Assessing the Suitability of Context Information for Ambient Display

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ABSTRACT
With the advance of pervasive technology, information from both the physical and virtual world is increasingly accessible to developers. Context-aware applications may consume relevant aspects of this information as they support user tasks. When conveying information to people, the mechanism for presentation must be carefully considered. As ambient devices are centred on the notion of calm-technology, it is logical that certain types of data lend themselves to ambient display more easily than others. In this paper we present our initial investigations into the properties of contextual information best suited for display using ambient technologies. We present the feature set extracted from our investigation, and apply examples that satisfy these criteria to our prototype ambient device, the visual calendar.

Keywords
Context, ambient devices, pervasive computing

INTRODUCTION
The boundary between personal computing and consumer electronic devices is becoming increasingly blurred, resulting in an environment in which technology is blended with everyday objects [1]. In addition to easing the path through which data from the physical world may be combined with data from the virtual world, application developers are afforded new opportunities for interacting with users outwith the bounds of the traditional personal computer.

Our recent work has focused on the development of frameworks that support the collection and distribution of *context information*, and on raising the level of abstraction over data that is available to applications [2]. Early applications that we developed made use of web pages, mobile devices, and wall-mounted displays to present information to and interact with users. We are presently investigating the use of ambient displays, and examining how they afford different opportunities for presenting context information to users in comparison with existing approaches.

Our notion of an ambient display is based around Weiser's idea of calm-technology [3]. With respect to this tenet, we take the view that ambient displays should be designed to be unobtrusive, with interaction completely driven by the user. They should be experienced as a tool that the user may refer to in the process of completing a task if he or she wishes.

Information manifests itself in many forms. It may appear in a single or number of discrete events, or flow as a continuous stream. Values may be relatively static or highly dynamic over time. The range covered by data may take the form of a finite set of values or have unbounded scale. Information must be appropriately represented for it to be understood by the user. This implies the need for a strong correlation between the nature of information and its presentation medium. As ambient devices adhere to the concept of calm-technology, it follows that certain types of data are more appropriate for ambient display than others.

In this paper we present our initial research towards identifying properties of context information that are well-suited for presentation via ambient technology. We consider the mapping between information and realisation by existing devices, and the need to "ask the right question" of the information. Throughout this paper we use examples of readily available sources of information to motivate discussion, and apply examples of information that match these properties to a prototype ambient device, the visual calendar.

This paper is structured as follows: In section 2 we discuss the mapping between information and display in existing ambient devices. Section 3 presents our initial investigation into the properties of context information best suited for ambient display. Section 4 describes the application of different types of information to a prototype ambient display. Finally, in section 5 we summarise our work and present a question designed to motivate discussion at the workshop.

RELATED WORK

There are many examples of ambient devices that aim to communicate a wide rage of information to users without placing significant demands on their attention. This section examines some well-known examples, and discusses the relationship between information source and display technology.

Ambient Devices' Ambient Orb [4] is a glass ball that changes colour to display variance in data obtained from internet sources. The Orb has many modes, which makes it an interesting case study. As an example of an intuitive and useful mapping, the Orb will change colour from green, through yellow, to red to indicate current traffic congestion levels. A less complete visualisation is the mode that displays changes to a stock portfolio, which is restricted to indicating performance swings of up to 2.5%. External information, namely the starting value of the stocks, is required for the interpretation to be fully meaningful. Finally, the Orb's weather forecast mode uses 11 different colours to indicate temperature intervals between -10 and 100 degrees Fahrenheit. When there is a chance of precipitation the Orb pulses. This more complex visualisation demonstrates that the Orb is not well matched to the problem of conveying weather information.

van Mensvoort's DataFountain [5] uses three water fountains to provide a visual comparison of the Yen, Euro and Dollar currency rates. Whilst it is an aesthetically pleasing display, and is straightforward to deduce the relative position of each currency, the scale on which the fountains operate is not visualised. The nature of the presentation medium greatly reduces the precision at which the data can be interpreted.

Jafarinaimi et al.'s Breakaway project [6] uses a morphing sculpture to encourage people with desk jobs to take breaks throughout the day. Information gathered from sensors in the user's seat drives changes to the shape of the sculpture. The sculpture is designed to mimic the human body - when upright, it indicates that the body is refreshed; when slouching, it represents that the user has been sitting for an extended period of time. The sculpture reflects a good mapping between information and its visualisation. The intention of the sculpture is more easily interpreted than, say, a numeric display of the time spent seated; providing a visual clue that suggests the user takes a break.

