Rehabilitation Support System for Patients with Carpal Tunnel Syndrome Using Smartphone

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ABSTRACT

"Carpal tunnel syndrome(CTS)" is a disease where the fingers turn numb making it challenging to move the thumb. In this paper, we propose a rehabilitation support system for patients with CTS using a smartphone app. Conventional rehabilitation programs for CTS are often boring and are challenging for medical doctors to observe the patient's condition. In our system, patients play a game using their thumb on the smartphone. Our aim is to maintain their motivation for rehabilitation. Our system transmits the game results to the server in order to share the patient's condition with the medical doctors.

CCS CONCEPTS

•Human-centered computing →Interactive systems and tools

KEYWORDS

Rehabilitation, Carpal Tunnel Syndrome, Gamification

1 INTRODUCTION

Thumb is important for different actions such as gripping and picking objects. However, people who have CTS due to frequent movements of the wrist, aging, bone fracture, swelling caused by pregnancy, numbness of the fingers will occur, making it difficult to grasp by moving the thumb finger.

During CTS rehabilitation, medical doctors recommend patients to stretch their wrist and practice grasping and pinching objects with their fingers. However, patients find it challenging to maintain their motivation for rehabilitations as they are often boring and hard to realise the effect for them. Medical doctors are also unable to observe patients' condition in daily life environment.

In this paper, we propose a rehabilitation support system for patients with CTS using a smartphone. In our system, patients play a simple game using their thumbs. Medical doctors can monitor the results on the cloud to observe patients' condition.

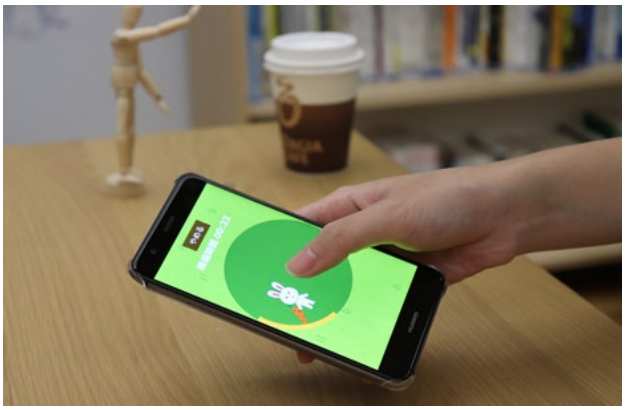

Figure 1: Overview of our system

2 RELATED WORK

2.1 Evaluation of CTS

One conventional method to measure CTS is the Perfect O Sign generated by connecting the index finger and the thumb. The shape of an O sign of patients with CTS is crushed as compared to an O sign of healthy people. However, quantitative evaluation is difficult as medical doctors observe the shape of O sign subjectively. Shirasu et al. [1] propose a system that can measure the area of the O sign by using camera with computer vision technology. As a result, they confirmed that the area increased by an average of 1.38 times after surgery as compared to preoperative observation.

Baic et al. used thermography to measure the temperature distribution of the patient's hands to diagnose CTS [2]. There is a difference in the temperature distribution between preoperative

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Figure 2: 12 directions in which vegetable characters appeared

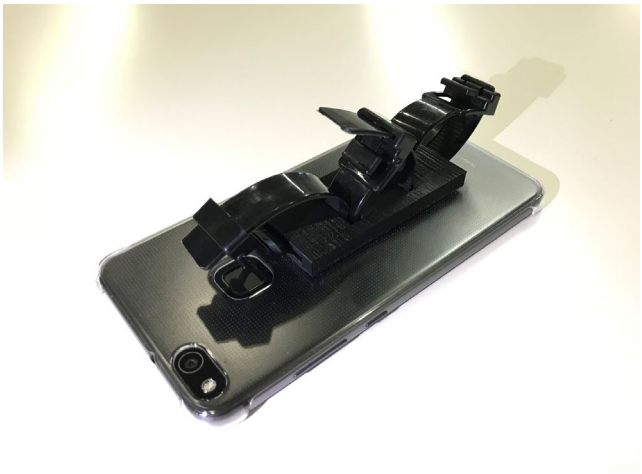


Figure 3: The finger guide attached to the back of smartphone

and postoperative hands of patients with CTS. Based on this system, indicating that the temperature distribution of the postoperative hand is similar to the temperature distribution of healthy hands.
In these researches, it is necessary to use cameras or thermography to evaluate the condition of CTS making it challenging to objectively evaluate at home environment. By using common devices such as smartphone, patients can objectively and easily check their condition.

2.2 Analysis of Rehabilitation

Ploderer et al. have developed a system that visualizes the behavior and analyzes the performance during rehabilitation by attaching multiple wearable sensors to the user's body [3]. However, it takes time to prepare for use and the user's body movement could be impeded.
Watanabe et al. proposed DanceDanceThumb, a rehabilitation support application for CTS using a tablet PC [4]. In this research, it is possible to share the patient's' condition with the doctors by recording the result of rehabilitation in the server. However, it is desirable that patients can be provided a rehabilitation easily especially for home use, but tablets are large and expensive as compared to smartphones, and they are less common to be used.

3 SYSTEM

In this paper, we propose a rehabilitation support system for patients with CTS using a smartphone. Since most patients with CTS are elderly people, we developed a simple game for the players to use their thumb. We aim for our system to enhance their motivation to do rehabilitation by showing their current condition in the game result.

