

Comparing the Effects of Two Semantic Terminology Models on Classification of Clinical Notes: A Study of Heart Murmur Findings

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Introduction

- There is an emerging convergence of approaches toward the use of a concept-based clinical terminology with an underlying formal semantic terminology model (STM).



Two types of STMs

- The existing SNOMED CT model
 - Mainly pre-coordination oriented
 - With support of post-coordination
 - Example:
 - [Hypophysectomy (52699005)]
 - +[transfrontal approach (65519007)]
- A template model (for a specific domain)
 - Mainly post-coordination oriented
 - A list of atomic terms is organized within a semantic structure
 - Example:
 - 7-Axis model in ICNP (nursing domain)



Problem:

- STM:
 - to support capturing structured clinical information that is crucial for computer programs
 - The structured recording has potential to improve information retrieval
- However, the functional difference in retrieval performance has not been clearly demonstrated between these two different semantic terminology models.



Objectives of the study

- To annotate the real clinical notes using the two schemas established from two models
- To compare and evaluate the effects of two models on classification of the clinical notes
 - A study for the domain of heart murmur findings



Methods & Materials

- Defining the annotation schemas
- Preparing clinical notes corpus
- Annotation software and annotators
- Coding for machine learning classification
- Outcome measures and statistical analysis



SNOMED CT Model Schema

- For the S-Model, we established a schema by extracting concept trees from the existing sub-hierarchy of heart murmur findings in January 2006 version of SNOMED CT.
- One root concept is “heart murmur (88610006)” which includes 86 sub-concepts of pre-coordinated terms of heart murmur findings.
- The other root concept is “anatomical concepts (257728006)” .



SNOMED CT Model Schema

The screenshot displays the Protégé 3.2 beta interface for editing the SNOMED CT Model Schema. The window title is "heartmurmur-smodel Protégé 3.2 beta (file:¥C:¥Racer¥sno medct¥Semantic Models¥OriginalSno medCTModel¥heartmurmur-smodel.pprj, ...)".

The interface is divided into several sections:

- Menu Bar:** File, Edit, Project, Window, Tools, Knowtator, Help.
- Toolbar:** Standard Protégé icons and a "Text source collection: ht-asfinal-fileline-smodel.bt" indicator.
- Navigation Tabs:** Classes, Slots, Forms, Instances, Queries, Knowtator, Annotation Results.
- CLASS BROWSER:** Shows the class hierarchy for the project "heartmurmur-smodel". The hierarchy starts with `:THING`, followed by `:SYSTEM-CLASS` and `knowtator support class`. The selected class is `Heart_murmur(SCTID_88610006)`, which is a subclass of `:SYSTEM-CLASS`. It has several subclasses, including `Aortic_murmur(SCTID_308687000)`, `Atrial_septal_defect_murmur(SCTID_301130004)`, `Functional_heart_murmur(SCTID_59935001)`, `Heart_murmur__categorized_by_configuration(SCTID_59495006)`, `Heart_murmur__categorized_by_duration(SCTID_128152005)`, `Heart_murmur__categorized_by_intensity(SCTID_128148005)`, `Heart_murmur__categorized_by_pitch(SCTID_128150002)`, `Heart_murmur__categorized_by_quality(SCTID_128151003)`, `Heart_murmur__categorized_by_timing(SCTID_128149002)`, `On_examination_-_cardiac_murmur(SCTID_268934006)`, `Organic_heart_murmur(SCTID_75431008)`, and `Shunt_murmur(SCTID_248689000)`. It also has subclasses under `Anatomical_concepts(SCTID_257728006)`, including `Cardiac_internal_structure(SCTID_277712000)`, `structure_of_apex_of_heart(SCTID_13383001)`, and `structure_of_base_of_heart(SCTID_60991002)`.
- CLASS EDITOR:** Shows the details for the selected class `Heart_murmur(SCTID_88610006)`. It is an instance of `:STANDARD-CLASS`. The name is `Heart_murmur(SCTID_88610006)`. The role is set to `Concrete`. The documentation and constraints fields are empty. The template slots table is as follows:

Name	Cardina...	Type	Other
finding_site	multiple	Instance of Cardiac_internal_structure(SCTID_277712000)	
procedure_site	multiple	Instance of Anatomical_concepts(SCTID_257728006)	

Template Model Schema

- For the T-Model, a schema was established from a concept-dependent attributes model published in a recent JAMIA paper of Green, et al.
- In this schema, one root concept is “heart murmur” which had eight semantic attributes.
- We adopted the model attributes directly from Green’s model, as well as their values (kindly provided by Green, interpersonal communication).