Ardern's Powerpoint [7] is a mains socket augmented with a set of LEDs that indicate the amount of energy consumed from the outlet. As the power consumption increases, the number of lit LEDs increases, and their colour changes on a spectrum between green and red. The intention is to increase user awareness of power being drawn by various appliances. Despite the fact that this mapping is intuitive, the decision to place the display on the wall socket may be questioned. There is an assumption that the socket is in full view and not, for example, behind a sofa or a bookcase. However, the idea of a central view for recording and displaying information is touched upon.

Finally, Stasko et al's InfoCanvas [8] allows people to specify mappings between information of personal interest and pictorial representations. These are realised in the form of a digital painting. The artefacts in the painting move, morph, or change colour to represent changes in state. Some mappings are intuitive, such as changes in colours representing traffic conditions. Others mappings, such as those involving scalar data types, are difficult to interpret visually without the presence of a scale. The InfoCanvas example employs a kite at varying highs to represent rise and fall of stock prices. Without a clear indicator as to the exact values being represented, the stock price cannot be read.

FEATURES OF CONTEXT DATA SUITABLE FOR AMBIENT DISPLAY

Context information can be derived from any data that describes the current state of a system, its users, and their surrounding environment. Examples of such data are user location, current task(s), goals, environmental conditions (temperature, weather, light conditions), capabilities of the system, and so on. When a user is the end point for delivery of context information, the presentation mechanism must be carefully considered. We hypothesise that ambient technology is only suited to conveying certain types of context information to the user. This section discusses five properties of context information that should be considered when selecting an appropriate presentation medium.

Precision is the first property that we consider. Ambient displays do not lend themselves to accurately conveying information with a fine granularity. A continuous range of values needs a scale to be fully understood. Without a scale, interpretation can only be approximate and precise comparison between different states is difficult. Linear scales may be represented where accuracy is not important, but other scales, such as logarithmic, may be more difficult to interpret. Where values are described from some offset, such as stock price fluctuations, the user needs to have an understanding of the base-level for that offset to make sense. Ambient displays cannot clutter the visualisation with scales for values or keys with labels, which increase the cognitive load on the user. Information should be instinctively interpretable without the requirement for extra indicators to enable understanding. Context data needs to be rounded or smoothed before displaying in a calm-manner. A small, discrete set of values are far simpler to map to a visualisation. Attempts to display a large number of related values with fine resolution are inherently more open to user reasoning error.

Criticality influences how aware the user must be with respect to changes in the state of information. If the user must pay significant attention to the information, the device should not be regarded as ambient. Similarly, if a change in information state requires immediate user attention, this too should not be regarded as ambient. Presented information must not be mission critical; it should be supportive of but not integral to the tasks at hand. If ignorance of information will cause the user's task to fail, the information should be presented in a more intrusive manner. The principle of calm-technology behind ambient displays makes them a poor mechanism for conveying data that must be acknowledged or acted upon.

The **periodicity** of context information is another factor in choosing appropriate presentation. Information that is repeated often is suited to ambient display. In some sense, repeated data is linked to the property of criticality. If the user misses a particular assertion, a future event in the sequence may be observed. Users should not be left wondering if they have missed a rare event. For example, train departure times between the user's local station and home may be a good example of repeated data.

The **interpretability** of context information is another factor. Information usage should be considered *a priori* in order to provide a representation that does not strain the user's cognitive load. Information is only appropriate for ambient display if it can be visualised in a way that lends itself to easy interpretation. An example of this is a system designed to show bus timetables. Displaying the raw data provides too much information: the user needs to aggregate times of buses with the current time and the time it will take to get to the bus stop. It is more appropriate if the data is pre-processed and conveyed in a personalised manner. Note that we do not imply the display of bus timetables is not useful, only that it is not ambient.

The final characteristic we consider is **self-descriptiveness**. When displaying context information to the user it is important to provide a stand-alone representation. The user should not require information beyond what is displayed to fully comprehend its meaning. We motivate this using two of the AmbientOrb applications discussed in section 2. The stock performance application provides an example of an incomplete representation of context information, where the user's interpretation is restricted by the need to know the starting price for the day. This can be contrasted with the traffic congestion application, where the user requires no external information to understand its meaning. The self-descriptiveness and interpretability properties of context information are closely related.

