TT-RecS: The Taxonomic Trace Recommender System

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***Abstract*—Traditional trace links are established directly between source and target artefacts. This requires that the target artefact exists when the trace is established. We introduce the concept of indirect trace links between a source artefact and a knowledge organization structure, e.g. a taxonomy. This allows the creation of links (we call them taxonomic traces) before target artefacts are created. To gauge the viability of this concept and approach, we developed a prototype, TT-RecS, that allows to create such trace links either manually or with the help of a recommender system.**

***Index Terms*—Traceability, Requirements, Domain-specific Taxonomy, Recommender System**

I. Introduction

Traceability from requirements specifications to downstream artefacts has shown to lead to more efficient and correct software maintenance [1], is a pre-requisite for requirements-based testing [2], and in certain application domains a necessity to demonstrate compliance to regulations [3].

However, manual creation and maintenance of trace links is in practice often not feasible due to their number and the complexity of information that needs to be maintained over time. Many requirements management tools support manual trace link creation or even automated trace link recovery. However, none of them supports, to the best of our knowledge, taxonomic traces, explained next.

II. Taxonomic Traces

In systems and software engineering, a "trace" is often defined as a triplet consisting of a source artefact, a target artefact and a link associating the two artefacts [4] (Figure 1a). We propose[1] to introduce indirect trace links to a taxonomy or similar knowledge organization systems such as controlled vocabularies, taxonomies or ontologies (Figure 1b).

Before we delve into the technical solution we prototyped with the Taxonomic Trace Recommender System (TT-RecS) described in Section III, we illustrate the limitations of the traditional artefact-to-artefact trace link approach. Conceptually, trace links connect artefacts along the following dimensions: abstraction, structure and time.

a) Abstraction: Traced artefacts usually exist on different abstraction levels of domain concepts. For example, a requirement may describe the capabilities of a bank account, while a class `BankAccount` in an object oriented design provides an implementation. Someone (or something, e.g. an algorithm) that aims to establish a direct trace link needs to be able to handle the difference in abstraction.

b) Structure: With the structure dimension we refer to how information about domain concepts in different artefacts is stored. For example, requirements are typically stored in tools that support natural language text (word processors or dedicated requirements management tools). Other artefacts (design models, source code, test cases) are stored and managed with different tool sets, specialized for the particular task.

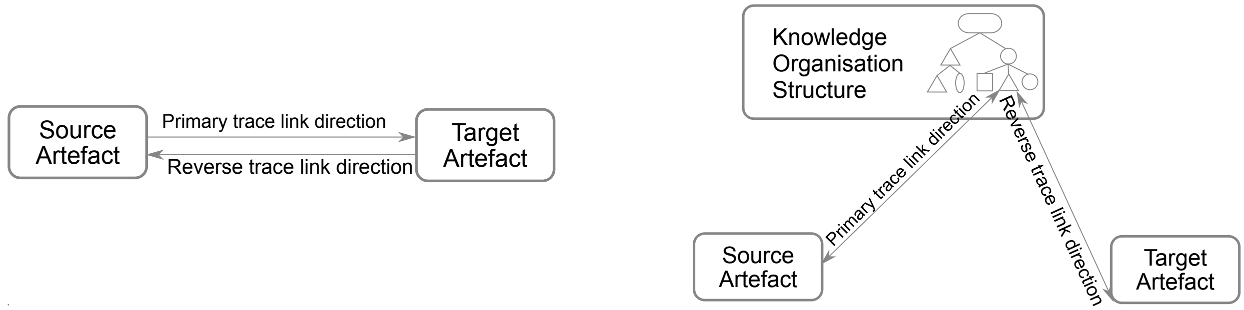
c) Time: The time dimension refers to the fact that artefacts typically are not created at the same time, making it impossible to create trace links when the source artefact is developed. For example, when a requirement is elicited and specified, typically the implementation and test cases do not exist yet[2].

We briefly outline motivations why taxonomic trace links (Figure 1b) address the above issues:

1) The abstraction level gap can be reduced as engineers need only their domain expertise and their skills specific to their profession. This might be less important for a scenario with full-stack engineers of DevOps. However, system and civil engineers are specialized and technical domain experts, without necessarily being proficient in design and implementation tasks. *Hence, experts in the problem and the solution domain respectively can create trace links to a common knowledge organization structure, without the need to tap into unfamiliar knowledge areas.*
2) The structure gap can be bridged by a common taxonomy that connects information silos by removing the need of direct interoperability. Profession specific information management systems (for requirements, design documents, source code) can be adapted to support traces to knowledge organization structures (such as a taxonomy) instead of directly supporting trace links

[1] We do not claim novelty of this idea since, as far as we know, Noll and Ribeiro [5] were first to outline in their position paper from 2007 on how to enhance traceability using ontologies in the Unified Process.

[2] Test driven- and behaviour-driven development are examples of means to reduce this time gap.



