ECG monitoring of cardiac patients at home: experiences with scenarios and signal processing methods

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Abstract—Controlled cardiac rehabilitation has shown to be an effective and cost-efficient form of treatment. However, it could be supported by technology. We used a scenario-based method to approach the issue and to consider it from the technical perspective. We also tried out signal processing methods in rejection of artifacts and quantization of ECG features from ECG data collected with two different portable recorders. For example correct R-peak detection rates ranged between 98.2% and 99.9% with 5 different tested R-peak detection routines. Conclusions: comments resulted from the scenario work was educative and simple ECG signal processing results promising.

Introduction
Our project objectives were to combine technology and needs of the target groups to create services focused to prevention, rehabilitation and safety at home. One important interest group was cardiac patients who could benefit new solutions. We used scenario based design to create new service concepts and tested some technical methods in the concepts.

Methods
Scenario evaluation 1:
health care professionals and decision makers were presented a cardiac patient scenario and interviewed (semi-structured interview)

Data collection:
6 recordings were collected with DEVICE 1 containing data over 8 hours and 40 minutes
3 recordings over 15 hours 30 minutes with DEVICE 2.

Signal processing (3 tasks):
1) artefact rejection,
2) heart rate calculation (detection of R-peaks)
3) detection of other ECG parameter (such as T- and P-wave)

Equipment:
Device 1:
- Tampere University of Technology (TUT)
- 2-channel ECG (Fs 200Hz, 8 bit)
- 2-channel accelerometers (Fs 28.57Hz, 8 bit).

Device 2:
- Alive Heart Monitor
- 1-channel ECG (Fs 300 Hz, 8 bit)
- 3-channel accelerometers (Fs 75Hz, 8 bit).

Results

Signal processing:
1) artefact rejection
Adaptive filtering
- acceleration as reference -> did not really improve the quality
- other ECG channel as reference -> helped to restore QRS (Fig. 1)

Independent component analysis (ICA)
- use 2 acceleration and 2 ECG channels as inputs (problematic)
- one has to associate the ICA channels with their possible meaning by visually looking at the data
- absolute amplitude information (including +/- sign) is lost in the ICA signals (Fig. 2 (problematic))

2) HR calculation (detection of R-peaks):
- the simplest method (curve-length based) does provide reasonable results at a very low computational cost (see Table 1)

3) detection of other ECG parameter (such as T- and P-wave)
- PWAVE freeware was used
- For a artefact-free signal the detection is reasonable accurate from single lead ECG (e.g. for interval calculation), but when the data quality decreases the number of wrong or missed detections is rapidly increasing. (see Fig. ->)

Conclusion
Quality of data, promising signal processing results, and affordable price were also encouraging information when we tested different ECG signal processing paradigms with simple, portable recorders. Smart combination of already developed technical methods, and good service concepts could have potential use in the cardiac rehabilitation.

Interviewed Health care professionals and decision-makers were interested in new technical possibilities if it support patient care and rehabilitation.