Form Subjects to Concept Clouds – Why semantic mapping is necessary

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Abstract. To realize the vision of the semantic web it is essential to be able to exchange formal modeled knowledge between applications and humans without loss of meaning. In this paper, we focus on questions relating to meaning, interpretation and subject identity in modern semantic web languages. Based on the semiotic triangle we show that topics as well as RDF resources are symbols, representing concepts and not referents as the common term "subject" would indicate. A subject can not be represented as a single entity, but rather as a complex and evolving system of different concepts. Based on this insight we explain how the resulting plurality and uncertainness of the interpretation of symbols can be handled using semantic mappings. By defining transformation rules, the exchange and integration of knowledge from different semantic models becomes possible. Concluding we define recommendations and design guidelines for a semantic mapping management system, which is needed to support users and applications in creating, reusing, managing and applying such semantic mappings.

1 Introduction

Tim Berners-Lee described in 2001 a use-case, where digital agents are able to arrange appointments collaboratively by searching various information vaults based on personal preferences and contextual information [1]. This well-known vision of Tim Berners-Lee is often used to explain what the World Wide Web will or at least should look like in order to support us in dealing with the complex and dynamic world of today [2].

One key challenges of the semantic web[2] is the expression of knowledge to enable a flexible exchange between users and software applications without loss of meaning [3, 4]. This implies that knowledge may be made available to applications other than those for which it was originally created. Sophisticated semantic technologies like the Resource Description Framework (RDF)[5], the Web Ontology Language (OWL)[6] or Topic Maps[7] can be used to formal model knowledge implicit and explicit contained in web content [2, 4]. The modeling of knowledge is inescapably bound to meaning and semantic aspects [8, 9]. To provide efficient mechanisms for communication and knowledge exchange, it is necessary to have a detailed understanding of how a statement about a subject is made, interpreted by the recipient and how meaning is established [10, 11]. However, research and discussion in the semantic web community seems to be dominated by technical and syntactical questions [2, 3]. Existing literature discussing the semantic principles of, e.g. Topic Maps or RDF, and how to connect it with existing theories of indexing, knowledge organization and semiotics is quite rare [8, 9, 11].

In this paper we will address these open questions by pointing out, what it might be about the semantic nature of semantic modeling that should, at the very least, be taken into account. Therefore we will focus in section two on the conceptual similarities between RDF[5] and Topic Maps[7]. In section three we discuss the semantic triangle in order to explain the factors involved whenever any statement is made or understood. In section four we discuss the implication of this insight on RDF and Topic Maps, especially in regard to the subject identity question [11]. In the next sections we will explain how the identified problems can be addressed by using semantic mappings. In section six we will conclude recommendations and design guidelines for a semantic mapping management system, which is needed to support users and applications in creating, reusing, managing and applying semantic mappings. The paper concludes with a summary and an outlook.

2 Subjects in Topic Maps and RDF

RDF and Topic Maps are common technologies for the formal encoding of knowledge [2, 7]. Despite the obvious technological and conceptual differences (e.g. languages, implementations, structure, elements)[12], we can note that there are significant similarities between the two with regard to semantics.

1. *Usage of symbols*
   Both technologies use special symbols or indices to represent the relevant subject of interest in their digital worlds (see Fig. 1). In Topic Maps these symbols are called topics [7] and in RDF resources [3]. Both act as proxies for the ineffable subjects of the real world in order to formally model statements about them [11]. The subject can be anything whatsoever, regardless of whether it exists or not [7]. In particular, it is anything which the creator chooses to discourse.
2. *One symbol per subject*
   The common goal of RDF as well as Topic Maps is to ensure that every subject is represented by one or more common symbols [4, 13]. Thus a topic or a RDF resource can be used as "binding point" for everything that is known about a given subject. If someone searches an information, he just have to find the right symbol (topic or RDF resource) representing the searched subject, and than he can access all subject related information [3, 4, 12]. However, this implies the common accepted assumption, that equal symbols represent the same subject [5, 7]. For example, if a user or an application finds two equal RDF resources in different semantic models, the user can

