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# Development of wearable devices and mobile apps for fall detection and health management

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***Abstract***

*As we enter a super-aged society, studies are being conducted to reduce complications and deaths caused by falls in elderly adults. Research is being conducted on interventions for preventing falls in the elderly, wearable devices for detecting falls, and methods for improving the performance of fall detection algorithms. Wearable devices for detecting falls of the elderly generally use gyro sensors. In addition, to improve the performance of the fall detection algorithm, an artificial intelligence algorithm is applied to the x, y, z coordinate data collected from the gyro sensor. In this paper, we develop a wearable device that uses a gyro sensor, body temperature, and heart rate sensor for health management as well as fall detection for the elderly. In addition, we develop a fall detection and health management system that works with wearable devices and a guardian's mobile app to improve the performance of the fall detection algorithm and provide health information to guardians.*

***Keywords:*** *Elderly Fall Detection, Arduino, Accelerometer Sensor, Body Temperature Sensor, Heart Rate Sensor, Mobile App*

## 1. INTRODUCTION

As the population of elderly adults over the age of 65 rapidly increases as we enter a super-aged society, falls are the main cause of death in elderly adults. A fall is an injury to the body caused by a fall, and the incidence is particularly high in the elderly. According to the research results, 15.9% of the elderly in Korea experience a fall at least once a year, and 64.9% of them visit a hospital. In addition, the elderly are at high risk of death or serious injury due to falls. For fall prevention interventions for elderly adults to reduce complications and deaths from falls in elderly adults, face-to-face exercise interventions for a group can help increase muscle strength and improve balance [1]. In addition, for elderly inpatients, a fall prevention education program using videos and leaflets is helpful in preventing falls [2]. In developing a system for preventing and detecting falls in the elderly, it is necessary to review the accessibility of the elderly to new technologies. In addition, more comprehensive and collaborative work is needed between users, caregivers, and clinicians, as well as researchers in the digital sciences, clinical sciences, and humanities that can be key to system development [3]. In general, gyro sensors are used in fall detection devices, and research is being conducted to improve the performance of fall detection algorithms [4]-[6].

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Most of the elderly patients admitted to nursing hospitals have difficulty in moving, so it is difficult for guardians or hospital officials to grasp in real time when a fall accident occurs, or a health problem occurs. As it is difficult to visit patients due to the shortage of manpower in nursing hospitals and COVID-19, it is necessary to develop a system that can efficiently communicate between the operation of nursing hospitals and their guardians by identifying the basic health conditions of patients. In this paper, we develop a fall detection and health management system to detect the fall of an elderly adult and develop a wearable device for health management and a guardian's vail app. The developed system is made up of WiFi as data transmission between a wearable device and fall detection and health management systems so that it can be used in hospitals or nursing hospitals.

## 2. WEARABLE DEVICES

Wearable devices worn by the elderly can be attached to the body and perform various functions. In this paper, we develop the wearable device that can measure the heart rate and body temperature of the elderly in real time and detect and respond to falls. Figure 1 shows the wearable device that detects falls of the elderly and collects health data such as body temperature and heart rate in real time. The developed wearable device was designed in a size that is not limited to activities in consideration of the convenience of the elderly. The developed wearable device has a band attached to the bottom so it can be attached to the upper arm of the elderly. The wearable device consists of an Arduino MKR WIFI board, a body temperature sensor, a heart rate sensor, a gyro sensor, and a battery as shown in Fig. 1.

