ECG Signal Pattern Comparison Via Internet

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Abstract

An internet-application for the telemedical ECG-analysis is presented. This solution is based on an ECG waveform recognition method, which allows to compare the wave forms of a 12 lead ECG with an ECG signal database. Using the results of cross correlation a conclusion is available for the likelihood of diagnosis. The developed software supports different computer and network configurations. Examples are presented for the ECG analysis in a stand alone configuration, in a intra- or local area network and in an Internet solution.

1. Introduction

A method is described in [1] by which - through comparison of the waveforms of an ECG beat with other ECGs stored in a signal pattern database - those ECGs are searched whose waveforms best match the waveforms in the corresponding leads. On the basis of the diagnoses made for the respective database ECGs, probable findings are stated after classification. The method was tested in a local network using a database which contained more than 10,000 ECGs. Depending on groups of cardiac diagnoses, sensitivities and specificities between 72% and 95% were achieved in 8,500 individual examinations [1].

Figure 1 shows the principle of the method. Starting point is the 12-lead ECG of conventional electrocardiographs. After receiving data from the electrocardiograph, signal conditioning and selection of a representative beat, the pattern of this beat is compared with the ECGs stored in the database. The similarity of two ECG patterns is determined by cross-correlation. The normalization of waveforms allows us to compare numerically rest-ECGs with different heart rates. The method is based on a database which, in addition to the ECG signal patterns, contains findings, anonymous patients' data, details of the anamnesis, medication, etc..

Special conditioning of the signal segments allows the comparison between the signal pattern and 10,000 ECGs stored in the database to be carried out on a PC within about 30 to 40 seconds.

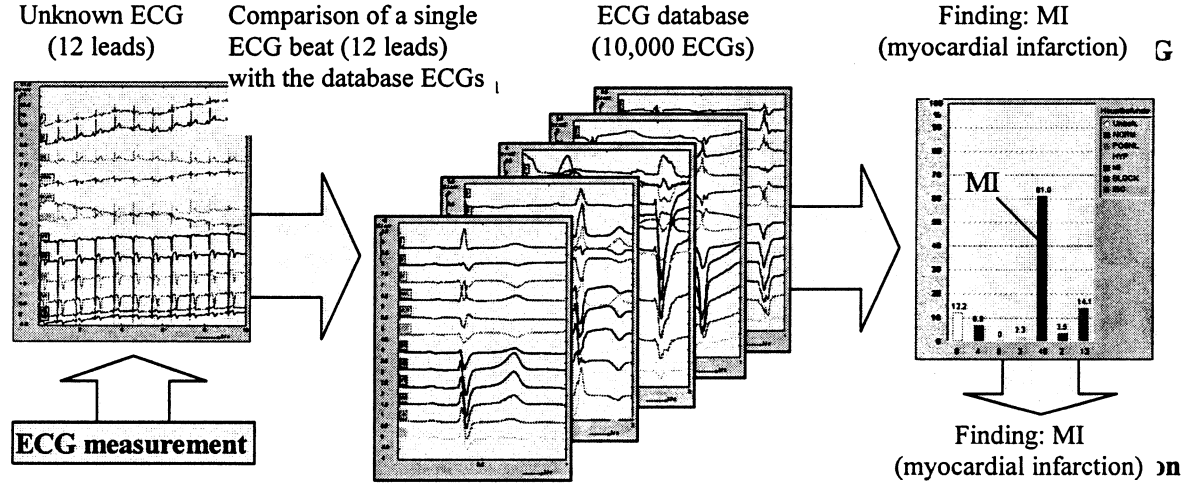

Figure 1. Principle of the method for ECG analysis by waveform comparison with an ECG database.

