Interfacing Information in Affective User Studies

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Abstract
In affective user studies, visual interfacing of data has received little attention. Such interfaces can support qualitative understanding, conveying insight about static and temporally evolving information; static information is exemplified by demographic data, while temporally evolving information is exemplified by physiological signals. In this paper we present *User Portrait* - an abstraction and visualization method that condenses the essence of a study's data in a single figure. It is an inverted pyramid design, where the information abstraction is communicated on the top view, while the details are displayed on a need-to-know basis. The method has been applied to a longitudinal study of student affect vs. exam performance, effectively visualizing its voluminous data set.

Author Keywords
Data Abstraction, Visualization, Affective Studies, Inverted Pyramid Design, Exam Studies

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: User Interfaces; D.2.11 [Software Architectures]: Data abstraction; H.2.8 [Database Applications]: Data mining.

Introduction

To make sense of the big data produced in longitudinal studies of user affect, appropriate data analytics tools coupled with effective visualization are indispensable. A typical data set in such studies comprises biographic, performance, physiological, and psychometric information. For instance, studying pilots' performances while interacting with airplane interfaces in critical moments may require to incorporate their trend anxiety (trait psychometric) and their physiological responses (dynamic information).

To the best of our knowledge no visualization method specific to affective studies has been reported in the literature. In a more generic context, Oefinger and Mark developed multi-resolution interactive web-based plots for cardiac signals [2]. Uckelmann *et al.* proposed an architectural concept for the *Internet of Things*, which enables everyone to access and contribute rich information about things and locations [4]. Becker *et al.* extended this concept to *Internet of Everything* by incorporating people's opinions to the collected data [1]. Their approach is primarily focused on environmental sensors.

The affective sciences community is interdisciplinary. Hence, one particular challenge in affective studies is intuitive visualization of certain variables (e.g., physiological signals), which otherwise would require technical expertise to comprehend. Another challenge is reconciling the diversity of data, which ranges from scalar values (demographic) to multi-dimensional signals (physiological). Yet another challenge is the longitudinal nature of these studies that calls for economy of design. Finally, the visualization interface should be easily accessible to the affective studies community, which is geographically dispersed.

Our research aims to support studies of user affect by providing an insightful data representation. In this context, we developed a visualization method that associates the subject's affective state with her/his performance, weaving in a comprehensive, yet compact portrait (aka *User Portrait*). The data handled by the User Portrait fall under two categories: static and dynamic. Static data include parameters that do not change or do not change frequently, such as the user's biographic information and her/his psychological traits (typical covariates). Dynamic data vary with time and are usually multi-dimensional, such as the user's physiological variables captured via wearable or imaging sensors.

The remainder of the paper details the User Portrait visualization method, using a student exam study as an illustrative example.

Student Exam Study

We undertook a longitudinal study to investigate the association between affective state and performance in student exams. Specifically, we monitored 23 students (10M/13F) in the Kinesiology class of the University of Houston during the 2012-13 academic year. The monitoring took place during the 5 exams of this class and was performed per an approved protocol from the university's Institutional Review Board (IRB).

The biographic information includes the student's sex and age. The psychometric information consists of the student's Trait Anxiety Inventory (TAI) score, and her/his State Anxiety Inventory (SAI) scores [3] before and after each exam.

The physiological signals include adrenergic (breathing/pulsation) and cholinergic indicators (palm perspiration) of sympathetic arousal. A wearable thoracic

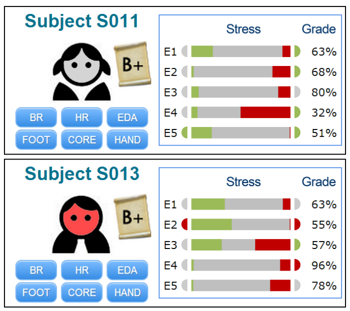

Figure 1: User Portrait of two students who participated in the exam study.

belt (the BioHarness sensor from Zephyr Technology) captured the breathing and pulse signals. An open glove electrodermal sensor (Q sensor from Affectiva) captured the palm perspiration signal from the student's non-dominant hand.

The performance measures are the student's percentile grade for each exam and her/his Grade Point Average (GPA).

Data Abstraction and Visual Interface

Visualizing Biographic Information

Gender and age are important covariates in an affective study. We visualize the gender information via a male or female icon. The same icons also communicate the age group the subject belongs to. In the student exam study all subjects are young adults ($\mu \pm \sigma = 23.0 \pm 5.6$ years), and for this reason the gender icons have a youthful appearance. This biographic information is situated on the left half of the User Portrait (Figure 1), giving the look and feel of an ID card.