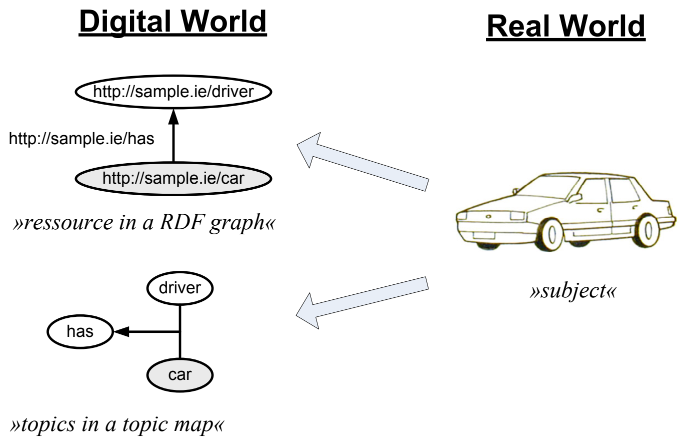

Fig. 1. Using symbols to represent subjects in Topic Maps and RDF

assume that both represent the same subject and all modeled information are relevant for the same subject [14].

3. *URIs are used to define the subject identity*
   The question is, how can we formally identify a symbol (topic or RDF resource), thus describing its subject identity. Each topic as well as each RDF resource contains an Uniform Resource Identifier (URI) [3, 7, 11, 14]. The URI or more commonly URL (as a subclass of URIs) can be used to identify any subject. As a result, if two symbols share the same URI they are considered identical by humans as well as by applications [12, 14]. Thus RDF as well as Topic Maps expects two symbols with the same URI to be referring to the same thing.[1]

In summary we can note, that Topic Maps and RDF uses a surprisingly similar approach for modeling knowledge. The cores of both technologies are symbols and URI's to represent subjects.

3 Making a Statement

What is a subject in regard to semantics and how is it interpreted by the user to create meaning?[8] To deal with this question, the standard documents of Topic

[1] Please note, Topic Maps defined two special scenarios in this context [7, 14]. First, a URI can be used as reference to a subject indicator resource in an attempt to unambiguously identify the subject represented by a topic to a human being. In other word the referred resource describes the represented topic. Second, the URI refers to the information resource that is the subject of the topic. The topic thus represents that particular information resource, e.g. a topic represents the web page http://www.dublin.ie. In RDF this distinction is not modeled explicit and has to be handled by the user or application [15].

Maps and RDF are not very helpful. In RDF the subject is simply define as "An entity; anything in the universe"[15] and in Topic Maps "anything whatsoever, regardless of whether it exists or has any other specific characteristics, about which anything whatsoever may be asserted by any means whatsoever" [7]. These very general explanation are not very meaningful, because the relation between the symbol and the represented thing is not defined explicitly [8].

For a better understanding it is helpful to view this question in the light of literature on semiotics. In particular the semiotic triangle[10, 16], which is also known as the triangle of reference, triangle of meaning and concept triangle, provide a valuable insight (see Fig. 2). This triangle figure has its genesis, in a diagram used by Ogden and Richards to explain the three factors involved whenever any statement is made or understood [16]. The basic elements of every

