

Ontologies for Business Networks Identification

Elżbieta Lewańska¹(✉) and Monika Kaczmarek²

¹ Department of Information Systems, Faculty of Informatics and Electronic
Economy, Poznan University of Economics, Poznan, Poland
`e.lewanska@kie.ue.poznan.pl`

² Research Group Information Systems and Enterprise Modeling,
University of Duisburg-Essen, Essen, Germany
`monika.kaczmarek@uni-due.de`

Abstract. Studies have shown that for the needs of the decision-making process, it is not enough to take into account the internal aspects of an organization, but its external business environment should be considered as well. Due to the rapid changes in the business environments and huge volumes of data that need to be analyzed, conducting analyses of the external environment is however challenging. In addition, the knowledge on the market rules and laws of economy is required in order to recognize existing relations between market subjects. We argue that the application of semantically annotated data can efficiently support the process of business environment analysis and allow for business network identification. Within this paper, we present a set of formal ontologies created to support such a process as well as identified requirements towards their scope and operational aspects.

Keywords: Ontologies · Semantic technologies · Business networks

1 Introduction

Business environments of organizations are undergoing rapid changes and are characterized by the ever increasing competition, turbulence and numerous transformations in, e.g., market relations [1, 2]. The main reasons of such changes are: increasing globalization, fast advancing information technology (IT) and numerous innovations in offered products and/or services. When making business decisions, an organization should not only take into account its internal structure and environment, but should consider the external business environment influencing it as well, and thus, analyze it on a regular basis [2].

1.1 Business Networks

A business environment may be analyzed either as a static model distinguishing between a proximal and distant environment [3], or as a ‘dynamic’ model focusing on relations between business entities. Within the latter approach, the concept of ‘business network’ is used (e.g., [4–6]). A business network is defined

as a set of relations – either formal or informal ones – connecting two or more business entities, characterized by a continuous interaction, interdependence (of resources, objects and actions), and a lack of clear boundaries and structures [7]. Although organizations are well aware of their formal relations (e.g., resulting out of the signed contracts), an awareness problem might arise regarding the informal ones [7]. The informal relations are not defined by contracts but are the result of long-term dependencies between entities on the market. They may for instance take a form of competition between organizations, informal cooperation when two organizations offer complementary products, or competition when two organizations share the same supplier. Those kinds of relations are difficult to keep track of, however, the knowledge about them is of great importance in the decision-making process, and thus, the identification of informal relations is a crucial element of every market or business environment analysis [4, 7, 8].

1.2 Research Problem

Each organization is said to be part of one or more business networks (e.g., [4, 8]). Although studies have shown that organizations that actively use information about their business networks gain a competitive advantage (e.g., [8]), organizations are not always aware which entities are in their business environment and what are their characteristics [8]. This is so due to a number of reasons. Firstly, in the fast-changing markets (e.g., digital markets), it is difficult to keep track of all arising start-ups, mergers, acquisitions and closing of businesses. Secondly, the volume of data on organizations and their offering, which is to a large extent available on the Internet and which needs to be analyzed in order to identify the business networks, is continuously increasing [3, 9–11]. This leads to an information overload that business analysts have to face while conducting the business environment analysis [2, 12]. Thirdly, the identification of the business networks requires knowledge about the market and existing relations and ability to ‘reason’ on the available data.

Taking the above into account, we argue that the business network identification process can be efficiently conducted by a tool using formal ontologies fed with the information from the semantic data sources available on the Internet. We assume that by applying ontologies with defined axioms formalizing the experts’ knowledge on the market and laws of economy, the designed tool would not only be able to process efficiently available volumes of data, but also to perform the reasoning required to discover a business network, i.e., to identify existing relations between business entities – market subjects (i.e., individuals or groups of legal persons who are capable of performing market activities) and market objects (i.e., products and services).

As already mentioned, for the needs of this process a set of formal ontologies providing information on the specific aspects of market subjects and objects is required. In this paper we focus on the requirements towards the scope and operational aspects of such formal ontologies as well as the proposed ontology stack.

