Evaluation of SNOMED3.5 in Representing Concepts in Chest Radiology Reports: Integration of a SNOMED Mapper with a Radiology Reporting Workstation.

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Standardized medical terminologies are gaining importance in the representation of medical data. In this paper, we present the evaluation of the SNOMED3.5 medical terminology to code concepts routinely used in chest radiology reports. Integration of this terminology mapper into a radiology reporting workstation that incorporates a speech recognition system and a natural language processor is also discussed. A total of 700 anatomical location terms (including synonyms) were tested and 72% of the terms had corresponding SNOMED terms. Of the 28% that did not result in a match, 16% were either morphological variants of SNOMED terms or could be found from a combination of terms from two or more SNOMED axes. Only 12% of the terms (primarily specialized radiology terms) were concepts not actually included in the SNOMED terminology.

INTRODUCTION: SNOMED, the Systematized Nomenclature of Human and Veterinary Medicine has been in development for the past 24 years and is a comprehensive set containing over 150,000 words distributed among twelve axes [1]. The advantages of representing data using standardized terminology are clearly recognized. These include the ability to implement a standardized electronic medical record, guidelines and best practices and conduct outcomes research [1]. This is the first report that evaluates SNOMED as a medical terminology to represent concepts in chest radiology reports. An extensive evaluation of the 'Topography' axis was carried out using an automated search. The SNOMED 'mapper' is integrated into a radiology reporting workstation that incorporates several features: a commercial speech recognition system, a natural language processor developed by one of the authors (RKT, [2]), and a visualization and editing interface [3]. This module supports report dictation, structuring and standard representation of the concepts in the free text report. The radiologist is provided with a user interface to edit the output at any of these stages. A pictorial representation provides a quick visual summary of the report findings and associated anatomical locations.

METHOD: A discussion of the automated search of the SNOMED terminology is followed by a description of the radiology reporting workstation.

Automated Search: Database Indexing: The 'Topography' and 'Morphology' axis of the SNOMED3.5 were loaded in a database (Java-based GemStone/J object-oriented database management system) [4]. All six fields associated with each SNOMED code in the Topography axis were included in the database, without any modifications. The field referred to as 'ENOMEN' stands for English Nomenclature and is the fully-specified name. A modified version of this field 'ENOMEN', was included with each SNOMED code to support string searches. The following modifications were made to the 'ENOMEN' field: (i) conversion to upper case, (ii) removal of punctuation, prepositions and the post term 'NOS'; and (iii) removal of leading and trailing spaces. This modified field is indexed by each word to facilitate keyword searches ignoring word order.

Database Search: The search was designed to work with the output of the Natural Language Processor (NLP) [2]. The output from the NLP is a frame, with each frame containing many logical relations. A logical relation includes a head, a relation, and a value (e.g., "mass", has_size: "equals", "5 cm"). The NLP parses location as anatomic reference ("lobe", denoted as keyword) modified by direction(s) ("right", "anterior", denoted as modifiers). The NLP also returns other pointers that facilitate the search: (i) a flag specifying the semantics of the term; e.g. 'finding type' or 'location type' which sets the SNOMED axis of the search and (ii) whether a word is 'singular' or 'plural'. The latter

specification is important since the default nomenclature in SNOMED is the 'singular' variant of a concept. If a term specified 'plural' by the NLP is not found in the initial search of the SNOMED database, the search is re-initiated with the 'singular' variant. After determining the axis of the search, the query is constructed from the NLP term that is normally made of two to four words. The first query consists of all the words and failure to locate this combination results in a search with a new query. The new query is formed by dropping modifiers from the combination. This process is iterative till a specific combination results in a retrieval. In forming these combinations, the keyword is never dropped since that may result in retrievals that are not related to the primary concept.

Match Quality: An index defining the quality of match is calculated for each term retrieved from SNOMED as follows: Index = $(N_{qr}/N_{qo})*(N_{qr}/N_{sr})$; where N_{qr} is the number of words in the query term that resulted in a retrieval, N_{qo} is the number of words in the original query term, and N_{sr} is the number of words in the SNOMED term. If the match is exact, i.e., all words in the original query term are found and the corresponding SNOMED term does not contain any other word, then this index is 1. The modified version of the 'ENOMEN' is used to calculate the index. This index is also used to order the retrieved terms and the user can browse the SNOMED terms in order of decreasing match quality. Note that several SNOMED terms could potentially have the same value for the index.

