27

AGENT-BASED BROKERAGE FOR VIRTUAL ENTERPRISE CREATION IN THE MOULDS INDUSTRY

Ricardo J. Rabelo [1]; Luis M. Camarinha-Matos [2]; Rolando V. Vallejos [3]
[1] *Federal University of Santa Catarina, BRAZIL (rabelo@das.ufsc.br)*
[2] *New University of Lisbon, PORTUGAL (cam@uninova.pt)*
[3] *University of Caxias do Sul, BRAZIL (RVVallej@ucs.tche.br)*

Brokerage and partners search is an important activity in the creation phase of a virtual enterprise (VE), where the most adequate consortium of enterprises should be selected to respond to a given business opportunity obtained by a broker. This paper proposes a multi-agent-based architecture to support this functionality in the context of a cluster of twelve enterprises in the moulds and die sector. The system includes a broker agent, a facilitator and consortium agents that plan the possible VEs, and a set of agents representing the enterprises participating in the cluster. The contract-net protocol is used to collect bids from cluster members and to select the most adequate ones. In case the cluster does not cover all the requirements a more general search for partners can be performed on Internet-based directories of enterprises.

1. INTRODUCTION

Brokerage and partners search is an important activity in the creation phase of a virtual enterprise. The need to select new partners arise both at the creation phase of a VE, when it is necessary to decide on the appropriate set of skills and resources required by the current business opportunity, or when it is necessary to replace a partner during the operation of a VE. The purpose is to find the most adequate group of enterprises to respond to a business opportunity. In the context of Virtual Enterprises (VE), the broker concept is usually seen as the entity designed to search for business opportunities over the world and to bring them into the cluster of enterprises it represents.

The prototype system described in this work is focused on a cluster of twelve mould and die enterprises placed in the south of Brazil. A *cluster* is seen as a group of enterprises that have the potential and the will to cooperate and therefore may become the partners in a VE (Camarinha et al., 99a). In this paper we will name this specific cluster as "Mould and Die Industry Cluster" (MDIC). MDIC created as a way to increase the business potentialities of the enterprises as they can be more competitive in the global market if they act as a more powerful entity – comprising the sum of their capacities – and not (only) as individual suppliers. Such framework

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35399-9_52
L. M. Camarinha-Matos et al. (eds.), *E-Business and Virtual Enterprises*

provides the profit improvement of its members by means of resources, processes, and skills leveraging (Bremer et al., 99).

The MDIC is legally represented by a broker and there is one expert responsible for getting (or receiving) and analyzing business opportunities. By means of a *broker agent* – an auxiliary software module – an acquired business opportunity is transformed into a business process that is split and distributed among the selected enterprises within the cluster. Depending on the BP requirements and the available capacities and skills, it may happen that various alternatives of consortia may be found. Therefore, a set of possible teams of enterprises ("internal" VEs) that can carry out this distributed business process (DBP) is formed and the most suitable team is suggested. Figure 1 illustrates the formation of a set of teams of enterprises within the MDIC to attend a given distributed business process. In the exemplified case, there are three VEs capable to accomplish the business process. Please note that a given enterprise can be involved in more than one possibility of VE and it can as well be involved in more than one opportunity simultaneously. In this picture, only VE1 has its internal production flow illustrated, assuming the enterprise (agent) E12 the role of VE coordinator.

