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INTEGRATING WIRELESS TECHNOLOGIES AND DATA WAREHOUSING FOR DISTRIBUTED IMAGING BASED SUPPORT IN AN ORTHODONTIC PRACTICE

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Abstract

Notoriously Orthodontic practices are busier than dental offices in general. This is due to the fact that patient control is a frequent procedure without necessarily performing a practical task. This is one and the most important reasons for which an orthodontist goes through a fast check on more than 40 patients a day. Updating data needs to be speedy as well as the orthodontic software in general. This paper outlines a new methodology that has been designed to meet these standards, involving use of the newest technologies available like Wi-Fi and remote database access. A real life application is presented and the main advantages are discussed.

Key Words: Medical Imaging, Wi-Fi, Web Services, XML, Simulation, orthodontic software

1. Introduction

Information Technologies (IT) in the medical field applications is becoming more and more frequent since it has been widely demonstrated that time to process information can be dramatically reduced. In this way medical centers and clinics can increase their productivity rates by simply reducing treatment lead times. The outlined point is more and more evident in the field of medical imaging diagnosis were the amount of data required is quite significant. In traditional x-rays investigation, the physical film has to be manually inspected. Distant medial diagnostics with digital information traveling across the world is now a reality, a DICOM image can be forwarded through a network and can be reported by a Medical Doctor (MD) in just a few minutes. Since usually medical records are screened by more than one doctor, a complete IT architecture is a needed requirement. This paper outlines an innovative IT solution in which all the medial records of a set of patients are provided available to the all MDs in a clinic by means of a TCP/IP connection. Several levels of information accessibility are outlined according to the various IT used; a Discrete Event Simulation [1] is then used to demonstrate the advantages of the proposed methodology and the results are compared with a real life example in which the methodology has been applied [2].

2. The Multi-Level, Multi-User Architecture

In an IT project, it is necessary to clearly identify the role of the users and their needs in order to properly design the system. In this application it is possible to identify several levels of Information Distribution according to the field of application. In the following paragraph taxonomy of such levels is presented.

- ***Stand-Alone:*** in this level, information is collected and presented in a unique software application that is a single POA (Point Of Access). Generally the applications that implement this level of information distribution offer only storage and processing capability to the system.
- ***First-Level:*** this level presents multiple POA connected in a LAN (Local Area Network), transaction and concurrence are generally addressed by using a Relational Database (i.e. Oracle™, Sybase™, SQLServer™, etc.). Information is available in each POA and multi-user application can be implemented.
- ***Second-Level:*** this is an extension of the First-Level approach, here application runs on PDA (Personal Data Appliances) and is connected with the overall system by means of a Direct Connection (i.e. Wi-Fi or proprietary) or in Batch Mode. Information is updated directly and the delays between events and information updating are reduced to the minimum.
- ***Third-Level:*** in this level information is accessible both to a WAN (Wide Area Network) and to a GAN (Geographical Area Network), the application can connect directly to a central server from different geographical locations; data compression and network load balancing technique must be properly applied.

In the medical field, Stand-Alone applications are common and each Medical Screening Device has his own software; First-Level applications are, by converse, not so used since the lack of standardization reduces the interoperability issues. Second-Level approach is turning extremely interesting since it can offer the possibility of performing "Mobile Computing" to a MD. In this way prescriptions can be directly assigned to a patient [3] during investigation and medical records can be accessed while the MD is walking around the patient's bed or the clinic [4].

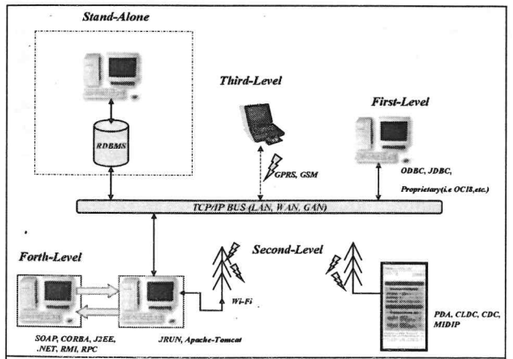

Figure 1 – Application Domain

Third-Level can be applied in order to distribute the investigation process among different specialists, also the patient could benefit from this approach since he can directly access his information from home and/or update it (i.e. new symptoms, prescription's reactions, etc.).

