The Application of Facial Expression Recognition in Reducing Inaccuracy in Pain Scale Intensity Identification

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Abstract

The correct assessment is essential to ensure the proper treatment for the patient and pain is relieved. Thus, the inaccuracy in identifying the pain scale intensity has to be at the lowest point. However, many studies point out that the existing pain scale intensity identification is mainly based on human perception and individual pain endurance threshold. Therefore, the results can be varied and also being manipulated by the patients. This article aims to propose a Machine Learning technique to recognise and analyse facial expression recognition during pain assessment. The paper describes the relationship of the problem, solution and the impact of the solution. It further explains how the application of machine learning in pain detection can be applied starting from features selection dan datasets collection, followed by analysing and concludes by discussing the idea of improvements of the solution.

Keywords: *Artificial Intelligence, Data Analytics, Facial Expression Recognition, Machine Learning, Pain Scale Intensity Identification*

1. Introduction

Pain is notoriously difficult to detect and manage since it is subjective and is usually quantified by patient self-report via clinical interview or visual analogue scale [1]. Deldar [2] states that an incorrect diagnosis of patients' discomfort can result in problems such as the increased risk of infection, extended mechanical breathing, hemodynamic disturbances, psychosis, immunological suppression, and even death. Thus, an accurate pain assessment is highly significant in a patient journey while receiving care. Turk, D. C., & Melzack, R [3] stressed that pain evaluation is one of the foundation pillars in the outcome assessment.

In this Fourth Industrial Revolution (4IR) era, we have witnessed the advancement of technology in most industries, including healthcare. We are already starting to see the 4IR technologies such as Artificial Intelligence (AI), Big Data Analytics, Cybersecurity, Autonomous Robots, Internet of Things (IoT), Augmented Reality (AR), cloud computing and simulation to bring transformational changes in the healthcare environment [4]. The application of AI has become a thing in the healthcare industry nowadays. Simply described, artificial intelligence is the capacity of a digital computer or computer-controlled robot to

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execute tasks typically associated with intelligent beings [5]. The AI has the human's intellectual processes characteristic, such as reasoning, discovering meaning, and learning from experience.

This capability of AI made it perfect to be applied in recognising and analysing pain. In conducting accurate pain assessment, the application of Machine Learning (ML) holds probabilities to aid clinical providers in reducing inaccuracy in pain scale intensity identification. According to Janiesch, C., Zschech, P., & Heinrich, K [6], ML is described as a data analysis technique that automates constructing analytical models. ML is a subset of AI-based on the premise that systems can learn from data, recognise patterns, and make judgments with less human interaction. In specific, the application of ML in pain assessment uses facial expression recognition of patients during pain assessment by clinical providers.

During the pain assessment, for example, in the emergency room, the ML will analyse the facial expression of assessed patients to scale their pain intensity. With that, clinical providers can predict and prevent early disease and plan for the correct treatment to manage the pain. Accurate pain evaluation, management, and therapy will result in successful pain management and will have a beneficial effect on patients' physical, emotional, and psychological well-being [7]; thus, it will ensure patient safety and improve satisfaction [8].

With the application of ML in measuring facial expression recognition during pain assessment, the inaccuracy in pain scale intensity identification can be reduced at a minimum and bias in human cognitive judgment can be removed. Therefore, this paper aims to propose a new pain scale intensity identification solution using ML facial expression recognition to reduce inaccuracy in pain scale intensity.

2. Related Works

At present, in this 4IR era, the healthcare industry has been a focus for AI due to the potentialities of AI in dealing with vast amounts of data daily [9]. There are various data sources available in healthcare, ranging from patient information, including medical histories, diagnostic results, hospital billing, clinical research, administrative and financial. Utilising this vast pool of data in training AI and ML helps healthcare organisations detect patterns and provide prediction results and treatment recommendations. According to [10], AI provides various opportunities across the healthcare industry as AI is beginning to see fruition, mainly in imaging diagnostic, drug discovery, and risk analytics applications.

