SpineCurer: An inertial measurement unit based scoliosis training system

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ABSTRACT

Scoliosis patients face problems like difficult ambulation and weak sit tolerance comparing to healthy people. In addition, scoliosis has potential to cause respiratory and neurological complications that seriously affect life quality. Treatments like Schroth best practice(SBP) are effective for scoliosis but need professional guidance. In this paper, we propose SpineCurer(SC), an inertial measurement unit(IMU) based scoliosis training system. The system detects the patient's posture in real time based on IMU, so that the patient can train without supervision. SC integrates two interaction games to assist training. We conducted a user study to evaluate the usability and effectiveness of the system, which showed a positive effect in assisting scoliosis treatment.

CCS CONCEPTS

• **Human-centered computing** → *Interactive systems and tools.*

KEYWORDS

Scoliosis Training, Wearable Device, IMU

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1 INTRODUCTION

Scoliosis patients face problems like difficult ambulation and weak sit tolerance comparing to healthy people. In addition, scoliosis may cause respiratory and neurological complications, which seriously affect the quality of life[10]. In recent years, the use of physiotherapeutic scoliosis-specific exercises(PSSE) to treat scoliosis has attracted attention. The purpose of PSSE is to reduce spinal deformities and prevent its progression, it also aims to consolidate the improvements achieved with the ultimate goal of limiting the need for orthosis or surgery[9]. Schroth best practice (SBP) is a form of PSSE[2]. There are many studies have verified its effectiveness in the treatment of scoliosis[5]. In general, SBP are performed under the supervision of scoliosis specialists. However, due to a lack of human resources for spinal rehabilitation specialists, patients often do not receive adequate professional guidance and long-term care during spinal correction. Thus, an intelligent spinal training system is urgently needed, which should be able to detect the patients' posture in real time and enable the patients to complete SBP training without supervision.

At present, inertial measurement units(IMU)-based human action detection and recognition methods have attracted widespread attention due to its low cost and strong real-time performance. This method has been widely used in various fields, such as gesture recognition[4, 6], behavior analysis[7], healthcare system[8, 11] and human-computer interaction[1].

In this paper, we propose an IMU based scoliosis training system, SpineCurer(SC). SC detects the patient's posture in real time and prompts when the posture is incorrect to assist patient complete the training independently. We design two interaction games that use body movement for game control to enhance the fun of training and the motivation of patients. Finally, we conducted a user study to test the usability, effectiveness and interest of the SC and to obtain evaluations from scoliosis specialists.

2 SPINECURER SYSTEM

2.1 System Overview

The SC was developed based on Unity. The structure of SC is shown in Figure 1. SC consists of three Xsens Dot sensors and a android application. Sensors are attached on the patient's back and transmit motion data through bluetooth low energy(BLE). The module of data processing receives the real-time data, analyzes the patient's spine orientation to evaluate whether the posture is correct, and gives multiple feedback in the interaction training module. Finally, the training records are automatically uploaded to the cloud and displayed in the visualization module.

2.2 Motion Detection

Real-time motion detection is based on three wearable sensors that capture the patient's motion data. The data formats by Xsens Dot includes acceleration, Euler angles and quaternions. We used Euler angles to detect the patient's spine posture. However, due to the

