Emotion-Driven Adaptation of Software Applications using User Requirements Notation Models

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ABSTRACT

Software applications aim to deliver intuitive user experiences that maximize adoption and effectiveness. However, accommodating individual differences poses challenges for universally accessible interface design. This paper proposes an emotion-driven adaptation approach to develop Adaptive user interface applications (AUIs) using User Requirements Notation (URN) Models. The approach focuses on eliciting emotional requirements, designing alternative adaptation strategies, and implementing dynamic UI adaptations based on user emotions. During the requirements phase, user emotional goals are elicited to construct emotion-aware goal models using Goal-oriented Requirements Language (GRL). These models are subsequently analyzed to inform the development of adaptation strategies for the interface at runtime, which are triggered by transitions in emotional states. Specifically, User Case Maps (UCMs) capture adaptive strategies that are enacted according to users' emotions inferred through interaction monitoring. The technique provides a flexible, requirements-driven methodology applicable across domains like healthcare, education, or finance that demands accommodating diverse individual differences and delivering optimized user experiences.

CCS CONCEPTS

• Human-centered computing → User models; Adaptive interfaces; • Software and its engineering → Requirements analysis; Self-adaptive systems.

KEYWORDS

Emotions, adaptive user interfaces, goal modeling, UCM, GRL, self-adaptive systems.

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1 Introduction

The digital transformation across domains has led to the development of many digital solutions. While these aim to cater to diverse groups of users and their unique needs, limitations persist in fully satisfying the diverse user base and providing optimal user experience. Adaptive user interfaces (AUI) are considered a promising solution for accessible and sustainable technology by modifying interface elements to accommodate diverse users and temporal variations [1]. Various users differ in their physical abilities, experience levels, and preferences [2]. Hence, adapting the application based on the user's emotions is important to ensure a positive user experience. The research community has demonstrated increasing consideration of users' emotions over the past several years to trigger and evaluate interface adaptations. In early work, Galindo et al.[3] proposed an architecture for adapting interfaces to emotions detected at runtime. Building on this, they categorized emotions based on interface usability, aesthetics, user age, and gender [4]. Through an experiment, they determined emotion thresholds that could serve as triggers for interface adaptation to detected problems. Subsequent studies further developed frameworks and techniques for emotion-based adaptation [5][6].

The existing literature indicates that current techniques for adaptive interfaces commonly rely on reactive approaches that utilize runtime monitoring. However, there is an opportunity to proactively drive adaptive behavior in applications by capturing relevant user emotions during requirements analysis.

This paper proposes an extension of the Emotion-Oriented Requirements Engineering (EmORE) approach [7] by integrating User Case Maps (UCMs) [8] to model alternative adaptation strategies based on elicited user emotions. By employing UCMs, emotional requirements can be mapped to flexible adaptation

scenarios, effectively bridging the gap between the analysis of user emotional needs and the implementation of emotions-aware adaptive interfaces. The integrated technique facilitates simulation and validation of adaptation strategies before implementation, rendering it suitable for engineering emotionally intelligent systems in diverse domains.

2 Proposed Approach

This approach aims to capture and address potential negative emotions and enhance positive ones by incorporating alternative adaptation strategies. The proposed approach leverages goal-oriented modeling and scenario modeling with User Case Maps (UCMs) [8] from the User Requirements Notation (URN) [9] standard to capture and drive emotions-aware UI adaptations for personalized and intuitive interfaces. The approach is depicted in Figure 1.

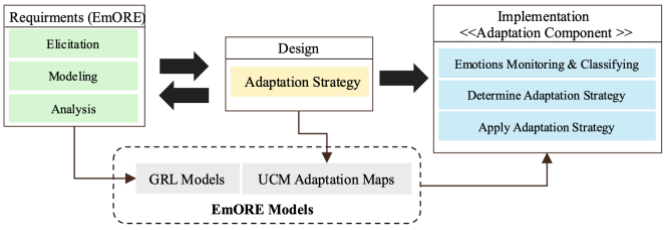

Figure 1: Emotion-Driven Adaptation Approach

Phase1. Requirements and GRL Models: For building GRL models, we utilize EmORE approach proposed in [7] for eliciting, modeling and analyzing user emotions. EmORE utilizes the Self-Assessment Manikin (SAM) tool during think-aloud sessions to capture users' pleasure, arousal, and dominance dimensions of emotional states in response to stimuli. These values are classified and linked with other model elements using contribution types "triggers" and "mitigates". High-level positive and negative emotional state goals are defined by aggregating multiple emotion softgoals. The quantitative emotional response computation is adopted to assign initial satisfaction values to emotion softgoals based on PAD vectors. The analysis assesses if emotions meet desired thresholds and identifies stimuli triggering emotions and potential mitigators. Emotional state goals are re-evaluated after incorporating new mitigating stimuli/strategies. This approach supports the incorporation of emotional requirements into models in a structured, measurable manner.

Phase2. Adaptation Strategies Design and UCMs: We design strategies to address identified negative emotions by investigating their root causes. Techniques such as user interviews and brainstorming workshops inform the creation of alternative interaction strategies. User Case Maps (UCMs) then visualize these strategies, linking emotional requirements to system responsibilities and components, allowing for flexible scenario modeling and validation. UCMs enable runtime reconfiguration of system behaviors in response to detected emotional states, ensuring that interfaces adapt to improve user emotional experiences.

Phase 3. Adaptation Component: The adaptation component enables detecting and representing user emotions to drive interface adaptations. Emotions are inferred through continuous monitoring of user behavioral signals and GUI interactions. This monitoring can be initialized by capturing various behavioral and physiological signals using sensors, including mouse clicks, screen taps, keystrokes, facial expressions from a webcam, and eye gaze tracked via eye tracking [10]. Machine learning techniques such as support vector machine (SVM) or k-nearest neighbor (KNN), trained on labeled datasets, are employed to detect emotions and transitions. Emotional states, once detected, are mapped to softgoals within the GRL model, influencing the re-evaluation of UCM scenarios to identify the most effective UI adaptations that could shift the user towards a more positive emotional state.

3 Conclusion and Future Work

This research establishes a foundation for emotion-aware adaptive interfaces to advance intuitive, emotionally intelligent software applications. The approach elicits emotional requirements using GRL models and employs UCMs to design alternative adaptation strategies. By integrating these models, the approach enables user interface adaptations that are tailored to detect and respond to user emotions by mapping softgoals to UCM scenarios. This technique bridges the gap between the analysis of stakeholder emotions and the implementation of emotion-aware adaptive interfaces. Further research can enhance the robustness and intelligence of emotion-driven UI adaptation. Large scale user studies can help evaluate the approach. Exploring different ML techniques to predict emotions from behavioral signals warrants investigation.

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