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# MaRRS : a software system for generating multimedia radiology reports using Adobe Acrobat

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*Ryerson University*

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# **MARRS: A SOFTWARE SYSTEM FOR GENERATING MULTIMEDIA RADIOLOGY REPORTS USING ADOBE ACROBAT**

by

Kristy Moniz, BSc, Ryerson University, Toronto, Ontario, 2007

A thesis

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Masters of Science

in the Program of

Computer Science

Toronto, Ontario, Canada, 2009

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# **MaRRS: A SOFTWARE SYSTEM FOR GENERATING MULTIMEDIA RADIOLOGY REPORTS USING ADOBE ACROBAT**

Kristy Moniz

MSc, Computer Science, Ryerson University, 2009

## **ABSTRACT**

Despite the proliferation of mature multimedia software technologies, radiology reports continue to lack image content that would improve the ability of referring clinicians to fully interpret and analyze radiological findings. This thesis demonstrates that it is possible to construct a radiology reporting software system that contains both text and image content using only “off-the-shelf” multimedia software. Specifically, a software system is presented that provides enhanced visual multimedia capabilities, structured content, and reduced report production time, using a well-known PDF program, Adobe Acrobat. The system, which we call the Multimedia Radiology Report System, or MaRRS, allows radiologists to quickly and simply create and deliver effective interactive multimedia medical reports. A detailed analysis describing the unique structure and functionality of MaRRS will be presented to demonstrate its advantages for both radiologists and referring clinicians.

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## Chapter I – Introduction

Radiology interpretation is a sub-process of radiology [16], which in turn is a part of the healthcare process. Its goal is to generate a diagnostic radiology report that captures the radiologist's interpretations and impressions, which is then made available to clinicians outside the radiology department. The radiology report is an element of the patient's healthcare record and contains important clinical information to assist in healthcare decisions. Yet despite its importance, many reports still consist primarily of a large amount of unstructured text and lack clear, consistent, content-rich information [13, 29, 51, 56, 59]. This outmoded format makes it difficult for clinicians to interpret and analyze the radiological findings [21, 29]. Recent radiology reporting software systems have attempted to reduce report production and turnaround time, improve the report structure, and provide speech recognition options to enable text entry through voice input. However, these custom packages are expensive and require the radiologist to learn a new system in addition to, or in place of, their existing software.

Moreover, with the proliferation and development of new, existing, and hybrid medical image scanners, new approaches to processing and reporting are needed that convey the rich sources of visual information generated by these devices. The concurrent widespread availability of powerful 3D medical image visualization software has allowed radiologists to effectively visualize and analyze anatomical structures contained within, for example, Computerized Tomography (CT) or Magnetic Resonance Imaging (MRI) scans. Current radiology reports do not take advantage of the high resolution, two-dimensional (2D) and three-dimensional (3D) views of medical images painstakingly generated by the radiologist using their favourite image visualization software. This is a major problem with existing radiology

reporting technology. Radiologists must be able to quickly and simply generate a secure, shareable, standardized report that conveys this visual analysis to the referring clinician in order to prevent misinterpretation and improve report timeliness and report structure [55].

The advent of new multimedia authoring programs and collaborative web-based software technologies [17] has created the potential to transform radiology reporting to meet these requirements. Mature, inexpensive, off-the-shelf software technologies now exist that provide the ability to generate a consistently structured, content-rich multimedia report. For example, 2D and 3D images, volume renderings, 3D data representations, and web hypertext links can all be embedded into a document. Furthermore, the report can be electronically signed and securely emailed to referring clinicians.

In addition to multimedia authoring software, many collaborative software applications have been developed that allow for real-time discussions and synchronized viewing of a radiology report over the Internet. With web conferencing technology, radiologists and referring clinicians may effectively collaborate anytime and anywhere, eliminating inconvenience, travel cost, and scheduling problems of face-to-face meetings. Web conferencing is considered a key strategy [33] for overcoming the long-standing obstacles to effective and efficient communication between radiologists and clinicians, resulting in more accurate diagnoses and faster turnaround times. Patients will also have peace of mind knowing that both the physician treating them and the radiologist have discussed and examined the results together.

## **1.1 Contributions of this Thesis**

The goal of this thesis is to demonstrate that it is possible to construct an inexpensive, interactive radiology reporting software system that addresses the problems of radiology reports

described above, using only off-the-shelf multimedia software. A further goal of the thesis is to demonstrate that it is possible to construct this system such that it maintains the use of existing image visualization software.

The result of this thesis is a software prototype called the Multimedia Radiology Report System (MaRRS). MaRRS has been designed for radiologists to create an interactive multimedia report that *tells a story* of a patient's radiological findings. With MaRRS, radiologists can simply and intuitively generate a visually rich report using the standard Adobe Systems Portable Document Format (PDF) [5]. MaRRS is essentially a software *bridge*, connecting any extendible image visualization package to the well-known, widely available PDF-authoring program, Adobe Acrobat. This flexible design allows radiologists to retain the use of their preferred visualization software and generate a report in a standard, well-accepted document format.

MaRRS allows for the creation of visually enhanced reports that can include 2D and 3D images, video, audio, and even 3D geometrical models of anatomical structures. In fact, the capability of embedding 3D geometrical models of anatomical structures relevant to the patient's condition is a substantial advancement over existing commercial radiology reporting applications. A radiologist might spend considerable time and effort processing a 3D dataset to reveal and render the often complex spatial interrelationship between anatomical structures. Hence, this multimedia content can be immediately transferred, with the click of a button, from the image visualization window to a PDF report displayed in an adjacent window on the computer screen. Furthermore, the enhanced PDF report can still be viewed and interacted with using the standard, freely available Adobe Reader program.

Adobe Acrobat offers functionality for creating, viewing, and managing PDF files. Recent versions also provide extensive functionality for forms, multimedia content, hypertext links, password protection, permission settings, and real-time collaboration of PDFs with synchronized document views. While the idea of a multimedia radiology report is not new, the mature and practical Adobe Acrobat technology provides the capability to create reports that are securely and reliably accessible by both radiologists and clinicians. By identifying and quickly transferring relevant multimedia components such as images or 3D models of anatomical structures extracted from large datasets, an interactive multimedia report is generated. The PDF radiology report displayed in the Acrobat window can then be further annotated by radiologists using the rich Acrobat toolset. In this manner, the radiologist can provide the clinician with the necessary quantitative measures along with helpful visual aids to assist in decision making.

The following list describes the key capabilities of MaRRS:

- 1) MaRRS allows radiologists to create a PDF radiology report which can be securely emailed to referring clinicians and displayed using Adobe Reader. This widely-accepted standard document format enables authorized users to review the report on any computer operating system.
- 2) MaRRS does not replace the existing image visualization package used by radiologists with an expensive custom solution that forces them to learn a new system. MaRRS also does not add a separate reporting system to the visualization system. Instead, MaRRS connects the preferred visualization package with Adobe Acrobat to smoothly produce PDF reports.
- 3) MaRRS provides a simple, intuitive interaction model that allows the radiologist to transfer multimedia components in real-time, from the visualization package to the

radiology report. This capability boosts the radiologist's productivity levels and reduces report turnaround time. It also provides visual feedback for clinicians, reducing the chance of misinterpretation and providing a mechanism for the clinicians to present the findings to their patient.

- 4) MaRRS supports 2D and 3D images, 3D video volume renderings, and 3D geometric models of anatomical structures. This facility provides radiologists and clinicians with the ability to interact with and control various multimedia components, allowing them to visually point out and describe areas of interest.
- 5) Finally, MaRRS provides report annotation and remote collaboration features in efforts to further improve the description of the radiological findings and prevent any misunderstanding between the radiologist and referring clinician, respectively.

The idea behind MaRRS is to avoid forcing radiologists to use expensive and custom reporting systems that may also have a steep user learning curve and that may disrupt their workflow. Another motivation is to provide a tighter coupling between the detailed and time-consuming image analysis performed by the radiologist with a visualization package and the subsequent report generation. These key features considered as a whole may improve the quality of the report and turnaround time [55], produce accurate patient analysis, and achieve higher confidence levels [51].

## 1.2 Thesis Outline

In *Chapter 2*, this thesis presents a literature review of healthcare solutions in the context of radiology reporting systems. In addition, a collection of image visualization packages is described, including *MeVisLab*, the package used in the MaRRS software prototype. Lastly, the

multimedia authoring program Adobe Acrobat 3D is presented, along with a rationale for its usefulness in radiology reporting.

**Chapter 3** describes the system architecture and implementation of MaRRS as well as the design of custom Acrobat plug-ins.

**Chapter 4** presents the results of this thesis and provides a detailed description of the MaRRS interface and functionality. It also describes annotation features for the radiology report that can be used in MaRRS to further enhance visual multimedia components. Finally, this chapter examines Acrobat Connect Pro, a web conferencing software system in order to illustrate how it can be used within MaRRS to allow remote collaboration between radiologists and referring clinicians.

Finally, **Chapter 5** concludes with final remarks regarding MaRRS along with recommendations for potential future work.

## **Chapter II – Literature Survey**

A number of today's radiology report authoring applications attempt to assist radiologists in minimizing report production time. However, it is still an ongoing challenge [51] to create an application that makes the radiology report process intuitive as well as timely. Supplements such as voice commentary, video files, and enhanced user interfaces are all under current consideration as additions to the standard report, driven by research suggesting that new technology plays a role in reducing the report timeliness.

In addition to report timeliness, radiologists and referring clinicians are finding that the traditional style report is no longer adequate [13, 43] to cover the necessary content. As we enter a new paperless era of radiology practice, new computer-based technologies are helping to transform radiology reporting. The following sections describe traditional as well as contemporary radiology reporting applications in some detail.

### **2.1 Early Methods of Radiology Reporting**

For many years radiology reports have essentially consisted of typed or handwritten text [10, 55]. In particular, these reports are stored as simple free-text [56] and printed on paper where referring clinicians signoff on the reports after reading the written documents. This outmoded report mechanism resulted in slow report turnaround time and suboptimal report quality. In fact, with text-only reports, accurate patient diagnosis was not always achieved [13, 14, 29]. Misinterpreting the written or typed examination results described in such reports was the most common reason for misdiagnosis. However, new technologies, such as structured

reporting systems [43] and speech recognition, have been developed to address these deficiencies with the goal of better patient outcomes, systematic cost savings, and improved report quality.

### 2.1.1 InfoRAD

The advent of structured reporting systems was introduced to Radiology with the intention of improving report organization and structure [56]. Radiologists began using structured report templates which were then processed by automated reporting systems. This allowed them to input text under headings such as “History”, “Findings”, and “Impressions”. Informatics in Radiology known as *InfoRAD* [59] is an example of such a system. It was designed to automatically structure medical information contained in a radiology report using a natural language processor to generate an Extensible Markup language (XML) report (Figure 1). InfoRad, under development since 1995, uses several natural language processing modules to scan the text in the report and structure the properties, location, and diagnostic interpretation of findings contained therein. The system architecture of InfoRad is shown in Figure 1.

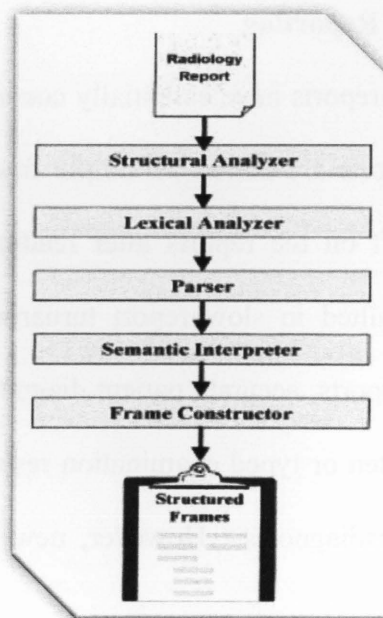


Figure 1: System architecture for InfoRad

More specifically, InfoRad uses a *structured analyzer* module to separate sections of the report, indicated by the report headings, and then requests the *lexical analyzer* to look up semantic and syntactic features of words. The *parser* then determines the relation between these words within sentences, and uses the *semantic interpreter* to link the parser results and output a set of logical relations. Finally, the *frame constructor* combines these relations into structured frames.

### **2.1.2 Medical Multimedia Document System**

In 2002, a new method was proposed to improve the structure of diagnostic reports using the document object model (DOM) [44]. The DOM is a platform- and language-independent standard object model for representing HTML or XML documents as well as an Application Programming Interface (API) for querying, traversing and manipulating such documents. This object model provides the ability to include Digital Imaging and Communications in Medicine (DICOM) files in the report [45]. DICOM is a standard in the field of medical informatics for exchanging digital information between medical imaging equipment (such as radiological imaging) and other systems, ensuring interoperability. The use of the DOM in resulted in a medical diagnostic report stored as a structured multimedia document, allowing it to contain information such as text, numerical values, spatial and temporal coordinates, and references to hierarchically-arranged images.

In summary, systems such as the two described above represented a step forward in efforts to provide radiologists with applications that formally structure the standard report [43]. These systems also addressed management issues, such as organization and structure, commonly

faced by radiologists while producing reports. However, report turnaround time and cost savings were left unchanged.

## **2.2 Recent Radiology Report Authoring Software**

More recent software solutions have focussed on creating radiology report authoring applications that lower report turnaround time and hence contribute to improved patient care [51]. One of the primary mechanisms to reduce the turnaround time is the use of speech recognition software. With speech recognition, radiologists have the ability to dictate patient diagnosis rather than typing it in words. This has resulted in a reduction of turnaround time by nearly fifty percent [47, 55], enabling radiologists to complete a report within minutes or hours rather than days or weeks.

Other techniques provided by competing vendors to improve radiology reporting include building a secure document to maintain patient confidentiality, and adding value to the report in the form of medical imagery by integrating other systems. Medical imagery is a vital component that allows radiologists to clarify textual descriptions found in the body of the report with multimedia objects. Visual aids give valuable information to clinicians while they are reviewing the report, enabling them to fully comprehend the material described by the radiologist. As a result, clinicians also have the authority to verify radiologist's diagnostic results and if necessary, modify the report accordingly. Without integrating visual aids, patients can be misdiagnosed [13, 14] and given incorrect treatment.

### 2.2.1 MedSpeak

As previously mentioned, the goal of many radiology reporting applications has been to reduce the overall report production time for radiologists through the use of speech recognition systems. These systems have been shown to reduce errors resulting from illegible, handwritten notes, and reports [23]. MedSpeak was the first radiology speech recognition solution, developed by IBM in 1996 [31]. It was described as a continuous dictation [55] product enabling radiologists to dictate findings from patient x-rays. Upon completion of a radiologist's diagnostic dictation, the system smoothly converts the dictated comments into a written report. The radiologist would subsequently verify the transcript, make adjustments if necessary, add an electronic signature, and send it to be processed [41]. IBM also designed MedSpeak to simplify the creation, alterations, and management of medical reports.

### 2.2.2 SpeechMagic

More recently, a system called *SpeechMagic* [46], developed by Philips Speech Recognition Systems, is recognized as among the most advanced speech recognition technology currently available and is widely used in today's healthcare facilities. With SpeechMagic, easy integration can be achieved with any Radiology Information System (RIS)<sup>1</sup>. It allows dictation, high accuracy speech recognition, and corrections to be made at any location using the Internet. SpeechMagic claims improved report turnaround time of more than seventy percent and reduced waiting times for referring clinicians and patients.

---

<sup>1</sup> **Radiology Information Systems (RIS):** A computerized database used in radiology to store, manipulate, and distribute patient medical scans and reports.

### 2.2.3 StructuRad ReportNow

Another radiology report system currently in use is known as *StructuRad ReportNow* [34, 55]. This application was founded by two radiologists in 1997 to improve radiology by optimizing the reporting process and reducing dictation and transcription delays. Like MedSpeak and SpeechMagic, ReportNow was developed to decrease report production time [41] and provide an easy and flexible interface. ReportNow is a Microsoft Word-based editor designed for multi-user organizations. ReportNow enables radiologists to import 2D medical images, produce tables, and plot graphs to allow greater visibility and quality information (Figure 2). ReportNow can also be integrated with (and launched from) a Picture Archiving and Communication Systems (PACS)<sup>2</sup> or RIS. In addition, ReportNow provides speech recognition through either SpeechStudio or Dragon Naturally Speaking.

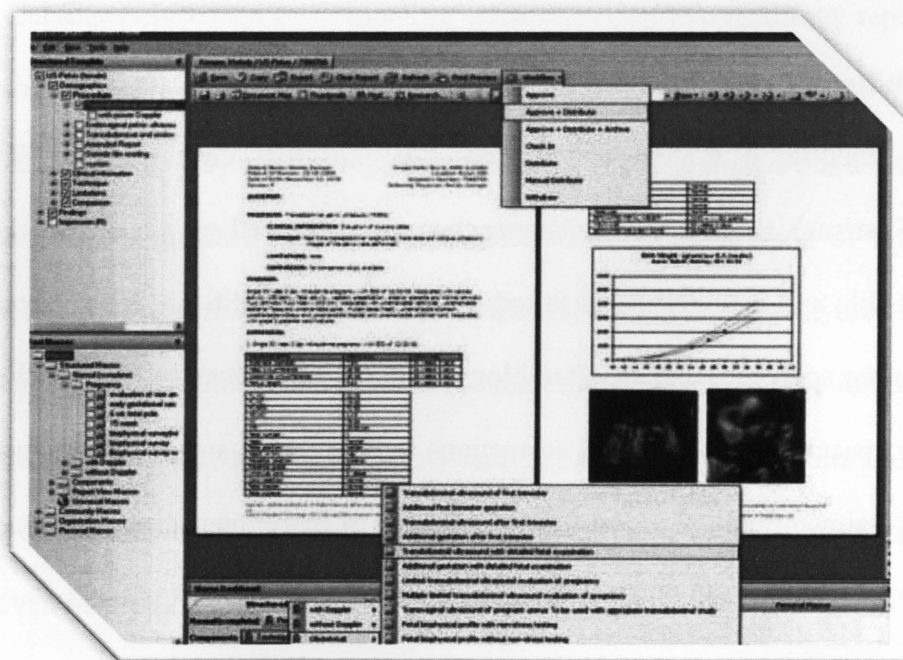


Figure 2: Snapshot of StructuRad ReportNow, an all-in-one radiology reporting system

<sup>2</sup> In medical imaging, **picture archiving and communication systems (PACS)** are computers or networks dedicated to the storage, retrieval, distribution and presentation of images. The medical images are stored in an independent format, typically DICOM.

#### 2.2.4 SoftRad RIS

An additional radiology reporting application called *SoftRad RIS* [24], created by SCC Soft Computer, provides hospitals and laboratories with integrated RIS/PACS image management clinical solutions. This product was designed to improve the workflow of a radiology department as well as share information, images, and reports across different departments. Like ReportNow, *SoftRad RIS* is a Microsoft Word-based system that provides custom reports, templates, and options to include 2D images. It also provides digital dictation, integrated voice recognition, automatic document delivery, and electronic signature signoffs. The digital dictation interface allows radiologists to link readings with exams to reduce transcription errors. Also, the integration of voice recognition and electronic signature tools allow radiologists to produce high quality reports. Management tools are also offered by SoftRad to enable resource scheduling and audit trails to be saved.

#### 2.2.5 VoxReports

*VoxReports* [8] is designed as a speech-recognition workflow management system with the goal of faster and easier interpretation and delivery of radiology reports. It is a client-server system that responds to all speech operations and can be integrated into any PACS, RIS, Hospital Information System (HIS), and Electronic Medical Record (EMR) systems. It features the ability to quickly create a report while a radiologist is observing medical data and to provide direct delivery to referring clinicians, all through speech-driven technology (Figure 3). Completed reports may then be faxed or emailed to clinicians and in turn, be presented to the patient.

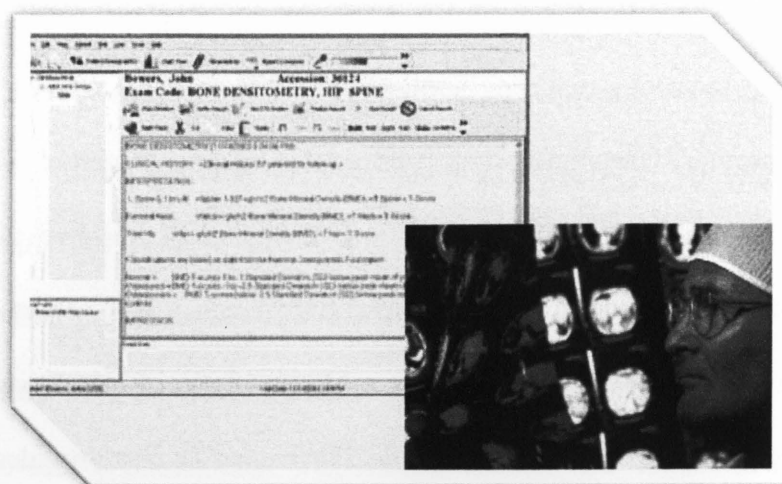


Figure 3: Radiologist dictating findings using VoxReports

In addition, VoxReports provides an advanced editing interface called *VoxEditor* in which referring clinicians may access and review reports from any location via the Internet. If changes have been made to the report, the editor adds an electronic signature and retransmits the file back to the server where the radiologist may review and resign the document.

## 2.2.6 Dragon Medical, PowerScribe, & RadWhere

*Dragon Medical* [47] is one of three front-end speech recognition reporting applications developed by Nuance. Dragon Medical, a medical version of Dragon Naturally Speaking, is a synchronized speech recognition program that operates with any Windows-based or Citrix application for efficient report generation and easy hands-free navigation. This system claims the ability to maintain up to ninety-nine percent accuracy, allowing radiologists to dictate their reports at up to 160 words per minute, as well as review, sign, and make the document available to referring clinicians. With Dragon Medical, voice dictations can be made by the radiologist anytime at their convenience using, for example, a mobile handheld device and later the recording can be imported into the report. In addition, Dragon Medical can be integrated with any radiology report authoring system, adding significant value to the system.

The second speech recognition reporting application developed by Nuance is *PowerScribe for Radiology* [47]. This system is a web-based speech-driven documentation solution. PowerScribe promotes the ability to enhance productivity by rapidly creating radiology reports and posting them on the web so that referring clinicians can access reports anytime, anywhere. Other features of PowerScribe include client-server architecture, options to integrate with PACS/RIS systems, and various workflow management tools. Research indicates that approximately forty percent of radiologists in the U.S. use this flexible application. Those who use PowerScribe reported increased referrals as a result of faster availability of reports.

The third speech recognition reporting solution developed by Nuance is *RadWhere for Radiology* [47]. Aside from speech recognition, it also offers diagnostic imaging workflow management. RadWhere allows for the creation of reports using dictation templates and data extraction tools that analyze productivity. Similar to PowerScribe, RadWhere also integrates with PACS, RIS, 3D, and teleradiology systems. In addition, RadWhere offers web-based access [16] for radiologists and technologists for data entry. It is managed through a secure web-based portal accessible anywhere within a hospital network. Authorized users may access information [15], view patient prescriptions, edit and review reports, and so on using this online management system. Reports can also be created and shared among other physicians within the hospital network using a collaborative chat session feature.

### **2.2.7 SpeechQ for Radiology**

*SpeechQ for Radiology* [39] is powered by the Philips SpeechMagic speech engine and claims the ability to ignore non-speech sounds, insert proper punctuation, and produce a report with information received from a PACS or RIS, resulting in faster report creation.

### **2.2.8 Radiology Web Application**

Another workflow management system co-developed by *Infosys* [27] is a secure radiology web application [16]. The user interface was designed such that radiologists may select a view from a multiple viewing screen. A dictaphone was also incorporated to dictate reports onto a webpage. In addition, the application contains a manageable communicative component between a PACS and the radiologist's web application. Another feature offered by this application is the development of an XML web service for the communication between the Magnetic Resonance (MR) and RIS systems. Accordingly, emergency patient care is achievable through the use of this system since reports are made accessible by online authorized users, with options to employ collaborative tools, resulting in a shorter turnaround time.

## **2.3 Remote Collaboration in Radiology Reporting**

Collaboration is essential to clinical work and is an important design consideration for future infrastructure in medical institutions [10, 36]. It is a new and heavily researched area with applications to any field where more than one individual must work together to achieve a common goal [11]. One classic example of collaboration in medicine is the communication between a radiologist and referring clinician that is often necessary to understand a diagnosis. Radiologists are typically extremely busy medical specialists, and referring clinicians are most often located outside of the Radiology department. This makes face-to-face meetings extremely challenging to schedule and therefore remote cooperative work must be made possible [12]. With the ability of physicians to collaborate remotely, accurate patient diagnosis can be more readily assured [12]. In other words, medical professionals who are able to collaborate despite their work schedules or physical location may obtain further patient insight or reasoning for the types

of symptoms being encountered. The sooner a clinician correctly diagnoses their patient, the greater the chances of providing a successful outcome.

Collaboration not only means voice communication but also includes the ability for radiologists and referring clinicians to remotely share and view patient reports [42, 50]. Furthermore, radiologists and clinicians who use web-based collaborative software have the advantage of viewing radiology reports in real-time [12, 42], communicating their diagnosis either verbally or by marking on the report itself. Communication between physicians using collaboration applications may be achieved through sending instant messages or using VoIP. Altogether, remote web-based collaboration is an extremely useful process providing benefits to all.

### **2.3.1 The Need for Collaboration in Radiology Reporting**

In medicine, remote collaboration applications provide vast benefits to both healthcare providers and their patients. One of the most significant advantages is that it enables radiologists and referring clinicians to communicate [22, 33, 48] in various ways, for instance through instant messaging, or VoIP using a microphone or headset. The most obvious need for remote collaboration is the reduction in travel cost and time required in attending meetings to discuss a patient's condition [11, 33, 36]. Effective and efficient remote collaboration technology provides the potential to communicate and collaborate as if they were in the same room, eliminating all airfare, gas, toll, hotel, and other expenses [33]. As technology continues to evolve, collaboration between radiologists and clinicians will eventually become effortless.

Web-based collaborative software solutions also allow users to remotely share documents [12, 22]. This capability is particularly useful when a referring clinician requires a quick and straightforward report clarification, or when a radiologist needs the referring clinician to review

the report to ensure no requested radiological test has been missed. As a result, this capability can help reduce the report turnaround time [42] and ensure accurate patient diagnosis.

Finally, remote web-based collaboration has the ability to improve clinical decision making [22, 33]. In fact, radiologists who communicate with other radiologists demonstrate more accurate diagnostic results [42] and treatment options. As a result, the quality of information [42] contained in radiology reports is also enhanced since radiologists have the ability to share the report with colleagues to verify patient diagnosis. Accordingly, patients may have a greater sense of relief knowing that all possibilities have been examined by more than one physician. Hence, one key to success in medicine is the ability to remotely collaborate, which assists radiologists in providing the best health care possible by confirming diagnostic results and treatment options with other specialists in a convenient fashion.

### **2.3.2 Web Conferencing Software**

In recent years, web conferencing software has become a second generation of collaboration technologies [17]. It is a powerful and useful technology solution that allows live meetings to take place over the Internet. Users log in to a secure URL to view meeting materials and use VoIP for audio communications. In fact, web conferencing has evolved from early peer-to-peer desktop conferencing tools and simple collaboration tools such as chat and instant messaging, to state-of-the-art solutions [17, 28].

Web conferencing software offers advanced capabilities that enable unrestricted communication between presenters and attendees. Today, with most web conferencing applications, a meeting host may perform several tasks. The person hosting the online meeting is usually in charge of administrative tasks [17] such as allowing attendees to enter the meeting.

The following list describes the typical events over which the host has full control during the meeting presentation:

- Chat with other participants through VoIP and instant messaging
- Share desktop and/or application windows
- Interact with shared documents
- Annotate or mark-up in documents on shared virtual whiteboards
- Make notes or draw on shared virtual whiteboards
- Record meetings

Attendees on the other hand, are given less control than the presenter [17]. Typically, a web conferencing application will allow participants to activate a live video webcam so that others can observe their responses. Some applications even allow presenters to pass control [28] of their screen over to attendees so that they can interact with applications shown on the presenter's screen.

## **2.4 Summary of Recent Radiology Reporting Systems**

Recent healthcare applications have primarily focused on reducing report production and turnaround time, improving the structure and workflow management, and provide new options to naturally input voice dictations within reports. With VoxReports, a wide integration of useful technology is provided to help improve productivity in both the generation and delivery of radiology reports. However, one major trade-off in utilizing VoxReports is the inability of including medical imagery within the report.

The goal of speech recognition systems such as SpeechMagic, Dragon Naturally Speaking, and RadWhere, is to reduce report turnaround time using advanced speech-driven

technology. Speech recognition can dramatically reduce report turnaround time from days to hours and even minutes, as well as lower transcription costs [47]. Nonetheless, these systems are only beneficial if they are integrated with other radiology reporting applications.

ReportNow and SoftRad visually enhance radiology reports through their ability to include 2D medical images such as x-rays. However, 2D images are no longer the only images used to diagnose disease. 3D CT and MRI scans, among many others, are now commonly used and report authoring systems need to be modified to take advantage of these sources of information.

## **2.5 Motivation for MaRRS**

Despite the plethora of existing radiology reporting applications, there is still a continual need for improvement. New inventive applications are required that focus on maintaining productivity and structure, while still improving the visual quality of the report itself. For example, the incorporation of high-quality volume renderings and annotated 3D anatomical structure models has the potential to dramatically improve the report. The ability to integrate these components and other significant multimedia components would result in content-rich, visually enhanced reports. Furthermore, recent multimedia authoring systems provide enabling interaction, manipulation, animation, audio dictation, and annotation capabilities with the potential to transform the referring clinician's ability to understand the radiologist's interpretation. In addition, multimedia objects synchronized with textual descriptions or audio dictation can further add to report clarity. In summary, the inclusion of multimedia components can greatly improve the prospect of delivering reports containing correct, clear, concise, and

content-rich information [51] as well as eliminate frustration levels experienced by referring clinicians.

