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Design of Multi-sensored Cardiac Decision System to Aid Telemedicine

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Abstract: This study demonstrates a method of acquiring ECG multi lead waveform recognition along heart rate, blood pressure data of the patient and comparing these inputs in an artificially intelligent decision support system to perform cardiac diagnosis. This interpretation can be transmitted over the network to obtain expert analysis of the doctor. The study aims to introducing a technique of waveform recognition for the 12-lead ECG interpretation.By comparing the waveforms of the selected lead of the ECG -under diagnosis with the same leads of different ECG's from the database, similarity of compared ECG beats is calculated using correlation function. This novel technique makes it possible to obtain the diagnosis for the unknown ECG from a comparison between the signal waveforms of this ECG with unknown diagnosis and an ECG of known diagnosis stored in the database, thus allowing automatic decision making. At the same time the blood pressure and heart rate values are compared with the normal values to interpret them as either normal or abnormal. Hence, by acquiring patient's cardiac data through multiple sensors, like ECG,Heart-Rate and Blood-Pressure sensors and comparing these values from the corresponding values in the artificially intelligent decision support system maintained at the patient side, cardiac diagnosis is done. With the help of networking technology, the diagnosis so made can be sent to a remote doctor at a telemedicine centre for his expert opinion. The possible diagnostic statement along with the future course of action may then be apprised to a nurse available at the patient site for effective co-ordination of a cardiac unit. This requires the use of a database that is sufficiently representative, annotated and clinically validated. In the above developed decision support system the database acts like a knowledge base. This ensures that the system is volatile since knowledge can be added or deleted from the database easily. This saves both the time and money of the patient concerned and also enables the patient to receive immediate emergency treatment if, any needed.

Key words: Multi-sensored, cardiac decision, ECG, diagnosis

INTRODUCTION

Patient monitoring, which involves a continuous surveillance over the vigil characteristics and parameters of the critically ill, has been one rapidly increasing familiarized under the area of biomedical instrumentation. By frequent monitoring, the imbalance in the body systems can be detected as they occur and appropriate remedies can be taken before these problems go out of hand. Patient-monitoring units in hospitals form a substantial part of the workload of the biomedical engineer or technician.

Telemedicine: Telemedicine is the investigation, monitoring and management of patients and the education of patients and medical staff, which allow easy access to expert advice and patient information, no matter where the patient or relevant information is located.

E-mail and internet access for regional and rural medical centers and hospitals could be extremely useful. The benefits from connecting as many hospitals and medical centers as possible to so called medical information system would be:

- Improved standard of medical practice;
- Improved epidemiological and other reporting;
- Educational benefits for doctors and medical staff outside the capital, continuous medical education.

The main goal is to prepare a model of self-sustaining telemedicine communication systems that would operate without further outside financial support. The utilization of telemedicine networks only for clinical application may not be sufficient to sustain a system. The idea is to offer several interactive tele service applications for different user groups in order to make a self-sustainable business plan by sharing telecommunication facilities between profitable and unprofitable applications in one business package.

Therefore, this task could only be done by the telecommunication partners of these telemedicine projects and it will be a key factor for the future extension of telemedicine services. Successful introduction of telemedicine services requires more than just the delivery of the right equipment to the users.Telemedicine can help to develop new ways to deliver medical and health education to professionals and to the community and

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improve the continuing medical education. Increased use of virtual reality and simulators, instead of training by experience on living objects, should become mandatory.

JUSTIFICATION OF NEED PHASE

Motivation for the proposed system: Kandu *et al*[1] proposed a rule-based system is proposed for the interpretation of the ECG patterns. It lacks the versatility of managing a wide range of variations in the input patterns. This approach requires that all the features be exactly matched for the rule base to fire. As a result, whenever the need arises for analyzing an ECG pattern the features of which differ slightly from those specified in the rule base, the rule base seems to be incomplete and inexact. In this case, diagnosis is made incorrectly which demerits the system.

