Heart Sounds and Murmurs in an Electronic Medical Record

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Outline

- Project background and purposes
- Medical background about heart sound and murmur
- Requirement analysis and system specifications
- EMR format adopted: LISP and XML
- System modules and data flow
- Graphical representation and screenshots
- Development process and future work
- Conclusion

Project Background

- Tripler Army Medical Center: digital PCGs (high quality heart sound recordings), patient histories, physical exams, and echocardiographic data.
- EE department: automated PCG interpretation through signal processing and analysis
- Fallot: A computational model of medical diagnosis based on expert reasoning, to identify heart defects based on patient data
- PATH: Pacific Asynchronous Telehealth system at Tripler
- Integrate Fallot and signal processing into same form for EMR in PATH.

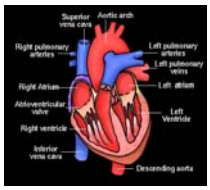
Purpose of Project

- To convert the patient data information from Tripler to EMR
- Problems with the existing raw data
  - Not formatted, messy
  - Terms not standard
  - Hard to read and analyze
  - Difficult to use and retrieve electronically
- To graphically display the result as of automatic interpretation of PCGs after signal processing
- To graphically show the patient information from a file generated by Fallot
- To improve Fallot knowledge-base to reason about new patient data
- To incorporate the output and analysis reports into PATH telemedicine system
- To design a user interface providing a familiar and intuitive visualization of heart sounds and murmurs for primary care physicians and cardiologists

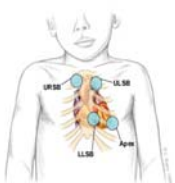
Medical Background

- Heart auscultation: listening to heart
  - Positions: sitting, supine, left lateral recumbent
  - Location: apex, aortic, pulmonary, Left Sternal Border(LSB)
- Heart sounds: S1, S2, S3, S4
- Heart murmurs
  - Loudest location:apex, aortic area, pulmonary area, LSB
  - Time: systolic, diastolic, continuous
  - Radiation
  - Intensity: 1 to 6
  - Quality: harsh, vibratory, blowing soft
  - loudest/diminished when: supine or stand
- Physical examination, X-ray and EKG data

Heart and stethoscope



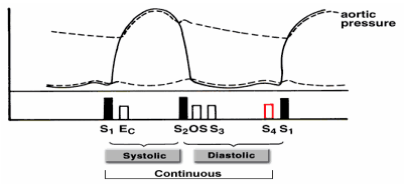
Ref:http://www.sciencebob.com/lab/bodyzone/heart.jpg



Ref:http://www.aafp.org/afp/990800ap/558.html

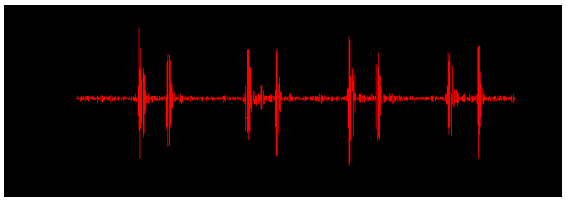
Ref:http://research.uiowa.edu/cto/public/gx/stethoscope.jpg

Cardiac Cycle



Ref: http://depts.washington.edu/physdx/heart/tech4.html

Heart sound – complex wave form



(Ref: http://www.isvr.soton.ac.uk/SPCG/CBSPC/heart/TerImg/pulmur.gif)

Difficult for anyone except specialist to listen and interpret correctly.

Signal processing can use sounds people can't hear.

Requirements analysis

- Create a standardized data format
- Transform and upgrade original patient data to new system
- Accept input from multiple sources
  - file in Lisp format, same as Fallot
  - standardized XML format
  - results of automated PCG interpretation via signal processing
  - user entry of new cases
- Parse and classify heart sound and murmur types
- Create images based on patient data
- Generate human-readable and printable report for patient data
- Images easily interpreted by physicians
- User friendly interface for medical workers of low computer skills

System Specifications

- GUI interface to run on multiple platforms/operating systems
- Select language: Java
- Internal data representation and data output storage format: XML
- Images representation format: JPG
- Use Java classes to create images to be portable and readily integrated into an existing Telemedicine web application