Another major improvement in radiology reporting is the integration of visualization software and report authoring software to allow radiologists to simply and quickly transfer essential elements of the detailed visual analysis created within the visualization package to the report. Advanced user interaction capabilities are required to achieve this seamless transfer of key information.

Since speech recognition software found in modern radiology applications is known to reduce report production time by fifty percent [47], it is important to maintain this feature or alternatively to provide the ability to include audio recordings directly into the report. Referring clinicians also benefit from voice recordings to quickly interpret the radiologist's findings instead of reading an abundance of information presented as simple text. In the past, referring clinicians who were obligated to read handwritten reports frequently had trouble due to poor cursive writing [10]. Even when radiologists create reports using programs such as Microsoft Word, detailed textual descriptions can sometimes be difficult to understand [55, 58]. This is especially true when details of the diagnosis are described in words without referencing any visual data objects such as an image. Hence, voice recordings and/or speech recognized text that refer to visual components in the report are easy for the radiologist to create as well as further eliminate interpretation issues commonly faced by clinicians.

Another area that requires improvement is the process of distributing the radiology report. This process of distribution can be integrated with a web-based collaborative software application [17] to allow radiologists and referring clinicians to remotely communicate anytime, anywhere. The implication of this feature is the decrease in time and money spent in attending

face-to-face meetings [33], making it much more convenient and efficient to simply distribute invitations to attendees [4] for the participation of an online meeting. Some radiology report applications use a client-server system to enable authenticated users to access documents that are available in the server. Another way of distributing reports is by utilizing a radiology web application [16, 27] to employ collaborative tools. With MaRRS, radiologists may initiate online meeting sessions using Adobe Acrobat Connect Pro. This collaboration software is conveniently integrated within Adobe Acrobat [5] and supports live meetings between radiologists and referring clinicians and allows them to cooperatively work together to analyze a patient's diagnosis in real-time. Altogether, MaRRS incorporates most of the above features to prove that a complete radiology reporting system can be constructed using powerful multimedia software that is connected to existing visualization software. In the following section, today's prevalent medical image visualization applications are considered briefly describing their capabilities.

## **2.6 Medical Image Visualization Applications**

Noninvasively visualizing human organs in their true shape and size [26] has intrigued society for over a century. Among the first non-invasive techniques used as part of a patient's physical examination were electrocardiography (ECG) and x-rays [21]. In the 1970's and 1980's, new medical imaging systems such as CT and MRI scanners were developed and radiology departments began to move towards digital images. Today 3D medical imaging techniques are increasingly used in Radiology to observe the shapes and contours of human organs [20, 21, 25, 26, 63]. Medical imaging systems such as CT, MRI and PET scanners have evolved to the point where it is possible to see certain anatomical structures with very fine detail. High-resolution CT systems, for example, now allow organs to be visualized at resolutions

approaching the sub millimetre level. Furthermore, fusion of data from different imaging modalities can not only yield images of the structural aspects of such organs but also the functional aspects. Through the power of volumetric analysis, radiologists can visually examine different views of internal organs rather than employing non-invasive methods based on physical parameters to assess body function in health and disease. Over the last 20 years, researchers have developed powerful new visualization and analysis algorithms which utilize 3D images, allowing radiologists to achieve greater accuracy levels in patient diagnosis.

### **2.6.1 Selecting a Visualization Tool**

Today, many sophisticated visualization packages are available that provide 3D finely-detailed views of human anatomical structures. Furthermore, these packages provide powerful visual interfaces and analysis tools that allow users to interactively analyze and manipulate 3D image data as well as control view transparency, color, and lighting [63]. They also allow users to extract meaningful information from the medical volume images and create annotated 3D models of anatomical structures [25, 63]. This visualization software has greatly influenced the way radiologists analyze data and diagnose patients to achieve greater accuracy [66].

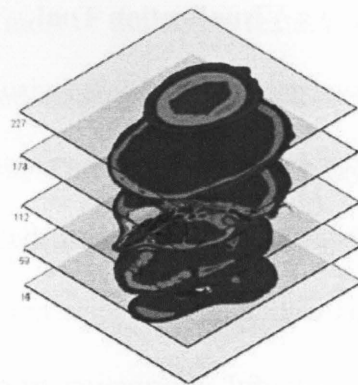
In selecting an image visualization package, radiologists must consider a number of factors. These include hardware requirements, data types, supported file formats, visualization tools, viewing techniques, and image analysis capabilities [63]. Depending on the imaging system, the data may be presented in a variety of file formats. Thus, it is important for the visualization package to interpret various formats to accommodate a variety of medical equipment within a clinical or hospital facility. In the following sections, a review of recent image visualization packages will be presented, along with a brief description of their

capabilities. However, before proceeding it is necessary to define two significant terms, volume rendering and 3D image dataset, respectively.

A *volume rendering* is a prevalent 3D visualization technique used to display human structures in high definition. This technique generates a specific 3D view of a sampled dataset on the 2D computer screen. To render this visualization, a virtual camera, positioned in space relative to the volume, is required. In addition, each sample value of the dataset must be mapped to a defined opacity and color. Figure 4 illustrates a 3D volume rendering of a CT Angiogram used to identify a mass lesion.



**Figure 4: Volume Rendering**



**Figure 5: 3D Image Dataset**

A *3D image dataset* is a collection of 2D image slices (Figure 5) obtained by a 3D medical imaging scanner. Typically, each slice is acquired in a regular pattern such as one slice every millimetre. A 3D image can also be referred to as a stack of slices (Figure 5) stored in one of several file formats that are interpreted by most current image visualization packages.

#### **2.6.1.1 Amira**

The Mercury Computer Systems Visualization Sciences Group is the provider of an advanced 3D visualization application for physicians, engineers, and scientists called Amira [57]. Amira is a highly interactive system that provides a visual interface allowing users to connect

image visualization and processing modules to form a graph (Figure 6). In this way, users generate 2D, 3D, or mixed views of anatomy that can be manipulated in real-time. Amira provides a set of powerful measurement and segmentation tools allowing users to extract and create 3D models from the medical volume images. Amira is a commercial product with several add-ons and extensions and is supported on any operating system. It also supports various sources of 3D medical images including CT or MRI scanners and ultrasound devices. Mercury provides an SDK to allow developers to extend Amira by writing custom modules in C++.

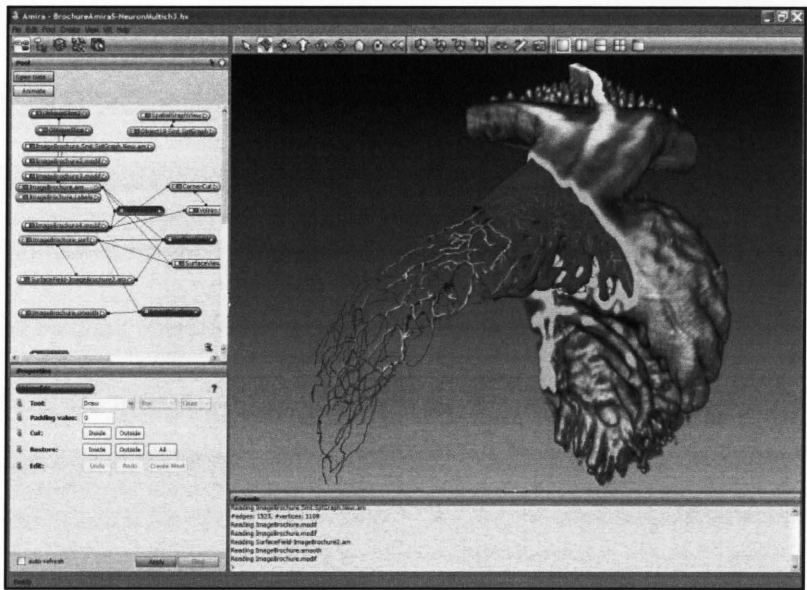


Figure 6: An illustration of the Amira interface

### 2.6.1.2 Analyze

The Mayo Foundation is another biomedical imaging group who have developed a well-known biomedical imaging software suite called Analyze [37]. Analyze is a powerful, comprehensive software package for multi-dimensional display, processing, segmentation, registration and measurement of multi-modality biomedical images. Analyze supports a large variety of imaging modalities including CT, MRI, SPECT, PET, ultrasound, and digital

microscopy. Analyze provides functionality for Volume Rendering, Virtual Endoscopy, Segmentation, Image Fusion, Surface Rendering, Region of Interest (ROI) measurement and many other imaging functions. The Analyze Developers Add-On gives software developers full access to a library of over 600 imaging functions to create customized add-on modules to Analyze.

### 2.6.1.3 3D Doctor

Another widely used package is Able Software's 3D-Doctor [1]. It is a powerful interactive system offering 3D medical volumetric functionality for CT, MRI, PET scanners and supporting common file formats such as DICOM, TIFF, JPG, PNG, and RAW. It also provides several segmentation tools to point out or extract internal organs represented in the 3D image (Figure 7). Using 3D-Doctor, radiologists can visualize the exterior surface of a 3D anatomical structure or use volume rendering to expose internal organs underneath the exterior layer [25].

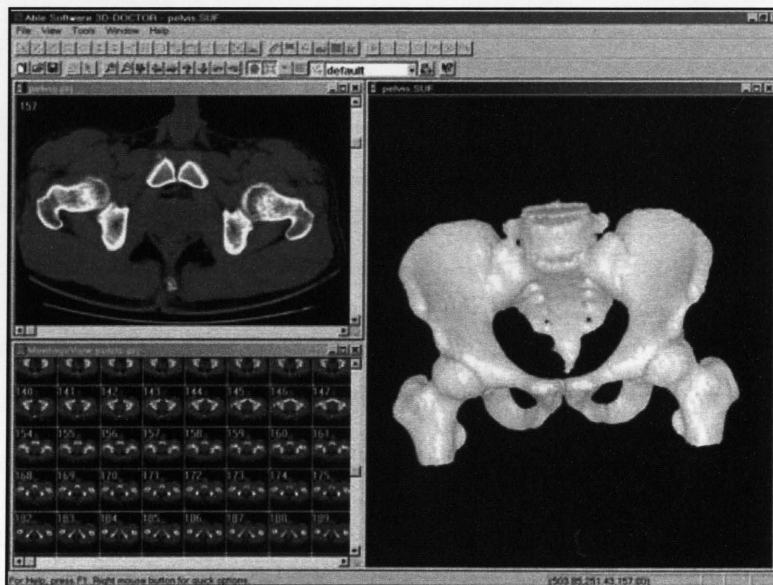


Figure 7: A snapshot of the 3D-Doctor interface

In addition, 3D-Doctor can also be used for surgical planning with the goal of improving the accuracy and performance of the surgery. This ability allows surgeons to not only look inside the body, but also create physical models from the CT or MRI image. By using 3D anatomical models, surgeons may perform what is known as *mock* surgery prior to entering the operating room [64]. Visual Basic scripts can be written for 3D-Doctor that enables users to execute complex tasks in batch mode.

#### **2.6.1.4 3DMed**

3DMed [26], which stands for Medical Image Processing and Analyzing System, is an open source product developed by the Medical Image Processing Group [60]. It provides medical imaging communities a freely available system to process and analyze 3D image datasets from CT and MRI scanners. Like most visualization packages, 3DMed provides advanced 3D visualization functions such as 3D reconstruction, extraction, measurement, and manipulations while supporting most medical file formats such as DICOM, JPG, TIFF, RAW, and Analyze.

#### **2.6.1.5 MeVisLab**

An alternative medical image processing and visualization package used in Radiology is MeVisLab [40], developed by MeVis Medical Solutions and Fraunhofer MEVIS. Like most contemporary visualization packages, MeVisLab offers advanced image processing techniques for segmentation, registration, volumetric, and quantitative analysis [18]. This application provides interactive and visualization tools to analyze 2D and 3D medical images (Figure 8) supporting common file formats including DICOM, TIFF, TIF, Analyze, RAW, JPG, and PNG. Based on MeVisLab, several clinical prototypes to assist in neuroimaging, dynamic image

analysis, surgery planning, and vessel analysis have also been developed. MeVisLab is designed as an open source, extensible development environment for fast integration and testing of new algorithms. It uses the C++ image processing library development platform to create new macro modules as well as JavaScript components to implement dynamic functionality on both the network and user interface level. It also offers full Open Inventor, ITK, and VTK support for leading 2D/3D algorithms and image processing techniques, making it possible to integrate these packages while designing new modules. MeVisLab also runs on most operating systems such as Windows, Macintosh, and Linux and can be integrated with a PACS. The MaRRS prototype software uses MeVisLab.



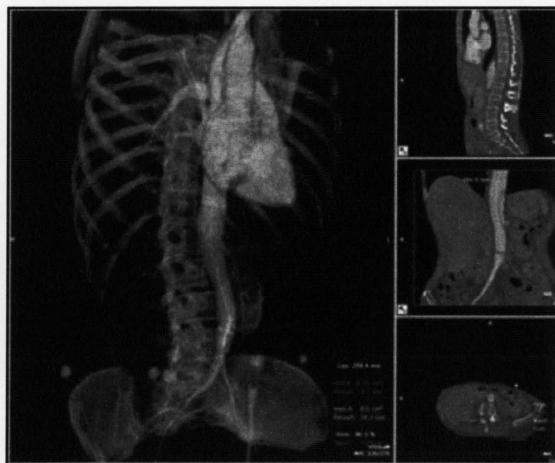
Figure 8: A snapshot of a MeVisLab window.

#### 2.6.1.6 MIPAV

The Center for Information Technology (CIT), National Institute of Health has developed a biomedical imaging tool called the Medical Image Processing, Analysis, and Visualization (MIPAV) application [19]. This software system provides quantitative analysis and visualization



structures of a given dataset (Figure 10). This package can be used in clinical diagnosis, surgical planning, and medical research [7]. It is currently installed in more than 150 facilities ranging from small clinics and hospitals to medical schools and research facilities. It also provides options for specialized needs such as cardiac, colon, and neurovascular disease. Hence, visualization tools and operations specific to an illness can be employed to effectively examine and pinpoint an area of interest (AOI). For instance, by selecting the Neuro option, special algorithms are administered for automatic artery and vein selection and motion correction [62]. Vitrea also uses clinical web-based workflow management settings through the integration of a web-client solution, ViTALConnect, intended to improve speed. It has also seamlessly integrated PACS to expand the access of information throughout an enterprise as well as to further improve workflow management. Thus, this company offers software solutions for both advanced image visualization and collaboration between radiologists and clinicians.

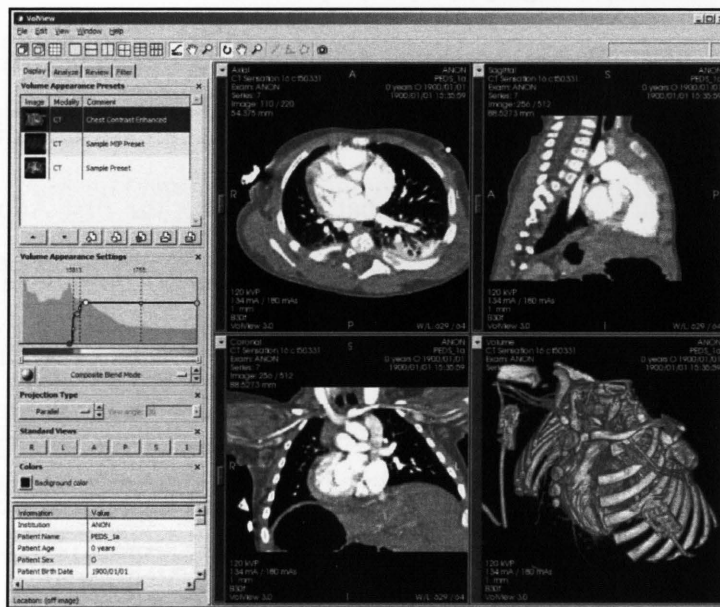


**Figure 10: Analyzing a 3D medical dataset using Vitrea**

#### **2.6.1.8 VolView**

VolView [30], from KitWare Inc., is an intuitive and interactive system for volume visualization enabling users to explore complex 3D medical or scientific data [18, 49] on

Windows, Macintosh, and Linux operating systems. It offers quick and easy import methods to analyze data using 3D tools such as volume rendering, intensity projections, and oblique-angle image slice reformatting [49]. Like most of the visualization packages, VolView supports standard medical file formats such as DICOM, TIFF, VTK, Analyze, RAW, PNG, and JPG. In addition, multiple datasets can be examined side-by-side to compare various components in high-quality rendering mode (Figure 11). Another useful feature of VolView is its ability to save visualization sessions making it convenient to continue previous examinations that have not been completed.



**Figure 11: An illustration of the VolView interface.**

## 2.7 Multimedia Radiology Reports using Adobe Acrobat 3D

Today, all image visualization packages provide functionality to generate high-resolution 3D renderings, models and animations of anatomical structures. In addition, many off-the-shelf multimedia authoring systems are able to import visual information in the form of images and videos. It therefore makes sense to take advantage of these powerful features and generate

multimedia radiology reports that more clearly convey the radiologist's diagnostic interpretation [13]. Acrobat 3D [5], from Adobe Systems Inc., is one such multimedia technology. Adobe Acrobat 3D can be used to create a PDF radiology report containing text, 3D models, volume renderings, image slices video, audio and so on. Adobe Acrobat incorporates flash-based media handling, allowing the inclusion of videos in various formats which can be played in Adobe Reader. In the following paragraphs, the functionality and benefits of using Acrobat 3D to generate a report is elucidated.

Over the years, PDF, a highly flexible, open standard for information exchange, has become extremely popular. Today, nearly all computer users employ PDF files in their daily work. In fact, it is widely used throughout nearly all companies since it eliminates the need to manage different document file formats. Acrobat Reader was the first Adobe Systems product introduced to enable users to view a PDF file. Some years later, Adobe developed a new product line called the Adobe Acrobat Family. This new family of computer programs was developed by Adobe Systems to view, create, manipulate and manage PDF files. Generating radiology reports in PDF format would allow the reports to be read and shared by referring clinicians worldwide using the freely available Adobe Reader software. A related Acrobat program, Connect, provides web conferencing facilities. Remote users can communicate using video, audio, screen sharing, and whiteboard features.

In Radiology, this program feature may be used to host online meetings between radiologists and referring clinicians to achieve fast and accurate decision making and report clarification. Together, Acrobat 3D, Connect, and Reader provide the capability for generating, distributing, interactive viewing and sharing of highly compressed PDF documents.

Furthermore, Acrobat 3D presents a simple interface that can be edited so that only necessary menu items are shown on the top toolbar (Figure 12).



Figure 12: Acrobat toolbar annotation tools

Another feature of Acrobat 3D is that it can be extended by developing plug-ins. The Acrobat 8 SDK [2] provides the necessary tools and header files required to create software and plug-ins and customize Adobe Acrobat and Adobe Reader. The process of implementing custom Acrobat plug-ins is described in section 3.4.

Acrobat 3D is an interactive 3D-based data interoperability system. It provides the capability to embed, view and navigate 3D content directly in PDF files. The Acrobat 3D Toolkit even allows developers to create basic exploded views and animations [2] which can be extended through JavaScript (Appendix B). Although mostly geared towards architects and engineers, this 3D capability can be very useful for medical professionals as it would allow the inclusion of annotated 3D anatomical structure models directly in the radiology report. Other 3D features include the ability to create cross sections of a 3D data model, to interactively rotate or zoom into a specific area, to perform a 3D measurement such as a point-to-point distance to calculate the size of a brain tumour, and annotate the area accordingly.

PDF document files provide cross-platform support to cater to all user needs. In medicine, radiologists and referring clinicians can view and interact with PDF radiology reports on any operating system such as Macintosh, MS Windows, UNIX, LINUX, and several mobile systems. This wide support represents a significant advantage over other file formats.

Adobe Acrobat provides a rich set of annotation features that may be used to label, highlight, or draw anywhere within the document. The key feature of adding rich annotations (Figure 12) is that it helps link text details in the report with corresponding regions of interest [51] in specific images, 3D models, and volume renderings. Radiologists can use the various annotation tools to help direct attention to areas of concern in a more consistent and reproducible fashion and provide referring clinicians with comprehensive reports. Text may be directly typed into the report to record diagnostic results observed by radiologists. However, to provide more rapid report production, another option is to directly embed voice dictations in the report. These voice recordings can be used as verbal annotations by positioning a voice recording icon next to the image or 3D model to which it refers. Annotation features in MaRRS are described in detail in section 4.1.

Once a radiologist has finished constructing the report, they may then save it as a PDF to maintain high quality and at the same time, compress the file size exponentially. The PDF optimizer within Adobe Acrobat provides this ability. For example, a radiology report generated by MaRRS containing textual descriptions, 20 image slices, a 3D data model, and a volume rendering video approximately 1 minute in length and encoded using the Cinepak video codec, is 1.83 Megabytes (MB) in size before compression. With the PDF optimizer, the report can be compressed to 1.49 MB. In fact, the PDF document can be further condensed by selecting other compression schemes and quality levels for embedded imagery.

Acrobat 3D also provides advanced security features and document control. These features help protect confidential information as well as control the information held within the PDF file while it is being shared outside a firewall. Acrobat 3D also provides password protection to restrict access to documents and assign permissions to help control authorized users

who can view or modify documents. In addition, electronic signatures [32, 52] may be placed within the document to indicate that it has been reviewed by a particular individual. Hence, the use of PDF-based radiology reports makes it easy to collaborate with confidence.

In a nutshell, Acrobat 3D has the potential to create highly compressed radiology reports containing a range of annotated visual multimedia components in the widely accepted PDF standard. The secure report can be interactively viewed with a standard Acrobat Reader program or interactively and remotely shared with Acrobat Connect Pro.

## Chapter III – Methodology and Implementation

MaRRS is a software prototype that runs on a Windows-based operating system. However, Adobe Reader is supported on Windows, Macintosh, and UNIX operating systems. This means that when a radiology report is generated by MaRRS, the radiologist may immediately send the PDF document to the referring clinician, which can be reviewed on any operating system. This increases the convenience of document delivery.

As previously mentioned, MaRRS enables radiologists to generate well-structured reports containing 2D and 3D images, 3D data models, textual descriptions, and/or audio descriptions. MaRRS also allows radiologists to record a short video of a volume rendering and instantly send it to the PDF report. Adobe Acrobat also enables insertions of 3D anatomical models which can then be rotated in 3D space, relit, and re-rendered using the standard Adobe Reader program. The advantage of 3D anatomical structures [51, 59] is that it may be helpful in visualizing anatomical structure/function and/or patient pathology.

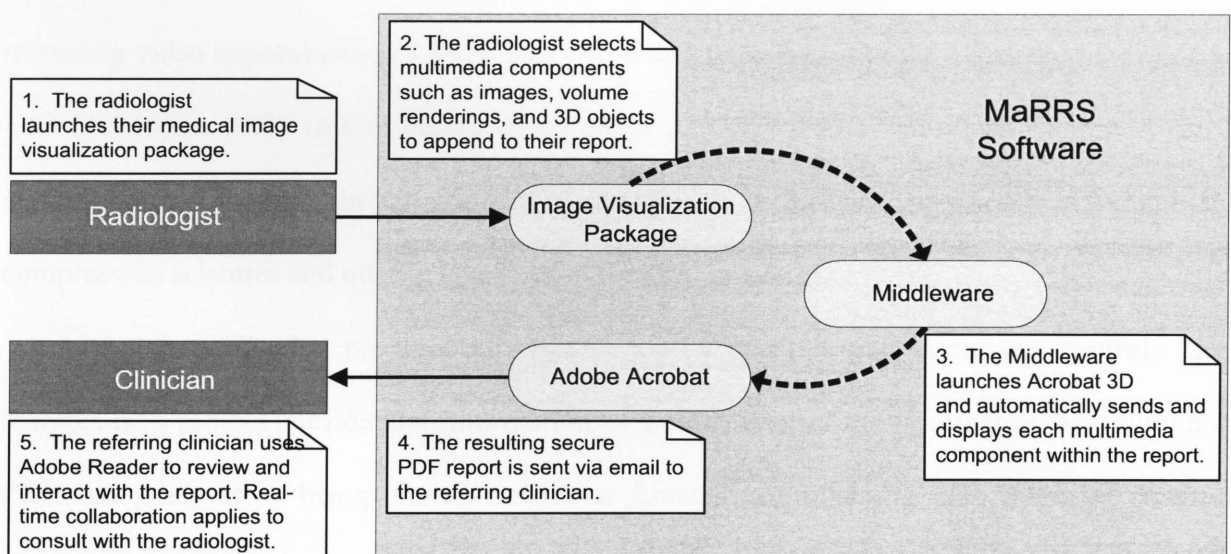


Figure 13: MaRRS Flow Diagram

The main software module of MaRRS may be perceived as a *middleware* component, bridging the software gap between a medical image visualization package and Adobe Acrobat (Figure 13). The MaRRS middleware utilizes custom plug-ins to start-up and remotely control Adobe Acrobat. MaRRS also provides a well-defined interface to the image visualization package allowing it to employ the functionality of MaRRS. The image visualization package must be extended with custom user interface software that executes the MaRRS middleware functions.

### 3.1 Development Platform

MaRRS was developed under the Microsoft Visual Studio 2005 environment, specifically using the programming language C/C++. This platform was used to develop new custom plug-ins [3] for Adobe Acrobat as well as the MaRRS middleware component software [6]. The reason for choosing Microsoft Visual Studio 2005 was based on Acrobat's SDK plug-in development recommendation when using the Windows platform.

The Acrobat SDK 8.0 was used to develop MaRRS Acrobat plug-ins. It contains header files, type libraries, and documentation [3] to integrate new software in three ways. Firstly, scripts may be written to extend the functionality of Acrobat either internally on an open PDF document or externally, in JavaScript (see Appendix B). Secondly, C/C++ plug-ins may be created (see Section 3.4) to dynamically link and extend Acrobat's abilities. Lastly, other external applications can be used to control Acrobat's functionality, such as to execute specific

menu items, using inter-application communication (IAC) through OLE<sup>3</sup> [6]. MaRRS utilizes all three methods to extend the functionality of Acrobat.

### 3.2 Extending the Functionality of MeVisLab

Currently MaRRS has been successfully integrated with the MeVisLab image visualization package. The primary reasons for selecting MeVisLab for the MaRRS software prototype were i) it is free, ii) it is extendable, iii) it contains a wide variety of image processing modules, and iv) it is able to interpret several medical image file formats. In addition, MeVisLab provides a user manual, online tutorial, and an online discussion forum to help novice users get started in operating its flexible interface and/or develop new modules using MeVisLab's SDK.

The main idea behind MaRRS was to provide radiologists with a fast, simple, and intuitive way of producing multimedia radiology reports while they were examining and analyzing medical datasets with a visualization application. To achieve this, each visualization package integrated with MaRRS will require some changes, primarily to its user interface software. The modifications made to MeVisLab include the addition of a generic, easy to understand, "Send to PDF" button located on several MeVisLab modules, as well as the addition of brief scripting commands that send multimedia transfer requests to the MaRRS middleware. Specifically, the "Send to PDF" button initiates a save action to store the specified multimedia component (for example, an image slice) on the disk, activates a *write* command which creates a message file indicating the type and location of the component, and then sends a *run* command to internally activate the middleware (Figure 14). The file containing the *message* is then interpreted by the middleware to determine which custom Acrobat plug-in to execute. The plug-

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<sup>3</sup> **Object Linking and Embedding (OLE)** is a technology that allows embedding and linking to documents and other objects developed by Microsoft. It is also used for transferring data between different applications.

in loads the multimedia component, creates a new PDF document with predefined properties, embeds the component in a predefined location and the document is displayed in a new Acrobat window.

The gray area shown on Figure 14 is called the *hidden layer* of this process since the user simply observes two applications, MeVisLab and Adobe Acrobat, respectively. It typically takes only seconds for the component to appear in the Acrobat window, providing the radiologist with immediate visual feedback. In the hidden layer, MaRRS sets up all the necessary components required to insert the desired multimedia component into the report, from verifying the object being sent, to populating the layout and displaying the results in Adobe Acrobat. Altogether, the write command written in MeVisLab scripts is used to send messages to the middleware, whereas the read command is used to interpret the request to remotely execute a custom plug-in and launch Adobe Acrobat to render a new PDF radiology report.

