telemedicine, teleconsulting,
remote medical care.

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COMPUTER SYSTEM OF TELEMEDICAL SERVICES FOR FAMILY DOCTOR'S PRACTICES

This paper shows the current state of research and development over the telemedical services system for family doctor's practices. The introduction of this telemedical system should result in improvement in accessibility to medical services for the patient and to actual medical information, publications and up-to-date consultations for the physician, regardless of the distance from physician's clinic to the consultation center. This system should reduce the total costs of basic medical services. The system consists of two autonomous subsystems, that work in two arrangements: patient ↔ family doctor's practice and family doctor's practice ↔ information & consultation center. The remote medical care system provides vital signs monitoring through telephone line – physician can observe electrocardiogram and oxidation of blood, while the patient is many kilometres away. In case of unstable state of health, this system is able to alert the physician. The teleconsultation system provides a videoconference service with shared multimedia document (audio-video streams, graphic, text, etc.).

1. INTRODUCTION

The range of the family doctor's required competence has increased significantly lately. This situation leads to escalation of the treatment risk, caused by physician's lack of time and/or lack of knowledge [1]. At the same time, a very dynamic development in the field of telecommunication and computer science has permitted to make an attempt to create a computer system, capable of supporting a family doctor's work. This system should not only help to improve quality of the medical services, but also should reduce their costs, especially on wide areas with dispersed health centers [2].

Introduction of this telemedicine system could result in:

– easier access to medical services for the patient, and
– easier access to up-to-date medical information, publications and consultations regardless of the distance from physician's clinic to the consultation center.

The structural scope of telemedicine services in created system is restricted to two arrangements:

– patient ↔ family doctor's practice, and

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– family doctor's practice ↔ information & consultation center.

This selection was dictated mainly by already existing (in region of planned experimental implementation) organizational system of family medicine. This system includes mainly two mentioned above types of arrangements, furthermore it contains good organized and equipped centers – Institute of Family Medicine at Wroclaw Academy of Medicine (*Katedra i Zakład Medycyny Rodzinnej Wrocławskiej Akademii Medycznej*) and Regional Center for Family Doctors Education (*Regionalny Ośrodek Kształcenia Lekarzy Rodzinnych*). Both units share the same location and in planned telemedicine system they will create the information & consultation center. Taking aforementioned arrangements into consideration, the entire system has been separated into two autonomous subsystems:

– the computer system to remote medical care,
– the teleconsultation system.

2. COMPUTER SYSTEM TO REMOTE MEDICAL CARE

The whole system might be splitted into two parts. First part is located in monitored patient's place. Second is installed on a physician's computer. There are measuring devices aside from computer with modem in the patient's part (electrocardiograph, pulse oximeter).

Signals are read from electrocardiograph and pulse oximeter on the patient's side by data canvassing unit. Next they are shown on the display by data visualization unit and exposed to analysis by data analysis unit simultaneously. When the health hazard situation is detected, data analysis unit through data transmission unit initiates connection with physician's part of system. After that, last ten minutes of recorded signals are transmitted to physician's computer.

The communication might be established on patient's or physician's initiative. In each case all operations are executed by data transmission unit.

On the physician's part the data transmission unit monitors state of connections with patient's part of system. If the connection request is detected, the system starts to receive data. Patients are identified on the basis of sended ID. The records of theirs signals from last ten minutes are shown

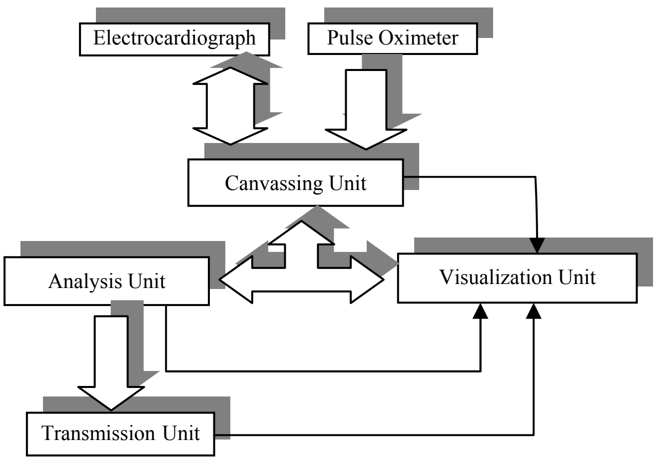

Fig.1. System's structure on the patient's side

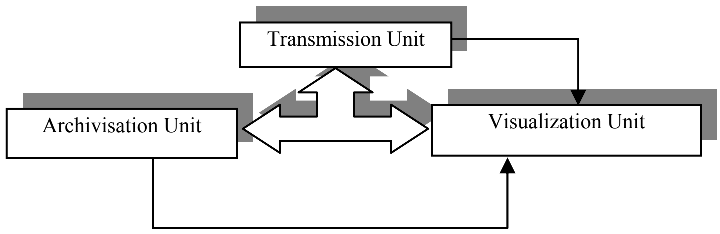

Fig.2. System's structure on the physician's side

on the physician's display. Physician may measure ECG parameters by special markers and on the basis of that, he can make decision if alarm is justified.

