Information Technology and Management Science
doi: 10.1515/itms-2014-0009
2014 / 17

Development of Ontological Knowledge Model for Raw Materials Management Task

Darya Plinere [1], Arkady Borisov [2], [1, 2] *Riga Technical University*

***Abstract* – Ontology application is widely used for different purposes and areas. This paper presents the difference between taxonomy and ontology, the steps of ontology development and an example of ontology development for raw materials management. Raw materials management is a process that is considered to be part of the overall supply chain management process and focuses on the tasks of securing the highest quality materials at the lowest rates possible, while also working within the company structure to make sure those materials provide the best possible benefit within the production process.**

***Keywords* – Agents, JADE, ontology development, Protégé, raw materials management.**

I. Introduction

Raw materials management is a process that is considered to be part of the general process of supply chain management, and focuses on solving the problems of providing high quality materials at the lowest rates possible, as well as working in the company in order to ensure that these materials provide the best advantage in the production process. Raw materials management begins with the acquisition and evaluation of the raw materials, goes through the use of these materials in the production process, and even includes evaluating the amount of waste that is present when these materials are produced into the finished product [1].

The task of raw materials management begins with the assessment and selection of the materials needed to produce the finished product. The manager devotes time and effort in order to find the right materials, using the company's resources to ensure that they have the appropriate level of quality, and then takes action to purchase the materials in the amounts desired [1].

As part of the purchasing process, the manager also attempts to reach an agreement in the best price possible of raw materials for the use in the production process. Here, the focus of raw materials management moves from the task of finding the right materials and focuses on the use of contractual arrangements complete with a reduced price or volume purchase pricing in order to make sure that the company has an appropriate supply of the right materials for the maintenance of operation [1].

The process of raw materials management is ongoing. At all times, the efforts to provide the proper quality level of raw materials and for the most competitive prices is in progress, this allows the manager to find new suppliers, and possibly to save the company more money on the front end. Always be aware of the options open to the company to provide the necessary materials for production purposes, the business can minimize any disruptions in the production that could happen if the usual seller is suddenly unable to meet the demand for some reason [1].

There are some reasons why the development of ontology is needed:

- to share common understanding of the structure of information among people or software agents;
- to enable reuse of domain knowledge;
- to make domain assumptions explicit;
- to separate domain knowledge from the operational knowledge;
- to analyze domain knowledge [2].

II. Problem Statement

The field of microelectronics on the example of the company for the production of chips is studied in this paper. Chip production requires timely saturation of crystals in a raw material warehouse. The order of crystals is made by a purchasing department manager right now by telephone, fax and e-mail.

In order to achieve maximum utilization of production capacity and minimize storage and procurement costs, it was decided to use a new method of raw material procurement. The system must meet the following requirements:

1. to ensure continuous production of chips;
2. to perform the analysis of production and sales of chips in order to plan the subsequent production orders and ensure timely delivery of the missing elements.

To ensure continuous production of chips, it is required to make timely coordination between the supplier and the customer of the name and the quantity of component parts, as well as price and delivery time.

III. Proposed Method

Multi-agent systems are widely used for problems of supply chain management, in particular for the raw materials management task. One of the features of multi-agent system is that it offers a decentralized system. Global behavior of the whole system is determined by the individual behavior of a family of agents who follow their own rules of behavior, exist in a shared environment and interact with the environment and other agents. This makes a multi-agent software system most appropriate for the task. Agents use a common ontology or taxonomy for negotiating, thus allowing agents to understand the substance of the negotiations (Fig. 1).

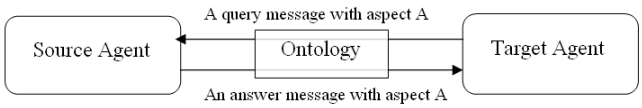

Fig. 1. Agent cooperation using a common ontology.

The implementation of the proposed method requires:
1. the development of an ontology or taxonomy;
2. agent system creation.

A. Taxonomy vs. Ontology

It was necessary to clearly define a taxonomy and ontology and understand whether it would be enough to use the taxonomy for the task.

