Multimodalities Pain Assessment System towards Robot Based Diagnostics

Nur F. M. Rozaini, Christina Pahl and Eko Supriyanto

Abstract**—**The aim of this study is to classify pain level using different modalities including Electromyography (EMG) and Electro Interstitial Scan (EIS) for the future robot based pain assessment. Eleven subjects had participated in this study with 6 of them already prescribed with pain and another 5 was a healthy subject. The survey has been conducted to access pain level using commercial Visual Analogue Scales (VAS). Data from EMG, EIS, and VAS were analyzed using a statistical method to find correlation, sensitivity, specificity and accuracy. Test results show that EMG and EIS data has a strong correlation which is 0.85. Diagnostics accuracy of using jointly EMG and EIS data in comparison with VAS data is 81.81%. Whereas using EMG only is 72.7% and EIS only is 54.55%. This is a good sign to implement the robot based EMG and EIS pain assessment.

Keywords**—**Electromyography, Electro Interstitial Scan, pain assessment and robot based diagnostics

I. Introduction

PAIN was generally known as physical suffering or discomfort caused by injury and illness. According to International Association for the Study of Pain (IASP), pain is defined as an unpleasant sensory and emotional which we primarily associate with tissue damage or describe in terms of such damage or both [2]. The pain was a most common presenting or associated symptom in hospitalized patients, and patient more concerned about being a pain rather than their primary reasons for being hospitalized [3]. There are three types of pain that were based on where our body can felt pain; somatic, visceral and neuropathic. All this three pain can be either acute or chronic pain. Acute pain was a postoperative pain, related to soft tissue damage and usually was a short duration but gradually resolved as the injured tissues heal. The different types of pain will respond differently to the various pain medication and treatment. Somatic and visceral pain is easier to treat that neuropathic pain. A pain assessment and management was one of the systems to a detected pain level of the patient.

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Types of pain rating scales included verbal scales, numerical scales, and visual analog scale. Different pain assessment tools were used for an infant, children, and adults.

Pain assessment scales are useful for a patient response about their comfort and discomfort, for enhancing in communication, and for supporting an individual pain management program. A survey made in Canada shows that majority of the nurses agree, 94% that pain assessment system was important for the patient to impress their feeling of pain for patient able and unable to communicate [5]. Therefore, clinicians should use suitable pain scales to evaluate and measure pain scale.

One major disadvantage of pain scales is that pain cannot accurately describe and measured. The pain was very subjective and can only be described in terms of its intensity. In order to increase the accuracy of pain assessment system, this project will design and develop systems that use more than one modalities of the system to assess patient scale.

This project will involve all possible modalities that can assess patient pain assessment scale. From the interaction of all possible modalities, multi-modalities pain assessment system will be designed. This project is designed to enable automatic diagnostic using either computer systems or robotics systems. Figure1 shows a block diagram of robot based pain assessment system by using a combination of EMG and EIS signal processing signal.

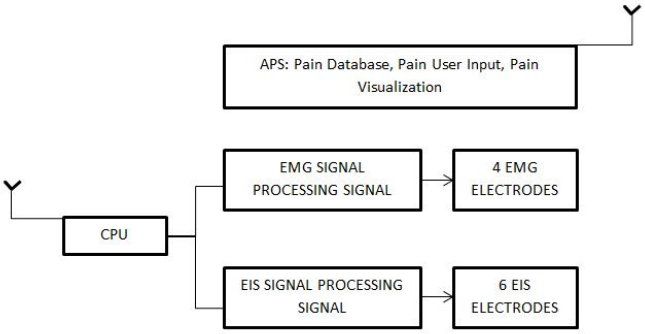

Fig.1 Block Diagram of Robot Based Pain Assessment System

II. LITERATURE REVIEW

A. Visual Analogue Scales (VAS) and Graphic Scales

VAS consists of a line that usually 10cm long, labeled as the extremes of pain from 'no pain' to 'worst pain'. A VAS has a specific point along the line that is labeled with a degree of adjective or numbers [7]. Scales that use an adjective as

points called Graphic Rating Scales. The patient needs to rate their pain along the line that represents the most similar scale of their pain[8].

