Automatic Pain Recognition Techniques: A State-of-the-art Review

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I. INTRODUCTION

Pain is a dynamic occurrence that has been still not clearly realized. The standard statement of pain is “a stressful associated with emotions response generated by probable muscle injury, or characterized in relations of certain destruction”[48]. Basic research, on the other hand, continues to advance scientific knowledge of pain, and there is an active discussion about changing the definition [49-50]. Such kind of pain, known as acute pain, supports in the identification of potentially hazardous situations, the prevention of tissue damage, and the facilitation of recovery by preventing behaviours which may cause further tissue damage [50]. Many humans, as well as community overall, are affected by pain. The growing demand for pain treatment has been aided by advances in medicine: Many people now a days are suffering diseases that were formerly deadly, such as HIV, cancer, and cardiovascular disease. However, they will have chronic pain as a result of either the existing disease or the surgery or even after the sickness has been cleared, by neurological damage caused by the condition [52]. Chemotherapy, Surgery, and radiotherapy are all common treatments that inflict pain [31]. Persistent pain has serious consequences for the person in pain, as well as her friends and family members.

Scientifically valid pain assessment is needed for diagnostic process, selecting a suitable treatment, evaluating progress, and deciding whether such a treatment should be maintained or improved. So that, assessing and managing pain is important besides for providing relief. But also for eliminating together instantaneous and lasting implication as decreases life eminence however, it also completely undermines the neurological system [41]. Unrelieved pain can rise to chronic pain condition, which also is marked by restricted movement, weakened immunity, difficulty concentrating, obesity, and sleep disturbances. However, incorrect therapy might cause complications and complications for patients.

Although advances in technology and knowledge, pain is still mismanaged [52-54], [69]. However this is a
prevalent difficult, it disproportionately disturbs patients with weak message skills, that are unable to communicate overall pain perception and those who’s express has low ecological validity. In the next decade, autonomous pain assessment systems based on pain behaviours will be developed (video facial terminologies, movements of body and vocalizations) and Physiological responses would be used to enhance current pain diagnostic tools in order to achieve better pain treatment. In comparison to conventional assessment methods, it might regularly monitor pain. This could lead to improved treatment outcomes, such as besides facilitating early diagnosis for patients being unable to request assistance on their own. Moreover, automatic structures will be much more accurate rather than a person observer, whom assessment will be affected with different aspects like as the patient’s appearance or relationship to the patient [53, 55, 69, 72, 73].

II. PAIN MECHANISMS AND RESPONSES

Pain is a unique, individual, sensory experience that originates in the brain. Pain is more than just a physical sensation [56]. The pain feeling should be identified from the cause of the pain (such as muscle destruction caused by nerve injury), the pain reaction (vocal communication and non-verbal Indicators) and pain assessment. The cause of pain is usually identifiable, and it can be managed by intentional pain stimulus.

A. Biological Mechanisms

The pain method involves numerous aspects of the neurological structure. The development usually starts with unpleasant mechanical, chemical cold, heat, or inflammatory stimuli activating sensory nerve cells. These signals stimulate nociceptors, which become primary sensory neurons with noxious stimuli-detecting specific receptors. The induced electrodermal impulses are transmitted to the spinal cord through nociceptive fibers. Excitatory network and also inhibitory interneuron network in the spinal cord can be stimulated, resulting in a protective reflexive retraction response. The perceptual exclusionary experience of pain is the result of next processing of nociceptive information in several spinal organs. Whereas a nociceptive signal usually causes pain, numerous factors can influence this response.

B. Biological Responses

Connections among neural network are complex, involved in Pain perceptions and autonomic control [57] because an increase in sympathetic outflow, leading in modifications in physiological signals that can be measurable [58].

Skin conductance is a signal [59] that changes in response to pain and is automatically modulated. Even though sweat organs are just stimulated by sympathetic excitatory sensory neurons [57], increased sympathetic flow in pain response leads sweat to be released into apertures on the surface of skin [59]. Heat influences the electrical performance of the skin (electrodermal, EDA and electrodermal activity), enhancing electrode potential until underarm sweat is evaporated or reabsorbed, sympathetic nervous system excitation also creates significant cardiovascular consequences. It has an influence on the heart rate [60], this induces tachycardia and heart rate irregularity, an indicator of autonomic heart rate control. Especially, Pain massively increases different frequencies power, as evaluated by energy power spectrum. Moreover, Peripheral vascular resistance and stroke volume also are boosted by pain.

C. Behavioral Responses

Facial expressions, gestures, and speech patterns are characteristics of behavioural pain reactions. Chronic pain typically results in significant changes in daily behaviour and public communication. Presently, various pain-related facial terms that happen comparatively constantly across a wide variety of laboratory pain situations and evaluation pain methods [61]. Consequently, the intensity of facial movement’s increases as the strength of painful stimuli increases [62]. The majority of pain-related bodily motions help to defend against future harm and to relieve unpleasantness. Pain behaviour also includes paralinguistic vocalisations (laughing, groaning, and moaning) and sound quality features including loudness, and insecurity detected throughout voiced report [61].
D. Emotion and Pain

Pain is classified as either a sensory or also an emotional reaction. It has an emotive element that covers a wide range of feelings, the majority of which are destructive and connected to the discomfort to potential consequences. Aggression and sorrow also performance key roles, particularly in chronic pain [62]. Lastly, physiological and behavioural responses indications and their groupings, the issue of whether pain can be consistently and objectively separated from its associated emotions remains unresolved.

