Emotion Scents – A Method of Representing User Emotions on GUI Widgets

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ABSTRACT

The world of desktop interfaces has been dominated for years by the concept of windows and standardized user interface (UI) components. Still, while supporting the interaction and information exchange between the users and the computer system, graphical user interface (GUI) widgets are rather one-sided, neglecting to capture the subjective facets of the user experience. In this paper, we propose a set of design guidelines for visualizing user emotions on standard GUI widgets (e.g., buttons, check boxes, etc.) in order to enrich the interface with a new dimension of subjective information by adding support for emotion awareness as well as post-task analysis and decision making. We highlight the use of an EEG headset for recording the various emotional states of the user while he/she is interacting with the widgets of the interface. We propose a visualization approach, called *emotion scents*, that allows users to view emotional reactions corresponding to different GUI widgets without influencing the layout or changing the positioning of these widgets. Our approach does not focus on highlighting the emotional experience during the interaction with an entire system, but on representing the emotional perceptions and reactions generated by the interaction with a particular UI component. Our research is motivated by enabling emotional self-awareness and subjectivity analysis through the proposed emotion-enhanced UI components for desktop interfaces. These assumptions are further supported by an evaluation of *emotion scents*.

Keywords: emotion visualization, GUI widgets, user interface toolkit, information scent

1. INTRODUCTION

Chances are that almost every person who can claim to have worked with a computer in recent years would immediately recognize the GUI of a desktop environment. But why is this the case? How come this paradigm of a pointer, of windows, of text fields and buttons has gained such deep roots in our minds? For sure, one of the reasons for this is the standardization of the desktop user interface. Today, almost regardless of what operating system or development environment a user employs, he has access to the standard UI components, all with roughly the same properties and functionality. But while this uniformity has its advantages, it also has its pitfalls; one of which is the difficulty of combining these standard components with a higher level of flexibility. At the same time, this rigidity of desktop GUIs means that they tend to remain solely means for interacting and communicating purely objective information and navigational commands between the user and the computer.

In recent years, researchers have considered enhancing the GUI with subjectivity and emotions[1–4] in order to enrich the user experience and support analysis, collaboration and awareness. However, most of the proposed solutions aimed at modifying the design of the common desktop by adding virtual (emotional or social) agents or by offering a highly dynamic interface capable of changing based on the user's emotions. In the following, we propose an approach aiming at enhancing the standard UI components with minimal emotional representations. Called *emotion scents*, these emotion-enhancements for common GUI widgets can encode and visualize the

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emotional states experienced by users while interacting with these widgets. As changes in system properties can have effects on the emotional states and reactions that the user experiences,[5] our hope is to capture user emotions in real-time through the use of brain-computer interfaces (BCIs) and offer the user a per-component overview of the experienced subjective states.

The motivation of this research consists in the fact that an additional level of emotional information included in the GUI can support the user's emotion awareness as well as, similarly to information scents,[6] improve post-task analysis and decision making. Furthermore, *emotion scents* has the potential of offering a viable alternative for emotional awareness of users in distributed communication and collaboration, similarly to emoticons.

In the following sections, we first offer a brief presentation of research relevant to our endeavor. We then continue by highlighting the design requirements that *emotion scents* need to satisfy, followed by information on the recording and storing of user emotion data as well as a description of the visual encoding and interactions that have been employed. Further, we highlight the functionality and possible advantages of *emotion scents* through a use case and an evaluation. We conclude with a discussion on current limitations and future developments of our research.

2. RELATED RESEARCH

GUI widgets—like buttons, lists and check boxes—have been present in desktop computing and window-based interfaces for decades now. More importantly, most of these widgets are standardized over an entire set of operating systems and programming languages, thus supporting aspects like portability and familiarity with the representation and interaction paradigm. However, these advantages come at the price of dedicated functionality and purely information and navigation driven interaction.

To overcome these aspects, many researchers have proposed extensions for the standard UI components that could enrich their informational and functional attributes. Baudisch et al.[7] present a graphical approach that briefly highlights those UI components that the user has recently interacted with in order to support improved user awareness without introducing delays or other interference in the interaction process. The topic of awareness is further discussed in the context of collaborative scenarios by Hill et al.,[8] where UI components are augmented with additional information about the interactions that other users executed on these widgets.

Besides awareness of interaction, another topic that is closely related to the design of the GUI is represented by the distribution of relevant information in highly complex systems or large structured datasets. In such cases, information scents or information cues[6] have the potential for guiding the user to the areas of the system that can offer more relevant information, support his analysis process and improve his decision making. An example in this sense is presented by Willett et al.,[9] where GUI widgets are enhanced with additional visual information cues in order to improve, among others, the information foraging process. Note that all the above mentioned approaches aim at offering new information without changing the layout or positioning of the various widgets, thus offering an enhancement and not necessarily an alternative.

The research highlighted up to this point focuses on general enhancements of the UI components and the GUI in general. But how can the GUI be altered in order to allow the incorporation of emotional information and even user affective states? Over the years, different approaches have been proposed to solve this issue. While some are simple enhancements like emoticons,[10] others focused on changing the desktop interface by incorporating human-like interfaces like emotional virtual agents,[1,2] adding affective widgets for emotional interaction and relief[3,4] or designing affective systems[11] that can perceive and react to the user's emotions in application and task-specific manner.

While emotions are increasingly reliably detectable through facial expression and gestures,[12] advances in BCI-based recognition of emotions have opened new possibilities for non-invasive and systematic detection, with applicability in evaluations,[13] affective modulation[14] and even measurements of mental and emotional states while working with visualizations.[15,16] Focusing on this direction of emotion-enhanced interfaces through BCI detected emotions, Liu et al.[17] employ a commercial mobile EEG headset to detect user emotions and reflect them in the GUI through a 3D virtual agent. Also, Inventado et al.[18] propose a system that supports the easy emotional annotation of user interaction.

