Ontology Based Virtual Enterprise System Domain Modeling

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ABSTRACT

A virtual enterprise (VE) is a product oriented temporary consortium which forms a collaboration platform to fulfil a specific common purpose (typically to create a product) by benefiting from various capabilities of multiple VE partner enterprises. VE lifecycle consists of 3 distinct phases including VE Formation, Operation and Dissolution. VE partner enterprises are selected from virtual breeding environment (VBE) based on specific criteria considering the new VE project specifications. In order to select the most appropriate partners for the forthcoming VE project, it is required to have comprehensive information regarding the VBE members, their current conditions, capabilities, capacities and their past performances. This database continuously changes and it is dynamic. Ontologies and the corresponding knowledge bases provide the best tools for modelling such complex domain knowledge and highly dynamic data requirements. Ontologies not only help model and capture complex domain knowledge, but also improve the sharing and reusability of data and knowledge providing a suitable environment for software agents and human communications. The VE system must be able to demonstrate what types of resources exist, where they are located, and how much resource capacity is available to be used by the consortium. In this paper a pilot Virtual Enterprise system model developed for OSTIM organized industrial park in Ankara will be presented in detail. The objective of this system model is to enable SMEs in the region to collaborate effectively in order to produce eco-friendly high value added products.

1. INTRODUCTION

Competition is the main characteristic of today's global markets. In order to gain more shares from market and maximize profits, corporations are trying to offer more competitive products or services [1]. New advanced technologies increase the level of expectations of customers and markets. Leading to highly dynamic market conditions which impose increasing pressure over suppliers and producers. Manufacturers need to develop innovative high technology products and services with better quality and with lower prices. This requires highly agile, flexible and reconfigurable infrastructures for enterprises, which will require high costs to afford even for giant multi-national companies [2, 3].

Small and Medium sized Enterprises (SMEs) are one of the main pillars of economies in developed and developing countries. About 67% of the employment in the non-financial business economy is provided by SMEs. Micro enterprises contribute about 30%, small enterprises about 20% and medium-sized enterprises about 17%. Apart from the impact of SMEs on the welfare in the EU, SMEs also have a positive effect on economic growth [4]. This means SMEs survival has a great importance from the employment point of view. In turbulent and unpredictable market conditions it is very difficult for smaller enterprises to stay on their own feet, maintain their competitiveness and continue their life alone in their market. SMEs mostly focus on a special field and have the lack of complementary capabilities which disable them from producing new complete high value added products or services. In order to survive in such a strict competitive environment SMEs have to collaborate with each other. Collaboration is the key enabler for multiple business partners (specially SMEs), to empower themselves to catch opportunities in order to pursue common business targets and to manage turbulent business environments, mainly characterized by demand unpredictability, shortened product lifecycles, and intense cost pressures of dynamic and competitive markets [5, 6].

Virtual Enterprise (VE) is a temporary collaboration framework between multiple business partners in a value chain to reach business goal(s) by sharing their fundamental capabilities using Information and Communication Technologies (ICT) [1]. The VE framework is particularly feasible and appropriate for SMEs and industry parks containing multiple SMEs with different vertical competencies. By cooperating within VE framework, SMEs will be able to combine their diverse competencies to develop new products with better quality and reduce market turbulence effects [1, 3, and 6]. In order to enhance the quality of the products, produce more innovative, high tech and high value

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added products, it is not enough to provide a collaboration network among multiple manufacturing SMEs. The main target of providing collaboration platform here is to include research centres and high technology research and development companies settled down in techno-parks and industrial-parks parallel to the manufacturing companies. In order to produce high value added products, it is necessary to benefit from research and development capabilities of R&D companies to utilize research outcomes and developed technologies. By sharing production capability of manufacturers in industrial-parks and research capability of R&D companies in techno-parks via a secure and trustable collaboration platform it would be conceivable to produce high value added products by SMEs. At the same time this system will improve SMEs economic situation and their competitiveness by shifting their production capacities from commodity products to high value added, high technology products.

