A SCIENCE OF INTERACTION
A Multidimensional Canvas

Robert Spence
Imperial College London, U.K.

Keywords: Interaction, information visualization, visual analytics, browsing, design actions.

Abstract: A recently proposed search for a science of interaction will involve the creation of a multidimensional canvas composed of many features: complex perceptual and cognitive processes, the many approaches to interaction design, the many models of interaction and the vast range of interaction modalities. In any attempt to meet this challenge this paper urges emphasis on precise definitions, especially for visualization and interaction, and reports the results of an exploratory study.

1 INTRODUCTION

In a publication (Thomas & Cook, 2005) setting out an agenda for research and development, the Department of Homeland Security in the United States encourages the creation of a new science of interaction to support Visual Analytics, the latter discipline being defined as:

> **Visual Analytics**: The science of analytical reasoning facilitated by interactive visual interfaces.

Because a major feature of this paper is the stress that it lays on the need for precision in concept definitions it must be pointed out that, unlike many definitions which have incorrectly separated the letters v-i-s-u-a-l from the term 'visualization', the aforementioned report on Visual Analytics does acknowledge forms of encoding (e.g., aural, tactile) other than visual.

In some respects the disciplines of Visual Analytics and Information Visualization are hard to disambiguate one from the other. However, because the definition of Information Visualization is relevant to the following discussion we repeat a common dictionary definition here:

> **Visualization**: to form a mental model of something.

Though apparently controversial, this definition removes any immediate consideration of technology and implies that a 'visualization' is not something that appears on a computer display. Indeed, in its mention of a mental model it supports the concern of visual analytics with cognitive science.

A Challenging Goal. In proposing a search for a science of interaction, the report on Visual Analytics describes an exceedingly challenging goal, assuming that 'science' refers to a body of knowledge, and hopefully one whose formulation is supportive of organised thought and design. Yi et al (2007) have recently addressed that challenge. What follows in this paper are some considerations regarding the challenge and an example illustrating one attempt to address the complexity involved

Precision. The prospect of making progress towards an entirely new science is fraught with difficulty in the absence of clear definitions of the concepts involved. Even if the sought-after science does not materialize as coherently as one would wish, clear definitions are in any case essential to support organised thought about a subject and vital for its advancement.

2 INFORMATION VISUALIZATION

Based on the above definition of visualization it is helpful to identify key features of a system designed to support information visualization. Those features are (Spence, 2007):

Spence R. (2008).
A SCIENCE OF INTERACTION - A Multidimensional Canvas.
In *Proceedings of the Third International Conference on Computer Graphics Theory and Applications*, pages 415-418
DOI: 10.5220/0001099604150418

1. **Representation**, in which raw or derived data (Tweedie, 1997) is encoded by graphical, aural, tactile or olfactory means.
2. **Presentation**, which involves the selection, and the spatial and temporal arrangement, of represented data for display, where 'display' is understood to include all means of presenting data.
3. **Interaction**, leading to changes in representation and presentation that have the potential to support the generation of insight into data.

While these three features can be separated conceptually, the potential for interplay between them is of course rich and available for beneficial exploitation by the interaction designer. Two comments should be made. First, as argued by Furnas (2006), the distinction between representation and presentation is important: the two should not be merged. It should also be pointed out that interaction *as usually understood* is *not* an essential component of a system designed to support visualization, otherwise all pre-computer representations (e.g., of Minard, Snow and Nightingale) and all static representations, whether printed or electronic, would be excluded from consideration.

3 INTERACTION

In the search for an interaction science it is essential to establish a classification of interaction types. Three such classes are

Continuous Interaction. In continuous interaction the value of some variable is changed continuously and the display of data is changed accordingly and usually continuously. An example is provided by a display in which the value of some parameter of a model is continuously varied – manually or autonomously – and the data corresponding to each parameter value is displayed, again normally continuously.

Stepped Interaction. In stepped interaction a single action such as a mouse-click causes a discrete change in the presented representation, either involving essentially the same data or a move to a completely new location in discrete information space. A very familiar example is provided by the transition from one web page to another following interaction with a displayed menu item.

Passive Interaction. Except for the rare occasions in which continuous interaction is employed, and the few milliseconds in which an action such as a mouse click is executed, most of a user's time is spent in passive interaction, simply examining and interpreting representations of data presented visually, aurally or tactilely. With the graphical encoding of data, for example, a great deal of eye movement is involved. An example is provided by a person undertaking a visual examination of Minard's map; another involves an online purchaser carefully studying the options available before proceeding to make a selection. There should be no problem with the term 'passive interaction': the prefix 'inter' means 'between' or 'among', and 'act' is defined as the process of doing something. We speak, for example, of social interaction, an exceedingly complex process in which there is no need for any physical act to take place; similarly it is appropriate to speak of passive interaction to refer to the complex visual and cognitive actions on the part of the person studying Minard's map or a temporarily static display.

Two comments may help to remove any doubt as to the validity of the class of passive interaction. First, it is important to note that passive interaction does *not* imply a static display such as a conventional map: a visual display can usefully be dynamic and designed in such a way that a user can derive considerable insight simply by watching it (Colgan et al, 1995; Wittenburg et al, 2003).

Second, there is a common misunderstanding that a static display is somehow inferior to an interactive one, a view that might unfortunately be reinforced by an emphasis on 'interaction' as it is conventionally interpreted. One only has to compare use of the Dynamic Queries interface (Williamson & Shneiderman, 1992) with a static instance of the Attribute Explorer (Spence & Tweedie, 1998) to realise that, in the former, a great deal of interaction is required to build up a mental model of the underlying data, whereas the latter provides considerable insight without any need to change the view.

