2014

Concept Design Of A Labview-MySQL Data Warehouse For Digital Recording of ECG-EMG

Kristine R. Suratos

Rosula SJ Reyes
Ateneo de Manila University

Custom Citation

Concept Design Of A Labview-MySQL Data Warehouse
For Digital Recording of ECG-EMG

KRISTINE R. SURATOS, ROSULA S.J. REYES
Department of Electronics, Computer and Communications Engineering
Ateneo de Manila University
Katipunan Avenue, Quezon City
PHILIPPINES
krsuratos@gmail.com, rsjreyes@ateneo.edu

Abstract: - To align with the recommendations set forth by the World Health Organization regarding eHealth, this study aims to develop a concept design of a suitable data warehouse for healthcare using electronic medical recording of ECG-EMG. This concept design once implemented aims to assist health care providers in improving patient's healthcare data management.

The system consists of three main layer: data source layer; software application layer; and data service database layer. The data source layer consists of patient profile, patient consultation, and patient test. Patient test was conducted using Olimex ECG-EMG shield and NI myDAQ module. The software application layer, developed using Labview 2012 is the main user interface. It allows users to access and store data into the database. The data service database layer is the main data warehouse, developed using MySQL with stored procedures.

Five male respondents between 22-44 years old have been identified as respondents for the ECG-EMG test. Validation of the ECG test results was done by a licensed physician. After conducting ECG-EMG tests on five respondents and duly validated by a licensed physician, the researchers have proven that this study entitled Concept Design of a Labview-MySQL Data Warehouse for Digital Recording of ECG-EMG can be used for electronic medical recording.

Key-Words: - electrocardiography, ECG, electromyography, EMG, electronic medical record, EMR, Labview, MySQL, database, data warehouse

1 Introduction

Information Technology in general has brought significant changes in our daily lives. For businesses, IT has greatly contributed cost effectiveness by helping businesses in digitizing information about their processes thereby increasing productivity and efficiency of their work force. Through the use of IT, businesses has also gained access to information of existing products and services and through proper analysis it has opened the possiblity of creating new information-based products and services. For communications, IT has helped make communication easier and cheaper. The internet has opened communication from different parts of the world. For education, IT has helped students, teachers and schools in enhancing the effectiveness of learning and teaching by interative learning and by preparing students for the information age. For health care, clinical transformation is supported with technology that provides patient- focused information to physicians and other clinicians. Maintaining fidelity to obtaining information at the point of care or the transaction level also facilitates the provision of relevant data for managing the care process. Quality and patient safety are truly enhanced with a patient-focused approach to information technology management [1].

The World Health Organization defines eHealth as the use of information and communication technologies (ICT) for health. In its broadest sense, eHealth is concerned with improving the flow of information, through electronic means, to support the delivery of health services and the management of health systems. eHealth has been described as a means to ensure that "the right health information is provided to the right person at the right place and time in a secure, electronic form to optimise the quality and efficiency of health care delivery, research, education and knowledge. Towards that end, information exchange such as through electronic health records, patient registries and shared knowledge resources is critical. Information systems

and tools for diagnosis, prevention and treatment support health care at all levels [2].

eHealth can be acheived by the use of EMR or Electronic Medical Record. EMR is an application environment composed of the clinical data repository, clinical decision support, controlled medical vocabulary, order entry, computerized provider order entry,pharmacy,and clinical documentation applications. This environment supports the patients electronic medical record across inpatient and outpatient envorniments, and is used by healthcare practitioners to document, monitor, and manage health care delivery within a care delivery organization (CDO). The data in the EMR is the legal record of what happened to the patient during their encounter at the CDO and is owned by the CDO [3].

Understanding the level of electronic medical record (EMR) capabilities in hospitals is a challenge in the US healthcare IT market today. Thus, HIMSS Analytics has created an EMR Adoption Model that identifies the levels of electronic medical record (EMR) capabilities ranging from limited ancillary department systems through a paperless EMR environment.

US EMR Adoption Model℠	
Stage	**Cumulative Capabilities**
Stage 7	Complete EMR; CCD transactions to share data; Data warehousing; Data continuity with ED, ambulatory, OP
Stage 6	Physician documentation (structured templates), full CDSS (variance & compliance), full R-PACS
Stage 5	Closed loop medication administration
Stage 4	CPOE, Clinical Decision Support (clinical protocols)
Stage 3	Nursing/clinical documentation (flow sheets), CDSS (error checking), PACS available outside Radiology
Stage 2	CDR, Controlled Medical Vocabulary, CDS, may have Document Imaging; HIE capable
Stage 1	Ancillaries - Lab, Rad, Pharmacy - All Installed
Stage 0	All Three Ancillaries Not Installed

Fig.1. United States Electronic Medical Record (EMR) Adoption Model

This study entitled Concept Design of a Labview-MySQL Data Warehouse for Digital Recording of ECG-EMG aims to achieve Stage 1 of the EMR Adoption Model. This study involves the development of an ECG - EMG device to be interfaced in a software application developed in Labview 2012. Data gathered from this device will be stored in a database designed for electronic medical recording. The overall system design

consists of three main layers : Data Source Layer; Software Application Layer; and Data Service Database Layer.

