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Data Acquisition System and Pattern Image Generations for Hand Grip Device

Ming-Horng Wong, Boon-Chin Yeo*, Poh-Kiat Ng, and Wei-Jun Choong

Abstract **- Grip pattern is essential to understand how an object being held in hand. One of the solutions is to use the pressure sensing glove to capture the gripping pressure distributed on the surface of the palm. The objective of this project is to develop a data acquisition system for a gripping device that can capture the grip patterns when a person is gripping an object. The design comprises of Velostat sheet, rows, and columns of conductive threads, that are sandwiched and layered to form a glove with pressure sensor grids. Arduino is used to generate the signals for data acquisition and interface with the MATLAB program through serial communication. On the MATLAB, the sensor data are organized and represented in hand pattern color image. Voltage Divider Rule (VDR) was used in an experiment with different resistor values and the effect of the image patterns were observed. Another experiment has been designed to find out the grip consistency. The results show that resistor values 330Ω can cause the image pattern create noises. Meanwhile, 4.7kΩ resistance value is sufficient to eliminate most of the noises made in the pattern images. In this paper, different grip images can be obtained from different grip activities, such as holding toothbrush, lifting dumbbell, and pressing syringe. Future works can be done in resolution improvement and grip pattern recognition.**

Keywords—Grip, tactile sensing glove, pressure sensors grid, data acquisition

I. Introduction

Grip is process of taking and keeping a firm hold of grasp common activity that is commonly happening in our daily life. With the presence of the sense of touch in the skin, human gains tactile sensation to interact with the environment or objects by control the hands or fingers positions [1].

Grip condition is important to indicate the health condition of patients, especially for the patients that suffer from stroke, heart disease, and the individuals who have suffered from trauma side effects in post-accident [2][3]. Studies have shown the importance of grip firmness to evaluate the overall health and endurance of the grip strength [4]. Individuals with disabilities and amputated individual are often encouraged to go through

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the gripping test to ensure vitality to fit for handling activities of daily living [5].

Grip condition is normally assessed with dynamometer, which indicate the force of grip applied to the device. However, the device does not indicate the way how a person grips the device. More importantly, some amputees (with hand injuries or missing fingers) may only be able to grip objects in an alternate way, comparing to normal people. Some of the amputated fingers may not be able to exert required force to hold objects firmly. A device that can capture the gripping pattern will be important to assess the grip condition. In this paper, a hand grip device with image pattern generations will be focused.

II. Literature Review

A. Dynamometer

Jamar's dynamometer is a device operated based on hydraulic principle to determine the gripping strength [6]. The handle of the device is designed in ergonomic shape for the patients to grasp and test on the device comfortably. However, re-calibration is required for every measurement to maintain the precision. The chassis of the device involves with the hydraulic function that requires maintenance efforts. Other than hydraulic dynamometer, Smedley dynamometer uses the spring elasticity to determine the force and pressure applied in the grasp. The design is simple, and the maintenance efforts are less. Smedley dynamometer has been widely used in the hospitals.

There are many works have been done to digitalize the conventional dynamometers. Modern dynamometer consists of strain gauge load cell, data acquisition system, and signal conditioning circuitries to process the electrical signals generated based on the grasp [7].

Domo-Grip ball is a spherical electronic device designed to determine the grip strength [8]. The ball is airtight, and it shields the electronic system that can detect temperature and pressure. Domo-Grip ball can be wirelessly connected to for data acquisitions during healthcare and rehabilitation exercises. Although the device captures grip pressure value, the pattern of the grip is unknown.

Analysis of the grip force applied to a cylindrical handle can be important for a dynamometer development [9]. ANSYS software has been used to analyze the stress and bending condition of the materials when grip force is applied.

Makino's work [10] has incorporated the pressure sensors onto a rectangle-shaped dynamometer. The device can be used to measure finger force distribution to hold and lift the device. With radio communication, the grip strength can be viewed on a tablet. The work mainly focuses on the grip condition on a 500ml bottle.

B. Pressure Sensor Grid

Pressure sensor grid contains 2-dimensional array of force sensors to capture the force distribution pattern, when there is an activity done on the grid. Pereira has used the sensor grid for hospitalized patients to prevent pressure ulcers [11]. Force Sensing Resistors (FSR) has been used to form the sensor grid on the mattress. However, the resolution of the sensor grid is constrained by the size of the FSR.

