# An Application for Wrist Rehabilitation Using Smartphones

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## ABSTRACT

In this paper, we propose a wrist rehabilitation support system using a smartphone app. There are several issues with the conventional wrist rehabilitation systems, primarily that there is no method for quantitatively evaluating whether it has been appropriately carried out or not, that it is difficult for doctors to observe the condition of patients at home, and that the content is often boring.

In our system, using a smartphone means that we can easily introduce it to homes and have medical doctors observe the condition of patients by accessing their data on the cloud. We also aim to help patients maintain their motivation for rehabilitation by playing a game using their wrist and a smartphone.


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**KEYWORDS**

rehabilitation; fracture; smartphone; gamification

Figure 1: Overview of proposed system.

**CCS CONCEPTS**

· Human-centered computing → Ubiquitous and mobile computing; Ubiquitous and mobile computing systems and tools.

## INTRODUCTION

Rehabilitation is often necessary after injury to the wrist due to an accident or age-related deterioration. If the rehabilitation is not sufficiently carried out, especially after a fracture, it may become difficult to move the wrist. Therefore, voluntary rehabilitation is indispensable not only in hospitals but also at home. However, rehabilitation can often be vague and monotonous, which makes it difficult for patients to see any effect and to maintain their motivation. In addition, medical doctors are unable to observe the condition of their patients in their daily life environment.

In this paper, we propose a wrist rehabilitation support system that uses a smartphone. In our system, patients play a game using their wrist, and doctors can monitor the results on the cloud.

## RELATED WORKS

### Wrist Rehabilitation

Ambar et al. [1] developed a wrist rehabilitation device using an acceleration sensor that was designed for use by patients at home without assistance.

Fabrizia et al. [4] developed a game for wrist rehabilitation using Leap Motion, which measures hand motion by combining sensor data with a human hand model.

However, with these systems, it is necessary to purchase new electronic devices in order to build the rehabilitation environment, which inhibits their use in environments with no doctor present, such as the home. By using a common, readily available device —a smartphone— we aim to provide an easy rehabilitation environment for general households.

### Rehabilitation Using Smartphone

In recent years, several prototypes for rehabilitation and monitoring systems using mobile devices have been developed.

Di et al. [3] developed a system that monitors changes in the motor function of patients with Parkinson's disease by using sensor data embedded in smartphones. In a similar vein, Rinne et al. [6] developed an application to assist with the rehabilitation of patients after stroke, where the ability of patients to control their smartphone cursor, such as by swiping or tapping, was measured.

One example of wrist rehabilitation using smartphones is WristDroid by Baranyi et al. [2]. Their prototype consists of multiple games that were designed on the basis of opinions from physical and occupational therapists.

However, patients who have difficulty moving the wrist often undergo rehabilitation using motor functions other than the wrist. There are called compensatory movements, and it is difficult for patients to notice them by themselves. In order to carry out appropriate rehabilitation of the wrist without the physical presence of a doctor, it is necessary to clarify the system and posture which naturally induce the motion of the wrist, and to instruct the patients.

We have developed a smartphone application that induces wrist movement and  to investigate the presence or absence of compensatory movements according to posture. Miyata et al. [5] measured the contact area and joint angle of the thumb with a limited range of motion, so here, we focus on compensatory movements of the wrist.

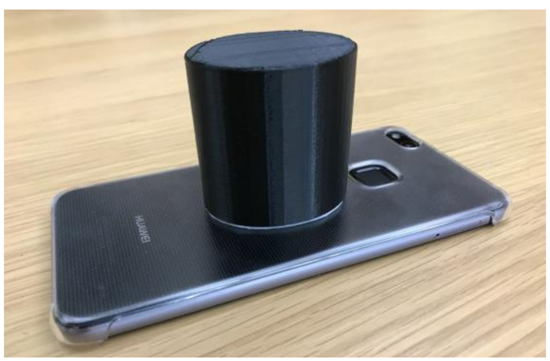

**Figure 2: Hand guide attached to the back of a smartphone.**

## SYSTEM

The proposed wrist rehabilitation support system is designed to quantitatively confirm whether the wrist is moving properly. Since injury and deterioration of the wrist are frequently observed in the elderly, we developed a simple game that patients can play by moving their wrist. Our aim is for the system to enhance their motivation for rehabilitation by showing them their current condition in the game result.

### Implementation

We utilized a HUAWEI P10 lite (Android 7.0), and developed the applications using Unity software. We also created a hand guide attached to the back of a smartphone (Fig. 2) to fix the position of the hand during play. The guide was output using a 3D printer.


**Figure 3: Vegetables appearing in 12 directions.**

An accelerometer embedded in the smartphone was used to detect the tilt of the wrist.

### Flow of Experience

In this application, the patient controls a farmer character with his or her wrist and collects vegetables that appear on the screen. These vegetables appear sequentially in 12 directions within a circle of radius 2, as shown in Figure 3, in a random order.

A vegetable appears alternatively in one of the 12 directions and at the center, and the patient collects the vegetable in one direction, then at the center, then in another direction, and so on. If the patient fails to collect a vegetable within five seconds, it disappears and immediately reappears at another place. The game ends after 60 seconds.

### Game Design

Our application records the number of vegetables collected during a game and displays this number along with high scores and log-in days for each user at the end of the game. These data are then stored on a cloud using the Nifty Cloud Mobile Backend service. Then, we can share the results with medical doctors remotely.

