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ARCHIVES of FOUNDRY ENGINEERING

DOI: 10.2478/afe-2013-0085

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 13
Issue 4/2013

73 – 78

The Framework of Agent-based Negotiation Platform for Foundries Cooperating in Supply Chain

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Received 03.06.2013; accepted in revised form 02.09.2013

Abstract

This paper concerns the domain of contracts in the metallurgy and heavy industry, that are the form of deals making between cooperating companies being suppliers and consumers of some goods. From a general point of view cooperation enables for small companies to realize orders that are too large for an individual producer, but contract negotiations, further scheduling and support of production are usually too difficult and complicated. This paper presents a proposition of an information system, that should make cooperation between companies more available. Such system should be distributed among cooperating producers, what is the reason for choosing of the agent technology as the main software paradigm. This system should also support interchanging of information in many norms and technical standards, what results in the use of ontology concerning metallurgy and heavy industry.

Keywords: Application of Information Technology to the Foundry Industry, Innovative Foundry Technologies and Materials, Ontology, Agent technology, Production support

1. Background of presented research

Nowadays transformations in the economy involve searching for opportunities that aim to save money spending for materials used at production together with searching of opportunities that have a goal to sell products made in the factory. Single enterprise is seen as the one element in the supply chain maximizing its benefits by searching for cheap input materials and consumers for its production. This phenomenon is noticed in many branches of industry, but especially in the metallurgy and heavy industry leads to a problem concerning specification of contracts made between consumers and producers of goods and one another problem concerning real capabilities of production. The first stated problem is caused by many different technical norms used simultaneously by many factories in the domain of metallurgy. The second stated problem induces cooperation between small enterprises at realizations of single contracts.

Presented in the above paragraph problems show a need for support at searching and realizing of contracts. Such support can be realized in the form of an information system, that should enable to announce, view and make contracts between enterprises being consumers and suppliers of some goods. Building of such system is one of main subjects in scientific research on supply chain management ([1]). Among most significant works the agent

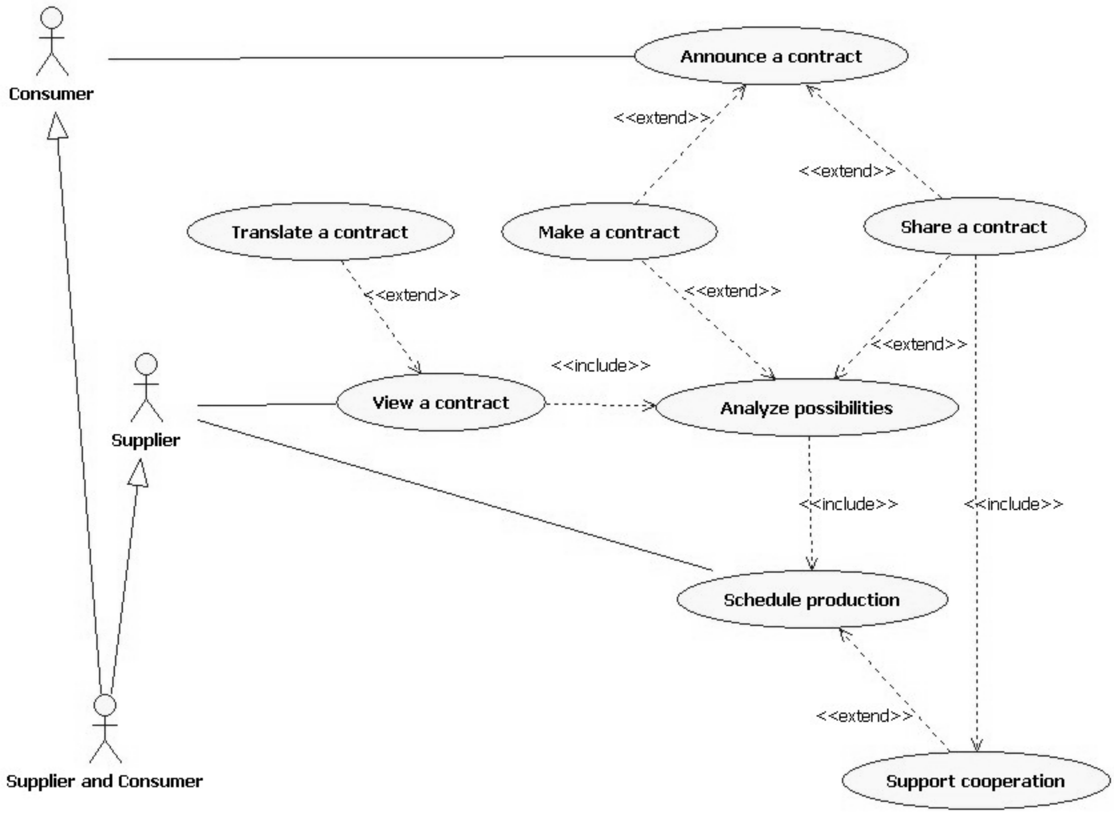

Fig. 1. Use case diagram of information system for cooperating enterprises of the metallurgical industry