Physician may establish communication with patient's system and get records of monitored signals. He can archive gotten records, so he could evaluate condition's changes of monitored patient later.

2.1. DATA ANALYSIS UNIT

Data analysis unit detects parameters of the ECG signal. Next it uses those parameters to recognize the type of heart beat.

2.1.1. SUBSYSTEM TO ECG PARAMETERS DETECTION

It is used a Pan-Tompkins method to QRS complex detection. This is a common method, and is a standard for intensive care systems. There are shown step by step in turn stages of obtaining detection function, which signales appearance of QRS complex [3].

Stage 1. Band-pass filter.

$$y(n) = 0{,}5y(n-1) - 0{,}25y(n-2) + x(n) - x(n-2) \tag{1}$$

Stage 2. Derivative filter.

$$y(n) = x(n) - x(n-1) \tag{2}$$

Stage 3. Non-linear filter.

$$y(n) = x^2(n) \tag{3}$$

Stage 4. Moving-average filter.

$$y(n) = (x(n-14) + x(n-13) + \ldots + x(n-1) + x(n))/15 \tag{4}$$

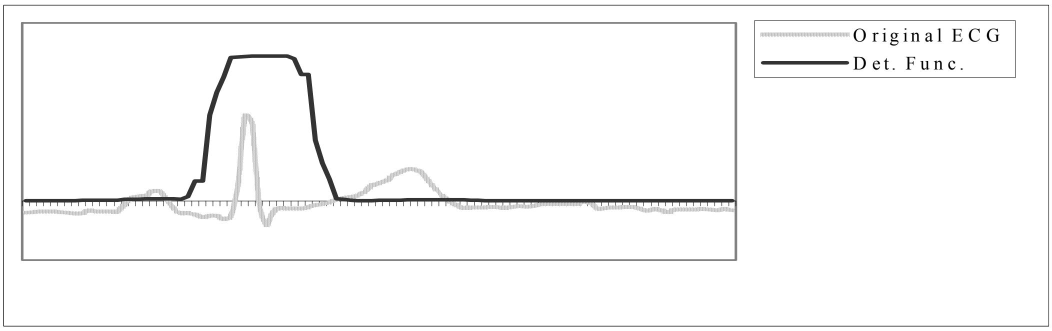

Fig. 3 Obtained detection function against original ECG signal

Stage 5. Phase shift of detection function by half of moving-average filter's window.

$$y(n) = y(n + 7) \tag{5}$$

2.1.2. BEAT RECOGNITION SUBSYSTEM

It is necessary to recognize the type of beat to make a decision about the alarm. The system analyses beat's sequence and other parameters (e.g. R-R length). There are assumed following types of beats:

S-	Sinus beat	i=1,
SV-	Supraventricle beat	i=2,
VP-	Ventricle premature beat	i=3,
SVP-	Supraventricle premature beat	i=4.

Assumed input data to beat recognition system:

- x_1- height of R wave,
- x_2- height of S wave ,
- x_3- QRS duration,
- x_4- interval between neighboring QRS complexes,
- x_5- 1 - if P-wave exists, 0 - if none.

Algorithm NM is used for beat recognition. It is characterized by low computational and storage complexity [5]. The size of storage depends on the size of following informations:

$$\mathbf{\bar{x}_1}, \mathbf{\bar{x}_2}, \mathbf{\bar{x}_3}, \mathbf{\bar{x}_4}, \text{ where } \mathbf{\bar{x}_i} = \begin{bmatrix} \bar{x}_{i1} \\ \bar{x}_{i2} \\ \bar{x}_{i3} \\ \bar{x}_{i4} \\ \bar{x}_{i5} \end{bmatrix}, \tag{6}$$

where $\mathbf{\bar{x}_{ij}}$ - e.g. average height of R-wave for sinus beat.

One of the disadvantages of this algorithm is that it doesn't take to consideration individual patient's features. There might be proposed some modifications, which will cause that algorithm adapts to individual patient's feature.

