Capture User Emotions during Computer- Aided Design

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Abstract: Facial expressions, gestures are artefacts of non-verbal human communication and imply affective states. Recent research on emotion-recognition has shown the potential for human-computer interfaces (HCI) to integrate affect in human machine interaction and mimic human communication models. Each mutually elaborates the other and both can be further elaborated by speech that accompanies the affective status. This paper investigates affecting properties in users performing an engineering design task in Solid Edge™. A fuzzy logic model is introduced so as to map psycho-physiological signals to associated affective emotions. By studying the psycho-physiological attributes associated to a CAD-based engineering design process it is envisaged that interrelated engineering behaviours can be more deeply understood and consequently, lead to more natural and intuitive CAD user interfaces.

Key Words: Psycho-Physiological signal, Human factors, CAD, Engineering Design, Emotion recognition

1. Introduction

Industry is always striving to improve the efficiency of the engineering design process. This has been accomplished through the gradual revision of user-interfaces (UI) in computer-aided design (CAD) systems and by the way of adding greater functionality and automation. However, an area of CAD that has received limited investigation is how human factors can influence the engineer.

Many researchers have investigated in the field of Human-Computer Interaction (HCI) to provide a natural and intuitive way for communication between human and machines. Human-centred system and personalised environment have also played an increasingly important role in recent times. Psycho-physiological based emotion recognition is one of the first key steps towards the evaluation and development of advanced affective human-computer interaction (HCI) [1-4]. HCI studies have shown that various changes in physiological activity are integrally related to emotional responses [5].

In this research, several bio-physiological properties of CAD users have been measured in a pilot study in an attempt to identify the emotions experienced during a CAD session.

2. Psycho-Physiological Signals and Emotion Recognition

2.1. Physiological Signals

Relationships between the electroencephalography (EEG) and galvanic skin response (GSR) in states of consciousness has been established and analyzed the last few years. The EEG in certain frequency bands indicates activities on different hierarchical levels. The research presented in this paper focuses on one of the EEG waves - alpha (α), which lies between 8 and 13Hz with 30-50μV amplitude [6]. Alpha waves indicate a relaxed awareness without any attention or concentration. Extremely high Alpha wave implies the high anxiety, and the mid-high Alpha is always linked with the positive emotions. The GSR measures the electrical resistance of the skin. It is correlated to arousal and indicates emotional responses (e.g. stress, excitement) and cognitive activity [7].

2.2. Mapping Psycho-Physiological Signals to Emotions

Many researchers and psychologists define emotions according to one or more dimensions. Arousal and valence are the most commonly used dimensions of 2D emotion model [8, 9]. Figure 1 presents the Affect Grid introduced by Russell et al [9].

There has been significant attention focused in the field of psycho-physiological signal based emotion recognition, however few indicate definite conclusions. Many target emotions derived simply from watching pictures or listening to songs with no interaction between the human and the stimuli [7, 10-11]. Given these studies are in a strictly-controlled circumstance it will be difficult to apply this to real applications. In recent gaming research, some researchers have identified certain emotions while the user plays games [12-13]. This paper proposes a fuzzy approach based on a general understanding of psycho-physiological signals, mainly on alpha waves and GSR.

3. Experimental Methodology

3.1. Experiment Procedure

Virtual Concept_P23 "HOME"
The experiment involved 15 users creating a 3D model of a car using Solid Edge™ with psycho-physiological properties measured using the NeXus biofeedback devices with Biotrace+ [14-15]. The GSR is monitored using 2 finger sensors with NeXus-10. Brain activity (EEG) is measured by an instrumented cap with 21 electrodes using the 10-20 system. All participants were engineering students with prior experience with Solid Edge and/or other CAD packages, and their ages ranged from 20 to 29 years old.

