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재활환자를 위한 IoT 기반의 실시간 모니터링이 가능한 ROM 측정 장치 개발

Development of ROM Measurement Device capable of IoT-based Real-time Monitoring for Rehabilitation Patients

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요 약 본 논문에서는 관절 각도계를 사용하여 관절가동범위의 측정하던 것을 각도계를 사용하지 않고 플렉서블 센서를 이용하여 측정하고 측정된 값을 스마트 디바이스와 연동하여 실시간 모니터링이 가능하게 하였다. 현재의 관절가동범위 측정은 관절 각도기를 활용하여 사람이 직접 측정하고 있다. 이러한 방법은 측정하는 사람의 측정 방법과 위치에 따른 오류로 일관성 있는 측정이 어려워 오차가 발생할 수 있다. 그래서 측정해야 할 관절에 센서를 부착하여 관절의 운동 범위를 측정하였다. 측정을 위한 센서는 플랙서블 형태로 관절의 움직임에 따라 변화되는 저항 값을 측정하는 센서로서 센싱 된 값을 ROM 센서노드를 통하여 무선으로 스마트 디바이스로 전송될 수 있도록 하였다. 개발 된 ROM 측정 장치는 일반적인 관절 각도기를 활용한 측정보다 일관성 있는 측정이 이루어 질 수 있고 스마트 디바이스와 연동하여 실시간 모니터링 함으로써 관절의 움직임에 따른 신속한 진단으로 환자의 빠른 치료와 재활의료 발전에 도움이 될 것이다.

Abstract In this thesis, the range of motion of the joint was measured using a flexible sensor without using a goniometer, and the measured values were transferred to a smart device. Current range of joint motion measurement is measured by a person using a goniometer. Since the method of measuring by a person is different according to the measuring method and position of the measuring person, it is difficult to make consistent measurement, and an error may occur. The sensor for measurement is a flexible sensor that measures the resistance value that changes according to the movement of the joint. The sensed value can be transmitted to the smart device wirelessly through the ROM sensor node. Also, the sensed analog values were converted to digital values using an ADC. The converted value can be transmitted to the smart device wirelessly through the sensor node. The developed ROM measuring device can perform more consistent measurement than the measurement using general articulator and real time monitoring by interlocking with smart device, so that rapid diagnosis according to the movement of the joint can help the patient's rapid treatment and rehabilitation medical advancement will be.

Key Words : ROM(Range of Measurement), IoT, Rehabilitation Medicine, Sensor node, Flexible sensor

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I. Introduction

Recently, although the social and economic environment of Korea has been improved much more than the past, the frequency of diseases including chronic diseases is increasing as the society becomes aging society. Diseases are caused by abnormal or damaged body functions, they are accompanied by pain and discomfort. Disease has a very large impact on individual and family societies, ranging from minor effects on human life to disability or death. Especially in Korea, the concept of health is changing as the environment is rapidly changing due to the increase of elderly people and the increase of medical expenses. Health care in the past is a trend that is focused on therapy, but more recently, on management. The largest 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 " care " 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 World Health Organization defines quality of life as the degree to which it accepts its own 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 serious 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 good for the elderly. The kinetic effects of arthritis patients increase the range of joint movement, maintain the flexibility, and relieve pain. I realize the importance of exercise, but the amount of exercise is bound to decrease 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 or smaller joints may mean smaller or larger joints. Larger angles mean greater 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 in order 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 standardized goniometer. The goniometer is measured by a medical practitioner in direct contact with the joint or muscle. The goniometer that are measured in contact with each medical practitioner may vary physically in the location at which they are measured. This 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 a 2009 Wan-Sung Hon Reliability of Materials for the Safety of Tools paper, the reliability of tools is essential[3]. Also Y.J. MOON also used the digital analysis method in its thesis titled, " The Development of Equipment of Posture Evaluation and Range of Motion, " which is a digital analysis method[4]. To increase the reliability of the measurement using these different methods, Megan M. Konor studied the method to increase the reliability by using the digital inclinometer. However, the way ROM is measured in real time is weak[5]. As a result, resistance sensors were used to measure joints using IT technology to reduce the angle of the joints, to measure consistent measurements, and to measure IoT technologies in addition to measurements in static settings.

