
TRIP™ Conference & Workshop Poster Abstracts

Poster Session:
Monday, January 31, 2005
4:30 PM - 6:00 PM

Visualization of Human Tissue Model for Radiation Transport Applications

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Topic: Visualization

Introduction:

The galactic cosmic radiation environment is dynamic and is a function of solar cycle and solar particle events that consists of protons (85%), helium (14%) and high dose contributing heavy ions (1%). The space radiation environment is being monitored by several spacecrafts in near earth orbit and with deep space probes for understanding the radiation environment to assess the space radiation risk for human exploration. The science of the space radiation environment and its transport through the human biological systems is much complex than the most recent advancements of proton and heavy ion radiation treatment plans [Radiation Climate Map for Analyzing Risks to Astronauts on the Mars Surface from Galactic Cosmic Rays, Saganti, P. B., Cucinotta, F. A., Wilson, J. W., Simonsen, L. C., and Zeitlin, C., Space Science Reviews, 110 (1-2), 143-156, 2004]. The aspect of space radiation transport not only includes the primary high energetic particles from the free galactic space and also the secondary particles generated in the shielding shell of the space vehicle [Visualization of Particle Flux in the Human Body on the Surface of Mars, P. B. Saganti, F. A. Cucinotta, J. W. Wilson, and W. Schimmerling, J. Radiat. Res., 43, S119-S124, 2002]. Though little, human tissue offers several gradations of self shielding for the radiation environment as a function of the tissue density and depth [Visual Assessment of Radiation Distribution in the ISS Lab Module and the Human Body, P. B. Saganti, N. E. Zapp, J. W. Wilson, and F. A. Cucinotta, Physica Medica, Vol. XVII, 106-112, 2001]. The human shield model developed and used by NASA for assessing the radiation transport into the human body includes eleven tissue densities and fiftieth percentile representation of the Air Force cohort. In this paper we present the human tissue model with more realistic and larger data set representation (~50) of tissue density variations based on the visible human body data. Our first attempt included the assessment with the visible human body data set specifically to represent

the human head. We present our reconstruction of the 3D shield model for radiation transport based on the CT, MRI, and anatomical cross-sectional data [Robot control from sequential image planes of a 3D Object, S. B. Premkumar, T. L Harman, A. G. Houston and L. A. Nguyen, SPIE Vol. 2028: Applications of Digital Image Processing XVI, 158-163, 1993]. The purpose of the present work is to enhance the radiation transport properties in tissue from 11 tissue types to more than 50 tissue types.

Methods:

Cross-sectional image planes of the visible human body from MRI and CT data sets are cross-correlated with the photographic cross-sections. Making use of the CT density model data, gradations of the human tissue densities are estimated for the photographic data. Then the developed human tissue model was used for estimating the radiation transport calculations. This data is then translated to the geometric model for radiation transport visualization. Once the transport of the radiation dose and particle flux is calculated, visualization of the data is achieved utilizing Matlab routines and in-house built algorithms.

Results:

As a first attempt of these expansions, we are limiting our calculations only to the human head at this time to conserve our resources of both computing and personnel time. As part of our on-going expansions of our project, we plan to extend these approaches for the remainder of the human body. Current results of the radiation transport and visualization of human head with dose points are promising.

Discussion:

Extension of the radiation transport to the highest possible density variations of a human tissue model will open several opportunities for understating the space radiation damage to the human tissue. Current proposed model and development is such considered to be such advancement from the traditionally used limited tissue type human model.

Conclusion:

Current visualization approaches with the visible human body data is promising to expand the intricate radiation

transport in the human body. Current approach carries a promise for assessing the secondary particle transport and their dose contribution in a typical radiation treatment scenario.

The “Radiological Archivist”

Sergio Camorlinga, MSc, St. Boniface General Hospital Research Centre
 Jeffrey Diamond, PhD

Topic: Databases and Integration

Introduction:

Hospitals face a looming medical data crisis that it is getting worse as more technology is installed. TRIP initiative has identified research areas where immediate action is needed to minimize data crisis. If unattended, the data crisis might jeopardize quality of delivered services and increase substantially costs to manage and operate the data. TRIP is calling for a paradigm shift in the way radiology is practiced and delivered.

Methods:

Figure 1 shows a simplified view of the radiology department. The view builds the radiology department from four major components: Medical scanners, information systems, archive and browsers.

Results:

We introduce the Radiological Archivist initiative to R&D technology and processes to provide the archive component (Figure 2).

Discussion:

TRIP identifies interdisciplinary research that it is focused primarily in the Browsers component. We

propose the expansion of the TRIP research agenda into four major areas that follow the radiology generic workflow. The expansion is needed to provide a more comprehensive coverage of the radiology department. It also gives a structure that encompasses all radiology workflow areas. TRIP Identified problems do not come in isolation at the browser component; they are highly interrelated to other radiology components, so a global research perspective is required. Without a global research view, the radiology community has the risk to develop limited approaches to their problems.

The Radiological Archivist research is interdisciplinary and requires research in the following profile areas:

- 1) Archival Services. Breaks the technology paradigm by focusing on archival services. This allows for a variety of medical vendors for browsers and opens the architecture for more competition that brings up quality and service, and reduces costs.
- 2) Scalability Services (Connectivity, Storage, Integration). Scales to any number of scanners and browsers that might be scattered across a group of hospitals (e.g. within hospital campus, city, state or country). Provides storage capacity that grows as required and integrates continuously new data with old data.
- 3) Self-Adaptability Services. Self-adapts to new technology as the new technology is made available. It is designed to be technology independent as possible to avoid obsolescence and technology dependency, i.e. it is an evolvable software product that leverages whatever hardware technology is available.

