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

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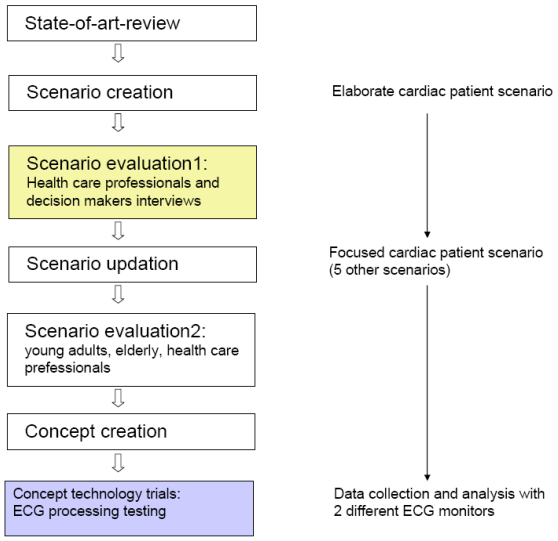
Abstract—**Controlled cardiac rehabilitation has shown to be an effective and cost-efficient form of treatment. However, it could be supported by technology. We used a scenario-based method to approach the issue and to consider it from the technical perspective. We also tried out signal processing methods 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.



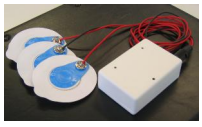
Methods

Scenario evaluation1:
health care professionals and decision makers were presented a cardiac patient scenario and interviewed (semi-structured interview)

Data collection:
•6 recordings were collected with DEVICE1 containing data over 8 hours and 40 minutes
•3 recordings over 15 hours 30 minutes with DEVICE2.

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:



Device1:
Tampere University of Technology (TUT)
2-channel ECG (Fs 200Hz, 8 bit)
2-channel accelerometers (Fs 28.57 Hz, 8 bit).

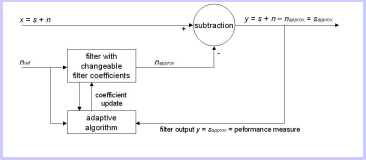
Device2:
Alive Heart Monitor
1-channel ECG (Fs 300 Hz, 8 bit)
3-channel accelerometer (Fs 75Hz, 8 bit)

Results

Scenario evaluation1:
New technical solutions could/should help
• lifestyle changes
• earlier discharging from hospital to home
• more cost-effective
• improve current diagnose making
•education for the users (health care professionals)
• one-fits-all idea does not work well in health-care -> adaptation
• trend in health care is to outsource simple diagnostics
Other issues:
•decision-makers have strong authority
•Decision-makers have to consider also ethical aspects together with cost-efficiency.
• patient's own responsibility in treatment (also responsibility of using new tools)
•negative experiences should be avoided with new technology

Signal processing:

1) artefact rejection
Adaptive filtering



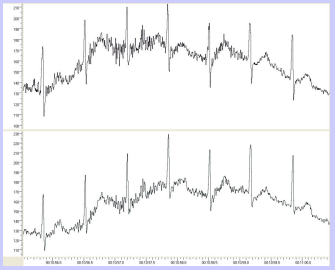


Figure 1: example from effect of adaptive filtering during an artifact, upper signal is original signal, and lower is after filtering (y-axis scale: 10mV, gain used in the recorder)

- 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)

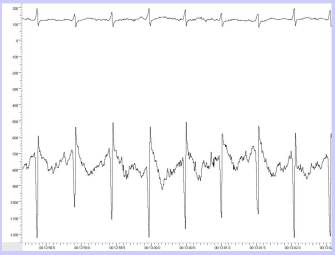


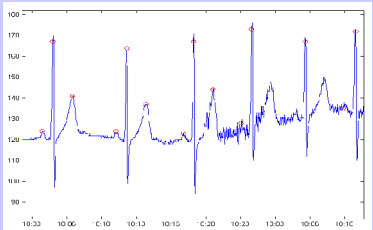
Figure 2: amplitude and sign changed in output of ICA, upper signal is original ECG waveform and lower signal is output of ICA (y-axis scale: 10mV, gain used in the recorder)

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)

TABLE I. ACCURACE OF R-PEAK DETECTION OF DIFFERENT ALGORITHMS : A (OPEN SOURCE), B (INHOUSE), C(TUT INHOUSE), D(SIMPLE), E(SUUNTO T6)

Algorithm	A	B	C	D	E
true positive %	99.77	99.85	99.21	98.19	99.77
false positive %	0.35	0.17	0.55	1.98	0.20

3) detection of other ECG parameter (such as T – and P-wave)
- PUWAVE 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 we interested in new technical possibilities if it support patient care and rehabilitation.

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