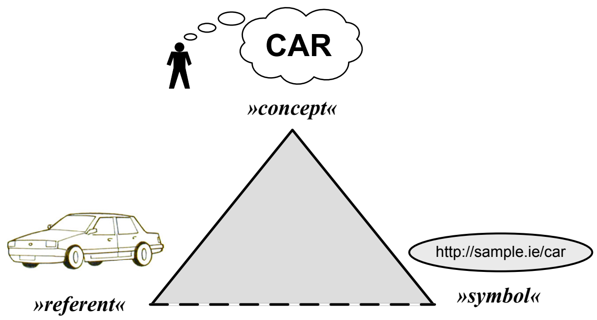

Fig. 2. Semiotic triangle

communication are the specific objects of the real or abstract world, which we like to talk about. In the semiotic triangle these are called *referents* or objects [8, 16, 17]. Every referent possesses an individual amount of attributes and characteristics. However, a user considers only the relevant characteristics and ignores the rest depending on his own interest, current situation or perspective [10]. For example, if a user wants to buy a car, he will probably consider the configuration, the mileage and the price. However, for most users the name of the person who installed the steering-wheel or the metal alloy used for the roof of the car is circumstantial. In general, there are endless attributes for every referent, but it is only the essential characteristics that define an object for a human. It is this ability of humans to differentiate between essential and non essential characteristics, which allows us to deal with our complex world and to communicate [10]. The sum of the essential characteristics of a referent is called *concept* or reference. This thought reflects the inner image of the relevant object, every human creates unconsciously [16, 17] It is highly subjective and depends on the context of the user, [8] e.g. for a person who works on an office desk, the weight is not relevant, but for a furniture remover it is, because of his profession. To enable a clear communication with others, we need to express these concepts by using appropriate *symbols*, like names, textual definitions, pictures, sounds, etc.[8, 17, 25] The symbols have to be defined in the community and must be suitable to highlight the relevant characteristics in order to allow a user to understand the meaning, e.g. a ISBN number is common symbol for a book.

Textual symbols can be split in the group of lexical and non-lexical expressions [17]. Lexical expressions are a defined term or a term combination for a specific concept. It allows a compact identification, e.g. AIDS is a common accepted term for the complex clinical pattern of the acquired immune deficiency syndrome. In contrast for many concepts a single name is not available and therefore a paraphrasing description is needed, e.g. aquaplaning describes a situation when a road get slippery during rain. But there is no single lexical term to describe, if a floor gets slippery by milk. To sum up the semiotic triangle consists of the following three elements [8]:

- referent, is the specific object of the real or abstract world, we what to talk about
- concept, is the thoughts of the object, that a human has in his mind of the referent
- symbol, is an expression of the concept which are used to communicate with others

Considering the relationships between these elements, we must note that there is a direct (almost causal) relationship between the referent and a concept, because the concept is a subset of the overall characteristics of the referent. User can have different concept of the same referent but normally they share at least some characteristics, which enable them to communication, even if it is reduced to the common denominator, e.g. a designer, assembly line worker and customer may not share the same view on a car but in a communication they are able to talk about the same thing.

Furthermore there is a less direct relationship between concept and symbol. In the end, any symbol can be chosen which (at least from the perspective of the creator) is suitable to encode the concept. Representing a concept in natural language or in an image can produce an infinity of variation. Hence, it is an inherently indeterminate process [2] and yields an unpredictable result [17].

Finally, there is only a *indirect relationship between symbol and referent*. In other words, there is no way of determining how any given symbol, refers to any given object of relevance [8]. In particular Heidegger explains that [3] a relationship between a symbol and referent exists relative to the needs of the acting individual: where one person might perceive a concept of a specific kind, another might perceive a concept of a different kind[31], or not perceive any concept at all, because the situation lacks relevance [8, 18]. For example, in

[2] An indeterminate process is one which can proceed in an infinity of variations so that its progress is rendered unpredictable [17].

[3] A detailed analysis of the philosophical interpretation of symbols and meaning of the philosophers Pierce and Heidegger can be found in [8].