More closely related to our work, Mehrabian[19] briefly suggests the representation of emotions in the interface, while Garcia et al.[20,21] analyzes the possibilities for supporting emotional awareness in collaborative systems. One of the solutions proposed by Garcia et al.,[20,21] the *emotion awareness graph*, is particularly relevant to our GUI emotion visualization, as it represents a custom UI component that consists of a histogram-like representation. The similarity is further supported by the encoded emotional facets, as both approaches use information related to the dimensions of pleasure/valence and arousal. But while the emotion awareness graph is a custom UI component used to suggest the emotions of other users in the interaction with the system, we aim at enhancing standardized GUI widgets with emotional representations that suggest past and current emotions of one or multiple users in the interaction with that particular widget. In other terms, the focus of our work is not on highlighting the emotional experience during the interaction with an entire system, but to concentrate on the emotional perceptions and reactions generated by the interaction with a particular UI component, the corresponding decision and the resulting highlighted information.

3. EMOTION SCENTS

The main concept behind *emotion scents* focuses on two aspects: enriching the GUI with user emotions and visualizing these emotions in correlation with the most probable event (or interface component) that generated or influenced them. Such a combination can, similarly to information scents,[6] guide the user towards new assumptions and discoveries that otherwise would not have been explored.

In terms of utility, *emotion scents* are aimed at offering support for real-time emotion awareness and post-task decision making and analysis. The visualized emotions can also have different sources: these can be the emotional states of the current user that also employs the scented interface, or the emotions of other users recorded in previous sessions. In the first case, the goal of the scents is to offer hints to the user about his emotions and behavior. This way, the user can have a better awareness of his emotions during the interaction with a UI component. Further, this increased awareness coupled with the correlation between the executed event and the recorded emotion can suggest links between emotional states and user decisions (e.g., selected one radio button or another) or reactions (e.g., clicking a button changes the amount or filtering of some information enabling the user to gather a novel insight).[5] In other instances, it might be useful to visualize a temporal distribution of user emotions for the same application or different versions of the same application, offering the user an overview of his past experiences and emotional states when interacting with the various components of the GUI.

But emotional self-awareness is not the only target for *emotion scents*. As suggested above, scented GUI widgets could also incorporate the emotions recorded in previous sessions by other users. In such cases, the experiences of a community of users can be detected and harvested, allowing following users to perceive the collective emotions and reactions of previous users that had to interact with the same UI component (i.e., make the same decisions, obtain the same data). For example, a user would need to manipulate a slider that is enhanced by the emotions of other users recorded in previous sessions. By means of emotion scents, the current user can now see that most people selected value towards the right end of the slider (90-100%), but at the same time, most of them experienced negative emotions while doing so. On the other hand, those that selected slider values around 20-30% experienced more pleasant emotional states. This information, correlated with the information about the application type and the concrete information that the slider is manipulating, should offer the current user the ability to make a more informed decision while interacting with the application.

The fact that in certain cases emotion scents should represent previously gathered emotional states means a decoupling of the emotion acquisition process from the visualization through scents. More precisely, in instances where the visualized emotion scents represent real-time emotional states the user need to be subjected to certain emotion detection methods (in our case BCI-based detection), while in cases when the user simply executes a post-task analysis or wants to use the collective emotional experiences of previous users for decision support, he/she can simply do so by accessing the emotional database containing the previously recorded emotion sessions.

In the following subsections, we will focus on detailing these two independent aspects of *emotion scents* (i.e., acquisition and visualization) as well as highlight the implementation details of our approach.

3.1 Design Guidelines

Before a GUI enhancement like *emotion scents* can be implemented, one has to consider the effects it can have on the already existing interfaces and the methods that can be employed in order to transmit the emotional information to the user. Thus, a set of design requirements should be established that consider particular aspects of the problem: the type of emotional information metrics, their visual encoding and their inclusion in the (potentially preexisting) interface. The following design guidelines have been derived through a set of preliminary studies and the personal experience of experts in the field of GUI design, user experience and human-computer interaction.

- The desktop GUI should suffer **minimal changes** in the process of adaptation. More precisely, if an application interface already exists, the *emotion scents* should be implemented on it without disturbing the layout of the window or changing the positions and sizes of the UI components.
- For the same type of GUI widgets or widgets that are similar in either functionality or representation, the *emotion scents* need to be located in the **same relative location** to the widget. This aids in making the scents more identifiable, while at the same time allowing users to easily establish the correspondence between scent and UI component.
- Together with the positioning, the size and shape of the scents should allow for **comparability** between the various instances in the interface. Thus, when inspecting emotion-enhanced UI components, the user should be able to differentiate, analyze and compare their content.
- The user should have the possibility to activate/deactivate the visualization as well as **customize the emotional representation** by changing data dimension priorities, employing temporal filtering or selecting a custom range of users for which to represent previous emotional states.
- Due to the restrictions in available GUI area and the necessity to maintain the initial aspect of the interface, *emotion scents* should offer a **cumulative overview** of the emotions experienced by the user or users for the corresponding UI components. As, for example, clicking a button can happen hundreds of times in a session, or even thousands of times in a set of user sessions, it seems more important to offer a high-level view of the experienced emotions than to include clearly browsable emotion information for every event instance.
- The *emotion scents* representations should be able to clearly and concisely **reflect the various dimensions of emotional attributes** (see Section 3.2) and their distribution over the user space. In other words, while it is not the goal of *emotion scents* to give the ability to inspect details about every pair of event-emotion instance in the GUI, they should still allow users to differentiate between various facets of the experienced emotions (e.g., pleasure and frustration versus excitement and calmness).
- Starting from the previous assessment, one should **avoid considering too many emotional dimensions** at the same time. As available space and the shape of the enhancements are vital to avoiding changes in the interface, finding the right amount of emotional and statistical information to be displayed is of key importance.

3.2 BCI and Emotion Data

The detection of user emotions is at the core of a visualization approach like *emotion scents*. A convenient and rather precise way of detecting emotional states is offered by modern mobile BCI devices capable of reading brain signals and interpreting them as emotions. For the *emotion scents*, the Emotiv EPOC* EEG headset has been employed together with the EPOC framework for easily recognizing the emotional states of the user. The headset is a lightweight wireless device that employs 14 electrodes in order to capture the electrical signals with brain activity data from the user. The device is further enabled by a framework that is capable of interpreting these signals as facial expressions, cognitive commands and emotional states (e.g., excitement, frustration). While the

