Integration of a Mobile Application using Medical Infrared Imaging to improve the Effectiveness of Physiotherapy Treatments

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Abstract—**Medical Infrared thermography (MIT) has been identified as a promising solution to locate inflammation within the human body. Infrared thermography is a non-radiating and non-invasive method which provides information about physiological functions related to the mapping of the body's thermal radiation. In this project, we investigate the use of a mobile phone combined with a low cost, high resolution infrared camera and the advanced image processing toolbox from MATLAB® as a basic diagnostic tool for location and detection of thermal abnormalities (abnormally high or low body surface temperature) in musculoskeletal conditions.**

The three aims of this project are: First, to design a functional thermal imaging mobile application for patient rehabilitation and therapy assessment. Second, to use pre and post treatment thermal images to assess the effectiveness of the therapy. Finally, to use deep learning techniques to simplify the process of identifying abnormalities by automatically learning similarities and differences of features within images to predict the best treatment for future patients.

In this paper the development of the mobile app as a proof of concept is reported with the future aim to use deep learning algorithms. The application will be used to help physiotherapists in NHS Tayside (Scotland) to enhance their best practice.

Keywords— **medical mobile application, medical infrared imaging, deep learning, machine learning**

I. Introduction

Currently, during physiotherapy, massage therapy or other related therapies medical attendants rely on intuition or their own experience to identify the area of the body to be treated. Body temperature is an acceptable indicator for health conditions and has long been used for assessing patient's health [1]. The average normal body temperature is 37°C and a few degrees Celsius difference to this range is considered as physiologically abnormal. In most cases a raised temperature in different regions of the body is an indication of inflammation, tensions, lack of blood circulation etc. [2].

Medical Infrared thermography (MIT) is a promising solution to measure the body temperature across a large area or the full body surface [1]. It is a non-invasive, non-contact, non-radiating and real-time imaging technology which provides information about variations in blood flow that are often related to injuries, resulting in a change of skin-temperature. This method consists of the detection of infrared radiation by an infrared camera and the intensity of the emitted radiation is directly converted to the temperature of the examined surface [1]. The different temperatures on the body surface are processed and recorded and converted by the computer into an image map which can then be analysed.

There are many benefits to using a smartphones as a "medical device". They are easily accessible, low cost, and easy to use. Their operating systems offer platforms for rapid development and implementation of apps as well as frequent updates at low or no cost to the developer. New smart phones are equipped with build-in cameras, accelerometers, microphones, speakers and near-field communications which make them great tools for clinical applications design. Medical mobile applications have already been implemented in Diabetes Management ("Welldoc BlueStar® app for people living with type 2 diabetes"), ophthalmology and medical education to mention only a few [3, 4]. In addition, medical apps can help clinical professionals organising their time, accessing patient records, communication, consulting, patient monitoring and medical training [5, 6].

Using a medical mobile application in combination with Thermography and Deep Learning techniques offers enhanced outcomes for the assessment of muscular skeletal injuries. Deep learning originates from Machine Learning which is based on the development of computer models and systems that automatically learn and improve their performance from experience. Deep learning is inspired by the biological nervous system and a deep learning network is composed of multiple processing layers making it more accurate than traditional machine learning methods [7]. It can be applied to identification applications such as image transformation and recognition, text translation and voice recognition. Different Deep Learning techniques have already been successfully applied to Breast Cancer Detection and healthcare applications based on physiological signals [8, 9].

Our approach is to provide clinical users as well as patients with a tool that will allow them a quick assessment of changes in body temperature in different areas of the body to identify the area of interest that requires clinical attention. Therefore rehabilitation professionals can accurately focus on areas of interest. A mobile application combined with an infrared camera will be able to provide the required solution.