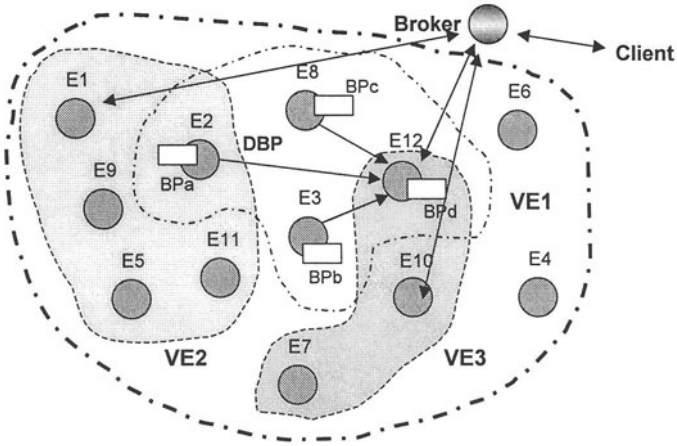

Figure 1 – A VE scenario within the MDI Cluster

The VE life cycle involves a number of phases, basically VE creation / configuration, VE operation, VE evolution, and VE dissolution (Camarinha-Matos et al, 98, 99), (Spinosa et al., 98). Other authors also include the activities of business opportunity identification, and partners search and selection as separate phases (Bremer et al., 99). This work is currently focused on the VE creation phase, one of the less developed subjects within the VE developments. It proposes a multi-agent-based system – The MASSYVE Mould Broker System (MMBS) – to support the MDIC's human broker in the decision-making process of selecting the most adequate consortium of enterprises that can satisfy a given business opportunity. In the case not enough resources or skills are found in the cluster, a complementary partners search and selection tool (the ESPT tool) is called to find the missing partners outside. As the cluster members are potential competitors, the final decision is made by a management board and not by the broker. However, the decision is

based on the broker's analysis, represented by the set of alternative consortia generated (and evaluated) by the system.

This work is being developed in the context of the INCO-DC MASSYVE project (Massyve, 2000) and also uses some results from the ESPRIT PRODNET-II project (Prodnet, 1999). This paper is organized as follows: Chapter 2 presents an overview of the problem in the MDIC context. Chapter 3 introduces the MMBS architecture. Chapter 4 illustrates some results of the proposed system and finally Chapter 5 discusses the results and suggests the next steps of this work.

2. PROBLEM SPECIFICATION

In the MDIC scenario, the enterprises receive client orders both directly (i.e. in the traditional way) and via the broker. A client order can comprise an individual product or a "package" of moulds and/or dies. The client may also indicate if the mould maker can or cannot subcontract other mould makers for each mould. A client order can arrive at the broker as a very well specified tender or in a very draft way, in which case several interactions with the client are required until the definitive tender is agreed.

For the following discussion, let us consider a simplified scenario where:

- a client order arrives via the broker;
- a client order arrives as a package;
- for each mould within a package, an enterprise cannot subcontract another enterprise, either for the entire mould or to contract some hours in a machine for the execution of a certain mould's operation;
- a client order is complete (all information in completely and precisely specified) and definitively set when it goes to the broker.

A client order specifies, basically, the mould size (in tons), its type (mould or die), the mould material (aluminum or plastic), and the due date (for each part or for the entire package). The mould drawing is sent as well (as a sample, or as a 2D or 3D CAD model). There are clients that sometimes indicate the maximum price for the package or some of its parts.

For the broker, the competence of each MDIC member is represented in terms of its capacities such as the mould size and type that each enterprise is able to deal with.

Therefore, at this stage of the system prototype, the problem comprehends the following macro actions:

i) for each business opportunity, the broker analyzes how the client order can be satisfied by a distributed BP and identifies who are the potential candidate enterprises for each sub-process inviting them to bid, and finally distributes the client order among the enterprises whose competence fits the tender;

ii) the involved enterprises should get, analyze and bid in the case they are interested and capable to satisfy the client order's requirements. A bid requires the direct intervention of the enterprise's manager so that he/she can indicate the price and eventually refine the proposed delivery date. Once the bid is sent the enterprise should (conditionally) book its agenda

for that business until it receives the final decision (whether the task was assigned to it or not);

iii) based on the positive bids, the broker tries to create one or more alternatives in terms of execution schedules and their quality, i.e. several possible VEs;

iv) if no satisfactory schedules can be fully generated out of the MDIC members bids, an external partners search tool is used in order to try to find some other enterprise – outside of the cluster – that can fulfill the missing requirements;

v) an alternative is set, i.e. the VE is then created, and the involved enterprises are noticed about the final result. Thus, they know if they should be or not be definitely committed to the given business.

