An IOT based Wearable Smart Glove for Remote Monitoring of Rheumatoid Arthritis Patients

M. Raad, M. Deriche, A. Bin Hafeedh, H. Almasawa, K. Bin Jofan, H. Alsakkaf, A. Bahumran and M. Salem

King Fahd University of Petroleum and Minerals, Dhahran, 31261, Saudi Arabia

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Abstract: Rheumatoid Arthritis is a disabling and painful disease of finger joints affecting mainly the elderly people and requiring continuous medications and physical therapy. Traditional arthritis measurements require labor intensive examination by clinical staff. These manual measurements are inaccurate and subject to observer variations. Nowadays the use of wearable technologies is spreading and rapidly becoming a trend promising to offer key benefits in the management of chronic diseases especially at home. Here, we propose an affordable Smart Glove instrument for assisting physiotherapists in remotely analysing patients finger flexions when performing diverse activities at home. An E-textile based glove uses flex and force sensors, and an Arduino platform to transmit motion data to the physiotherapists using a smart phone using a dedicated App. The flex sensor on the index finger detects and estimates the motion, a BLE (Bluetooth Low Energy) Nano is used for processing and wireless transmission. The wearable smart glove uses a lithium ion 3.3V rechargeable 400mAH battery for consuming power. This Smart Glove also helps in monitoring the patient's response to either medication and/or diverse recommended movements. The data collected can be used to analyse the status of the patient with time and also in assisting care givers to change planned activities or exercises when needed.

1 INTRODUCTION

Improving the efficiency and quality of health care services in both hospitals and homes, has always been very important and challenging at the same time. Among the different diseases affecting the elderly people, in particular, is Rheumatoid Arthritis (RA). This disease is an autoimmune disease, that results in stiffness, swelling and possibly deformity. Stiffness may arise from physical damage around the joints, and the symptom of stiffness is quantified by the degree of difficulty in joints movements. Stiffness intensity varies between patients and occurs most commonly in the hands (O'Flynn et al., 2013).

Clinical manifestations of RA can be confused with similar unrelated musculoskeletal and muscular disorders. Outcome measures such as Disease Activity Score (DAS) and Health Assessment Questionnaire (HAQ), are used to asses the patient's disease severity. These measures are partly subjective and can be influenced by other factors such as depression or unrelated non-inflammatory conditions. Patients suspected to suffer from RA are at first examined by an Occupational Therapist (OT) to quantify joint Range Of Motion (ROM) and hand function. Traditional objective measures of RA using the universal goniometer (UG) and visual examination of the hands is labor intensive and open to reliability problems and human bias. Consequently, there is a crucial need to use technology like wearables to detect stiffness of fingers. Moreover, emerging technologies like Internet of Things (IOT), is expected to offer advanced connectivity of devices, systems, and services that go beyond machine-to-machine communications. As a part of reaching every sector with the connectivity of IOT, eHealth services are gaining a lot of grounds. Primarily, eHealth is a healthcare practice supported by electronic processes and wireless communications (Chatterjee et al., 2015),(Holler et al., 2014) and (Connolly et al., 2018). Such technology is helping doctors in remotely monitoring their patients and treating them even when they are not in hospital. One application of

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major importance is home based motion sensing specially for the elderly people. Wearable sensors can be used to monitor patients at home and track their movements (OQuigley et al., 2014). Researchers have discussed E-textile devices for data collecting to support work on Parkinson's disease. Parkinson Disease (PD) is a neurodegenerative motor disorder that targets and breaks down the nervous system. It occurs more frequently with the elderly people. Affected individuals can become unable to perform fine motor movements of hands and arms. Collecting objective movement data from a device such as a smart textile can help in accurately monitoring the patient state (Plant et al., 2014). Also, patients with post-strokes can suffer from hand disabilities and would benefit from Smart Gloves during rehabilitation (Hidayat et al., 2015). Several smart clothes were developed for tracking the activities of users by using textile-based sensors for monitoring deformation along textile, positions, angles, and accelerations of body segments or joints during motion (Goncu-Berk et al., 2017). In (Jung et al., 2017), the researchers developed the RAPAEL smart glove by involving video games to help patients in their rehabilitation process at home. Various sensitized gloves have been discussed in the literature, for example, gloves that track hand and finger motion for providing feedback to rehabilitation systems (Escoto et al., 2017). For a review of wearable sensors, the reader is directed to read the survey by Duarte Dias in (Dias et al., 2018). In this paper, we propose a novel Smart Glove design that provides accurate readings and send relevant information to doctors especially physiotherapists enabling them to monitor patients and provide them with the most suitable prescriptions. The Smart Glove has several therapeutic functions. One of these functions is to provide doctors with flex related measurements through simple smart phone applications. An additional novel feature that is added is the ability to measure hand gripping capabilities of patients by holding house hold objects like a tea cup for instance, while the patient is holding a cup of tea, the therapist can monitor remotely the rehabilitation process of the patient by looking at the data sent from the gripper sensors through the smart glove. The proposed smart glove can be used for several other purposes as will be discussed in the next sections. It is worth noting that the proposed system has been implemented using off-the-shelf components which were combined with our algorithms for data analysis and information transmission.