4 HUMAN INTENT

The need to recognise the involvement of the human user of a system designed to support visualization has already been acknowledged by the very definition of visualization. However, to work towards some useful classification there is a need to examine the perceptual and cognitive aspects of that user in more detail. In the context of a search for a science of interaction a first step in this direction has been made by Yi et al (2007) who draw attention to the importance of human intent.

This human characteristic can be further subdivided by considering the activity of browsing. Definitions of browsing are notorious for their lack of precision so we offer the following definition:

Browsing: the perception, interpretation and evaluation of content,

a definition which, on its own, identifies the Gulf of Evaluation in Norman's Stages of Action (Norman, 1988) and often involves little or no conscious cognitive effort (Potter, 1999). Unfortunately, in the literature, the term 'browsing' carries with it the connotation of casual intent. Instead, and broadly in agreement with Foster and Ford (2003), de Bruijn & Spence (2007) define three classes of browsing, each simply described by the presence or absence of intent and by the awareness or otherwise of a goal:

- **Search browsing** (SB) is intentional, and the user is aware of a goal;
- **Opportunistic browsing** (OB) is intentional, but the user is unaware of a goal;
- **Involuntary browsing** (IB) is unintentional and the user is unaware of a goal.

An example of SB is demonstrated by the familiar use of the Web to locate either specific or initially ill-defined information. OB is characterised by the attitude "I wonder what's there? Let's have a look". IB occurs all the time that a user is conscious, normal rapid eye movements (typically 3 per second) providing the change of visual stimulation of the eye (the 'change in the world' in Norman's Action Cycle) and which is continuously categorised and consolidated (Potter, 1999). As an example, all three forms of browsing are almost certainly invoked when using the Web to search for a present for Mother's Day.

5 DIMENSIONS

Although our definition of browsing provides classes of *intent*, that is only one of many dimensions within which the optimum choice of an interaction scheme for a given application needs to be considered. In addition to human intent there is the perceptual and cognitive dimension, a variety of models of interaction (e.g., GOMS), the many modes of interaction (e.g., eye-gaze, mouse, voice) and a range of design levels. The latter can range, for example, from the use of sketching to support ideation and creativity (Craft, 2006; Buxton, 2007) through the use of Patterns (Borchers, 2000) and guidelines, to other complementary concepts such as Design Actions (de Bruijn & Spence, 2007) that provide detailed and often quantitative advice to the interaction designer. The science of interaction would seem likely, therefore, to occupy a multidimensional canvas and one, moreover, which is still largely unpainted. It seems inevitable that many exploratory investigations will take place in the search for such a science.

The result of one exploratory study, described in the following section, is a potentially useful framework associated with three of the many relevant dimensions, in that it links the human behaviour supported by an interface, the cognitive theory underlying that behaviour and the design decisions made by an interaction designer.

6 DESIGN ACTIONS

The framework is shown in Figure 1. Each of the three components is identified both generically and by the specific example to be used for illustration. The human behaviour for which an interface must be designed is at the centre, and in the illustrative example is opportunistic browsing. The behaviour invokes perceptual and cognitive processes, and in our illustration the relevant example is that of human visual processing as represented by the model of Conceptual Short-term Memory (Potter, 1999). On the right are Design Actions which inform the interaction designer: their nature is described below.

The motivation for the proposed framework is the perceived advantage that an interaction designer *need not be familiar with or understand the underlying cognitive theory*: that theory is 'reflected' via human behaviour into Design Actions which are couched in the language of the interaction designer.

To illustrate the nature of Design Actions we refer to an example chosen by de Bruijn and Spence (2007): the opportunistic browsing, on a PDA, of news items (de Bruijn & Tong, 2003). Each news item is represented by an appropriate image and very few words, and they are presented in sequence by Rapid Serial Visual Presentation. The question "how rapid?" is one that Design Actions (DAs) can

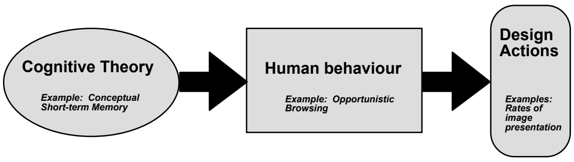

Figure 1: The Framework involving Design Actions.

answer. For example, one DA is appropriate if a satisficing strategy is adopted by the user, and suggests a maximum presentation rate of 10 per second. Another DA is relevant to an 'optimising' strategy, for which the rate could be as high as 2 per second. Yet another DA is relevant if a user wants to preview all news items and then choose one after all have been considered: here the rate is about 1 item per second. Thus, the relevant DA depends upon the interaction designer's assessment of the user's intent. As well as providing detailed advice each DA describes the 'upsides' and 'downsides' of its application as well as associated issues.

7 CONCLUSIONS

Three conclusions with regard to the search for a science of interaction can be drawn. First, there is a need for such a science to be based on concept definitions which are precise. Second, the definitions of visualization and interaction in particular need to be sufficiently inclusive as not to exclude many of the common modes of interaction. Third, that the search for a science of interaction will require many exploratory studies over a considerable period of time. Thus, the Design Actions concept described above may well be only a tiny speck of paint on the forbidding multidimensional canvas that will become the science of interaction.

ACKNOWLEDGEMENTS

I thank the authors of Yi et al (2007) for providing a preview of their paper. I'm especially grateful to Dr. Oscar de Bruijn for many discussions about interaction design.

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