CardioZip: an ECG Compression Library for Mobile HealthCare

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Mobile Healtcare vs. Cardiovascular and Ishemic Deseases

- Heart Attack — the leading cause of sudden death in developed countries and Russia
- Long-term continous monitoring — is the way to alarm a doctor timely
- Impossible in hospital circumstances and with standard 12-lead ECG monitors
- We need simple personal-use devices

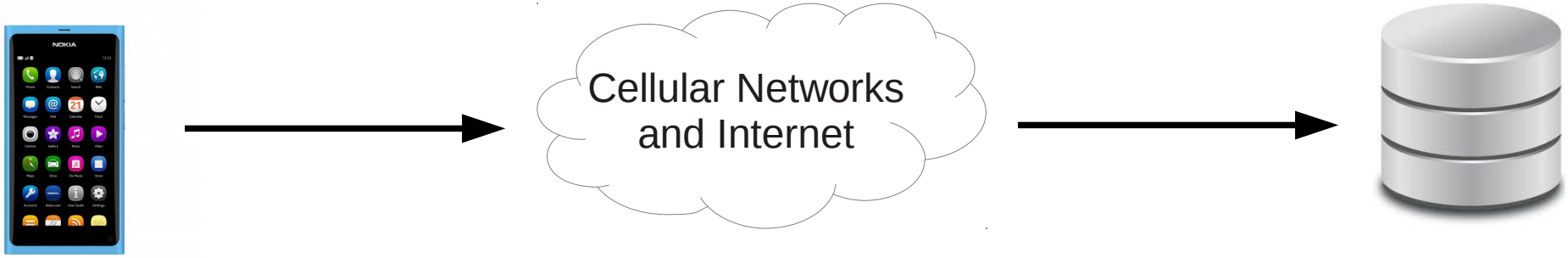
Mobile HealthCare System Architecture (just a reminder)

Cellular Networks and Internet

Emergency tracking

Telemedicine server

Why compression?



Traffic consumption

Disk consumption

The CardioZip library

- Lossy ECG data compression based on wavelet transform
- The pilot project aimed at growing the competences in Mobile HealthCare area in PetrSU

Project schedule

- June'11. Related work overview. Project planning
- July' 11. API Design
- August'11. Library prototyping
- September'11. Coding and testing
- October'11. Coding and testing
- November'11. First release. Report at FRUCT'10

The Team

- Management and prototype development
  - Alexander Borodin
- Developers
  - Yulia Zavyalova, 3rd year student
  - Anna Sapankevich, 3rd year student
  - Maxim Obryadin, 3rd year student
  - Evgeny Cvetkov, 5th year student

Wavelet compression

- Wavelet compression steps
  - Compute coefficients of wavelet transform for given signal.
  - Set to zero coeffs that are smaller than predefined limit (thresholding — for lossy compression)
  - Apply the data compression algorithm (entropy encoding are preferable)

Daubechies 9/7 filter pair

- Easy and efficient computation of transform coefficients
- Lifting coefficients are floating point
- Used in JPEG2000

