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Development of wearable Range of Motion measurement device capable of dynamic measurement

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Abstract

In this paper, we propose the miniaturization size of wearable Range of Motion(ROM) and a system that can be connected with smart devices in real-time to measure the joint movement range dynamically. Currently, the ROM of the joint is directly measured by a person using a goniometer. Conventional methods are different depending on the measurement method and location of the measurement person, which makes it difficult to measure consistently and may cause errors. Also, it is impossible to measure the ROM of joints in real-life situations. Therefore, the wearable sensor is attached to the joint to be measured to develop a miniaturize size ROM device that can measure the range of motion of the joint in real-time. The sensor measured the resistance value changed according to the movement of the joint using a load cell. Also, the sensed analog values were converted to digital values using an Analog to Digital Converter(ADC). The converted amount can be transmitted wireless to the smart device through the wearable sensor node. As a result, the developed device can be measured more consistently than the measurement using the goniometer, communication with IoT-based smart devices, and wearable enables dynamic observation. The developed wearable sensor node will be able to monitor the dynamic state of rehabilitation patients in real-time and improve the rapid change of treatment method and customized treatment.

Keywords: *Range of Motion, Arthritis, Musculoskeletal disease, Joint angle measurement.*

1. Introduction

Recently, Korea had already entered an aging society in 2000, and it is expected to open an aging society in 2018 and an ultra-aging society in 2026. Despite the rapid progress of aging, Korea's social safety net for the elderly is considerably lacking, and the support function for the elderly is weakened by changes in the social structure such as nuclear familiarization, the spread of individualism, and increased economic activity of married women. Compared to developed countries, Korea is expected to enter the aging society from an aging society much faster due to severe low birth rate and increased life expectancy. Aging of the population can

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lead to severe socioeconomic problems such as increased social stimulus burden, shrinking investment and slowing economic growth due to falling national savings rates, reduced tax revenues and increased fiscal spending and fiscal soundness.

Especially in Korea, the concept of health is changing as the environment is rapidly changing due to the increase of older adults and the increase in medical expenses. Health care in the past is a trend that is focused on therapy, but more recently, on management. The most significant portion of personal medical expenses is treated after the disease has developed, but it is predicted that it will also cost a lot of management to keep the health in the future. Health concept changes have changed from " cure " to " care. " In other words, there is a growing interest in living longer in good health. So, the importance of living a pleasurable life rather than merely maintaining life is growing. The WHO defines the quality of life as the degree to which it accepts its state in terms of its ideals, expectations, standards, and interests in the culture and value system in which individuals live. However, in recent years, it is argued by many scholars that the quality of life should be understood as a general concept made up of several factors that could affect it [1]. The quality of life is a right that should be enjoyed by anyone of all ages, especially in the aging society, and another major challenge is one of the most severe health and medical problems in this country. In particular, in an aging society, rheumatism is the most common type of disease, while rheumatism symptoms are painful to the core.

Light exercise and movement, not extreme exercise, are suitable for the elderly. The kinetic effects of arthritis patients increase the range of joint movement, maintain flexibility, and relieve pain. Even if the patients know the importance of exercise, the amount of exercise inevitably decreases due to pain. To treat musculoskeletal pain, check the movement and strength of the bone, and the strength of the muscle occurs through the joint, but as a decisive factor in muscle strength, the joint angles are found. Larger angles mean much flexibility, and smaller angles mean less flexibility. The joint angle determines the length of the muscle and the amount of force. It is possible to measure and compare rehabilitation therapy patients or people with joint problems to restore the body's motor skills as they behave differently depending on the angle of the joint [2,3]. Most of the tools used to measure the range of operation of today's joints use a standardized goniometer. The goniometer is measured by a medical practitioner in direct contact with the joint or muscle. The goniometer is measured in contact with each medical practitioner may vary physically in the location at which they are measured. It is because even if the position to be attached is attached to the prescribed position when measuring joints, errors can occur because there are no automatic or mechanical devices present. Consistent measurement is difficult because the tolerance range is also different. According to W.S. Hon, they stated that the reliability of the tool is essential [3]. Also, Y.J. Moon published a measurement paper using digital vision analysis [4]. To increase the reliability of the measurement using these different methods, Megan M. Konor studied the method to increase the reliability by using a digital inclinometer. However, the way ROM is measured in real-time is weak [5]. Therefore, the resistance sensor was used to reduce the error when measuring joint angle by using IT technology, and IoT technology was applied to measure consistently and to measure in the dynamic condition as well as in the static situation.

