A Breathing Game with Capacitive Textile Sensors

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Abstract - **Computer games are developed to encourage practice of thoracic or abdominal breathing for physiological and pathological treatment. It is demonstrated by using an exercise shirt embedded with two sets of dual sensors controlled by LM555 and PIC24FJ256 microprocessors, with animated display onto a computer screen. Results and future work are discussed.**

Keywords: **Sensor on textile, breathing games, micro controller driven games.**

I. INTRODUCTION

Computer games [1] are trialed to promote the health of players by encouraging them to practice thoracic or abdominal breathing, according to their physiological and pathological conditions. For an ordinary player, abdominal breathing benefits more to the human body than thoracic breathing [2]. Yoga, Qi-Gong, Lamaze, and wind instrument players often practice with abdominal breathing. However, for the patients with certain kind of diseases, they have to practice thoracic breathing to survive. A computer game is developed to encourage both breathing practices.

Our work started by using only one 4-stage breathing belt and a non-clinical breathing sensor which was proven to accurately detect breathing rates during Yoga exercise and breathing therapy[3][4]. The breathing signals were collected and transformed by a PC to images that could be used for biofeedback treatments. Recently we have employed two sets of capacitive sensors with analog output to detect thoracic and abdominal breathing, respectively, and demonstrate the results wirelessly with a computer game to stimulate the player doing more practice in abdominal breathing.

II. MATERIAL AND METHODS

Capacitive textile sensor principle

When the conductive textiles contact the body surface, the body can be considered as a dielectric material paralleled with a finite resistor. Thus change in the body shape due to breathing can cause a detectable change in the capacitance. We have designed an oscillator which can charge and discharge the body with a fixed and low current, and the charging time is proportional to the capacitance. By measuring the frequency of the oscillator, we can detect the change caused by breathing.

Game system configuration

The game system is comprised of the shirt receiving the breathing signal input, the control box, and a computer that runs the game program, as shown in Figure 1. Two thoracic breathing electrodes are fastened on the upper side of the shirt, and two abdominal breathing electrodes on the lower side. The control box is comprised of two LM555, one PIC24FJ256 micro controller, Bluetooth wireless module, and a battery. The control box charges and discharges the human capacitor, counts the frequency signal from the LM555s with 10 Hz sampling rate, and wirelessly transmits the data to the game program. The program calculates the frequency variation of both thoracic and abdominal sensors to display results, further animated by a cartoon chicken on the screen.

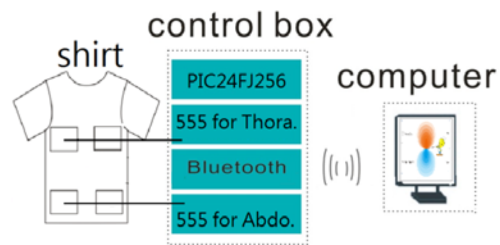


Fig. 1. Breathing game system configuration.

The shirt is made of fiber containing 65% polyester and 35% spandex to provide enough tension to keep the electrodes well contacted to the skin, but not too tight to feel uncomfortable. The electrodes are made of silver yarn fiber with sponge inside, and they are connected to the control box with very tiny multi-thread copper wire, which is flexible and washable, as shown in Figure 2. The upper two electrodes comprise of the thoracic breathing sensors and the lower two the abdominal sensors, as shown in Figure 3(a). The size of the electrode is close to that of a conventional electrode, shown in Figure 3(b). The control box detects thoracic and abdominal breathing signals, and then wirelessly transmits the data to the computer, as shown in Figure 3(c).

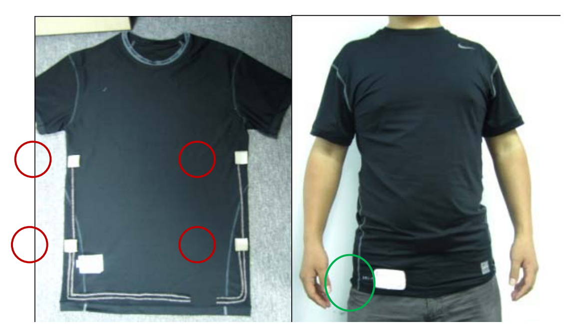
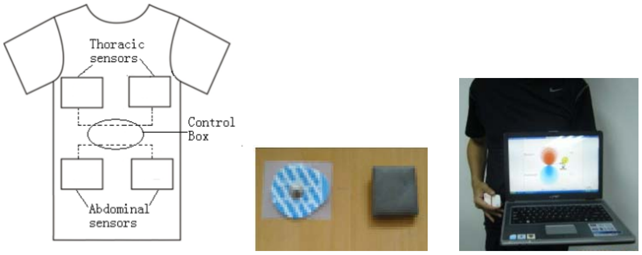


Fig. 2. Electrodes in red circles are placed on the inside of the shirt (left). Player wearing the shirt with control box in green circle.



(a) (b) (c)

Fig. 3. (a) Schematic diagram of the shirt, (b) the textile electrode (right) and conventional electrode (left), (c) player's signals transmitted wirelessly to the game program where results are animated on the computer.