(a) Traditional trace link (adapted from [4])

(b) Taxonomic trace link

Fig. 1: Traditional vs. taxonomic trace links

between myriads of different systems. This is especially important for scenarios where engineering work is outsourced, and clients rely on trace links to perform delivery verification. *Hence, knowledge organization structures represent a conceptual Application Programming Interface (API) that information management systems can implement independently, enabling interoperability.*

3) The temporal gap is removed as engineers can create trace links at the same time they create the artefact, removing the necessity to recover trace links when downstream artefacts become available. Furthermore, the taxonomic trace links can be used to analyse the artefact, for example in case of requirements for their completeness or consistency. *Hence, by benefiting the creators of taxonomic trace links through their immediate usefulness, they provide intrinsic motivation and are therefore more likely to be created at all.*

While these benefits of indirect, taxonomic tracing are very promising, they have, to the best of our knowledge, not yet been evaluated in practice. We have therefore implemented a prototype system, evaluated in a pilot experiment [6], and present here its basic design and functionality.

III. Taxonomic Trace Recommender System

TT-RecS is built on top of INCEpTION [7], a general purpose text annotation platform that can be extended with custom recommenders. INCEpTION allows importing knowledge organization structures from RDF files or connect to a remote knowledge base using SPARQL. Since we developed TT-RecS in the context of a collaboration with Trafikverket, the Swedish Transport Authority, we used the domain specific taxonomy *CoClass*[3] which organizes concepts from the construction domain in a hierarchical taxonomy. Figure 2 shows an example of the imported data from *CoClass* in INCEpTION's knowledge base.

The recommender configuration (Figure 3) provides two relevant options:

1) The threshold value for the recommendation confidence (a value computed by the different predictors explained in [6]). Recommendations with a lower value than specified here are not shown.
2) The maximum number of rejects after which a suggestion is not shown any more.

INCEpTION allows the user to import documents in different formats (plain text, JSON, HTML, PDF and different