*http://www.emotiv.com

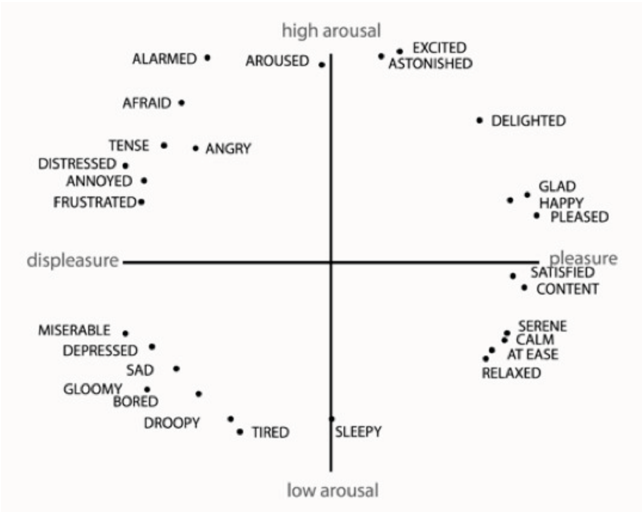

Figure 1. Russell's circumplex model of affect.[22, 23] The model focuses on the distribution of affect concepts based on a two dimensional encoding of the emotion space: valence and arousal.

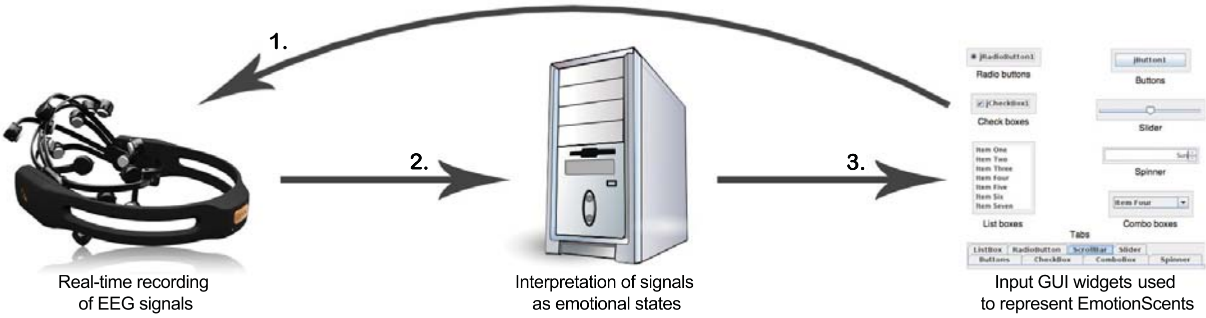

Figure 2. Emotion data acquisition and representation loop. Whenever the user interacts with an input GUI widget, the system records the EEG brain signals via the EPOC headset (1). The signals are then interpreted as emotional states and stored with a reference to the generating GUI widget (2). The emotions captured this way can be visualized on their corresponding widget via emotion scents, in real-time for emotion awareness or post-task for analysis and decision support (3).

framework itself is proprietary, previous research suggests that the detection of facial expressions and emotional states through the device framework is reasonably accurate.[13] However, the focus of this research is on the visual representation of emotions on desktop GUIs and less on the detection techniques. More precisely, *emotion scents* are designed to function with any technique capable of detecting user emotions in real-time (e.g., interpretation of facial expressions).

As the emotional continuum is extremely vast, we have focused on using an emotional variance space that would offer sufficient information, while at the same time maintaining a low complexity and dimensionality. One such emotional model is Russell's circumplex model of affect[22, 24] (Figure 1) that focuses on mapping a large set of emotions in a two dimensional space. The axes of the emotional space are represented in this case by the valence of the emotion (positive or negative) and the arousal (excited or calm). One advantage of this model is that the emotions supported by the EPOC framework are also present in the model. As the values outputted by the framework have been validated in an evaluation,[13] it is possible to use the reported emotions from the EPOC framework as direct input for Russel's model. At the same time, using a model like this one that maps a large set of common emotions to a 2D space allows us to decouple the visual representation of emotions on GUI elements from the medium that executes the actual detection. This means that *emotion scents* could be used together with other techniques for emotion detection, like real-time interpretation of facial expressions or voice analysis.

While other models are available,[25] Russell's model is widely accepted and used also in other affective systems in visualization.[23] Additionally, arousal has been found to be related to valence, as "arousal increases when valence extends towards extremely positive of negative values. But for low values of valence, regardless of the polarity, arousal is almost always low."[24] This interconnection has the potential to further reinforce the correct interpretations of the detected emotions.

Figure 2 highlights the acquisition and visualization loop of *emotion scents*. In a first step, a user is interacting with the GUI widgets of an application or system. In parallel, he is wearing the EPOC device that continuously reads his brain signals. If the user interacts with a particular UI component, e.g., a button, at that instance a signal is sent to read the current brain signals; these signals are then interpreted as emotions by the framework on the computer and the results are stored in a database. Depending on the selected mode, these emotions can be then represented in real-time on the UI component the user interacted with. Alternatively, users have the possibility of querying this database of collected emotions and show *emotion scents* for entire sets of emotional experiences.

Furthermore, there are different types of emotional triggers that have to be considered: "triggers that result in an action (physical response) or a reaction (emotional response)".[26] More precisely, the assumption we make is that both emotions that the user experiences slightly before and slightly after the interaction can be related to the action he exerted. This is due to the fact that users might experience affective states on action (e.g., because of a previous decision) or on reaction (e.g., due to new information that has been added to the system). As such, emotional states are recorded for a couple of seconds before, during and after the interaction. Later, the user that displays this information has the possibility to customize the *emotion scents* by selecting between the modes *emotion on action* and *emotion on reaction*.

User emotions are not the only information that are being stored in the emotion dataset of an application. Besides the valence and arousal values that are detected when a user interacts with a UI component, the system also stores the exact time when the interaction took place and the identifier of the UI component for subsequent correlation. Finally, in the case of UI components where the user can select multiple states (e.g., slider with multiple values, combo boxes, lists, etc.) an additional values is stored representing the selected value. On one hand, this is relevant because the emotion of the user should be coupled to the actual event and decision; on the other hand, as highlighted in the next subsection, GUI widgets can have separate *emotion scent* representations for each available component state.

