Automatic Contact-Free Assessment of the Source of Pain Using Artificial Intelligence

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- ## Motivation

  During the past decade, there have been numerous research and development efforts in the field of wearable health-monitoring systems that were motivated by the need to monitor a person's health status outside of the hospital. However, most existing techniques for health monitoring typically require users to strap on bulky sensors, chest straps or sticky electrodes. This obviously discourages regular use because the sensors can be uncomfortable or encumbering. Hence, to make health monitoring part of the fabric of everyday life, we believe that there is a need for novel technologies that are comfortable (e.g. non-invasive and contact-free), simple to use and unobtrusive. The idea of using computer vision for non-contact healthcare and wellness has the promise to change the future of healthcare by enabling proactive and unobtrusive personal health, mental and activity management.

- ## The objectives of this Project

  The focus of this project is on the development of new contact-free technologies for estimating the level and the source of pain from the facial expressions. Pain is indeed a vital indicator of our health condition that places an enormous economic burden on healthcare systems. In Europe, there are approximately 740 million people, and most have experienced an episode of severe pain at some point in their life. Automatic pain assessment has an important potential diagnostic value for populations that are incapable of articulating their pain experiences. Technologies that can accurately recognize the affective state of an individual using contact-free sensors would represent an important tool for providing personalized diagnostics and therapeutic treatment plans. The objective of this project is to investigate and develop systems needed for accurate personalized assessment of pain intensity based on multiple contact-free sensor modalities captured in videos, in scenarios where patients cannot describe their pain. The focus will be on developing new methods not only to assess the level of pain but importantly to determine the origin of the pain. Imagine a baby crying: the visual symptoms can be the movements in facial expressions including prominent forehead, eye squeeze, naso-labial furrow, taut tongue, and an angular opening of the mouth. Starting from the hypotheses that different sources of pain potentially produce different visual symptoms, we want to use the recent advances in machine learning (ML) and artificial intelligence (AI) to learn to characterize the source of pain at the micro-expression level. The visual analysis of the source of pain has never been investigated before.

- ## The preliminary Investigations

  The PI has also conducted investigations on pain level assessment obtaining encouraging results on some benchmark databases. These results will be used as key starting points, and ensure the success of this current proposal. The following publications give an example of the PI's recent work closely related to the current proposal.

  - [IJCV 2019]: A Spatiotemporal Convolutional Neural Network for Automatic Pain Intensity Estimation from Facial Dynamics, International Journal of Computer Vision, 1-13, 2019
  - [ICIP2019] Depression detection based on Deep Distribution Learning, International Conference on Image Processing, 2019
  - [JBHI 2017]: A Survey on Computer Vision for Assistive Medical Diagnosis from Faces, IEEE Journal of Biomedical and Health Informatics, 2017

- [FG 2019]: Learning to Detect Genuine versus Posed Pain from Facial Expressions using Residual Generative Adversarial Networks, 2019 14th IEEE International Conference on Automatic Face & Gestures, 2019
- [Nafath 2024] From mind-reading to health-reading machines: Towards contactless health diagnosis using generative artificial intelligence, A Hadid, Nafath 9 (25), 2024.

- **The Proposed Methodology**

This project focuses on developing innovative machine learning techniques for accurate assessment of pain intensity levels and the source of the pain based on facial micro-expressions caused by different source of pain. This is considered to be among the most complex visual recognition problems, and continues to drive much academic research (and beyond). A key challenge in real-world scenarios is the significant variations over time of the expressions for different persons, sensors, computing devices and operational environments. Despite the recent advancement of various facial based technologies, developing an efficient system for expression recognition remains a challenging task. We propose to approach this problem from the perspective of Deep Learning (DL), a subfield of Machine Learning (ML) concerned with algorithms inspired by the structure and function of the brain called artificial neural networks, and where layers are trained using large amounts of data. DL models, like convolutional and recurrent neural networks (CNNs and RNNs) learn discriminant feature representations from labelled training data, and provide state-of-the-art performance in many visual recognition applications (e.g., image classification, object detection, as well as assisted medical diagnosis). DL models are also considered to be state-of-the-art in video-based pain intensity assessment. Our objective is to develop systems capable of assessing the pain intensity level and the source of pain based on multiple contact-free cues (e.g. facial features, facial movements, head movements etc.). These systems shall also characterize the type (e.g. chronic vs non-chronic). In order to establish a performance baseline for comparison, we will consider ECG signal captured with a contact sensor. In this project, new DL models will be investigated, developed and compared for accurate and robust spatio-temporal micro-expression analysis. These models are novel as they will combine information from multiple visual modalities over time, and dynamically adapt the model's fusion or gating function according to operational capturing conditions. To enhance robustness and accuracy, these new DL models will also incorporate specialized techniques for weakly-supervised learning from videos with limited and ambiguous annotations, and for deep domain adaptation to calibrate DL models with unlabeled operational data.

- **About the Experimental Data**

For the experimental analysis, we will chimerically consider three publicly available databases of pain, including the BIOVID heat pain database (heat pain), the UNBC-McMaster database (shoulder pain), and the MIntPAIN database (electrical pain). So, we do not plan to record nor distribute any sensitive data during this project (in longer-term research, we will probably need to collect a larger database containing other sources of pain). We have always adopted strict privacy and ethical rules in the past and we will adopt similar rules in this project as well. When needed, we will ensure that all required approvals will be obtained from the ethical review boards in France. We will always operate within European and international regulations. The validation will be done in close collaboration with university hospitals in France. To be the best of our knowledge, the analysis of the source of pain is novel, making this project ambitious.

- **About the Targeted PhD Student**

Independently from the gender, age and ethnicity, the suitable PhD candidate for this project should have a good background in machine learning with an interest in healthcare applications. Excellent programming skills (Python) are also needed.