IoT-based Pain Monitoring and Management System

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Abstract

Patient suffering from pain is in need for an immediate medical intervention, however in some cases self-pain assessment is not available due to unconsciousness or prone to errors due to observer's biases. Therefore, automated pain assessment and management is needed. The internet of things (IoT) revolution along with biosensor technology could be convenient for pain assessment and management application. Therefore, this paper is a mini-survey of the literatures in this field published in six years (2016–2021) was conducted in three online databases. Hundreds of papers were found, however after title, abstracta and contents screening only 13 papers were included. This paper is aimed to review the papers that suggest a pain assessment model in a IoT philosophy, in order to summarize the present work and propose new suggestions for future work. Research with different pain levels, in a bigger and real patient population with different diseases were suggested in the conclusion for future work.

Keywords

Internet of Things, pain monitoring, pain management, biosensor.

1. Introduction

Pain is the fifth vital sign besides the temperature, pulse rate, respiration rate and blood pressure. Furthermore, it is one of the most warning signs for seeking medical consideration [1]. Mostly, pain could significantly contribute the quality of life and cause psychological disturbance including depression, sleeping disorder, anxiety and fatigue which lead to physiological problems. Therefore, adequate assessment of pain is essential for precise determining of appropriate treatment [2].

Commonly, pain assessment is done through a self-report or different observational pain scales such as Numeric rating scale (NRS) [3] and Visual Analogue Scale for Pain (VAS) [4]. However, self-reporting method could be prone to different types of errors, including the subjective biases of the observer and patient's ability to express the amount of perceived pain. Moreover, under special circumstance as in the patients who are noncommunicative it is not possible to assess the amount of pain. On the other hand, accurate pain management relies on continuous and precise pain assessment, however, it is impractical to continuously monitor pain by humans. Furthermore, overdosing of pain-killers could be a life-threatening problem that may cause a prolonged sedation or hepatic injury [5].

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Therefore, researchers through the last decade tried to identify the alter of different physiological signals as a consequence of pain suffering, including electromyography (EMG) [6], electrocardiography (ECG) [7], electroencephalography (EEG) [8] and photoplethysmography (PPG) [9] in real-time monitoring. ECG are the process of measuring the small electrical fluctuation produced by the cardiac muscle and it gives as indication about blood flow, while EEG evaluated brain's electrical activity and the EMG tracks the electrical activity of the muscles. Moreover, PPG signal measures blood volume change using irradiation light applied non-invasively to peripheral body sites. All these signals show alteration and abnormalities during suffering from pain. Galvanic Skin Response (GSR) is another characteristic that exhibits fluctuation in the signal during pain due to change of skin conductance.

In the last years, physiological parameters such as heartbeat is not assessed through a clinical and physical examination. Today, a smartwatch can identify heartbeat and the observed data is sent to a cloud through a wireless network to be observed by physician, hospital, and other stake holders. Furthermore, data is stored in a digital form and analyzed for machine deep learning (ML) purposes. All the previous process is done through what is known as the internet of things (IoT) which connect computer and healthcare provider together to make our life easier [10]. Figure 1 illustrates the lifecycle of the IoT assisted wearable sensor system in health care.

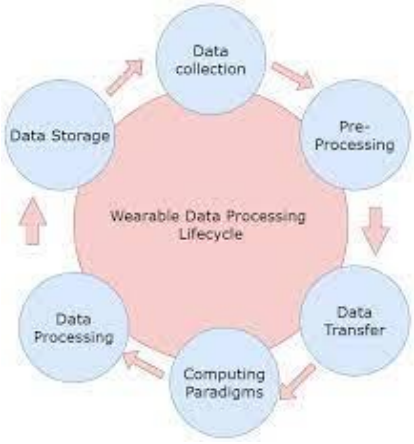


Figure 1: Data processing lifecycle IoT assisted wearable sensor systems in healthcare [11]

In this mini-review, the aim is to overview, consolidate and summarize the work that has been done over the last six years to automatically assess pain from different biomedical signals including EEG, EMG, PPG and GSR, to identify the challenges and determine the direction of future researches. In this paper, a survey of "IoT" and "pain" database is done in three different online databases. Then a focused reading, studying and categorization followed by concluding is performed and many papers were excluded in this stage according to the methodology described in the second section of this paper. All the results of the survey of the databases containing IoT using in paint monitoring and controlling were discussed and presented in section three. Section four concludes the paper and discusses the future opportunities of such work.

2. Methodology

Papers in this mini-review were collected by searching three online database, including google scholar, ScienceDirect and IEEE Xplore. All the research articles, review articles, book chapters, conference papers were included in the research, however, the review articles were excluded during results analysis and discussion. The research was conducted during December 2021 and is limited to six years period, which

is between 2016 and 2021. Furthermore, the search was limited to English language papers and the search keywords was 'IoT' OR 'Internet of Things' AND 'pain assessment' OR 'pain monitoring'.