There is not much evidence to support the validity of VAS for use in measure pain intensity. VAS demonstrates positive relations to another self-report measure of pain intensity to observed pain behavior and is sensitive to treatment effects. Healthcare nurses reported that patient that unable to communicate used a self-tool report more than 50% of the time rather than a patient that able to communicate [4]. The problems with VAS included required more time because involve more steps of measuring pain intensity that lead to more opportunity to patient make an error. This scale required patient to have the ability to make a mark along the line [9]. The patient finds VAS difficult to understand and need careful explanations for the patient to use them accurately.

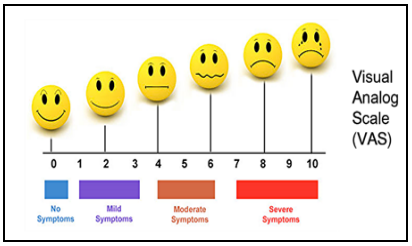

Fig. 1 Example of visual analog scale

B. Verbal Rating Scales (VRS)

VRS consist of a list of adjectives that described the different level of pain intensity. VRS included adjectives that show the extremes of pain; from 'no pain' to 'extremely intense pain' and have an additional subsection that shows the gradation of pain intensity between these two extremes. The patient is asked to read and choose the word that described the most similar pain they feel. Many different VRS scales have been created. According to University Hospital of Wales, VRS consists of 4 point scale of no pain = 0, mild = 1, moderate = 2 or severe = 3 [10]. VRS usually scores by listing the adjectives in order of pain severity and assigning each score based on its ranks.

VRS are easy to comprehend, valid and also related positively to other measures of pain intensity. Even though VRS was extremely unlikely to be perfect, patients may not find a description that accurately described their pain level and patient needs to be familiar with the terms before they can select the adjective that most closely to their level of pain.

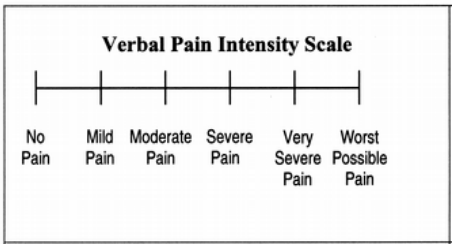

Fig. 2 Example of verbal rating scale

III. METHODOLOGY

The study of "Multi-modalities Pain Assessment System towards Robot Based Diagnostics" generally carried out by stages on Figure 3 below with a complete explanation in Section 3 to 4.

A. Data Collection

Eleven subjects who are prescribed with pain and also no pain were analyzed. The subjects were divided into following two groups: (1) with pain and (2) without pain. The subject criterion was chosen based on multiple pain that they have, such as menstrual pain, injury from sport, lower and upper back pain, the majority of the subject that prescribed with pain already aware about the causes of their pain. The longer pain was recorded, within one year (daily or almost daily). This study was approved by the Faculty of Biosciences and Medical Engineering University Technology Malaysia (UTM) and the subjects was signed a written consent form before the experiment was conducted.

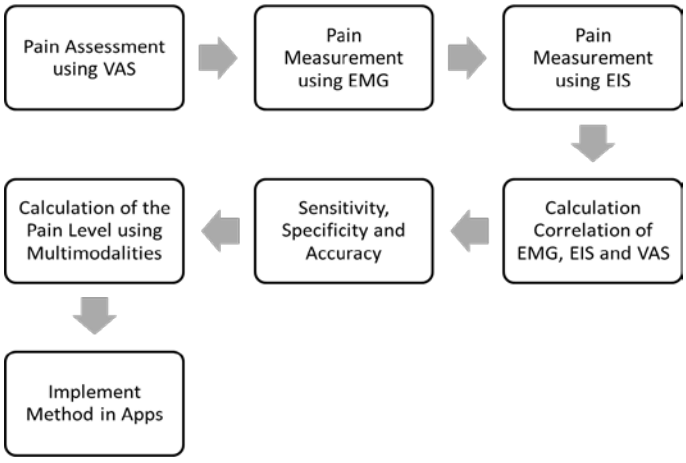

Fig. 3 Method for Development of Pain System Assessment

B. Electromyography (EMG) Procedure

Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). Motor neurons transmit electrical signals that cause muscles to contract. Bio radio FJ was used to detect signals of patient pain, Bio capture, and MATLAB R2013a software was used to process and analyses the EMG signal, while doing this experiment patient was positioned in a proper sleeping posture to avoid muscle from the contract [11]. Before subjects were placed in proper sleeping posture, 4 electrode pads were placed on the right and left the side of the thoracolumbar fascia.