2. Range of motion measurement

Range of motion (or ROM), is the linear or angular distance that a moving object may usually travel while adequately attached to another. It is also called range of travel (or ROT), mainly when talking about mechanical devices and in mechanical engineering fields. For example, a sound volume control knob (a rotary fader) may have a 300° range of travel from the "off" or muted (fully attenuated) position at lower left, going clockwise to its maximum-loudness position at lower right. If it is less than the physiological range of motion, it is said that there is a limit of movement range and If it exceeds the normal range, it is called flail joint. Usually, the operating range distinguishes two types, automatic and manual, in which case there is a mismatch. Even if you cannot move freely by yourself when paralyzed, it's most likely that you can move with the help of someone else [6]. The bone moves around the joint, and the structure of the joint can affects all the movements that can occur between the two bones, as well as the connected flexibility and integrity of the soft tissues that pass through the joints. As the body part move through the range of motion, all the structures associated with the articular capsules, ligaments, fascia, vessels, and nerves are affected. The measuring range is the range of measured values for a measurand in which defined, agreed, or guaranteed error limits are not exceeded. It is divided into a lower and upper measuring range limits that define the measuring span. Measured values are used in metrology. The ROM test is a method to measure the automatic or manual range of motion of each joint between the limbs and body, joints with a limited range of movement become apparent, and furthermore, it is possible to know how much the limitation of ROM is involved in disorders of walking and other activities of daily living. It also makes it possible to set an appropriate treatment program and to estimate the functional prognosis. By conducting this test over time, the treatment effect can be determined.

2.1 General method for measuring joint range of motion

The ROM is measured using an instrument equipped with a goniometer. The goniometer is composed of two arms, which are fixed at the center of the goniometer and the arm that is connected to the goniometer is called stationary arm and the other is called a moving arm. The moving arm can rotate 360° from side to side to align the axis of the goniometer with the axis of the joint and to calculate the angle between the two arms on the goniometer to the axis of the body. Since the angle of the joint is measured by a person so that an error may occur depending on an inspector. This not only causes errors but may also require real-time measurements. Four broad categories are used to measure the range of operation of joints [7]. First, the Passive Range of Motion (PROM) measures the movement only by external force without active muscle contraction. Second is the Active Range of Motion(AROM) measures the angle of joint formed by muscle contraction. Third is Active Passive ROM, which measures the ROM by checking changes in muscle contraction and non-contraction. The fourth is Active Assisted Range of Motion (AAROM), the inspector or assistive device assists the subject while the subject moves the target of the joint area. In fact, there is no active muscle contraction at all, and it is difficult to measure how much a person moving by an external force is benefited from gravity, the machine, others, his own body, and so on. In the field of rehabilitation, we are looking for a method to measure the range of motion of elderly people and the degree of movement of degenerative arthritis patients after aquatic exercise, but there is no proper study.

2.2 General method for measuring joint range of motion

Biofeedback is the process of gaining greater awareness of many physiological functions, using instruments that provide information on the activity of those same systems, with a goal of being able to manipulate them at will [8,9]. Biofeedback may be used to improve health, performance, and physiological changes that often occur in conjunction with changes to thoughts, emotions, and behavior. Eventually, these changes may be maintained without the use of extra equipment, for no equipment is necessarily required to practice biofeedback [9]. Already developed countries have been trying to objectively analyze the results of clinical studies in order to provide standard recommendations for each disease. By providing highly validated therapy through these efforts will reduce the cost of unnecessary treatment and enhance the quality of medical services. According to T.G. Yun and M.H. Kang, they conducted research that determines a medical diagnosis and important test items through artificial intelligence-based on clinical results [10,11]. The clinical result is that the patient can visit the hospital and confirm the diagnosis through appropriate tests, but the patient has to come to the hospital for examination. Measuring the range of joint motion may be the same. The patient will measure the range of motion of the joint by wearing a measuring device in the hospital or with the help of a medical practitioner. However, the normal range of motion and the range of motion during measurement may vary. So, if the ROM can be measured in real-time, clinical results can be utilized well and consistent measurements can be made. In the case of rehabilitation patients, getting real-time feedback on their condition could affect the pace of rehabilitation [12]. Rehabilitation patients may feel satisfaction by checking their degree of movement through sensors in real-time at a consistent location, and medical care providers may apply them to quick diagnosis and prediction using information stored in real-time [13].