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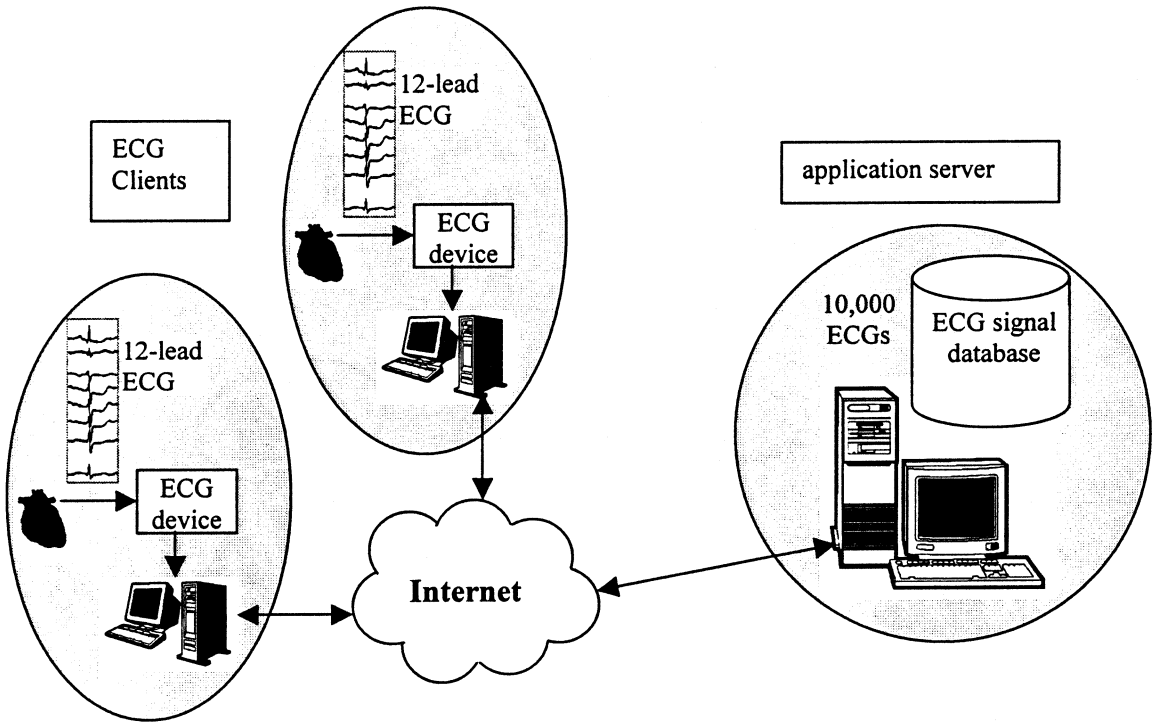

Figure 2. ECG pattern identification on an application server with two connections via Internet.

Subsequent classification of the correlation results as well as the assignment of primary and secondary findings, among other things, make an evaluation of the unknown ECG possible.

Modular software variants for PC are developed in order to implement the method. Structuring of the problem leads to three program packages which must be executed one after the other. The programs may be stored on different computers. Provision of the 12-lead ECG from the electrocardiograph as well as the required signal conditioning and beat selection are typically performed by the peripherals at the place where the ECG is recorded (client's computer). The comparison of the patterns with the database ECGs is the task of a central computer (application server). The presentation of the results and interactions between users and database takes place again on the client's computer.

2. Configurations

The method described can be used in different environments.

2.1. Stand-alone variant

The stand-alone variant is the simplest configuration. The ECG database, including the programs allocated to the server for pattern comparison, and the software packages for communication with the client are installed on the PC of the PC ECG device, in addition to the software of the instrument manufacturer. Depending on the configuration, the database can be placed on a CD or, after installation, on the hard disk. If, for functional reasons, the database is to be made available on a single CD only, the amount of data could be extended up to a total of about 50,000 ECGs. The variant described was tested with the most recent Windows systems and can be used also on a laptop.

2.2. Network variant

The structure of the user software allows a network variant. The database - including the software for pattern correlation - is installed on a server accessible via a local network. Client and server software are stored on separate computers. User communication and pattern comparisons

with the database ECGs are made on the client's computer which therefore must have a sufficiently great computing capacity. It is a disadvantage of this structure that the scope of network communication between the software packages is large and the program execution time may become unacceptably long.

2.3. Terminal variant in a network

Prerequisite for the terminal configuration is a network environment of the type described above. But in this case a device of the server is not mounted at the client's computer. In contrast to the network variant the connection between client and server is realized by terminal solution. The server environment appears at the client's computer in a separate window. All program communications for pattern correlation are executed in the terminal window. The decisive difference compared with the network variant is that applications, in particular pattern comparisons with the database ECGs, which require intensive computing, are executed on the server. Therefore computing capacity must be sufficiently great. The client's computers then only serve as terminals for communication. The advantage of this variant is that only small amounts of data are exchanged via the network connection. As a result, no network of great bandwidth is required between client's computer and server. Then the connection can be realized via telephone, for example through ISDN network or modem with adequate transmission rates.

2.4. Variant with web browser

The above network variant requires that a point-to-point connection is established between Client's computer and server. This can be achieved via a long-distance data transmission network and the extension of "terminal-server-client", using the functions offered by Windows. Installation and operation of the Client's computer are, however, facilitated when solutions are chosen which have proved themselves in the development of Internet and which are widely used there. If Internet technology is used, ECG pattern identification requires only a PC with Internet access and web browser. It is of no importance for the method whether Internet access is ensured via provider or via web server of a local network. In any case the web browser of the Client's computer is the interface for the user. Internet connection is established by the computer, through selection of a web site.
After having checked access authorization, the web server examines whether a corresponding ActiveX-Control for the establishment of a TCP-IP already exists. If necessary the Control is made available by the server. The ActiveX-Control establishes a TCP-IP connection to the server. The server acts as an application server which organizes and executes the software components for the ECG pattern identification method. This means that, for the pattern identification method, no application software is required on the Client's computer. Only standard components of the Windows operating system or the Internet explorer from version higher than 3 are used.

Figure 2 shows as an example the connection of two client configurations with symbolized ECG recording by an electrocardiograph, as well as the connection between a PC and an application server via Internet. Communication for the pattern identification method is in accordance with the schematic diagram in Figure 1.

