Augmented Symbology:
A New Approach to Data Visualization

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Abstract

Augmented visual tools are necessary in order to push information through the diversified domain of computing systems, especially when cross-cultural, complex ideas are involved. One area of communication that is relatively new and yet is perhaps the oldest relevant method of communication is symbology. Combined with new sophisticated visualization techniques made possible by advances in computing power and display characteristics, simplification through the use of symbology can help optimize situational awareness, reducing the complexity of displays thereby enhancing a users' ability. With combinations of symbol sets, aggregation is possible and can be expressed in indicators providing both trending and predictive visuals. Indicators can display additional information by drilling down into the indicator interface, when enhanced with augmented symbol capability, and then further expanded into intelligent data and ultimately into its potentially multiple data sources.

Symbology is an image that can be transmitted by non-bandwidth intensive codes, which when compared to more bandwidth intensive text, vector graphic and bitmap graphic images, are significantly more efficient in both speed and bandwidth resource requirements. Symbology however, has to meet the overarching concern that it meets the requirement of accessible computing. Accessible computing applies to the individual user's capability to derive actionable information from the data supplied. With this in mind, symbology can be augmented with other attributes, such as subthreshold extreme gradual change (STEGC), a method of visual presentation that prevents visual spikes, as are evident in secondary task discrete notifiers and alerts (stop light, real-time, etc.), to convey more information. With augmented symbology, a given symbol can layer information prioritization and alerts. Prioritization changes as real-time data and information stream to the symbol and alert the operator. More information can be conveyed through changes in symbol characteristics such as color, size, and shape.

A paradigm shift in relation to the human machine interface is needed to allow for new developments. One development is the increase in computing power and the range of display screen enhancements. Another development is field usable neurophysiologic monitoring capability and augmented cognition. The implementation of neurophysiologic monitoring systems allows for closed loop communication between the human and computer with the attendant provision of tailored graphic display attributes. Where text was a major method of communication in the past, augmented symbology may be better suited for the display of notifiers and alerts in today's computing.

1 GENERAL INTRODUCTION

Augmented symbology can improve human cognitive performance by simplifying communication across both the human and system level. By effectively monitoring the user's neurophysiological data and delivering the data to the computer, this data can be interpreted by the computer and used to control the rate of information delivery back to the user. This higher fidelity data allows the computer to provide more finely tuned display attributes to the user. On the system level the transmission of information from user to user and sensor to user can be enhanced through the lower data flow requirements of symbology. Symbols/icons (symbols being similar to font sets including icons that are referenced by a tag and reside on the user machine) are easier to transmit (less bandwidth) and are more easily actionable, allowing more exact information to be conveyed in less time. Communication through augmented symbology can be from the remote sensor-to-user, user-to-user manager or computer system-to-user. Symbols conserve bandwidth and Centralized Processing Unit (CPU) load from the system point of view. Augmented symbols can help balance the user' workload and mitigate disruption, reducing return to task times by using subthreshold extreme gradual change (STEGC) as the method of augmentation. The neurophysiologic monitoring aspect of the symbiotic relationship that is comprised of augmented cognition and augmented symbology allows actionable information to be conveyed at the fastest rate possible without being disruptive to the primary task.

In this paper, we discuss the application of augmented symbology as a means of reducing cognitive workload in environments where large volumes of data are available. It is possible to expand on the displaying of augmented symbology by associating physiological measures of workload from the operator and use this as a method of directing the level of augmenting the symbology displayed. By monitoring user performance during tasks subthreshold extreme gradual change can decrease the workload on both the user and the system or allow for more information processing to be accomplished at the same workload balance with less error.

2 BENEFIT OF USING SYMBOLOGY OVER REDUCED BANDWIDTHS

2.1 Conserving Bandwidth

Bandwidth conservation and CPU load reduction is attainable using augmented symbology. There are several aspects to consider in providing an optimal solution.

2.1.1 Types of Data Transmission

First, the type of communication or data transmission, being either synchronous or asynchronous, where synchronous is a method of data transmission where there is a constant time interval between successive bits, characters, or events. No redundant information is used to identify the beginning and the end of the characters or events, and synchronous transfer is faster and more efficient than asynchronous transmission, which uses start and stop bits. Also, the timing is achieved by transmitting sync characters prior to data; usually synchronization can be achieved in two or three character transmission times. Whereas asynchronous transmission allows characters to be sent at irregular intervals by preceding each character with a start bit and following it with a stop bit. This also applies because the timing of the transmission is not determined by the timing of a previous character.

