Biomedical and Wireless Technologies for Pervasive Healthcare

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Active Research Areas

• Biomedical instrumentation and processing
  – Processing of physiological signals
  – Non-invasive stimulation

• Wireless communication
  – RFID systems

• Computer architectures
  – Software/hardware acceleration
  – New hardware architectures
Objectives

• Introduction to Pervasive Healthcare

• My recent research projects related to biomedical engineering and pervasive healthcare:
  – Blood pressure and ECG
  – Biomedical radar
  – Radio frequency Identification
  – Tongue display unit
  – Non-invasive brain stimulation
Pervasive Healthcare

Support continuous well-being, treatment and care of people rather than focusing on acute treatment and care.
# Pervasive Healthcare

Sensors and Actuators

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Actuators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wearable</strong></td>
<td><strong>Infrastructure (remote)</strong></td>
</tr>
<tr>
<td>Heart Rate Monitor</td>
<td>CCTV camera</td>
</tr>
<tr>
<td>Pulse Oximeter</td>
<td>Property exit sensor</td>
</tr>
<tr>
<td>Sensor</td>
<td>Pressure mat</td>
</tr>
<tr>
<td>Accelerometer</td>
<td></td>
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</table>

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Pervasive Healthcare Applications

• Monitoring
  – Monitoring of health signs
  – Monitoring daily life activities and social interactions
  – Monitoring for falls, wandering, location tracking

• Assistive technologies
  – Supporting elderly and disabled people

• Technologies for rescuing

• Treatment and stimulation

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My Current Research

Applications
• Monitoring of health signs
• Monitoring daily activities and interactions
• Rescue
• Assistive systems
• Stimulation devices

Technologies
• Blood pressure and ECG
• Biomedical radar
• Radio-frequency Identification (RFID)
• Tongue display unit
• Non-invasive brain stimulation
Blood Pressure

Applications

• Monitoring of health signs
• Localization, detection of activities and interactions
• Rescue operations
• Stimulation devices
• Assistive systems

Technologies

ECG-assisted blood pressure
# Blood Pressure – Research

<table>
<thead>
<tr>
<th>Problem</th>
<th>Approach</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inaccurate blood pressure monitors for: • atrial fibrillation, • diabetes</td>
<td>• Multifunctional device: ECG+Blood pressure • Novel way to determine blood pressure</td>
<td>• Developed dry ECG electrodes • New ECG-assisted blood pressure algorithms • Mathematical Modeling</td>
</tr>
</tbody>
</table>

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[Image of multifunctional device: ECG+Blood pressure]
Blood Pressure - Experiment
Biomedical Radar

Applications

- Monitoring of health signs
- Localization, detection of activities and interactions
- Rescue
- Stimulation devices
- Assistive systems

Technologies

- Biomedical radar

Chest movement due to breathing
Biomedical Radar - Applications

• Through-the-wall radar
  – Police, firefighters

• Finding people under the rubble

• Detection of posture and activities of people

• Detection of stop-breathing events
  – Suicide events
  – Independent living
## Biomedical Radar – Research

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<tr>
<th>Problem</th>
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<tbody>
<tr>
<td>• Reliable detection of a single subject</td>
<td>• Remove noise</td>
<td>• New signal processing algorithms for breathing extraction</td>
</tr>
<tr>
<td>• Distinguish between multiple subjects</td>
<td>• Localize subject(s)</td>
<td>• New method for posture detection</td>
</tr>
<tr>
<td></td>
<td>• Obtain clear breathing signal</td>
<td></td>
</tr>
</tbody>
</table>

• Future direction
  – Distinguishing between people and animals for rescuing operations
  – Detection of stress level of people
  – Detecting suicide attempts

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Biomedical Radar - Experiments
Ranging and Detection of breathing
Radio Frequency IDentification-RFID

Applications

• Monitoring of health signs
• Localization, detection of activities and interactions
• Rescue
• Stimulation devices
• Assistive systems

Technologies

RFID
What is RFID?

