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2D-Visualization of 3D Medical Images within A Distributed System: A Short Survey

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***Abstract*—Current standalone systems in the area of Minimally Invasive Cancer Treatment (MICT) are not providing satisfying possibilities for researchers and Interventional Radiologist (IRs) to share their contributions. There are a lot of standalone simulation software implementations, which provide different services for the mentioned purpose. However, in all of the services, one of the most important concepts, transferring the experience which has gained from one simulated procedure, is missed. In contrast, by using a web based system, different communities would be capable of sharing the medical data and simulation. These potential advantages lead us to developing a web based system for visualizing the medical data. Furthermore, 2D-visualization and applying image processing algorithms in 3D medical images is one of the most important elements of the very front-end of the software framework and also technically demanding. Therefore, we are obliged to answer the question "What is the efficient method for web-based 2D representation of 3D medical images in distributed system?". Based on the evaluation of performance result in different test cases, such as evaluating the architecture, method usage and modularity in distributed systems, and readability of the most used case scenario image extension (extensively publishing aided library) we propose an optimized method for 2D-visualizations of 3D medical images which can be accessed by any standard browser.**

***Index Terms*—Medical Image Visualization, Medical Image Processing, Web-Based Solution, Overlaying Models, Nifti-VTK data Manipulation.**

I. Introduction

DEVELOPMENT in medical imaging industry has made it possible to gain access to the high resolution of three dimensional image of human's organs. Nowadays, the number of 2D images per exam varies from 150 images for screening up to 700 to 3000 for the diagnosis of complex cases. [16] This tight binding of the number of images and diagnosis complexity has made a huge workload for radiologists, which hovers the role of computer-assisted medical image analysis. However, the large potential for 3D visualization in medicine and biomedical science as a need of practical tools is significantly undeveloped. Still human being is dealing with life-threatening disorders and disability in life-routine with harmful affliction. This hover the need of physical interventions to lessen the harmful or defeating diseases [16]. Yet minimally invasive or noninvasive interventions are concretely moving forward to establish effective steps in curing diseases, which lead to reducing the pain and complication. What is yet required is to focus more on visualization technology advances, studies and estimating tools which are needed by physicians for treatment.

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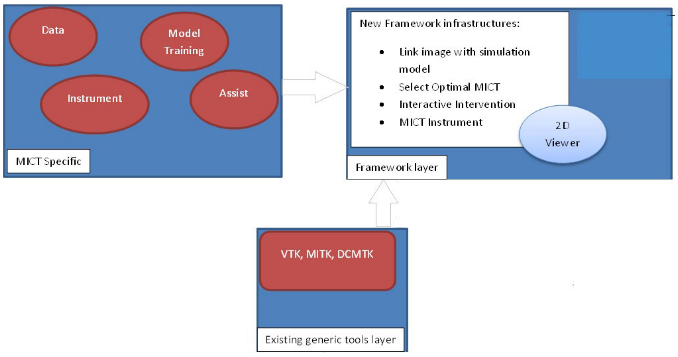

Fig. 1. Overview of the sample structure for medical image data visualization and its relation to the 2D viewer system with functionality.

A. Motivation

Imaging has become an important element of medical and laboratory researches. Doctors study the 3D volume of the human organs to diagnose the disease or dignify the exact organ malfunctions; radiologists quantify the tumors lesion from the CT scan. These are all researched in a very intensive format to prevent from prescribing an inappropriate medication in order to attack the main disorders. Analysis of these various types of image requires the complicated computerized visualization tools. By employing more equipped tools a precise decision will be concluded, for instance in the area of cancer treatment, whose more precise images leads us to the more accurate treatment. Nowadays, much visualization and analysis are performing in the non-distributed systems with the predefined hardware specification. Although the application domain of these standalone software has gained the large share of the user market in the last couple of years, these softwares are lacking the main secure concept in treatment which is real-time discussion. Moreover designing an independent platform which enables doctors to transfer their own experiences with another in special cases (special patients), is an issue. Visualization of n-dimensional data and platform-independent with different medical images modalities is an ideal work space. As an end-user application, the web-based interface provides a several vital and complicated image analysis and visualization tools.