Taxonomy – a set of concepts presented in a hierarchical structure, covering the domain area. As a rule, the concepts are arranged in a relationship "IS-A", focusing on the wide to narrow concept, and implies the inheritance of class characteristics of its superclass.

Ontology – a set of concepts and relationships that represent a wide range of knowledge of domain area. In addition to the relationship "IS-A" it has an unlimited number of relationships between concepts, as well as properties with their restrictions and values and logical inference support [3].

The ontology is used for this task solving, not a taxonomy, because the taxonomy involves only the relationship of class-superclass, and in this task, there are such relations as *consists_of*, *has_proper_base* linking classes together. The other types of relationships are used, such as *employees_position*, *documents_name*, *order_status* and others.

B. Ontology Development Step by Step

Ontology is a formal, explicit specification of a shared conceptualization [4].

Formally, an ontology can be defined [5] as the tuple (1).

$$O = (C, H, I, R, P, A), \quad (1)$$

where

C – the set of entities of the ontology - concepts;

H – the set of taxonomic relationships between concepts, which define a concept hierarchy;

I – the set of relationships between ontology elements and its instances.

R – the set of ontology relationships that are neither "kind_of" nor "is_a";

P – the set of properties of ontology classes;

A – the set of axioms [5].

The development of an ontology consists of:
1. definition of classes or concepts in the ontology;
2. location of classes in the taxonomic hierarchy (a subclass – superclass) if this possibility exists;
3. properties and a description of the allowed values of these properties;
4. identifying the restrictions of property values;
5. instances.

If it is determined that there is no suitable taxonomy/ontology, its development begins with definitions of key concepts used to express the necessary knowledge for a particular business (commercial) activities.

List of concepts for this task: crystal, plate, the number of crystals on the plate, appropriate base, crystal size, the quality of the plate, defect, valid, the coefficient of the output production of the plate, the production, the order of the plate, the return of plate, price, discount, delivery time, number of plates, currency, total cost, document, contract, invoice, specification, license, order status, seller, buyer, buy, sell, exchange, return, contractors, etc.

The next step is the definition of the class hierarchy, (see Table I). Describing terms and concepts, it is necessary to use the following rule:

If class A is a superclass of class B, then every instance of class B is an instance of class A.

TABLE I
CLASS HIERARCHY OF INITIAL ONTOLOGY

Class	**Subclass**
Crystal	
Plate	
Document	
	Invoice
	Contract
	License
	Specification
Order	
Base	
Company	
	Buyer_company
	Seller_company
Employees	
	Seller_employees
	Buyer_employees
Money	

The definition of the properties of classes is the next step in the development of the ontology. Properties of the class are a distinctive type of information for different instances of the same class.

The domain area's terms have already been allocated in the classes; most of the remaining terms are likely to be the properties of these classes. It is needed to determine which class it describes for each property in the list. These properties become slots attached to classes.

The class "Crystal" has the following properties: name of the crystal, crystal size, appropriate base (the relationship between the classes "Crystal" and "Base"). The class "Plate" has following properties: plate name, consists of (the

relationship between the classes "Plate" and "Crystal"), coefficient of the output plate, quality of the plate, cost of the plate. The class "Documents" – document name, serial number of the document, participants of document; subclass invoice, contract, license, specification inherit in these properties. The class "Company" has the following properties: company's name, company's address, has employees. The property of the class "Base" – name of the base. Class "Employees" has the following properties: name, surname, personal identity number, position, works for. The class "Order" has the following properties: order's number, order's contact person, order's status.

The next step is defining facets of the slots. The slots may have various facets, which describe the type of value, allowed values, the number of values and other properties of the slot. For example, the value of crystal's name property is one string, i. e., crystal's name is a slot with value type "String". Appropriate base slot as values may be instances of the class "Base" and plate's value slot has type "Float". Numbered slots determine the specific list of allowed values for the slot. For example, we can establish that plate's quality slot can take one of two possible values: valid or defect. Numbered slots in Protégé are of type "Symbol".

Last step is the creation of instances [6].

