Smart T-shirt for Rheumatism

Wearable solution for arthritis and osteo-arthritis treatment

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ABSTRACT

Rheumatoid arthritis and osteo-arthritis are the most two common types of rheumatic diseases, a condition that damages joints and affects their function. In this paper, we present a new solution to assist the arthritis and osteoarthritis treatment by the use of a new kind of t-shirt based on the method of heating and vibration controlled via a mobile device. The system is tested on different patients with different levels of Rheumatism and the obtained results show that the treatment is robust against body pain.

Categories and Subject Descriptors

J.3: Life And Medical Sciences – *health, medical information systems.*
C.5.3: Microcomputers – *portable devices*

General Term

Design, Measurement, Experimentation.

Keywords

rheumatism, arthritis, osteoarthritis, disease treatment, wearables, IoT, fabrics, body sensor networks, diseases, self-computing, patient monitoring, telemedicine, connected health.

1. INTRODUCTION

Due to genetic and environmental factors, roughly one percent of the world's population suffers from rheumatoid Arthritis (RA) and/or Osteoarthritis (OA). These diseases deteriorate the articular cartilage; as a result, bones and joints could be damaged. This situation leads to movement obstruction. [1]

The main purpose of this work is the development of a mobile solution that reduces pain to RA/OA patients and allows patient to heat or vibrate the affected location of his upper body, and to practice some exercises of stretching articulations. The system could be used easily anywhere by patients without the need of unnecessary visits to the reeducation centers.

The deployment of IT in healthcare seems to be a vital need as it can prevent troubles and health issues. The progress in embedded system and telecommunication has led to a new generation of miniature devices with the propriety to be wearable and may be equipped with sensors that can monitor the health and the well-being of patients.

This is completely new way for doctors to rapidly get the information they need when they need it the most.

The bold statement for wearable technology is that it could lead to a revolution in self-care by enhancing patient's monitoring with a host of long-term conditions as well as encouraging individuals to live more healthily. Patients with special conditions such as rheumatism, liver disease or diabetes could benefit from wearable devices that can detect issues and alert them or anyone else they choose. Wearable technology can also be useful to clinicians and medical staff from a development and analysis perspective.

2. STATE OF THE ART

This section discusses some existing approaches that have been proposed as a treat for rheumatism disease to reduce pain, and some existent implementations that target other types of diseases by means of wearable technologies.

2.1 Common treatments methods for joint pain

There are several common treatments for joint pain caused by RA/OA; the following propose most known methods to reduce Rheumatism pain.

Heating method uses patch that allow heat radiation to the painful area, it increase muscle's temperature to minimize RA/OA pain and improve blood circulation.[2]

Massage method uses the pressure and heat, which can increase the exchanges between cells, detoxify tissues, and send messages to the brain reflexes. The massage also has a very important psychological aspect on the reeducation of muscles affected by rheumatism.

Reeducation exercises and rehabilitation is important in the early inflammatory OA and RA, to stop as soon as the process of destruction of the joints and maintain mobility. It is even one of the most recommended treatments. In addition to preserve the flexibility and the strength of joints, exercise helps to enhance muscles and slows the degeneration of cartilage.[3]

2.2 Related work on wearable systems

Therapists broadly use therapy gloves as rehabilitative treatment for sufferers from RA.

Conor & all [1] propose a comparison between a *vicon* glove and their own solution: a Piezo-Resistive Fabric Stretch Sensor Glove for Home-Monitoring of Rheumatoid Arthritis. The in house developed glove, can control patient's exercises and save their progress day by day.

This solution is limited as gloves are used just to measure finger joint flexion and extensions, and do not allow any treatment for the specified parts.

Siti Hana & all [4] present different gloves solutions for rheumatoid arthritis. Among the existent solutions, some of them are designed to

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provide warmth, extra support or compression and others provide both heat and compression.

Bächlin & all [5] implement a solution that detects the freeze of gait (FOG) in real time and provides more information about the patient's behavior. Researchers exploit the collected FOG information in order to invent new treatments.

3. SOLUTION ARCHITECTURE

In this section we present the detailed project architecture, the composition of the T-shirt and the possible user scenarios.

3.1 Big Picture

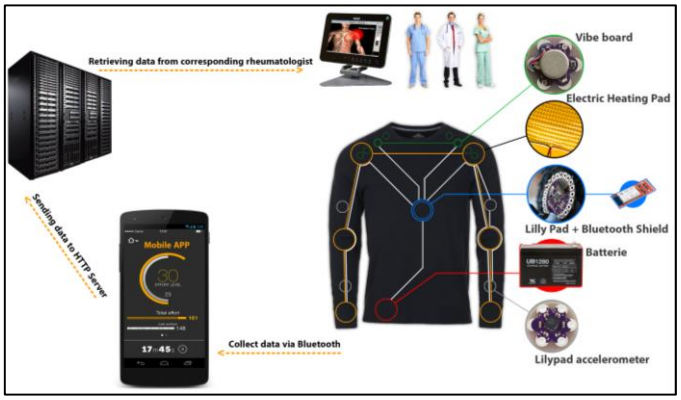

Fig. 1. Global solution architecture

The solution is composed of three principal parts, our smart T-shirt, the mobile application and a cloud system where patient's status will be shared with different shareholders (clinics centers, doctors…).