B. Contribution

As it's discussed earlier, by knowing the infra-structure of the project and essence of the image visualization in the cancer treatment; we are obliged to define the technical specification for representation of the medical images in the area. Since web-based method considered as the convenient solution for sharing and contributing the information; we established a 2D viewer based on 3D volume data. More importantly, we provide several services in a term of image processing functionality which enables users to interact with the 2D environment interactively.

C. Outline

This remainder of this paper is organized as follow: section II investigate on visualization in local based related works, section III review state-of-the-art approaches and the existing literature in web based medical image visualization. Section IV concludes the literature review in the paper and highlight the ideas for future.

II. General Literature Review

The main aim of the all software in the area of research is providing a user friendly environment to interact within some certain functionality. During last decade a lot of software in the area of clinical application has been developed. Of course during the process of development some generic solution has been published. In this section two main categories of related softwares will be investigated. First we will present the application and non-application based softwares which focuses more on Registration, Segmentation, Visualization, Reconstruction, Simulation, and Diffusion. The second investigates on the status of the current web-based solution in image visualization with definition of distributed systems. First category basically focuses on the local and operating system (OS)-oriented softwares, in which they are restricted to the specific hardware and software requirement. A common specification of these softwares is that they are all customized for predefined user needs. Therefore they are not following some certain standardization. Moreover, based on the adaptability problems most of them are not proper for diagnostics issues. In fact, the application domain of these software is restricted to clinical research and bio-medical studies.

A. 2D Visualization

Interestingly, visualization images can be re-sliced into multi-planer reformatted images (MPR) and curved slices; multi-temporal image data can be visualized as co-registered images; and also stack of 2D slices can be rendered as 3D volumes[16]. Based on the visual characteristics in a term of user interaction, visualization in medicine categorized in three major classes such as Illustrative Visualization, Investigative Visualization, Imitative Visualization[3]. Figure 2 will demonstrate the detail in simple graph:

Typically 3D medical images are sequences of 2D images. An interventional radiologist diagnoses the disease based on these two dimension images. These images demonstrate the organ or function of thin slices through the human body and mostly are derived from medical devices. One of the most important issues in these images are orientation of the slices which are defined by the constraint of imaging modality. As slices can be positioned in diverse orientations, calculation of these orientations is an important task which would be accomplished by simple interpolation. Regarding to the interpolation every medical image includes of certain

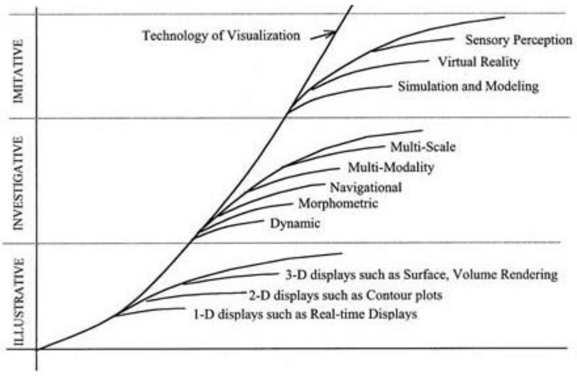

Fig. 2. This scheme illustrates Visualization Phenotype

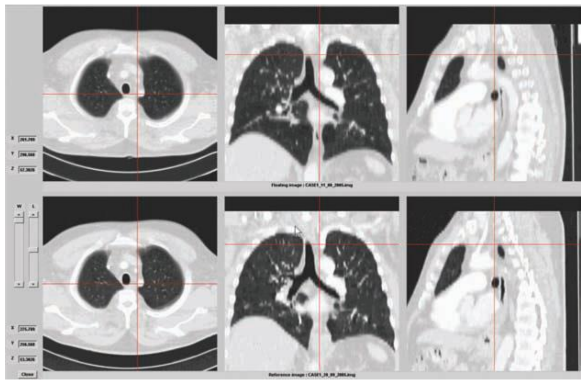

Fig. 3. This user interface shows corresponding thoracic 2D slices of the same patient over time after no rigid registration. When navigating through one of the image stacks and pointing to a position with the cursor, the corresponding position in thorax registered images is shown.

number of pixels in a range of 128×128 to 512×512. Normally the resolution of the displays is high, above 72 pixels/inch, making these images relatively small. By using a bi-linear interpolation technique these images can be enlarged. In this technique, pixel value will be computed based on the weighted sum of pixel values at the corner location of smallest rectangular cell in the image which surrounds the point [4].

