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A SMART LIMB-STRENGTH PROMOTER SYSTEM

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Abstract. *Smart living is an important application domain of information and communication technologies. The smart limb-strength promoter system proposed in this paper provides several creative features, including vocal encouraging, proper LED indication, learning and setting for personal preferences, 2-in-1 exercise for arms and legs, and keeping records in APP via Bluetooth for exercising history. The system is not only applied for physical fitness exercise but also for medical limb-strength rehabilitation. The implemented prototype system is properly integrated and verified with the designed functions.*
Keywords: Smart sensing, Limb-strength, Promoter, APP

1. **Introduction.** Under the trend of the Internet of Thing (IoT), more and more smart devices are invented for the smart living [1-3]. This paper presents a novel design and implementation of a smart limb-strength promoter system.

The system contains a hardware sensing device, which is in charge of the limb-stretch sensing, and includes an APP run on a smart phone, which is in charge of the personal customization, the selection of which limb to exercise, and the historical data of exercising. The hardware sensing device measures the instant stretching gravity value and accumulates the result to the stretching counter if the stretching movement is large enough. The device also sends the counting results to the APP for the display to the user and for further recordings.

The target of the system is to friendly assist the exercising user in promoting the exercising effect by proper encouraging sound and LED flashing, to faithfully monitor whether the stretching movement is effective in strength or not, and to exactly record the exercising history for long term inspection. Furthermore, the system could be applied on any limb either for physical fitness or medical rehabilitation [4,5].

The structure of this paper is organized as follows. Section 1 introduces the motivation and the applications of the smart limb-strength promoter system. The background of limb exercising researches is reviewed in Section 2. Next, the basic analysis and design together with related technologies are explained in Section 3. Section 4 presents the details of the system implementation. The results of the system implementation and its discussions are described in Section 5. Section 6 is the conclusions of the research.

2. **Background Review.** Strength exercise can build muscle, improve capability for the activities in daily life [6], and reduce the rate of falls in older people [7].

For the stroke rehabilitation of upper limb, a lot of devices are developed and are classified into two categories, i.e., mechanical and robotic [8]. The limb-strength training results appear to be effective with added advantage that training devices allow an increase in training intensity and frequency as well as the opportunity to train independently [9]. Yet, the number of the exercising devices is not enough in clinics. Therefore, reducing cost of home-based training devices is an important need for the shortage of exercising equipment and professional caregiver in future.

The limb-strength promoter system is proposed as a low cost system for exercising at home. In addition, it is integrated with APP for the possibility to extend its functionalities, including personal setting, exercising history, faithful companion, etc.

3. **Analysis and Design.** The smart limb-strength promoter system is designed to be a smart fit system. The system is composed of two devices. The first one is a smart stretch-sensing device. The second one is a smart phone pre-installed with a limb-strength promoting APP. The configuration diagram of the smart limb-strength promoter system is shown as Figure 1 and is analyzed as the following.

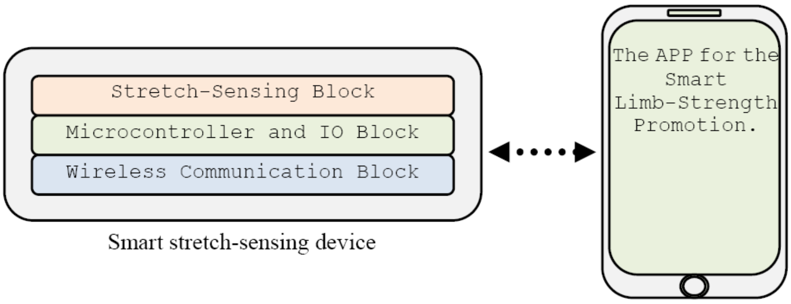


FIGURE 1. Smart limb-strength promoter system configuration

3.1. **Smart stretch-sensing device.** The left device in Figure 1 is the smart stretch-sensing device (S3D). S3D majorly consists of three blocks, i.e., the stretch-sensing block, the microcontroller and IO block, and the wireless communication block [10].

Before stretch-exercising, the user has to put the S3D on a dumbbell or a sandbag. Therefore, the dumbbell or the sandbag should have a slot or a pocket to stably hold the S3D. The stretch-sensing block of the S3D is designed with an accelerometer. The accelerometer can detect the acceleration gravity during stretch-exercising. The measured data is acquired by the microcontroller block. A control firmware program burned in the microcontroller would judge the stretching exercise effective or not by comparing the acquired data to a preset threshold, accumulate the stretching count if it is effective, and transmit the counting result to the smart phone through the wireless communication block.