2. VIRTUAL ENTERPRISE

Collaborating under VE model, it will be possible for SMEs and start-ups to combine their diverse competencies to develop new products cheaper and with better quality. Besides alleviating market turbulence effects, the other important advantage of VE is minimum investment for each SME and risk sharing. However for a successful implementation of VE, there are difficulties [10, 13, 14, and 15]. The key prerequisite in implementing VE system is to ensure an Information System infrastructure capable to integrate distributed and diverse business modules of partners (currently used systems in enterprises like CAD/CAM, MRP and etc., databases and communication networks) under the VE platform while it should be guaranteed that secretive information of SMEs are protected [15, 16, 17, 18]. In order to prepare such an information system infrastructure, it could be benefited from several technological enablers like agent based systems, engineering applications, information management systems, supply chain management systems and etc. [19].

As Jagdev and Browne have mentioned in their research, the quality is no longer a factor of competitiveness but it is a prerequisite to be competitive. So the key factors in establishing a new VE consortium to improve the

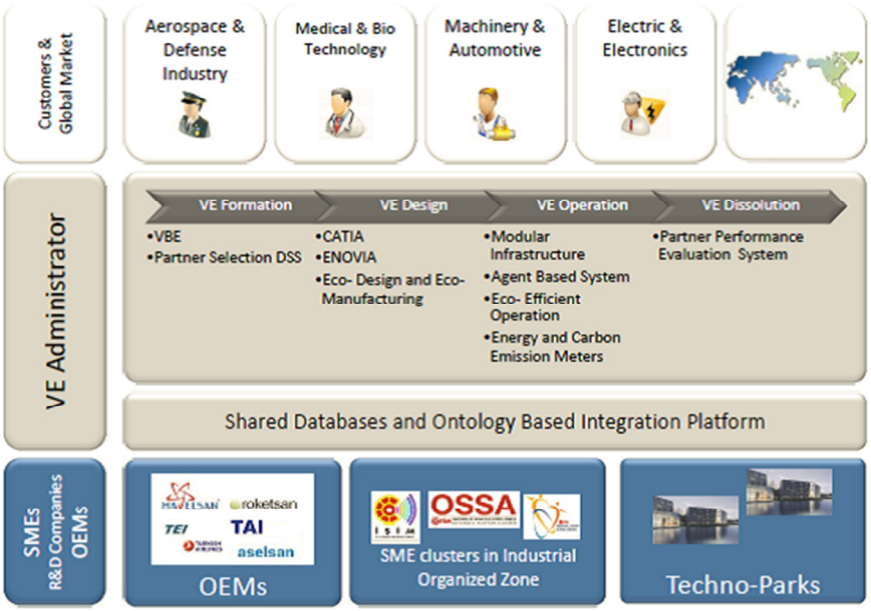

Figure 1. Proposed VE Business Architecture in OSTIM Industrial Park.

competitiveness of the VE partners are no longer simply cost and time [20, 21].

Surfing on VE relevant literature, it can be seen that VE lifecycle is divided into three distinctive phases: formation, operation and dissolution [19]. These phases should be considered as the minimum requirement for a collaboration network of SMEs. If however new innovative and high value added products are aimed, which is most likely the case, additional phase(s) may be needed to include. Collaborating enterprises need a step prior to the operation phase in order to include design activities concerning utilization of innovative research, or redesign and

optimize a surviving product(s), both in operation and environmental aspects,. This phase(s) were embedded inside the operation phase in some VE projects. This approach can be effective when there are only some little facelifts or design procedures which can done inside an organization or enterprise cooperating in VE as a partner. This type of design is not a collaborative design procedure because there are very little or almost no contributions from other partners. The proposed VE architecture in this paper therefore separates design phases from operation and proposes a completely distinct phase inside the VE. The three layered VE architecture proposed in this research is illustrated in Figure 1.