Two modes of the game

There are two modes in the breathing game. The player must pass Mode 1 before he/she can play Mode 2.

- Mode 1

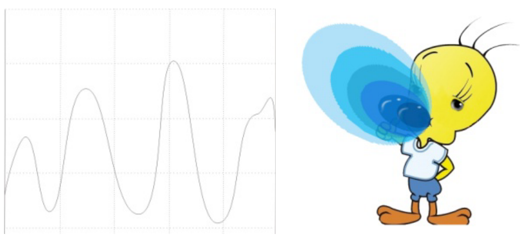


Fig. 4. (Left) The sum of both breathing signals, not shown to the player; unit of horizontal axis: 5 sec/div. (Right) The size of the balloon varies with the sum of signals.

The breathing signal is actually the "variation" of the resonance frequency of the oscillator during breathing, not the absolute frequency value. It is changing not only due to breathing, but also the pressure put on skin, the humidity of the skin, the blood flow of the player, etc. The frequency difference between individual players can be so large that it is necessary to measure the full range of variations in frequency. Hence the program requires the player to play Mode 1 first. In Mode 1, the game program prompts the player to breath as hard as possible for four times at the frequency of 10 rpm, and then checks whether both breathing signals (thoracic and abdominal) go up and down accordingly. If not, e.g., one of the signals becomes saturated or it remains constant, then the program prompts the player to check the control box placement in the shirt for proper contact. If the signals respond as expected, the program then saves the maximum variation of both signals, denoted as MaxT and MaxA, which would be used to normalize all signals in Mode 2, and the player can start Mode 2. The player sees the sum of both signals in terms of the size of the balloon, as shown in Figure 4.

- Mode 2

The program records both signals every 25 seconds continuously and calculates the variation, i.e., the maximum minus the minimum, denoted as VarT and VarA. Two parameters are tallied: the percentage of thoracic and abdominal breath, denoted as PT and PA, where

$$PT = (VarT/MaxT) / [(VarT/MaxT) + (VarA/MaxA)] \text{ , and}$$

$$PA = (VarA/MaxA) / [(VarT/MaxT) + (VarA/MaxA)]$$

as shown in Figure 5.

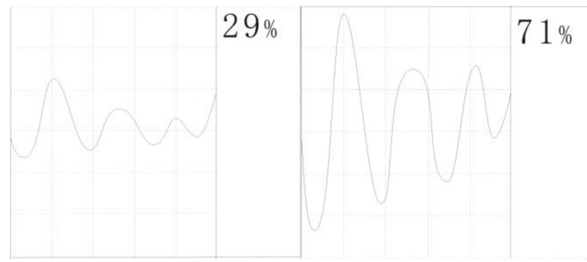


Fig. 5. Normalized thoracic (left) and abdominal (right) signals.

The player sees the cartoon chicken on screen blowing two balloons reflecting his/her breathing, and the percentage is displayed in Figure 6. The player could adjust the magnitude of breathing to obtain higher PA. The computer will recorded the PA continuously and sketch a diagram from which the player can see how well he/she has improved breathing.

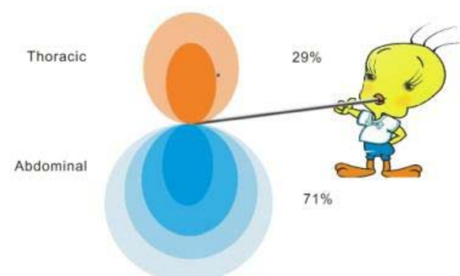


Fig. 6. A cartoon chicken blowing two balloons proportional to the normalized thoracic and abdominal signal, respectively.

III. RESULTS AND DISCUSSION

After experimenting with dozens of players, it is identified that the key factor to obtain good signals is to set appropriately the tension of the shirt. However, a shirt fitting the player has to be comfortable for the player as well.

Most of the players are too anxious to breathe naturally, when they play this game for the first time, that they end up feeling dizzy. The player should not breathe too hard to lose the fun of the game. It is advised to set a reliable goal based on personal medical facts (e.g., abdominal breathing reaching 50% capacity in 12 months) to the player before starting.

Few people can change breathing habit at will immediately. It needs time and patience to improve breathing skill for sickness treatment or preventive measures. It is known many Qi-Gong and Yoga player spending years to practice abdominal breathing. A few players going through our trials felt frustrated when they did not obtain high PA in a short period of time. Therefore, informative advice in advance is necessary.

Like other respiratory sensor, the present sensor can be interfered by many factors including humidity, room temperature, and other body movements. As a component of a breathing game, it might be good enough; however, long-term stability is not proven. To extend such sensor application, stability needs to be reinforced.

IV. SUMMARY

A breathing game system, with two sets of capacitive textile sensors on a shirt, is presented. The game configuration is simple, the shirt washable, flexible, at low cost; which suggests the potential for commercialization and broader applications. However, our textile sensor needs to be optimized for stability, and the system still requires fine calibration to withstand noise and interference caused by the fitness of the shirt and physiological conditions.

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