2.1. AI in Healthcare

Jiang et al. [10] define AI to mimic human cognitive function. AI is utilised in analytics techniques such as machine learning and natural language processing for structured data and current deep learning and natural language processing for unstructured data. The study discusses several advantages of having AI in healthcare, such as obtaining insights from the high volume of healthcare data in assisting clinical practice. AI helps clinicians in making more informed clinical judgments. Additionally, AI may support clinicians by giving up-to-date medical information from the research and clinical trials that may be used to guide patient care. [11] Yu, K. H., Beam, A. L., & Kohane, I. S. [11]. also explained that AI

system able to lessen unavoidable diagnostic and therapeutic errors in human clinical practice.

However, it is highlighted that the availability and quality of data may limit ML applications in pain research due to the need to maintain knowledge bases and the success of enrolling the required large number of subjects in clinical studies [12]. This gap and limitation can be bridged with the support of big data analytics engagement with ML.

2.2 Existing Pain Intensity Identification Scales

The existing general standard in clinical practice in identifying pain experienced by the patient is the self-reported approach by the patient. The two most widely used self-reported quantitative pain scales in clinical settings for pain assessment in both medical and computational field are the Numeric Rating Scale (NRS) [13] and Visual Analog Scale (VAS) [14]. The NRS is an 11-point scale used for patient pain self-report, which are used for children aged ten (10) years old and above and for adults. Meanwhile, VAS is a unidimensional measure of the pain intensity that mainly used in adult populations. VAS is generally depicted as a 100-mm horizontal line where the pain intensity is denoted by a point between the "no pains at all" and "worst pain imaginable", affixed by two verbal descriptors for each symptom. Figure 1 illustrates the sample of the NRS, while Figure 2 depicts the example of the VAS.

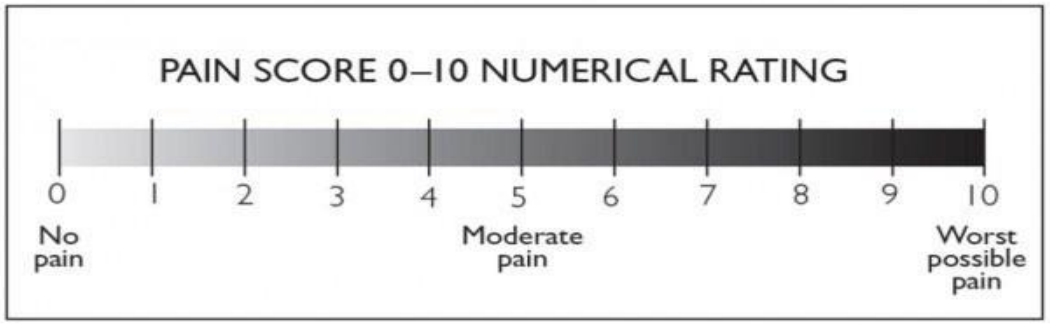

Figure 1. Sample of Numeric Rating Scale (NRS) [13]

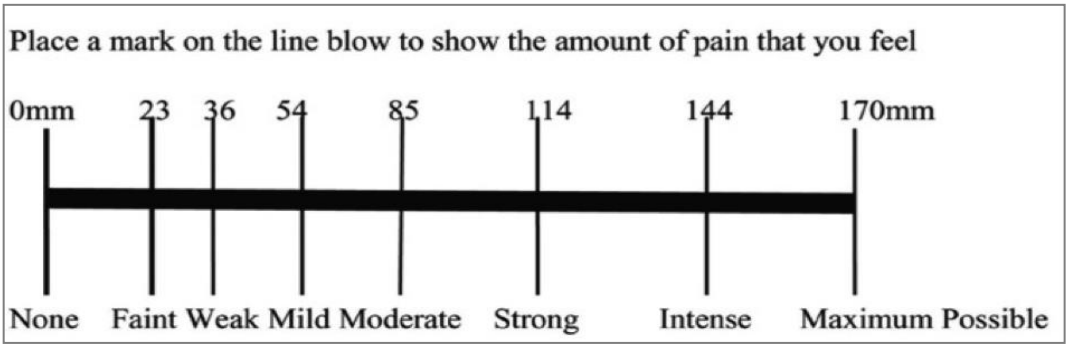

Figure 2. Sample of Visual Analog Scale (VAS) [14]