To improve the resolution, conductive threads and cotton fabric with polystyrene sulfonate are used to form a flexible sensor grid [12]. Reviewed by [13], skin-inspired flexible sensor systems can provide even higher resolution. Generally, the higher the number of conductors is deposited per unit area, the higher the resolution. Sufficient high resolution is required to capture the grip pattern, as the area of the fingers and palms are small. FSRs can be suitable for mattress-size sensor grid but constraining the resolution for grip pattern capturing process.

C. Tactile Sensing Glove

Tactile sensing glove is a device that can capture the grip pattern. The glove can be applied in automation industry, rehabilitation, military, virtual reality, etc. The work in [14] involves the glove designed based on pneumatic principle. The pneumatic actuators that can create accurate reading on the pressure with small hysteresis effect, are used.

A high-resolution tactile glove was designed in 2011, in which the sensors are positioned according to the hand structure [15]. The microcontroller was sewn on the glove. However, the design is complex, and the sensors are not evenly distributed on the glove surface, which can pose the challenge for data representation and analysis.

On the other hand, the grip sensor is a flexible sensor that has a set of sensing points that can be attached on the hand for pressure measurements, especially at the contact regions when gripping an object [16]. Grip patterns are only available at the sensing points.

Kazuya Matsuo had developed a low-cost high resolution tactile glove [17]. Similar to the work in [15], the sensors are positioned according to the hand structure. The glove was able to produce different pressure patterns when different objects were held in hand.

In a recent study [18], Sundaram had proposed a high-resolution tactile sensing glove, in which the sensors are formed with conductive threads, and Low-Density Polyethylene (LDPE). The sensors are uniformly distributed over the hand. With deep Convolutional Neural Network (CNN), the system can estimate the weight and identify the object based on the grip pattern.

In this paper, a 2-dimentional sensor grid is designed to evenly distribute the pressure sensing spots on a glove. In this way, an image representing the grip pattern can be formed. Image representation of grip pattern can be important for further analysis that involves deep learning applications in the future works.

III. METHODOLOGY

A. Hardware Design

The hardware design of the glove involves the Velostat sheet, and the pressure sensor structure is shown in Figure 1(d) is adopted [19]. The conductive threads are used as the conductors to connect the sensors. Meanwhile, the protective layers are formed with PVC sheets. The sensors are sewn according to hand shape, as shown in Figure 2. The figure also shows the whole construction in the form of 16x16 matrix with the empty region between the index finger and the thumb. The circuits are sewn in a long strip cloth to secure the sensor structure and the conductors. The circuitry on the glove is connected to the microcontroller (Arduino Nano) for data acquisition and interfacing with the MATLAB program in the desktop computer. Similar approach has been used in the previous work for fall detector system [20]. The sensor circuit has 16 rows of conductor connected to 2 shift registers 74HC595, in which each of them can drive 8 channels. On the other hand, 16 columns of conductor are connected to the multiplexer CD7HC4067 with the grounding resistors that forms the voltage divider circuit. In total, there are 170 pressure sensors formed on the glove. The photo of the developed hardware is shown in Figure 3. Different resistors will be tested to determine the suitable resistance value for grip pattern image generations.

B. Algorithms for Data Acquisition

The firmware for the microcontroller will be developed with Arduino IDE as Arduino Nano is used for data acquisition. The code begins by generating initialization signals for the shifters and the multiplexer. Figure 4 shows the flowchart of the firmware. Generally, the microcontroller waits for the command from the MATLAB program before it generates the activation signals to the sensors. In the system, the command is implemented with a ‘s’ character.

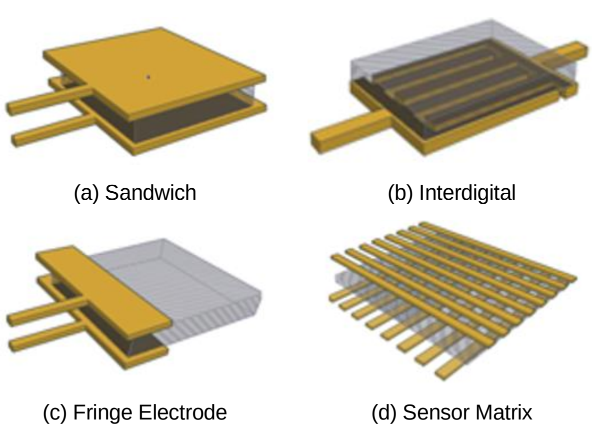

FIGURE 1. Structures of pressure sensor [19].