2 System Architecture

Figure 2 below shows the overall system design of the developed ECG-EMG Data Warehouse. The system consists of three main layers : Data Source Layer; Software Application Layer; and Data Service Database Layer.
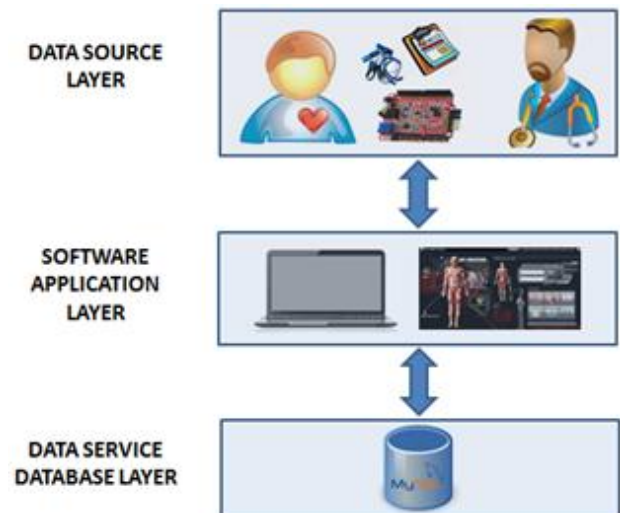

Fig.2. ECG-EMG Data Warehouse Architecture Concept Design

2.1 Data Source Layer - ECG-EMG Hardware Components

2.1.1 Olimex ECG-EMG Shield
The ECG-EMG Shield is an extension module for Arduino compatible boards. The board is powered by the host board it is mounted on. There is the option to be powered either by 3.3V or 5.0V host board. It has input connector for passive or active electrodes. [5]. The Shield is a two-in-one ECG - EMG module that can be interfaced with any microcontroller.
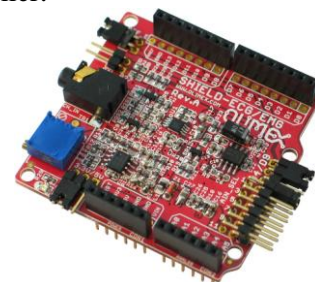

Fig.3. Olimex ECG-EMG Shield

2.1.1 National Instrument's myDAQ

National Instrument's (NI) myDAQ is a low-cost portable data acquisition (DAQ) device that uses NI LabVIEW-based software instruments. NI myDAQ provides analog input (Ai), analog output (Ao), digital input and output (Dio), audio, power supplies, and digital multimeter functions in a compact USB device. The analog input channels can be configured as general-purpose high-impedance differential voltage input or audio input that can measure up to ±10 V signals [6].

Fig.4. National Intrument's myDAQ Module

2.2 Software Application Layer

National Instrument's LabVIEW is a graphical dataflow language in which nodes (operations or functions) operate on data as soon as it becomes available, rather than in the sequential line-by-line manner that most programming languages employ. The flow of data is layed out through the application graphically with wires connecting the output of one node to the input of another. LabVIEW tailors the G programming language to engineering and scientific use by incorporating hundreds of specialized functions and algorithms that are not typically included with general-purpose programming languages [7].

Fig.5. ECG-EMG System Main Interface

The developed ECG-EMG System contains the following features:

- User Login
- Staff Profile Enrollment
- Patient Profile Enrollment
- ECG System
- EMG System
- Generic Tab System

2.2.1 User Login

The software application provides access restriction. Only enrolled users tagged as "Staff" can access the user application. There is a validation thru a username and password combination checking of inputted values against the credentials saved in the database.