Using MIT during Physiotherapy assessments can enable the practitioner with the visualization of the precise localization of inflammation to define the appropriate treatment. Since inflammation usually causes a local increase in skin temperature, it is ideal to be monitored by a thermal imaging camera and it makes clearly visible what is invisible to the naked eye. Taking pre- and post-examination images and videos support the physiotherapy diagnosis and helps to assess the efficacy of the treatment. The safety, accuracy and low cost of this technology make it a promising diagnostic tool to locate and detect thermal abnormalities in musculoskeletal conditions.

Implementing Deep Learning techniques into the image processing procedures using MATLAB® will further improve the diagnosis, producing heat maps of the affected body areas that automatically predict and recognize an improvement or deterioration of the condition.

Incorporating this technology and the standard patient recording procedure into a mobile app enables the practitioner to quickly assess the patient and record specific data electronically, making the treatment process more effective. Additionally, the patient is provided with a visual proof of the condition and it is therefore beneficial in terms of psychological aspects, improving the outcome of the rehabilitation process even further.

In this paper, we present a mobile application in combination with thermal image processing technologies, providing the practitioner with a diagnostic tool to aid the rehabilitation treatment and record specific physiological measurements related to human body area of interest electronically.

II. Materials and methods

Literature research and surveys with physiotherapists within NHS Tayside (Scotland) have revealed the potential need for this application. Current treatment options rely on the description of the patient, as well as on the experience of the individual practitioner, making the diagnosis more difficult. No visual analysis is available although MIT has gained popularity as clinical analysis method.

To ensure a successful outcome of the treatment long-term it requires adherence to the provided exercise programs. Studies have shown that physiotherapeutic rehabilitation is more efficient when patients are provided with a mobile app, in addition to illustrative materials, that assists in establishing an exercise routine for everyday life, leading to an improved health outcome [10-12].

An MSc project has previously been completed, resulting in the development and evaluation of a first simplified version of the mobile app, uncovering advantages for rehabilitation professionals when utilizing the app [13]. The patient data, which was made unidentifiable, was recorded together with an assessment of pain location and images were acquired using a 1.56 Megapixel Infrared Camera (FLIR One gen 3 for Android, Thermal resolution of 4800 pixels). Figure 1 shows the display of the simplified Android mobile app. The camera was connected to a smartphone (Sony Xperia Z3) and several images were obtained 10 minutes prior and after each rehabilitation treatment. One additional image was obtained one week after the first treatment. The images were obtained in a room with a temperature of about 20ºC (68°F) with the camera being placed at a height of 150 cm and a distance of 2 m away from the patient, to be able to take a full body image. Figure 2 displays the images of one participant before and after the therapy and after one week. The top images in Figure 2 show the body outline with a color temperature scale. The rainbow scale color or spectral range of color are the most used in clinical applications [14]. Rainbow scale color consist of white as hot, then red, yellow green and blue as the coolest one. The bottom images in Figure 2 present grayscale thermal images highlighting “hot spots” (red area) to visualize the inflammation. No ethical approval was required since each individual participant was unidentifiable. No names or other personal information was collected and the photographs do not contain any faces. The acquired images were saved to the participants records on the mobile app together with the patient assessment protocol, making them easily retrievable at the next appointment.

It was demonstrated that this application can be used to qualitatively evaluate thermal images in different stages of the therapy. The system is non-invasive and every step of the process is associated with an image that provides information about patient condition or therapy outcome. The red hotspot areas shown in Figure 2 suggest the source of a musculoskeletal condition, but does not necessarily indicate the location of the sensed pain. The “after” images display the changes of the condition triggered by the therapy. Collecting this information together with the patient’s state of condition (improvement/deterioration) enables the rehabilitation professionals to utilize this data to decide and modify their choice of therapy to improve the patient treatment

