The Annotation and Image Mark-up Project

In the image interpretation process, the radiologist is called upon to make observations, characterize these observations, and make inferences from them in the text report. Most observations are made on the basis of image findings, but there is other “evidence” available to the radiologist in certain settings—for example, measurements made by using the imaging modality (eg, obstetric ultrasonography) or computer-aided detection information. We define image annotation as the explanatory or descriptive information regarding the meaning of an image that is generated by a human observer. Some observations are measurements, while some may be arrows or circles displayed on the image. We define image markup as the graphic symbols placed on the image to depict an annotation. The output of this image interpretation process is the radiology report and often a set of marked-up images.

In current clinical practice, images are created, stored, and manipulated in the standard Digital Imaging and Communications in Medicine (DICOM) format. Computer-aided detection objects and measurements from imaging modalities can be integrated as DICOM-structured report objects. The majority of all human image annotations, however, are captured in dictated text, which is typically transcribed manually or by means of automated speech recognition. Markups are typically captured as vendor-private data in the picture archiving and communication system (PACS). Both types of data capture are problematic in terms of enabling the re-use of this information for clinical, research, and educational purposes.

With speech recognition systems, the text report can be semistructured through the use of macros, templates, and section headings. In other words, the speech recognition software inserts similar wording in specific patterns, and this verbiage is then modified through dictation. Still, it is difficult for both humans and machines to index, query, and search free text in order to retrieve images or image features on the basis of these free text descriptions.

The other problem with free text descriptions in the radiology report is that they often are not well associated with the spatial location of the observation, so it is difficult to relate image observations to their corresponding image locations. As an example, consider a section of a report that any of us might create: “Pulmonary parenchyma: There is a 2.3 × 2.7-cm enhancing mass adjacent to the minor fissure in the right middle lobe (best seen in series 3, image 42).” It is very hard, even given the state-of-the-art technology in natural language processing (NLP, the branch of computer science related to the extraction of information from human language), to query free text reports to “find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm2.” More sophisticated queries—for example, “Find all pairs of lung nodules that have decreased in volume by 20% in less than 6 months”—are impossible to perform in current environments, despite the large use of such queries to radiologists, researchers, and educators.

This is true even though the information desired was probably initially recorded by the interpreting radiologist. It is also very difficult to compute the spatial location of a lesion on the image on the basis of the statement “best seen in series 3, image 42.”

These examples point out the need for computer systems to be able to access image annotations and markups. Note that human observation...
capture is complementary but distinct from content-based image retrieval—the branch of computer science that involves the quantitative analysis of images and the identification of images of similar quantification.

Analyzing image annotations and markups is important in the management of disease changes in specific patients, but it is critical in image-based clinical trials where changes in image observations and the characteristics of the observations may constitute midpoints or endpoints in the trial. More important, a computable format for image annotation can be used to correlate the imaging observations regarding the phenotypic expression of a disease process with the genotypic expression of the disease and other laboratory data.

Structured annotations can also be used to improve the process of annotation and interpretation. It is possible to examine large collections of structured annotations and the associated images across patients and providers for consistency and variability. In some cases, the use of specific terms can be correlated with specific image-processing analysis to reduce variance in the use and meaning of terms. Consider the concept heterogeneous attenuation. In this case, heterogeneous is a subjective descriptor—that is, it is in the eye of the beholder. Yet analysis of large numbers of annotations of “heterogeneous attenuation” might yield more precise terminology. Best practices for annotation can be developed.

Correlations between the structured annotations and inferences derived from structured radiology reports have the potential to reduce variance in the interpretation of observations. The results of these analyses can be fed back into the annotation creation tools of imaging workstations in much the same way that decision support is built into physician order entry systems. This cycle is the imaging equivalent of the National Institutes of Health benchtop-to-bedside paradigm.