SNOMED Browser: A simple user interface was built to evaluate the search engine. Users can enter in a keyword, modifiers and specify the search axis ("Topography' or 'Morphology'). This format of the query term is similar to the output of the NLP. The top five SNOMED terms that match the query term are displayed in a panel with options to view more, if the search yielded more than five matches. The match quality is indicated and the user has the option to select any term from the list. The selected terms are stored in a file for further analysis. **Radiology Reporting Workstation Integration of the SNOMED mapper:** The process flow for the system is shown in Figure 1. The interface is written in the JAVA language and is thus platform independent. CORBA wrappers are used to access the natural language processing and SNOMED mapper modules. The report is dictated in a manner analogous to traditional report dictation. The speech recognition module transcribes the speech input to a text format. The free text format is then processed by a natural language processing module that extracts the radiological findings of the report. The structured findings can be edited including deletion, modification or creation (or both) of findings and related attributes. The structured findings are then mapped to SNOMED codes using the automated search and the user has the option to either select a code from the automated search or initiate a new search. The final process involves visualization of the findings (and locations) on a graphical schematic. The schematics are composed of anatomical overlays labeled with SNOMED codes. In order to decrease user intervention, a 'caching' process is incorporated.
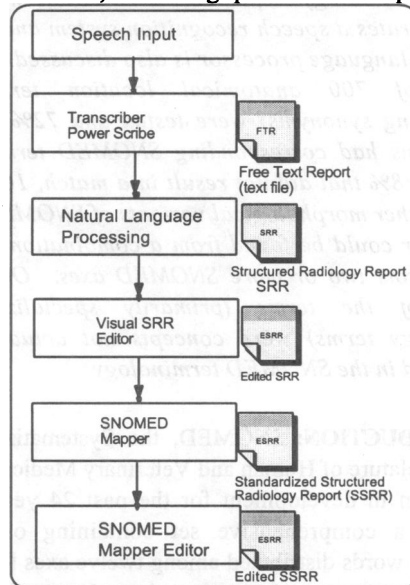

Fig. 1: The process flow of the workstation.

Caching: A verified SNOMED mapping is stored in a database independent of the original SNOMED database. This ensures that the system builds up a list of commonly used terms that have a verified SNOMED mapping decreasing user interactions. The mapper first searches the 'cache' and in the absence of an exact match proceeds to search SNOMED. Terms found in the 'cache' database are indicated as such in the interface so that the user does not have to verify the mapping. Caching increases the speed of retrieval and decreases user interactions with increased usage of the system.

RESULTS: Evaluation of SNOMED: Seven hundred terms compiled from various resources were used to test the SNOMED 'Topography'

800

axis. The terms had three main sources: the Unified Medical Language System [5], a thoracic radiology glossary compiled using thoracic imaging texts and glossaries published by cardiopulmonary subspecialty societies and terms extracted from free text radiology reports. Synonyms comprised 20% of the seven hundred terms, but terms that differed only in the order of words were counted once in the evaluation. An expert selected the appropriate SNOMED term from the list of terms retrieved automatically. Fig. 2a is a chart of the percentage of terms in each rank that the expert chose as the corresponding SNOMED code. The choice of the expert coincided with the first ranked term in 65% of the cases. An additional 6.5% of the selected cases had lower rankings. 28% of the terms were not found in the SNOMED 'Topography' axes. Fig. 2b is a chart of the match index distribution for each SNOMED term selected by the expert from the automated list. The total number of terms that were included in this analysis was 502 (total evaluation list minus the terms not found in the automated search). In this plot, a match index of 1 means an exact string match excluding prepositions, word order, and punctuation.
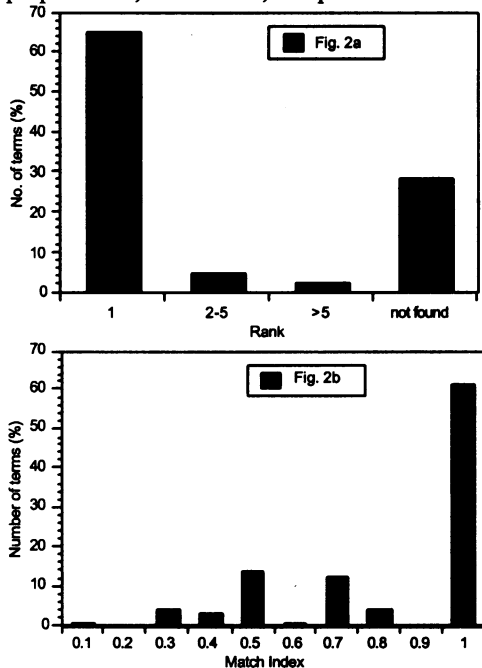

Fig. 2: Histograms of the ranking (2a) and the match index value (2b) of the expert selected SNOMED code.

