Chapter 8
Technological Infrastructure and Business Intelligence Strategies for the EDEVITALZH eHealth Delivery System

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Abstract. In the recent years, the sociological importance of the elderly has grown significantly because of the increase of the prevalence of degenerative disorders, among which Mild Cognitive Impairment (MCI), Alzheimer's Disease (AD) and other cortical dementias should be highlighted. Using actual diagnostic criteria, by the time a patient is diagnosed with AD, the pathology has spread itself during several years. Besides, the unique certain AD diagnosis can only be performed *post-mortem*. Thus, it becomes absolutely necessary to accomplish early detection and MCI diagnosis. This chapter presents the advances achieved in the fields of Medical Informatics and Telemedicine by means of the EDEVITALZH eHealth Delivery System. On one hand, and of remarkable importance to succeed in a certain diagnosis, a standardization of the clinical protocol is proposed and digitally implemented to provide clinicians with the adequate procedures, methods and tools to perform more accurate early and differential diagnosis, and prognosis of patients affected by these neuropathologies. On the other hand, EDEVITALZH technological infrastructure is described, regarding computer architecture, databases and software engineering, with special focus on the embedded mechanisms that allow integration between EDEVITALZH Core components and the Intelligent Systems for Diagnosis (ISD) and the Intelligent Decision Support Tools (IDST), providing Computational Intelligence to the described virtual clinical environment. These integrations upgrade EDEVITALZH to an intelligent Clinical Workstation, being able to aid clinicians in decision making for early and differential diagnosis, prognosis and in performing evolution studies of patients and their pathologies, no matter which healthcare level patients are being assisted in, Primary or Specialized.

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8.1 Introduction

The population of the developed occidental countries is suffering a remarkable aging process with a clear increasing tendency in the elderly census. Several research studies reveal an extraordinary increase of people's life expectancy and a significative decrease of the birth rate and of child mortality, [1]. In the recent years, the sociological importance of the elderly has grown significantly, mostly due to the increase of the prevalence of degenerative diseases and their secondary functional disorders, causing severe socio-sanitary consequences. Alzheimer's Disease (AD) must be pointed out among aging-associated pathologies; a slow evolution neurodegenerative disorder featured by the loss of memory, orientation and language skills. AD, Vascular Dementia (VD) as well as Mild Cognitive Impairment (MCI), both of high prevalence too, could be considered as cognitive disorders in the aging process of a healthy brain. These disorders make up the most interesting group, estimated to affect between 5%-10% of people aging more than 65, because of the damages they cause to the patient's family, and to his/her caregiver.

Currently-used diagnostic procedures are, by excellence, clinical, hispathological and imaging ones, becoming very complex to perform a correct differentiation between dementias. In the particular case of AD, the unique certain diagnosis, and even when knowledge about these disorders is rising in such a way never seen before, nowadays the *ante-mortem* diagnosis of probable AD is confirmed *post-mortem* in 80%-90% of cases only in specialized centers, estimating the existence of a high level of underdiagnosis, reaching 95% of the cases in normal conditions. The International Working Group for New Research Criteria for the Diagnosis of Alzheimer's Disease (IWGNRCDAD) has proposed a new terminology which considers symptomatology and the behavioral-cognitive evolution as well as the possibility of complementing diagnosis by employing protein biomarkers [2], being able to arise several diagnostic cathegories, even years before the disease has started to manifest symptomatically. On the other hand, several handicaps emerge in the way to accomplish a certain diagnosis of these disorders. In first place, the spread spectrum of usual diagnostic criteria (CAMDEX, DSM-IV, CIE-10) and the very limited coincidence between them [1], not higher than 5%, if taken as a set (not yet having specific clinical valid criteria for each dementia). Second, the so-cited clinical-pathological duality. It is estimated that, by the time a patient is diagnosed with AD, the disease has spread itself during several years.

Geriatric and neurological valorations should be diagnostic instruments to analyze biological, mental, functional and psychosocial disorders of the elderly, to achieve an adequate treatment plan and an optimal management of the sociosanitary resources. Primary Care (PC) centers do not have specialists in AD and other related pathologies at their disposal. Hence, used procedures, techniques and diagnostic tools are not especially conditioned for the care needs to perform an accurate diagnosis of patient's disease (type of dementia) neither to provide the disease stage. In the particular case of Specialized Care (SC) centers, diversity and variability of procedures and diagnostic methods employed by clinicians to perform patient-evaluation and valoration are of remarkable importance. Continuity in patient care, a detailed monitoring of any variable associated to the disorder, fomenting collaborative work between specialists and giving the patient's familiar environment the importance it deserves become a must to build a solid knowledge base about MCI, AD and other dementias. This knowledge base will be highly important in the path to achieve two of the main goals in the field. First one, to implement mechanisms to early detect the disease. Second one, to improve efficiency in decision making to accomplish a more accurate and trustable diagnosis by means of differential diagnosis of dementias. It becomes necessary to search for new methods and techniques to speed up and increase reliability of diagnosis of these pathological syndroms, gaining knowledge about MCI, AD and other dementias and, moreover, improving patient's quality of life. In the same line, these new tools should boost a better use of resources of the sanitary system, that is to say, new management models are needed which improve the relationship between healthcare quality, efficiency and budget, [16].

A great quantity of the data-harvesting work taken in consultation rooms is still performed in paper or small standalone media such as local databases stored in personal computers, [8]. Digital gathering, access and store of clinical data in a centralized and structured way decreases the time a clinical professional needs to manage patients' medical records, which instantly increases the time a clinician is able to dedicate to his/her patients. Grouping the information provided individually by all clinicians involved in a patient's diagnosis and treatment plan makes it able to find key relationships inside data, empowering knowledge about diseases. To achieve this, a standardization of the clinical protocol to succeed in a trustable and accurate diagnosis of MCI, AD and any other dementia is needed; a clinical protocol customized to be used in both PC and SC.