2.2.2 Staff Profile Enrollment

This page is where the Staff is enrolled in the database. Staff can either be an administrator, a technician or a doctor. For this study, the main researcher were tagged as an administrator that has full access on the system.
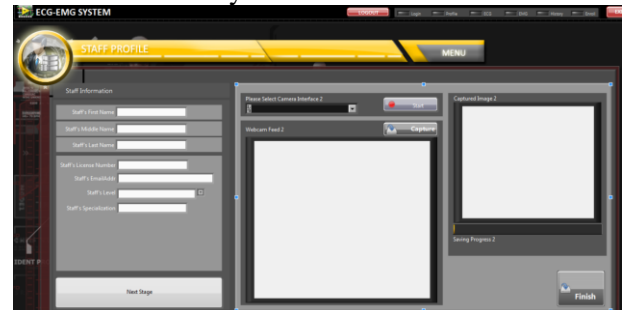

Fig.6. Staff Profile Page with Picture

2.2.3 Patient Profile Enrollment

The Patient Profile Enrollment page is where the Patient is enrolled in the database. A staff can enroll the patient's profile such as personal information, contact information, personal medical history and family medical history.
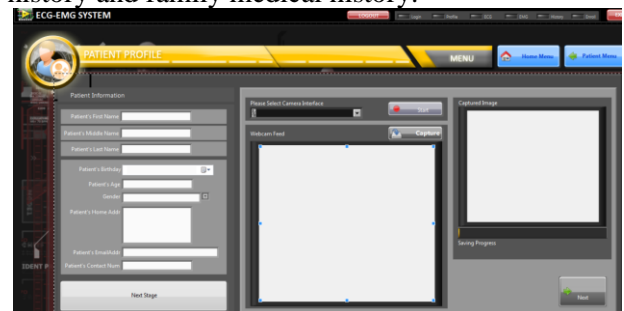

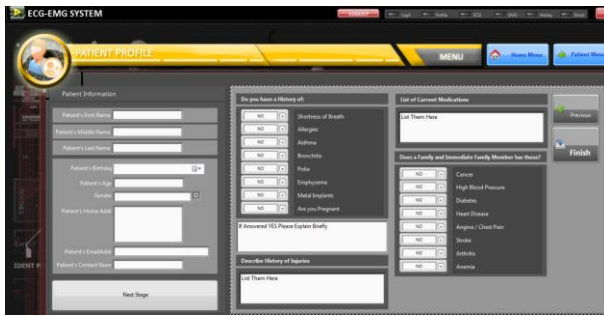Fig.7. Patient Profile Page with Picture

Fig.8. Patient Profile Page with Medical History

2.2.4 ECG System

The ECG System has two main options: New and History. New is for conducting new consultation or new test, History is for viewing previous records.
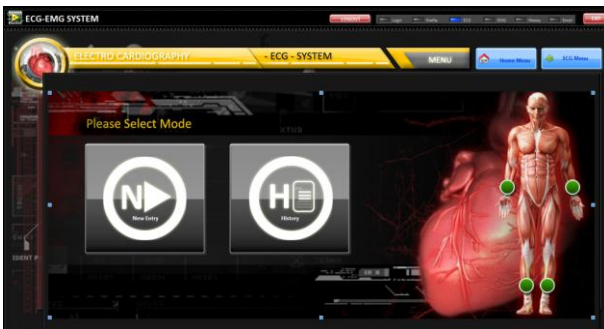

Fig.9. ECG System Main Page

Selecting the New option will proceed to the selection of patient. After selecting a patient, the user will select either a Consultation or a Test.

Consultation page is used during patient's visits to the physisician. Height, Weight and Vital Signs such as: Temperature; Blood Pressure; Pulse Rate; and Respiratory Rate, are to be inputted for every consultation. Textual information about the patient's chief complaint, experience, medication and the staff's analysis about the patient's condition are also to be inputted in this page. Data are saved in the database upon clicking the Saved Consultation button.
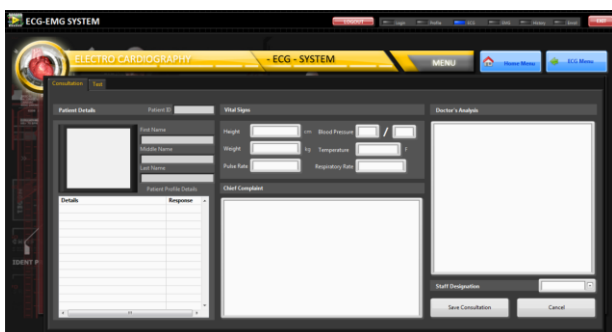

Fig.10. ECG Consultation Page

Test page is for data acquisition of ECG. For this study, the Eithoven's limb lead ECG was used therefore three tests must be conducted to complete the ECG.
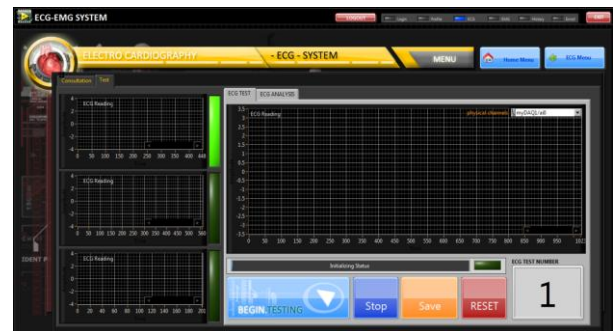

Fig.11. ECG Test Page

After completing the ECG, a staff can provide his analysis about the patient's test results. The staff should also input the five major ECG paramaters namely: Heart Rate; PR Interval; QRS Interval; QT Interval; and QTc Interval. These parameters can be used on the search by values function.