1.3 Research Approach Followed and Structure of the Paper

The presented work is part of a research project that aims at designing a method for automated identification of business networks. We follow the proactive research path based on the design-oriented research paradigm [13]. The resulting method aims at providing a benefit to organizations by contributing to conducting automated business analysis on the large amount of semantically enhanced data sources. The main vision of the method is described in [3]. In this paper, we focus on the ontologies required to create profiles of business entities. In order to create the proposed ontologies, we followed the approach proposed by [14]. To the best of our knowledge, no similar set of formal ontologies for the needs of business networks identification has been proposed so far. Moreover, no method or tool support for the business network identification operating on and taking advantage of the semantic annotations has been proposed.

The structure of the paper is as follows. First, the proposed method for business entities analysis is shortly presented. Then, after mentioning the existing initiatives in the area of semantic enterprise description, the requirements towards the formal ontologies that are to support the business network identification process are identified. Next the created ontologies for the needs of the developed method are described. The paper concludes with the short overview on the evaluation results and an outlook on the future research.

2 A Method for Business Network Identification

The main aim of the proposed method is to support the identification of business networks based on the semantically annotated data. Thus, the designed method is in fact an expert system as it constitutes a computing system capable of representing and reasoning about some knowledge-rich domain and provides information/advice [15]. In order to identify a business network, the data on the market subjects (business entities) as well as their offering (market objects) is required. It is assumed that the designed tool is continuously obtaining (via push and pull modes) information about new entities and their offering as well as changes in the existing data sets. Therefore, the main artifact on which the proposed solution operates, is a dedicated semantically annotated profile of a business entity encompassing all relevant information on the business entity itself as well as its offering.

A profile is built based on the information extracted from several semantic data sources (e.g., DBpedia¹, FreeBase²; for more details, cf. [3]). Once, the semantically annotated profiles of business entities are created, two subsequent stages follow: pre-reasoning and business analysis. The pre-reasoning stage belongs to the back-end and encompasses several steps. First, profiles that describe the same entity, but were extracted from different sources are integrated into one normalized profile. At the same time, all semantically described attributes are mapped to the appropriate domain ontologies. Then, based on

¹ <http://dbpedia.org>.

² <http://www.freebase.com/>.

the defined rules, the system reasons about relations between business entities. Those relations are identified based on the values of the organizations' attributes and based on the discovered relations between offerings of different organizations. All pre-reasoned information is stored in the profiles database.

Within the business analysis stage, based on the attributes and relations stored in the profile, a user can identify a business network of a specific organization, or run a clustering analysis in order to analyze its business environment. The clustering method operates on semantic profiles and analyzes not only similarities among entities, but also relations between market subjects and objects by taking advantage of the rules formalizing economic knowledge defined in the form of axioms. Such an analysis might help to identify niches, groups of similar competitors or ways to segment the market.

Thus, from a user perspective, the main scenario that is to be supported by the proposed method is as follows. A business expert needs to identify a business network of the specific business entity. In order to do that he/she needs to (1) point to the business entity that should be analysed, (2) define the context of the analysis, i.e., narrow its scope to, e.g., business entities that meet the defined criteria, e.g., that offer a specific product or are situated in some geographical region; if no context is set, then all profiles stored in the database are initially considered; (3) define the depth of the analysis, i.e., indicate how deep (i.e., to which level) the analysis of the relations between organizations should be performed. The deeper analysis is conducted, the more entities and relations will be included in the result, but at the same time, the results might be hard to understand due to their complexity. The method returns all relations and related business entities as a graph, which may be a subject of further analysis.

To support the above sketched scenario, a semantic representation of business entities is required providing information on the enterprise and its environment.

3 Ontologies for Business Network Identification

3.1 Ontologies for the Semantic Description of Enterprises

Numerous ontologies have been developed for the needs of enterprise description. One of the first initiatives is the REA (Resources Events Agents) ontology designed originally for accounting systems [16,17], which later has been extended with additional concepts in order to support e-commerce and virtual organizations [18]. TOVE (TOronto Virtual Enterprise) [19] is another example of ontology trying to capture enterprise's characteristics. TOVE offers an ontology stack, with the separate ontologies for enterprise activities, resources, costs, quality, time, etc. It is not designed for any particular industry. Finally, there are many ontologies developed for a specific purpose (e.g., the SUPER ontology stack [20], or GoodRelations [21] for modeling e-commerce companies and related products, prices, etc. in order to build semantically annotated e-shops).

