PainSense: Pain Assessment through Reality Sensing

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Abstract. We propose a pervasive computing framework which can support diagnosis of psychosocial factors related to diseases and disorders in the elderly population. An Internet-enabled health-kiosk system or mobile device lessens the barriers for the elder to record their psychosocial diary and produces long-term monitoring data for physicians. Daily conversation between elders and family members over mobile phone can be utilized as a natural way to characterize and analyze the elder's pain or mood. The PainSense framework monitors and analyzes pain behavior such as sensory perception, affective cues, and physiological pain behavior. Users self-report their pain experience via touchscreen-based kiosk or a Nokia N95 mobile phone. PainSense also provides a historical data visualization interface for physicians. Future work will explore potential reinforcing indicators of pain conditions through behavior mining and will exploit unobtrusive and inexpensive sensor technologies to improve pain management.

1 Introduction

It is difficult to treat a problem that is difficult to measure in a consistent and timely way. Pain management challenges include: (1) Elders are reluctant to make logistically challenging and time-consuming office visits. (2) The elder's description of his/her pain may mislead medical care professionals. (3) Physicians lack long-term, frequent pain data with which to interpret pain conditions adequately. One current method of pain management utilizes a paper-based pain inventory such as Cleeland's Brief Pain Inventory, which an elder fills out during an office visit [1]. This method provides a momentary snapshot of the elder's condition. But the occasionally administered inventory does not provide adequate, ongoing monitoring of the elder's pain experience and misses valuable verbal and non-verbal indicators of the elder's pain status. Verbal information gained during regular phone interaction with family members, such as voice quality and non-verbal information such as facial expression might be useful as reinforcing indicators of pain experience, which could be analyzed to improve pain management. We are developing PainSense, a touch screen-based kiosk and mobile device-based system that helps elders to record their pain experience naturally in their everyday lives and to present and analyze the acquired data for use by healthcare professionals, so that they can better support the elder.

2 Background

Over the past forty years, the concept of pain has morphed from that of a simple sensory event to something multidimensional [2]. We now understand that the experience of pain includes “sensory intensity and affective unpleasantness” [3]. Persons experiencing pain behave differently: They may rest in bed, take medication, move cautiously, or display “pain-related facial expressions” [4]. Pain researchers have also studied pain-affect models. In general, the relationship between negative affect and pain experience has been found to be stronger than the relationship between positive affect and pain [5].

Given the findings of previous pain research, we believe pain assessment can be significantly improved by exploiting pervasive interaction and sensor data that are integrated with the elder’s everyday life. We believe pain-related behavior can be captured via existing mobile sensing techniques. We define the four sensing channels shown in Fig. 1 to probe and monitor pain behavior in daily life.

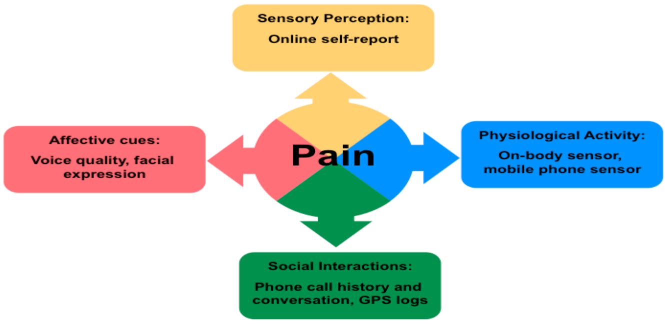

Fig. 1. Four sensing channels to probe pain behavior

For example, pain-related affective cues such as facial expression can be recorded while the elder is filling out an online pain assessment tool via a camera embedded in the kiosk system. The voice quality can be monitored via daily conversation over mobile phone with an elder’s family members. Furthermore, the sensors of a smart mobile phone can detect pain indicators such as the changes in gait pattern and in social interaction. Finally, the sensory perception of pain experience such as pain intensity/quality can be reported via an online questionnaire, using a mobile phone or kiosk system. The goal of our PainSense framework is to enable an easy-to-use daily pain assessment, to provide physicians with a longitudinal and summarized picture of the elder’s pain condition, and to exploit unobtrusive and inexpensive mobile sensor technologies to improve pain management by providing regular, automatic readings of pain indicators.