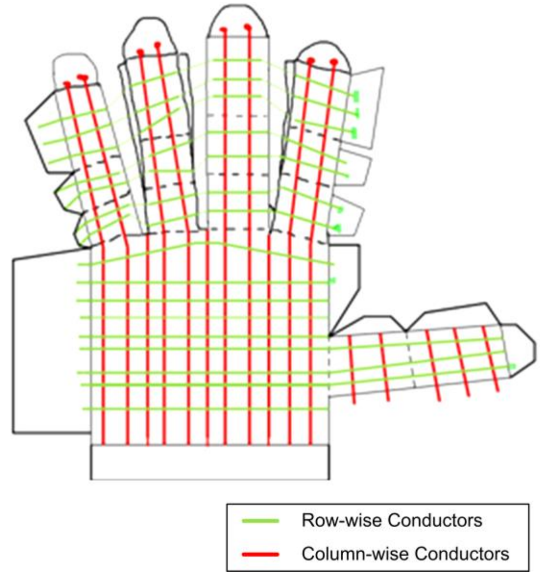

FIGURE 2. Conductor layouts of sensor grid on the glove.

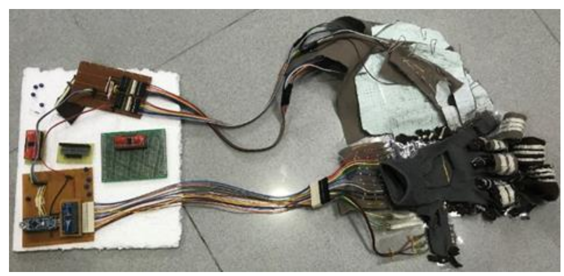

FIGURE 3. Hardware of the hand grip device.

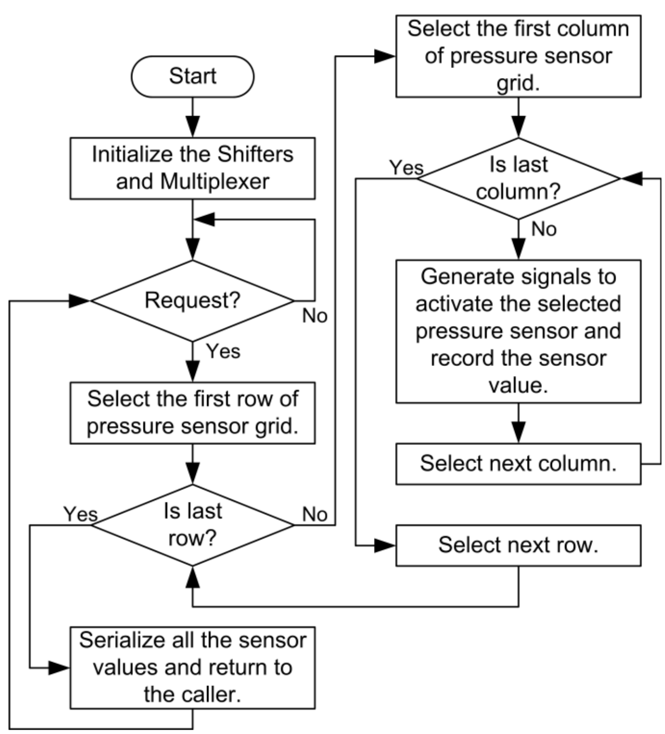

FIGURE 4. Flowchart of the firmware.

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Upon receiving the command, the microcontroller will activate every channel of the shifter one-by-one. In other words, all the sensors in the respective row will be powered when a channel of the shifter is activated. Then, the microcontroller will generate signals to select the channels from the multiplexer one-by-one. Selecting a channel in the multiplexer will pass the signals from a sensor in the selected row to the analog input of the microcontroller. The sensor value will be recorded. After looping all rows and columns, all the sensor values in the grid are recorded and returned to the MATLAB program through serial communication.