3. Experiments

3.1 ROM sensor node

Products and services in the form of collecting and analyzing patient health information in real time using sensors are continuously increasing. There are various forms such as skin attachment type and wearable devices. In this study, we propose a wearable ROM measurement device using sensors [14]. A wearable sensor node was fabricated to measure the range of joint movement in real-time, shown in figure 1. The controller consists of a communication unit capable of wireless communication, and I / O unit capable of connecting sensors, and a control unit for controlling communication, ADC, and sensor measurement.

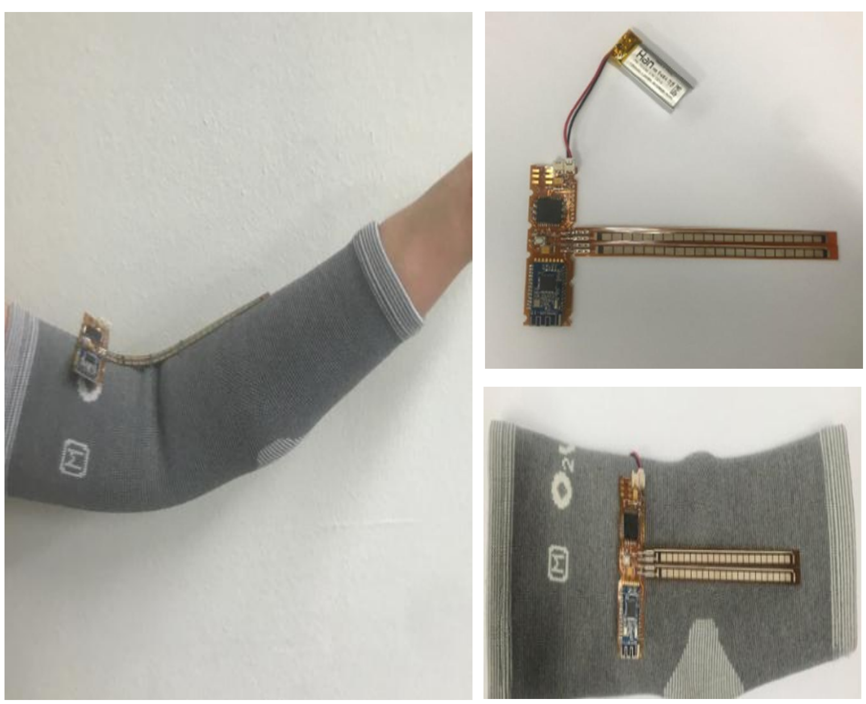


Figure 1. Miniaturized ROM sensor node

The Communication Ministry configured it to enable I2C to communicate with the PC. Bluetooth communication is also available to provide real-time information. In the I / O unit a sensor that can measure the change of the resistance value was applied to measure the range of motion of the joint. A flexible sensor was used to allow attachment or wearable to the body. Flex Sensor is a sensor whose resistance value changes in analog form according to the degree of bending. The amplification circuit is applied because the change of resistance is very small [15]. The control unit is equipped with an 8bit microcontroller to enable I2C communication for interworking with PC and to enable communication with a smart device via Bluetooth. Table 1 shows the specifications of the sensor node that can measure the range of motion of the joint.

Table 1. Sensor node specification

Specification	Range
Clock	11.05M
CPU	8-bit AVR RISC-based
Flat Resistance	25KΩ
Bend Resistance Range	45K to 125KΩ (depending on bend radius)
Power Rating	0.5W continuous, (1W Peak)
Communication	Bluetooth(Wireless) I2C(Wired)
Power consumption	3.3~5.5V, 15~20mA

3.2 Smart device and real-time interworking system

The developed wearable sensor node enables patients with arthritis or rehabilitation to monitor their condition in real-time using smart devices and sends data to medical personnel. It is manufactured in a wearable form to monitor in real-time. First, the sensor node was manufactured in a flexible form and attached to the compression band. The compression band with the sensor node transmits the data to the IoT-based smart device according to the joint movement. In the case of rehabilitation patients, it is possible to confirm the improvement status by monitoring the status of the patient in real-time, which will help rehabilitation. The healthcare provider will be able to monitor the patient's condition in real-time or collect data to identify the current weakness or to change the treatment direction. Figure 2 shows the system configuration for transmitting ROM data in real-time.