The performances of classifier systems as underlined by Chazal and Reilly[2] are degraded when one or more of the features are redundant or irrelevant. During feature selection finding an optimal subset is computationally intractable. This is because the number of possible subsets rises exponentially with the size of the feature set.

The use of Syntactic approach in the diagnosis of ECG patterns as proposed by Panagiotis[3] produces inferior results when compared to that produced by non-syntactic approach. The use of primitive pattern extractor in this approach produces certain boundary errors that alleviate to the various stages of the algorithm. Also, the noisy peaks are not recognized by this procedure.

When a neural network is being trained to analyse the ECG data as proposed by the paper, neural and traditional techniques in diagnostic ECG classification, human bias will be introduced into the system. As regards these systems, when the complexity of the data is increased, the complexity of the individual neural network is also increased. This approach facilitates that only certain feature vectors can be selected for each neural network. This simulates that the generality of the system is lost.

Merits of the proposed system: This study employs no feature extraction technique for the analysis of the ECG thereby making the procedure simpler and adaptable for slight variations in the patterns. Further more the procedure dictates no limitations for the diagnostic statement allowing for identifiers like more or less and very. This study also facilitates the inclusion of rare diseases which cannot be provided by the earlier systems.

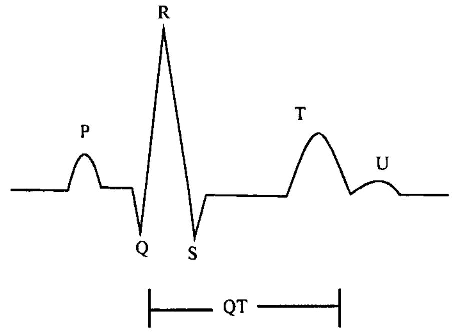

Fig. 1: depicts a normal ECG waveform

ECG segment	Normal range
P wave	Less then 0.12,
PR	0.12-0.22,
QRS	Less then 0.10,

Fig. 2: depicts the duration of various events within the ECG cycle

This study revolves around the use of pattern correlation to identify the diagnosis of a particular ECG waveform and its associated parameters like blood pressure and heart rate. Further the diagnosis thus obtained can then be sent to a telemedicine centre for a doctor's expert opinion on the diagnosis and the future course of action to be taken.

Analysis of multi-sensored data:

Understanding the ECG: An electrocardiogram - commonly abbreviated to ECG (or EKG) is a recording of the electrical activity of the heart.

The P wave corresponds to atrial contraction. The QRS complex relates to the contraction of the ventricles, it is much larger than the P wave due to the relative muscle masses of the atria and ventricles (Fig. 1and 2).

SYSTEM DESIGN

The presented system focuses on the need to develop a multisensored cardiac decision support system that uses the concept of telemedicine to obtain expertise from a remote doctor. Here the cardiac data considered are ECG patterns, blood pressure and heart or pulse rate.

The data formulation module focuses on the preprocessing, formatting, clipping and storing of the ECG patterns in the database. Once the test ECG data is obtained it is also put into the same procedure to make the test ECG scans to be compatible with that of those present in the database. This module can be further categorized into three sub modules as:

* **Preprocessing:** It Involves conversion of image pixels to an array and analysing the gaps in the image. This module ensures that the ECG data gets freed of all gaps and random pixels that are scattered. This module deals with the process of obtaining, processing and storing the ECG signals in a database for the purpose of correlation. This first step ensures the computational preparation of the derived and digitized ECG waves. The preprocessing of the ECG signals is required to solve "aliasing problems. waveform images..

* **Background Formatting:** The background grid lines of the ECG are changed to white and the ECG patterns changed to black. Due to the presence of inconsistent grid lines some patches of black may penetrate into the white background. Also there may be some white points in the ECG pattern. To make the ECG patterns to be fully compatible, they are again preprocessed to fill the gaps. This stage involves the removal of the background grid lines and color resolution of the ECG image. The ECG scans are depicted on the foreground of a criss cross pattern of grid lines. These grid lines must be removed since different ECG scans may possess different grid structure and also with different colors. The generality of the system can be ensured by removing the background and presenting a uniform format of white background with the ECG pattern in the foreground represented as black. The final output of the stage is a background removed ECG pattern in black.