3. A MULTI-AGENT ARCHITECTURE

Multi-agent Systems (MAS) represents a suitable approach for modelling the enterprises that can participate in a VE, since they can exhibit some relevant capabilities like autonomy, adaptability, ability to interact with the other agents, also providing the system with decentralized decision-making capability, scalability, flexibility in the creation of teams by means of negotiation, and dynamic behavior (Rabelo et al., 98) (Rocha et al., 99). Therefore, the MAS approach is quite suitable to support the MDIC requirements and the necessary macro actions explained in the previous chapter. In other words, applying a MAS approach to this brokerage activity implies that agents have to exchange information with each other so that a set of teams of enterprises capable to perform a given business process are identified. Once these teams are generated, the selection criteria are based on the lowest global cost and shortest final delivery date, in this priority order.

3.1 The MASSYVE Mould Broker System Architecture

In order to cope with the MDIC scenario requirements, four hierarchical and heterogeneous classes of agents have been designed. They are based on the HOLOS framework (Rabelo, 97) and can be considered as the MASSYVE Mould Broker System reference architecture:

① Mould-Broker (MB): it is the global system supervisor, acting as the more direct interface between the system and the human broker. There will be one – and only one – mould-broker agent in a particular system. It can interact with the *facilitator* and *consortium* agents.

② Facilitator (F): is a representative of a set of enterprises, within the cluster, that possess a given competence. Each facilitator is dedicated to a particular competence. Therefore, the mould-broker agent first sends a call for tenders to the facilitators whose competence area fits the client's order *type*. This speeds up the contract process as well as avoids the unnecessary message exchange among agents that are not potential bidders. There will be as many facilitator agents in a particular system as existing competence areas. The facilitator can interact with the *mould-broker*, the *consortium,* and *enterprise* agents.

③ Enterprise-Agent (EA): represents a given enterprise, member of the cluster. There will be as many enterprise agents in a particular system as existing enterprises in the cluster. The EA can interact with the *consortium* and *facilitator* agents.

④ Consortium (C): is a temporary agent created to manage the process of generating scheduling/VE alternatives for a certain business process based on the bids received from the enterprise-agents. It corresponds to a strategy to decentralize the broker-mould agent in the process of receiving bids and generating schedules. Once the broker and MDIC board decides for the best schedule and awards it to the involved enterprise-agents, the respective consortium agent gets ready to supervise its execution and the other consortia dismantle themselves. There will be as many consortium agents in a particular system as existing client orders / VEs under creation. A consortium agent can interact with the *mould-broker* and *facilitator* agents.

3.2 Control Information Flow

Figure 2 illustrates the essential control information flow among the MMBS agents' *classes* at this stage of the system prototype, according to the five macro actions described in chapter 2. In the current version the negotiation process is mono-stage / mono-criteria, it is based on complete and precise information, and there is no intelligent constraint relaxation. One important aspect to point out in this architecture is a more direct involvement of the enterprises' representative in the negotiation process, where he/she must feed "its" agent with the proposed price and eventually with a refinement in the planned delivery date. In other words, although agents are used to facilitate the logistics of the brokerage process, the decisions are made by humans.

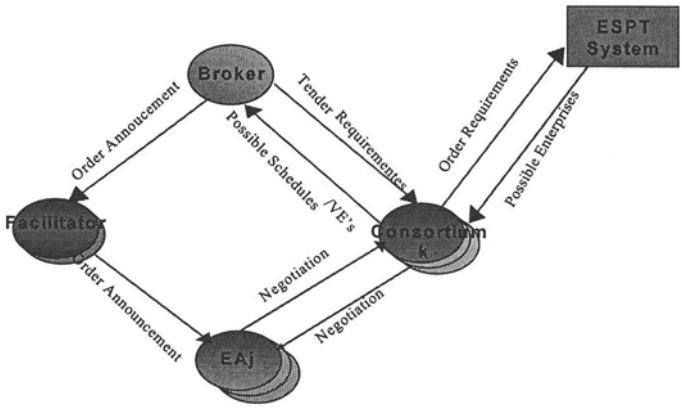

Figure 2 – The Control Information Flow in the MMB System

The interactions among agents must be coordinated in a way that the desired agents' behavior – and then the multi-agent system behavior – can work properly according to the MDIC requirements. The Contract-net protocol (Davis, 80) is used to co-ordinate the information exchange between agents in order to create a VE. The

agents use a particular high-level multi-agent protocol to communicate with each other and as the support to interact with the user.

