Functionalised Fabrics and Wearer Interaction

Dr. Shirley Coyle
CLARITY Centre for Sensor Web Technologies
Dublin City University, Glasnevin, Dublin 9, Ireland
Overview

Introduction

Breathing feedback application

Wearable chemical sensors – sensing the body and environment

TennisSense
Vision: Sensing Mind, Body & Place

Understanding and leveraging key sensory information channels

Mind
Sensing people's preferences and intentions

Body
Sensing physical status and wellness indicators

Place
Sensing interaction between people and their environment
Sensors – “Smart shirt”

Fabric stretch sensors monitor the expansion and contraction of the ribcage and abdomen during breathing.

Piezo-resistive textiles – change in resistance due to stretch

Carbon-elastomer (CE) is coated onto fabric

Sensors connected using conductive stainless steel thread.

Resistor leads are embroidered

Wireless micro-controller to collect data
Breathing feedback system

Project in collaboration with Adelaide and Meath Hospital, Dublin and National University of Ireland, Maynooth

Aim is to develop an encouraging biofeedback game to help children with cystic fibrosis to perform exercises correctly

Wearable Sensor - detect body movement due to breathing

Data capture and Wireless connection

Data processing and User feedback
Respiratory feedback system

Step 1 – Record reference signal, under therapist’s supervision

Step 2 – Avatar instruction with real-time feedback
Respiratory feedback system

Step 3 – Cross correlation between reference and recorded signal at end of exercise

Step 3 – Encouraging feedback with grade (3-5 stars)
Physical vs Chemical sensors

Physical transducers (temperature, pressure, light density, movement...) do not need to be in direct contact with ‘the sample’ – can be shielded in a protective enclosure.

In contrast, chemical sensors and biosensors depend on selective reactions happening at a active surface which must be directly exposed to the sample.
Wearable chemical sensors

Smart clothing – interface between the body and environment

“Looking inwards”
- Body fluids (blood, urine, tears, sweat)

“Looking outwards”
- Warning of hazards in the surroundings (e.g. toxic gases)
Wearable chemical sensors

A chemical sensor is a device, consisting of a transducer and a chemically sensitive film/membrane, that generates a signal related to the concentration of particular chemical species in a given sample.

The sensing surface **MUST** be directly **exposed** to, and **interact intimately** with the sample.

Wearable chemical sensors need to include sample delivery:
- Fluid transport in a textile
- Air permeability of textiles
Sweat analysis

Real-time analysis of electrolytes and volume loss is important for re-hydration strategies.

Extreme cases of dehydration or hyponatremia can have serious consequences.

Current techniques for analysis are time-consuming and awkward.

Need real-time measurements.

Wash-down technique

Patches for sweat collection, PharmChek®
Sweat analysis – Sample handling

Inlet
Fluidic channel (Hydrophilic region)
Fabric
Hydrophobic region
Absorbent
Hydrophilic liquid collection layer
Sample delivery in textiles

Fabric fluidic system – mixing reagents

Wearable chemical sensors

BIOTEX (EU FP6 project, 2005-2008)
Real-time analysis of sweat
Fabric fluidic structure with integrated sensors
Sweat analysis

Need to reduce “priming time”
- Miniaturise device so that it functions at lower sweat rates and reduce dead volume
Microfluidic Device for Sweat Analysis

Microfluidic chip

200μm wide channel

Inlet

Sensing area

Super absorbent

pH = 4.2

pH = 9.2

Flow direction

Detected light intensity (μS)

Time (s)

pH = 4.2

pH = 9.2
Microfluidic Device for Sweat Analysis

Dye flow

39±3 μL

Micro-chip absorbent loading capacity

Adsorbent
Microfluidic chip

Circuit diagram for microfluidic pH sweat sensor.
Real-time pH measurements with simultaneous measurements of heart rate and breathing rate using QinetiQ vest
Barcode and Microfluidic Devices Based on Ionic Liquids

Barcode and Microfluidic Fabrication
Barcode and Microfluidic Devices Based on Ionic Liquids

On-Body trials

Colour profile of each of the indicators at different pH’s (pH range: 3-8).

Picture of the back of a trainer with a micro-chip (1) and barcode (2) systems.
Barcode and Microfluidic Devices Based on Ionic Liquids

Results

![Ph sensor ionogel](image)

- Reference
- MR
- BCG
- BCP
- BTB

Time /min

pH

Channels
Adsorbent
Textile (Clothes, sweat band)
Protecting the wearer

PROETEX is an EU project which develops textile based sensors to improve the safety and efficiency of emergency workers. 23 partners in consortium

DCU’s role
Monitoring the individual’s exposure to CO and CO₂ gases

Oxygen deprivation can result in permanent brain damage, coma and even death.

Garment provides a warning when a significant threshold has been reached, indicating that the individual should go to a secure place to breathe clean air and detoxify.
Protecting the wearer – CO₂ monitoring

Response profile of a 4-step calibration, from atmospheric (initial base line) to (1) 9750 ppm, (2) 19500 ppm, (3) 29300 ppm, and (4) 42800 ppm CO₂
Protecting the wearer – CO monitoring

Sensor integrated into jacket

Sensor in pocket

Testing chamber
**TennisSense**

**Infrastructure** to gather data – contextual, biomechanical and physiological

**Real users** - Feedback to athletes/coaches
- Real-time feedback during training
- Longer-term analysis: fitness levels, performance

Sports Performance **Research**
What factors lead to peak performance?

**Platform** for exciting research and new technology
Multi-source data-mining and data fusion
Wearable sensors
TennisSense

Nine Networked Digital Video Cameras
Placed around Tennis Court

UBISENSE Sensors
Allow players to be 3D-tracked in realtime

Distance covered: 2189.96m
Average speed: 1.23 m/s
Max Speed: 9.03 m/s
Biomechanical data

WIMUs (Wireless Inertial Measurement Units)

Vicon – Motion Capture System

3-axis Accelerometers
3-axis Gyroscopes
3-axis magnetometers
Physiological Data

QinetiQ physiological monitoring vest – measures heart rate (HR), respiration rate (RR)

Parameters of interest
- Heart rate and Respiration rate between shots
- Average HR and RR across sets
- Peak HR and RR
- Difference between training and matches
- Comparison on different surfaces (e.g. clay can have longer rallies)

A Sensing Platform for Physiological and Contextual Feedback to Tennis Athletes, Damien Connaghan, Sarah Hughes, Gregory May, Philip Kelly, Ciaran Ó Conaire, Noel E. O’Connor, Donal O’Gorman, Alan F. Smeaton and Niall Moyna, BSN 2009
Conclusions

Challenges in adding functionality to garments, signal processing, noise reduction etc.

Wearable chemical sensors – new tool for healthcare and wearer safety

Wearable sensors can gather vast amounts of information over long periods of time. Feedback methods are important – must be beneficial, easy to use, appropriate.

Interaction with end users is crucial throughout the development phase
Acknowledgements

Prof. Dermot Diamond, Dr. Fernando Benito-Lopez, Dr. Tanja Radu, Mr. Edmond Mitchell, Prof. Noel E. O’Connor, Prof. Niall Moyna

CLARITY: Centre for Sensor Web Technologies

Dr. Tomas Ward, National University of Ireland, Maynooth

Staff at the Adelaide and Meath Hospital, Dublin

This work is supported by Science Foundation Ireland under grant 07/CE/I1147