The above mentioned ontologies have been developed for a specific purpose (not inline with ours), or for a specific industry. Thus, they focus on describing organization's internal characteristics and relations, or on communication with

external partners and do not usually encompass concepts describing a business environment of an enterprise or its business relations. Also, market objects are usually not covered by the existing initiatives.

On the contrary, the already available general semantic data sources (e.g., DBpedia, CrunchBase, FreeBase) provide information on the often substantial areas of knowledge that may be used to obtain a wide range of information on business entities and their offering (for details see [3]).

3.2 Requirements

In order to identify the scope of information that should be modeled for the needs of business environment analysis in general and business networks identification in particular, the relevant literature on the business analysis as well as on market characteristics was analyzed (e.g., [2, 4–8, 22, 23]). As result, along with attributes pointing to the distinctive name allowing for a unique identification of an entity and a set of characteristics allowing to determine the entity’s size (e.g., the number of employees, total sales), the following features of business entities were identified as crucial for the analysis: *type of ownership, industries in which the entity is active and the type of undertaken business activities, the geographical location, and finally, applied technologies* (Req. 1). These features provide the foundation for reasoning about the relations between organizations. For instance, such attributes as country and location should allow for the identification of business clusters and groups of entities that operate in the same geographic region. In turn, the type of activity defining the activities performed by the organization should enable to reason based on the hierarchy of available types in order to identify relations between market players. Next, the industry defines the sectors in which the organization is active. Finally, the ontology focusing on the types of the ownership should allow for the identification of additional informal and formal relations between entities.

Market objects are not part of a business network. However, based on market objects’ characteristics, one is able to reason about relations between business entities that offer those market objects. The following relations between business entities and market objects may be distinguished: formal relations between business entities, e.g., cooperation based on contracts, investments, takeovers; informal relations between business entities, e.g., competition, indirect cooperation (e.g., companies offering complementary products but not bounded by legal contracts); relations between a business entity and market objects, e.g., a developer of a product, or a service offering; relations between market objects, e.g., complementary, substitutes. Thus, *the formal ontologies used need to provide information about the offering as well as support the process of reasoning on the relations between business entities and market objects* (Req. 2). The most important characteristic of market objects is their type. Other characteristics, like, e.g., distinctive names or price, are of less importance for the given task.

The proposed method employs the data and cluster analysis algorithms. Therefore, in order to ensure the expected precision of the returned results,

it requires ontologies which are *based on compatible paradigm and have a compatible degree of details* [24] (Req. 3). Especially the lack of the compatible degree of details, taking into account the requirements of the data analysis algorithms, e.g., to cluster objects (cf. [3]), may hamper the precision of the results returned by the proposed method.

Finally, in order to identify a business network, it should be possible to reason on the entire set of ontologies and conduct cross-domain analyses (cf. [3]). Thus, the formal ontologies used *should include the alignment relations and be specified in the single ontology language, for which the required reasoner engine is available* (Req. 4).

3.3 Fulfillment of the Requirements

The conducted analysis revealed that only a small number of the existing ontologies can be directly used to describe business entities for the needs of business networks identification. The existing enterprise ontologies do not provide the required information as they were not designed with this aim in mind. In the general semantic data sources (such as, e.g., DBpedia) one can find information that might be used to describe, e.g., product and services types or geographical data. However, those sources were not developed for this specific purpose either and the data is sometimes too general, or, on the contrary, too detailed in order to be directly used for the needs of the proposed method. Moreover, the usefulness of general semantic data sources is sometimes limited due to the lack of a comparable level of details (cf. Req. 3) (e.g., semantic data sources define lines of business, sectors and markets related to the business entity on different levels of granularity). Moreover, the data sources have different structures and understanding of some concepts, e.g., one source lists the product types offered by a company while others use the very similar categorization to provide values of the industry types. In addition, only few initiatives define alignments between various ontologies (cf. Req. 4) and the ontology languages used to model them vary significantly. Finally, the analysis revealed that not all characteristics listed in literature are available in the data sources, e.g., technology used by a business entity is often part of internal or restricted knowledge and such information is not included in any of the analyzed sources.

