

Organizing Thematic, Geographic, and Temporal Knowledge in a Well-Founded Navigation Space: Logical and Algorithmic Foundations for EFGT Nets

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ABSTRACT

We introduce a family of symbolic logical formalisms for reasoning with named entities, associated topics or thematic fields, geographic areas, and temporal periods. We argue that this kind of knowledge is useful for various applications in a Semantic Web context, in other words, for the content-oriented description of Web services and yellow pages. In our approach, entities and their relationships are positioned in a well-founded (i.e., acyclic) navigation space, called an EFGT Net. Large (small) entries regarding the navigation order represent general (specific) topics and large (small) geographic or temporal areas. This acyclic organization of knowledge aims to support indexing, search, and classification tasks directly. Each entry comes with a unique identifier that describes the role of the corresponding concept, using techniques from description logics. A formal semantics for the language of identifiers is given. For the resulting logic, role hierarchies and role-value maps are characteristic and crucial. Based on the semantics of identifiers, a set of intensionally typed links is defined that induces the aforementioned navigation structure on the set of all entries. We then introduce a set of deduction rules and a saturation procedure for computing all links between concepts, as well as intensional types for links. We prove soundness, completeness, and termination of the link derivation calculus.

Keywords: data organization; data semantics; geographic and temporal information; hierarchical model; knowledge classification; knowledge models; knowledge utilization logic; ontologies; semantic matching; term hierarchies; Web services

INTRODUCTION

The present paper represents an outcome of a project striving to formalize the knowledge that humans associate with named entities, and to use this knowledge in a Semantic Web context or related scenarios. Named entities such as “Daimler-Chrysler”, “Kofi Annan”, “Leonardo

da Vinci”, “International Conference on Logic Programming”, “July”, “Royal Albert Hall”, “Niagara Falls”, and so forth are ubiquitous in Web documents. For human users, the list of named entities occurring in a text yields a good profile, a kind of abstract for the document. This shows that the information carried by named

entities, once brought to the surface, represents a valuable kind of metadata. EFGT¹ Nets formalize this kind of knowledge in order to support indexing, search, classification, hyperlinking and related tasks directly. The motivation for EFGT Nets has been thoroughly described in earlier work (Schulz & Weigel, 2003) where we also introduced a naive (semi-formal) systematic for EFGT Nets.

EFGT Nets in a Nutshell

A closer look at the kind of information that is formalized explains why EFGT Nets may be very useful for formulating and querying content-oriented profiles and semantic metadata for Web services and Web directories like yellow pages. In EFGT Nets, three axes of orientation are of primary interest:

1. A hierarchy of *thematic fields* (*F*), ranging from universal areas (“technology”, “arts”) to specific topics (“digital cameras shop”, “museum for contemporary art”), yields a global orientation. For Web directories such as Yahoo (www.yahoo.com) or the Open Directory Project (www.dmoz.org), thematic hierarchies represent the fundamental rationale for organizing knowledge. Yellow pages are naturally ordered using more specific thematic hierarchies (Laukkanen, Viljanen, Apiola, Lindgren, & Hyvöninen, 2004; Guarino, Masolo, & Vetere, 1999), focussing on classes of products or services and particular application areas.
2. A hierarchy of *geographic areas* (*G*) allows to refine this picture. Using this hierarchy, entities, documents and thematic fields can be localized (“German car industry”, “Italian wines”), which often helps to judge their relevance regarding a given user need. Geographic conditions are particularly important for Web services and directories in a commercial context, in other words, to position organizations (“Munich enterprise”), to localize products (“Japanese cars”, “Spanish guitars”) and services (“Services of type *x* in Bavaria”), and to deduce the validity of offers or certain legal aspects.
3. The third important axis of EFGT Nets is the *temporal hierarchy* (*T*). Temporal features help to characterize service operation (“Opened on Sundays”), specific classes of products (“Weekend trips”, “Oldtimers”, “Literature from the 19th century”), periods/durations where special offers are valid (“until end of 2005”), periods of production (“Car built in 2002”), deadlines in payment conditions, and so on.

Combining these three axes into the DAG structure of the EFGT Net has two main benefits. First, links in the hierarchy naturally model the inherent transitivity of all three axes. For instance, a sports club in Barcelona is also a sports club in the region of Catalonia, a museum that is open during the weekend is certainly open on Sundays, and an Italian deli can be considered as a grocery. Besides, the DAG structure makes the EFGT Net flexible enough to subsume the same concept under multiple generalization terms (unlike tree classifications). For instance, the city of Innsbruck is at the same time part of Austria, the federal state of Tirol, the Alpine upland and the zip code area 60XX. Note that the three axes just introduced do not simply span a three-dimensional space where each concept is positioned according to a single scalar thematic, geographic, and temporal property. Rather any part or aspect of given concept may have its own thematic, geographic, or temporal orientation which combine into more complex expressions. As an example, consider an antiques shop for Baroque furniture which is open only on weekdays. Here, the temporal notion “on weekdays” describes the opening times of the shop, whereas “Baroque” refers to the products it sells. A similar case for the geographic axis would be a Paris real-estate agent specialized in properties in Tuscany.

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