- ***A Forth-Level*** can also be outlined since Third-Level systems can be interconnected into B2B architecture by acting as Web Services. In this way information can be exchanged between EDI (Electronic Data Interchange) systems by means of a standardized coding system.

Recent development in this filed has been made by defining a set of XML (eXtensible Markup Language) formats, as example the National Guideline Clearinghouse™ (NGC™) uses controlled vocabulary concepts to classify various guideline attributes contained in the NGC Complete Summary. This standard "classification scheme" is designed to facilitate searching and retrieving information from the NGC Web site. In addition, the classification scheme attempts to standardize key guideline attributes to facilitate review of the guidelines, as well as comparisons between guidelines, particularly in the areas of methodology.
In table 1 the various application levels are presented related to the available IT technologies able to support them.

3. Medical Data warehousing for Imaging Base Diagnosis

The key role in the proposed methodology is played by the database engine (DB), every medical record is stored in it and is virtually accessible from everywhere; medical images are kept in the DB as BLOB (Binary Large Objects), by using a simple Query. The image is converted into a byte stream and forwarded to the client application. Since this process can spawn the methodology also into a WAN, a low size copy of the image is generated in order to save connection bandwidth. As soon as the client stores a new image data, a jpeg thumbnail is automatically generated and stored for hi-speed look up. The MD can now visualize all data into a simple application GUI and decide which image should be used for Medical Examination & Reporting. Only at this point the full size image could be delivered to the client (where a MD can examine it). Reporting results are immediately updated on the same GUI and the related information kept available for the next medical examination step. At this application level, it is possible to manage more than one medical cabinet at the time. In fact by updating in real time the patient's medical file another MD can report and store data from another location; obviously this way of operation was virtually impossible to do with the classic stand-alone or paper-based medical records.

Level	Application Area	Enabling Technology
Stand-Alone	-	Databases
First-Level	LAN	TCP/IP; RMI, RPC, CORBA
Second-Level	LAN, PDA	Wi-Fi, SOAP
Third-Level	WAN, GAN	Web App, SOAP, GPRS, GSM, J2EE, .NET
Forth-Level	LAN, WAN, GAN	Web Services, SOAP, WSDL, XML, J2EE

Table 1 – Technology Survey

The centralized DB allows also having, if necessary, a real time diagnosis from other Specialists involved on other explicit requests made by the treating MD.
As an example, a MD is examining a patient's X-rays Image. He might need to have a second opinion from his college radiologist that can simply access the patient's clinical records and respond promptly; he accesses the patient's records from his client application with the result of more MD resource sharing.

Three different layers of connectivity characterize the methodology. First layer is the lowest and it has coverage in terms of local Intranet: it is possible to consult the database from every PC in the cabinet or in other specialized cabinets (i.e. Administrative Desk, First Examination Room, X-ray Room, etc.). The second layer allows connecting and updating the database using Wi-Fi enabled devices (i.e. palmtops) reducing three times the lead times of the classical medical filing activity. The third level of connectivity has coverage in terms of World Wide Web, so the information can be updated everywhere in every moment, even in another parts of the world: in this case a Web Application is used via an Internet connection.

Business Logic placed on this layer could also perform complicated tasks such as post-pone a medical check-up date for a patient by informing all the involved parties by means of a Fax, an e-mail or a simple SMS (Short Message Systems) on their Pager/Cellular Phones.

Third level enables also to exploit the new technologies added to mobile devices and last generation cellular phones: it is possible, in fact, using a GPRS enabled device to connect the mobile phone with the office's EDI. Even the patient could consult remotely his files: for example he could check his accounting, calculate how many payments he has done, view and print the last invoice, check his ID number, pay a visit, or simply query for a therapy date.

User Profiling Access is used to guarantee that the information exposed cannot be corrupted by a system's misuse, and each transaction could be secured by using SSL Connection (Secure Sockets Layers).

