Linking DICOM Pixel Data with Radiology Reports using Automatic Semantic Annotation

Sayan D. Pathak[1a], Woojin Kim[b], Indeera Munasinghe[c], Antonio Criminisi[c], Steve White[a], and Khan Siddiqui[a]
[a]Microsoft Health Solutions Group, 1 Microsoft Way, Redmond WA, USA
[b]Department of Radiology, The Hospital of the University of Pennsylvania, Philadelphia, PA, USA
[c]Microsoft Research Labs, JJ Thomson Ave, Cambridge, Cambridgeshire UK

ABSTRACT

Improved access to DICOM studies to both physicians and patients is changing the ways medical imaging studies are visualized and interpreted beyond the confines of radiologists' PACS workstations. While radiologists are trained for viewing and image interpretation, a non-radiologist physician relies on the radiologists' reports. Consequently, patients historically have been typically informed about their imaging findings via oral communication with their physicians, even though clinical studies have shown that patients respond to physician's advice significantly better when the individual patients are shown their own actual data. Our previous work on automated semantic annotation of DICOM Computed Tomography (CT) images allows us to further link radiology report with the corresponding images, enabling us to bridge the gap between image data with the human interpreted textual description of the corresponding imaging studies. The mapping of radiology text is facilitated by natural language processing (NLP) based search application. When combined with our automated semantic annotation of images, it enables navigation in large DICOM studies by clicking hyperlinked text in the radiology reports. An added advantage of using semantic annotation is the ability to render the organs to their default window level setting thus eliminating another barrier to image sharing and distribution. We believe such approaches would potentially enable the consumer to have access to their imaging data and navigate them in an informed manner.

Keywords: Machine learning, Natural Language Processing, DICOM, semantic association, classification, regression

1. INTRODUCTION

Currently, physicians face ever increasing volumes of studies to be interpreted in conjunction with decreasing reimbursement and thus face pressure to become more productive. All this leads to rapidly shrinking time allocated to analysis of each patient's image data. The radiology report is used to get a textual impression of the radiologist's interpretation of the images. Even though access to both images and radiology reports are increasingly becoming more common, lack of semantic mapping between the textual representations and the DICOM pixel data limits the optimal use of the healthcare data. If one were able to associate regions in the DICOM imaging study with the textual representation in the radiology reports, one could navigate to regions of interest by clicking hyperlinked text in the report.

In our previous work we have developed technology to automatically add semantic annotation to DICOM CT scans via the use of a Random Regression Forest [1] based algorithm. With such technology, when a DICOM CT scan is received from the scanner, our system can automatically tag different body organs that are present within the image data set. Along with the receipt of DICOM scans, our system can also receive the corresponding radiology report. For known anatomic entities, say "liver" in the image data, one can link the corresponding anatomic entities in the report data via simple keyword searches. Furthermore, medical literature and radiology reports often present clinical interpretations that refer to anatomic entities. For example, the term "hepatocellular carcinoma" refers to a type of liver cancer. As a result,

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[1] Further author information: Send correspondence to S.P.
S.P.: E-mail: sayanpa@microsoft.com, Telephone: 1 425 538 7386

in our application, we hyperlink the term “hepatocellular carcinoma” within a radiology reports to the organ liver, such that when a physician clicks on the hyperlinked text, the application navigates to the liver within the imaging study. Because the application knows that the liver has been selected for display, additional intelligence can be applied that would automatically render the image in the liver window/level settings.

The Montage™ software application that allows end-users, typically physicians, to be able to search and mine data in radiology reports within hospital and radiology information systems [2]. The application leverages natural language processing supplemented by various medical ontologies and other algorithms, taking advantage of domain expertise specific to the field of radiology to provide efficient and highly relevant search results. One of the algorithms used within the application has been utilized to parse the radiology reports to identify anatomical entities that exist and referred to within the report text.

This paper demonstrates that automatic annotation of image regions with semantic labels (such as those derived from the RadLex® ontology), when combined with NLP technology for automated interpretation of radiological reports, enable improving navigation between the text and the image data. This is expected to improve productivity in the clinical workspace.

2. METHODS

2.1 Random Regression Forest Summary

The random regression forest algorithm estimates the position of the bounding box around an anatomical structure by pooling contributions from all voxels in a CT volume. This approach clusters voxels together based on their appearance, their spatial context and, above all, their confidence in predicting position and size of all anatomical structures.