2 METHODOLOGY

This work focuses on the development of a Smart Glove system for helping the elderly people at home suffering from joints movement disability. The main objective is to design, implement and test a device for remotely monitoring hand and fingers movements. The system uses Smart Glove and a multitude of E-textile sensors to measure the range of motion (ROM) of fingers, and a microcontroller. This system can collect and send rehabilitation related data to physiotherapists. The microcontroller allows the control of the activity of the Smart Glove in an easy and effective way. The Smart Glove is connected to a Bluetooth Module for observing the state of patient`s palm and alerting the physiotherapist if an error or an abnormality has occurred. The main advantage of the proposed solution is its simplicity, cost-efficiency, and scalability with home based IOT systems. The whole proposed system costed less than 100$ to build and has low power requirements, compared to the commercial Rapael Smart glove for arthritis Rehab, which has a rental cost of 99$/month, and a total cost for hospital amounting to 15,000$. Nevertheless, the proposed smart glove is only intended to be worn while collecting measurements. Additional research is needed to make the system more user friendly and non-invasive, in addition to collecting patient's data in a clinical setting with the aid of a physiotherapist.

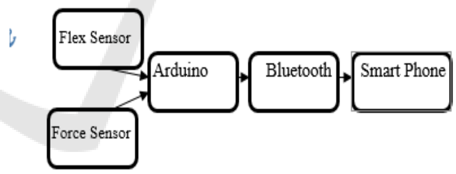

Figure1: System Design.

We display in Fig1 the overall proposed system. The Smart Glove comprises two flex sensors and one force sensor. Finger motion is measured by a flex sensor while the force sensor measures the applied pressure on each finger and transfers all these data to the microcontroller. The Arduino Lilypad processes the data and sends them to a physiotherapist by using a Bluetooth module. In this research, we use LilyPad Arduino, which is designed for E-textiles and wearables e-health applications. It can be sewn to fabric and similarly mounted power supplies, sensors and actuators with conductive thread. Two E-textile force sensors and one E-textile flex sensor were used only due to the limited I/O ports on the

Lilypad Arduino. It has an Analogue /Digital (A/D) converter built on the chip and a clock speed of 8 Mhz. The Main Board is based on the ATmega168V (the low-power version of the ATmega168). The Arduino board has a USB connector to enable it to be connected to a PC to upload or retrieve data. The board exposes the microcontrollers I/O (Input/output) pins to enable it to connect those pins to other circuits or to sensors, etc. The Bluetooth module used in this research is called BlueSMiRF silver and it uses the RN-42 module. A Smart Glove system is developed in order to effectively demonstrate the activity daily living of a patient including the grasping of objects for a certain task. The process involving transmitting electrical signals from the sensors to the LilyPad Arduino to analyse the data is the most challenging task in the circuit design. As shown in Fig. 2 (Gloves), the flex and force sensors are attached on the Smart Glove. The hand glove incorporates a sensory system which can detect the force of grasping any object and the finger degree of bending.

3 EXPERIMENTAL RESULTS

Fig. 3 shows the Smart Glove sensor readings as shown in the Smart Phone of the therapist for remote monitoring of the patient’s hand joint movements. The glove has been synthesized from normal stretched clothe and the sensors were glued on this layer. Another nylon layer covers and protects the sensors. The flex and force sensors were calibrated based on instructions provided in the datasheet.

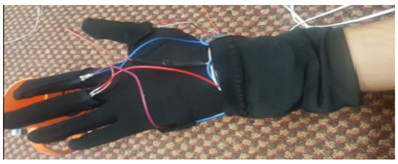

Figure 2: Smart Glove Prototype.