For the sterile purpose, alcohol swab was used to prepare patients for the experiment. After targeting muscle was located, EMG electrode was placed, which are connected to wireless Bio Radio on the surface of the muscle group to detect muscle signals and controlled muscle group. Muscle activity of the patient in term of waveform signal will be displayed on Bio capture software. For this experiment, the

patient needs to stay the same position for about 10 minutes for a signal to be analyzed.

This experiment was done to measure the amplitude of the signal and also see the pattern of the waveform between a patient with pain and without pain. Although we know that patient that claim them has no pain supposedly has no change or flat signal we still perform the test to prove the claim. A patient without pain need to execute the experiment exactly like a patient with pain, in order to investigate the different between both conditions, with and without pain

C. Electro Interstitial Scan (EIS) Procedure

The Electro Interstitial Scanning (EIS) System is used to provide useful information by measuring and interpreting resistance to the flow of electric current through the interstitial fluid (fluid between the cells) throughout the body.

For EIS experiment we used LD technology software to perform and analyzed the data from the patient, during EIS experiment patient was placed in proper sitting posture; shoulders over hips, feet flat on the floor, the lower back support provided, and chin aligned over the chest. After subjects were placed in proper sitting posture, 6 electrodes are placed in contact with the skin; 2 electrode pads were placed on the right and left the side of frontalis area, 2 flat pad electrodes were placed on the hand and another 2 was placed on the feet. Before taking measurements, the electrodes and the skin in contact with them are cleaned with an alcohol swab. The plates also cleaned with a bactericidal solution such alcohol swap for sterilizing purpose. For this experiment, the patient needs to stay the same position for about 15 minutes for a signal to be analyzed.

The software controls the hardware for sending between 2 electrodes a tension of 1.28V+/-0.05 during 3 seconds [12]. The tension with DC current is sent in a chronological way of a negative electrode towards the positive electrode and according to a programmed sequence. Thus the electrodes will be alternatively cathode then anode and will record 22 tissue volumes located between the electrodes. The hardware transmits via ports USB measurements of intensity (255 measurements in 3 seconds) in numerical form to the data-processing program.

D. Data Analysis

1. Data Correlation

Correlation is a technique for investigating the relationship between two quantitative, continuous variables, in this experiment we want to find correlation values between patient assumption of pain level and pain level prescribed from the device. Pearson's correlation coefficient (r) is a measure of the strength of the association between two variables [13].

$$r = \left| \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2)][n\sum y^2 - (\sum y)^2]}} \right|$$

Fig. 4 Pearson correlation coefficient

From this method, we can know which modalities have a stronger correlation. The following points are the accepted guidelines for interpreting the correlation coefficient:

- 0 (no relationship)
- $0 < r \leq 0.3$ (weak relationship)
- $0.3 < r \leq 0.7$ (moderate relationship)
- $0.7 < r \leq 1.0$ (strong relationship)

2. Performance Testing Calculation

In order to find sensitivity, specificity, and accuracies of the test, performance testing was performed [14]. Test performance consists of two types, between the measure of agreement between tests or measure of concordance. And measured of disagreement or measured of discordance [15]. From the result that has been collected, we separated it into 4 groups; true positive (TP), true negative (TN), false positive (FP) and false negative (FN) based on the data EMG, EIS, and EIS+EMG that has been compared it with patient data assumptions. True positive rate (TPR) or sensitivity is same as a diseased patient that has a positive test is given by the proportion of the unhealthy patient with a positive test to every disease patient;

$$TPR = \frac{TP}{TP + FN}$$

Then, for specificity or true negative rate (TNR), is resembled a non-infected patient that has a negative test outcome. As far as a restrictive likelihood, specificity is the likelihood of a negative test given that disease that is missing [15]. TNR is the quantity of non-unhealthy patient with a negative test separated by the total number of non-disease patients;

$$TNR = \frac{TN}{TN + FP}$$

The false positive rate (FPR) and the false negative rate (FNR) have a comparative definition, a disease patient with a negative test outcome. Accuracy was a degree to which the consequence of an estimation, calculation, or specification fits in with the right value or a standard. Measures of demonstrative accuracy are not fixed markers of a test performance, some are extremely touchy to the infection predominance, while others in the range and the meaning of the sickness [15]. Besides, measures of analytic accuracy are to a great degree delicate to the plan of the review.

$$ACCURACY = \frac{TP + TN}{TP + TN + FP + FN}$$

Fig. 5a

IV. RESULT AND DISCUSSIONS

A. Data Collection

Two experiments by using EMG and EIS modalities were done for 11 respondents in FBME, UTM. A total of 20 data and patient level assumption was obtained and was successfully collected by using Bio capture software and LC technology software.