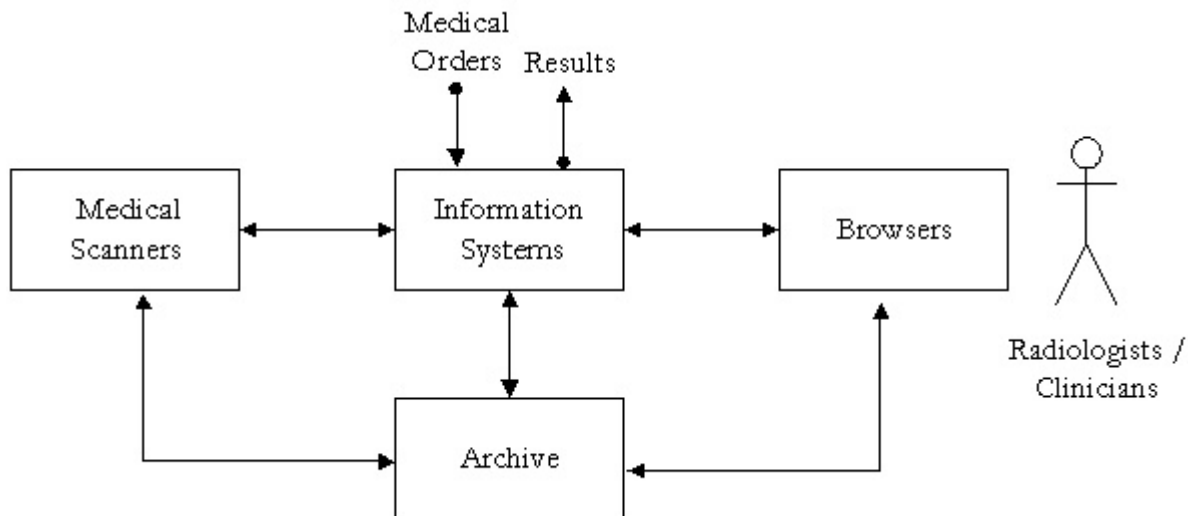


Figure 1

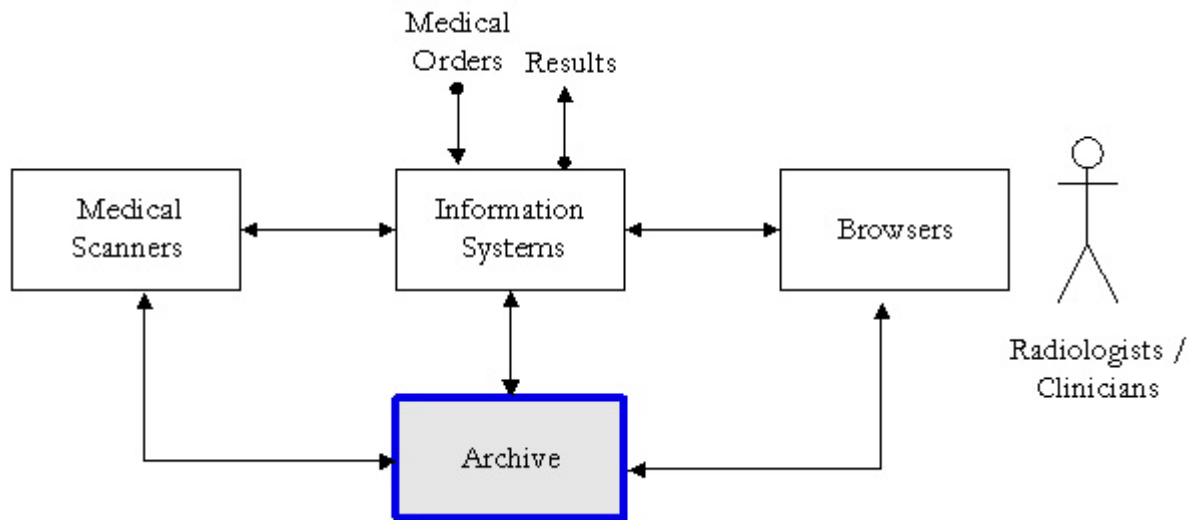


Figure 2

4) Security Services. Manages security services automatically, controls patient teams and roles to administrate security. It complies with regulations stated for confidentiality and security (e.g. HIPAA).

5) Migration Services. Integrates with legacy implementations, exchanging control information with existing systems to keep previous investments but also providing tools to migrate data to a more robust platform easily and cost effective.

6) Tool Services. Provides design and performance tools to evaluate current hospital workflows, identify technology issues and provide a tentative guidance to design archival services.

7) Mining Services. Does data mining on clinical cases to improve correlation and access to prior cases for medical diagnosis and treatment, statistical information and data warehousing.

8) Network Services. Secures a less than 'n' seconds data delivery across the network. If technology does not allow achieving it, notifies corrective actions, and informs access time with current technology deployed (e.g. auto-diagnosis, class and quality of services).

Conclusion:

A wider and global view for radiology workflow research has been proposed. The Radiological Archivist initiative is presented for the archive component.