History page is for viewing the patient's records on consultation, test, and analysis. Searching for records can be done easily by using pre-defined filters namely:
- Search By Patient
- Search By Keyword
- Search By Heart Rate (greater than or between values)
- Search By PR Interval (greater than or between values)
- Search By QRS Interval (greater than or between values)
- Search By QT Interval (greater than or between values)
- Search By QTc Interval (greater than or between values)

A staff can also input additional analysis on a consultation record or test record in this page.

2.2.5 EMG System

The EMG System has two main options: New and History. New is for conducting new consultation or new test, History is for viewing previous records.

Selecting the New option will proceed to the selection of patient. After selecting a patient, the user will select either a Consultation or a Test.

Consultation page is used during patient's visits to the physisician. Height, Weight and Vital Signs such as: Temperature; Blood Pressure; Pulse Rate; and Respiratory Rate, are to be inputted for

every consultation. Textual information about the patient's chief complaint, experience, medication and the staff's analysis about the patient's condition are also to be inputted in this page. Data are saved in the database upon clicking the Saved Consultation button.

Test page is for data acquisition of EMG. For this study, the biceps branchii was investigated with five defined positions namely:

- Test 1 – 0° Angle (at rest)
- Test 2 – 30° Angle Flex
- Test 3 – 60° Angle Flex
- Test 4 – 90° Angle Flex
- Test 5 – 120° Angle Flex (maximum)

These five tests must be conducted to complete an EMG. After completing the EMG, a staff can provide his analysis about the patient's test results.

History page is for viewing the patient's records on consultation, test, and analysis. Searching for records can be done easily by using pre-defined filters namely:

- Search By Patient
- Search By Keyword

A staff can also input additional analysis on a consultation record or test record in this page.

2.2.6 Generic Tab

The Generic Tab is the same as the EMG System. Generic Tab is a provision for additional Consultation or Test other than ECG and EMG that the user may want to conduct.

2.3. Data Service Database Layer - Relational Database Components

A relational database is a structured collection of data. It stores data in separate tables rather than putting all the data in one big storeroom [8]. Common usage of the term "Relational Database Management System" (RDBMS) technically refers to the software used to create a relational database [9]. For this developed system, MySQL was used for the RDBMS.

2.3.1 MySQL Version 5.5.24

MySQL is an open source, SQL relational database management system. [10]. The MySQL Database Software is developed, distributed, and supported by Oracle Corporation [8].

2.3.2 Structured Query Language

Structured Query Language (SQL) is the language used for the developed system to access, insert, update data on the database.

SQL is a set of character string commands that is a widely supported standard for database access. SQL statements allow user to use a common set of commands to access different databases [11].

2.3.2 Stored Procedure

A database can be accessed by using direct SQL query on the application side or by using parametized SQL query thru stored procedures.