Visualizing Performance Information

The exam grades represent snapshots of the student's performance that need to be associated with her/his affective states during the corresponding exam periods. This dual performance vs. affective state information of dynamic nature is situated on the right half of the User Portrait. It is organized row-wise per exam (E1 to E5), with the data in the rightmost column corresponding to the grades in percentiles (Figure 1).

The exam grades should be interpreted in the context of the student's overall standing, as expressed by her/his GPA. This more static piece of performance information is located on the left side of the User Portrait, clustered with the other static data (Figure 1).

Visualizing Affective Information

Breathing (BR), pulsation (HR), and palm perspiration (EDA) during the exams are temporal signals, indicative of the subject's evolving affective state. We relegate them to the hidden view of the User Portrait interface, which can be accessed via buttons below the biographical information (Figure 1).

Figure 2 gives a glimpse of the User Portrait's hidden view, by illustrating the evolving pulsation data from a student's E1 session. The plot on the right side of the figure shows the pulsation signal. The plot on the left side shows the normal distribution model that has been generated from the student's pulse responses in all five exams (baseline). This baseline model is used to index the student's instantaneous affective state according to her/his incoming pulse sign. Specifically, pulsation values less than -1σ of the baseline's mean denote a relaxed state, while pulsation values higher than $+1\sigma$ of the baseline's mean denote an aroused state. Pulsation values in the middle area of the baseline's distribution denote a normal state of affect (Figure 3).

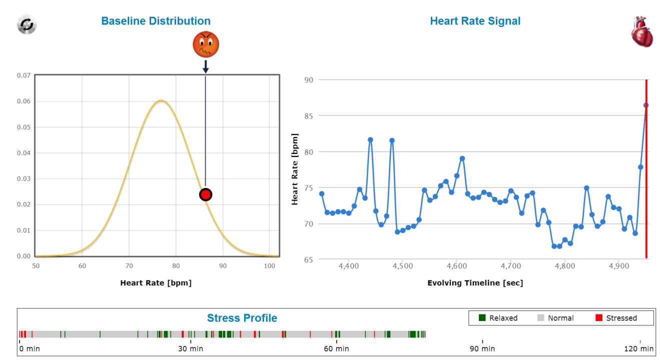

Figure 2: Dynamic display and affective indexing of an evolving pulsation signal (HR) for a student in E1.

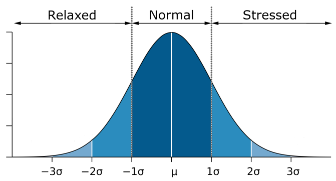

Figure 3: The normal distribution model for constituting the student's baseline physiology. The three bands correspond to the relaxed, normal, and aroused affective states.

The affective states are visualized via a circular marker, whose appearance and location on the baseline plot are dynamically updated as the pulsation signal unfolds to the right. A red-colored marker with a stressed face icon in Figure 2 indicates an aroused state for the student. A green-colored marker with a happy face icon indicates a relaxed state for the student. A gray-colored marker with a neutral face icon indicates a normal state for the student. The color bar at the bottom is a compact reflection of the student's dynamic evolution of affect. It shows the times during the exam that the student was relaxed, normal, or aroused according to the pulsation sign.

We compose a fused affect profile for the specific exam out of the affect profiles suggested by all three physiological indicators. Specifically, this fused profile is composed of the mean percentage of time the student felt stressed, or normal, or relaxed during the exam, as computed by averaging the corresponding percentages in the pulsation, breathing, and palm perspiration bars. This overall affect indicator bar is juxtaposed to the left of the exam grade on the top view of the User Portrait, facilitating performance - affect associations. For instance, Figure 1 reveals that both students tend to perform sub-optimally when they are aroused for significant amounts of time during an exam session (E4 for S011 and E3 for S013).

While the student's affect during the exam is captured physiologically, his/her affective state when s/he arrives and when s/he leaves are captured psychometrically. The former may affect her/his exam performance, while the latter may be indicative of her/his stress recovery mechanism. This information is given by the SAI scores before and after the exam, which are depicted as semicircles on the left and right end of the exam's affect bar, respectively.

In turn, the SAI scores may be conditioned to the TAI scores, which are used to color the subject's face icon on the top view of the User Portrait. Interestingly, the student with trend anxiety in Figure 1 (red face) is the only one who sometimes arrives in an aroused state and leaves in an aroused state. This is an example of how the covariate information depicted on the left section of the User Portrait enables conditioned interoperation of the affect-performance results on the right section. The visualization of the entire study can be found at: http://www.cpl.uh.edu/projects/stress-studies/css/.

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