EIS and EMG must do on the same day but at a different location to get the same result from both modalities. EIS and EMG data were saved in Document format (*docx) and Excel format (*xlsx) respectively. EMG signal will be processed and analyzed with Matlab R2013a before saved in Excel format.

B. Electromyography (EMG)

After the image has been analyzed by using Matlab R2013a, the data has been compared with the patient assumption as shown in Figure 5a and 5b. From this data, we can show that patient assumption and EMG modalities don't have many different, the highest different was ±5, for patient 7 and ±4 for patient 5. From the data, patient 1, 4, 9, 10 and 11 records that no different between the data from EMG and patient itself. For patient 2, 6, and 8 the different between data from device and patient was ±1. For patient 3, it's shown that the different between the device and patient was ±2.

We consider the data from EMG and patient was same if the different between both data ≤ ±2, considering the factors that affect the experiment and also patient health during the experiment has been taken.

For the device, this different caused by patient movement during the experiment, EMG modalities were very sensitive towards muscle activity. For the patient assumption, the data given by patient is not surely 100% correct because it was an assumption from patient itself. In order to know the correlation and also the accuracies of the EMG and patient data, we did the data calculation by using correlation and performance test techniques.

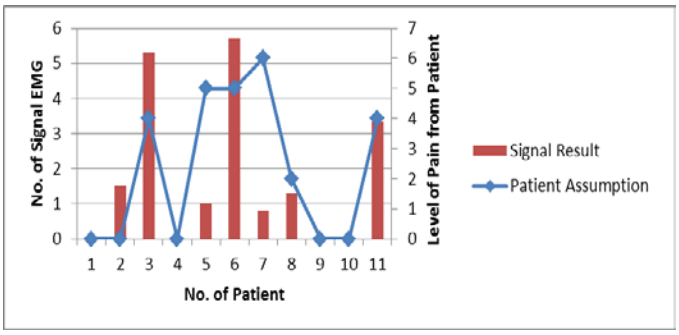

Fig. 5a

SUBJECT	PAIN FROM PATIENT	PAIN FROM DEVICE
1	0	0
2	0	1
3	4	6
4	0	0
5	5	1
6	5	6
7	6	1
8	2	1
9	0	0
10	0	0
11	4	4

Fig. 5b

C. Electro Interstitial Scan (EIS)

EIS data was analyzed by using LD technology software, the data from EIS was divided into 4 groups; sky blue, dark blue, yellow and red before the data was compared with patient assumption data. Each of the groups; sky blue, dark blue, yellow and red represent 21%, 30%, 40% and 63% respectively. The highest risk of pain from EIS data was 63% and the lowest risk was 21%. After the data from the EIS has been calculated based on the percentage given it has been compared with the patient assumption data that shown in Figure 5c and 5d. The data quite similar but not really similar because we know that EIS modalities do not capture the signal of pain in that time, it captures the risk of pain for whole human body systems. From the Figure 5d, it shows that patient 3 and 5 has different of ± 1 for both data, EIS and patient assumptions. For patient 1, 4, 7, 8 and 10 the table shows that it has different of ± 2 for both data. From the table, patient 6 and 11 records that no different between the data from EIS and patient itself. For patient 2 and 9, it records the highest different between the device and patient that was ±3.

Same as data from EMG, we consider the data from EIS and patient was same if the different between both data ≤ ±2, considering the factors that affect the experiment and also patient health during the experiment has been taken. After the data has been recorded and compared, it will proceed to data correlation and performance testing calculation in order the accuracies, sensitivity, and specificity of the EIS and patient assumptions data.