In this chapter, we present the technological advances performed over EDEVITALZH, a Personalized, Predictive, Preventive, and Participatory Healthcare Delivery System (4P-HCDS) [11, 12, 15], in the fields of computer architecture, databases, software engineering and systems integration, modelling, managing and exploiting clinical information of patients potentially affected by MCI, AD and/or other dementias according to healthcare level and research needs. The first section presents a brief overview of the EDEVITALZH Environment, describing its structure and objectives. Next, EDEVITALZH Systems Tier is analyzed, detailing the implementation of a High Performance Computer, Grid type, especially focused to improve computing throughput in the execution of Intelligent Systems for Diagnosis (ISD) and Intelligent Decision Support Tools (IDST), which provide EDEVITALZH with Computational Intelligence to aid in the tasks of diagnosis, prognosis, monitoring and patient/pathology evolution studies. Subsequently, EDEVITALZH Database Tier is presented, describing its data model, according to the Patient Management (PMS) and Clinical Workstation (CW) paradigms and being fundamented on the Global Clinical Protocol for Dementias (GCPD) [11, 12, 15], which provides a detailed set of clinical procedures, forms, tests and diagnostic criteria, validated by medical experts in the fields of Geriatrics and Neurology, reflecting in an schematic way specific data of interest focused on the diagnosis of MCI, AD and other dementias. Furthermore, it correlates clinical and therapeutical parameters simultaneously.

The following section describes the User Interface (UI), also according to GCPD, which makes EDEVITALZH a CW developed to guide and aid clinicians in their workflow. Besides, EDEVITALZH is considered an intelligent CW (iCW) because of the integration of the EDEVITALZH Core with ISDs-IDSTs to aid physicians in diagnosis, prognosis and studying how these disorders spread through time. Last section presents our conclusions and future work in this research field.

8.2 EDEVITALZH Clinical Environment

EDEVITALZH is a Personalized, Predictive, Preventive, and Participatory Healthcare Delivery System (4P-HCDS) following the phylosophy of CW [11, 12, 14, 15]. EDEVITALZH Environment provides an Electronic Medical Records Database (EMRDB) as well as the digital implementation of the Global Clinical Protocol for Dementias (GCPD), a detailed set of clinical procedures, forms, tests and diagnostic criteria, validated by medical experts in the fields of Geriatrics and Neurology, which correlate clinical and therapeutical parameters focused on the diagnosis of MCI, AD and other dementias [14, 15].

EDEVITALZH Environment is based on a robust, secure, scalable and fault-tolerant technological architecture which provides users around the globe the capability to connect from anywhere and at any time. Its implementation follows the Spanish LOPDCP15/1999 policy, one of the hardest information security policies in the world, providing cyphered transactions over the web, database and systems security policies, patient data anonimization on sharing data between systems, and users authentication, profiling and control. Moreover, the entire environment is constantly being monitored and controlled by several network security systems. The main set of systems, applications, tools and mechanisms for information management, exploitation and integration inside the EDEVITALZH Environment is known as EDEVITALZH Core, (Figs. 8.1, 8.3). Any system, application or tool that shares data from/to the EDEVITALZH-Core must follow the EDEVITALZH policies about abstraction, modularity and security. This way, the Production EDEVITALZH Environment has passed code, systems and security benchmarks to assure it is a stable and safe platform.

EDEVITALZH web applications have been developed using the Model-View-Controller (MVC) design pattern, (Fig. 8.2), offering capabilities to improve, update and scale the environment with new resources, wizards, assistants and/or tools. This software engineering model has reduced both development complexity and time, as well as the needs of hardware resources. EDEVITALZH Environment is considered to be an iCW thanks to the Intelligent Clinical Wizards and Assistants (ICWA), which consist of the integration of EDEVITALZH-Core UI applications (ICWA-App) with ISDs-IDSTs, [5, 6, 14], providing the environment of Computational Intelligence. In this line, EDEVITALZH-Core has embedded the needed business logic to handle several ISDs-IDSTs working simultaneously on different requests

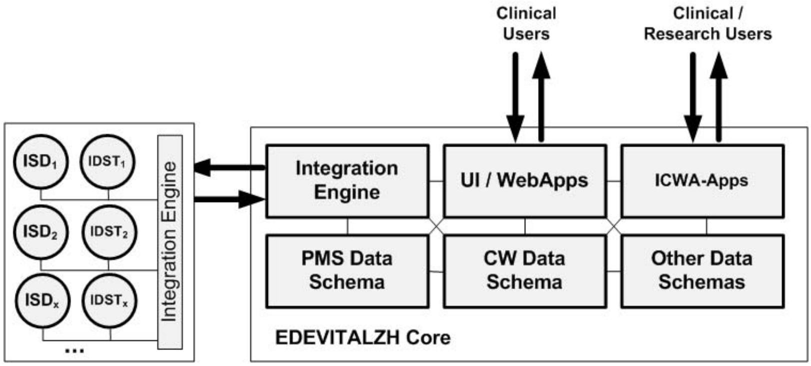

Fig. 8.1. High Level Architectural Diagram of the EDEVITALZH Environment

according to the clinical criteria selected, (Figs. 8.1, 8.3). Furthermore, EDEVITALZH incorporates the Electronic Medical Interconsultation (EMI), (Fig. 8.8). EMI empowers collaboration between clinicians by means of an internal messaging system, providing mailboxes and message send/receive operations at users' disposal so they can ask for colleagues' opinions, participate in discussions and collaborate in the monitorization of colleagues' patients. EMI is a powerful and valuable tool for professionals at PC and other welfare centers where there are no specialist physicians in MCI, AD and other dementias, giving the PC clinicians the possibility to assist patients who suffer these neuropathologies with a greater level of quality, efficiency and accuracy in the diagnosis and prognosis processes.

In short, thanks to the provided clinical protocol guideline, wizards, assistants and ISDs-IDSTs, EDEVITALZH is able to aid clinicians and researchers in decision making, focusing on the diagnosis and prognosis tasks, improving accuracy in early and differential diagnosis, reducing the needed time to perform a certain diagnosis as well as in carrying out evolution studies of patients and their pathologies.

8.2.1 EDEVITALZH Systems Tier

EDEVITALZH Systems Tier (ST) is the basis over which the clinical environment is built. Emerging from basic project concept requirements, there exist great influences which have important effects on the way systems architecture have been designed and constructed. Hence, it was taken into consideration that the EDEVITALZH Environment must:

- Provide services of PMS to manage patients' medical records in a computerized way. This item is directly related to database systems and storage.