III. TOOLS FOR PAIN ASSESSMENT IN CLINICAL APPLICATION

In clinical practice, pain is typically based mainly on the patient's report intensity and variables that relieve and increase the pain. Self-reporting is the explicit presentation of pain associated information through a person in pain, generally through verbal or gestures such as directing to an illustration that signifies their feelings in answer to a request. Patient care regulations underline that report is the utmost reliable method of measuring pain if the person is able to speak [63-69].

IV. DATASETS

The best frequently used database is the BioVid Heat PainDatabase [35]. It was acquired through a partnership between the University of Magdeburg's Neuro-Information groups. Total 90 patients were submitted to four intensities of experimentally induced heat sensitivity. Table 1 represents the properties of publicly accessible datasets for pain recognition research.

V. METHODOLOGIES OF PAIN RECOGNITION

We directed an efficient literature search, as described in introduction, to evaluate the existing automated pain recognition approaches. In the next subsections, we explore the recognition input systems and the system processing techniques.

A. Modalities and Sensors

Pain assessment needs at minimum single sensor information stream to share information to the machine. A medium of this type is sometimes referred to as a modality. The most significant pain recognition modalities may be classified into two parts: behaviour and physiology. Face expression; body motions like rubbing, guarding, and skull movements; vocalisations and vocal arguments that can be shared by communication and may contain self-report information are all examples of behavioural modalities. In the physiology area, brain action, cardiac action are all of interest. A uni-modal system consist of only one modality; a multimodal approach takes input from multiple modalities.

1) Camera-Based Methodology: To date, the large majority of pain detection systems have relied at camera imagery with facial expressions. The majority of existing pain recognition research focused on Facial expression modality. In general, cameras have a narrow range of view, thus understanding images is much more complicated than processing other instrument inputs. Cameras, on the other hand, are non-contact devices that may be more comfortable or patients and more efficient for healthcare workers than contact-based sensors [42].

2) Contact-Sensor Techniques: The direct interaction sensors EDA and ECG have been the second-most extensively utilised. Since, the introduction of the BioVid database, followed by sEMG of the trapezius muscle-Sensor techniques. Pain was identified using a variety of physiological indicators acquired from electronic flow spreadsheets in institutions. EDA consistently outperforms the only one modalities that have evaluated [25], [33].
TABLE I. Databases for Pain Recognition that are available to the public for research

<table>
<thead>
<tr>
<th>Database</th>
<th>Subjects</th>
<th>Stimuli</th>
<th>Data Modalities (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioVid Heat Pain [30], [66], [67]</td>
<td>Total 90 adult participants</td>
<td>14k heat pain (20 repetitions 4 intensities 2 parts 90 adult patient)</td>
<td>Video signal, biomedical indicators</td>
</tr>
<tr>
<td>BP4D-Spontaneous [64]</td>
<td>Total 41 adults</td>
<td>emotion elicitation, 41 cold pressor task</td>
<td>Color and 3D video of face</td>
</tr>
<tr>
<td>BP4D+ [68]</td>
<td>Total 140 adults</td>
<td>emotion elicitation, 140 cold pressor task</td>
<td>Face of color video 3D and thermal, medical signal such as respiration rate, blood pressure, heart rate and EDA</td>
</tr>
<tr>
<td>UNBC McMaster Shoulder Pain [65]</td>
<td>Total 25 patients shoulder pain</td>
<td>Total 200 video signal,</td>
<td>Face video such as low resolution, social interaction and talking</td>
</tr>
<tr>
<td>MIntPAI N [41]</td>
<td>Total 20 adults</td>
<td>40 stimuli in 4 intensities of 2 trials and 20 participant of 2k electrical pain</td>
<td>Fave video of color, thermal and depth</td>
</tr>
</tbody>
</table>

