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Health Information Systems Abstracts

Session – Medical Informatics
Room 1, Thursday 3 May, 09.00 – 10.30

Modelling of the visual sleep stage scoring procedure by a modular algorithm based on elements of artificial intelligence - ARTISANA

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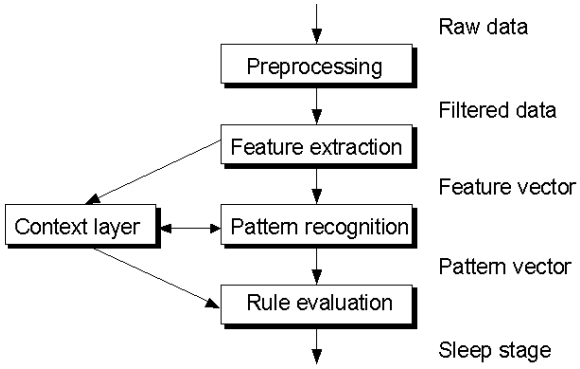
Introduction: Sleep medicine remarkably increased its clinical relevance during the past 20 years because of the exploration of pathophysiological mechanisms and the high prevalence of sleep disorders. Sleep analysis according to Rechtschaffen and Kales [5] proved to be complex, ambiguous and hardly solvable by classical digital signal processing but currently is the core task in the evaluation of polysomnography [2,4]. The manual assessment of the recorded data is to be replaced in order to reduce temporal and monetary expenditures. Since achieving either unsatisfactory quality or insufficient transparency, automated algorithms gained low acceptance in upper-grade clinical practice so far. The presented ARTISANA (Artificial Intelligence In Sleep Analysis) approach is based on the imitation of the stepwise procedure of a human expert, components of Artificial Intelligence and a fuzzy rulebase. First validation results emphasize the potential of the system to overcome the mentioned shortcomings in automatically accomplishing the complex task of sleep stage scoring.



The ARTISANA algorithm: The ARTISANA algorithm contains two layers of knowledge based systems (Fig. 1): pattern recognition by artificial neural networks (MLP-networks) and rule evaluation by a neuro-fuzzy-system (NEFCLASS). The MLP-networks were trained by the RPROP method to detect one of the following patterns each: α-, δ- and θ-activity, K-complex, vertex sharp wave, sleep spindle, rapid eye movement, slow eye movement, body movement and artefact. The input vector consists of para meters extracted from the 5 data channels (2 EEG, 2 EOG, 1 EMG), e. g. Power Spectral Densities or correlation coefficients. For K-complexes and vertex sharp waves, direct waveforms are used additionally. The patterns are identified with a temporal resolution of 1 s and are stored in the context layer for the relevant interval (up to 3 minutes of recording time). Based on patterns and features, the NEFCLASS system detects the current sleep stage, initially for 1-s-intervals. It contains a predefined fuzzy-rulebase and self-learning membership functions. Finally, the maximum likelihood for the 30-s-interval is calculated by defuzzification to detect the sleep stage defined by Rechtschaffen and Kales.

Methods: As a proof of concept, a demonstrator of the system was trained by the polysomnographic records of 4 healthy subjects and a first validation was performed by 8 records of patients with obstructive sleep apnea syndrom (OSA). All data were recorded and manually analysed in the sleep centre of the University Hospital Marburg, Germany. Sample frequency was 200 Hz, EEG channels C3A2 and C4A1 were assessed as well as EOG channels E1A1 and E2A2 and the submental EMG channel.

Results: The obtained results are shown in Tab. 1. The mean epoch by epoch agreement was 84.6 %. The interobserver agreement among human scorers from different laboratories lies in a similar range [3]. The distribution of sleep stages with higher and poorer agreement also was similar.

Discussion: Even though the number of records in the training set was limited, an acceptable agreement rate was obtained. Thus, the potential of the ARTISANA algorithm

automatic analysis / *manual analysis*	Wake	REM	LS	SWS
Wake	87,4	0,5	12	0,1
REM	6,2	79,3	14,5	0
LS	10,6	3,5	85,1	0,8
SWS	3,3	0	22	74,7

Tab 1: Agreement of manual and automatic analysis (% of manual analysis) in 8 OSA patients. LS: light sleep (NREM 1+2); SWS: slow wave sleep (NREM 3+4)

to simplify sleep evaluation in clinical practice was proved to be considerably high. The detailed imitation of the human decision process and the use of Artificial Intelligence components were confirmed to be a useful method to solve complex tasks in biosignal processing. Additional decisive features are the transparency of the evaluation process by the fuzzy rules and the option of an uncomplicated integration of the ASDA arousal analysis [1].

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Evaluating the accuracy of intelligent systems designed for medicine

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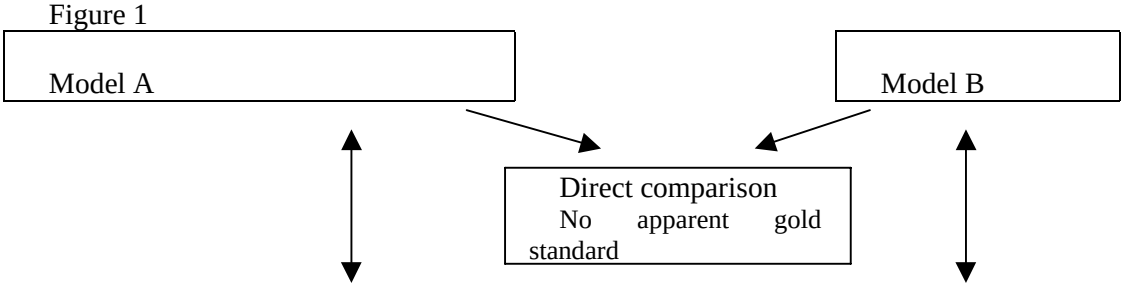
Background: Evaluation of any system designed for medicine can be thought of as being either subjectivist or objectivist in nature. Subjectivist evaluation, involves mostly qualitative measures of organisational and human-interface issues. These evaluations are considered to be essential to the impact of any system on clinical usage, but can lead to accusations of a flawed and incomplete evaluation process. Objectivist evaluation centres on the use of quantitative measurement techniques to assess a system's effectiveness. Such an approach utilises all the identifiable stages of the development from needs assessment through to cost-effectiveness analysis [1] in order to try to identify the "truth" at each stage. Many reports of "objectivist" approaches, however, leave out the core measurement of the system's inherent performance.

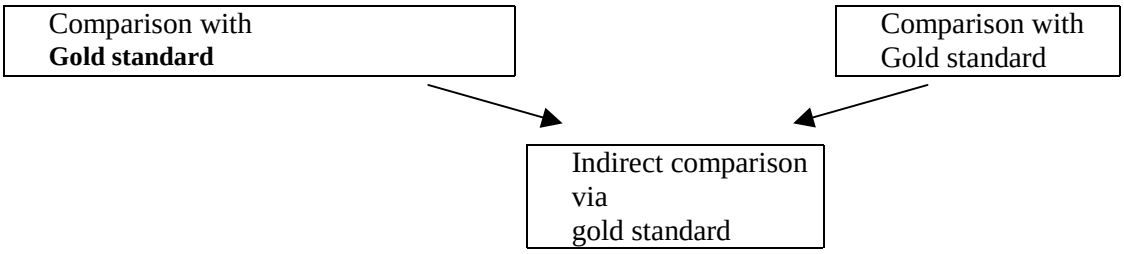
The Issue for Researchers: Artificial Intelligence (AI) Researchers often complain that they cannot be expected to be expert statisticians, and that too rigorous an evaluation means that many systems and ideas will not reach all the intended recipients who may benefit from it. However, a sufficiency of evaluation is required and so some sort of structure of approach is required for guidelines. Figure 1 is the start of such an approach for the comparison of two models, or one model with a gold standard. The aim is a sufficiency of performance evaluation, consistent with the goals and the data. The intention is to expand this, giving details of the specific statistical tests appropriate to the type of data output, along with examples and constraints. These measures essentially treat the system as a "black box" and this is considered necessary, as the processes need to be hidden at this particular stage of evaluation [2].

Some helpful websites exist, e.g. the STATLOG PROJECT [3], with comparison studies of different machine learning, neural and statistical classification algorithms. This site included the development of a software tool, "Evaluation Assistant", which tests by applying N cross validity, leave one out, bootstrap and train & test methods, but appears to give minimal statistics. The tool is a self testing approach, which only examines the one system rather than making valid comparisons, especially output measurements against other methodologies.

Overall, very little guidance on the practicable evaluation of inherent performance is available. Classification books tend to be written by academics who cover the theory very well but are

Figure 1





presented in such formal language that it is difficult for non-mathematicians to understand. Our goal is to reduce the emphasis on attainment of some optimum and replace it with adequacy of evaluation that is realistically achievable.

Conclusion: Researchers in the AI community are increasingly aware of the need for response to real healthcare issues, in a problem driven approach, rather than just an academic exercise. They recognise the need for their systems to be seen to have met the specific goals of the medical decision requirements, but attempts at compliance are hampered by lack of guidelines. Indeed colleagues in AI have stated that it is very difficult for them to find out this information and not all of them have access to expert statisticians. The core evaluation of performance accuracy, as defined, appears to be the area that gets least attention in the literature. It is hoped to rectify this in the future concentrating on developing the methodology and disseminating the information, which will progress towards the production of guidelines for a sufficiency of evaluation. This is required for Health Technology Assessment and also publication (CONSORT guidelines), plus the acquirement of the CE kite mark for commercial products.

Furthermore, not carrying out this core evaluation avoids answering the question - "Does the system do what it claims and is it more accurate than current methods?" Such questioning is essential for giving evidence that a real, scientific process has been applied to meet the safety - critical requirements of medicine.

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Intelligent algorithm to counting and classification of cells

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Introduction: The goal of the present work is to build a tool to help the realization of chirurgical pathology reports where is needed the quantification of cells is needed. In this case the system was tested in immunohistochemical analysis to determine the ratio between the number of positives and negatives cells.

The ratio of positives/negatives cells is, in general, made in a subjective form or through the manual counting that need time and a large inter and intraobserver variability [1], growing the counting errors

ratio. The use of a intelligent computational tool that proceed the cell classifications and counting is very useful to help in qualitative and quantitative aspects of final diagnosis.

Methods: The cells image is acquired in a RGB format using a digital color camera coupled to a microscope and a frame grabber installed on a computer.

The Hotelling transform [2] is applied to the acquired image, using X = { r, g, b, ur, ug, ub} as the attribute vector, where ur, ug, ub are the medians of colors around the pixel. This linear transform leads to a better axis alignment, allowing a better color separation. The transformed image is submitted to an automatic segmentation algorithm using a competitive neural network that performs the clustering [3] needed by segmentation.

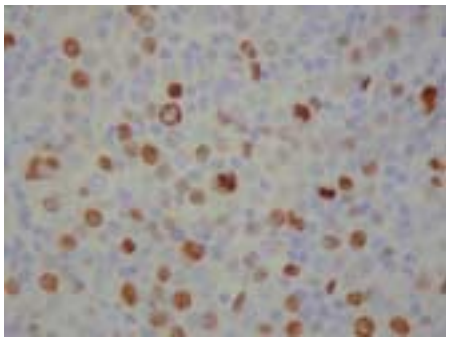
Once the neural network has been trained, each neuron will represent a pattern that will be assigned to kind 1 cells, kind 2 cells and image background. The various aspects of texture and color are incorporated in the image descriptors supplied by the neural network.

Mathematical morphological techniques [4] are applied on the segmented image to perform shape analysis and filtering. Traditional techniques are used to count the classified cells.

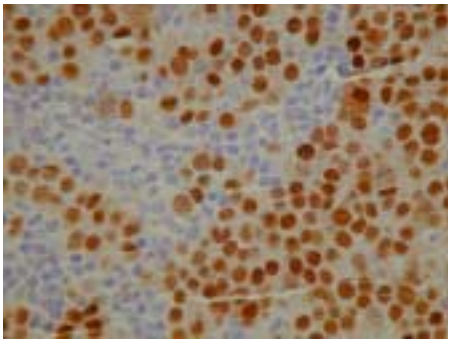
Results: Some results were obtained with the system for two test images. The table, show the reports values in an automatic diagnostic and in a manual diagnostic. The manual counting was made only to evaluate the accuracy of the developed method. Usually, this counting is not realized.

	Automatic		Manual	
	Kind 1	Kind 2	Kind 1	Kind 2
IMG1	289	81	293	105
IMG2	167	157	235	167

Table



IMG 1



IMG 2

Discussion: The whole system presented very good results. The use of morphological operators minimizes the counting errors, allowing a better shape analysis, noise filtering and the needed memory to proceed the counting.

According to the results, the system is efficient either in the counting as in the classifying when compared with manual method actually used.

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Building Bayesian belief networks to express the cause and effect relationship for dietary intake and pregnancy

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Introduction: The purpose of this report is to introduce a new major medical study that has just started at the Royal Victoria Hospital (Belfast) and justify a proposal to engineer Health Information Systems, specifically utilising AI & statistics. Bayesian belief networks (BBNs) will be the initial technique applied.

The multi-centre NIH funded HAPO (Hyperglycaemia and Adverse Pregnancy Outcome) Study will involve the enrolment of 1500 pregnant women. Each person will be interviewed at 28 weeks gestation for completion of a food frequency questionnaire. The main objectives of the study are to investigate the dietary intake of the pregnant women and consider the effects of their diet on various aspects of pregnancy outcome.

In AI, Rule-based Expert systems have achieved much success in the medical domain [1] largely because the decisions obtained can be traced and understood by domain experts. However, their development has suffered due to the "knowledge acquisition" bottleneck, their inability to handle uncertainty and the "maintenance burden" [2]. Other AI techniques have been presented as alternatives for instance neural networks, but clinicians and healthcare providers have shown reluctance to accept these. Neural networks use a black box approach providing little insight into how the overall system works and thus leads to a possible lack of confidence in the decisions made [3].

Methods: BBNs are statistical graphical models that provide a framework for describing and evaluating probabilities when there is a network of interrelated variables. A key feature of BBNs is their ability to represent causal relationships between variables and therefore ideal for representing causal medical knowledge [4]. Not only does such a causal model potentially overcome the disadvantages of other AI approaches, but it also provides a great communication tool between medical and non-medical researchers due to its graphical nature. It is this visual representation that makes a BBN more acceptable to clinicians as it provides a better insight into the understanding of how the model works so that a clinician or manager can view the whole process, and thereby have more 'trust' and see more value in the decisions made.

We wish to take advantage of this synergy of understanding, by using the BBNs not only as a tool for the representation of a final model but also as a research development technique, potentially uncovering knowledge (causal theories) which are unknown as of yet.

Results: The medical study has now commenced with the first set of participants' details being recorded. A BBN is being derived in the first instance from analysing the research literature and study questionnaires for implicit causal relationships, to be followed by a second derivation of a BBN from the experts involved in the study. For example a simple causal relationship from [5], which may be a valid component of the final BBN model can be expressed (fig. 1) in graphical form. As the data collection continues, it is planned that learning algorithms will be used to induce a BBN from the data alone, allowing comparative investigations to be made.

Summary: In this presentation, we have introduced plans to utilise AI and statistical techniques in analysing a new medical research project concerning the causal relationships within dietary intake and pregnancy scenarios. The data collected during the life-span of the project will offer many opportunities for the development of Health Care related systems around the study, for example diagnostic and predictive systems can be enhanced by utilising AI techniques such as knowledge discovery and data mining, probabilistic reasoning and others. The technique being used initially is a BBN, an established technique, derived from probability theory, that can deal with uncertainty. Due to its graphical nature, it is also ideal for communicating the causal relationships under research.

References

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Predicting patient survival using Bayesian belief networks

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Introduction: The proportion of elderly people in the population has dramatically increased over the last century. This ageing population puts increasing demands on the limited medical resources. In order to efficiently manage and allocate medical resources, hospital managers require accurate bed usage measures. Several attempts have been made in the past to model patient behaviour, many of which have been time-consuming and costly requiring a lot of data. A more realistic approach is to model patient duration of stay in hospital.

Recently, Bayesian belief networks (BBNs) have been used to perform a survival analysis of elderly patients in hospital [1]. In this presentation we report on the application of such BBNs to model the duration of stay of patients in geriatric hospital.

