Telehealth using ECG Sensor and Accelerometer

Hristijan Gjoreski*, Aleksandra Rashkovska**, Simon Kozina*, Mitja Luštrek*, Matjaž Gams*

* Department of Intelligent Systems, **Jožef Stefan Institute, Ljubljana, Slovenia**
** Department of Communication Systems, **Jožef Stefan Institute, Ljubljana, Slovenia**

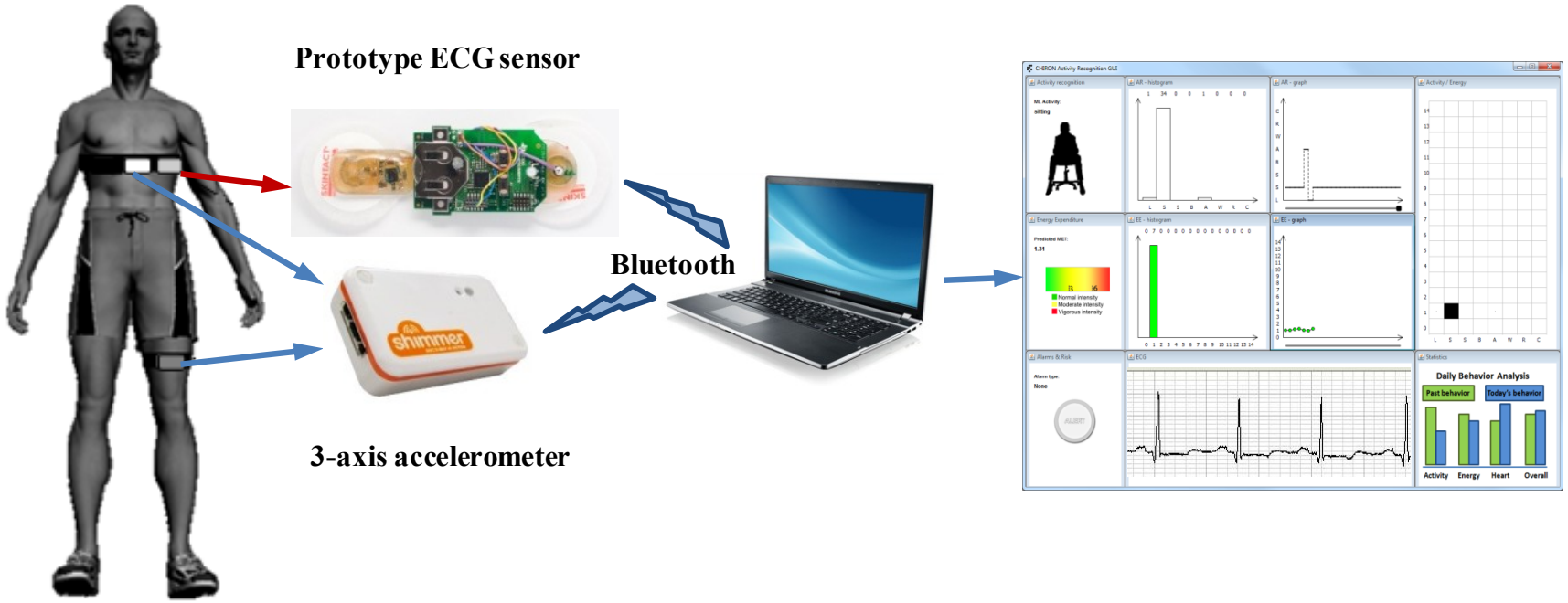
{**hristijan.gjoreski**, aleksandra.rashkovska, simon.kozina, mitja.lustrek, matjaz.gams}**@ijs.si**

Introduction

- **Problem**
  - The world's population is aging rapidly, threatening to overwhelm the society's capacity to take care of its elderly members
  - Elderly (> 65 years) - 7.5% in 2009 to 16% in 2050
- **Solution**
  - Development of innovative **telecare** technologies to help the elderly live independently for longer and with minimal support of the working population
- **Key components in our telecare system**
  - **Activity Recognition (AR)** – telecare systems must understand the user's situation and context, making AR an essential component
  - **Fall detection (FD) –** half of the hospitalizations of the elderly are caused by falls, making the FD an essential component
  - **Electrocardiography (ECG) –** the monitoring of vital signs, like the ECG, has a key role in telecare and telemonitoring systems.