3.3 Visual Encoding

Guided by the requirements from Section 3.1, the *emotion scents* (Figure 3) were designed to encode two emotional dimensions (valence and arousal) as well as for certain UI components the user selected values. Scents are visualized as thin, horizontal, colored bars, composed of horizontal segments of equal length x, see Figure 4. The overall width n of the bar is constant over all the *emotion scents* in an application in order to allow better comparability. As such, the size of a segment x is computed by querying the database for the number of distinct emotional readings available for the current control. For example, if an emotion bar has the width of $n = 60$ and there are ten distinct emotional readings in the dataset for the current control and timeframe, the width of a segment will be set to $x = 6$. This also means that the higher the number of available emotion samples for a scent, the smoother seems the transition between the colors as segments can take widths of one pixel or less (Figure 3c).

As each bar segment represents an actual emotional reading, the encoding of the nuance of the emotion (positive or negative) or the overall excitement is done through colors. But a particular difference between the two emotional channels of valence and arousal consists in the fact that while valence is perceived to be bi-polar, arousal on it's calm-excited scale seems to be a more unified characteristic, as suggested by our initial discussions with GUI designers and HCI experts. Thus, we encoded the two axes as following: red for negative valence; green for positive valence; and blue for excitement. Similar settings have been used in emotion-related

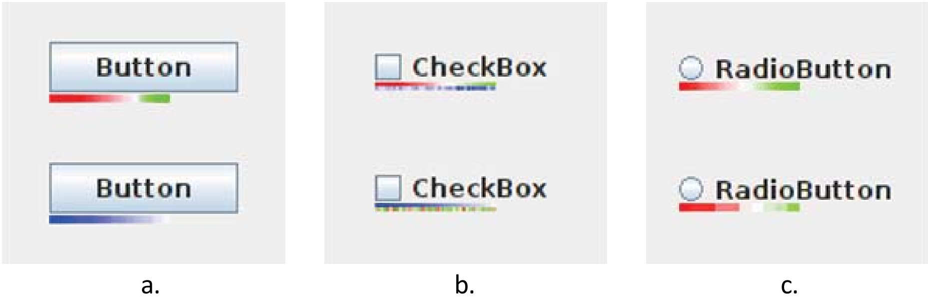

Figure 3. Different representation of emotion scents: (a) Two buttons with their corresponding emotion scent representations for valence (top) and arousal (bottom). (b) Two check boxes with the valence and arousal emotion scents displayed in parallel. Depending on the sort priority (i.e., based on valence intensity (top) or arousal intensity (bottom)), the position of the segments in the second dimension are established by their correspondence to the sorted ones. (c) Two radio buttons presenting their emotion scents encoding valence. The top bar includes over 50 separate EEG readings, thus resulting in over 50 segments that—depending on the interface—can have a width of under one pixel, resulting in a smooth transition between colors and suggesting a high number of emotional readings for that particular widget. For the bottom bar the segments are more visible, as they encode only 10 EEG readings, resulting in wider segments (i.e., larger x values).

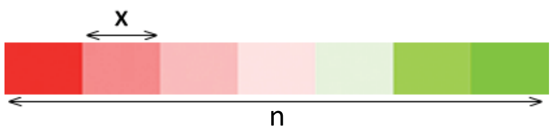

Figure 4. The emotion scent representation. The length n of the bar is predefined. Each colored segment encodes an emotional state measured during the user's interaction with the current GUI widget. Green segments represent positive emotions, while red ones encode negative emotions. In this particular representation the segments are sorted based on the valence of the emotions in order to allow a better recognition of the emotional distribution. Note that the length of one segment x is inversely proportional to the number of emotional states stored for the current widget ($x = n/n_{readings}$).

applications,[18,27] as using the trichromat characteristic of the human eye should improve the visibility of the colored areas—a vital aspect for visualizations with limited display space.

Further, scents are positioned immediately over the lower-left corner of the corresponding UI component (Figure 3). However, the user has the possibility of adjusting both the size and positioning of the scent to fit the layout and needs of the application. This is achieved through a context menu that the user can open by right-clicking on any *emotion scent* in the application.

Changes executed in the context menu of an *emotion scent* can have both local (only this scent instance) and global effects (all emotion scents in the application). One important attribute that can be modified is the length of the scents, cf. Figure 5. The bars are set by default to equal lengths, supporting the comparison of ratios between positive, negative and aroused states. Still, if the user is interested in focusing on the ratio of existing emotional readings for each UI component, he/she can switch to a view that computes a constant segment width x and variable bar with n.

Moreover, the user has the ability to choose between representing either one emotional dimension (Figure 3a) or both valence and arousal in the same bar (Figure 3b). In both situations, the context menu allows emotion segments to be sorted based on different criteria: based on the intensity of the emotional channel (Figure 3a) or on the temporal order of detection (Figure 8). A special case appears when both valence and arousal are displayed simultaneously. As the two emotional dimensions recorded for a particular user are closely coupled, one should consider this connection when representing valence and arousal next to each other. Therefore, in settings where both axes are visualized, the user has the possibility to sort only based on one emotional intensity, while the ordering of the second dimension results from the correlations with the first. Figure 3b shows two check

Figure 5. Emotion scents representation applied for a combo box control: (left) normalized representation where the width of each bar is equal to the maximum width n, independently of the number of emotional readings available for each combo box item (i.e., n is constant); such a representation enables a better ratio comparison. (Right) relative representation where each emotion segment x has a constant width computed as $x = n/max(n^i_{readings})$. This representation supports the comparison of the emotional states quantified by the ratio of users that interacted with the corresponding items.

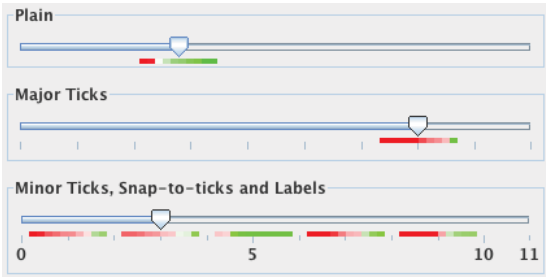

Figure 6. Emotion scents represented for slider widgets. The particularity of these widgets consists in the possibility of having multiple different values for a single GUI item. The top two sliders support the representation of emotion scents by displaying a single colored bar that follows the slider head and encodes the cumulated emotions for the corresponding slider values. In cases like the bottom slider, where the distance between the possible slider head positions is large enough to accommodate the width of emotion scents, multiple bars can be displayed at the same time.

boxes enhanced with emotion scents. In the top scent, for example, the valence bar is sorted by the intensity of the emotion (starting from very negative to very positive). The arousal segments from the blue bar below are sorted simply by establishing the correspondence to the same emotional instance/reading. This approach can have certain advantages, as the *emotion scent* for the top check box shows: while there seems to be a slightly higher prevalence of negative emotions, the users that experienced positive feelings while interacting with the widget have also experienced higher levels of excitement.