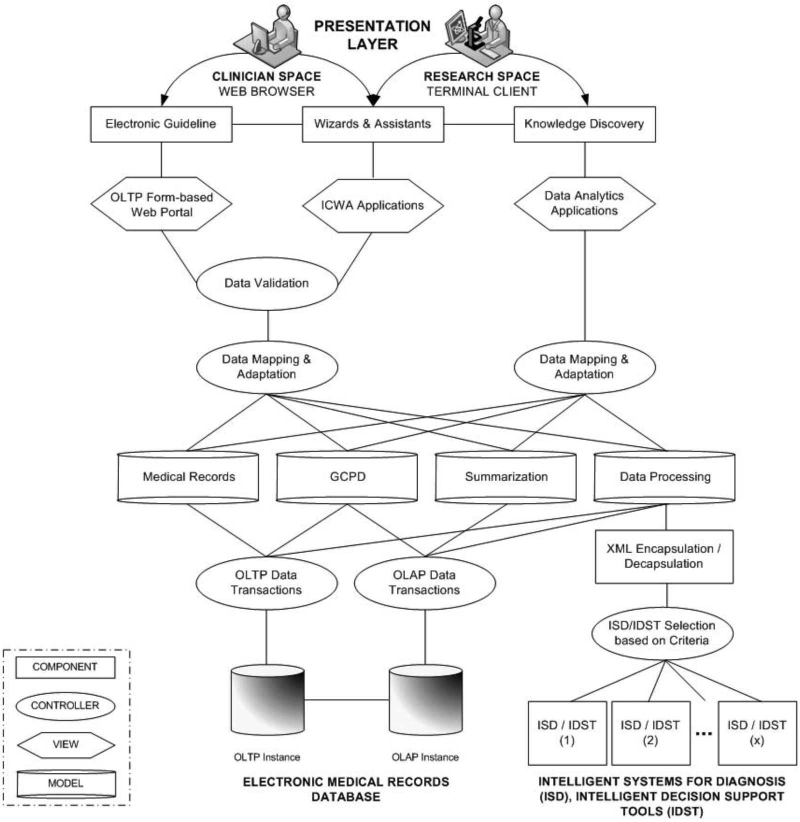

Fig. 8.2. Model-View-Controller Diagram of the EDEVITALZH Environment

- Provide services of CW by means of the set of clinical procedures, forms, tests and diagnostic criteria used by physicians to accomplish patient's diagnosis. This item has direct implications with UI Applications, database systems and storage.
- Provide the necessary technological mechanisms to integrate and communicate EDEVITALZH-Core with ISDs-IDSTs, enabling EDEVITALZH to become an iCW. This item is directly related to processing systems, database systems and communication procedures.
- Be a multi-user environment, allowing several clinicians to request, simultaneously, aid in the diagnosis process.

One of the basic concept requirements of EDEVITALZH forces to exploit the architectural model of the Internet network, that is to say, to take approach of influences, both technological and of resources, that global interconnection has provided through the last 40 years, [10]. In this line, ST design should take approach of the advantages the Distributed Computing Model (DCM) offers, [13], enhancing

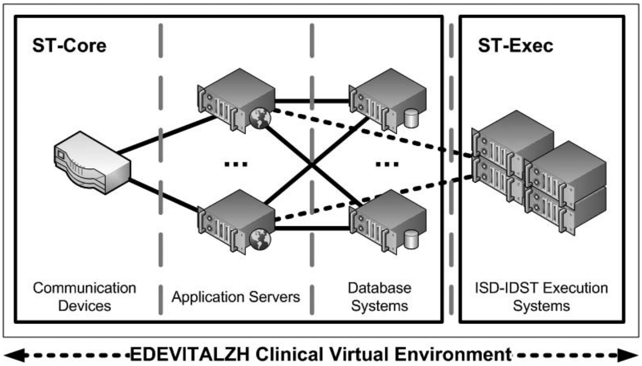

Fig. 8.3. EDEVITALZH Modular High-Level Organization regarding Systems Architecture: Core Module (ST-Core), ISDs and IDSTs Execution Module (ST-Exec)

Modularity. This means that every part of the environment has to be developed as self-reliant. To support this independence, two determined parameters become of maximum importance:

- *Fault Tolerance*: The clinical environment should be capable of minimizing damage upon failure of any of its modular parts. Furthermore, it should be provided of the needed redundancy on its critical components.
- *Scalability*: ST must be able to support the requirements of processing, storage and networking that the EDEVITALZH Environment may have through its lifetime. A scalable infrastructure, capable of being increased or decreased in physical resources according to its workload (processing cores, storage systems, communication and security devices) must be proposed.

Fig. 8.3 shows a high-level modular vision of the two main environment components, especifically:

- *EDEVITALZH ST Core Module (ST-Core)*: It consists of the main hardware systems that support Application Servers, Database Servers and Communication Devices, which allow users' requests to be served.
- *EDEVITALZH ST ISDs-IDSTs Execution Module (ST-Exec)*: It consists of the hardware systems that support processing and storage of ISDs-IDSTs and related components.

8.2.1.1 ST-Core: Components of the Systems Tier Core

The Systems Tier Core (ST-Core) is the hardware basis to support the EDEVITALZH-Core, (Figs. 8.1, 8.3). It consists of the group of systems that manage databases, user applications and internal and external communications of the EDEVITALZH environment, (Fig. 8.3):

- *Web Application Servers*: These are the systems serving the pages of the different web applications of the EDEVITALZH environment, which run instances of Apache Foundation's HTTP Server specifically configured for every web application of the environment.
- *Database Servers*: These systems store and manage the data schemas shown in Fig. 8.1, running MySQL as Database Management System.
- *Networking Devices*: These systems connect internally and externally the several components of the EDEVITALZH environment. Internally, the network is switched and monitored by 1Gbps Ethernet devices. Externally, the EDEVITALZH Environment is protected by a firewalling device and connected to the mainstream network of the University of Las Palmas de Gran Canaria, (Fig. 8.5).

8.2.1.2 ST-Exec: Components of the Systems Tier ISDs and IDSTs Execution Module

The Decision Support Tools Execution Module (ST-Exec) consists of the group of systems which handle processing load and storage by means of execution policies regarding ISDs-IDSTs workload. As every part of the environment has to be developed as self-reliant, each ISD-IDST component must be developed as an autonomous entity which receives input data under a user request and returns results according to that data. This way, every time a user demands a *Decision Supported Operation* (DSO), one or several ISDs-IDSTs are first selected upon a selection procedure and then asked to generate certain results according to the provided inputs. This description defines perfectly the concept of *execution job*. Hence, DSOs will be considered as execution jobs, demanding a certain amount of computing resources to accomplish their task.

Taking into account that EDEVITALZH is considered a multi-user platform, the environment must be able to handle several simultaneous DSOs. This condition demands EDEVITALZH to be capable of planning and managing its global processing resources to handle all user DSOs in an efficient mode, hence requiring execution policies to queue, prioritize and execute DSOs.