Methods: BBNs are statistical graphical models which encapsulate causal information and provide a framework for describing and evaluating probabilities using a network of inter-related variables. A BBN consists of a set of random variables (nodes) and a set of relationships between the variables (arcs) where each variable has a finite set of mutually exclusive states [2]. Directed arcs (arrows) between nodes represent the probabilistic relationships between the variables which together form a directed acyclic graph (DAG). The networks are based on Bayes Theorem which provides the conditional probability that an event occurs given that some other prior event has already happened.

Phase-type (Ph) distributions [3] are a special type of Markov model which provide an intuitive and robust way of describing probabilistic processes. They describe the time to absorption of a finite Markov chain in continuous time, where there is a single absorbing state and the stochastic process starts in a transient state [4].

In this work we combine the advantages of BBNs in incorporating the model with the elegant and intuitive process representation of phase-type distributions. The discrete variables and their dependencies are represented in a causal network which feeds into a phase-type distribution representing the process. In this presentation, the continuous variable is the time that a patient spends in hospital (fig. 1).

The data analysed in this application has been taken from 'CLINICS', a clinical computer system used in elderly care at St George's Hospital, London. Patient information was recorded for a total of 4730 patients between 1994-1997. The personal details, admission reasons, and patient outcome form the causal network and the *length of stay* of patients in hospital the process model.

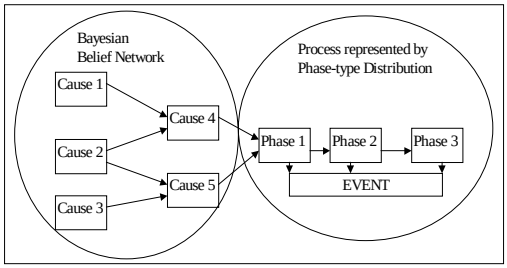

Fig. 1: General case BBN model with phase-type distribution.

Results: In general, the maximum likelihood function of the BBN model may be described by the following formula

$$L = \prod_i P(C_i \mid pa(C_i))^{n_i} \prod_i f_i(t_i)$$

where the causal nodes in the network are defined as $\mathbf{C}=\{C_1,\ldots C_m\}$, $pa(C_i)$ is the parent set of C_i, f_i represents the probability density function of the phase-type distribution with i representing all possible levels of the causal variables contained in the BBN. An example of the nature of a BBN model achievable from the above methods is included below. The model considers the duration of stay of elderly patients given that we know their gender and whether they suffered a stroke. This simple model is illustrated in fig. 2 where the causal network consists of two nodes *Gender* and *Stroke* and the process model represents the continuous length of stay in hospital. The joint probability distribution of the BBN model is displayed in Table 1.

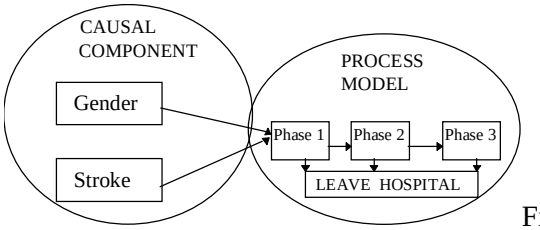

Fig. 2. Example BBN model

Table 1: The joint probability distribution of the causal network

Stroke?	Male	Female
Yes	0.0618	0.0450
No	0.9382	0.9550

Summary: In this presentation, we have introduced a particular type of model to describe local dependencies in relation to a stochastic process. Our resulting BBN model is hybrid, in that we use discrete variables for the causal model and a continuous variable for the stochastic process, represented by a phase-type distribution. A simple example is taken from the analyses to demonstrate this concept.

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An Internet-based project All-Net: technology of scientific collaboration

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Introduction: The All-Net project forms part of the INCO-Copernicus actions (PL 977135) of the Health and Telematics Program of the 4th framework R&D program of the European Union. Its main objectives are:

To produce an Internet-based multilingual, dynamic textbook of intensive care pediatrics

To develop the methodology for Web-based scientific educational tools that can serve as template for future similar efforts

To demonstrate collaborative techniques for the educational, scientific and telematics communities

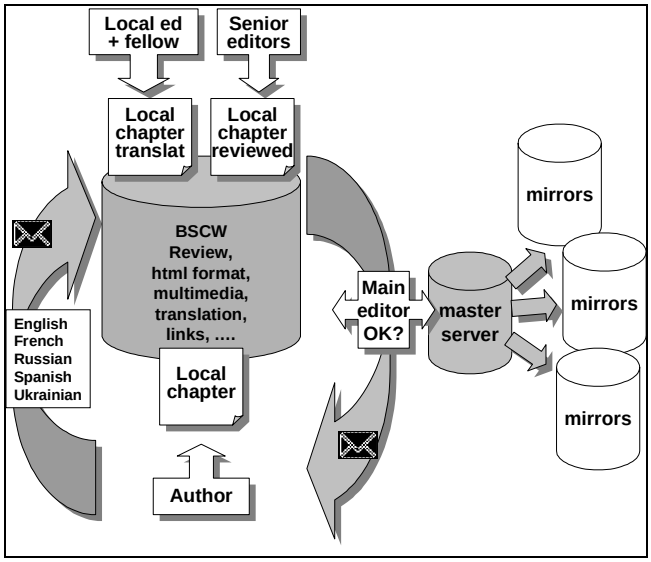
To help into the establishment of original web sites in the project sites of Eastern European countries

The project began during 1999.

Materials and Methods: Seven teams were engaged in the project from the countries and institutions listed in the authors affiliation subtitle of this paper. All of the teams have a senior editor who is the scientific responsible for the specific medical subjects, related in this case to the field of Pediatric emergencies and critical care. Four teams have also technical personnel involved in the project, in order to cover the different aspects of it.

The first approach was done using the general purpose tools based in the IP protocol: personal email as main communication tool, an email distribution list, and a master web-site for the resource accessed via FTP. Also it was accorded an style for documents with fully multimedia incorporation. The HTML pages are classified by the different languages used in their writing and by a clinical criteria according to the system more closely related with the information offered in them. In order to make the translation job as much as easy as possible, the directory structure is maintained identically and also with the same name in English language in all the html directories and subdirectories. This allows to maintain the internal consistency of the links and use the media shared directory.

For the purpose of collaboration improving we introduced a new model of workflow process with a key tool BSCW© (Basic Support for Cooperative Work - URL http://bscw.gmd.de/). The BSCW is accessed only by user registration invited by the General Manager of the project who can control the levels of access. Any action done upon it is registered and it can be daily emailed to the users. It allows to store in a common and shared place on the net any kind of documents, notes and links. FTP is pretty integrated with the web interface with an easy “drag and drop” icon. The documents can be put under branch and version control. This allows for the All-Net project to incorporate any material into the production folder of the BSCW and left it for reviewing by the senior editors and for translating by the fellows as it shows the Figure.



Results: There are about 61 completed chapters many of them from the US collaboration. There are also 80 committed chapters coming from all the partners. Some of them have been delivered, mainly in word-processor format. These materials are being reviewed by the senior editors, enhanced with multimedia or hypertext links and translated from the local language into English by the fellows contracted with the project funds. Statistics of the resource show the following data:

Total number of files: 2256, size: 59493 Kb
Number of Image files: 989; size 14500 Kb
Total number of links: 51415;
Number of external links: 18258
Number of internal links: 33157
The Websites actually in use can be visited at:
http://pedsccm.wustl.edu/All-Net/main.html
http://www.med.ub.es/All-Net
http://picubook.fbm.msu.ru/All-Net/main.html
http://www.univer.kharkov.ua/PICUbook/

Conclusions: The new technologies are changing the classical paradigms of learning, teaching and research. Internet, as a new multipurpose media, offers an incredible amount of possibilities not imagined before. But the search of the best ways to put them in practice needs more research, development, testing and evaluation. Our project shows how easy is to think globally and how difficult is to act locally. Nevertheless, in spite to change the approaches for the achievement of the goals of the project, each step done has improvements that can be useful for other teams searching the same. Those efforts must allow the clustering between projects and create synergies to establish a consolidated and efficient methodology.

Session – Computers in Medicine
Room 1, Thursday 3 May, 16.15-17.30

Uroembryology: The millennium modality

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Concept: Subjects such as molecular biology, embryology and reconstructive surgery require concentration, imagination and three-dimensional visualisation to understand, interpret and assimilate. A programme has been designed on a CD Rom, which gives information on Genito-Urinary Embryology in a user-friendly method which is easy to assimilate.

Technology: The current 3D animation uses a variety of software tools to produce a 1000 frame. FLC file at 640 X 480 resolution. The principal tool used was soft F / X, a sophisticated 3D rendering and animation solution for the Microsoft windows environment. A number of 3D CAD solid and

surface models were created and imported into soft F / X using the STL format. These triangulated meshes were extensively deformed to create key frame versions of the various organs, which the software then morphed over a range of frames creating the impression of natural growth. Scanned artwork was superimposed on the outline of the human embryo to give a reference location for the developing organs.

Product: The CD ROM is designed to run in Microsoft PowerPoint. Buttons show up at points of maturation arrest or developmental anomaly which on clicking would guide the user to a different screen having details of all the anomalies concerned. The programme ends with practice MCQ questions and answers. The entire explanatory part of this programme is in a 3 dimensional format with movements, rotations and structures reaching out to each other now becoming a virtual reality.

Future: The work done so far shows the value of 3D modelling as an aid to better understanding and visualising but is limited as it can only run as a predefined motion. More work is being done to make the programme interactive using VRML (virtual reality modelling language) a powerful and interactive 3D virtual world environment. Objects will have assigned actions that can be triggered by user interaction. The user will be able to change his viewing position (in real time) as events develop. Existing VRML plug-ins for common web browsers will allow the delivery of these simulations over the Internet. Further versions will feature 3D animated programmes for reconstructive urology and molecular biology for the Urologist.

A labview program for measuring auditory evoked potentials

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Introduction: Auditory evoked potentials (AEP) are signals that reflect the central nervous system (CNS) after an stimulus has been presented to a subject These signals are embedded into the electroencephalogram (EEG) and can be recorded at the scalp using surface electrodes. They are used in various clinical applications, such as detection of lesions in the auditory pathway. Another application is monitoring of depth of anaesthesia in patients during surgical operation [1-2].

We present a system used for acquisition, extraction, drawing and storing AEP. It is a modular and ease-of-use system. There are two main blocks: the hardware block, which implements the acquisition and data conditioning of the EEG, and the other one, the software block, which controls the hardware, extracts and stores the AEP. The stimulus is generated by this block, which has been developed in LabVIEW [3].

An example of the acquired signals are shown here.

Actually, this system is being used successfully in the monitoring of MLAEP durring surgical operations with general anaesthesia.

Methods: The hardware block of this system is composed by the MP100 system (Biopac Systems, Inc.) and its modules for acquisition and data conditioning of evoked potentials and the stimuli generator. It contains a 32Kbytes buffer for storing samples and a microprocessor which communicates with the software block. The input gain can be 5000, 10000, 20000 and 50000. Analog

high-pass filters (1Hz and 30Hz) and analog low-pass filters (3kHz and 10kHz) are included. The stimulus level can be adjust manually or by the software.

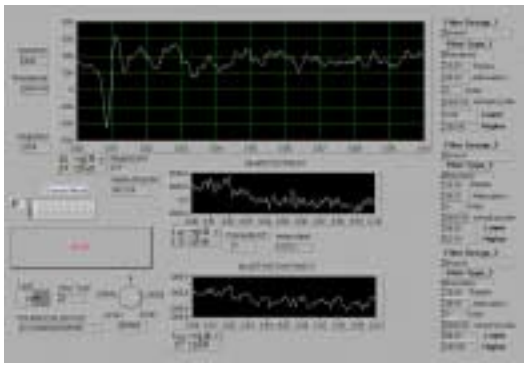

Fig. 1 Main screen of the software block developed in LabVIEW.

The software block has been developed in LabVIEW (National Instruments), a graphical programming language which lets the user create 'virtual instruments' and controls data acquisition systems. Drivers delivered by the manufacturer are used for the communication between both systems. In Fig. 1 we can see the main screen of the program.

We can choose the number of channels to be acquired, the sampling rate, the temporal window, and the number of EEG epochs to be averaged for extracting the AEP. The stimulus level can be adjusted in 1 dB steps. We can use a digital filters bank when we needed it. It is possible to select a file for storing acquired data.

The raw EEG and the latest EEG epochs are displayed. The AEP are extracted using a moving average technique. Besides, another extraction technique, based in the ARX model, are being developed.

An epoch rejection algorithm is included in the extraction of the AEP. An epoch containing a voltage value that exceeded a user-defined threshold is eliminated. We have implemented an algorithm for the calculus of an index of depth of anaesthesia using the AEP. For the application noted above.

Results: The AEP are obtained using Ag-AgCl surface electrodes, placed in the right mastoid, (+), and the middle line of the forehead (-) and Fp2 as the reference. In Fig. 2 we represent an example of the signals acquired.

Discussion: The presented system facilitates the acquisition, drawing and file-storing of the AEP. This system is modular and easy to use. Any algorithm you can think of is able to be incorporated to the software block.

Nowadays, we are trying to improve the both blocks. New analog filters are being designed and developed. Another AEP extraction algorithm, based in the ARX model is being programmed and new analysis methods are being studied. These methods, which include complexity analysis and entropy, can be used, in the study of the EEG of patients under determinated conditions.

Finally, notice the monitoring of depth of anaesthesia during surgical operation with this system has been successful.

As can you see in Figure 2 the displayed evoked potential is a MLAEP. Its duration is 100 msec. The sampling rate is 6kHz, and it is extracted from 512 epochs of raw EEG. The duration of the stimulus is 1 msec. and the frequency is 7.5Hz.

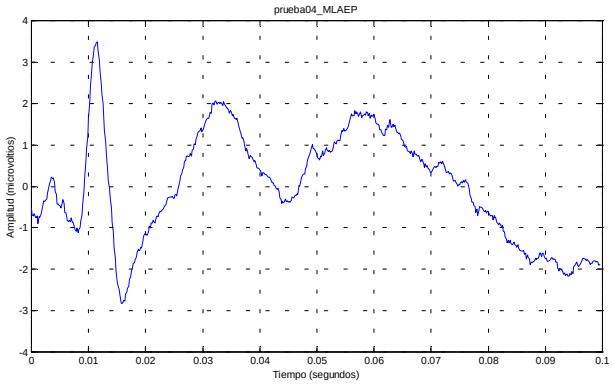

Fig.2 Graphical representation of the MLAEP.

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First clinical experience with a personalised titanium membrane for bone reconstruction in tumour surgery

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Introduction: Large bone tumours may occur in the extremities just adjacent to the joint surface. The surgical treatment consists of two stages: removal of the tumour and reconstruction of the defect [1]. A window is made in the cortex and the tumour is excised. Then the remaining cavity is filled with bone cement or bone grafts to restore the bone. Although surgeons usually get good results, there are still improvements possible. A better containment or even pressurisation of the filling material in the cavity would be a major pro. Also a restoration of the cortical surface, hence adding a significant amount of strength would make an early normal functioning of the patient possible.

Therefore we introduce a custom made pre-formed titanium 'membrane' (fig. 1) to be fixed to the periosteal surface of the bone around the cavity with a number of small screws. The aim of this study is first to look to the design and the biomechanical evaluation of such a titanium membrane and second to discuss the clinical application of the titanium membrane for the reconstruction of a juxta-cortical chondroma of the left distal femur.

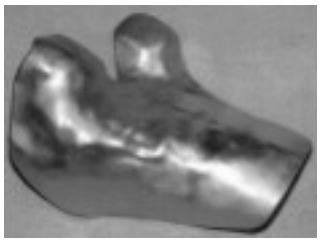

Fig.1. Titanium membrane

Methods: Titanium is chosen as implant material because of its established biocompatibility and because it allows the use of medical imaging for post-operative follow-up.

Based on the CT-scans (2 mm slice thickness) of the affected bone, a 3D-computermodel of the bone with tumour is created, which uses the surgeon to plan the cortical window and the bone to be resected during surgery. Then using CAD techniques the membrane is designed so as to reconstruct the cortical surface. The titanium membrane is produced using rapid prototyping technology and hydro forming. Also a transparent Perspex membrane is made on the same mould as a trial model for per-operative use.

A biomechanical evaluation of the design was performed to define the design parameters: membrane thickness, surface macrostructure, and number and diameter of screws required to fix the membrane to the bone. Therefore experiments were performed to determine:

-the critical pressure load that starts the buckling of the membrane,

-the force at which a perforation in the membrane ruptures,

-the shear load a screw can withstand.