$$s_l^{(0)} = x_{2l}$$

$$d_l^{(0)} = x_{2l+1}$$

$$d_l^{(1)} = d_l^{(0)} + \alpha\,(s_l^{(0)} + s_{l+1}^{(0)})$$

$$s_l^{(1)} = s_l^{(0)} + \beta\,(d_l^{(1)} + d_{l-1}^{(1)})$$

$$d_l^{(2)} = d_l^{(1)} + \gamma\,(s_l^{(1)} + s_{l+1}^{(1)})$$

$$s_l^{(2)} = s_l^{(1)} + \delta\,(d_l^{(2)} + d_{l-1}^{(2)})$$

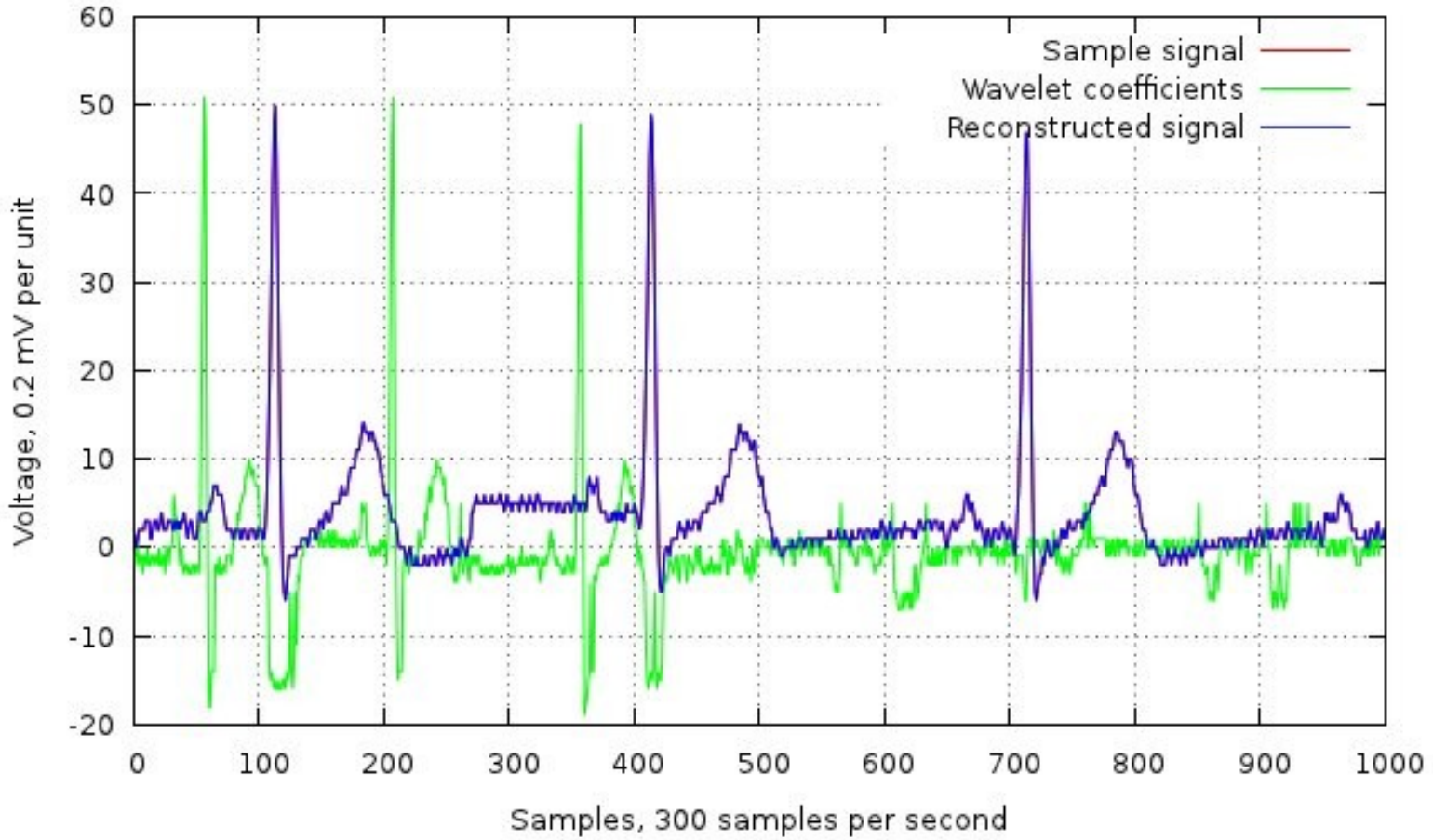