TABLE II

CLASSES, PROPERTIES AND INSTANCES OF ONTOLOGY

Class	Property	Instances
Crystal, Plate, Document, Invoice, Contract, License, Specification, Base for Crystal, Company, Buyer_Company, Seller_Company, Employees, Buyer_Employees, Seller_Employees, Money	Crystals_quantity, appropriate_base, crystal_size, plate_quality, output_coefficient, order_status, currency, name, surname, address, crystal_name, order_number, consists_of, company_name, etc	Contract 145-14/1, Invoice 14-10, ABCTrade, Waleo, Crystal Bi005, Base 301.8, Plate H005R, Armands Elksnis, Order 14/10

Horizontal links

The horizontal links [7] are properties or relations, which link individuals or classes that are not in hierarchical relationships. To create the horizontal links, the logical properties were used with one or more arguments. Examples of logical property are the following:

1) "Plate consists of crystals", where plate and crystal are arguments, consists of – a property;

2) "Elksnis works for ABCTrade", where Elksnis and ABCTrade are arguments, works for – a property;

3) "Plate has a certain number of crystals" where plate is an argument, has a certain number of crystals – a property.

C. Ontology Development in Protégé

Domain area's ontology development and editing are implemented in Protégé ontology editor, see Fig. 2. See [2], [8], [9] as a guide of building ontology in Protégé.

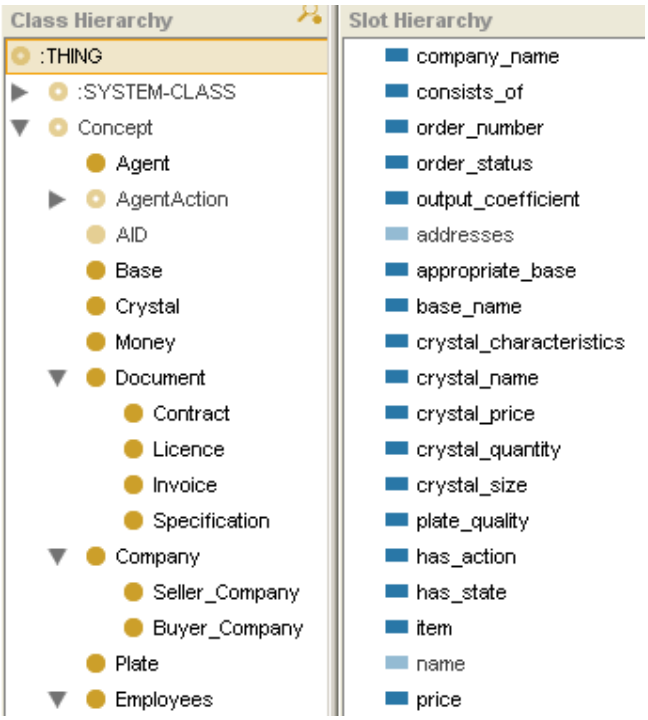

Fig. 2. Ontology development in Protégé ontology editor.

D. The Agent-based System Development

The proposed agent-based system consists of two agents – Seller Agent and Buyer Agent. Buyer Agent orders for the purchase of raw materials, negotiates with the Seller Agent for price and delivery time. The interaction between the agents is via a common knowledge ontology. For the interaction software, agents use the knowledge ontology *Ontology*, common to the agents involved in the negotiations. Negotiation requires knowledge of the size of the crystals, the possible bases and knowledge of the possible alternatives.

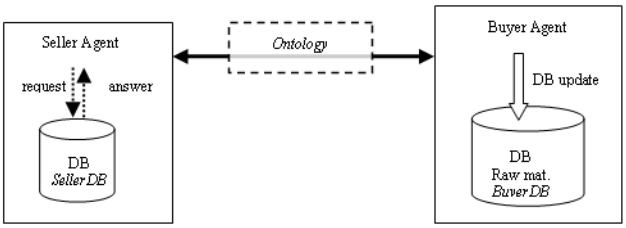

Fig. 3. Agent system with two agents and a common ontology.

The following infrastructure was used for constructing the system: Java and JADE – platform in which agents exist and interact, it gives agents the basic services necessary to their

existence, Protégé ontology editor for ontology development, Ontology Bean Generator to convert the domain ontology in JADE classes, MySQL for database support, Apache Ant to compile the code and NetBeans IDE as an integrated development environment. For the interaction of the agents ACL messages was used [10].