Images and Patient Chart Information Integrated through a Hospital Information System Database

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 Peter M. Kuzmak, MS; Michael Henderson; Stuart A. Frank; John H. Christensen; Harold G. Rutherford, PhD
 Topic: Databases and Integration

Introduction:

Complete online patient data including both traditional medical chart information and clinical images is essential in providing healthcare in a multi-facility environment. To meet this need, the US Department of Veterans Affairs has developed a multimedia online patient record that integrates traditional medical chart information with a wide variety of medical images from specialties such as cardiology, pulmonary and gastrointestinal medicine, pathology, radiology, ophthalmology, dentistry, hematology, and nuclear medicine. The use of the hospital information system database to integrate images and chart information is critical to the safety and effectiveness of the multimedia record.

Methods:

The VA implemented IHE Scheduled Workflow Integration Profile enterprise-wide, not just for radiology, but also to allow DICOM capture of clinical specialties images such as ophthalmology, dentistry, endoscopy, and cardiology. A careful workflow study of the automated capture process allowed comfortable integration with existing patient care processes. The patient and study identifiers from the database are used by every step of the process and allow the integration of images, chart and database. This key information is provided to the image acquisition modality and is inserted into the headers of the images when they are captured. Then when the images are sent to the hospital information system, they

are automatically associated with the correct radiology studies and clinical specialty consults in the database.

Results:

At the present time, over 220 million images are part of online patient records at 158 VA medical centers treating more than 7 million military veterans. These images can be displayed on over 100 thousand provider desktop systems throughout the VA.

Discussion:

As the multimedia patient record has become almost complete, regulatory requirements for a single source of the patient record have dictated that the VA scan the remaining few non-electronic documents including signed forms, flowsheets, and outside reports. A diagram annotation tool is provided so that clinicians may select a diagram from the library, annotate it, and save it as an attachment to a progress note.

Image and chart information retrieval and viewing is integrated through the use of the hospital database. The VA's computerized patient record system (CPRS) user interface is modeled on the patient chart tab paradigm to allow users to locate individual notes, procedure records and other documents. However, retrieval mechanisms that were successful for a limited patient record have become less viable as the record became larger.

A multi-axis indexing scheme was implemented for rapid image and scanned document retrieval regardless of the associated tab in the online medical chart. These indices include database elements such as procedure/event, specialty/subspecialty, and type of document or image. Users can filter and sort images and documents based on these database elements. The index terms also serve to standardize retrieval of images and documents across medical centers. Thus critical database elements integrate a wide range of medical data throughout the image acquisition, document creation, record searching and retrieval processes.

Conclusion:

The VA's multimedia online patient record was the first of its kind, and remains unique in the world for its integration of images from a wide range of medical specialties with a complete interactive electronic patient chart capability.

Using The Semantic Web and Proof Technologies to Reduce Errors in Radiological Procedure Orders

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Helen H. Chen, PhD; Jos De Roo, MSc

Topic: Databases and Integration

Introduction:

The obvious benefits of radiological procedures often come with harmful side effects and high costs. The Radiation Protection 118 - Referral Guideline for Imaging [1], cautions against the wasteful usage of radiology such as unnecessary or too frequently occurring investigations, investigations that result in little or no impact on patient management, and wrong investigations. In each case, the patient may be subjected unnecessarily to irradiation and scarce medical resources are wasted.

This paper presents a highly scalable framework based on semantic web technologies for integrating the medical knowledge contained in such guidelines and heterogeneous patient information. It demonstrates how proof technology can be used to significantly reduce the wasteful or wrong usage of radiological procedures by detecting inconsistencies. The techniques involve integrating knowledge across a wide range of sources.

Methods:

Our study uses N3 notation [2] and the OWL Web Ontology Language [3] to transform the Referral Guideline for Imaging [1] into a machine-readable medical knowledge base based on ontologies. The ontology (radGuideline) associates clinical problems with preferred investigations, and captures in rules the recommendations and comments that contain the imperative wisdom of the medical community. The probabilistic nature of the data is captured through the use of a special vocabulary developed to capture the explicit meaning of the recommendation. The Ontology enables the reuse of existing medical knowledge by linking this specialized information with other medical ontologies such as SNOMED CT [4] for standard description for clinical problems and the patient's history.

Medical histories are often stored in various databases in a hospital, and even at different locations in a community healthcare setting. The ontology provides structure and meaning of patient medical data and enables the proof engines to understand and utilize patient data without having to deal with the differences in data format or location.

Semantic web engines Euler [5] and CWM [6] are able to generate proofs based on the given patient conditions (medical history and physical condition) and the radGuideline ontology.

Results:

We apply these techniques to a number of clinical scenarios pertaining to radiological orders for female patients at reproductive age. The system is able to validate the proposed order against the specific patient demographic data, medical record that are stored at dispersed locations and rules prescribed by the Radiation Referral Guideline.

Discussion:

The true potential of the proposed method is its capability of integrating cross-domain knowledge and data seamlessly on explicit and unambiguous terms expressed in ontologies. The explanations generated by proof engines provide evidence to clinicians for a decision. It can even provide alternatives. The final decision still lies in the hands of a clinician, but making such key information and evidence readily available to him/her is extremely important in the presence of the large volume of data. It can help to eliminate medical errors caused by overlooking vital facts when making medical decisions.