$$s_l = \zeta\, s_l^{(2)}$$

$$d_l = d_l^{(2)} / \zeta.$$

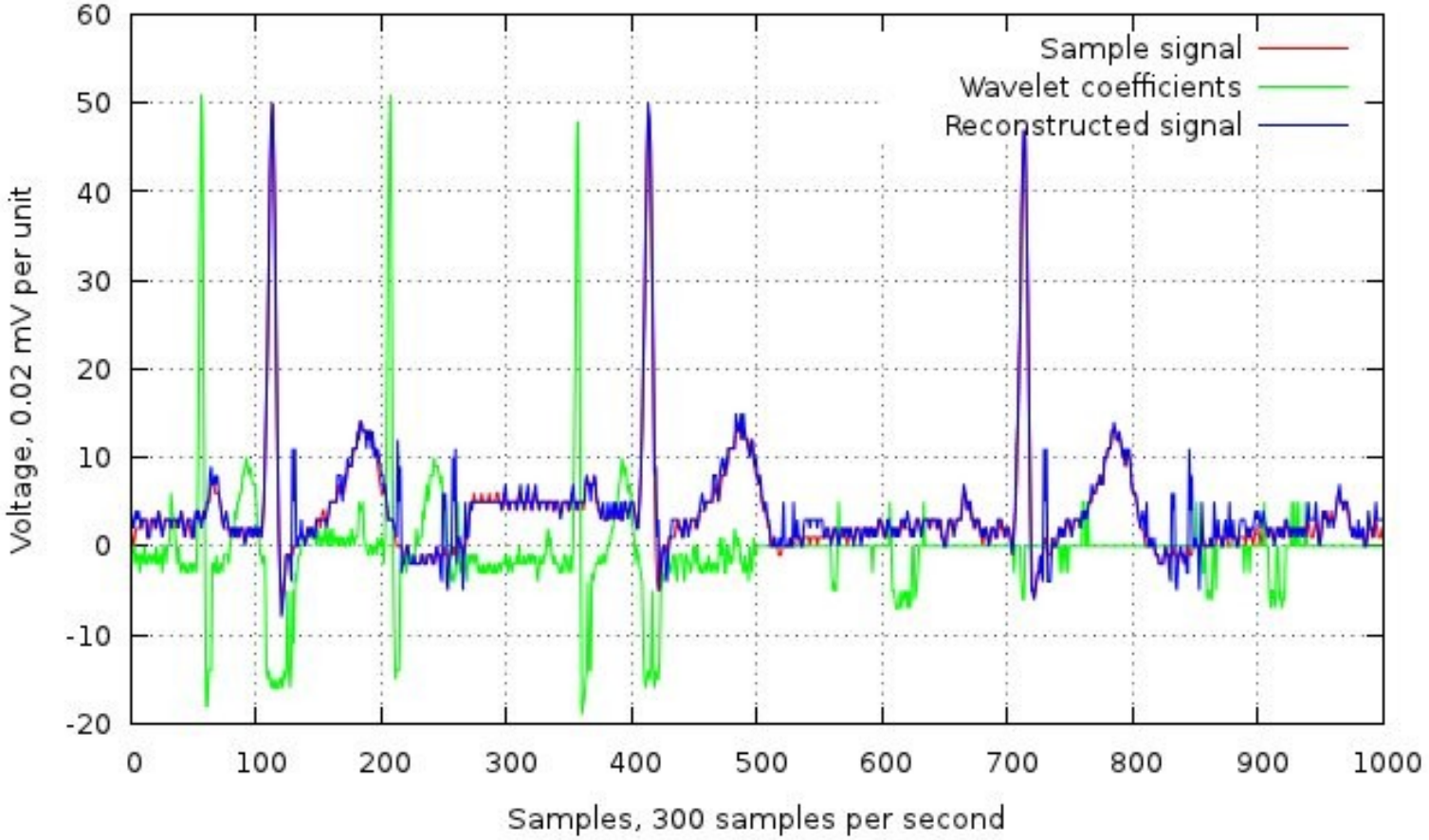
Integer arithmetic 9/7 DWT

- The lack of FPU on some devices
- Multiplication by floating point rational equals to a set of bit shifts and additions
- The library implements binary 9/7 DWT without the need the floating point arithmetics