To implement the model, the following steps were taken:

1) domain ontology constructed and presented in a form suitable for use in JADE;

2) multi-agent system constructed in the JADE environment.

IV. Proposed Method Application

Purchase of the crystals before the application of methodologies is presented in Fig. 4.

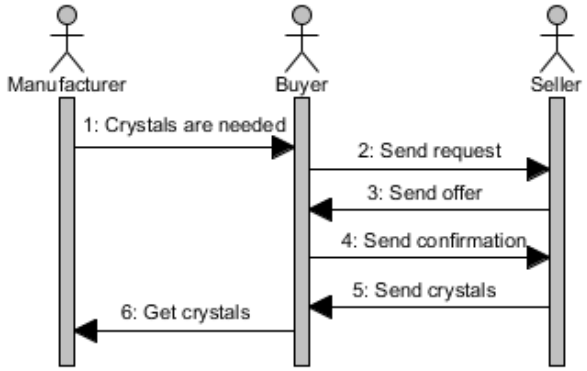

Fig. 4. Communication between buyer and seller managers in case of crystal requirement in raw material warehouse.

Production department needs crystals for chip assembly. Therefore, it is necessary to purchase crystals. Buyer manager sends a request to the seller manager by phone, by e-mail and-/-or fax. Request is received by a seller manager and the offer with price, quantity and the time of delivery is dispatched by e-mail and-/-or fax. Offer is received by a seller manager and the confirmation is sent to the offer by e-mail and-/-or fax. Confirmation is received by the seller manager and requested crystals are sent to the buyer manager. Invoice is sent inside the parcel, and also by e-mail and-/-or fax. The communication between the buyer and seller ends.

The purchase of crystals using the proposed method is presented in the following steps:

1. Seller agent and buyer agent use the same ontology for cooperation. It starts when raw material for chip production is needed. Buyer agent fulfills the user Profile ontology [11], [12] and it becomes an instance of domain ontology [11], [13].

2. Cooperation begins with the buyer agent's call for proposal (CFP) in the JADE environment. Seller Agent receives a call for proposal for the Buyer Agent with a detailed description of his order. Seller Agent offers to buy the batch from the warehouse. The offer (PROPOSE) is sent with the price, quantity and the time of delivery to the Buyer Agent via the JADE environment.

3. The offer (PROPOSE) is received.

Confirmation (ACCEPT-PROPOSAL) is sent to Seller Agent via the JADE environment.

4. Confirmation is received.

Requested crystals are dispatched to the buyer. Invoice is sent in the parcel. Electronic invoice is dispatched to Buyer Agent (INFORM) (see Fig. 5).

Interaction between agents is suspended until a new request from the Buyer Agent.

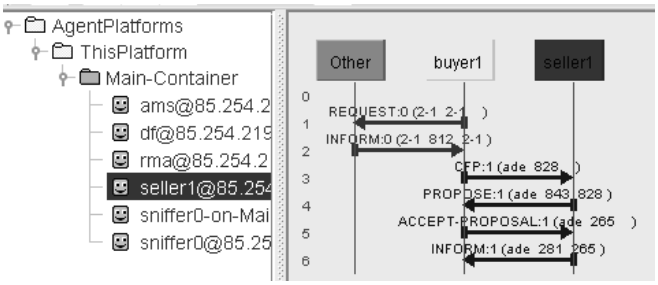

Fig. 5. Agent system with two agents and a common ontology.

V. Conclusion and Future Research

Ontology is widely used in different problem areas. Multi-agent system uses ontology for agent collaboration. Before ontology can be used, the development of it is needed. This paper presents a detailed description of ontological knowledge model development.

For this study, a multi-agent system was built for the raw materials management task. Implementation of the model in the software environment JADE has demonstrated the interaction of two agents from different parts of the supply chain. To match the name, quantity and price of crystals, agents use ACL messages, in which the domain ontology is a means of structuring knowledge and used for the sharing of knowledge between software agents. The effectiveness of a multi-agent system is proved by precision execution of tasks, quick and timely response to changes in the environment, and the lack of human factors. The study has shown that for the approval of purchase of crystals between the supplier and the customer has been spent just a few seconds using multi-agent system. If a question of time is not relevant, it is possible to the Buyer Agent to bargain and get a better price.