A stored procedure is like subprogram in a regular computing language that is stored in the database [12].

```
▼ 🗐 Tables
    ▶ 🏿 ecg_consultation_analysis
    ▶ 🏿 ecg_consultation_record
    ▶ 🏿 ecg_consultation_staffrecord
    ▶ 🏿 ecg_test_analysis
    ▶ 🏿 ecg_test_record
    ▶ 🏿 ecg_test_staffrecord
    ▶ 🏿 emg_consultation_analysis
    ▶ 🏿 emg_consultation_record
    ▶ 🏿 emg_consultation_staffrecord
    ▶ 🏿 emg_test_analysis
    ▶ 🏿 emg_test_record
    ▶ 🏿 emg_test_staffrecord
    ▶ 🏿 generic_consultation_analysis
    ▶ 🏿 generic_consultation_record
    ▶ 🏿 generic_consultation_staffrecord
    ▶ 🏿 generic_test_analysis
    ▶ 🏿 generic_test_record
    ▶ 🏿 generic_test_staffrecord
    ▶ 🏿 patient_family_history
    ▶ 🏿 patient_medical_history
    ▶ 🏿 patient_profile
    ▶ 🏿 patient_profile_history
    ▶ 🏿 patient_profile_login
    ▶ 🏿 staff_level
    ▶ 🏿 staff_profile
    ▶ 🏿 staff_profile_history
    ▶ 🏿 staff_profile_login
    ▶ 🏿 staff_specialization
```
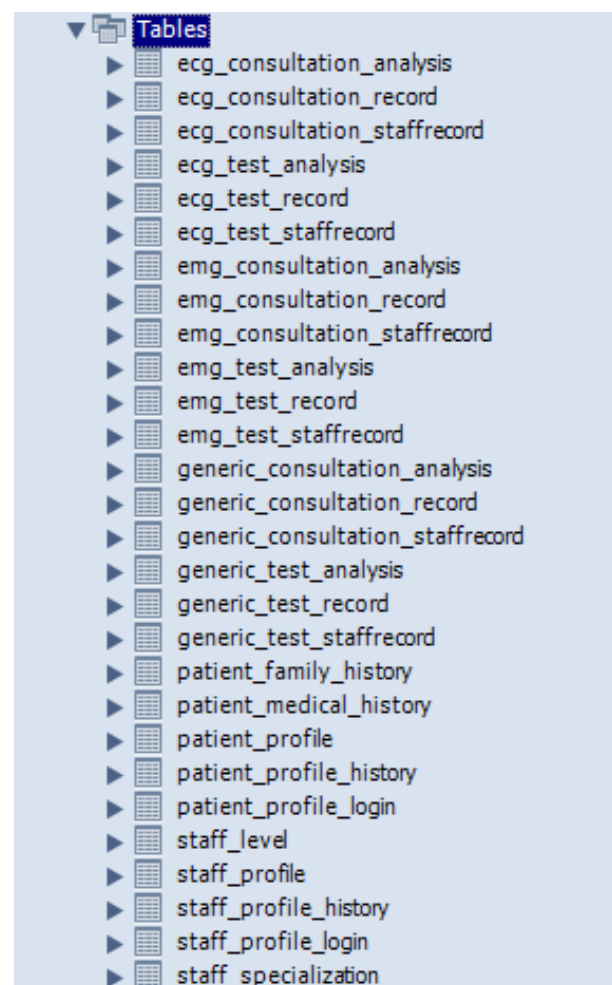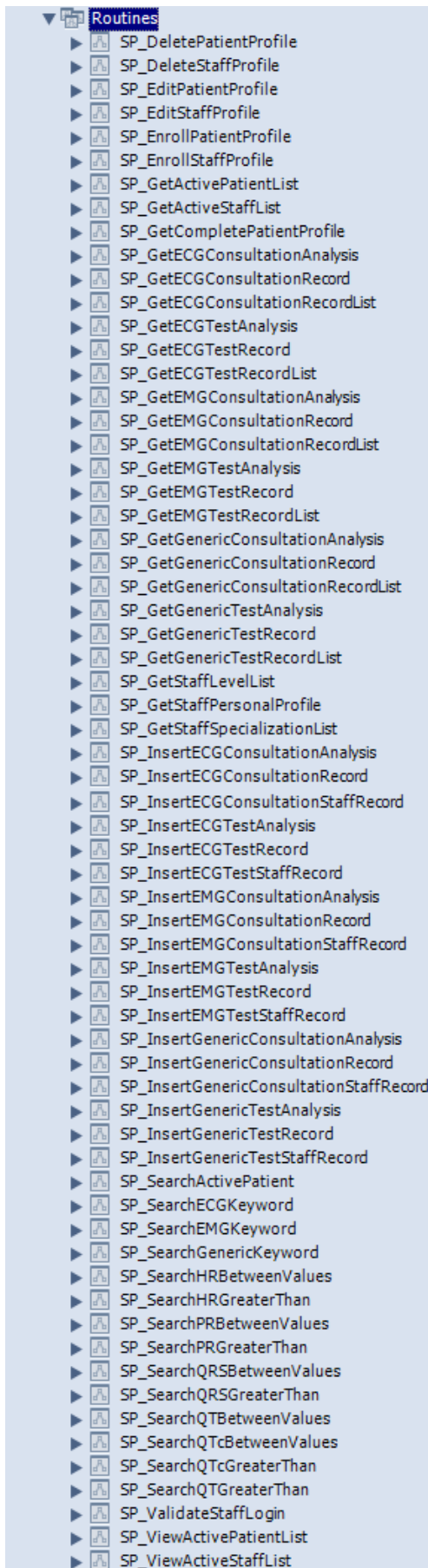
Fig.12. Database Tables

Fig.13. Database Stored Procedures

3 Data Gathering and Results

3.1. Equipment Set-up

The equipment used for the data gathering is the ECG-EMG device and a laptop installed with the software application and emgecgDB database. Figure 25 below shows the pre-gelled Silver/ Silver Chloride electrodes, the wire straps, Olimex ECG-EMG Shield and a NI myDAQ for the data acquition.

