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Tele-Medicine Decision Support Platforms: An Application

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Abstract:- A new Decision Support Platform (DSPm) is presented, as the basis of a ready-to-be-applied multi-level Tele-Medicine Service (TMS) that addresses an open multi-disciplinary group of medical care providers working in the medical area of epilepsy. Being the outcome of a close collaboration between engineers and Medical Doctors (MDs), this Platform's features plan to satisfy the demands of medical care providers. This DSPm enables the user to make a decision based on the identification of critical interaction factors amongst predefined data categories through a correlations model on the Integrated Clinical Picture (ICP) of the patient in real time. ICP refers to the ability of the DSPm to record, describe, and classify the epileptic cases on the basis of their type, frequency of occurrence, duration of symptoms, and correlate them to respective pharmacological treatment and period of application as well as respective specialized EEG and vEEG pictures. The entities of the DSPm and its major characteristics as issued from the TMS's pilot implementation and the evaluation procedure utilised during this period of time are presented, along with an extensive discussion for handling the DSPm.

Key-Words: - Decision Support Platform –DSPm, Tele-Medicine Service –TMS, EEG, SDSL, Distributed Computing System - DCS

1. Introduction

The pre-surgical assessment of epileptic patients involves a wide range of tests (EEG, vEEG, postictal and interictal, PET, brain activity recording with implanted electrodes, anatomic and functional MRI, MEG, WADA tests) that are employed for the functional evaluation of their cases and the exact anatomic localization of the focal point [8]. Therefore, a complete clinical picture of an epileptic patient requests a specially designed dynamic database for storing, analysing, and correlating a range of non-homogeneous data in order for the medical practitioner to be able to make a decision regarding the pharmacological and/or operational treatment to be followed [2]. A number of already mature technological fields was utilised to the new DSPm so as to comply with the many arising prototyping specifications [10], [13], [14] such as personal computer-based design, tele-communication networking facets, and software applications as the tool towards remote collaboration between distant parties [18].

The DSPm offers [2]:

- **Access Security**. No unauthorized admission to the Platform is permitted.
- **High-grade Performance**. Special attention was given to achieve minimal access and

response times and encourage MDs to become familiar with the new technology.

- **Scalability**. The DSPm handles either small or large numbers of users.
- **Multi-platform architecture**. The DSPm was strategically built to enact a Distributed Computing System (DCS) thus permitting the exploitation of printers, file servers, etc. while facing resource-consuming tasks calls. Data, which are presented within the DSPm, may be shared across all DSPms (nodes). This task-scheduling facet gave the platform flexibility, robustness, and nearly limitless access potential.

The DSPm was developed so as to be fault tolerant and enable a non-stop availability. By making use of all processing power and by 'load balancing' all the utilized nodes in the distributed system, its overall efficiency was increased. Synchronization across the TMS system also was a particular management challenge that required special care; moreover, security enforcement was harder than trivial to achieve [12].

The impact of the DSPm is significant since it can be seen as a tool to support and justify the decisions of neurologists. In any case, the DSPm needs to be implemented carefully and managed well since concerns could be raised about liability, confidentiality, competition and other ethics, policy, and regulatory issues when used in conjunction with Telemedicine Systems for the collaboration amongst professionals. For these reasons, the International Telecommunications Union (ITU), Geneva, Switzerland, organized an expert study group (ITU-D) in order to cope with the problem of the diffusion of telemedicine and other social services in a national or international level [9].

Herein, Section 2 describes DSPm/TMS architecture issues and in Section 3 their pilot implementation is presented. Evaluation of the Platform and the Service is reviewed in Section 4 and a conclusion concerning the whole system is offered in Section 5.

2. Architecture

The novel system's architecture is described in three sub-Sections. The first one presents the TMS general characteristics and the key points of the DSPm architecture. Sub-Sections 2 and 3 portray respectively the Client and the Server domain structure.