System design

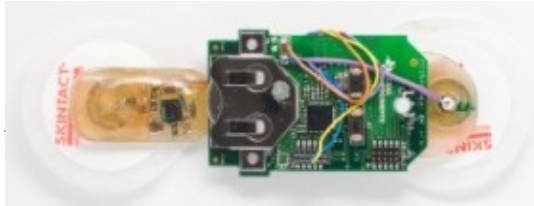
- Combination of the two solutions (sub-systems):
  - Accelerometer (ACC) – motion analysis (AR and FD)
  - ECG – analysis of heart-related parameters



ECG Sensor

- Two self-adhesive electrodes positioned 5 cm apart
- Analog front-end (designed to suppress radio frequency interference)
- Ultra-low-power (ULP) microcontroller
  - 16-bit, 32 kB of FLASH, 1 kB of RAM
- ULP Bluetooth V4.0 radio
- Ceramic chip antenna
- Lithium coin battery

Prototype ECG sensor

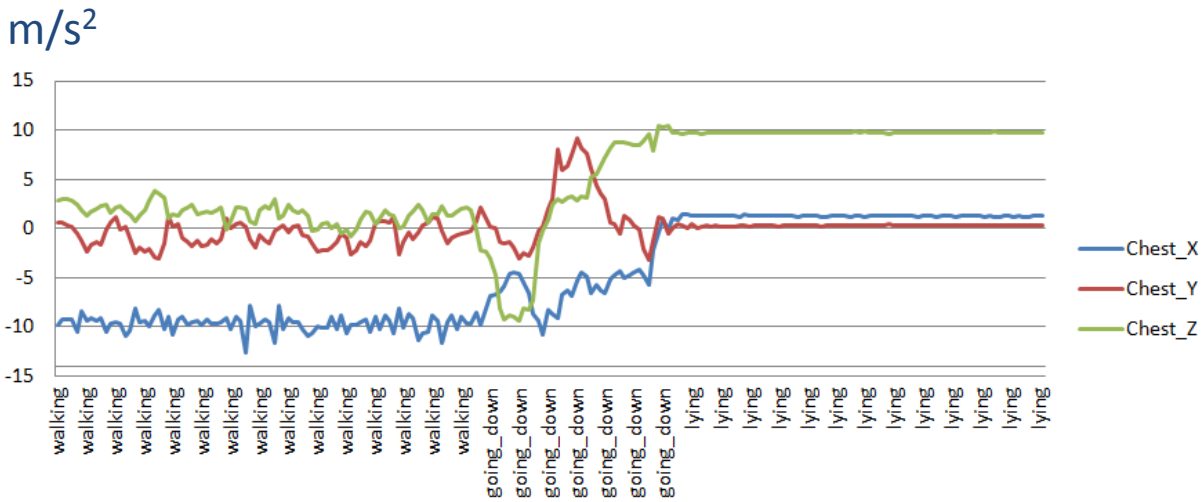


ECG Data Analysis

- The measurement of ECG can support:
  - heart rate variability analysis [23]
  - repolarization variability [24]
  - ST-segment denivelation [25]
  - detection of atrial fibrillation [26]
  - characterization of arrhythmias, syncopes [27]
  - **respiration rate extraction [16]**
  - **reproducing a standard 12-lead ECG with 3 ECG sensors [17]**