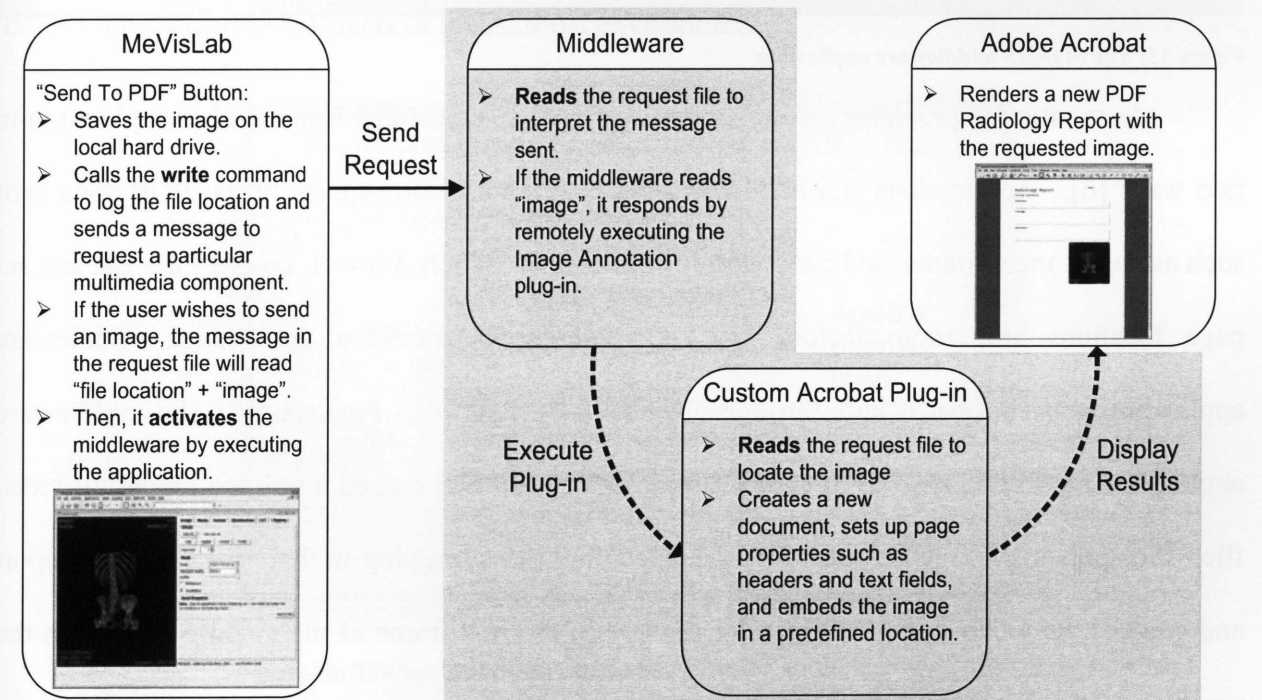


Figure 14: Detailed flow diagram describing the process of creating a radiology report.

### 3.3 MaRRS Middleware

The MaRRS middleware application was designed such that any extendible image visualization package can utilize it with minimal software adjustments. The middleware component (Figure 15) is a concealed and standalone application designed to take advantage of the ability to remotely control Acrobat.

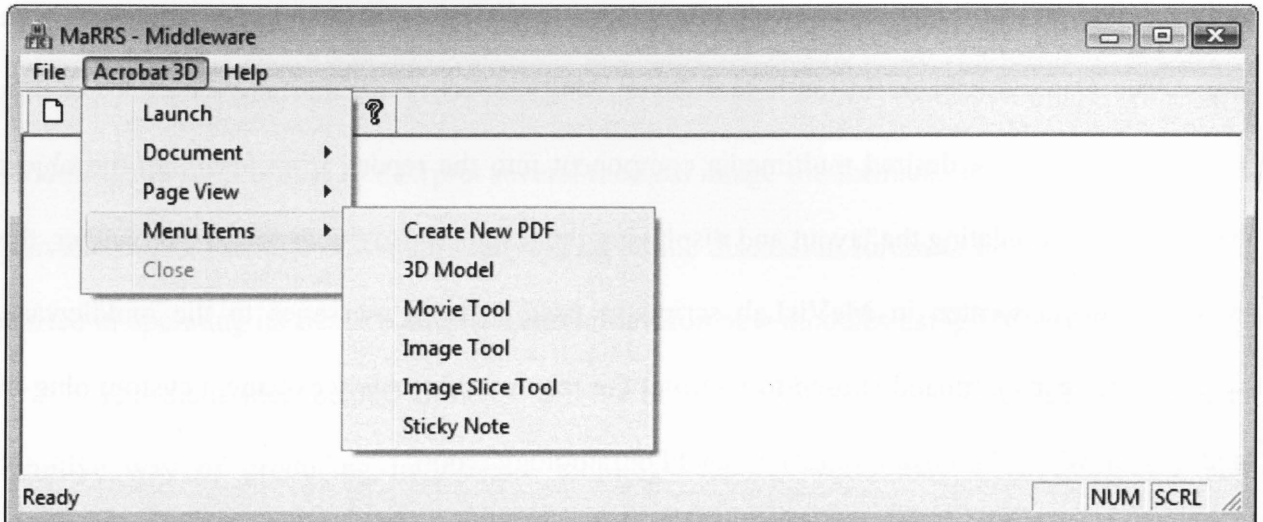


Figure 15: The MaRRS middleware application

As mentioned previously, Acrobat can be remotely controlled from another application in two ways [6]. Applications can either be written to manipulate aspects of the PDF document such as pages, menu items, and annotations, or to simply launch Acrobat, open a PDF file and set page locations and zoom factors [6]. Communication between the hidden middleware application and Acrobat occurs through objects and events [6]. For example, the middleware application receives a *request* to create a radiology report and embed a volume rendering video file. It responds by launching Acrobat and executing a custom plug-in that creates a PDF report and embeds the video in a predefined location, with the first frame of the video displayed in the report.

A function called *validateUserRequest()* is used to handle each of the four multimedia requests (image slices, 3D model, single image, video) messages. This function reads a request file and compares the file contents with four predefined strings (*'slice'*, *'3D'*, *'image'*, and *'movie'*). After validating the request, it executes another function which i) launches Acrobat, and ii) executes the Acrobat plug-in associated with the request type. Unrecognized requests are ignored.

### 3.4 MaRRS Acrobat Plug-ins

An Adobe Acrobat plug-in is a program which dynamically links extensions to Acrobat's functionality. Each plug-in must be implemented using Acrobat's API [3] to create applications that will further enhance or manipulate PDF document content or simply customize Acrobat to meet any needs. The Acrobat API is divided into a number of layers (Figure 16), where each layer controls different aspects of the Acrobat environment.

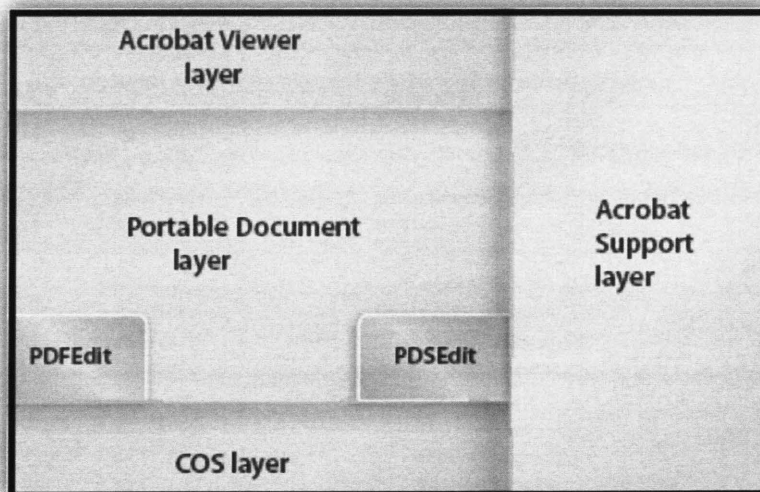
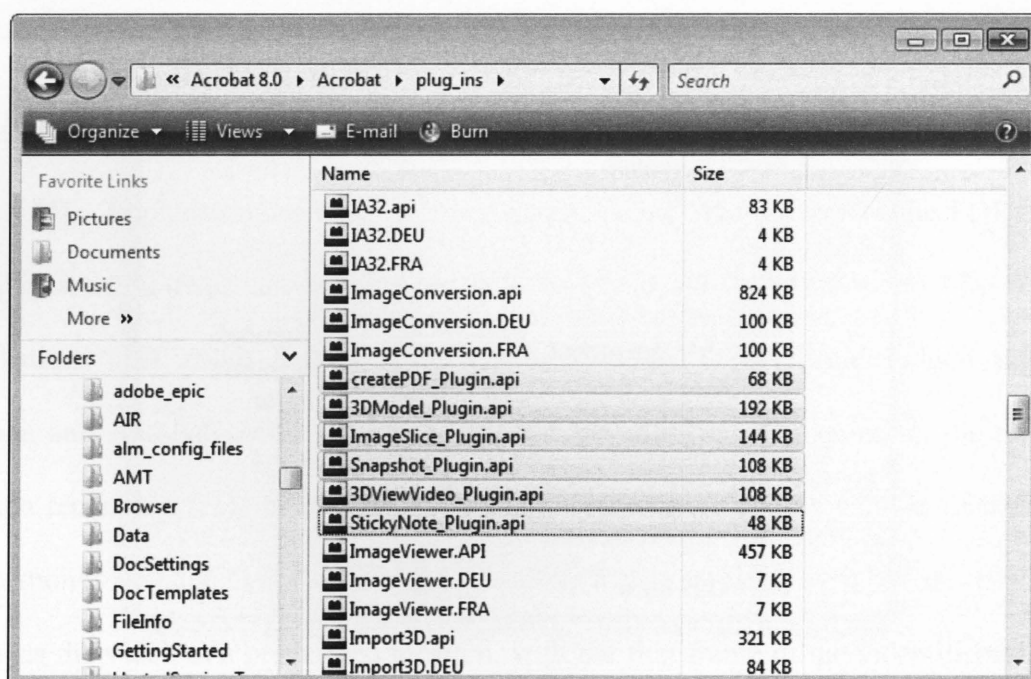


Figure 16: The layers of the Acrobat API.

Developing custom plug-ins using the Acrobat SDK involves the creation of a project containing header files, SDK source files, and, of course, the project source files [3, 5]. Once

completed, a project is compiled and a resulting output file with an “.api” extension is created. This output file is known as a dynamically linked library (DLL) file, which must then be copied into Acrobat’s *plug-ins* folder. When Acrobat is restarted, it automatically recognizes newly developed plug-ins located within this folder. In the following sections, new Acrobat plug-ins developed in this thesis will be described in detail.

Four custom plug-in programs have been developed using Acrobat’s API and SDK. These plug-ins were designed to read multimedia component files from the local disk and embed the files into the PDF report. In addition, two other plug-ins have been implemented to provide a standard report template or layout, as well as to broaden the idea of adding comments to a radiology report using *sticky notes*. The complete list of plug-in programs shown in Figure 17 will be described in the following subsections.



Name	Size
IA32.api	83 KB
IA32.DEU	4 KB
IA32.FRA	4 KB
ImageConversion.api	824 KB
ImageConversion.DEU	100 KB
ImageConversion.FRA	100 KB
createPDF_Plugin.api	68 KB
3DModel_Plugin.api	192 KB
ImageSlice_Plugin.api	144 KB
Snapshot_Plugin.api	108 KB
3DViewVideo_Plugin.api	108 KB
StickyNote_Plugin.api	48 KB
ImageViewer.API	457 KB
ImageViewer.DEU	7 KB
ImageViewer.FRA	7 KB
Import3D.api	321 KB
Import3D.DEU	84 KB

Figure 17: List of MaRRS Acrobat plug-ins added to the *plug\_ins* directory

### 3.4.1 Create Radiology Report Template

The first plug-in is called *createPDF\_Plugin.api* (Figure 17) and its task is to create a standard radiology report style and template. It creates a blank PDF document with a set of predefined medical headings, such as *Clinical Indication*, *Technique*, *Findings*, and *Impressions* (Figure 18). It also executes a JavaScript program (see Appendix B) to construct editable text fields (Figure 18) under each heading. The radiologist uses the text fields to describe the radiological examination results. This plug-in is executed when a new report is created.

Interactive Radiology Report - Adobe Acrobat 3D

File Edit View Document Comments Forms Tools Advanced Window Help

Radiology Report

Date:

Clinical Indication:

Technique:

Findings:

Impression:

Figure 18: A new PDF radiology report with predefined headings and text fields

### 3.4.2 3D Model Plug-in

The plug-in called *3DModel\_Plugin.api* (Figure 17) was designed to read a file containing a 3D anatomical structure model (previously saved on the local disk when the radiologist click the “Send to PDF” button (Figure 19)) and embed it into the report (Figure 20). Technically speaking, this plug-in uses the *Cos layer* (Figure 16) of the Acrobat API to enable PDF objects to work with 3D geometric mesh models.

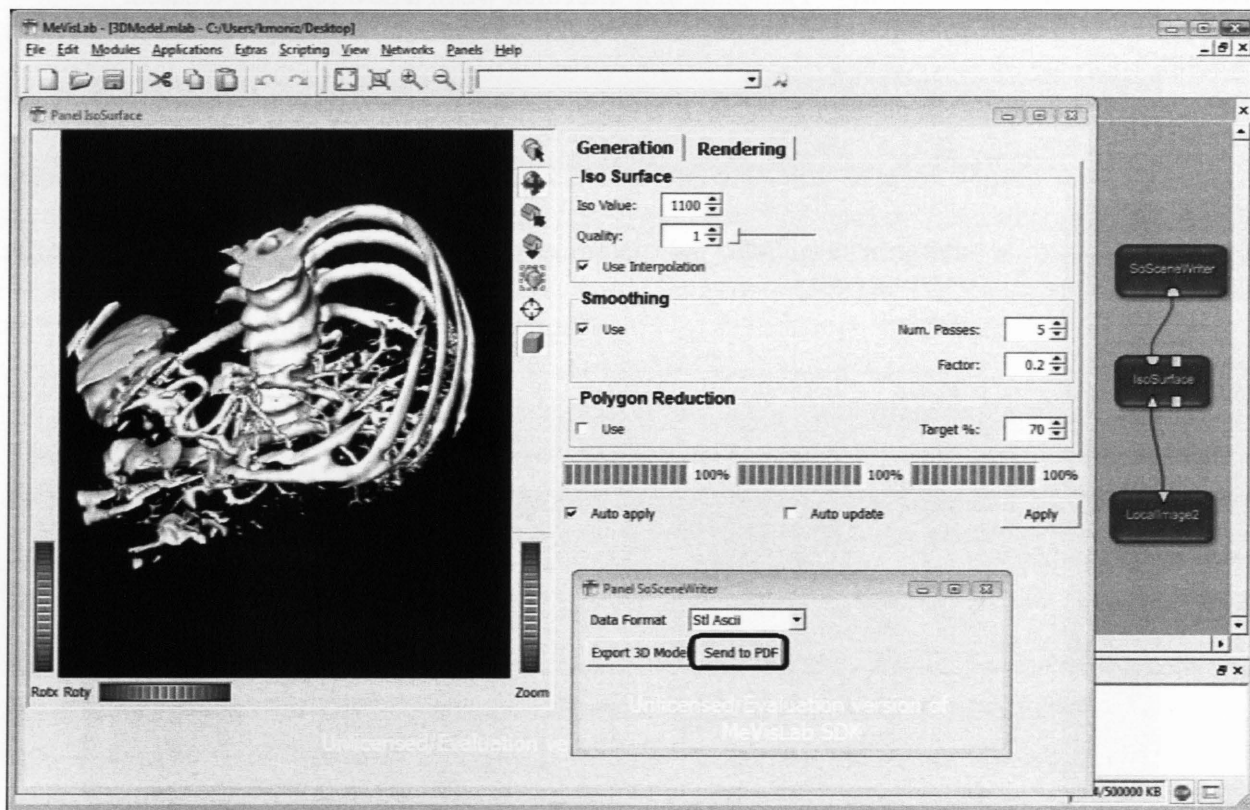


Figure 19: Example of sending a 3D model to the radiology report from MeVisLab

Currently Acrobat 3D accepts 3D data models only in the U3D file format. MeVisLab does not support U3D so the data model is output in STL format and then seamlessly converted into a U3D file before the plug-in is executed. The process of converting an STL object file to U3D is performed using an open source 3D file conversion application called *MeshLab*.

Meshlab is a concealed application (hidden from the user) that was modified so that it accepts an STL object file as input and automatically converts it to U3D.

The 3D model is embedded in two stages. First the plug-in creates a *poster* image of the 3D model with the message “Click to activate 3D” located on the top left corner (Figure 20). By clicking anywhere within the rectangular region of the poster image, the 3D model file is loaded and the user can interact with the 3D model using various Acrobat controls (Figure 21).

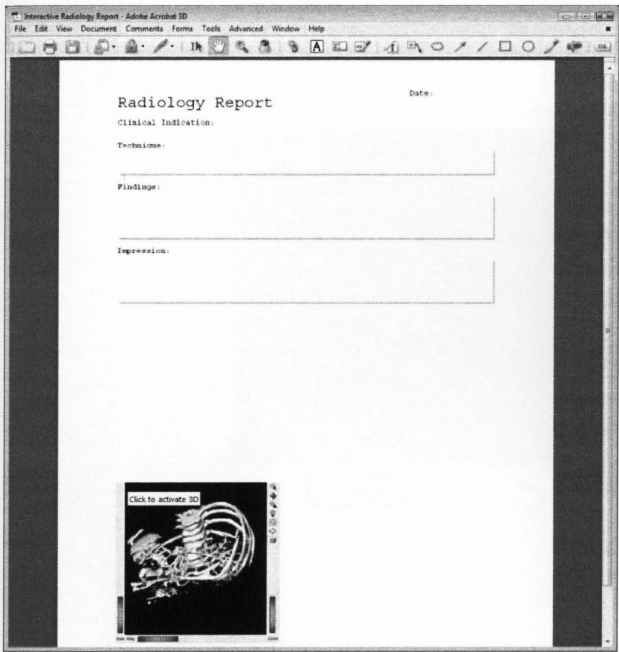


Figure 20: A radiology report containing a 3D model

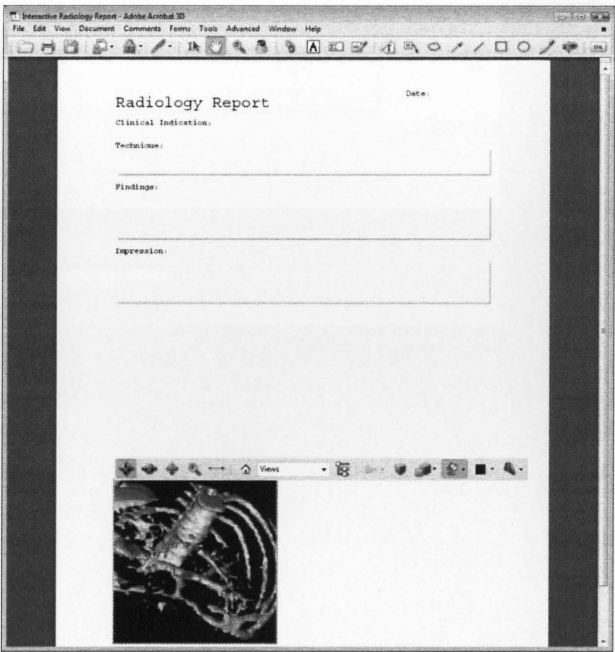


Figure 21: The 3D model along with its interactive toolbar

### 3.4.3 Image Slice Plug-in

The plug-in called *ImageSlice\_Plugin.api* (Figure 17) was designed to embed a range of image slices from, for example, a CT or MR volume image. On the MeVisLab (Figure 22) window, the radiologist indicates the desired range of slices and this range information, along with the image slice files, are saved on the local disk. The image slice plug-in is executed by the middleware and it loads and embeds the image slices into the report. The middleware also executes a JavaScript program (see Appendix B) that sets up two buttons next to the image slice display (Figure 23). These buttons are used to navigate forward and backward through the range of image slices.

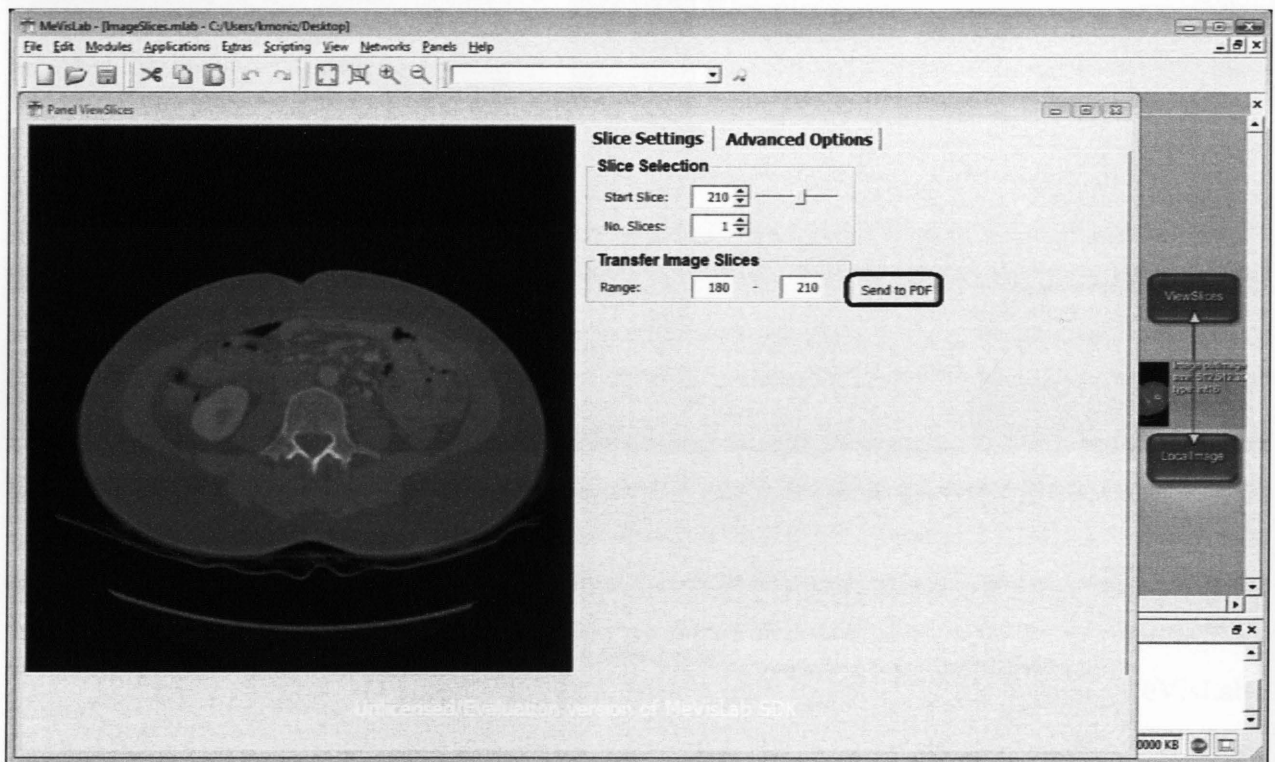


Figure 22: Example demonstrating the image slices transfer in MeVisLab

In addition, a label located below the bottom left corner of the image slice display is created to indicate the slice number currently being viewed (Figure 23). This label gets updated each time a new image is displayed with the navigation buttons.



### 3.4.4 Snapshot Plug-in

The plug-in called *Snapshot\_Plugin.api* (Figure 17) was created to embed a MeVisLab screen snapshot (i.e. a single 2D image) of a 3D data view or of a 2D data view into the radiology report. In this particular scenario, the radiologist may interact with a 3D dataset of a CT/MRI scan (Figure 24) and find a view that reveals a region of anatomy pertinent to the medical condition of the patient. The radiologist then simply clicks the “Send to PDF” button and a snapshot image is instantly taken and saved on the local disk. Upon execution by the middleware, the snapshot plug-in reads the image file from a known location on the disk and embeds it into the report (Figure 25).

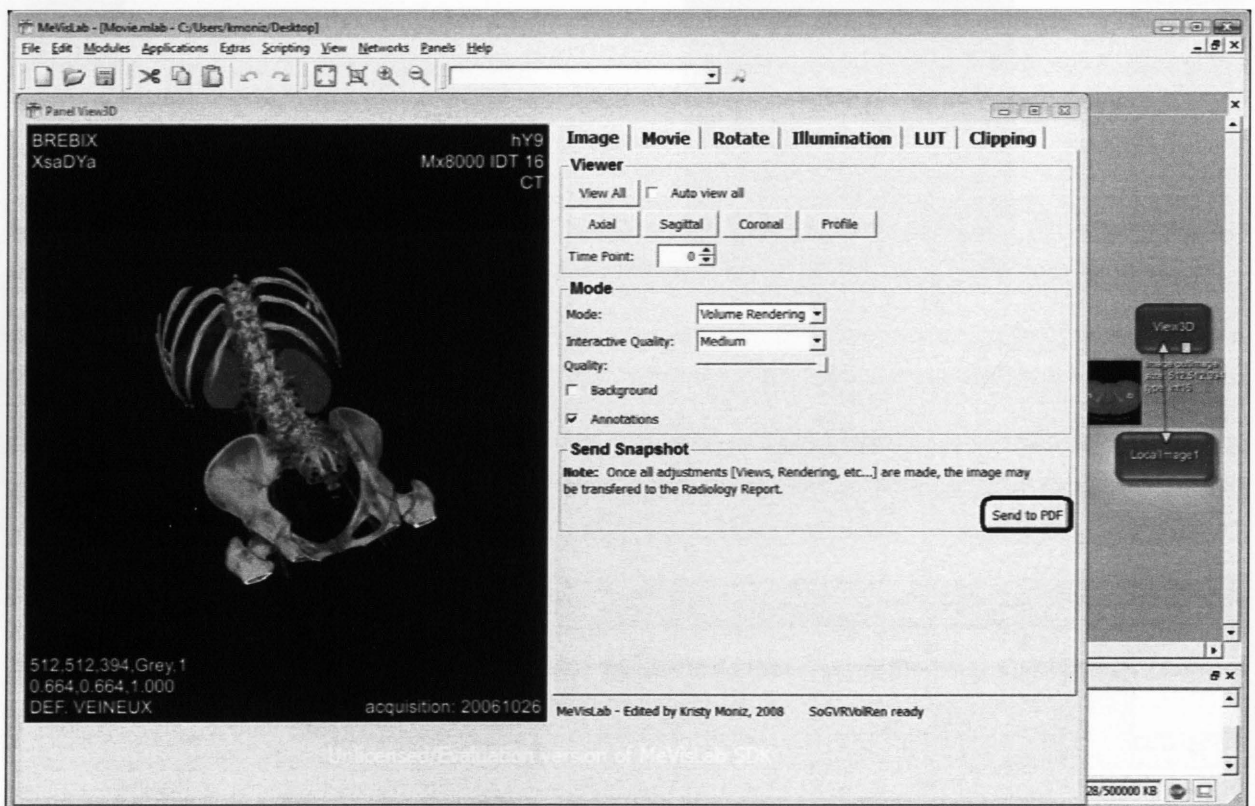


Figure 24: Example of sending a snapshot image of a 3D data view from MeVisLab to the report.

Interactive Radiology Report - Adobe Acrobat 3D

File Edit View Document Comments Forms Tools Advanced Window Help

Radiology Report


Date:

Clinical Indication:

Technique:

Findings:

Impression:



312.512.394.Grey.1  
0.88A.0.88A.1.000  
DEF. VEINEUX

acquisition: 20061028

Figure 25: A radiology report containing a snapshot of a 3D data view.

### 3.4.5 Video Plug-in

The development of a video plug-in called *3DViewVideo\_Plugin.api* (Figure 17) was designed to embed a video of a volume rendering (i.e. a rotating 3D view of the data) constructed on MeVisLab (Figure 26), into the report. The plug-in loads the previously stored video (in .avi format) and sets up video controls to allow user interaction.