The full functional blocks diagram is shown in Figure 2. In addition to the functional descriptions of the 3 major blocks given above, there are 3 more necessary blocks to complete whole S3D functions, including the electric power block to supply DC source to

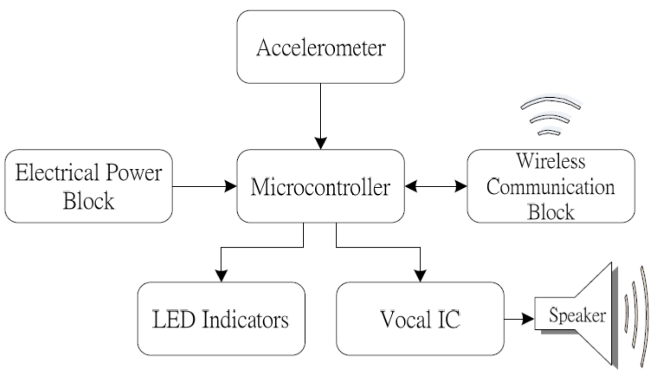
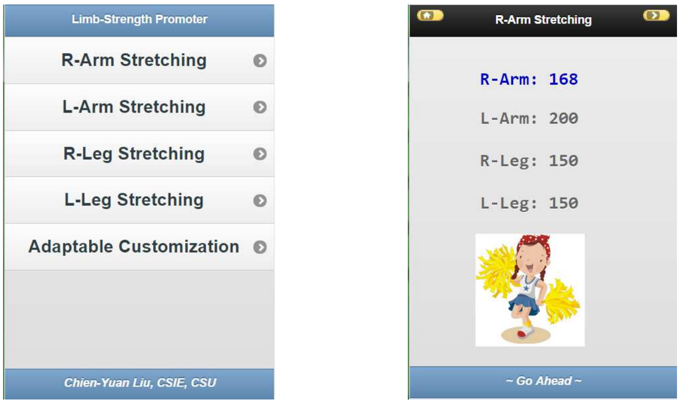


FIGURE 2. Functional blocks diagram of S3D

the S3D, the vocal IC and speaker to pronounce the recorded encouraging messages, and the LED circuit to indicate status of the S3D.

3.2. **Smart APP.** The APP should provide a graphic user interface (GUI) for a stretch-exercising user. The GUI displays of the APP are shown in Figure 3. Figure 3(a) is the display of the main operation menu. Within the main menu display, there are four rows for the user to select a limb to exercise, i.e., right arm, left arm, right leg, left leg. For instance, the right arm is currently selected by the user. The GUI display is switching to the detailed counting display as shown in Figure 3(b). During the user exercising, the counting value on the detailed stretching display is increased by one if the current stretching movement is effective.



(a) (b)

FIGURE 3. (a) Main menu display, (b) Detailed counting display

The last selection row on the main menu display is designed for personal preferences for separate stretching limbs. The effective stretching thresholds for different limbs are decided by the user oneself. In addition, the user can conveniently proceed to next limb by touching the next button on the top-right link icon on the detailed counting display.

4. System Implementation.

4.1. **Smart stretch-sensing device.** The circuits of S3D shown in Figure 4 are designed and laid out according to the basic functions specified in Section 3.1. The kernel component of S3D is the ATMEGA328P microcontroller. The acceleration gravity is sensed by the ADXL345 chip which is manufactured by Analog Device Inc. The Bluetooth Bee module is chosen as the wireless communication interface to link to a smart phone [11]. The ISD1720 from Winbond Corp. is selected as the vocal chip. ISD1720 can record multiple voice messages and the total length of all recorded messages is limited within 20 seconds.

4.2. **Smart APP.** Although the iOS, Android, and Windows Phone are the three popular platforms for smart APP development, the Android is adopted as the target platform for this implementation for the sake of limited resources of the pilot project. In addition, under Android, there are several APP integrated development environments (IDE), e.g., Java by Eclipse, Web by HTML5, or APP by MIT APP Inventor 2 [12]. With similar reason, only one language and one IDE is chosen, i.e., MIT AI2.

The MIT AI2 is a cloud-based IDE. The IDE consists of two tools as shown in Figure 5. The first one is the designer which supports the GUI layout design. The second one is the block editor in which a programmer would construct visual blocks instead of literal statements. In this way, the programmer may focus on the programming logic rather than the syntax of the statements. The IDE only uses a browser to develop an APP project.