In general there are several methods for image visualization in biomedical research and clinical applications. Three important types of multi-planner sectioning for 2D visualization, including orthogonal, oblique and curved planes.

- Multi Planner Reformatting: Isotropic normal 3D volume image, enable us for efficient computation of image along orthogonal orientation of the volume.[6], [13]
- Oblique Sectioning : In some cases, in 3D volume image, 2D images may not be parallel to orthogonal orientation; but go along an arbitrary oriented plane at some oblique angle to the perpendicular axes of volume data. For identifying the orientation and also creating oblique images, an additional visualization technique is required. [9], [14], [13]
- Curved Sectioning: In the other common case, the structure may not follow a normal and straight morphology that multi planar or oblique images are not able to represent them in one single image[14], [13].

TABLE I
THREE IMPORTANT LIBRARIES

Name	Platform	License
VTK	Windows/ Unix/Linux/ Mac	Open Source
ITK	Windows/ Unix/Linux/ Mac	Open Source Cross-Platform.
MITK	Windows/ Unix/Linux/ Mac	Open Source Research Education Purposes.

B. Libraries

Libraries are playing a major role in software packages. In the following the three important libraries with a description and the status of their required platform are mentioned. These categories have been placed in Table 1 [2], [17]
The first, Visualization Toolkit (VTK) is a freely available software system for 3D computer graphics, image processing, and visualization used widely around the world. This supports a lot of visualization algorithms such as scalar, vector, tensor, texture and volumetric methods; and advanced modelling techniques such as mesh smoothing and cutting. VTK is provided by Kitware, Inc. VTK is including C++ library classes. The design, implementation and architecture of the library is based on object-oriented principles. Second one, National Library of Medicine's Insight Segmentation and Registration Toolkit (ITK) is an open-source software system to support the Visible Human Project. Basically they provide developers such tools for image analysis Application domain of ITK is restricted to registration and segmentation in two, three and more dimensions. The Insight Toolkit has been developed by six principal organizations, three commercial (Kitware, GE Corporate R& D, and Insightful) and three academic (UNC Chapel Hill, University of Utah, and University of Pennsylvania). One main goal of ITK is developing a platform for advanced product development. The last and foremost, is part of the complete package including software and library MITK. MITK stands for Medical Imaging Toolkit. It is a C++ library for integrated medical image processing and analyzing developed by the Medical Image Processing Group (guided by Dr. Tian), Key Laboratory of Complex Systems and Intelligence Science, Institute of Automation, the Chinese Academy of Sciences. The development of MITK is because of the significant success of the other prior mentioned libraries. Interestingly the design of MITK like VTK is simple and based on traditional object-oriented design is spite the ITK which is based on generic programming style.

C. Local Software Solution (Visualization)

Every software application has focused on certain are in clinical research. Here the related local software solution in the area of visualization will be presented.

1) ITK-SNAP: Snap is a software solution basically for visualization and segmentation of 3D medical images. Some of the basic functionality of this open source software is summarized as following: Reading several medical images data type, converting work place coordinate systems, visualizing in real world coordinate system, visualizing active contour, as well as manual delineation and image navigation. In addition of these main functions, Snap support number of supporting utilities. One of the most important advantages of this application is its well written documentation and training videos which act as training course. Allegedly provided source code on the website is well documented and well commented. Moreover, in our approach we used some part of the ITK-Snap method for visualization. TK-SNAP provides interactive image representation with a certain work flow for medical image manipulation. The image viewing in ITK-SNAP user interface emphasizing in three-dimensional nature of image by displaying three orthogonal viewers. In each view the cursor click identify the exact slice of the other two related viewer in the 3D volume data. As this application is considered as open source software then there is no any on call support. Yet problems are mainly issue in mailing-list platform. Despite of some other application, ITK-Snap directly specified the users. So their target user includes clinical researcher which dealing with medical images and bio-medicine researcher.