We observe that data-driven processes can be well-supported through the use of ambient displays. This encompasses situations where the aggregate of information from multiple sources is considered useful to the user, and the individual information not so. Aggregated data should be displayed in the form that is most meaningful for the task at hand. For example, a system that takes multiple inputs to predict weather patterns may be of most use to the user by answering the question: "should I carry an umbrella with me today?" Boolean outputs such as these are examples of context information well-suited for ambient display.

THE VISUAL CALENDAR EXAMPLE

We have designed a prototype ambient device called the Visual Calendar, which provides users with a personalised display of context information. The device is similar in principal to the InfoCanvas [8], and takes the form of a digital picture in which artefacts are placed that visualise context information relevant to the user.

The visual calendar is realised using a widescreen display. It provides a view of the state of the world relevant to the user's current context through animated icons and symbols. Context information is selected and processed to ensure that it adheres to the feature set identified in the previous section. This is illustrated in figure 1.

Artefacts in the foreground of the picture move from right to left as time advances. They may take the form of either a representation spanning the horizontal axis, or may appear as a number of discrete values.

Figure 1: The timeline of the visual calendar.

The background of the picture is used to represent contextual data viewed as a Boolean question. When artefacts in the background are present, they indicate that a condition is true; they disappear when the condition is false. Reducing context information to a Boolean representation satisfies the *precision* and *interpretability* properties we outlined above. It is the responsibility of the developer to ensure that the question being asked of the context information is appropriate to satisfy the other properties.

In our scenario, buses on the road represent the approach of a bus on the user's route home from work. The visualisation takes into account the time required for the user to walk to the bus stop, and the estimated time the bus will reach the bus stop. Buses move along the road on the

display from right to left, each bus disappearing from view once it is no longer possible for the user to catch it. Note that this representation satisfies each of the criteria we set out. The visualisation of the bus travelling along the road provides adequate *precision*. No explicit scale is required, as the user can interpret meaning from the position of the bus on the road. Missing a bus is not important when others will follow. This satisfies the *criticality* property of the system. The timetable and user location data have been pre-processed from their raw forms into a personalised version. This yields a satisfactory degree of *interpretability* as the system includes the time the user takes to get to a bus stop. Simplicity of visualisation further meets this requirement. The representation is also *self-descriptive*, requiring no external information to be understood. It is important to note that this representation may not be suitable for all users at all times. For example, if the next bus is the last (*criticality*), or there are only 2 buses a day (*periodicity*).

Figure 1 also illustrates the use of the visual calendar to display traffic congestion, and person location information. The three buildings in the background represent home, office, and school. When a family member is sensed in one of these locations, their image appears in front of the building. The cars travel along the road indicating current and predicted traffic congestion on the route between the user's work and home. The number of cars on the road indicates the current level of congestion, while cars stacked closer together on the right edge of the road indicate that congestion is expected within the next hour. Historical data is used to predict congestion based on the day of the week and the time of day. We believe that the number of cars on the road clearly conveys whether there is congestion to the user. There is no need to apply a fine-grained scale in order to make the representation meaningful. As with the example of the buses, if you miss a time period when the roads are clear, another will follow. The nature of traffic flow follows this repeated pattern, satisfying our criticality and periodicity properties. Interpretability is eased by pre-processing traffic reports for the user's route home from work. The resultant visualisation, which uses cars, is simple and self-descriptive - cars are a symptom of congestion and therefore aid user understanding of the representation.

Finally, the three images in the upper-half of the display represent weather forecasts for now, rest of today, and tomorrow. These well-known representations satisfy all five of the properties identified in this paper.

CONCLUSION

Increased availability of information from both the physical and virtual world provides developers with new opportunities for supporting user tasks. Ambient devices, based around the notion of calm-technology, are one approach to exposing such information to users. In this paper we hypothesised that only certain types of context information are suitable for display via ambient technology. Our initial research into the properties of information that fit this display modality has identified precision, criticality, periodicity, interpretability and self-descriptiveness as key factors. We illustrated our findings using a prototype ambient device, the visual calendar.

We posit that it is important to consider the above properties when deciding if an ambient device provides an appropriate choice of display for exposing context information to the user.

Based on our recent work with context information, we have witnessed a clear trend between the need to "ask the right question" of the information and the ease in which it can be presented using ambient technology. The question we bring to the workshop is: **"to what extent can views of information be adapted to render it suitable for ambient presentation?"** The complex interplay of factors involved in choosing adequately processed data for visualisation via ambient display will benefit from cross-collaboration between computer scientists, visual and interaction designers and psychologists.

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