Results: From the performed tests it appears that a titanium membrane of 0.3 mm thickness, fixed with 7 trabecular screws (4 mm diameter and 28 mm length) is capable of carrying the mechanical loads during normal daily activities.

For safety reasons a 0.4 mm thick titanium membrane was chosen for the first clinical application. Through a medial incision the tumour in the left distal femur was resected en-bloc. The titanium membrane was placed on the bone to control the fit. This evaluation being positive, the transparent membrane was used to check the overlap and to determine the final shape. The titanium membrane was cut to this final shape and the holes for the screws were punched out. Bone grafts were pressed in the cavity and then the membrane was placed on the bone and fixed with the screws.

The post-operative CT-scan showed that the tumour was fully resected, that the titanium membrane fit perfectly onto the remaining cortical bone, that the tumour cavity was well filled with bone grafts and that the membrane was well fixed with the screws.

Discussion: The risk of drifting of the bone graft into the joint space is eliminated for a patient with a tumour treated as earlier but reconstructed with a custom made titanium membrane. In our limited experience the membrane did not reduce the mobility of the knee and the post-operative revalidation was promising. This membrane is designed and produced pre-operative, hence the surgical procedure

is not complicated. Although the gross shape of the implant is defined pre-operatively, the surgeon is not restricted regarding the removal of the tumour, because a per-operative fine-tuning of the implant shape and punching of the screw holes is possible. The membrane provides a pressurisation of the bone graft, hence a better contact of the graft to the walls of the cavity, which leads to a good ingrowth.

The introduction of a medical image based, preformed titanium membrane may well contribute to enhancing the quality of bone tumour surgery. It is a new application of computer aided surgery principles to custom implant design and production.

Acknowledgement

This research was performed in the Brite Euram project PISA (NR. BRPR CT97 0378).

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The application of pressure mapping techniques to evaluate commercially available pressure relief cushions

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Introduction: Pressure sores present a major problem for people with reduced mobility (Shappcott and Levy, 1999). Many factors contribute to their development, with high interface pressure being the predominant cause (Veit, 1999). Pressure monitoring of this interface between the body and support surface is important in the continual assessment of tissue viability (Veit, 1999). That is, to identify those most 'at risk' from pressure sore development and to assist in prescription of pressure relieving cushions. This may be achieved through the use of pressure mapping techniques. One pressure mapping system. The Force Sensing Array (Vista Medical, Winnipeg), has been favourably described by several authors in terms of easy calibration, operation and data management, and reliable measurement (Ferguson-Pell and Cardi, 1992 and 1993; Ranalli and Moynahan, 1997; Scott et al, 1999).

Aim: The aim of this study was to evaluate the pressure relieving properties of a range of 6 commercially available pressure relieving cushions using the Force Sensing Array pressure mapping system.

Method: Six cushions were selected for pressure mapping testing. Cushions made from foam, polyester fibre, visco-elastic foam and air were chosen on the basis of being commercially marketed as providing varying levels of pressure relief ranging from 'low', 'medium', to 'high'.

Forty non-disabled subjects took part in the study. Pressure measurements were recorded with the participants seated in a non-adjustable armchair. Participants were seated in a relaxed position with 900 flexion at hips, knees and ankles, with their arms placed on their lap. Feet were supported if necessary.

During assessment, the pressure mat was placed between the participant and each of the six cushions in turn. Interface pressure in the form of Average and Maximum Pressures (the mean of the sensor values and the highest individual sensor value respectively) were recorded at two minute intervals to a maximum of eight minutes.

Analysis: Statistical analysis in the form of a Repeated Measures ANOVA was performed using the Statistical Package for the Social Sciences (SPSS, version 9.0), to compare changes in both Average Pressure and Maximum Pressure between the different cushions tested after an eight minute sitting period. The distribution or spread of pressure beneath the buttock and thighs was also analysed using a Repeated Measures ANOVA technique. This compared the mean number of sensors activated by participants making contact with the mat for each of the six cushions tested.

Result: This study provided results to challenge traditionally held beliefs about pressure relieving products. That is, the commercial cushions being marketed as offering 'medium' or 'high' levels of pressure relief, frequently demonstrated poorer Average or Maximum Pressures than those cushions made from polyester fibre or foam which are currently marketed as providing 'low' levels of pressure relief. Similar results were also evident in terms of pressure distribution analysis.

Conclusion: This study demonstrated the usefulness of a pressure mapping system in evaluating commercially available pressure relief products. A replication study is planned using a cohort of disabled subjects at risk of developing pressure sores in order to ascertain whether similar results would be found. If this is the case, the Health Service (and others) could make cost savings when planning their pressure care strategies and purchasing pressure relief products, and patient care could be enhanced by the use of such systems.

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Introducing a clinical information system: re-engineering patient care in cardiac surgery

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St. James's Hospital Dublin has recently opened a new Cardiac Surgery Unit consisting of a six bed I.C.U., an associated fifteen bed ward area and two operating theatres. As in other theatres and intensive care units, the staff in the new Cardiac Surgery Unit record and maintain very extensive clinical records for each patient. Although much of this patient data is derived from physiological monitoring equipment, it is normally entered manually in the patients notes, mostly by nursing staff. In addition extensive information on drug prescriptions, pathology tests, personal data, care planning and clinical course are normally entered manually into the patient notes by other healthcare professionals. This new development offered an opportunity to implement a clinical information system within the Cardiac Surgery Unit. Such a system interfaces with other hospital information systems, electromedical equipment and automatically records and processes patient data. The potential benefits of the system include: improved quality of care, particularly with regard to patient risk management; reduced nursing time spent on charting; facilitating clinical and financial audit consistent with best practice in the area; reduced exposure to allegations of medical negligence; improved education and training facilities; enhanced facilities for clinical research regarding benefits from various patient management approaches, development of objective measures of patient clinical status etc..

Such systems demand that users review established ways of working, change some aspects of current practice and invest in staff training. Those clinicians, nurses and paramedics who are currently acting as decision makers are well trained in the medical sciences, such as physiology, biochemistry and anatomy, and understand the theories behind the measurements they use. However, they may have had very little training in information technology and system science. The idea of getting more information from patient data by means of computer technology is not familiar to most of them. For the implementation of a clinical information system to be successful, it requires that the combined skills and knowledge of computer scientists, clinicians, nurses, paramedical professionals and researchers be brought together in a harmonious collaborative effort. Consequently, the implementation such a system includes not only the purchase of hardware and software systems but also re-engineering the Theatre/ I.C.U. process.

The project to implement a clinical information system took approximately two years from initial project proposal to the 'Go-Live' date. Key to the success of the project was the management approach taken. Rather than view the project as implementing new technology, the focus and goal was to re-engineer the care process in a way that was consistent with maintaining optimum patient care, while facilitating extensive data capture. In this way, the project developed a multidisciplinary team who have developed and taken ownership of not only the new technology, but also the new way of working. This team was established early on and has strong contributions from Surgical and Anaesthetic Medical Staff, Senior Nursing Staff, the Hospital's IT Department and Medical Physics and Bioengineering Department. The project was led by a Senior Clinical Engineer from the Medical Physics and Bioengineering Department, who have extensive experience at introducing new technologies into the clinical environment and also of facilitating the work of multi-disciplinary teams.

The solution was implemented using the CareVue® System from Agilent© (Hewlett Packard©). Rather than buy a solution off the shelf, the hospital bought the technology, software and consultancy it needed to develop its own solution based on the Agilent© hardware and software platform. This required the hospital multi-disciplinary team to work in partnership with the supplier at all stages of development.

This paper presents a review of the implementation process which identifies what we consider to be the critical success factors for the project. In particular we discuss the challenges experienced by individuals from different organisations and backgrounds in working outside their normal professional boundaries; the relationship between objective information and clinical decision-making; changes to working practise necessitated by the re-engineered approach; patient management questions and issues of confidentiality highlighted by the change process. The paper emphasises the need for sensitive and careful management of all of these various strands to the implementation process, and thereby provides many useful guidelines for the successful introduction of new information technology into clinical practice.

Session – Technology for Assessment & Homecare
Room 1, Friday 4 May, 09.00 – 10.30

Application of image analysis to detection of tubercle bacilli in stained human sputum

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Computerised image analysis has been in use for some years in medicine, with the automated system for examination of cervical smears now licensed for clinical use in the US. Most microscopy uses colour stains. Colour imaging requires much more powerful computing capabilities than grey-scale, and to date there has been no application of colour image analysis in medicine.

Current automated techniques for TB diagnosis take up to a week, but in some cases an immediate diagnosis is essential. The Mycobacterium tuberculi is small, approximately 3µm by 1µm. Identifying the bacillus on stained specimens where there is heavy contamination is not difficult, but with sparse contamination finding the occasional bacillus may prove problematic. Computerized colour image analysis technology was used to develop a semi-automated method of examining stained smears of human sputum for Mycobacterium tuberculosis.

Hardware included an Olympus microscope with an automated stage, 3-chip JVC Video camera, Digitizer Card and Pentium II 200/192 running Windows NT4.0. The main software used was Optimas, an imaging application written in ALI (Analytical Language for Imaging), an interpreted language with syntax similar to C.

+ve and -ve controls and 17 test smears of human sputum were received blindly from the Microbiology Laboratory of the Mater Hospital, who had a definitive Bactec diagnosis on each.

Using the control specimens, the system learned the RG&B pixel values of bacilli (+ve pixel values). The 17 test smears were analyzed. On the automated stage at predefined coordinates, the microscope stopped, was focussed and the image grabbed. The image was checked for +ve pixel values. It binarized the image showing positive pixel values as white. The programme then subtracted

1 from all pixel values (so the black became -1), and counted the number of pixels with a positive value.

If there were more than 5 such pixels this was identified as a positive field and the stage coordinates exported to Excel. All the "positive" fields were reviewed.

Seven of the specimens were classed as "positive" by the computerized system. After microscopic review, technician was uncertain of diagnosis on Specimen L.

The Laboratory confirmed six of our +ve specimens. All -ves correlated. They reviewed Specimen L and reported the staining acid-fast but not M. tuberculosis, and the Bactec culture negative.

Computerised grey-scale image analysis is well established clinically in the examination of cervical smear specimens. This study demonstrates that semi-automated colour image analysis can be used to examine stained smears for tubercle bacilli and this could be a model for other microbiological work. This is we believe the first application of microscopic digital colour image analysis in medicine.

Computing power, both in terms of chip speed and storage capabilities have increased enormously in the recent past. Colour image analysis is now technically feasible and can make an important contribution to clinical pathology.

Ultrasonic velocity of uterine tumours

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Background: Velocity of propagation of ultrasound is required to be studied with respect to density and elasticity of the transmitting medium [1-4]. In an organ such as uterus, average velocity is related to the density and elasticity of its tissues and when abnormality arises average velocity may change. The loss of energy in the tissue medium is also an important parameter, which is estimated in terms of attenuation. Thus the purpose of the study is to determine if such measurements could provide data which would characterize the tissue present in the uterus (in this case Leiomyoma, a type of solid tumour). The average velocity and attenuation of the particular leiomyoma samples used here, are found to be 1535.25 ms^{-1} and 624.8 dBm^{-1} respectively at 3.5 MHz frequency.

Material and Method: Several samples of uterus tumour (Leiomyoma) and normal uterus of human females of age between 40 to 45 years (paramenopausal age group) have been collected from King George's Medical Hospital, Lucknow, India. Six samples studied here were 2 to 4 months old from different patients. Parallel sections of these samples were made by using a sharp knife so as to make proper contact with the ultrasonic transducers. Samples when taken from hospitals were preserved in 10% formaline solution.

A double-probe through-transmission technique was used to avoid multiple reflections, scattering and energy loss, which are the problems with single-probe-pulse-echo technique. The sample was kept between two-matched ultrasonic transducers, T as the transmitter and R as the receiving transducer, of the same frequency (3.5 MHz). An ultrasound jelly was used for better coupling as well as for eliminating air pockets, if any. The samples were kept in the near field of these transducers. An ultrasonic pulser-receiver (Panametric model 5052 PR) was used here to excite both the transducers in continuous wave (CW) mode. Ultrasonic waves passed through the specimen and pulse transit time for known propagation distance was measured from the calibrated cathode ray oscilloscope screen that gave a direct measurement of the velocity and the attenuation. By knowing velocity, other parameters

like acoustic impedance ($Z = \rho v$), dynamic modulus of elasticity ($E_d = v^2\rho$) and compressibility ($\beta = 1/\rho v^2$) were also determined. Here v is the ultrasonic propagation velocity and ρ is the density of the sample, (measured by Archemede's principle), in this case *in vitro* uterus tissue specimens. The attenuation coefficient α was calculated by using $\alpha = (20 \log V_1/ V_2) / d$ where V_1 and V_2 are the amplitudes in terms of voltages of the reflected signal with and without the specimen of the uterus tissue having a thickness of d.

Discussion: The average values of ultrasonic parameters for selected six samples of uterine tumours and particular normal uterus sample, are shown in Table 1 Measurements were taken in different directions of the sample, almost five times in each case and then average of all the readings is taken as measured value. Ultrasonic velocity of the normal uterus sample has been found as 1551.17 ms^{-1} and attenuation as 246.5 dB m^{-1} . In tumour samples, the velocity has been found to vary from 1466 ms^{-1} to 1590.91 ms^{-1} and attenuation from 326dBm^{-1} to 1065 dBm^{-1}. A large variation observed in these results is due to the varied structure of the connective tissues and chemical constituents of the specimens, as each specimen is from different human females and abnormality changes from specimen to specimen.

Table 1: Average ultrasonic parameters of uterus specimens at 3.5MHz

Sample Code	Density ρ 10^3 kg m^{-3}	Velocity v ms^{-1}	Acoustic impedance $Z=\rho v$ 10^6 kg $m^{-2}s^{-1}$	Dynamic modulus $E_d=\rho v^2$ 10^9kg $m^{-1}s^{-2}$	Compress-ibility $\beta=1/\rho v^2$ 10^{-10} ms^2kg^{-1}	Attenuation α dBm^{-1}
+ U1	1.0391	1466.00	1.5233	2.2332	4.4779	995.0
+ U2	1.0547	1509.43	1.5920	2.4030	4.1614	333.0
+ U3	1.0569	1578.94	1.6688	2.6349	3.7952	482.0
+ U4	1.0559	1538.46	1.6247	2.4991	4.0014	548.0
+ U5	1.0569	1590.91	1.6815	2.6751	3.7382	1065.0
+ U6	1.0571	1527.77	1.6150	2.4673	4.0530	326.0
++ UN	1.0440	1551.17	1.6194	2.5120	3.9809	246.5

+ Uterine Tumour Sample, ++ Normal Uterus Sample

Attenuation in tumour samples has been found more than that of the normal tissue sample. The attenuation was found larger in first sample (U1) with spongy feature and in the fifth sample (U5) which is one of the hard samples. Ultrasonic propagation velocity in the same sample (U5) has also been found to be maximum (1590.91 ms^{-1}). These results explain the haphazard and unrestricted growth of the soft tissue of the uterus. As all the samples were formaline fixed in the present

investigation, as reported earlier, the propagation speed has been found to decrease by 10 ms^{-1}, with formaline fixing.

Conclusion: Ultrasonic parameters in different specimens of uterine tumour have been determined. The average velocity and attenuation have been found as 1535.25 ms^{-1} and 624.8 dBm^{-1} for the particular samples used. The data obtained may be useful in investigating the abnormality in the uterus as compared to the normal one.

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Assessment of leg ulcer color images through digital image processing

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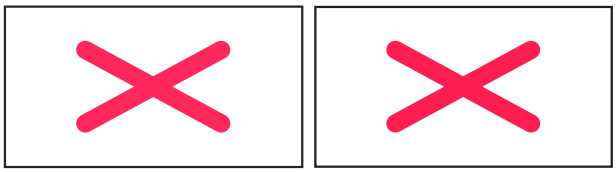
Introduction: Leg ulcers are wounds who origins can be arterial, venous or diabetic [1]. Three main tissue types are found in the wound site: granulation tissue, which has a reddish hue, slough or exudate, which is creamy yellow and necrotic tissue, tending to black [2]. One aspect that had to be considered, is the fact that the exudate mixes with the granulation tissue, forming regions where exudate cover the granulation tissue. This form layers of The methodology consists in segmenting the leg ulcers images followed by a tissue analyzes algorithm. The segmentation aims to delimit the wound site to evaluate the tissues inside that. To reach different thickness where the under granulation tissue can be seen more or less easily.

