<u>Original Paper</u>

An ECG Data Management and Processing System for Teaching and Research

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Abstract

Background: There is a need for integrating Information technology into the realm of medical care. As noted by Ball [1], "Building a new Health System for the 21st century … requires that we use Information Technology2. The American Institute of Medicine is quoted as saying [1,2] "that the Internet will be the choice for many, if not most health applications". The use of health informatics with patient care is an area that is well explored with health care Information Technology systems researched and deployed in a number of countries [3-5]. These systems address the need for the patient care but information Technology can also form a useful and integral part of research and training for healthcare professionals.

Objectives: This paper describes the database design of a medical information system for Electrocardiogram signals for teaching and research.

Methods: This system uses the "access" and "excel" components of the Microsoft Office suite [6] since this software is ubiquitous, easy to program, contains many powerful methods and has a user-friendly interface which is familiar to most computer users. Excel is used to hold the ECG data and the database is used to hold the records for each patient and point to the particular ECG spreadsheet file for that patient. The program has been developed employing a modular design to allow extended functionality to be easily added through "plug-ins". The "plug-ins" interface to the system through buttons in the forms of the access database. The functionality for the buttons is then added using VBA code. This means that that new algorithm and visualization techniques can be easily added.

Results: Excel spreadsheets with 12 lead data for normal and abnormal ECGs were used in the testing of the system. A plug-in for ECG display was also used which allowed for a comparison between the normal and abnormal ECG. It is envisaged that biomedical students and researchers will use this system both as a trainer as well as a testing ground for new data processing algorithms.

Conclusions: Overall this program will be a useful tool for teaching and act as an engine to allow researchers to explore new visualization and analysis techniques for the ECG.

KEYWORDS

Electrocardiogram; Database; Information Processing; Medical Informatics

Introduction

There is a need for integrating Information technology into the realm of medical care. As noted by Ball [1], "Building a new Health System for the 21st century … requires that we use Information Technology". The American Institute of Medicine is quoted as saying [1,2] "that the Internet will be the choice for many, if not most health applications". The use of health informatics in patient care is an area that is well explored with health care Information Technology systems researched and deployed in a number of countries [3-5]. However, Information Technology can also form a useful part of training for healthcare professionals [7,8] and a useful tool for researchers.

The students require a system that is able to easily retrieve data and display the data to them in a meaningful way. This may simply just be the graphing of the data as a visualization method or the application of some more advanced data manipulation algorithm before it is presented to the student. The researcher has a similar need. The researcher needs a simple engine for the storage and retrieval of ECG data which allows the researcher to apply new analysis and visualization techniques. This means that for both the teacher and researcher there has to be an easy and yet powerful way to interface or hook into the system. Therefore they both need an easily adapted Data Management and Processing system. This paper will discuss the philosophy, the design, and the use of an ECG data management and processing system.

Methods

System Design Philosophy

The core philosophy that underpins the design of the system is that the system must be easy to use, modify and adapt. Therefore we have chosen to use the Microsoft Office suite [6] range of products. Using the Microsoft products has a number of advantages:

1. *Commonly used software*. Microsoft Office is one of the most common pieces of software available today. It can be found on most computers that run or use the Microsoft Operating System [9].
2. *User familiarity*. Most users are familiar with the look and feel of the environment. Since users are familiar with the operating environment then it means that the learning curve for use of any program is reduced.
3. *Powerful applications*. The Office suite contains a lot of powerful applications. It has database applications which are useful for data storage and retrieval, spreadsheet applications which are useful for data manipulation and mathematical analysis, and charting applications which are useful for visualization of data.

4. *Programmability*. Each of these applications are programmable which allows them to easily adapted to the program requirements. Also there is a common scripting language (VBA) for automation which is used between all the applications. This allows the applications to send and retrieve information to each other and to use the functions/methods available in another application. For example the Access database can call and use the formula and data manipulation methods that are contained in Excel.
5. *Interoperability of applications and OS*. The applications are designed to interact with each other because they belong to the same suite of software. This means that one application can inherent features of other applications and pass data to other applications. Since it operates in a Microsoft OS environment then it can take advantage of the interoperability of the features inherent in the operating system. Also this allows these applications to be used in web server applications.

In order to make the software easy to modify and adapt, it was created using a modular design techniques. One of the key features of the architecture is that allows extra functionality (plug-ins) to be added easily.