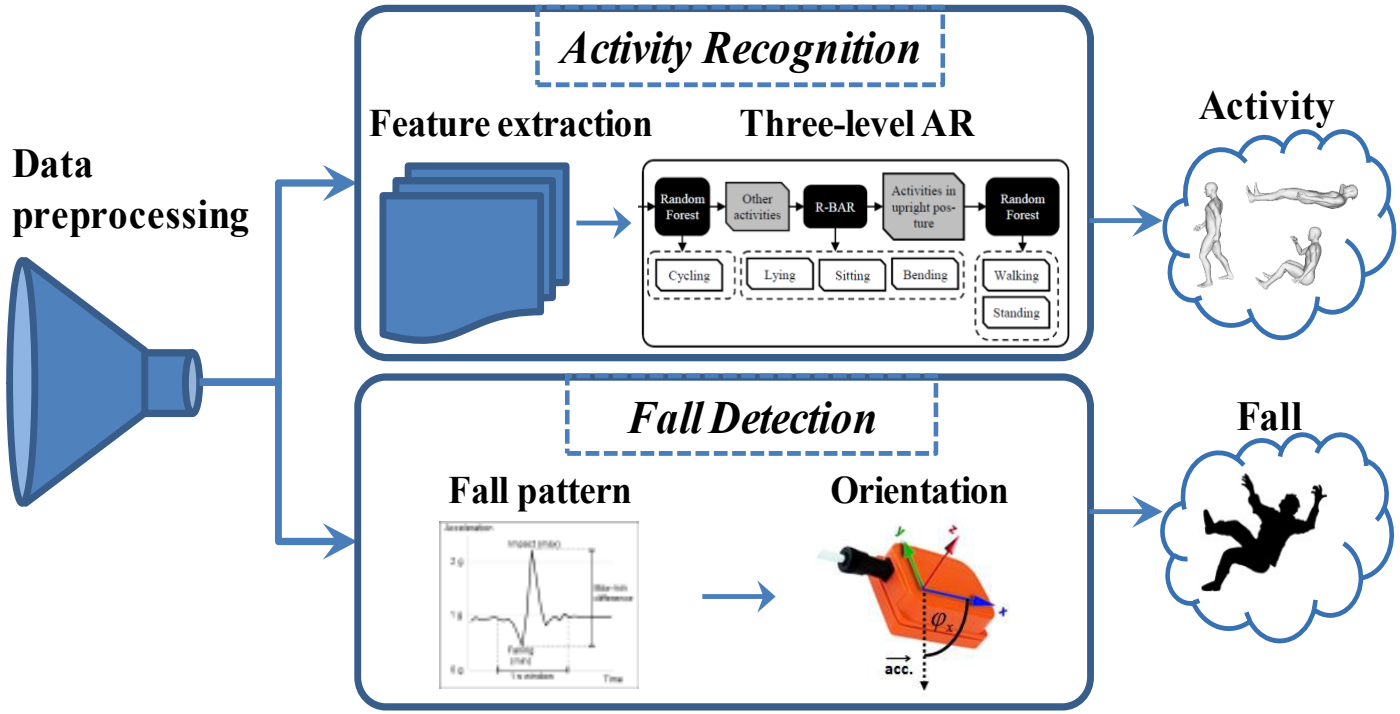
Accelerometer

- 3-axis accelerometer
- Raw data – acceleration vector projections (x, y and z)
- Acceleration due to human movements and Earth's Gravity



Activity Recognition and Fall Detection

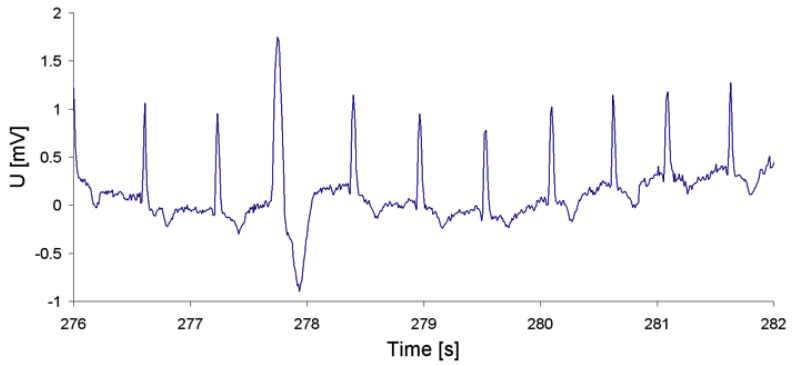
- Real-time Activity Recognition and Fall Detection system - **“RAReFall”**
- Winner the annual competition in Activity Recognition – **EvAAL** ’13.