To satisfy the described requirements, a High Performance Computing architecture is proposed, (Fig. 8.5). It is needed to implement this architecture in the Grid Computing (GC) scope to be capable of having different physical computing resources placed and operating in different geographical locations. The term Grid refers to an infrastructure that allows integration and collective use of high performance systems, communication networks and databases, shared by several institutions. Because collaboration between institutions means data exchange and computing time, GC proposal is to easily integrate computational resources by means of any type of software which implements this concept. GC allows to use, in a coordinated way, all types of computing resources (processors, storage systems

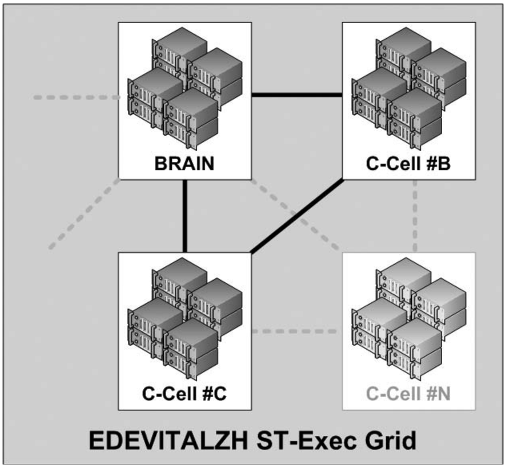

Fig. 8.4. Grid Computing Topology used in the implementation of ST-Exec. Several C-Cells can cooperate, being able to disconnect already-linked C-Cells or connect new ones to increase computing power. The environment offers scalability and fault tolerance.

and specific applications, among others) without being subject to a centralized control. In this line, it can be considered as a new way of distributed computing in which resources can be heterogeneous (different computing architectures) and be connected by means of Wide Area Networks as the Internet. Computing power offered by a crowd of GC interconnected systems is practically ilimited. Some of the main advantages of GC are listed in the following lines:

- *Load Balancing*: There is no need to calculate systems' capabilities in function of workload peaks. Resources can be reassigned according to needs and priorities.
- *High Availability and Fault Tolerance*: If a system fails, assigned tasks to that system will be reassigned to the rest of Grid nodes according to workload.
- *High Performance and Low Implementation Costs*: Thanks to distribution and heterogeneity properties, a performance similar to big mainframes can be gathered by using low-cost resources.

It is a high scalable solution, potent and flexible, that will avoid lack-of-resources problems and will never be obsolete due to the possibility of modifying the quantity and features of its components. On the other hand, communications and networking between systems become highly critical. Therefore, GC is a versatile, scalable, fault tolerant, distributed computing paradigm by means of the combination of many local systems to achieve a great global performance.

ST-Exec has been implemented using Oracle Grid Engine (OGE), an open-source distributed process management system capable of creating and managing GC architectures, [18]. Architecturally speaking, ST-Exec consists of Computing Cells

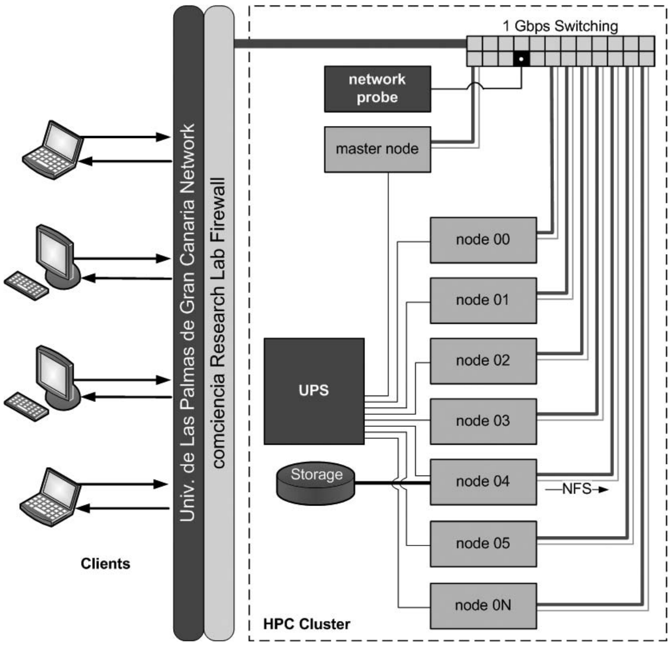

Fig. 8.5. Topology of 'BRAIN', the main EDEVITALZH Grid Computer C-Cell

(C-Cell), (Fig. 8.4). Every C-Cell is made up of a farm of servers running Linux operating system and connected by a high-speed communication network, linked to the Internet. Every C-Cell, identified by a Cell-ID parameter, is made up of the following structural components and parameters:

- *Master Host*: It is the responsible for managing, scheduling and assigning execution jobs. In practice, C-Cells can have one active Master Node and several shadowed Master Nodes for Fault Tolerance.
- *Execution Hosts*: They are responsible for execution of tasks assigned by the Master Host. They receive the needed binary executable image and inputs to run the process and gather results.

The main EDEVITALZH C-Cell has been identified as 'BRAIN' (Fig. 8.4) and it is located at COMCIENCIA Lab. It consists of two different computing architecture servers: ix86 and x86_64. 'BRAIN' is set up by 1 Master Host (no shadowed Master Hosts were provided at this stage of the project) and 5 Execution Hosts, (Fig. 8.5). A distributed filesystem has been configured by using Network File System (NFS). It is a stable and widely used filesystem. Following the same phylosophy, Network Information Service (NIS) has been configured as user credential management service.

It can be said that the max C-Cell performance will be the one of the node with highest performance. The performance of each node will integrally depend on its job-type orientation and configuration. To gather the performances of the different nodes integrated into the C-Cell, Intel Math Kernel Library - LINPACK has been used, [17]. LINPACK describes performance to solve a 3-sizes dense general matrix problem $Ax = b$. Table 8.1 shows the minimum and maximum execution results of LINPACK, individually on every node that make up the implemented C-Cell. Results show that, aparently, same hardware configuration nodes offer different performance ratios, although reality is that systems have been configured to increase performance in determined scopes; that is to say, determined nodes were enhanced for I/O performance, while other ones were enhanced for execution performance.

Table 8.1. LINPACK Execution Statistics on 'BRAIN' C-Cell Nodes

Node	Arch	CPUs	Cores	CLK (Ghz)	LINPACK min	LINPACK max
axon	x86	2	2	2.791	0.2535	4.1106
hipocampo	x86_64	2	8	2.660	16.4393	20.2175
nucleo	x86_64	2	8	2.494	31.2284	70.8108
sinapsis	x86_64	2	4	1.994	18.7492	27.8162
soma	x86	2	2	2.791	0.2624	4.3343

8.2.2 EDEVITALZH Databases Tier

The Database Tier (DBT) consists of the Electronic Medical Records Database Infrastructure (EMRDB) that stores, manages and relates the social, administrative and clinical data of EDEVITALZH patients. DBT is able to provide both online transactional (OLTP) and analytical (OLAP) processing mechanisms by means of different database instances, (Fig. 8.6). OLTP is focused onto single-patient data entry and retrieval, while OLAP is focused on knowledge discovery, performing tasks over summarized and aggregated data, data processing, visualization and mining.