* **Clipping:** In the clipping stage a cycle of ECG pattern representing all the leads of the ECG interpretation is obtained. The analysis of the ECG waveform can be done by using a single ECG pattern or one ECG cycle. A typical ECG waveform consists of several cycles being repeated as a pattern. Instead of processing the entire data, a single pattern can be used. A pattern can be constructed if its endpoints are known by taking the intermediate points from the base image. Once the points in the array are identified, the pattern may be displayed on screen by setting the pixel points on the picture box. Sample ECG scans which are considered to be the reference patterns are processed, formatted, clipped and stored in the database. They are stored as bitmap images along with their corresponding diagnosis.The complete database forms a knowledge base for the proposed expert system.

PATTERN RECOGNTION MODULE

This module represents the important implementation work of analyzing the ECG patterns obtained from the previous model and interpreting its diagnosis. The current work uses an approach of image correlation to find similarity between the test ECG and many ECG's that are stored in the database. Once a correct match is found the diagnosis corresponding to the sample ECG can be assigned for the test unknown ECG. The module can be classified further into three sub modules.

* Pattern Correlation.
* Classification.
* Evaluation.

Pattern recognition: Apart from analyzing the ECG patterns, associated parameters like blood pressure and heart rate are also tested for their abnormality.

Pattern Correlation: In this module the test ECG pattern which is processed, formatted and clipped is correlated with all the ECG's stored in the database to derive those ECG's which are at most similar to the test ECG pattern. To start with the assessment of the similarity of the ECG signal patterns of equal ECG leads is carried out by the calculation of correlation functions whose function values are formed from the correlation coefficient k:

$$\frac{\sum_{n=1}^{N} x_n\, y_n = \frac{1}{N}\sum_{n=1}^{N} x_n \sum_{n=1}^{N} y_n}{\sqrt{\left[\sum_{n=1}^{N} x_n^2 = \frac{1}{N}\left(\sum_{n=1}^{N} x_n\right)^2\right]\left[\sum_{n=1}^{N} y_n^2 = \frac{1}{N}\left(\sum_{n=1}^{N} y_n\right)^2\right]}}$$

The correlation functions vary from maxima according to the periodicity of the ECG for similar and dissimilar patterns Fig. 3 and 4, respectively. The result of each reference ECG comparison is a 12-dimensional vector or array whose elements give the correlation values for the corresponding leads. The range of values corresponds to the extremes of +1 to -1. For the further considerations, only the positive correlations are taken into account. The correlation measure of k=1 means identity of the patterns. A correlation statement towards k=0 indicates completely different signal patterns in the waveforms of the leads considered.

The above mentioned technique represents a rough estimate of pattern recognition. So further steps are taken to refine the search process. In the next stage the number of points that constitute the ECG pattern. The test ECG pattern is scanned to retrieve the number of points that