Figure 14 below, shows the block diagram of the connection of the hardware components. Silver/ Silver Chloride electrodes connected to the respondents were used for ECG and EMG tests. The electrodes were connected to the wirestrap cables. The wirestrap has three cables labeled as positive lead (+), negative lead (-) and a ground lead. The other end of the wirestrap is a stereo male connector connected to the stereo phone jack of the ECG-EMG shield. This is the channel for the input signal from the electrodes to the ECG-EMG shield. The output channel of the ECG-EMG shield is the A0 (analog channel 0). The NI myDAQ analog input Ai0+ is connected to the A0 of the shield, this is the channel for the data acquisition. NI myDAQ analog input Ai0- is then connected to the gnd of the ECG-EMG shield for common ground reference. NI myDAQ is powered via USB. This USB connection is also used to transmit the data to the laptop computer. Aside from data acquisition, the NI myDAQ was also configured to run as an oscilloscope for data validation before each actual test was conducted.
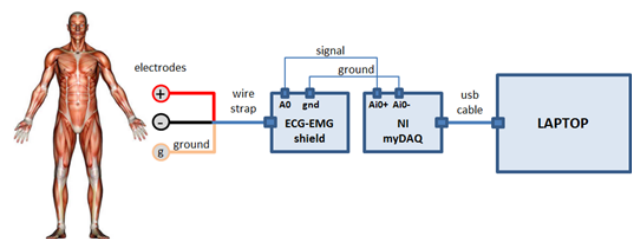

Fig.14. ECG-EMG Setup Block Diagram

Fig.15. ECG-EMG Actual Set-up

3.2 Respondent's Information

Table 1. Respondents' Information

Number of Respondents	5
Gender	Male
Age Group	22- 44 years old
Body Built and Condition	Normal

Each respondent was enrolled in the System using the Patient Profile Page. Personal information such as complete name, birthday, contact information, medical history and family history were all recorded.

Table 2. Respondents' Medical Profile

Respondent	1	2	3	4	5
Age	44	22	23	27	25
Height	172.72	182.88	177.8	167.64	167.64
Weight	77.27	85	84.1	69.1	88.64
Family History					
Cancer	Yes				Yes
High Blood Pressure			Yes	Yes	Yes
Diabetes	Yes		Yes	Yes	Yes
Heart Disease					Yes
Angina/Chest Pain	Yes				
Stroke	Yes				
Arthritis	Yes	Yes			
Anemia	Yes				
Personnal Medical History					
Cancer					
High Blood Pressure	Yes			Yes	
Diabetes					
Heart Disease					
Angina/Chest Pain	Yes				
Stroke					
Arthritis	Yes				
Anemia					
Shortness of Breath	Yes				
Allergies			Yes		
Asthma					
Bronchitis	Yes				
Polio					
Emphysema					
Metal Implants					
Pregnant					
Surgery				Yes	
Nausea/Vomiting	Yes				
Fever/Chills/Sweats	Yes	Yes			
Unexplained Weight Change					
Numbness or Tingling	Yes				
Muscular Weakness	Yes				
Fainting Spells					
Dizziness		Yes			
Night Pain	Yes				
Bowel or Bladder Changes					
Headaches	Yes	Yes			

Each respondent was asked about their recent medical conditions, experiences and injuries. All data were recorded using the ECG or EMG Consultation Page.

Table 3. Respondents' Consultation Profile

Respondent 1

Surgery	
Nausea/Vomiting	Went with acidity and lbm, two months ago
Fever/Chills/Sweats	Went with acidity and lbm, two months ago
Unexplained Weight Change	
Numbness or Tingling	Numbness on the left little finger up to the shoulder, occasional
Muscular Weakness	From time to time, felt on the biceps and pectorals
Fainting Spells	
Dizziness	
Night Pain	At the lower left of the back
Bowel or Bladder Changes	
Headaches	Occasional, mostly migraine
Describe any history of injury:	Rightward deviation of the thoracic spine - dextroscoliosis
List current medications:	Essentialle, Re-leaf

Respondent 2

Surgery	
Nausea/Vomiting	
Fever/Chills/Sweats	
Unexplained Weight Change	
Numbness or Tingling	
Muscular Weakness	
Fainting Spells	
Dizziness	
Night Pain	
Bowel or Bladder Changes	
Headaches	
Describe any history of injury:	
List current medications:	