Conclusion:

By using semantic web technology, we are able to link different medical knowledge-bases to enlarge our medical expertise in order to deliver relevant information to the clinician, when and where they need it. The information system is also capable of raising flags when a prescribed radiological procedure is not safe for a patient or is not normally the most effective means according to the latest medical advancement or protocol.

Optimizing Workflow when Integrating Multi-Vendor RIS and PACS Solutions

Kevin C. Ehlers, MSEE, Medical College of Wisconsin
Ivan Cvekic; Paul Hebble; Mike Henderson; Ashish Sant;
Charles E. Kahn, Jr., MD, MS

Topic: Navigation & User Interface Design

Introduction:

Radiologists interact with several information systems for image interpretation and report generation. In addition to a radiology information system (RIS) and a picture archiving and communication system (PACS), radiologists may require access to a computer-based patient record (CPR) system for viewing additional

patient information and/or a system for dictation. Particularly when institutions implement products from different vendors, the systems may not share information, and may have separate logons, user interfaces, and input devices. This scenario can introduce inefficiency in radiologist workflow, make it difficult to locate critical information, and introduce the possibility of error. This presentation summarizes the design and functionality of a multi-vendor RIS/PACS workstation, which addresses these issues.

Methods:

The Radiology department of Froedtert Hospital and the Medical College of Wisconsin (Milwaukee, WI) utilizes the Horizon Medical Imaging PACS (McKesson Medical Imaging Group, Richmond, BC, Canada). The department is in the process of migrating to the Radiant RIS (Epic Systems Corporation, Madison, WI), which includes dictation functionality. The RIS implementation is part of an enterprise-wide CPR installation. A set of integration options and high-level requirements was developed. The integration option selected was RIS client software installed as a thick client on the McKesson Horizon RadStation (HRS) workstation. This option required a custom COM/ActiveX interface. The high-level requirements for this integration included: single sign-on for both applications, RIS displays on a separate third color monitor, patient context preserved between applications, and radiologist workflow driven by the RIS worklist.

Results:

The integrated workstation provides a RIS-centric approach to radiologist workflow. A single logon (username/password) opens the RIS and PACS applications. The RIS opens on a dedicated color monitor, separate from the high-resolution grayscale monitors. A radiologist selects a study to review from the RIS, which automatically opens the associated images on the PACS. Image manipulation, adjustment, and hanging protocols are controlled through the PACS. Patient context is preserved between applications at all times.

A Radiologist can dictate a report, or create a report utilizing templates in the RIS. Closing the study review activity advances to the next exam on the worklist, and opens the associated images automatically.

Discussion:

The integrated workstation provides a RIS-centric approach to improving radiologist workflow and productivity. The workstation utilizes a single CPU, keyboard, mouse, and microphone. Advanced microphone support provides an alternate input and

control mechanism for the radiologist. Access to the patient's CPR data is available through the chart review function in the RIS. Likewise, radiology results are also available to the enterprise via the CPR. The status of the closed study is automatically updated in PACS.

Conclusion:

Radiologists are often required to interact with a number of separate information systems in order to complete their work. Improving radiologist workflow, providing easy access to information, and improving patient care, are common goals shared with our RIS and PACS vendors. To this end, an integrated workstation utilizing separate RIS and PACS applications has been developed.

Image-based Biomedical Geometry Extraction and Mesh Generation for Computer-Aided Engineering Applications

Yasushi Ito, PhD, University of Alabama at Birmingham (UAB)

Alan M. Shih, PhD; Philip C. Shum; Bharat K. Soni, PhD; Kazuhiro Nakahashi, PhD; Andreas S. Anayiotos, PhD

Topic: CAD and Image Processing

Introduction:

Computer-aided engineering (CAE) has been widely used for decades in many engineering applications to design, analyze, and optimize models of interest. Computational fluid dynamics (CFD), for example, has been widely used to analyze the performance of aerospace vehicles. Its application to biomedical problems has gained enormous attention during recent years. It demonstrates great potential to help predict the outcome of a medical procedure, or design of a treatment. However, geometric modeling and mesh

generation from computed tomography (CT) or magnetic resonance imaging (MRI) data are often major barriers that prevent CAE researchers from tailoring their mathematical methods for biomedical applications. The objective of this effort is to develop accurate geometry extraction and high-quality mesh generation algorithms to facilitate the process of CAE analyses for biomedical applications.

Methods:

For extracting surfaces from CT/MRI data, we mainly use open source libraries, the Insight Segmentation and Registration Toolkit (ITK), and the Visualization Toolkit (VTK). Although the resulting geometry surface can be triangulated, such meshes are not suitable for CAE simulations due to the existence of many low-quality triangles, which are defined as triangles with poor geometric shapes and size variation. To create high-quality surface meshes, we propose two approaches. One is a direct advancing front method, and the other is a modified decimation method. The former emphasizes the controllability of local mesh density, and has been applied many geometries. The latter combines quality enhance methods (including edge swapping based on the Delaunay property, an angle-based node smoothing, and the removal of nodes that have too small number of neighbors), a Delaunay triangulation method to subdivide too large triangles, and a function-based mesh coarsening based on local curvature and volume thickness. This approach enables semi-automated mesh generation. An advancing-front based volume meshing method is employed.