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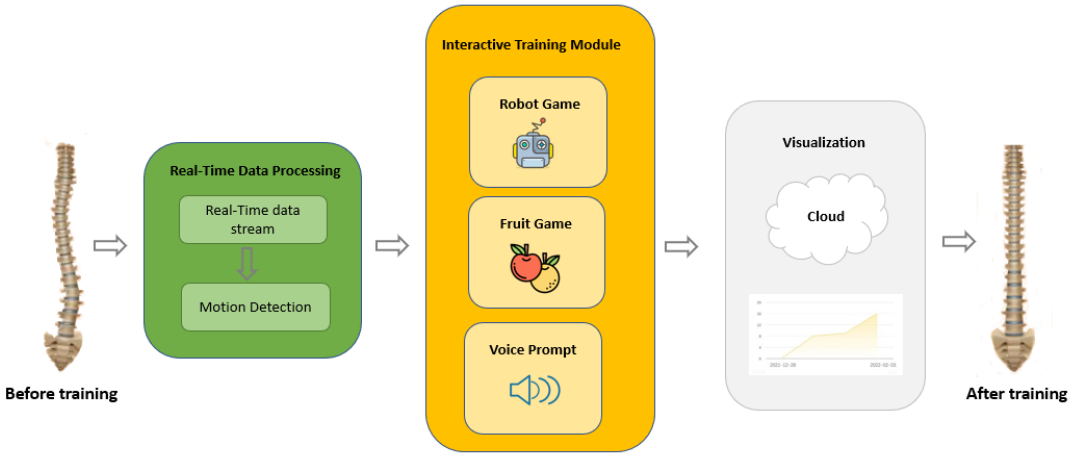

Figure 1: SpineCurer Overview

rotational order of the Euler angles, Xsens Dot limits pitch value between $[-90°, 90°]$. To solve this problem we used quaternion and convert it to Euler angles.

Three sensors record quaternion data from spine during orthodontic exercise and transmit the real-time data to SC application via Bluetooth 5.0. We applied the method of sliding window to detect the user's pose in training process. The length of the sliding window is six and the overlap is 50%.

2.3 Interaction Games

In order to improve the interest of training process and stimulate the enthusiasm of users, we have designed two interaction games: robot game and fruit game.

Robot game: As shown in Figure 2(a). A robot model named Kyle from the unity assets store is used in this content. When the user's spine posture is incorrect, Kyle's upper body posture is synchronized with the user. The prompt message is displayed at the bottom of the screen: "incorrect posture" and accompanied with audio prompts. Otherwise, Kyle stays still and the messages will be "correct posture".

Fruit game: In this game, fruit constantly falls from the top of the screen. User controls the basket to move left or right to pick up fruit. As shown in Figure 2(c). When the user translates upper body to left, the basket moves to left synchronously. When the user returns to the initial state, the basket returns to initial position. This process is accompanied with audio prompts.

3 USER STUDY

3.1 Participants

A total of 18 subjects are recruited to participate in this study. Four participants (1 male, 3 females) are scoliosis rehabilitation coaches. All of them have extensive experience with SBP. The remain of the participants (10 males, 4 female) are college students majored in computer science. None of them have SBP experience.

3.2 Study Procedure

We divided the 18 participants into three groups:

- Group 1: four professional scoliosis rehabilitation coaches.
- Group 2: seven students(5 males,2 females) who performed a 15 minutes SBP training before the task.
- Group 3: seven students(5 males,2 females) without SBP training.

The study was divided into three sessions, includes a 10-min tutorial session, a 15-min training session(only group 2) and a follow-up questionnaire and semi-structured interview. In the tutorial, we introduced the main functions of the system and where are sensors placed. Three sensors are worn on the back in the following positions: the bottom of scapula, the bottom of ribs and the top of ilium. Besides, three actions that subjects were required to do in the following tasks are also introduced. There are two static actions and one dynamic action, as shown in figure 2. Then each participant wore the Xsens Dot for training and finished two tasks.

- Participants performed the 50X training and cylindrical standing training respectively, keep the posture for 30 seconds, and used robot game to check the correctness of posture. This process was repeated 5 times.
- Participants were required to 20 repetitions of thoracic spine training and use fruit game to test the range of motion was adequate. This process was repeated 5 times.

During the trail, participants can see the text description of the action and hear the voice prompts. Each subject took approximately 15 minutes to complete the tasks. Finally, participants were asked to evaluate the SC by using the system usability scale (SUS) introduced by[3] and a semi-structured interview.

