Mobile Doctor: The Smartphone ECG Monitor

Presenter: Vinod Ravikumar, Group # 35
Partners: Samir Unni, Stacy Yae
Mentor: Dr. Dennis Barbour
BME Senior Design

Presentation Overview

- ✓ Introduction
- ✓ Background, Need, Project Scope
- ✓ Design Requirements
- ✓ Existing Solutions and Patents
- ✓ Preliminary Analysis
- ✓ Design Schedule
- ✓ Team Responsibilities

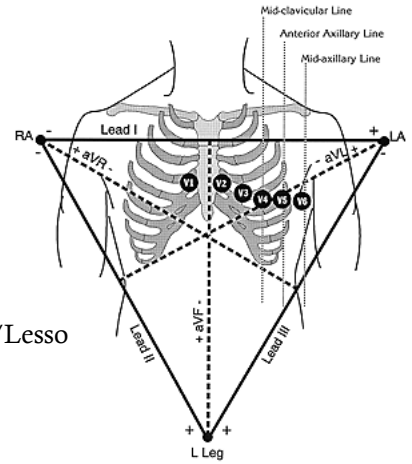
<http://www.freepik.com/free-photo/hospital-ecg-paper-checking-emergency_473904.htm>.

Context

- US: 25 seconds – 1 Heart Attack
  - ~28 Heart Attacks in 12 minutes
  - 12 Deaths
- 26% of population affected
- 20 year olds and higher
- 1,255,000 Heart Attacks per year

Background – the Electrocardiogram

- Electrocardiogram (ECG)
  - Detects electrical activity during cardiac cell depolarization
- Two electrodes' output = 1 Lead
  - Placement determines a vector from point-point potential difference
- Resting, Ambulatory, Stress Test



http://library.med.utah.edu/kw/ecg/ecg_outline/Lesson1/lead_dia.html

Need

- Outpatient Monitoring
- Need #1
  - Pre- and post-operational ECGs are required for most medical procedures
  - Contributes to high medical costs for both patients and insurance companies
- Need #2
  - Outside of the big cities, there are far fewer medical specialists, particularly cardiologists, cardiovascular disease specialists, and cardiac electrophysiology specialists
  - MobileDoctor can be used as a remote diagnostic tool by any medical aide
  - The city-centered doctor can receive this patient's data in real time and can advise them to come in for a check up if necessary

Project Scope

How does MobileDoctor addresses this need?

- ✓ Components
  - ✓ Wearable device to measure bioelectrical data
  - ✓ Smartphone application that syncs with this device to collect and interpret incoming ECG waveforms
  - ✓ Bluetooth connection
  - ✓ Program outputs whether a patient has a disease, and if so, what type of cardiac dysfunction
- ✓ Software
  - ✓ Android
  - ✓ Diagnosis will be easily comprehensible and will explain fundamentals of the disease
  - ✓ Patient should follow up with additional medical assistance from a provider

http://www.iconspedia.com/icon/bluetooth-3127.html,
http://jannanphones.blogspot.com/2011/07/htc-android-phone.html,
http://www.visualphotos.com/image/2x4755222/doctor_talking_with_patient_in_doctors_office

Specific Design Requirements

ECG Measurement	
Signal bandwidth	0.05 Hz-150 Hz
Leads/Electrodes	12/10
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

Specific Design Requirements Continued

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
Mechanical	
Length	≤10.2 cm (4 in)
Width	≤7.6 cm (3 in)
Height	≤5.1 cm (2 in)
Weight	≤300 g (0.6614 lb)
Stress	181.5 kg (400 lb)
Housing material	ABS (Plastic)

Existing Solutions and Patents

AliveCor's iPhone ECG

AliveCor

- Snap on iPhone case
- 2 electrodes
- Records about a minute of data
- Easy-to-use

Disadvantages

- Far fewer leads versus MobileDoctor
- No Analysis software

http://www.transhumanistic.com

Patent # 7,933,642

- Encompasses AliveCor idea
- Wireless ECG system
- Transmits information to the base station (iPhone)

iRhythm Technology's Zio

Zio

- Adhesive electronic patch
- Records 45 seconds of data
- Patient must hold button during recording
- 1-channel ECG
- Transfer data to a base station