The bottom level of this architecture contains data and information of system members and partners, like SMEs, OEMs and research institutes and companies from techno-parks. All the data regarding these companies and institutes will be stored on this layer. VE shared data warehouse, and VE applications are on the middle layer which is the administrative layer of VE architecture. Shared data base is containing all the required data and information regarding the undergoing project. There will be strict rules how to generate, share, process and access the knowledge, data and the information within the VE. Various applications are used in each step of the VE lifecycle. These applications are placed in the upper part of the administrative level. The applications are served to the system members based on Software as a Service concept (SaaS). All members are able to benefit from these applications independent from their using platforms. VE customers' interfaces are in the upper layer of VE architecture.

User friendly and platform independent VE interfaces are on this layer in order to communicate and interchange information and data with customers.

3. ONTOLOGY BASED DOMAIN MODEL

In order to support flexibility in Virtual Enterprise business processes and enhance their integration to available manufacturing planning and control systems (e.g. MRP or MES) an ontology based domain model of the system has been developed. The main reasons to develop an ontology based domain model for virtual enterprise are:

- To share common understanding of the structure of information among software agents
- To enable reuse of domain knowledge
- To separate domain knowledge from the operational knowledge
- And to analyze domain knowledge

VE system will be based on a modular software infrastructure, all the entities of this modular infrastructure need to be properly integrated to the VE system. Virtual enterprise applications and services will be installed on a central server and partners can benefit from these services based on Software as a Service (SaaS) model. Partners will be able to have access to the system data repository via developed protocols and security levels. These applications need an up to date, flexible, dynamic and reliable system database structure to handle heterogeneous data produced from diverse sources with different formats. By developing an ontology based database structure it will be possible to properly integrate all the entities and manage large amount of heterogeneous, dynamic data and knowledge.

From the representation point of view, an ontology can be presented in several ways. Generally, concepts in an ontology are first grouped into several taxonomies with the "is a" and subclass relations. Then, these taxonomies are linked together with other relations.

3.1. ONTOLOGY REPRESENTATION AND ENCODING

XML is an effective way of exchanging information, and data sharing but it doesn't solve semantic data sharing problem [23]. Semantic information is represented as a set of statements which consist of three parts; subject, predicate and object. Because of these three parts, the statements are also called triples. In order to model, share and interchange of semantic data Resource Description Language (RDF) has been developed. Resource Description Format (RDF*) is the first layer on top of XML, which adds semantic information to the data. RDF allows for representation of ground binary relations in the form of triples <subject, predicate, object>. RDF Schema (RDFS) is used to describe RDF data (metadata) such as specifying classes, subclasses and properties to be used in the encoding process [24]. RDFS† allows adding more meaning within the definition of classes, properties, and other resources. For instance, it allows giving the range and domain of the properties that are defined [25]. RDFS solves some semantic problems and is appropriate for encoding lightweight ontologies. But for heavyweight ontologies it still lacks

* www.w3.org/RDF

† http://www.w3.org/TR/rdf-schema/

expressive power. A step toward heavyweight ontologies encoding was made with Web Ontology Language (OWL*). OWL is based on the description logic formalism and is divided into three sublanguages: OWL Lite, OWL DL, and OWL Full. The main advantage of OWL is that description logic has been an established research field for many years and thus, it benefits from all the reasoning algorithms already developed and optimized. The knowledge expressed in such a language is formally defined and contains axioms that restrain its usage to a certain context, thus removing ambiguities during the reasoning process. When building an ontology, one or more of these can be used depending on the comprehensiveness requirements.

3.2. AN ONTOLOGY MODEL FOR VIRTUAL ENTERPRISE

Virtual enterprise is a product oriented temporary consortium. It aims to integrate entities without excess costs for fulfilling a special target which is mainly producing a product by providing a collaboration network among participants. After accomplishing the task, VE disappears. Hence, VE has a dynamic nature. It is a task based platform based on opportunities. VE system model should be independent of specific tasks and provide a generic model of tasks.

