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eIMES 3D: An innovative medical images analysis tool to support diagnostic and surgical intervention

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Abstract

Diagnostic and clinical support is performed by using ever improving DICOM image systems. Huge quantity of clinical images are generated from clinical devices with increasing high performance. Nevertheless, extracting useful information from DICOM images for diagnosis as well as integrating information from different data sources is still a complex task.

We present eIMES 3D (standing for Evolution Imaging System 3D), a system that supports clinicians for images studies, diagnostic and images reconstruction. The tool has been developed within a project called ReCaTuR for RAre Cancer Network (i.e., Network of Rare Cancer), aiming to define a network for the management, organization and distribution of medical information. Moreover, it was implemented following the requirements of oncology department of an Italian Hospital.

By using eIMES 3D a cancer network data infrastructure has been defined and implemented aiming to integrate information regarding rare and complex diseases. Data provided by different departments, external structures and research institutes are used to improve knowledge and to support physicians.

eIMES 3D allows (i) full control and management of the data by means of artificial intelligence algorithms; (ii) advanced stereoscopic 3D visualization by using the WebGL innovative technology; (iii) sharing of medical data; (iv) distribution of 3D imaging on different output devices (web, TV, mobile); (v) querying the system through a search of the various case studies.

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Keywords: Diagnostic Imaging, Distribution of Medical Information, Advanced Stereoscopic 3D Visualization.

1. Introduction

The problem of defining diagnosis starting from images is an important task and highly relevant in the medical domain. Emerging applications such as telesupport to give advise from remote, increases the difficulties in giving advises from image analysis. Similarly, during monitoring and ambient assisted living, where the patient's condition

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is continually monitored and diagnosed for anomalies and therapy adherence, the image analysis and interpretation is relevant task. The key element for a proper diagnosis is, in the general case, a correct use and a proper sharing of all the information related to patient health. Collaborative system give the possibility of sharing opinion and advices among clinicians. Also, for chronic disease, correct interpretation of images may be crucial for early disease detection. To this end, the use of innovative technology instruments for supporting medical interdisciplinary collaboration among different teams (belonging to different departments, external structures and research institutes), geographically distributed in the network, is a crucial task. A collaborative tool allows to integrate skills, expertize, knowledge and more in general information. This facility helps in clinical case resolution as gives the opportunity to a specific structure to share a clinical case with external specialized structures so that obtaining what is called in the medical field, a "second opinion" (without phisically moving neither the patient nor his documentation).

In this paper we report about eIMES 3D, standing for Evolution Imaging System 3D, a system that supports the oncology medical team by providing facilities for case studies analysis and diagnostic imaging. The system has been developed for oncology domain and uses the "Hub-Spoke oncology model. The system complies with the idea of the ReCaTuR project [1], aiming to define a professional network that allows the management, organization and distribution of medical information within one or more networks. Oncologist provides facilities for case studies analysis and diagnostic imaging [5]. Through the use of a connection interface the system allows to interact, among others, with the italian network of cancers and the PACS networks that allows to acquire and managing the diagnostic imaging in DICOM (Digital Imaging and Communications in Medicine) [4] format. [1]

eIMES 3D can create one or more workspaces used by the medical team to effectively share data and image into a geographical virtual space. The WebGL (Web-based Graphics Library) technology, allows the remote transfer of imaging dataset in non-destructive mode allowing a 3D visualization of a real model of the DICOM image by taking advantage of the hardware acceleration of own device. Thanks to this innovative technique it is possible to distribute clinical cases and 3D images among different teams so that sharing knowledge and cooperate to the formulation of a diagnosis. Each team, joining the virtual space, can connect from remote locations and view, with the same resolution, the same image in a stereoscopic 3D environment on different output devices.

The paper presents the architecture and preliminary features of the tool as well as preliminary experimental results.

2. eIMES 3D: Architecture and Features

The system is based on an enterprise-type development model that allows to design an integrated software platform suited for medical and technical specialists of the Complex Operative Unit of Medical Oncology, for the management, analysis and visualization of imaging data in 3D stereoscopic environment. This platform is supported by innovative technologies in 3D stereoscopic domain, as it makes use of programming paradigms and patterns based on advanced development framework, thus ensuring scalability and modularity.