II. Range of Motion Exercise

Exercise in body segments is caused by bone movement caused by muscle contractions or external forces. The bone moves around the joint, and the structure of the joint can occur between all two bones, as well as between the flexibility and completeness of the joint. The complete movement that occurs is called the range of joint operation (Range of motion, ROM). Terms such as flexion, extension, transfer, and rotation are used to explain the range of motion. The range of joints is measured by the goniometer and the angle recorded. By performing ROM tests as a way to measure the automatic or passive range of operation of each joint between the limbs, it is more likely that joints with limitations on the range of motion, such as the range of daily operations, are apparent and further limited. It also makes it possible to set up appropriate treatment programs or to estimate functional outcomes.

1. Normal Joint Operating Range Measurement Method

The range of joint operation is measured using a goniometer. The goniometer is composed of two arms, which are attached to the goniometer and called the moving arm. The moving arm is configured to rotate 360° from side to side, and reads the angle between the axis of the eccentric and the joint after aligning it with the axis of the joint. Figure 1 shows the Goniometer of DanMic Global Company and how it is measured.

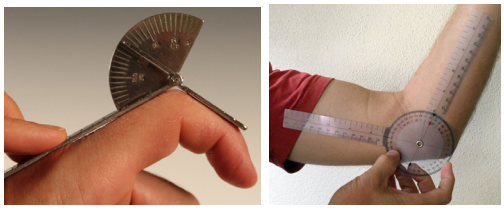


Fig. 1. Goniometer and method of measurement
그림 1. 지오메터와 측정 방법

As shown in Figure 1, the angle of the joint is measured directly by a person, so an error may occur depending on the measurer. This not only causes errors, but may also require real-time measurements. Three broad categories are used to measure the range of operation of joints.

- Passive ROM :Measure whether it is only moved by external force without active muscle contractions.
- Active ROM :The angle of the joint formed by muscle contractions
- Active Passive ROM :Measure to provide an external force by the machine as assistance is required to ensure full range of movement by verifying muscle contractions and changes in the dagger shaft. 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 after aquatic exercise and the degree of movement of degenerative arthritis patients, but there is no proper study.

2. Real-time biofeedback

As medical information grows in volume and a variety of clinical practices increase, diagnosing and predicting diseases is the time to gain objectivity when making medical decisions and to require comprehensive information support. Already, advanced countries have been striving to objectively analyze clinical research results for years to provide standard recommendations for each disease. Providing a highly validated therapy through these efforts will reduce the cost of unnecessary therapy and enhance the quality of medical services. According to Taegyun Yun, Kang, and Min-Hyeok's research, medical diagnostic and critical test items were determined through artificial intelligence[6][7]. The patient may visit the hospital and confirm the diagnosis through proper examination, but it is difficult to determine the patient's condition by visiting the hospital. Measuring the range of joint operation may be the same reason. 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 range of motion of a normal joint and the range of motion of a joint at the time of measurement may be different. So if you can check the range of joints in real time, you will be able to increase the utilization of clinical results and make consistent measurements. In particular, in the case of rehabilitation patients, getting real-time feedback on their condition could affect the pace of rehabilitation[8]. Figure 2 shows a conceptual diagram for real-time joint motion range measurement.

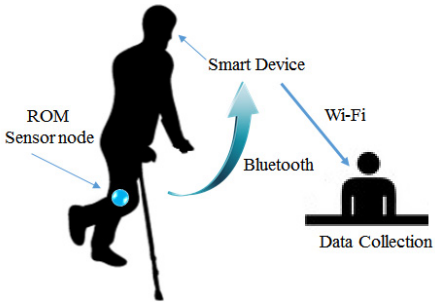


Fig. 2. Real-time biofeedback process
그림 2. 실시간 바이오피드백 처리

The real-time biofeedback picture shown in Figure 2 suggests a method using IoT-based sensor nodes to enable the rehabilitation patient to measure joint motion range[9]. 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 real-time stored information and quick diagnosis[10].