[3]https://coclass.byggtjanst.se/about#about-coclass

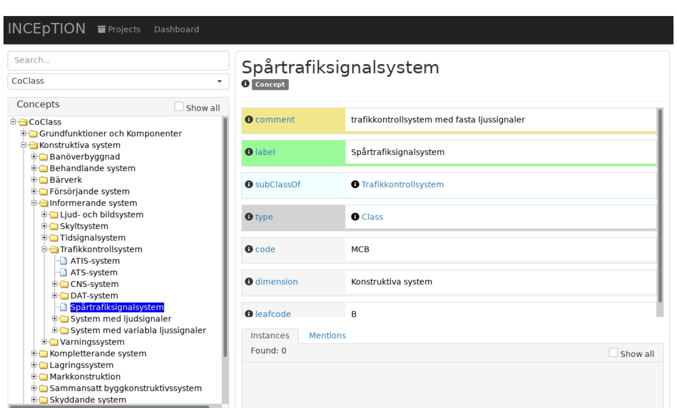


Fig. 2: Example objects from CoClass

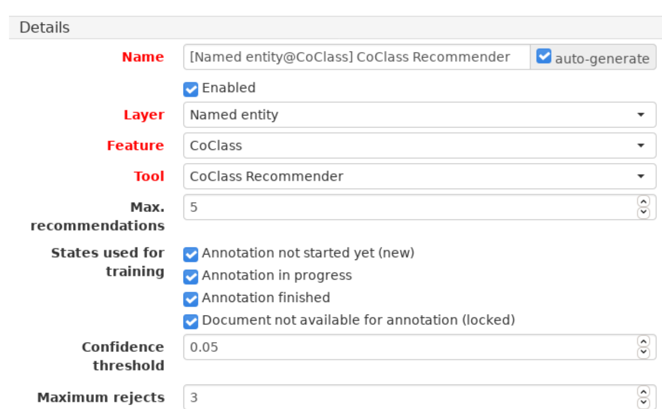


Fig. 3: Recommender settings

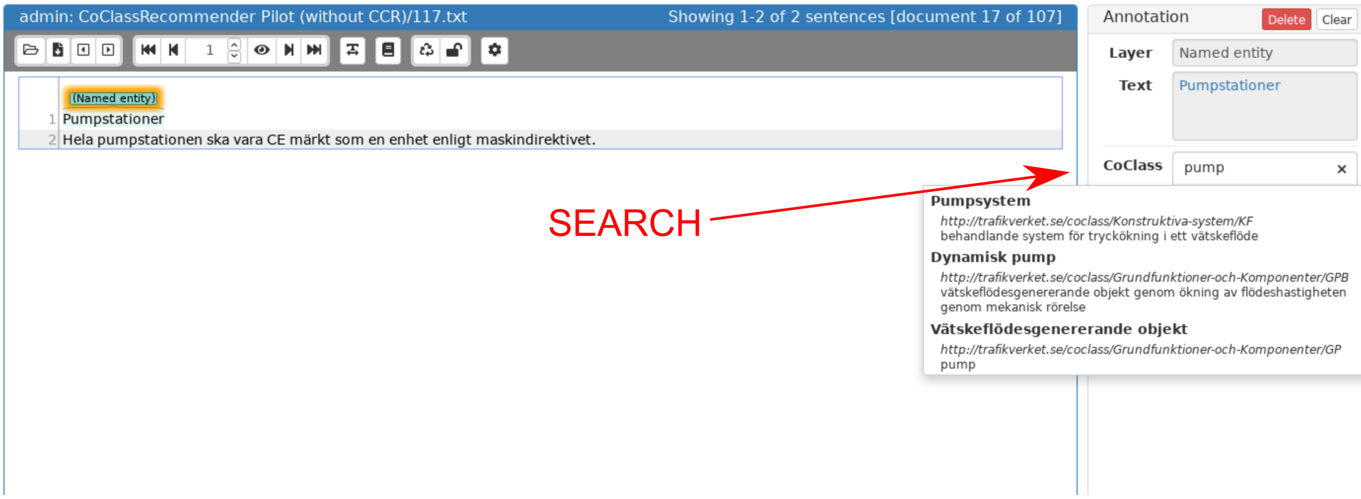


Fig. 4: Manually identified taxonomic traces through search

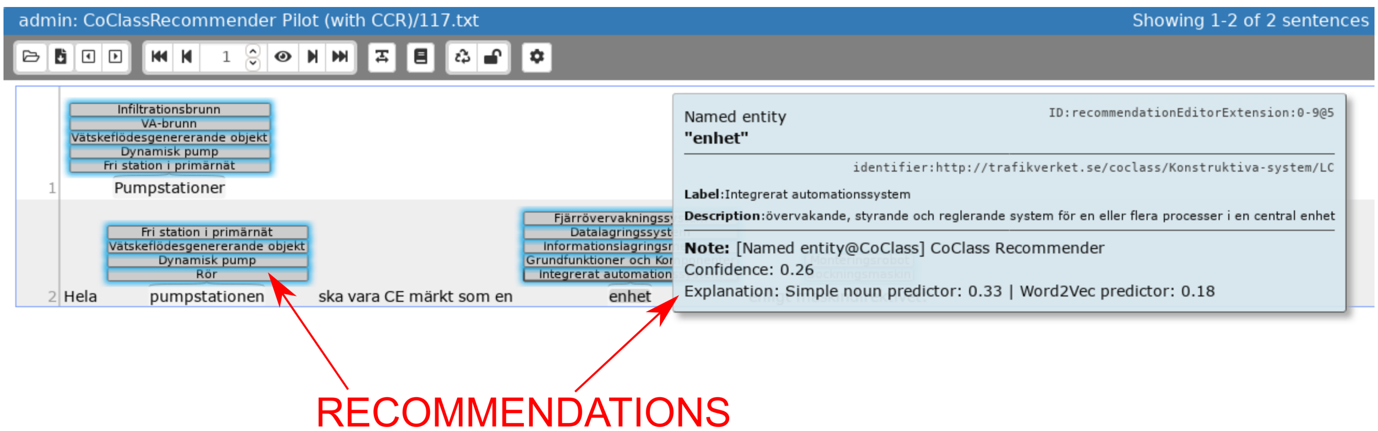


Fig. 5: Taxonomic traces identified by the recommender

NLP tool exchange formats). These documents can in turn be opened in INCEpTION's annotation interface.

Figure 4 shows an example where a document with a requirement is opened without TT-RecS. The user must use his/her domain knowledge, i.e. use the correct search terms, to find the objects from CoClass that can be associated to the requirement in question.

Figure 5, on the other hand, shows the same requirement with CoClass objects suggested by TT-RecS. The user can now either accept or reject the suggestions, based on the information shown about the suggested CoClass object.

We have evaluated TT-RecS in a pilot experiment with seven domain experts with varying experience in CoClass and reading/writing requirements [6]. The goal of the pilot was to validate the experiment instrument and get some indication whether domain experts are able (with or without recommender) to create taxonomic trace links. The main take-away of that study is that the trace task was challenging, independently of whether the recommender was used or not. While this result was not encouraging, we are currently improving TT-RecS and incorporate the lessons learned from the qualitative analysis from the experiments results. We conjecture that the main gain can be achieved by tuning the recommendations such that they take the context of nouns into account. Since the tracing task is challenging even for domain experts, we conjecture that recommendation systems are essential to make taxonomic traces practicable.

IV. Demonstration Plan

Since the concept of taxonomic traces is novel, and as far as we know not yet implemented in a tool, we preface our demonstration with an explanation of the concept and pointing out the differences and advantages w.r.t. traditional trace links. Then we illustrate how to set up the demonstrator[4] and point to

[4] Available here: http://doi.org/10.5281/zenodo.3827169

the source code of TT-RecS that is under active development[5].

The demonstration proper illustrates how to configure INCEpTION with the recommender and import documents. We then compare the manual creation of trace links using INCEpTION's annotation interface with the recommender suggested trace links.

V. Conclusions

We believe that our research will serve as a base for future studies on taxonomic traces, in particular as we have developed a working prototype that has been used in an experiment with industry participants. While the precision of the recommender needs to be improved, we think it is important to evaluate novel ideas in realistic settings, early in the ideation process, in order to gauge the practical viability of the idea.

References

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