Results:

Figure 1 shows a surface mesh for an iliac artery model using the direct advancing front method. We specify high-density node distribution around the bifurcation. Figure 2 shows a surface mesh for a mouse skull model, while illustrated in Figure 3 is the same mouse skull mesh with interior surfaces including the brain. A

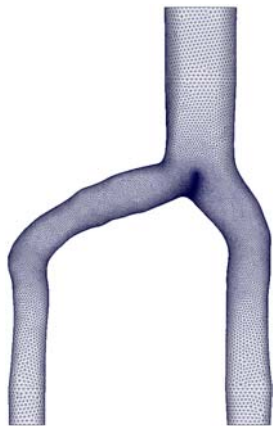


Figure 1

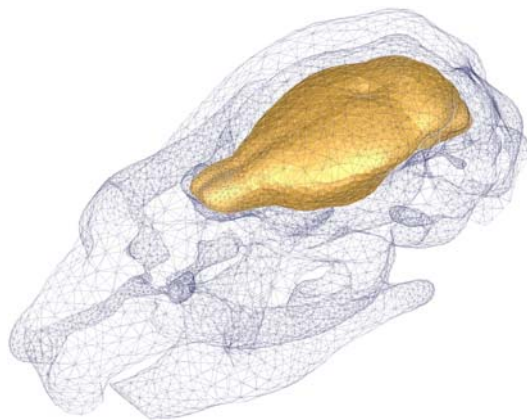


Figure 2

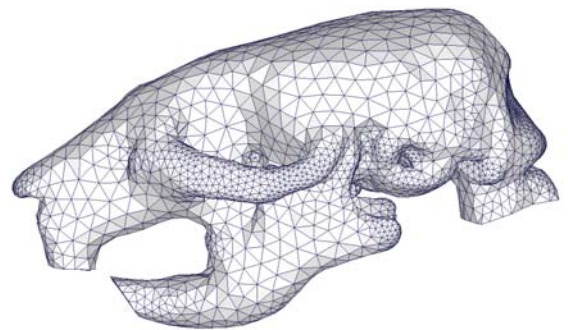


Figure 3

triangulated surface is extracted from MRI data, and then it is modified to create a high-quality mesh. The triangles of the skull mesh are smaller in high-curvature regions and in the rear due to the existence of the brain surface inside. [Figure 1: Surface mesh for an iliac artery model] [Figure 2: Surface mesh for a mouse skull model] [Figure 3: Surface mesh for a mouse skull model with brain inside]

Discussion:

As shown in the figures, our surface mesh generation methods guarantee the quality of resulting meshes and the volume mesh generation method also produces quality meshes. Such meshes can be used for high-fidelity numerical simulations using CAE techniques.

Conclusion:

We have developed efficient unstructured mesh generation methods based on geometry extracted from CT/MRI data. High quality numerical meshes from these methods are shown and they are used for high fidelity CAE analyses.

Semantic Models for PACS Integration

Charles E. Kahn, Jr., MD, MS, Medical College of Wisconsin

David S. Channin, MD; Kevin C. Ehlers, MSEE

Topic: Databases and Integration

Introduction:

Effective radiology workflow in a digital environment requires knowledge about the structure and content of diagnostic imaging studies. This knowledge can be used to improve clinical service by its use in decision support - for example, in image-display protocols and clinical decision support. It also can enable more efficient operations by providing operational logic and improving interoperability with enterprise information systems through the use of common semantics. The Integrating the Healthcare Enterprise (IHE) initiative defines a model for radiology operations. Orders placed by clinicians are mapped to requested procedures, which are the units of work for the radiologist. The requested procedures are in turn mapped to scheduled procedure steps to be performed at the modality. Content information relates to the anatomical content and knowledge of the orientation and position of these elements. A semantic network describes an ontology of concepts and the relationships among them. We explored whether knowledge of the structure and content of radiology workflow could be encoded as a semantic network.

Methods:

The NEON (Network-based Ontology) software suite - a Web-based environment for creating, viewing, and updating semantic network models - was used to create an ontology of radiographic and CT imaging procedures of the chest and abdomen. The ontology for imaging procedures included subsumption and component relations. Subsumption (usually termed the "is-a" relation) expresses the hierarchical relationship between a more general concept and a more specific one. The component relation indicates that one concept is a part of another concept. We created a limited semantic network model of IHE-compliant radiological procedures and explored the potential impact on PACS integration.

Results:

The semantic network incorporated concepts for imaging orders, requested procedures, scheduled procedure steps, anatomical descriptors and organ systems. For example, an order for "CT Chest, Lung Cancer" would be mapped to a requested procedure of "CT Chest, Tumor Protocol, With Contrast." In turn, this requested procedure might be mapped to four scheduled procedure steps: "CT Chest Frontal Scout View," "CT Chest Lateral Scout View," "Intravenous Contrast Injection," and "CT Chest, Axial acquisition, tumor protocol, with contrast." Using the knowledge encoded in the semantic network, a PACS display manager could recognize that a CT Chest Frontal Scout view is an appropriate comparison image for a PA chest radiograph, as both are frontal projection images of the chest.

Discussion:

One advantage of this approach is that the knowledge about imaging procedures can serve several purposes. The ontology provides a normative model for imaging procedures that indicates their structure and what they should include. The ontology also could be used to define clinical history requirements for each of the procedural elements and to drive the contents of radiology reports and reporting templates. The model's terms would be integrated with RadLex, SNOMED and DICOM terminologies.