The Wong-Baker FACES Pain Rating Scale [15] is another sample of the pain scale, which utilises six faces with different expression assigned to a rating from 0 (no hurt) to 10 (hurts worst). This pain scale is used for patients' age three (3) years old and older. Figure 3 depicts the Wong-Baker FACES Pain Rating Scale.

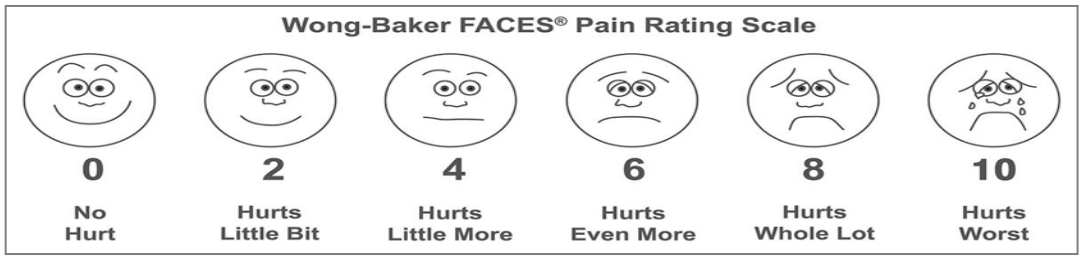

Figure 3. The Wong-Baker FACES Pain Rating Scale [15]

There are several more pain scale currently being widely practised in the healthcare setting for pain assessment, such as Stanford Pain Scale, Brief Pain Inventory (BPI), Global Pain Scale, and McGill Pain Index, as stated by [16]. There is a commonly shared similarity of these pain scales, which are unidimensional pain assessment tools, which only assess one dimension of the experience (pain intensity). According to [16], unidimensional tools have the problem of oversimplifying the pain experience. Certain patients have difficulty expressing their subjective multidimensional pain experience as a number or a point on a line. This results in inaccuracy in pain scale intensity identification during pain assessment, which leads to inadequate pain treatment and relief, besides the wrong diagnosis of pain, which will bring danger to patient safety.

2.3 Facial Expression Recognition

The term "facial expression" refers to one or more movements or postures of the muscles beneath the facial skin. To observers, these motions convey an individual's emotional condition [17]. Perez [18] outlines the common components of facial expression recognition systems that typically begin with image pre-processing and feature extraction, followed by training on predefined training models. Figure 4 illustrates the common facial expression recognition system architectures.