As mentioned in the beginning of this section, for some UI components the user has the possibility to select a value. One such component that we considered is the slider (Figure 6). In order to maintain consistency and avoid visual overload, for sliders only one single emotion scent is represented that follows the position of the slider head and indicates the emotional states of the users that made the same selection. In cases with sliders that allow selecting a high number of values (40+), the scent can be customized to consider a window region around the current selection of the slider head and display all the emotions for users that selected values inside this window. On the other hand, is a slider has very few selectable values (Figure 6-bottom), *emotion scents* can be displayed for the entire length of the slider, encoding the emotional states of the users that selected values in the corresponding selection windows.

In terms of implementation, the *emotion scents* have been implemented in Java using the Swing GUI widget toolkit. The representation was obtained by implementing an alternative Look&Feel (or theme) that incorporates these colored scents. After the *emotion scent* theme is included in an application, the user has the possibility of enabling this interface by the simple click of a menu button. In the current version, only input or navigational

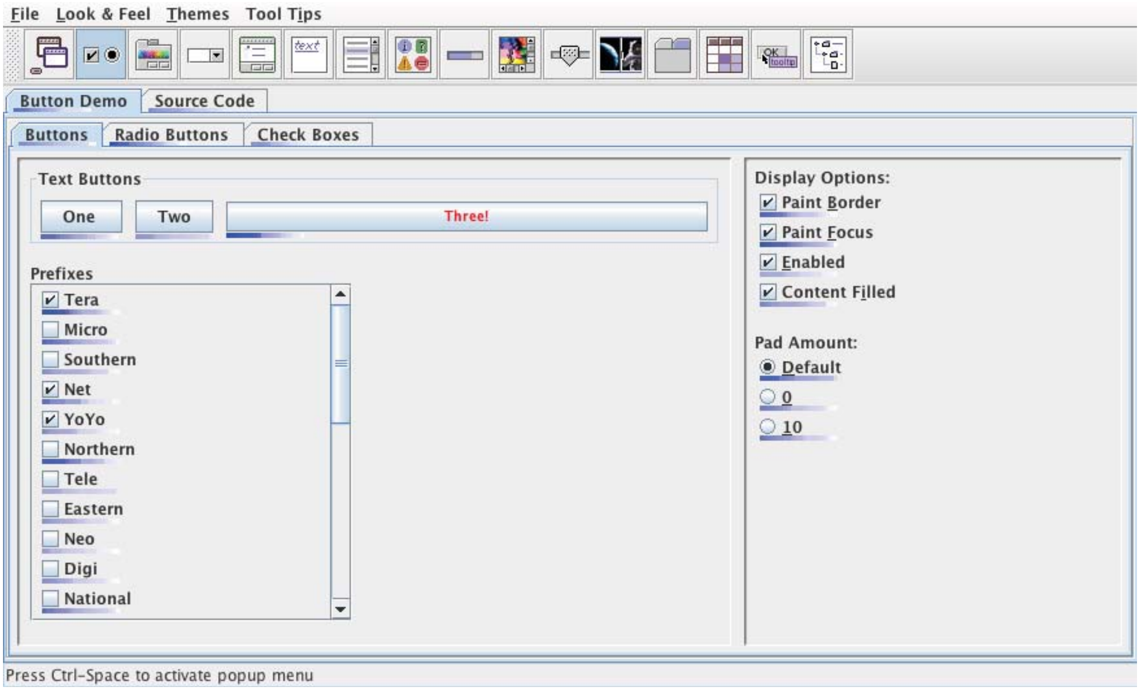

Figure 7. Emotion scents encoding the user arousal during the interaction with the SwingSet demo interface‡. For certain GUI widgets, one can detect a greater incidence of higher arousal values.

widgets have been enhanced with emotion bars (Figure 7): buttons, combo boxes, check boxes, radio buttons, tabs, lists, tree views, sliders, and spinners. This is partly due to the fact that the user does not need to interact with all GUI widgets (e.g., labels or icons), which in turn means that in some cases there is no possibility to establish a correlation between an event and an emotion.

4. USE CASE

Figure 8 highlights a use case for the *emotion scents* visualization: A programmer called John starts a coding session in his Java development environment. During a two hour period in which he is wearing a mobile BCI and/or is recorded by a facial expression system, he extends an already existing code by making changes in multiple code files, and compiles the application several times. At the end of his session, he goes to the *view* section in the menu bar and selects another Look&Feel (i.e., theme) that displays the emotion cues inside the application GUI (Figure 8). By right-clicking on any of the *emotion scents*, he can filter the time period for which the emotion data is considered and customize their representation through a context menu. After selecting the data for the last two hours, he notices based on the valence representation that he accessed two files very often and that in most cases his experiences when selecting these files were positive. At the same time, John observes that the debug button was executed quite often and that especially in the second half of the session, debugging operations were becoming frustrating to him. A similar pattern is valid for the execution button. He thinks back and remembers that he had to handle a set of errors that appeared due to his initial design. John switches to the arousal visualization and notices the same pattern: higher excitement value for the second half of his session in the case of the debug and run buttons. He now realizes that the errors he was trying to solve put him under more stress than he initially realized. Thus, he decides that in the future he should invest a bit more time in the design process to avoid unnecessary stress and obtain a better productivity.