Taking in consideration the mix between the granulation and slough, the quantitative analysis of the two wound tissues cannot be a simple separation of they in two classes. A more sophisticated technique should be used. The algorithm presented, attempts to solve this problem and it is divided in two stages: segmentation and tissue analysis.

Methodology: The first step consists in a calibration algorithm. The goal is to normalize the image colors, correcting variations introduced in the acquisition stage. The figure 1 shows a leg ulcer image before and after calibrated. After calibrating, the median filter is applied in the R,G and B channels with the purpose of noise removal. The segmentation consists in the automatic choice of the color channel that had better conditions to be segmented. Six channels are analyzed which are: R,G and B of the RGB color space and the H, S and I of the HSI color space. The chosen channel is the channel with most contrast between the wound and background and less standard deviation in the wound site. To determine what is wound and background, the software user's selects with the mouse a rectangular region inside the wound and three regions outside. After that, the image is segmented with a region growing algorithm [3].



(a) (b)

Figure 1. (a) Result of the wound acquisition in bad illumination conditions. (b) The same image after calibration.

The segmentation finishes with the labelling algorithm, used to eliminate objects that don't belongs to the wound. Some results of the segmentation can be seen in figure 2.

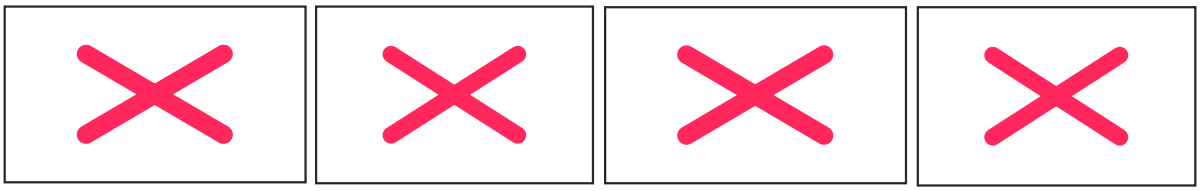
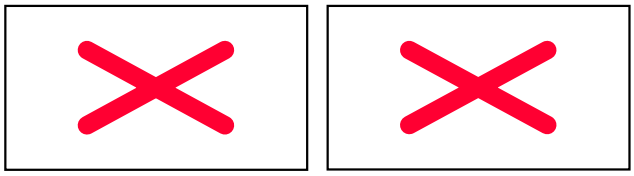


Figure 2. Examples of segmented images of leg ulcer patients

After segmenting, the wound inner tissues are analyzed with an algorithm that apply triangular functions in the R,G and B channels separately. To generate that function, some samples of granulation tissue and slough, from many patients images, are acquired. The RGB histograms of that samples are analyzed and the triangular functions similar to the histograms shapes generated. Two functions are created for each channel, the first function analyzes the granulation tissue and the second the slough tissue. To analyze quantitatively the wound tissues, the functions attributes weights to each pixel. The weights indicates the membership grade of the pixel to the tissue being analyzed. Figure 3 shows an image before and after processed to analyze the slough tissue. Finally, the images are transformed to graylevel in his pixels are counted.



(a) (b)

Figure 3. (a) Leg ulcer image after segmented. (b) The same image after processed by the slough analyzes algorithm.

Results: Obtained results from analyzed images, compared with clinician diagnosis, had show the efficiency of the presented methodology. Figure 4 shows the granulation growth rate compared with slough growth rate. It can be seen in the figure, that the two tissues are always growing. This is due to the fact that the size of the images are out of scale. However, the growth rate of the granulation tissue is greater than the slough growth rate, this means that the patient is healing.

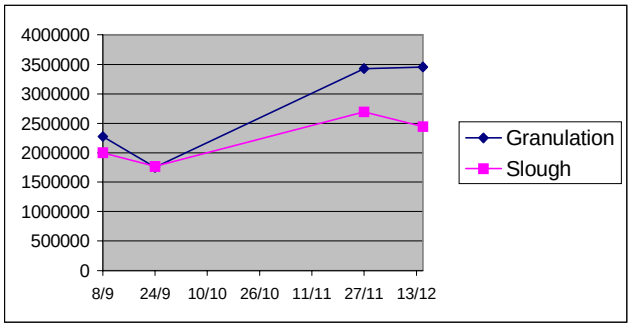


Figure 4. It can be seen in the graph that the granulation growth rate is greater than slough rate. The image shows the methodology results obtained from 4 images of the patient 13. According the clinicians, this patient has presented improvement.

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Development of a multimedia software application to help carers cope with caring problems

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Introduction: When caregiving is needed, family members provide most of the support, yet, frequently find that they are unprepared for their new roles (Kellett & Mannion 1999). Research has indicated that carer support enhances care competence and reduces the need for hospitalisation and intervention from health care professionals (Nolan *et al.* 1996). While the stress and burden involved in being a caregiver has been well documented, little research addresses how carers cope with emergency situations. This presentation describes the development of a multimedia program to provide carers with information and education to assist them in preparation for crisis situations. The software application was developed as a part of ACTION (Assisting Carers Using Telematics Interventions to meet Older persons' Needs), an EU funded project involving Sweden, Northern Ireland, England, the Republic of Ireland and Portugal.

Methods: Three distinct qualitative research techniques were use in the development process – focus group discussions, individual interviews and critical incident technique. The software application was developed in two stages – focus group discussion to identify the needs of users and individual interviews to further develop these needs. Five focus group discussions were conducted across the partner countries with the purpose of identifying common emergency situations, how carers would respond and how their thinking helped them to cope. The resultant preliminary data was used to construct an interview schedule for fourteen individual interviews. A modification of critical incident technique (Flanagan 1954) was used to focus the attention on particular crisis situations, or critical incidents.

Results: Carers described their decision-making process, how they responded to a crisis, how they approached solving ongoing problems and what information they would find helpful. Particular issues which emerged were how to cope with everyday caring problems such as pressure sores, the need for advance preparation for certain crisis situations such as falling or choking, and first aid training for a range of emergency situations.

Discussion: These findings were used to design a three-part multimedia software application to help family carers prepare themselves to deal with sudden, unexpected and difficult situations that may arise during their time as a carer. Experienced healthcare professionals developed the program, in consultation with skilled family carers, experts in the field and in accordance with appropriate EU legislation. The first section considers how other carers deal with caring problems. The second section provides information on three everyday caring problems – eating problems, pressure sores and feeding tubes. The third section introduces the main principles of first aid and gives information on how to put someone in the recovery position and deal with choking, bleeding and falling. The rationale behind the program is that carers should view the contents during quiet moments in order to prepare for a crisis. This information and education will help increase the preparedness of caregivers and have a positive influence on their self-efficacy and confidence.

The hardware consists of a multimedia Windows 95 or 98 PC with ISDN and modem capability connected into the TV of the patient's family, all operated by a handheld remote control. The ISDN card allows video-conferencing with professional staff and other carers using complimentary equipment. A small video camera and microphone/speaker completed the video conferencing arrangement. Access to the Internet is possible via the built in modem.

All information systems and presentations (incorporating pictures, diagrams, sound clips and video clips) were built using hypertext mark-up language (html). Macromedia inc. Shockwave player was used to present some of the custom built presentations that were then available via a www browser. Javascript programming language was used to improve overall control, presentation and assist user input. The system is menu driven and as far as possible images were used to compliment text instructions. To aid readability the amount of information displayed per screen was limited and designed with a tv as the viewing device. A switching program written in c++ programming language allowed the user to switch back and forth between the www browser and the video-conferencing system. All of this was achieved from the comfort of the users armchair by using the remote control.

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Technology to enhance the quality of life of family carers: the ACTION project

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Introduction: Increases in the older adult population are occurring concurrently with the growth of new technology (Campbell et al. 1999). In addition, older adults are often faced with chronic conditions that limit their ability to perform the activities of daily living (Zimmer & Chappell 1999). Action (assisting carers using telematics interventions to meet older persons' needs) is a pan-european project involving Sweden, Northern Ireland, England, the republic of Ireland and Portugal. The overall aim of the action project is to enhance the independence, autonomy and quality of life of frail older people and their family carers by offering information, education and support via information and communication technology (ict).

Within the action system, telematic technology along with the carers' own television and a remote control device, allows carers to gain access to educational and support material as well as communicate with professional carers and other family carers through a videoconferencing system. This presentation provides an overview of the research and development process of the action system and services.

Methods: During the first phase of the project focus group and questionnaire methods were used to identify the needs of the prospective users across the partner countries. These findings were used in the second phase to develop a series of multimedia programs, in consultation with family carers, professional carers and user representatives. In the third phase, verification, the ACTION system was tested in 13 health care settings and the homes of 20 families in four of the partner countries. This preliminary testing phase produced detailed feedback to improve the quality of the ACTION system. In the demonstration phase, a combination of qualitative and quantitative research methods was used to evaluate the system in terms of quality of life, user acceptance and usability. The prototype was field tested in 25 health care sites and 39 family carer's homes, and 1802 casual users completed evaluation questionnaires.

Results: Family carers identified unmet needs in the areas of practical skills based training in daily caregiving such as moving and handling and care of incontinence. They requested accurate, up to date information on social security claims and benefits and local respite facilities. Caregivers also expressed the need for psychological support in their caregiving situations. Five multimedia programs were developed covering these areas, which were modified according to user feedback. When this refined service was evaluated users rated usability of the system above average, particularly in relation to attractiveness, helpfulness and efficiency. Family carers felt that ACTION had improved their knowledge and skills and competence in their caregiving role. Family carers found the system easy to use after overcoming their initial reservations. They also welcomed the social support it provided and felt it reduced isolation and provided easier access to care professionals. They highlighted the importance of the early introduction of the service to new carers and having the system in an appropriate setting to ensure privacy.

Discussion: From these results it can be seen that the ACTION system enables the potential benefits of technology for frail older and disabled people and their family carers to be realised. Early access to the ACTION system enables family caregivers to have access to information, education and support to enhance their confidence in their caring role and help maintain the independence of the person they care for. Utilising the key outcomes of this research, the ACTION system and services are currently being exploited in the partner countries, across Europe and beyond.

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An IT approach to the control and management of medication in the home; requirements analysis

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Abstract: Many illnesses within the population are treated using orally administered prescription and non-prescription medications. Despite the prevalent use of such medications, patients frequently fail to comply with medication regimens, with the most typical failure being 'under' medication [0]. Hence, the need to provide a system capable of addressing and assisting this problem. It has been the aim of this study to identify all persons involved in the supply to intake chain of medication with the goals of obtaining requirements for future development of an IT based medication Care Model.

Introduction: Non-compliance or the lack of adherence to prescribed medication causes adverse effects on both patient well being and governmental health care costs ($100b). A significant number of lives are lost annually due to non-compliance, approximately 125,000 in the us alone. In addition a significant amount of hospital costs are related to non-compliance with prescription regimens and additional costs from lack of follow up of prescriptions. Recent findings have indicated that an improvement in patient compliance to prescribed medication could have significant impacts on cost/benefit ratios. Also, as high as 60% of people cannot identify their own medications and as patient age increases, so too does this level of identification. By providing a controlled methodology which can independently identify medication and provide a timely regimen for dispensing will have benefits for patient healthcare in terms of extending the quality of life and additionally reduction of hospital administration and costs (currently approximately 10%).

Methods: What is of paramount importance in the design and development of such an automated care model and its associated peripherals is consideration of the requirements of all stakeholders in the supply to intake chain of medication. It can be identified that this chain has a number of such stakeholders each with differing, yet to a certain degree, complimentary requirements and roles in the entire process. Table 1 identifies the stakeholders and summarises the nature of their involvement.

In addition to those identified in table 1 a number of indirect stakeholders can also be highlighted namely national healthcare bodies, medical device agencies and telecommunications companies [2].

Stakeholder	Role
Patient	The patient is central to this model as it is their primary requirement to have sufficient control over their compliance regime.
GP	The GP is the first point of contact a patient will have in the entire supply to intake chain. Following medical examination a GP will prescribe suitable medication.
Pharmacist	The pharmacist issues the patient with the medication as prescribed by the GP.
Service platform	This can be identified as an independent entity, whose role is some instances is to act as a go-between for the patient and the interaction with the pharmacy in instances of collection of medication and repeat prescriptions.

Table 1 Major Stakeholders and their roles in the supply to intake chain of medication.

Although a number of automated systems are currently available at present, aiming to address this problem, not all stakeholders (direct or indirect) have been involved, hence it may be argued that what is currently available is incomplete and substantial improvements may be attainable if all are involved under the framework of one large, integrated and distributed care model.

Conclusions: The problem has been identified as one of an extremely complex nature involving a multitude of stakeholders each with individual and specific requirements. All of these must be considered and addressed to ensure high levels of patient compliance in the home environment. It is the aim of the current study to individually address the needs of each of the stakeholders, both from direct and indirect points of view and hence provide the requirements necessary to produce an integrated it care model which will optimise and satisfy the requirements of patient compliance.

Acknowledgments

The authors wish to acknowledge the input from the following people for their contributions to provision of information in the given study: Prof G Papadopoulos, Dr G Kotrotsios, Dr C Paggetti, Dr J Barlow and Dr E Neophytou.

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Session – Expert & Decision Support Systems
Room 1 – Friday 4 May, 16.15 – 17.30

Automated explanation of attribute relevance in decision-tree induction

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Introduction: Strategist [2] is an algorithm for building decision trees from data in which attribute selection is based on the reasoning strategies used by doctors in diagnosis, such as confirming a target diagnosis or eliminating a competing diagnosis [4]. The advantage is that in problem-solving applications of an induced decision tree, the relevance of attributes (or tests) can be explained in strategic terms. However, it is possible that an alternative approach to attribute selection may produce a more accurate decision tree than Strategist for a given data set. In applications such as medical diagnosis, even a slight improvement in accuracy may outweigh the benefits of explanation.

In this paper, we present a new approach to explanation in decision-tree induction in which there is no such trade-off between explanation and accuracy. We show that the relevance of attributes can be explained in terms of their *effects*, such as confirming the likeliest outcome class or eliminating the likeliest alternative outcome class. Though resembling the explanations that Strategist provides, such explanations are independent of the attribute-selection method used to construct the decision tree.

Methods: The contact lens data set [1] is based on a simplified version of the real-world problem of selecting a suitable type of contact lenses (none, soft or hard) for an adult spectacle wearer. To illustrate how the relevance of attributes can be explained in terms of their effects,

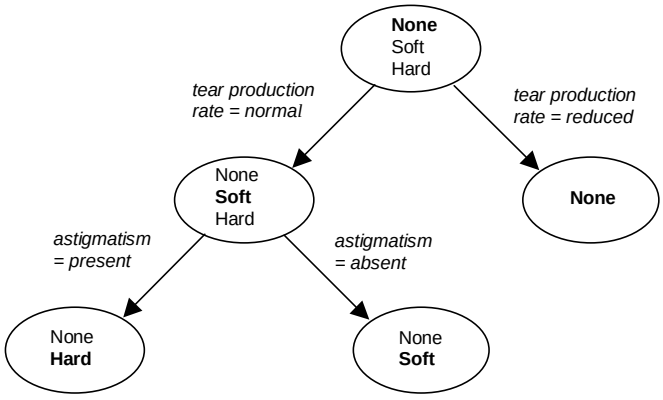

Fig. 1: Partial decision tree induced from the contact lens data set with test selection based on information gain.

Fig.1 shows part of a decision tree induced from the data set with attribute selection based on the *information gain* criterion [3]. The likeliest outcome class surviving at each node is shown in bold. The relevance of *tear production rate*, the attribute selected to appear at the root node of the decision tree, can be explained by the fact that one of its values (reduced) confirms the outcome class that is initially most likely, no contact lenses. In the subset of the data set with *tear production rate* = *normal*, the likeliest outcome class changes to soft contact lenses. Neither value of *astigmatism*, the attribute selected to partition this subset, confirms the likeliest outcome class. However, its relevance can be explained by the fact that one of its values (absent) eliminates hard contact lenses, now the likeliest alternative outcome class. If a selected attribute has no value that confirms the likeliest outcome class or eliminates the likeliest alternative outcome class, its relevance can usually be explained in terms of a value that increases the probability of the likeliest outcome class.

