UNIVERSITY of MARYLAND
SCHOOL OF MEDICINE

Department of Physical Therapy
& Rehabilitation Science

WEARABLE SENSORS & SYSTEMS WITH APPLICATION IN REHABILITATION

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George R. Hepburn Dynasplint Professor and Chair

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


NATIONAL INSTITUTES OF HEALTH


AAAS
ADVANCING SCIENCE, SERVING SOCIETY


NIBIB
National Institute of Biomedical Imaging and Bioengineering


National Institutes of Health
Workshop on Personal Motion Technologies for Healthy Independent Living
June 22-24, 2010

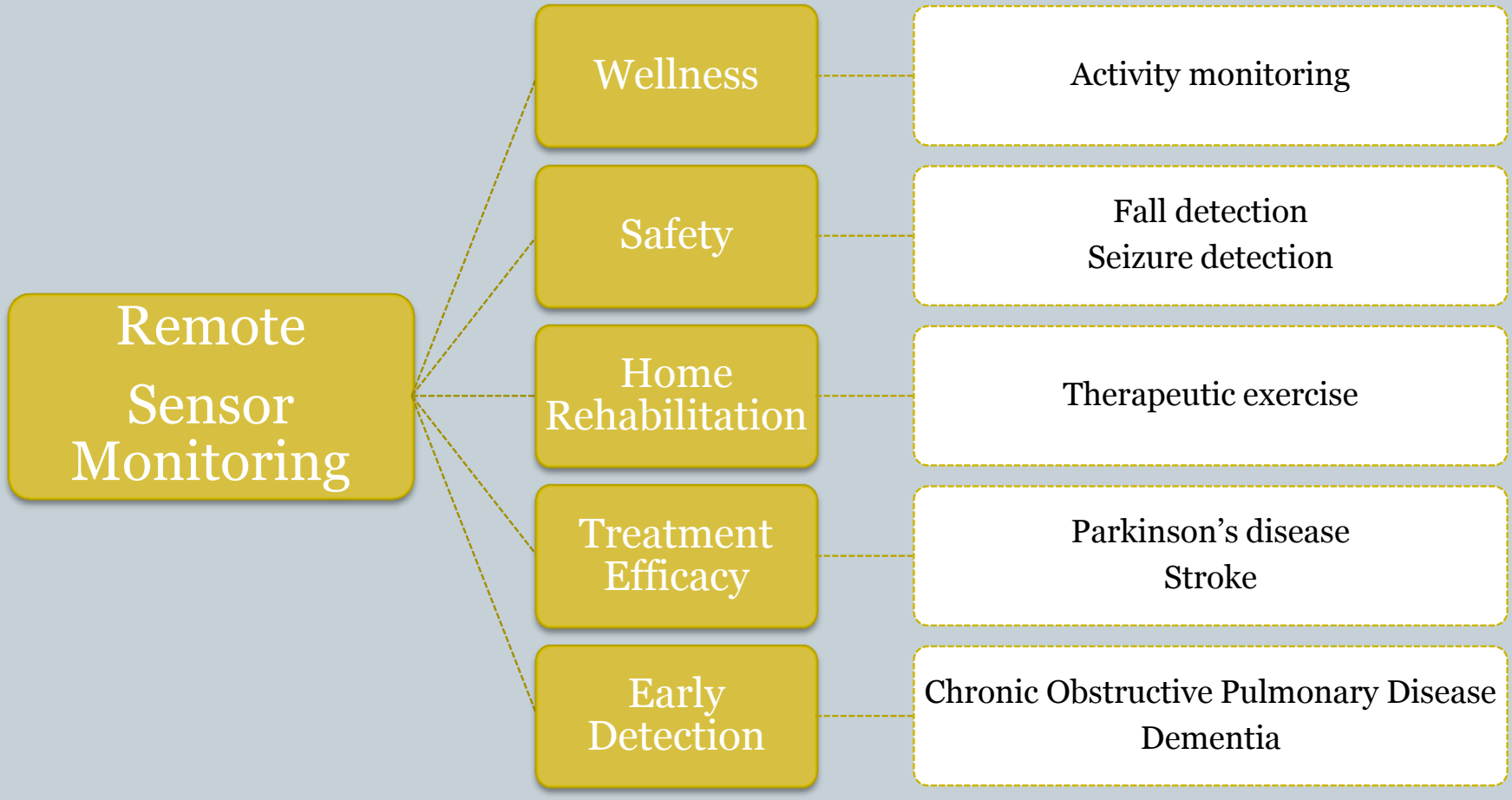
Background

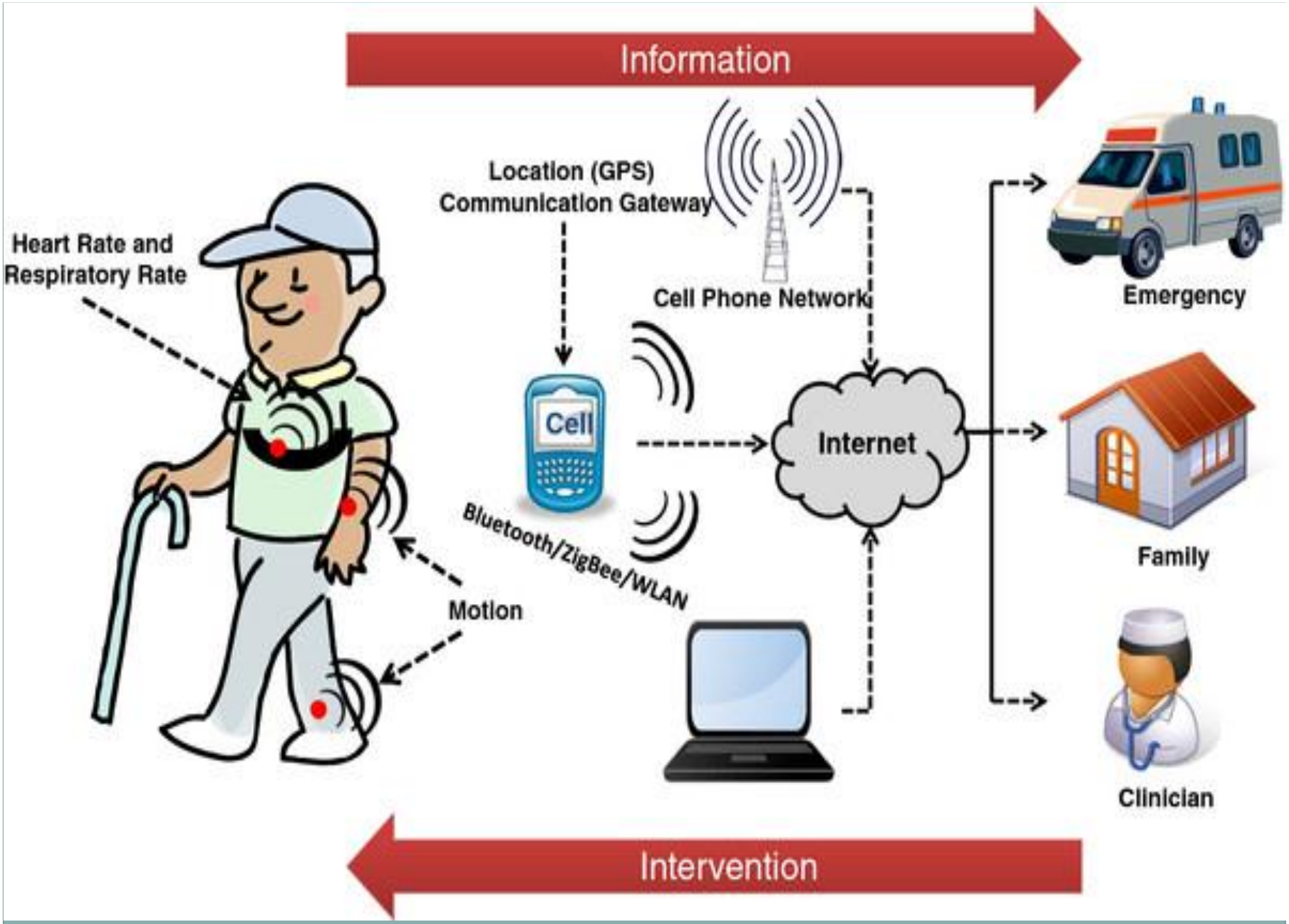
- WTEC (World Technology Evaluation Center, Inc.)
  - conducts international technology assessments via expert review
- European Research and Development in Mobility Technology for People with Disabilities (2011) Sponsored by NSF, NIH, &DVA
  - Patel P, Park H, Bonato P, Chan L, Rodgers M: A review of wearable sensors and systems with application in rehabilitation. *J NeuroengRehabil, 9:21, 2012*