It should be pointed out once again in this context that no user software must be installed on the client's computer and that no ECG measurement data are stored as files on the server. Only the numerically conditioned waveforms of an isolated ECG beat must be available on the server for pattern comparison. This data record is the prerequisite for a comparison with the ECG database. This means that the program started on the application server in fact opens the ECG files on the clients computer, that it selects individual samples in order to set up the graph, but that it does not transmit the entire file to the server. If necessary, this data traffic can be additionally encoded.

On the application server, the different user requirements are handled in separate address spaces and disk areas. The individual program configurations are stored separately, and they are available when the software is called again. This ensures that the users, at their own discretion, can make those settings which are feasible within the scope of the software used (e.g. window size, colouring, evaluation modes, etc.). When the program is invoked again, execution takes place in the well-known environment.

For the time being, within the framework of a test project, the server has been laid out for a limited number of connections to cardiology institutes. Stepwise expansion has been envisaged.

3. Application example

The following example shows on the basis of different screen displays how the program interfaces appear to the user in the web browser. Figure 3 shows the selection of a representative ECG beat through line cursors. Figure 4 represents the result of the comparison of the signal segment selected in Figure 3 by bar diagram.

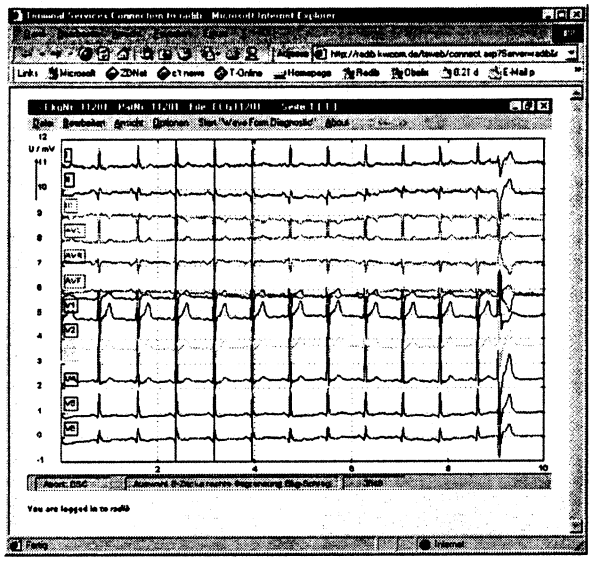

Figure 3. Example of the selection of a representative ECG beat in the browser window.

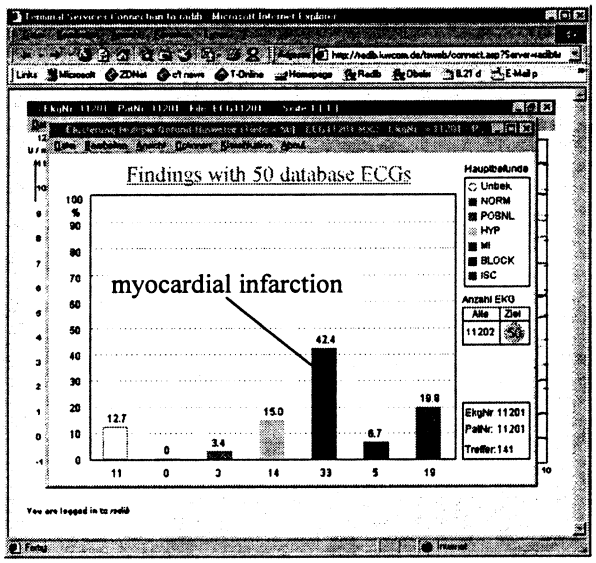

Figure 4. Bar diagram showing the distribution of the primary findings of the 50 database ECGs whose signal patterns best match the pattern of the test ECG (primary key: 21201)

This bar diagram indicates the distribution of the primary findings of the 50 database ECGs whose signal patterns best match the pattern of the test ECG. The bar length is a measure of the number of weighted components of the findings and can be regarded as the probability with which the finding in the test ECG is correct.

In the example represented in Figure 4, the longest bar stands for the group of findings 'myocardial infarction'. Similarly we can classify the finding subgroup of infarct location, for instance. The same bar technique would yield the result 'inferior myocardial infarction'.

4. Summary and outlook

The use of the developed software package for ECG signal pattern identification was described for different configurations. Starting from the "stand-alone" variant on the laptop, the possibilities of a software structure distributed in the local network were discussed, ranging from the terminal variant to application via Internet. In a next step, the practical applicability of the method – so far tested locally – will be investigated in co-operation with selected clinical partners. Expansion of the database will be continued. The Internet variant described will be used for this purpose.

Additional information can be obtained at http://www.berlin.ptb.de/8/82/821/ecg/index.html.

References

[1] R. Bousseljot, D. Kreiseler. Wave Form Recognition with 10,000 ECGs. Computers in Cardiology 2000;27:331-334

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