The LilyPad Arduino microcontroller has been used in this device to process and control signals generated from sensors. The Arduino microcontroller is powered by a lithium ion rechargeable battery embedded in the gloves. The Arduino microcontroller processes the raw data collected from sensors and transmits it to the mobile screen as shown in Fig. 3. In addition to monitoring the progress of rehabilitation through improvement of hand joint motion based on the prescribed exercises, the therapist or the doctor can also monitor the gripping capability of the patients. The system was tested successfully in the lab. Further extensive lab experimentation is planned to evaluate the performance of the smart glove utilization in a clinical setup in collaboration with a physiotherapist in a nearby hospital. The open platform software for Arduino was used compatible to C language. This feature with the advent of IOT opens lots avenues as this valuable data can be sent on the spot or later to a therapist for analysis which saves lots of physical interaction with the therapist and hence decreases the cost. Fig. 4 shows the Analog data (ADC) is directly proportional to the force (Newton) of the force sensor. This is vital to detect the gripping force needed based on the physiotherapist plan, particularly in monitoring the activity of daily living like making tea. Also, the experiment shows that the flex's resistance is directly proportional to the bending as shown in Figure5. The flex sensor is a carbon strip that measures the resistance which is directly proportional to the amount of bending and deflection as shown in Fig. 5. The force sensor is basically a variable resistance that changes its value depending on the amount of pressure applied. The experiment shows that when the flex sensor is bend inward, resistance value increased significantly as the angle of flex sensor is bend further. However, when it is bent outward, the resistance value decreased gradually. These preliminary findings suggest that flex sensor is clearly suitable to detect finger bending angle by utilizing inward bend of the flex sensor.

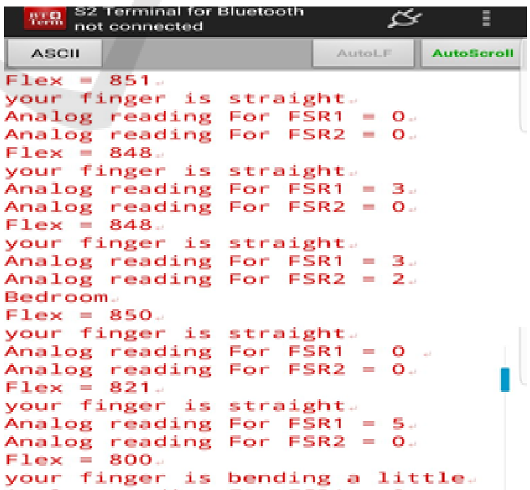

Figure 3: Sensor readings as shown in the smart phone.

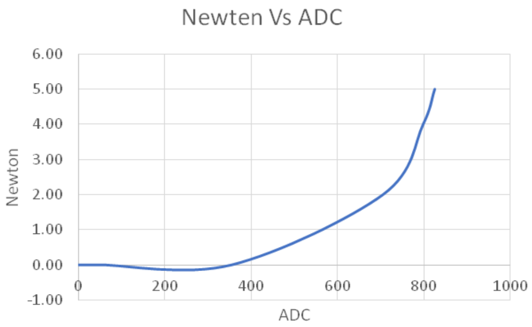

Figure 4: Force sensor, Newton Vs ADC.

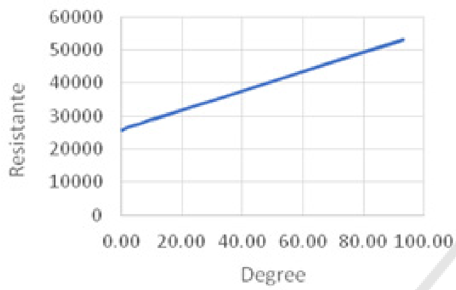

Figure 5: Flex sensor, Resistance vs Bending Degree.

4 CONCLUSION

We discussed in this paper a Smart Glove based system for monitoring joints and fingers movements for patients suffering from RA. The system is useful from remote monitoring of patients staying home. The system enables doctors to diagnose and identify the states of mobility and joints stiffness of the patients without requiring them to be present at the hospital. The system provides the doctors with accurate readings of the flexion and applied force via a smart phone. With the advent of IOT & communication technology like 5G, it opens lots of avenues for E-health and results in cost saving. The system was tested successfully in the lab both for the force and flex sensors utilizing volunteer students. Nevertheless, further research need to be done in the future in collaboration with a physiotherapist in a clinical setting. The main limitation of this research was the limited input/output interface of the used Arduino microcontroller which limited the number of sensors used to detect symptoms of the disease or immobility. Work is in progress to accommodate more sensors and add machine learning algorithms on top to give the proposed solution the unique feature of learning and adapting with the patient situation.

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