WEARABLE SENSORS & SYSTEMS
WITH APPLICATION IN
REHABILITATION

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Outline

• Key enabling technologies
• Recent developments in the field of wearable sensors and systems relevant to rehabilitation
• Major areas of application of wearable technology
• Conclusions and forecasting
Background
Background

- WTEC (World Technology Evaluation Center, Inc.)
  - conducts international technology assessments via expert review
- European Research and Development in Mobility Technology for People with Disabilities (2011) Sponsored by NSF, NIH, &DVA
Wearable Sensors

• Capabilities
  ○ Physiological
  ○ Biochemical
  ○ Motion

• Potential Applications
  ○ Diagnostic
  ○ On-going treatment
  ○ Monitoring
Potential Applications

Remote Sensor Monitoring

Wellness
- Activity monitoring

Safety
- Fall detection
- Seizure detection

Home Rehabilitation
- Therapeutic exercise

Treatment Efficacy
- Parkinson’s disease
- Stroke

Early Detection
- Chronic Obstructive Pulmonary Disease
- Dementia
Design Requirements

Clinical
- Secure
- Reliable
- Interactive
- Unobtrusive

Functional
- Scalable
- Adaptive
- Modular
- Remote control
Key Enabling Factors

**Micro Fabrication**
- Miniaturization
- System-on-chip
- Low cost

**Communication Technology**
- Low-power
- Wireless standards
- Ubiquitous

**Mobile Technology**
- Gateway
- Localization
- Computation
Flexible wireless ECG sensor with a fully functional microcontroller
Example of e-textile system for remote, continuous monitoring of physiological and movement data

(Courtesy of Smartex, Italy)
Smartex products

- Shirt (commercialized) with ECG and respiratory rate sensors.
- Jumpsuit/pants with position sensors.
E-textile Products

- Bed sheet (ECG, Resp Rate, Movement)
- Elbow Sleeve (EMG, FES in development)
- Glove (conductive elastomers, microbubbles for force measurement in development)
ProeTEX Project

(Courtesy of Smartex, Italy)
Remote Monitoring Cycle

1. Collect Health Data
2. Transmit Data
3. Evaluate
4. Notify
5. Intervene

The cycle repeats as indicated by the arrows.
## Key enabling technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Max Range</th>
<th>Power Consumption</th>
<th>Data Rate (max)</th>
<th>Frequency</th>
<th>IEEE Standard</th>
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<tbody>
<tr>
<td>MICS</td>
<td>2m</td>
<td>25uW</td>
<td>500Kb/s</td>
<td>402-405 MHz</td>
<td>X</td>
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<tr>
<td>UWB</td>
<td>30m</td>
<td>30mW</td>
<td>100Mb/s</td>
<td>3.1-10.6 GHz</td>
<td>802.15.4a</td>
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<td>ZigBee</td>
<td>75m</td>
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<td>250Kb/s</td>
<td>0.915 /2.4 GHz</td>
<td>802.15.4</td>
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<tr>
<td>Bluetooth</td>
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<td>2.5-100mW</td>
<td>3Mb/s</td>
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<tr>
<td>WiFi</td>
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<td>1W</td>
<td>150Mb/s</td>
<td>2.4/5 GHz</td>
<td>802.11</td>
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<tr>
<td>WiMAX</td>
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<td>50Mb/s</td>
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<td>3G LTE</td>
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<td>1-2W</td>
<td>100Mb/s</td>
<td>0.7-3.6 GHz</td>
<td>X</td>
</tr>
</tbody>
</table>
Smart Environment Technologies for Health Assessment and Assistance

R01-EB-9675 WSU/Cook

- **Sense**: Unobtrusively sense and visualize activities
- **Identify**: Real-time activity recognition
- **Assess**: Automate functional health assessment
- **Intervene**: Activity-aware prompting
- **Evaluate**: Measure intervention effectiveness

**30 in-home testbeds, on-campus testing with 400 participants**
Smart Environment Technologies for Health Assessment and Assistance

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Time to meditate

I will do it now  I will do it later  I've done this task  I won't do this task
Smart phone based ECG monitoring system by IMEC
Wearable sensors are being combined with virtual reality (VR) environments for rehabilitation in the home.
SmartCane System: An Assistive Device for Geriatrics
Safety Monitoring

Wearable airbag system

Independent demonstration with IMU (inertial measurement unit) and deployment system
XSENS 3D Motion Tracking

Dr. Per Slycke

- University of Twente spin-off company
  - First Generation Sensor Technology
  - Wired suit with power packs required.
  - Usable indoors or outdoors (difficult for video motion capture) with no marker occlusion issues.
  - Integration drift an issue for position estimates.
Second Generation Sensor Technology

- Real-time motion capture.
- No wires or power packs required.
- Increased accuracy.
- Usable indoors or outdoors with no occlusion issues.
- Integration drift resolved through UWB RF technology.

Second Generation Sensor
Recharge Station
UWB RF Receiver
Compensatory Limb Motion Estimation

- Powered Knee Control
- Estimate movement of missing limb from healthy leg
- Allows stair ascent with leading leg

Fig. 4: Stair Ascent Controlled by CLME (Video available upon request)
Conclusions

• First decade of research in the field of wearable technology was marked by an emphasis on the engineering work needed to develop wearable sensors and systems.

• Recent studies have been focused on the application of this technology toward monitoring health and wellness.

• The enabling technologies developed over the past decade have facilitated the deployment of wearable sensors and systems for clinical applications, including rehabilitation.
Conclusions

• The interest of researchers and clinicians in pursuing applications of wearable sensors and systems has caused a shift in the field of wearable technology from the development of sensors to the design of systems.

• Consequently, a great deal of work is directed toward the integration of wearable technologies and communication as well as data analysis technologies so that the goal of remote monitoring individuals in the home and community settings can be achieved.

• When monitoring has been performed in the home, researchers and clinicians have integrated ambient sensors in the remote monitoring systems.
Wireless Telehomecare Technology
Thank you!