Respondent 3

Surgery	
Nausea/Vomiting	
Fever/Chills/Sweats	High Fever (over fatigue), 8/1/2013
Unexplained Weight Change	
Numbness or Tingling	
Muscular Weakness	
Fainting Spells	
Dizziness	During sudden movements ex. standing 9/30/2013
Night Pain	
Bowel or Bladder Changes	
Headaches	Almost often during work hours
Describe any history of injury:	Left Foot Bone Fracture, June 2013
List current medications:	Sore Eyes (Conjunctivitis), October 2013; Dengue, May 2012

Respondent 4

Surgery	
Nausea/Vomiting	
Fever/Chills/Sweats	
Unexplained Weight Change	
Numbness or Tingling	
Muscular Weakness	
Fainting Spells	
Dizziness	
Night Pain	
Bowel or Bladder Changes	
Headaches	Due to migraine or lack of sleep, 09/01/13
Describe any history of injury:	
List current medications:	

Respondent 5

Surgery	Removed wisdom teeth
Nausea/Vomiting	
Fever/Chills/Sweats	
Unexplained Weight Change	
Numbness or Tingling	
Muscular Weakness	
Fainting Spells	
Dizziness	
Night Pain	
Bowel or Bladder Changes	
Headaches	Due to migraine or lack of sleep, 09/01/13
Describe any history of injury:	Left ankle sprain Dec 2010 and September 2013
List current medications:	

3.3 ECG Test

For ECG, four electrodes were used. One electrode on the anterior part of the left wrist, one electrode on the anterior part of the right wrist, one electrode on the medial aspect of the left leg, one electrode on the medial aspect of right leg. The placement of the two wirestrap (positive and negative lead) on the

first three electrodes depends on Eithoven's Limb Lead position combinations to complete Lead I, Lead II, Lead III Tests. The right leg electrode is always connected to the ground.
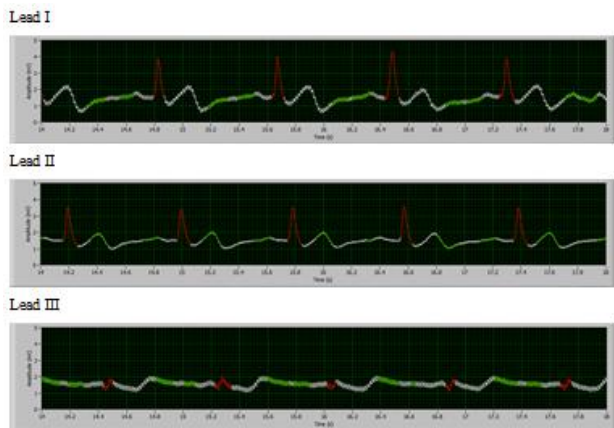

Fig. 16. Respondent #5 ECG Test Result

Table 4. Respondent #5 ECG Test Reading

	Physician's Reading	Normal Range
Heart Rate (beats per minute)	94	60 - 99
PR Interval (sec)	0.12	0.12 – 0.2
QRS Interval (sec)	0.08	0.08 – 0.12
QT Interval (sec)	0.28	< 0.44
QTc (sec)	0.35	

To assess the cardiac rhythm accurately, a prolonged recording from one lead is used to provide a rhythm strip. Lead II, gives a good view of the P wave and is most commonly used to record the rhythm strip [13]. Thus, in this study, the licensed physician read the Lead II waveforms. These analyses were shown after each respondent's test results.

Through visual inspection, an ECG signal can be validated. Normal ECG signals have these characterictics: [13]
• The P wave is upright in leads I and II
• Each P wave is usually followed by a QRS complex
• Tall R waves
• T wave should generally be at least 1/8 but less than 2/3 of the amplitude of the corresponding R wave
• QT Interval should not be more than half of the interval between adjacent R waves

ECG Lead II test results of the five respondents all showed these characteristics. It was also observed that signals are noisy when the skin's contact to ground is not good. Therefore, the main researcher saw to it that the gound electrode is in proper contact with the respondent's skin.
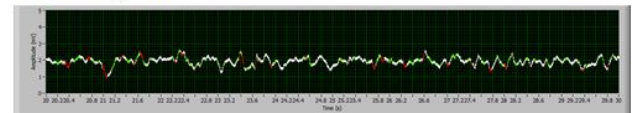
3.4 EMG Test