technology is indicated as the software paradigm for the system design and implementation [2,3,4]. The common part of this approach is that software agents perform complex problems in supply chain management. Presented by us work largely uses the achievements of this research field, but we would like to take into consideration specific for the metallurgy and heavy industry issues related to properties of products or characteristics of services. We assume, that usage of ontology should comply all problems related to the specification of properties of products in the domain of foundry and heavy industry. Presented conceptions are related with creation of framework for cooperating foundries focus on using of agent-based approach and ontology as a means for ensuring the clarity and correctness of communication.

2. Analysis of information system for the metallurgical industry

The diagram onto Fig. 1 presents results of functional analysis made according to introduced information system. Three main types of actors are assumed: Consumer (which is interested to buy some goods), Supplier (which is interested to sell some goods) and Supplier and Consumer (which sells and buys some goods). Supplier and Consumer is generalization of Consumer type and Supplier type, what means that this type of actor can participate in all use cases of both types of actors.

The use case named Announce a contract concerns all activities of Consumer that aim to specify a contract. The Consumer has to state all properties of goods he wants to buy, amounts, prices and deadline, what should be done according to existing norms and standards. The Supplier can view a contract using possible help of projected system in the form of automatic translation of used norms and standards. This activities are included in the use cases named View a contract and Translate a contract. Viewing a contract should involve use case named Analyze possibilities, that aims to help in analyzing production possibilities of the Supplier in order to realize contract. If activities grouped in the use cases named Analyze possibilities and Schedule production appoint, that realization of a contract is possible and profitable, the Supplier can finally make a contract with Consumer, what is the aim of Make a contract use case.

Analysis of possibilities can also appoint, that production is profitable, however the Supplier has not sufficient possibilities to realize a whole contract (e.g. not sufficient volume of production). In this case the Supplier can be interested only in realization of part of a contract. If some other Suppliers can complete the realization of a contract, this contract can be made between many interested Suppliers and a Consumer. This case Consumers and Supplier take part in Share a contract use case, which involves Support cooperation. The use case named Support cooperation aims to synchronize scheduling of production of many cooperating Suppliers, which realize one shared contract.

3. Agent technology for distributed issues in foundry processing

The central paradigm of agent technology is autonomy which specifies the way, how agents act in environment of a system. An intelligent agent should operate flexibly and rationally in a variety of environment conditions in order to achieve some set of goals or perform some set of tasks [5, 6]. The behavior of an agent can be seen as behavior of an intelligent entity. Agent technology is especially useful in distributed problems, like the domain of presented information system, that is distributed among individual enterprises. It enables to keep natural decomposition of a problem assigning individuals goals and aims to individual agents.

The general model of a multi-agent system is presented by the formula [7]:

$$MaS \equiv \{Ag, Env, Res, Com, Org\} \tag{1}$$

where:

Ag – set of agents,
Env – environment,
Res – accessible resources,
Com – communication,
Org – organization (relations between agents).

In the case of presented here system, both the organization of the system (*Org*) as well as the means of communication (*Com*) are determined by the appropriate variant scheme onto Fig. 1. The environment of system functioning (*Env*) is a set of considered industrial companies (foundries) and potential recipients of their services. The available resources (*Res*) are the sum (the set) of all opportunities and means available for the individuals that are in the domain of projected system (the used technology, machinery, raw materials, financial resources).

Agents ($A_i \in Ag$) are individuals possessing the ability to make decisions, possessing a part of the resources ($R_i \in Res$) and possessing the ability to transmit and receive information ($C_i \in Com$). In addition, each of these units possess own purpose of activity (G_i) (it can be also a set of objectives($G_i = \left(g_i^1,\dots,g_i^k\right)$). Thus, the general model of an agent can be expressed as:

$$A_i \equiv \{D_i, G_i, R_i\} \tag{2}$$

where:

D_i – set of activities of agent A_i,
G_i – goals of agent A_i,
R_i – resources of agent A_i.