Wearable Sensors

- Capabilities
  - Physiological
  - Biochemical
  - Motion
- Potential Applications
  - Diagnostic
  - On-going treatment
  - Monitoring

Potential Applications



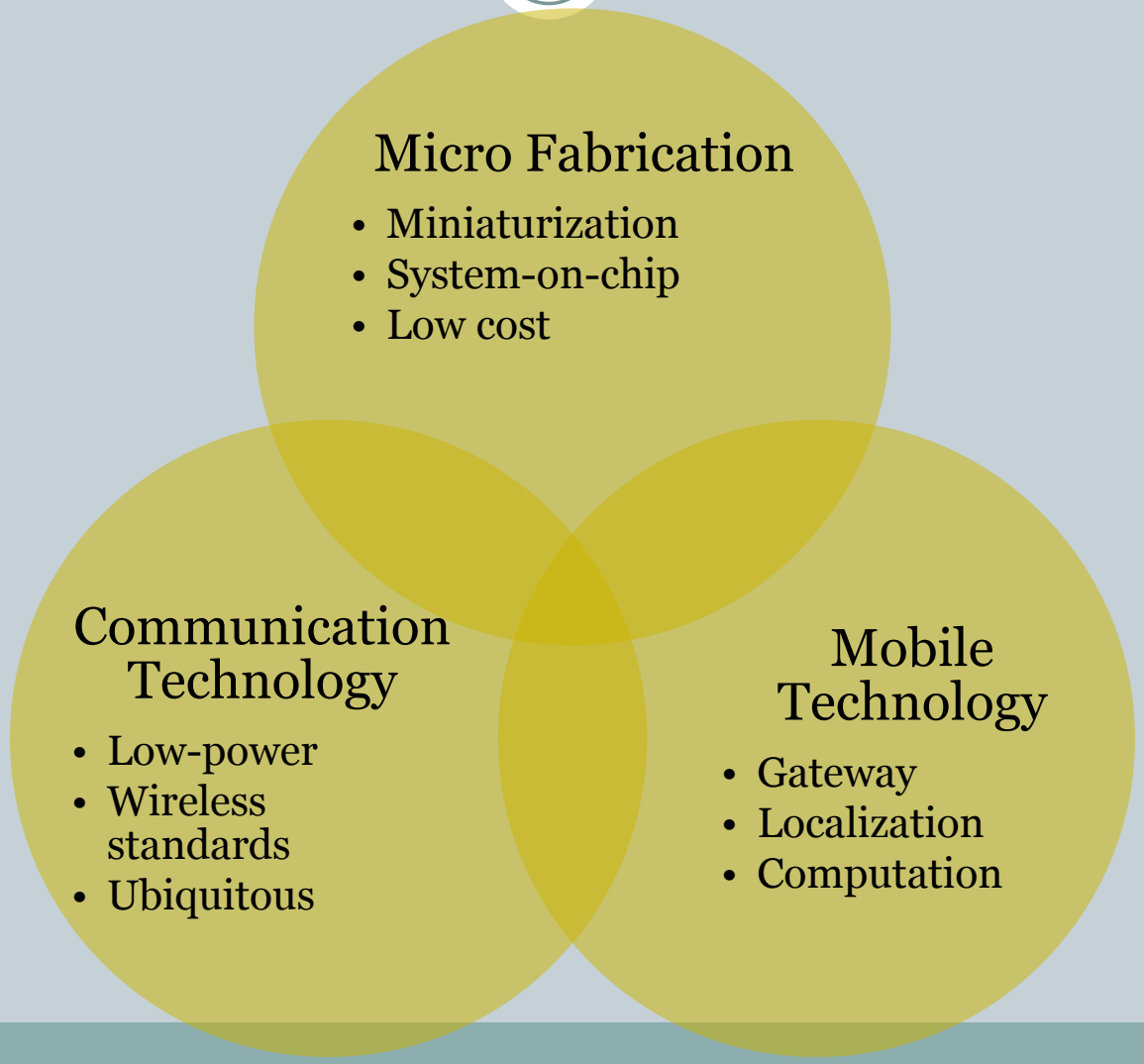


Patel *et al.Journal of NeuroEngineering and Rehabilitation* 2012 **9**:21 doi:10.1186/1743-0003-9-21