Figure 5 shows the flowchart of the MATLAB program. When the program is started, the 's' command will be issued to the microcontroller in every iteration. In every iteration, the sensor values will be colored with heatmap for good visualization. The regions with low pressure are represented with cold color (close to blue color). Meanwhile, the regions with high pressure are represented with hot color (close to yellow color).

IV. RESULTS AND DISCUSSIONS

A. Grounding Resistor Determination

In this section the suitability of the grounding resistance value is investigated. The process is important to determine the suitable resistor values to give lesser noise in the pattern images. Three commonly used resistors are considered. The resistance values in the test are: 330Ω, $1k\Omega$, and $4.7k\Omega$. For each resistance value, the pattern images for no grip and grip with toothbrush are recorded.

Figure 6 shows the images recorded for no grip condition. From Figure 6(a), the grounding resistor value is 330Ω. The image shows that high pressure (yellow) in little finger, ring finger, middle finger, thumb tip, and the upper and lower palm regions. Besides, the background was quite runny. The noise dominates the pattern image. For Figure 6(b), $1k\Omega$ grounding resistors are used. The noise decreases as the yellow color only appear slightly at the ring finger, little finger, middle finger and lower palm. The background condition is less runny. However, the ring finger still has more yellow regions. For Figure 6(c), $4.7k\Omega$ grounding resistors are used. The yellow and green colored regions are completely vanished except at the region near to the little finger, which can be caused by the continuous pressure asserted due of the hardware itself. In the following discussion, the fault spot is ignored. Less noise (light blue regions) appeared at the other regions of the image.

Figure 7 shows the sample images obtained from the grip with toothbrush. Similarly, three different resistor values were tested. During the experiments, the toothbrush is gripped with normal force. However, Figure 7(a) shows larger yellow region covering almost cover the entire palm, when 330Ω resistors are used. With $1k\Omega$ resistors, Figure 7(b) still shows large yellow region. The noise elimination is not effective. In Figure 7(c), the image shows the noises have been mostly eliminated.

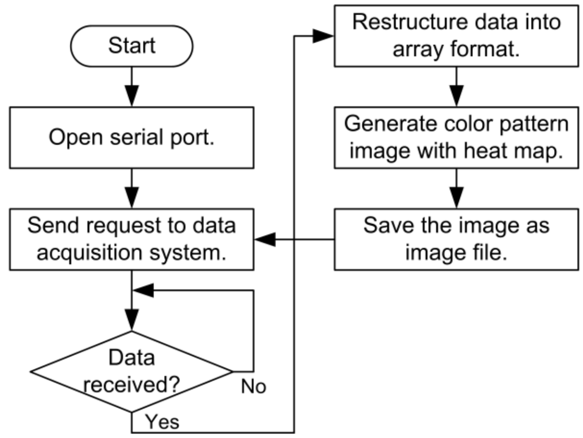
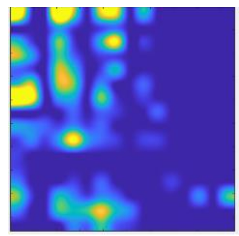
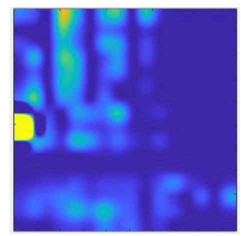


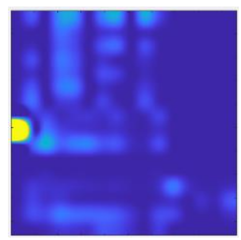
FIGURE 5. Flowchart of MATLAB program.



(a) With 330Ω Resistors

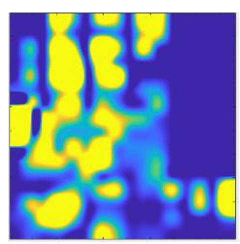


(b) With $1k\Omega$ Resistors

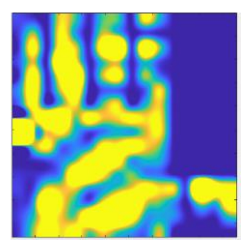


(c) With $4.7k\Omega$ Resistors

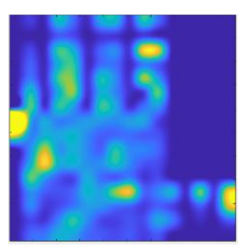
FIGURE 6. Pattern images for no grip.