A similar example, but where the emotion information of multiple users is visualized, can be given with the following case. A company is creating a complex software solution. The developers and designers want to find out

‡http://java.sun.com/products/plugin/1.4/demos/plugin/jfc/SwingSet2/SwingSet2.html

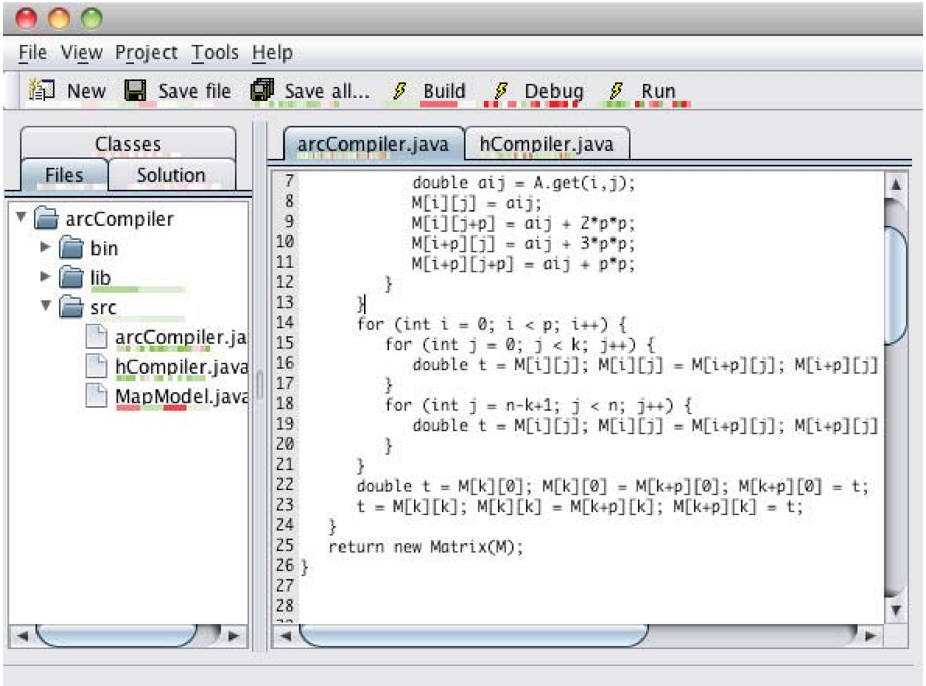

Figure 8. Emotion scents displayed on the interface of a simple Java IDE. The colored bars represent the valence of the emotion and the emotional states are in temporal order. The multiple red segments on the debug button could suggest that the programmer experienced difficulties in his coding process, especially in the second part of his coding session.

which modules and corresponding interfaces of the application induce frustration to the users. For this purpose, during the testing stage they collect—with the consent of the users—anonymous emotion data correlated with the various GUI widgets present in all the windows of the application. With this emotion database, they can now inspect what events produced intense emotions on user-side and analyze how these states might be influenced by user decisions, system interaction or displayed information.

Certainly, in both examples the *emotion scents* visualization work only under the assumption that a method has been employed in order to record the emotional states of the user. While emotion detection based on facial expressions or speech is also a viable alternative, we focus on mobile BCI technologies that present a great potential. Even if current BCI approaches can be still cumbersome by requiring wet sensors and exact positioning on the scalp, *emotion scents* is aimed partly at future generations of these mobile headsets, where using a BCI could already become as simple as putting on a hat.

5. EVALUATION

An evaluation was devised in order to capture some of the advantages that an emotion-enhanced interface can offer. For this purpose, a tool was implemented that visualizes the U.S. foreign aid over the last decades, see Figure 9. The visualization was implemented in Java, while the interface was coded in the Swing widget toolkit; the represented data was obtained from the ManyEyes[§] website. Additionally, the standard GUI widgets have been extended to implement *emotion scents*.

The evaluation included a group of 24 participants (9 women, 15 men) with ages between 19-55 years and an average of 28.25 years. The group consisted of people with at least intermediate experience with computers and mostly with previous experience in working with visualizations. After a brief introduction to the visualization tool, the group was randomly subdivided in two equal sets of 12 participants. The members of both groups

[§]http://www-958.ibm.com/software/data/cognos/manyeyes/

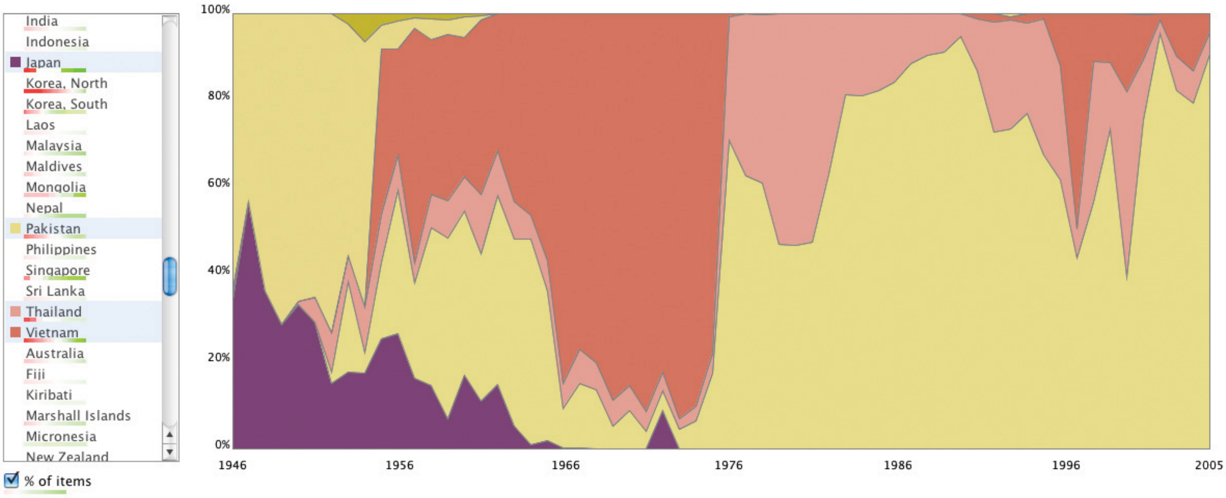

Figure 9. Visualization application for a dataset obtained from the ManyEyes website showing the distribution of U.S. Foreign Aid in the recent decades. The GUI widgets have been enhanced with emotion scents to give another dimension of information to the navigation and analysis process of the data.

received the task of gathering insights from the proposed visualization. More specifically, they were asked to inspect if they could detect any patterns between armed conflicts that the U.S. were involved in over a period of 50 years and the distribution of foreign aids. One of the simplest possible connection that we were looking for was the detection of an increased foreign aid to the nations with which the U.S. has been previously involved in a conflict.