4 Ontologies for Business Network Identification

Thus, taking into account the identified requirements as well as the conducted analysis of the existing semantic data sources (both when it comes to their content as well as structure), the decision was made to use them not directly but instead, design a dedicated ontology stack, gathered around a business entity profile, which would be fed with the selected data from the existing semantic data sources, pre-processed to ensure the required data characteristics.

4.1 Ontology Stack

A business entity profile, being the central ontology of the proposed stack, encompasses a number of attributes organized into four layers: (1) distinctive attributes allowing for unambiguous identification of a business entity (e.g., organization name, tax identification number); (2) structured attributes encompassing attributes normalized to the defined format (e.g., founding year, geographical longitude and latitude, number of employees); (3) semantically described attributes encompassing concepts from corresponding domain ontologies (e.g., type of activity, type of ownership); (4) unstructured attributes encompassing data stored in the free text form and currently not used by the method, but instead, providing additional information on an organization for the method's users. Supplementary to the business entity profile, an offering profile has been developed encompassing, among others, a semantically described attribute – offering type (cf. Fig. 1). Thus, selected elements of a business entity profile and an offering profile are mapped to the specific elements of the developed ontologies, which in turn are fed with data coming from the semantically described data sources.

The semantic description is used for those attributes, which can be related to each other in hierarchical and non-hierarchical ways and based on which the business relations between objects may be reasoned. Thus, the ontology stack encompasses (cf. Req. 1 and 2) an ontology for classification of economic activities, an offering types ontology, a location ontology, a types of ownership ontology and finally, an ontology of types of activities³. The proposed ontology stack integrates the data coming from various semantic data sources. It means that for each data source a set of mappings has been manually defined that specifies which data elements from the source are relevant to which elements from the ontology stack. In this way the inclusion of new data sources requires the creation of mappings, but the core elements of the ontology stack remain unchanged. In addition, all ontologies were designed in such a way that the core elements are independent of the specific domain the considered organizations are operating in. For instance, the main part of the offering types ontology is constituted by the core terms related to the products and services and their characteristics, identified based on the literature study. The core concepts are then later on extended with the specific domain-dependent concepts (e.g., relevant to IT products or financial services) extracted from the semantic data sources. Finally, in order to enhance the interoperability of the proposed ontology stack, it is to be linked to/specialized from one or more of the upper-level ontologies.

Each ontology was designed following the guidelines defined by [14]. Therefore, for each ontology a set of competency questions was defined in order to determine the scope and the required expressiveness. Having the identified requirements in mind as well as the characteristics of the existing semantic data sources, the ontologies were modeled using OWL-DL. The created ontologies are presented subsequently.

³ Due to the mentioned lack of publicly available data, the information on the technology used is not considered in the proposed method and formal ontologies.

Ontology for Classification of Economic Activities. The International Standard Industrial Classification of All Economic Activities (ISIC) [25] is a widely used standard by legal entities. Thus, an ontology was reconstructed based on this standard (see Fig. 1) with the aim to provide values for the business profile attributes: *category* and *typeOfActivity*. As semantic data sources do not use ISIC, but instead they introduce their own classifications for lines of business, sectors and markets, the data about the ISIC classification for a specific business entity must be extracted from the statistical data sources or government’s data bases. In addition, during the evaluation phase we noticed that in many countries a company is allowed to declare unlimited ISIC items as being relevant to its business activities, so many companies declare a few dozens or more categories. This affected negatively the effectiveness of the data analysis method. Finally, the ISIC classification is quite flat (up to four hierarchy levels) and general. In case of narrow lines of business, most companies from this line of business would fit into one or two categories. Thus, this classification alone turned out to be not detailed enough to enable the required level of reasoning on the category attribute. Thus, in order to obtain the expected level of details, a set of domain ontologies, specialized from the ISIC ontology is additionally created. For instance, for the needs of the evaluation of the method, a domain ontology for personal computers and mobile devices has been developed based on the data extracted from DBpedia, FreeBase and CrunchBase, and linked to the ISIC ontology.