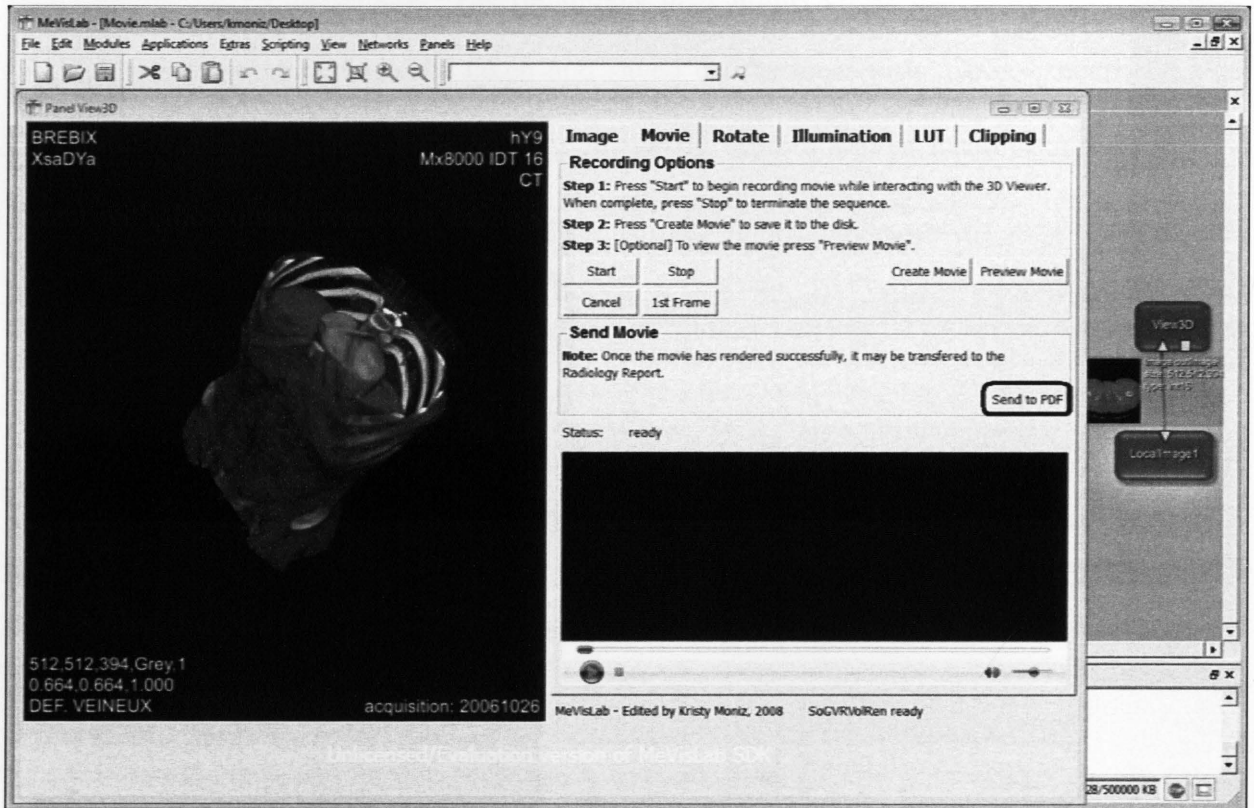
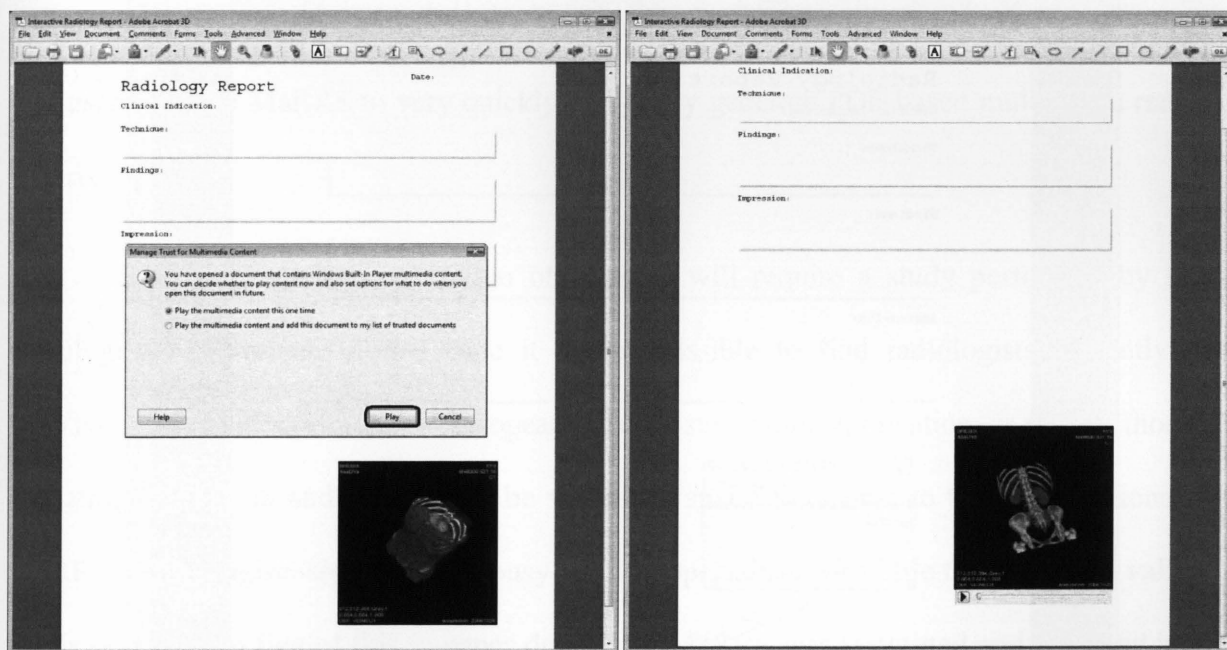


Figure 26: Example illustrating the process of sending a volume rendering in MeVisLab to the report

The first frame of the video is used as a “poster” image and is automatically displayed in the report (Figure 27). By clicking anywhere within the poster image, another window appears to prompt the user to trust the multimedia content that is about to be viewed. By clicking the play button (Figure 27), the volume rendering is instantly loaded and played. Finally, users can interact with the volume rendering using specific video controls shown below the video (Figure 28).

This plug-in provides referring clinicians with a simple, well understood video playback interface to interactively visualize a region of interest in the patient's anatomy which is usually only seen by radiologists. The alternative to embedding a short video was to embed the entire colossal 3D CT/MRI volume image, and provide a plug-in that implemented the highly complex, computationally expensive volume rendering algorithm software, along with the complicated volume rendering control interface. This option was rejected as impractical and unusable. Radiologists and technicians are highly trained specialists who spend considerable time and effort analyzing a 3D patient image scan. Therefore, it is more appropriate to transfer a volume rendering in the form of a video showing the final 3D rotating view of the patient's 3D scan.



**Figure 27: Initiating an embedded volume rendering video    Figure 28: The video and its associated video controls**

### 3.4.6 Text Annotation

The text annotation plug-in called *StickyNote\_Plugin.api* (Figure 17) enables radiologists to add extra comments once the report is generated. The idea is to provide *post-it* notes as a way to add the extra comments and associate these notes with a multimedia component using a notes icon (Figure 29). This plug-in is executed by clicking a button located on the Acrobat toolbar (see circled icon, Figure 29). By clicking on this toolbar button, a sticky note will instantly appear on the page, in which radiologists may enter comments and then reposition it where appropriate (Figure 29).

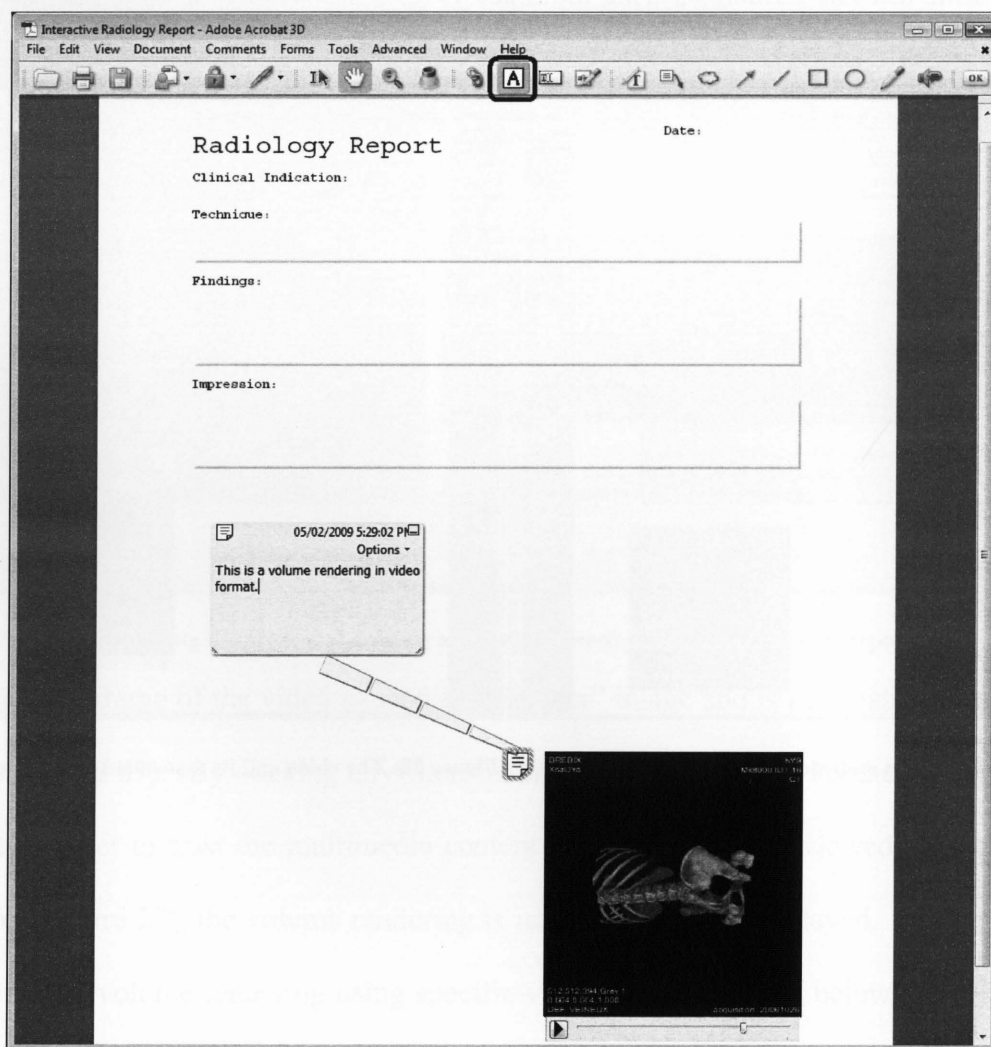


Figure 29: Adding a comment next to the video using the sticky note feature

## Chapter IV – Evaluation

To evaluate MaRRS, a number of report generation scenarios have been successfully carried out using a real dataset. The dataset used in the scenarios is a CT 64 scan<sup>4</sup> illustrating hypernephroma (a common type of kidney cancer). It was obtained from the Internet DICOM Sample Image Repository (<http://pubimage.hcuge.ch:8080/>). All of the experiments were conducted on a PC with an Intel Core 2 Duo CPU clock speed of 3.16 GHz and 4 GB of memory. These scenarios will serve to demonstrate the potential of MaRRS as an alternative, inexpensive radiology reporting mechanism with advanced multimedia capabilities that are not found on existing commercial systems. The results of these experiments will further demonstrate that users can use MaRRS to very quickly and easily generate PDF-based multimedia radiology reports.

Ultimately, rigorous validation of MaRRS will require a study performed by several radiologists. However, at this time it is not possible to find radiologists currently using MeVisLab, since it is primarily a European-based visualization application, as well as those who are using MeVisLab and who would be willing to spend their time to test the functionality of MaRRS. Radiologists are extremely busy medical specialists with little time to spend validating thesis projects. In lieu of this, a paper describing MaRRS was submitted and accepted into the peer-reviewed international symposium on Bio- and Medical Informatics and Cybernetics (BMIC), to be held in Florida in July of 2009. MaRRS will be presented at this conference where it will be demonstrated to medical and scientific specialists.

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<sup>4</sup> A **64 Computed Tomography (CT)** scan refers to the newest generation in CT scan technology. It is also known as "64-slice CT" where 64 "slices" refers to the number of detectors that are present on a CT scanner.



**Figure 30: Transferring image slices 5 – 20 to the radiology report from a volume image in MeVisLab (Scenario I)**

In the first scenario, the CT volume image is loaded in MeVisLab. Using the controls within MeVisLab, the image slices were sequentially scanned and a range of slices were selected (slices 5 through 20). This scenario mimics the case where the radiologist has determined that only a specific set of slices are significant to a patient’s medical condition (Figure 30). The “Send to PDF” button was then clicked and the MaRRS middleware was immediately activated. It successfully created an Acrobat window containing a new PDF report. The image slices immediately appeared in the report along with the forward and backward navigation buttons (Figure 35, middle left).

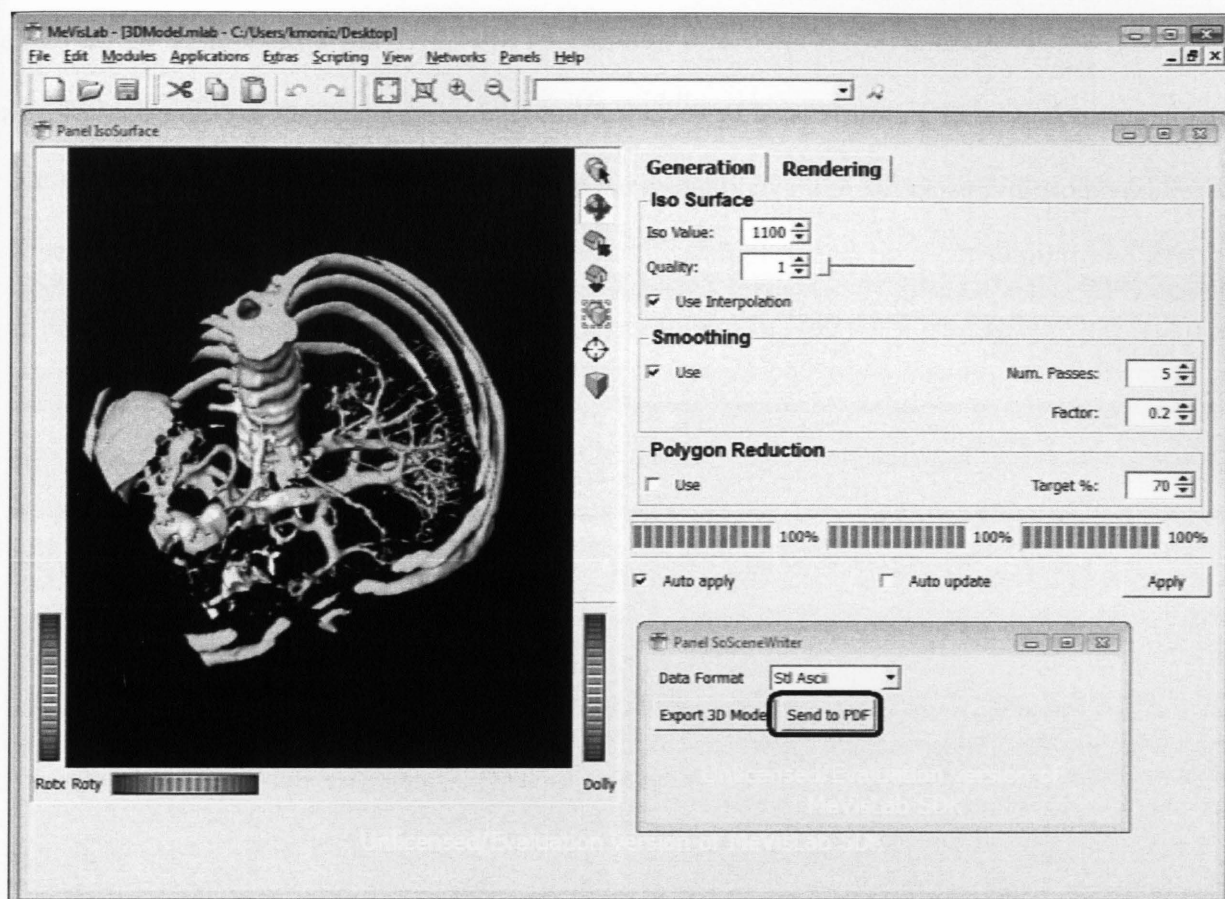
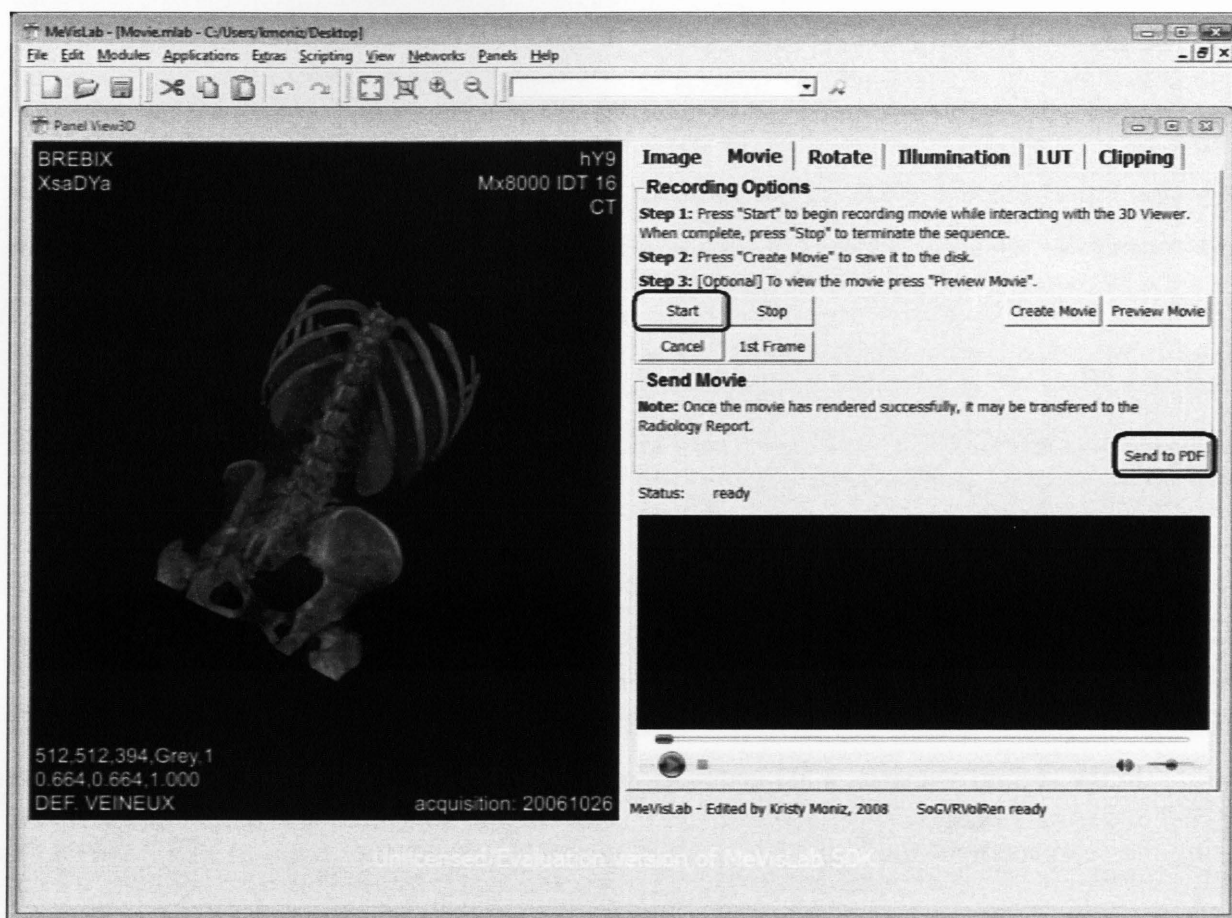


Figure 31: Transferring a 3D model to the radiology report from a volume image in MeVisLab (Scenario II)

In the second scenario, a 3D geometric model was generated from the CT volume image using the segmentation<sup>5</sup> tools of MeVisLab (Figure 31). Again the “Send to PDF” button was clicked and the 3D model immediately appeared at the bottom left corner of the report document (Figure 35). The capability of embedding 3D geometrical models of anatomical structures relevant to the patient’s condition is a considerable advancement over existing commercial reporting systems. A radiologist might spend considerable time and effort processing a 3D dataset to reveal and render the often complex spatial interrelationship between anatomical structures – for example, a tumour situated inside the cerebral cortex. Furthermore, allowing the

<sup>5</sup> **Segmentation** refers to the process of extracting all voxels (3D pixels) belonging to a specific anatomical structure from the 3D image and then using this set of voxels to construct a 3D mesh of triangles representing the boundary surface of the anatomical structure.

3D models to be interactively rotated and zoomed by the referring clinician, or to be made transparent so that inner structures can be revealed and examined, opens up exciting possibilities for robust report interpretation and even patient education.



**Figure 32: Transferring a recorded video volume rendering from a volume image in MeVisLab (Scenario III)**

In the third scenario, a video of a 3D volume rendering from the sample dataset was created (Figure 35, bottom right) using the movie controls in MeVisLab (Figure 32). A video recording was initiated by clicking the “Start” button and interacting with the 3D volume rendering, using the mouse to rotate around or zoom-in to an area of interest. Upon completion, the “Stop” button was used to deactivate the recording. The “Create Movie” button was then clicked to save the video (in .avi format), and the “Send to PDF” was used to transmit the video

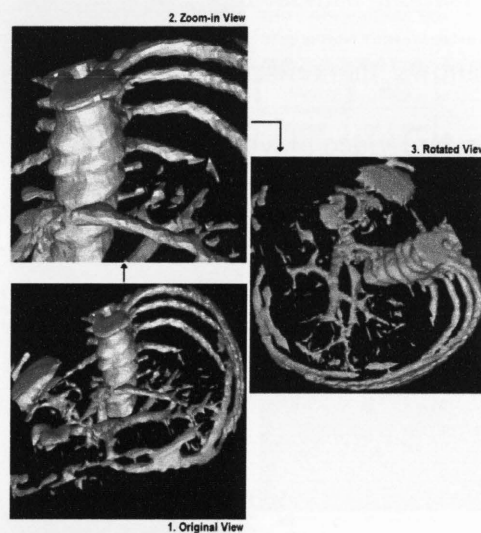
to the report (Figure 32). In addition to a video of the volume rendering, a 2D snapshot of the volume rendering was also created (Figure 35, middle right) and was transferred in to the report. Similar to generating a 3D anatomical model from the volume image dataset, the process of generating a useful volume rendering can be quite complex and time-consuming and involves highly specialized knowledge. The radiologist is able to interactively pan, rotate, and zoom and use interface controls to examine the 3D views of the patient's anatomy. Using a video to capture this 3D view and interaction, without replicating all of the volume rendering software with its complex interface, allows the referring clinician to benefit from the radiologist's expertise while providing a standard video playback interface.

Based on these scenarios, it can be seen that through the simple click of a button or two, MaRRS enables radiologists to instantly generate a visually-rich PDF report that includes any specified multimedia component (Figure 35).

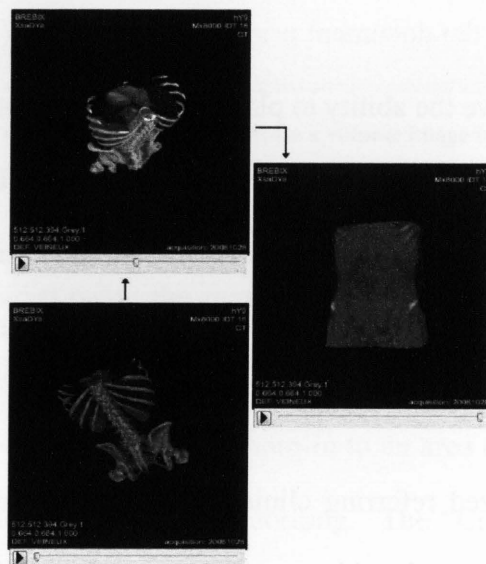
MaRRS also promotes a secure environment for reviewing radiology reports via Adobe Acrobat's extensive security features. For example, once the report is complete, the radiologist may set a password to access the document prior to forwarding it (email) to referring clinicians. Furthermore, all reviewers have the ability to place electronic signatures [32, 52] at the bottom of the document. These security features may be applied to any PDF document to help protect confidential information as well as control the information held within the document while it is shared outside a firewall. Hence, by using Adobe Acrobat, radiology reports can be made easy to distribute with confidence.

In a nutshell, authorized referring clinicians may view and interact with the radiology report once it is successfully completed by a radiologist. The clinician can traverse through the

embedded image slices, playback volume rendering videos and/or manually control the video using a slider (Figure 34), and interactively view a 3D model using rotate, pan, and zoom controls (Figure 33). In addition, at any time, the radiologist or clinician may annotate and mark-up the document using a variety of Acrobat's advanced *comment and mark-up tools* such as arrow, highlighting, and pencil tools. In the following section, Acrobat annotation features are discussed in detail.



**Figure 33: Clinicians can rotate, pan, and zoom a 3D anatomical model**



**Figure 34: Video controls are provided to play the video of a volume rendering**

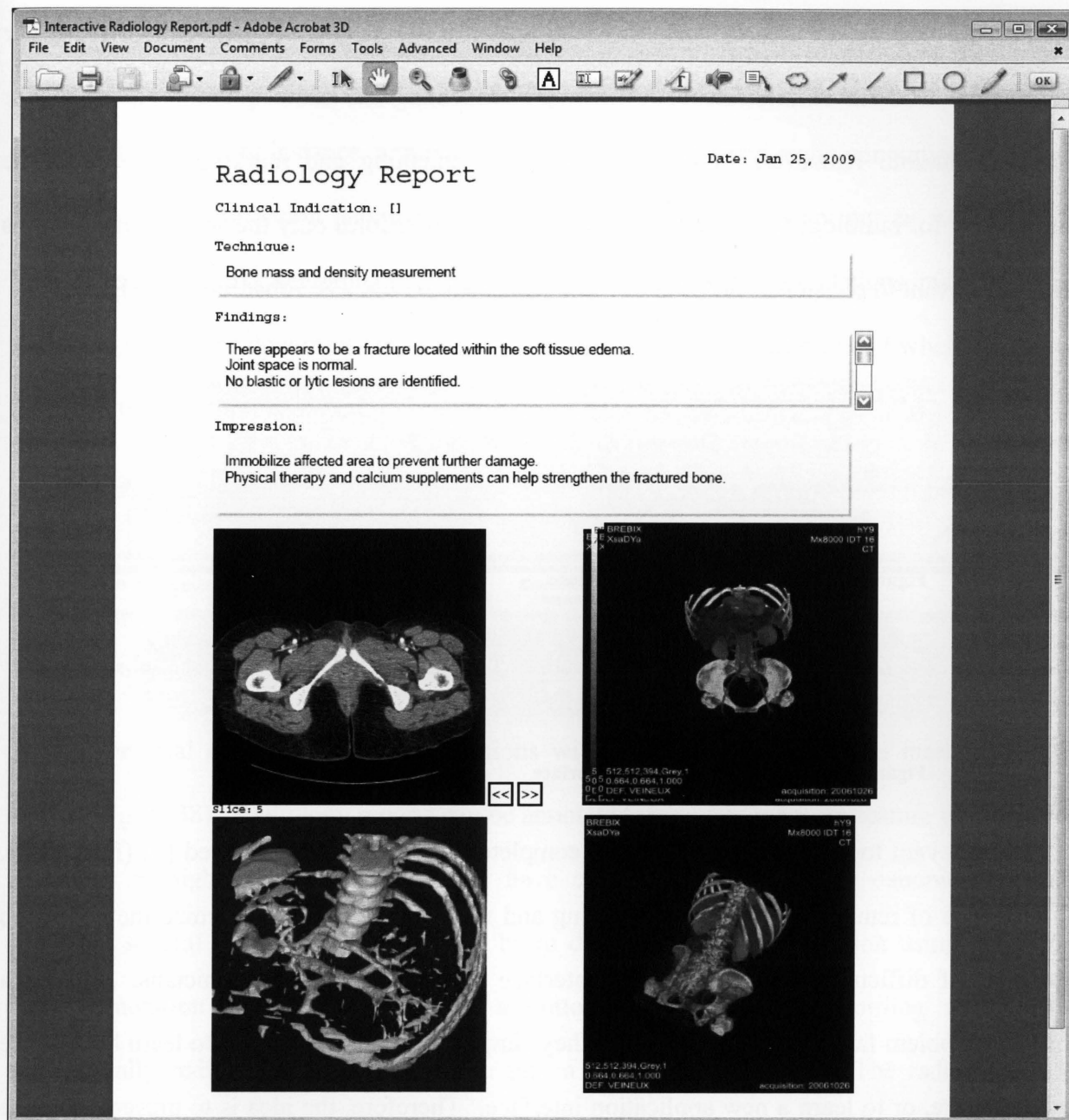
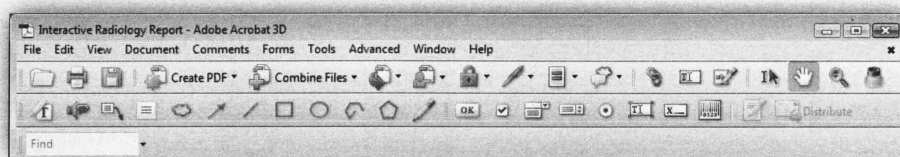


Figure 35: A new PDF radiology report generated by MaRRS containing four different multimedia components

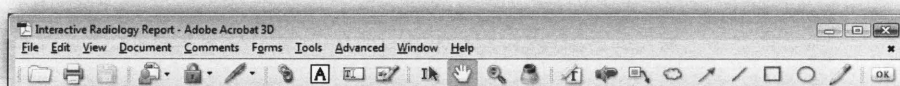
## 4.1 Report Annotation in MaRRS

As previously described, MaRRS is designed such that an interactive multimedia radiology report can be generated and rendered as a PDF document within a new Acrobat window. Once this report is produced within Acrobat, useful mark-up tools can be used, for

instance, to pinpoint an area of concern found within a 3D anatomical structure or particular image slice. MaRRS utilizes Acrobat's existing commenting and mark-up tools (Figure 36) for report annotation. However, Acrobat's complete commenting and mark-up toolset may be unnecessary for radiologists. Therefore, MaRRS currently enables only the set of mark-up tools deemed relevant to physicians and makes these tools visible on the Acrobat toolbar (Figure 37).



**Figure 36: Original Acrobat user interface**



**Figure 37: Simplified Acrobat user interface**

Irrelevant toolbar buttons have been completely removed and destroyed [3] (Figure 37). The purpose of removing various commenting and mark-up tools is to minimize the confusion and level of difficulty of Acrobat's user interface for radiologists and clinicians. In fact, a common problem faced by all physicians is they simply do not have the time to learn how to use new software, or to learn a new application interface. Therefore, the idea is to present a simple user interface that allows radiologists and clinicians to use basic annotation tools presented as recognizable icons located on the top toolbar (Figure 37).

#### **4.1.1 Synchronizing Annotation Features**

Adobe Acrobat [3] provides a set of annotation features which can be used to enhance the quality and clarity of the radiology report. Annotations associate objects, such as sound, with a

location on a page of the PDF document. Acrobat also provides user interaction with the keyboard and mouse. As a result, by clicking on annotations, the report reader activates the associated object. For instance, a radiologist may select the *record audio* annotation to verbally dictate specific information pertaining to particular image slice or point out an AOI (Area Of Interest) within a 3D anatomical structure model. These audio annotations may be placed anywhere within the document (indicated by a speaker icon, for example) and when clicked on, the audio transcription is played.

