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# Multi-Sensor Glove Design and Bio-Signal Data Collection

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## Abstract

In many fields such as biomedical, robotics, mobile devices, multi-sensor systems are used to solve problems that have low performance when performed with a single sensor. These systems are used in many applications like pedometers, emotion recognition and navigation. In this paper a multi-sensor glove system is proposed to measure stress and effort parameters of a person. The multi-system includes sensors for galvanic skin response (GSR), oximeter and inertial measurement unit (IMU). The GSR sensor simply measures the electrical conductivity of the skin, which increases when sweating due to the salt in the sweat. The GSR sensor is placed on the glove with the index finger. The oximeter sensor is used to measure the heart rate and blood oxygen saturation. It is an infrared sensor and measures the reflecting infrared light from the blood cells. The heart rate sensor is used to detect both effort and stress levels based on the heart pulse rate. The IMU is a ready-to-use multi-sensor sensor that includes a gyroscope and an accelerometer. In this study an IMU sensor with 6 degrees of freedom was used to measure acceleration and angular rotation values generated by hand movements. All these sensors are connected to a microcontroller. Due to the lowest sampling rate of the multi-sesnor system, the IMU sensor, includes the entire system configured for measurement at 100Hz. These measurements are combined on the microcontroller and sent to the computer via Bluetooth. The computer program stores the incoming data and visualizes the individual channels simultaneously. Measurements were taken during standing, walking, climbing and jumping activities performed by wearing a multi-sensor glove. It has been observed that measurements can be taken successfully from all sensors on the system.

**Keywords:** Multi-Sensor, Signal Collection, Glove.

## 1. INTRODUCTION

Techniques for how to combine data from multiple and various sensors to make inferences about a physical event, activity or situation are defined as multi-senor data fusion [1]. Sensor Fusion is defined as a method of combining sensor data or data derived from these data and thus obtaining a more successful system [2]. In many fields such as biomedical [3], sports [4], robotics [5], mobile devices [6], multi-sensor systems are used in many applications such as pedometer, emotion recognition and navigation. With multi-sensor systems, different quantities and qualities of data are obtained and these data are analyzed with sensor fusion methods and analyzed with emotional, physiological, mechanical, etc. deductions can be made together.

Multi-sensor studies on wearables are divided into head, body, foot and hand. Studies in the head region have examples of brain activism, sweating and head movements [7-9]. In body applications, there are samples in which information such as heart, effort measurement and posture are collected [10-12]. Studies in the foot area are pedometer, footprint analysis applications are intense [13-15]. However, today, both scientific and commercial applications are most common in the hand / arm area. There are works such as smart watches, wristbands and gloves. Most of the studies in the hand area are on hand gesture recognition [16, 17], Heart Pulse Rate (HPR) measurement [18] and human computer interaction [19, 20] applications.

In this study, different from existing studies, it is aimed to design a multi-sensor glove system to collect data on heart rate, blood oxygen level, sweating and physical activity. It is aimed to develop a system that can simultaneously collect data from the sensors and transfer this data to a computer and monitor it. Thanks to the targeted system, it is aimed to collect data about effort, sweating and physical activity by wearing a single glove. The targeted system is to be a system that can contribute to scientific, sports and health investigations by collecting information about effort, sweating and physical activity of the person simultaneously with a single glove instead of using multiple devices such as a GSR sensor, pedometer, smart watch or oximeter.

## 2. MATERIALS AND METHODS

The main circuit that constitutes the system, the wearing of the glove and the general structure of the system are presented in Figure 1. The system consists of two main parts, computer and glove. The computer part is responsible for processing, displaying and storing data coming from the multi-sensor glove. The multi-sensor glove listens the different data from the sensors sequentially and sends them to the computer periodically. In the main circuit shown in Figure-1, the microcontroller, inertial measurement unit (IMU), Bluetooth module and Galvanic Skin Response (GSR) sensor are located on the circuit. Among the sensors in the system, only the oximeter sensor circuit module is placed at the fingertip and is connected to the main circuit with the help of cables placed in gloves. The microcontroller used in the circuit is Arduino Pro-Mini and collects data from the sensors via IMU, Oximeter and GSR respectively. The data collected as a result of reading the sensors once is transferred wirelessly to the computer via the Bluetooth module (HC-05).