2.1 General Characteristics

The infrastructure sharing and our experience ensured that the DSPm would present a high quality of service, while operation costs are significantly reduced. The TMS's DCS consists of a Decision Support Platform Layer (DSPmL) addressing, linking the communication facilities that each node provides, and the required application from the Service [4],[19],[20],[21]. The DSPmL acts like an in-between service amid application programs and networks, managing the interactions among disparate applications across heterogeneous computing platforms. The introduction of a set of DSPm components, such as the middle tier, serves to decouple client applications requests from the data access code as shown in detail in Fig. 2. The introduction of this tier also eliminated cost dependence between DSPm client applications and multiple DBMSs up to 70%. The DSPmL:

- Provides the framework to safely distinguish different clients or groups of clients. The DSPm acknowledges who is trying to perform an operation on a component.
- Hides a component's location; it also hides the security requirements of a component. The same binary code that works in a single-machine environment, where security may be of no concern, can be used in a distributed environment, securely [18].
- Achieves security management by allowing administrators to configure the security settings for each component and it stores

access control lists for each of them.

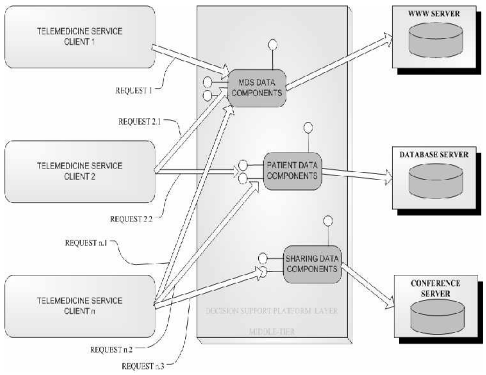

Fig. 2: Decision Support Platform Layer

Whenever a client submits a request to access a component, the DSPmL obtains the client's username associated to the current process (i.e. the current thread of execution). The DSPmL then passes it to the machine or process where the component is running. The DSPmL on the component's machine validates then the username using the authentication mechanism that is configured and checks the access control list for the component.

These components ensure a high degree of independence between the underlying systems (DBMSs, Application Servers, etc.) and the TMS applications. Each client's DSPm's operating system had to be provided with a software object in order to support the set of distributed applications required for the host to participate in the DCS. This DSPmL provides a set of services specifically geared towards supporting DCS. The services ensure that DSPm is scalable, reliable, secure, and available, while providing for high performance.

Another advantage is that a middle-tier programmer can update the DSPm components without requiring a re-compilation and re-distribution of client applications [4],[3]. Thus, the process of changing a DSPm application's data access code is facilitated and the client applications are screened from the system's infrastructure. A system's data can change storage formats and new database servers can be brought on-line with little effort. The necessary modifications are made in the DSPmL, allowing client applications to remain always on-line and in-operation. TMS architecture's key points are as follows:

- The Communication Entity satisfies the ITU standards, such as SMTP, POP3, IMAP4, LDAP, and NNTP for handling data exchange [7].
- The Administration Entity (§3.2) bridges the interoperability of the multiple database servers that are integrated in the TMS network, the calls, and the router connections according to the number of free server ports in the network layer.
- Local and remote databases and apposite servers are used, incorporating service, querying, and maintenance tools as well as user interfaces.

2.2 The Server Domain Structure

The Client and the Server domains have modular structure including diverse type of entities, each one performing a specific set of processes. This structure allows the service developer to utilise diverse operational and development tools in order to implement any entity and to introduce the appropriate functions and facilities for the client's supported application. The laboratory exam modules are introduced manually by the user or automatically by medical modalities are linked to a telemedicine service.

The data are being administrated and contain the following general entities and interfaces (Fig. 3 shows this Domain Structure):

- The Communication Entity (CE) administrates the DSPm [1].

The Network Service Elements Entity is responsible for the safe data transfer between the collaborating clients (i.e. MDs) [5], [7], [16].

