e-Health – For Continuity of Care
C. Lovis et al. (Eds.)

doi:10.3233/978-1-61499-432-9-8

Using TimeML to Support the Modeling of Computerized Clinical Guidelines

Reinhardt WENZINA[a,1] and Katharina KAISER[b]
[a] *Institute of Software Technology and Interactive Systems Vienna University of Technology, Austria*
[b] *University of Applied Sciences St. Pölten, Austria*

Abstract. The modeling of clinical guidelines in order to apply them in computerized medical tools is a challenging and laborious task. In this project we show that conditional subordination links – a temporal relation concept of TimeML – can be used to describe condition-based activities in a guideline. Therefore, we extend the specification of TimeML concerning events and subordination links. Subsequently, linguistic and semantic rules are developed to automatically generate annotations for these links and classify them as relevant for the clinical care path. Finally, the evaluation of the method shows that this categorization supports the task of the guideline modeling expert.

Keywords. computer-interpretable clinical guidelines; medical guideline modeling; TimeML; subordination links; Information Extraction (IE)

Introduction

Clinical Practice Guidelines (CPGs) are defined as "systematically developed statements to assist practitioners and patient decisions about appropriate health-care for specific circumstances" [1]. They are commonly published in a narrative format and have to be represented in specialized languages (see [2,3] for comparison and overview) in order to be used in computer supported medical systems. The modeling process is laborious and has to be done manually by experts in medicine and computer science. Thus, various approaches based on natural language processing (NLP) have been developed to automate this task [4,5]. The fact that guideline documents are often very extensive, contain complex sentence structures, and describe concepts rather vaguely or incompletely, limit the success of this methods to specific application areas.

As CPGs describe activities (corresponding to events in TimeML) and contain temporal expressions for arranging and relating them we propose the application of the TimeML specification language for our project. TimeML has become the de-facto standard for annotating events and temporal expressions in NLP and addresses the problems of (a) identifying an event and anchoring it in time, (b) chronologically arranging events, (c) reasoning with contextually incomplete temporal expressions (e.g., temporal functions such as "*post-dinner*" or "*fasting*"), and (d) reasoning about the duration of events [6]. Generally, the TimeML specification describes "events" as

[1] Corresponding Author: Reinhardt Wenzina, Institute of Software Technology and Interactive Systems, Vienna University of Technology, Favoritenstrasse 9-11, 1040 Vienna, Austria; E-mail: reinhardt@wenzina.com

umbrella term for situations that *happen* or *occur (*which can be punctual or last for a period of time) [6].

Originally, TimeML was successfully implemented in the newswire domain but soon the capability of this formalism was also applied to other areas. In the medical domain TimeML has been applied to medical narratives and clinical discharge summaries [7] but these documents differ from clinical guidelines in many ways (e.g., in narratives the document creation time could be used for the time anchoring of the events, whereas in guidelines this is of no informative value). Therefore, the related results can only partially be re-used. Subordination links between events (TimeML distinguishes among temporal links, subordination links, and aspectual links) were not investigated in these projects but are of fundamental significance in the description of condition based activities in guidelines. Consequently, our project focuses on the identification of such links and possible consequences for an automatic modeling process of clinical guidelines.

1. Methods

The goal of this project is to show that the application of TimeML complying annotations on clinical guidelines (particularly on conditional sentences) can support the translation process of CPGs into their computer interpretable format. Therefore, we propose a rule-based, heuristic method using linguistic and semantic patterns to annotate subordination links in sentences and classify them as relevant for describing condition-based activities.

The TimeML specification for subordination links (SLINKs) distinguishes among different types of relations: *modal*, *factive*, *counter-factive*, *evidential*, *negative evidential*, and *conditional* [6]. Generally, the nature of SLINKs is either lexically-based (e.g., indicated by reporting verbs, perception verbs, intentional processes, etc.) or structurally-based (e.g., purpose clauses and conditional constructions) [8]. As condition-based activities play an important role in describing clinical care paths, we set our focus on structurally-based subordination links of the type *conditional*.

The automatic generation of SLINKs requires the correct identification and categorization of the underlying events within a sentence. Therefore, conforming to the TimeML specification, we manually annotated the events in conditional sentences from an Asthma guideline [9]. A few examples are illustrated below. The introducing event is marked "in bold" and the consequence is "underlined".