2.1.3. ADAPTATION VERSION OF NM ALGORITHM

First, it should be discussed how changes of algorithm's parameters should look like. If an adjusting takes place without any physician's care, it should be based on algorithm's classifications. Changes of mean vectors' features should have quick-concurrent character at the beginning of adaptation process, then the adjusting will be quick. The changes should decrease to zero as adjusting will be achieved. It is used a numeric algorithm to computing mean, which was optimized to save the memory.

$$\overline{x}(n) = \frac{\overline{x}(n-1)(n-1) + x(n)}{n}, \qquad (7)$$

It can be seen that it isn't necessary to remember all temporary values of given sequence. Last computed mean and number of previous values are enough to compute next mean. This relation can be used to modify mean value for given decision. It is assumed that the first mean value for given decision is the first temporary value. In each time when system classifies input vector, this vector modifies right mean vector. In this way, meaning of average vectors is the same, like at the beginning of this discussion, but the algorithm adapts to individual patient's feature.

Initial number of classified vectors, may be defined by physician on the basis of other diagnostic methods. Physician can judge if input parameters are much differed from typical. If they are, he gives a low value of p parameter otherwise he gives high. As this value is high as difficult is to modify values of right decision vector.

The final formula to modification of mean values' vectors:

$$\overline{\mathbf{x}}_{\mathbf{i}}(n_i) = \frac{\overline{\mathbf{x}}_{\mathbf{i}}(n_i-1)(n_i-1) + \mathbf{x}_{\mathbf{i}}}{n_i}, \quad \overline{\mathbf{x}}_{\mathbf{i}}(1) = \frac{\overline{\mathbf{x}}_{\mathbf{i}}\, p + \mathbf{x}_{\mathbf{i}}}{p+1} \qquad (8)$$

where $\overline{\mathbf{x}}_{\mathbf{i}}(n_i)$ - n_i mean value of i mean vector,
$\mathbf{x}_{\mathbf{i}}$ - input vector classified as beat i,
p - difficulty coefficient of mean vector's modification,
n_i - counter of class i vectors.

If difficulty coefficient is the same for all mean vectors, or if it is different for each, it will be discussed in the future. It might be put into algorithm some kind of convergence coefficient by introducing maximum number of mean vector's modifications. Future problem is to find the optimal values of these parameters.

2.2. DATA TRANSMISSION UNIT

Data transmission is based on the remote access service (RAS), Winsock 2.2 interface and TCP/IP protocol. First two technologies are making possible communication between two computers by various network protocols as easy as they are connected by LAN, therefore it is ensured possibility of integration with other medical systems (e.g. medical databases) and TCP/IP protocol opens the system for dynamically expanding Internet reality.

It is used DES algorithm to ensure security and secrecy of transmitted data. It has been chosen because, even though it is completely public, it had resisted any attack for 20 years. It is faster than other algorithms of the same class too, so it has been judged as the best algorithm for medical data exchange.

3. THE COMPUTER TELECONSULTING SYSTEM

One of the main reasons why an attempt to create this system has been made, was the necessity to relieve the family doctor of some of his time-consuming duties, by supporting a real-time consultations via a computer network. With the use of videoconference techniques, special designed software and freely available hardware, it is possible to carry out such consultation at a distance of many kilometers.

3.1. APPLICATION'S MAIN FUNCTIONS

So far (July 2002) a majority of scheduled tasks have already been executed.

The application works under Microsoft Windows 2000 operating system and uses available system functions, such as windows, icons, short keys, etc. The system consists of server application (which works in the information & consultation center) and client application, which is used by the physician. Since the functions incorporated in both of the application types are almost equal, the following specification applies to both server and client applications. Figure 4. shows the application's main modules:

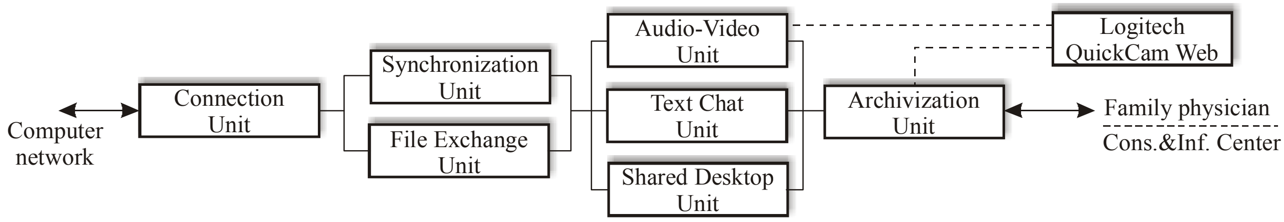

Fig.4. System's basic structure

The **connection** establishing process can be executed in two ways – the physician's computer (client) can connect to the Center's computer (server) by using the Internet or directly through the ISDN line. Using the Windows Sockets interface the client application sends unique login and password to gain access to the server. However, the server may reject this request if the login &

password combination is unknown or not correct. For the sake of classified medical data safety, the direct ISDN modem connection is more favored. All exchanged data can be ciphered using the DES algorithm, which ensures acceptable level of safety. Additionally, in forthcoming release of the system (planned for the end of year 2002), a public-key (RSA) ciphering will be available.