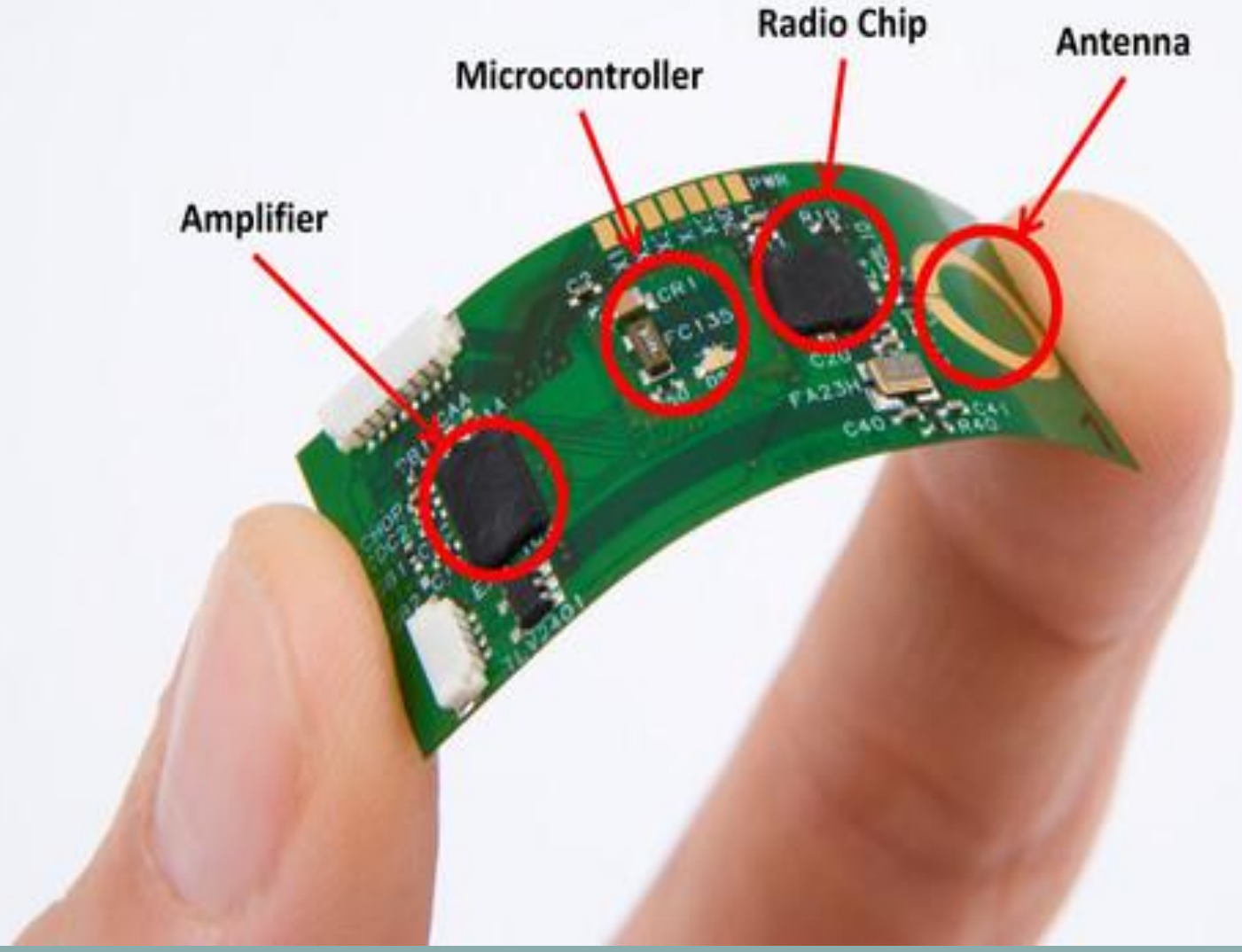
Design Requirements

Clinical	Functional
Secure	Scalable
Reliable	Adaptive
Interactive	Modular
Unobtrusive	Remote control

Key Enabling Factors

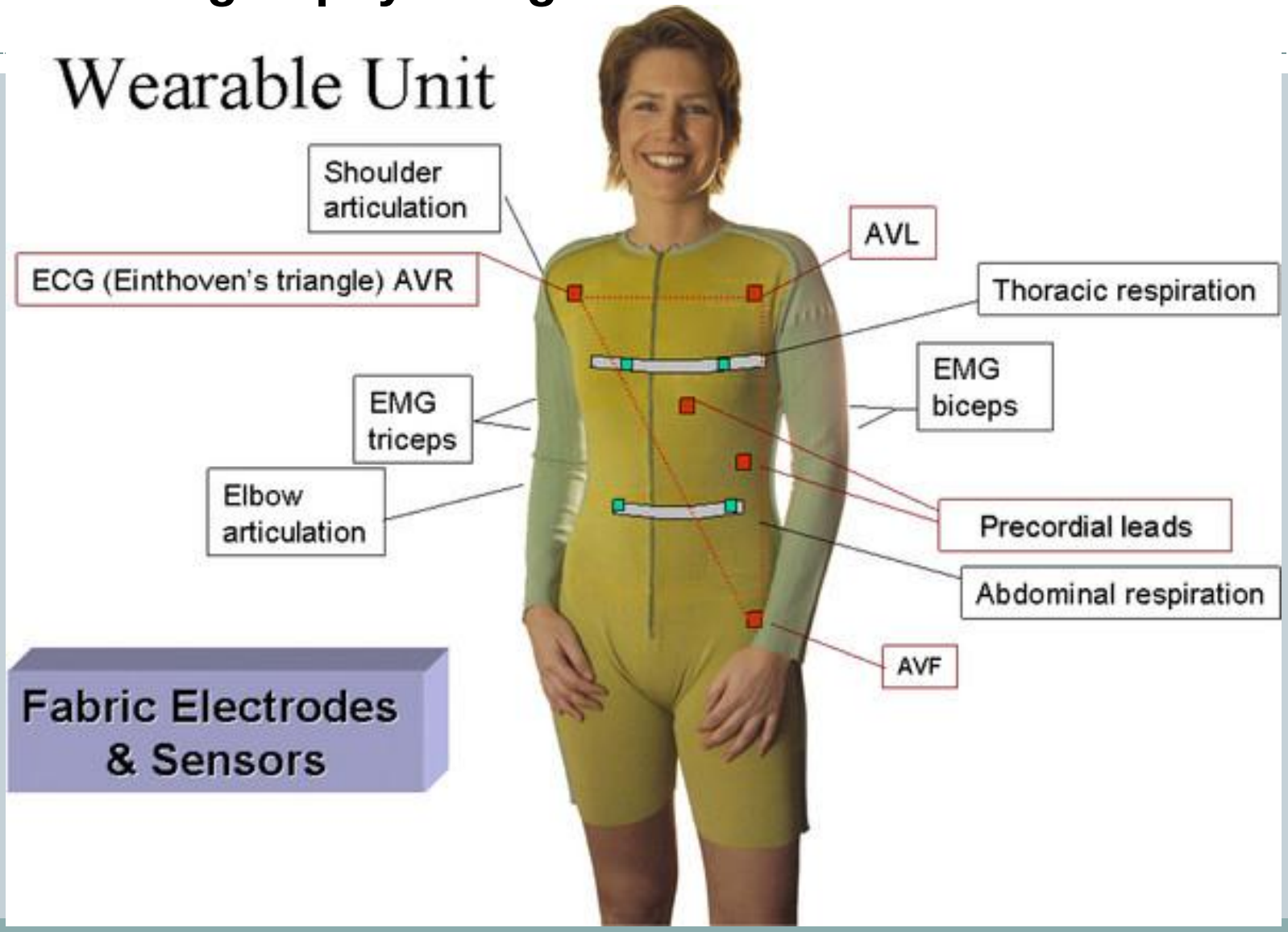


Flexible wireless ECG sensor with a fully functional microcontroller



(Courtesy of IMEC, The Netherlands)

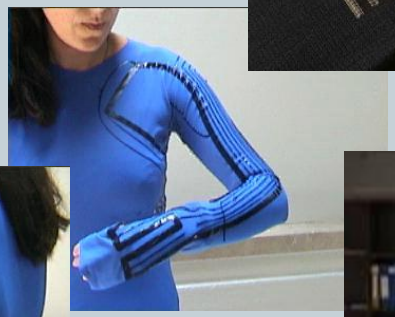
Example of e-textile system for remote, continuous monitoring of physiological and movement data