If there is no response to ***treatment*** *the drug should be* <u>*discontinued*</u>*.* (1)

They should be <u>*stopped*</u> *if no improvement in* ***steroid dose*** *is detected.* (2)

If both ***tests*** *meet diagnostic criteria for diabetes, then* <u>*diagnosis*</u> *of diabetes can be made.* (3)

To discover whether an event is subordinated or not, required a syntax analysis of the sentence in order to identify the antecedent (representing the condition) and the consequence clause (indicating the subordination). This segmentation was accomplished by structurally-based information extraction rules.

Subordination links are found all over the guideline document – not only in the descriptions of clinical care-paths (e.g., see sentence (3)). Consequently, a rule-based algorithm was developed to exclude irrelevant sentences (see details in section 2.1). Hence, we analysed the events of our guideline concerning their workflow relatedness and developed a categorization scheme for representing this new feature. Finally, we manually annotated the events of condition-action sentences of six guidelines from different medical areas and evaluated our heuristic method.

2. Results

As we need additional semantic information for events in respect to our task, adaptations to TimeML were necessary.

2.1. Extensions to TimeML

TimeML specifies different types of events (e.g., *occurrence, state, reporting,* etc.) to enable temporal reasoning. However, these types did not prove sufficient for the annotation of control-flow related aspects in guidelines. Therefore, we analyzed our training sentences (from the Asthma guideline) and defined a new categorization type "workflow concept" called "wfcon" (see **Table 1**).

Table 1. Type "wfcon" (ant: category appears in the antecedent; cons: category appears in the consequence of a sentence)

type	wfcon	ant	cons	examples from the training sentences
treatment/therapy	trth	x	x	add-on therapy; add-on treatment; exercise
medication/pharmac. substance	meph	x	x	long-acting beta2 agonist; inhaled steroids
status	status	x		is established; is required
action	action		x	discontinue; stop; increase; continue

Based on that, we implemented rules which served as a filter mechanism to classify an SLINK as a control-flow related one. This is indicated by a new attribute in the SLINK specification called "relWF" (short for the "related to workflow") with its values "true" or "false".

The following example[2] (see **Figure 1**) shows the manual annotations of the events of sentence (1) and the automatically generated annotation for the SLINK by our method.

If there is no response to <EVENT eid="e1" ***wfcon="trth"***>treatment</EVENT>
the drug should be <EVENT eid="e2" ***wfcon="action"***>discontinued</EVENT>.

⇩

<SLINK eventInstanceID="e1" subordinatedEventInstance="e2"
relType="conditional" ***relWF="true"***>

Figure 1. Generation of the SLINK annotation

2.2. Prototypical Implementation

The TARSQI Toolkit (TTK) was one of the first implementations which generated TimeML compliant annotations in order to enable temporally based questions about

[2] The EVENT-tags only show the attributes relevant to our method

events in news articles [10]. Due to the absence of structurally-based rules in the latest TTK version, we decided to implement our prototype built on the open source framework for text engineering GATE [11]. We extended the information extraction rules of a former project about the identification of condition-action sentences where we combined several text engineering components (ANNIE: a set of IE components, distributed within the GATE system, and the Apache OpenNLPChunker) [12]. Based on that, we implemented nine filter rules using the categories of the events in the antecedent and the consequence of a conditional sentence as described in section 2.1.

2.3. Evaluation

We manually annotated the events in a corpus of six different guidelines[3] according to the definition presented in subsection 2.1. As these guidelines were already used in a former project, the condition-action sentences were already annotated. The corpus contained 68 conditional sentences including 147 events. 34 of these sentences described conditional activities which should be identified by our method. 35 events which did not follow the categorization scheme were annotated as type "*other*". After applying our prototype to the corpus, the sentences were classified as shown in **Table 2**.

Table 2. Results of the classification process of the 68 conditional sentences

classification	true	false	total # of sentences
positive	22	10	32
negative	24	12	36
total	46	22	68

These values lead to a precision of 68,8%, a recall of 64,7%, and an accuracy of 67,6%.

3. Discussion

The precise identification of subordination links requires the identification of the antecedent and the consequence in a conditional sentence. Even though every if-sentence in the corpus was found, the segmentation of three sentences failed due to missing IE patterns.

