Investigating Hand Dexterity in Patients with Hand Injuries through A Self-made Data Collection Glove

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***Abstract*—The flexibility of people's fingers plays a very important role in our daily life. Many people lose some degree of finger dexterity due to finger injuries. In this study, a self-made Arduino data acquisition glove was used to collect data on 8 daily hand movements of healthy participants and patients. From the data collected on healthy participants, we established a norm of finger movements of healthy participants. We analyzed how people used different fingers to perform different movements. Furthermore, we collected data on some patients with finger injuries and compared their hand dexterity with healthy individuals.**

Keywords- sensors; hand dexterity; data glove; wearable device.

I. INTRODUCTION

Fingers play an important role in people's lives. Many daily life movements require a high degree of cooperation and coordination of different fingers to complete. However, when people’s hands are injured, those seemingly simple daily actions might become quite difficult. In order to maintain the daily life movements of patients, rehabilitation has become an indispensable element. Rehabilitation can be a difficult task for patients. This is because, on one hand, it requires a lot of perseverance of the patient, and on the other hand, it takes a considerable amount of time. In addition to the above-mentioned factors, what is more important is whether the patient’s rehabilitation is moving in the right direction. If the direction is correct, of course, the patient's hand health will gradually improve over time. However, if the direction is wrong, it is not only unhelpful to the patient, but may even cause further secondary damage.

In the process of rehabilitation, patients often face problems that they have no way of knowing in advance, and so it is difficult for them to determine whether they are moving in the right direction with their rehabilitation. If there is an objective assessment method that can provide appropriate information to patients in a timely manner, it is generally believed that it can effectively help improve the recovery of patients. In general, effective assessment methods can be roughly classified as invasive or non-invasive. The information obtained by the former assessment of the patient may be more direct or accurate than the information obtained by the latter. However, its disadvantage is that it might more or less directly or indirectly affect the patient’s physical health. In this case, it might not be suitable for long-term evaluation. In contrast, non-invasive assessment methods may have less impact on patients. From a certain point of view, it may be more suitable for long-term assessment and tracking.

Faced with the above problems, this study hopes to establish an economical, non-invasive method that can detect the finger usage of patients at any time, so as to help patients understand the situation of hand rehabilitation in time. With this information, it can also provide physicians with an understanding of a patient's condition and provide appropriate diagnosis and treatment. With the joint efforts of both patients and physicians, the pace of patient recovery can also be accelerated. Several researchers have conducted investigations along this line of study [1]-[4].

The rest of the paper is structured as follows. In Section II, we describe the design of this induction glove and the method of data analysis used in this study. The experiments and results are presented in Section III. Finally, we draw our conclusions in Section IV.

II. METHOD

As mentioned above, in order to understand the activities of people's fingers, a self-made sensing glove was developed. The glove MS-100M produced by 3M company was selected in this study. MS-100M is a foam-coated glove with excellent breathability, anti-slip, and oil-repellent properties. We first manually sew the curvature sensors and the pressure sensors on the glove. After that, we connected these sensors to the Arduino Mega 2560 board to capture the experimental data. The Arduino Mega 2560 board has 16 analog input pins and can accept 16 input signals. Five out of these 16 pins were connected to the curvature sensors while the remaining 11 pins were connected to the pressure sensors. A curvature sensor was sewn on the back of each finger near the joint to obtain the bending degree of each finger when a person performed a certain action. A total of five curvature sensors are required for five fingers. In terms of finger pressure, each finger has its connections to two pressure sensors. One is sewn to the DIP (distal phalange) joint and the other to MCP (metacarpal) joint of each finger (Figure 1). Finally, considering that the thumb has one more degree of freedom than other fingers, a pressure sensor is added to the PIP (proximal phalange) joint of the thumb. The entire induction glove design is shown in Figure 2. Each subject was asked to perform 8 daily life actions, as demonstrated in Figure 3.