The effectiveness of ontology application in an agent system can be measured by ontology evaluation techniques, which is a future research topic.

References

[1] WiseGEEK, [Online] Available: http://www.wisegeek.com/what-is-raw-materials-management.htm

[2] N. F. Noy, D. L. McGuinness, "Ontology Development 101: A Guide to Creating Your First Ontology," Stanford Knowledge Systems Laboratory Technical Rep. KSL-01-05 and Stanford Medical Informatics Technical Rep. SMI-2001-0880, 2001.

[3] Wand [Online] Available: http://www.wandinc.com/taxonomy101.aspx

[4] T. Gruber, "A translation approach to portable ontology specifications," *Knowledge Acquisition*, vol. 5, no. 2, pp. 199–220, 1993. http://dx.doi.org/10.1006/knac.1993.1008

[5] I. Serra, R. Girardi, "A Process for Extracting Non-Taxonomic Relationships of Ontologies from Text," *Intelligent Information Management*, vol. 3 no. 4, 2011, pp. 119–124. http://dx.doi.org/10.4236/iim.2011.34014

[6] J. Bermejo, "A Simplified Guide to Create an Ontology," *The Autonomous Systems Laboratory*, Universidad Politecnica de Madrid, 2007.
[7] E. D'Avanzo, A Lieto, T Kuflik "Manually vs semiautomatic domain specific ontology building," Thesis in Information and Commercial Electronics, 2008.
[8] M. Horridge, "A Practical Guide To Building OWL Ontologies Using Protégé 4 and CO-ODE Tools – Edition1.3," The University of Manchester, 2011.
[9] C. Lagoze, "Building OWL Ontologies with Protégé," Cornell University, 2008, [Online]. Available: http://www.cs.cornell.edu/courses/cs431/2008sp/Lectures/public/lecture-4-09-08.pdf,
[10] D. Plinere, A. Borisov, "A Negotiation-Based Multi-Agent System for Supply Chain Management," *IT and Management Science*. vol. 49, pp. 128–132, 2011.
[11] M. Laclavik, Z. Balogh, M. Babik, L. Hluchý, "AgentOWL: Semantic Knowledge Model and Agent Architecture," *Computers and Artificial Intelligence*, 2006.
[12] A. Sieg, B. Mobasher, and R. Burke, "Web Search Personalization with Ontological User Profiles," *Proc. 16th ACM Conf. Information and Knowledge Management*, CIKM .07, pp. 525–534, 2007.
[13] M. Golemati, A. Katifori, C. Vassilakis, G. Lepouras, C. Halatsis "Creating an Ontology for the User Profile: Method and Applications," 1*st IEEE International Conference on Research Challenges in Information Science (RCIS)*, Morocco, 2007

Darya Plinere received the *Mg. sc. ing.* degree from Riga Technical University in 2006. She is a Researcher at the Faculty of Computer Science and Information Technology, Riga Technical University. Her research interests include multi-agent systems, ontology engineering and supply chain management.
E-mail: darja.plinere@rtu.lv.

Arkady Borisov received the Doctoral degree in Technical Cybernetics from Riga Polytechnic Institute in 1970 and *Dr. habil. sc. comp*. degree in Technical Cybernetics from Taganrog State Radio Engineering University in 1986. He is a Professor of Computer Science at the Faculty of Computer Science and Information Technology, Riga Technical University. His research interests include fuzzy sets, fuzzy logic, computational intelligence and bioinformatics. He has 235 publications in the field. He is a member of IFSA European Fuzzy System Working Group, Russian Fuzzy System and Soft Computing Association, honorary member of the Scientific Board, member of the Scientific Advisory Board of the Fuzzy Initiative Nordrhein-Westfalen (Dortmund, Germany).
Address: 1 Kalku Str., Riga, LV-1658; phone: +371 67089530
E-mail: arkadijs.borisovs@cs.rtu.lv.