Disadvantages

- Patient input is a subjective measure
- Small quantity of data acquisition
- Recording is inconvenient for patient
- Only 1 channel
- No real time data acquisition
- No instant data analysis

http://www.irhythmtech.com/

Patent # 7,904,133

- Wearable wireless device for monitoring, analyzing, and communicating physiological status
- Adhesive surface electrodes
- ECG monitoring
- Wireless transfer of data to a base station

SmartHeart

SmartHeart

- Chest Strap Electrodes
- Smartphone connectivity
- Sends information to doctor's office

Disadvantages

- Does not have built-in analysis
- Cost - $499
- Targeting private buyer market

http://www.dailymail.co.uk/sciencetech/article-1393089/Smartheart--Gadget-turns-mobile-cardio-monitor.html

Patent # 7,896,811

- Portable device having biosignal – measuring instrument
- Electrodes relay information to a portable unit
- Ambiguous analysis component

Analysis, Schedule, Responsibilities

Terminology

- RR Interval
- QRS
  - 60-100 ms
  - A = 3-5 mV
- P Wave
  - 80-110 ms
  - Amplitude <.25 mV
- T wave
  - 120 ms
  - A = .25 mV

Case: Ventricular Fibrillation

Characteristics

- Arrhythmia
- Quivering of muscle fibers
- Insufficient blood pumped from ventricles
- Cardiac death

ECG

- Irregular contractions
- High frequency of low amplitude waveforms
- Wandering baseline

Logic

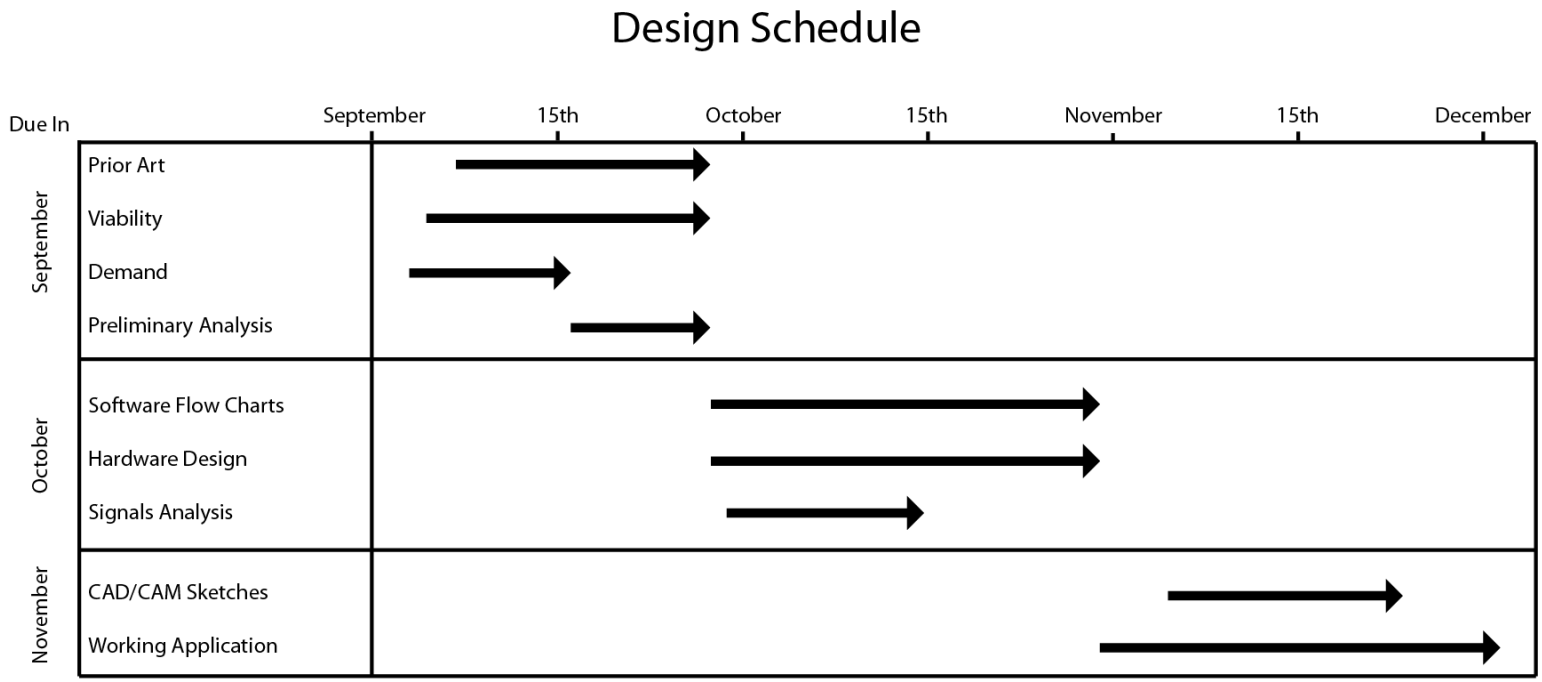
```
qrs_thr = 0.8; // mV
qrs_cnt = 0;
hr = 80; // bpm
        for(i=0,i<length(data.t),i++){
                if(data.a[i] > qrs_thr) {
                        qrs_cnt++;
        }}
        if(length(data.t)/qrs_cnt < .85*hr){
                vfib = true;}
        else { vfib = false;}
```