The regression trees at the basis of the forest predictor are trained on a predefined set of volumes with associated ground-truth bounding boxes. The training process selects at each node the visual feature that maximizes the confidence on its prediction for a given structure. The tighter the predicted bounding box distribution, the more likely that feature is selected in a node of the tree.

During the testing phase, voxels in an image volume are provided as an input to all the trees in the forest, simultaneously. At each node the corresponding visual test is applied to the voxel and based on the outcome the voxel is sent to the left or right child. When the voxel reaches a leaf node, the stored distribution is used as the probabilistic vote cast by the voxel itself. Only the leaves with highest localization confidence are used for the final estimation of each organ’s bounding box location. Please see [3] for details.

2.2 Radiology Report Mapping

Figure 1 shows the algorithm used to parse a radiology report. A given report is first parsed to detect for presence of normal anatomical terms, such as “liver” and “kidney”. By using query expansion, synonyms and related terms of a given anatomical entity are searched for. For example, in addition to liver, other related terms like “hepatic” are searched for within the text and subsequently mapped to liver. Various pathology terms are also searched for and subsequently mapped to corresponding anatomical entity when possible. For example, “renal mass” is a tumor of the kidney. By definition, it is associated with the organ kidney. However, a term like “sarcoma” is nonspecific and does not have a specific anatomical entity associated with it and thus would not be mapped. Once both anatomical terms and pathology terms that map to a specific anatomy have been detected and parsed, these terms are filtered through negation algorithm (that looks for words indicating absence of anatomic entities using an approach similar to NegEx [4]) to ensure the report does not refer to a structure meant to be negated within the report text. For example, if a radiologist reported, “there are no findings of hepatocellular carcinoma”, the application would not tag the “hepatocellular carcinoma” term. Because of frequent use of negation within radiology reports, this is an important component of the overall algorithm for parsing out these anatomical terms within reports. The terms are subsequently mapped to RadLex® terms and an XML schema that can be tied to the aforementioned application. The application adds semantic annotation to DICOM CT scans using random regression forest, and displays radiology reports with hyperlinks that tie to the semantic annotation by utilizing the mapping information contained within the XML output.

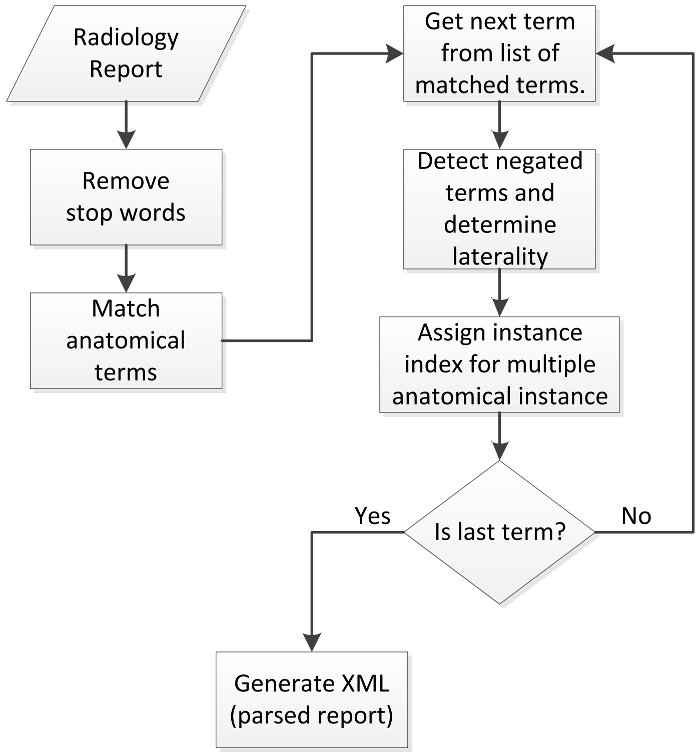

Figure 1: Flowchart of the report mapping algorithm

2.3 System Architecture

The integration of the semantic image annotation engine for DICOM data with the semantic mapping of the anatomical entities in the radiology report from textual data via a separate text mapping engine by the nature of the data allows us to perform parallel processing.