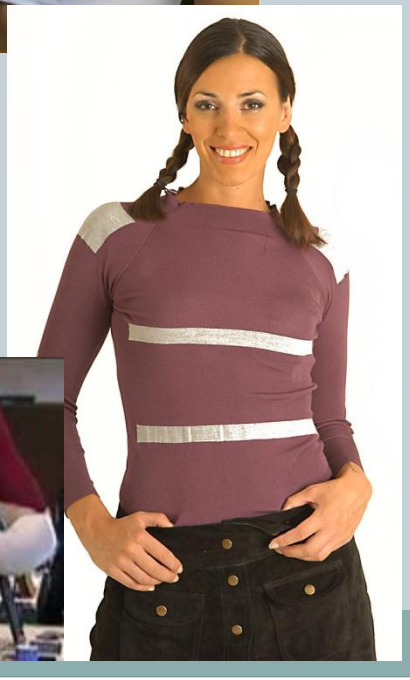


(Courtesy of Smartex, Italy)

Smartex products

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

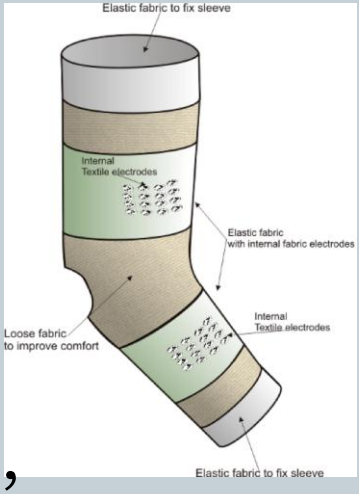




E-textile Products

- Bed sheet (ECG, Resp Rate, Movement)

- Elbow Sleeve
(EMG, FES in development)

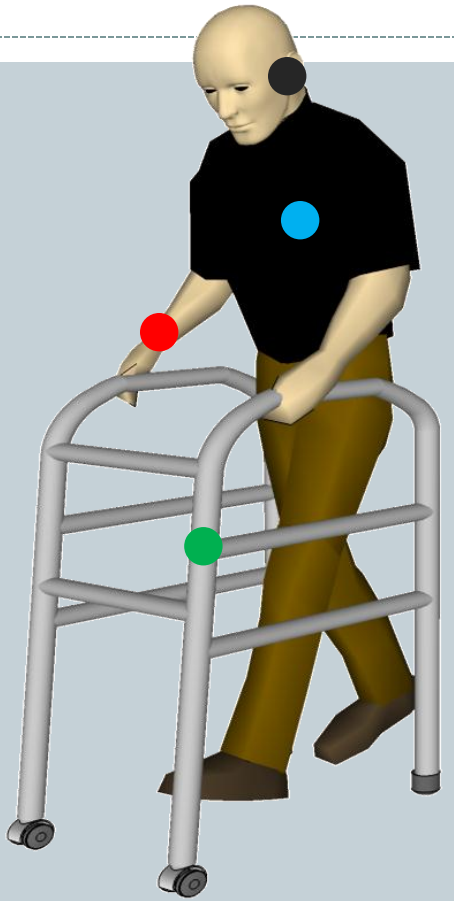


- Glove (conductive elastomers, microbubbles for force measurement in development)

ProeTEX Project

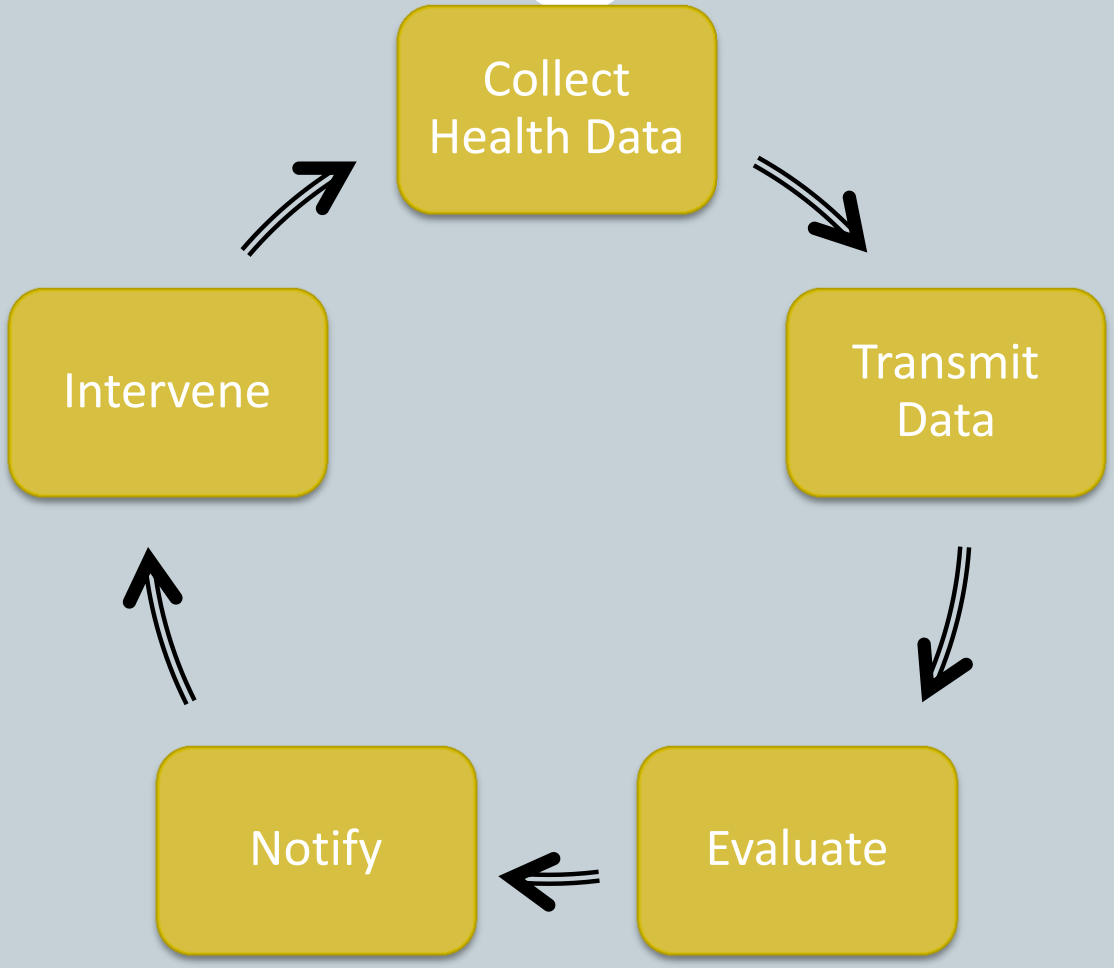
(Courtesy of Smartex, Italy)


