Applying Perceptual Layers to Colour Code Information in Hand-Held Computing Devices

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Introduction

The aim of this paper is to show how a new methodology for automatically colour coding displays can provide quantifiable gains in information acquisition and performance over those formats using current methods and approaches design complex tabular displays in hand-held mobile computing devices.

According to Joachim, Shinar and Lieser (1997) tables are best for recalling specific values. In their study they found that tables led to faster responses and the accuracy for tables was equally high or higher than for graphs.

Most current hand-held mobile computing devices are based on the EPOC32, PalmOS or Windows CE operating systems. These devices usually include a variety of built-in software such as word-processors and spreadsheets as well as databases and the Internet. Therefore, it is likely that most users may find themselves interacting with tabular information.

Although tabular displays are an efficient and effective means to display information there are a number of problems in displaying tables in mobile devices. Small, hand-held mobile devices lack screen space, and this can be a serious handicap in their efficient use (Brewster, Leplatre and Crease, 1998). If the device must be small and the screen must fit the device, text will necessarily be small and graphics will tend to be cramped. As a result, complex tables are often too small to read or much larger than the display size.

Typical interactions involving recalling or comparing information on such displays require repetitive scrolling and navigating actions, which will result in an increase in the time taken to complete tasks and lead to user frustration, confusion and lowered performance.

Mobile computing is predominantly based on monochrome displays. However, a number of companies have now introduced palmtop computers with 256 colour displays (e.g. Sharp HC4600C, HPJornada™ 420, Compaq® Areo™ 2100, Philips®Nino™ 51). More recently, Casio introduced the Cassiopeia E-100, a hand-held device with a 65,536 colour display. In addition to colours, the quality of the displays is increasing, for instance, the Compaq Areo 2100 includes a TFT colour display. This paper will describe a method of using colour coding to provide support for tasks that involve navigating around more than one screen full of information.

The Perceptual Layers Methodology

Previous work in cartography has advocated the use of perceptual layers as a means to organise task relevant data elements on a map or display (Wood, 1968). A perceptual layer exists in a map when information on one layer, such as motorways or main roads, appears to sit above or below information on other layers, such as land use or minor roads.

The Perceptual Layers methodology employs principles of human factors, cartography, colour science and colour perception to generate displays that use colour coding to emphasise task relevant interface components. This is achieved by producing the illusion of perceptually different layers, upon which supports the structure of the user's task.

The methodology has been tested in complex safety critical applications (Van Laar, Williams, Umbers and Smalley, 1997), and is now being developed for use in other areas. The Perceptual Layers methodology has been found to be of use in a number of different display types, including mimic diagrams, bar, trend, and tabular displays.

The main principle of the method is that more important and task relevant layers appear more conspicuous and usually on a perceptually higher layer than less relevant information. A simple task analysis is used to allocate each group of display objects to an appropriate perceptual layer. Each interface component is analysed in terms of its frequency of usage, the extent that it supports the user's task, relationships between different components or variables, and existing information structure and hierarchies. These inform the allocation of colour to each interface component.

The methodology is used to generate a set of colour palettes that may be used to code components of the display. Colour codes within a palette whilst appearing quite different from one another in terms of hue all have the property that they appear to sit on the same perceptual layer as one another. Colour codes from different palettes may well be of the same hue, but will appear to sit on different perceptual layers – in the same way that motorways appear to sit on top of land use information in road maps.

Because predicting how colours will appear on different perceptual layers is a multi-dimensional mathematical problem where each colour has a three-dimensional co-ordinate in colour space (Van Laar and Flavell, 1994). The methodology has been instantiated within a computer program. This program uses parameters based on the properties of the display (size, phosphor colour), the environment (illumination, screen viewing distance) and the task (number of components, task analysis) to generate the colour palettes. Properties of the human visual system are also employed to ensure that the layering technique works for all users including those with colour vision difficulties.

The methodology ensures that the designer is provided with a set of colours with which to code display formats according to current psychological principles and theories governing the perception of colour from emissive displays. The colour sets have also been designed to comply with colour in displays standards for discriminability and legibility (ISO/FDIS 9241-8, Part 8).

The perceptual layer methodology offers a way of visually emphasising task relevant information. Furthermore, The colour sets produced in this way are applicable across a range of different displays and thus help maintain consistency (i.e. perceptually the same colour code can be generated for all displays) and ensure that the display produced is device independent. Using the Perceptual Layering methodology, areas of the display can be related using their colour code, rather than relying on memory, or codes that use screen real estate (such as labels).