Template Model Schema

The screenshot displays the Protégé 3.2 beta interface for editing a template model schema. The window title is "heartmurmur-tmodel Protégé 3.2 beta (file:¥C:¥Racer¥sno medct¥Semantic Models¥OriginalTemplateModel¥heartmurmur-tmodel.pprj, P...". The menu bar includes File, Edit, Project, Window, Tools, Knowtator, and Help. The toolbar contains various icons for file operations and editing. The main interface is divided into several panes:

- CLASS BROWSER:** Shows a class hierarchy for the project "heartmurmur-tmodel". The hierarchy includes:
 - :THING
 - :SYSTEM-CLASS
 - knowtator support class
 - heart_murmur (selected)
 - cardiac_murmur_characteristic_values
 - cardiac_circle_timing_values
 - continuous
 - part_of_cardiac_cycle_timing
 - systolic_timing
 - holosystolic_timing
 - part_of_systolic_timing
 - early_systolic_timing
 - mid_systolic_timing
 - late_systolic_timing
 - diastolic_timing
 - to_and_fro
 - murmur_intensity_values
 - cardiac_auscultation_and_radiation_area
 - murmur_configuration_values
 - murmur_pitch_values

- CLASS EDITOR:** Shows the details for the class "heart_murmur" (instance of :STANDARD-CLASS).
- Name:** heart_murmur
- Role:** Concrete
- Documentation:** (empty field)
- Constraints:** (empty field)
- Template Slots:** A table listing slots with their names, cardinalities, and types.

Name	Cardinality	Type
has_cardiac_cycle_timing	multiple	Instance of cardiac_circle_timing_values
has_murmur_configuration	multiple	Instance of murmur_configuration_values
has_murmur_duration	multiple	Instance of murmur_duration_values
has_murmur_intensity	multiple	Instance of murmur_intensity_values
has_murmur_pitch	multiple	Instance of murmur_pitch_values
has_murmur_quality	multiple	Instance of murmur_quality_values
has_point_of_maximum_intensity	multiple	Instance of cardiac_auscultation_and_radiation_...
radiates_towards	multiple	Instance of cardiac_auscultation_and_radiation_...

Preparing clinical notes

- We extracted notes with these criteria from Mayo repository in an automatic way:
 - 1) created between January 1, 2005 to January 31, 2005;
 - 2) Having a heart murmur description in *Physical Examination* section;
 - 3) age ≥ 21 ;
 - 4) Having a Hospital International Classification of Disease Adaptation (HICDA) code of the Heart Valvular Disease,
 - and 5) removing patients with a code for status prosthetic valve or complication of a prosthetic valve.



Sampling (matched by Gender & Age)

AS

Non-AS

AS

Non-AS

Age	Male	Control	Female	Control	Total
21-30	1	2	0	0	3
31-40	0	0	0	0	0
41-50	0	0	2	4	6
51-60	4	8	0	0	12
61-70	7	14	5	10	36
71-80	26	52	7	14	99
81-90	24	48	21	42	135
91-	2	4	4	8	18
Total	64	128	39	78	309

Annotation using Knowtator

- A general purpose text annotation tool, Knowtator, was used to map text contents to our schema.
- One author (GJ) performed the annotation task and then the other author (CGC) verified the annotations for 10% of all documents. Differences were mutually adjudicated and lessons generalized to the remaining 90% of cases.



