A MULTIMEDIA TELEMEDICINE SYSTEM
TO ASSESS MUSCULOSKELETAL DISORDERS

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ABSTRACT

Assessing of the physical condition of the human body, and concretely musculoskeletal disorders, frequently requires evaluating different tests performed by different devices. This information has to be analysed simultaneously to derive conclusions, and so a temporal relationship must be established between the data sources. Synchronization of the data sources of information is achieved by synchronising the clocks of computers connected in a Local Area Network (LAN) by means of NTP. The added time-stamp is used to playback the data in a synchronised way. Although the proposed system is valid for any medical application in which data synchronisation is needed, it has been specifically used to capture, process, and analyse data generated by electromyographs, lumbar equipment, isotracks and video. Afterwards, the data can be distributed through Internet using a Biomedical On Demand (BoD) server. The whole system has been developed using JAVA and the Java Media Framework (JMF) libraries.

1. INTRODUCTION

Musculoskeletal disorders are one of the most important illnesses affecting people. During the period 1998 to 1999 almost 8 million people in the EU were suffering from health disorders, other than accidental injuries, caused or aggravated by their current or past employment. The prevalence rate for employees is 5372 cases per 100000 persons per year. From 1998 to 1999, an estimated 350 million working days were lost each year in the EU owing to work-related health problems. One single type of problem covers more than half of the victims: musculoskeletal disorders (disorders of the musculo-tendinous-osseous-nervous system that are caused, precipitated or aggravated by repeated exertions or movements of the body) which affect 4.1 million people (53% of cases). Their annual prevalence rate in the EU from 1998 to 1999 is 2645 cases linked to the current main employment for 100000 employees. It is highest in the health and social work sector (4283) and among 55-64 years olds (3555).

The prevalence rate for musculoskeletal disorders resulting in absence from work of two weeks or more is highest in the construction industry (1292 compared to an average of 817) [1].

In this paper we describe the system that has been developed during the last years jointly with the medical researchers [2] and which main features are:

1) A distributed system capable of recording data from different sources (electromyograph, electrocardiogram, electroencephalogram, biomedical images, video, audio, kinematics data etc.) and generating a synchronised multimedia output based on the processed data (Wavelets filtering, 3D body representation) as a tool to help the doctors in their diagnosis.

2) The normal and altered patterns of the musculoskeletal functioning in healthy people and patients suffering from musculoskeletal disorders (mainly related to work problems) will be determined by means of the proposed multimedia distributed system. In order to get a standard, populations will be ranked by clinical diagnosis, jobs, ages, sexes anthropometry, disability questionnaires, pain visual analogical scale grade; and will be tested during standardised movements.

3) And finally, a new tool for the medical community will be implemented: A multimedia server will manage the generated databases (BioMedia On Demand). So, clinicians from all over the world can access to real-time complex multimedia presentations (video, audio, 3D, electromyography, trunk kinematics etc.) of the data recorded from healthy people and patients previously stored in the database. The medical applications is been used in the Anatomy Department of the University of Valencia for deciding the most adequate exercise in the treatment of musculoskeletal disorders by lumbar pathology, and for the evaluation of the rehabilitation process [3].
The paper is structured as follows: Section 2 presents an overview of the system proposed. In Section 3, the synchronization process is introduced. The data capture phase is showed in Section 4 and the playback process in Section 5. The BioMedia On Demand is described in Section 6. Finally, the conclusions and the future work are presented.

2. OUTLINE OF THE SYSTEM

Figure 1 shows graphically the order in which the tasks processes of the developed system are carried out.

![Figure 1. Processes of the system](image)

The system has been developed in Java making use of the JMF 2.1.1 Sun libraries and offers an end-to-end solution starting with the synchronization and allowing the on-demand distribution of the multimedia data by means of RTP (Real Time Transport Protocol).

Among the different alternatives to implement our telemedicine system, we decided to use Java for its current importance in web-based multimedia applications the Java Media Framework (JMF) using as development library. JMF is an API defined jointly by Sun Microsystems and IBM Corporation to develop multimedia applications. The main aim of this product is the provision of real-time delivery and multimedia data control (video and audio) by means of streaming techniques. The API can be used in applets and in stand-alone applications developed in Java. The eases provided by the JMF library and the availability of the source code, have led us to choose this library.

Figure 2 shows the architecture of the system, in which the synchronization and capture (audio (.wav), video (.avi, .mpg, .jpg, etc.), electromyograph data (.emg), lumbar device data (.lmm),...) blocks are shown. The synchronized playback of the data can be done locally or through Internet providing access to the BoD Server that has been developed within the system and using RTP as communication protocol.

![Figure 2. Architecture of the system](image)

3. SYNCHRONIZATION

The synchronisation subsystem is the core of the data acquisition system. The synchronisation process is executed in two steps. Firstly, a clock synchronisation protocol provides a global time reference, and secondly, a time stamp is added to every new sample captured by a PC. The time stamping of the packets is a common practice in other fields of communications – like RTP, which is widely used in multimedia data transmission over the Internet.

To achieve clock synchronisation, we are using SNTP. Temporal synchronisation requires long time periods and multiple comparisons, with the objective of keeping an accurate global time. Due to long delay and jitter, the time needed to achieve certain synchronisation accuracy is higher in Wide Area Networks (WAN) than in LAN’s. However, our system uses a dedicated LAN, which provides a reliable communication channel with very short delays, so millisecond accuracy between computer clocks is guaranteed. The synchronisation process remains active during the measuring process – in order to correct time deviations.