The advantage of the methodology for hand-held mobile computing devices is that information can be displayed in *virtual tables*, much larger than the screen size. As different parts of the table may be related using the colour-coded regions, users can navigate between areas of the display without spending time and effort trying to read or remember irrelevant information. Colour-codes are allocated to increase the performance with respect to the tasks the display is designed to support. Once users locate the desired area of the table, scanning information within the area is faster, as more important objects appear more conspicuous due to their colour coding. When a specific area is located, the target will appear on a higher perceptual layer than its background and, as a result, be located more quickly. Finally, as the allocation of perceptual layers is consistent with the users' understanding of the task, users can apply categorical, semantic and knowledge-based visual search strategies to locate information more quickly, and thus reduce repetitive scrolling and confusion due to location disorientation.

Applying the Methodology to solve a Design Problem in a Specific Domain

A typical application of this methodology might involve the performance of hand-held mobile computing devices designed to support medical practitioners. Medical practitioners are increasingly turning to computer based solutions to increase the effectiveness of their practice. For instance, Sullivan and Wilson (1997) found in their survey that most general practitioners use a parallel electronic record system on their practice computer. Mobile computing devices can be carried with the user and provide doctors with immediate access to material such as medical histories, referrals and patient and emergency contact information. Mobile computers also have the advantage of allowing doctors to access critical information whilst working in different clinics, visiting patients, working in community based services or being on emergency call.

The major usability problem for user who use mobile computing devices to access medical information will be the lack of screen space available to display the amount of information required to complete a task. For instance, the amount of information that a patient table-object has includes the attributes of personal details, admissions, complaints, prescriptions and medical history. In addition, for each patient, the user needs to keep track of critical medication information.

In applying the Perceptual Layers methodology to solve the design problem, the first stage is to explore user requirements, tasks and needs. This can be based on task and domain analysis. Alternatively practitioners needs can be gathered and analysed on the basis of Contextual Inquiry (Vaananen and Ruuska, 1998) which, it is argued, is particularly suitable to support mobile computing interface design. These methods can guide the interface design, but can also be integrated with the new methodology to inform the allocation of colours and perceptual layers to different parts of the interface. Areas of the table that relate to the same task, patient or medical procedure. For example, in a table that displays patient information, personal details will have a different area code than symptoms or prescriptions. The colours define area code, background and borders. The colours are subtle and do not clutter the screen or grab the user's attention. These colours would sit on the first (lowest) perceptual layer.

The second layer might code different parts of the table area. These could be coded in the same hue as the background area code to enhance their appearance and give the impression of related information. The third layer adds static or reference text to the display. This includes any table titles and subtitles. Because colours are used to code information, the number of labels can be reduced and hence saves screen space.

The fourth layer contains dynamic text, that is, values that the user locates, compares or needs to recall. Such text must be easily seen, and thus it is coded with high luminance contrast. Labels, subtitles and titles are allocated to a lower layer than dynamic text. Clutter in the visual search is, therefore, reduced and information scanning becomes more efficient.

Finally, critical information is allocated to the top layer using particularly saturated colours. Information in this layer is the most conspicuous. For instance, the fact that a particular patient has an allergy to a specific medication is more important than their address or date of birth.

Although the Perceptual Layers methodology offers a number of benefits, performance is a two-factor concept (Dowell and Long, 1989). Firstly, it includes the quality of the product, or how well the desired state of the domain is achieved compared with the state specified. Secondly, performance includes system and user costs. Task quality can only be achieved if designers have a clear idea of the user requirements. Unless these are integrated with the new colour methodology, the methodology can only address user-costs; that is, reducing time spent in navigation, scrolling and comparing values.

A design problem expresses an inequality between *actual performance* and *desired performance* of some worksystem with respect to some domain (Dowell and Long, 1989). A successful design solution is one that achieves desired performance. In applying the Perceptual Layers methodology, the first stage involves selecting a design problem where the methodology can contribute to performance improvements. Typically, performance problems that the methodology would offer a design solution are based on users interacting with hand-held devices to access complex data to perform their work. Besides medical practitioners, examples inculde on-site engineers who use technical data to support diagnosis and troubleshooting, and financial professionals who require access to monetary and commercial data.

Summary

This paper has described a new methodology to colour code complex data on tabular displays. This is based on generating perceptual layers on displays and employs human factors, cartography, colour science and colour perception principles, guidelines, standards and methods. The aim is to increase the effectiveness and efficiency of interacting with large information areas with small displays. Validation of the methodology should be based on redesigning displays to support different classes of users in different domains.

Research is currently being undertaken to evaluate the performance advantages of this methodology in supporting users who employ mobile computing devices. The research will include a number of phases. Firstly, a domain of application will be analysed, and users tasks, needs and requirements will be captured. This information will be used to inform the allocation of colour codes and perceptual layers to the structure and organisation of the table. These will be then tested experimentally by employing a computerised simulation of the domain and once refined, in a field based study. Actual performance will be compared with desired performance and implications for the design and application of the perceptual layering methodology will be reported in the future.

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