Coding for machine learning classification

- We coded the annotated corpora for retrieval using a machine learning classification algorithm.
 - The target category of the classification is binary, i.e. aortic stenosis (AS) or non-AS.
 - In other words, the goal of the classification is to predict whether a document with a heart murmur description belongs to AS category or not.
 - The annotations of each document were used as the predictive features and coded as binary.
- We used a Weka implementation of the decision tree (J4.8).

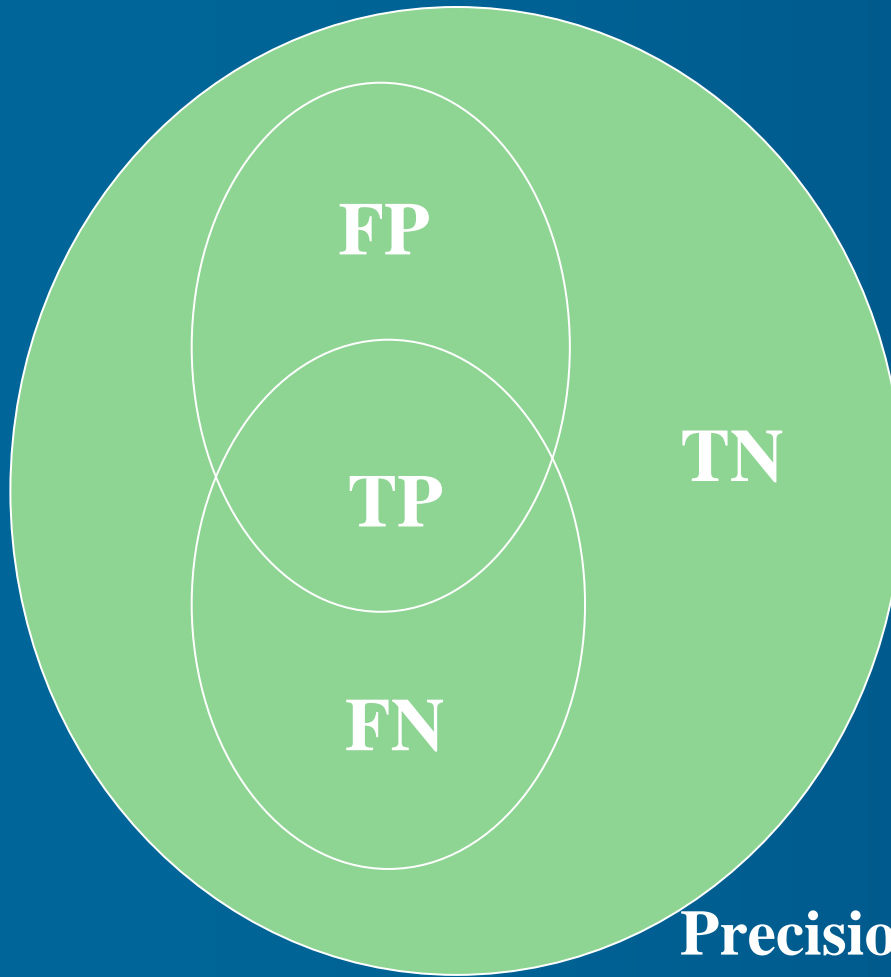


Outcome measures and statistical analysis

- For the annotation task
 - the description completeness
 - The annotators were asked to judge whether the heart murmur descriptions of each document could be described completely through using the schema of a model while they performed annotation task. If they judged a document as “incomplete”, they indicated a reason for the judgment.



Standard evaluation measures



	AS	Non-AS
Hit	TP	FP
Non-Hit	FN	TN

$$\text{Precision} = \text{TP}/(\text{TP}+\text{FP})$$

$$\text{Recall} = \text{TP}/(\text{TP}+\text{FN})$$

$$\text{Accuracy} = (\text{TP}+\text{TN})/(\text{TP}+\text{FP}+\text{FN}+\text{TN})$$

$$\text{F-score} = 1/(\alpha/\text{P}+(1-\alpha)/\text{R})$$

$\alpha=0.5$ indicating equal weight of P & R

Four datasets

- SM: original SNOMED CT Model
- TM1: original Green's Template Model
- TM2: completing the values for all eight semantic attributes whenever a description appearing in the clinical notes corpus did not have a corresponding value in TM1.
- TM3: adding a new semantic attribute “has an inference to specific murmurs or etiological mentions” to the root concept “heart murmur” and also completing its corresponding values from those descriptions appearing in the corpus.