Second, device/platform/sensor generated and formats such as text or graphic impact the approach. To transmit a character code where the object (symbol, font or image) resides on the client/operator/user (hereinafter referred to as user) device typically requires significantly less bandwidth than sending the object itself. Custom or predefined symbols might look like these @#$ or🏡✈⮌☼✆✉.

2.1.2 Example of Reduced Bandwidth Using Symbology

The following example also applies to any symbol set that is predefined as in a typical font set. Using a paragraph similar to the one above as the sample text, we found the following results based on several experiments. In experiment number (1), we found that the text with the font embedded or included within the document to be 17.0 KB (17,410 bytes) in size. Conversely, in experiment number (2) we found the text where only the font code, not the font itself, was included in the document reduced the file size to only 7.60 KB (7,784 bytes). If you factor in error correction and redundancy, the overall savings is even greater.

This approach leads to reduction of bandwidth and CPU loads by well over 50 percent without factoring in the added system and cognitive value of augmenting the symbols to convey even more information with higher fidelity and less overhead.

2.1.3 Operational Requirement for Reduced Bandwidth

There are two main scenarios for bandwidth and CPU load conservation. First, you have the remote sensor/operator to user communications scenario such as from an Unmanned Air Vehicle (UAV) or other sensor platform, and human centric chain of command communications. Second, you have the Augmented Cognition loop that while helping to maintain a balanced workload for the user and increasing cognitive capability must also function within the parameters dictated by the system CPU, power source and other constraints. For both scenarios enhanced error reduction and correction in the transmission of data is desirable and when properly employed reduces bandwidth and CPU loads. For example, an augmented symbol provides a reduced load compared to text because the strings are shorter. Augmented symbol transmission, when compared to transmitted bitmapped graphics greatly reduces the load on the system. By using smaller transmissions more redundancy and other error reduction methods may be used in the same bandwidth parameters. This can also be used to mitigate the CPU load demands. Since symbols can reside on the user device just as font sets (like Arial or Times Roman) do, and with only the delta or change in the data being transmitted for augmentation, for example the shape, size, color and/or luminance of a symbol, more information can be conveyed with less burden on the system.

3 BENEFIT OF PRESENTING INFORMATION IN ICON FORMAT

With the current emphasis upon technological developments within human-computer interaction, the visual display upon which information is presented (and acted upon) is of vital importance. The human machine interface represents the fundamental point of interaction, the site of communicating knowledge between the system and the individual mental model of the user. It is, therefore, essential that information communicated through the interface is presented as effectively as possible. Poor interface design produces poor user performance and usability (such as navigation, search).

3.1 Icon Characteristics

An icon is composed of a cluster of characteristics, each of which can affect the ease with which it may be interpreted and acted upon. There are a number of icon properties that have been shown to contribute to icon usability, including concreteness, visual complexity, familiarity, semantic distance, meaningfulness and global and local features (see Rogers, 1986; Byrne, 1993; McDougall, Curry and de Bruijn, 1999; Navon, 1977). There are other cues that may act across the interface as a whole (rather than just being characteristics of individual icons), and which also determine usability are color, location, distinctiveness and similarity (see Carter and Cahill, 1979; Gentner and Medina, 1998; Richards, 2004). These measures are discussed briefly below:

3.1.1 Concreteness

This traditionally refers to how the icon depicts actual objects, places and people with which we are already familiar in the real world. In contrast, abstract icons do not pictorially represent objects, places or people, and tend to use more graphic features to convey information (e.g. arrows, shapes).

3.1.2 Visual Complexity

In the past, research has usually concentrated upon the complexity of the visual display (Galitz, 1993) rather than the visual complexity of the individual icons. Design guidelines tend to encourage the use of simple icons, to assist in the reduction of the user's mental workload. Indeed, very early findings suggested that simple icons enhanced user performance (Ryan & Schwartz, 1956). Easterby (1970) and Byrne (1993) also supported the use of simple icons and suggested that simplicity reduces ambiguity and decreases reaction times.

3.1.3 Familiarity

Familiarity is determined largely by the frequency with which icons are encountered. If we think of the icons and symbols that we tend to see on an everyday basis, then it is not surprising that we will tend to recognize these stimuli more readily than a less familiar one. It has also been found that the learning of icon sets can produce familiarity effects and can directly influence their usability (e.g. Brems & Whitten, 1987; Margano & Schneiderman, 1987).