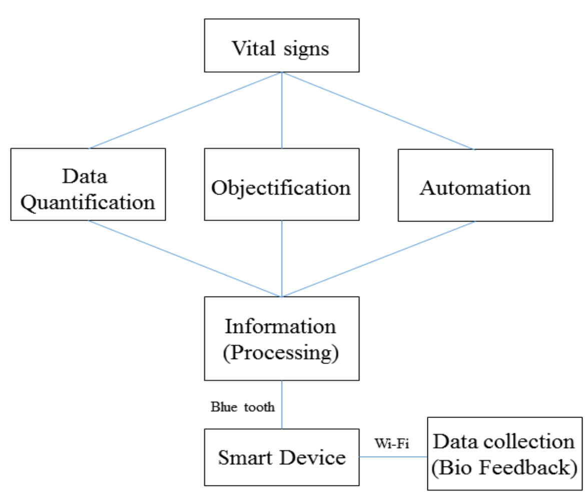
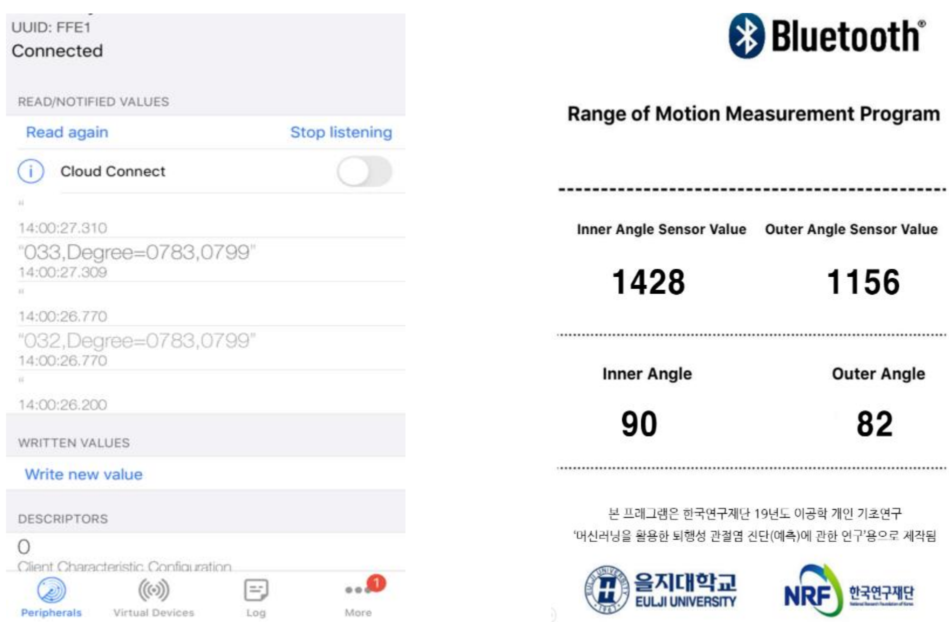


Figure 2. System configuration

The system transmits data to the smart device so that the patient can see their range of motion in the rehabilitation situation. The healthcare provider and patient can confirm the operation status of the patient with the transmitted data. Based on the transmitted data, the direction and method of treatment may be changed.

4. Experimental results

The developed sensor node was attached to the compression bandage so that wearable. The performance was tested by putting the pressure bandage with a sensor node on the arm. To obtain the data, the resistance value is changed to digital value when the sensor is bent or twisted at right angles. As a result, it was found through experiments that the sensor values were typically processed. The wearable sensor node was directly worn on the arm joint, and the moving data was transmitted in real-time. The wearable sensor node converts the bio-signal into a digital value and sends the converted data to the smart device through Bluetooth communication. The received data was programmed to monitor the condition of the joints state. Figure 3 shows the data transfer from the wearable sensor node to the smart device.



(a) received Bluetooth data **(b) smart device(iOS/Android) application**

Figure 3. Smart device display

In Figure 3, (a) is a picture receiving Bluetooth data, and (b) is the application display. Convert the raw data collected by Bluetooth to the angle and present it to the application. As shown in figure 3, the data received from the wearable sensor node can be processed into a meaningful form on the smart device or transmitted to the central system through Wi-Fi communication.

5. Conclusion

In this paper, we developed a wearable sensor node that is a biofeedback system for rehabilitation patients, elderly patients and patients with rheumatoid arthritis. The wearable sensor node not only sends data to the user in real-time, but also enables the user to immediately understand his or her condition so that the user does not have to wait for the result through the medical personnel. The attending physician treating the patient will be able to change the direction of diagnosis and treatment quickly because it measures the state of operation rather than the measurement from the stationary state. The developed wearable sensor node makes personalized treatment possible because it affects the treatment of rehabilitation patients and rheumatism patients. It is also expected that the spread of evidence-based medicine will contribute to the improvement of the quality of medical services and the improvement of the public health level.

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