For semantic tagging of images, the computations can be carried out either on-the-fly while the DICOM images are being loaded (since the tagging algorithm only takes couple of seconds) or asynchronously pre-computed during data arrival in our backend storage followed by storage of the semantic information as image metadata. In either of the cases, our design allows us to leverage web services exposed by 3rd party software application for semantic tagging of textual information. While the images are processed, a parallel call is made into the web service where the report content is sent to the web service and the resulting annotated content is sent back to the application/service.

Figure 2 shows how we achieve fully automated linking of radiology reports with the DICOM images.

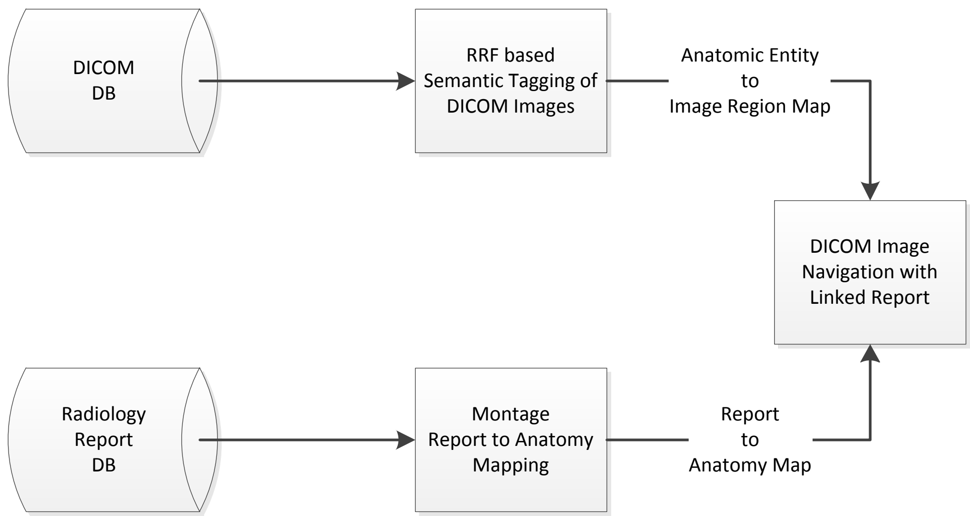

Figure 2. Schematic for DICOM image navigation with linked report viewing.

The semantic processing service needs to be done in a secure environment whether remotely hosted or hosted on the local site. Additionally, the data transfer between the services must be encrypted using cryptographically secure mechanisms and may require additional pre / post processing to safeguard against any potential breach of privacy.

The report linking application is then able to associate the anatomic entities from the images with the corresponding entities in the report. Following the linkage between the two, one can efficiently navigate to regions of interest in large CT scans with automated window/level setting [5] from radiology reports with hyperlinked text.

3. RESULTS

We have developed a Windows application that implements the aforementioned algorithms. Since both the process can be run in a fully automated manner at the time of receipt of the DICOM images and the reports, the processing overhead is not perceived by the end user.

