Biomedical and Wireless Technologies for Pervasive Healthcare

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Outline

• Pervasive healthcare
  – Wearable devices
    • Challenges and some Research Directions
  – Infrastructure sensors
  – Directions in pervasive healthcare
• My research group projects related to pervasive healthcare
• Future Directions
Pervasive Healthcare

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

• Contact-based

• Designed to monitor physiological processes in the human body

• Challenges:
  – Quality of data
  – Sensing modalities
  – Form factor
  – Power consumption
Data Quality and Content

• Unsupervised data collection – automatically or by the patient.

• Quality: How do we know that data is accurate/correct?
  ❖ Quality of raw data, data aggregation data, learning algorithms
  ❖ Identity and quantify noise, artifacts, activities ...
  ❖ Automatic signal quality analysis and mitigation

• Content: When data implies emergency, No false alarms, ...
Sensing and Form Factor

- Smart-phone
- Shirts
- Smart watches
- Smart jewelry
- Arm band

- Headphones
- Hearing aids
- Shoes
- Dental appliances
- Eyeglasses, ...
Power Consumption

• Battery-less sensors
  – Temperature sensing patch
  – Knitting the antenna into a sweater

• Rechargeable batteries, energy harvesting
  – Radio-frequency
  – Temperature
  – Movement

• Low power design
  – Communication
  – Processing
Pervasive Healthcare: Contactless Sensors

• Infrastructure sensors
  – Remote:
    • Radars, cameras
    • Using smartphone as a sonar to detect sleep apnea
  – Close proximity detection
    • Pressure mats
    • Bed occupancy sensors
Pervasive Healthcare - Actuators

An actuator is a mechanical or electrical device for moving or controlling a mechanism, thus enabling a system to perform a physical function

• Usually sensor input is used to trigger output

• Several types:
  – Initiate movement
    • Leg actuator
  – Initiate reaction
    • Fall prevention due to balance loss
  – Treatment
    • Neurostimulation for pain management
Traditional Pervasive Healthcare

• 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
Extended Pervasive Healthcare

• Monitoring

• Assistive technologies

• Rescuing technologies

• Treatment and stimulation
My Current Research

Stimulate

Monitor

Assist with neural interfaces for sensing + neuromodulation

Monitor to capture daily activities and vital signs
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>
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- Developed dry ECG electrodes
- New ECG-assisted blood pressure algorithms
- Mathematical Modeling
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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<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
Biomedical Radar - Experiments
Ranging and Detection of breathing

May 20, 2015
Radio Frequency IDentification-RFID

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

Technologies
RFID
## RFID - Research

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<th>Problem</th>
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</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 |

**Standard RFID system**

![Diagram of Standard RFID system](image)
# RFID - Research

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**Sensatag (ST) equipped RFID system**

![Diagram of 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)
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

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<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>• Redesign electrodes</td>
<td>• Clinical studies for opiate addicts</td>
</tr>
<tr>
<td>• Optimizing parameters of the stimulation</td>
<td></td>
<td></td>
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![Electrical circuit diagram](image-url)
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
### Problem Approach Method

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

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

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<td>Tongue stimulation - Stroke</td>
<td>Turn on electrodes selectively to simulate desired patterns</td>
<td>Several applications/games have been developed.</td>
</tr>
<tr>
<td>rehabilitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gaming</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
Future Directions in the Field

• Measure
  – *Everything that we wear* becomes wearable device
  – *Everything that we hold* becomes hand-held device (steering wheel, book, ...)
  – *Everything used for remote detection* (cameras, smartphones, radars, sensors) will provide information about our health.

• Assist
  – Use all this measured information *for intelligent actuation/stimulation*