Wearable sensors and feedback system to improve breathing technique

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Overview

- Introduction
- Sensors
- Data acquisition and processing
- User feedback
- Conclusions
Importance of Breathing

Breathing – naturally occurring

Unique system – both voluntary and involuntary
We can influence the involuntary autonomic nervous system using our voluntary breath

By breathing in a slow, deep and regular manner, the heartbeat becomes smooth and regular, blood pressure normalizes, stress hormones drop, and muscles relax.
Importance of breathing technique

Sports performance

• Use of full lung capacity to maximise oxygen delivery to muscles

• Use of breathing techniques to calm and focus, e.g. before kicking a penalty in soccer or a serve in tennis

Clinical applications

• Chronic Obstructive Pulmonary Disease (COPD)

• Anxiety treatment

• Cystic fibrosis

• Respiratory rehabilitation
Breathing exercises for patients

Breathing monitoring system – system requirements

Aim – to develop a feedback system for patients to improve their breathing technique, by monitoring thoracic and abdominal movements. Give feedback to the user graphically

Sensor must be
  Comfortable
  Robust
  Straightforward to use
Wearable sensor/"Smart garment"

Feedback/Application must:
  Grab users attention
  Have a simple interface
  Focus user for the full duration of the program
  Encourage user to correct their breathing rate

and low cost, easy to install on computer systems
Breathing monitoring system

Wearable Sensor - detect body movement due to breathing

Microcontroller and Wireless connection

Data processing and User feedback

UNIVERSITY COLLEGE DUBLIN • DUBLIN CITY UNIVERSITY • TYNDALL NATIONAL INSTITUTE
Fabric stretch sensors to measure body movements

Carbon black + Elastomer → Piezo-resistive sensor

Wacker ELASTOSIL® LR 3163 A/B Liquid Silicone Rubbers (LSR)

Screen printed onto fabric
Carbon elastomer stretch sensors

Stretch sensor - Carbon loaded rubber screen printed onto lycra fabric. Elongation causes increase in resistance

![Graph showing the relationship between elongation (cm) and kOhm for different sensor widths (2mm, 4mm, 7mm, 11mm).]

Sensor widths 2mm, 4mm, 7mm, 11mm, (length 10cm)

Average Gauge factor \( \frac{l(R-R_0)}{(R(l-l_0)} = 1.6 \)
Carbon elastomer stretch sensors

Sensor lengths
20cm, 14cm, 10cm
(width 5mm)

<table>
<thead>
<tr>
<th>Sensor Length</th>
<th>GF</th>
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<tbody>
<tr>
<td>20cm</td>
<td>2.170494</td>
</tr>
<tr>
<td>14cm</td>
<td>1.006246</td>
</tr>
<tr>
<td>10cm</td>
<td>0.486631</td>
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</table>
Fabric stretch sensors monitor the expansion and contraction of the ribcage and abdomen during breathing.

4 Carbon-Elastomer (CE) sensors (piezo-resistive) are screen-printed onto the front of the t-shirt.

Sensors connected using conductive stainless steel thread.

Resistor leads are embroidered

Sew-in micro-controller
Breathing monitoring t-shirt

Investigation of thoraco-abdominal movement using CE sensors

Breathing signal (Normalised data)

Thoracic breathing
Abdominal breathing
Breathing monitoring system

Arduino
- open-source electronics prototyping platform

Arduino Pro Mini
Size: 1.7cm x 3.4cm
Analog Input Pins: 6
Digital I/O Pins: 14
Microcontroller: ATmega168 or ATmega328

Arduino Lilypad
Sewable microcontroller

Bluetooth connection
BluesmiRF
Wireless serial cable replacement
Transmits any serial stream from 9600 to 115200 bps
Breathing monitoring system

Sensor ➔ Arduino microcontroller ➔ physput ➔ Flash Application

The name Physput is derived from **Phys**iological **put**

Allows a user to emulate standard computer input using non-standard input.

Primarily designed to facilitate the design of alternative input devices.

Reads data from the serial port and maps this data to standard input e.g. mouse movements and key presses.

Physput
Written by Edmond Mitchell
Breathing monitoring system

Sensor → Arduino microcontroller → physput → Flash Application

Most popular method for adding animation and interactivity to Web Pages.

Can create rich Internet applications

Available free for web browsers such as Internet Explorer and Mozilla Firefox

99.3%¹ of all Internet desktop users have the Flash Player installed
User feedback interface

Breathing patterns measured using the textile sensor and gold standard Sensormedics Vmax

Feedback application encourages constant breathing rate in synchronisation with the avatar

Sensormedics Vmax
Deep breathing exercise

Before breathing exercise

During breathing exercise
User feedback

Results

After performing the exercise the user is presented with a breathing efficiency grade.

The grade is calculated by cross correlating the user's breathing pattern with a reference breathing pattern embedded in the program.
User feedback – multiple sensor input

Real-time sensor signal versus computer generated accurate signal

The avatar encourages the user to perform diaphragmatic breathing.

The user aims to synchronise their breathing signal with the avatar

Real time feedback is given

Score given at the end of the exercise

Two sensors - placed at chest and abdomen
Breathing trainer

Correct Breathing Guide

START
Conclusions/future directions

- Developed wearable wireless system to measure breathing patterns, using textile sensors
- Developed user-friendly interface to help users improve their breathing
- Low cost, accessible system
- Next stage to consult the target user groups for feedback – Physiotherapists and Occupational therapists
- Clinical trials
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