventional input/output (two-handed input, eye-movement, virtual walking for exploring 3D virtual spaces, 3D presentation), also presented at the conference. The interested reader may refer to the AVI 2002 website (`http://www.diel.univaq.it/avi2002`) to find information about the complete conference programme, and contact the AVI 2002 Conference Chair to purchase copies of the proceedings.

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