The Electronic Partner Selection Tool (EPST) shown in Fig. 2 is a system developed in the PRODNET II project that aims at finding partners in existing electronic catalogs available in the Internet (Camarinha et al., 99) and is used as a complementary source when the cluster doesn't have all the required competencies or resources.

Brokerage involves, in fact, a number of aspects as depicted and generally formalized in (Janowski et al., 99). Manual or strongly human-assisted brokerage based on more complex competencies descriptions and relationships are proposed in (Bremer et al., 99) and (Molina et al., 98), also based on real industrial cases. Some other works such as (Rocha et al., 99) have pursued a MAS-driven automated brokerage is proposed based on hypothetical scenarios. One of the distinctive aspects of the MMBS approach is its hybrid / semi-automatic philosophy in which agents are used as human assistants. Regarding the MDIC characteristics, the enterprises' representatives are called to participate in the negotiation scenario. Furthermore, the broker participates in the selection of partners suggested by the EPST system as well as in the analysis of the generated VE schedules.

4. IMPLEMENTATION EXAMPLE

The MMBS system prototype was developed on a PC / Windows-NT / TCP-IP / C++ platform. The multi-agent system was derived using the MASSYVE KIT (Rabelo et al.,99c) development tool, which is available in the Internet (MASSYVE, 00).

4.1 "Derivation" of the Massyve Mould-Broker System

The developed system corresponds to a set of instances of each of MMBS classes, "derived" according to the MDIC characteristics. Therefore, the particular system is composed of:

- ⇨ *1 Mould-Broker*
- ⇨ *3 Facilitators (plastic mould, aluminum mould, and die* competence areas)
- ⇨ *12 Enterprise-Agents*
- ⇨ *n Consortia, as many as client orders exist*

Figure 3 shows the MMBS agents derived for the MDIC case. It represents the MDIC scenario modeling, the first action the user should do in order to launch the system itself. In this derivation, three PCs are involved, although each agent can run on individual/distributed PC. The links among agents represent the necessary communication possibilities. Since the consortium agents are dynamically created when a business process arrives, they are not initially modeled. Furthermore, each agent has its particular graphical interface when launched, through which the user can interact with it.

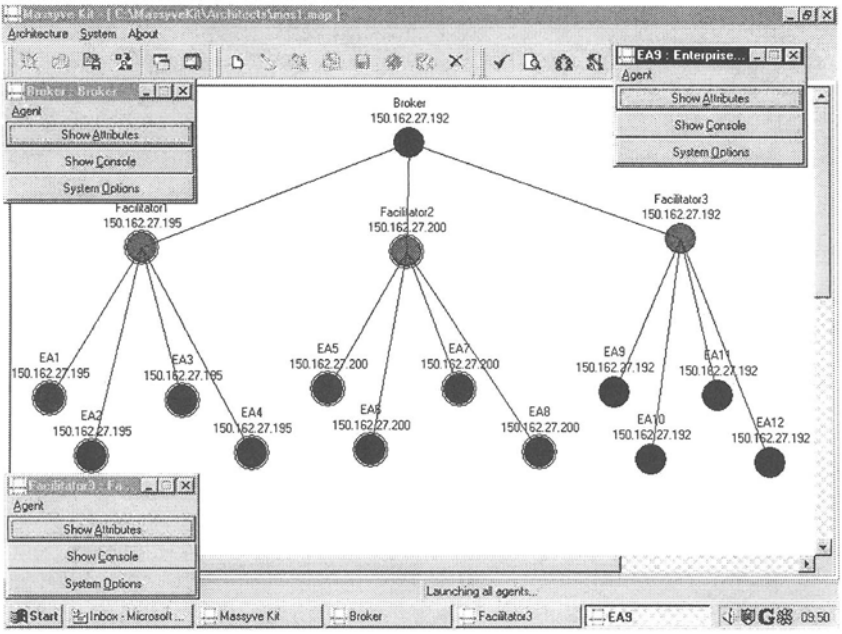

Figure 3 – The MMBS agents derived for the MDIC case

4.2 Scheduling / VE creation

After the contract-net process according to the MMBS control information flow, a set of possible schedules / VEs are created. Depending on the package characteristics and on the enterprise availability, one enterprise can get more than one mould.