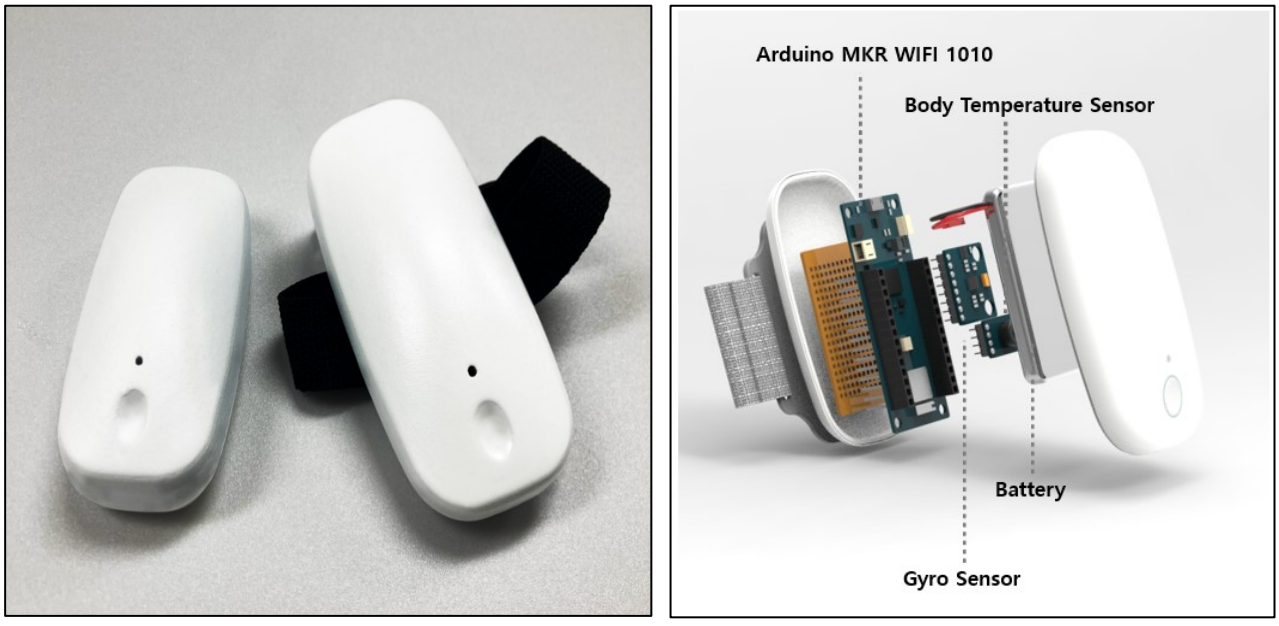



**Figure 1. Wearable device for fall detection and health management**

We choose the miniaturized Arduino MKR WIFI board considering the size of the wearable device. The Arduino MKR WIFI board can send and receive data between the sensor and the system using WIFI communication. The body temperature sensor and heart rate sensor are attached to the bottom of the device and placed in contact with the skin of the elderly to measure body temperature and heart rate data in real time. Wearable devices can be charged using lithium polymer batteries, and the battery can be used for up to 25 hours when fully charged. The MPU 6050 6-axis tilt sensor that detects the fall of the elderly measures 3-axis

tilt and acceleration. We develop a prototype using a 3D printer considering the size of Arduino, sensors, and battery for the wearable device worn by the elderly as shown in Fig. 1.

## 3. FALL DETECTION AND HEALTH CARE SYSTEM

Falls of the elderly can lead to serious injuries or even death due to complications caused by falls. In this paper, we develop a fall detection and health management system that detects the fall of the elderly in real time, informs the guardian of the fall, and provides the elderly's body temperature and heart rate data when requested by the guardian. By using the real-time fall detection system, we can detect and respond to falls in the elderly, which account for more than half of the elderly's physical injuries, in real time, reducing complications and deaths of patients. Figure 1 shows the real-time fall detection of the elderly and the fall detection and health management system that manages the health data of body temperature and heart rate and the guardian's app proposed in this paper. In Figure 1, the wearable device worn by the elderly consists of an Arduino board, a WiFi communication module, a gyro sensor for fall detection, and a body temperature and heart rate sensor for health management of the elderly. The fall detection and health management system detects fall accidents in real time using sensors embedded in the wearable device of the elderly and collects gyro sensor, body temperature, and heart rate data for patient health management and manages them in MySQL database. The elderly's wearable device uses WiFi communication to transmit sensor data to the fall detection and health management system. The guardian can use the user app to check the patient's health status and fall accidents provided in real time from the fall detection and health management system.