4 RESULT

SUS scores are shown in Figure 3. IQR is the interquartile range of SUS score. The score of the SRC (scoliosis rehabilitation coaches, Median = 85, IQR =5.0) is higher than that of the UTS (Students without SBP training, Median = 77.5, IQR = 5.0) and the TS (Students

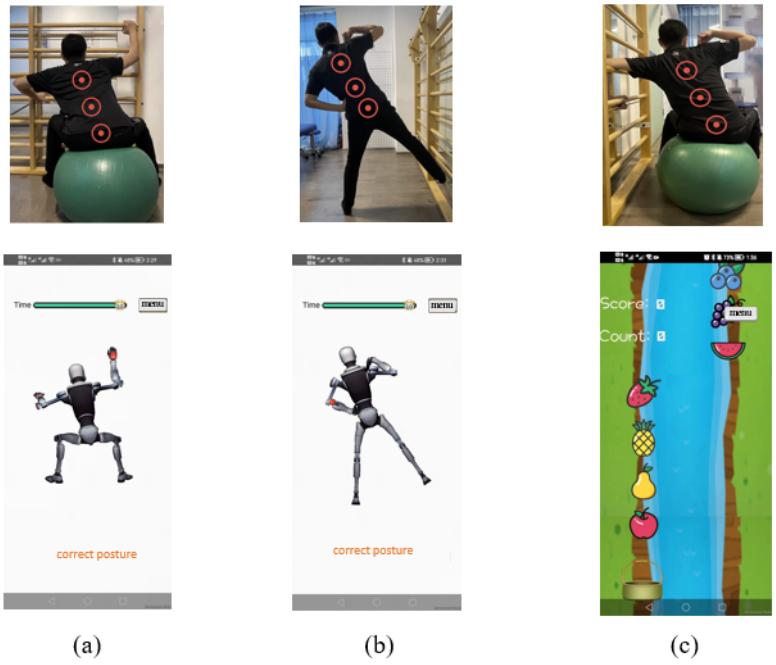

Figure 2: (a) The 50X training. Patient sits on the yoga ball, lean forward slightly and to the left, move the pelvis to right. (b) Cylindrical standing training. Patient keeps standing and to raise the right foot, the pelvis moves to the right, the body leaning and extend the spine. (c) Thoracic spine training. Patient sits on the yoga ball and upward spine, the upper body moves to the left, keep two seconds to return.

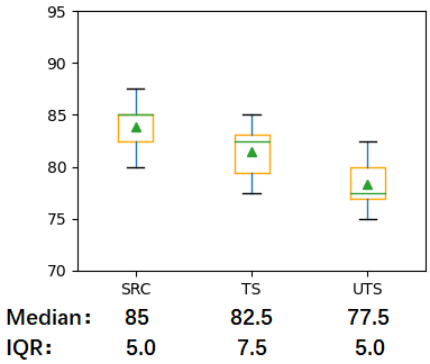

Figure 3: Scores for SUS. SRC-Scoliosis rehabilitation coach, TS-Students have been trained in SBP, UTS-Students without SBP training

have been trained in SBP, Median = 82.5, IQR = 7.5). The student group scored lower than the coaching group, which is due to the different SBP experiences of different groups. Overall, the usability of SC is good, even for users without SBP experience.

In the interview, we mainly focus on the effectiveness of the training, the interactive interest and whether it is easy to learn. More than 90%(17 participants) of the participants thought that the system is interesting, the games can promote training and enhance the effect, and all coaches agreed that the system has a positive effect on scoliosis correction training.

5 CONCLUSION AND FUTURE WORK

In this work, we present a scoliosis training system SpineCurer, which is based on IMU sensors to facilitate patients to complete SBP training independently. The user study have shown the effectiveness of the system in scoliosis treatment. In future work, we plan to add more SBP actions and interaction games. In addition, the clinical trials will be conducted. Patients and physiotherapists will be inspired from this innovative training system.

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