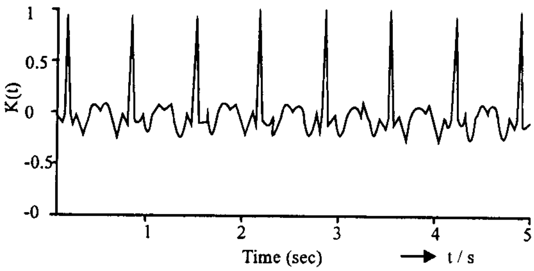

Fig. 3: shows the correlation function for very similar signal patterns

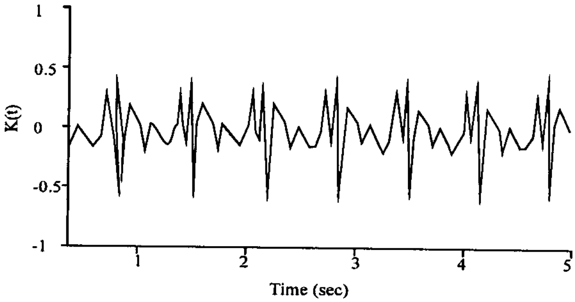

Fig. 4: The correlation function with distinct differences of signal patterns

make up the pattern. We then analyse the patterns stored in the database and calculate the number of constituent points. Depending on the number of points in the test ECG pattern the patterns in the database are modified enabling consistency. Hereby additional points are added or certain points removed. Again the same correlation function is applied. This approach produces a lesser number of search matches since we alleviate those ECG patterns that fall outside the range of the test ECG pattern.

Classification: It is the aim of classification to summarily assess the agreement of the lead related correlation results obtained from the comparison of the unknown ECG with any reference ECG. The important lead points in an ECG are P, Q, R, S and T points. The present study focuses on the hypothesis that those ECG's whose signal waveforms are in best agreement in their leads can in all possibility be assigned to the same diagnosis. This module therefore focuses on the similarity of these five points between the test and reference ECG's.

Analysis of lead points involves the tedious process of identifying the lead points in the ECG pattern. Here difference in slope between consecutive points is found to determine the morphology of the waveform. This initiates the identification of the QRS peak which is vital to any ECG waveform.

The QRS complex represents a slope in the waveform of the ECG pattern. The slope of the waveform is obtained by rooting the difference in pixel value points of adjacent samples or pixel points. The obtained values are stored in an array called the slope array. In Order to minimize errors, four adjacent slopes are taken and their average is taken. This ensures the effective detection of noise spikes. This method determines a peak by a change in sign of the slope. The slope array is scanned to determine the change in sign. In such a way a peak is detected. Since the peak point is represented by R lead point it facilitates the detection of R point.

Once the R point is obtained it can be kept as reference for the classification of P and T points. The P and T points are also slope points but with a lesser magnitude. The slope array is scanned element by element. Changes in sign can be noted in three places. The higher magnitude represents the R point. The next higher magnitude represents the T point and the last change in sign represents the P point.

When these lead points are identified their corresponding pixel point values taken from the two-dimensional array constructed earlier are stored in separate variables. These points are calculated for both the test patterns and the patterns that were selected in the pattern recognition stage. It may be noted that even if two patterns correlate together they may be different in their lead points which may not be detected by the algorithm prescribed earlier. This arises due to the fact that the correlation algorithm takes all the points together, constructs their average and proceeds with the average value. This average value may not depict the intricate positioning of the lead points.

Evalution: As a result of the classification stage only a certain number of matched patterns will be selected for the test ECG pattern. This module evolves to obtain a unique match to the pattern and thereby report the diagnosis for the unknown ECG. The similarity between the test and matched patterns in their lead points are identified. The particular ECG's whose lead points are all similar to that of the test ECG is taken to be the correct match. In certain cases, reference ECG's cannot have all their lead points matched. Some lead points may vary. In such situations, we identify that particular ECG in the database that has maximum number of lead point match with the test ECG.

The diagnosis corresponding to the selected ECG is taken from the database. This diagnosis can then be inferred for the unknown ECG. This technique is intended to enable the doctor in contrast to conventional methods of computer-aided ECG interpretation to separately evaluate the results including the patient information available.

Along with the ECG data two other parameters associated with the cardiac system namely Blood Pressure and Heart Rate are also analyzed in the current work. These are numeric values that are in tandem with the ECG data. The values of these parameters are compared with the original values to detect the abnormality condition.

The normal blood pressure value is 120/80 Mm/Hg. Here 120 represents systolic value and 80 represents diastolic value. The blood pressure of the patient is obtained as the operator enters the value in the clinical information form. The systole and diastole values are compared separately. The systole values are classified as follows:

Value (mm/Hg)	Diagnosis
110 to 130	Normal
130 to 145	Super normal
Above 145	Extermely high
90 to 110	Sub normal
Below 90	Extermely Low

Similarly the diastole value is classified as:

Value (mm/Hg)	Diagonsis
70 to 85 Normal	
85 to 95 Super normal	
Above 95	Extermely high
60 to 70 Sub normal	
Below 60	Extermely low

The pulse rate or the heart rate gives an indication of the number of QRS complex present in an ECG per second. These values are also entered by the operator. The normal pulse rate is 65 to 74 beats/min. Based upon this categorization the pulse rate may be classified as either normal or abnormal.