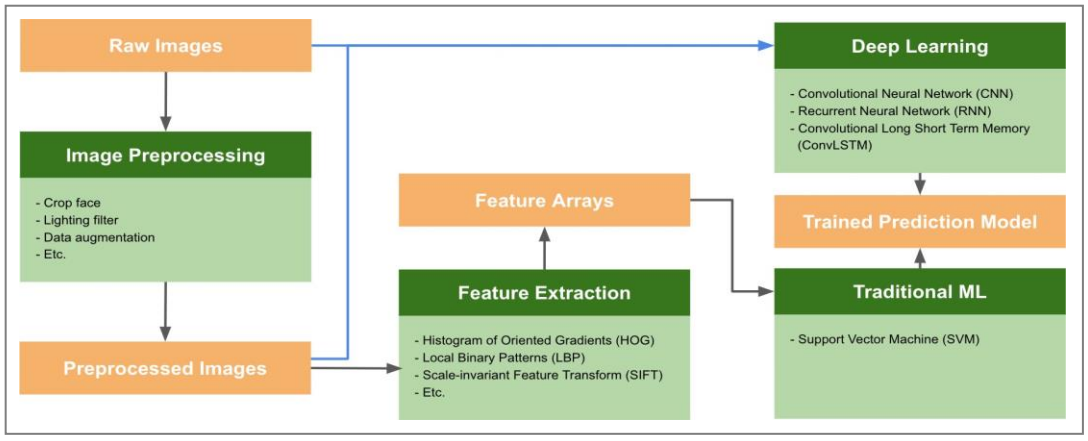

Figure 4. Common Facial Expression Recognition System Architectures [18]

Based on Figure 4, as the image pre-processing or feature extraction stages are complete, the training algorithm able to produce a trained prediction model for the facial expression. There are several algorithms used for facial expression recognition such as Hidden Markov Model (HMM), Ada Boost, Sparse Representation (SRC), Multiclass Support Vector Machines (SVM), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Convolutional Long Short-Term Memory (ConvLSTM). These algorithms can be applied in expression recognition methods for pain assessment. There are two commonly used expression recognition methods: Frame-Based Expression Recognition, which uses the information of current input image with/without a reference frame and Sequence-Based Expression Recognition, which uses the temporal information of the sequences to recognise the expressions of one or more frames.

3. Proposed AI Solution in Pain Intensity Identification

Figure 5 illustrates the summary of the relationship between the problem of inaccuracy in pain scale intensity identification, the solution, which is the application of ML to identify pain scale intensity via facial expression recognition, and the impact of the proposed solution.

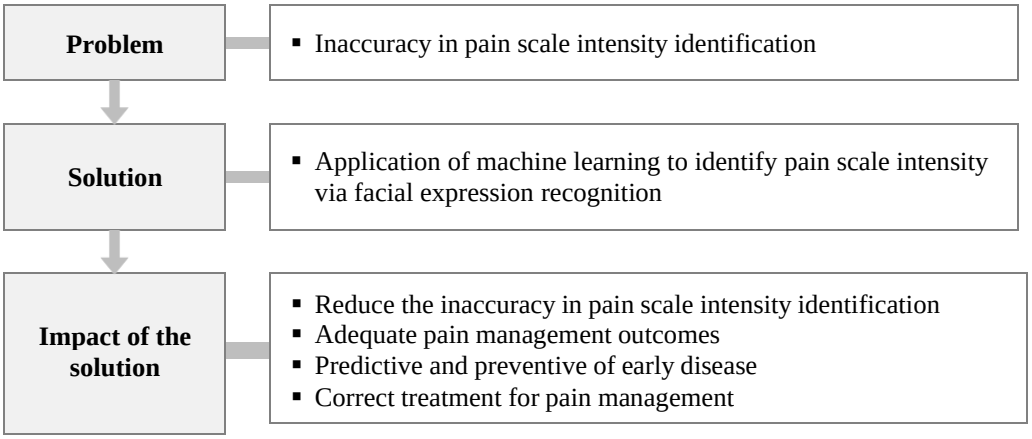

Figure 5. Summary of Relationship between Problem, Solution and Impact of the Solution

The problem discussed in this study is depicted in a cause-and-effect diagram or also known as Ishikawa Diagram, as in Figure 6. The study has identified six factors: Environment, Machine, People, Technology, Measurement and Process. The cause of each factor is identified to configure the root cause of the problem.