Thus, EMRDB is the resulting database structure of representing the EDEVITALZH Data Model (DM), which models the patients' electronic medical records and their detailed set of clinical procedures, forms, tests and diagnostic criteria defined by GCPD [11, 12, 15]. GCPD, which has been validated by medical experts in the fields of Geriatrics and Neurology, reflects in an schematic way specific data of interest focused on the diagnosis of AD and other dementias, correlating clinical and therapeutical parameters simultaneously. DM is based on 2 principal entities, formally named Axis Entities: the 'Patient' entity and the 'Clinical Episode' entity. Around them, another set of 13 entities coexist (alphabetically listed): 'Analytics', 'Caregiver ', 'Complementary Test', 'Diagnosis', 'Disease', 'Exploration', 'Family', 'Habit', 'Interconsultation', 'Physician', 'Prescription', 'Symptom' and 'Test'. The SQL implementation of DM produces two types of tables:

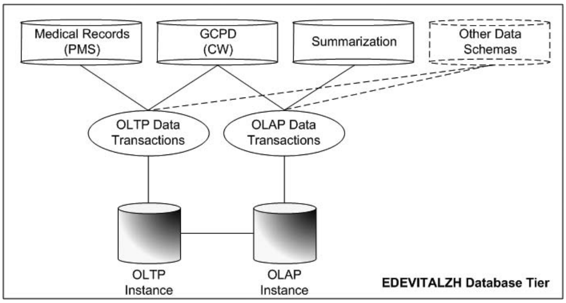

Fig. 8.6. EDEVITALZH Database Tier High-Level Diagram. On the upper part, Data Schemas. On the middle part, Transactional Components. On the down part, Databases.

- *Master Tables*, containing default values for GCPD parameters and other ones relating EDEVITALZH configuration needs. The number of Master Tables in EDEVITALZH DM is 39.
- *Activity Tables*, the ones where inserted data will be stored. They will contain data about patients and their medical records. The number of Activity Tables in EDEVITALZH DM is 18.

To provide acceleration in data access to EMRDB, two sets of customized data views have been developed: 'Summarization' and 'Data Processing', (Figs. 8.2, 8.6). 'Summarization' views speed up access to global clinical-parameter statistics. 'Data Processing' views help in the data extraction stage, previous to data encapsulation and transfer to ISDs-IDSTs.

The EDEVITALZH DBT provides mechanisms to manage and store relevant data for patients- and pathologies monitoring as well as to speed-up access to data of interest during the execution of ICWAs.

8.2.3 Presentation Tier: User Interfaces (PT-UI)

User Interfaces should be considered as the set of controls and tools which allow representing information that both, human and machine, will share and exchange in a work process, the work-flow, during which the machine will be the human's guide to accomplish a certain goal. Douglas Engelbart mentioned *Augmenting Human Intellect* [3, 4] in the beginning of the 1960s, where he proposed '*increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems*', [3]. Engelbart's essay set a start point on research about interfaces and how to improve human results by using computers. In this line, EDEVITALZH virtual environment can help clinicians to improve their capabilities to perform evaluation of patients, by supporting them in decision making for a more accurate diagnosis and prognosis

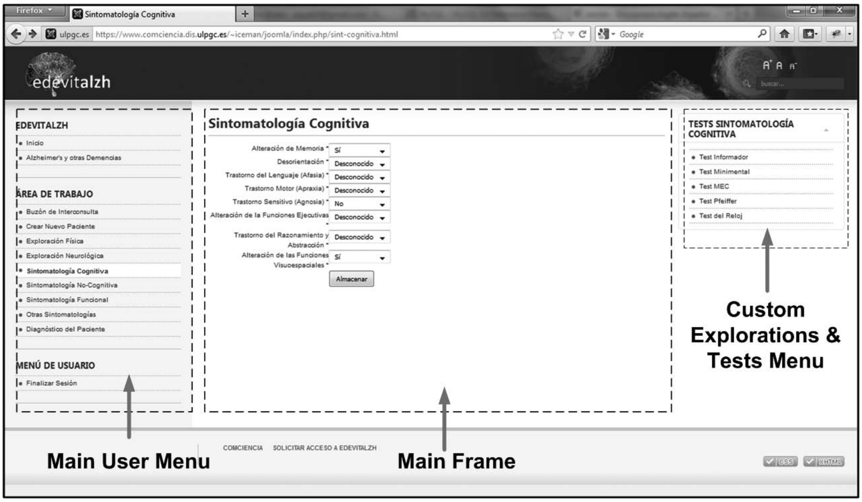

Fig. 8.7. EDEVITALZH User Interface Screenshot representing the *Cognitive Symptomathology* iCW Section. Left frame shows the Main User Menu, which allows users to browse through the different iCW GCPD-defined sections. Main frame depicts the clinical forms relating the requested section. Right frame offers explorations and test to perform custom patient evalution.

of their patients; furthermore, to provide computational intelligent tools for them to carry out evolution studies about patients and their pathologies.

Following the technological evolution of other disciplines, in PC medicine as well as in SC one, information systems have evolved by using new paradigms to develop them. Despite during the 1990s the client-server architecture was the primary tendency, since the last half decade of 2000s until today, web application modelling has burst into the information systems development business sector. EDEVITALZH applications have been developed using this paradigm by means of the MVC design pattern. This development model provides several advantages:

- Costs of installation and support are extremely reduced. Any computer platform or operating system is valid. Just a web browser is needed. No additional software or special package download is required.
- Any authorized user, no matter where he/she is geographically located, is able to access and use the provided applications and tools.
- Software updates, changes or even any problem arised during any of the software production stages, can be managed by developers and published for every user instantly. Furthermore, all these operations are performed in just one place, where the web applications and their generated pages are served, thus minimizing the required updating time.

