

Computers in Radiology

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Interactive Software for Generation and Visualization of Structured Findings in Radiology Reports

OBJECTIVE. Our objectives were to develop a user-friendly graphic interface for a module that integrates traditional radiology reporting, natural language processing, and editing capabilities; to facilitate the structuring of radiology reports as part of routine clinical practice; to use a commercial speech recognition module for online transcription; and to implement the module in a hardware-independent environment.

CONCLUSION. After implementation, the module was tested with 150 chest radiology reports by two radiologists and assessed for ease of use and accuracy. Overall, accuracy was close to 90% and user satisfaction was high. When radiology reports are structured as a part of routine clinical practice, it is possible to accomplish intelligent indexing and retrieval to facilitate teaching and research.

Traditionally, radiology reports have been dictated and then transcribed into free text format by a human transcriptionist. Structured data entry using preformatted reports has been recently proposed by different groups but has yet to gain widespread acceptance [1, 2]. An advantage of free text reporting is how radiologists can tailor radiology reports and include details and nuances of the current case, instead of having to structure reports around a predefined format. An advantage of a structured report is how it facilitates intelligent indexing, searching, and retrieval of documents. Obviously, it is desirable to combine the advantages of both methods: free text and structured data entry. This objective is realized in the system we describe; the system incorporates a natural language module that can analyze the free text radiology report and automatically extract relevant features. We have previously reported on the design and implementation of a natural language processing algorithm that analyzes free text radiology reports [3]. To

achieve better accuracy, it is important to provide an efficient method of editing the output of the natural language processing module. We describe a prototype system of a structured report generator that incorporates speech recognition (though not restricted to this method of data input), natural language processing, and editing functions.

System Design

Process Flow

Figure 1 depicts the process flow of our system. The radiology report is dictated in a manner analogous to traditional report dictation, and the speech recognition module transcribes the speech input into a free text format (these steps may be replaced by manual data entry). The free text format is then processed by a natural language processing module that extracts the radiologic findings of the report. The final process involves the visualization of the structured output in a tabular format and as a graphic schematic. The structured findings can be edited using either the tabular or graphic template. Editing options include the deletion, modification,

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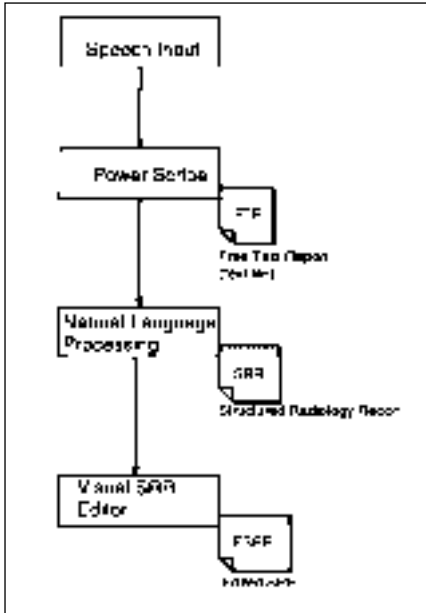


Fig. 1.—Diagram shows process flow for structured radiology reporting module. If report is typed directly into software, then first two steps can be omitted. In addition, natural language processing module may also be replaced by structured report input. System allows easy visualization and editing of reports.

or creation of findings and related attributes. The structured data are archived along with the traditional free text report. Each component of the system is detailed below.

Speech Recognition Module

The speech recognition module (PowerScribe; Fonix, Salt Lake City, UT) converts the speech input into text format. The inclusion of a speech recognition module enables the entire process to be completed in a single session. As previously mentioned, this task can also be accomplished by typing the report.

This module is included to support the most familiar method of reporting used by radiologists (i.e., dictation). An initial training session is required to enable the speech recognition module to accurately interpret the radiologist's dictation. This training session is used to characterize the user's speech profile. If the profile closely matches one of the predefined profiles, the system can achieve a high accuracy with limited training. The user has the option to edit the output of the speech module using speech or keyboard commands. The text output of the speech module is written as a flat file to a directory. The module report manager polls this directory every 10 sec for the arrival of new reports. In addition to the dictated report, the text output of the speech module has a header that includes fields for patient demographics, radiology information system accession number, and radiologic procedure code. Under routine clinical operations, the text output of the speech module can be directly stored in a

radiology information system database and accessible using the information in the header.