It is a compression smart T-shirt which helps to reduce or prevent rheumatism pain, also it allows patient to practice some specific stretching exercises and get stats of his progress. The T-shirt integrate connected devices, controlled via a mobile application, offering the possibility of warming up, vibrate the articulations and also activate a massage feature to trigger the stress zones in order to relieve and ease the pain. Simultaneously, data is collected and analyzed via a statistics mobile based module.

3.2 T-shirt layout:

Figure 2 presents the smart T-shirt design. It integrates the main board, sensors, actuators and a removable battery. We specify in the following technical details of these components:

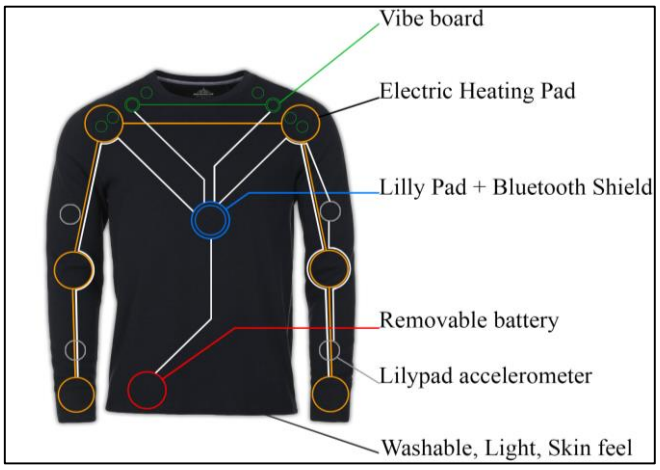

Fig. 2. Hardware composition of the solution (T-shirt side).

We use LilyPad Arduino as the project main board; it is based on an ATmega328 and a minimum number of external components to keep it as small as possible. The latest version of the Lily Pad supports automatic reset for even easier programming.

We interfaced this board with the other components, and we sewed them into the t-shirt. This technology is also washable, which will grant a more user friendly and casual use of the solution.

To establish a point-to-point communication between the T-shirt and the mobile device, we used Bluetooth shield in order to exchange data from accelerometers and heat pads to the mobile application, also to receive commands to activate/deactivate heat pads and vibrators.

Regarding the warm articulations, we used six electric flexible and light Heating Pads; composed of stainless steel fibers so this heating fabric will warm up, creating a little heating pad. The temperature reached varies with voltage. For our case the temperature attempt 65° for a configurable period (between 40s and 120s for this prototype).

Eight Vibe boards insure the massage function; this powerful vibration motors works great as a physical indicator without notifying anyone except the wearer. This version uses a surface mount motor that is less likely to be damaged during use; the user can activate this vibe a period to simulate a local massage on several parts on body.

Patient movement acceleration is detected by four accelerometers, two in each hand. The patient can use it like a movement tilt. It is a three-axis accelerometer, based on the ADXL335 accelerometer from Analog Devices; it can measure the affinity and the stability of exercises.

A removable 8 hours life, 12 volts, and 1.5A battery power the system.

3.3 User Scenarios

We developed a mobile application in order to monitor and command the whole system across Bluetooth.

Fig. 3. Features of the mobile App.

3.3.1 Scenario 1 – Heating

The osteoarthritis patient can activate the local heating functionality available in the mobile menu. Following the activation, orders will be sent via Bluetooth to the onboard card in the T-Shirt. Once the card receives commands, the six heat pads are triggered and temperature is gradually raised to a certain level (45 °) for x seconds (40s up to 120s).

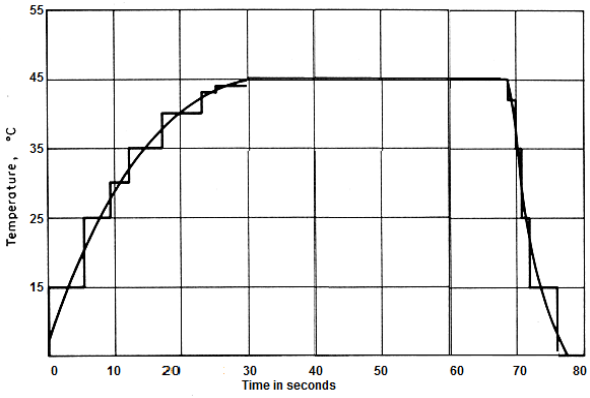

Fig. 4. Temperatue curve of the heating pad.