4. Orthoflash™: A Case Study:

Mindrevolver's Orthoflash™ is a commercial application as a result deriving from completed Project "Orfeo" of the University of Genoa. The Orfeo Project was intended to underline the advantages of using advanced IT in the medical field and, specifically, in an orthodontic practice.

IT can save time in the Medical Practice by concentrating in a easy-to-access POA images [5], medical information, anamnesis and prescriptions. Particularly the proposed methodology stores diagnostic imaging information directly into the Database Records allowing each operator to access it regardless the POA[6] (figure 2). Since a small PDA (Personal Digital Assistant) can be connected via Wi-Fi to the TCP/IP Bus, a small POA can be embedded into the hardware.

This porting involves some technological aspects that must be taken into consideration: the computing power of this kind of devices is extremely low so a Thin-Client architecture must be used. PDA Applications should reduce their Business Logic to the minimum and transfer it to the Application Server.

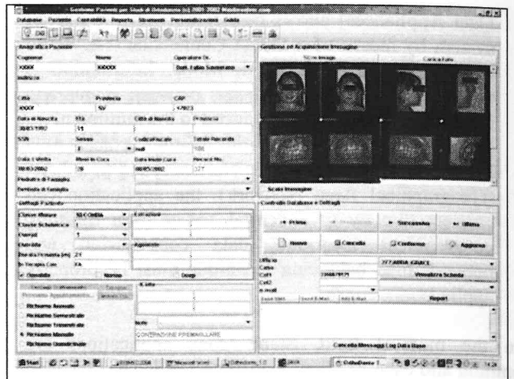

Figure 2 – Orthoflash™ GUI

Orfeo Project uses J2EE technology in order to provide the MD with a Light Client, supporting Wireless Distributed Medical Records updating capability. Working as an Intranet Web Application, the Light Client can access all Patient Medical records, trigger Printing Events and Complex Diagnostic Device Control (i.e. digital x-rays). Since the Intranet Application Server can be accessed also from the Internet via an ADSL Connection , Light Clients can be built in Java-Enabled Cellular phones and access the same information using the GPRS Technology [7][8]. The J2ME Virtual Machine has only a subset of the J2SE API but it can access the Orthoflash™ Application Server via kSOAP (kilobyte Simple Object Access Protocol). This allows Patient's Date information to be accessed and managed easily. In order to demonstrate the advantages of the Orthoflash™ Methodology, a set of implementations were used for a Pilot Test. A Discrete-Event Simulation Model was used to generalize the results.

Collected data from the Experimental Campaign was compared to the Pilot Test Case for Model Validation.

5. Orthodontic Practice an Approach Comparison

The process that the patient follows when he is visited for a first time (First Date) by the Orthodontist is quite simple. The assistant secretary uses "Orthoflash™" to create a new identity in the database, assigning an ID number with all personal information (i.e. name, surname, address, zip code, cells phone numbers, etc.).

This task usually takes about 1,5 minutes to be completed; the orthodontist who collects general medical information then screens the patient. A preliminary photo of the face is taken and a barcode is automatically generated. During the First Date visit the orthodontist formulates a preliminary diagnosis, obviously the time needed to accomplish such a task is quite variable depending on the patient situation and the operator's speed. We believe that a mean time of twenty minutes is for most of the

practitioners assuming that clinical records have been completed (x rays, complete photos, casts etc. 7 to 13 min.). The practitioner then decides the therapy and a printed proposal is generated and printed for patient approval.

A backup paper version of the patients' records is generated in batch mode daily

By using a wireless PDA the Light-Client is kept in touch with the central Application Server, the full updating process takes a mean time of about 25 seconds with a variance of more or less five seconds.

From the Light-Client, the practitioner has to log in (once a per session). A list of the patients is alphabetically sorted and displayed by last name initial, he then selects from a list of previously setup tasks. The update operation takes a mean time of about 25 seconds versus the minute and ten seconds of the traditional paper update. We can assume that an assistant has to go to the archive, find the paper personal records, bring it to the doctor, update it by adding the date and the kind of operation done and finally bring back the written records to the archive. With the mean of three patients checked every fifteen minutes, saving one minute for each patient can increase the throughput and use less use work power, thus allowing assistants to proceed with other tasks. Another important aspect of the proposed methodology is given by the implemented Business Logic that is able to reduce lead times. Orthoflash™ can enhance Medical Reports by dynamically filtering the events that are of higher interest during therapy. The Agenda (Scheduler) tracks the periodical checks, remainders and sends SMS messages to patients with the click of the mouse.