Conclusion:

A semantic network can represent information about imaging procedures that can be used to guide both technical and clinical operations. The information captured in the ontology serves as a reference to the "corporate knowledge" of medical imaging.

Paperless Method for Correlating X-Ray Interpretations Between the Radiology and Emergency Departments: Implementation of an Electronic Tickler File to Optimize patient Follow-up

Ralph M. Koenker, MD, Sutter Novato/Marin General
Gary Woodruff RT; Tom Hepburn

Topic: Evaluation of Methodologies and Validation of Performance

Introduction:

Accurate correlation of X-ray interpretations between the radiologist and emergency physician is important to insure correct patient follow-up. We report a paperless method that helps physicians keep track of those cases where interpretation discrepancies have occurred.

Methods:

Using a soft-copy diagnostic workstation in the emergency room (Siemens MagicView 1000), preliminary interpretation comments are entered by the ER physician using the “study comment” box, which appears automatically at the moment of study closing. These comments become part of the study Dicom header. Once the study is opened by the interpreting radiologist, the ER physician typed comment is viewable (e.g., neg wrist.... ER DOC1). In the occasional case of a discrepancy, the radiologist appends the comment with the alternate interpretation (e.g., neg wrist...ER DOC1... ..+ navicular fx....Rad1) ; following this comment step, the radiologist then clicks on an icon which flags the case for follow-up.

Cases flagged for follow-up can be viewed by the ER physicians, using an icon that filters the list for flagged cases from the last 4 days. The ER doctor determines if additional treatment or phone calls are needed. The follow-up plan is then amended in the comment field with the dictation ID# if additional digital dictation was placed into the chart transcribed record (e.g., neg wrist....ER DOC1.. ..+ navicular fx....Rad1..... patient called0115437) In the emergency department, flagged cases are viewable by all emergency physicians for a four-day period. After that, flagged cases are viewable only by the radiology chief or ER department chief using a filter, which searches, for flagged cases on the archive.

Results:

The filter “follow-up cases” is used by ER physicians prior to completing their shift. Adjustments to patient follow-up and care are then pursued. Semiannually, the department chiefs review a cumulative list, and the cases

with educational value are presented at the ER physician group meeting.

Discussion:

Traditionally, discrepant interpretations between the emergency room and radiology department are handled using a paper based tracking method. Paper based techniques have problems associated with transporting the forms between the main x-ray department (frequently in a different wing) and the emergency department. Moreover, the papers can easily be lost in a busy emergency room environment. Accordingly, a paperless method for QA tracking was developed. The importance of a “tickler file” or listing of patients requiring follow-up was quickly identified as a key requirement, and the employment of a comment field with multiple appended comments allows for thorough tracking and documentation of physician follow-up steps.

Conclusion:

Using multiple amended comments to the “study comment field, “ we describe a paperless method which affords tracking of QA cases requiring additional follow-up necessitated by a discrepant interpretation of the radiograph.. The availability of an electronic “tickler file” facilitates the process. This workflow solution assists the on-duty ER physician in keeping track of those cases that have been flagged by the radiologist as requiring additional follow-up or call back.

Overcoming Image Analysis Overload by Using Structural Feature-Based Paradigm

Boris Kovalerchuk, PhD, Central Washington
University

Florian Delizy; Logan Riggs; James Ruiz, MD

Topic: Visualization

Introduction:

Modern medical imaging systems produce a large number of images at the speed that is much higher than the speed of their analysis. The number of images that can be analyzed by an imagery analyst per hour is limited. It has become clear that any acceleration of human reading of images cannot solve the problem in the long run, and fundamentally new ways to solve the problem is needed [Andriole et al., 2003]. The goal of this paper is proposing a new paradigm that may overcome image analysis overload in the long run. In essence, a fundamentally new paradigm of reading images requires avoiding the actual reading of images

as a massive enterprise. This seems an impossible and non-constructive paradigm. However, a difficult but a constructive way was discovered in the defense community - feature-based image analysis for image registration, change detection, and targeting [DARPA, Air Force, NGA, 2004]. In the ideal realization of this paradigm the imagery analyst will not view and analyze a massive set of images. The analyst will view and analyze the features that were extracted and generated from images automatically, and may manually examine some images that contain features of interest.

Methods:

In the feature-based paradigm, the challenge is in: (1) extracting and generating features automatically, and (2) viewing and analyzing features of images much faster than the actual images without losing the quality of analysis. Significant progress in solving problem (1) has been achieved and new productive directions have been proposed. Many features can be extracted using current tools and then can be used to generate secondary features. This process of feature generation can continue and finally generate diagnostic features directly or using data mining techniques. The problem (2) is much less explored. In this paper we are proposing a new visualization and visual data mining method for solving the problem (2). This method has an advantage over other methods known in information visualization and visual data mining. It allows a user to see not only image representation, but also its structural relationships to other images of the same patient and other patients along with the representation of the images that were already identified to be in specified diagnostic categories (e.g., highly suspicious for malignancy or highly suspicious to be benign). This visualization is based on the theory of monotone Boolean functions.

Results:

This visualization paradigm has been used to represent 10 features of 100 mammograms in a single display that clearly shows their relations to each other and to the breast cancer diagnostic feature. This visualization allows the viewing of the representation of 1024 different images. The software is written in C++ using OpenGL and has a user-friendly interface.

Discussion:

In our future work we will concentrate on expanding structural feature-based paradigm for larger sets of features.