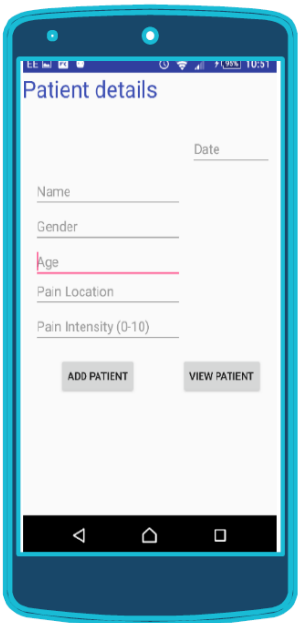

Fig. 1 Display of simplified mobile app

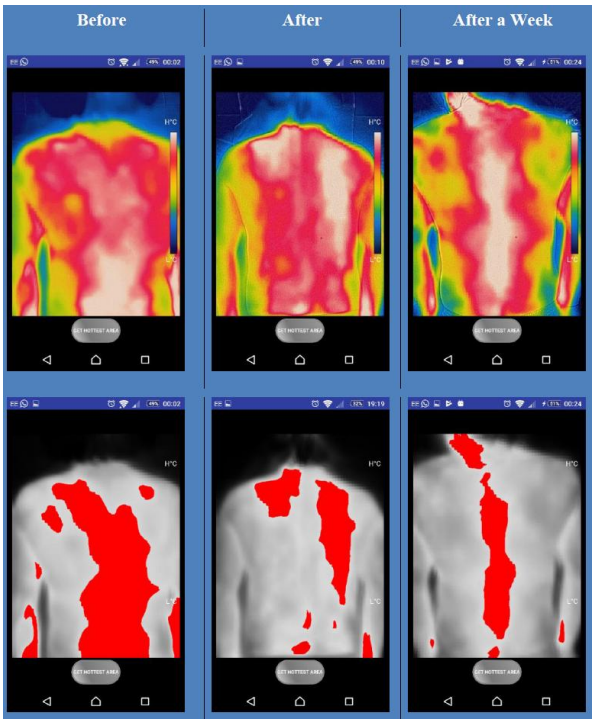

Fig. 2 Participant images during different stages of therapy: Infrared images rendered using a rainbow colour scale(top) and grayscale (bottom) with hotspots (red areas indicating inflammation) prior to treatment, after and after one week

outcomes. Incorporating deep learning algorithms during image processing can be used to automatize and streamline the treatment options.

III. Future Work

To improve the benefits of the utilization of this app, it will be accessible to both mobile operating systems, Android and iOS. The app will provide the therapist with the patient information and images to enable the analysis of the rehabilitation progress. Further developments will involve the evaluation of the performance of the system by embedding image processing using Deep Learning algorithms, to identify areas of interest on a heat map, in combination with gathered data of successful treatments to predict the optimal therapy for the best rehabilitation outcome.

As part of a student project two versions of the mobile application, one for Android and one for iOS, will be designed. Infrared images of patients that are going through therapy will be acquired. This could be at a physiotherapy clinic or chiropractic therapy clinic.

After image acquisition, the images can be converted into heat maps using MATLAB® to implement deep learning processes, simplifying the process of image comparison and improving the accuracy of classifying areas of interest.

To improve the outcome of the experiments and data collection further, certain factors need to be taken into consideration. Considering all individual, technical and environmental factors can improve the use of IR thermography and potentially reduce errors. Among the environmental factors, the room temperature is required to be around 18ºC to 25º [15]. Additionally, isolating the room from external radiation sources and introducing time for the patient to acclimatize to stabilize the body temperature is also important for IR thermography applications [16].

On successful completion of this project, the mobile app will be tested by clinical professionals to assess the effectiveness of the therapy.

IV. Conclusions

The safety, accuracy and low cost of MIT, make it a promising diagnostic tool to locate and detect thermal abnormalities in musculoskeletal conditions. Combining this technology with a mobile app, image processing and deep learning techniques aides the clinical professional by visualizing the affected areas clearly and helping to tailor the therapy to the need of the patient, therefore improving the effectiveness of physiotherapy treatments.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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