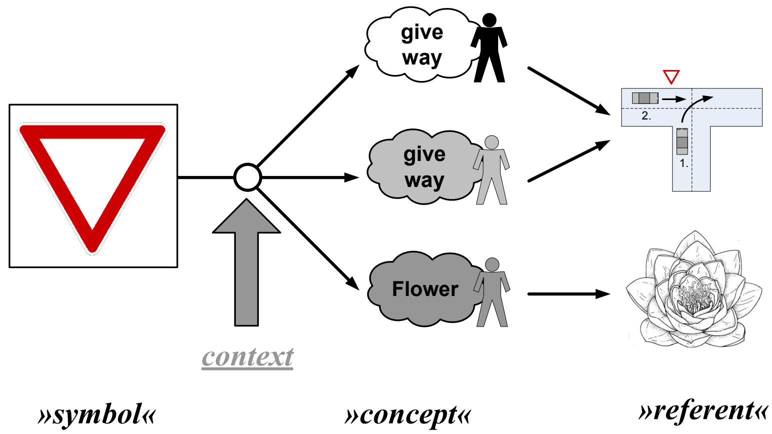

Fig. 3. Example for the uncertainty of symbols interpretation

Europe a give way sign is a well known symbol for a specific traffic rule, but not for an aborigine form the deep Amazon's jungle. It is uncertain, that he will association the symbol with the same concept as we did (see Fig. 3). It is more likely that he will associate it with a different set of essential characteristics (e.g. red, long trunk) and will therefore refer to a different referent, e.g. flower. Keeping in mind that symbols are a kind of communication tool, it is clear that the issue of meaning relates to the receiver of the information, and not to the transmitter [8]. In other words, in the case of choosing a symbol for a specific concept, its meaning derives from how the user understands it, not from how it was constructed [20]. To put this more forcefully: one can choose a symbol as artfully or in as sophisticated a manner as possible; while this may facilitate the interpretive process for the user [17], it cannot cause the user to understand (the meaning of) the individual symbols, any more than someone can force another to understand (the meaning) of what she or he is saying. It is like Friedrich Nietzsche once said "there are no facts, only interpretations"[19].

4 Implication for Topic Maps and RDF

As we have seen in making a statement three factors are involved: symbol, concept, referent. But what does this means for Topic Maps and RDF.

1. *Topics and RDF resources represent concepts not referents*
   Topic and RDF resources clearly act as symbols for the representation of subjects[12, 5, 7]. We have seen that the commonly used term "subject" is not accurate enough in the context of meaning and interpretation [11]. The term subject implies that a topic and RDF resource respectively represents a referent. But as we have seen in discussing the semantic triangle this can

not be true, because the relation between a symbol and a referent is always indirect [8, 16]. In fact topics as well as resources are representing concepts. If we take a look at the modeling approach, we find evidence which supports this thesis [21]. If an ontology designer needs to represent something, he has to find a suitable symbol (topic or RDF resource). The subject identity is defined by a URI and a corresponding definition (external or by the linked subject indicator resource). In order to decide, if an available symbol (a) is appropriate, he has to identify the characteristics (c) of the referent (r) described in the symbols' definition ($r = c^a$) and has to compare it with his own interpretation on the object ($r = c^b$). Only if they are identical or at least similar enough, the symbol is a suitable representation of the subject. [4]

2. *Multiple concepts represented by topics or RDF resources for every referent* This has considerable implications for RDF and Topic Maps. As we have seen in section two, the concept creation for a referent depends on context (time, place, opinion) [8] as well as on personal preferences and on previous knowledge. Even, if its looks (based on equal URIs) that two ontology designer model knowledge on the same referent, this does not necessary mean that the symbol represent the same concept. Their individual set of essential characteristics can be different, e.g. a sub set of each other, a union or even contradictorily. As a result the semantic web is not as consistent as we might think. Instead of one symbol per subject [7, 3], it looks more like a complex and evolving system of concepts, in terms of different interpretations [8, 22]. For a single referent multiple concepts exist and each of them can be represented by a unique symbol, e.g. topic or RDF resource.
3. *Definition of symbol identity via URI is inaccurate* This insight has implication on the way how subject identity of topics and RDF resources respectively are defined. For example a Topic Maps created by a car producer contains knowledge on price (URI: http://price). In addition a customer could model his preferences on cars in a personal topic map, e.g. max price (URI: http://price). As described in the use-case of Tim Berners-Lee, suitable software agents could import these information from both sources [1]. Based on the URI of the symbol an agent would come to the conclusion that both models contain information on the same subject. However, if we keep in mind that topic and RDF resources represent concepts this can be problematic. Concepts are the sum of the individual essential characteristics and these can be different [8, 17]. Producer as well as customer talk about prices but may be from a different perspective, e.g. different types of price like end user price, re-seller, minimum price etc. Because the relation

[4] In analyzing Topic Maps we must not, that there is the option to explicit define, that a topic represent a certain digital addressable resource via a subject locator [7]. This may look like the symbol represent a referent directly. However, even in this case the topic act as a symbol representing a certain concept. The only difference is, that the definition of the concept is commonly agreed and well-known. Thus what the essential characteristics are, in term of the amount of digital data which can be download from the defined URL.

between the referent and the symbol is only indirect, it is uncertain that two symbols with the same URI represents the same referent.
As a results a software application could import or merge symbols with identical URIs but it is uncertain if they represent the same concept. From a problem-oriented view of the user the knowledge could be to low grained, to detailed information, not relevant or even wrong. Using URI's to identify a topic or RDF resource is only suitable inside a closed domain, e.g. if a controlled list of symbols is used. If the knowledge is made available to applications other than those for which it was originally created [3], URIs are not accurate enough.