System Architecture

The system architecture can be seen in figure 1. The ECG data collection is performed by the clinician and the data is stored in an Excel spreadsheet. An Access database is used as the database engine. The records in the database have links to the Excel spreadsheet containing the ECG data. When the ECG data is required then the Access database accesses the spreadsheet sheet and obtains the data. Therefore the database does not have to store the ECG data. This not only saves space in the database but it allows for much faster searching of the database. A further advantage of this method is that it allows separate storage of the ECG data allowing other software to have access to the data.

Figure . The system architecture

Spreadsheet Design

The spreadsheet program used is Excel. The ECG is collected and imported into the Excel spreadsheet. The data used is a plain text file which makes it compatible with most ECG data collection equipment. Excel consists of worksheets which are used to logically group the data. Each excel worksheet contains multiple columns which contains the data.

It is envisaged that there will be multiple patients with multiple ECGs grouped into different dates. Therefore there will be a different spreadsheet for each patient who will be identified by using a unique patient identification number and a different worksheet for each ECG measurement which will be identified by the date of collection of the ECG. The ECG data will consist

of a number of leads. The data obtained for each lead is represented by a column in the worksheet.

Database Design

The database program used is Access. Each record in the database contains the patient details including the Name, Age, Gender, Date of Birth etc and a primary key consisting of the patient ID. There is also a field to hold the dates that the ECGs were taken. These fields are used to access the ECG data in the data object through automation.

The GUI to the database is based around forms. There is a form to allow the user to search and select a particular patient. Once that patient is selected then the user is presented with the "ECG-data VIEW" form as shown in figure 2. From this form

it is possible to select the date for the ECG and the particular ECG lead. The button labeled "Show" is used to access the plug-in feature. In this case it is used to graph the ECG data. The arrow buttons allow the user to step through the records.

Figure . The design of the "ECG Data View" form showing the fields and the plug-in interface
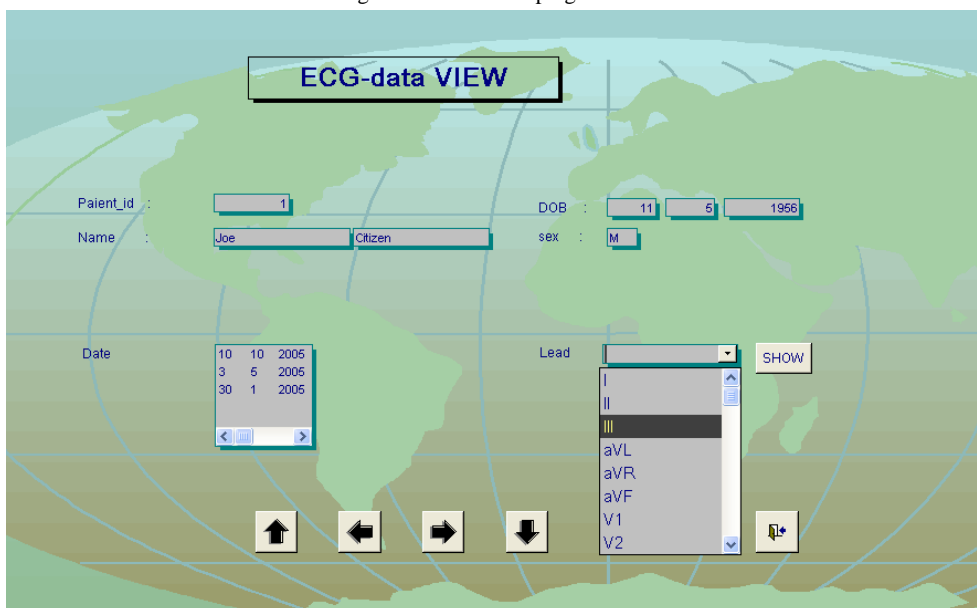
Plug-in Design

The system was designed in a modular fashion to allow for the addition of "plug-ins". The plug-in is a separate module that can be called upon to perform an action on the ECG data selected in the "ECG data view" page. The link to the module is through the button widget and the "on-click" event. The button is added to the form when creating the form in Access.

The programming of the module is done using VBA code. This is a very powerful environment because it gives the programmer access to automation. The automation allows the programmer to access all the methods inherent in the OS or other Microsoft Applications. This allows the programmer to manipulate the data in an environment more powerful than Access. For example Excel has a very powerful suite of functions which are not available in Access. However automation allows these functions to be applied to the data through the use of the Excel object and its inherent methods.

