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Ontology-based economics knowledge sharing system

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ABSTRACT

The objective of this paper is to argue the need for economics knowledge sharing and to demonstrate that it can be achieved with Semantic Web technologies. To this end, we first designed an economics knowledge sharing ontology (EKSO) to describe economic domain knowledge. We then implemented an ontology-based economics knowledge sharing system (OEKSS) based on the EKSO and Semantic Web technologies. The OEKSS included three search functions – basic search, knowledge navigation, and instrumental variable recommendation – to demonstrate how we can use shared economics knowledge in future research. In particular, an instrumental variable recommendation is made based on an instrumental variable recommendation algorithm (IVRA), which is a systematic and efficient way to find instrumental variables through EKSO in limited experimental environments. Finally, the paper presents a case study for IVRA that illustrates the usefulness and significance of the algorithm.

1. Introduction

Economics knowledge consists of verified research and analyses of economic phenomena. This acquired knowledge is usually conveyed in digitalized forms, such as journal articles. To generate economics knowledge, economists follow three steps: modeling the target economic phenomenon; specifying the independent and dependent variables of the model and their relationships; and verifying the model by analyzing the corresponding data. This procedure is not so different from that of other experimental studies except in the third step.

Economists rarely perform experiments to gather data due to limited budgets, resources, space, and time. For instance, they cannot change a nation's interest rate as part of an economic experiment. Therefore, in most cases, economic studies must be observational rather than experimental, and this makes it difficult to infer precise relationships among economic variables. Simply observing a correlation between two variables is not enough to conclude that there is a causal relationship between them (Wooldridge, 2001). Instead, economists need to conduct controlled experiments before drawing such a conclusion. This example highlights the need to share previous knowledge in economics. Although there have been few economic experiments, it is possible to understand the hidden ideas that coincide with our interests by sharing previous knowledge.

An instrumental variable (IV) of an economic model is a variable that is not included in the model, but it indirectly affects the dependent variable by being correlated with the independent variable (Hayashi, 2000). In economics, IVs are useful for identifying precise causal inferences when controlled experiments are impossible (Goldberger, 1972), but unfortunately, it is extremely difficult to find a suitable IV for a model. As a result, in most previous studies, the IV has been found for the model based solely on the author's intuition. However, in this paper, we offer a systematic and an efficient way to find IVs by sharing economics knowledge.

To share economics knowledge in this article, Semantic Web technologies were used. The Semantic Web is an extension of the World Wide Web, whose content can be manipulated without human intervention (Berners-Lee, Hendler, & Lassila, 2001). One of the core technologies of the Semantic Web is ontology, which constitutes formal and consensual specifications of conceptualizations that provide a shared understanding of a domain (Gruber, 1993). In the Semantic Web, the content (i.e., semantic data) is expressed in a machine-interpretable format based on the concepts and relationships of the ontologies. Therefore, intelligent agents can understand the meaning of the content and share the domain knowledge (Fensel, 2001; Vesin, Ivanovic, Milicevic, & Budimac, 2012; Yoo, 2012).

Using such Semantic Web technologies, we proposed an ontology-based economics knowledge sharing system (OEKSS) to demonstrate a way of sharing economics knowledge. To this end, an economics knowledge sharing ontology (EKSO) was designed to describe economic domain knowledge such as the metadata for the knowledge, concepts representing economic variables and their relationships. Economics knowledge can be collected from user participants. When a user registers economics knowledge pertaining to a certain economics paper, he or she can define not only the metadata for the paper, but also the relationships between

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the independent and dependent variables discussed in the paper. To assign the correct meaning to the variables, the user can also freely link the variables with their upper variables, without being constrained by a predefined set of variables. According to EKSO, the system transforms this knowledge into semantic data that the machine can interpret. To support economics knowledge sharing, basic search and knowledge navigation were implemented, and we also suggested a new method: the instrumental variable recommendation algorithm (IVRA) utilizing EKSO.

The rest of the paper is organized as follows. Section 2 reviews several systems to share specific domain knowledge closely related to this study. Section 3 presents the OEKSS architecture that we implemented on top of EKSO and illustrates how we can use the shared economics knowledge, including IV recommendations. In Section 4, the algorithm for the IV recommendations is examined more closely, and a case study is described using previous economics knowledge. Finally, Section 5 provides the conclusion to this paper, including possible limitations of our approach and potential direction for future researchers.

2. Related work

In knowledge sharing systems, the use of ontologies provides rich semantics for specific domain knowledge. In the Semantic Web, ontologies are defined as sets of concepts and relationships among these concepts using a specific language, such as Web Ontology Language (OWL) (McGuinness & Harmelen, 2004). One of the most commonly used methods for representing the semantic data of the domain knowledge is the Resource Description Framework (RDF) (Klyne & Carroll, 2004), which represents the data according to concepts and their relationships in OWL ontology. To support ontology-based knowledge sharing, the domain ontologies should have (1) concepts for knowledge structure and (2) concepts for domain-specific terms. The former includes structured information about the knowledge such as *title*, *creator*, *type*, *subject*, and *description*, while the latter includes domain terminology that has hierarchical relationships. When expressing semantic data based on the above concepts, intelligent agents can understand the meaning of the semantic data and provide structure-based and semantic-based searches to the users.