4. *Many incorrect ways to model a domain, but no single correct way*
Many users got the impression that semantic modeling languages are more precise than natural language. This is probably true to a certain extent, because natural language is indeterminate resulting in an infinite amount of possible expression of a concept [17], e.g. see the endless poems on love. However, this is also true for semantic modeling. On one hand you have different modeling languages, like Topic Maps, RDF, OWL etc, which can be used to model the same statement but are not fully compatible amongst each other [12]. On the other hand there are many incorrect ways to model a domain, but no single correct way [21]. There are often modeling alternatives and the best solution depends on the application. Modeling tends to be an aesthetic activity rather than a technical construction.
For example, if someone wants to model the statement that the web resource http://www.ilmenau.de contains relevant information on the German town Ilmenau (see Fig. 4) he could model it as an external occurrence in Topic Maps (variant 1), as a association in Topic Maps (variant 2) or as a RDF triple (variant 3). The modeling approaches and used symbols may be different but the meaning is identical. A human may be able to understand this. Using the common method for subject identity, software application are limited by URIs and the structure of relations and get therefore the wrong impression that these three statements are different. This makes the exchange and integration of formally modeled knowledge of different sources so difficult, because information can be incompatible or undetected although the meaning is relevant for the recipient. In addition, semantic modeling is a very dynamic and iterative process. During the modeling the designer get a better and more detailed understanding of the domain and so it is often necessary to revisit earlier decisions and modify some of them during the modeling process [4, 21]. Therefore during time the same symbol evolves, e.g. new names or associations are added or even removed. A fixed URI cannot reflect these changes and is therefore not enough for identification of changes over time.

In summary, to grasp the plurality of interpretations we can not represent a subject as a single entity, but rather as a complex and evolving system of different concepts depending on context, domain, origin or focused task. Each concept is represented by formal symbols, e.g. topic or RDF resource. Instead

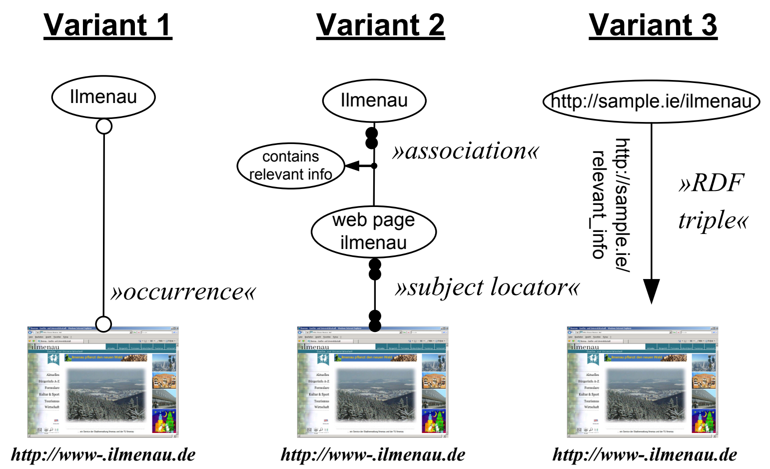

Fig. 4. Modeling alternatives

of the traditionally promoted 1:1 relation between a subject and a symbol [7, 4], it seems to look more like a cloud of multiple symbols representing individual interpretation of a common referent Fig. 5.