NETWORKING

It is a well known fact that the results that are produced by a medical expert system are not a complete diagnostic statement. They represent only a probabilistic statement of what a specialist makes. It is therefore essential to send the results produced by the system to a cardiac specialist to verify the result. Also the correlation based algorithmic procedure does not yield an output always. Only if a parallel sample ECG with associated diagnosis is present in the database, can it produce a result. Theses facts clearly indicate the need to send the medical data along with the diagnosis obtained; to a doctor present a remote site. This provides the verification of the result and also an indication of the immediate course of action to be taken for the patient.

The present study represents a snapshot of an exact networking model where in the networking module is based on a LAN network. The network works using the TCP/IP protocol. The module can be extended by connecting the computers to the internet and passing data through the yahoo messenger service.

Sample network implementation:

- The ECG, the associated diagnosis and further information are displayed on the computer at the patient side (called server).
- At the doctor's computer (called client) the project is opened.
- To view the server information, the user has to click the connect button present at one of the forms of the client machine. This ensures the establishment of a connection between the server and client.
- Once the connection is established the server sends the information to the client which can be viewed on the client forms.
- The doctor at the client side views the received ECG and the diagnosis. He then reviews the diagnosis and proposes the immediate course of action of action to be taken.
- The doctor then sends the diagnosis he made along with any other information to the server or patient side by clicking the send button.
- The send button is coded with all the functionality to establish connection wit the server using the abovementioned steps.
- The server can then receive the final correct diagnosis from the doctor and his expert opinion by clicking the Receive Doctor's Report button.
- After all the processes are done, the server and client application are disconnected.

CONCLUSIONS

The present study demonstrates a method of ECG multi lead waveform recognition using a predefined sample database and implementing it on the network to obtain expert analysis of the doctor. A large ECG database offers new paths for the interpretation of ECG signals without feature extraction. ECG interpretation through waveform recognition calls for several cardiac classifications. The use of pattern recognition to identify the ECG patterns ensures that the system is error - free and non time consuming.

The result of the signal pattern comparison is not a diagnostic statement which can be accepted or rejected but a probability statement on the basis of similar cases of ECG database. Accordingly, the quality of this database as regards the extent and the validation is a decisive prerequisite for the function of the technique presented. This requires the use of a database that is sufficiently representative, annotated and clinically validated. In the above developed expert system the database acts like a knowledge base. This ensures that the system is volatile since knowledge can be added or deleted from the database easily.

The inclusion of multiple parameters further enhances the system to the core. This indicates that apart from the parameters specified further more cardiac oriented data can be analyzed that aids in improving the quality of the diagnostic statement made.

FUTURE SCOPE

In the past years several ECG interpretation analyses based on statistical methods, clustering method, markov models have been developed. This study focuses on the intelligent decision support model. The proposed system can be further enhanced to produce high sensitivity and reliability and at the same time to enable it to work with new and ambiguous ECG patterns.

The algorithm quoted in this study focuses on unidimensional clustering. This can be extended to multi-dimensional clustering by using a database consisting of 10,000. The current system works by using the LAN network to send the information to a remote doctor. This can be further enhanced by bringing in the concept of internet technology. In this particular technology, features can be added to make the system to use the yahoo messenger service thereby connecting to the yahoo server.

Once the local PC is connected to the yahoo server access can be provided to any computer situated in the world wide network. The internet address of the remote doctor can be specified programmatically such that a vision of dedicated connection between the local PC and remote PC is available. Also instead of connecting to a single doctor multiple doctors can be connected so that expert opinion from around the world can be obtained by a patient sitting at a lab centre.

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