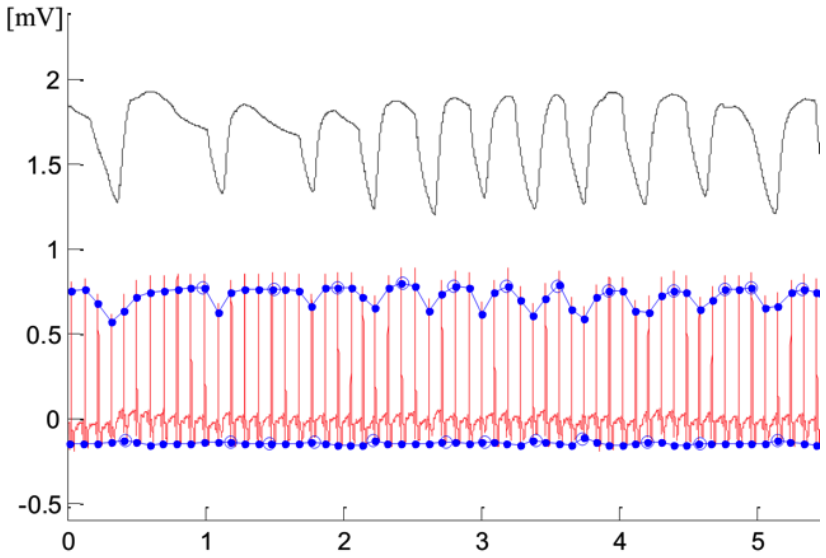
- http://videolectures.net/solomon_gjoreski_kozina_rarefall/

Experiments - ECG

- Raw ECG signal from electrodes at a distance of 5 cm. The person is walking around. The third heart beat is a ventricular extra systole with large amplitude and prolonged timing of the QRST complex.

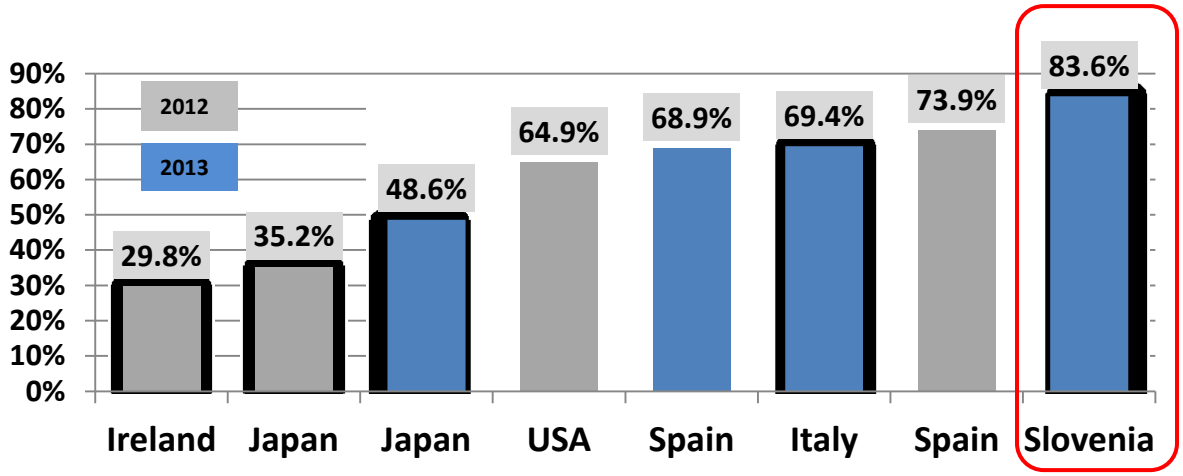


- 53 seconds interval of an ECG (red) measured with a WBBE positioned in the chest center and 11 respiration intervals (black) measured by a thermistor near the front of the nose. 58 R-peaks (blue filled points) are detected and all 12 respiration interval are identified (blue circles).



Experiments – Accelerometer

- International competition in activity recognition – EvAAL



- Offline – Activity dataset (publicly available at: http://dis.ijs.si/ami-repository/)