Offering Types Ontology is used for the needs of products’ and services’ classification. Based on the classification and hierarchical dependencies, the reasoner is able to identify relations between offerings and in consequence, between business entities that offer those products and services. For example, if two business entities offer the same type of a digital product to the same customer group,

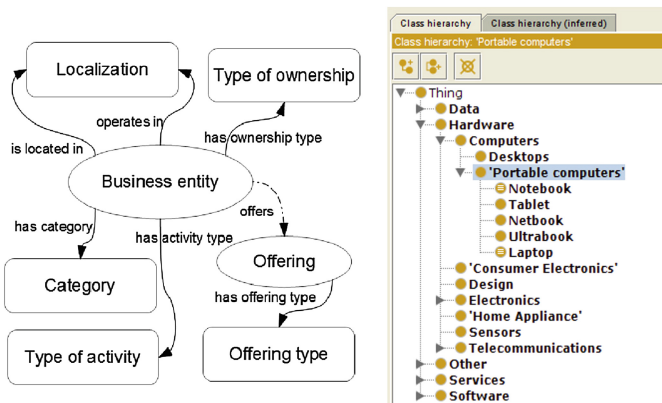


Fig. 1. Left: Profiles (ellipses) and related ontologies (squares). Right: a fragment of offering types ontology.

then they are probably competitors. For instance the following rule is used to identify potential competitors⁴:

```
isOfferentOf(?be1,?prod1), isOfferentOf(?be2,?prod2),
hasType(?prod1,?s), hasType(?prod2,?t), isAlikeTo(?s,?t), implies
isCompetitorOf(?be1,?be2)
```

Moreover, business entities that offer similar but not exactly the same products might become competitors in the future because it is possible that they will extend their product portfolio.

The currently available offering types classifications are usually developed for a specific tool or method and thus, are not generic enough to be used for other purposes. Especially the level of granularity is an important aspect because the effectiveness of the analysis algorithm depends heavily on the granularity of the data description. Thus, domain ontologies needed to be developed in order to define the offering at the appropriate level of details. Taking into account the planned evaluation on the business entities related to personal computers and mobile devices, a corresponding offering types ontology was built in the first step. However, the offering types ontology is not limited only to personal computers and mobile devices offerings because many companies have in their portfolio other products and services as well. The designed ontology has more than 100 concepts and is continuously extended with additional ones.

Location Ontology. The goal of using a location ontology is to enable reasoning about the geographical location of business entities, e.g., to identify business clusters. The spatial ontology is used to define markets on which a business entity is operating or to define localization of its headquarters (depending on the information available). The importance of this factor heavily depends on the specific industry and analysis context. For example, considering business entities that offer only digital products and services, their geographical location is not of the highest importance (however, it might be quite the opposite with respect to legal regulations). However, in industries focusing on customers from a specific region, e.g., logistics companies, or for companies that offer products and services related to a certain location, e.g., the tourism industry, it is one of the most important factors.

Although, a number of spatial ontologies exist, they are either not freely available, or they are too narrow (e.g., only a list of countries, without any regions defined), or too specific and focused more on geographical phenomena than on the countries' boundaries (e.g., included information about rivers, mountains and many more geographical objects and thus, their processing and/or reasoning time was unacceptable). As, none of the identified spatial ontologies could be directly used thus, a new ontology has been developed based on (as a subset of) the more comprehensive ones. In the ontology, continents, regions and countries as well as capital cities are defined. The ontology consists of more than 400 concepts and includes, among others, a transitive property *isLocatedIn*, used to describe geographic dependencies between objects, e.g., when one object is located in the other (e.g., Poland is located in Europe).

⁴ Property *isAlikeTo* describes substitutes (e.g., smartphone isAlikeTo tablet); *be1* and *be2* stands for business entities; property *hasType* defines relationship between offering and its type (e.g., iPhone hasType smartphone).