The members of the first group were asked to undertake the task first. Further, these participants were equipped with an EEG headset in order to record their emotional states during their interaction with the interface. However, none of them did benefit from having any *emotion scents* displayed on the interface. Also, each participant was asked to signal whenever he/she reached an insight. This approach would, on the one hand, allow the recording of the emotional reaction while interacting with the visualization and the data, and on the other hand it would offer a set of time intervals that each participant required to detect the above-mentioned pattern. After the task, each member of the first group was additionally asked to fill in a short questionnaire focused on their emotional reactions. Most users reported having no emotional reactions while interacting with the visualization. At the same time, four participants mentioned being surprised at some of the findings they made. However, the measurements from the EEG device suggested additional events with emotional aspects. Finally, six participants suggested that the EEG headset was uncomfortable to wear, while four expressed concerns about possible privacy issues (”You mean someone else can now see what I'm feeling?”).

Once the members of the first group finished the task and the questionnaire, the participants from the second group were given the same task, this time with the *emotion scents* constructed based on previous user experiences displayed on the GUI of the visualization. Again, the time interval was recorded that each group member required in order to detect the pattern. Note that while the *emotion scents* can offer information about the views or GUI widgets that were more often visited, this is only a secondary purpose of the representation. Compared to the work of Willett et al.,[9] *emotion scents* focus on offering information about the emotional states the users experienced during or right around the period of their interaction with a certain widget. If this information is not available or not relevant, the information about the frequency of visit is also not included (i.e., a white emotion bar does not allow the detection of gradients).

After analyzing the results from the evaluation, we found that the first group that did not have the aid from the *emotion scents* took on average 310s to find the pattern ($AVG_1 = 310$, $SD_1 = 68$). At the same time, the second group managed to gather the same insights in 248s ($AVG_2 = 248$, $SD_2 = 44$). These values suggest that representing the emotions that users had during their interaction can offer new users orientational cues about application features that were emotionally remarkable to their predecessors.

To briefly inspect the potential for self-awareness, the participants from the second group were also presented the simple Java compiler from Figure 8. After a similar scenario to the one highlighted in Section 4 was presented to them, they were asked the utility of such a representation for self-awareness. In this case the results were more evenly distributed, as six participants could imagine having *emotion scents* included in various interfaces for enabling emotional self-awareness, while the others were more skeptical.

Finally, the members of the second group were asked to fill in a questionnaire. This time, the questions were focused in the representation of *emotion scents* and their utility. All participants considered that the color coding is useful, while five participants suggested that the size of the emotion bars is rather small not allowing them to see details. Still, after a informal inquiry, these participants agreed that they still had the possibility of detecting the different colors and their ratio in the bar.

6. DISCUSSION

Our findings from the evaluation of *emotion scents* suggest that this integrated, in-place visualization of user emotions can enhance window-based interfaces and offer additional information about the subjective impressions and experiences of users while interacting with the GUI. Also, the supplied emotional information incorporates two facets of the emotional space, namely valence and arousal, offering an overview of the emotional reactions of one or multiple users in previous or the current session. While inspecting the design guidelines, we can notice that the enumerated requirements have all been considered in the current representation. In terms of integration, the GUI has suffered only minimal changes, and the location of the scents allows for good comparability. More importantly, the visualization encodes emotional information in a way that allows the detection of emotional trends on each UI component but without overloading the interface or the emotion bars. Additionally, the low resolution offered by a representation within a small display area is also intended to reflect elements like: the complexity of human emotions, a limited precision of the acquisition of emotions, and a certain level of uncertainly in the correlation of user emotions and events (i.e., in some cases, the emotional states recorded at the moment when an event takes place might be generated by other environmental or user-internal aspects).

Furthermore, it seems important to highlight that one should not directly interpret emotion scents as indicatives of right and wrong. Scents represent basically an additional level of information that is being collected and reflected, and that capture the user's subjective views. Having negative emotions in a certain case or when manipulating a certain UI component might in some cases even be desired, e.g., positive feelings after saving an image one has just modified in a photo editor, or negative feelings after exiting an application the user really enjoys.

Another vital aspect of recording and visualizing emotions in the interface is privacy. As one would expect, people are in general concerned about having their emotions recorded, distributed, analyzed. While some of these issues can be solved by collecting only anonymous data and, of course, with the consent of the user, there are other important aspects that need to be addressed. Currently, the implemented *emotion scents* system stores the emotional readings in a database local to the machine on which the toolkit was installed. Therefore, the security and distribution of emotion data is entirely under the user's control. At the same time, in order to support data transfer and analysis, users have the possibility of importing emotion information from external sources and represent them on a system where *emotion scents* is running.

7. CONCLUSION AND FUTURE WORK

In this paper, we have introduced a solution for visualization of user emotions during his interaction with a specific UI component. We proposed a set of design requirements that would not require a complete redesign of the standard desktop interface paradigm, and highlighted our solution entitled *emotion scents*. We suggested one approach for obtaining information about user emotions through a mobile, wireless BCI headset and showed how *emotion scents* are integrated in the GUI. A set of examples and an evaluation suggest that *emotion scents* can be used successfully in desktop environments for emotional awareness and decision support, as well as for analysis of user emotions over the various GUI widgets of a system, a set of users, and/or a particular timeframe.

Aim of our future work is to improve the management of the emotion database, as well as the flexibility of the privacy settings. To this end we plan to implement a privacy management system that allows users to view and select emotion frames/intervals or emotions related to a UI component and decide if they would like to make these public or private. These features would than need further refinements to clearly establish the different sublevels of privacy: Can public emotions be visualized on the same computer if another user starts the application? Or can public emotions be transmitted to a server and used by the developer of the application to improve the user experience and get feedback on how the application is perceived?

The current implementation only focuses on navigational and input GUI widgets as these are the only ones where the user needs to focus on or interact with the widget. For output widgets, like UI labels, the user only perceives the information displayed without him needing to execute mouse clicks or manipulate the component in any way. As a result, it is difficult to establish a correlation between the GUI widget and the generated emotion. Still, the incorporation of methods like eye-tracking should support a better detection of the user's focus point, thus offering a stronger correlation between the interface and the user experience, while at the same time removing some of the emotional noise generated by internal (e.g., the user daydreams and looks away from the screen) or external (e.g., someone approaches the user and starts a discussion) factors.

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REFERENCES

[1] Masuch, M., Hartman, K., and Schuster, G., "Emotional agents for interactive environments," in [*Proceedings of the Fourth International Conference on Creating, Connecting and Collaborating through Computing*], *C5 '06*, 96–102, IEEE Computer Society, Washington, DC, USA (2006).

