Care that makes sense
Designing assistive personalized healthcare with ubiquitous sensing
Care that makes sense

- The population is constantly aging
- Chronic diseases are getting more prominent
- Increasing pressure on the healthcare system
- Self management through intelligent sensor systems!
Background

- Inertia Technology is a spin-off from the Pervasive Systems group at University of Twente
- Originated from cutting edge research in 2004-2008
- Pervasive wireless sensor networks
- Main focus on motion sensing
Applications

Healthcare & Ambient Assisted Living

Sports

Industrial process monitoring
ProMove: versatile platform for motion capture
Healthcare: chronic diseases

- COPD
- Dementia

- Smart wireless sensors can support people with chronic conditions to manage the disease and improve quality of life
COPD

- COPD: the 4th cause of death worldwide, the 3rd in 2020!

Are You At Risk?
The World Health Organization (WHO) projects that by the year 2020, COPD will be the 4th leading cause of death or disability.

COPD Checklist
- Do you smoke?
- Do you need to rest after walking or climbing stairs?
- Do you have chronic cough with sputum in the morning?
- Do you have frequent upper respiratory infection?
- Are you over 40 years old?

If you answered YES to more than 3 questions, you are at risk of COPD.

Coronary Heart Disease
-59%

Stroke
-64%

Other CVD
-35%

COPD
+163%

All Other Causes
-7%

Proportion of 1965 Rate

Source: NHLBI/NIH/DHHS
IS-ACTIVE

- European initiative on Ambient Assisted Living
- Develop solutions for self-management of COPD
- Validation with COPD patients in 3 countries:
  - The Netherlands
  - Romania
  - Norway
IS-ACTIVE

- No cure
- Can be managed and slowed down through **physical activity**
- IS-ACTIVE system
  - Stimulate and encourage activities
    - Activity monitoring
    - Exercise coaching
Activity monitoring

- **Requirements**
  - Reliable activity level measurements
  - Unobtrusive, used during daily life
  - Simple, intuitive, personalized feedback

- **Solution**
  - Measure the amount of movement using an accelerometer (ProMove)
  - Real-time personalized feedback on the mobile phone
Activity monitoring

- Amount of activity computed online

- Real-time feedback on smartphone
Activity monitoring - feedback

- Adaptive timing of feedback messages
- Look at feedback compliance
  - Under which circumstances do people comply? When not?
  - What are the deciding factors?
  - Predict compliance based on context features e.g. timing, message features, weather, history, activity
  - Use Machine Learning to predict Compliance
Activity monitoring - evaluation

- Initial trials – lab tests
  - COPD patients in 3 countries: The Netherlands, Romania, Norway
  - Total of 26 participants
  - The system is acceptable and has a good to excellent usability
  - For patients in Romania, the safety feeling was important, and required a pulseoxymeter to be integrated in the system
  - Patients in Norway preferred an alternative home-based system
Activity monitoring - evaluation

- **Field trials**
  - COPD patients in 2 countries: Romania and The Netherlands

- **Romania**
  - Safety feedback, with pulse oxymeter integrated
  - Oxygen saturation transmitted to the smartphone
  - Red, yellow, green -> indication of oxygen deficiency in blood
  - 8 COPD patients wearing the system for one month
  - 6 MWT improved with 4.55% -> improvement of physical condition
  - Good acceptance among patients
Activity monitoring - evaluation

- The Netherlands
  - Individually-tailored feedback, with adaptive feedback algorithms
  - 10 COPD patients wearing the system for three months
  - A statistically significant increase in levels of physical activity
  - High score on user satisfaction
Activity monitoring – implementation in healthcare

- Improve the usability of the sensor node through a smaller and more ergonomic form-factor
- Low cost
- Introduce IS-ACTIVE system at physiotherapy and rehabilitation clinics
- (Partially) cover the costs of the system through healthcare insurance
Dementia

- A progressive disorder - decline in mental ability severe enough to interfere with daily life
- Becomes more common with age
  - 3% of people between the ages of 65–74
  - 47% of people over the age of 85
- No cure
- Average lifetime after diagnosis – 8 years, 4 years at home
Dementia

- Prolong the amount of time the patients stay at home
  - Desired by the patients
  - Needed for economical reasons
- Give informal care givers (family) peace-of-mind
- How?
  - Constant monitoring of the patients
  - Informal care givers get informed about:
    - Possible dangerous situations
    - Changes in behavior
The CareBOX idea

- A box with intelligent wireless sensors
  - Easily installed in a home
  - Gather information about the activities of patients
  - Detect possible dangerous situations
  - Compute changes in the duration and distribution of daily activities
  - Mobile phone app for the informal care givers
Methodology

- Requirements analysis and specification
  - Literature research
  - Interviews with informal care-givers
- Selection of sensors
- Design of detection algorithms
- Design of interfaces
  - Interviews with informal care-givers
  - Workshops
  - Evaluation with scenarios and mock-ups
- Controlled testing of the system with multiple users
- Uncontrolled testing – field trials
Requirements

- Sensors present only in the environment
- Sensors are plug-and-play
- Energy efficient – operate for at least 1 year
- Accurate algorithms – 95% accuracy
- Fast algorithms, low memory usage
Detected activities

- Sleeping and dressing pattern
- Preparation of food and eating
- Personal hygiene pattern
- Social pattern
- Physical activity pattern
- Unusual behavior

Livingroom

Bathroom

Kitchen

Bedroom

Going outside
Sensor types

- Door sensor
  - Inertial

- Presence sensor
  - Passive infrared (PIR) sensor

- Pressure sensor

- (Modified) ProMove-3D
CareBOX system

- Leaving/entering house
CareBOX system

- Preparing a meal
Sleeping and dressing

- Node with pressure mat and accelerometer
  - PIR Node detection area

- Bed
- Bookshelf

Diagram shows a bed with a sensor placed under it, indicating a node with pressure mat and accelerometer.
CareBOX algorithms

- **Low-level**
  - Door opened/closed
  - Drawer opened/closed
  - Lying/not lying in bed
  - Presence

- **Medium-level**
  - Fusion of low-level detections to activity recognition

- **High-level**
  - Trends and changes in behaviour
CareBOX trials

- Controlled trials
- 2 houses, 5 subjects, 36 activity sessions
- 96% accuracy 1\textsuperscript{st} session, 97% accuracy 2\textsuperscript{nd} session
- False positives for leaving house

Problems
- Placement of the PIR sensors – no overlap
- Cat in the house
- Power consumption
  - Wireless protocol
  - Hardware
  - Low-power radio
CareBOX user interfaces

- Easy-to-use interface of the mobile app
CareBOX user interfaces

Warning of behavioral change

Chat function among care-givers
Implementation in healthcare

- Preparation for field-trials
- Commercialization through established service providers in the field
- (Partially) cover the costs of the system through healthcare insurance
Conclusions

- There is a clear and acute need for smart healthcare solutions for chronic diseases
- Self-management
- Home as the care environment

- Keep it simple for the user!
Thank you!