2) MITK: The Medical Imaging Interaction Toolkit (MITK) is a free open source software system for development of interactive medical image processing software and analysis. MITK combines the ITK and VTK with an application framework, it is also a complete package in a term of flexibility and consistency. Not only MITK provides workbench for direct manipulation with medical images, but also it delivers such a flexible platform which can be easily integrated to other solution [17]. MITK goal is accelerating the efficiency and productivity of software development in the domain of medical imaging. Interestingly it supports medical diagnosis within the medical image processing and moreover can be used for development of therapy planning. The major usability of MITK is as following three distinctive levels:

- MITK at toolkit level is basically adding de-facto standards to ITK and VTK with concept for interactive applications, such synchronized 2D and 3D rendering of this repository, interactive manipulation of images or derived data, and a set of useful GUI widgets. MITK toolkit often known as library.
- At the application framework level MITK offers an infrastructure for end-user applications based on the OSGi[1] inspired C++ component framework BlueBerry. Thus MITK at this level is completely adaptive with the user need and predefined specification.
- At the application level MITK is distributed with an application called ExtApp, which allows medical end-users to perform regular image processing tasks such as visualization of 3D and 3D+t images with three orthogonal viewers, rigid and deformable fusion (registration) of multiple image volumes, or interactive organ segmentation.

3) 3D Slicer: Basically 3D slicer is categorized as a generic solution in the local software medical imaging classification. This forms a software platform for the analysis (including registration and interactive segmentation) and visualization (including volume rendering) of medical images and for research in image guided therapy. This application is

[1]OSGi is a module system and service platform for the Java programming language that implements a complete and dynamic component model, something that does not exist in standalone Java/VM environments.

also designed for visualization and image analysis of medical Images and extensible, with powerful plug-in capabilities for adding algorithms and applications.This multi-platform software only supports the bio-medical research, other facets are not covered with this research package. the 3D slicer is an ongoing software package in a term that it is improving over a time through testing process. In spite of the existence of such a lot of functionalities, most of them are not tested.[1]. The 3D slicer consists of more than over 370K lines of code, mostly C++. This large source code is produced by support of several communities and funding source. This open source software does not have any restriction on use and consequently no guarantee of performance. [11] Despite of the other prior related works, this package is not benefiting from good documentation and there is still need for testing of functionality. Moreover, the support is not like the other mentioned software solution and also there are some difficulties for loading the nifty file format and visualization of this data type. But the 3D slicer is providing a productive wiki platform for users and developers.

4) Complementary Solutions: So far the most important software packages in a domain of visualization have been investigated. In the following the other solutions in different application domains will be briefly summarized. Hence, several packages with corresponding description are provided in below

- ImageJ is a common application in the image processing domain especially the medical imaging one. This supports diverse raw image formats with different value support for each pixel. In addition it has an extensive use in segmentation also in customizing the image for a certain contrast, which is quite easy and straight forward.
- AMIDE is a completely free tool for viewing, analyzing, and registering volumetric medical imaging data sets. It supports several platforms such as windows UNIX based systems, developed with GTK. It offers also many features: arbitrary data set orientation, multiple data sets, thresholds, interpolation.
- GIMIAS is another generic software package which is a work-flow oriented solution for biomedical image computing and individualized simulation problems. GIMIAS provides an open source framework for efficient development in clinical research and biomedical studies, in order to motivate the contributor to convey qualified commercial development. Essential functionalities of this software are visualization, segmentation (manual and automated), and mesh editing.
- 3DView is a single platform software which supports only windows and was developed by using Visual C++. The Rendering issue is handled by OpenGL, therefore it is designed to work with a standard desktop and standard laptops. 3DView uses 2D or 3D textures to render volumetric data.
- SPM stands for Statistical Parametric Mapping which refers to a process which is used to test hypotheses about functional image data. This solution has been proposed for the analysis of brain imaging data sequences. The SPM platform has got an acceptable documentation with relevant courses for clinical research.
- MIA is a general purpose image processing toolbox written in C++ that puts its focus on 2D and 3D gray scale medical image analysis. This is an open source software which extensively supports software development through the Linux platform.
- MeVisLab represents a powerful, modular framework for the development of image processing algorithms and visualization and interaction methods, with a special focus on medical imaging. In addition to visualization it also focuses on segmentation, registration and functional image analysis.
- MILXView is a 3D medical imaging analysis and visualization platform. This platform was basically designed and developed to provide a viable and robust environment for clinical application, and to meet the needs of the AEHRC [2] . The needs of this organization are mostly summarized in the area of 3D model visualization and analysis in clinical application.