The concept of activity of agent can be interpreted as both exchange messages with other agents, as well as decisions regarding the negotiated contract.

From the most general point of view, presented here domain is distributed among suppliers and consumers performing its activities in order to maximize profits. This leads to proposition of two main types of agents: the consumer agent and the supplier agent. Other types of agents should be subordinated to one of this two type. Because some enterprises are simultaneously consumers and suppliers, such enterprises should be represented by two types of agents.

The consumer agent represents an enterprise, that is interested in buying some goods. This agent provides an interface for specifying contracts. It enables to enter individual properties of a good, that the consumer aims to buy. In this context, the consumer agent (A_i^C) appears with an offer of purchasing a set of resources, so sent by him messages may include the following elements:

$$D_i^C = \left(prod^C, tech^C, time^C, prop^C\right) \tag{3}$$

where:

prod – products,
tech – technologies,
time – delivery time,
prop – proposed purchase price.

The supplier agent helps by viewing of existing contracts (that are sent by consumer agents) and by deciding which one contract can be realized by the company, which this agents represents. The supplier agent (A_i^S) taking into consideration resources of the represented company occurs with an offer in an analogous form:

$$D_i^S = \left(prod^S, tech^S, time^S, prop^S\right) \tag{4}$$

In the environment of the projected system many consumer and supplier agents can exists, so in a global scale similar offers (even roughly) are regarded, namely the condition of balance between offers made by consumers and suppliers should be fulfilled:

$$\sum_{i=1}^{C} D_i^C \cong \sum_{j=1}^{S} D_j^S \tag{5}$$

when simultaneously the efforts of all individual agents to achieve their local objectives have to be regarded:

$$G_i^C\left(D_i^C\right) \to \max,\ G_i^S\left(D_i^S\right) \to \max \tag{6}$$

As a result, the fulfillment of the condition of balance between consumers and suppliers (5) requires a complex process of negotiations based on the exchange of messages between agents (adjusted to the accepted forms of information protocol). Description of this process is beyond the range of this paper, however, it is obvious that common means of communication should be applied in order to enable proper interpretation of individual messages. Thus, it