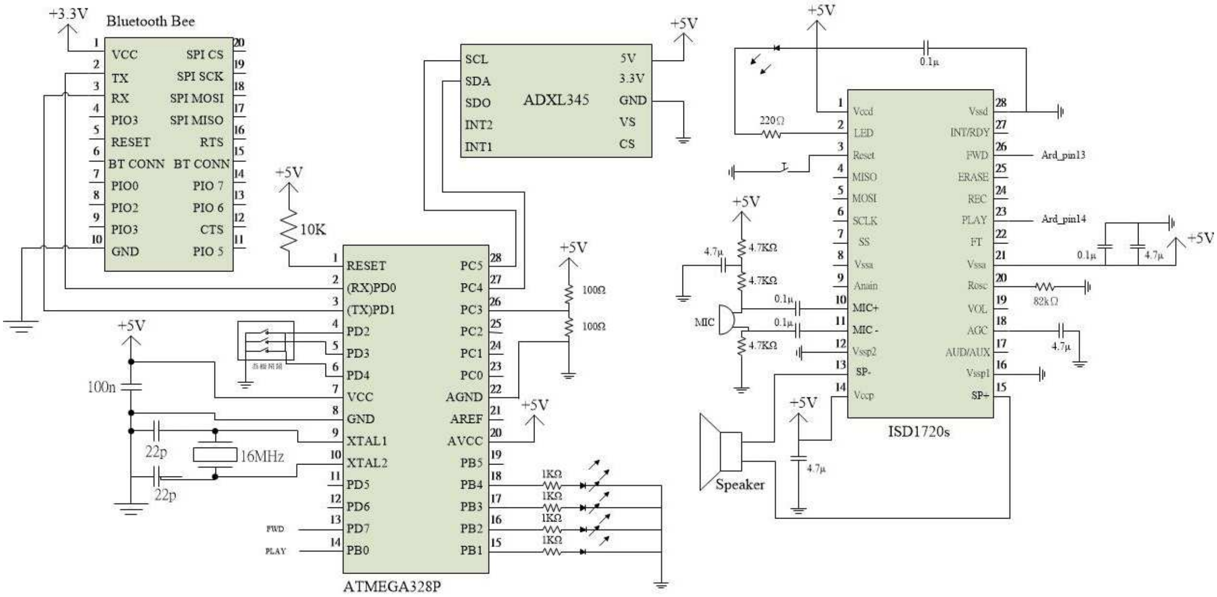
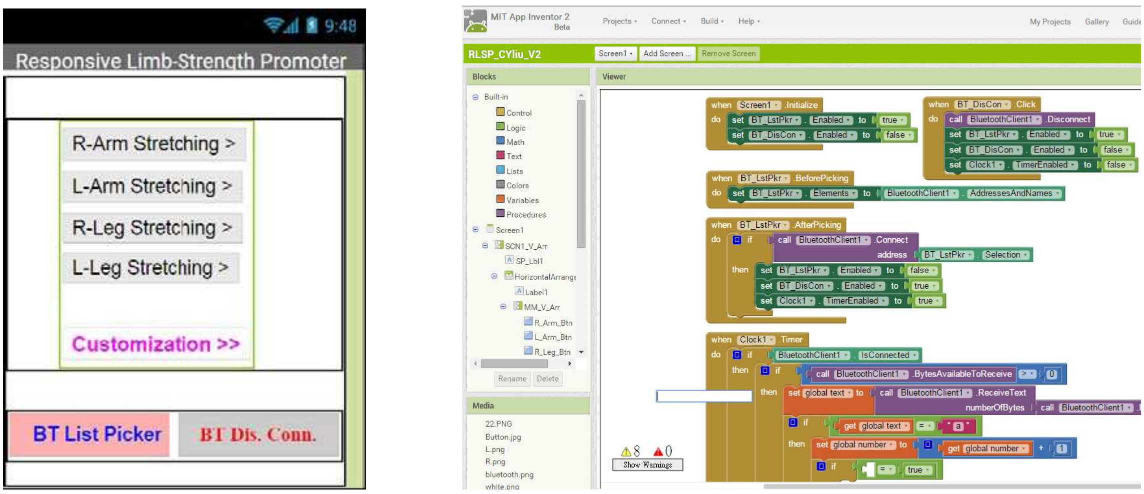


FIGURE 4. Hardware circuits of S3D



(a) (b)

FIGURE 5. (a) Designer of MIT AI2, (b) Block editor of MIT AI2

The GUI display file, the blocks program file, and project related files are stored and fetched over the cloud. The installable package (.apk) could be downloaded onto a smart phone by scanning the generated QR code for the APP. The GUI display in Figure 5(a) and the blocks in Figure 5(b) for the smart limb-strength promoter APP are designed and constructed according to the basic functions specified in Section 3.2.