III. Web-Based Literature Review

As the web-based method being the key issue of this survey, the similar work from two different perspectives will be analyzed. On the one hand, the available single purpose of applications will be investigated which focuses mainly on the research and scientific based representation. On the other hand, the multiple purposes solution will be presented which in addition to bio-medical researches, focusing on clinical diagnosis. These solutions made a lot of progress in medical image visualization development and more importantly could take a significant step in the diagnostics process. In principle these packages most of the computation overhead performed on the server-side and tried to keep a low cost on the client-side. In the following the first category will be presented.

A. The X Toolkit

This solution is mainly using the WebGL/javascript library for visualization and allegedly this is a well-known toolkit for scientific visualization. The credit of this solution points to the Harvard medical school and Boston Children Hospital [7]. This useful library has been applied in several projects which we will accordingly introduce after highlighting the features of this toolkit. The main feature consist of opportunity to read diverse file format and Surface Models/Mesh Files such as (VTK (Visualization Toolkit), STL (Standard Tessellation)) and also DICOM/Volume Files such (NII(Nifti file), single file DICOMM format (NRDD, MGZ, and MGH)).

B. SliceDrop

Slicedrop is a famous platform for manipulating medical images in a web based platform. This package is known as x toolkit library demo. However, there is such a large number of packages using X toolkit as a library although slicedrop due to straight forward user interface counting proves the most applicable. Slicedrop supports a variety of scientific file formats out of the box including DICOM, meshes, scalar overlays and fiber tracks. It uses WebGL and HTML5 Canvas to render the data in 2D and 3D. Web application is mostly done in pure javaScript/jQuery and

[2] Australian E-Health Research Centre (AEHRC)

HTML5 and Completely client-sided. Moreover it posses and MIT License and is fully open source, making it openly accessible. The accessibility regarding file format is granted by using X Toolkit as a library which is supporting DICOM, Nifti, MGH/MGZ, NRRD, VTK Poly Data, Freesurfer, STL, TrackVis, ColorTable and Scalar. The last and foremost it is supporting Mesh and Scalar overlay.

C. LEADTOOLS Medical Web Viewer Framework SDK

This Developer kitenables users who are mostly programmers to develop quickly high standard feature and secure web medical image viewer applications. The OEM-Ready ASP.net web application uses web service streaming and LEADTOOLS features for an unsurpassed web experience for healthcare professionals. This technology is a rich client-sided viewer, in a term that computation overhead is handling in client side. The modularity design of this solution makes users to customize their required component in an acceptable way. The main important feature of this package is 3D reconstruction and 2D visualization of medical images. One of the newest support that this company and package provides is thin client image viewer for low bandwidth clients and mobile devices with diverse operating systems such as android and IOS. In addition to .Net technology which has been used in this framework LEADTOOLS also HTML5, javascript DICOM viewing and PACS communication are used for cross-platform DICOM imaging. Client caching of downloaded image data for fast reloads and network traffic reduction is another feature of this package which promises an acceptable interaction response. Using options for low-memory usage in large-study viewing is a last overview of this framework.

D. Web-Based Multilayer Visualization

Since the result of investigation in medical visualization domain lightened the role of education more than diagnostics in web-based solutions. Thus in this solution package, the question, "what is the result of evaluation in web based medical image visualization?", will be answered in order to understand the user needs and implement such a system for concrete purpose. 3D visualization is in a direct relation with 2D representation, in a way that visualization in virtual space provides such depth information for 2D representation. Hence by providing such a web based system for the user to interact in 2D/3D visualization, usability evaluation would directly form. There are some user studies which highlight this evaluation; as in this evaluation some methods for visualization have been proposed we just here name the used technology in this section and we analyse the experimental research in the evaluation section of this thesis later on. [12]Predominantly in the initial scientific methods, medical images visualized over the web by using XD modeling. However, this player is restricted in interaction and operation. [15] Actually there is a framework which is extensively using this player. In the early work in [15] scientific research they proposed a framework using Web 3Ds standard file format which is applicable for web services and contains all interactive 3D content. X3D is ISO standard file format, which is XML-based. As this framework has a modular design pattern thus they integrate it with web based Model View Controller (MVC) framework which they accordingly introduced in their previous works. This method focuses more on constructing the 3D model from 2D cross-sectional based on the marching cube algorithm that creates triangle models of constant density surfaces. This solution does not provide that much functionality and more importantly not support variety of medical data format. One major issue in this framework is browsing through reconstructed model, which needs continuous page reloading and to some extend is unnecessary for 2D models.