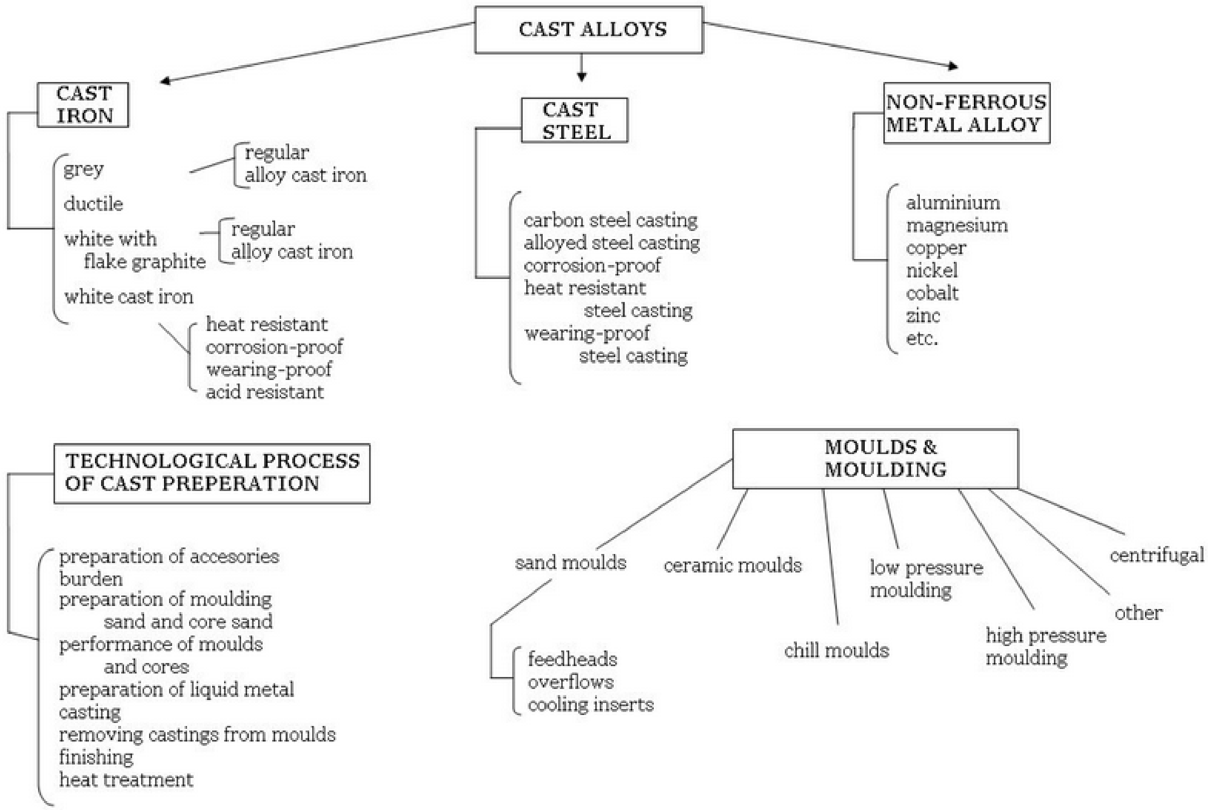

Fig. 2. Material- and technology-related aspects of casting production

becomes necessary to create an ontology that allows a mutual understanding in the problem domain.

Presented above model of multi-agent system can be extended. One of possibility is creation of a translation agent, that can besubordinated to the supplier agent. The aim of translation agent is to help in understanding description of offers formulated in unknown standards. One another possibility is, that the supplier agent can look for other supplier agents aiming participation in realization of the same contract. In this case, such group of supplier agents can make a shared contract with the consumer agent. To such shared contract an additional support agent should be created, that aim is to harmonize production taking place in different production places (different foundries).

4. Creating ontology for the domain of metal processing

Being a knowledge model, a dictionary of terms and their relationships, ontology is expected to enable the knowledge interoperability and reuse. Ontology is not a database schema, but a simplification is also possible: an ontology for the repositories of knowledge is what the diagram of entity is for a database; it is a schema, a model of a certain field of knowledge, readable by both computers and people [8]. Nowadays computers are expected to understand, and not only to archive, data, and also the knowledge. Not only data should be available for the user, but also the knowledge i.e. in the form of production rules [9].

According to the agent technologies assumptions, with the use of ontologies agents will be able to process information according to the user's intentions. They also will be able to communicate with each other without losing any of the information [10]. The agent based information system for cooperating enterprises involves different types of agents. Each one of them operates on data, that corresponds with different nomenclature: assortment, technical standards, different properties or coefficients. To perform the dialogue between agents it is necessary to set an agreed sense [11].

The problem in the multiuser systems, including agent-based systems, is also copying of resources and knowledge redundancy. Co-creation of the system by many users causes a situation, when for the same substantive term, there are in several documents (resources) in various forms (e.g. L200HNM cast steel which is also G200CrMoNi433 cast iron). In this situation it is required to integrate the redundant resources and create a redirection from individual objects to integrated class. Ontology facilitates the analysis of overlapping terms owing to the property rdf: seeAlso, which allows placing adequate terms directly in the ontological description which will greatly facilitate the performance of agent-based systems.

Another problem that is solved by this structure of the model of knowledge is the problem of homonyms. Ontology also solves the problem of homonyms: a model simply cannot have two classes with the same name, which forces the ontology engineer to extend the class name in such a way as to make it reflect the context in accordance with the namespace. Also an issue on synonyms is solved. Agents are supposed to check the context of the term in ontology in case that certain term is ambiguous.

The first step of creating ontology is compilation of the available sources of knowledge. The primary source of knowledge for the domain of metallurgy is literature completed with expert reviews (e.g. prepared by the Foundry Research Institute in Krakow) and standards (e.g. Polish Standard PN-85/H-83105 - casting defects) [12, 13]. The possible obsolete character of some knowledge sources in the form of textbooks entails the risk that the currently analyzed process has already been simplified, or various stages of the process have already been replaced by another technology. Therefore the system of gathering knowledge should consist of two stages. Basic knowledge is taken from the literature, and then this basic scheme of ontology should be submitted to experts analysis for possible updates.

In the second step, a hierarchical system of key concepts should be created, where concepts at lower tiers inherit the characteristics (attributes) of superordinate concepts.

Analyzing the knowledge concerning materials, in particular the areas associated with cast iron alloys, attention should be drawn to a hierarchical system of key concepts comprised in this knowledge, where concepts at lower tiers inherit the characteristics (attributes) of superordinate concepts. Often these attributes differ only in values. One of the important characteristics of modern foundry is a large diversity of castings produced in various metals and metal alloys, which entails a large number of applied technologies, requiring proper equipment, measurement and control systems as well as raw and auxiliary materials.

Fig. 2 shows a fragment of a hierarchical classification of cast alloys and basic variants of the most important components of a technological process [14].