Outcome measures and statistical analysis

- Ten-fold cross validation for retrieval was performed 10 separate times over all four datasets.
- The paired t-test was performed to test the statistical significance of performance measures between the dataset of S-Model and three datasets of T-Model.



Results: For annotations

	Total No. of annotations	No. of annotations per document
S-Model	995	3.2
T-Model	1377	4.5



Description completeness

	No. of incomplete cases	Incompleteness	Completeness
S-Model (SM)	88	28%	82%
T-Model (TM1)	201	65%	35%

Reasons for the incompleteness of four datasets

	SM	TM1	TM2	TM3
Auscultation area	1	78	0	0
Radiation	47	47	0	0
Configuration	8	8	0	0
Quality	7	5	0	0
<i>Specific murmurs</i>				
Ejection murmur	0	107	107	0
Regurgitant murmur	3	3	3	0
Flow murmur	2	2	2	0
<i>Etiological mentions</i>				
Aortic valve related	19	25	25	0
Mitral valve related	4	4	4	0
Pulmonary valve related	1	1	1	0
Septal defect	1	1	1	0



Results of the evaluation metrics of the four datasets

	Precision (<u>mean±sd</u>)	Recall (<u>mean±sd</u>)	F-score (<u>mean±sd</u>)	Accuracy (<u>mean±sd</u>)
SM	74.2% ±13.7%	59.4% ±15.6%	64.5% ±12.7%	79.0% ±6.1%
TM1	67.5% ±14.9%	*44.6% ±13.8%	*52.1% ±11.5%	73.6% ±5.4%
TM2	71.0% ±14.0%	53.2% ±18.9%	59.0% ±15.3%	76.9% ±6.8%
TM3	80.0% ±12.2%	*69.8% ±14.6%	73.5% ±10.4%	*83.6% ±5.8%

*p< 0.05 (paired t-test)



Discussion

- We found that the description completeness of the S-Model was better than the original T-Model with original value set, correspondingly the performance of the S-Model on classification was also better.
- The extensions of T-Model that improved the description completeness, did improve its performance on classification.
- We clearly demonstrated that the domain coverage of a terminology model was directly correlated with its performance on classification; this is not surprising.



Discussion

- We could see that the effect of a terminology model on its functional performance in a specific domain mainly depends on its ability to represent the contents of the domain.
- In other words, the key issue for a terminology model is how to achieve complete domain coverage. If two different terminology models could represent the contents of a domain to achieve the same coverage, their performances on classification should have no difference.



- An important conclusion of these experiments is that a template-style terminology model more readily identifies gaps in coverage, and facilitates their completion for retrieval tasks.



Merits of Knowtator

- The first merit is that Knowtator uses the Protégé ontology editing environment to build the annotation schema. The frame-based knowledge representation system provides a flexible and expressive way to efficiently make schemas of the two model types in this study.
- The second merit is that Knowtator provides visualization of annotations, making the annotation task and confirmation process simple and efficient.
- The third merit is that the Java API of the system, which supports the annotation query that exports our coding of annotations to a classifier format automatically.



Limitations

- We regard the evaluation in this study in its comparative context across models; absolute measures of precision and recall are subject to factors beyond the scope of this study.
- The annotations of clinical notes depends entirely on what clinicians decide to document for each patient, who they may or may not know has AS at the time. The local culture around documentation seems possible that these findings could be different on another corpus.
- We only collected a relatively small size of clinical notes corpus given that the intensive annotation tasks were required.



Conclusion

- In conclusion, the domain coverage of the two models and their performance on classification clearly differ when applied to real clinical notes.
- Our approach provides an effective framework to evaluate the coverage and functional performance of the semantic terminology models in a specific domain for potential improvement.



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