3.1.4 Semantic Distance

Semantic distance represents the closeness of the mapping between an icon and its meaning. Early thoughts on this topic suggested that semantic distance was the degree to which the icon matched its function. Moyes & Jordan (1993) highlight the importance of semantic distance, and postulate that it is the degree of the relationship between icon and referent that determines its usability

3.1.5 Meaningfulness

The ability to understand and interpret an icon may be said to derive from the way the user seeks to find meaning from an icon. Meaningfulness is thought to be closely correlated with concreteness. Rogers (1986, 1989) examined this topic extensively and found that, when participants were asked to match written functions to icons, performance was poor for abstract icons, and worse when concrete analogies were employed to depict functions.

3.1.6 Other Icon Characteristics

Other icon characteristics may be classed as either pertaining to *Global* or *Local* features that make up the icon. For example, a global feature would correspond to the most salient aspect of the icon such as its outer shape or its dominant color. While a less salient icon characteristic could be a (local) feature of the icon that is less distinct.

In the past, researches have predominantly used color as a primary manipulation in relation to information conveyed via the visual display. The literature suggests that there is a compelling argument for using color in terms of presenting information. Indeed, the human visual system can recognize up to nine different colors, and can discriminate about twenty-four more (Feallock, Southard, Kobayashi, and Howell, 1966). Previous evidence has clearly indicated that color was processed at an early stage within information processing, and occurs automatically (Ellis and Chase, 1971). This automaticity in color processing suggested that color utilized a primitive indexing system (Pylyshyn, 1989), which allowed color to act as a redundant, or extra coding dimension, which enhanced processing in visual displays at little extra cost (Christ and Corso, 1976). This is also reflected in human performance when visual search times were reduced when color was introduced (Burkell and Pylyshyn, 1997). Remington, Johnston, Ruthruff, Gold, and Romera (2000) also found that the introduction of color in air traffic displays was found to reduce mental workload and increased detection rates for Air Traffic controllers.

3.2 Augmenting Icon Characteristics via Incremental Change

By manipulating a specific icon characteristic, it would be possible to allow the operator to discriminate between different icons based on the gradual change in perceptual salience. When an operator is confronted with a visually rich display of tracks then the ability to discern between them is greatly reduced.

3.2.1 Distinctiveness

In terms of icon research, the issue of distinctiveness is important because it can help reduce the time in which a target is located on the visual display (see Aspillaga, 1996; Fisher & Tanner, 1992). Eysenck (1978), and Hunt and Mitchell (1982), proposed a ‘distinctiveness hypothesis’ which stated that distinctive events or items were different in terms of their storage from other events or items. Thus, memory traces that were distinctive (in one way or another) would be more readily retrieved when compared with less memorable events or items because they tended to be viewed as being more similar. This understanding of distinctiveness was also applied to the effect of concreteness, whereby more concrete items were seen to stand out amongst less concrete, or abstract, items (Marschark et al, 1987). To summarize, it was thought that the more distinctive a stimulus appeared, then the more likely a qualitatively different memory trace was created, and that the distinctiveness and quality improved subsequent recall.

It is, therefore, extremely important to determine which particular features are responsible for causing such an effect of distinctiveness. McDougall, de Bruijn and Curry (2001) undertook a series of experiments that found that the distinctiveness of an icon (in relation to its component features) depended on the context, or icon array, in which the icons were presented. In their study, a mixture of physical characteristics (for example, the darkness or lightness of the icons, and their relative visual complexity) and semantic characteristics (for example, concreteness versus abstractness) served to create contrasts of distinctiveness in displays that were seen to facilitate visual search.

3.2.2 Examples of Augmenting Symbology

The ability to select an icon characteristic and then manipulate that feature in order to represent the changing status of that icon can be beneficial to an operator that is confronted with a lot of information at any given time. When presented with various tracks on a display the operator may find it difficult to discriminate between other symbols, especially when contextual cues determine the change in symbol status. For example, if a track was classed as 'unknown' and data was constantly being updated about that specific track then the degree of confidence in that track may be increased somewhat, but in some instances it may be best not to change the status of the symbol from it's original state. Therefore rather than changing a symbol from Sate A to State C, it may be better to represent the change in information associated with the symbol as State B. This would represent the process of active change to the symbol that would reflect the growing amount of data associated with that specific track. In Figure 1, color is used as the quantifiable symbol characteristic for State B incremental change.