(a) With 330Ω Resistors



(b) With $1k\Omega$ Resistors



(c) With $4.7k\Omega$ Resistors

FIGURE 7. Pattern images for grip with toothbrush.

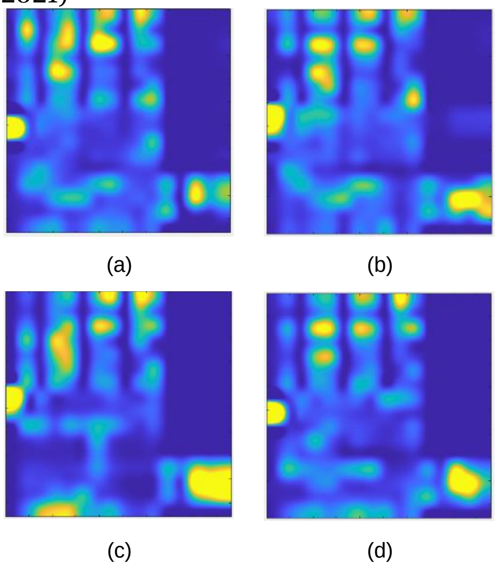


FIGURE 8. Pattern images for holding dumbbell during performing shoulder press.

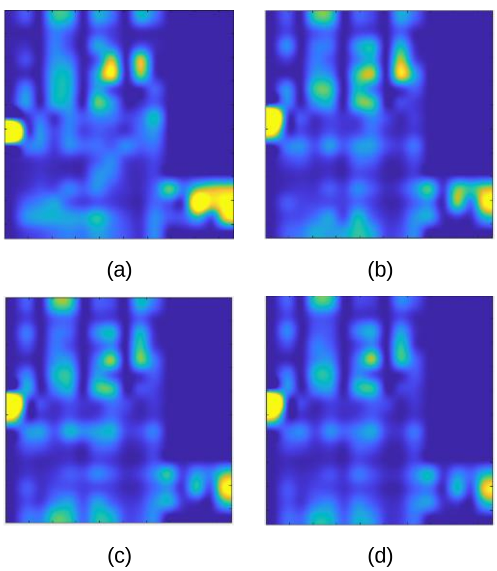


FIGURE 9. Pattern images for pressing syringe.

The pressure image shows green and yellow patterns at certain regions. The yellow regions show the contact regions that exert higher force to the toothbrush. The image confirms to the results in the work [21], in which different forces will be exerted to different parts of the object in a grip. The grip pattern on the toothbrush is messy due to the folding on the palm area. The folding effect can lead to significant pressure exerted on the sensors. However, $4.7\mathrm{k}\Omega$ grounding resistors are sufficient to produce the pattern images to differentiate the objects in the grip.

B. Grip Patterns for Different Activities

In this section, the pattern images are discussed when dumbbell and syringe are handled. Figure 8 shows the sample pattern images recorded when a dumbbell was held to perform shoulder press. While holding the dumbbell to perform shoulder press, the palm area requires to show lesser pressure applied on it. The main reason is to prevent the gym trainer from taking up more energy when performing the exercise. In Figure 8, the pattern images are consistent, and it is observable that the pressures are applied on the fingers and the thumb tip.

Figure 9 shows the pattern images when the fingers involve in pressing the syringe that is placed at the middle of at both middle and index finger. When pressing the syringe, thumb will exert the force. From the sample images in Figure 9, larger pressure can be seen on middle finger, index finger and thumb.

V. Conclusion

In this paper, a tactile sensor glove has been developed. The pull up resistor value $4.7k\Omega$ is considered sufficient to clear the unwanted noises to get clear and accurate data. The results have shown different pressure pattern images when gripping different objects: toothbrush, dumbbell, and syringe. In the future works, the resolution and the wiring of the system can be improved to provide clearer pattern images.

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Author contributions

Ming-Horng Wong: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Wei-Jun Choong: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Poh-Kiat Ng: Project Administration, Writing – Review & Editing;

Boon-Chin Yeo: Project Administration, Supervision, Writing – Review & Editing.

Conflict of interests

No conflict of interests were disclosed.

Ethics statements

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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