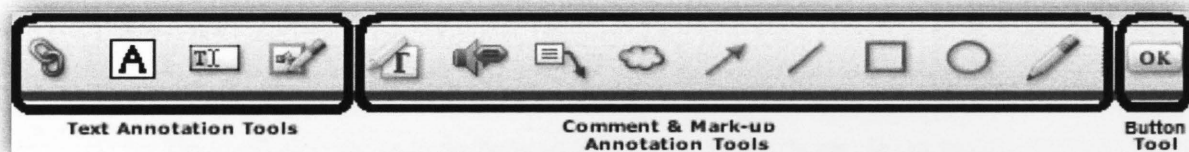


Figure 38: Annotation tools available for radiologists

The goal of synchronizing annotations with visual information is to maximize report clarity (Figure 38). Radiology reports can be annotated using any mark-up feature to effectively point out or highlight an AOI that may have clinical relevance. One canonical example involving several annotation features may be to dictate an audio description using the *record audio* annotation and additionally, add a button adjacent to the recording and have it automatically redirect the page and zoom into a 3D data model view. The radiologist may suggest within the audio recording to click this button to allow the clinician to visualize an AOI while simultaneously listening to the audio description. Synchronizing multiple annotation features can help the radiologist quickly apply their ideas or comments in areas where needed and ensure the referring clinician fully understands the report. In the following sections, three scenarios for synchronizing multiple annotations will be presented in detail.

#### 4.1.1.1 Scenario I – Annotating a 3D Model View

In this example, a radiologist selects a 3D anatomical structure of their patient, currently rendered in the visualization package display window, and sends it to the report (Figure 39) where it appears in the Acrobat window. By interacting with the 3D model within Acrobat, the radiologist may then find an optimal view that best illustrates the area of interest in the 3D model. Drawing around the AOI or drawing an arrow pointing toward the AOI while zooming into the model are some examples of useful annotation tools that can be used to mark-up a 3D data model.

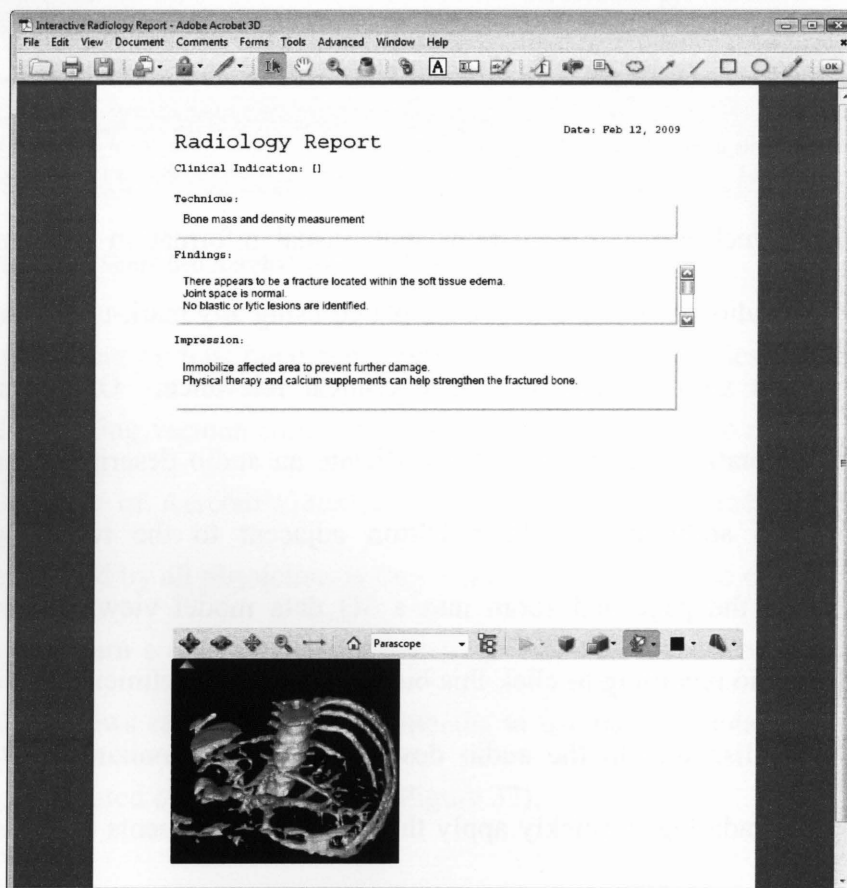


Figure 39: A 3D data mode view before annotation.

In this synchronization scenario, the radiologist uses the *Highlight Text tool* to highlight the word *Findings* in the report in order to attract the clinician's attention (Figure 40). The *Link*

*tool* is then used to place a link on top of the highlighted word to perform some action within the 3D model (Figure 41). Links let you jump to other locations within a document, to other electronic documents, and to initiate actions. Example actions include: go to a 3D view, go to a page view, play a video, draw arrows, and so on. In this example, the link may be setup such that it initiates actions to zoom-in to the pre-specified view of the 3D model defined by the radiologist and then to draw an arrow (using the *Arrow tool*) toward the area of interest. Actions can be added or deleted to a link and can be modified anytime by right clicking and selecting properties.

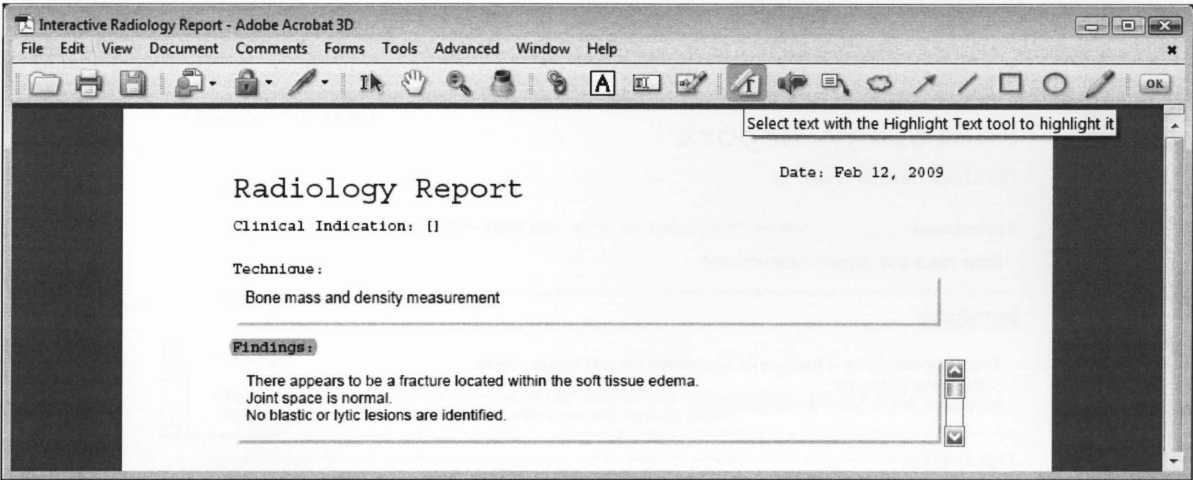


Figure 40: Highlighting a word

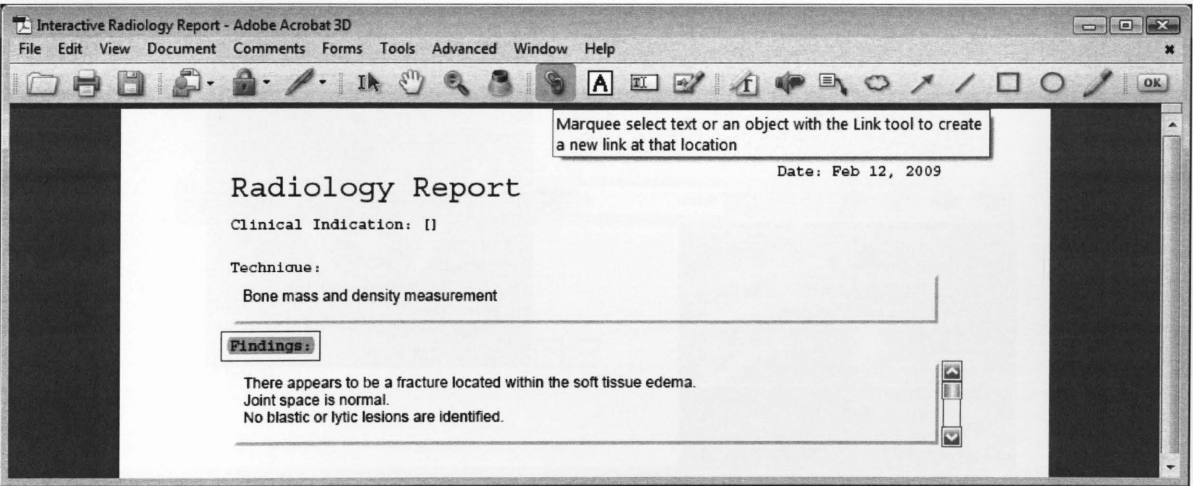


Figure 41: Inserting a link around a word

Once the link and actions have been set up by the radiologist, it can be clicked on and activated by the referring clinician while he/she is reviewing the report (Figure 42). In the example above, by clicking on the highlighted word *Findings*, report reviewers can instantly observe the fractured bone more closely and also examine the surrounding area to make sure that it correlates with the textual descriptions made by the radiologist. The use of these synchronized annotation links and actions has the potential to significantly improve the quality and accuracy of the report.

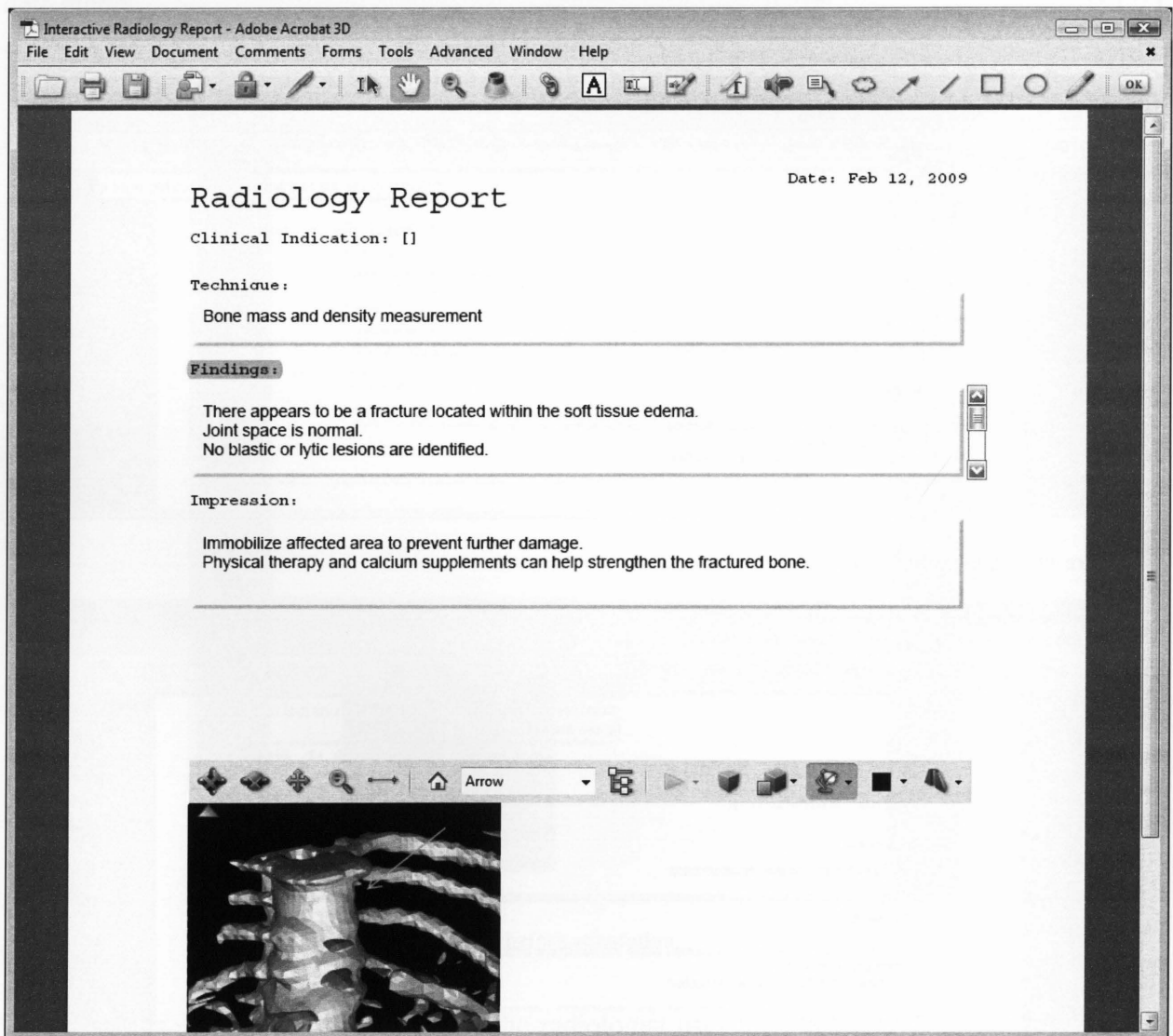


Figure 42: Example illustrating the end results of scenario I

4.1.1.2 Scenario II – Marking an AOI on an Image Slice

In this example, the radiologist transfers a set of image slices of their patient from the visualization window to the report window (Figure 43). By interacting with the image-forward and image-back buttons, located next to the image slice display in the report, the radiologist finds a region of interest in one of the image slices (Figure 43). A number of annotation features may be applied directly on top of an image slice to maximize the visibility of, for instance a tumour mass or lesion. This scenario demonstrates the use of several annotation tools that will help identify an epiglottic mass of a middle-aged male, found in image slice 15.

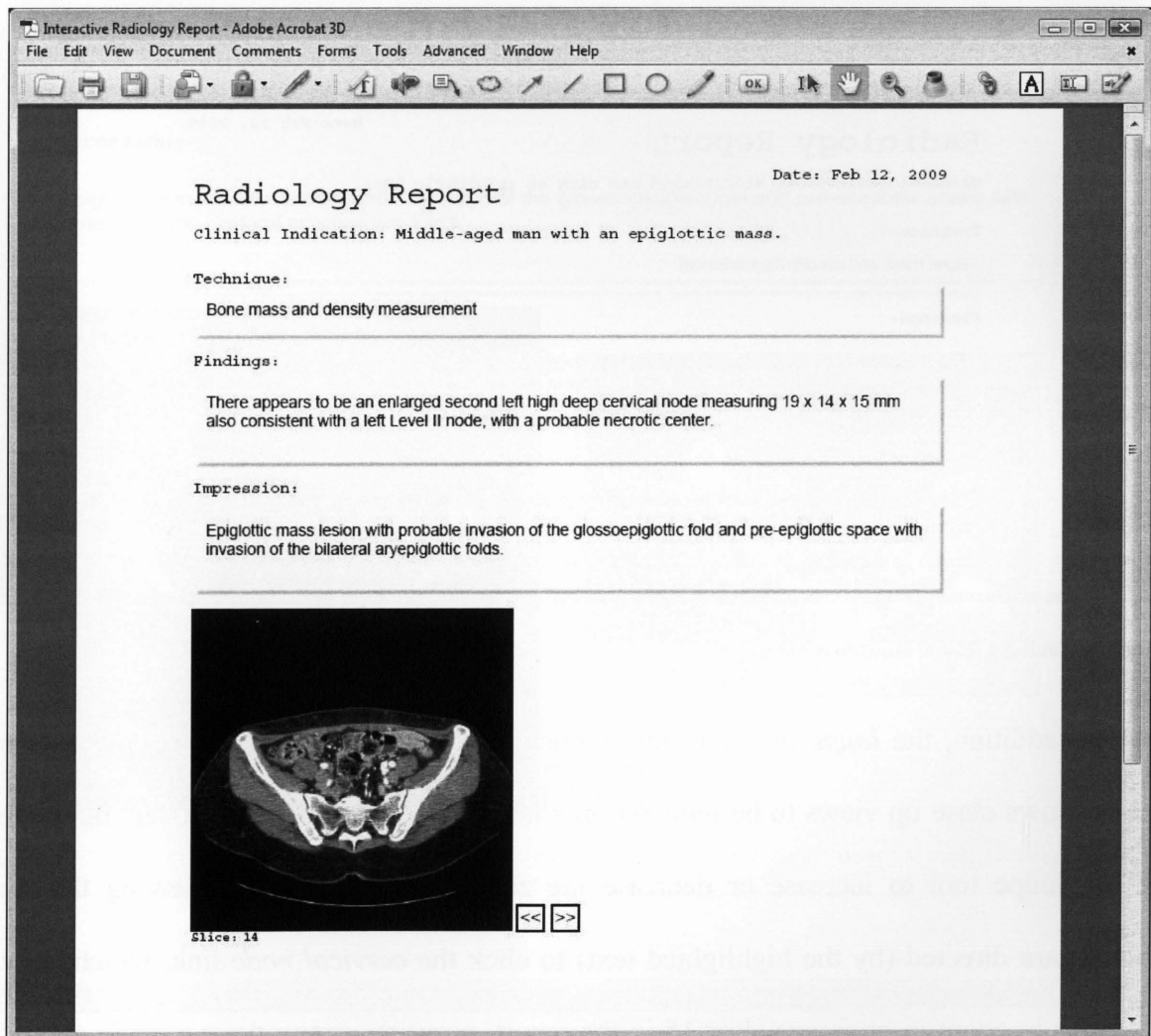


Figure 43: Image slice before annotation.

To begin, the *Link tool* is selected to create a link around the words, *cervical node* under the *Findings* subheading (Figure 44). After creating the link, radiologists can then assign various actions to take place. The “*Go to page view*” action can be used to attain a close-up view of any object on the page. This way, radiologists may choose to zoom-in to the location of the mass within image slice 15. From there, they may want to annotate on top of the image slice to emphasize the mass shape and size. The *Circle* and *Arrow tools* are used to isolate the mass so that referring clinicians will not miss this important finding (Figure 45).

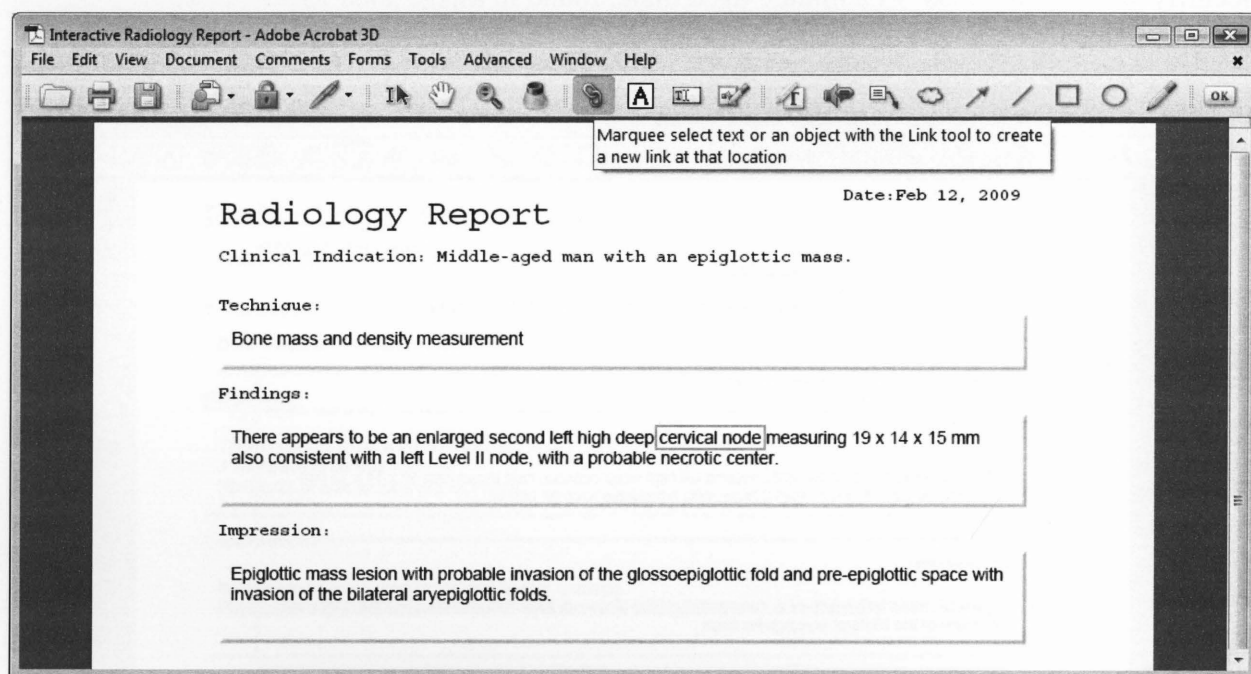


Figure 44: Placing a link around two words

In addition, the *loupe tool* can help clinicians to better distinguish the epiglottic mass since it allows close up views to be rendered in a new window (Figure 45). Users may interact with the loupe tool to increase or decrease the zoom feature. Upon reviewing the report, clinicians are directed (by the highlighted text) to click the *cervical node* link, which activates the actions to zoom in on image slice 15 in the report, insert an arrow, draw a circle around the

mass lesion, and activate the loupe tool (Figure 45). Hence, the radiologist is able to *tell a story* about the radiological findings that include not only (potentially ambiguous or confusing) textual descriptions, but synchronized visual annotations that guide the clinician toward the correct interpretation.

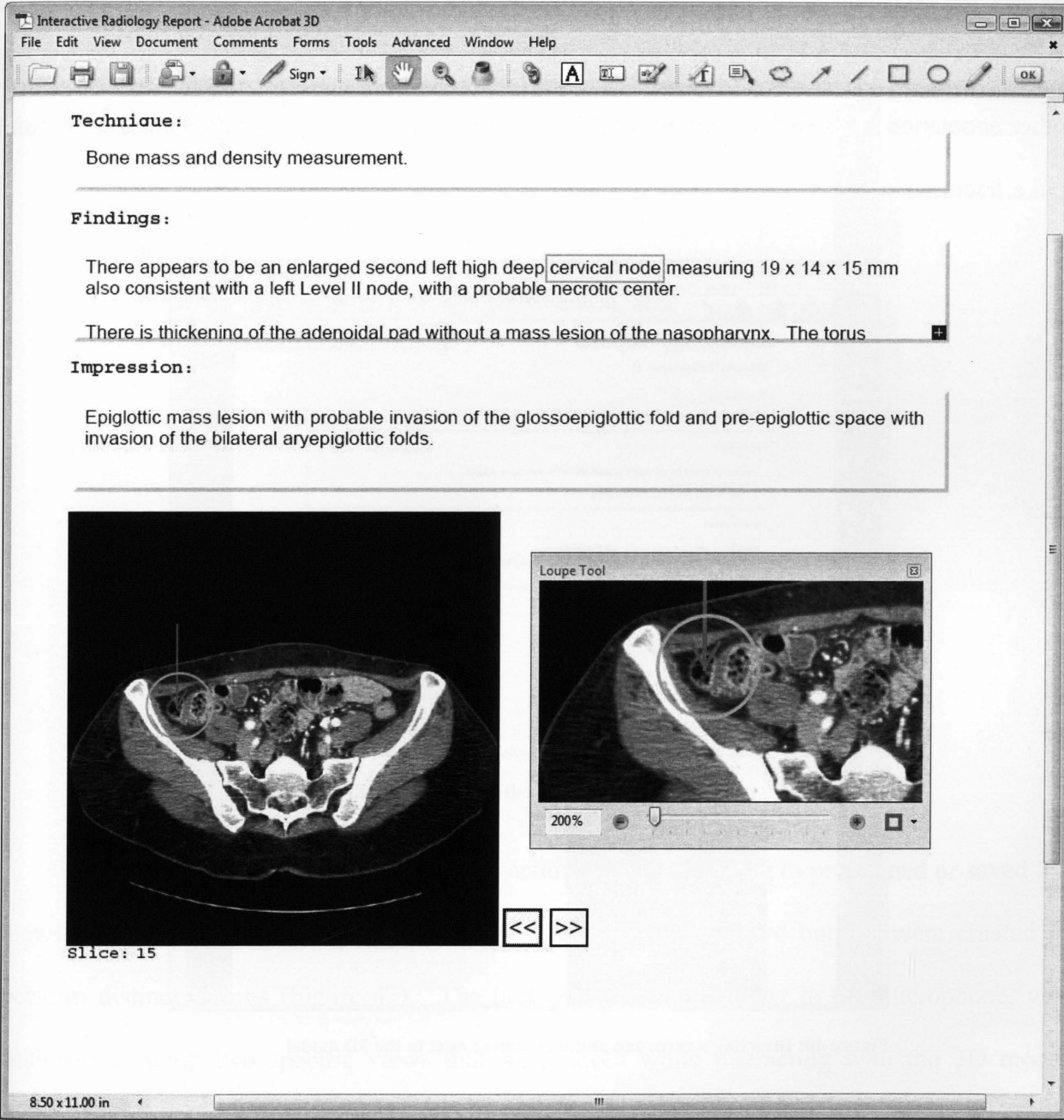


Figure 45: Example illustrating the annotation of a region in an image slice (scenario II)

#### 4.1.1.3 Scenario III – Record Audio Dictation + Annotation of a 3D Model

In this last example, the radiologist selects a 3D geometric model of the patient's spine and ribs and wishes to dictate comments regarding a specific AOI within the 3D model (Figure 46). By interacting with the 3D model (rotating and zooming etc) in Acrobat, the radiologist locates the AOI and saves this specific view for future reference. In addition, a number of annotation tools may be applied directly over the 3D view and then saved to be executed later by other annotation tools such as *buttons* and *links*. In this scenario, the radiologist wants to point out a fractured bone.

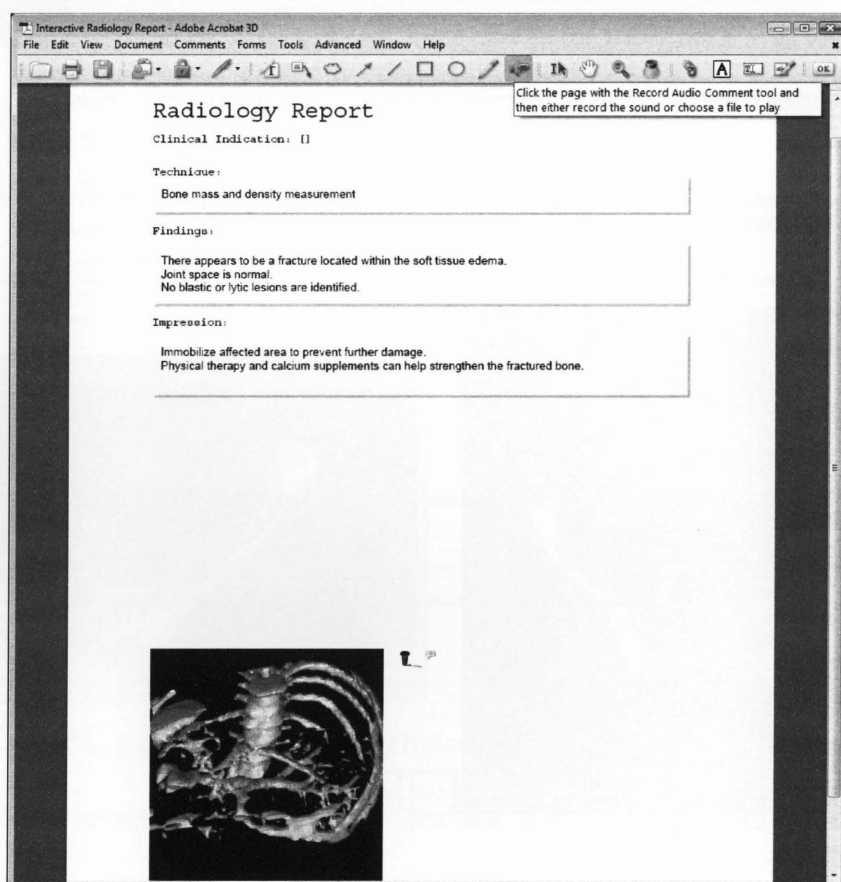


Figure 46: Inserting a recorded audio comment next to the 3D model

To begin, the radiologist uses the *Record Audio Comment tool* to create a voice dictation of the radiological findings for this patient and then places the *microphone* icon containing the

recorded audio next to the 3D model (Figure 46). The recorded audio can then be played at any time by double clicking on the microphone. Secondly, it can be beneficial to provide a visual aids that can help the clinician fully comprehend the audio and textual material included in the radiology report.