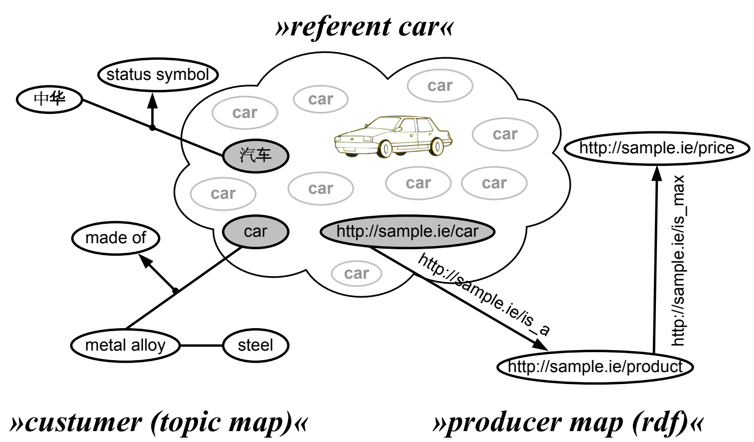

Fig. 5. Concept cloud

5 Semantic Mapping

To realize the vision of the semantic web it is essential to exchange formally modeled knowledge between applications and humans without loss of meaning [3]. Fact is that a topic and RDF resource represent different concepts, thus different sets of essential characteristics (c). In order to be able to integrate knowledge on a relevant referent (r) from different sources (a,b),we need know the available concepts (r - c^a,r - c^b) are related. Are they identical and if not what needs to be done to adapt them in order to be able to integrate c^a in the semantic model of b. Such rules for transformation or adaption are called semantic mappings [24]. For example think of an appointment software agent of

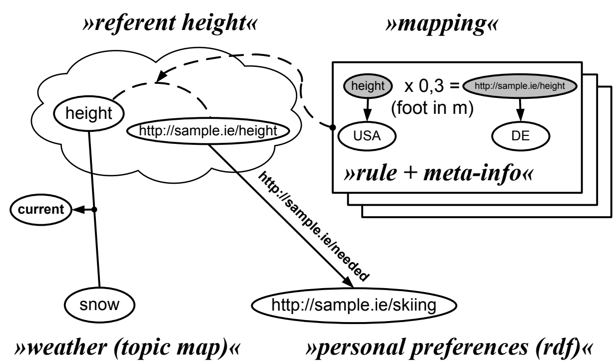

Fig. 6. Subject cloud

a German tourist. If he goes to the USA the agent "knows" based on the modeled personal references that the tourist likes to ski and that a certain height of snow is needed for this activity. The agent could then exchange knowledge with a weather information system, where the knowledge of the current snow height is modeled, e.g. in a topic map. Combining both pieces of information allows the agent to conclude, if the snow height is sufficient for a skiing appointment.

Obviously, the weather model as well as the preferences model must contain a symbol representing the height of the snow (see Fig. 6). As we have seen in the previous section the symbol are only indirect connected to the referent "snow height" and in fact represent individual concept, which can be different, e.g. the whether model represents height in foot and the preference model in meters. In addition both model can uses different URIs or modeling languages to identify the symbols, e.g. in the USA RDF and in Germany Topic Maps are used. However, both models contain information more or less on the same referent. To exchange and share the knowledge, it is necessary to create a semantic mapping, which in this case defines a transformation rule for the conversion of foot in meters and a linkage of the different URIs. These enable the agent to reuse the modeled knowledge of the American information system without loss of meaning.

Such a conversion is a very simple mapping problem. But the same idea can be applied to more complex tasks, too. If for example a semantic model uses a meta-model and another one does not. Then a mapping rule can define how a relevant sub graph of the first model can be extracted and transformed to be compatible with the second model. Currently enormous efforts are made to formally model knowledge in medicine, engineering and many other domains [2]. But in many of these project different schemas, different symbols and modeling languages are used. Only with efficient and flexible mapping a exchange of knowledge between these different domains and source is possible without loss of meaning. However, these semantic mappings are created for a specific purpose in term of bridging one knowledge space with another. Mapping rules are only valid in a specific context, e.g. time, place, creator or task and can change. As a result for two symbols an endless amount of possible mappings can exist, similar to the plurality of concepts - each for any user or field of application. In addition mappings can contain complex transformation rules, and it is obviously not suitable to reinvent them over and over again for similar tasks. Therefore reuse of mappings is a big issue, but for this it is necessary to find existing suitable mappings and to know: who, how and why these mapping were created.

6 Semantic Mapping Management System

To handle these multiple and complex semantic mappings in an efficient way and to deal with the plurality of concepts, which is inherent to each semantic model, a sophisticated management system for semantic mappings (MSM) is needed.

A first question for the design of such an MSM is, how to *represent the symbols or the fragments which need to be mapped*. To enable a software application to process them automatically, it may be suitable to represent the symbols using a formal knowledge language. This language should be flexible and powerful enough for the ubiquitous identification of the concepts as well as to deal with linkage type mappings, complex mappings including the required mapping rules.