Types of Ownership Ontology. The types of ownership for business entities are regulated by law and vary between countries. The type of ownership usually is part of the company description in the semantically described data sources, or may be acquired from governmental data bases. An ontology of Polish and US ownership types has been developed in the first step and will be extended further with the ownership types relevant for other countries. Currently, the proposed ontology has around 30 concepts, connected through the following attributes: *isAbbreviation* and *hasAbbreviation* – connects a full name and its abbreviation (in data sources usually abbreviations are used); *isEquivalentTo* – connects the same type of ownership defined in different countries.

Types of Activity Ontology. Type of activity defines whether a business entity is a distributor, buyer, producer, investor, etc. Type of activity might be used in reasoning rules, e.g., to decide what kind of business relation occur between two business entities. However, information about business entity's activity type is rarely directly stated in information sources thus, this ontology is not part of the developed prototype.

4.2 Evaluation of the Developed Ontology Set and Designed Method

In line with the followed approach to ontology creation, we evaluated the developed ontology stack against such criteria as clarity, coherence and extensibility. Additionally, we checked the assumed ontology coverage against the defined competency questions using the Pellet reasoner⁵. For each competency question, a corresponding SPARQL query has been formulated and the returned results have been successfully compared to the defined information needs.

As incorrect information may lead to 'wrong' decisions made by business analysts, it is of utmost importance to assess whether the proposed method delivers correct results. Therefore, a first round of experiments was run on two sets of business entities' test profiles in order to evaluate the results returned by the proposed method and thus, also to evaluate the adequacy of the proposed ontologies. The first set consists of profiles from a single data source (DBpedia), while the second one was created by extending the first set with the information coming from other data sources (FreeBase and CrunchBase). The developed method has been evaluated using a variation of the Turing test: a number of test cases have been processed by the method and simultaneously solved by an expert. Then, a third-party judge evaluated anonymized results delivered by a human and the method, marking each object as *correctly assigned to a cluster*, *partially correctly assigned to a cluster* or *incorrectly assigned to a cluster*. The judge annotated the results returned by a human as follows: 80–90% as correct, 8–10% as partially correct and 0–5% as incorrect. For the results returned by the method, the annotations were as follows: 60–85% correct, 10–40% partially correct and 0–10% as incorrect⁶. Human experts pointed out that their decisions were based not only on the data included in the test sets, but also on their additional knowledge on

⁵ <http://www.w3.org/2001/sw/wiki/Pellet>.

⁶ Results vary depending on data set and initial centroids.

the market. Therefore, the results of the performed evaluation need to be treated with precaution. Nevertheless, the proposed method returns satisfactory results in a much shorter time than a human could do (the analysis of data within the second stage of the proposed method is performed in 5 to 20 s, depending on the number of profiles and the number of clusters that should be identified).

5 Conclusions and Future Work

In this paper we focused on the formal ontologies for the needs of business networks identification. We argue that the designed ontology stack linked to and fed with the information from the semantic data sources enables identification of business networks conducted using the designed analysis method. However, we acknowledge that the effectiveness of the method depends heavily both on the availability and quality of data it operates on. In the current prototype we followed the assumption that the content provided by the semantic data sources is rich, reliable and up to date. Nevertheless, the methods aiming at verification of the data quality will be the objective of our future work. In addition, the possibility to automate the definition of mappings between the semantic data sources and the developed ontology stack will be investigated.

In addition, our future work focuses on integration of proposed ontology stack with the selected upper level ontologies, as well as on conducting further extensions to and evaluation of the developed formal ontologies and the proposed method, e.g., based on the data from the tourism industry. The tourism industry heavily depends on geographical location (of both the company and destination/localization of offerings). Finally, it is planned to extend the offering description in order to allow for more complex reasoning based on the offerings' attributes.

Acknowledgments. The work published in this article was supported by the project titled: "Clustering Method to Support Strategic Decision-Making Process in the Semantic Web" financed by the National Science Centre (NCN) (decision no. DEC2012/05/N/HS4/01875).