3.3.2 Scenario 2 – Vibration

Both patient's arthritis and osteoarthritis may also activate the vibration feature available in the mobile menu that offers a massage-like

treatment based on activation of eight little motors situated in the top part of the body, to relieve all the pain of rheumatism in that locations.

3.3.3 Scenario 3 – Articulations movements

Arthritis and osteoarthritis patients need to do exercises that keep their bones strong, because thinning of the bones can be a problem with rheumatoid arthritis. Also exercises helps patients to maintain muscles strength, for this reason our project offers to them some rheumatoid exercises and allows to patients the control of their moves by four accelerometers which are sewed in the T-shirt. All data are sent in real time to the smartphone, and saved in a local storage (inside the smartphone) in order to use it in a next release of the project and send all data to a cloud database.

4. TEST AND RESULTS

The prototype of Smart T-shirt for Rheumatism was presented to a specialist in physical medicine and rehabilitation "*Dr Chokri Hentati*" and we tested it on twelve patients with RA and OA to get feedback. In addition, like any other prototype we faced patients who encourage the finalization of the prototype and others who thought that Smart T-shirt for Rheumatism is far yet from being a final product.

4.1 Screenshots and prototype

In this section, we present some screenshots of the mobile application and some pictures of the prototype of the T-Shirt.

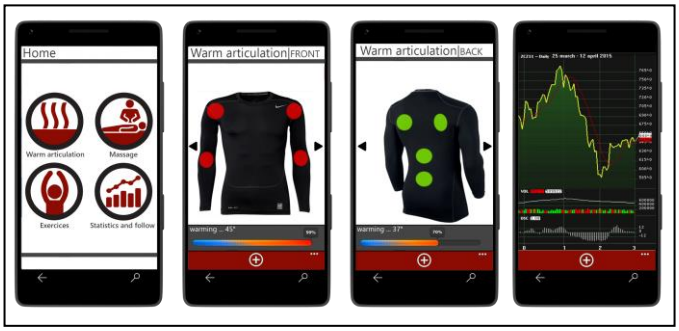

Fig. 5. Features of the mobile App.

The figure five presents some screenshots of the developed mobile app. First one is the main menu; it allows the user to choose between four options: Warm Articulations, Massage, Exercises or Statistics. The second and third screens show the interface of Warm mode, where the user can control and observe the heating procedure and adding a new program. The fourth interface provides a statistics data related to a period. It calculates the rate of use of all options every day and the intensity of practicing some treatments.

Fig. 6. Interior side of the T-Shirt in prototyping phase.

Fig. 7. Connecting and wiring all parts with the main board.

4.2 Feedback and data analysis

The effect of wearing smart t-shirt was investigated in three situations. Table 1 presents some collected data from the case studies on twelve patients:

Table 1 - Case studies

Study design	No of subjects	Concurrent therapies	Trial durations	Follow up
Home	8	yes	1 week	daily
Home	3	no	4 days	daily
reeducation cabinet	1	yes	1 week	daily

The studies reported significant improvement in articulations and joints and reducing pain after the use of the T-shirt, even for the second one. Potential patients say that they found the T-shirt as a relaxation and a way to prevent cold.

For the impressed patients by the smart T-shirt, they admire the way of combining these very common and used treatments "heating" and "massage" to reduce rheumatism pain in order to create an easy way to prevent the pain, in addition to the use of a mobile application to control it.

The prototype did not help some patients who suffer from serious RA or OA as they need other treatments with doctor's supervision.

Overall, we consider these results as promising. The system can also help patients to relieve their muscles by practicing stretching exercises and muscles building and get statistics of his progress.

Looking to enhance the performance of the system, we would like to add a server part in which we can store the data collected from different patients.

The limitation of this study is the short time where patients experienced the system. Another limitation is that we did not test the prototype in more than one reeducation cabinet. A follow-up study will have to tackle these limitations.

5. CONCLUSION

In this paper, we have presented a prototype to treat rheumatism disease and try to reduce pain via a smart T-shirt, equipped with sensors and actuators, controlled by a mobile application over a Bluetooth connection. It makes use of several common medical treatments in order to follow the patient needs, and generates statistics by accumulating and normalizing histograms of captured exercises under various conditions that reflect the treatment process for each patient.

This is the first step towards RO and OA self-treatments. Our approach is simple and robust against pain as shown in the results obtained, but not very optimized for many other types of Rheumatism.

This can be solved by integrating a profiling feature to the application that can be directly connected to a distant data server. Furthermore, this

feature can improve treatments thanks to big data analysis and reduction of errors of similar types of Rheumatism.

6. ACKNOWLEDGMENTS

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