These set of alternatives are evaluated by the human broker who consults, following the MDIC rules, all of its members before making the final decision about the selected consortium for a given business process / opportunity. This evaluation is based on the global lowest cost and shortest delivery date, whose information are the base of an enterprise bid.

4.3 Integration with EPST system

When the cluster cannot fulfill the required skills or capacities for a given business opportunity, it is necessary to look for partners outside the cluster. As external companies are not represented by agents, a different procedure has to be used.

The figure 4 illustrates the approach followed in the EPST module (Camarinha-Matos et al., 99b), developed by the New University of Lisbon in the context of the PRODNET II project to support this process, which includes the following main steps: Definition of general profile for partners search (general query generation), send query to selected External Suppliers Directories, Receive and filter results, Generate "Call for Tenders" and send it to potential suppliers, Collect bids, and Decide on the partners to be selected. Another functionality, not implemented yet,

could support the generation of contracts between the VE and the newly selected partners.

The Call for Tenders can in fact split into several phases, such as: Call for Tenders generation, Call for Tenders dissemination, Reception of Bids, Negotiation of contracts, Contract award, etc.

The ESPT tool supports the partners' search and selection through the public directories of suppliers available on the Internet. External suppliers' directories (ESD) are new Internet services already existing for several countries. These ESDs, a kind of electronic yellow pages, are lists of registered enterprises normally organized by industry sectors or by the class of products they supply. A major problem is that each ESD has its own data organization and interfacing rules and is maintained by an independent or private organization. There is, in general, an associated search engine prepared to give the user a set of enterprises as a query result, turning the database structure transparent for the user. The query specification is however dependent on the specific ESD. Due to the lack of standardization of current external suppliers' directories found in the Internet, part of the process has to be customized to each information source.

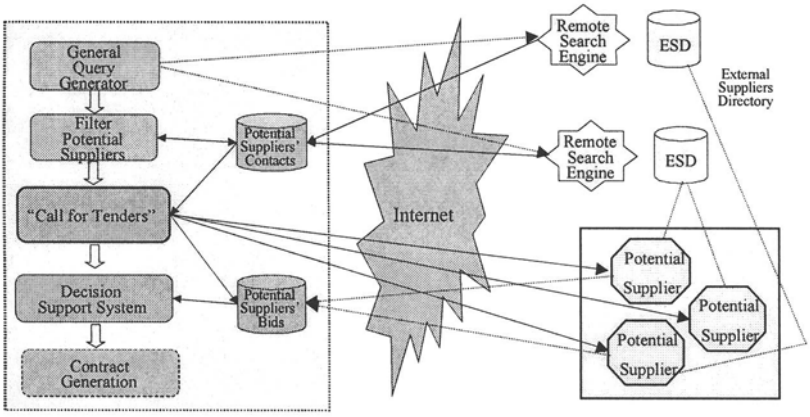

Figure 4 – Partners search based on external suppliers' directories

5. CONCLUSIONS AND NEXT STEPS

A multi-agent-based architecture and prototype - the MASSYVE Mould Broker System (MMBS) – was developed to support a broker in the process of handling the VE formation within a cluster of twelve enterprises to better respond to a given business opportunity. In the case no sufficient partners are found in the cluster, an external partner's search and selection tool is called. The selection of the most suitable "consortium" of enterprises is supported by the set of alternative consortia generated and evaluated by the system.

This work is part of an ongoing initiative towards a wider and more generic brokerage tool, which is planned to be installed for testing in a virtual organization located in the south of Brazil. In this sense, and although already useful for this organization as it is now, next developments are planned. In a short-term period we

intend to implement procedures to support subcontracting as well as to refine the information models used while the enterprises get more awareness and confidence with the system. In a medium-term period we intend to improve the negotiation protocol among the enterprises/agents, also including negotiation with incomplete and non-precise information, and VE scheduling execution supervision.