RFID is a wireless technology that uses radio-frequency waves to transfer data between a reader and a tagged item to identify, categorize and track the items.

- **Identification**
  - Every item will have a unique identification number

- **Radio frequency**
  - 900 MHz
## RFID - Research

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</tr>
</thead>
</table>
| • Detection daily activities of people  
  • Detecting their interactions | • Detecting proximity between tagged people and tagged objects  
  • Localize moving objects with RFID tags | • New component - sensatag (ST) that detects proximity of RFID tags  
  • New algorithms for localization |

**Sensatag (ST) equipped RFID system**
Non-Invasive Brain Stimulation

**Applications**
- Monitoring of health signs
- Localization, detection of activities and interactions
- Rescue
- Stimulation devices
- Assistive systems

**Technologies**
Transcranial direct current stimulation (tDCS)

![Diagram of tDCS device and electrodes on a human head]
What is transcranial Direct Current Stimulation?

• **Device**
  – Current: 2 mA DC
  – Current delivery: 2 wet electrodes
  – Duration of session: 20 min

• **Effect**
  – Long lasting effect in modulating the neurons

• **Applications**
  – Depression
  – Pain relief
  – Recovery from stroke
  – Addiction treatment
## tDCS - Research #1

<table>
<thead>
<tr>
<th>Problem</th>
<th>Approach</th>
<th>Method</th>
</tr>
</thead>
</table>
| Optimizing parameters of the stimulation | • Determine  
  • Salinity  
  • Stimulation time  
  • Number of sessions | • Developed electrode array board  
• Phantom  
• Simulation of current propagation |

- Developed electrode array board
- Phantom
- Simulation of current propagation
## tDCS - Research #2

<table>
<thead>
<tr>
<th>Problem</th>
<th>Approach</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Is patient responding?</td>
<td>Obtaining feedback during stimulation</td>
<td>• Measuring bioimpedance</td>
</tr>
<tr>
<td>• Does patient need more sessions?</td>
<td></td>
<td>• Clinical studies for opiate addicts</td>
</tr>
<tr>
<td>• Non-responders?</td>
<td></td>
<td></td>
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![Diagram of a brain with electrodes showing current and voltage](image.png)

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Tongue Display Unit

Applications

- Monitoring of health signs
- Localization, detection of activities and interactions
- Rescue
- Stimulation devices
- Assistive systems

Technologies

Tongue display unit
What is Tongue Display Unit?

• Why Tongue
  – highly mobile
  – very sensitive to touch
  – It has a large representation in the brain

• Device
  – Electrode array that faces the tongue
  – We can selectively activate electrodes as well as measure their impedance
  – Wireless communication
  – Smartphone control

• Applications
  – assistive devices
  – for diagnosis
  – for rehabilitation
Tongue Display Unit - Assistive Device

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<td>Translation of tongue gestures into mouse cursor movements and clicks</td>
<td>Detect contact between the tongue and the electrodes – transfer the map to PC</td>
<td>Bioimpedance measurements of the each electrode</td>
</tr>
</tbody>
</table>

Electrode Array

Display of the electrode contact map
**Tongue Display Unit - Rehabilitation**

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</thead>
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<tr>
<td>Tongue stimulation</td>
<td>Turn on electrodes selectively to simulate desired patterns</td>
<td>Several applications/games have been developed.</td>
</tr>
<tr>
<td>- Stroke rehabilitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gaming</td>
<td></td>
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Concluding thoughts

• Home healthcare monitoring requires
  – Inexpensive, maintenance-free, reliable sensors and electrodes
  – Ways to express confidence in the measurement
  – Knowledge of situation awareness

• Stimulation and treatment requires
  – better understanding and utilizing feedback from the human body

• Combining everything together
  – based on sensing information, location and user actions
  – adaptively determine parameters of treatment/stimulation
Acknowledgements

• Thanks to my students
• Thanks to NSERC, OCE, MITACS, IRAP and for industrial partners for support
• Thank you for your attention