Results: Automated explanation of attribute relevance in terms of effects has been implemented in an intelligent system prototype called DECIDE with integrated support for decision-tree learning, problem solving, and explanation. Fig. 2 shows an example consultation based on the contact lens data set [1], with attribute selection based on information gain [3]. The likeliest outcome class is continually revised as the data set is partitioned and the user informed when it changes. Before answering any question, the user can ask why it is relevant. The explanations generated by DECIDE closely resemble those provided by Strategist [2], which in fact produces the same decision tree when applied to the contact lens data set. As the example dialogue illustrates, the user can answer *unknown* to any question, in which case DECIDE selects the next most useful attribute. A unique classification may still be possible when the result of a selected test is unknown, though not in this example.

The likeliest outcome class is no contact lenses.
What is the tear production rate? why
Because if tear production rate is reduced, this will confirm no contact lenses
What is the tear production rate? normal
The likeliest outcome class is soft contact lenses
Is astigmatism present? why
The absence of astigmatism will eliminate hard contact lenses
Is astigmatism present? unknown
What is the age of the patient? why
Because if the age of the patient is young or pre-presbyopic, this will increase the probability of soft contact lenses

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Fig. 2: Explanation of reasoning in DECIDE.

Discussion: We have shown that regardless of how attributes are selected in the construction of a decision tree, their relevance can be explained in terms of their effects, such as confirming the outcome class that is currently most likely or eliminating the likeliest alternative outcome class. The ability to explain the relevance of tests in a way that relates to the reasoning strategies used by doctors in diagnosis [4] may help to increase the acceptability of computer-based clinical decision aids in which test selection is based on decision trees.

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Blood dynamics control in anaesthesia by complex systems engineering

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Introduction: Anaesthesia as an applied science is based on various research environments, like neuroscience, biochemistry, physiology, pharmacology, with the support of special technologies applied to the human body. The amount of information required during surgical interventions (mainly

in organ transplants or open heart operations) is very large. In medicine, as well as in overall scientific disciplines, the theoretical approach is based on decomposition, but in this way the cognitive and decisional process is strongly conditioned, with the consequent risk of a lack in global vision. Frequently the modifications in circulatory function observed under anaesthesia derive from multiple implications between anaesthesia, surgery and patient status. So, surgical operations require the management of relations "*n to n*" in order to model *whole - parts* interactions. For this reason, an environment useful to support the decision process by the anaesthetist in operating phases *intra* (during) and *meta* (before-after) is required. In this presentation a methodology for the development of a simulation and control system for the haemodynamics, based on knowledge engineering, is presented.

Methodology: To set up a Decision Support System in anaesthesia starting with haemodynamics, a human body model must be developed according to different points of view. The overall human body knowledge can be organised according many layers [1].

Four layered abstraction levels are assumed, by the Authors, to be in the human body organisation:

1) basic (knowledge pertains physics, chemistry and biology),
2) human organs behaviour and structure (anatomy in relation with functional reserve),
3) control of the whole human body (central vegetative nervous system and hormonal system),
4) teleological level system aimed to the homeostasis.

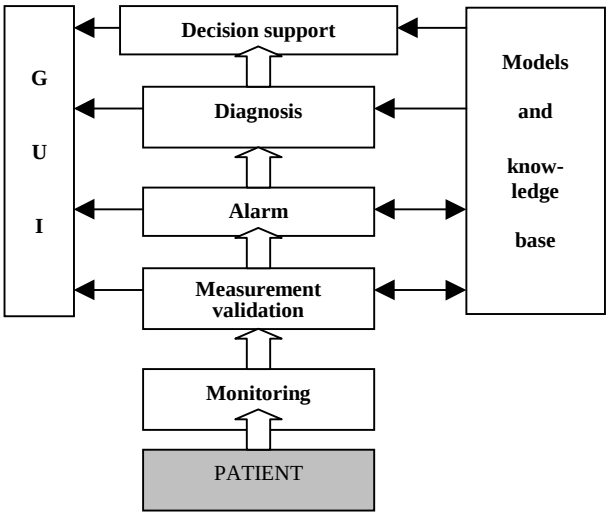
Many different approaches can be used within artificial intelligence techniques and researchers within qualitative reasoning have developed methods to derive behaviour from structure. The organisation in terms of causal logic of the knowledge is fundamental to make a DSS able to scan in the right way the reality of the patient and to store in the DSS the fundamentals of entity, event and characteristics to make possible that the DSS can support in the right way the decisions.

An implementation: The study is based on MFM (Multilevel Flow Modelling) in the context of TAM (Teleological Approach to the Management), methodologies defined to achieve the ontological knowledge of human body as a closed system, ruled by whole-parts, means-ends structure behaviour interactions. MFM is a logical approach which represents the system behaviour by mass, energy and information flows on multiple levels of abstraction [2, 3, 4]. TAM is a methodology for complex system management developed by Sebetia. [5]

TAM is carried out in five phases: system characterisation and aims identification (teleology), analysis, system design, object design, implementation. Within TAM, the anaesthetist supports the knowledge engineer in constructing the model, by defining links between physical components, functional areas and model ends. Models and knowledge base can be implemented and updated by a simulation environment, named Visconte (Visual Simulation and Control Environment), developed within an Esprit Research project by Sebetia [6].

Visconte is written in C++ and uses an OODBMS for model storage. The description of a system through the use of objects and classes is at the base of a modular description approach and can be readily used for simulation programming. Visconte is an environment for different domains, initially used for simulating distribution water network [5].

Discussion: We want to highlight that the scope of this system is to support and never to replace



Architecture of a medical DSS

the anaesthetist decisional process: the DSS system is based on human decision.

At the moment the authors are involved to transfer the knowledge, typical of a medical environment, in the syntax and in the semantics MFM, in co-operation with surgeons and anaesthetists of the largest hospital in Southern Italy.

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Prediction models for the design of neural networks for myocardial infarction classification: A genetic programming aproach

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Abstract: Neural Networks (NNs) have demonstrated to be a useful approach in the classification of the electrocardiogram (ECG) in recent years. A critical design issue, i.e. when to stop training to attain maximum generalization is addressed in this work by means of Genetic Programming (GP) optimisation techniques. A GP individual has been evolved to generate a model that predicts the optimal number of training epochs for three different ECG myocardial infarction classifiers: Anterior Myocardial Infarction (AMI), Inferior Myocardial Infarction (IMI) and Combined Myocardial Infarction (CMI). The GP model demonstrated to be a very accurate method showing no significant differences between the optimal number of epoch values and the predicted values for both: train and test data sets for the three aforementioned pathologies (AMI, CMI and IMI).

Introduction and Methods: The present study is based on an already developed 12-Lead ECG classification framework, based on a set of bi-group NNs (BGNNs) [1]. GP is used to develop an arithmetic model for the prediction of the number of epochs for maximum generalization on three groups of BGNNs. GP can be defined as a search method based on natural selection rules [2, 3]. In GP a population of candidates to solution programs (individuals) is evolved. In this study an individual consists of a transfer function that outputs a predicted value of the optimal number of epochs and takes 5 input parameters: Number of nodes in the hidden later (***n***), Feature Selection method employed (***fs***), Number of files in training set (***N***), Size of input feature vector (***s***) and the number of epochs at which the NN attained maximum performance during training (***m***).

GP	Number of cases	Mean Rank -ve	Mean Rank +ve	z-value	2-tailed sig
AMI Train	29	13.08	16.56	-1.027	p= 0.304
AMI Test	15	4.17	10.56	-1.989	p= 0.047
IMI Train	31	16.17	15.89	-1.058	p= 0.290
IMI Test	15	9.67	6.89	-0.114	p= 0.910
CMI Train	37	19.56	18.47	-0.008	p= 0.994
CMI Test	14	9.38	5.00	-1.412	p= 0.158

Table 1: Wilcoxon's signed rank sum results for GP prediction models

Results: For the GP model, populations of 3000 individuals were evolved and arithmetic functions: add, minus, protected division, and product, were defined as the function set. A set of random float type constants between 0.0 and 5.0, 0.0 and 50.0 and, 0.0 and 500.0 were defined as the terminal set as well as, the aforementioned 5 input parameters (n, fs, N, s, m). The fitness function was based on absolute errors for the desired output parameters and the complexity of each individual. Figure 1 illustrates a comparison between desired and actual values of epochs for the three myocardial infarction models (AMI, IMI and CMI) for both, training and testing. Performance was measured following the Wilcoxon's signed rank sum (Table 1) showing no significant differences ($p > 0.05$) between training data and test data for the 3 data sets.

Conclusions: GP has demonstrated, in the current study, to be a very good method in the NN reengineering problem. Figure 1 and Table 1 show that a GP based prediction model not only performs very well with training data, but also demonstrates high generalization capabilities. The results from this study show that is possible, given the design parameters of a NN ECG classifier, to predict the point at which training should cease.

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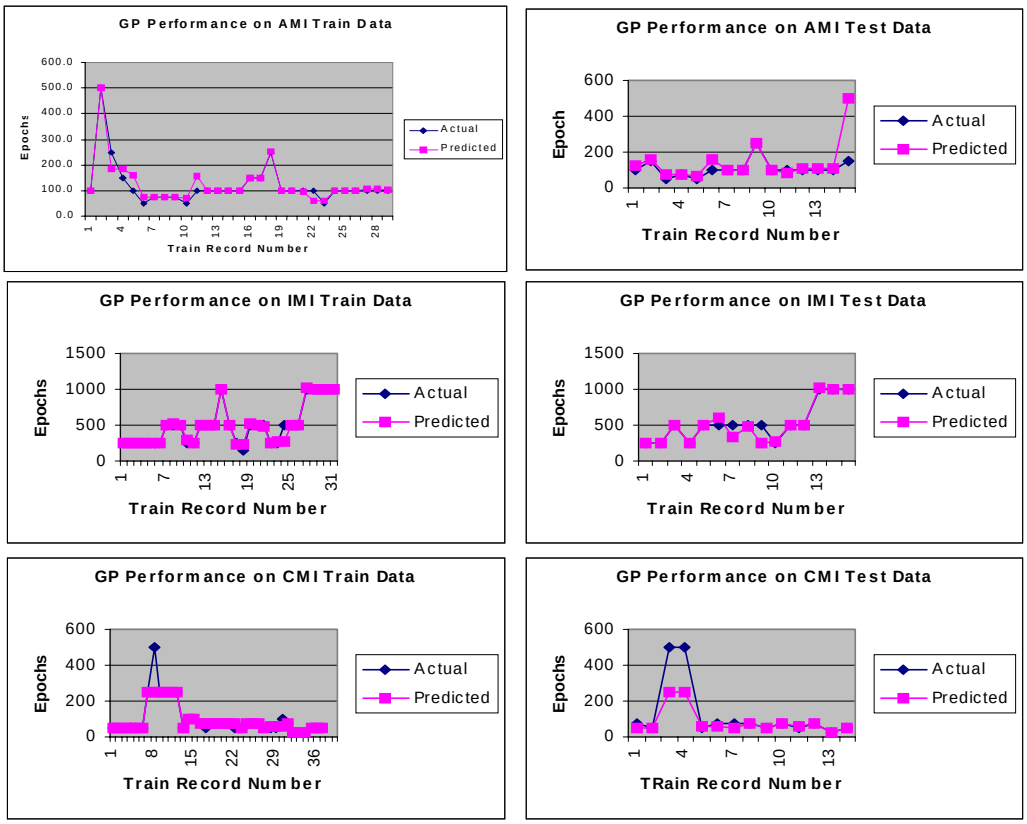

Fig 1: GP performance for the three myocardial infarction models (AMI, IMI and CMI) in data used for both, training and testing purposes.

A computer-based training system for breast fine needle aspiration cytology

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Introduction: Fine-needle aspiration (FNA) cytology is a rapid and inexpensive technique, which has been used extensively in the diagnosis of breast disease. The simplicity of the technique and its safety, along with the possibility of rapid diagnosis, are some of the important advantages of this technique compared to surgical biopsies. However, the subsequent microscopic diagnosis is a subjective process and this may be inconsistent. One mechanism for the reduction of subjectivity has been the introduction of computer-based diagnostic decision support (DDSS) systems.

Bayesian belief networks (BBN) are becoming an increasingly important area for research and application in the entire field of artificial intelligence. BBNs use probability theory to manage uncertainty by explicitly representing the conditional dependencies between the different knowledge components. They provide an intuitive graphical visualization of knowledge. A system CytoInform© has been developed for aiding in the diagnosis in breast fine needle aspirates based around a BBN. This highly visual diagnostic tool has potential to significantly enhance the diagnostic process by instilling consistency and repeatability into the process. It is suggested that the use of this system together with pre-interpreted diagnostic information could also provide an effective computer based training (CBT) system for breast FNA cytology.

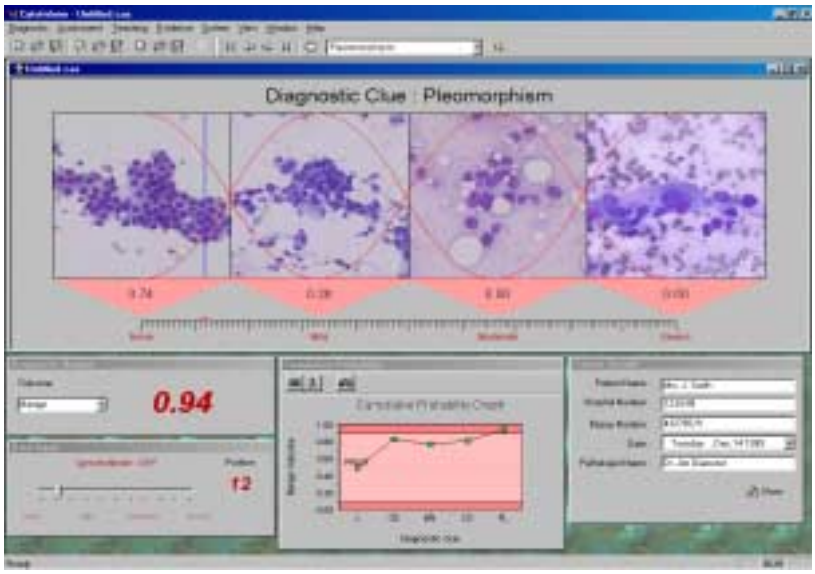

Fig. 1 Graphical User Interface provided by *CytoInform*©

Methods: The BBN adopted was expressed in the form of a shallow network with an open-tree hierarchic topology. This form provided a single diagnostic outcome node with two possible states (benign and malignant). Feeding this node were ten first-level descendent diagnostic evidence nodes linked directly by conditional probability (CP) matrices, defined by an experienced cytopathologist (NA).

CytoInform© is a Bayesian belief DDSS developed at The Queen's University of Belfast, as shown in Fig. 1. The system offers a graphical user interface (GUI) to the above-mentioned BBN. CytoInform© guides the trainee cytopathologist through the complete diagnostic process allowing the user to grade each diagnostic feature using a set of on-screen reference images as visual clues. The trainee positions a slider on a spectrum relative to these images, reflecting the similarity between the reference image and the microscope

image. From this an evidence vector is generated to allow the current diagnostic probability to be updated by the BBN. As the trainee assesses each clue, the evidence entered is compared with that of the expert which has been previously stored for a given case. When all clues in the teaching case have

Fig

been completed, the system informs the user of inaccuracies and offers the ability to reassess problematic features.

Results: Two junior pathologists were assessed using the system. Using a series of 10 training cases both pathologists performed system evaluation individually. The system recorded the diagnostic route taken and the number of attempts to evaluate each clue correctly. It is important to note that each pathologist misinterpreted only one case and a total of 86/88% of all clues were interpreted correctly. Significantly, in all cases that produced the final diagnostic probability, the route taken to that solution was also consistent with the ideal solution provided by the expert.

Discussion: The grading of cytologic abnormalities is a problematic area, in that pathologists can differ in their understanding of what characteristics define the diagnostic domain and what grades constitute these characteristics. In training a junior pathologist it is necessary to convey this important information in a concise and informative manner, together with removing the subjectivity that occurs in this diagnostic scenario. CytoInform© defines the domain in question and provides visual prompts on how to access diagnostic clues together with their relative importance to the overall diagnosis. It is evident that expert systems and DDSS in particular are going to be increasingly important tools in the areas of diagnostic cytology (and histology). It is believed that CBT systems such as *CytoInform*© may lead to improvements in the field of diagnostic pathology through the instillation of improved consistency and reproducibility in pathological training.