E. Web Interface for Visualization

By flipping the pages through scientific researches we will come up with some methods which have been exclusively proposing web-accessible image visualization for medical application. This method is a well-structured method between all researches, and for that I found it important to introduce it in this section. This medical software provides 2D and 3D medical data representation whereof we mostly focus here on 2D visualization. Abstractly this web interface solution uses HTML5 and WebGL technology and allows the user to interact and visualize an image in an out-of-core (OOC) manner which will be introduced later in this section. Basically the work flow of their approach is based on the excessive communication between server and client with remote procedure calls (RPCs). In other words, medical image data is first uploaded to the server, what allows handling a lot of format. Subsequently, it communicates via RPC with the client side in order to finish the process of visualizing the medical data with simple manipulation of received string messages.[8]. All in all a web-based platform is necessary for data visualization due to the following advantages; it is the dramatic growth of medical data, which is centralized repositories, can make a stable base for diagnosis and research purposes. Secondly development process in improving the application and researches due to the direct interaction of end-users is much faster. Ultimately, due to advances in image acquisition, medical data set requires a large RAM capacity [8]. As explained above in the architecture, files will be uploaded to the server and then with an asynchronous process JavaScript and XML (AJAX) will be revealed to the user. For the client side communication considered JSON parameters as the important platform for RPCs between server and client side. After getting to know the infrastructure of the framework, we will discuss now the front-end and features of this solution. This package like the similar packages focuses more on DICOM and VTK. Thus they implemented a C++ application on the server which hand over the required data through the JSON messages. It is obligatory to say that due to wide usage of VTK library in image processing they tend to use MetaImage format (.mhd header to indicate necessary information to read the corresponding volume data). So by simple communication between server and client they send meshes data over a time and visualized it on the client side.

F. Web-based interactive 2D/3D medical image processing and visualization software

This solution is also categorizing in the web based systems packages. The first important aspect that it has been mainly addressed is the conventional user interface. Basically the main problem of all web based user interface is that after every interaction the entire page should be reloaded. This type of the client-server interaction doesn't let developers to provide a maximum feature with good quality for user [5]. Thus in the following the process of solving this problem will be discussed and also techniques and algorithm interfaces will be explained.In Web user interface based on the design, the main goal is developing a web application which is available across all types of clients. Therefore the best and most important option for this purpose is JavaScript which is an excellent choice for handling the client UI. Their main challenge is summarized in usability of JavaScript and passive client tools. In the other word, there are some limitation in interaction between client and server. Basically JavaScript requires all information reside in the client side, in order to completely accomplish the interactions. Therefore to tackle the problem necessity of continuous connection between clients and sever for two purposes is essential, first to answer the problem second to make the application as interactive as possible. This technology conceptually is combination of AJAX and JavaScript [10]. By this combination the web page refreshment for transferring data and connection establishment will be eluded. The communication protocol is also established based on the XML framework which is based in HTTP protocol. Surprisingly this combination has solved security problems and does not make them to setup new security and managing facility other than conventional web browsing setting. [10]