Recognizing the importance of such computation for cancer research, the National Cancer Institute in 2004 created the cancer biomedical informatics grid (caBIG) (1). The mission of caBIG is “to develop a truly collaborative information network that accelerates the discovery of new approaches for the detection, diagnosis, treatment, and prevention of cancer, ultimately improving patient outcomes” (1). One specific goal of caBIG is to “build or adapt tools for collecting, analyzing, integrating, and disseminating information associated with cancer research and care” (1). Since imaging plays such a large role in cancer management and research, there is a correspondingly large effort focused on developing tools to support imaging research.

The Annotation and Image Mark-up (AIM) Project is one of these image tools. While the DICOM file contains a large amount of “meta data” about whom, where, and how the images were acquired, it contains little information about the content of the image or the meaning of the image pixels. The AIM Project is a standardized semantically interoperable information model with storage and communication formats for image annotation and markup. The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers. It allows the software application to associate specific terms for anatomic entities, imaging observations, and imaging observation characteristics with regions on the images to which they correspond by using controlled terminologies such as RadLex® (2).

The AIM model also defines types of calculations that, along with the calculation result, can be stored in the annotation.

An important aspect of the AIM Project is that it provides interchangeable DICOM-SR, XML (extensible markup language), and HL7 (Health Level 7) formats for storage and communication of the image content recorded in the AIM. These formats can and will be used to store, transmit, and process these annotations in much the same way that DICOM is used for images. As a National Cancer Institute–funded project, the AIM Project provides a free and open source software tool kit for implementing annotation and markup–compliant systems and a software application to validate and translate AIM annotations (3). Vendors can use this tool kit to jump-start their implementation efforts. Several research projects destined to generate large collections of AIM-annotated images are in the planning stages.

When AIM is used to describe annotations, each information component, anatomic entity, observation, measurement, etc. is explicitly captured in a semantically precise and computationally accessible manner. Thus, in the example above, an AIM-enabled PACS workstation would generate a pick list of RadLex® anatomic terms, from which the radiologist would select middle lobe of right lung. The specific RadLex® identifier for that location (RID1310) would automatically be embedded in the annotation. Similarly, the PACS workstation would generate pick lists for the AIM observation (mass, RID3874) and the AIM observation characteristic (enhancing, RID6065). The AIM can also contain the x and y coordinates of an outline drawn around a lesion or the coordinates of an arrow pointing to a lesion, as these are generated by the user of the PACS workstation. If calculations—for example, longest diameter or area—were performed by the workstation, then AIM could store these results. The latter are part of a list of standardized measurements. The details of the AIM information model are described elsewhere (3).

Once an annotation is defined in the AIM model, making sophisticated queries becomes relatively simple. Our query “Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm” becomes “Find all image references in AIM annotations where AIM: Anatomic Entity = RID1310, AIM: Imaging Observation = RID3874,
AIM: Observation Characteristic = RID6065, AIM: Calculation = Area and AIM: Calculation Result >5 and <6 cm$^2$.” The exact syntax and the mechanisms used to execute such a query are more complicated than those presented here but are well defined.

The image interpretation process is undergoing change. At the 2007 Intersociety Conference, it was concluded that structured reporting is the optimal method for reporting, provided the tools do not impede radiologist work flow (4). A Radiological Society of North America project to develop a set of best-practice templates to advance structured reporting is underway (5). With use of the AIM Project, the annotations and markups made by the interpreting physician can also be incorporated into a structured report and thereby become available for subsequent processing.

To take advantage of AIM and the sea change in reporting, one needs to have the right tools. If you develop your own imaging and reporting tools, caBIG can provide free and open source AIM tool kits to incorporate this functionality. On the other hand, several vendors have expressed interest in the AIM Project and are starting to implement it in their systems. When you purchase imaging and reporting systems, you need to consider how you are going to integrate AIM and structured reporting in your environment. Including AIM functional requirements in your purchase documents will improve your ability to perform advanced analyses, search for image content, use the results in clinical and research practice, and participate in image-based clinical trials.

We believe that AIM eventually will be incorporated into formal imaging standards and technical frameworks such as IHE® (Integrating the Healthcare Enterprise®). In the meantime, with a little foresight, you can anticipate the importance of such open annotation standards and help us to advance the adoption of this important framework. Remember to simply take AIM at images!

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