References

1. Drucker, P.F.: Managing in the Next Society. Butterworth-Heinemann, Oxford (2002)
2. Citroen, C.L.: The role of information in strategic decision-making. *Int. J. Inf. Manag.* **31**, 493–501 (2011)
3. Bukowska, E.: Semantically enhanced analysis of enterprise environment for the needs of business networks identification. In: Abramowicz, W. (ed.) *BIS Workshops 2013. LNBIP*, vol. 160, pp. 232–243. Springer, Heidelberg (2013)
4. Jarillo, J.: *Strategic Networks*. Taylor and Francis, Routledge (1993)
5. Campbell, A., Wilson, D.: *Managed networks*. In: Iacobucci, E. (ed.) *Networks in Marketing*. Sage Publications, Newbury Park (1996)

6. Ford, D., Gadde, L., Hakansson, H., Snehota, I.: *Managing Business Relationships*. Wiley, Chichester (2011)
7. Ratajczak-Mrozek, M.: *Sieci biznesowe a przewaga konkurencyjna przedsiębiorstw zaawansowanych technologii na rynkach zagranicznych*. Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, Pozna (2010)
8. Hkansson, H., Snehota, I.: No business is an island: the network concept of business strategy. *Scand. J. Manag.* **22**(3), 256–270 (2006)
9. Li, A.: *The relationship between Internet usage and decision making: The case of information technology (IT) managers in China*. Ph.D. thesis, Nova Southeastern University, USA (2002)
10. Sajor-Wood, R.: *The Internet: A decision-support information technology for public managers*. Ph.D. thesis, University of La Verne, CA, USA (2000)
11. Yip, G., Dempster, A.: Using the internet to enhance global strategy. *Eur. Manag. J.* **23**(1), 1–13 (2005)
12. Edmunds, A., Morris, A.: The problem of information overload in business organisations: a review of the literature. *Int. J. Inf. Manag.* **20**(1), 17–28 (2000)
13. Österle, H., Becker, J., Frank, U., et al.: Memorandum on design-oriented information systems research. *EJIS* **20**, 7–10 (2011)
14. Uschold, M., Grninger, M.: Ontologies: principles, methods, and applications. *Knowl. Eng. Rev.* **11**, 93–155 (1996)
15. Jackson, P.: *Introduction to Expert Systems*. Addison-Wesley Longman Publishing Co., Inc., Boston (1986)
16. McCarthy, W.: An entity relationship view of accounting models. *Account. Rev.* **54**(4), 667–686 (1979)
17. McCarthy, W.: The rea accounting model: a generalized framework for accounting systems in a shared data environment. *Account. Rev.* **57**(3), 554–578 (1982)
18. Geerts, G., McCarthy, W.: An ontological analysis of the economic primitives of the extended - rea enterprise information architecture. *Int. J. Account. Inf. Syst.* **3**, 1–16 (2002)
19. Fox, M., Barbuceanu, M., Gruninger, M., Lin, J.: An organisation ontology for enterprise modeling. In: Prietula, M., Carley, K., Gasser, L. (eds.) *Simulating Organizations: Computational Models of Institutions and Groups*, pp. 131–152. AAAI/MIT Press, Menlo Park (1998)
20. Filipowska, A., Kaczmarek, M., Kowalkiewicz, M., Markovic, I., Zhou, X.: Organizational ontologies to support semantic business process management. In: *SBPM 2009*. ACM (2009)
21. Hepp, M.: GoodRelations: an ontology for describing products and services offers on the web. In: Gangemi, A., Euzenat, J. (eds.) *EKAU 2008. LNCS (LNAI)*, vol. 5268, pp. 329–346. Springer, Heidelberg (2008)
22. Glinka, B., Hensel, P.: *Projektowanie organizacji*. Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa (2007)
23. Kramer, T.: *Podstawy marketingu*. PWE, Warszawa (2004)
24. Filipowska, A., Hepp, M., Kaczmarek, M., Markovic, I.: Organisational ontology framework for semantic business process management. In: Abramowicz, W. (ed.) *Business Information Systems. LNBIP*, vol. 21, pp. 1–12. Springer, Heidelberg (2009)
25. United Nations Statistics Division: International standard industrial classification of all economic activities, rev. 4. <http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27>

Formal Ontologies Meet Industry
7th International Workshop, FOMI 2015, Berlin,
Germany, August 5, 2015, Proceedings
Cuel, R.; Young, R. (Eds.)
2015, IX, 139 p. 34 illus., Softcover
ISBN: 978-3-319-21544-0