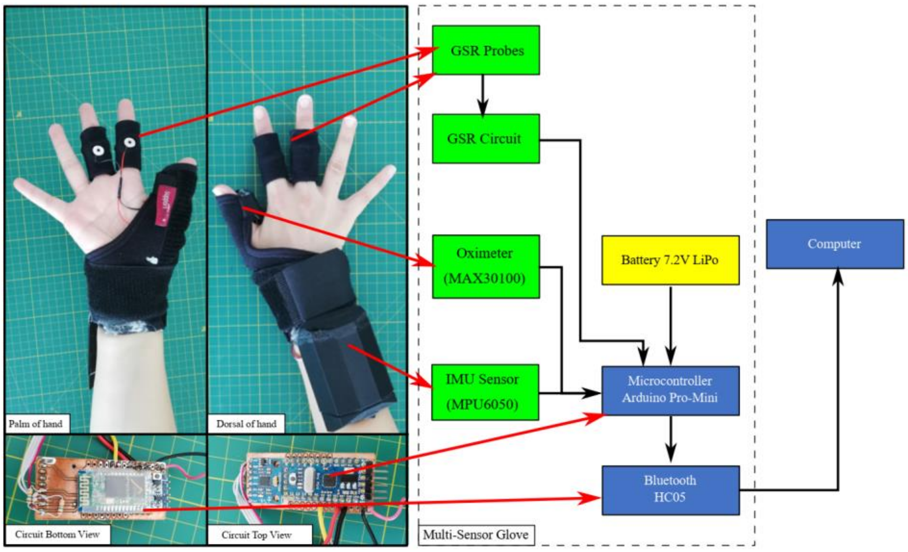



**Figure 1.** General System Design.

The IMU is actually a microelectromechanical sensor made up of multiple sensors. With IMU sensors, very successful applications have been made in detecting body movement, especially actions such as walking and hand-arm movements [21]. The MPU6050 IMU sensor used in this study is 6 degree of freedom, there is an accelerometer that measures acceleration against force in three axes and a gyroscope used to determine the amount of angular rotation in three axes. Data was de-noiseed using a Kalman filter. The device with the slowest sampling rate in the circuit is the IMU sensor (100Hz). Therefore, other sensor data is accumulated at this interval and sent along with the IMU sensor data.

Oximeters are sensors that provide information about heart rate and oxygen saturation ($SPO_2$) in the blood. Oximeters are sensors that work with the principle of sending infrared light to the body and measuring the reflected light intensity. Light can reach the veins under the skin. The infrared LEDs used in these sensors emit light at a wavelength of 700-900 nm. The emitted light reflects according to the oxygen level carried by the blood cells. Oxygen saturation in the blood is measured according to the amount of reflected light. In addition, the amount of light reflected changes with the heartbeat and the pulse per minute is measured by counting the time between heart beat waves [22].

GSR is a method used to observe the continuous change of an electrical characteristic of human skin. Sweating is controlled by the sympathetic nervous system, not conscious control, and skin conductivity is an indicator of psychological or physiological arousal [23]. In the study, the circuit shown in Figure 2 was used for GSR measurement. In this circuit, the reference resistance and the skin resistance comparison principle of unknown value is used to measure the change of skin resistance. R6 resistance of the circuit is the reference resistance. R1 and R2 are the resistors to be divided into voltage and have the same value. JP1 shows the tips of the probes that measure the resistance on the finger. R6 is set to 100 KΩ to display the change of JP1 value more easily. After the applied supply voltage (VCC) passes through the reference resistor and the GSR probe voltage divider, it reaches two separate voltage followers and a typical differential amplifier circuit. After the difference between the two voltages is taken, it is given to the analog input end of the microcontroller. The resistance calculation from the value reaching the microcontroller is calculated according to Equation 1. n this equation, R is the resistance in ohms and x is the value read from the analog pin of the microcontroller. According to this system, the voltage value reaching the analog end varies between 0-5 V and on the analog pin, this is measured with 10-bit (0-1024) resolution. A low pass filter with 5 Hz cutoff frequency is applied to the GSR signals after reaching the computer.