III. Experiments

1. Development of ROM device

In order to measure the range of motion of the joint, we made a board that can communicate in real time. The controller consists of a communication unit capable of wireless communication, an I/O unit capable of connecting sensors, and a control unit for controlling communication, ADC, and sensor measurement. Test Board was produced to enable real-time communication. Figure 3 shows the ROM Module.

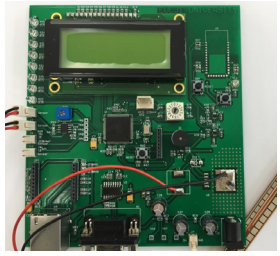


Fig. 3. ROM Module
그림 3. ROM 모듈

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 part, a sensor that can measure the change of the resistance value was applied to measure the range of motion of the joint[12]. A flexible sensor was used to allow attachment or wearable to the body. Flex Sensor is a sensor that resistance value changes in analog form according to degree of bending. Since the amount of change of resistance is very small, an amplifier circuit is applied.[11]. The control unit is equipped with an 8bit micro controller to enable I2C communication for interfacing with a PC and enables communication with a smart device via Bluetooth. In addition, we developed a sensor node (JR-1) that can communicate with smart devices in real time by applying ADC with 10 bit resolution to convert analog value to digital value. Table 1. shows specifications of the sensor nodes that can measure joint motion range.

Table 1. Sensor node Specification
표 1. 센서노드 사양

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

2. Application of smart device and real-time communication system

The developed JR-1 allows patients requiring arthritis or rehabilitation to monitor their status in real-time using smart devices and transmit data to healthcare providers. 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. In addition, 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[13]. Figure 4 shows the configuration of a system that transmits joint movement range data in real time.

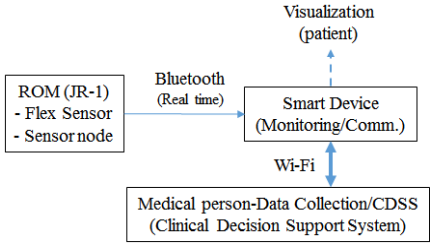
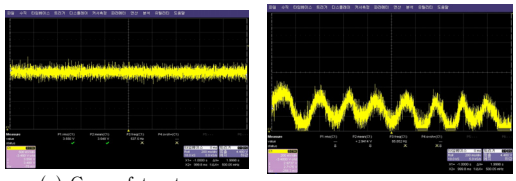


Fig. 4 System diagram
그림 4. 시스템 사양

In Figure 4, the system architecture sends data to smart devices so that the patient is rehabilitating and can see his or her range of joint operations. The transmitted data can compare the patient's current situation with the previous one, making comparisons between the patient's deficiencies and improvements. Medical person can monitor in real time and understand the condition of the patient. You will also be able to change the direction and method of treatment based on stored data.

IV. Results

The developed JR-1 board was tested and tested to determine the operation possibility. As a result, it was found through experiments that the sensor values were normally collected. Figure 5 shows that the resistance changes when the sensor is stressed.



(a) Case of to stress
(a) 외압이 없는 경우

(b)Case of stress
(b) 외압을 가했을 경우

Fig. 5. Test waveform
그림 5. 테스트 파형

The output value of the sensor was converted to AD and the output value was matched by using the protractor. Figure 6 shows the data collected when the JR-1 board transmits data to the smart device in the form of a gauge.

V. Conclusion

In this paper, we have developed JR-1, a bio-feedback system for patients with rehabilitation or rheumatoid arthritis in real time. The JR-1 transmits data to the user in real time, so the user can immediately grasp the status of the user and do not have to wait for the results through the medical person. Medical persons may also be able to change the direction of rapid diagnosis and therapy as they measure active rather than static. The development of JR - 1 will have a new impact on rehabilitation patients and rheumatism and could contribute to the improvement in the quality of medical services and the improvement in the national health level by promoting evidence-based medicine extensively.

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