Radiology Reporting Workstation: A prototype system was implemented and evaluated. The screenshot of the user interfaces for the SNOMED browser and for the report workstation are shown in Figs. 3 and 4 respectively. The qualitative evaluation of user responses showed satisfaction to be high. User interaction is required at three stages: to edit the output of the speech transcription, natural language processing and SNOMED mapping. The speech transcription is performed by a commercial system that requires little intervention with sufficient training sessions to characterize the users' speech profile. Extensive evaluation of the NLP, reported elsewhere, has shown recall and precision to be 90% and 89.4% respectively [2]. Thus the user intervention required to edit the output of the NLP is also not substantial. However, each term mapped to SNOMED has to be verified by the user. A preliminary evaluation of the system showed that 'caching' decreased the number of terms requiring user verification by approximately 70% after the first hundred reports.

DISCUSSION: The majority of the terms used in the evaluation test were retrieved from SNOMED (72%). The terms not retrieved from SNOMED could be classified in the following categories:
(i) plural terms (4%)--- by default SNOMED lists most terms in the singular;
(ii) morphological variants (7%)--- SNOMED terms may contain a variant of the query word. For example, the SNOMED term may contain 'lobe' as opposed to the search word 'lobar';
(iii) composite words (5%)--- this refers to those terms that are not found in the 'Topography' axis alone but can be formed as combinations of SNOMED terms from the 'Topography' and 'General Modifiers' axes. An example of this is : anterior rib; and
(iv) concepts not found (12%)-- these are terms that do not exist in SNOMED. A closer inspection of the terms in (iv) reveals that most of these are specific to radiology reports; e.g., 'silhouette', 'anterior junction line'.
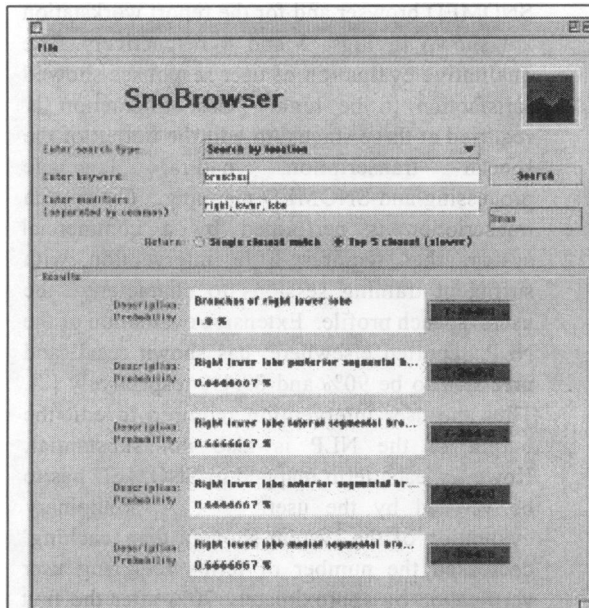
Fig.3: The user interface of the SNOMED browser: the query term is entered as a keyword followed by modifiers. The results are displayed in the center panel ordered by decreasing values of the match index. A similar panel is also displayed from the reporting workstation where the user can choose from the retrieved list of SNOMED codes.
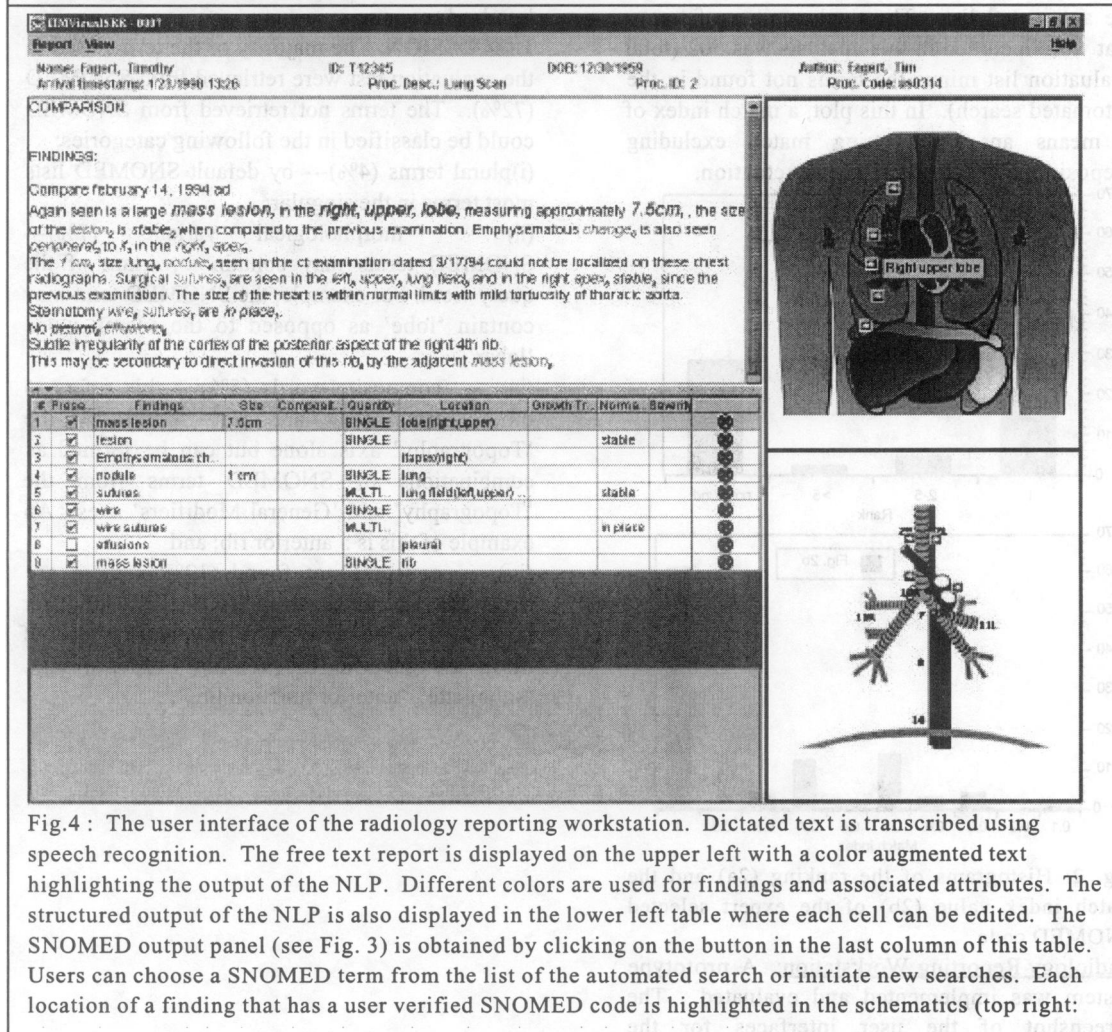

