Machine learning classification of design team members' body language patterns for real time emotional state detection

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Design team interactions are one of the least understood aspects of the engineering design process. Given the integral role that designers play in the engineering design process, understanding the emotional states of individual design team members will help us quantify interpersonal interactions and how those interactions affect resulting design solutions. The methodology presented in this paper enables automated detection of individual team member's emotional states using non-wearable sensors. The methodology uses the link between body language and emotions to detect emotional states with accuracies above 98%. A case study involving human participants, enacting eight body language poses relevant to design teams, is used to illustrate the effectiveness of the methodology. This will enable researchers to further understand design team interactions.

Engineering design is "widely considered to be the central or distinguishing activity of engineering" (Bucciarelli, 1994). Yet, it remains an insufficiently researched and understood topic (Ackroyd, 2006; Dym, Agogino, Eris, Frey, & Leifer, 2005). In particular, interactions within design teams are amongst the least understood aspects associated with the engineering design process. This is due to the dynamic, nonlinear and often loosely coupled nature of design (Edmondson & Nembhard, 2009). While there are established methods of evaluating the ideas and concepts generated by a design team (Goldschmidt & Tatsa, 2005; Liu, Chakrabarti, & Bligh, 2003; Shah, Kulkarni, & Vargas-Hernandez, 2000), the process of generating these ideas and concepts remains difficult to study. Existing approaches rely heavily on hand coding of video-recorded or observed interactions and design team member surveys (Brannick & Prince, 1997). An important aspect of the team dynamic is the interpersonal interactions between its team members. The emotions expressed by the individuals during these interactions can lead to insights about the team's dynamics. Traditional self-reported feedback of team interactions is often unreliable because it is susceptible to user

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reported biases (Barker, Pistrang, & Elliott, 2002). Additionally, this feedback is not in real time. Thus, there is a need for a system that can capture individuals' emotions in real time. Such a system would allow for a better understanding of interpersonal interactions in design teams.

Body language has been linked to emotional states by past studies (Panksepp, 1998). An individual can exhibit various body language poses, depending on whether he or she is interested, bored, frustrated, delighted etc. (Birdwhistell, 2010; Panksepp, 1998). Unfortunately, having a human observer assess body language poses exhibited by design team members can be costly and time consuming. Thus, there is a need for an automated system. Studies have been conducted that quantify body language using various sensors such as pressure sensitive chairs and motion tracking suits or by measuring other reactions such as pupil dilation (Craig, Graesser, Sullins, & Gholson, 2004; Kapoor & Picard, 2005). Unfortunately, such methods require expensive specialized, wearable hardware. To address these factors, the authors of this work propose a machine learning driven approach that utilizes off-the-shelf, non-wearable sensors to detect individuals' body language in a real time minimally-invasive manner. This approach enables researchers to quantify the emotional states of individual team members in a design team and thus, better understand the team dynamics. The methodology outlined in this work demonstrates the efficacy of non-wearable sensors and machine learning algorithms to model individuals' body language in non-design tasks with the ultimate goal of applying these methods to quantify design team interactions.

This paper is organized into four sections. In Section 1, the authors provide an overview of related literature, followed by the methodology in Section 2. Thereafter, the authors illustrate the methodology in practice with a case study in Section 3, before finally concluding in Section 4.

1 Literature review

1.1 Team dynamics and human emotions

Team dynamics is a complicated research topic. In engineering design teams in particular, the process rarely follows a linear, prescribed methodology (Stempfle & Badke-Schaub, 2002). A variety of factors such as team members' work load, time pressures, etc., are at play. Studies have shown that design team interactions are an interplay of design discussions, walkthroughs and progress evaluations (Olson, Olson, Carter, & Storrosten, 1992). Within this context, past research has shown that social aspects also interact significantly with the technical and cognitive processes of design (Cross & Cross, 1995). Additionally, conscientiousness, agreeability and emotional stability are positively related to job performance involving interpersonal interactions (Mount, Barrick, & Stewart, 1998). The success of teams is modeled using team