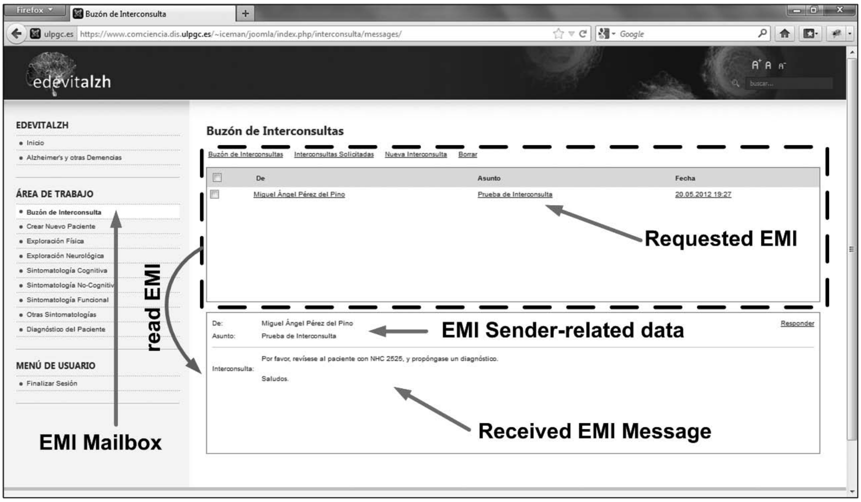

Fig. 8.8. EDEVITALZH User Interface Screenshot: Electronic Medical Interconsultation Mailbox

- Needed resources at clients is minimum; most of the business logic is performed by servers. The storage requirements for client devices is highly minimized because applications and pages are stored in servers, not client devices.
- Collaboration and information sharing between users of the service is empowered.

Hence, EDEVITALZH PT-UI consists of the web applications that make up the iCW UI. PT-UI represents a set of web forms and screen controls that guide clinical users in their workflow, improving patient dedication and consultation time. Two main web applications have been implemented, based on the GCPD. The PC web application (PCapp), focused on PC clinicians, manages a reduced set of the GCPD which groups the needed medical criteria to perform a basic diagnosis at any not-specialized center. The SC web application (SCapp), focused on SC clinicians, handles the complete version of GCPD to perform a more accurate differential diagnosis, prognosis and to carry out evolution studies of patients and their pathologies. Both applications follow a 3-frame screen scheme, thought to facilitate user experience on EDEVITALZH, (Fig. 8.7):

- The Main User Menu Frame, containing labels linked to all GCPD sections.
- The Main Frame, which represents each GCPD section upon request. This frame groups the set of related parameters and criteria. Furthermore, it can also handle customized tools as EMI, (Fig. 8.8).

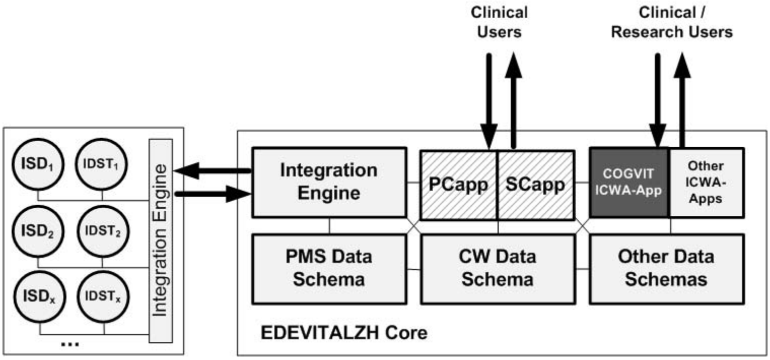

Fig. 8.9. High Level Architectural Diagram of the EDEVITALZH Environment with PCapp, SCapp and COGVIT ICWA embedded. Filled with light pattern, PCapp and SCapp web applications. In dark grey, COGVIT Sanger artificial neural network based IDST and COGVIT ICWA-App are highlighted.

- The Custom Explorations and Tests Menu, which can be shown or not, lists all the provided procedures and methods to gather information and perform certain evaluations of patients.

EDEVITALZH has electronic medical interconsultation (EMI) capabilities, (Fig. 8.8). It can be performed shared consultation by several physicians, at PC or SC, or a colleage can be asked for opinion or specialized valoration. Moreover, since both applications, PCapp and SCapp, share the database environment, physicians can refer their patients to any other specialist physician in a simple and easy way.

EDEVITALZH PT-UI supports ICWA-Apps, which make use of the EDEVITALZH Integration Engine, to perform decision supported analytical- and research operations, aiding clinicians in carrying out customized studies about patients evolution and/or pathology spreading (Fig. 8.9), such as COGVIT ICWA-App, (Fig. 8.10). COGVIT extracts knowledge about the patient's symptomathology, visualizes the relationship between the symptomathology and the used clinical criteria by means of a representation of them in a transformed space. In concrete, in the Principal Component Analysis space provided by the analysis performed by the Sanger neural network.

8.2.4 Integration Mechanisms

EDEVITALZH integration mechanisms are grouped in the logical component of Integration Engine, (Fig. 8.1). This logical component specifies processes relating

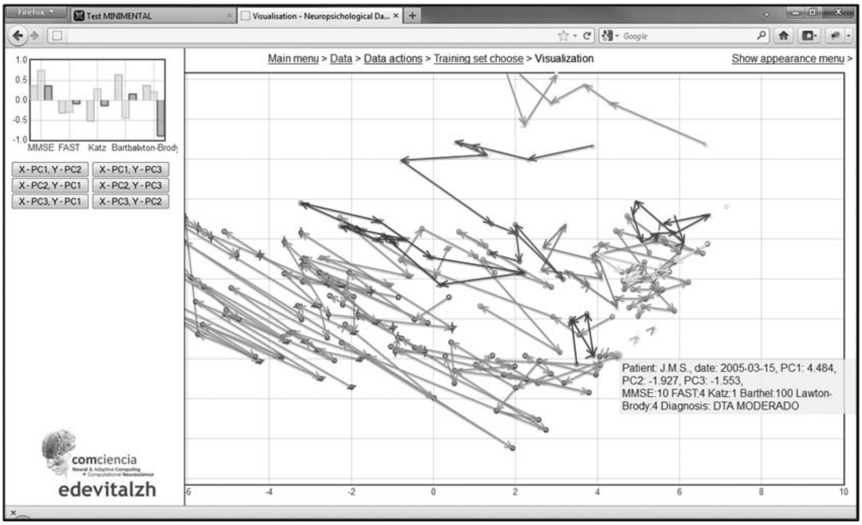

Fig. 8.10. COGVIT ICWA-App Screenshot. It allows to evaluate and visualize the evolution of patients according to the monitoring of their clinical episodes.

extraction, deidentification (if needed), encapsulation and transfer of information between ICWA-Apps, hence the EDEVITALZH-Core, and ISDs-IDSTs, (Fig. 8.11).