e-AR
Body Sensor Network
Magnitude
Sway



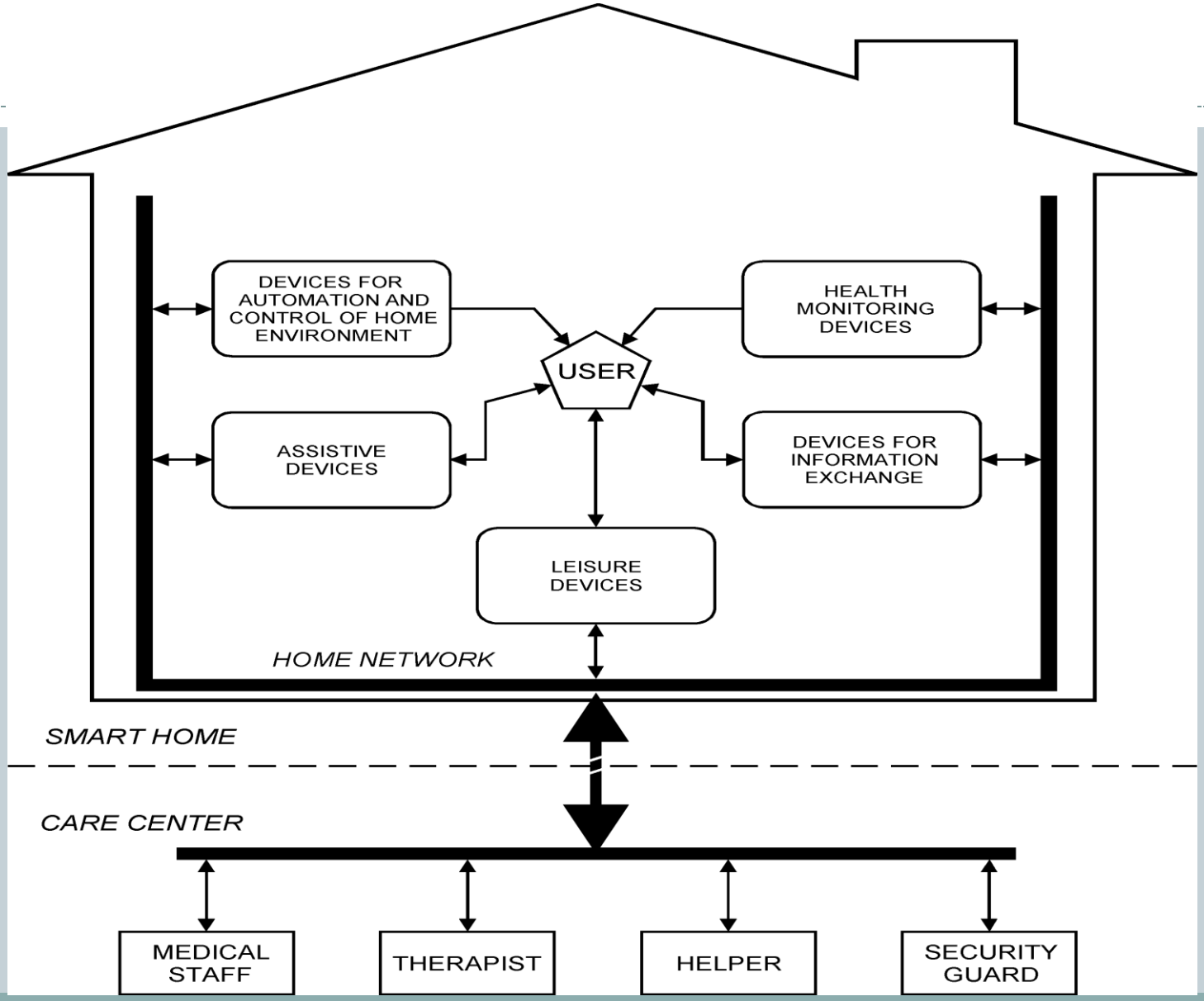
Motion PPG/SpO2 ECG/Respiration Impact Pressure

Remote Monitoring Cycle



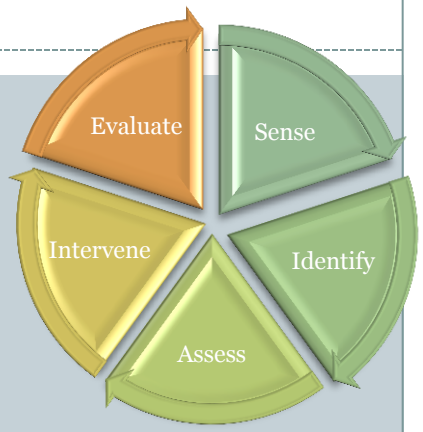
Key enabling technologies

	Max Range	Power Consumption	Data Rate (max)	Frequency	IEEE Standard
MICS	2m	25uW	500Kb/s	402-405 MHz	X
UWB	30m	30mW	100Mb/s	3.1-10.6 GHz	802.15.4a
ZigBee	75m	30mW	250Kb/s	0.915 /2.4 GHz	802.15.4
Bluetooth	100m	2.5-100mW	3Mb/s	2.4 GHz	802.15.1
WiFi	250m	1W	150Mb/s	2.4/5 GHz	802.11
WiMAX	50Km	10W	50Mb/s	2-10GHz	802.16
3G LTE	100Km	1-2W	100Mb/s	0.7-3.6 GHz	X


DEVICES FOR AUTOMATION AND CONTROL OF HOME ENVIRONMENT
HEALTH MONITORING DEVICES
USER
ASSISTIVE DEVICES
DEVICES FOR INFORMATION EXCHANGE
LEISURE DEVICES
HOME NETWORK
SMART HOME
CARE CENTER
MEDICAL STAFF
THERAPIST
HELPER
SECURITY GUARD

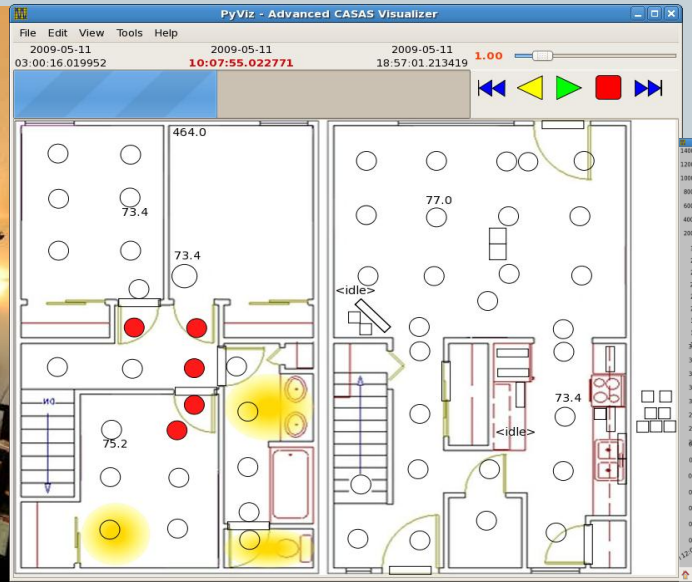
Smart Environment Technologies for Health Assessment and Assistance