[2] Lisetti, C. L. and Nasoz, F., "Maui: a multimodal affective user interface," in [*Proceedings of the tenth ACM international conference on Multimedia*], *MULTIMEDIA '02*, 161–170, ACM, New York, NY, USA (2002).

[3] Hole, L. and Millard, N., "Affective widgets: supporting the daily work experiences of contact centre advisors," in [*Proceedings of the Nordichi User Experience Workshop 2006*], (2006).

[4] Millard, N. and Hole, L., "In the moodie: Using 'affective widgets' to help contact centre advisors fight stress.," in [*Affect and Emotion in Human-Computer Interaction*], Peter, C. and Beale, R., eds., *Lecture Notes in Computer Science* **4868**, 186–193, Springer (2008).

[5] Thuring, M. and Mahlke, S., "Usability, aesthetics and emotions in human-technology interaction," *International Journal of Psychology* **42**(4), 253–264 (2007).

[6] Chawla, S. and Bedi, P., "Improving information retrieval precision by finding related queries with similar information need using information scent," in [*Proceedings of the 2008 First International Conference on Emerging Trends in Engineering and Technology*], *ICETET '08*, 486–491, IEEE Computer Society, Washington, DC, USA (2008).

[7] Baudisch, P., Tan, D. S., Collomb, M., Robbins, D. C., Hinckley, K., Agrawala, M., Zhao, S., and Ramos, G., "Phosphor: explaining transitions in the user interface using afterglow effects.," in [*UIST*], 169–178, ACM (2006).

[8] Hill, J. and Gutwin, C., "Awareness support in a groupware widget toolkit," in [*Proceedings of the 2003 international ACM SIGGROUP conference on Supporting group work*], *GROUP '03*, 258–267, ACM, New York, NY, USA (2003).

[9] Willett, W., Heer, J., and Agrawala, M., "Scented widgets: Improving navigation cues with embedded visualizations.," *IEEE Trans. Vis. Comput. Graph.* **13**(6), 1129–1136 (2007).

[10] Huang, A. H., Yen, D. C., and Zhang, X., "Exploring the potential effects of emoticons," *Inf. Manage.* **45**, 466–473 (Nov. 2008).

[11] Akgun, M., Akilli, G. K., and Cagiltay, K., "Bringing affect to human computer interaction," in [*Affective Computing and Interaction*], 308–324 (2010).

[12] Castellano, G., Kessous, L., and Caridakis, G., "Affect and emotion in human-computer interaction," ch. Emotion Recognition through Multiple Modalities: Face, Body Gesture, Speech, 92–103, Springer-Verlag, Berlin, Heidelberg (2008).

[13] Cernea, D., Olech, P.-S., Ebert, A., and Kerren, A., "Measuring subjectivity - supporting evaluations with the emotiv epoc neuroheadset.," *Journal for Artificial Intelligence (KI)* **26**(2), 177–182 (2012).

[14] Garcia Molina, G., Tsoneva, T., and Nijholt, A., "Emotional brain-computer interfaces," in [*ACII 2009: Affective Computing & Intelligent Interaction*], Cohn, J., Nijholt, A., and Pantic, M., eds., 138–146, IEEE Computer Society Press, Los Alamitos (September 2009).

[15] Cernea, D., Olech, P.-S., Ebert, A., and Kerren, A., "Controlling in-vehicle systems with a commercial eeg headset: Performance and cognitive load," *OpenAccess Series in Informatics (OASIcs)* (2012).

[16] Anderson, E. W., Potter, K. C., Matzen, L. E., Shepherd, J. F., Preston, G., and Silva, C. T., "A user study of visualization effectiveness using eeg and cognitive load.," 791–800, Proceedings of Comput. Graph. Forum. 2011 (2011).

[17] Liu, Y., Sourina, O., and Nguyen, M. K., "Real-time eeg-based human emotion recognition and visualization," in [*Proceedings of the 2010 International Conference on Cyberworlds*], *CW '10*, 262–269, IEEE Computer Society, Washington, DC, USA (2010).

[18] Inventado, P. S., Legaspi, R. S., Numao, M., and Suarez, M., "Observatory: A tool for recording, annotating and reviewing emotion-related data.," in [*KSE*], 261–265, IEEE (2011).

[19] Mehrabian, A., "Framework for a comprehensive description and measurement of emotional states.," *Genetic, social, and general psychology monographs* **121**, 339–361 (Aug. 1995).

[20] García, O., Favela, J., and Machorro, R., "Emotional awareness in collaborative systems," in [*Proceedings of the String Processing and Information Retrieval Symposium & International Workshop on Groupware*], *SPIRE '99*, 296–, IEEE Computer Society, Washington, DC, USA (1999).

[21] García, O., Favela, J., Licea, G., and Machorro, R., "Extending a collaborative architecture to support emotional awareness," in [*Emotion Based Agent Architectures (ebaa99*], 46–52 (1999).

[22] Russell, J. A., "A circumplex model of affect," *Journal of Personality and Social Psychology* **39**, 1161–1178 (1980).

[23] Stahl, A., Sundström, P., and Höök, K., "A foundation for emotional expressivity," in [*Proceedings of DUX '05 conference on Designing for User eXperience*], (2005).

[24] Gokcay, D., "Emotional axes: Psychology, psychophysiology and neuroanatomical correlates," in [*Affective Computing and Interaction: Psychological, Cognitive and Neuroscientific Perspectives, Information Science Publishing, IGI Global*], 56–73 (2010).

[25] Dryer, C. D., "Dominance and valence: A two-factor model for emotion in hci," in [*Emotional and Intelligent: The Tangled Knot of Cognition.*], *TR FS-98-03*, 75–81, AAAI Press, Menlo Park, CA, USA (1998).

[26] El-Nasr, M. S., Morie, J., and Drachen, A., "A scientific look at the design of aesthetically and emotionally engaging interactive entertainment experiences," in [*Affective Computing and Interaction: Psychological, Cognitive and Neuroscientific Perspectives, Information Science Publishing, IGI Global*], 281–307 (2010).

[27] Ohene-Djan, J., Sammon, A., and Shipsey, R., "Colour spectrum's of opinion: An information visualisation interface for representing degrees of emotion in real time," in [*Proceedings of the conference on Information Visualization*], *IV '06*, 80–88, IEEE Computer Society, Washington, DC, USA (2006).