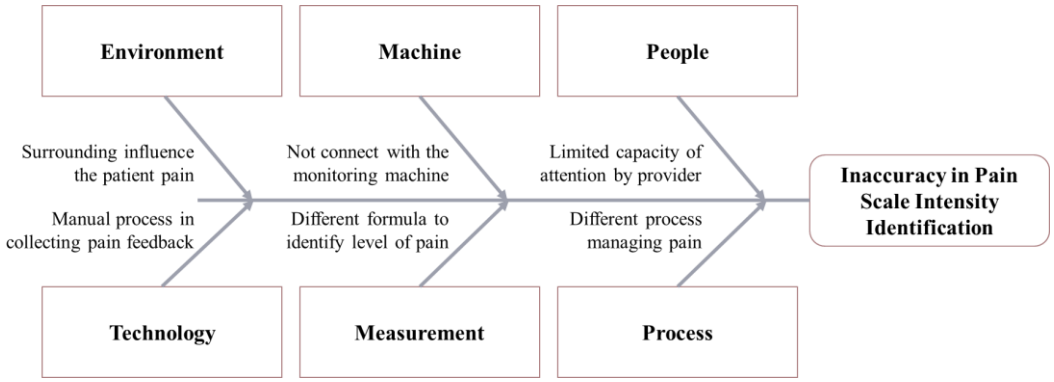

Figure 6. The Ishikawa Diagram of the Study

This study focuses on the Technology factor of the problem discussed. Manual process in conducting pain assessment using quantitative pain scales such as NRS and VAS is one of the causes of inaccuracy in pain scale intensity identification. This study proposes the application of ML to solve the problem of inaccuracy in pain scale intensity identification. ML can classify complicated features to predict a pain phenotype class from a complex pattern of acquired information [12]. Via facial expression recognition, the ML will analyse, identify and recognise the pain of the assessed patient with provided pain-related data to come out with an accurate pain assessment and suggestion of treatment. With that, clinical providers can plan and deliver the best care services.

The proposed solution to reduce pain scale intensity identification inaccuracy was defined and described using the 5W1H method as a guideline basis. Knop, K., & Mielczarek, K. [19] explains that the 5W1H approach is used to describe and analyse a problem by answering five questions beginning with the letter W (What, Where, When, Who, Which) and one question starting with the letter H (How). However, this proposed solution uses "Why" in the 5W1H method instead of "Which" to define and describe the proposed solution. Table 1 describes the 5W1H of the proposed solution.

Table 1. 5W1H of the Proposed Solution

5W1H	Question	Answer
What	What is the proposed solution to reduce inaccuracy in pain scale intensity identification?	The application of facial expression recognition in reducing inaccuracy in pain scale intensity identification
Where	Where can the solution be implemented?	Emergency room, operating theatre, critical care area and screening room

5W1H	Question	Answer
When	When can the solution be implemented?	During pain assessment
Who	Who responsible for managing the solution?	Clinical providers (Doctor, nurse, allied health professionals)
Why	Why should the solution be implemented?	a) Predictive and preventive of early disease b) Pre-emptive treatment to be delivered based on personalised precision, pervasive and patient centralised healthcare c) The correct treatment for pain management
How	How to implement the facial expression recognition solution?	The implementation of a machine-learning algorithm to recognise and evaluate the facial expression for accurate pain scale intensity identification

As depicted in Table 1, the solution proposed to reduce inaccuracy in pain scale intensity identification is the application of ML to recognise facial expression during pain assessment. Since facial expressions are a behavioural indicator of pain, clinical professionals will be able to use the solution to conduct pain assessments on patients to detect and assure appropriate pain management medication and be predictive and preventative of early disease. Based on our review, the most effective method in recognising pain is the Facial Action Coding System (FACS), written in the Manual for the Facial Action Coding System by Rosenberg, E. L., & Ekman, P. [20] FACS utilises an anatomical and descriptive approach to facial expressions, identifying and analysing the unprecedented changes produced by individual facial muscles or muscle combinations. Data of facial expressions such as brow lowering, eye closure, skin is drawn firmly around the eyes, straight stretched mouth opening, and more can be used to train the ML in recognising pain. From the review and assessment done through the 5W1H method, we conclude the idea in a set of questions as shown in Table 1 into an evaluation form to be distributed to the experts in ML.