The eIMES 3D Software System consists of two main software layers:

- The "back-end" level accessible by the technical operators is constituted by a series of software modules that allow the complete management of the database, as well as the maintenance of the whole system and the procedures of import / export of data for populating the database.
- the "front-end" layer accessible by the medical team and by the specialist includes all the software interfaces that allow the usability for the end user (medical staff and specialists) and the exploration of data in the storage archives, as well as the three-dimensional navigation of the 3D imaging dataset. The interaction and the interpretation of the data is facilitated by a number of tools that support the user: simple search, advanced search through the use of parametric queries, the possibility of using knowledge revision algorithm to select and group data in homogeneous sets.

[1] DICOM is a standard, developed by the DICOM Standards Committee and hold by the National Electrical Manufacturers Association (NEMA), for handling, storing, printing and transmitting information in medical imaging. DICOM is known as NEMA standard PS3, and as ISO standard 12052:2006 "Health informatics – Digital imaging and communication in medicine (DICOM) including workflow and data management". It includes a file format definition and a network communications protocol. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format.

The system uses an advanced programming paradigm, called MVVM (Model-view-viewmodel), that allow the direct binding of medical information with three-dimensional graphics objects. As known, this fundamental framework for the logical design model, segments an application's components into three tiers of services. These tiers correspond to logical layers of the application. Following are brief descriptions of the services allocated to each tier:

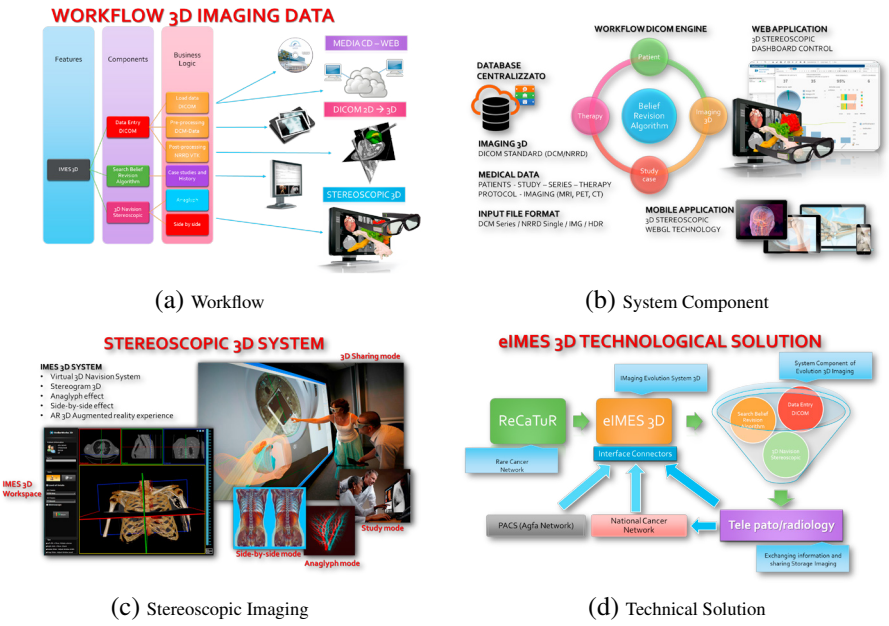
- **Data services layer**. The data services layer, or data tier, separates the logical data access from the presentation layer and is the only layer that directly interacts with the archives. eIMES 3D has a structure of archives capable of storing in an systematic way structured information with a high degree of complexity (3D image, stereoscopic image, textual data, hybrid data, etc ...). The repository is represented by different levels of storage that can be linked to different data sources (MySQL, Oracle, SQLServer, etc ...), thus constructing a single virtual database. The virtualized data source, therefore, constitutes the entry point for all software modules that connect to the data services layer.
- **Business Services Layer**. The business services layer, or middle tier, consists of business and data rules. It specifies the logic and the functionalities of the system. (Figure 1). Among the provided main functionalities the system allows (i) to upload DICOM data into the local storage; (ii) to build a lossless 3D model from a 2D DICOM data. Specifically, it processes the native information in DICOM format (DCM) and builds a new information layer containing processing data in a three-dimensional virtual environment (NRRD); (iii) to display all information (that can be processed by using artificial intelligence algorithm and/or the result of a query over the system) on different 3D stereoscopic output devices.
- **Presentation Layer**. The presentation Layer, or user services layer, gives user access to the application. This layer presents data to the user and, in eIMES 3D, permits data manipulation and data entry. The GUI-Interface, in eIMES 3D, is equipped with a data representation of imaging through a three-dimensional navigation system, with the possibility of user interaction and point variation of the prospective observation of the 3D image (3D Controller). Moreover, eIMES 3D is based on an innovative framework, called Universal App Platform (UAP), that allows to visualize data and image on the various devices available in the system (Monitor stereoscopic, Laptop, WorkStation Graphics, tablets, smartphones, etc ...) and on various platforms (web, desktop, iOS, Android , WindowsPhone, blackberry and the mobile device legacy).