Once the computers have been synchronised, a time stamp is added to each data and video sample. Using a time stamp in each LDU (Logical Data Unit) [4] allows: the chronological ordering of events (even those generated in different computers); synchronised playback of images and stored data; visualisation of all data and image information using the same selection parameters (time, image number, individual sensor data, etc.).

All the information captured by the digitizer video card and by the data-acquisition card is stored with the
event generation time. These generation times are given at capture time by each computer’s synchronised local clock. All this temporal information is used later in the playback process locally or over Internet.

4. DATA CAPTURE

Once the local clocks of the computers have been synchronised, the capture process can begin. The format selected to store the video is Microsoft Windows standard AVI, although other video formats like MPEG could be used. The application offers a set of options, which permit the modification of the previously established default values. The whole capture application has been developed in JAVA and the Java Media Framework (JMF) libraries.

The configurable parameters are: video frames per second; recording time; and optionally, an audio voiceover commentary. Also, the parameters can be configured in relation to the video format, such as image depth, which relates to the number of bits used to codify a pixel; and image dimension (96x72, 192x144, 284x288, and 768x576 points per image). The video source option permits the modification of hue, saturation and contrast, as well as enabling the selection of the video source (RGB, Composite Video and Separate Video). Finally, because video data files are large, a video compressor can be used. This would enable the size to be reduced by a factor of between 5 and 10 – with little image degradation.

Data is captured using a data acquisition card. The data is stored in ASCII format and using a database. As with images, it is possible to modify certain format parameters. For example: the specification of the channel number associated with data entry (the card used has 8 channels available); the amplification factor; and the sampling frequency. The number of samples per second depends on the device and on the number of sampled channels. The sampling frequencies available on the card used are: 10 kHz, 5 kHz, 2.5 kHz, and 1.25 kHz, for 1, 2, 4, and 8 channels respectively. During image and data capture, the time-stamping process is carried out locally in each PC. Time is the same on all the computers after the execution of the global synchronisation protocol, so data can be listed chronologically using the same temporal reference. This means data can be played back in a synchronised way, regardless of the device that generated it, and despite the distributed structure of the system.

Information transfer to the local PC or server allows data centralization for subsequent playback or distribution respectively.

5. PLAYBACK

The playback process begins when the capture process and signal and video processing (wavelets, images 3D, etc.) has finished. When the image and data files are opened they can be visualised continuously using the normal video controls (play, stop, pause,…).

During image and data playback medical, researchers can select a data sample or an image of interest. For example, once a data sample generated by a device (i.e. an electromyograph) has been selected, the remaining windows are updated and show the images and data acquired in the same instant as the selected sample. Along with the data display, information associated with the sample is also provided, i.e.: its amplitude in micro-volts, the sample generation global time in milliseconds, and the position occupied by the sample in the file.

As well as the main options described earlier, the multimedia medical application permits an information file to be generated for each measuring process. This information is stored on a database and refers to: the subject; the measuring session identification number; the type of study; and includes useful observations for future queries. The multimedia medical application also generates a file containing the configuration parameters for each data source.

6. DATA DELIVERY

Figure 4 represents the architecture of the Biomedia On Demand (BoD) system and the communication flow between the different elements. BoD system allows the possibility to create presentations for broadcast the results across the Internet [5].

Basically five elements can be distinguished: the authoring presentation tool, the client, the web server, the database and the media server.
Figure 4: BoD architecture

- Authoring Presentation Tool: corresponds with the developed standalone tool which allows the medical researchers the creation of medical multimedia presentations. The user has available different options to include sensors data, audio, video, text, and slides files (obtained from the devices or generated by the medical researchers) together with their temporal relationships and select audio and video compression formats adequate to the bandwidth connections.
- Client: the client application is based on a Java applet which is started when the correspondent HTML page is loaded from the web server. Through the graphic interface, the users can select from the database the presentation (medical study, medical record, etc.) they want to playback remotely.
- Web server: stores the initial page and the Java applet. It also holds the authentication procedures and the database access management.
- Database: keeps the information catalogue of the available medical multimedia presentations.
- Media server: stores the media files (data, text, video…) and send them to the clients as they request them.

In the developed system, the Web Server and the Media Server run over the same station (Windows 2000 Server), whereas the client application and the Authoring Presentation Tool run over Windows 98 or Windows 2000. As database, Microsoft Access has been used.

With regard to the generic system operation, five stages can be considered:
- Stage 1) Deals with the creation of medical multimedia presentations (media specification and their temporal relationships), the data base updating and also the storing of the media files in the media server.
- Stage 2) Clients access the web server using an http connection for loading the initial page and the java applet. After selecting the media presentation, the users run an authentication procedure to cipher the information. Personal information is validated by the web server. Without authentication the clients only will be able to visualize the presentations catalogue.
- Stage 3) At this point, the client starts the reception and synchronized playback of the multimedia files.
- Stage 4) The client has to be able to control the media reproduction (stop, rewinding, pause, etc.) through a TCP connection using an easy proprietary control protocol.
- Stage 5) Finally, the last step corresponds to the disconnection from the system, closing RTP sessions and TCP control connections.

7. CONCLUSIONS AND FUTURE WORK

The features of this Medical Multimedia Application provide some advantages and possibilities – all of which are independent of the field of application: a) it provides a platform and necessary interfaces for interconnection and synchronisation of data generated from physically distributed devices; b) it increases in the accuracy of medical studies, by guaranteeing millisecond accuracy between the images and recorded data; c) the possibility of creating customized multimedia medical presentations that include as many audio, video, text and slides flows as the research author wishes for its delivery on demand trough Internet, and d) The synchronized playback (intra and interframe) of all the media, for which the functions that provides the JMF library have had to be extended.

8. REFERENCES