Continuous wavelet transforms reveal the rich structure of ventricular fibrillation

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Introduction: Ventricular tachyarrhythmias, in particular ventricular fibrillation (VF), are the primary arrhythmic events in the majority of patients who present with sudden cardiac death. Considerable interest has focused upon these particular rhythms as it is recognised that prompt therapy can lead to a successful outcome. For these reasons there has been considerable interest in analysis of the VF waveform. Until recently, the surface electrocardiogram recorded during ventricular fibrillation (VF) was thought to represent disorganised and unstructured electrical activity of the heart. This is in stark contrast to the information rich ECG in other states of health and disease. Recent work by the authors [1,2] has found that, in fact, by using continuous wavelet transform analysis a rich structure can be found in many cases of VF. This takes the form of both high frequency spiking and low frequency modulation of the high energy region found at around 10Hz corresponding to the median frequency of the VF signal.

Methods and Results: The surface ECG is displayed as a wavelet transform-based energy density plot (in the time-frequency plane) – the 'scalogram'. This enables excellent resolution of the high frequency components in the signal in contrast to the current techniques employing the short time Fourier transform (STFT) which smearinformation across the time-frequency plane at time scales below the window width. A continuous complex Morlet wavelet was selected by the authors for the task of signal decomposition. The continuous nature of the transform allows for high resolution in wavelet space, useful for examining structures within the signal, and the complex nature of the wavelet allows local phase information to be studied.

Figure 1 shows an example scalogram constructed from 7 minutes of porcine VF. CPR has been initiated after 5 minutes and manifests itself as the high energy red band appearing in the scalogram in the lower right hand quadrant. The plot on the right of figure 1 contains the relative proportion of energy contained in the scalogram in the 5-12Hz region (against the energy at all other frequencies) through time. There is an obvious decay in the relative energy associated with this region which is believed to be associated with the degeneration of underlying structured electrical activity in the heart muscle.

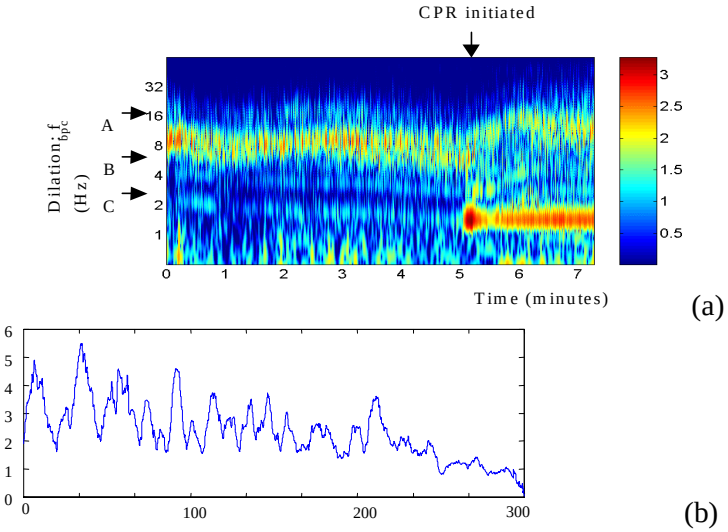

Figure 1: (a) Scalogram of 7 minutes of porcine VF. High energies are shown grey and low energies are shown black. (b): The smoothed plot of energy at the 8Hz level in the scalogram against time. (Smoothing window length = 30secs.)

Discussion: Hidden information within the ECG during VF has been found using a high resolution continuous wavelet transform decomposition. Current work by the authors seeks to use this new information in a number of ways, including the provision of measurable characteristics of the ECG signal for estimation of downtime (i.e. time since cardiac arrrest) of the patient; the disassociation of cardiopulmonary resuscitation (CPR) artefact from the ECG signal through temporal filtering; and the prediction of defibrillatory shock outcome using markers identified within wavelet space. The use of a number of advanced post-processing techniques is currently being evaluated including: artificial neural networks, intermittency measurements, entropy techniques and Bayesian statistics. In addition, we have shown that it is possible to compute the scalogram in real time using a continuous wavelet

transform which may provide useful additional information to the clinician treating cardiac arrhythmias.

Acknowledgement

We wish to thank Ken Morallee of Laerdal Medical Ltd for his assistance. The porcine experimental work is supported by grant No. 6168 of the 'Jubilaeumsfond' of the Oesterreichische Nationalbank, Vienna, Austria and was carried out in accordance with institutional guidelines.

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Session – Telemedicine
Room 1 – Saturday 5 May, 09.00 – 10.30

A framework to support 3D telemedicine applications

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Introduction: The advantages of telepresence medicine in remote consultations, diagnosis and surgery have long been recognised and a number of applications exploiting Computer Graphics have been built [1]. Examples include interactive visualisation of data acquired from a CT or MR scanner for non-invasive diagnostics and craniofacial reconstruction. These applications reconstruct the acquired data into a format suitable for 3D visualisation, where users can interactively rotate, zoom and pan around the data, and in this way improve clinical knowledge of the patient in a non-invasive environment. Up to now these applications typically operate in single-user mode, with one user interacting with the data at one time. This paper reports on work done on building a system suitable to take such applications into a telepresence environment, where more than one user can visualise and interact with the data simultaneously in real-time.

Background: Three-dimensional scenes (Virtual Environments) have long been used to represent real and imaginary worlds—applications include flight simulation, oil exploration and the entertainment industry. In medicine, the challenge is to deal with an extremely large dataset with which the user wants to interact in real-time. Our motivation for the work described in this paper is that in the near future medical applications exploiting 3D visualisation will move from single-user mode to one where several users (geographically distributed) can visualise and interact with the data in a collaborative environment.

Collaborative Virtual Environments (CVEs) are rich, complex applications which contain many different services and styles of interaction [2]. The ability to interactively visualise data and

communicate with other participants means that CVEs have additional functional requirements to single-user applications. This includes providing communication support for the collaboration of multiple participants and the distribution, maintenance and synchronisation of the virtual environment data. Typical challenges associated with all distributed applications are also present - performance and scalability.

Bespoke solutions often require considerable effort on the part of the developer. The Common Object Request Broker Architecture (CORBA), however, defines a standard for how applications can interoperate across heterogeneous operating systems and networks. Recent real-time extensions to CORBA can support many of the interactive requirements of medical applications [3]. We have developed NOMAD, a software framework which exploits CORBA to accelerate the development of collaborative medical visualisation applications.

NOMAD: NOMAD consists of over 30 components and application objects that together form a hierarchical object-oriented framework. The components—*environment server, session managers, area managers* and *locale managers*—coordinate the management of the VE data and the events that occur as a result of user interaction. The Figure below illustrates the NOMAD architecture and shows how the system could be configured to support multiple users across 3 distributed sites.

Users joining the CVE first connect to the *environment manager,* at the root of NOMAD. These requests are passed to the appropriate *session manager,* which manages all the users on one site and maintains a complete copy of theVEdata.

Results and Conclusions: The system has been tested for 2, 5 and 15 users across a standard 10Mbit/s network. Average latency times of 1.9ms, 2.0ms and 2.1ms were recorded for a 100KB data packet sent between 2, 5 and 15 users respectively. In all tests, the event delivery time began to increase dramatically once the data packet was greater than 100KB, irrespective of the number of users. This is more than adequate to communicate event data, such as changes in user position as users collaborate. These results indicate that the NOMAD architecture is suitable to support scalable, interactive, collaborative 3D medical applications. Further research is ongoing to develop a working prototype 3D medical application based on the NOMAD architecture

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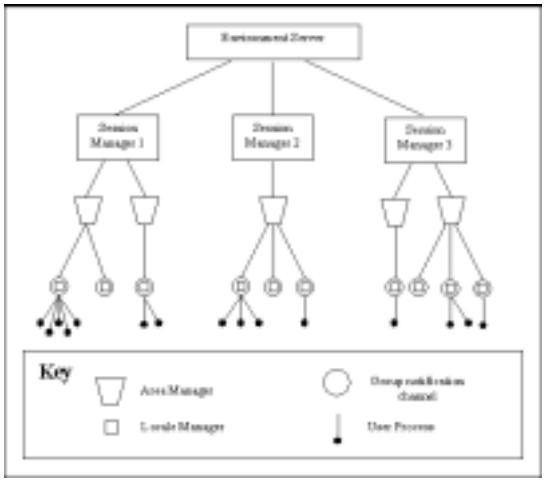

Below each *session manager* lie a number of *area managers*, which handle communication and ensure environment consistency among the users. To provide scalability, our approach divides the VE

data into more manageable sub-regions – *locales* – which are managed by *locale managers*. As more users join the collaborative virtual environment more *locale managers* are spawned by the appropriate *area manager*

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Development of a high-performance ISDN-to-ATM telemedicine gteway in support of the NCI All Ireland Cancer Consortium

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Introduction: The TELESYNERGY™ Medical Consultation WorkStation is a multimedia, medical imaging workstation that was developed at the National Institutes of Health (NIH) for use in a collaborative, electronic medical imaging environment. Designed to provide for the high-resolution display of medical images from numerous modalities and real-time communication, the TELESYNERGY™ System includes mechanisms to allow remote medical specialists to advise and consult between wide geography and time zones, via inherently secure ATM and ISDN circuit switched networks.

Methods: Two high-resolution monochrome image display systems each function as an Electronic View Box (EVB) for the display of 14 X 17 inch format "electronic films." Utilizing the EVBs, organ and disease contouring, for example, is performed via a shared-cursor technique in consultation mode, which allows physicians to collaborate in identifying features by outlining. The contour boundaries are transmitted in real-time between all participating TELESYNERGY™ sites.

A remote-controlled microscope capability allows biopsy specimens to be discussed and manipulated by both sites concurrently. In addition, a patient exam camera allows high resolution viewing of a live or recorded patient exam, including dermatologic lesions, skin coloration, and other diagnostic evaluations.

An Asynchronous Transfer Mode (ATM) telemedicine network is utilized within the NIH campus and the surrounding area, whenever feasible, to provide connectivity for the TELESYNERGY™ System. Audio and video data streams, and an IP data path, are implemented bi-directionally through 155 Mbits/sec ATM links connecting the National Cancer Institute (NCI), to local off-campus collaborative sites. Microphones and speakers allow bi-directional voice communication, and video capability is provided with S-video sources and monitors.

A novel ISDN-to-ATM Telemedicine Gateway was developed, which effectively splices an ATM network leg into an Integrated Services Digital Network (ISDN) Primary Rate Interface (PRI), to allow the implementation of TELESYNERGY™ nodes in regions within the United States and internationally, where ATM networks, supporting the Switched Virtual Circuit paradigm, have not yet been implemented. Audio and video data streams, as well as IP data paths, continue bi-directionally

through the gateway in a transparent fashion, to allow an ISDN-based TELESYNERGY™ node to function seamlessly with the TELESYNERGY™ nodes located within the ATM cloud in Bethesda, MD.

Results: During the NCI All Ireland Cancer Conference, held in Belfast, Northern Ireland, from October 3-6, 1999, the prototype ISDN version of the TELESYNERGY™ System was installed for demonstration to the conference participants. This initial implementation illustrated bi-directional audio and video data streams, but not IP connectivity.

In January 2000, a TELESYNERGY™ System was permanently installed at the Lawrence Livermore National Laboratory, in Livermore, California, approximately 3,000 miles from the NIH campus. This ISDN-based system includes a bi-directional IP data path, in addition to the audio and video pathways implemented in Belfast several months earlier. An additional ISDN-based TELESYNERGY™ System was permanently installed at the Holy Cross Hospital, in Fort Lauderdale, Florida, in June 1999, approximately 1,000 miles distant. This system also includes bi-directional pathways for audio, video, and IP data streams.

An ISDN-based TELESYNERGY™ System is currently being implemented at St. Luke's Hospital, in Dublin, Republic of Ireland, in support of the Ireland-Northern Ireland-NCI Cancer Consortium. This Consortium was initiated during the 1999 NCI All Ireland Cancer Conference, and will provide a five-year window of opportunity during which the NCI will collaborate with the major cancer centers in Belfast and Dublin, in all aspects of the fight against cancer.

Discussion: Within the United States, the ISDN PRI implementation is based upon a T1 circuit, with 23 B Channels and 1 D Channel allocated within a bandwidth of 1.544 Mbits/sec. In Europe, it is based upon the E1 Circuit, with 30 B Channels and 2 D Channels allocated within a bandwidth of 2.048 Mbits/sec. It was, therefore, necessary to employ a protocol converter, on the European side of the international ISDN link, to allow U.S. Standard ISDN components to be utilized in Europe during the Belfast event. Overall, as a result of the ISDN-to-ATM Telemedicine Gateway, there is only a slight degradation in video quality, and a reduction in the datarate of the IP pathway to 512 Kbits/sec.

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A compression-decompression client-server architecture supporting the progressive transmission of medical images included in web-documents

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Introduction: In the future, it will be common that digital medical images will be directly included into medical reports. However, due to their huge sizes and the large quantities/volumes that are daily produced in the hospital, medical images demand very large storage capacity and high bandwidth communication channels. Therefore, flexible and powerful compression techniques are required.

Novel compression algorithms have the advantage compared to the existing JPEG image compression standard, that they offer the possibility to fetch the images progressively without any duplication in the data stream, so that it becomes possible for the user to even consult medical

documents containing images via slow connections to the internet. Typically, the images are transmitted in a number of steps, in such a way that the user can decide whether an image is interesting or not and abort the transmission of superfluous ones, on the basis of the low-quality decompressed image obtained from the data sent in the first step. In addition, the latest compression technology enables the transmission of regions of interest, defined around areas of highly diagnostic value, at a higher priority and better quality. As these regions often only occupy a small percentage of the complete image, it is possible to convey their content via a limited stream of bits.

Architecture: As the classical HTML-standard was built for publishing passive documents on the web, it is insufficient to provide the flexibility that novel compression algorithms should offer to the user. In order to cope with the active content needs, a web-based compression-decompression client-server architecture was elaborated (fig 1) using XML, ActiveX and Active-Server-Page technology in addition to the HTML language. The scenario supported by this architecture is the following:

A medical report (Report.htm) is fetched as an html-file from a remote web-server and visualised via the web-browser on the client computer.

An IViewer component is generated for each compressed image of the html-file. This component will retrieve the xml-file (Image.xml), describing the image data, from the server (not necessarily the same machine as the Remote Computer). It will activate a number of other ActiveX components, such as the IXMLParser component for parsing the xml-file, and the IDecompressor component for decompressing the data collected for a certain step in the progressive transmission. Further the IViewer component will set-up an “http” based connection by means of the Active-Server-Page file GetImage.asp. The IViewer component will also take care of the visualisation of the progressively refined images.

Upon request of the IViewer component, the server will execute the Active-Server-Page file GetImage.asp, which will activate in its turn different ActiveX components. In case the image file is not yet compressed, the ICompressor component will compress the data and save them to disk. The IFile component will read the compressed data and send them progressively to the client.

The compressed image is sent as a continuous data stream and divided into a number of steps to be decompressed and displayed. The IDecompressor component will wait till the amount of transferred data corresponds with the compression ratio of a certain step. When this is the case, the data are decompressed and passed to the IViewer component to visualise them. Note that the transfer, the decompression and visualisation processes all run in parallel. The transfer is ended, as soon as the data corresponding to the compression ratio of the final step have arrived.

The same scenario occurs in parallel for every image, present in the Report.htm file.

Discussion: In the application we have elaborated, we make use of a state-of-the-art proprietary lossy to lossless wavelet compression-decompression scheme [1], [2] producing an embedded data stream to achieve progressive transmission and prioritised region of interest coding. The benefits of the underlying compression scheme are illustrated by the following example: an acceptable view of a 2048x2048 radiographical image can be obtained in 8 sec. on a Pentium II 300 MHz (decompression time included) via a single ISDN-channel (64 kbit/sec) at a compression ratio (CR) of 200. An image that almost cannot be distinguished from the original (CR = 25) can be obtained in 45 sec, while waiting for the complete uncompressed image would take 1000 sec. The lossless compressed image (CR = 2.5) can be obtained somewhat faster, namely 400 sec. Yet, as regions of highly diagnostic

value (either defined in advance by the editor of the document or by the medical user during the consultation of the document) can be sent with priority up to the lossless stage, it is still possible to achieve considerable time gains (compared to the previously mentioned 400 sec) since the required ROIs are often significantly smaller than the original image size.

Currently, the architecture is being clinically validated and will be made JPEG 2000 compatible in the coming months. An alternative way to address the IDecompressor (ActiveX) component via the SOAP standard is currently investigated.