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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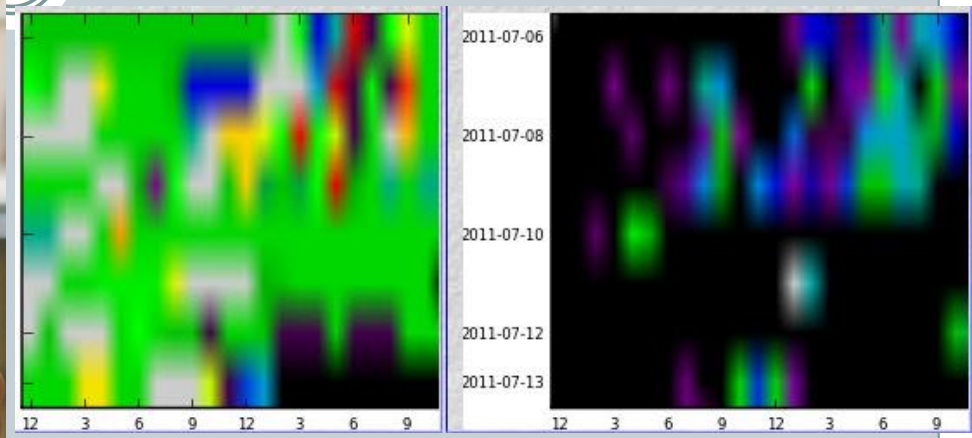
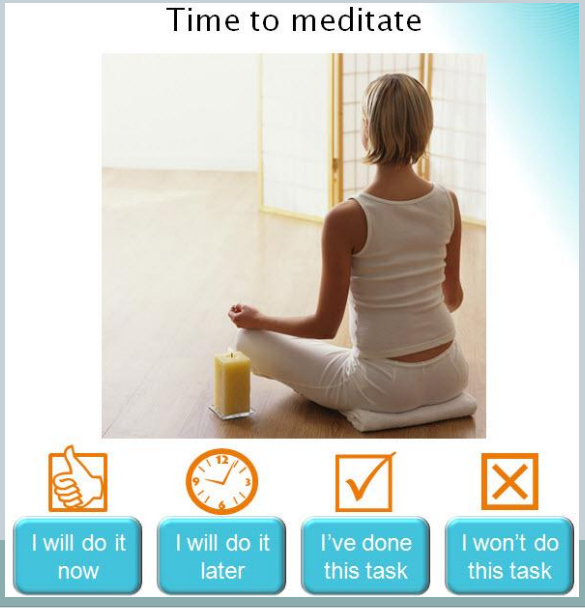
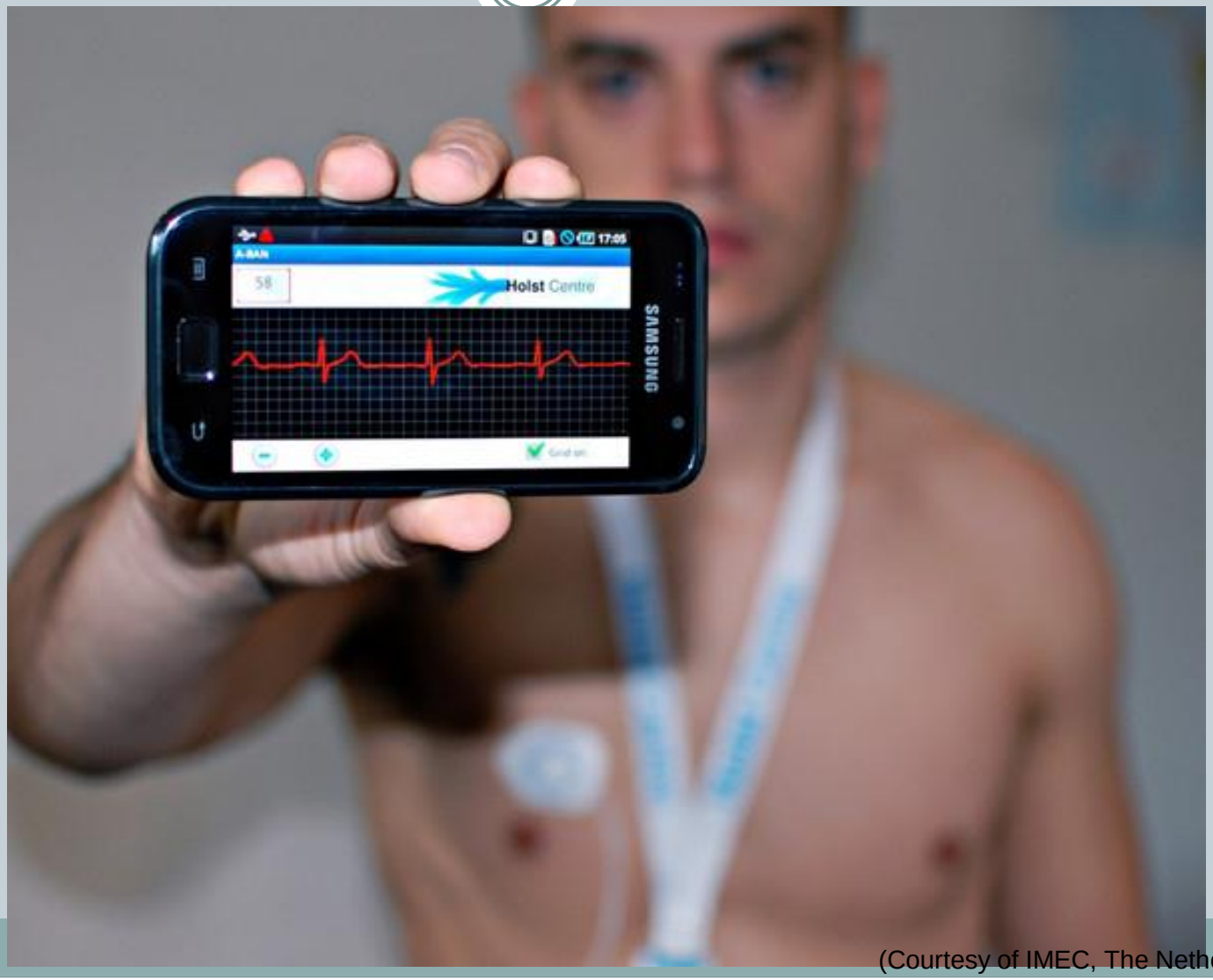




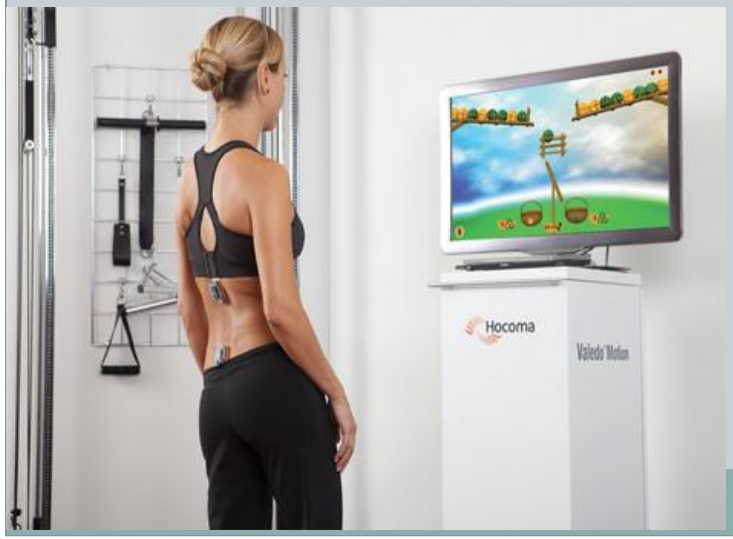
Smart phone based ECG monitoring system by IMEC