The structure of the eIMES 3D system is based on different information layers implemented with the latest generation of design patterns and directly interconnected through web services. The latter are developed using certified and consolidated software connectors, web-based communication protocols and SSL secure channels. The safety in the authentication process is guaranteed by oAuth 2.0 technology and digital certificates defined on SSL-protected communication channels, with respect to the distribution rules related to private intranet network.

The tree main componenet of the eIMES 3D system (Figure 1) are :

- **DICOM Data Entry**, which populates the system with the 3D Imaging. The system allows the import and export of 3D Imaging content. Data are in the standard DICOM format so that they can be easily exchanged within the Network in a non-destructive mode and displayed on different devices [2].
- **3D Navision System**, a 3D display system in a virtual environment that provides the possibility of applying stereoscopic effects in order to create the depth effect on the available data and to provide more information from a diagnostic point of view. In more details eIMES 3D uses an innovative technology for the representation of three-dimensional data called WebGL. The WebGL library provides an API (Application Programming Interface) for 3D graphics for all browsers that support this technology and implements advanced methods and algorithms for the representation of data in stereoscopic mode. One of the advantages of this technology is the ability to render images on different devices, from desktop workstation graphics to web browser, OLED Monitor and mobile device of latest generation. The stereoscopic effect is achieved by building a 3D stereogram. It is possible to construct the stereogram by selecting different mode. At the present, the system implements two different mode (see Figure 1): (i) in the Anaglyph mode a 2D transformation is performed using filters of differ-

[2] eIMES 3D manages different types of images: Monochrome (eg: CR, CT, MR) and color (eg US, 3D reconstruction) ; Static images (eg: CR, MG, CT) and dynamic sequences (eg XA, US); Tablets and uncompressed (RLE, JPEG Lossy, Lossless JPEG, JPEG 2000)