TABLE II. Bio-Vid Database has been used to evaluate Pain Recognition systems

<table>
<thead>
<tr>
<th>Author</th>
<th>Feature</th>
<th>Classification Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. Amirian et al. [71]</td>
<td>Descriptor with time series statics signal.</td>
<td>Radial Basis Function networks</td>
</tr>
<tr>
<td>S. Gruss et al. [72]</td>
<td>159 features based on statistical analyses</td>
<td>radial basis function kernel and SVM</td>
</tr>
<tr>
<td>M. Kachele et al. [22]</td>
<td>Head pose, peak height and difference, B.W. and entropy.</td>
<td>SVM and Random forest</td>
</tr>
<tr>
<td>M. Kachele et al. [23]</td>
<td>Physiological signal and geometric-based and appearance-based from video.</td>
<td>Random Forest (RF)</td>
</tr>
<tr>
<td>M. Kachele et al. [24]</td>
<td>Mean and the standard deviation from EMG.</td>
<td>KNN and Random forest</td>
</tr>
<tr>
<td>M. Kachele et al. [25]</td>
<td>frame level, skewness, spectral entropy, entropy and density</td>
<td>Random Forest</td>
</tr>
<tr>
<td>Lopez-M. 17 [26]</td>
<td>calculated the Skin conductance (SC) and Electrocardiogram (ECG) features</td>
<td>multi-task neural network (MT-NN)</td>
</tr>
<tr>
<td>Lopez-M. 18 [27]</td>
<td>Mean, max, range, AUC</td>
<td>Recurrent neural network-based regression algorithm</td>
</tr>
<tr>
<td>Walter 15 [29]</td>
<td>Features based on signal amplitude and frequency also based on entropy, stationary and statistical moments, statistical parameters from video signal</td>
<td>KNN and Random forest</td>
</tr>
</tbody>
</table>
B. Features and Models

The raw data is analysed for patterns that can be used to predict a pain state in the person being studied. Features are collected from the input signal, which are a more exclusionary and generally lesser dimensional representation. There are an amount of diverse kinds of features classified as (1) learned features, (2) generic features, (3) hand-designed. Generic features are useful in other domains, but pain recognition they not provide better result. Such as, LBP image features. Hand-crafted features are constructed for a specific objective through dedicated knowledge; they are generally simple to interpret and low-dimensional. Another feature such as use during the training procedure, the extracted features is optimized for the specific task termed as learned features. These are typically higher dimensionality and hard to interpret.

1) Face Expression Features: Feature extraction is a process in the processing system during camera-based facial pain expression analysis. It might include 1) identifying facial characteristics (points around the mouth, brows and eyes and among others) 2) To improvement invariance to translation, scaling, and rotation, utilize facial texture. A range of frame-based features have utilized to pain recognise [1], [8], [11], [15-16], [19], [20], [35]; simplest pixel representations represent illustrations using generic appearance features [3], [21], [37], LBP [8], [12], [16], [18], [20], [35], HOG [1], [6], [12], [34], Discrete Cosine Transform (DCT) [35], Gabor [9], [12], [20], [39], [44], Scale Invariant Feature Transform (SIFT) [10], [14], neural network-learned features [7], [13], [17], [21], [41].

2) Physiological Features: All other sensor signals, apart from camera images and neuroimaging, are interpreted as time signal. In the evaluation of sEMG, EDA signals, we identify numerous variations of Time series signal Descriptors (TSD). Walter [48] investigated the effectiveness of amplitude, variability, and frequency. sEMG (corrugator, zygomaticus muscle and trapezius) and stationarity, EDA frequency, entropy, linearity and, entropy features for pain recognition. Based on physiological objectives, EDA has divided into two aspects while retrieving information from both components independently [23], [25], [28], [33].

3) Recognition Models: After feature extraction, the framework that relates the features to the implicit pain status is the second essential processing component. The model may also include data fusion, especially for system integration in a multimodal system, which can be done at the decision, feature, or intermediate levels. The most of methods utilise Support Vector Machines (SVMs) to categorise pain, either linearly or with a Radial Basis Function (RBF) kernel [11], [28], [30], [38], [39], [42]. Relevance Vector Regression generates continuous-valued output [1], [5] and related Support Vector Regression [2], [4], [16], [20] models. Random Forests are another popular model (RF) [29], [32], [35], [36], [41] variations of Conditional Random Fields (CRF) [3], [8], [15], Nearest Neighbor (NN) classifiers [6], [19], [24], [36], [37], and various neural networks. Convolutional Neural Networks are one of the CNN architectures utilised for pain identification [13], [17], [21], [41], Radial Basis Function (RBF) networks [25], Long Short-Term Memory (LSTM) networks [8], [13], [41], Data fusion is a process of integrating various modalities, features, judgement score, or even other information sources to create a single final prediction [22], [23], [25], [33].
C. Ground Truth

Different objectives being explored by the evaluated automated pain assessment systems. The most common are evaluating the existence of pain (a binary classification) and assessing the intensity of pain. Such systems require adequate ground truth for development and evaluation. The majority of other studies employed the provided stimulus as ground truth, either with [46], [47] or instead of customized assessment [39], [40], [43]. The most of these studies aim to investigate the occurrence of pain or anticipate the intensity of symptoms in separate categories [40],[41], [45]. The later researches revealed that an integrated computer vision system outperformed skilled human observers in identifying realistic from manufactured pain signals on the face.

VI. CONCLUSION

Health services are complicated processes which include interaction among people, organizations, and equipment. Researcher kept in mind these information as an initial phase to design an intelligent health-care system. This article provides a complete overview of pain assessment techniques that depend on several machine learning techniques. The dataset utilized for pain assessment was consider as video or image-based facial expression or biomedical signal.

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