Based on how to generate domain knowledge for semantic data, two categories of ontology-based knowledge sharing systems can be identified, one that depends on human intervention and another that depends on the conversion of existing data sets. Systems that belong to the first category include *CS AKTive Space* (Shadbolt, Gibbins, Glaser, Harris, & Schraefel, 2004), *CONFOTO* (Nowack, 2006), *Revyu.com* (Heath & Motta, 2007), and *GroupMe!* (Abel et al., 2007). A common feature of these systems is that humans register domain knowledge in the system directly. *CS AKTive Space* is a Web application that provides ways of exploring the computer science research domain in the UK for funding agencies and individual researchers (Shadbolt et al., 2004). After individual researchers register their information through the hyphen.info Web site, the information is transformed into RDF data according to the AKT Reference Ontology. Based on the data, services such as ontology-based network analysis and geographic visualization are conducted. *CONFOTO*, which extends a Web content management system, supports a semantic annotation service and navigation service for conference photos (Nowack, 2006). When users register a conference photo, they can enter annotation information such as title, type, names, date, and keyword, and then the information is automatically stored in repositories in the form of triple structure according to domain ontology. The system demonstrates the advantages of an RDF-based photo browsing services. *Revyu.com* allows people to review and rate their interests, including places (e.g., pubs, restaurants, hotels, and tourist attractions), books, music, films, and products (Heath & Motta, 2007). The style of interaction with this system is similar to that of other review Web sites (e.g., Amazon.com), except that the system transforms user-generated content into machine-readable RDF metadata according to the FOAF and Tag ontology. The system can export the RDF content to share and reuse the users' reviews in other Web applications and provide basic navigation methods (e.g., recent reviews, top reviewers), as well as a tag-based search method using the semantic relationships between tags. In *GroupMe!* (Abel et al., 2007), users can build groups of arbitrary multimedia Web resources they are interested in and can arrange the resources contained in such groups by simple drag-and-drop operations. In addition, users are free to attach tags to the group and its resources to share the grouping resources. The grouping resources are transformed and stored as RDF descriptions based on several ontologies such as the FOAF, RSS, or DCMI element set, and a *GroupMe!* vocabulary. The system reflects the enhanced search for tagged Web resources by deducing the additional contextual information about the grouping resources.

Systems belonging to the second category include *Flink* (Mika, 2005), *Personal Publication Reader* (Antoniou et al., 2004), *MuseumFinland* (Hyvönen et al., 2005), and *MultimediaN E-Culture* (Schreiber et al., 2006). In general, they create semantic data from existing data sets using data conversion techniques. *Flink* supports semantic portal services regarding Semantic Web researchers (Mika, 2005). Personal information is extracted from a number of Web sources, including FOAF profiles, Web pages, email, and publication archives, using different methods, but all the knowledge is represented in similar RDF data according to the same ontology. The RDF data are used for social network analysis and providing Web-based presentation of the community. The *Personal Publication Reader* provides personalized access to online publications and supports navigation services through the publication (Antoniou et al., 2004). Two steps are required to generate information about publications in semantic data. In the first step, the system extracts the relevant data from distributed Web sources, and extracted data are mapped to another format (e.g., XML). In the next step, the application designer can combine the XML documents into a single document using Lixto Transformation Server, and the document can be mapped to a defined RDF structure based on REWERSE-Ontology. *MuseumFinland* demonstrates how to solve the interoperability problems of heterogeneous museum collections using Semantic Web technologies (Hyvönen et al., 2005). Syntactic homogenization was obtained by transforming the collections in museum databases into XML data, and semantic interoperability was obtained by transforming the XML data into RDF data. This process was based on the seven domain ontologies: artifacts, materials, actors, situations, location, times, and collections. Because each collection is semantically interconnected with the others, the system gives museum visitors intelligent content-based search and browsing services to distributed museum collections on the Semantic Web. *MultimediaN E-Culture* uses a similar approach to support indexing and search in large collections of cultural heritage resources (Schreiber et al., 2006).

Even though previous work has demonstrated knowledge sharing methods for various domains, very little research into economics knowledge sharing using domain ontologies has been conducted. Specifically, there is no way of defining economic variables and their relationships regarding certain economic phenomena in economics research into semantic data. Therefore, this paper proposes a new system, OEKSS, that generates economics knowledge that is registered by users' collaboration into semantic data according to EKSO and that provides various types of economics knowledge sharing methods, including IV recommendations.