In order to provide an appropriate decision making tool for various parts of VE, e.g. partner selection, VBE benchmarking, risk management of VE and etc., it is necessary to have a comprehensive domain knowledgebase where all concepts, relationships and constraints will be defined and also VE specific data should also be stored in a logical and reliable manner. Ontologies and the corresponding knowledge-bases provide the best tools to model such complex domain knowledge and also the highly dynamic data requirements. Ontologies are not only helpful in modelling and capturing the complex domain knowledge, but also improve the sharing and reusability of data and knowledge and provide a suitable environment for agents and humans communication [26].

VE platform will be extensively implemented in organized industrial zones or techno parks with different types of enterprises in different sizes, product ranges, automation and technological levels whereas the system data and information require to be continuously updated. This level of flexibility and room for expansion for VE platform database is next to impossible with traditional database approach. Therefore for VE platform database structure a triple store concept has been proposed and the VE ontology model will be the back bone of the data store.

Ontologies represent knowledge that formally specifies agreed upon concepts and their relationships for an application domain. Unlike task-specific and implementation-oriented data schemas, ontologies should be as much generic and task-independent as possible [27]. Ontologies play an important role in defining the terminology that the agents use in the exchange of knowledge-level messages and therefore the choice of an ontology representation language is a significant issue in designing a multi-agent system [28]. As VE system will be implemented directly in industry it should be considered to be fully compatible with current commercial tools and software. In this work a partially complete model of the VE ontology has been developed using Protégé ontology editor†.

4. PROPOSED VE ONTOLOGY MODEL

4.1. MODEL SPECIFICATIONS

In order to find and select best possible SMEs for different project tasks, it is highly required to have a large enterprise pool (breeding environment) and comprehensive data and information of registered enterprises in the pool. In Turkey and especially in Ankara SMEs are mostly distributed in different organized industrial zones. Acquiring needed information from these enterprises is difficult not only because of their geographical locations but also because of their automation levels and their contribution in organized industrial zone (OIZ) management. Therefore finding most appropriate SME for a specific task highly depends on experience and knowledge of OIZ management staff about enterprise pool, enterprises prestige and their known history to connect project owners to the right enterprises. It is obvious that this method is not efficient and most of the qualified enterprises ignored unintentionally just because of lack of information and inaccurate partner selection process.

Development of a comprehensive database to collect the information about SMEs, their competitiveness, capabilities, Machine Park and also their past performances is one of the top priorities of VE platform to increase the transparency of enterprises network. With the intention of optimizing the industrial organization zone performance it's necessary to monitor and organize all resources available in different companies. In order to form up a virtual

* http://www.w3.org/2004/OWL/

† http://protege.stanford.edu

enterprise, it's compulsory to find out which company has what resources and capabilities and whether the company's qualifications meet the customers project requirements or not. In this way and to fulfil these requirements the VE system must be capable to demonstrate that where and what type of resources are accessible and how much capacity of these resources are available to be used by VE consortium. All these activities and access to all the information must be parallel to the protection of the all private information of companies and it should be guaranteed that all private information and data getting from various companies are kept secret and are inaccessible from other system members. Therefore all these aspects must be considered in the VE system model which is going to be the VE platform backbone and all the information system hierarchy will be developed based on ontology based VE system model.

Next target in this model development is to provide required information to select the most appropriate enterprise from virtual breeding environment which is considered as enterprise pool for virtual enterprise system. Different type of predefined information and data are kept in the system. In order to satisfy all these requirements and at the same time to handle this huge amount of dynamic information it is necessary to form up a flexible, extensible and at the same time machine interpretable data warehouse. All needed applications in VE system should be based on software as a service approach to serve the customers independent from their individual computing platforms. Prerequisite data and information from system members and customers are gathered through multi-agent system, in the case of enterprises equipped with automated manufacturing and ERP systems or from web browsers manually if enterprises do not have prerequisite infrastructure.