5.1 Acknowledgments

The authors thank the CNPq (The Brazilian Council for Research and Scientific Development, project ProTeM-CC 680004/00-9) and European Commission (project INCO-DC 962219 MASSYVE) for the financial support, and Mr. Maurício Andrade and Mr. Tiago Cardoso for the programming support.

6. REFERENCES

1. Bremer, C.; Mundim, A.; Michilini, F.; Siqueira, J.; Ortega, L. (1999), A Brazilian Case of VE Coordination, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.377-386, October 1999.
2. Camarinha-Matos, L.M.; Afsarmanesh, H. (1999a), The Virtual Enterprise Concept, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.3-14, October 1999.
3. Camarinha-Matos, L.M.; Cardoso, T. (1999b), Selection of Partners for a Virtual Enterprise, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.259-278, October 1999.
4. Davis, R. (1980), The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver, *IEEE Transactions on Systems, Man, and Cybernetics*, 29, pp.1104-1113.
5. Janowski, T.; Yonghe, L.; Biqing, H. (1999), Automating Partner Selection for a Virtual Organization, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.433-448, October 1999.
6. Klen, A. P.; Rabelo, R. J.;Ferreira, A. C.; Spinosa, L. M. (1999), Distributed Business Process Management, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.241-258, October 1999.
7. MASSYVE (2000), http://centaurus.dee.fct.unl.pt/~massyve.
8. Molina, A.; Flores, M.; Caballero, D. (1998), Virtual Enterprises: A Mexican Case Study, in *Intelligent Systems for Manufacturing – Multi-Agent Systems and Virtual Organizations*, Eds. Luis M. Camarinha-Matos, Hamideh Afsarmanesh and Vladimir Marik, Kluwer Academic Publishers, pp. 159-170.
9. PRODNET-II (1999), http://www.uninova.pt/~prodnet.
10. Rabelo, R. J., Klen, A. P., Spinosa, L. M., Ferreira, A. C (1999a), Agile Supply-Chain Coordination in the Virtual Enterprise Environment", in Proceedings 4th IFAC/IFSA Brazilian Symposium on Intelligent Automation – SBAI'99, pp.289-294.
11. Rabelo, R. J.; Camarinha-Matos, L.M.; Afsarmanesh, H. (1999b), Multi-agent-based Agile Scheduling, In *International Journal of Robotics and Autonomous Systems*, Special Issue on Multi-Agent Systems Applications, N 27 pp. 15-28, North-Holland.
12. Rabelo, R. J.; Geszychter, M.; Jacomino, A (1999c), MASSYVE-KIT - Kit for the Development of Multi-agent Systems (Version 2.0)", Technical Report GSIGMA 004/99, http://www.gsigma-grucon.ufsc.br/english/publicat.htm.
13. Rabelo, R. J. (1997), A Framework for the Development of Manufacturing Agile Scheduling Systems – A Multi-agent Approach [in portuguese], Ph.D. Thesis, New University of Lisbon, Portugal.

14. Reis, J.; Mamede, N.; O'Neill, H. (1999), Agent Communication for Scheduling in the Extended Enterprises, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.353-364, October 1999.
15. Rocha, A.; Oliveira, E. (1999), An Electronic Market Architecture for the Formation of Virtual Enterprises, in *Infrastructures for Virtual Enterprises – Networking Industrial Enterprises*, Eds. L. M. Camarinha-Matos and H. Afsarmanesh, Kluwer Academic Publishers, pp.421-432, October 1999.
16. Spinosa, L. M.; Rabelo, R. J.; Klen, A. P. (1998), High-Level Coordination of Business Processes in a Virtual Enterprise, in Globalization of Manufacturing in the Digital Communications Era of the 21st Century: Innovation, Agility, and the Virtual Enterprise, Edited by Jacucci, G., Olling, G.J., Preiss, K. and Wozny, M., Kluwer Academic Publishers, pp. 725-736.