5. **Results and Discussion.** Figure 6 shows the accomplished S3D product. The firmware preloaded in the microcontroller can serve the applications in two modes instructed by the APP, i.e., customization mode (extended option in future) and exercising mode. During the customization mode, the S3D learns the major axis for stretching exercise, records the maximal and minimal gravity data of the axis, and sends the results to the APP on the smart phone through Bluetooth communication. During the exercising mode, the S3D receives the configuration data of the stretching strength and the major axis from the APP. Then, it uses the data to compare to the real-time gravity value from the axis and to decide whether it is effective or not. The S3D increases the stretching count and sends the result to the APP if the stretching strength is large enough. Otherwise,

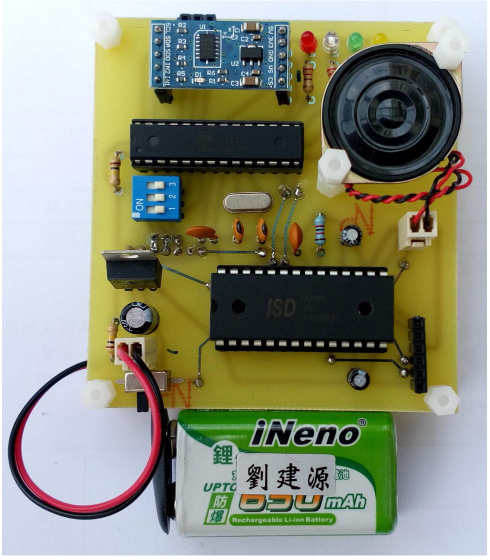
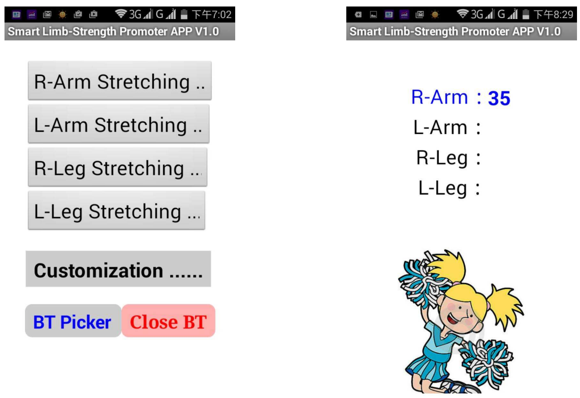


Figure 6. Smart stretch-sensing product



(a) (b)

Figure 7. (a) Main menu display, (b) Detailed counting display

it is ignored. The S3D flashes the LED once for each successful stretch. Furthermore, it pronounces the recorded voice from the speaker to encourage the user by every 10 stretches.

The smart APP is smoothly integrated with the S3D. At the beginning of system execution, the APP scans and connects to the Bluetooth module on the S3D. Next, the APP sends the service mode to the S3D to configure it to the corresponding functions. At present, only the exercising mode is implemented. Thereafter, the S3D can start to sense the stretching action of the exercise. The stretching count is sent to the APP for displaying to user and to be stored in the tiny database (tinyDB) within the APP to be utilized as the exercising history. Figure 7(a) is the picture of the main menu display of the accomplished APP. Figure 7(b) is the picture of the detailed counting display of the APP. The integration of the APP and the S3D is verified successfully.

6. Conclusions and Future Work.

This article presents the design and implementation for the system of the smart limb-strength promoter. The system is an integration of a microcontroller-based stretch-sensing device and a smart APP. The performance validation shows that stretching exercise is correctly sensed by the smart stretch-sensing device and the stretching count is properly shown on the GUI display of the smart APP. In future, the customization mode will be extended to support different limbs of respective persons. Moreover, the smart APP will be developed on a new programming paradigm, named hybrid model, which creates an APP by web-approach with jQuery Mobile and empowered by Cordova (PhoneGap) wrapper framework for various mobile platforms.

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