MobileDoctor – Smartphone Bioelectric Body Monitor

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Overview

1. Project Need
2. Specific Design Requirements
3. Design Alternatives
4. Analysis in Choosing Design
5. Selected Design Details
6. Updated Design Schedule
7. Team Responsibilities

Project Need

Problem

- 1 in 4 Americans have a cardiovascular disease
- Irregular and intermittent conditions
- Lack of access to medical facilities
- Preventative Care

Solution

- MobileDoctor – portable, wireless ECG monitor with smartphone software program

Specific Design Requirements

Table 1: Quantitative specific design requirements for hardware and software components.

ECG Measurement	
Signal bandwidth	0.05 Hz-150 Hz
Leads/Channels	12
Sampling rate	200 Hz
Heart rate range	30-250 bpm
Active channels	LL, LA, RA, RL, V1, V2, V3, V4, V5, V6
Input impedance	≥2.5 MΩ at 100 Hz
Internal noise (Ch - Ch)	300 μV p-v maximum
Gain difference (Ch - Ch)	0.1% maximum at DC – 150 Hz
Data storage	100 MB
Average processing time	< 60 seconds
Operating Conditions	
Operating temperature	0 to 40°C (32 to 104°F)
Storage temperature	-20 to 70°C (-4 to 158°F)
Pressure	700-1060 mbar
Operating time	24 hours before recharge
Power	rechargeable battery
Lifespan	1-2 years

Table 1 (cont.): Quantitative specific design requirements for hardware and software components.

Mechanical	
Length	≤10.2 cm (4 in)
Width	≤7.6 cm (3 in)
Height	≤5.1 cm (2 in)
Weight	≤300 g
Stress	181.5 kg (400 lb)
Housing material	ABS
Software	
Platform	Android
Version	2.2+
Bluetooth Version	2.0+
Language	Java (on Dalvik VM)

Design Alternatives

- Form Factor
  - Stationary (PC)
  - Mobile (Smartphone)
- Smartphone Platform
  - Android
  - iOS
- Data Transmission
  - Wired
  - Wireless
- Environment for Use
  - In-patient
  - Out-patient
- Data Collection
  - ECG
  - Pulse Oximetry
  - Accelerometry
- Analysis Method
  - Algorithmic Analysis
  - Human Analysis
- Arrhythmia Classification
  - Beat Typing
  - Power-Frequency Analysis
  - Beat-to-Beat Statistics