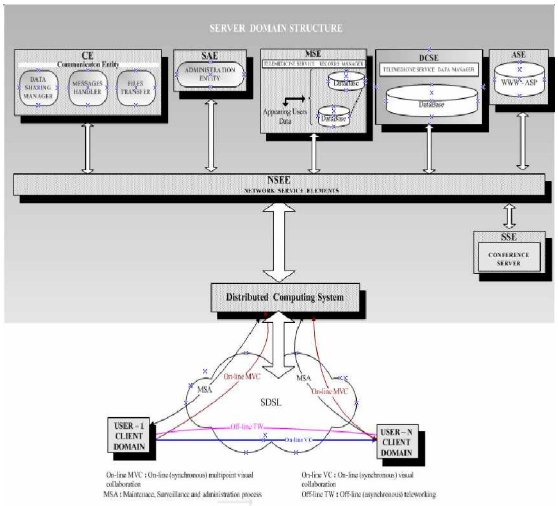

Fig. 3: Server Domain Structure

- The Service Administration Entity (SAE) correctly synchronizes the combined procedures: the time-schedule of the main application, the timing of the asynchronously started operations while in an active application (e.g. participants' identification) [6], [11], [17], and the various procedure synchronization levels [5], [16].
- The Storage Service Entity (SSE) is responsible for compensating the high cost of the data amounts that multi-user applications exchange.
- At the Application Service Entity (ASE) the patients' catalogue is hosted. This information is derived from the MDs' personal databases and can be arranged to appear in the private personalized web site of each MD through the central database.
- At the Messaging Service Entity (MSE) several databases are hosted. Every MD accesses a Local Database (portrayed in Fig. 3) where private information is stored, and exchanges data with the remote DBMSs.
- The Data Centre Service Entity (DCSE) contains the patients' directory. This is mainly a database (which has similar structure with the Local Database), storing the personal and medical data of all the TMS patients.

2.3 The Client Domain Structure

The resulted modules are stored in the ASE. The application data evaluating entity (AEE) is responsible for the report, review, and evaluation of the examination data. It includes suitable operators for the processing and annotation of medical still images (simple and series). The laboratory examinations are automatically evaluated using a control mechanism that compares patient values with user-normalized values. It also includes tools for the creation, modification, and deletion of the report modules.

The AEE is supported by an image processing library that includes several operators such as zooming in/out, filters, rotation, edges enhancement, contrast control, mirroring, etc. With respect to the examined anatomical area and the type of handled image (e.g., CTs), the user is able to select the appropriate operators through a supporting tool. The system is customizable to various environments of neurosurgery units and its main entities are:

- **Personal Data Entity**: This section contains the patients' personal data. It includes tools for the creation, modification, and deletion of these data (Fig. 4).

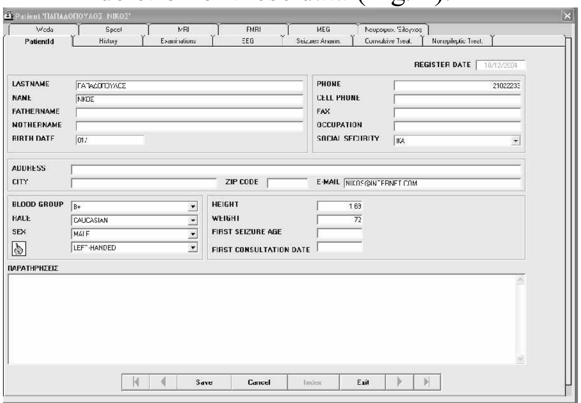

Fig. 4: Personal Data Form

- **Pre-surgical Patient's History Entity**. Patient's history regarding presurgical epileptic events is categorized in type, frequency and age period. Description entries of epileptic seizures are selected by windowed directed options to automatically correlate to other data of the application (Figures 5 and 6).

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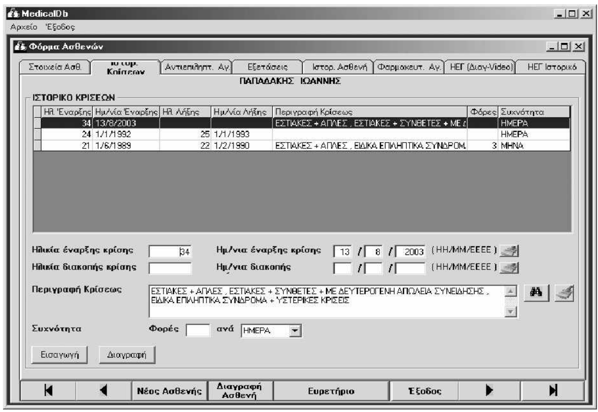