QRS threshold = .8 mV
QRS counter

If amplitude of waveform is greater than threshold, increase qrs count by 1

Frequency of qrs<frequency of a heart beat = Ventricular fibrillation!

Design Schedule



Team Responsibilities

- Vinod Ravikumar
  - Signal analysis research
  - Logical steps for software
- Samir Unni
  - Incorporation of Bluetooth
  - Translate logic to code
- Stacy Yae
  - Hardware Specifications
  - CAD/CAM sketches
  - Website

References

- Dr. Dennis Barbour, MD, PhD
- http://www.freepik.com/free-photo/hospital-ecg-paper-checking-emergency_473904.htm
- "15. 12-Lead ECG System." *Bioelectromagnetism*. Web. <http://www.bem.fi/book/15/15.htm>.
- "AHA Statistical Update." American Heart Association, 15 Dec. 2010. Web. <http://circ.ahajournals.org/content/123/4/e18.full>.
- "CDC - DHDSP - Heart Disease Facts." *Centers for Disease Control and Prevention*. Web. <http://www.cdc.gov/heartdisease/facts.htm>.
- "Digital Multimeter Measurement Techniques and Definitions - Developer Zone - National Instruments." *NI Developer Zone*. Web. <http://zone.ni.com/devzone/cda/tut/p/id/3296#toc2>.
- "ECG Timeline - History of the Electrocardiogram." Web. <http://www.ecglibrary.com/ecghist.html>.
- Fulford-Jones, Thaddeus, Gu-Yeon Wei, and Matt Welsh. "A Portable, Low-Power, Wireless Two-Lead EKG System." Proc. of 26th Annual Internatoinal Conference of the IEEE EMBS, CA, San Francisco. Web. <http://www.eecs.harvard.edu/~mdw/papers/ekg-embs04.pdf>.
- "Heart Signals." *Boston Scientific*. Web. <http://www.bostonscientific.com/templatedata/imports/HTML/CRM/heart/heart_signals.html>.
- "H&H Medical Corporation Specifications for the Simple ECG Hand Held ECG Monitor." *H&H Medical Corporation Elite Diagnostic Solutions for Home Healthcare, Clinics, Sports Medicine & Dental*. Web. <http://www.hhmedicalcorp.com/specifications.html>.
- "Low Pass Filter." *Basic Electronics Tutorials and Revision*. Web. <http://www.electronics-tutorials.ws/filter/filter_2.html>.
- "The Electrocardiogram – Looking at the Heart of Electricity." *Nobelprize.org*. Web. <http://www.nobelprize.org/educational/medicine/ecg/ecg-readmore.html>.
- "Practical Considerations: OPERATIONAL AMPLIFIERS." *All About Circuits: Free Electric Circuits Textbooks*. Web. <http://www.allaboutcircuits.com/vol_3/chpt_8/13.html>.
- "Revolutionary ECG Solutions." 2008. LifeSync. Web. <http://www.lifesynccorp.com/assets/pdfs/reference/Product_Spec.pdf>.

Thank You