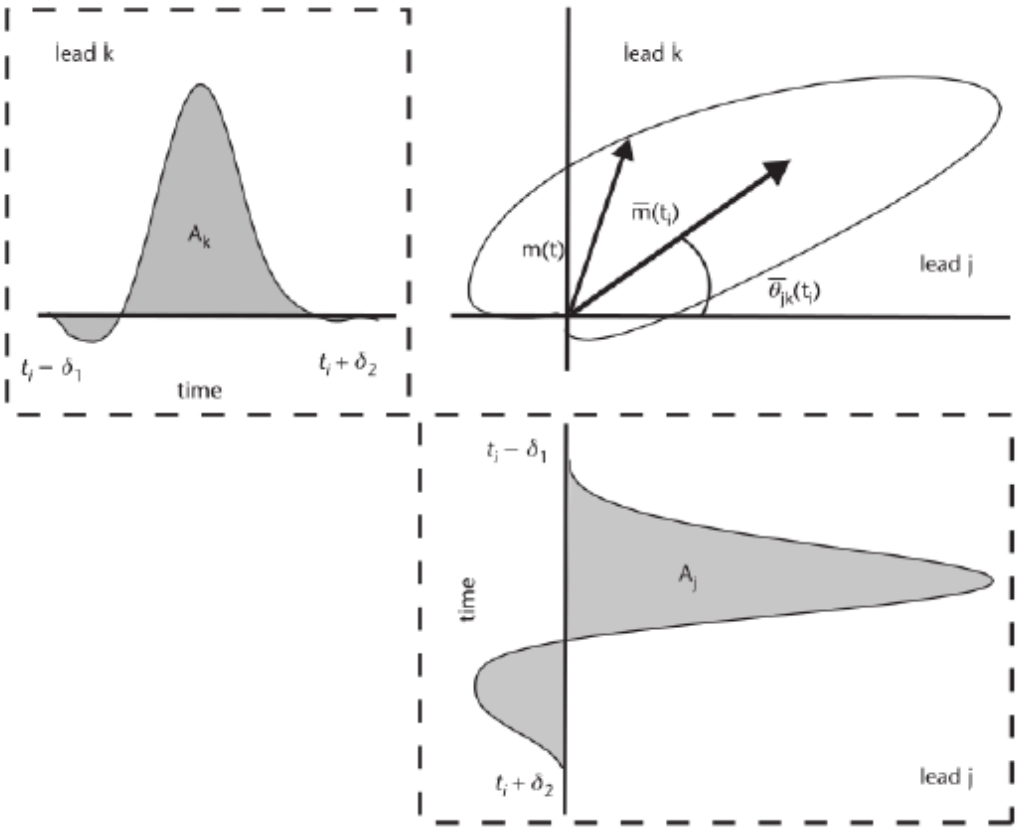
Alternatives / Analysis

- EDR Algorithms
  - Preprocessing requirements:
    - QRS complexes detected and clustered
    - Baseline wander attenuated
    - VCG signal available
  - Alternatives:
    - Amplitude EDR Algorithms
    - Multi-lead QRS Area EDR Algorithms
    - QRS-VCG Loop Alignment EDR Algorithm

- EDR Algorithms

Multi-lead QRS Area EDR Algorithms

Figure 1. The mean electrical axis of a cardiac signal in the plane ***jk***.



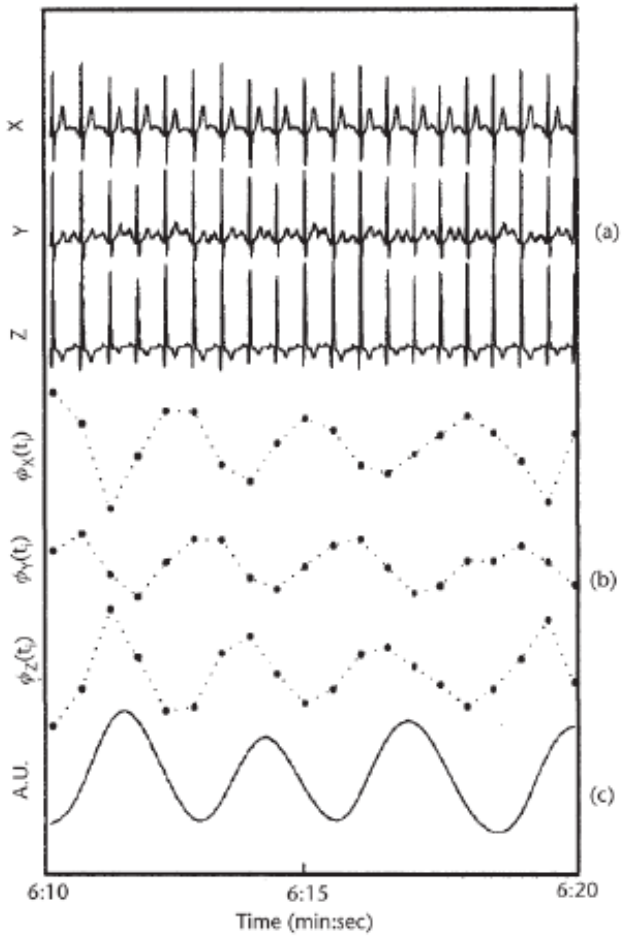
$$\overline{\mathbf{m}}(t_i) = \begin{bmatrix} \frac{1}{\delta_2 + \delta_1} \int_{t_i - \delta_1} \|\boldsymbol{m}(t)\|_2 \cos\left(\theta_{jk}(t)\right) dt \\ \frac{1}{\delta_2 + \delta_1} \int_{t_i - \delta_1}^{t_i + \delta_2} \|\boldsymbol{m}(t)\|_2 \sin\left(\theta_{jk}(t)\right) dt \end{bmatrix} = \frac{1}{\delta_2 + \delta_1} \begin{bmatrix} A_j(t_i) \\ A_k(t_i) \end{bmatrix}$$

$$\bar{\theta}_{jk}(t_i) = tan^{-1}\left(\frac{A_k(t_i)}{A_j(t_i)}\right)$$

- EDR Algorithms

QRS-VCG Loop Alignment EDR Algorithm

Figure 2. (a) The vector-cardiogram leads used for the EDR approximation, (b) The EDR approximation using the QRS-VCG loop alignment EDR algorithm, and (c) The actual corresponding respiratory signal.