Conclusion:

The general problem of overcoming the image analysis overload can be solved in an unconventional way of

substituting analyst work with images with the work with features extracted and generated from images. This new opportunity has several challenges that should be addressed in future research.

Merging Human Interpretations with Computer Analysis to Improve Diagnostic Accuracy of Breast MRI

Alan I. Penn, PhD, Alan Penn & Associates, Inc.
Scott F. Thompson, PhD

Topic:
CAD and Image Processing

Introduction:

Differences in protocols and interpretation standards have led to large variability in diagnostic accuracy when interpreting breast MRI. A CAD (computer-aided diagnosis) system is being developed that provides a 2nd opinion of likelihood of malignancy with the goal of improving diagnostic accuracy of radiologists.

Methods:

A combination of reader interpretations and computer analysis are merged into a 2nd opinion of likelihood of malignancy, which the reader can use in making a final diagnosis. Improvement is measured by increase in ROC area when 2nd opinion is provided over image-only assessment. Study design builds on methodology developed by Getty, Pickett, D'Orsi, Swets (Invest Radiol 23:240-252) for mammograms in which interpreted features were merged into 2nd opinion. In the current study, two reader interpretations involving the lesion margin were combined with three computer-generated, image-based features: signal intensity (SI), enhancement curve (EC), and adjacent heterogeneity (AH). The computer features had two determinate values: "benign" and "cancer;" and "indeterminate." Computer feature discrimination is measured as accuracy (determinate values only) and fraction of values that are determinate. Twenty radiologists (5 specialists, 15 non-specialists) each assessed 60 cases from a set of 169 biopsy-proven cases (89 cancer; 80 benign) from 6 breast MRI systems.

Results:

Mean ROC areas for experts was .75 without CAD and .80 with CAD. Mean ROC for non-specialists was .72 without CAD and .77 with CAD. 15/20 radiologists showed improvement with CAD, 2 were statistically significant (2-tailed; $p < .05$) and 3 nearly significant ($.05 < p < .10$). The t-test for paired data resulted in $p = .004$ (2-tailed), indicating strong significance when

case-sample variance is not considered. Accuracies for computer features were: SI= 0.65; EC=0.61; AH=0.63. Fraction of feature values that were determinate: SI=1.00; EC=0.99; AH=0.41. Kappa statistics showed high levels of agreement between sessions (based on determinate values only): SI=0.94; EC=0.88; AH=0.77.

Discussion:

The study included a diverse mixture of clinical cases, which were generated from a variety of imaging systems and interpreted by radiologists with varied backgrounds and areas of expertise. These results are believed to be reasonably representative of a clinical environment in which the patient population has a relatively high likelihood of cancer and are interpreted by non-specialists. The improvement in diagnostic accuracy in this study along with those reported in the aforementioned mammogram study support the hypothesis that radiologists are positively influenced by computerized merging of interpretations into a likelihood measure. The computer features used in this study had accuracies comparable to the interpretive features used by radiologists, and high intra-observer consistency between readings; these features are believed to have improved the overall accuracy and reliability of the likelihood measure presented to readers.

Conclusion:

A breast MRI CAD system that merges radiologist interpretations and computer analysis into a 2nd opinion of likelihood of malignancy may serve an important role in improving diagnostic accuracy.

Assessing Brain Tumor Progression on Interval MRI: Benefit of Automatic Image Registration

Jeffrey M. Solomon, MS, Medical Numerics, Inc.
Jianhua Yao, PhD; John A. Butman, MD, PhD

Topic: CAD and Image Processing

Introduction:

Monitoring brain tumor progression involves comparison of serial MRI scans for changes in tumor size. Radiologists perform this task by visually comparing MRI slices with corresponding anatomy. Despite the use of standard anatomic landmarks, considerable variation in slice orientation can be present from scan to scan. This variation makes side by side image comparison difficult, particularly for irregular tumors. Computer based automatic MR image registration of the brain is a solved problem [Woods,

Smith], but has not been used routinely in the clinical setting. We have implemented a "Registration Engine" to automatically perform this process, and found it to be extremely beneficial to the radiologist, particularly in the assessment of complex cases. To quantify this benefit, we measured the interpretation time required to assess pairs of brain MRIs for presence or absence of brain tumor progression.

Methods:

Brain MRI was performed in 169 patients for clinical purposes on at least two separate occasions. The volumetric 3D SPGR T1 weighted post contrast sequences were co-registered using the Registration Engine (RE). The RE was developed to integrate co-registration into clinical workflow by automatically co-registering 3D datasets to prior references and to send such co-registered data to PACS for clinical review. To assess interpretation time, a customized interface was developed to present pairs of 3D T1 weighted MRIs to the radiologist. The radiologist was asked to choose whether scan A or scan B showed progression of tumor, or whether there was no change. A button click initiated viewing of the two scans as axial 3mm sections. The radiologist could then scroll through slices side by side. Following choice of A, B, or no change, a button click logged the radiologist's choice as well as the time interval. The temporal order of the image pair was randomly chosen. There were 252 pairs of images to compare of which 133 were unregistered and 119 were registered.

Results:

The average time taken to assess brain tumor change for patients with unregistered scans was 23.75 ± 11.43 seconds. The average time to assess registered scans was 15.45 ± 8.61 seconds. This difference was statistically significant ($p < 1 \times 10^{-9}$, unpaired t-test).