Wavelet transform with no thresholding



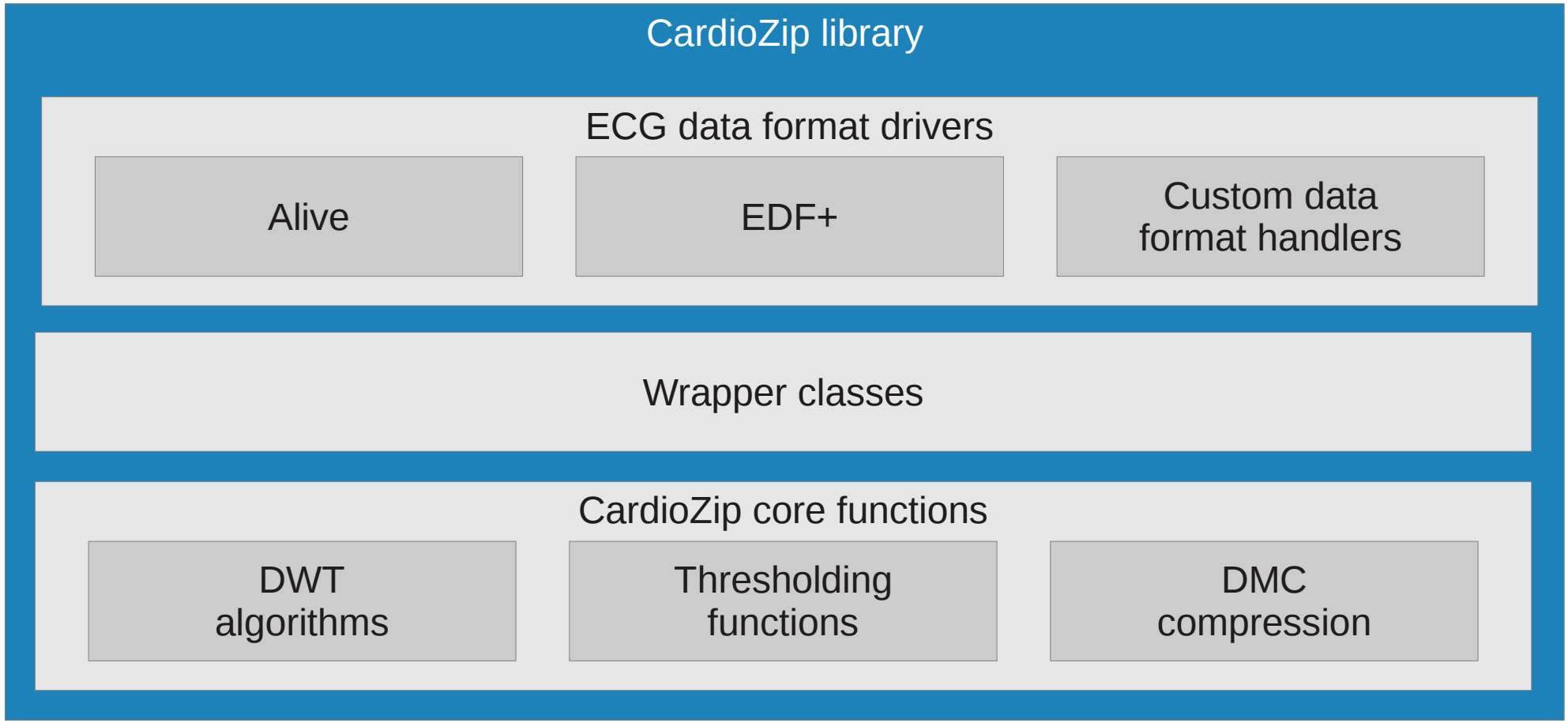
Wavelet transform with thresholding



Compressing the coefficients of wavelet transform

- Currently we use Dynamic Markov Compression and Arithmetic Coding algorithms
  - Quite efficient, but should be tested on lengthy signals.
  - Relatively easy-to-use but what about legal issues?

Library architecture



Current results overview

- Recent version of the library can be considered as a first release
  - In the near future the code will be provided for discussion within the mHealth WG
- The mHealth team was formed in PetrSU

Future proposals: CardioZip library improvement

- What about other kinds of transforms?
- Adaptive thresholding
- Repeat [Testing → Coding → Refactoring]

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Future proposals: Hardware implementation

- Working with foreign device prototype tends to some inconveniences and idle situations
- Currently our team member Evgeny Cvetkov is waiting for components and is ready to try to implement the analog part and communication (Bluetooth) module.

Future proposals: Signal processing toolkit

- Signal processing toolkit can be represented as a set of filters with adjustable parameters.
- It is quite difficult to select appropriate filters to achive better analysis purposes.
- In order to speed-up estimating good filter set for specific ECG data analysis task we need to decrease programming work as well as math tools (Maple, Maxima and so on) use.

Future proposals: Signal processing toolkit

- The idea is to develop a biosignal processing toolkit for medicine scientists.
  - One can build a pipeline of filters using such metaphors as a workspace and filter palette, drag'n'drop and so on.
  - Constructed pipeline can be saved as a script and played on mobile device.

Future proposals: Signal processing toolkit

- Architectural decisions of GStreamer can be easy applied to this project.
- Currently a couple of abstractions such as an element, a pipeline, tee element are implemented in Qt.