## MEASUREMENT OF COMPENSATORY MOVEMENTS

We measured the range of wrist motion in order to determine the posture in which patients could move their wrist widely. Effective rehabilitation can be achieved even in an environment with no doctor presents once we know this posture. Figure 4 shows the posture conditions in our trial. We utilized Xsens [7] for the measurement.

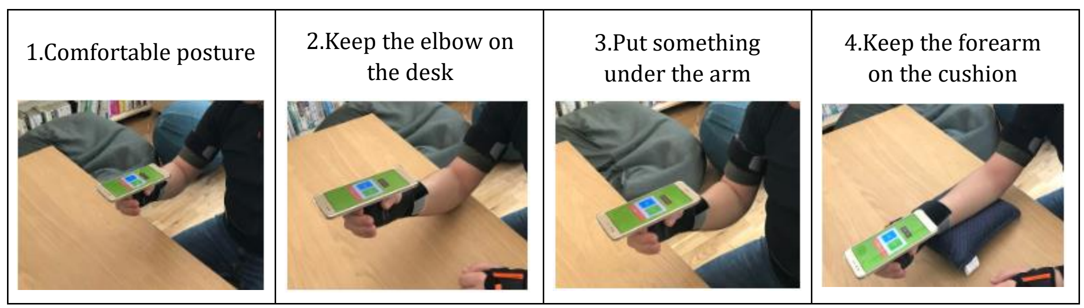


**Figure 4: Posture conditions in trial.**

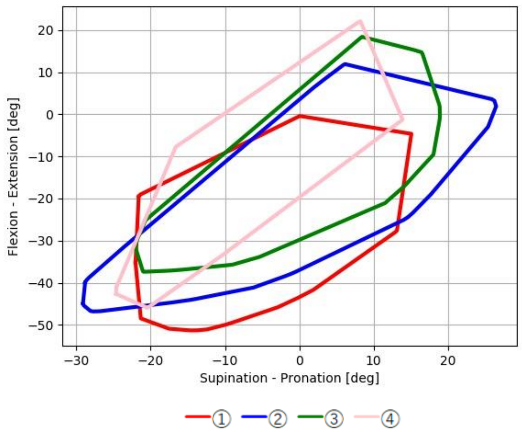


**Figure 5: Range of wrist motion.**

Figure 5 shows the range of motion of the wrist under each condition. In condition 2, supination and pronation of the wrist occurred in the widest range.

## DISCUSSION

Figure 6 shows the movement of one participant's arm measured with Xsens. Compared with condition 1, in which the posture was not determined, conditions 2 and 3 showed fewer arm movements and reduced compensatory movements. In condition 4, the posture gradually shifted since the position was not fixed, though the arm did not greatly move. These results demonstrate that quantitatively measuring the movements of the wrist and arm under certain conditions can reveal the appropriate posture for rehabilitation.

As future work, we will determine the appropriate posture by increasing the number of participants, measure the effect of the rehabilitation, examine whether the patients are able to maintain their motivation, and evaluate the range of motions of the wrist and the effect of the rehabilitation using our system.

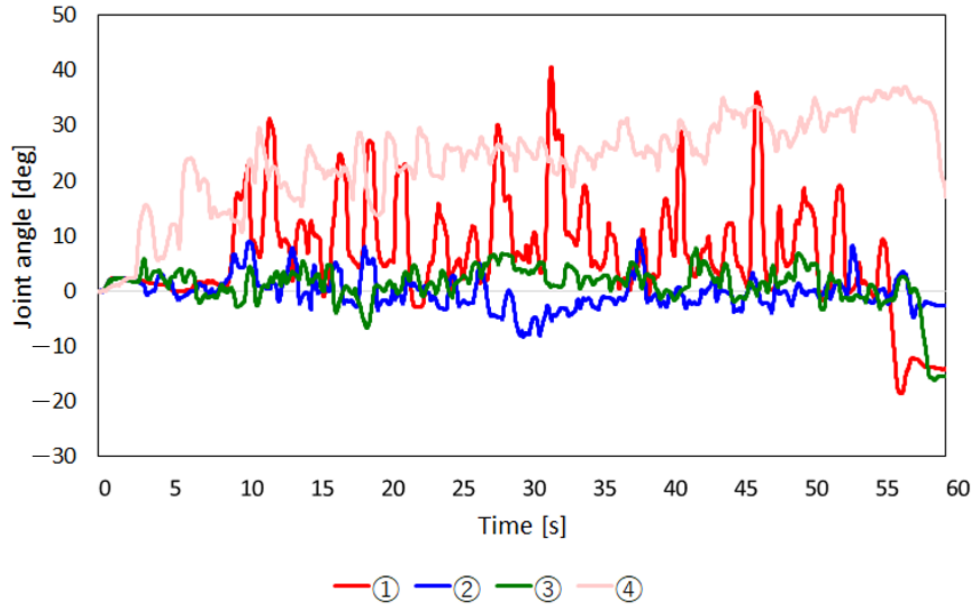


**Figure 6: Joint angle of the elbow.**

## CONCLUSION

In this paper, we presented our wrist rehabilitation support system using a smartphone. Our system provides a rehabilitation program where patients play a game using their wrist in their daily environment and the results are shared with their doctors.

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