The inclusion criteria in this mini-review were based on 1) any scientific paper that describe IoT-based solution for pain management, 2) all included papers should mentioned the word 'internet of things' or 'IoT' or any technique used in IoT, 3) review articles, mini-review articles, papers with only an abstract and case reports were excluded.

The papers were collected for review and the following points were focused on during reading:

- The paper is about pain detection or assessment not targeted emotions, mental health, happiness or sadness and stress.
- The paper is targeted a patient with pain or a disease that causes pain not affecting the healthy person with a painful stimulus like heat to cause pain and assess that pain accordingly.
- The physiological parameters detected, or the biosensor used, on the other hand the IoT technology used in the work.

3. Results and Discussion

Three databases were searched for suitable papers depending on the review methodology of this mini-review. Hundreds of papers were found then they were filtered after reading the abstract. For instance, in the ScienceDirect database 274 papers were found in the period between 2017–2021, and they are distributed as per Fig. 1. As per figure the subject started to gain interest more after 2019.

However, after reading the abstract many papers have been excluded due to many criteria, for instance miss understanding between pain and mental health and emotions which is not an indication of pain specifically. Moreover, papers that were not about medical application of pain assessment were excluded too.

The over all papers after all the exclusion were 12 papers as listed according to the year of publication in Table 1. Physiological parameter or biosensor used, medical problem targeted, IoT-based technology used and wither the paper worked on pain assessment or pain management or both were mentioned in Table 1.

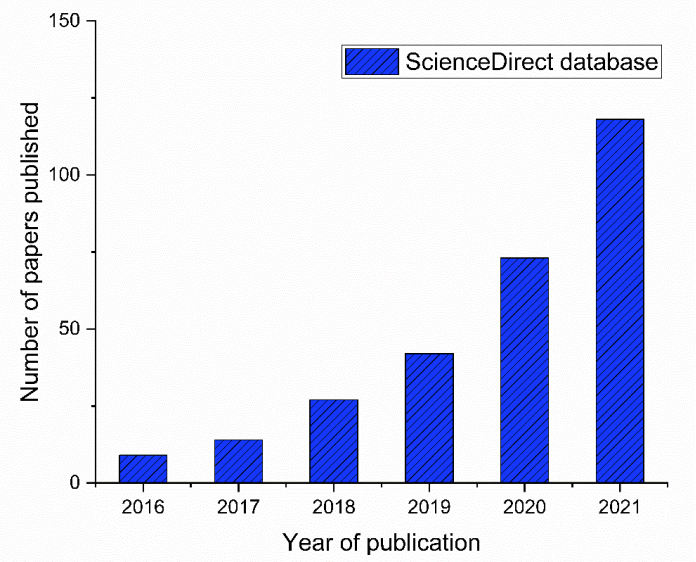


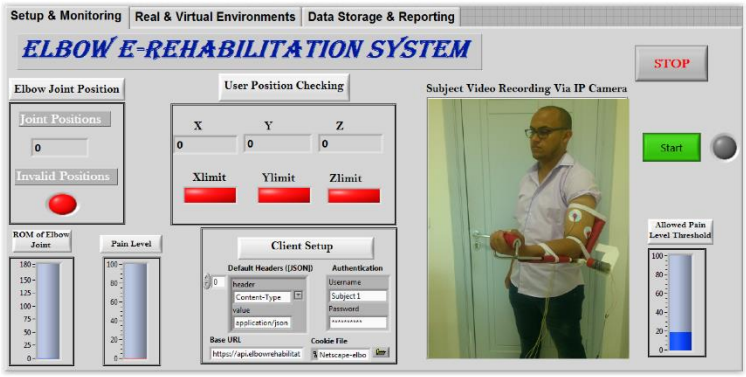
Figure 2: Numbers of papers published during the period 2017–2021 in the ScienceDirect database

As per Table 1 the "pain assessment" and "IoT" subject work started to increase after 2019. For instance, in 2020 (6/12) papers in pain assessment and IoT technology in medical application were published. Furthermore, (7/12) of the papers were on patients after surgeries especially orthopedic ones like joint replacement surgeries and in intensive care unit. Mostly, the reason behind that is poorly controlled post-operative pain correlated with prolonged duration of recovery, impairment of daily life and eventually increase morbidity, according to reference [24]. Therefore, continuous assessment and control of pain through applying of drug analgesia according to pain intensity is a cutting-edge subject that would cost lower health-care expenses in addition to adequate treatment and recovery. Furthermore, few papers were about specific disease and pain caused by them like tension-type headache (TTH) and Sickle cell disease. One paper was about remote rehabilitation of elbow and control of pain due excessive movement, through a feedback process. Fig. 3 shows an overview of the control architecture.