In the application, when one clicks on the term "right renal", the organ navigator takes the user to the location of the right kidney. Note, the kidney is rendered in the suitable window level setting automatically. For the same term, the returned results from the report parsing by the web service in addition to identifying negated anatomical terms (an important component) also returns the laterality of the identified anatomic entities. In this case, a "right renal" pathology, allows one to associate the text with the "right kidney". Fig. 3 shows a snippet of the parsed XML report sent back by the web service to the report linking application. The field Instance index in the returned query allows one to associate multiple instances of the word "renal". Fig. 4 shows the screen shot of our application that demonstrates the aforementioned algorithm.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<ReportParsingWebService>
  <RadiologyReportRelatedTerms>
    <QueryResultInfo>
      <Server_Status>
        131.0.0.0 - - [27/Dec/2011:13:57:59 -0600] "GET / HTTP/1.1" 200 &#13;
      </Server_Status>
      <app_id></app_id>
      <QuerySuccess>TRUE</QuerySuccess>
    </QueryResultInfo>
    <Results>
      <OrganNames>
        <Term>renal</Term>
        <OrganName>Kidney</OrganName>
        <Laterality>Right</Laterality>
        <Negation>FALSE</Negation>
        <InstanceIndex>1</InstanceIndex>
      </OrganNames>
    </Results>
    </RadiologyReportRelatedTerms>
</ReportParsingWebService>
```

Figure 3. Sample result of XML files returned by the report parsing web service.

4. CONCLUSIONS

Traditionally, DICOM imaging studies and radiology reports (textual information associated with those images following radiologist interpretation process) have lived in their own separate worlds even though they anatomically depict findings from the same patient. By combining our previous work on random regression forest based semantic annotation of DICOM images with the efficient mapping of text in radiological report to anatomic entities, we, for the first time, demonstrate an application that bridges the gap between the imaging world and the textual world of the medical imaging. We have demonstrated the "reduction to practice" of this powerful new technology and how it can improve clinical navigational efficiencies.

Specifically, our application allows for semantic annotation of DICOM images for various anatomical parts where a separate algorithm analyzes and tags the radiology reports associated with those DICOM images for anatomic parts that can be mapped to the semantic annotation within images. Our application demonstrates practical application of such integration where it can be used for more efficient and meaningful navigation of DICOM image data.

References

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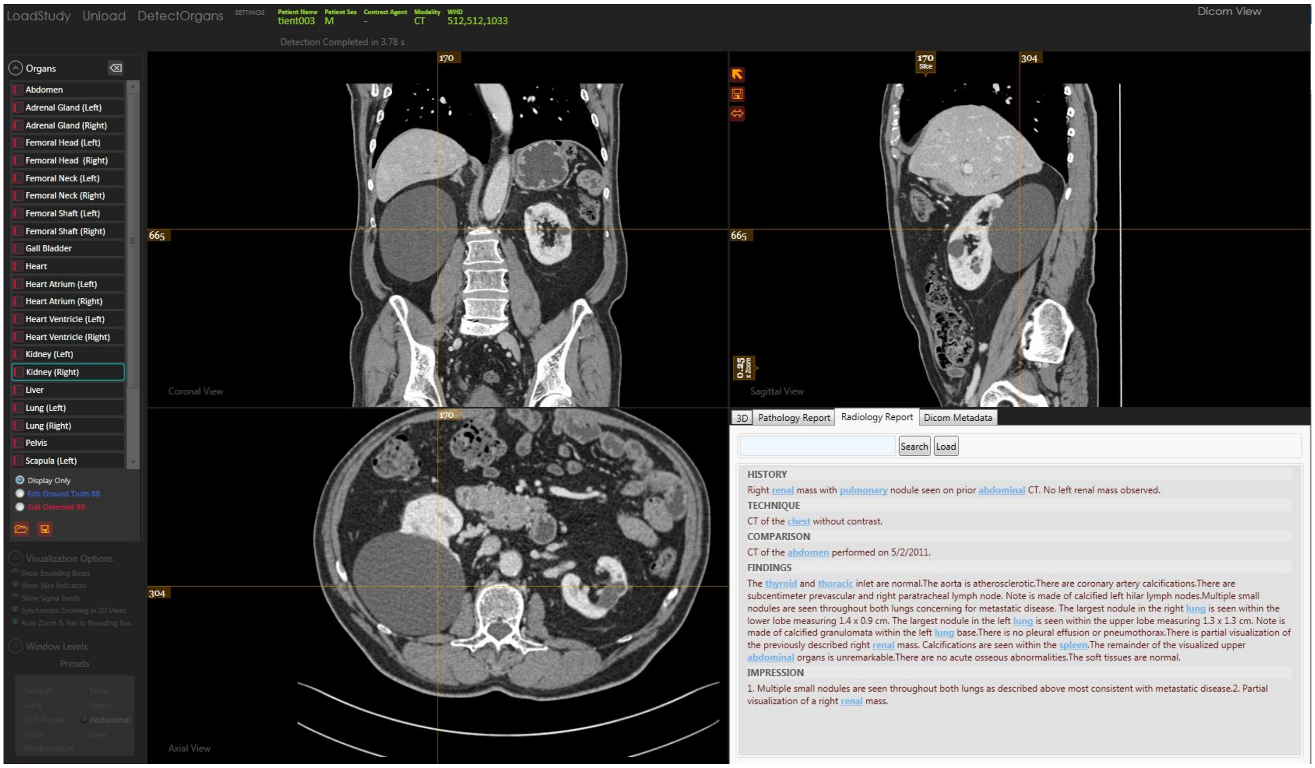

Figure. 4. Our application for the single-click semantic navigation through a CT study showing axial, coronal and sagittal with linked radiology reports via sematic annotation and NLP based automated report tagging. The view is shown for clicking on renal. Note: The kidney is rendered with suitable window/level settings.