EMOTIONALLY INTELLIGENT BUILDINGS: RESPONSIVE VIRTUAL ENVIRONMENTS USING BIOMETRIC SENSING

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The built environment is essential in shaping the physical and psychological well-being of humans. According to the U.S. Environmental Protection Agency (EPA), people spend 87% of their time in enclosed buildings. Various architectural design features (e.g., presence and size of windows, space layout, and texture of the space) can enhance or reduce human experiences (e.g., motivation to work, pleasure, and restorativeness) in the built environment. Although it is essential to consider human experience when designing spaces, architects and civil engineers have limited knowledge of how architectural design features influence human experience.

Our previous studies showed the feasibility of quantitatively understanding the human response in distinctively designed environments by integrating body area sensor networks (BSNs) (e.g., electroencephalography, galvanic skin conductance, and eye-tracking) and virtual environments (VEs). However, there is still a lack of (1) a formal approach to determine if a proposed design space conforms with the goal of maximizing human experience; (2) an accurate and automated method to label the human experience in a virtual space using the BSN data; and (3) an emotionally intelligent responsive virtual environment capable of dynamically changing the architectural design configuration based on human experience captured by BSNs. To address these questions, this study proposes a three-step approach: 1) automatically checking BIM of a new design against requirements for enhanced human experience in designed spaces, (2) automatically labeling human experiences on the arousal and valence scale using biometric data captured in distinctly configured virtual spaces, (3) developing reasoning mechanisms to transform spaces based on the streaming BSN data.

For the first step, I propose a web-based crowdsourcing study, where the subjects are asked to rank randomly picked designed spaces from a large interior design database captured using 3D laser scanned data. The designs will be put in the virtual reality format for the maximum immersiveness. A reasoning mechanism will be developed to extract the underlying design features represented in these virtual environments. For the second step, I propose a supervised-learning based method to label human experience in designed spaces on the arousal-valence scale. I will conduct user studies to collect subjects' bodily response data using BSNs when they are doing walk-throughs in virtual spaces. The human experience will be calculated on the valence-arousal scale for identifying spaces that are maximizing human experiences on various sensations (e.g., relaxing for homes and motivating for workplaces). Finally, I will create a reactive virtual environment that is capable of changing the configurations of the architectural design features on-the-fly using streaming BSN data. The goal is to have the virtual environment transform to the configuration of architectural design features that achieves the maximum human experience based on the objective sensor reading of the human subject. The underlying mechanism is a reinforcement learning model capable of self-improving based on newly collected data.

The contributions of this research include: (1) a method to identify non-conforming spaces in an architectural design with respect to requirements for enhancing human experience, (2) a quantitative method of labeling human emotions in virtual spaces, (3) reasoning mechanisms to enable responsive virtual environments based on human emotions captured through biometric sensing. Practical implications include the much-needed design guidelines for architects to follow when designing spaces with human experience in mind.