IV. Conclusion and Future Work

In summary, the essence of precise visualization by demand of radiologists and interventional doctors is getting more and more severe. This essence would hover much more where an exact diagnosis followingly requires an appropriate treatment. As mentioned above, several software solutions are proposed in order to address this problem. However some of these packages are just answering academic and research studies. Based on this article classification, current software solutions in a domain of academic researches and also diagnosis are divided into two main categories. The first one is general literature, which is covering the current local based software solution and the second is more specific literature, which includes all web-based libraries, applications and the framework in the domain of medical image visualization. However, local based solution mainly bringing some advantages such as scaleability, fast responsiveness and robustness. They are restricted to a local system customization which brings many software and hardware limitations. These solutions are not relying on several doctors diagnosis and they are so-called single doctor oriented. Therefore despite of the general advantages, they are not addressing to the main issue which is reliable ubiquitous diagnosis. In contrast, in web-based solution packages, the main idea is providing a shared platform, in which users (Mostly interventional doctors and radiologists) are able to initiate their work flow and get a quick feed back regarding the testing of special treatment based on the specific characteristics. Doctors and especially radiologists will be well-informed regarding the other sample treatment in the same use case scenarios, which consequently leads them to find an efficient treatment for a patient. As proposed above in web based approaches, they are mostly focusing on balancing the computation overhead in server and client. But still the main image processing functionality is handling on the server side which is bringing some dependency such as internet connectivity and stability. These two factors make us to think of a novel and efficient approach which addresses the ubiquitous medical image processing by eluding the connectivity limitation. An approach which handles the important medical image data visualization such as nifti and vtk meshes and image segmentation with an acceptable responsiveness.

References

[1] "3d slicer, is a free, open source software package for visualization and image analysis. available at www.slicer.org".
[2] An open source software developed as an initiative of the u.s. national library of medicine and available at www.itk.org.
[3] Isaac Bankman. *Handbook of Medical Imaging: Processing and Analysis Management*, pages 659–660. Academic Press, 2011.
[4] Isaac Bankman. *Handbook of Medical Imaging: Processing and Analysis Management*, pages 685–686. Academic Press, December 2011.
[5] Elfriede Dustin, Jeff Rashka, and Douglas McDiarmid. *Quality Web Systems: Performance, Security, and Usability*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2002.
[6] Morton PE Dwyer SJ Glen Wv Jr, Johnson Rj. *Image Generation and display techiniques for CT scan data*, pages 403–416. 1975.
[7] Daniel Haehn, Nicolas Rannou, Banu Ahtam, Ellen Grant, and Rudolph Pienaar. Neuroimaging in the browser using the x toolkit. *Frontiers in Neuroinformatics*, (101).
[8] Hector Jacinto, Razmig Kchichian, Michel Desvignes, Rmy Prost, and Sbastien Valette. A web interface for 3d visualization and interactive segmentation of medical images. In *Web3D'12*, pages 51–58, 2012.
[9] Bruce A. Kall Frederic B. Meyer Richard A. Robb Lisa M. Bates, Dennis P. Hanson. Implementation of an oblique-sectioning visualization tool for line-of-sight stereotactic neurosurgical navigation using the avw toolkit. *SPIE 3335, Medical Imaging*, 3335(219), 1998.
[10] Seyyed Ehsan Mahmoudi, Alireza Akhondi-Asl, Roohollah Rahmani, Shahrooz Faghih-Roohi, Vahid Taimouri, Ahmad Sabouri, and Hamid Soltanian-Zadeh. Web-based interactive 2d/3d medical image processing and visualization software. *Comput. Methods Prog. Biomed.*, 98(2):172–182, may 2010.
[11] Steve Pieper, Michael Halle, and Ron Kikinis. 3d slicer. pages 632–5, 04 2004.
[12] Chueh-Loo Poh, R. I. Kitney, and R. B.K. Shrestha. Addressing the future of clinical information systems—web-based multilayer visualization. *Trans. Info. Tech. Biomed.*, 11(2):127–140, March 2007.
[13] Rob Ra. *Three-Dimensional Biomedical Imaging Principles and Practice*. VCH, New York, 1994.
[14] Azzawi YM Rhodes ML, Glen Wv Jr. *Extraction oblique plan from serial CT sections*, pages 649–654. 1980.
[15] S. Settapat, T. Achalakul, and M. Ohkura. Web-based 3d visualization and interaction of medical data using web3d. pages 2986–2991, Aug 2010.
[16] Paul Suetens. *Fundamentals of Medical Imaging*, pages 158–159. Cambridge University Press, 2009.
[17] Ivo Wolf, Marcus Vetter, Ingmar Wegner, Marco Nolden, Thomas Bttger, Mark Hastenteufel, Max Schbinger, Tobias Kunert, Hans peter Meinzer, and Deutsches Krebsforschungszentrum. The medical imaging interaction toolkit (mitk) a toolkit facilitating the creation of interactive software by extending vtk and itk, 2004.

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