Virtual enterprise ontology based system model has been developed to satisfy all the requirements addressed above. An overall view of ontology model is presented in figure 2.

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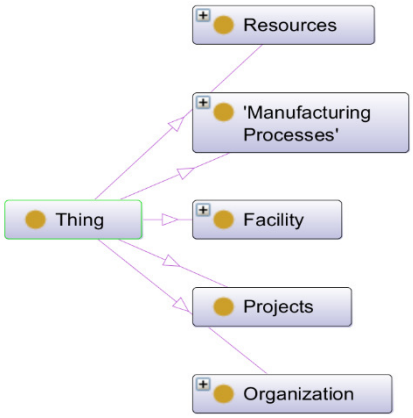

Figure 2. First Level Class Diagram of VE Ontology Model.

Different VE system requirements and entities are classified in designed VE ontology model accordingly. These entities, their properties and relations with each other play very critical roles and various stages of VE platform. Virtual Breeding Environment (VBE) which is considered as enterprise pool for VE platform keeps all the information and data of potential VE partners in different industrial sectors. These data and knowledge are kept up to date and in partner selection phase these data are recalled and used by partner selection and decision support system to choose the best possible partners for different tasks of VE project. For instance in partner selection phase, enterprise enablers, like standards, machinery, human resources, free capacity, and etc. are evaluated and based on these criteria, the most efficient enterprises are selected and ranked for each project task. Then a VE consortium is established with the collaboration of VE task projects' winner enterprises.

In VE design and operation phase also with the help of multiple agents, partners' performances and their activities during the project are monitored and reported to the project manager and required actions are taken based on incoming reports from agents. Here in this system based on automation level of partner enterprise, agents, could be software, human or semi-autonomous software agents. In all these cases agents communicate based on developed domain ontology and provided object, subject and predicate definitions given in VE ontology model. Figure 3 shows an

example of how an enterprise can gain new manufacturing capabilities by owning a machinery equipment and consequently gain a new potential to take part in new projects.


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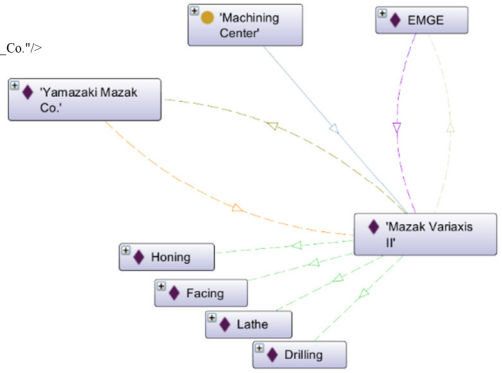

Figure 3. Sample SME enterprise, its resource Machine Center Attributes and Its Connections.

As an instant, EMGE (as a SME) acquired a 5-axes machining center (MAZAK), therefore this company attains some special machining capabilities by purchasing this machine. These machining capabilities enable the company to accomplish some specified machining processes. So as it can be seen these are all connected to each other like chain rings. By obtaining all the list of resources of the members of VBE it seems quite reasonable to assess companies' capabilities and their competitiveness and it would be more accurate to choose the right companies to take part in a VE project. At the same time all these processes and capabilities have their special attributes and properties. For example in figure 3-left, machine center attributes are presented.

In figure 4 a full view of VE ontology model including more than 347 classes and 137 individuals are depicted. Connection lines in this view represent predicate properties (object relations) defined in model to describe the relations and interactions among model entities. Data type properties are not shown in this picture. System data store and number of entities, their properties, and relations are increasingly extends daily by including new manufacturing and research capabilities, enterprise types, equipment and their properties and etc.