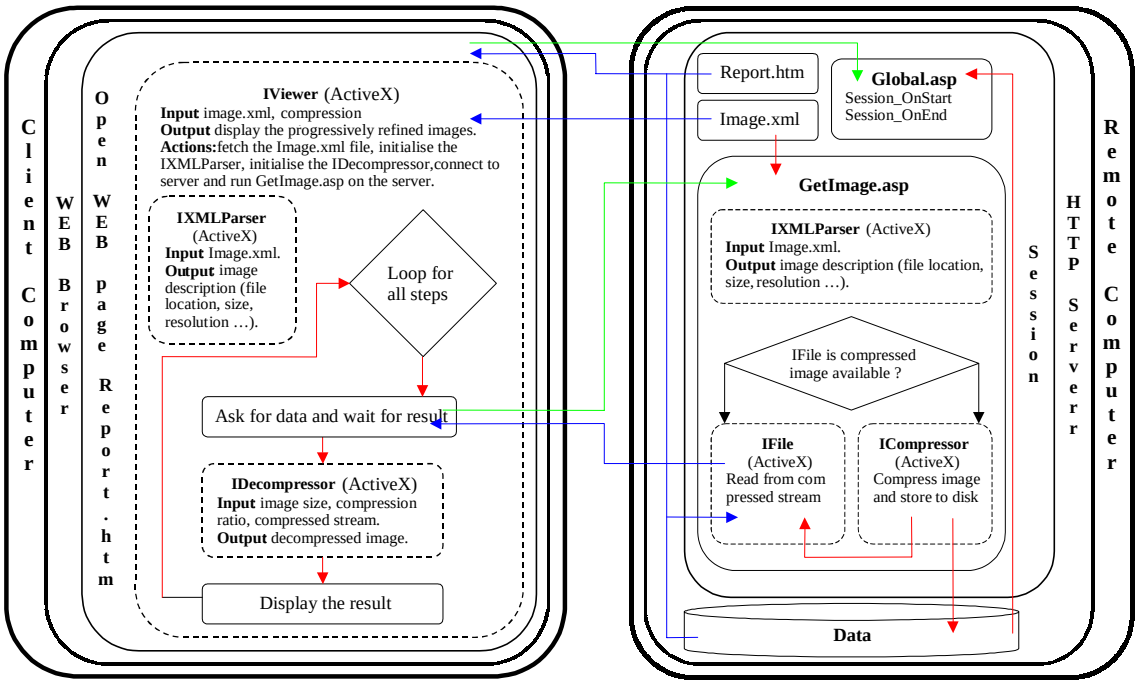

Fig1: The web-based client-server architecture

Acknowledgement

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Computer supported collaborative medical diagnosis

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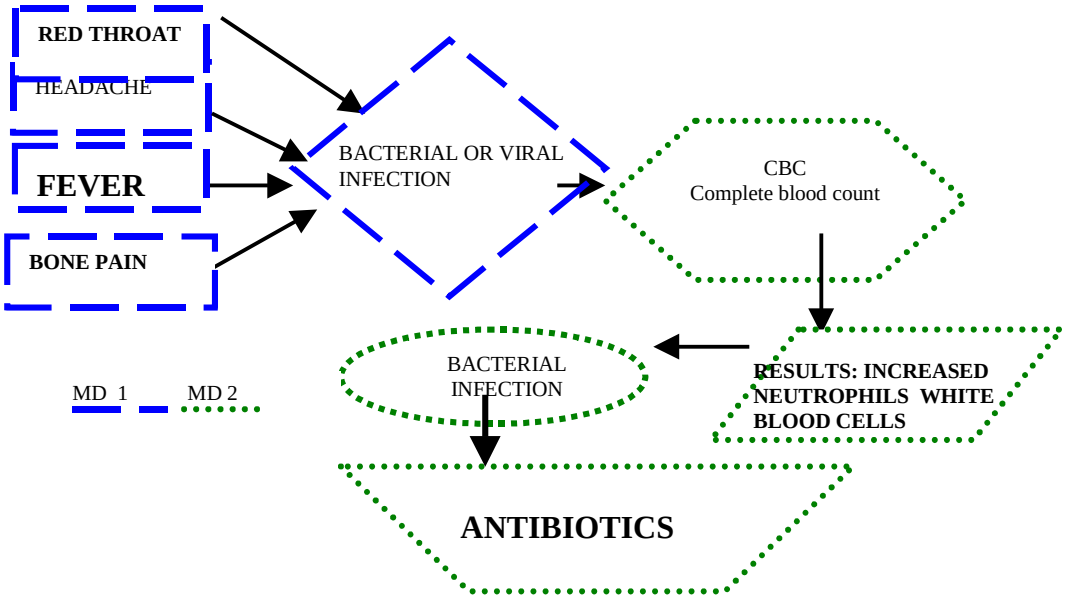
This paper presents a cooperative system that enables a medical teleconference. Although the participants are apart, they can interact as if they were in the same place. This interaction is enabled through software that displays the same image in the computer of each participant. The computer displays the diagnosis in progress by means of a visual language. The elements of this language are symptoms, medical history, hypothesis, tests to be performed, final diagnosis and treatment. This medical reasoning graphically displayed is simple and easy to read and can be captured and stored. The relationship among elements is clearly established. The diagnosis can be stored in a database that can be readily accessed.

This system was implemented using Groupkit Tcl/Tk extension to build a cooperative environment in a client-server scheme. The system runs in Unix and Windows NT.

The developed prototype allows a diagnosis to be made by geographically separate physicians who work in a collaborative manner synchronously. Each participant may add new information to the diagnosis in progress, displayed in his or her computers.



Graphical Representation of a Cooperative Bacterial Infection Diagnosis

The figure above displays the representation of a cooperative Bacterial Infection diagnosis developed simultaneously by two medical doctors (MD1 and MD2) geographically distant. There are a group of symptoms, all of which suggest two hypotheses: bacterial or viral infection, the physicians decide to make CBC (complete blood count). The results show an increase in white blood cells neutrophils. The symptoms and analysis indicate a bacterial infection that should be treated with antibiotics. (MD1 performs the physical exams and MD2 is the expert remotely located. MD1contribution is represented in interrupted lines and MD2 in dotted lines.)

Reference

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Communication reliability in home-care telemetry using the 1800 MHz GSM network

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N. Ireland, UK
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Introduction: The increasing need for remote vital-signs monitoring in applications such as the care of post day-surgery patients recovering at home or in emergency trauma signalling from accident sites has resulted in the growth of mobile biotelemetry systems [1]. The transmission of human vital-signs for remote expert analysis now takes place on a world-wide basis, via PSTN lines, private radio networks and, increasingly, over UHF cellular telephony systems. The basic parameters that may be transmitted range from simple heart rate and body temperature, to full-bandwidth ECG waveforms and blood glucose measurements, the latter being an essential parameter in the care of diabetic patients.

A biotelemetry platform must provide 100 % reliability to be effective: in normal telephony an element of dropout may be tolerated. Cellular networks such as GSM 900 and DCS 1800, ITS 1900 and third generation (3G) systems may have reliability problems because of body-antenna interaction, nearby pedestrian traffic and in-building propagation effects leading to weak signal provision. This is especially true in rural areas where base station density is lower.

Body shadowing implications: The body-shadowing effect for a cellular telephone held close to the user's head is well known and validated [2]. Additional signal attenuation due to body proximity and through-loss at waist height, when compared with measurements made with the phone at head height or in isolation (1 m away from body), ranges from 20-25 dB, respectively. However, in a biotelemetry application, the handset must operate effectively when body-worn at waist height. This is a convenient location for fixed use over 24-72 hours – a likely monitoring period – and allows the routing of cables to localised biomedical signal acquisition modules. Under these conditions the shadowing can be investigated either by using numerical techniques such as FDTD, or by measurement.

For example, Figure 1 shows the azimuthal co- and cross-polar patterns (Ev and Eh, respectively) achieved from simulating a 1800 MHz $\lambda/4$ monopole mounted on a conducting enclosure and placed

at waist height on an adult-male. We will present further models that include wire leads emanating from the telephone package, as seen in Figure 2; this will permit an examination of the effect that the lead has on the cell-phone's polar pattern.

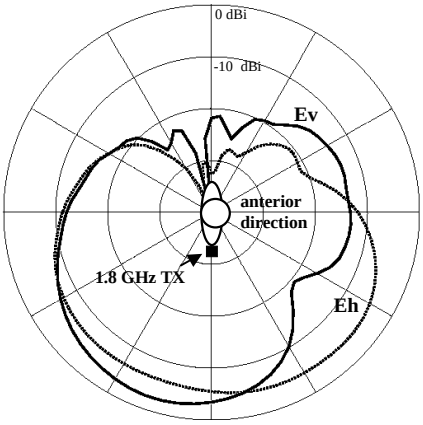

Fig. 1: Polar patterns produced when a cell-phone transmitting at 1800 MHz is placed at waist-height (using FDTD modelling). *The mid-section of the whole body model is shown on Figure 2.* Note the 'through-body' nulls.

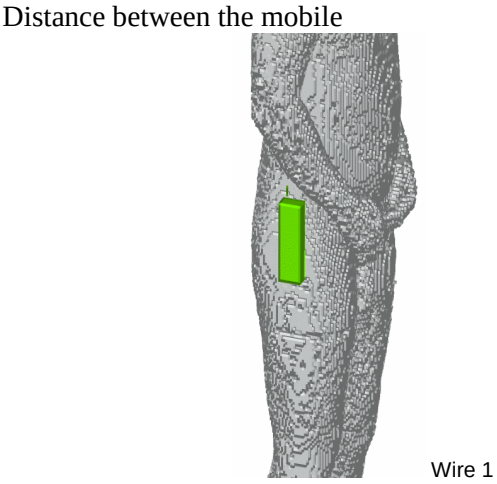

Fig. 2: Illustrating sensors connected to a chest-worn instrumentation pack, which is in turn linked to the cell-phone via wire 1. Close proximity of sensor wires or wire 1 to the handset's antenna is a potential cause for service degradation and RFI.

Temporal fading caused by pedestrian movement: From measurements, the telemedicine radio link has been found to be vulnerable not only to shadowing caused by the user's body, but from temporal fading caused by nearby pedestrian movement. Figure 3 shows the effect that *high-density* traffic (more than 10 adults per 10 m^2) has on the indicated received signal strength of an isolated mobile handset when compared to *low-density* traffic (less than 10 adults per 10 m^2). The mean values of a

temporal recording made over 4 minutes were –91 dBm and –83 dBm for high and low-density traffic, respectively.

Building signal penetration: Building penetration is the final factor affecting communication reliability; the paper will report on a penetration measurement campaign carried out in buildings at two different city locations. The first was an urban apartment-block model in the highly populated centre of Athens, Greece, whilst the second was a private dwelling in a rural environment on the outskirts of the city.

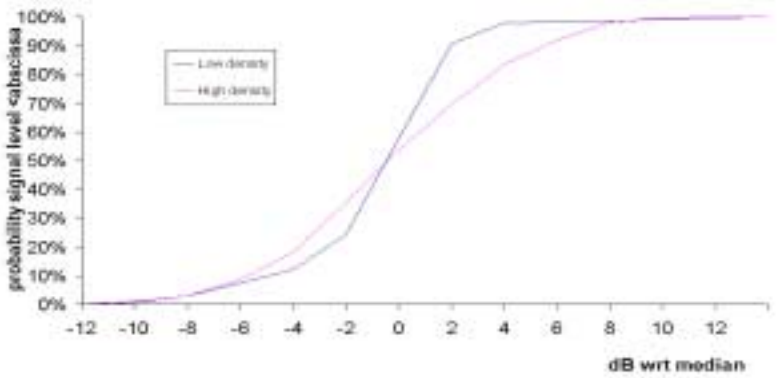

Fig 3: Cumulative distribution function of temporal measurements. Note the adverse effects of *high-density* traffic.

Conclusions: Reliability in 1800 MHz cellular telemedicine systems can be negated by: a) user's body-antenna interaction, user-orientation (sitting, lying, standing up, etc.) and interaction between leads recording the biological information and the handset's antenna, b) proximal human traffic in hospital wards, home environments and public places and c) in-building signal penetration due to construction materials. Further investigation needs to take place, with more accurate measurements made under *high-density* pedestrian traffic conditions and detailed correlation with FDTD simulations of the complete transmission platform.

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An new image compression method for telemedicine using statistical characteristics of wavelet coefficients

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[b]*Research Institute of Surgery, the 3rd Military Medical University, China*

Introduction: Telemedicine provides a new medicine service by means of communication technique. It is well suited for home-health-care, teletherapy and battlefield rescue. Because of the need of data transmission, especially medical image, image compression is needed. However, there is still not an ideal image compression method for the limited bandwidth of data transmission channel, in this paper, we describe a novel image compression scheme, which is based on statistical characteristics of wavelet-transform coefficients of the image.

Methods: In recent years, researchers have done much work in image compression based on wavelet-transform [1-3], and presented many image compression schemes. However, all of them have not considered the statistical characteristics of the wavelet-transform subimage coefficients. By our analysis and other person's study, the PDF (Probability Density Function) of the subimage coefficient is approached to the Gaussian distribution. As we know, almost 69 percent power of a Gaussian distribution is focused on the range between $\mu+\delta$ and $\mu-\delta$ (μ and δ is the mean and the standard deviation respectively), and near 95 percent power focused on the range between $\mu+2\delta$ and $\mu-2\delta$. Thus, we can quantify the subimage coefficients according to the standard deviation. Our scheme is simply described as follows:

Computing Wavelet Transform: The original image is decomposed into four stages including 13 subimages.

Calculating Standard Deviation: Exception for the lowest frequency subimage, the standard deviation of each subimage δ_i (i=1, 2, ...12) is calculated respectively.

Quantifying Coefficients: Exception for the lowest frequency subimage, each subimage coefficient is quantified according to their standard deviation respectively by setting the quantifying threshold as $2\delta_i$, δ_i, $0.5\delta_i$ et al. As the high frequency subimages contain high frequency details that are insensitive to our eyes, we quantified the higher-frequency-subimages coarsely, and quantified the lower-frequency-subimages accurately. Finally, we got a map at every threshold.

4) *Coding:* All the quantified maps were coded with run-length scheme. At the same time, the lowest frequency subimage was coded with DPCM.

Results: In comparison with other image compression algorithms, such as EZW(Embeded Zerotree Wavelet) [4], SPIHT(Set Partitioning In Hierarchical Trees) [5]and LVQ(Lattice Vector Quantizer) [6], et al., we found our scheme is much simpler in calculation, while other schemes are complicated. Especially, with our algorithm, the initial threshold is very few to Gaussian distribution. But, in other scalar quantifying methods, the initial threshold has been set as the maxim coefficient, and the efficiency of quantifying is much lower. Also, based on our algorithm, the compression ratio and reconstructed image quality (PSNR) is satisfactory.

This scheme is very useful in image progressive transmission, which is important in telemedicine. Fig. 1 illustrated the experimental result of our scheme with a fundus retinal image.

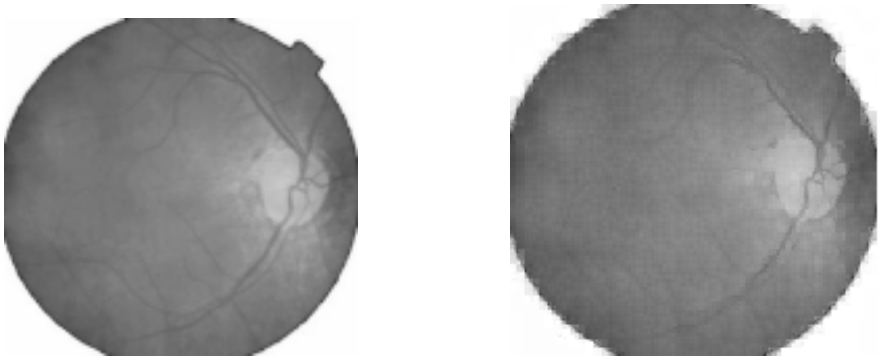

Fig. 1 comparison of original fundus retinal image and compressed one (PSNR=28.3dB, 0.25b/pixel)

Session - Technology for People with a Disability
Room 1, Saturday 5 May, 16.15-17.30

Espastics filtering interface for technical aids switches. -A hardware approach

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Introduction: The Industrial & Medical Electronics (EIMED) research group of the Polytechnic University of Cartagena has been designing technical aids for the disabled since 1989 in close collaboration with the Tutelary Association for the Disabled of Cartagena (ASTUS).

