

Towards Pain Monitoring: Facial Expression, Head Pose, a new Database, an Automatic System and Remaining Challenges

Philipp Werner¹
Philipp.Werner@ovgu.de
Ayoub Al-Hamadi¹
Ayoub.Al-Hamadi@ovgu.de
Robert Niese¹
Robert.Niese@ovgu.de
Steffen Walter²
Steffen.Walter@uni-ulm.de
Sascha Gruss²
Sascha.Gruss@uni-ulm.de
Harald C. Traue²
Harald.Traue@uni-ulm.de

¹ Institute for Information Technology and Communications,
Otto-von-Guericke University,
Magdeburg, Germany
² Department for Psychosomatic Medicine and Psychotherapy,
University of Ulm,
Ulm, Germany

Pain is what the patient says it is. But what about these who cannot utter? Automatic pain monitoring opens up prospects for better treatment, but accurate assessment of pain is challenging due to the subjective nature of pain. To facilitate advances, we contribute a new dataset, the BioVid Heat Pain Database which contains videos and physiological data of 90 persons subjected to well-defined pain stimuli of 4 intensities. We propose a fully automatic recognition system utilizing facial expression, head pose information and their dynamics. The approach is evaluated with the task of pain detection on the new dataset, also outlining open challenges for pain monitoring in general. Additionally, we analyze the relevance of head pose information for pain recognition and compare person-specific and general classification models. For a visual overview, see Fig. 1.

BioVid Heat Pain Database: We introduce a newly collected experimental pain research dataset, named BioVid Heat Pain Database. It was recorded in a study with 90 participants aged from 18 to 65 years. In contrast to existing databases known to the authors, it does not only provide video information, but also physiological data. Thus, it promotes advancements in both, observational and physiological pain measurement and facilitates the fusion of both in one automatic recognition system. Other key features include well-defined pain stimulation through a thermode, stimulation of four pain intensity levels, recording of high resolution video from different points of view, recording of depth information, measurement of pain threshold and tolerance, posed and spontaneous emotion, and filled in questionnaires about the participants' personality and psychosomatic health. The database will be made available for non-commercial research purposes.

Pain Recognition System: A new approach to recognize pain from facial expression and head pose information is proposed. It utilizes dynamics through a time window descriptor which is calculated from frame level features. To the best knowledge of the authors, our pain recognition system is the first which takes up the challenges arising with fully automatic feature extraction when permitting non-frontal head poses. Lucey *et al.* [2] rely on manually labeled key-frames. Werner *et al.* [4] assume that 3D landmarks are available. Hammal and Kunz [1] and Niese *et al.* [3] rely on frontal view on the face. Our approach is also the first utilizing head pose information for classification. The head pose is estimated from depth data, and facial landmarks are detected from color images, both employing methods known from literature. Next, for each image frame a set of distance and gradient features is extracted. These are selected to capture pain related facial actions. Facial distances are calculated in 3D to uncouple them from head pose. To utilize dynamics, a time window consisting of multiple frames is considered. Each frame level feature forms a discrete-time signal which is condensed in a time window descriptor through statistical parameters of the signal and its derivations. The descriptors are used for classification with a support vector machine.

Experiments: We conduct experiments applying our recognition system to the BioVid Database. Whereas the others evaluate their systems based on observational measures (e.g. facial actions) or do not even specify the source of their ground truth labels, we compete with the gold standard of pain assessment, i.e. self-report. Since our focus is on recognizing pain, not only facial expressions of pain, we try to classify the stimulus. This does not only reveal strengths and weaknesses of the recognition

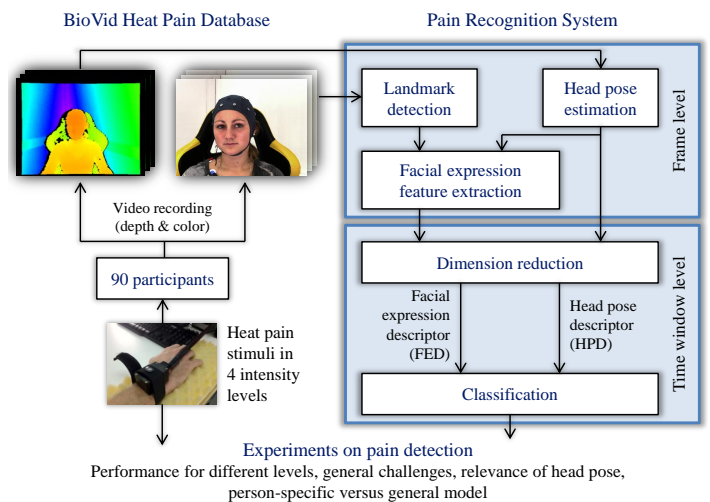


Figure 1: Overview on the new database, the recognition concept and the conducted experiments.

system, but also challenges caused by the nature of pain. First, we investigate which level of pain can be detected by our system. We obtain good results for the two highest intensities, whereas they are better for younger age. Lower pain intensities yield less observable reaction and are much harder to detect. In addition, there are large differences in expressiveness between persons. Whereas some persons already show considerable facial expressions at low pain intensities, other seem not to react at all, even when stimulated with high temperature at their pain tolerance level. Further, we discuss age related differences and the need for very accurate and robust landmark detection. In another experiment, we analyze the role of head pose for pain recognition. It is shown that head movement is not only a personal trait. When combined with facial expression information it can also improve predictive performance of a general model.

Future work includes research in how to handle the diversity of persons, and multi-modal pain recognition integrating physiological information.

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