Since the database could be updated in remote, the practitioner could access information everywhere, in every moment, by using the Internet.

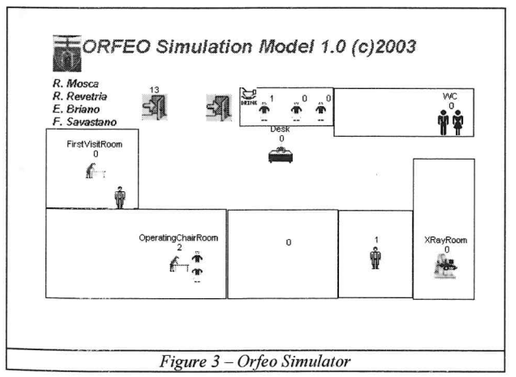

Figure 3 – Orfeo Simulator

The implemented methodology is also able to manage accounting, as well as receiving personal patient requests by e-mail and web interface. Each patient can access proper financial accounting, print invoices (i.e. ID number, amounts already paid, operations list, etc.) .

Keeping in touch with suppliers could be done easily by using the Inventory Manager. The implemented methodology works in perfect synergy with back-offices applications like MS-Excel or with imaging software (i.e. Adobe™ Photoshop, Image [TM]) .

A Complete User Configurable XML Reporting system extends the information capability and increases general communication. Web Service Integration with the SOAP protocol is a dynamic feature in Orthoflash™ making this software take all the advantages offered from computing integration (i.e. SSN Information retrieving, Network Messaging, Financial Accounting Information Management, etc.).

5.1 The Implemented Simulation Model

In order to demonstrate the practical application of the proposed methodology a Discrete Event Simulator was implemented using Simul8™ [9].

The entire process was modeled according to the Simul8™ building blocs and two configurations were considered. On the first model a common Orthodontic practice was considered using traditional information tools (i.e. paper based files, hard copy X-rays, etc.) while on the second case proposed IT implementation was considered [10].

The medical cabinet was designed to have a Desk for administrative tasks (i.e. personal information updating, payement management, insurance's reimbursement practice, etc.), a X-Ray diagnostic room (used both for pan-X-Rays and cephalometry), a two chair visiting room and a special treatment area [11].

Patient's timing for various operations were collected during a month of real practice and data were used to identify statistical distributions. Since for several operations no reliable statistics were available a triangular distribution was used in order to approximate data coming from doctor's interviews.

Preliminary results were used to validate the model by using face validation technique and subject matter expert walkthroughs.

5.2 Experimental Campaign

The simulation model was used to test the proposed approach and it shown interesting results, in table 2 such results are presented.

As is possible to see there is an interesting reduction of the average number of people in queue that can turn into an increase of the patient feeling. In effect patients are quite sensible to an overcrowded waiting room and they can feel not very pleased facing a long line also in the case where the effective average time in queue is low. In the presented case such situation is evident: a reduction of 25% in the total processing time is associated to a reduction of more than 214% in the average size of the queue. In this way the adoption of the IT in the medical practice has increased the image of the medical studio as well as the comfort of the patient.

Case 1 – IT Integration – WiFi Remote Patient Records Tool			
	Low 95% Range	Average	Upper 95% Range
Time in System [m]	12.05	12.77	13.49
Max. Queue Size [pat]	0.72	1.40	2.08
Av. Queue Time [m]	1.09	2.28	3.46
CaseII – Traditional Practice – Paper Work			
	Low 95% Range	Average	Upper 95% Range
Time in System [m]	14.66	17.05	19.44
Max. Queue Size [pat]	0.00	4.40	9.18
Av. Queue Time [m]	2.44	4.80	7.17

Table2- Simulation Results Comparison

6. Conclusions

The proposed methodology has demonstrated to be very effective and increase the output of a Medical Unit.