Table 1: A list of the reviewed references according to year of publication. The physiological parameter or biosensor, medical problem, IoT-based technology and Pain monitoring and management are mentioned

Year of publication	Physiological Parameter or biosensor	Medical problem	IoT-based Technology	Pain monitoring	Pain management	Ref.
2016	Facial expression using surface EMG	Patient with pain	Wi-Fi with a cloud serve	Yes	No	[12]
2018	Facial expression using surface EMG	Intensive care unit patients	Mobile web application with cloud server	Yes	No	[13]
2019	PPG depending on pulse counting analysis	Post operative patient	A model builds on multiple logistic regression	Yes	No	[14]
Year of publication	Physiological Parameter or biosensor	Medical problem	IoT-based Technology	Pain monitoring	Pain management	Ref.
2020	High-density pain-evoked EEG potential	Patient with pain	Auto encoder model based on CNN[1]	Yes	No	[15]
2020	Clinical notes	Sickle cell disease patient	Four binary ML[2] classifier	Yes	No	[16]
2020	Peripheral blood flow and skin ability to conduct electricity using PPG and GSR	Patient with pain	Several communication protocol for IoT	Yes	No	[17]
2020	GSR, EMG and EEG signals	TTH	FOG computing	Yes	Yes (Biofeedback therapy)	[18]
2020	EMG signal	Remote elbow rehabilitation	Fuzzy logic	Yes	Yes	[19]
2020	Force and sweat sensor	Indication of labor pain	GSM through cloud server	Yes	No	[20]
2021	Electrodermal activity of GSR	Post-operative patient	ML algorithms	Yes	No	[21]
2021	PPG spectrogram	Post-operative pain in conscious patient	CNN	Yes	No	[22]
2021	Heart rate and body temperature	Post-operative bone and joint replacement surgery	System based on NOA[3]	Yes	Yes (Drug analgesia)	[23]

[1] CNN is a convolutional neural network; [2] ML is a machine learning; 3 NOA is a neuro optimization algorithm.



(a)

(b)

Figure 3: Control architecture overview.

Facial expression using a surface EMG biosensor for pain assessment was one of the technique used to quantify the pain, however no works were found after 2018. The reasons behind this is claimed to be that this technique faces several challenges related to data acquisition and development, on the other hand pain assessment system should be capable to be adapted according to patient facial morphology and texture [25]. However, Yang et al. [13] have designed a wearable mask based on surface EMG signal for continuous pain assessment as per Fig. 4.

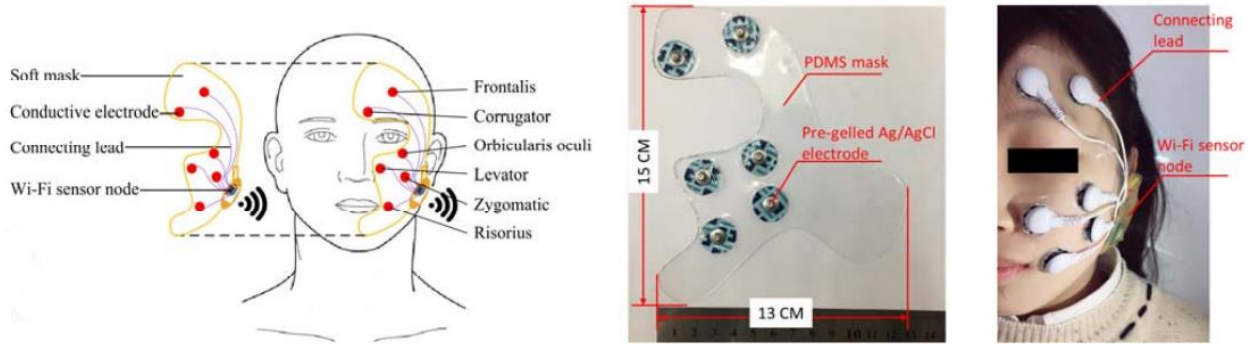


Figure 4: Facial mask for continuous pain assessment design concept and electrode embedded in addition to the complete wearable device

Furthermore, a paper was about labor pain assessment using a belt around the belly that sense the sweat using a GSR sensor and the force generated by delivery contractions. Biosensors used in papers were

equally used in (4/12) for GSR, EMG and PPG, however EEG was the less commonly used due the artifacts and requirement of high data transmission rate and large storage capacity [17].

4. Conclusions

As a conclusion, pain monitoring and control is a worthy and wide-range research topic. The studies mentioned in this mini-review are poor in many aspect, for instance, number of applied patients, scale of pain level and connection with medication management system. However, several biosensors and IoT technologies have been covered by the researchers, but the effective application of the automated pain assessment is yet to come.

This mini-review discussed a total of 12 paper in pain assessment ant management using IoT-technology in many medical applications. Future studies can be more precise in the medical application they targeted, for instance, considering cancer patients who suffers from sever pains and in need for medication control, also patients with high rate of heart stroke who suffers from severe chest pain and in need for immediate medical intervention.

Furthermore, future studies concentration on Fog networking, that can support the big data structure and large cloud system with large geographical distribution are expected to further improve performance.

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