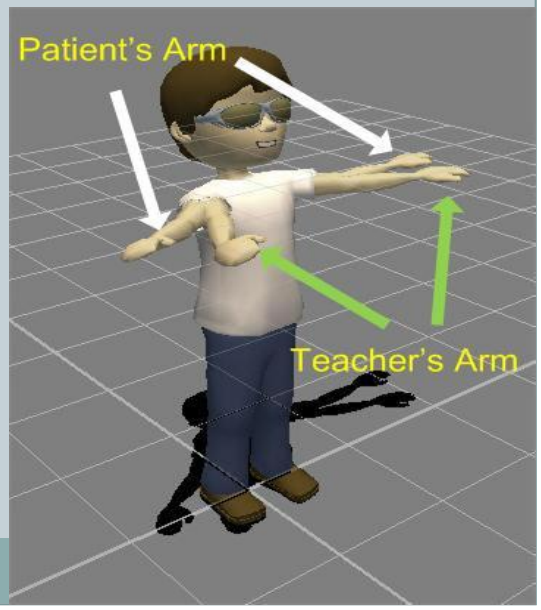


(Courtesy of IMEC, The Netherlands)

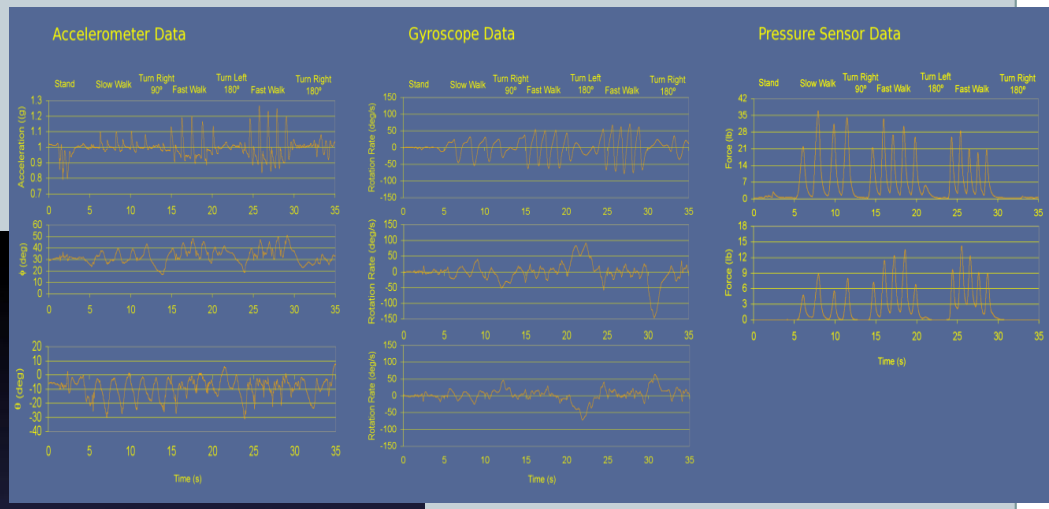
Home Rehabilitation

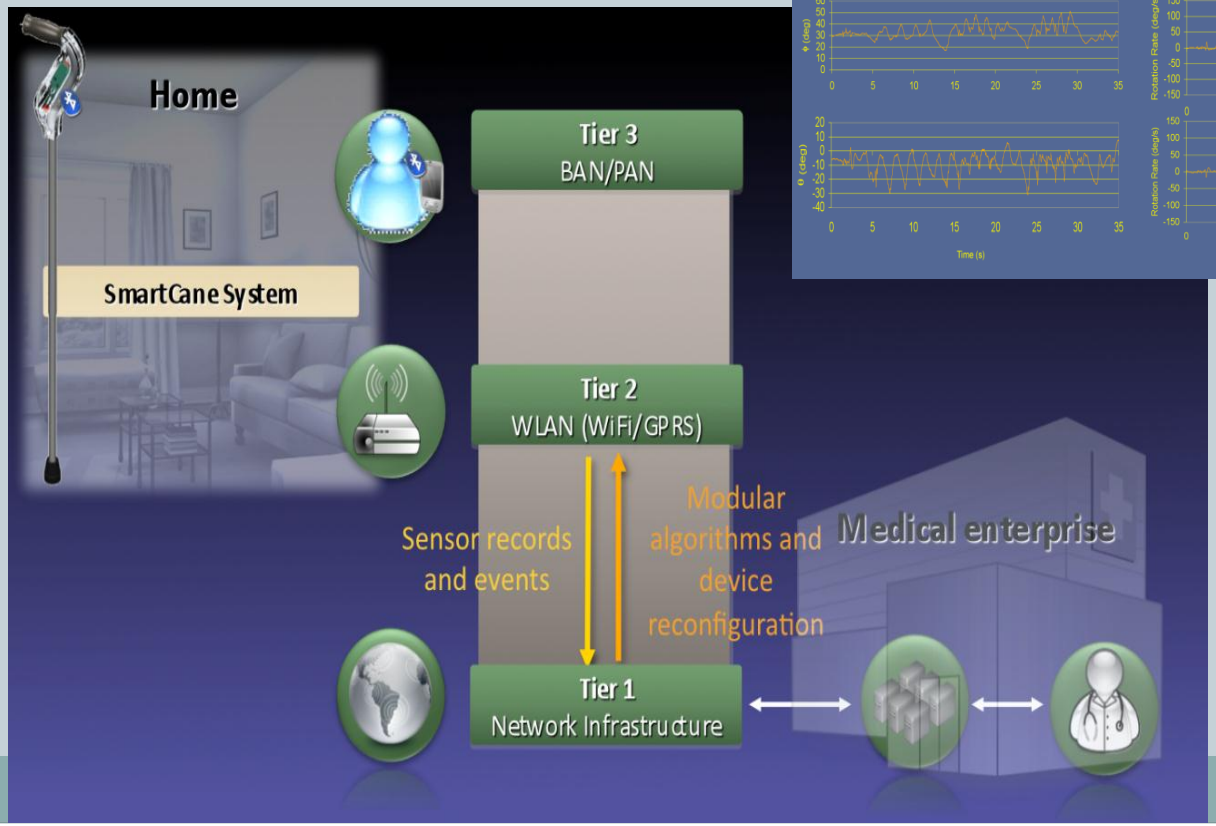
Wearable sensors are being combined with virtual reality (VR) environments for rehabilitation in the home



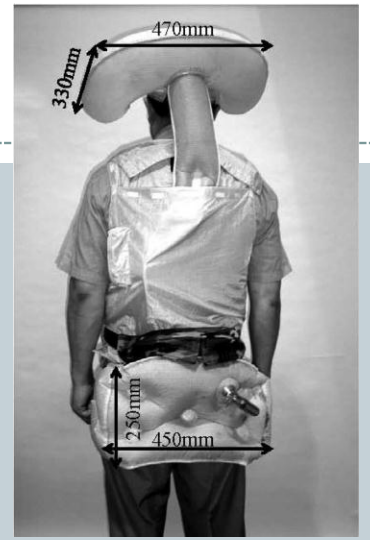


SmartCane System: An Assistive Device for Geriatrics

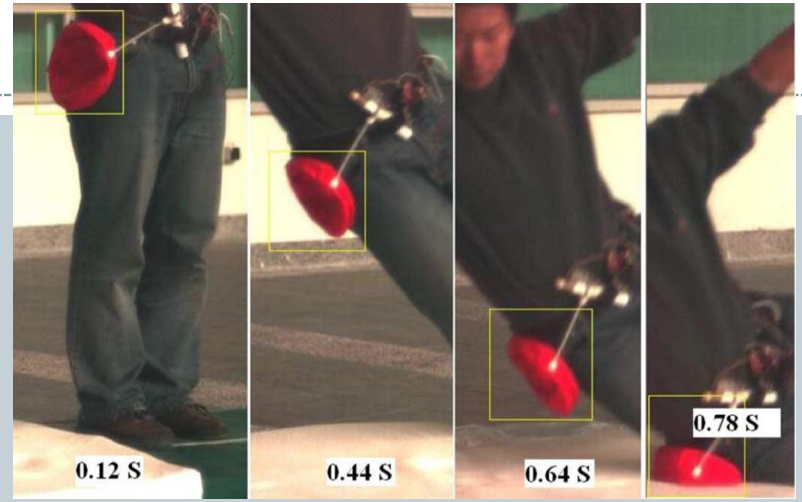




Safety Monitoring



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.