EMR Format

- LISP format
  - Generated by text-based program in Fallot
  - Entered by an undergraduate student
  - Easy to read and interpret

LISP format

```
;;; -*- Mode: Lisp; Syntax: Common-Lisp; Package: User -*-;;;
;;; -*- Su-Ping Cheng Jun 07 2006
   (heart
     (s2
       (p2 soft))
     (systolic_murmur
       (location
         (aortic_area
           (heard_best under_right_clavicle)))
       (loudness 4)
       (time regurgitant)
       (quality harsh)
       (radiation carotids)
       (disappears_when no_difference)
       (loudest_when_the_patient_is no_difference))
     (peripheral_pulses
       (in_each_extremity 2+)))
```

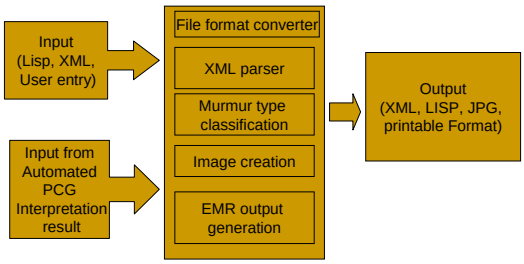
XML format

- XML format
  - Widely adopted in EMRs
  - Portable, easy to integrate into other applications
  - Parsers available for different languages, C++, C#, Java, .NET, etc.
  - Convertible between LISP and XML, database as well

XML format

```
<heart>
        <s2>
          <p2> soft</p2>
        </s2>
        <systolic_murmur>
            <location>
              <aortic_area>
                <heard_best> under_right_clavicle</heard_best>
              </aortic_area>
            </location>
            <loudness> 4</loudness>
            <time> regurgitant</time>
            <quality> harsh</quality>
            <radiation> carotids</radiation>
            <disappears_when> no_difference</disappears_when>
            <loudest_when_the_patient_is> no_difference</loudest_when_the_patient_is>
        </systolic_murmur>
        <peripheral_pulses>
            <in_each_extremity> 2+</in_each_extremity>
        </peripheral_pulses>
</heart>
```

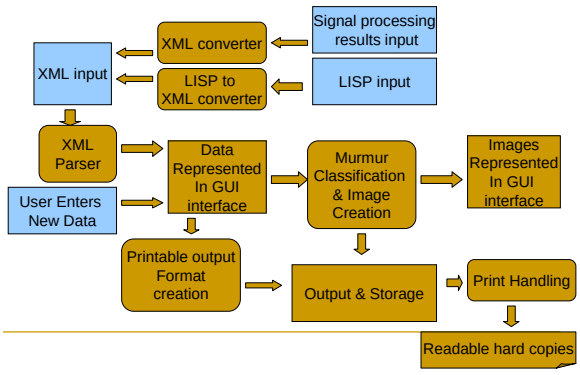
System Prototype



System Modules

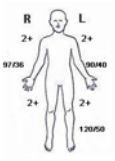
- Input from files or entry (Lisp, XML, entry)
- PCG signal processing results
- Lisp -> XML converter
- XML parser
- Murmur type classification
- Picture creation
- Output and storage of images
- Output and storage of printable and human-readable patient data

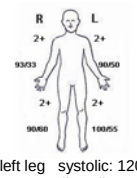
Data Flow



Graphical Representation

- Blood pressure and peripheral pulses



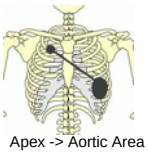


blood pressure
right arm systolic: 97
diastolic: 36
left arm systolic: 90
diastolic: 40

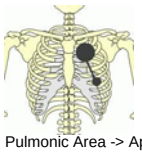
left leg systolic: 120
diastolic: 50
right leg systolic: 90
diastolic: 60
Peripheral pulses in each extremity: 2+

Graphical Representation

- Murmur location and radiation



Apex -> Aortic Area

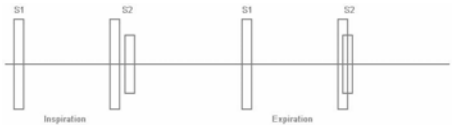


Pulmonic Area -> Apex

- The murmur is loudest or disappeared when

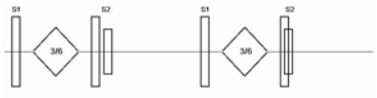
Graphical Representation

- Two cycles, one inspiration, one expiration, S1, and S2 (no murmur)