Fig. 5: Clinical Examination Form

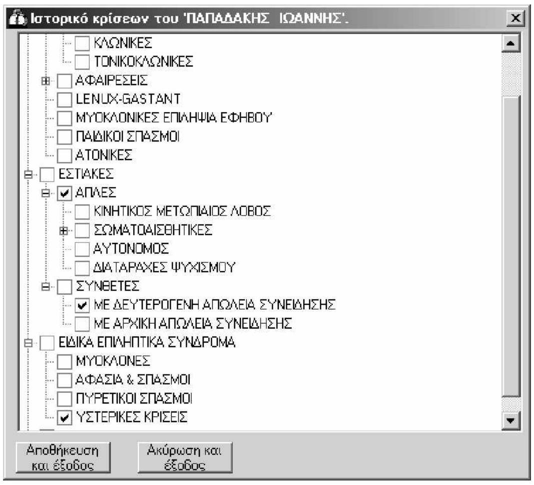

Fig. 6: Seizure's Analysis and Classification

- **Pharmaceutical Treatment Entity.** Anticonvulsant therapy and other pharmaceutical treatment evaluation is monitored and automatically correlated to data from other entities (Figure 7).

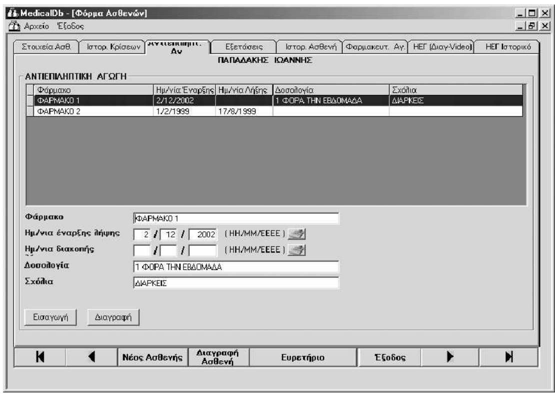

Figure 7: Pharmaceutical Treatment Evaluation Form

- **Other Examinations Entity:** This group contains the results of biochemical, blood, urine, and lung laboratory examinations that are organized in laboratory-exam modules based on the primitives of the HL7 and CEN/TC 251 WG4 standards.
- **Family History Entity**. History data are entered using predefined keywords so that automatic link to certain diseases and entities of the application, e.g. pharmaceutical treatment or characteristics of the topology.
- **Non-Epileptic Pharmaceutical Treatment Entity.** The history of any other pharmaceutical treatment with the corresponding prescription. The same procedure, as in the case of antiepileptic medicament, but without the special process.
- **Post-Operational Monitoring Entity**. All data are saved in the MDs' Local Database as illustrated in Fig. 8:

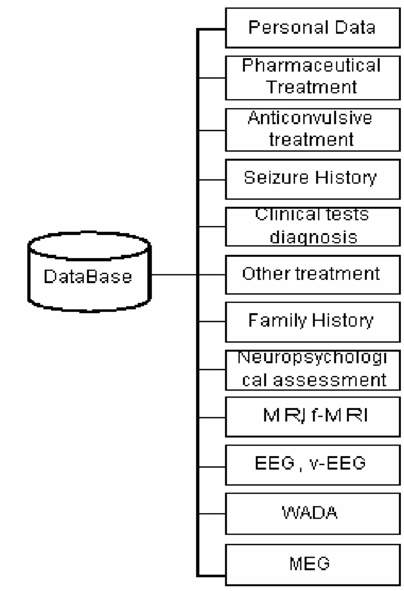

Fig. 8: Data Base structure

- **Elementary Presurgical Assessment Entity:**
  - o *Interictal EEG*: characteristically epileptic findings lateralization, localization and seizure's topography.
  - o *VEEG*: three-seizures, inter-/post-ictal findings,

lateralization, imaging (Fig. 9).