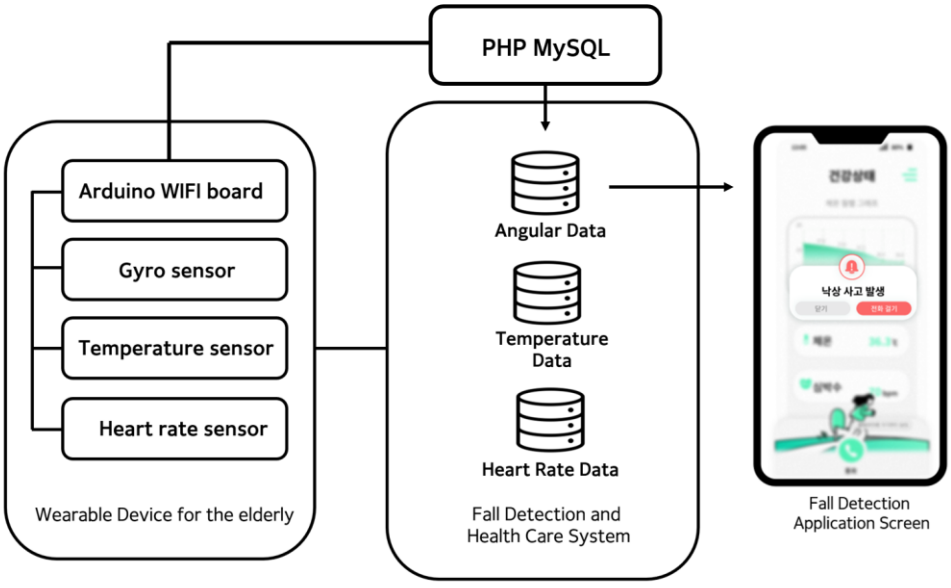



**Figure 2. Fall detection and health care system**

Figure 3 shows an elderly health management app for guardians. Guardians can check not only the elderly's fall detection, but also the elderly's body temperature and heart rate data measured in real time as the elderly's health status data with the mobile apps. Guardians of the nursing hospital can check the patient's meal plan or schedule provided by the nursing hospital through the mobile apps.

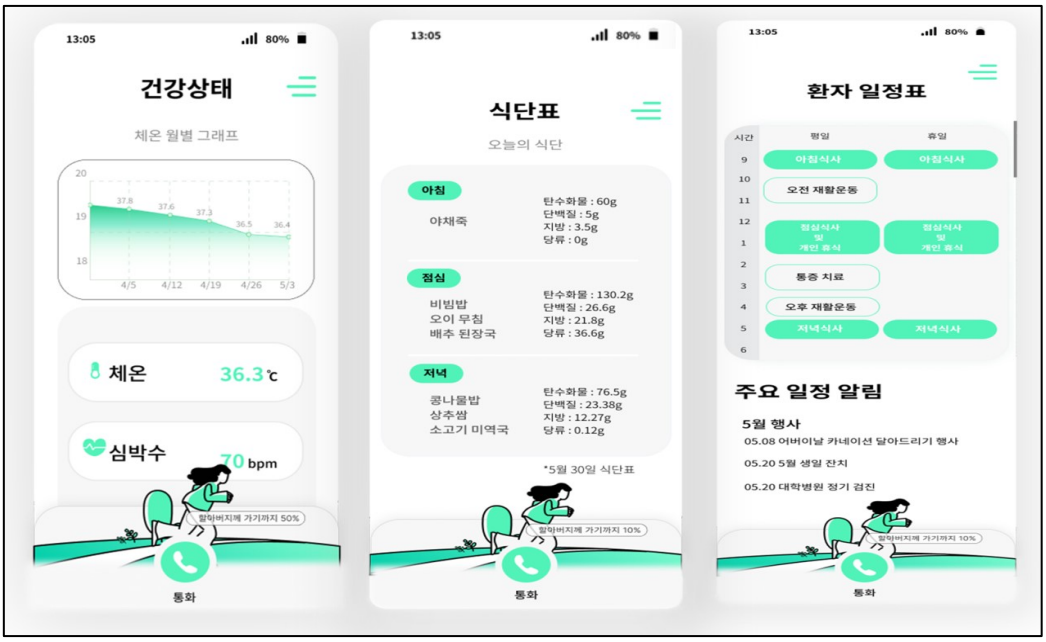



**Figure 3. Guardian's app for fall accident and health management of the elderly**

## 4. FALL ACCIDENT DETECTION ALGORITHM

In this paper, we develop the wearable device to detect falls, a major cause of death in the elderly. The gyro sensor built into the wearable device is a 6-axis acceleration and tilt sensor that measures acceleration and tilt changes in x, y, and z coordinates. The movement of the elderly measured by the gyro sensor of the wearable device is stored in the server through WiFi communication and provided to the app when the guardian requests. In the fall detection experiment using the MPU 6050 gyro sensor of the wearable device, the case of falling backwards or from side to side on a bed is tested.