3.1 Flow of Experience

In this application, the patient controls the rabbit character with his thumb and collects the vegetable characters that are appearing on the screen. Vegetable characters appear sequentially in 12

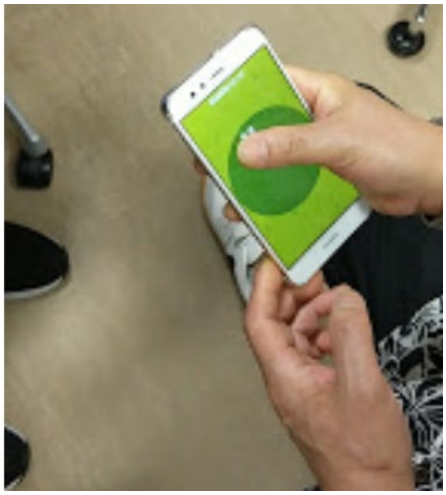
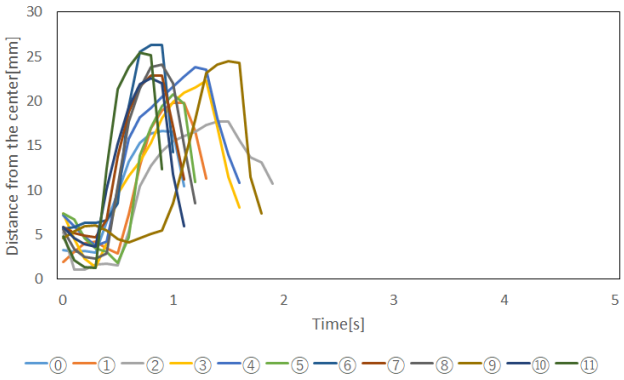


Figure 4: A patient using application

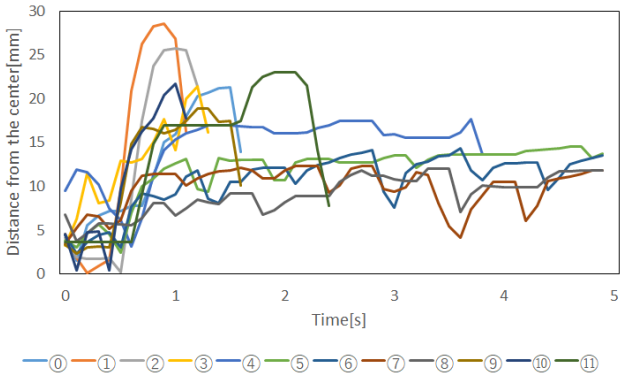
directions within a circle of radius 2 as shown in Figure 2 in a random order. The vegetable will appear alternatively on 1 of the 12 directions and the center. Therefore, the patient will collect the vegetable on 1 direction, then the center and then another direction and so on. If the patient failed to collect a vegetable character within 5 seconds, the character will disappear and appear on another place. In the practice phase, vegetable characters appear randomly in 4 directions. The game ends after two sequences of vegetable appearance in 12 directions.

3.2 Implementation

We utilize a HUAWEI P10 lite (Android 7.0), and develop the applications using Unity software. We also created a finger guide attached to the back of smartphone to fix the position of the fingers other than the thumb during rehabilitation. The guide consists of a part that was printed using a 3D printer and 3 binding bands. The



(a)A mid person



(b)A severe person

Figure 5: The trajectory of the rabbit characters in the game between a mild person (a) and a severe person (b)

length of the binding band can be adjusted to be able to adapt to the thickness of the patient's fingers. Figure 3 shows the appearance of the finger guide attached to the back of smartphone.

Our application records the (x, y) coordinates of the rabbit character every 0.1 seconds. It will send a trajectory data of 12 directions × 2 laps to the server collectively after the game. A direction trajectory is characterized as collecting the vegetable in the center and then in one direction and then collecting at the center again. We use the cloud service (Amazon Web Service) to store the data in the database. Then, we can share the results of the rehabilitation with the medical doctors remotely.

4 USER TRIAL

We conducted user trials with 4 patients with CTS. 1 person has mild CTS and another 3 people have severe CTS. The doctors of Tokyo Medical and Dental University Hospital are involved in the experiment. Figure 4 shows a patient using our system. 2 of the severe patients looked tired making it difficult to continue the experiment as data in several directions could not be collected. Figure 5 shows the trajectory of the rabbit characters in the game between the two other patients (1 mild and 1 severe).

5 DISCUSSION

Patients with CTS has difficulty moving their thumb. Severe patient takes a longer time to recover than mild people and could not collect vegetable characters in the specific direction. From our results, our system have the capabilities to measure the improvement of the symptoms. As it can measure the degree of the symptoms, it can be used to estimate the CTS symptom level. As future work, we will implement a system that can change the range of vegetable characters' appearance according to the size of the patient's hand. The number of patients in this trial was small. However, as the percentage of patients with CTS will increase in the winter, we plan to increase the number of data and continue on with the analysis.

6 CONCLUSION

In this paper, we developed a rehabilitation support system for patients with CTS using a smartphone. Our system creates a rehabilitation program by playing the game using their thumb in their daily environment and can share the results with doctors.

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