Table 1. Procedure of the experiment

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set up signal acquisition devices</td>
<td>Appr. 10</td>
</tr>
<tr>
<td>Fill in general participant information</td>
<td>Appr. 1</td>
</tr>
<tr>
<td>Relaxation 1</td>
<td>2</td>
</tr>
<tr>
<td>Experiment Stage 1</td>
<td>5</td>
</tr>
<tr>
<td>Questionnaire (feeling report of stage 1)</td>
<td>Appr. 3</td>
</tr>
<tr>
<td>Relaxation 2</td>
<td>2</td>
</tr>
<tr>
<td>Experiment Stage 2</td>
<td>10</td>
</tr>
<tr>
<td>Questionnaire (feeling report of stage 2)</td>
<td>Appr. 3</td>
</tr>
<tr>
<td>Relaxation 3</td>
<td>2</td>
</tr>
<tr>
<td>Experiment Stage 3</td>
<td>15</td>
</tr>
<tr>
<td>Questionnaire (feeling report of stage 3)</td>
<td>Appr. 3</td>
</tr>
</tbody>
</table>

Each experimental session lasted approximately 60 minutes and was split into 3 stages. The participants were initially presented with a 3D solid block in Solid Edge and by working through a 3-part tutorial; produce a 3-D model of a car. The procedure of the experiment is listed in Table 1.

3.2. Experiment Hypothesis

The objective of the experiment is to monitor each individual’s emotional status as they carried out an engineering design task. The psycho-physiological data, synchronized with video capture of the participant’s screen and a feedback questionnaire with interview notes were recorded. According to the literature of the correlation between EEG signals and emotion mapping, it is hypothesized that:

1. GSR is linear with the mental arousal [2];
2. Extremely high Alpha indicates low valence and negative emotions are dominant; high Alpha is always related to high valence while positive emotions are dominant; low Alpha is linked to medium low valence [16].

Psycho-physiological signals captured are then mapped to arousal-valence space to identify emotions, namely frustration, satisfaction, engagement and challenge accordingly.

4. Analysis and Results

According to the fundamental psycho-physiological theories, a fuzzy approach is chosen to map continuous psycho-physiological signals to affective emotions. Our fuzzy model takes peak Alpha frequency and GSR as inputs. The modelling procedure follows two steps. First, the physiological signals are mapped to arousal and valence space using the above hypothesis in section 3.2, then the arousal and valence values are employed to generate the emotion values of frustration, satisfaction, engagement and challenge using simplified Affect Grid. The surface graphs of the two steps are in Figure 2.

The baseline varies significantly among all the participants; it is difficult to obtain the general distribution of participants due to small database size. Hence, our psycho-physiological to AV space fuzzy model adjusts the membership functions of the inputs according to the data distribution of baselines. The rules are the same for all the participants, which are generated according to our hypothesis and our understanding of emotion mapping on Affect Grid. Continuous emotions are modelled from the outputs of this fuzzy model using centroid defuzzification method. The emotions are synchronized against the video captured during the design process and the interview notes after each step. The emotion changes from 26 samples have a similar trend as reported in the interview. It is straightforward to recognise the emotional experiences of the participants from the continuous modelling emotions.

Figure 3 plots the dynamic emotion status of participant 10 in the second design step. During the first two minutes of the second step, the participant was satisfied with the outcome of the first step and planned his own strategy to complete the second step. As the difficulty increased in the second step, the challenge the participant felt was rising and he started to look for the functions he planned to use. From 200s to 320s, the participant was working as planned; the frustration level was the lowest. However he did not manage to locate the function to complete his plan, the frustration level rose significantly and he started to try different methods to finish the design. The engagement and challenge level was yet again increased. The satisfaction level varied until the time was up, and the participant was not happy with the outcome.
of the second step. The continuous emotion output of the fuzzy model enabled the clear indication of the emotion while the participant was engaged with the engineering design task, most significantly, with no interruption of the design process. This provides considerable potential as an analysis tool to potentially help to improve the CAD interface and the design process including training support for inexperienced designer engineers.

More psycho-physiological analysis methods will be investigated to improve the performance. The future work includes establishing the psycho-physiological database for engineering CAD design process and engineers’ behaviour.

6. Acknowledgement

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7. References