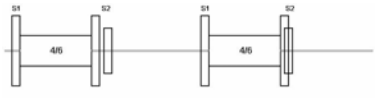


Graphical Representation

- Single systolic murmurs



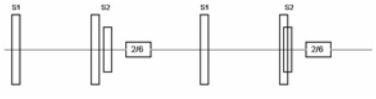
Mid-Systolic Murmur (Ejection)



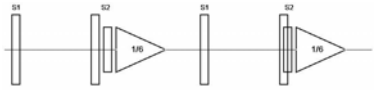
Pan-Systolic Murmur (Regurgitant)

Graphical Representation

- Single diastolic murmur



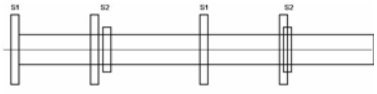
Mid-Diastolic Murmur (rumble)



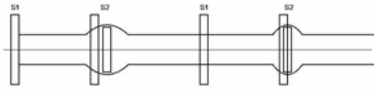
Early Diastolic Murmur (clear)

Graphical Representation

- Continuous murmur



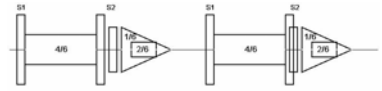
Continuous Murmur



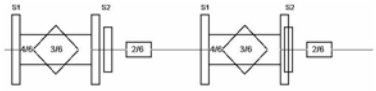
Continuous Murmur, Accentuated at S2

Graphical Representation

- Multiple murmurs



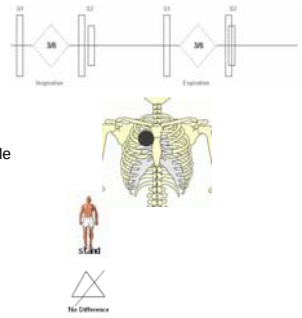
Pan-Systolic Murmur + Early Diastolic Murmur + Mid-Diastolic Murmur



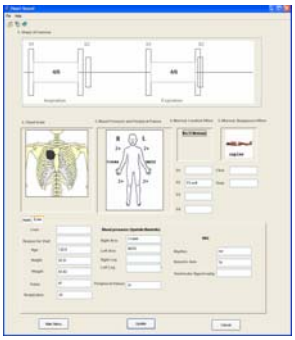
Pan-Systolic Murmur + Mid-Systolic Murmur + Mid-Diastolic Murmur

Case Example

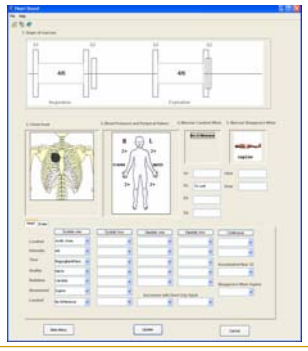
S1:single
S2: split, p2 soft
S3: absent (normal)
S4: absent (normal)
Systolic murmur
location: aortic area
heard best: under right clavicle
loudness: 3
time: ejection
quality: harsh
radiation: no radiation
disappears when: stand
loudest when the patient is: no difference



GUI Application Screenshot 1/2



GUI Application Screenshot 2/2



Development Process

- Development platform: PC windows XP
- IDE: JBuilder, Eclipse
- Java version: 1.5
- Lisp environment: LispWorks personal edition
- Monthly meetings with Dr. Mahnke from TAMC
- Frequent Email with feedback about GUI layout and image representation
- Cooperation with a Java programmer from TAMC who is responsible for PATH

Current Status & Future Work

- Current Status:
  - Handles input of Lisp, XML and data entry
  - Classifies murmurs and creates corresponding images based on input
  - Saves and storages patient data output as XML and JPG
- Future Work
  - Directly include results of PCG signal processing
  - Output EMR (text and images) as PDF printable format
  - Implement print function
  - Integrate into PATH (primarily by the TAMC programmer)

Conclusion

- Requirements achieved
- Enthusiastically response to interface and images by physicians
- To be used by primary care physicians and cardiologists and medical students
- Aim to include in worldwide military EMR format

Application Demo

Questions & Comments