$$R = \frac{(1024 + 2x) * 10000}{512 - x} \tag{1}$$

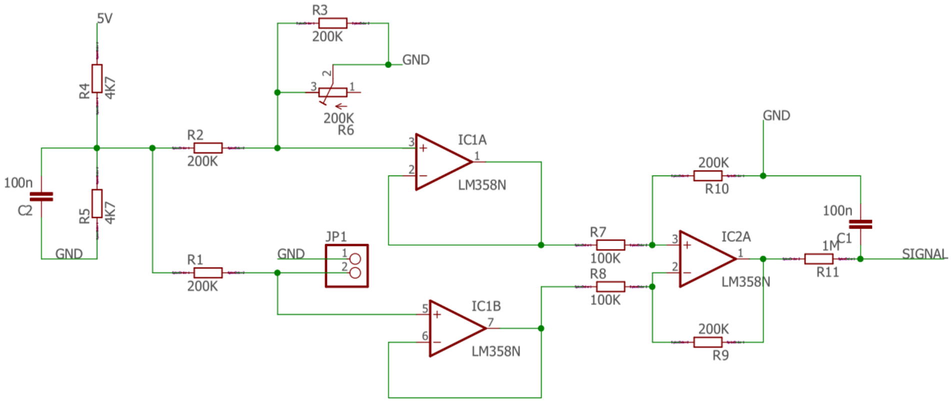
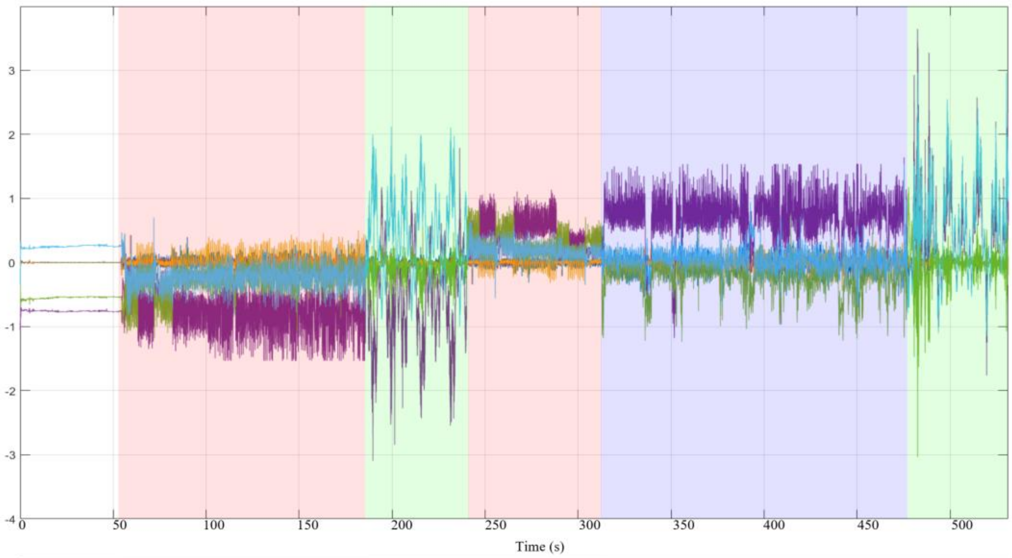



**Figure 2.** GSR Circuit.

## 3. RESULTS AND DISCUSSION

The system has been tested while standing, walking, jumping and climbing stairs. Data were collected in two consecutive rounds of gloves. Time-action marking was done manually during data collection. Walking, jumping and stair climbing actions in the measurements are marked as red, blue and green regions in Figure 3, respectively. Average GSR value, Heart rate and $SpO_2$ values corresponding to the obtained IMU signals are presented in Figure 3. According to these values, it is seen that the increase in heart rate, the amount of oxygen in the blood and sweating data can be measured with the prepared system according to the change in the amount of movement. It is observed that as the amount of physical activity increases in the system, the conductivity and HPR increase.




| Standing | Walking | Jumping | Walking | Climbing | Jumping |
|---|---|---|---|---|---|
| GSR: 578 Kohm | GSR: 147 Kohm | GSR: 124 Kohm | GSR: 138 Kohm | GSR: 104 Kohm | GSR: 140 Kohm |
| Heart Rate: 69 bpm | Heart Rate: 85 | Heart Rate: 99 | Heart Rate: 94 | Heart Rate: 97 | Heart Rate: 112 |
| $SPO_2$: 97 | $SPO_2$: 98 | $SPO_2$: 97 | $SPO_2$: 99 | $SPO_2$: 97 | $SPO_2$: 99 |

**Figure 3.** Multi-Sensor Glove Signals.

## 4. CONCLUSION

The aim of the study is to develop a multi-sensor glove system and collect data on effort, sweat and physical activity by wearing only this glove. In system experiments, the relationship between increased physical activity and conductivity and HPR can be easily determined. Instead of using multiple devices with the targeted system, it has been observed that a single glove can successfully collect information about a person's effort, sweating and physical activity at the same time. The proposed system can contribute to future studies in scientific, sports and health data collection research.

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