$$\varepsilon_{\min} = \underset{\gamma,\tau,\boldsymbol{Q}}{\min(\varepsilon)} = \underset{\gamma,\tau,\boldsymbol{Q}}{\min} \frac{\|\mathbf{Y_R} - \gamma \mathbf{J}_\tau \mathbf{Y}\mathbf{Q}\|_F^2}{\|\gamma \mathbf{J}_\tau \mathbf{Y}\mathbf{Q}\|_F^2}$$

$$\mathbf{J}_\tau = [0_{\Delta-\tau} - \mathbf{I}0_{\Delta+\tau}]$$

$$\hat{\gamma}_\tau = \frac{tr(\mathbf{Y_R}^T \mathbf{Y_R})}{tr(\mathbf{Y_R}^T \mathbf{J}_\tau^T \mathbf{Y}\hat{\mathbf{Q}}_\tau)}$$

$$\mathbf{Y_R}(i+1) = \alpha \mathbf{Y_R}(i) + (1-\alpha)\mathbf{Y}(i+1)$$

Table 2: The Pugh chart quantitatively analyzes the stated alternatives and states which one is the best according to the defined categories.

		Cost	Portability	Deadline	Computational Power	Processing Time	Signal Detection	Signal Accuracy	Total Power Draw	Total
	Weight	8	10	10	8	10	10	10	10	
Form Factor	Stationary	8	1	10	8	10	10	10	10	63.8
	Mobile	7	10	10	6	8	10	10	9	**67.4**
Mobile Platform	Android	8	10	10	8	10	10	10	10	**72.8**
	iOS	1	10	10	8	10	10	10	10	67.2
Data Transmission	Wired	8	1	10	8	10	10	10	10	63.8
	Wireless	6	10	10	8	9	9	10	7	**66.2**
Environment	In-patient	6	10	10	8	10	10	10	10	71.2
	Out-patient	8	10	10	8	10	10	10	10	**72.8**
Data Collection	ECG	8	10	10	8	10	10	10	10	**72.8**
	Pulse Oximetry	8	10	10	8	10	6	4	10	62.8
	Accelerometry	8	10	10	8	10	7	7	10	66.8
Analysis Method	Algorithmic	10	10	10	8	10	10	8	10	**72.4**
	Human	10	7	10	8	7	10	10	10	68.4
Arrhythmia Classification	Beat Typing	10	10	10	10	10	5	4	10	65
	Power-Frequency Analysis	10	10	10	8	8	7	6	10	65.4
	Beat-to-Beat Statistics	10	10	10	7	9	10	10	10	**72.6**
EDR Algorithms	Amplitude	10	10	10	9	10	5	4	10	64.2
	Multilead	10	10	10	8	8	7	6	10	65.4
	QRS-VCG Loop Alignment	10	10	10	6	6	10	10	10	**68.8**