It is envisioned that many plug-ins will be added to the form by the teacher to illustrate a particular concept or by a researcher who is testing various analysis algorithms.

Results

Two Excel spreadsheets with 12 lead data for normal and abnormal pathologies were used in the testing of the system. A plug-in for the ECG display using the Excel graphing object was also used. Figure 3 is a screen shot showing the use of the "charting" plug-in. It shows the two windows created containing the graphs for the normal and abnormal ECG. As can be see the program allows for clear viewing and discrimination between the healthy and the unhealthy ECG. In a teaching situation it is envisaged that the student is presented with a range of pathologies and analysis tools.

Figure . A screen shot showing the use of a "charting" plug-in
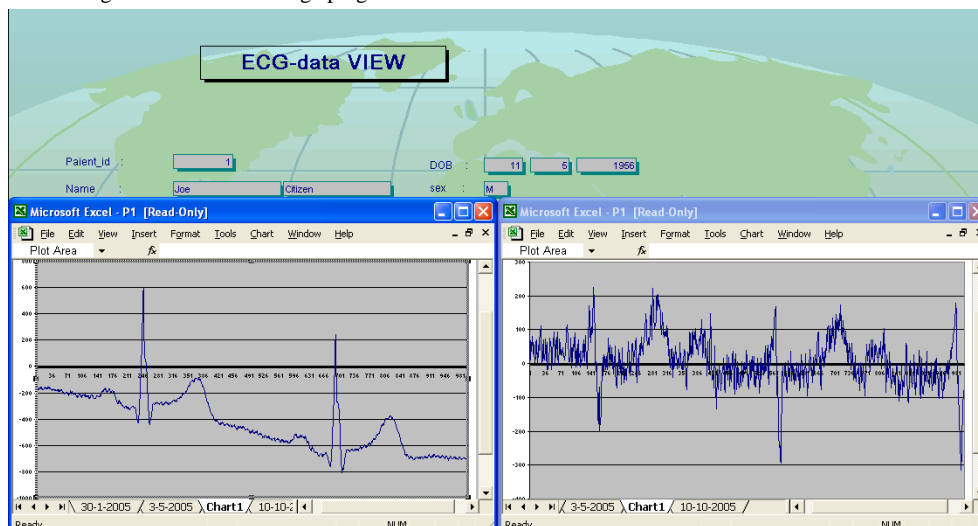
Discussion

The ECG data management and processing system is the initial step in a larger project. It is envisaged that this work will be ported to a web server using the .NET framework to allow distributed access especially in the teaching situation. Further work also involves the development of new and novel ECG visualization and analysis tools.

Overall this program will be a useful tool for teaching and act as an engine to allow researchers to explore new visualization and analysis techniques for the ECG.

Conflicts of Interest

None declared

References

1. Ball MJ, Hospital information systems: perspectives on problems and prospects, 1979 and 2002, International Journal of Medical Informatics, 2003.
2. C. o. Q. H. C. i. America, Crossing the Quality Chasm: A New Health System for the 21st Century. Washington DC: National Academy Press, 2001.
3. Anderson JG, Evaluation in health informatics: computer simulation, Computers in Biology and Medicine, 2002;32:151-164
4. Marsh A., The creation of a 21st century telemedical information society, Future Generation Computer Systems,1998;14:3-22
5. James DA, Rowlands D, Mahnovetski R, Channells J, Cutmore T, Internet based ECG medical information system, Australas. Phys. Eng. Sci. Med., March 2003;26(1):110 - 114
6. Microsoft. Microsoft Office [computer software]. Version 2003. URL: http://office.microsoft.com/en-us/default.aspx [accessed 2006 Jun 29]
7. González C , Burguillo JC , Llamas M. ,Vidal, JC, López, DM , Web-Based Intelligent Medical Tutoring Systems, 10th World Congress Internet in Medicine, December 2005:464
8. Feberová J, Kasal P, Mazánek J, et al, Distance Learning Course in Open Source Software, 10th World Congress Internet in Medicine, December 2005:461
9. Microsoft. Microsoft Windows [computer software]. Version XP. URL: http://www.microsoft.com/windows/default.mspx [accessed 2006 Jun 29]