Natural Language Processing Module

The natural language processing module processes the findings section of the radiology report [3]. It does not process the entire report but addresses only specific concepts in a specialized glossary. The glossary has two main sources: the Unified Medical Language System [4] and a thoracic radiology glossary compiled using thoracic imaging texts and glossaries published by cardiopulmonary subspecialty societies [5]. Phrases or words with similar meanings share a common base concept code. The details of this module, which comprises four sub-components (lexical analyzer, finding analyzer, reference resolver, and joiner), were described earlier [3]. The output of the natural language processing module is represented as either concepts or frames. Each concept is based on a glossary entry that maps the word or phrase from the free text to a structured representation. Frames group concepts together to represent radiologic findings and their attributes. Frames can contain many attributes to model the radiologic findings; further, an attribute can store either a concept or a frame.

The output of this module for a given report is a list of the radiologic findings and related attributes (e.g., a mass may have attributes of location, size, and growth trend). Each data element is stored as an attribute-value pair in a hierarchy. The natural language processing module returns information re-

garding the findings, related attributes, concept identifiers in the corresponding glossaries, relative locations in the free text report, and presence or absence of findings. The output of the natural language processing module is accessed by the module through a Common Object Request Broker Architecture wrapper. The latter technology was chosen because it is currently recognized as the standard for heterogeneous computing and complements the Java platform by providing distributed objects framework services and by supporting interoperability with other languages. In the implementation described here, Common Object Request Broker Architecture allows data to be exchanged between software written in different languages (C, C++, and Java) and running on different platforms (Unix and NT; Server, Microsoft, Redmond, WA). The header associated with the free text report is appended to the structured report so that the free text and structured text are accessible with the same keywords. The natural language processing module was implemented in C and C++ on a Unix platform.

Visual Structured Relevant Report

This module has four main functions that also translate to four subcomponents in the user interface: display of the free text in which the findings of the natural language processing module are highlighted, visual overview of the extracted relevant findings, tabular view of the relevant findings, and editing capabilities for individual findings (Fig. 2). The interface is written in Java and is platform-independent.

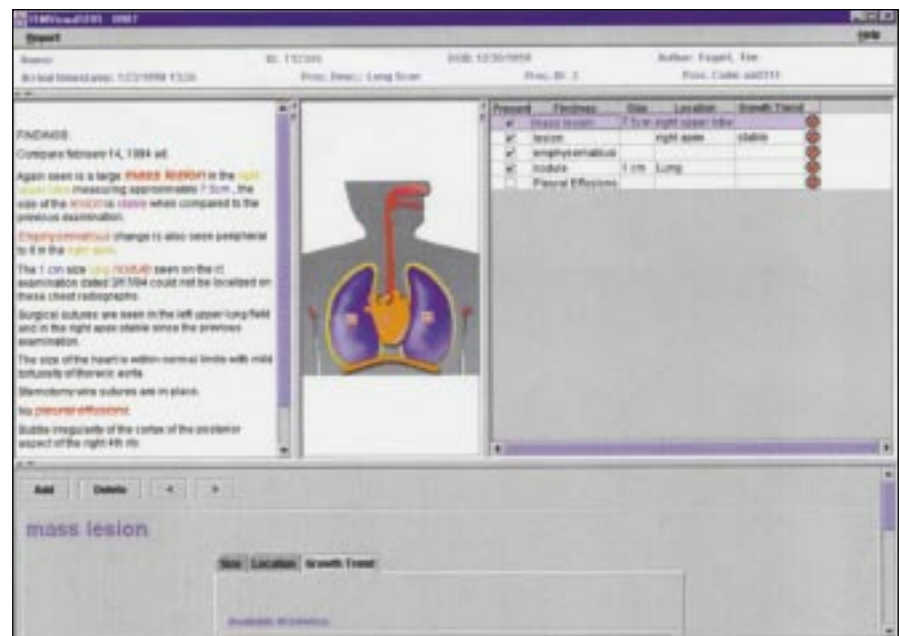


Fig. 2.—Screen capture of graphic user interface of structured radiology reporting module shows relevant patient information in top panel. In left panel, interface shows augmented free text display with radiologic findings highlighted in red and anatomic sites in green. Negative findings (e.g., pleural effusion) are crossed out automatically. Center panel shows schematic of lung anatomy with findings displayed as an overlay. Selection of region on this schematic highlights findings present at that location. In right panel, tabular view of findings and attributes is shown. Lower row panel allows users to edit structured output.

tained from a survey of five users (radiologists and scientists). Users evaluating the system were provided with a list of questions that was a modified and simplified version of an established user survey questionnaire for user-interface satisfaction [6]. Survey questions covered topics including ease of use, organization, content and clarity of the interface, learning curve, and willingness to use the module. All answers were graded on a scale from 1 to 10.