First Generation Sensor

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

InstitutfürAutomatik (ETH)
Sensory Motor Systems Laboratory

Professor Robert Reiner (Zurich)

Zurich, Switzerland

Compensatory Limb Motion Estimation

- Powered

Knee Control

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

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

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.

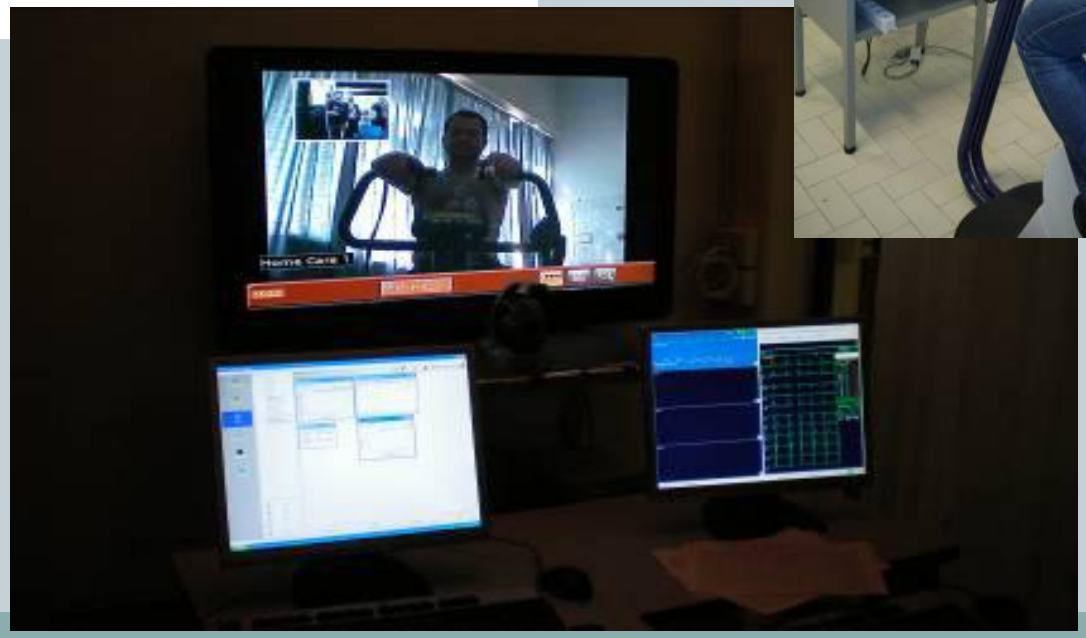
Conclusions

•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.

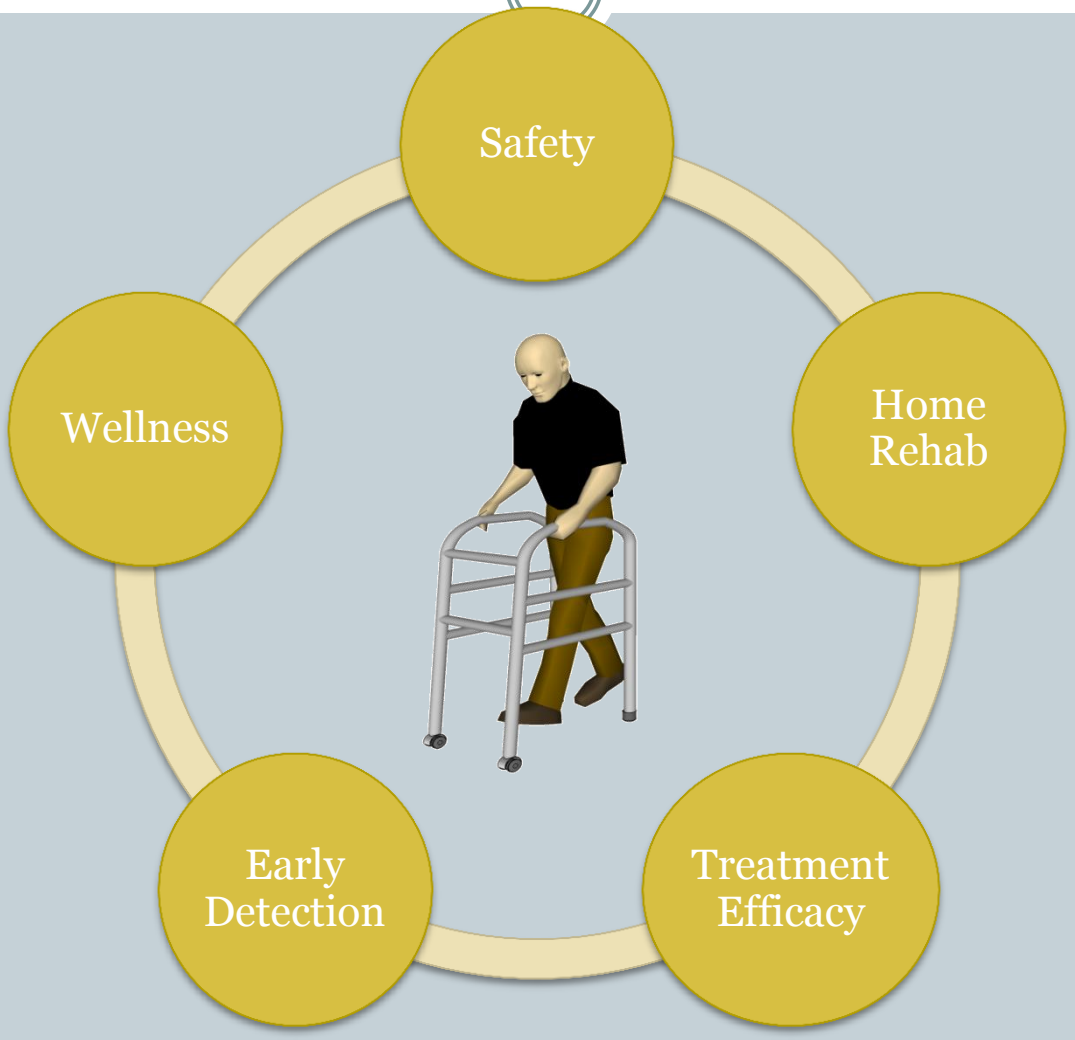
•Consequently, a great deal of work is directed toward the integration of wearable technologies and communication as well as data analysis technologies so that the goal of remote monitoring individuals in the home and community settings can be achieved.

•When monitoring has been performed in the home, researchers and clinicians have integrated ambient sensors in the remote monitoring systems.

Wireless TelehomecareTechnology



Costs & Reimbursement



Thank you!

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