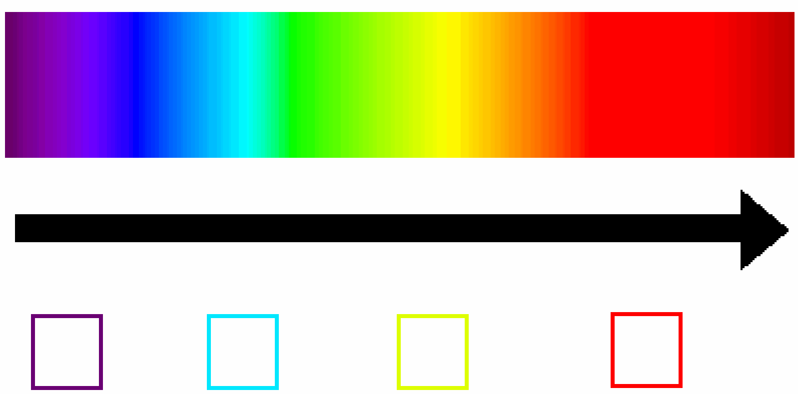

Figure 1. Direct mapping of color to symbol incremental change.

Another global feature that can be altered may be reflected in the manipulation of the outer shape of the symbology, this may be especially effective with recognized symbol sets. In Figure 2, the MIL STD 2525 is used as an example of an unknown track being upgraded to a known track (in this case classed as 'hostile'). If the operator is not directly involved in classifying the track as a certain type, but dependent on external players or data fusion then incremental change may present a viable option for introducing the state change without distracting the operator from their current task.

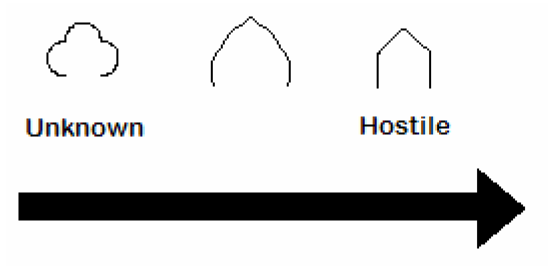

Figure 2. Direct mapping of global cue to symbol incremental change.

Of course, augmenting symbol status represents a significant change for the operator's situation awareness and it is imperative that the status change is reflective of the context within which such change occurs. If the operator has a high level of mental workload on a task then introducing augmented symbology presents a manner in which to enhance SA without alerting the individual to every change within the operating environment. However, contextual cues may also dictate that some instances would demand the operator's immediate awareness and attention grabbing techniques could be used to direct the operator in taking the corresponding action.

4 CONCLUSION

By introducing incremental changes to an existing symbology set, it is possible to assist the operator in gaining a better understanding of the information that is available. Using augmented cognition this information can be presented to the user in an optimal manner by defining the temporal and other aspects of delivery. As we have discussed, the nature of the augmented symbology may take a number of different forms that may draw upon the nature of icon characteristics and the cognitive properties that are associated with them. Rather than providing the operator with a visually distracting sudden shift in attentional resources, augmented symbology can reflect the dynamic state of information flow via the manipulation of icon properties. This may be a direct manipulation along the lines of a global feature, or a less salient transformation of a local feature within the icon.

It is important to remember that symbols are presented to the operator within a specific context, which may (or may not) be a dynamic and cognitively demanding environment where the operator is expected to monitor and/or respond to multiple tasks and events. An evaluation of the context is therefore crucial before deciding on the type of icon manipulation that may be implemented in order to assist the operator (and the effect this may have on subsequent training requirements) .

Adopting augmented symbology may be seen as enhancing operator awareness and mitigating operator workload, especially during times of mission intensiveness where high tempo can affect the operator's awareness and ability to respond to increasing amounts of information. By changing the representation of symbology on the interface, the distraction is informative and functional rather than an accidental consequence of limitations in graphics technology.

Augmented symbology objects convey aggregated multivariate data on a single object by conveying continuously updated information without the intrusion of visual disruption and noise that cause distraction. These are the only Situation Awareness (SA) tools that present the user with modifiable indicators and alarms with appropriate levels of disruption, which range from absolute non-disruption - through unobtrusive - to total disruption, in a seamless manner. If an alarm threshold is crossed, promoting the information to primary task status, a discrete change (such as flashing, audio and other multi-modal signals) may be used to prompt action.

The combined goals for the user and the computer system as related to augmented symbology include reduced error rates, workload balancing and the delivery of the maximum rate and amount of actionable and informative data without negatively impacting primary task assignments. Enhanced cognition, lowered bandwidth and CPU requirements will also allow for maximum collaboration and communication between platforms, operators, and the chain of command.

QinetiQ and TransLumen are currently working towards demonstrating the application of augmented symbology for a UAV Control Station and an Air Traffic Control workstation.

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