EDEVITALZH processes for data extraction are implemented as SQL views inside the database and located in the logical *Data Processing* data schema. Each one of these views is custom developed to extract a specific data set, according to the input needs of the ISD-IDST or ISDs-IDSTs that are going to be requested. Thus, there exists a logical mapping between SQL views and ISDs-IDSTs. The exploited data from the EMRDB will be deidentified if necessary, to preserve patient's anonimity. Subsequently, the data set will be encapsulated as an XML structure and saved into a physical file in the EDEVITALZH-ST storage system. In case there exists any restriction (i.e. special parametrization of any ISD-IDST), all XML files contain an *ISD-IDST ID* parameter section, which will allow ISDs-IDSTs to identify when they should operate or not upon a certain request.

Once the file is generated, the corresponding ICWA-App will send an execution job order to the Cluster Submit Node, asking for a determined process or set of processes (matching each requested ISD-IDST) to be executed with the dumped XML file as input. This way, the needed ISD-IDST or ISDs-IDSTs will be addressed. The Cluster Submit Node will handle the requested job and assign computing resources for its execution when available. Once results are ready, the requested ISD-IDST or ISDs-IDSTs will call the Write-Later Database Driver, writing the generated results to the corresponding patient's medical record in the EMRDB, (Fig. 8.11).

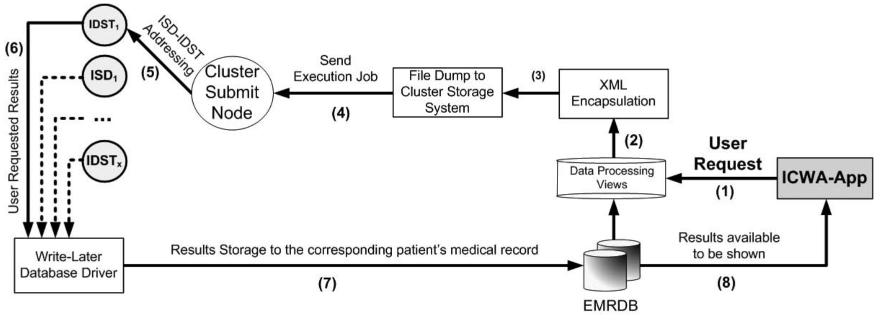

Fig. 8.11. Mechanism to integrate Intelligent Systems for Diagnosis (ISD) and Intelligent Decision Support Tools (IDST) with the corresponding ICWA Application to provide aid in decision making tasks. The flow diagram shows the operative since the clinical user requests aid in decision making until results are available to be used.

This integration protocol has several benefits to the way EDEVITALZH functions, among which the following ones can be highlighted: First, it offers the possibility to request a certain support for decision making to accomplish, while the user is performing any other task without interfering with his/her workflow. Second, it allows the ST-Exec to handle requests in an asynchronous way; that is to say, there is no need for the requester application to wait until there are free computing resources to attend the requested jobs. Results will be notified to EMRDB when available.

8.3 Conclusion

In this chapter, the technological fundamentals of the EDEVITALZH environment, a Personalized, Predictive, Preventive, and Participatory eHealth Delivery System have been presented. EDEVITALZH is considered an intelligent Clinical Workstation able to aid clinicians in early and differential diagnosis and prognosis of MCI, AD and other dementias. The proposed environment presents advances in the field of Medical Informatics, focused on the Geriatrics and Neurology scopes.

The EDEVITALZH Systems Tier consists of the Core, made up by the database and application servers as well as by all the networking devices involved in communications, and the Execution infrastructure, a High Performance Cluster, based on the Grid Computing paradigm, to manage, plan and execute Decision Supported Operations by means of Intelligent Systems for Diagnosis (ISD) and/or Intelligent Decision Support Tools (IDST). Its distributed architecture allows to scale the entire system by adding computing resources, even located in different geographical places, by means of the Internet or any wide area network. Furthermore, the architectural model of EDEVITALZH offers high performance, high availability, high scalability and fault tolerance.

The EDEVITALZH Database Tier stands the Electronic Medical Records Database. Its data model is based on GCPD, the clinical protocol validated by specialists in the fields of Geriatrics and Neurology that standardizes the set of clinical procedures, forms, tests and diagnostic criteria needed by Primary or Specialized Care clinicians to gather the required clinical data to perform a more accurate evaluation of patients regarding MCI, AD and other dementias. Its implementation relates specific data of interest focused on early and differential diagnosis and prognosis of patients affected by these neuropathologies. Moreover, several customized SQL views have been constructed, to speed up access to data of interest during the execution of Decision Supported Operations by means of Web Applications or Intelligent Clinical Wizards and Assistants (ICWA) by user request.

EDEVITALZH Presentation Tier is based on the web applications paradigm, which means the entire environment is accessible just by using a web browser on any device or operating system connected to the Internet. Therefore, this tier consists of web applications that make the environment a Clinical Workstation. In a first stage, the main web applications provide web forms and screen controls to guide clinicians in their workflow. Two main web applications are considered: PCapp, which manages a reduced set, and SCapp, which manages the entire parameter set, both representations of the GCPD in terms of user interface. In a second stage, and improving user experience, EDEVITALZH is able to support ICWAs based on two well-differentiated but integrated components: ICWA-Apps, representing the required user interface, and ISDs and/or IDSTs, providers of intelligence to our environment and responsible for EDEVITALZH to be an intelligent Clinical Workstation.

Last, EDEVITALZH presents a potent and flexible Integration Engine, consisting of the embedded mechanisms that allow ICWA-Apps and ISDs-IDSTs to communicate with each other to provide aid in clinicians' decision making tasks.

The result is a light-weighted distributed-computing web clinical environment, which implements a standardization of the needed diagnostic criteria to perform a more accurate evaluation of patients, no matter what healthcare level the patient is being assisted in, Primary or Specialized Care. EDEVITALZH aids clinical professionals in a more accurate decision making, focusing on early and differential diagnosis and prognosis of MCI, AD and other dementias. In addition, it provides intelligent wizards and assistants to carry out complex tasks such as patient- and pathology spreading analytical studies by means of ISDs and IDSTs. The most relevant effect of EDEVITALZH is that it ensures that no patient with MCI, AD or other dementias, or with the potential to suffer it, will go without the adequate medical attention, without a proper diagnosis and finally, without the appropriate treatment to alleviate their condition, due to lack of human and/or necessary clinical resources.