In order to demonstrate the feasibility of managing virtual enterprises based on an ontology model via an information system, a prototype of a virtual enterprise management system using the ontology was designed and developed. Unlike other standard management information systems, where standard database design models are used, in this information system ontological data model for knowledge and data representation is used. Like all modern information systems, a web-based information system usable and accessible via a standard web browser is designed. The system is a three-tiered software and developed using Java technologies, specifically using Java Enterprise Edition (Java EE) software. Per portability features of Java, the developed software is platform independent; it can be deployed on any operating system platform including Linux, Unix, Microsoft, etc. The distinguishing feature of the application design is the ontology-based data and knowledgebase in the lower layer of the three-tiered model.

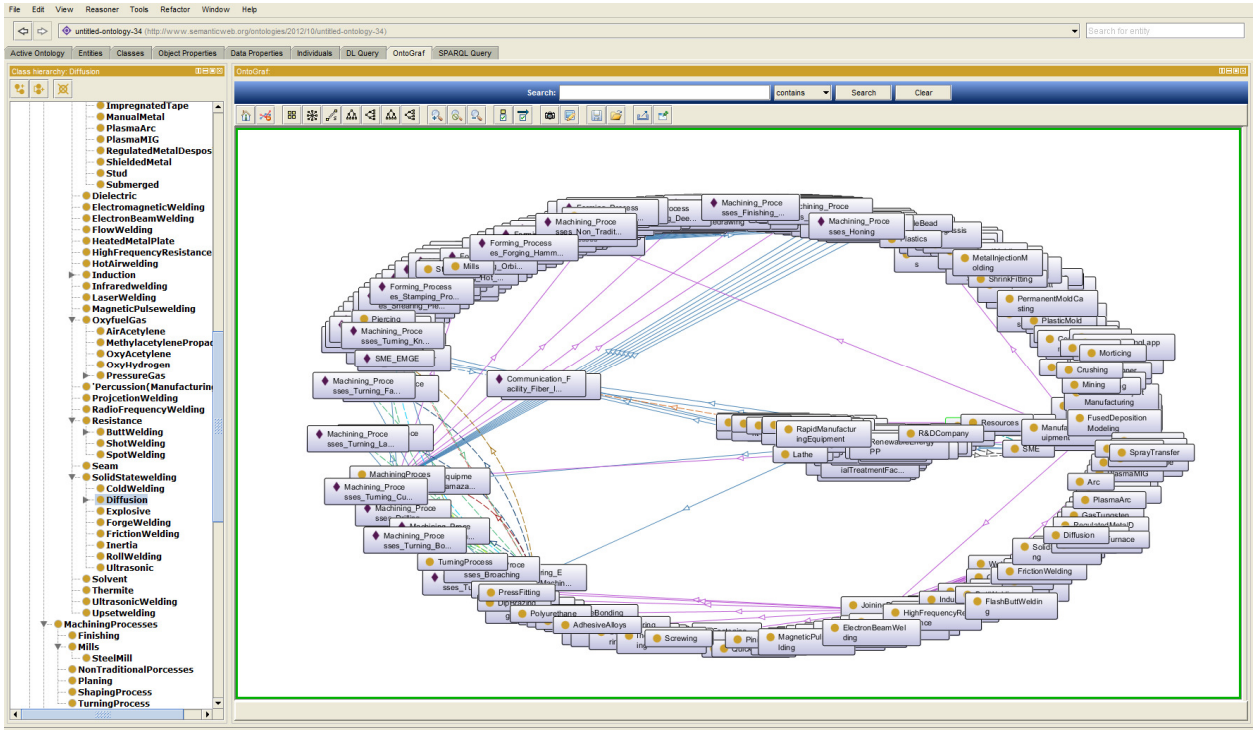

Figure 4. Overall view of VE Ontology Model.