Darja Plinere, Arkādijs Borisovs. Ontoloģiskā zināšanu modeļa izstrāde izejvielu pārvaldības uzdevumam
Šajā rakstā ir detalizēti aprakstīta ontoloģiskā zināšanu modeļa izstrāde. Ontoloģija plaši tiek izmantota dažādās jomās. Šajā rakstā tiek piedāvāti ontoloģijas izstrādes soļi izejvielu pārvaldības uzdevumam. Izejvielu pārvaldības uzdevums ir piegādes ķēdes kopīga procesa sastāvdaļa, kas koncentrējas uz tādiem uzdevumiem kā augstākas kvalitātes materiāla sagāde par iespējami zemāko cenu, tajā pašā laikā darbojas kompānijas struktūras ietvaros, lai pārliecinātos, ka šie materiāli nodrošina vislabāko labumu ražošanas ietvaros. Šajā darbā tiek pētīti – preču nosaukumi, daudzums un vienošanās starp klientu un piegādātāju par piegādes laiku. Uzdevuma risināšanai tika nolemts pielietot multi-aģentu sistēmu un izmantot ontoloģiju kā saziņas kanālu. Ontoloģija ir saziņas kanāls starp aģentiem, kas ļauj kopīgi izmantot zināšanas un piedāvā vienādu izpratni par viņu sarunu būtību. Lai izmantotu ontoloģiju, tā ir jāizveido. Ontoloģija ir priekšmeta apgabala formālais attēlojums, tā aprakstīšanai ir savi likumi. Dotajam uzdevumam tika izstrādāts ontoloģiskais zināšanu modelis, kā arī rakstā ir parādīta atšķirība starp taksonomiju un ontoloģiju. Aģentu sistēmas tālākai ontoloģijas izmantošanai, ontoloģijas izstrāde tika veikta ontoloģiju redaktorā *Protégé*, pēc tam tā tika pārveidota JADE ontoloģijas klasēs, izmantojot *Ontology Bean Generator*. Aģentu sistēma, konstruēta JADE vidē, parādīja mijiedarbību starp diviem aģentiem un atrada uzdevuma risinājumu. Piedāvātās pieejas efektivitāti nodrošina izpildes precizitāte, savlaicīga reaģēšana uz vides izmaiņām un cilvēka faktora trūkums. Ja laika faktors nav svarīgs, ir iespējams organizēt konkursu vai izsoli.

Дарья Плинере, Аркадий Борисов. Построение онтологической модели знаний для задачи управления материальными ресурсами
В данной статье детализированно описывается построение онтологической модели знаний. Онтологии широко применяются для различных предметных областей. В данной статье представлено пошаговое построение онтологии на примере задачи управления материальными ресурсами предприятия. Задача управления материальными ресурсами предприятия является частью общего процесса управления цепочками поставок и концентрируется на решении проблем обеспечения высокого качества материалов, по возможности, по самым низким ценам. В то же время работа ведется и внутри структуры компании, чтобы убедиться, что эти материалы обеспечивают наилучшую выгоду в рамках производственного процесса. В данной работе исследуется согласование между заказчиком и поставщиком наименования, количества и времени доставки заказа. Для решения поставленной задачи решено применить много-агентную систему и использовать онтологию в качестве канала общения. Онтология является каналом связи между агентами и позволяет совместно использовать знания и иметь одинаковое понимание о сути их переговоров. Для использования онтологии необходимо ее построить. Онтология – это формальное представление предметной области, и существуют правила для ее описания. Для данной задачи построена онтологическая модель знаний, а также в статье показана разница между таксономией и онтологией. Для дальнейшего использования онтологии агентной системой, построение онтологии выполнено в редакторе онтологий Protégé, затем онтология была преобразована в JADE классы с помощью Ontology Bean Generator. Агентная система, реализованная в среде JADE, продемонстрировала взаимодействие между двумя агентами разных частей цепи поставок и нашла решение поставленной задачи. Эффективность применения предложенного подхода доказывается точностью выполнения, своевременным ответом на изменение среды и отсутствием человеческого фактора. Если временной фактор не важен, становится возможным организовать конкурс или аукцион.