(a) Workflow (b) System Component

(c) Stereoscopic Imaging (d) Technical Solution

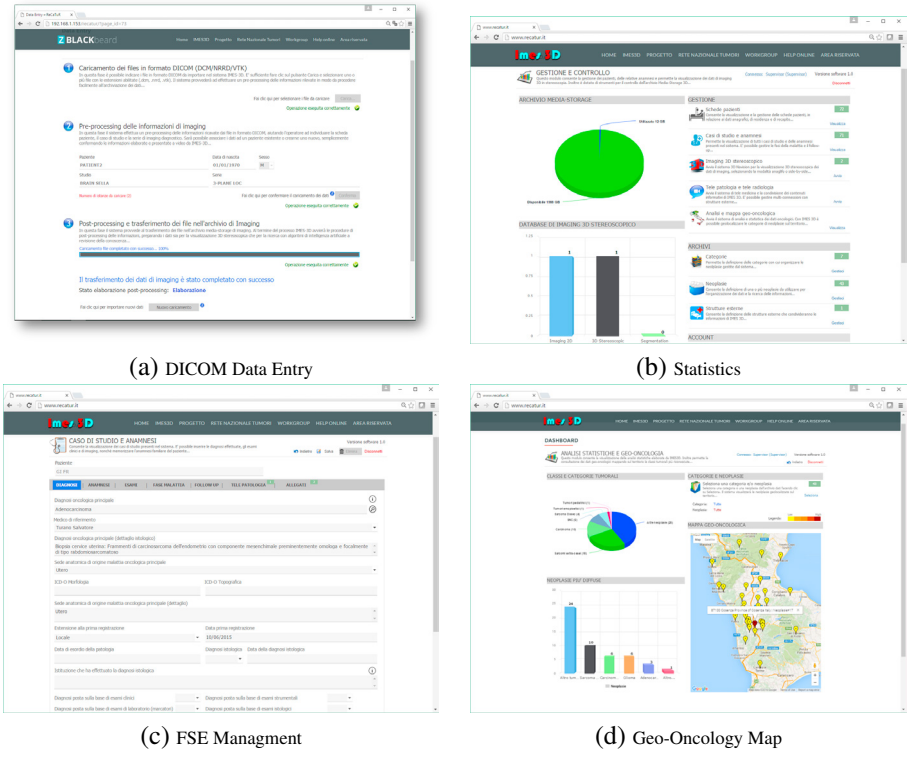
Fig. 1. eIMES 3D

ent (usually chromatically opposite) colors; (ii) in the Side-by-side mode, a 3D transformation is performed. In this case the trasformation does not alter the image, but splits it into two different images each of them situated at a precise focal distance. The 3D effect can be visulaized by using 3D glasses.

- **Artificial Intelligence (AI) Algorithms**, which allows the implementation of a knowledge structure in which it is possible to define algorithms that provide new layer of information by applying set of rules fixed by international protocols or by expert of the domain. This algorithms conceptually use known information and a set of production rules to derive new information, or to change beliefs as a result of new knowledge. In our context the logical formalization of AI algorithm is fixed by the medical team, or in the general case by the expert of the domain, that defines a set of logical rules that allow to extract from the basic information (data and imaging) contained in the database a new layer of information obtained by deriving new information. In this perspective the algorithm performs a *deductive process*. As an example suppose we deal with liver cancer. Typical symptoms include: loss of appetite, nausea and vomiting, abdominal pain, whites eyes, yellow discoloration of skin, weight loss, weakness. Obviously, known the set of symptoms associated to the disease, whoever has all them has the disease. But, rules could be fixed in order to alert the medical team in the case of a patient having a strict subset of these symptoms. The AI algorithms can also apply a kind of *abductive process*. That is, in the presence of a new observation, that modifies the existing protocol, the information can be updated in order to be consistent with new specifications. This process can be performed on both stored data and imaging.

In the following we report some additional interesting features of the system:

- eIMES 3D implements a “dashboard” for the management and control of all the activities in which the system is involeved in. This feature allows, at each instant, to keep under control the state of the repository, know which images are currently displayed, know the users currently logged, make statistics on data and 3D stereoscopic imaging (Figure 2) .
- eIMES 3D presents a technological innovation that consists in the implementation of a map called “Geo-Oncology Map”, which allows the geographic representation of the most common form of neoplastic disease. In particular, the system combines the personal information of the residence and the clinical information of the patient. The combination produces a map that illustrates the distribution and the intensity of a particular cancer (Figure 2-d) in a territory. In addition to geographic information the system allows the statistical analysis of the major neoplastic categories established by international protocols.