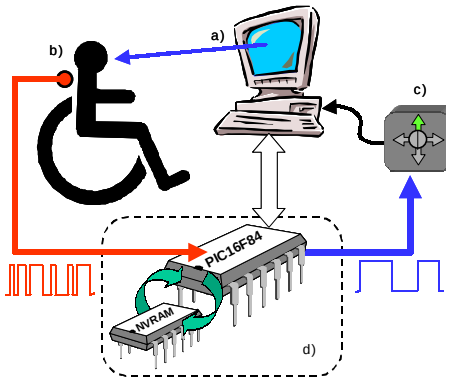
As results of this partnership, many Technical Aids (TAs) have been developed to grant computer access to disabled people affected of cerebral palsy and very limited mobility, through the use of sweeping techniques. [1][2]

This selection process requires of synchronization between the choice sweeping rate and the activation of the switch used as input selector, which is very often disturbed, by the presence of involuntary movements that usually, and unfortunately, accompany the voluntary ones in people with this kind of disabilities.

Methods: In order to minimize the effect of these perturbations, a filtering technique was developed in order to recognize the involuntary activations preventing the TA to process it as a selection order. The first approach set off a simple filtering algorithm called as “Temporal Hypothesis” which was based on pulse length analysis. This technique was improved by considering the relationships among consecutive on-off pulse trains, windowing the results within three ownership functions (similar to those used in fuzzy systems) defined by three simple parameters: T_{ON} ,T_{OFF} and T_{ELIM}, which are

defined in what has been called as “Extended Temporal Hypothesis”[3]. In order to set up the output discrimination rules, an analysis of the EMG associated to the movements allowed the classification of the input within twelve groups, six of them related to voluntary activations while the other ones identified as involuntary.

The following step focused on a hardware device, designed to implement this filtering. Due to the low sample rate and calculation requirements for the filtering, the device was designed upon a low-cost microcontroller in order to make it affordable, instead of using a more expensive processor such as a DSP. The RISC processor employed was a popular microcontroller, the PIC16F84. The system is structured, as might bee seen in figure 1. The figure shows a typical adapted workplace, where there is a standard PC, running standard OS & applications (a).



The disabled (b) operates on a functional switch placed near his neck, which offers the selection signal (very noisy due to spastics) to the mouse emulator (c) in order to carry on the task currently highlighted (mouse up). Then, at the interface proposed (d), the PIC analyzes the switch signal, filtering it according to the parameters stored at the NVRAM (previously downloaded from the PC). Finally, a clean selection signal is applied to the emulator, the task is done and the disabled receives feedback from the screen.

Fig. 1 System diagram

The processing parameters are obtained during training lessons for each user, where a custom developed software (TP4) finds the proper values based upon its knowledge base, programming the NVRAM through the serial port. A simpler and not so efficient version, which allows configuration through dip switches selection, has been developed to reduce costs.

Results: The tests made consisted of composing several different MsWord formatted documents (A4 size), using a complete computer access TA (keyboard + mouse). These experiments, proved the interface’s efficiency for reducing the total time to complete de task a 35% off, by filtering a large amount of the involuntary activations recorded.

Discussion: The equipment proposed in this paper offers a simple low-cost alternative despite of performance. Although the filtering methods based upon the joint time-frequency analysis of the EMG signal are more efficient, the calculations they relay at require powerful (and expensive) processors, which are not so likely to be integrated within new or existing TAs. Future developments should look at the use of more complex fuzzy controllers based upon EPROM mapped matrixes obtained after a joint EMG–switch activation recording analysis for each user, as those made before to get the general model.

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Tele-homecare in an urban area utilising commercially available technology

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Introduction: Throughout Europe there is an increasing awareness of the need to provide universal and equal access to health services, and to improve the uptake of services by disadvantaged groups.

The recent e-Europe 2002 action plan aims to bring Europe on line. This will impact on the infrastructure availability and cost that health service providers can choose to access.

Nationally the government has reinforced its commitment to the utilisation of technology in the NHS. ('Building the information Core: Delivering information for health Jan 2001)

There is no positive correlation between expanding demand for NHS services and monies available. The challenge faced is to provide high quality, equitable service in a cost effective and efficient way that will adequately meet the needs of the client and service providers.

Each Trust has the responsibility to consider all options to meet the demands on services. The competitive market in the world of communications technology has ensured that the hardware is now affordable and accessible to health service providers.

South and East Belfast Trust is a community trust in an urban area of Belfast. The total population is 202,000. A wide range of clinical specialities are provided. These range from Adults services/ Childrens services, Mental Health/Physical disability, Learning disability/Forensic psychiatry. For the past two years the trust has explored video conferencing as a method of delivering therapy.

Aims of project:
-To demonstrate how health care providers can offer cost effective care to patients at home in Belfast, taking advantage of the emerging cable network.
-To explore the clinical potential of a basic technological platform.
-To enhance the health service delivery to the citizens of SEBT.

Two different clinical areas where chosen to explore the potential of one hardware solution:
-Speech and Language Therapy for pre-school children with a learning difficulty.
-Intensive home care for adults who are care managed, totally dependant for all care needs and receive care throughout the 24hour period.

Point to point conferencing from the service provider to the home of each of the service users was established. On one of the services, intensive home care, the technology was used a multi-professional group of staff, with 24 hour contact to the Trust, to assist in risk management.

The infrastructure was low cost broad band ISDN2 over cable. A motion media set top box and a PTZ camera where used. At the service user end the clients own TV with a scart adaptor functioned as the monitor. This system was also used on intensive homecare. The Speech and Language Therapist however used a pc based solution, with additional VCON Cruiser software.

This work was undertaken as part of a European project 'Attract'.

Methodology included:
-Literature review of tele-medicine
-Establishing inventory of appropriate technology.
-Establishing relationships with potential infrastructure providers.
-Determine clearly defined specific clinical objectives to be achieved over the technology.
-Establish end user (client) requirements. This included issues of equipment accessibility which could accommodate physical impairment.
-Establish service provider requirements.
-Explore ethical, legal and risk implications of delivering health care in this way.
-Demonstrate the use of the system in clinical practise.
-Evaluate delivery of therapy over the chosen system.
-Development of a business case for future roll out into other clinical areas.

Core value of the work was that the technology providers would not pre-determine a hardware solution which had to be slotted into clinical work. The full capacity of the technical specifications must be essential and not utilised because it is available commercially.

Conclusion: The literature search demonstrated that this is the first time a Health Service provider has explored the potential of delivering therapy services over commercially available communications technology in an urban area.

Exploration of the potential to use one hardware solution in a variety of clinical settings was demonstrated.

The needs of the clinicians and clients determined the technical specifications required.

The successful implementation of technology to health service providers is dependent on end user drive, thorough user training and detailed exploration of ethical, legal and risk issues.

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Phone communication by means of synthetic speech for deaf-mute people

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Introduction: The telephone network is almost inaccessible for people who cannot speak at all. Inside the society of deaf and mute people they can communicate using specialised TDD (Telephone Device for Deaf). Recently fax machines became very popular. There are special intermediary services also. Computers with modems can act as TDD. But still the converser has to be equipped with a special device to exchange information.

In the proposed solution it is assumed that the converser can be completely unprepared.

The most natural way of communication among hearing and speaking people is the speech. The main problems connected with the utilisation of speech synthesiser as a prosthesis of speech organs are: the quality of speech and the speed of utterance generation. The quality problem (with Polish language) was solved when the SMP speech synthesiser was developed in IBBE PAS.

Methods: Program "DIALOG": To provide enough speed of utterance generation a special computer program called „DIALOG" has been designed. It contains a set of ready-to-say sentences prepared by the user. It allows speeding up speech significantly

To ease the choice of the right sentence, they are grouped in 100 categories by subject or situation. Each category can contain up to 20 different sentences. Each sentence can contain replaceable parts chosen from one of 100 dictionaries. There is a possibility of defining the grammar form of replaceable words during the creation of the set of sentences.

The system implementation: The system will contain several devices. We called them: T-EAR, W-EAR, V-EAR and S-EAR. T-EAR (T for „text") is the portable device acting as the receiving part of the TDD. W-EAR (W for „write") will be in fact the small portable TDD. V-EAR (V for „Voice-modem") is a PC computer with voice-modem running program that performs functions of TDD and generates synthetic speech. S-EAR (S for „speak") will be a portable TDD with speech synthesizer and database of sentences. Currently two of them (V-EAR and T-EAR) are at prototype state.

The schemes on figure 1 show possibilities of communication which gives each of described devices.

V-ear: A program implementing all of theese functions on standard PC class computers with voice-modem was written. It consists of a modified „DIALOG" module, speech synthesis module, voice-modem control module and module of DTMF detection, interpretation and generation. The DTMF interpretation module ensures compatibility with TDDs transmitting text via DTMF signals according to ITU-T Recommendation V.18. It also allows receiving text encoded in several standards used in Poland. There is a special mode in which received DTMF codes are interpreted as a choice of sentences from standardised part of „DIALOG's" set of sentences.

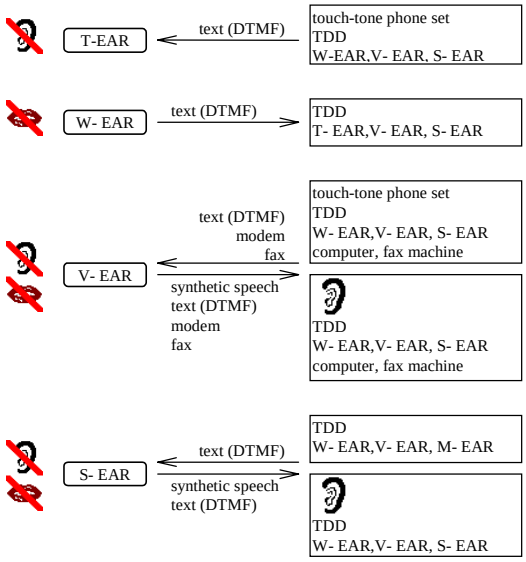

Figure 1

T-ear: The T-EAR device is designed to communicate by means of DTMF signals. It is prepared for deaf people and allows to come into contact with a person with touch-tone dialing telephone or with TDD.

The prototype has 2 x 16 characters LCD display, the LED indicating phone line state, control buttons, microphone and elastic strip for mounting on the handset as. It can display received DTMF codes directly or decode them in standards mentioned above.

Results: The system containing a computer with „DIALOG" program, SMP synthesiser was tested by a mute but hearing person. Several phone conversations have been performed. There were no cases of misunderstanding during these conversations.

Several conversations were arranged between the hearing and the deaf but speaking person equipped with T-EAR device. The hearing person answered with key strokes on the phone keyboard using simple code: 1='yes', 2='no', 3='don't know'. These conversations showed that information exchanging is possible in that way.

Several tests were done by two deaf people. They both were equipped with T-EAR device and touch-tone telephones. There were problems with separation between signals transmited and received. For communication between two deaf persons the W-EAR device will be a better solution.

Creative interfacing - The development of appropriate assistive technologies for real-time music performance

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Abstract: The research activities of The Drake Music Project Ireland centre on the development and provision of assistive technologies for musicians with physical disabilities. The objective is to provide accessible interfacing to music technology equipment to afford real-time independent control by the disabled musician.

Introduction: The Drake Music Project Ireland exists in order to afford physically disabled adults and children the opportunity to independently compose and perform their own music using music technology equipment. It is the objective of the research team of The Drake Music Project Ireland to design appropriate assistive technologies to enable the musician to perform independently in real-time, with no third party interruption to artistic expression.

Methods: In what is envisaged as the first phase of a large-scale development program, the research team has formulated a three-fold strategy to initiate the development of appropriate human-computer interfaces for physically impaired musicians for use in real-time performance set-ups:

Feasibility Study: A comprehensive feasibility study has been conducted, to evaluate the current provision of technologies in human computer interfacing (HCI) and their appropriateness for physically disabled musicians operating in a real-time environment. In addition to an audit of current technologies in music systems, the use of speech as an assistive technology for people with disabilities, [1], the potential use of electromyography in HCI applications for musicians, [2], and a

review of general HCI research in the area of assistive technologies has been conducted [3]. These reviews have been collated and results are being evaluated for appropriateness to this application.

Performance Parameters Audit: Musicians from the Drake Music Project Ireland were audited with respect to the performance parameters required to be controlled during a real-time performance. Test situations involving several students, able-bodied and disabled, were evaluated, and conclusions were drawn with respect to the number and range of parameters any appropriate HCI would provide the musician with once developed.

Preliminary MIDI-controllable Musical Interfaces developed: During this first phase of the development program, the research team, working closely with the test musicians of The Drake Music Project Ireland, developed two innovative musical interfaces to be incorporated into current Project music performance workstations. These designs are based on augmented versions of current instrumental interfaces, taking full advantage of the industry standard MIDI protocol for message transfer. Both devices, the "GIANT KEYBOARD"™ and the "PADDLE PLAYER"™ [4] have been tested on a cohort of users with varying degrees of abilities and high levels of user acceptance and usability have been recorded [5]

Results: At present both the "GIANT KEYBOARD"™ and the "PADDLE PLAYER"™ [4] are in use in The Drake Music Project Ireland weekly workshops and performances. Further refinements of both of these instruments are planned following testing and evaluations by end users.

The feasibility study and user skills audit have been completed and results and recommendations are being drawn to formulate the second phase of this development project.

Conclusions: Based on the development of accessible interfacing it has been possible to improve the provision of real-time control for musicians with physical disabilities. The Drake Music Project Ireland plan to continue this development program to provide higher level control of the real-time environment for disabled musicians and by inference for the wider community of people with physical disabilities.

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Esot radio frequency beacon system as the mobility aid for the blind

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Introduction: One of the most important problems related to the rehabilitation of the blind people is the possibility of the independent movement outside building. The disabled people have to be able to independently get to work from home and make some shopping. On the way they usually meet some dangerous and difficult places where the long white cane is not good enough to give security and guide them in the right direction.

The new electronic system has been designed to help the blind people to travel outside the buildings. It is based on the set of small and cheap radio transmitters placed at some dangerous and important places on the blind people way, and a receiver carried with the user. The system is designed to be very small and personally oriented. This system is an alternative for expensive and not easy to use satellite (GPS based) systems.

System description: The system consists of several small transmitters located on the objects and in places, which are difficult to recognise, by the blind person. Usually up to five transmitters are sufficient to sign the most difficult way. The ambiguous and/or dangerous places include: the crossroads, the horizontal bars or panels, the poles and holes on the footpath. The user carries the receiver, which can localise the transmitter radio signals and can alert the user with an acoustic signal (voice or beeper). Then using the long cane the blind person can easily localise the right way or avoid the dangerous objects.

The construction of the system allows the user to install the transmitters by himself at any places it's needed. This makes the system very suitable for the personal needs. The public navigation system is very expensive and in many cases useless for the blind people whose walk about other than signed way. However in some cases like the public transport, shops and medical the public transmitters may be very useful.

The transmitters send short radio signals every 0.5s. PWM modulation with on-off keying was used for good interference immunity and circuit simplicity. The signals contain coded information about the transmitter number and category. The coded word consists of 20 bits.

The transmitters are working on the ISM frequency band (433MHz) with the radiated power of about 20μW. at this power the reception range is from several meters up to 40 meters depends on the transmitter localisation (building, tree, fence, underground). Due to low power consumption, the transmitters can work up to 3 years without exchanging the battery.

Results: One of the most important parameters of the system is the accuracy of localisation of signed places and the stability of localisation, especially in the big town in the presence of a number of radio noise sources.

Using the Rohde & Shwarz EB200 radio receiver the radio noise on the high traffic streets in Warsaw downtown on the public band 433MHz has been measured. The noise was so high that the system with simple binary keying appeared to be useless. In this situation the implementation of pulse width modulation was necessary. However, in very noisy place some transmitted codes were skipped.

The new system has been tested on the streets at Warsaw downtown and at suburban area of the school for the blind people. In both places the blind users could easily recognise the most difficult places thanks the ESOT radio beacon system.

Conclusion: The ESOT system is designed as a simple, low-cost solution, intended primarily for personal use. It can be further upgraded with public transmitters. Using the ESOT system blind people have speech information or beeper signal for their outdoor orientation and can effectively avoid some

dangerous and difficult places on their way. Speech information is recorded by user himself inside the receiver and can be upgraded. The system is language independent.

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