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Acronym Glossary

- *AD*: Alzheimerś Disease.
- *App*: Application.
- *C-Cell*: Computing Cell.
- *CW*: Clinical Workstation.
- *DBT*: Database Tier.
- *DCM*: Distributed Computing Model.
- *DM*: Data Model.
- *DSO*: Decision Supported Operation.
- *EDV*: EDEVITALZH.
- *EMI*: Electronic Medical Interconsultation.
- *EMRDB*: Electronic Medical Records Datababase.
- *GCPD*: Global Clinical Protocol for Dementias.
- *iCW*: Intelligent Clinical Workstation.
- *ICWA*: Intelligent Clinical Wizards and Assistants.
- *IDST*: Intelligent Decision Support Tools.
- *ISD*: Intelligent Systems for Diagnosis.
- *IWGNRCDAD*: International Working Group for New Research Criteria for the Diagnosis of Alzheimerś Disease.
- *MCI*: Mild Cognitive Impairment.
- *MVC*: Model-View-Controller Model.
- *NFS*: Network File System.
- *NIS*: Network Information Service.
- *OGE*: Oracle Grid Engine.
- *OLAP*: OnLine Analytical Processing.
- *OLTP*: OnLine Transaction Processing.
- *PC*: Primary Care.
- *PMS*: Patient Management System.
- *SC*: Specialized Care.
- *ST*: Systems Tier.
- *UI*: User Interface.
- *VD*: Vascular Dementia.

References

1. Campillo-Páez, M., San Laureano-Palomero, T., Sánchez de la Nieta-Martín, J.: ¿Hacemos correctamente la valoración geriátrica en Atención Primaria? Revista Centro de Salud, Marzo, 157–162 (2001)
2. Dubois, B., Feldman, H.H., et al.: Revising the definition of Alzheimer's disease: a new lexicon. The Lancet Neurology 9(11), 1118–1127 (2010)
3. Engelbart, D.C.: Augmenting Human Intellect: A Conceptual Framework (1962), `http://www.dougengelbart.org/pubs/papers/scanned/Doug_Engelbart_AugmentingHumanIntellect.pdf` (cited May 27, 2012)

4. Engelbart, D., Landau, V., Clegg, E.: The Engelbart Hypothesis: Dialogs with Douglas Engelbart. NextPress, Berkeley (2009)
5. García Báez, P., Fernández Viadero, C., del Pino, M.A.P., Prochazka, A., Suárez Araujo, C.P.: HUMANN-based systems for differential diagnosis of dementia using neuropsychological tests. In: 14th International Conference on Intelligent Engineering Systems (INES), pp. 67–72 (2010) ISBN: 978-1-4244-7650-3
6. García Báez, P., del Pino, M.A.P., Viadero, C.F., Araujo, C.P.S.: Artificial Intelligent Systems Based on Supervised HUMANN for Differential Diagnosis of Cognitive Impairment: Towards a 4P-HCDS. In: Cabestany, J., Sandoval, F., Prieto, A., Corchado, J.M. (eds.) IWANN 2009, Part I. LNCS, vol. 5517, pp. 981–988. Springer, Heidelberg (2009)
7. Herrera-Rivero, M., Hernández-Aguilar, M.E., Manzo, J., Aranda-Abreu, G.: Enfermedad de Alzheimer: inmunidad y diagnóstico. Neurología 51(3), 153–164 (2010)
8. Hernandez Salvador, C.: Modelo de historia clínica electrónica para teleconsulta médica. Doctoral Thesis. Polytechnical University of Madrid (2004)
9. Papez, V., Jaros, P., Suárez Araujo, C.P., del Pino, M.A.P., García Báez, P.: A new cognitive component of visualization tool for diagnosis and monitoring Alzheimer's disease and other dementias: COGVIT. Front. Neuroinform. Conference Abstract: 4th INCF Congress of Neuroinformatics, doi:10.3389/conf.fninf.2011.08.00012
10. del Pino, M.A.P., García Báez, P., Fernández Viadero, C., Suárez Araujo, C.P.: Self-Organizing Maps for Early Detection of Denial of Service Attacks. In: Fodor, J., Klempous, R., Araujo, C.P.S. (eds.) Recent Advances in Intelligent Engineering Systems. SCI, vol. 378, pp. 195–219. Springer, Heidelberg (2012)
11. del Pino, M.A.P., Suárez Araujo, C.P., García Báez, P., Fernández López, P.: EDEVIT-ALZH: an e-Health Solution for Application in the Medical Fields of Geriatrics and Neurology. In: 13th International Conference on Computer Aided Systems Theory (EUROCAST 2011), pp. 382–383 (2011) ISBN: 978-84-693-9560-8
12. del Pino, M.A.P., García Báez, P., Fernández López, P., Suárez Araujo, C.P.: Towards a Virtual Clinical Environment to Assist the Diagnosis of Alzheimer's Disease and other Cortical Dementias for use in Telemedicine. In: The 3rd Students' Scientific Conference Man-Civilization-Future (KNS 2005), vol. 1, pp. 177–183. Politechnika Wroclawska (2005) ISSN: 1732-0240
13. Stalling, W.: Comunicaciones y Redes de Computadores, 6th edn. Prentice Hall (2000) ISBN: 84-205-2986-9
14. Suárez Araujo, C.P., del Pino, M.Á.P., García Báez, P., Fernández López, P.: EDEVIT-ALZH: Predictive, Preventive, Participatory and Personalized e-Health Platform to Assist in the Geriatrics and Neurology Clinical Scopes. In: Moreno-Díaz, R., Pichler, F., Quesada-Arencibia, A. (eds.) EUROCAST 2011, Part II. LNCS, vol. 6928, pp. 264–271. Springer, Heidelberg (2012)
15. Suárez Araujo, C.P., del Pino, M.A.P., García Báez, P., Fernández López, P.: Clinical Web Environment to Assist the diagnosis of Alzheimer's Disease and other Dementias. WSEAS Transactions on Computers 6(3), 2083–2088 (2004) ISSN: 1109-2750
16. Weir, D.R., Wallace, R.B., Langa, K.M., Plassman, B.L., Wilson, R.S., Bennett, D.A., Duara, R., Loewenstein, D., Ganguli, M., Sano, M.: Reducing case ascertainment in U.S. population studies of Alzheimer's disease, dementia, and cognitive impairment Part 1. Alzheimer's & Dementia 7, 94–109 (2011)
17. Intel Math Kernel Library (LINPACK) for Linux, `http://software.intel.com` (cited May 27, 2012)
18. ORACLE Grid Engine, `http://www.oracle.com/us/products/tools/oracle-grid-engine-ds-075946.pdf` (cited May 27, 2012)