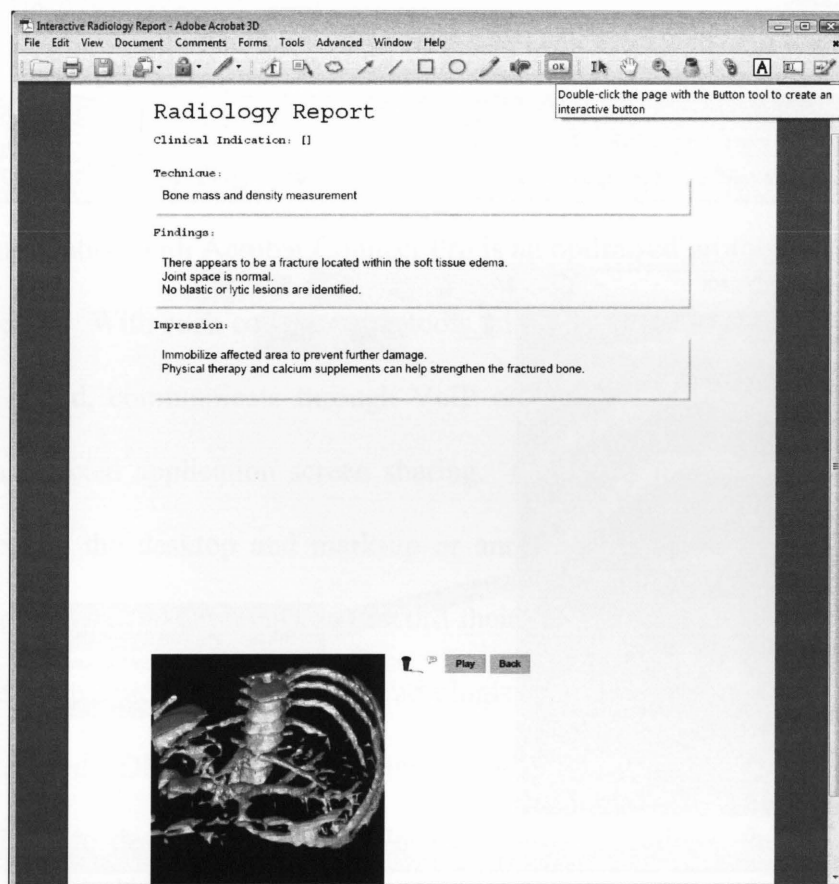
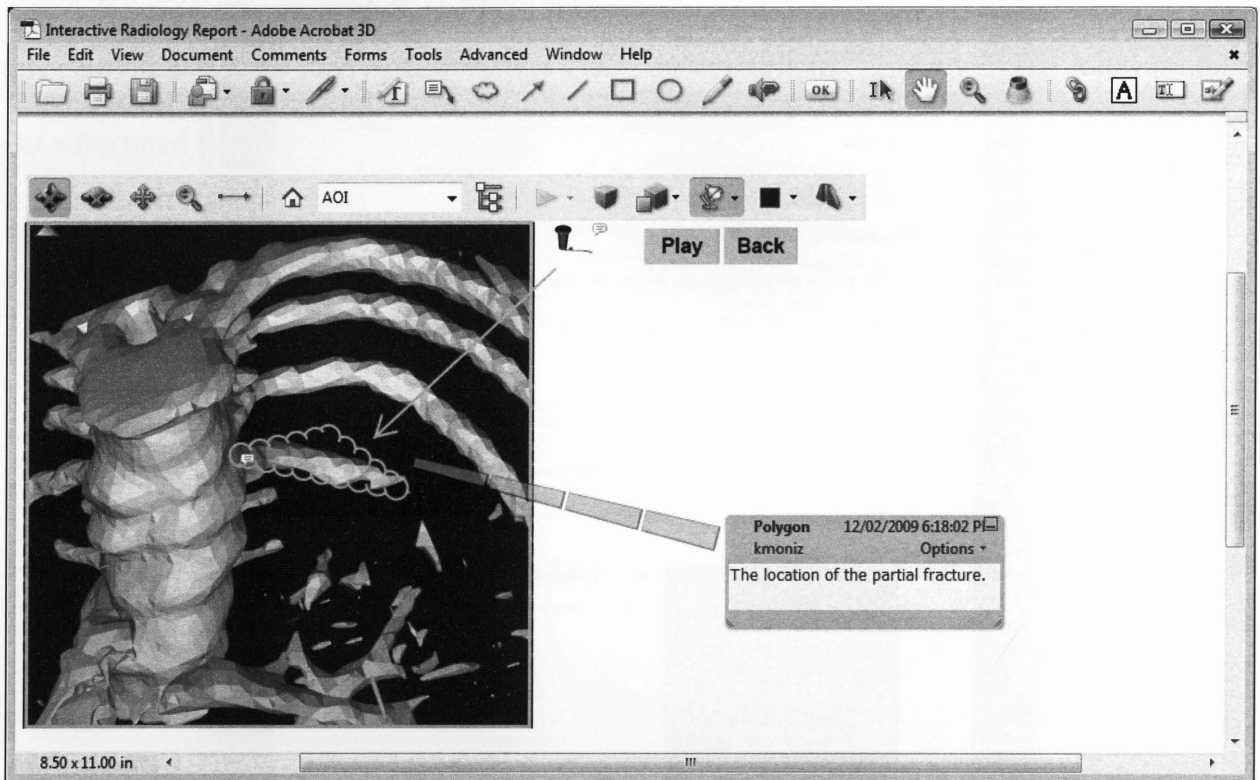


Figure 47: Applying the button tool to the 3D model.

The *Button tool* can be used to assign actions such as jumping to predefined or saved 3D views of the 3D model or drawing an arrow. In this example, two buttons were created to perform distinct actions (Figure 47). The button labelled *Play*, next to the microphone, was designed to setup two specific views that were saved while interacting with the 3D model (Figure 30). When clicked on, this button executes a close-up view of both the document page and 3D model view labelled *AOI*, and inserts an arrow and “cloud” polygon around the fractured

bone, respectively (Figure 48). As previously mentioned, a radiologist may suggest within the audio recording for the clinician to click the *Play* button to allow her/him to visualize the AOI at this time. To return to the original view of the document page and 3D model, the clinician may click the *Back* button. This causes the report to be displayed back in its original state (Figure 47).



**Figure 48: Example illustrating the end results of scenario III**

To summarize, in addition to the wide array of visual and audio information that can be included in a radiology report, the use of Acrobat's powerful set of annotation/mark-up tools will ensure that miscommunication between radiologists and referring clinicians can be minimized. Nevertheless, there will always be situations where the two need to communicate and discuss the report. In the following chapter, the mechanism by which this communication can be achieved in MaRRS will be described.

## 4.2 Collaboration in MaRRS

MaRRS provides remote collaboration using Acrobat Connect Pro. This web conferencing program is conveniently integrated within Adobe Acrobat [5] and supports live meetings between radiologists and referring clinicians, allowing them to cooperatively work together to analyze a radiology report in real-time.

Acrobat Connect Pro [4] includes features such as web conferencing with multi-person audio and video capabilities, shared screens and whiteboards, and an integrated VoIP telephone system. VoIP integration with Acrobat Connect Pro is an optimized protocol that transmits voice through the Internet. With such collaborative tools, clinicians can create online meetings, invite radiologists to attend, communicate through VoIP or instant messaging, and share radiology reports through selected application screen sharing. Clinicians may also allow radiologists to interactively control the desktop and mark-up or annotate on top of the document using the whiteboard feature. Lastly, clinicians can record their meetings and later download and replay the video at their convenience. Altogether, radiologists and referring clinicians may intuitively interact with a shared PDF report, make changes, and communicate specific problems that are sometimes difficult to describe in words. In the following sections, the key features of this program will be described in detail in the context of radiology reporting.

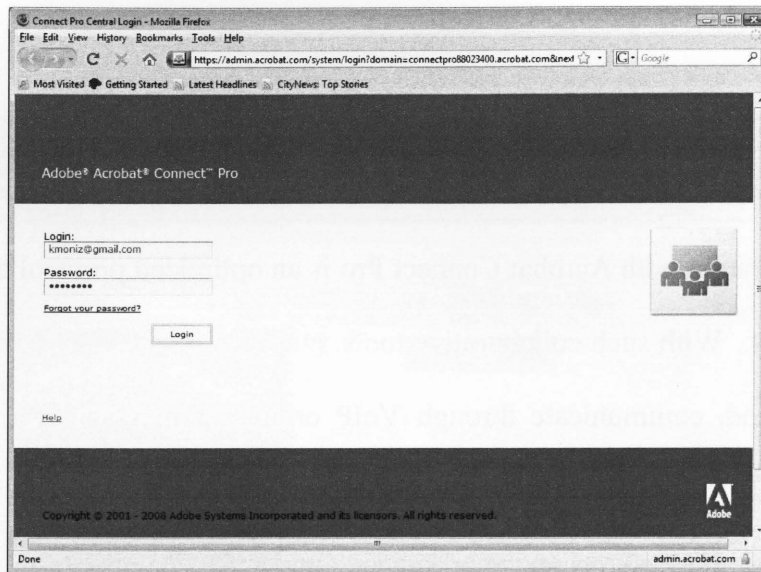
### 4.2.1 Create a Meeting

Acrobat Connect Pro allows users to create personal web conferences [53]. To create a meeting, the user must first login to the Connect Pro Central<sup>6</sup> (Figure 49). Upon a successful login, the user may then click the *Create new Meeting* button, in which meeting information

---

<sup>6</sup> The user must be a licensed or pay-per-use member.

(Figure 50), participant selection (Figure 51), and permission settings (Figure 54) may be entered. As soon as the *meeting room* is created, the host may re-enter the meeting room using a more efficient login process integrated with Adobe Acrobat's user interface, illustrated in section 4.2.3.



**Figure 49: Connect Pro meeting login process**

Acrobat Connect Pro also allows users to automatically save custom URL meeting rooms and content for access on any Internet browser virtually anytime, anywhere [2]. This URL represents the online meeting room, in which participants would subsequently be invited to attend. In addition, Acrobat Connect Pro will save previously invited participants with their corresponding permission settings. New participants may be added in the *Administrative* section. However, existing members may be invited to attend a meeting by clicking on *Select Participants*, selecting the available users within the list, and then clicking the *Add* button (Figure 51). This archiving capability can dramatically reduce preparation time for recurring meetings issued by a clinician or radiologist.

Enter Meeting Information - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://connectpro88023400.acrobat.com/admin/meeting/folder/list/new/1?account-ids=81

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ADOBE ACROBAT CONNECT PRO

My Profile Help Logout: Kristy Moniz

Enter Meeting Information

Enter Meeting Information > Select Participants > Send Invitations

Meeting Information

Name: \* Radiology\_Report\_Discussion

Custom URL: http://connectpro88023400.acrobat.com/radiology

(Leave this field blank for a system-generated URL, or include a unique URL path. For example: "productdemo" will result in http://connectpro88023400.acrobat.com/productdemo/)

Summary: (max length=1000 characters) This is a study used to evaluate the quality, flexibility, and control of Adobe Acrobat Connect Pro.

Start Time: 23 January 2009 01:15 AM

Duration: 00:30 hours:minutes

Select Template: Shared Templates\Default Meeting Template

Language: \* English

Access: ☐ Only registered users may enter the room (guest access is blocked)

☒ Only registered users and accepted guests may enter the room

Transferring data from connectpro88023400.acrobat.com...

Figure 50: Entering meeting information

Select Participants - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://connectpro88023400.acrobat.com/admin/meeting/folder/list/new/2/partici

Most Visited Getting Started Latest Headlines CityNews: Top Stories

ADOBE ACROBAT CONNECT PRO

My Profile Help Logout: Kristy Moniz

Select Participants

Enter Meeting Information > Select Participants > Send Invitations

Available Users and Groups

Administrators	Administrators
Administrators - Limited	Administrators - Limited
Authors	Authors
Training Managers	Training Managers
Event Managers	Event Managers
Learners	Learners
Meeting Hosts	Meeting Hosts
Jorge Mori	jorgearturo777@gmail.com
Kristy Moniz	kmoniz@gmail.com

Q Search Add

Current Participants For test

Kristy Moniz	Host	kmoniz@gmail.com

Q Search Permissions Remove

Cancel < Previous Next > Finish

Transferring data from connectpro88023400.acrobat.com...

Figure 51: Selecting participants to attend the meeting

Once all administrative tasks are handled, a summary of the meeting information is presented, followed by a button labelled *Enter Meeting Room* (Figure 52). At this point, the host may enter the meeting and accept invited participants also attempting to enter. In addition, the

meeting room may be assembled either within any Internet browser or desktop by installing the Acrobat Connect Add-in (Figure 53), which enables the host to share their screen with others, upload files, and utilize enhanced VoIP services.

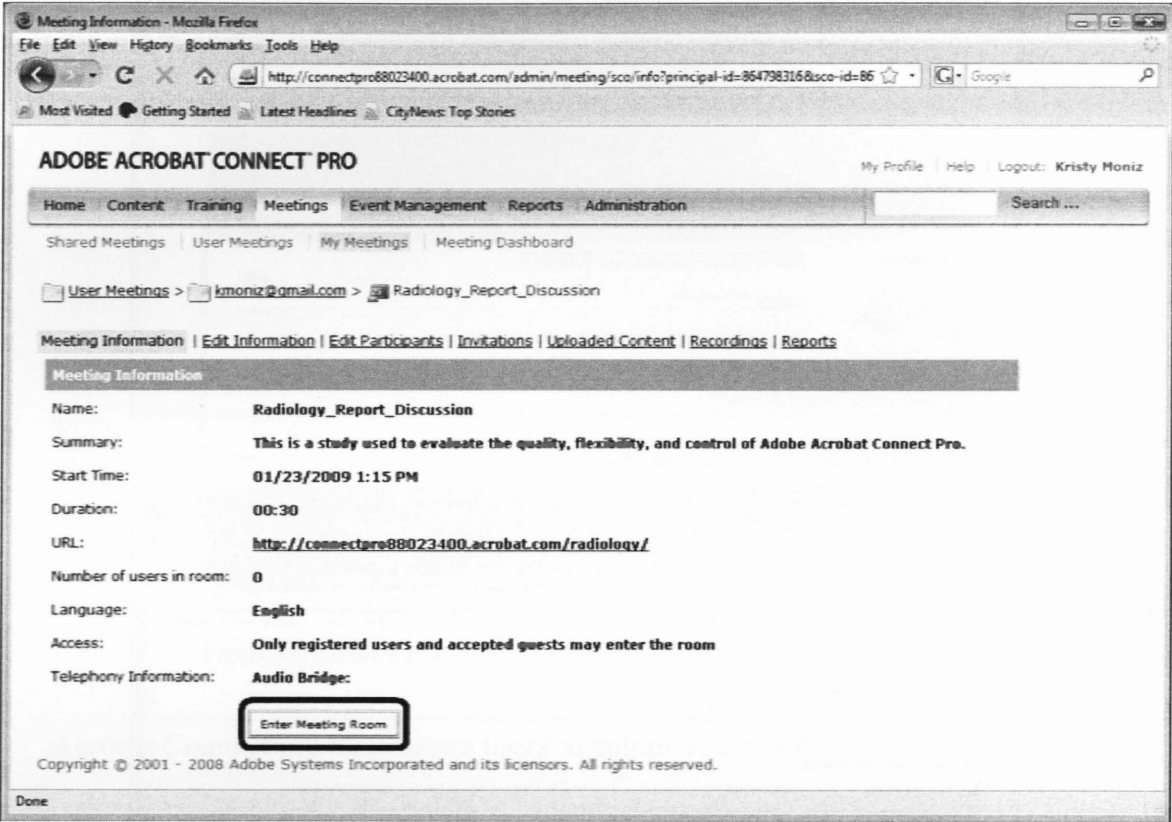


Figure 52: Meeting information summary

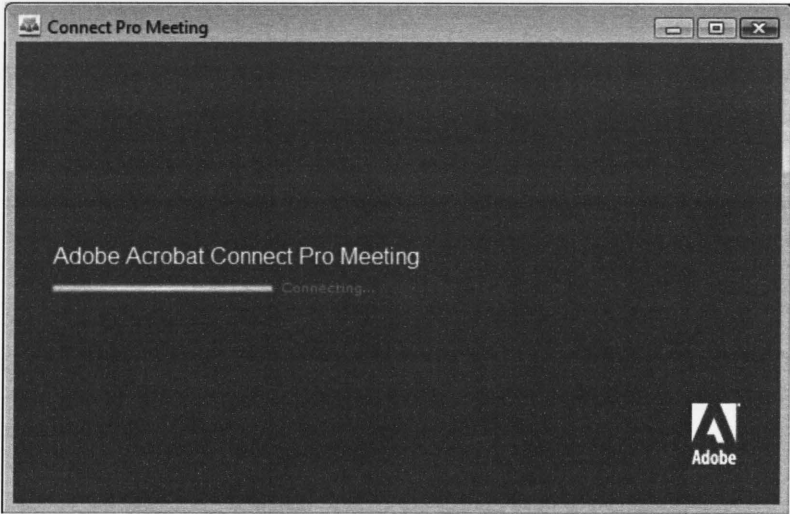


Figure 53: Connecting to the meeting room

## 4.2.2 Meeting Permissions & Settings

Acrobat Connect Pro allows users to set specific permissions on their participants before sending out the invitations. Each attendee in the meeting is assigned one of three roles, a host, presenter, or participant, which determines what actions they can perform in the meeting. These roles can be assigned by the host through the *Set Permissions* option (Figure 54).

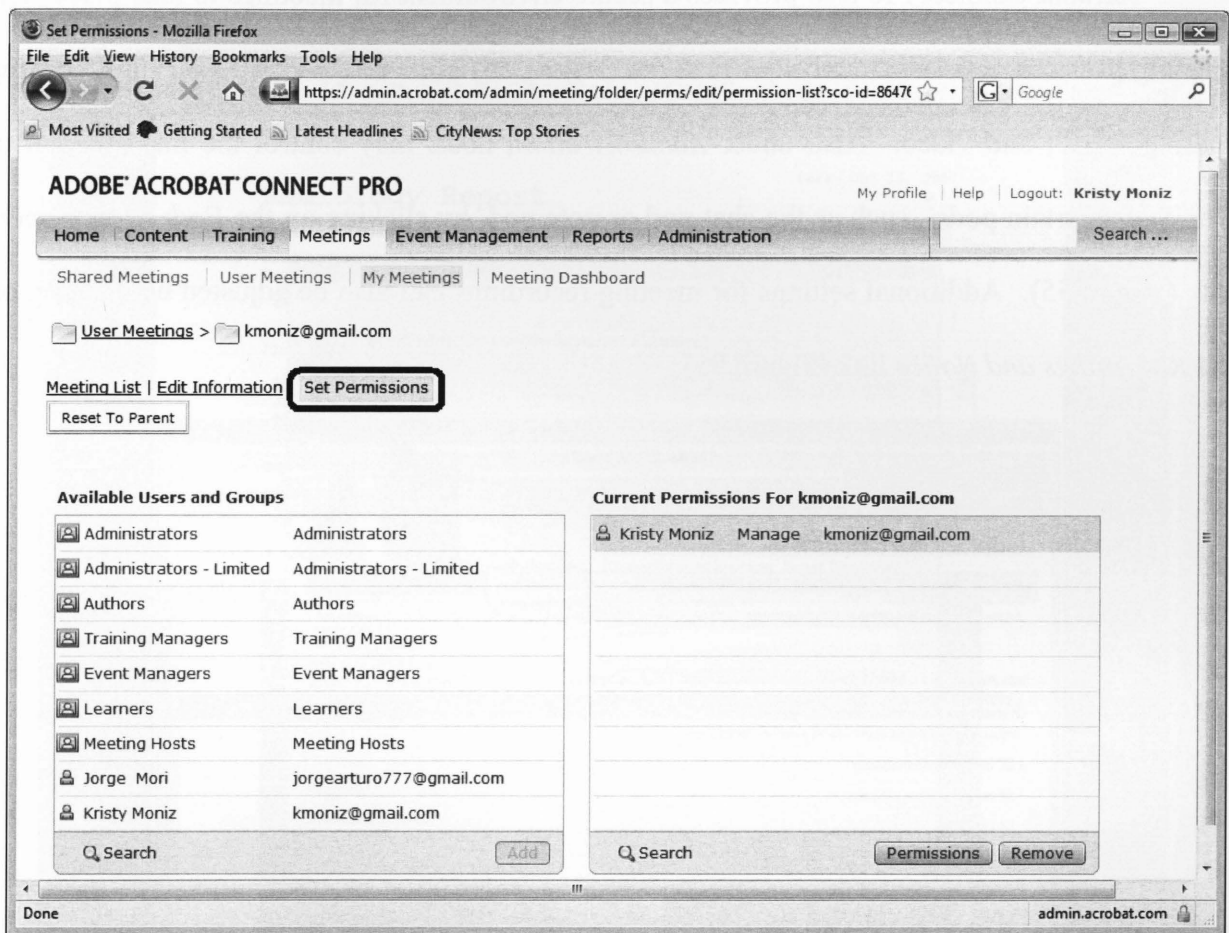


Figure 54: Setting participant permissions

A host is the primary meeting organizer and facilitator. A host sets up meetings, invites guests, accepts attendees upon entering, and puts meetings on hold or simply ends them. They can also show content, share their screen, broadcast audio and video, change meeting room properties, and start/stop a meeting recording. A presenter is responsible for presenting material

in the meeting. They can share their screen, chat, answer questions, and broadcast live audio and video. Finally, participants, who are typically invited by the host, can view the content being shown, listen and observe the presenters' broadcasts, chat with other attendees, download files, and, if given permission, broadcast their own audio and video.

Acrobat Connect Pro also provides a secure environment for meetings to take place. The meeting host can restrict a number of features (Figure 55) such as disabling chat logs, desktop sharing, VoIP, and video. Also under *Administration*, hosts may control the management of displaying certain pods<sup>7</sup>, such as the chat pod or note pod, by clicking on the *Pods Management* link (Figure 55). Additional settings for meeting recordings can also be adjusted by clicking on the *Recordings and Notice* link (Figure 55).

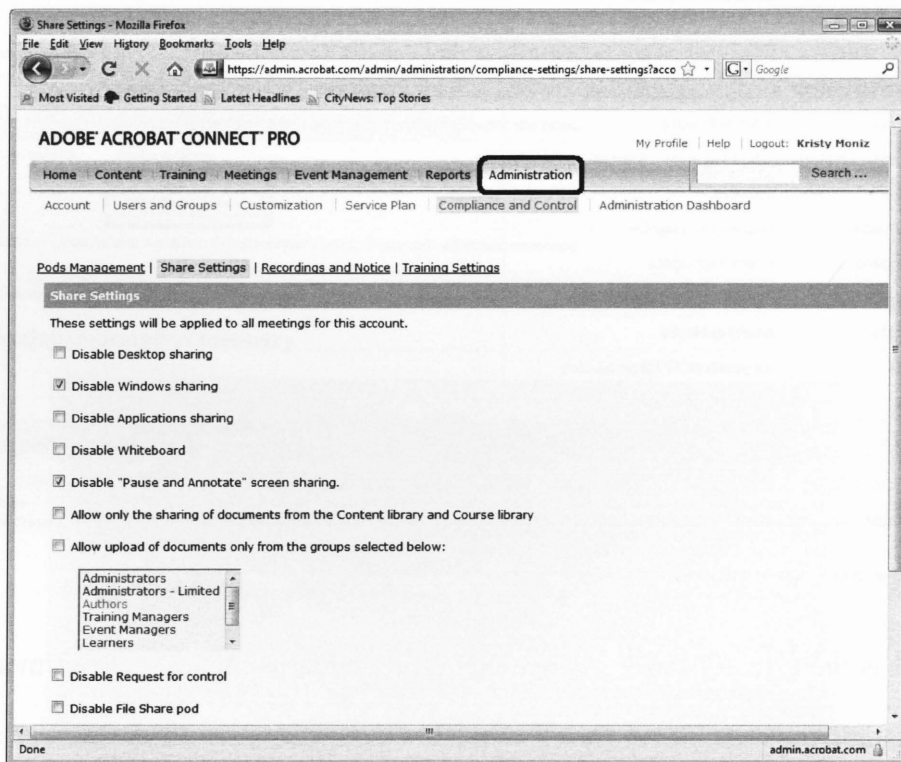


Figure 55: Building a secure meeting by managing various settings

<sup>7</sup> All meeting workspaces are organized into 'pods'; with each pod performing a specific role (i.e. chat, whiteboard, note, etc.).

4.2.3 Start a Meeting

The most common reason for the radiologist and referring clinician to have a meeting is that the clinician has received the PDF report (via email) and needs clarification on some of the report findings. The clinician then selects the *Start Meeting* option situated on the top left toolbar within Acrobat and enters the Meeting URL, user id, and password (Figure 56).

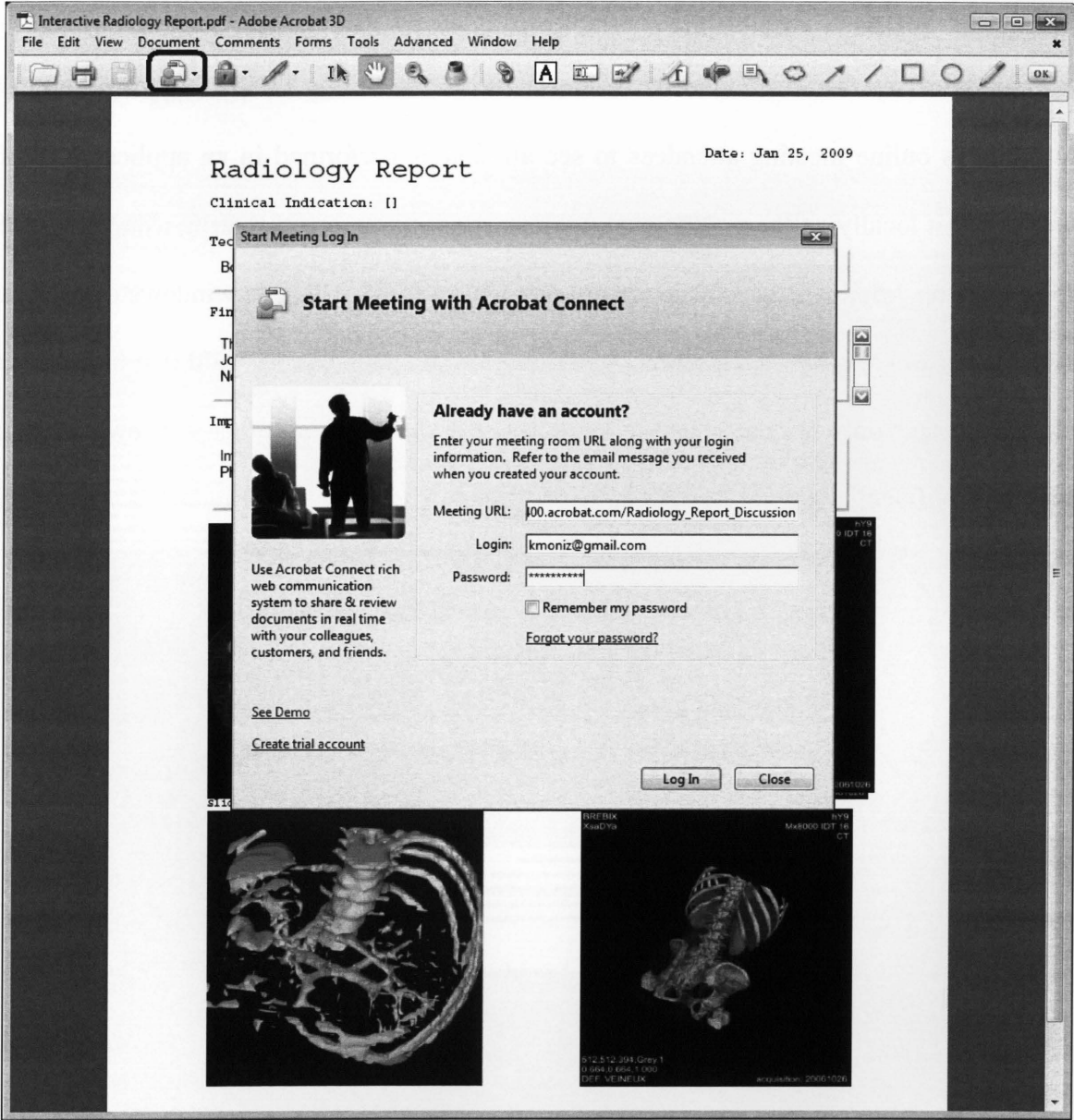


Figure 56: Starting a meeting inside Acrobat 3D using Connect Pro.

Once the meeting room is initialized, the clinician may send the meeting URL to the radiologist via an e-mail invitation. The radiologist receives the email with the request to join the meeting. Participants who receive email invitations are also given the URL meeting room to attend.

#### 4.2.4 Screen Sharing & Application Sharing

Another key feature of Acrobat Connect Pro is the ability to share applications. This feature allows online meeting attendees to see all actions performed in an application without having to run it locally on their computers. A host can initiate screen sharing using one of three options, desktop, windows, or application sharing (Figure 57). Through windows or application sharing, a host can specify which screen windows or applications they would like to share. As a result, participants only see the specified windows or applications all other windows are blurred to maintain confidentiality.