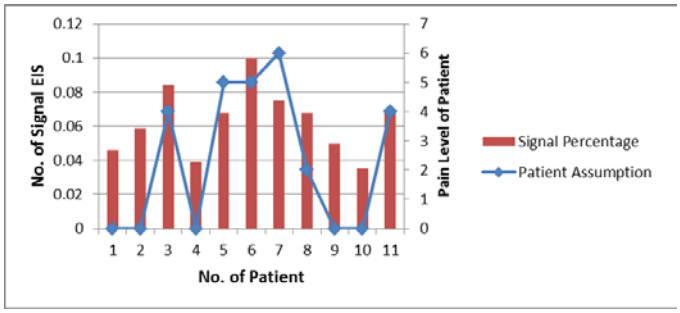

Fig. 5c

SUBJECT	PAIN FROM PATIENT	PAIN FROM DEVICE
1	0	2
2	0	3
3	4	5
4	0	2
5	5	4
6	5	5
7	6	4
8	2	4
9	0	3
10	0	2
11	4	4

Fig. 5d

D. Data Analysis

1) Data Correlation

To determine how strong the relationship is between two variables, a formula must be followed to produce what is referred to as the coefficient value, in this research we want to find the relationship between EMG and EIS with patient assumption data. Correlation calculation has been conducted for 5 types of data; EMG vs EIS, EMG vs Patient Data, EIS vs Patient Data, Cumulative (EMG + EIS) vs Patient Data and Average (EMG + EIS) and Patient Data. The correlation value for all data was a positive value, that's mean the relationship between the variables is positively correlated, or both values increase or decrease together.

From table 6a, EIS and patient data have a stronger relationship rather than EMG and patient data because of the correlation coefficient value for EIS vs patient data between the ranges of 0. 7< r ≤ 1. 0. The correlation coefficient between both modalities; EMG and EIS have shown stronger relationship, 0.85411. It means that if the EMG values decrease, EIS values follow in tandem. If the values for EMG increase, so does the values for EIS. For the cumulative and average value for EMG and EIS with patient data it shows the moderate relationships because the values of the correlation coefficient between the range 0. 3 < r ≤ 0. 7.

DATA	CORRELATION RESULT	RELATION
EMG VS EIS	+0.85411	STRONG
EMG VS PATIENT DATA	+0.588468	MODERATE
EIS VS PATIENT DATA	+0.823724	STRONG
CUMULATIVE VS PATIENT DATA	+0.59143	MODERATE
AVERAGE VS PATIENT DATA	+0.59143	MODERATE

Table 6a

2) Performance Testing Calculation

Performance testing calculation was carried out to determine data sensitivity, specificity and also accuracies. As state in the methodology of performance testing calculation, the data has been divided into 4 groups before it been calculated; TP, TN, FP and FN. In this calculation the range as being a state before the analysis has been made; the pain was (0-1) pain and (2-10) no pain. From the EMG data, the sensitivity was only 50%, this is because of the device not sensitive toward others parameters such as temperature, surrounding and etc., it only sensitive towards muscle movement. EMG records 100% for the specificity of the test performance, in this research the pain signal has been collected using EMG because the device can determine the patient signal of pain at that time. Accuracy for the EMG in this study was a 72.7 % higher than accuracy for EIS device that only 54.55%. The sensitivity value for EIS was 100%; this is because EIS can detect all the parameters in human body system by release some flow of electric current through the interstitial fluid between human cells.

For the specificity, its recorded 0% means that the device not specific at certain condition and parameters. EMG and EIS data has been combined to find the accuracy of the device when using more than one modality. The accuracy of the data for more than one modality is higher than the data that only use one modality. The accuracy of the data for using two modalities was 81.81%.

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EMG and EIS data has been combined to find the accuracy of the device when using more than one modality. The accuracy of the data more than one modalities is higher than the data that only use one modality. The accuracy of the data for using two modalities was 81.81%.

DATA	SENSITIVITY	SPECIFICITY	ACCURACY
EMG	50%	100%	72.7%
EIS	100%	0%	54.55%
EMG + EIS	100%	60%	81.81%

Table 6b

V. Conclusion

Based on these results, a combination of EMG and EIS improve the accuracy of pain assessment. In test performance result of jointly, EMG and EIS data in comparison with VAS showed the highest value of accuracy, rather than using EMG and EIS data only. Data analysis of correlation calculation shows that EMG and EIS have a strong relationship that can be implemented in robot based diagnostics for multimodalities pain assessment system.

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