(a) DICOM Data Entry (b) Statistics

(c) FSE Managment (d) Geo-Oncology Map

Fig. 2. eIMES 3D Dashboard

- eIMES 3D introduces a new technology in the way stereoscopic 3D is applied. Traditional methods take advantage of stereoscopic hardware, that process and display images on the screen. The disadvantages consist in having mandatory a stereoscopic source, full-screen and no possibility of interaction. The new steroscopic method implemented by eIMES 3D, can be called "Software Stereoscopic 3D" as it moves the key element for the right management of stereoscopic component from hardware to software. The benefits of this approach are: (i) the possibility of applying any stereoscopic effect (anaglyph, side-by-side, etc.), (ii) take advantage of hardware acceleration, (iii) possibility of modifying the source code for the implementation of stereoscopic effect (this component is very important in medicine context), (iv) deploy the result via web and on any remote device, (v) take in input a real 3D model.
- eIMES 3D is in charge of constructing the electronic health record of the patient, following the italian specification of the FSE (Fascicolo Sanitario Elettronico). More specifically, it populates the FSE of a patient by extracting and integrating data from DICOM format so that obtained a complete vision of the patient: demographic information, medical history, cares and allergies, immune status, laboratory test results, radiology images, vital signs, personal statistics such as age and weight, and billing information (Figure 2-c). The electronic managment of data in Health, often reported as eHealth, is a relevant topic also in European Community, that has recently established an eHealth strategy and plan the definition of a common specification framework in the coming years. The commitment is also testified by the great ammount of resources planned to be invested in the eHealth in next years.
- eIMES 3D realizes a 3D virtual laboratory in which different information from different diagnostic tests are combined to order to provide to the clincians a powerful and comprehensive tool for diagnostic and case study analysis. The system, can be profitably used to simulate in a virtual environment the "surgical track so that reaching the neoplastic point by means of a 3D navigation system. This feature brings considerable advantages instrument in the surgical field for both the that can "prepare" the surgery and for the patient as it reduces the complications in the choice of the surgical cutting area.
- IMES 3D, by using the WebGL technology, allows the remote transfer of imaging dataset in non-destructive mode, that is without applying compression of images or other changes that would alter the nature of the image.

Moreover, by using the innovative framework, called "Universal App Platform" (UAP), it allows to visualize data and image on different devices (Monitor stereoscopic, Laptop, WorkStation Graphics, tablets, smartphones, etc ...) and on heterogeneous platforms (web, desktop, iOS, Android , WindowsPhone, blackberry and the mobile device legacy). The GUI-Interface, in eIMES 3D, is equipped with a data representation of imaging through a three-dimensional navigation system, with the possibility of user interaction and point variation of the prospective observation of the 3D image (WebGL 3D Controller library).

- eIMES 3D allows the sharing of Information (data and images) in videoconference sessions. To this aim the system contains a software module, Cisco System WebEx, that provides different and innovative functionalities for file sharing and team connectivity. Specifically, it allows to share multimedia content by activating cooperative sessions not only using PC Desktop and Workstations, but also using different app WebEx for iPhone, iPad, Android or BlackBerry. WebEx products are provided by the cloud Cisco WebEx, they allow to easily work in team, to obtain and offer expertise and knowledge while maintaining high levels of security.
- eIMES 3D allows to acquire information by integrating the knowledge distributed over the network. The 3D virtual laboratory, is an environment that gives the possibility to researchers, to prepare and run queries using a distributed "Grid" infrastructure, without requiring a deep knowledge of technologies of "Grid Computing". By virtualizing the hardware, the computational infrastructure and databases, the laboratory becomes a user-friendly environment for the user, suitable to facilitate and automate many tasks such as data storage, integration, data mining and simulations. The system provides a set of user-friendly tools that allow to easily perform customized queries, simulations with similar cases, deduction of diagnosis and abduction on the base of knowledge. It provides ontological vocabularies and taxonomies that simplify the entry of a query for the user as well as the subsequent reading and interpretation of the results. Queries are answered ensuring accuracy and completeness of the result, and the implementation of sophisticated data integration techniques allows to deal with multiple and possibly heterogeneous information sources as a single source of virtual data.

3. Concluding Remarks

The system is based on an enterprise-type development model that allows to design an integrated software platform suited for medical and technical specialists of the Complex Operative Unit of Medical Oncology, for the management, analysis and visualization of imaging data in 3D stereoscopic environment. This platform is supported by innovative technologies in 3D stereoscopic domain, as it makes use of programming paradigms and patterns based on advanced development framework, thus ensuring scalability and modularity.

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