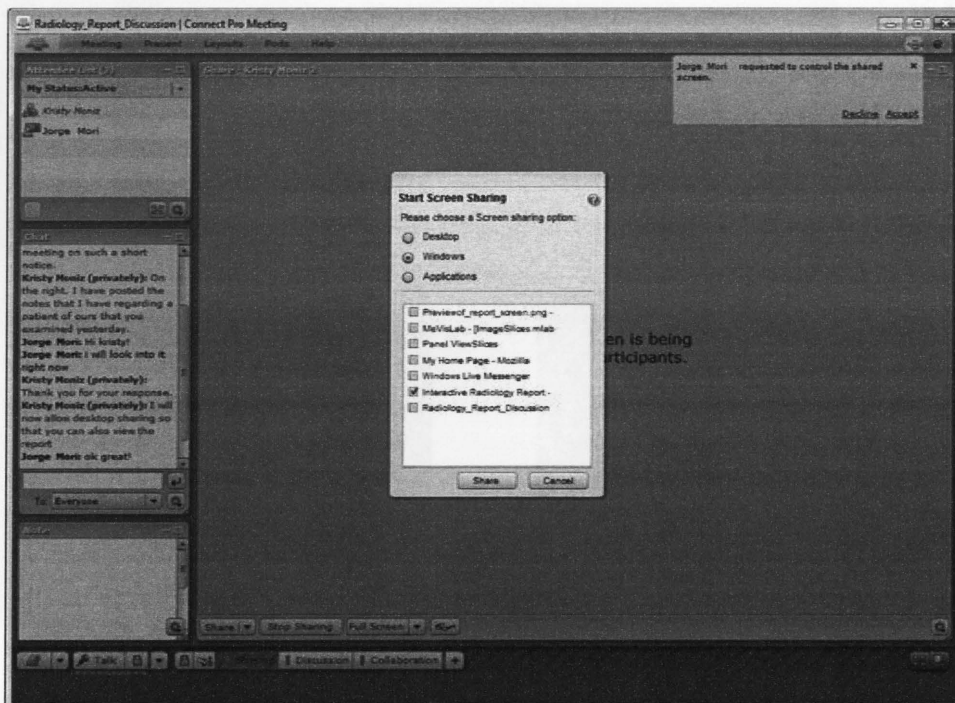
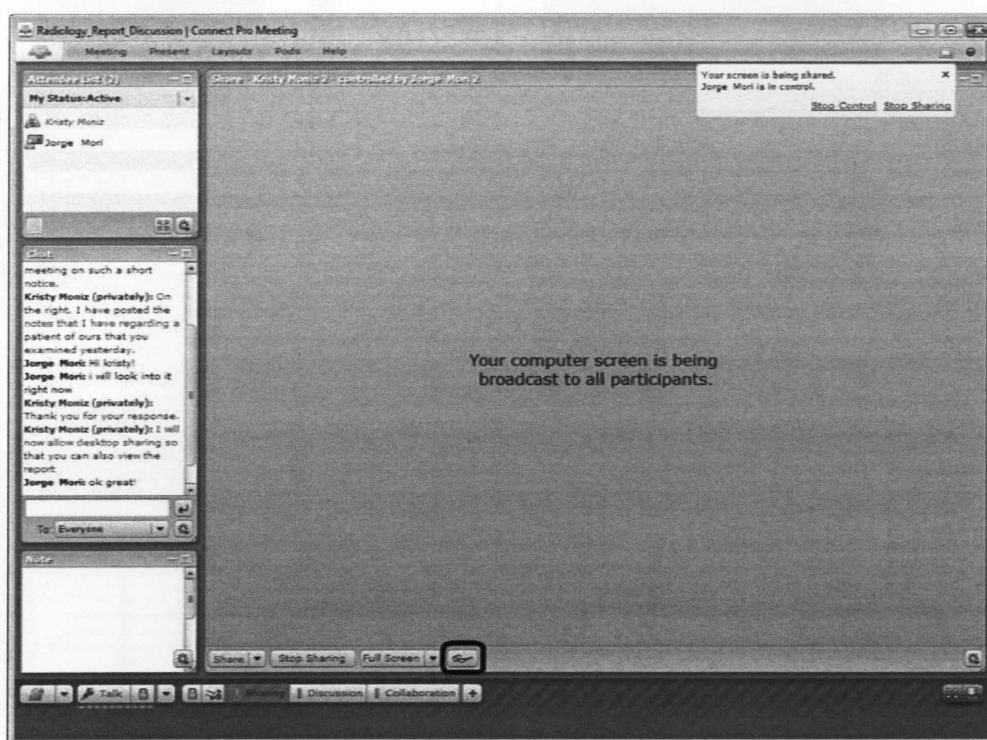


Figure 57: A host initiates screen sharing with participants.

During screen sharing, participants may request to control the shared screen. This will enable the participant (the radiologist, for example) to collaboratively interact with the application being shared. The host (referring clinician) will immediately receive this screen control request and may accept or decline it (Figure 57). Upon accepting the request, Acrobat Connect Pro will remind the host of this action on the top right corner, and at any time, the host may stop participant control and screen sharing by clicking *Stop Control* or *Stop Sharing*, respectively (Figure 48).



**Figure 58: Broadcasting the host's screen and accepting screen control**

In addition, hosts may *preview* their shared and participant-controlled screen in standard (Figure 59) or full screen mode (Figure 60) by clicking on the glasses icon situated on the bottom of the screen (Figure 58). This feature enables the host to also interact and view the same window being broadcasted to all participants, keeping all members of the meeting up-to-date through chat and file sharing.



Figure 59: A participant controlling a host's desktop

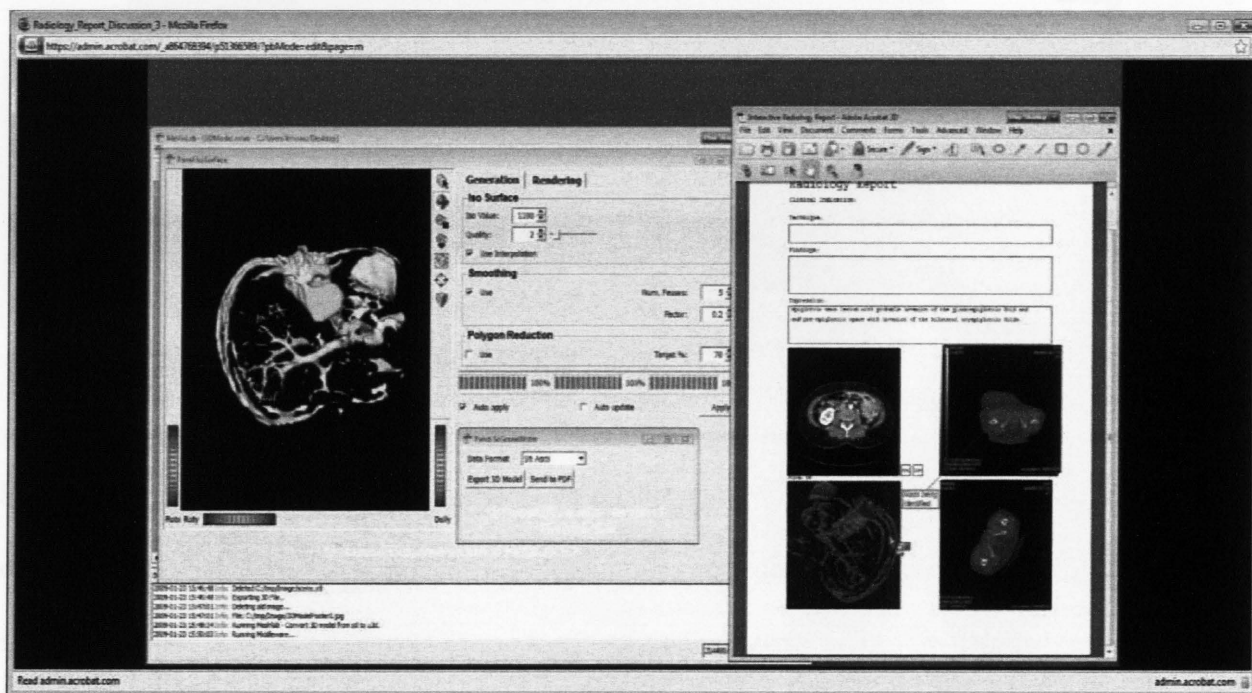


Figure 60: Preview in full screen mode

4.2.5 Discussion

Another feature of Acrobat Connect Pro allows attendees within the meeting to discuss the material being shared in a *Discussion Pod* (Figure 61). Participants can talk to other participants through their computers using integrated audio VoIP controls or using chat (Figure 61) and entering text in the chat pod. The host can also create discussion notes (Figure 61) on a related topic or prepare questions to be answered by attendees to produce a survey. The host may also start a webcam to broadcast a presentation by communicating live audio transcriptions to all participants (Figure 61).

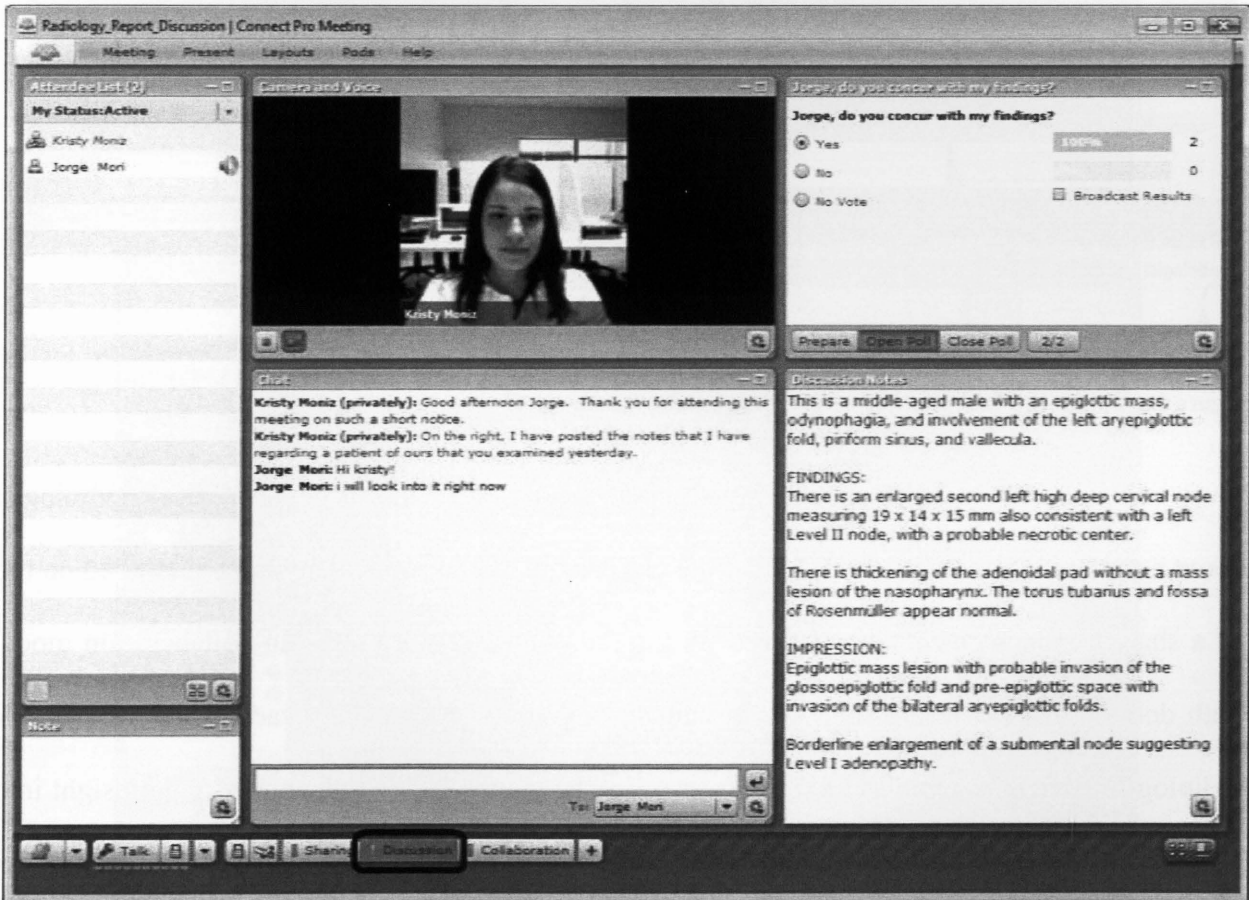


Figure 61: Example illustrating the discussion pod

## 4.2.6 Collaboration

Acrobat Connect Pro also allows users to annotate on top of documents using the shared whiteboard feature in the *Collaboration pod* (Figure 62). The whiteboard can provide participants with the ability to visually send messages more efficiently and help convey ideas. This feature also provides a great way to brainstorm or come to an agreement in team meetings. During screen sharing, participants can also control the whiteboard to convey their thoughts or ideas to everyone.

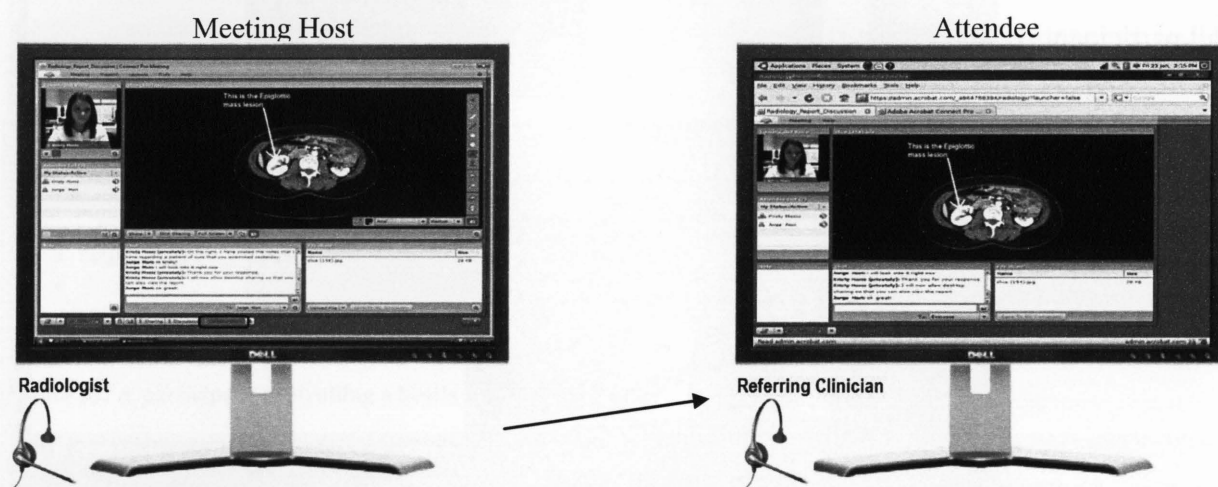


Figure 62: A radiologist and clinician collaborating online with headsets

For instance, the clinician may pose as the meeting host and collaborate with a radiologist about a particular case. This means that the clinician is in control and anything annotated on top of a shared document will be observed by the radiologist (Figure 63). In collaboration mode, both doctors may send messages via instant messaging or VoIP using headsets. Several mock radiologist-clinician meetings were performed by the author and a colleague to gain insight into the performance of Acrobat Connect Pro within a Linux environment using the Mozilla Firefox Internet browser (Figure 64). Anecdotal evidence suggests that a report can indeed be shared and marked-up by a “radiologist” and “referring clinician” while they simultaneously communicate through speech or text.



Figure 63: The mock radiologist side

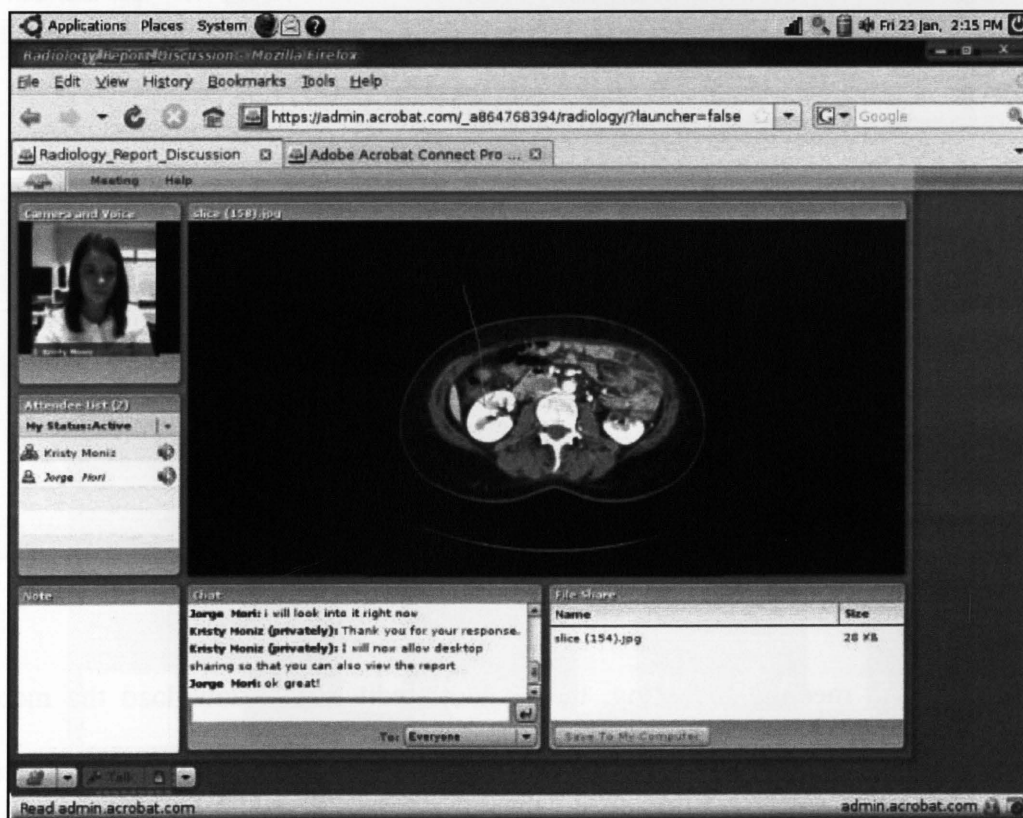


Figure 64: The mock referring clinician's point of view

## 4.2.7 Recording a Meeting

Acrobat Connect Pro permits meeting hosts to instantly record meeting sessions. Meeting recordings are an excellent way to save a record of the meeting for compliance or archival purposes. To record a meeting, the host may simply select this feature under the *Meeting* drop down menu of the Acrobat Connect Pro interface. The host may then enter the corresponding name and description of the recording and select the option to record audio from speaker phone. When this option is chosen, audio is also recorded using a computer microphone. In addition, at anytime during the meeting the host may stop the recording, which can later be accessed and retrieved within their accounts (Figure 65).

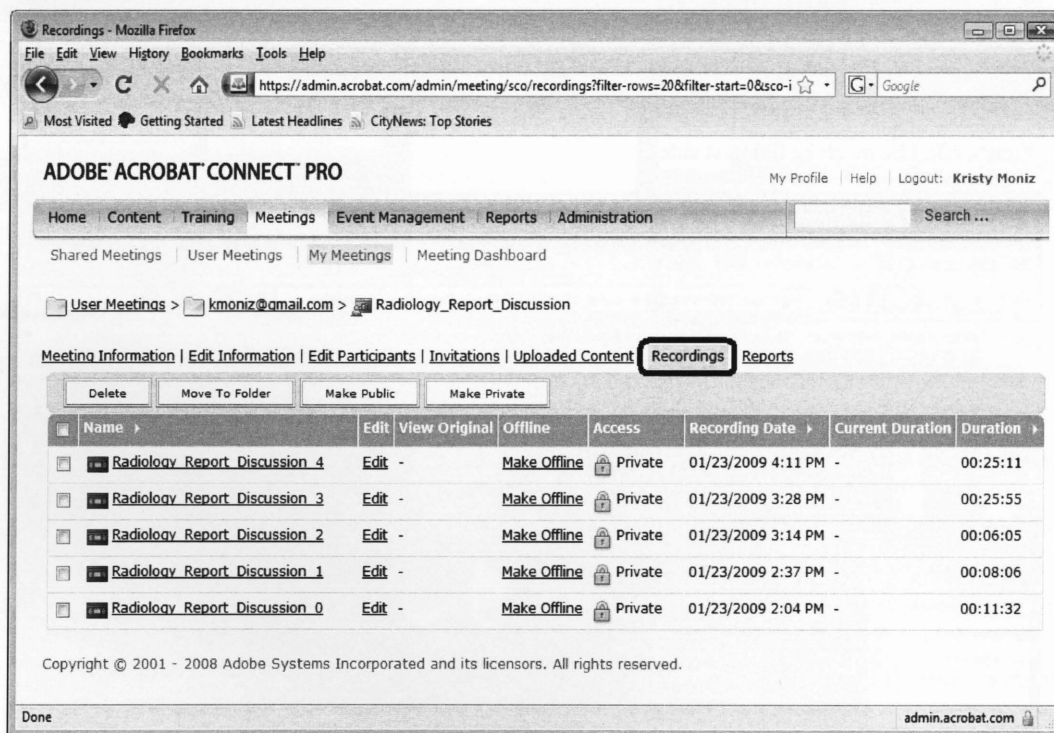


Figure 65: Recorded meetings stored online

To retrieve a meeting recording, the host can edit and/or download the meetings by selecting the specific recording (Figure 65) and clicking the *Edit Recording* or *Make Offline* button, respectively (Figure 66). When the *Edit Recording* button is triggered, the recording is

loaded in a new window where it begins to play (Figure 67). The recording can then be modified within the window by seeking through and deleting frames using video controls. However, if the *Make Offline* option is selected, meeting hosts may save the meeting recordings on their desktop to be played at a later time (Figure 66).

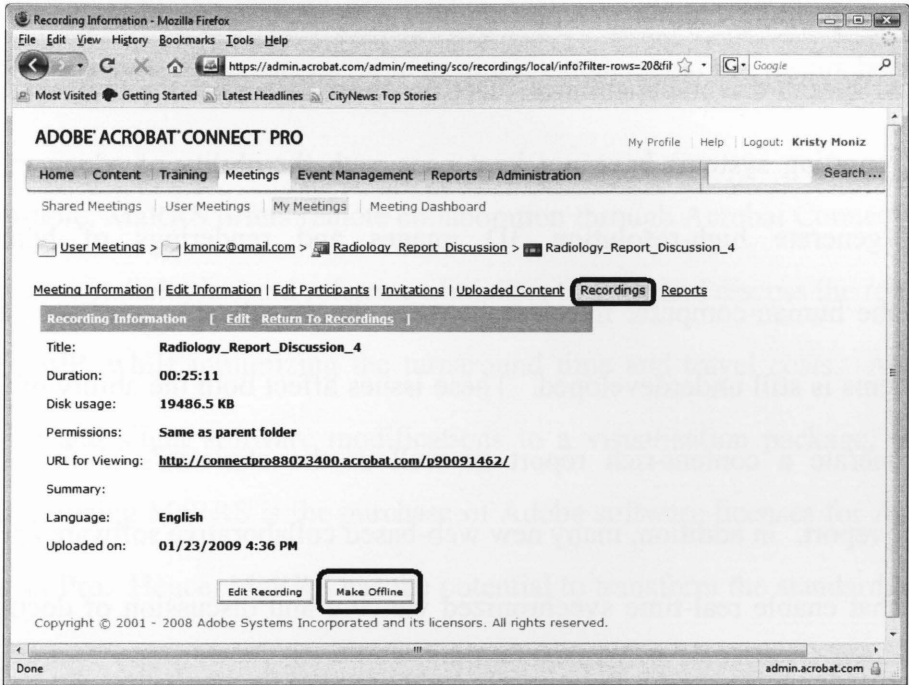


Figure 66: The retrieval of recorded meetings



Figure 67: Editing recorded meetings

## **Chapter V – Conclusion, Summary and Future Work**

In recent years, radiology reporting has been dramatically transformed from standard text-only documents into structured, clear, and concise reports. Today, researchers and developers are expanding radiology report authoring systems to provide greater accessibility, interaction, and speech-driven capabilities. Despite these advances, the multimedia capabilities of radiology reporting systems have not kept pace with the ability of advanced visualization packages to generate high-resolution 3D images and renderings of human anatomy. Furthermore, the human-computer interface between the visualization packages and the report authoring systems is still underdeveloped. These issues affect both the ability of the radiologist to quickly generate a content-rich report as well as the clinician's ability to review and understand the report. In addition, many new web-based collaborative software applications [17] are available that enable real-time synchronized viewing and discussion of documents. These applications provide the ability for radiologists and clinicians to simultaneously review, mark-up, and interact with the report from the comfort and convenience of their own offices.

### **5.1 Summary**

In this thesis, a software prototype called MaRRS has been presented in detail. MaRRS is an integrated system designed to connect existing image visualization packages to Adobe Acrobat 3D. Radiologists can use MaRRS to quickly and easily create secure, well-structured, content-rich multimedia radiology reports in the well known PDF format, while they are viewing and analyzing medical images with their preferred visualization package. In fact, there is no need to purchase expensive custom report authoring software as well as learn a new application.

MaRRS has demonstrated that with off the shelf software, it is possible to develop an *all-in-one* system for radiologists that can potentially minimize workloads, increase productivity levels, and most importantly, minimize misinterpretation of radiological findings. In addition, this proposed system can be beneficial for referring clinicians since it allows visually enhanced, annotated, and interactive multimedia-driven data to accompany detailed diagnostic findings described with text. With these features, clinicians are able to quickly understand the results both visually and verbally.

Furthermore, MaRRS offers remote collaboration through Acrobat Connect Pro. Acrobat Connect Pro allows radiologists and referring clinicians to view and discuss the report via instant messaging or VoIP, while minimizing the turnaround time and travel costs. Aside from new custom plug-ins and slight software modifications to a visualization package, the only other requirement in utilizing MaRRS is the purchase of Adobe software licenses for Acrobat 3D and Acrobat Connect Pro. Hence, MaRRS has the potential to transform the standard and traditional methods of radiology reporting by providing intuitive interactive, editable, sharable, and visually enhanced documents all within one integrated system.

## **5.2 Future Work**

As discussed in previous chapters, MaRRS has the capability of instantly producing multimedia radiology reports. This process requires the user to send a request by clicking on a button within the medical visualization application, which will in turn embed a specific medical component into the report. Nevertheless, in order to produce such a report, the radiologist can only select one component at a time. A future extension would be to provide options to process more than one component, which will ultimately further reduce the report production time.

In addition, this thesis has claimed that MaRRS can be integrated with any extendable visualization package. However, currently the only visualization application successfully integrated in this thesis was MeVisLab. Therefore, in future work, MaRRS could be integrated with other popular visualization applications used in today's healthcare, such as Amira and Analyze.

In Radiology, speech recognition is an essential report authoring tool since it boosts productivity levels by more than fifty percent [55]. Today's market offers numerous competing speech recognition software programs designed for medical purposes. Leading hospitals and clinics use speech-driven software to produce diagnostic reports. Dragon Naturally Speaking [47] is one speech-driven system that claims it can be integrated with any Windows application. Therefore, in future work, this application could be integrated with Acrobat 3D to provide MaRRS with the ability to input text through speech commands.

### **5.2.1 Evaluating MaRRS**

One of the most important sections of future work is the evaluation of MaRRS by radiologists and technicians. A direct comparison of MaRRS with existing radiology reporting systems would be difficult because each one emphasises different aspects of radiology reporting. Nevertheless, probably the best way to evaluate MaRRS would be to perform an informal user study which would include some feature comparison with other systems. Ideally the user study would involve as many radiologists as possible who would evaluate MaRRS for approximately one hour and answer a series of questions. One problem to contend with would be the radiologists' potential unfamiliarity with MeVisLab. However, most visualization packages have similar image processing and rendering capabilities and interfaces so presumably the

learning phase would be very short. As radiologists are among the busiest of all medical specialists, the informal evaluation would have to take place in the radiologist's office. Each radiologist would receive a complete system that contains MeVisLab, Adobe Acrobat, and MaRRS. The intention of the study would be to analyze the results and obtain feedback in the form of comments and answers to questions a series of questions. The following are a list of questions that may provide insight of the effectiveness of MaRRS:

1. What radiology reporting system and image visualization package are you currently using?
2. What features of MaRRS did you find the most useful?
3. What features of MaRRS did you find the least useful?
4. What features of MaRRS are missing?
5. What features of MaRRS are inadequate?
6. What features are available in your system that isn't available in MaRRS?
7. What features are available in MaRRS that isn't available in your system?
8. Did you find it difficult to interact with MeVisLab because you don't normally use this package?
9. Overall, would you rate MaRRS as more effective or less effective than your current system?

1. The first of these is

the second of these is

the third of these is

the fourth of these is

the fifth of these is

the sixth of these is

the seventh of these is

the eighth of these is

the ninth of these is

the tenth of these is

the eleventh of these is

the twelfth of these is

the thirteenth of these is

the fourteenth of these is

the fifteenth of these is

the sixteenth of these is

the seventeenth of these is

the eighteenth of these is

the nineteenth of these is

the twentieth of these is

## **Appendix A: Glossary**

**Anatomical Structure:** A particular complex anatomical part of a living thing.

**Analyze:** A file format for storing MRI data consisting of a header file and image file.

**Annotation:** An addition made to information in a radiology report.

**Application:** A tool that functions and is operated by means of a computer.

**Application Program Interface (API):** A set of routines, protocols, and tools for building software applications.

**Area of Interest (AOI):** The area of concern to the commander (radiologist).

**Computerized Tomography (CT):** Sometimes referred to as Computerized Axial Tomography (CAT) scans; a process of imaging anatomical information from a cross-sectional plane of the body. Each image is generated by x-rays that are obtained in different directions on the plane (cross sections) to visualize internal structures.

**Clinician:** A health professional engaged in the care of patients within a clinical practice.

**Collaboration:** A recursive process where two or more people work together toward a common goal.

**Digital Imaging and Communications in Medicine (DICOM):** The standard in the field of medical informatics for exchanging digital information between medical imaging equipment and other systems.

**Dynamic Link Library (DLL):** A library of executable files that allows programs to share code and other resources to perform a specific task.

**Document Object Model (DOM):** A specification for an API that allows programs to update content of HTML and XML documents.

**Electrocardiogram (EKG / ECG):** A test that records the electrical activity of the heart.

**Electronic Medical Records (EMR):** A medical record in digital format.

**Extensible Markup Language (XML):** A flexible way of producing information to share both the format and the data via the Internet and elsewhere.

**Food and Drug Administration (FDA):** A regulation made by the federal agency for the release of new foods and products.

**JPG:** A file extension denoted as Joint Photographic Experts Group (JPEG).

**Hospital Information System (HIS):** An integrated information system designed to manage administrative, financial, and clinical aspects of a hospital.

**Interapplication Communication (IAC):** A method for programmatically taking control of another application and automating its toolset.

**Image Slice:** An abstraction of one large medical dataset in which pieces of it can be loaded more quickly (2D slices).

**Interaction:** A kind of action that occurs as two or more objects have an effect upon an application. This effect is typically done by computer users.

**Interface:** An abstraction of a software component.

**Integration:** The process of incorporating something to another component.

**Insight Segmentation and Registration Toolkit (ITK):** An open source system that provides software tools for image analysis.

**Magnetic Resonance Imaging (MRI):** A medical imaging technique used to visualize internal structure and function of the body by providing greater contrast levels between organs and soft tissues through the use of powerful magnetic fields and radio waves.

**Megabyte (MB):** A term used to describe a unit of computer memory or data storage capacity equal to 1,048,576 ( $2^{20}$ ) bytes.

**Middleware:** Computer software that connects software components or applications.

**Multimedia:** Media and content that utilizes a combination of different content forms. It is usually recorded, played, displayed, and/or accessed by computer or electronic devices.

**Object Linking and Embedding (OLE):** Used to create objects with one application and link or embed them into a second application.