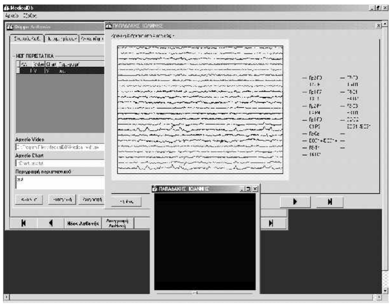

Fig. 9: vEEG

- *MRI*: hippocampal sclerosis, hippocampal volume try, multiple focuses, fusion.
- *Neuropsychological examination*
- *WADA* test. This entity, accepts digital bio-signals from EEG recordings during WADA test (Fig. 10), at pre-surgical control in epilepsy. The particular process consists of the digital acquisition of 21 channels EEG, where the system is able to cover up to 128 different recordings from equal in number channels.

Fig. 10: WADA Test

Data acquired from a medical device are saved separately. MDs can analyze the EEG waveform as a whole, or as a part from a selected channel and/or time range. Bio-signal modeling refers to certain waveform pattern identification (e.g. alpha, theta waves etc), correlation to known types. Statistical processing refers to bio-signal parameters calculation, like frequency, voltage, synchronization, and periodicity. When these tools are used by an MD and are tuned so as to successfully identify pathological EEG waveforms, they can be used to automatic recognition and analysis in pre-surgical control, epilepsy, and telemedicine.

- *Functional MRI*
- *SPECTICTAL - INTERICTAL*
- *MEG*

3. Pilot Implementation

The implementation of the pilot project took place between the Neuro-Surgical Clinic of the IASO General Hospital in Athens and the Wire Communications Laboratory, of Electrical and Computer Engineering Department, at University of Patras. As aforementioned, the TMS facilitated the MDs' business, as will be shown.

3.1 General Characteristics

Two terminal schemes were considered for the implementation of the client domain:

- A unique terminal, integrating all entities. This choice allows the lowest possible hardware complexity as well as simplicity in terminal operation and maintenance.
- A number of terminals, each one integrating different set of entities. The terminals may be interconnected through a LAN composing an Intranet that allows the optimum handling of distributed resources within the client's domain.

Both terminal schemes achieve full compatibility on the level of the system's basic structure and management functions. Data generated by different systems, are uniformly handled independently of the DSPm, the employed communication, and the computing infrastructure. Conversely, for the implementation of the Service Provider domain, the design aspects were focused on the size, the total number, the geographical distribution of clients and traffic load, the data security and the service's reliability (low/no traffic congestion).

3.2 Implementation Choices of the Client Domain

The current version of the client's terminal is based on MS-Windows 98/me/2000/XP operating systems. All the software entities that are included are implemented as modules using the MS-Visual Basic v6.0 programming language. MS-ADO (database) function calls are used for communication among the implemented databases, the GUI and the software modules. The Local Database has implemented with Microsoft Access.

3.3 The implementation of the Service Provider Domain

The Domain includes a fast Ethernet LAN and suitable Entities, the LAN being based on a CISCO DSL server. It is connected to a 1012Kbps SDSL line. It allows communication with the clients' domains according to the TCP/IP protocol as it is supported by the operating system. The CISCO IOS software implements the Communication Entity.

Due to the nature of the TMS requirements, a potentially huge number of simultaneous clients must be able to perform a great number of requests while maintaining sort response times. The TMS thus is designed to allow the applications to be scaleable: it is possible to add more server machines to accommodate more clients.

Because of the fact that the client service components and the DSPm ones do not maintain any shared states between invocations, it is possible to simply run multiple copies of them on different machines. Thus, the problem is to efficiently share the data services between different machines running replicas of the client and business service components.

The SAE consists of 3 software modules implemented using the MS-Visual Basic v6.0 programming language, and MS-ADO function calls. The first module implements the DCSE, the second the MSE, and the third the ASE management.

The on-line sessions are implemented using the MS-Live Communications Server (that follows the ITU H.320/T.120 standards), supporting efficiently up to 60 clients participating in one or multiple active sessions. The administration and management functions of the MS- Live Communications Server include its hardware configuration, directory management (sites, participants, calendar), and the sessions' scheduling, monitoring, reporting and handling.

4. Evaluation

A combined network of 6 nodes was installed with the purpose to link the IASO Neuro-Surgical Clinic and the Wire Communications Laboratory.

The TMS responded successfully throughout the pilot project (6 months), while the project itself is considered to be a success. In this period of time over 120 cases were serviced (75/190 ratio of test/real cases); a total of 354,458,986MB were exchanged amid the nodes; usage time during collaborative sessions was 90min in average; the topics covered were 76% service in nature, 14% administrative, and 10% social talk.

