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An Approach for Automatic Pain Detection through Facial Expression

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Abstract

Automatic pain detection is an emerging area of investigation with convenient applications in health care. The variation in facial expression often provides a clue for occurrence of pain. It provides an important window for the person who cannot verbally describe or rate their level of pain. To meet up the specific necessities, a framework has been designed for extraction of features from the face for automatic pain detection through facial expression. In this framework, Gabor filtering and Principal Component Analysis (PCA) are used as contributive steps that improves the performance of the system in terms of accuracy. To verify the accuracy and robustness of the system, experiments have been conducted on UNBC-McMaster Shoulder Pain Expression Archive Database at both frame level (person dependent) and image level (person independent). The methodology achieves 87.23% accuracy for detection of pain at frame level. Also the methodology achieves 82.43% accuracy for classifying the frames between four pain level (i.e. PSPI of 0, 1, 2 and >=3). The success rate of the methodology for pain detection at image level is 95.5%.

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Keywords: Pain; Pain Expression; Facial Action Coding System (FACS); Generalized Procrustes Analysis; Affine Warping; Gabor Filtering.

1. Introduction

Man-machine interface is one of the promising area from the beginning of computing machines and plays a crucial role for designing a system that could accurately distinguish and understand the human behavior. The present study focuses on one specific properties of pain behavior i.e. automatic pain detection through facial expression. Pain is a highly unpleasant sensation caused by illness or injury or it can be the mental distress or suffering [1]. It is

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often regarded as fifth vital sign in regard to healthcare because it is considered now in healthcare that pain, like other critical signs, is an objective sensation. According to National Centers for Health Statistics, about 76.2 millions of people in world suffer from pain.

Generally medical abnormalities are difficult to assess and manage and are typically measured by patients self-report [2]. This and analogous procedures are accepted because it is simple and easy to understand and often provide information that validates the level of pain that is experienced by the person. However these methods only work when the patient is sufficiently alert and cooperative, which is not always possible in the medical field. But beyond this pain assessment using self-report measures is a significant challenge and is not always reliable and valid in critically ill adults, especially those who are unable to communicate their pain level, e.g. with individuals of dementia and certain types of neurological disorder and also patients in Intensive Care Unit (ICU) needing oxygen mask for breathing. Furthermore, it cannot be applied for unconscious or new born patients. To overcome these restrictions observational and psychological measures has become indispensable.

Human face is a rich resource of nonverbal information that provides clues for understanding social emotions and can be helpful to reveal mental condition via social signals. The variation in facial expression often symbolizes the occurrence of pain. Clinicians and laypeople place great importance on the credibility of these behaviors and view them as consistent and convincing sign of pain. Facial activity has been in cooperated as a primary or major component of most multidimensional behavioral checklists or rating scales for assessing pain. There is a considerable amount of literature in which Facial Action Coding System (FACS) [2][3] has been applied to pain expression. Although the configuration displayed during pain shares the components with facial displays during pain and other negative emotional states have unique patterns that can be distinguished when the detail and configurations of actions are examined.

The paper mainly explores a newly framed approach for automatic pain detection through facial expression. The framework includes Gabor filtering as a contributive steps for extraction of features from faces and reducing dimensions using Principal Component Analysis (PCA) which increases the detection rate based on the comparative study described in section 5. The strength of the system is assessed by testing on UNBC-McMaster Shoulder Pain Expression Archive Database [3]. Also Graphical User Interface (GUI) based software is designed that could automatically detect and estimate four levels of pain at both frame level and image level.

The whole paper is organized as; section 2 describes the literature survey on pain detection. Section 3 explains the proposed methodology. In Section 4, a performance evaluation measure has been illustrated and reports the experimental results with discussion of the proposed methodology. In Section 5, a comparative study of the proposed methodology with respect to other techniques is provided. Also Section 5 gives an overview of Graphical User Interface (GUI) design of the proposed methodology for pain detection. And finally, section 6 concludes the paper.

2. Literature Review

From an arrangement of facial actions that signals pain through analyzing the presence of facial actions can reduce a difficulty of pattern recognition. In the recent year, the research communities have sparked off thunder for developing computed based techniques to advance this area. The analysis of these papers is shown in Table I. In [4], Ashraf et al. used Active Appearance Model (AAM) on digital videos containing pain expressions and then used machine learning procedure to classify between pain and no pain. With the advantage of representing dynamic alterations in pain-related actions the best performing predictive model gives a hit rate of 83%. In [5], Lucey et al. revised an AAM and Support Vector Machine (SVM) to develop an automatic system for frame level pain detection in two ways on the images of patients with rotator-cuff injuries: first straight from the facial features that is in a direct manner and second through the fusion of individual Action Unit (AU) detectors. In [3], Lucey et al. extended their work as described in [5] to detect pain from a patients face using an AAM approach on a frame-by-frame basis. They have shown that fusing all AAM representations together using linear logistical regression (LLR) provides a noticeable performance for detection of pain and action units in frame. In [6], Kaltwang et al. [6] proposed used a different shape of facial landmarks and appearance features i.e. Discrete Cosine Transformation (DCT), Relevance Vector Regression (RVR) and Local Binary Pattern (LBP) and then fused these features and thus showed that fusion of these features leads to better estimation of pain level as compared to feature specific estimation of pain intensity. In [7], Hammal et al. also used AAM to extract the canonical normalized appearance of the face (CAPP) and then passed through a set of Log-Normal filters. Finally SVM classifier is used to detect pain level on a frame-by-frame level and obtained 73% accuracy.