Fig.4 : The user interface of the radiology reporting workstation. Dictated text is transcribed using speech recognition. The free text report is displayed on the upper left with a color augmented text highlighting the output of the NLP. Different colors are used for findings and associated attributes. The structured output of the NLP is also displayed in the lower left table where each cell can be edited. The SNOMED output panel (see Fig. 3) is obtained by clicking on the button in the last column of this table. Users can choose a SNOMED term from the list of the automated search or initiate new searches. Each location of a finding that has a user verified SNOMED code is highlighted in the schematics (top right:

Terms not found in (i) through (iii) can be retrieved by more sophisticated searches that include a 'morphological variant generator' (available as part of the UMLS [6]) and multiple-axis searches. Also, the output of the NLP can specify morphological variants of some words. These extended searches will however increase time to retrieval since additional string combinations and/or axes are now involved in the query mechanism. The 12% of terms that do not have some form of SNOMED concept stem primarily from the fact that these are specific to radiology.

As explained earlier, terms with a match index of 1.0 have the exact same words as the terms in the SNOMED browser. These accounted for 62% of all the terms identified automatically. Lower match indexes occurred for various reasons:

(i) the SNOMED term is identical in concept to the search term except for some words in the term being synonyms; e.g., (heart valve, cardiac valve). The retrieval is still successful since a sufficient number of common words are present.;

(ii) the search term is not complete. This occurred often since the glossary contained terms from free text reports that had terms such as 'hilum' whose appropriate SNOMED term is 'hilum of lung'. In the free text report, the term is taken in the context of the entire report and it is inferred that 'hilum' is 'hilum of lung'. In these cases, an additional advantage of the mapping to the SNOMED code is that it removes ambiguity in specification. In future implementations however, the NLP will be able to provide the context reference, resolving this issue; and

(iii) the SNOMED concept is either broader or narrower in concept than the query term. An example of a SNOMED concept that is broader: the query term 'large airway' retrieves the SNOMED term 'airway' and a search revealed that there was no narrower classification for 'airway' in SNOMED. An example of a SNOMED concept that is narrower than the search term: the query term 'peribronchial' retrieves the SNOMED term 'peribronchial tissue'.

CONCLUSIONS: Most of the concepts in chest radiology reports can be represented using the SNOMED3.5 terminology. The current work is focused on anatomic locations but is readily extendable to other concepts such as diseases and diagnoses. The workstation allows users to create a verified, standardized structured report while allowing the radiologist to maintain traditional methods of reporting (dictation of a free text report). User intervention will be reduced with further improvements in the underlying three technologies: speech recognition, NLP and SNOMED mapping. This will lead to increases in user acceptability and in the routine creation of standard, structured radiology reports.

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