The main reason why some subordinating clauses were not found was the fact that the events did not correspond to the defined categories. For example, in the sentence "*Consider referral if patient has* ***symptoms*** *of peripheral vascular disease such as loss of pulses and/or claudication*" a category for the event "symptoms" was not defined. The next sentence showed an equal problem: *"If two different* ***tests*** *are available ..., then the test whose [sic] result is above the diagnostic threshold should be repeated".* The event "tests" had no corresponding category.

Sometimes conditional activities were described repeatedly in a guideline. In such cases only the first appearance was modeled and the others were ignored. The sentence *"Use of statins if tolerated"* was correctly identified by our algorithm, so was the sentence "*Use of statins in all adult type 2 diabetes patients if tolerated*". However, the

[3] Guideline topics: Chronic Hypertension in Pregnancy; Diagnosis and Management of Type 2 Diabetes Mellitus in Adults; Hypertrophic Cardiomyopathy; Gestational Diabetes; Breast Cancer; Chronic Heart Failure

second one was not modeled in our corpus because the first one already contained the relevant information for the clinical care path.

The discussion shows that the improvement of the precision and recall values is possible if the pool of IE patterns for the segmentation of conditional clauses is extended and the coarse grained categories for events are adapted and expanded.

In this project we showed that our method automatically identified condition-based activities for control flow related aspects in a guideline document based on the temporal concept of subordination links (as shown in **Figure 1**) and therefore supports the modeling process of clinical guidelines.

Ongoing steps will be (1) the extension of the linguistic pattern set to improve the identification of the antecedent and the consequence in conditional clauses, (2) the refinement of the categories of events, and (3) the implementation of our algorithm in a model authoring tool.

Acknowledgement.

This research was carried out as part of project no. TRP71-N23 funded by the Austrian Science Fund (FWF) and of the MobiGuide project partially funded by the European Commission under FP-7 grant #287811.

References

[1] Field MJ, Lohr KN, editors. Clinical Practice Guidelines. Directions for a New Program. Washington DC: National Academies Press; 1990.
[2] Isern D, Moreno A. Computer-based execution of clinical guidelines: a review. Int. J. Med. Inform. Elsevier; 2008;77(12):787–808.
[3] Peleg M, Tu SW, Bury J, Ciccarese P, Fox J, Greenes RA, et al. Comparing Computer-Interpretable Guideline Models: A Case-Study Approach. J. Am. Med. Informatics Assoc. 2003;10(1):52–68.
[4] Kaiser K, Akkaya C, Miksch S. How can information extraction ease formalizing treatment processes in clinical practice guidelines? A method and its evaluation. Artif. Intell. Med. 2007 Feb;39(2):151–63.
[5] Kaiser K, Seyfang A, Miksch S. Identifying Treatment Activities for Modelling Computer-Interpretable Clinical Practice Guidelines. In: Riaño D, ten Teije A, Miksch S, Peleg M, editors. Knowl. Represent. Heal. Springer Verlag; 2011. page 115–27.
[6] Pustejovsky J, Ingria R, Setzer A, Katz G. TimeML: Robust Specification of Event and Temporal Expressions in Text. In: Bunt H, Van Der Sluis I, Morante R, editors. IWCS5 Fifth Int. Work. Comput. Semant. AAAI Press; 2003. page 1–12.
[7] Gooch P. A lightweight, pattern-based approach to identification and formalisation of TimeML expressions in clinical narratives. Proc. Sixth Informatics Integr. Biol. Bedside Nat. Lang. Process. Chall. Clin. Rec. Chicago, IL; 2012.
[8] Saurì R, Littman J, Knippen B, Gaizauskas R, Setzer A, Pustejovsky J. TimeML Annotation Guidelines Version 1.2.1. 2006.
[9] Scottish Intercollegiate Guidelines Network (SIGN), British Thoracic Society. British Guideline on the Management of Asthma. Edinburgh (Scotland); 2005 Nov.
[10] Verhagen M, Pustejovsky J. Temporal processing with the TARSQI toolkit. Proc. 22nd Int. Conf. Comput. Linguist. Association for Computational Linguistics; 2008. page 189–92.
[11] Cunningham H, Tablan V, Roberts A, Bontcheva K. Getting more out of biomedical documents with GATE's full lifecycle open source text analytics. Prlic A, editor. PLoS Comput. Biol. Public Library of Science; 2013 Jan;9(2):e1002854.
[12] Wenzina R, Kaiser K. Identifying Condition-Action Sentences Using a Heuristic-based Information Extraction Method. Proc. Jt. Int. Work. KR4HC/ProHealth 2013.