Fig. 3 shows an example of hierarchical system, according to which the fragments of knowledge about the cast materials and casting defects have been arranged. As we can see, creating a hierarchy for the class called "metals" in the ontology totally corresponds to the structure of knowledge derived from sources. Creating a hierarchy is therefore quite a labor-intensive step, but does not require such depth of experts' knowledge as the next steps.

The goal of the third step is to determine object properties (Fig. 4). In this step, for each class, its specific properties, if any, should be defined. These properties are sometimes referred to as attributes. An example of an attribute for the class "Alloy" may be its chemical composition. When defining properties it should be remembered that objects have been arranged in a certain hierarchy, which implies the fact that the class of objects will receive a set of properties that are the sum of the properties of its parent classes. In this step, the relationships between the classes are determined.

The fourth step is related to increasing the power of expression of the ontology, what can be done by:

- Determination of rules, which object in a given class should be classified as belonging to this class, such as e.g. the required values of properties and their cardinality,
- The imposition of restrictions on the domain and the range of properties or restrictions in the form of a specified set of classes, to which the property in question relates and a set of classes or values, which the property in question indicates,
- Determination of the characteristics of relationships such as symmetry, transitivity, reversibility.

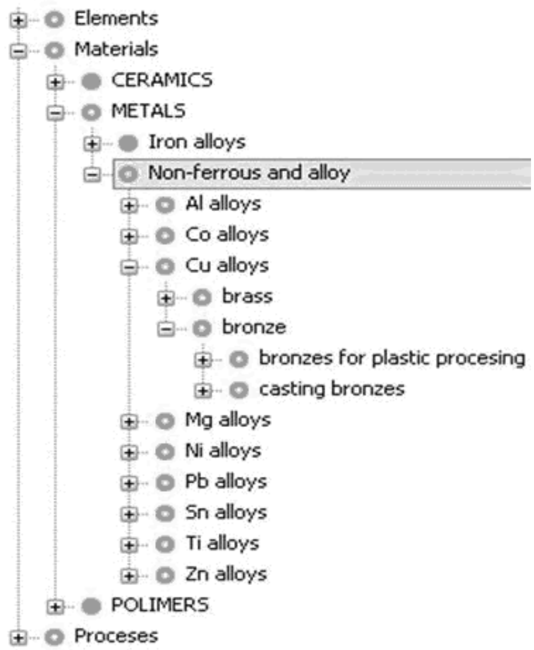

Fig. 3. Hierarchical way of organizing the fragments of knowledge about cast materials

After completing the ontology with the above mentioned elements, it is possible to check its coherence and correctness and finally to create the instances of classes. Creation of instances is perhaps the most laborious stage due to the fact, that all real objects are introduced to the knowledge base.

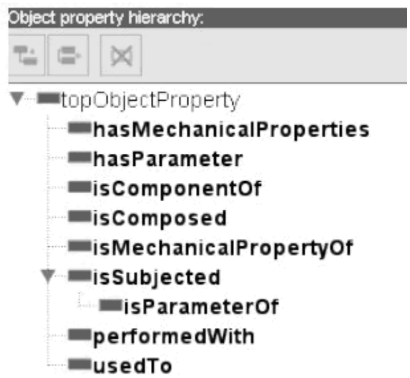

Fig. 4. Object properties

5. Conclusion

The paper presents the assumptions of an agent based information system for a network of metal processing enterprises. The problem of support for realization of large orders through a network of cooperating small and medium-sized enterprises is presented, which would not be able in other case to carry out such large projects by themselves. The significant problem for metallurgical factories is to unify the technological parameters of products and materials, as well as estimating the usefulness of certain alloys. Authors suggested a specification of a number of parameters as the knowledge model, which will be used at implementation and functioning of the agent based system. The elaborated knowledge model enables to process by humans and software agents information according to offered products and according to cooperation between manufactories. The proposed system requires the creation of solutions, procedures and tools in order to enable the acquisition and effective use of information about available resources and information about the demand for semi-processed products and opportunities to satisfy them by different members included in the workgroup.

Use of the agent techniques in conjunction with the use of ontologies as a platform for communication, creates a space of cooperation agents, whereby agents are able to perform a number of tasks, such as recognition, translation and analysis of contracts, the division of tasks between the individual members of the consortium, and production scheduling in realization of major projects.

Acknowledgements

The work was financed in the framework of the international project No. 820/N-Czechy/2010/0 of 30 November, 2010 and financial support of the AGH 11.11.110.085

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