The integration of Wireless Technology and Distributed Database Application could be applied also to small medical Business Units resulting in improved performance for both the patient and operator.

Adopting IT solution also in small medical units can increase the feeling of the patients as demonstrated in the proposed real life application.

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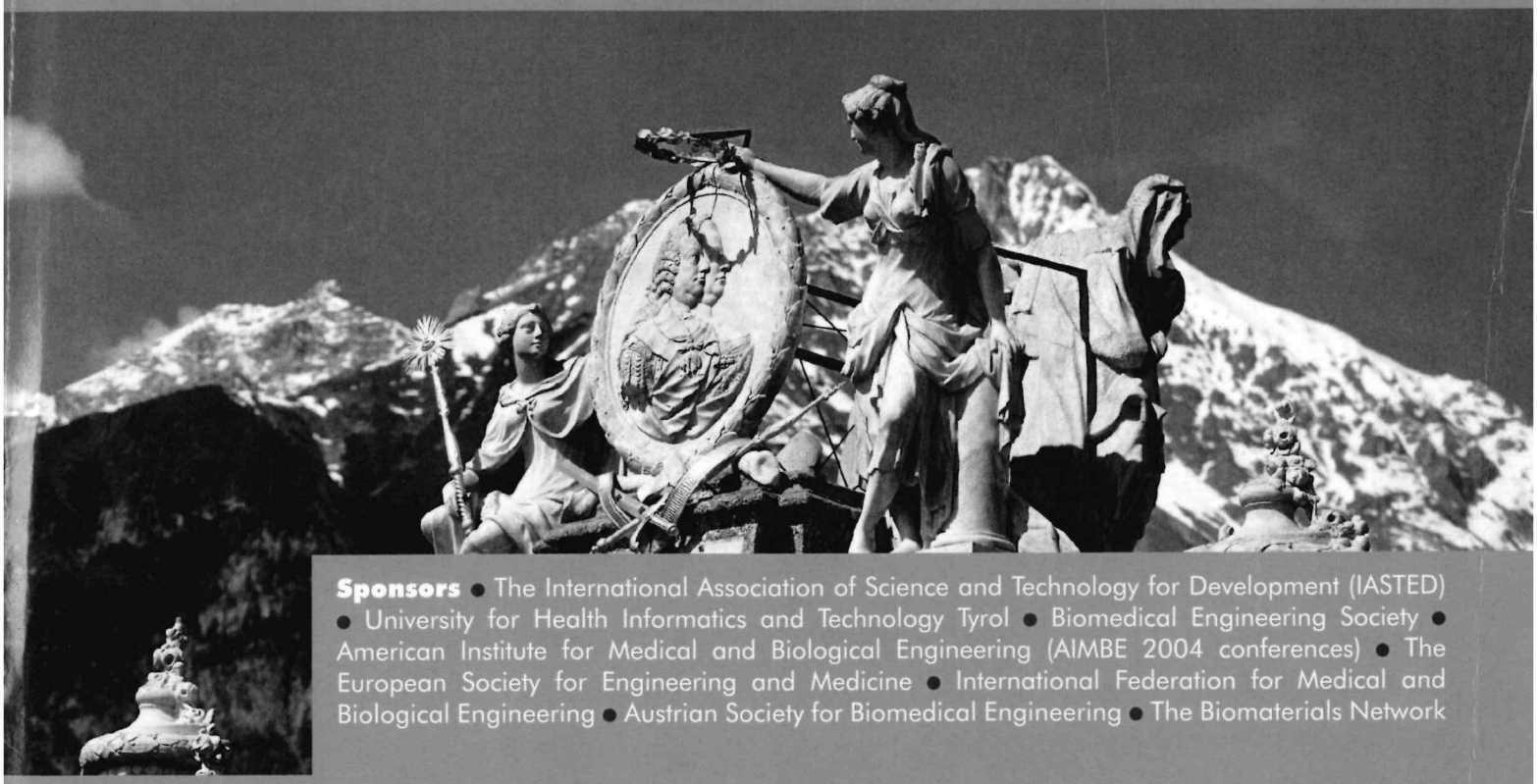

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