**Open Inventor:** A C++ 3D graphics API used to provide a higher layer of programming for OpenGL.

**Plug-in:** Consists of a computer program that interacts with a host application by extending its functionality.

**Picture Archiving and Communication Systems (PACS):** A storage and management system for high-resolution images related to patient information.

**Portable Network Graphics (PNG):** A bitmapped graphics file format that provides advanced graphic features.

**Portable Document Format (PDF):** A file format developed by Adobe Systems enabling users to send formatted documents and has them appear as intended.

**Radiology Information Systems (RIS):** A computerized database used in radiology to store, manipulate, and distribute patient medical scans and reports.

**Radiologist:** A healthcare professional who specialises in x-ray, ultrasound, and other similar examinations.

**Radiology:** The medical specialty directing medical imaging technologies to diagnose and treat diseases.

**Radiology Report:** A document containing an official interpretation of a radiology examination.

**RAW:** A file format that is digital photography's equivalent of a negative in film photography.

**Software Development Kit (SDK):** A library of software that helps programmers develop applications and utilities.

**Single Photon Emission Computed Tomography (SPECT):** A nuclear procedure in which a camera rotates around the patient to take pictures from different angles (cross sections).

**Tool Command Language (TCL):** A scripting language most commonly used for rapid prototyping, scripted applications, GUIs, and testing.

**Two-Dimensional (2D):** An object represented only with two dimensions, length and width.

**Three-Dimensional (3D):** An object that has height, width and depth, like any object in the real world.

**Tagged Image File Format (TIFF):** A bitmapped graphics file format that handles monochrome, gray scale, 8-and 24-bit colour.

**Uniform Resource Locator (URL):** A global address of documents and other resources on the World Wide Web (WWW).

**User Interaction:** A kind of action that occurs when the user interacts with an interface.

**Universal 3D (U3D):** A 3D graphics format for sharing 3D drawings on the Web and in common office applications such as Adobe Acrobat.

**Volume Rendering:** A technique used to display a 2D projection of a 3D discretely sampled data set. It is generally created by radiologists within a medical image visualization package using complex visualization algorithms.

**Voice over IP (VoIP):** A technology that allows telephone calls to be made over the Internet by converting analog voice signals into digital data packets to support real-time, two-way transmission of conversations using Internet Protocol (IP).

**Visualization Toolkit (VTK):** An open-source system for 3D computer graphics, image processing, and visualization.

**VOLume piXEL (Voxel):** A 3D pixel that represents a quantity of 3D data as small box-shaped pieces used in scientific and medical applications that process 3D images.

**X-ray:** A type of high-energy radiation with waves shorter than those of visible light. In low doses, x-rays are used for producing images that help to diagnose disease, and in high doses to treat cancer.

## Appendix B: JavaScript Source Code

```
// -----  
// JavaScript Program 1 - Populates text fields.  
// File Name: textField.js  
// -----  
var inch = 72;  
  
function loadTextFields(doc)  
{  
    try {  
        createTextField1(doc,0,1.0,1.5,6.5,0.5);  
        createTextField2(doc,0,1.0,2.3,6.5,0.8);  
        createTextField3(doc,0,1.0,3.4,6.5,0.8);  
    }  
  
    catch (e) {  
        app.alert("ERROR: Cannot Create Text Fields.");  
    }  
}  
  
function createTextField1 (doc, nPageNum, x, y, width, height)  
{  
    var aRect = doc.getPageBox( { nPage: nPageNum} );  
  
    aRect[0] += x * inch;  
    aRect[1] -= y * inch;  
    aRect[2] = aRect[0] + width * inch;  
    aRect[3] = aRect[1] - height * inch;  
  
    // create a read only text field as label  
    var f = doc.addField("Input Technique", "text", nPageNum, aRect);  
  
    // Properties:  
    f.textSize = 10;  
    f.textfont = font.Times;  
    f.textColor = color.black;  
    f.fillColor = color.white;  
    f.lineWidth = 2;  
    f.borderStyle = border.b;  
    f.alignment = "left";  
    f.multiline = true;  
    f.readonly = false;  
    f.richText = true;  
    f.doNotScroll = false;  
    f.doNotSpellCheck = false;  
    f.defaultValue = "Enter techniques here.";  
}  
  
function createTextField2 (doc, nPageNum, x, y, width, height)  
{  
    var aRect = doc.getPageBox( { nPage: nPageNum} );  
  
    aRect[0] += x * inch;  
    aRect[1] -= y * inch;  
    aRect[2] = aRect[0] + width * inch;
```

```

aRect[3] = aRect[1] - height * inch;

// create a read only text field as label
var f = doc.addField("Input Findings", "text", nPageNum, aRect);

// Properties:
f.textSize = 10;
f.textfont = font.Times;
f.textColor = color.black;
f.fillColor = color.white;
f.lineWidth = 2;
f.borderStyle = border.b;
f.alignment = "left";
f.multiline = true;
f.readonly = false;
f.richText = true;
f.doNotScroll = false;
f.doNotSpellCheck = false;
f.defaultValue = "Enter findings here.";
}

function createTextField3 (doc, nPageNum, x, y, width, height)
{
    var aRect = doc.getPageBox( { nPage: nPageNum} );

    aRect[0] += x * inch;
    aRect[1] -= y * inch;
    aRect[2] = aRect[0] + width * inch;
    aRect[3] = aRect[1] - height * inch;

    // create a read only text field as label
    var f = doc.addField("Input Impressions", "text", nPageNum, aRect);

    // Properties:
    f.textSize = 10;
    f.textfont = font.Times;
    f.textColor = color.black;
    f.fillColor = color.white;
    f.lineWidth = 2;
    f.borderStyle = border.b;
    f.alignment = "left";
    f.multiline = true;
    f.readonly = false;
    f.richText = true;
    f.doNotScroll = false;
    f.doNotSpellCheck = false;
    f.defaultValue = "Enter impressions here.";
}

app.addMenuItem({
    cName:      "KM2008:createTextFields",
    cUser:      "Create Text Fields",
    cParent:    "Advanced",
    cExec:      "loadTextFields(this);",
    nPos:       0
});

```

```

// -----
// JScript File Program 2 - Creates two buttons to navigate
//                               back and forth between image slices
// File Name: sliceNav.js
// -----
var inch = 72;

function loadNavButtons(doc)
{
    try {
        AddButtons(doc,0,3.8,6.85,0.25,0.25,"Prev","<<","Previous
        Slice","app.execMenuItem(\"KM2008:myPrevImageSlice\");");

        AddButtons(doc,0,4.1,6.85,0.25,0.25,"Next",">>","Next
        Slice","app.execMenuItem(\"KM2008:myNextImageSlice\");");
    }

    catch (e) {
        app.alert("ERROR: Cannot execute these image slices");
    }
}

function AddButtons(doc, nPageNum, x, y, width, height, strText, strCaption,
strToolTip, strAction)
{
    var aRect = doc.getPageBox( { nPage: nPageNum} );

    aRect[0] += x * inch;
    aRect[1] -= y * inch;
    aRect[2] = aRect[0] + width * inch;
    aRect[3] = aRect[1] - height * inch;

    // Add the field "button"
    var f = doc.addField(strText, "button", nPageNum, aRect);

    // Properties:
    f.setAction("MouseUp", strAction);
    f.userName = strToolTip;
    f.delay = true;
    f.borderStyle = border.s;
    f.highlight = "push";
    f.textSize = 0;
    f.textColor = color.black;
    f.strokeColor = color.black;
    f.fillColor = color.white;
    f.buttonSetCaption(strCaption);
    f.delay = false;
}

app.addMenuItem({
    cName:      "KM2008:sliceNavButton",
    cUser:      "Create Next Button",
    cParent:    "Advanced",
    cExec:      "loadNavButtons(this);",
    nPos:      0
});

```

## Appendix C: Installing MaRRS

By creating an installation package (Figure 68), MaRRS can be quickly installed on any Windows operating system. However, this system requires a set of prerequisite programs and library packages such as Adobe Acrobat 3D, MeVisLab, MeshLab, Python Software, and Qt toolkit. Aside from Adobe Acrobat 3D, all the other prerequisites are open source and freely available to download on the Internet. This installation package provides a README file which describes a list of steps to follow after installing all the contents of MaRRS to the local hard drive (Figure 72).

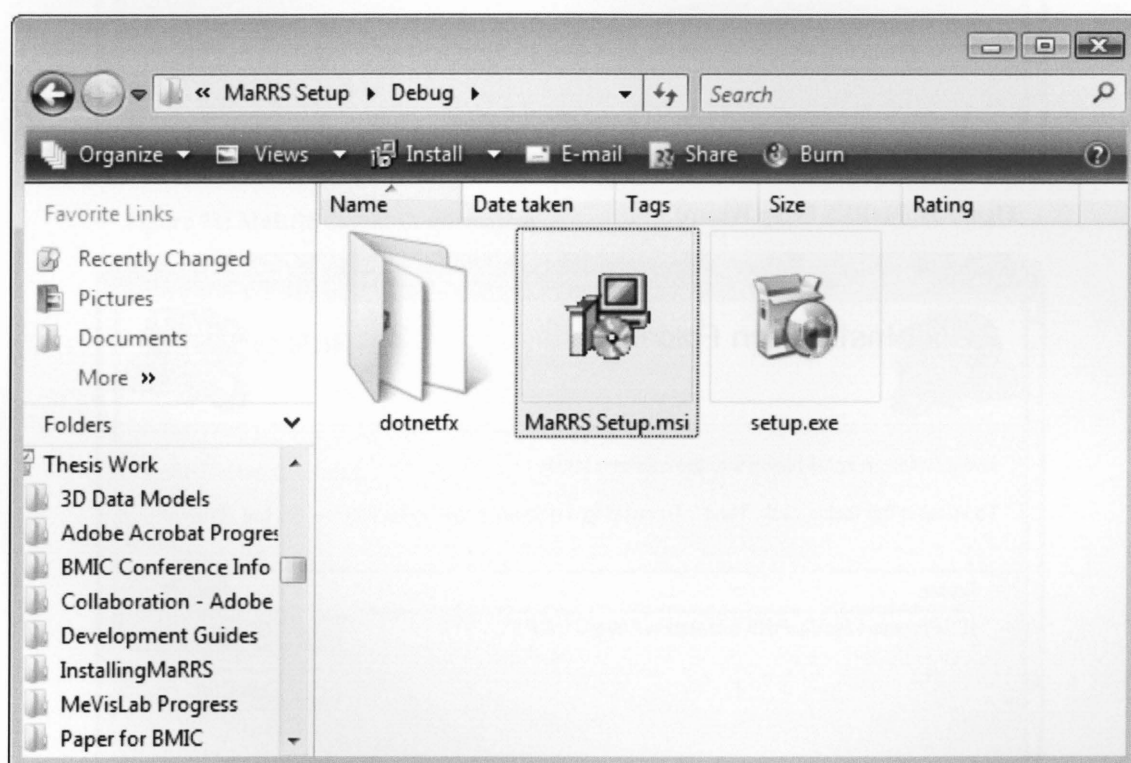


Figure 68: MaRRS Installation Package

To begin, launch *MaRRS Setup.msi* (Figure 68), and simply click *Next* on the Setup Wizard (Figure 69). Then, verify that the destination install path is “C:\Program Files\” and click *Next* (Figure 70). Click *Next* to confirm the installation (Figure 71) and when complete, click *Close* (Figure 74).

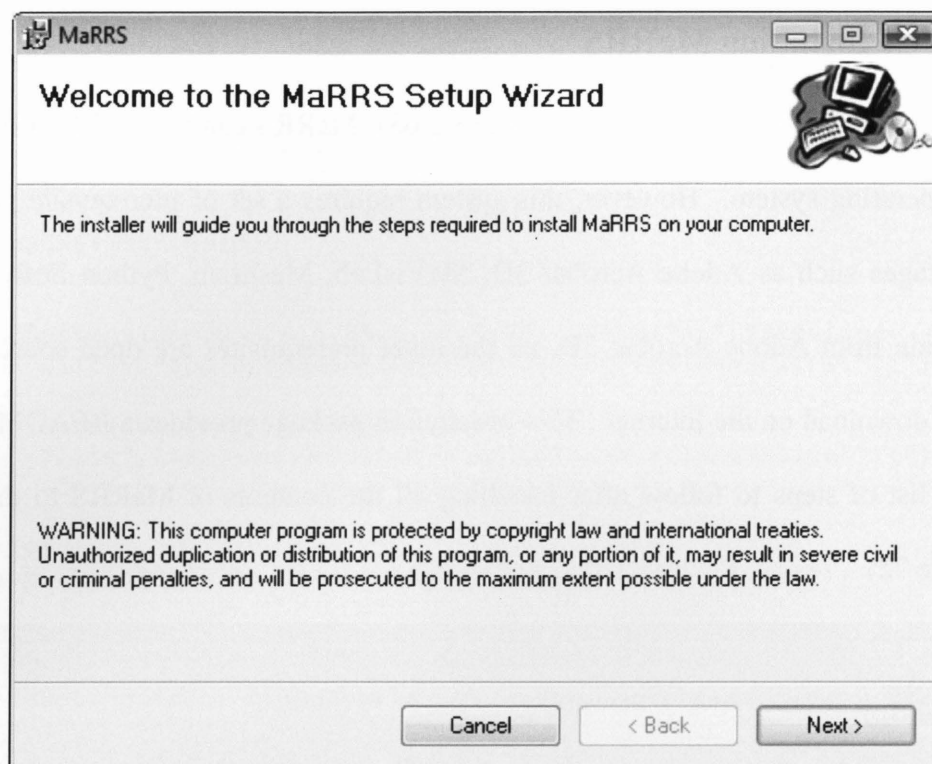


Figure 69: MaRRS Setup Wizard

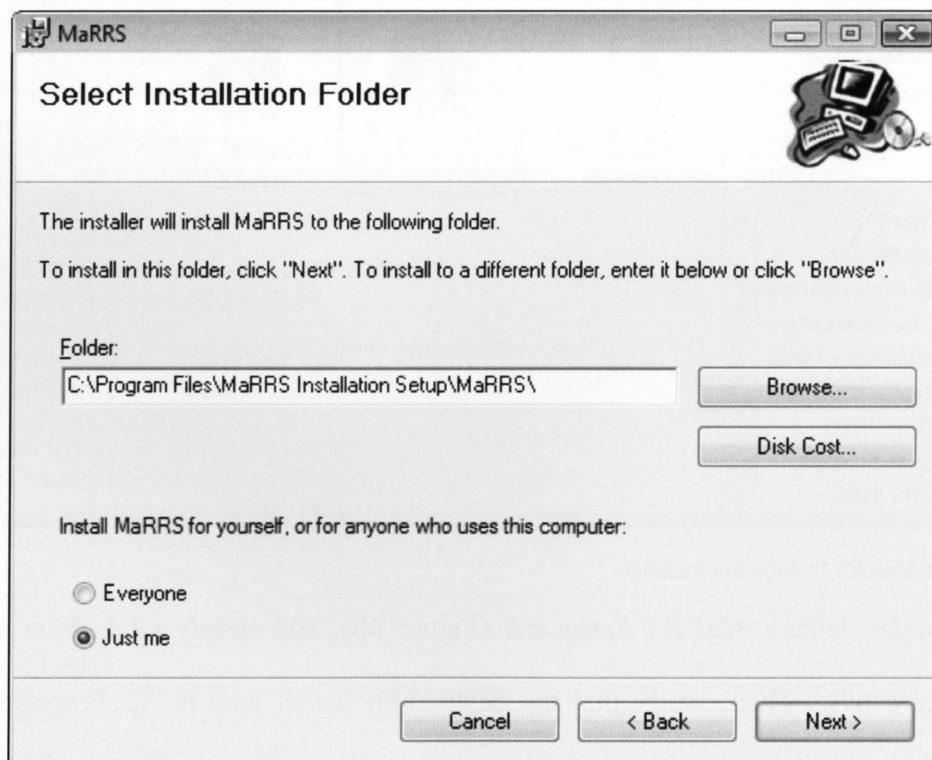


Figure 70: MaRRS Install Path

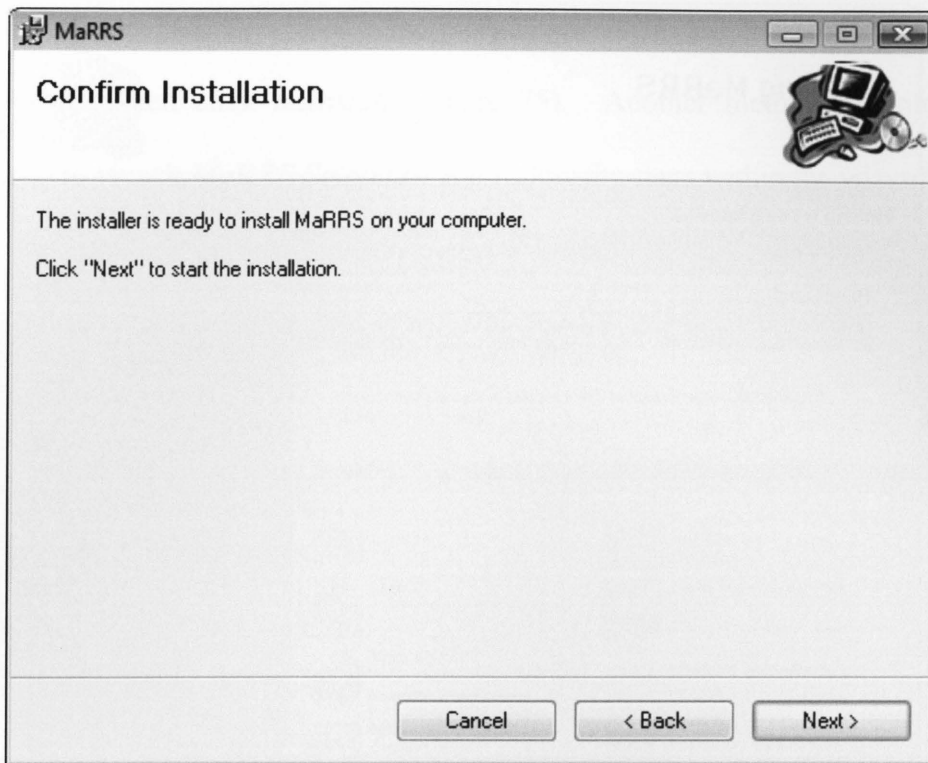


Figure 71: MaRRS Install Confirmation

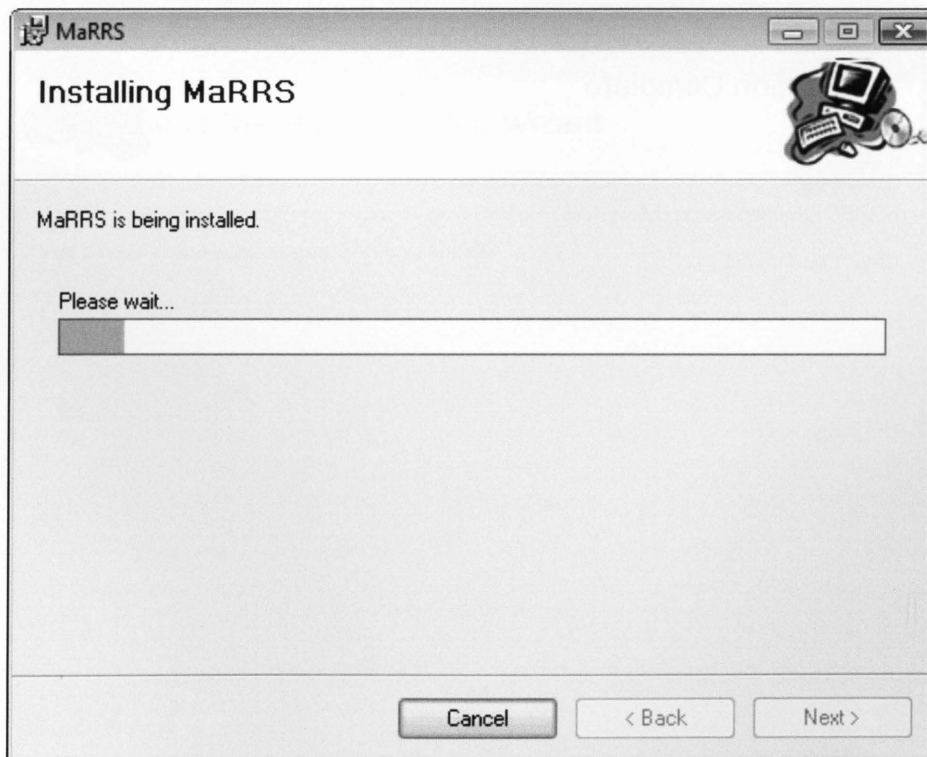
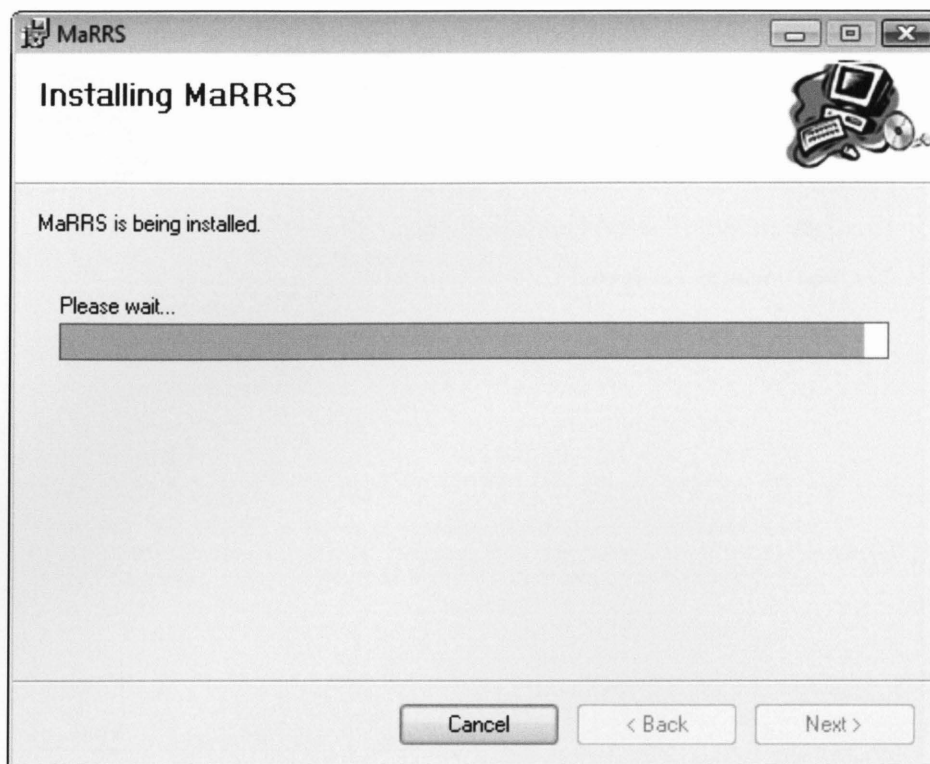
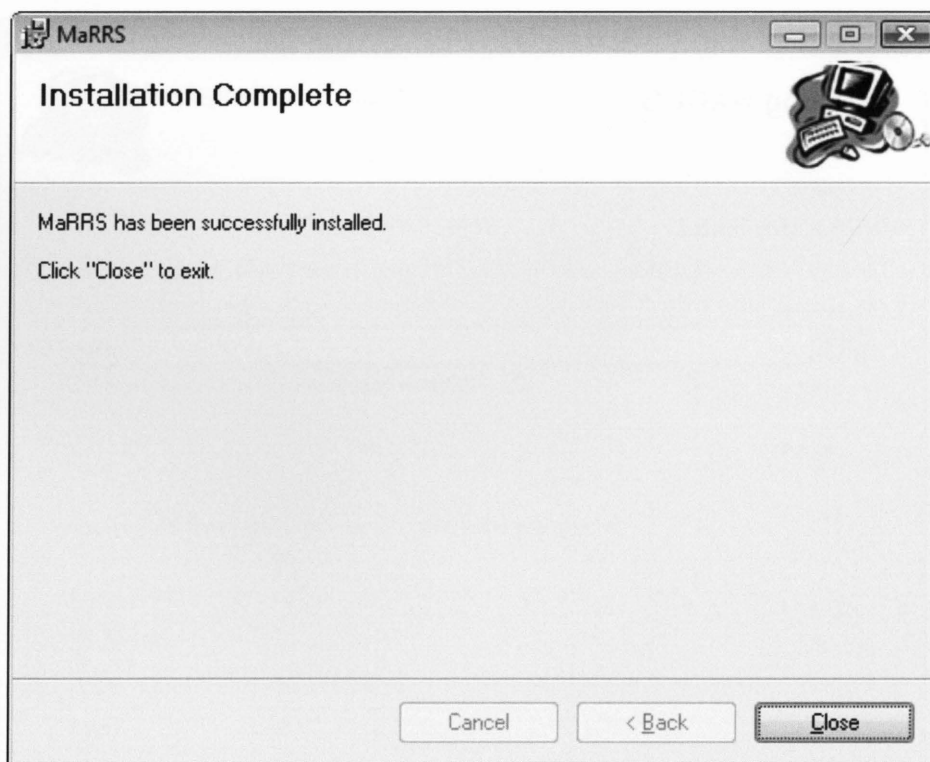


Figure 72: MaRRS Installing I



**Figure 73: MaRRS Installing II**



**Figure 74: MaRRS successfully installed**

To uninstall MaRRS, simply navigate to the *control panel*, click *add/remove programs*, select MaRRS and then click *uninstall* (Figure 75). Another method of uninstalling this application is to re-launch *MaRRS Setup.msi* and follow the steps within the wizard (Figure 76).

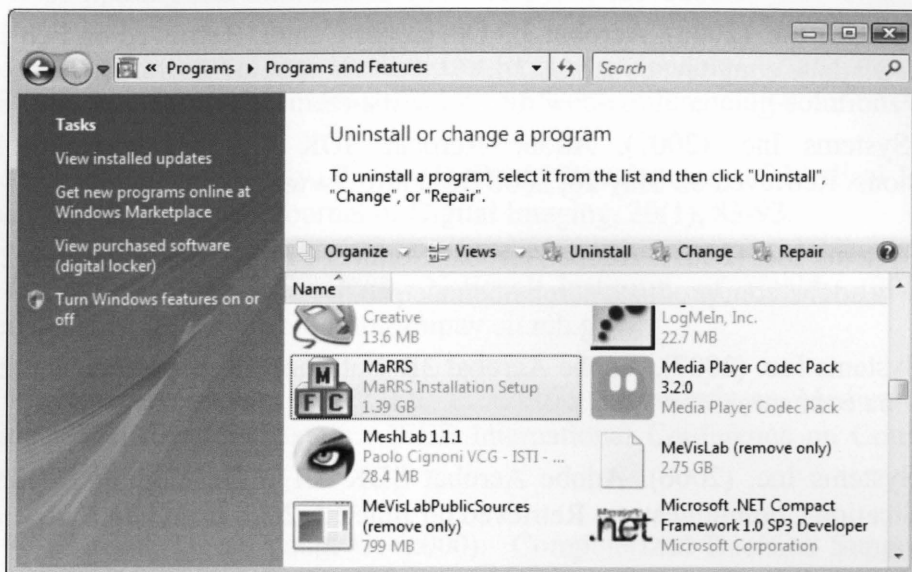


Figure 75: Uninstalling MaRRS Method I

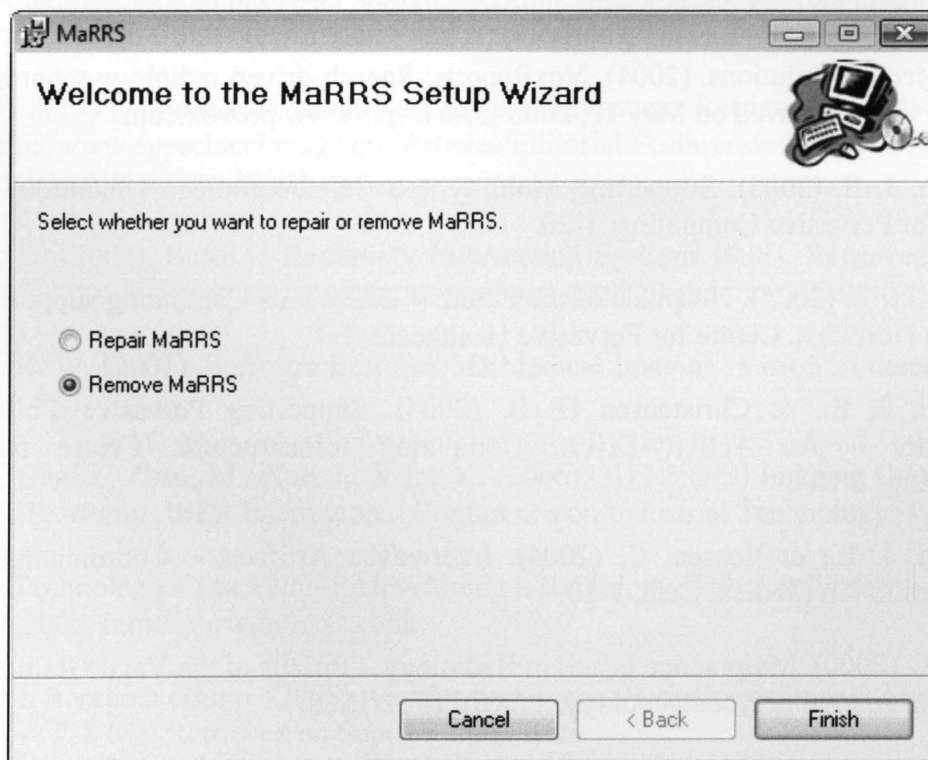


Figure 76: Uninstalling MaRRS Method II

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