For EMG, three electrodes were used. Two electrodes were placed on the biceps branchii and one electrode is connected in the posterior part of the wrist. The first two electrodes were connected to the positive and negative lead of the wirestrap, the one on the wrist is connected to the ground wirestrap.
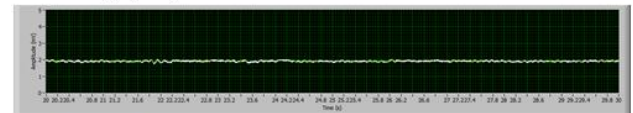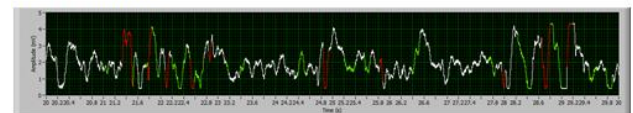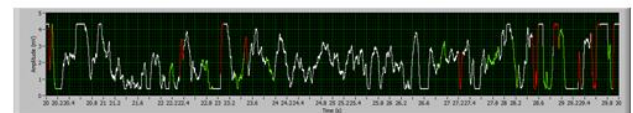

Fig. 17. Respondent #5 EMG Test Result

The amplitude of the EMG signals are dependent on the following factors: [14]
• The intensity of the muscle contraction
• The distance of the electrode from the active muscle area
• The quality of contact between the electrodes and the skin

These were evident in the EMG test results of the five respondents. The signal from each respondent at Test 1 – 0° Angle (at rest) all showed the expected baseline signal which is almost flat. The remaining tests, Test 2 to Test 5 shows varrying waveforms since these waveforms depend on each respondent's ability to contract their biceps. It was also observed that signals are noisy when the skin's contact to ground is not good. Therefore, in the next tests, the main researcher saw to it that the gound electrode is in proper contact with the respondent's skin.

4 Conclusion

The main researcher had undergone patient profiling and EMG test at the University of Santo Tomas Hospital before doing this study to get familiarized with the EMG procedure and results. Thus, the researchers firmly believes that this design could be possibly validated against the IEC60101-1 Standard [15]. The IEC60101-1 standard specifies tests and requirements that medical devices must pass before they can be used on humans. After such validation, this ECG-EMG Data Warehouse Concept Design could be further implemented by different agencies for medical informatics. It is also recommended that further development must be done based on the stages specified in US ERM Adoption Model.

This concept design can provide right health information to patients at the right place and time in a secure, electronic form which optimizes quality and efficiency of health care delivery.

The researchers firmly believes that this Concept Design of a Labview-MySQL Data Warehouse for Digital Recording of ECG-EMG can be used for electronic medical record

References:

[1]   Fickenscher, K., *The Value of Clinical Transformation,* Dell Services Dell Inc., 2010.

[2]   *National eHealth Strategy Toolkit* http://www.itu.int/dms_pub/itu-d/opb/str/D-STR-E_HEALTH.05-2012-PDF-E.pdf, 2012.

[3]   Garets, D., Davise, M., Electronic Medical Records vs. Electronic Health Records:Yes, There I s a Difference. *HIMSS Analytics*, Chicago, IL 60611-3270, 2006.

[4]   *U.S. EMR Adoption Model Trends.* www.himssanalytics.org. 2011

[5]   *Shield-EKG-EMG Bio-feedback Shied User's Manual.*Olimex Ltd. https://www.olimex.com/. Revision D, 2013.

[6]   *NI myDAQ User Guide and Specifications,* http://www.ni.com/pdf/manual/373060e.pdf ,2010

[7]   *What Is LabVIEW?,* http://zone.ni.com/devzone/cda/pub/p/id/1141.

[8]   *Overview of the MySQL Database Management System.,*http://dev.mysql.com/doc/refman/5.5/en/what-is.html.

[9]   Davis, M., Philips, J., *Learning PHP and MySQL*. O'Reilly Media, Inc. 2006

[10]   Suehring, S., Converse, T., Park, J. *PHP6 andMySQL Bible*.Wiley Publishing, Inc., Indianapolis, Indiana. 2009.

[11]   *LabVIEW Database Connectivity Toolkit*. http://www.ni.com/pdf/labview/us/database_connectivity_toolkit.pdf.

[12]   Gulutzan, P., *MySQL Stored Procedures.* http://cis.csuohio.edu/~paul/331mysql-stored-procedures.pdf. 2006.

[13]   Morris, F., Edhouse, J., Brady, W., Cman, J. *ABC of Clinical Electrocardiography*. BMJ Books, BMA House, Tavistock Square, London, 2003.

[14]   Day, S., *Important Factors in Surface EMG Measurement*, Bortec Biomedical Ltd. www.bortec.ca.

[15]   *International IEC 60601-1* Third Edition 2005-12,International Electrotechnical Commission, Geneva, Switzerland, 2005.