Figure 4 shows the changes in the acceleration and slope of the 3D coordinates of the accelerometer and tilt sensor for walking in daily life. In Fig. 4, the change in the acceleration and slope values of wearable device sensors does not significantly occur in daily life. This means that the sensor of the wearable device attached to the upper arm of the elderly does not show significant changes in acceleration and slope of 3D coordinates during walking in daily life.

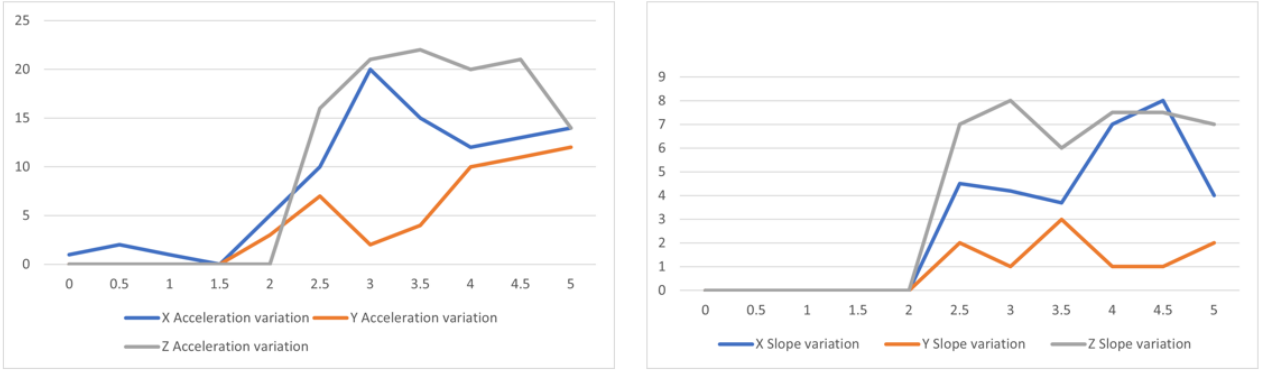
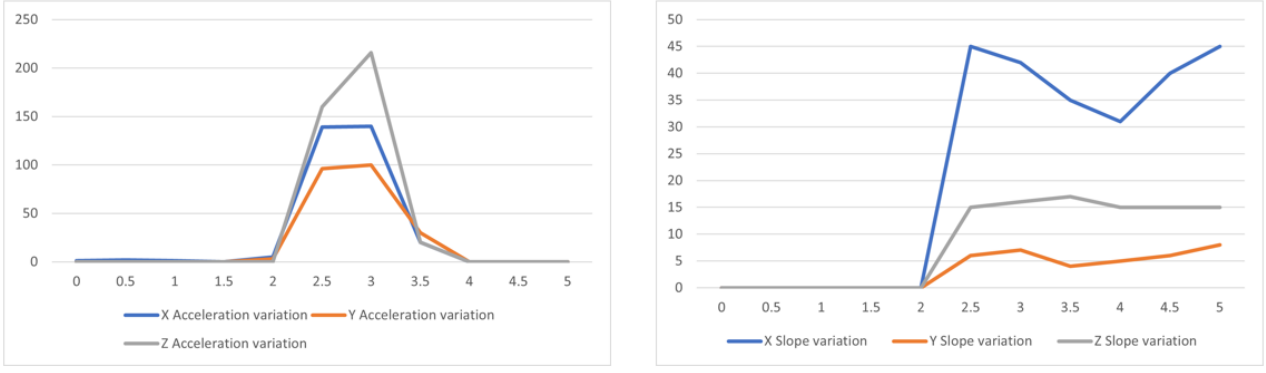
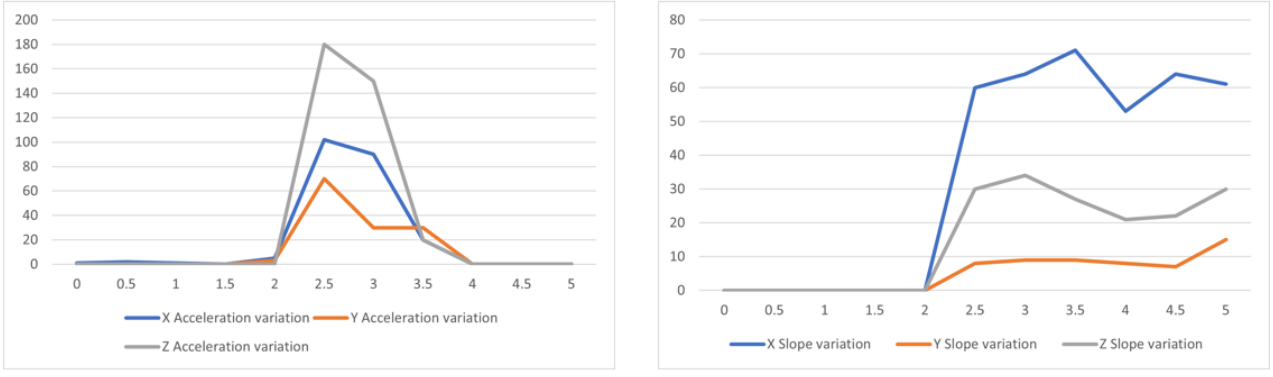