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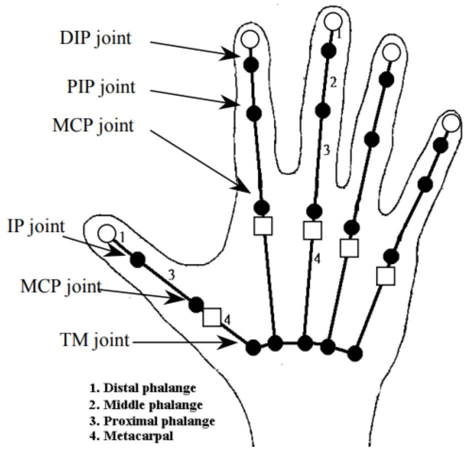

Figure 1. A homemade bending and pressure sensing glove.

Figure 2. A homemade bending and pressure sensing glove.

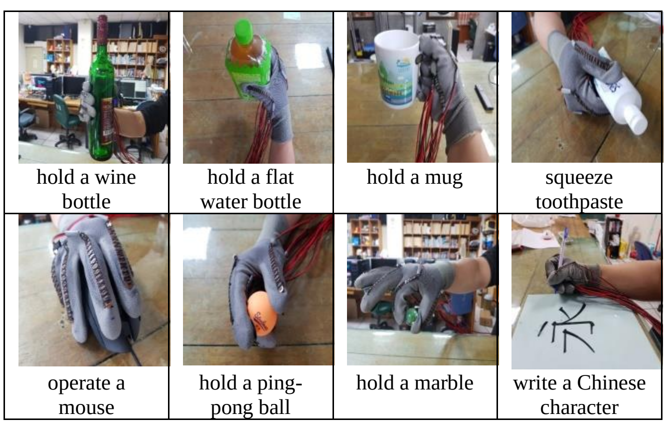

Figure 3. Eight daily life actions.

In this study, the time series data of the action process and the data of the completed action were analyzed respectively. When analyzing the time series data of the action process, this study uses the Pearson similarity method to analyze the consistency of the two action curves. The above analysis method is for activities of people with healthy hand. However, for patients with hand issues, this approach is not very appropriate. This is because each patient's finger injury is different. For example, some are unable to bend, while others are unable to be straightened after being bent for a long time. The approach of this study is to find out the maximum of all movements of each patient when performing movements. Then, we compare whether their maximum values differ from each other. When this difference is relatively small, it is considered normal. Otherwise, it represents an exception. The minimum value is handled in the same way. Through the above-mentioned comparisons, it is possible to discover the differences between each patient and others.

III. EXPERIMENTS AND RESULTS

This research experiment is divided into three parts. The first is to establish a data norm of 30 healthy participants. The second is to compare and analyze the data of patients and healthy participants. The third part is to analyze the rehabilitation situation of a specific patient in different rehabilitation stages. The results showed that some patients' index fingers showed significantly lower curvature values in certain movements than others. In addition, in some patients, the curvature of the middle finger was significantly different from that of healthy participants. This result indicates that the patient may not be able to bend the fingers on both sides because the middle finger cannot bend normally. In addition, there was a patient whose little finger shows a fixed value in any movement, which indicates that the patient's little finger mobility was lost.

IV. CONCLUSION

The purpose of this study was to explore how people use their fingers in curvature and acupressure for daily activities. The method adopted in this study was to first make a glove with induction curvature and acupressure sensors. We then invited thirty healthy participants to perform eight daily activities. The first thing we did was to test whether we could use the sensors of this homemade glove to judge the difference between two different actions. After we confirmed the discriminative ability of this homemade glove system, our next step was to try to build a reference dataset from the collected data to analyze the role of each finger.

There are two future research directions. The first is to continuously increase the repertoire of sensory data to establish healthy human hand activity norms. In addition to the 8 activities of daily living used in this study, this study recommends more data collection on other hand movements. The second direction is to allow patients to compare rehabilitation outcomes at different stages under the guidance of clinicians. In this way, we can see whether the patients have been improving clinically through the data provided by this system, that is, whether the patient's hand function is improving. This is a more objective analysis, which is its real practical application. Finally, in the future, we hope to collect enough data on the use of this technology to integrate Artificial Intelligence (AI) systems into this field of research and to further capture the specific biological characteristics of individuals.

ACKNOWLEDGEMENT

Ethical Approval: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Human Research Ethics Committee of the National Cheng Kung University (Approval No.: NCKU HREC-E-110-319-2, date: July 13^{th}, 2021).

Informed Consent Statement: Written informed consent has been obtained from the patient to publish this paper.

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