Using the USB Logitech QuickCam Web camera with integrated microphone, the application allows to carry out a typical videoconference session by intercepting, processing and transmitting **audio-video data**. The properties of those data can be modified – easy to adjust are for example: window size, framerate and audio-video codecs (compression parameters). Application allows also to open two video-windows – one with received signal and second (optionally) with preview from local camera. Both audio-video streams can be saved to an AVI file.

In situation where connection between two computers is slow and the transfer isn't efficient enough, physicians may use the **text chat** utility. It is a typical ICQ-like service, it offers character-by-character or sentence-by-sentence working modes. The whole session can be saved as a text file for further edition and/or archivisation.

One of the most important function is the ability to do **shared work** with any multimedia document, especially with a picture file. This function is similar to Microsoft Neetmeeting's *shared desktop* or *whiteboard.* Synchronization of the cursors, desktop layout and opened files allows to work in WYSIWIS (*What You See Is What I See*) mode – each one user sees everything, what user on the "other side" also sees. The synchronization process is activated automatically after the connection is initiated and on every major desktop change. It can be initiated by the user also.

Within the confines of shared work a **viewing** and simple **editing** of picture files is possible. The main picture file types supported by the system are: DICOM (uncompressed 24bit RGB), Windows bitmap (BMP), GIF and TIFF. Tools available for use are: rotation, scale, intensity and contrast adjust, and advanced histogram processing (equalize, local equalize, adaptation filters).

3.2. THE TESTS RESULTS

The research and development process is still running. Simultaneously the compatibility and functionality requirements are forcing continuous improvements and sometimes even major changes to systems functionality.

Tests of the Logitech QuickCam Web camera, carried out with use of internal loop-back, are showing that this particular camera cannot be called as a professional class device. Even with an effective video-codec (Intel Indeo® Video 5.06), the achieved framerates was far from satisfying.

Tests made with a 56K modem connection are showing even worse (as was actually expected) functionality. As Table 1. shows, 2 fps achieved at the smallest window size are not enough to establish a real-time videoconference connection.

Window size 640x480 RGB24	0.2 [fps]
Window size 320x240 RGB24	0.6 [fps]
Window size 160x120 RGB24	2 [fps]

Tab.1. Results of the video transmission test (modem 56K)

It seems that increasing the connection bandwidth to 128Kb/s (two ISDN B channels) will raise the audio-video streams quality to very satisfying level.

4. HARDWARE & SOFTWARE

The software development process is being carried out on a PC computer, with software and hardware configuration showed in Table 2. This system is efficient enough to operate on data, audio-video streams and high-resolution graphics processing. It also allows to efficient use of the Windows 2000 Professional operating system and all of it's services, e.g. RAS and WinSock.

The implementation works are being carried out in Microsoft Visual C++ 6.0 environment. This choice was dictated mainly by very good cooperation between this environment and the Windows operating system, along with this system's services [6] – with this tool the programmer has freely access to all available services and resources.

1.	Devices	PC Athlon 1GHz, 256MB RAM, HD 40 GB
		Modem ISDN (final version), analog modem 56K (pilot version)
		Electrocardiograph AsCard B5 model B
		Pulse Oximeter PalmSat 2500
		Logitech QuickCam Web USB Camera
2.	Operating System	Windows 2000 Professional
3.	Software Environment	Microsoft Visual C++ 6.0
		Logitech QuickCam SDK 1.0
4.	Software Technologies	Remote Access Service (RAS)
		Interface WinSock API 2.2
		Data Encryption Standard (DES)
		Win32 API, MFC

Tab.2. Hardware and software

5. CONCLUSION

This computer system has a chance to become a useful tool for physician's daily work. It should not only help to improve accessibility and quality of the medical service (reducing at the same time their costs), but should also provide real-time consultations regardless of the distance from physicians practice to the consultation center.

However, the system is still in development phase, so many tasks such as finding optimum parameter's values for beat recognition subsystem or finding ECG signal archivisation standard, must be still realized.

It is necessary to use more efficient devices, i.e. electrocardiograph with 250 Hz sample rate, a video camera with better frame-rate and faster Internet connection (an ISDN modem would be satisfactory) in the final version of this system.

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