The second open question is how to *represent the mapping rules*, which can involve all kinds of transformations, e.g. from simply mathematical function to complex transformation of sub graphs. The mapping should be flexible and directly executable. For RDF the XSPARQL[27] language may be a good candidate, because it combines the powerful query functionally of SPARQL[26] with the transformation features of XQUERY. For Topic Maps such a sophisticated query and transformation language is missing. However, XSPARQL may be promising, but using a RDF or a Topic Maps specific language is not suitable. A mapping can require the transformation from one into another modeling language (RDF in Topic Maps) or from quite different sources and therefore a semantic language independent solution is needed.

Another relevant question for such a MSM is the *identification of the symbols*. Inside the individual models, the symbols are identified by URIs. However, this is not sufficient inside the semantic mapping, because symbols with identical URIS from different origins can represent different concepts. As a result a distinction beyond URIs is needed inside the MSM and therefore additional contextual information must be added, e.g. creator, source, time, place etc. For a manual as well as an automated processing and reuse of the mappings extensive meta data on the mapping itself is required. In the end to be able to draw conclusion why and how a certain mapping was created, may be the whole involved sub graph of the original and targeted model is needed.

The *process* involved in creating and using context-based semantic mapping is not sufficiently researched. Based on the presented argumentation at least the following steps are relevant. They key question for a MSM is: how to support the users in this process.

1. Analysis of the symbol or model fragments, which need to be integrated or exchange. The objective of this phase is to identify the set of essential characteristics of the concept represent by each symbol.
2. Search for existing semantic mapping, which describes how the set of essential characteristics of the source concept can be transformed into the set of the target concept.
3. If no suitable semantic mapping exists, create a new one.
4. Document the semantic mapping, for searching and reuse. In particular import are information on the creator, traceability, reasons for the mapping, level of confidence as well as used matching algorithm.

In the creation process of semantic mappings different groups of *users* are involved. For example human domain experts are needed, because they possess the required back-ground knowledge of the domain and can interpret the contextual information. Only these experts are able to create a valid task or domain specific mapping rule. In addition knowledge engineers are required to translate this mapping rule in a formal knowledge representation, which can be processed and executed. In general domain expert do not process the necessary experience in Topic Maps or RDF, therefore they need assistance. Suitable matching algorithms (e.g. string or structure based) can be used to assists users in the identification of possible mapping candidates. However, fully automatic derivation of mappings are not possible, yet [23]. Tools as well as algorithms are limited to matching and can not create a creative cross-domain connection because the necessary formal knowledge for an automated deduction is missing, which is the reason for creating a mapping in the first place.

In addition individual software applications need to be able to flexible integrate the functionality provided by an MSM system. For example the appointment agent in Tim Berners-Lee's vision, needs to be able to send a request to the MSM containing the source and the target symbol and receive a mapping. The *software architecture* of such an MSM must consider these requirements, therefore a services-oriented architecture (SOA)[28] may be suitable. A SOA groups functionality around business processes and packaged them as interoperable services. By separating functions (search, creating, management, etc.) into distinct services [28], they can be made accessible over the Internet in order to be flexible combined and reused in any application needed [29].

7 Conclusions

In this paper we discuses question relating to meaning, interpretation and subject identity in modern semantic web languages like RDF and Topic Maps. Based on the semiotic triangle we described the three factors involved whenever a statement is made, or understood (symbol, concept, referent) and what implication these have for Topic Maps and RDF. In particular topics as well as RDF resource are symbols representing concepts and not referents as the common term subject would indicate. Based on this insight, we explained how the resulting plurality and uncertainness of the interpretation of symbols can be handled using semantic mappings. Concluding we define recommendations and design guidelines for a semantic mapping management system, which is needed to support users and application in creating, reusing, managing and applying these semantic mappings.

We could show the necessity for the support of semantic mapping but many detail questions are still not solved sufficiently , e.g. how semantic mappings can be represented, how and which meta knowledge on semantic mapping is needed as well as how the process of mapping is conducted and how can it be supported. Overall, we came to the conclusion that the remarkable efforts made in formally annotation the World Wide Web are just the first step. In a second the creation of semantic mappings is essential to achieve the goals of "global knowledge federation"[22, 30] and even to begin to enable the aggregation of information and knowledge by humans and software agents on a scale large enough to control the overall informationglut[11].

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