**Figure 4. Gyro sensor data measured in daily life**

Figure 5 shows the changes in the 3D acceleration and slope values of the sensor measured in the experiment where a fall occurs. In the left-right, forward-backward fall occurrence experiment, the 3-dimensional acceleration and slop values greatly change as shown in Fig. 5. From the experimental results in Figs 4 and 5, we can distinguish between walking and falling in the daily life of the elderly by measuring the 3-dimensional acceleration and slop change of the wearable sensor. In the fall accident experiment, the sensor's three-dimensional acceleration change shows a larger change in the Z axis than in the X and Y axes. In addition, in the fall accident experiment, the 3D slope change shows a large change in the X axis. In the fall accident experiment, the sensor's three-dimensional acceleration shows a larger change in the Z axis than in the X and Y axes. In addition, in the fall accident experiment, the 3D slope shows a large change in the X axis. We determine the occurrence of a fall accident by using the Z-axis acceleration and the X-axis slope change measured by the wearable device's acceleration sensor. The gyro sensor of the wearable device transmits 3D acceleration and slope measurement values in real time to the fall detection and health management system through WiFi communication, and the fall detection and health management system determines fall accident. The fall detection and health management system notifies the guardian's app in real time when an elderly person's fall is detected. When a guardian is notified of a patient's fall accident through a mobile app, they can access the fall detection and health management system to check the patient's body temperature and heart rate data in real time. By using a wearable device for the elderly, a fall detection and health management system, and a mobile app for guardians, it is possible to quickly respond to falls in the elderly and reduce complications and deaths caused by falls of patients.




3D acceleration and slope data of a left-right fall accident experiment




3D acceleration and slope data of a front-back fall accident experiment

**Figure 5. 3D acceleration and slope data of the fall accident experiments**

## 5. CONCLUSIONS AND FURTHER STUDY

In this paper, we develop a fall detection and health management system to check the patient's health status and detect fall accidents in real time for the safety of the elderly, especially patients admitted to a nursing hospital. The fall detection and health management system detects the occurrence of a fall accident in real time by measuring the amount of change in the x-coordinate of the gyro sensor received from the wearable device of the elderly. The guardian can check the patient's body temperature and heart rate data in real time when notified of a patient's fall through a mobile app. Guardians who are notified of a patient's fall accident can reduce the patient's complications by acting quickly. The fall detection and health management system can be widely used not only for patients in nursing hospitals, but also for elderly people living alone and areas with underdeveloped medical systems. The currently developed system is made up of WiFi as data transmission between a wearable device and a fall detection and health management system so that it can be used in hospitals or nursing hospitals. We plan to improve the WiFi module with an NBIoT module or a smartphone-linked function to expand the function to a fall detection and health management system for climbers or hikers [7].

## ACKNOWLEDGEMENT

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