3 PainSense System

The PainSense architecture shown in Fig.2 includes four key components:1) front-end input consoles such as a touchscreen-based kiosk and mobile phone, 2) sensors such as microphone, camera, accelerometer, and GPS, 3) web server and database, and 4) pain visualization tools.

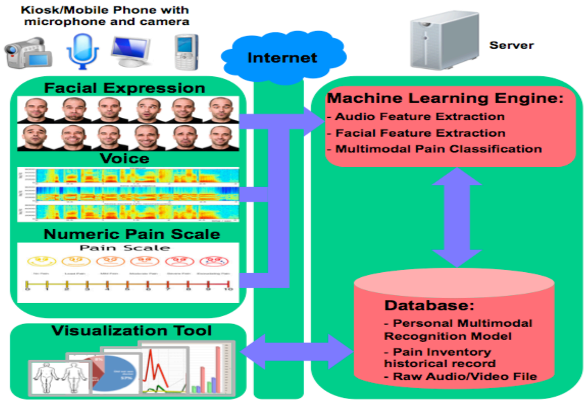

Fig. 2. PainSense Architecture

We have adapted Cleeland's Brief Pain Inventory and have created an online, touchscreen-based version for elderly pain sufferers. The advantages of the online pain assessment tool include a senior-friendly user interface with daily pain perception monitoring. Fig. 3 shows the question sets on the Nokia N95 that query about pain location, pain quality, and pain intensity. When the elder finishes the online pain assessment tool, the system generates the results as an XML file and forwards it to a back-end server for later analysis.

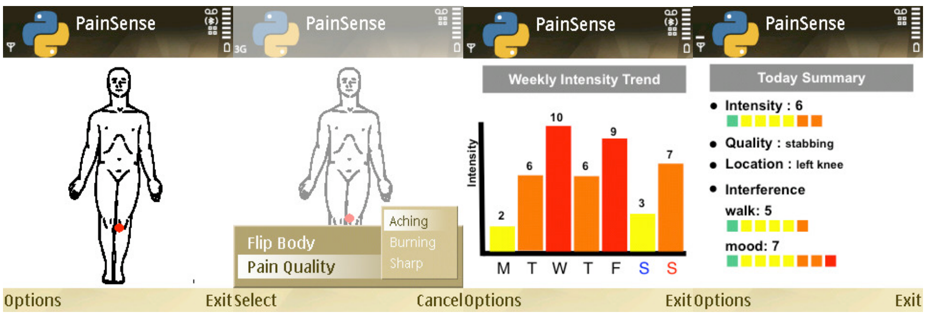

Fig. 3. Pain Assessment Tool on Nokia N95

Acoustic features play a major role in pain behavior observation. We are exploring the relationship between acoustic feature changes in the elder's conversation and the presence of pain. We implemented a voice recording application on a Nokia N95 which recorded conversations. The audio file was uploaded to the back-end sever. We use audio analysis software, Marsyas, to extract acoustic features and to construct a feature vector for training and classification. It extracts several standard acoustic features such as Mel-frequency cepstral coefficients (MFCC), time domain zero-crossing, and spectral centroid. Once the acoustic feature vectors are computed, they are prepared to train the support vector machine classifier (SVM) and Naïve Bayes Classifier. The classification result is stored in a database and can be downloaded to a mobile device or to a front-end console for graphical display. The data from the online pain assessment questionnaire can be used to label each sensing channel's data.

The PainSense system also includes an online pain data visualization tool that helps caregivers and physicians to visualize the stored data and to review summarized data. The pain data visualization shows the trend, distribution, and percentage based on the historical pain-related symptom over a certain period of time. For this work, we are collaborating with medical care providers to ensure that the data visualizations are intuitive and information-dense.

4 Conclusion

The work presented in this paper describes a pain assessment and management framework that takes advantage of mobile computing technology, affective computing, and diverse human-computer interaction approaches. The PainSense framework also aims to address several important issues. First, context-dependent, multimodal data fusion and analysis is a highly relevant issue. Second, since the essential components of psychosocial health are not clearly understood, the choice of data signals monitored for psychosocial health needs to be explored. Third, since the computing power of mobile devices is dramatically increasing, the role of the mobile device in the healthcare system will be expanded and redefined. Computational model learning based on the data streams may need to be done on the mobile phone, and the decision-making mechanism may need to happen on the mobile phone in order to reduce data transmission frequency.

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