5. SUMMARY

Collaboration is the main factor to increase the competitiveness of the SMEs in the today's highly dynamic global markets. In order to enhance the collaboration it is inevitable to benefit from newly developed Information Technologies (IT) and Computer Sciences. One of the most recent developments in the field of networking and information technologies is the semantic web concept which is a machine interpretable web of knowledge. Semantic web concept is targeting to convert the current web of unstructured documents to a web of meaningful data, based on W3C developed Resource Descriptive Formats (RDF). Using such a technology in VE systems boost up VE abilities in order to provide a better collaboration platform for various SMEs with different core competencies. In this paper, the presented VE ontology model is an enabler for providing semantic virtual enterprise information infrastructure. Different agents mounted in the companies' manufacturing facilities gather all required information like, energy consumptions and product data. These agents should be able to communicate among themselves and administrator agent as well. In order to realize this machine to machine communication a machine interpretable semantic communication infrastructure is required.

All VE applications will be designed based on SaaS concept. Incoming raw data and information from agents in member enterprises will be analysed and valued by VE administrator then the results will be served back based to these member enterprises. Based on this information the authorized people in the member organizations and also VE administrator are able to make the right decisions regarding project progression, energy consumption and etc.

ACKNOWLEDGEMENTS

This study is being funded by SAN-TEZ project No. 00979.stz.2011-12 of Turkish Ministry of Science, Technology and Industry. Authors are sincerely thankful for continues support of OSTIM Industrial Park management.

REFERENCES

[1] *Unver, H. O., LotfiSadigh, B., 2011. An Agent-Based Operational Virtual Enterprise Framework enabled by RFID. M. Cruz-Cunha, & F. Moreira Eds., Handbook of Research on Mobility and Computing: Evolving Technologies and Ubiquitous Impacts. Hershey, PA: Information Science Reference.*

[2] *LotfiSadigh, B., Unver H. O., Kilic, S. E., 2011. Design of a Multi-agent based Virtual Enterprise Framework for Sustainable Production, Proceedings of 1st Int. Conf. On Virtual and Networked Organizations Emergent technologies and Tools, July 2011, Ofir, Portugal.*

[3] *Camarinha-Matos L. M., Afsarmanesh H., 2007. A framework for virtual organization creation in a breeding environment, Annual Reviews in Control 31 (2007) 119–135.*

[4] *Camarinaha- Matos L. M. and Afsarmanesh, H., 2001. Virtual enterprise modeling and support infrastructure: applying multi-agent system approach. Lecture Notes in Artificial Intelligence (LNAI), 2086, 335–364.*

[5] *Petersen S. A., Divitini M. and Matskin M., 2001. An agent-based approach to modelling virtual enterprises, Production Planning and Control: The Management of Operations, 12:3, 224–233.*

[6] *De Kok J., Vroonhof P., Verhoeven W., Timmermans N., Kwaak T., Snijders J. and Westhof F., 2011. Do SMEs create more and better jobs?, Available from: http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/performance-review/pdf/do-smes-create-more-and-better-jobs_en.pdf, [January 2012].*

[7] *Eurostat yearbook 2003, the statistical guide to Europe data 1991-2001, European Council, ISSN 1681- 4789, 2003 Edition.*

[8] *OECD (1994), "OECD Economic Outlook No. 56", OECD Economic Outlook: Statistics and Projections (database).*

[9] *Lukacs E., 2005. The Economic Role of SMEs in World Economy, Especially in Europe. European Integration Studies, Miskolc, Volume 4, Number 1, pp.3–12.*

[10] *Jagdev, H.S. and Thoben, K. D., (2001). Anatomy of enterprise collaborations. Production Planning and Control, 12 (5), 437–451.*

[11] *Sari B., Sen T., Kilic S. E., 2008. AHP model for the selection of partner companies in virtual enterprises. , International Journal of Advanced Manufacturing Technologies V. 38, Numbers 3-4, Pages 367–376.*

[12] *Browne J., Zhang J., 1999. Extended and virtual enterprises - similarities and differences, International Journal of Agile Management Systems, Vol. 1 Iss: 1 pp. 30 –36*