Results

A recall and precision of 85% and 90%, respectively, were calculated for 477 findings in 150 reports. The time required to generate a structured report was determined by the number of manual edits required, which in turn depended on the accuracy of the speech recognition and natural language processing modules. The speech recognition and structuring processes execute tasks quickly (in seconds) and do not significantly impact the time required for the creation of a structured report. The number of manual editing operations required for the speech recognition and natural language processing modules ranged from two to six depending on the user and the length of the report. The type of editing required also varied from editing an attribute of a finding to deleting or creating a finding. The throughput using the current system was 15 reports per hour, compared with an average of 24 reports per hour for a conventional dictation system. However, it should be noted that in a conventional system, the radiologist spends additional time editing transcribed reports, which are normally available from 4 to 24 hr later depending on the turnaround time of the transcription service. Further, the final output of a conventional dictation system is a free text report compared with a structured report in the system described here.

The qualitative evaluation of user responses showed satisfaction to be high. A detailed evaluation study involving more radiologists is currently under way. The visualization of the findings in an anatomic overview was helpful as a guide to the location of findings. Initial feedback suggested that users may require a finer granularity of the schematic than was available on our current design. Users preferred the flat interface design because it avoided navigation through multiple layers of graphic user interface windows. Editing features were intuitive and the wizard interface permitted easy creation of findings. For the evaluators, the major advantage of our system was the integration of speech, structuring, and editing, enabling the creation of structured reports in a single session.

Discussion

There are several advantages to creating structured data. It will enable efficient retrieval of information from patient and medical literature databases that is not possible using free text reports. The structured data can be used to index each report and can also be automatically mapped to standard coding schemes such as Medical Subjects Heading (MeSH) [7] to retrieve relevant medical documents from databases such as MEDLINE. This option will offer support to the radiologist or resident at the time of reporting by providing transparent access to medical literature. In addition to the retrieval of medical literature, the radiology information system database can be queried for other documents matching some search criteria. This type of data mining can provide information required for outcomes analysis.

We can also use improved natural language processing modules as they become available. The version of the natural language processing module used in this investigation has a recall and precision of 85% and 90%, respectively. Considerable progress has since been made to the natural language processing module that has raised the recall and precision of mass findings to 98% and 100%, respectively (Taira RK et al., presented at the American Medical Informatics Association fall symposium, Orlando, FL, 1999). These improvements would have a considerable impact on reducing the time required to create a structured report. The visualization and editing module is written in Java to support platform independence. The modular nature of the system permits us to incorporate other improved speech recognition modules as they become commercially available.

Currently, the prototype implementation is as a standalone system. However, it can be fully integrated into the radiology information system so that dictation, transcription, structuring, and editing could be performed from a workstation for routine radiology reporting. In the integrated version, both the free text and structured reports can be stored and accessed by common keywords in the header file. The module can be used to retrospectively structure legacy free text reports stored in radiology information system databases. These structured reports can then be optionally edited by radiologists. This option will provide a powerful method to index existing documents and provide retrieval access to information that was either nonretrievable or had to be manually extracted.

In addition to our current methodology of incorporating natural language processing

techniques for the creation of structured radiology report data, efforts are also under way to investigate the direct entry of structured data [1, 2]. Initial usage of these systems has been limited to focused areas such as sonography, in which it was fairly successful [1, 2]. However, it remains to be seen whether this methodology will gain widespread acceptance because it deviates from the current practice of generating radiology reports such as dictation. Our approach allows physicians to dictate their free text report and obtain a graphic summarization of an automatically generated structured report. The preliminary results are positive, although natural language processing techniques are by no means a solved problem. Both methods, structuring using natural language processing methods and direct entry of structured data will have to be investigated in greater depth to determine the applicability and acceptability of these techniques.

Conclusion

A module for the creation of structured radiology reports has been implemented and tested as a prototype. It provides a visual display of the findings extracted by a natural language processing module and capabilities for editing these findings. The incorporation of the speech recognition module permits the radiologist to create a verified structured report in a single session with minimal impact on work flow. User acceptance of the system was high in our small test group. Currently, the system awaits deployment and testing at the department level.

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