Discussion:

The marked reduction in interpretation time reflects our clinical experience in using the registration engine, that is, using co-registered data sets facilitates interpretation. By using a simplified viewing interface, we minimized tasks that did not directly apply to interpretation of the data, so the times recorded reflect minimal times needed to assess progression. In the clinical setting, many other image attributes are often evaluated, (e.g. mass effect and ventricle size), and multiple sequences are performed, so that the temporal benefits may be magnified. Future studies will determine whether image registration not only improves the efficiency of scan interpretation, but also improves the accuracy of image interpretation.

Conclusion:

Image co-registration facilitates assessment of brain tumor progression with MRI. The time taken to interpret unregistered scans was 54% greater than for registered scans.

A Proposed Paradigm for Deploying Processing Software

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Topic: Databases and Integration

Introduction:

Many new imaging and interpretation techniques, such as molecular imaging, depend on the availability of sophisticated, targeted post-processing to extract meaningful information out of the base image data. Users expect this software to run on their particular flavor of diagnostic workstation. The creators of such post-processing software are faced with the dilemma of how to deploy their software in a world of proprietary workstations with proprietary interfaces. A version of the software created for one particular vendor's system typically must be totally re-engineered in order to run on a different vendor's system. Such re-engineering consumes precious resources that could be better utilized in advancing new processing techniques instead of re-creating the same processing technique for multiple proprietary systems.

Methods:

One proposal for overcoming this drain on engineering resources is to create an open, standardized Application Program Interface (API) to medical computing systems. Users would be able to plug any post-processing application written to that API into any medical computing system that supports the interface. Since most medical imaging systems utilize DICOM, the proposal suggests using DICOM semantics for communicating information about images and related data between the hosting application (e.g., the medical imaging workstation) and the hosted application (e.g., the post-processing module).

In addition to the standard API the proposal also would create a standardized methodology for describing hosted applications. This meta-data about applications could facilitate the selection of an appropriate application to address the task at hand.

Results:

The DICOM Standards Committee has assigned a new working group (WG 23) to this topic of "Application Hosting". The proposed first phase of standardization would allow a hosting application to provide a set of DICOM objects (e.g. images) to the hosted application for analysis or processing. The hosted application would be able to return results in the form of new DICOM objects (e.g. images or structured reports). The working group is gathering use cases for this first phase, and will draw specific requirements from those use cases to guide the standardization effort. WG 23 plans to review the available technology prior to selecting methodologies for describing and implementing the API.

Subsequent standardization phases could include access to non-interactive application services, such printing and archiving, and possibly access to interactive services such as GUI elements. If there is a need, other potential directions might include interactions between hosted applications or descriptions of workflow (i.e. how to accomplish a task utilizing multiple 'plug-ins' at various stages).

Discussion:

The notion of software add-ons or 'plug-ins' is quite common in the computing world, and has been successfully employed to extend the capabilities of web browsers, media players, graphical editors, publishing programs, etc. But even in the computing world plug-ins are often tied to a particular host program. For example, a plug-in written for the Netscape browser does not work in Microsoft Internet Explorer. This proposal would allow the same application to run in the context of multiple host medical systems.

Conclusion:

This work is just beginning. Interested parties are invited to participate in the effort.

Clinical Image Processing Services at the National Institute of Health

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Topic: CAD and Image Processing

Introduction:

The accurate visualization of anatomy could be arduous, especially when the clinician is presented with large volumes of images of detailed and sometimes obscure

anatomy. Fortunately, this process is facilitated with the services provided by Clinical Image Processing Services (CIPS) of Clinical Center at the National Institute of Health (NIH). CIPS provides accurate and timely advanced image processing of diagnostic radiology images for clinical care, research, and training. CIPS takes large amounts of multiple image data sets and processes them into 3D visualization. These are more manageable, clearer visualization for diagnosis, surgical planning, research, and training. The process is done to the satisfaction of the clinician and it reinforces pertinent information which is beneficial to the treatment of the patient.

Methods:

The CIPS manage and process large image data sets by utilizing proprietary workstations, multiple image processing software applications, and Picture Archive Communication Service (PACS). CIPS provide six categories of services: Image Processing (IP) measurement, IP dynamic enhancement, IP perfusion, IP 3D reconstruction, IP virtual endoscopy, and IP angiography.

Results:

CIPS converts and processes Magnetic Resonance Image (MRI) and Computerized Tomography (CT) images into studies that yield additional and viable information, as well as smaller image data sets.

Discussion:

For the purpose of this poster, IP Angiography category will be discussed. IP Angiography is 3D CT and/or MRI imaging sets that are obtained after the administration of intravenous contrast. For instance, a CT abdomen and pelvis exam was ordered for a 25 year old female for renal transplant donor screening. For this study, 337 images were obtained at 1.2mm slice thickness. On a General Electric 4.1 advantage workstation, the images were processed using the Volume Rendering protocol, which produced a 21 image data set that demonstrated and confirmed the initial reporting of a left accessory renal artery. The processed data set is made available to the clinician as an animation (which rotates 360 degrees), color DICOM images, and MIP (Maximum Intensity Projection) images. The clinician is able to see a 3D image set of the kidney and veins, artery, aorta, plus the accessory renal artery and their relation to each other during the surgical procedures.

Conclusion:

Using the services of the CIPS department, CT and MRI studies, which normally consist of large image data sets, can be successfully processed into more expressive and manageable 3D visualization.