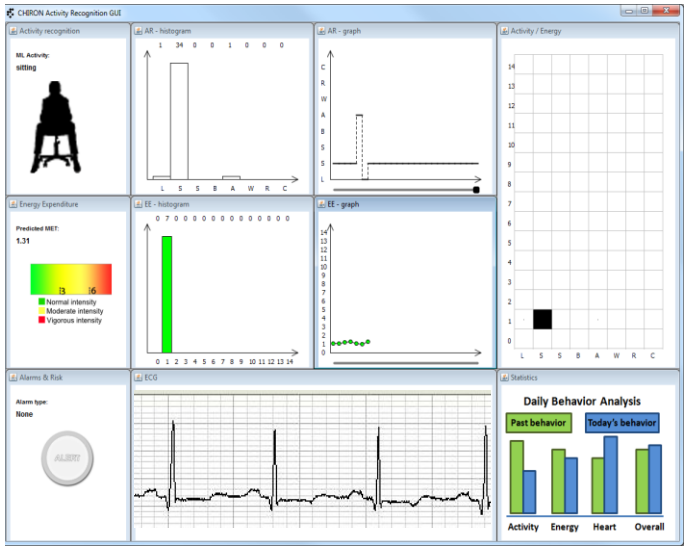
Performance	*Activity Recognition*	*Fall Detection*
Recall	99.22%	93.33%
Precision	98.85%	66.67%
F-measure	99.04%	77.78%

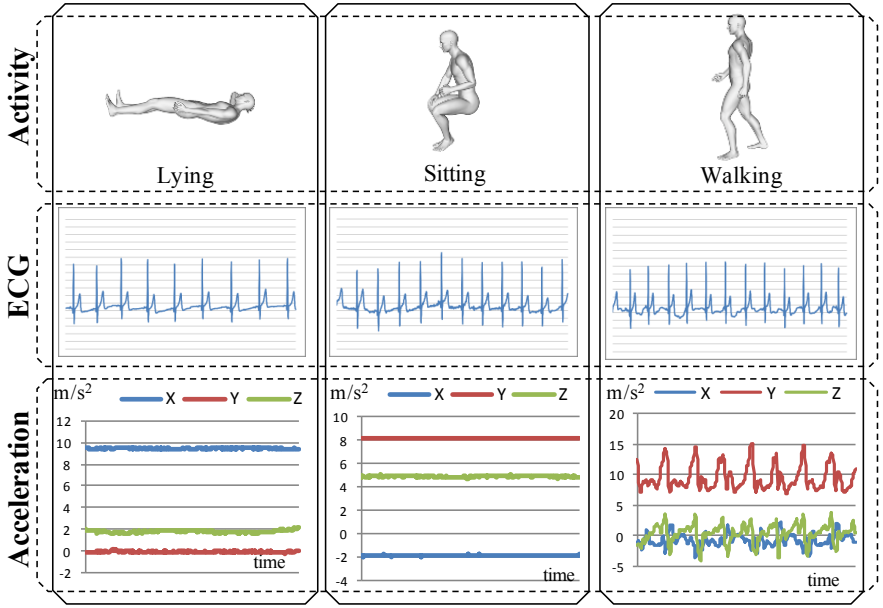
Fall detection detailed results

Events	Detected/All
Tripping	15/15
Fainting	13/15
Quickly lying	13/15
Quickly sitting	1/15
Other	0

Possible applications

- Daily activity analysis
- Detection of alarming situations (e.g., falls)
- Energy expenditure estimation (calories burned)
- Analysis of heart-related parameters
- Analysis of respiration parameters (sleep apnea detection)





Conclusion

- Fusion of ECG and ACC sensors data can provide supplementary information about the status of the monitored user.
- Better understand the context of user's health state and activity and therefore better reason about his/her health and behavior status.
- The reasoning may include classification of the detected anomaly into several levels:
  - **low-risk warning** (e.g., higher heart-rate detected during sedentary activity)
  - **medium-risk warning** (e.g., gait anomaly detected)
  - **high-risk warning** (e.g., high heart-rate detected during longer period of time)
  - **alarming situation detected** that requires medical attention, e.g., the user has fallen and is lying without movement.

Further Development

- **Multifunctional sensor node** that consists of **several sensors** to obtain synchronized data about vital bio-signs and activities of the monitored users.
  - ECG, accelerometer, gyro, magnetometer, temperature, GSR …
- **Smartphone implementation**
- **Three-phase monitoring** and data analysis:
  - **short-term** behavior and health analysis - focusing on the last several minutes of data (alarming situations, falls, arrhythmias)
  - **medium-term** behavior analysis - focusing on the past day (gait analysis)
  - **long-term** behavior analysis (daily/weekly anomalies) related to heart problems, less active days, etc.