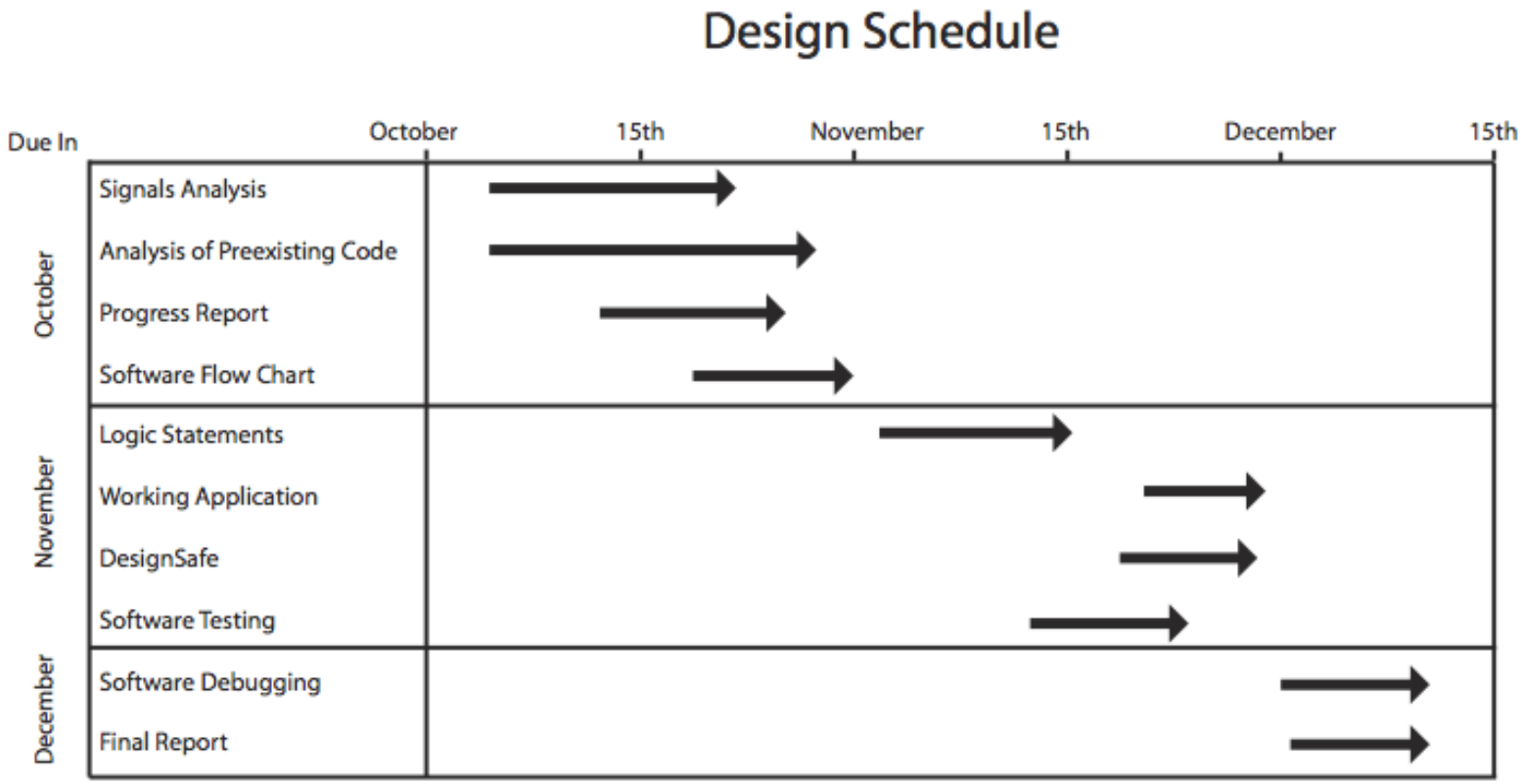
- Form Factor
  - ▫ Stationary (PC)
  - ✓ **Mobile (Smartphone)**
- Smartphone Platform
  - ✓ Android
  - ▫ **iOS**
- Data Transmission
  - ▫ Wired
  - ✓ **Wireless**
- Environment for Use
  - ▫ In-patient
  - ✓ **Out-patient**
- Data Collection
  - ✓ **ECG**
  - ▫ Pulse Oximetry
  - ▫ Accelerometry

- Analysis Method
  - ✓ **Algorithmic Analysis**
  - ▫ Human Analysis
- Arrhythmia Classification
  - ▫ Beat Typing
  - ▫ Power-Frequency Analysis
  - ✓ **Beat-to-Beat Statistics**
- EDR Algorithms
  - ▫ Amplitude EDR Algorithms
  - ▫ Multi-lead QRS Area EDR Algorithms
  - ✓ **QRS-VCG Loop Alignment EDR Algorithm**

Selected Design Details

- Form Factor
  - Smartphone software program
  - Bluetooth wireless sync
- Software
  - Google's Android mobile operating system
  - Code components:
    - Set-up tutorial
    - Real-time ECG display
    - System checks
    - Data output options
- Environment
  - Out-patient monitoring
  - Patients without easy access to medical facilities

Updated Design Schedule



Team Responsibilities

- Vinod
  - Target Diseases for Diagnosis
  - Algorithmic Signal Analysis
- Stacy
  - Prototype Construction on Desktop
  - Electrode Placement
- Samir
  - Data Analysis
  - Wireless Interfacing with Electrodes
  - Electrode Placement Directions

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