The MD's attended a two-day Seminar which was guided by a team of two of the original DSPm and TMS developers. A day was used to demonstrate the capabilities of the Service with the use of presentation material (organizing two-hour repeating lectures) and another day was needed for training each employee to a DSPm (free training time).

After the pilot project's implementation time elapsed, the MD's were asked to compile questionnaires with standardized metrics for evaluating both the DSPm and TMS. Approximately 20 employees of varying ranks and task schedules contributed to the results that the following Tables summarize. The overall results are considered more than satisfactory.

Table 1 shows how MD employees judged the service's performance. All answers were positive; the best ratio was achieved for the one regarding execution time. Service reliability rated second, whereas recovery performance with regards to the TMS's and MDs' errors was satisfactory. System resources management was also well accepted.

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	Rates		
	(-2)+(-1)%	0%	(1)+(2)%
Response/Task execution time	0	9	91
System Reliability	9	11	80
Recover Capability/ /Terminal Errors	14	15	71
Recover Capability/ MDs Errors	6	18	76
System Resources Management	5	19	76

Table 1: Service's Performance Rates

In Table 2 it is shown that 75.1% of the MDs found that on-line help was useful and easy to handle. The user documentation was found comprehensible and handy by 98% of them. As related in Table 3, 96% of the answers certify that the quality of video images captured, processed (real-time), and transmitted was very good. The illumination of the rooms was adjusted properly, in order to have clear video capture. Answers corresponding to Audio/Video quality were also good, only limited by standard Audio/Video equipment which was used. The implemented graphical user interface was positively rated too.

	Rates		
	(-2)+(-1)%	0%	(1)+(2)%
On-line Help	10.6	14.3	75.1
User Documentation	0	2	98

Table 2: Manuals and On-line Help Rates

	Rates		
	(-2)+(-1)%	0%	(1)+(2)%
Video Images Handling	0	4	96
Video quality	0	17	83
Sound Quality	0	19	81
Quality of User Interface	0	6	94

Table 3: Quality of Multimedia Agents

In Table 4, the conference, handling was judged very well. MDs found satisfaction in collaborating with and for the patients' cases or/and among themselves, utilizing all their remote resources (e.g. archives).

	Rates		
	(-2)+(-1)%	0%	(1)+(2)%
Conference	0	8	92
Cases Enhancement	14	4	82
Patient File	3.2	7.6	89.2

Table 4: Tele-Medicine Service's Tools

As shown in Table 5, the learning process of the system is comprehensive for almost all the users. The main functions were rapidly learned, while the advanced ones required more training. The required time for learning and exploring the full capabilities of the system was also good. MDs asked for more time to further utilize the terminal stations (DSPm).

	Rates		
	(-2)+(-1)%	0%	(1)+(2)%
Learning Process	1	5	94
Main Functions	2	10	88
Advanced Functions	5	20	75
Learning Time	5	8	87
Exploratio n	9	4	87
Required Actions	7	13.5	79.5

Table 5: Functions Learning

Table 6 shows the results that relate to the collaborative sessions. MDs found the connection process and the needed time good. When handling data operations -both file transfer and application sharing- they were satisfied with the quality of service and required time. Utilization of real time communication and sharing tasks was also positive.

	Rates		
	(-2)+(-1)%	0%	(1)+(2)%
Connection process	3	12	85
Connection time	0	8.3	91.7

Real Time Communication	0	3	97
File Transfer	8	10	82
Sharing Tasks	2.7	3	94.3

Table 6: Cooperative Sessions

5. Conclusion

The developed Decision Support Platform was focused in order to establish Tele-Medicine service and the many applications that spring from its use in a flexible, user friendly, foolproof, fruitful and most convenient manner. It seeks to convey unexploited resources and to combine high-end technological solutions, especially in rural, remote regions where no other MDs collaboration means is available.

Attributes of the platform and service such as its adaptability and promptness to satisfy many work demands, are going to be enhanced by future, Tele-Centers. They will all combine the many, disparate subsets (small networks) of the main platform

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