4. Pre-Test Evaluation

An evaluation session was conducted to evaluate the solution impact. Three external evaluators evaluated the proposed solution for reducing the inaccuracy in pain scale intensity identification. The evaluation of the solution was conducted using an evaluation form, divided into three main sections: Problem, Solution, and Impact and Evaluators Comments. The Problem section explains the problem's problem, while the Solution section explains the solution proposed for the problem. Impact and Evaluator's Comments section was divided into four (4) perspectives based on the Triple Bottom Line (TBL) framework: i. Stakeholder (users/participants); ii. Business & Economy

(profit); iii. Social (people); and Environment (planet). The TBL is a framework that incorporates three dimensions of performance and has been widely used in determining sustainability in healthcare research [21]. It consists of social, environmental and financial, generally called the three (3) Ps: people, planet and profits. Each of the perspectives is organised for the impact and evaluator's comment: agree/disagree, why agree/disagree, and idea for improvement. Table 2 explains the summary of the solution impact evaluation.

Table 2. Summary of the Solution Impact Evaluation

Perspectives	Impact	Agree / Disagree	Why Agree / Disagree	Improvement
Stakeholder (users / participants)	Assist clinical providers in assessing the right pain intensity to ensure right pain management ▪ Right pain assessment via facial expression recognition	All agree	▪ Able to get the faster result in pain identification ▪ Facial expression recognitions will remove the bias of judgment ▪ ML technology helps and sets the bias of judgement to the minimum level	▪ Combination with mood and personality detection of patient ▪ Combination with electrical pulse and heart rate monitoring
Business & Economy (profit)	Ensure patient safety and increase patient satisfaction. ▪ This will indirectly promote healthcare among the community.	All agree	▪ Safety in healthcare is essential. All new technology must have the safety element in handling the patient. ▪ Help to increase patient satisfaction, thus giving good reputation to the health provider ▪ Make the patient feel comfortable to undergo treatment	Reduce dependencies on doctors and nurse, thus reducing cost for the health provider
Social (people)	Properly assess the society needs in healthcare. ▪ Improve the well-being of society with optimal healthcare treatment.	All agree	▪ Helps healthcare resource in fulfilling the demand in healthcare of the ageing population ▪ Improves the healthcare culture by correctly diagnosing the pain ▪ Contributes to longer life and better healthcare management.	Change the healthcare culture, remove dependencies on rarely skilled worker and reduce medical cost
Environment (planet)	Help transform traditional sectors and systems to protect biodiversity and human well-being.	All agree	▪ AI is the solution for a community that continuous natural deteriorate ▪ It helps to improve the human lifespan in the long run ▪ Increase numbers of cure of diseases	The technology can be expanded to another medical task.

Based on the evaluation of the proposed solution in Table 2, some improvements were noted to improve the solution for reducing pain scale intensity identification inaccuracy. The proposed solution is to use ML to recognise and analyse the facial expression of the assessed patient during pain assessment. Based on the evaluation, the answer will include the new elements: mood and personality detection of the patient, electrical pulse and heart rate monitoring to be included with facial expression recognition to achieve a better and accurate result of pain assessment. Combining these elements will produce the result for pain scale intensity at the lowest point of inaccuracy and free from the bias of human cognitive judgment.

Conclusion

Inaccurate pain evaluation can result in suboptimal outcomes and interventions for pain management. It can have a detrimental effect on the patient's physical, emotional, and psychosocial well-being. With the application of ML in measuring facial expression recognition during pain assessment, the inaccuracy in pain scale intensity identification can be reduced at a minimum and bias in human cognitive judgment can be removed. This paper was concluded with emerging improvements to the proposed solution of using facial expression recognition to reduce inaccuracy in pain scale intensity. With accurate pain assessment, clinical providers able to deliver better care and treatment to the patients.

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