[13] *Camarinaha- Matos L. M. and Afsarmanesh H., 2003. Elements of a base virtual enterprise infrastructure. Computers in Industry, 51 (2), 139–163.*

[14] *Sari B., Sen T. and Kilic S. E., 2007. Formation of dynamic virtual enterprises and enterprise networks, International Journal of Advanced Manufacturing Technologies, 34:1246–1262.*

[15] *Sari, B., 2006. Methodology Development for Small and Medium Sized Enterprises (SME) Based Virtual Enterprises, Ph.D. Dissertation, Middle East Technical University, Ankara, Turkey.*

[16] *Camarinha-Matos, L. M., Afsarmanesh, H., 2001. Virtual Enterprise Modeling and Support Infrastructures: Applying Multi-Agent System Approaches. In Carbonell, J. and Sickmann, J. (eds), Multi-agents Systems and Applications, pp. 335–364, Sanibel Island, FL, 2001.*

[17] *Bellifemine, F.L., Caire, G., Greenwood, D., 2007. Developing Multi-agent systems with JADE. Wiley, New York.*

[18] *Villar-Medina, I., Lopez-Ortega, O. Hernandez-Gomez, R., 2009. Implementation of a supervised learning technique in a multi-agent system for building production orders. International Journal of Advanced Manufacturing Technology, 40:808–818.*

[19] *Cho Y., Leem C., Shin K., 2006. An assessment of the level of informatization in the Korea mold industry as a prerequisite for e-collaboration: an exploratory empirical investigation, International Journal of Advanced Manufacturing Technology, (2006) 29: 897–911.*

[20] *Alzaga A., Martin J., 1999. A design process model to support concurrent project development in networks of SMEs, Networking Industrial Enterprises, Kluwer Academic Publishers, ISBN 0-7923-8639-6.*

[21] *Bremer C. F., Michilini F. V. S., Siqueira J. E. M., and Ortega L. M., 2009, VIRTEC: An example of a Brazilian virtual organization, Journal of Intelligent Manufacturing, Volume 12, Number 2, 213–221.*

[22] Jon Rush, 2010. IBM i and SaaS Positioning IBM i as a software as a service platform. IBM systems and Technology Group Lab Services. Available from: https://www-304.ibm.com/partnerworld/wps/servlet/ContentHandler?contentId=XhrjdgScEXMiPCA$cnt&roadMapId=IbOtoNReUYN4MDADrdm&roadMapName=Education+resources+for+IBM+i+systems&locale=en_US. [Accessed 1st January 2013].

[23] Corcho, O., M. Fernández-López and A. Gómez-Pérez. 2009. "Ontological Engineering: What are Ontologies and How Can We Build Them?." Semantic Web Services: Theory, Tools and Applications. IGI Global, 2007. 44-70. Web. 24 Jul. 2012. doi:10.4018/978-1-59904-045-5.ch003

[24] Brickley D. 2004. RDF vocabulary description language 1.0: RDF Schema. W3C recommendation published online [Online]. Available: http://www.w3.org/TR/rdf-schema/.

[25] McGuinness D. L. and van Harmelen F. 2004. OWL Web ontology language overview. W3C recommendation [Online]. Available from: http://www.w3.org/TR/owl-features/.

[26] Chandrasekaran B., Josephson J. R., Richard B. V., 1998. Ontology of Tasks and Methods, In: The Eleventh Workshop on Knowledge Acquisition, Modeling and Management, 18- 23 April, Banff, Alberta, Canada.

[27] Meersman R., Jarrar M.. 2002. Data modeling versus Ontology engineering. ACM SIGMOD Record, vol. 31, N 4, 2002.

[28] Cranefield S., Hausteiny S. and Purvis M., 2001. UML-based ontology modeling for software agents, In: Proceedings of the Workshop on Ontologies in Agent Systems, 5th International Conference on Autonomous Agents, Montreal- Canada. 28 May-1 June 2001.