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Open Source Supply Chains

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ABSTRACT: Enterprise Resource Planning (ERP) systems tend to deploy Supply Chains (SC), in order to successfully integrate customers, suppliers, manufacturers and warehouses, and therefore minimize system-wide costs while satisfying service level requirements. Although efficient, these systems are neither versatile nor adaptive, since newly discovered customer trends cannot be easily integrated. Furthermore, the development of such systems is conformed to strict licensing, since the exploitation of such kind of software is most of the times proprietary. This leads to a monolithic approach and to sub-utilization of efforts from all sides. Introducing a completely new paradigm of how primitive Supply Chain Management (SCM) rules apply on ERP systems, the developed framework is an Open Source MAS that introduces adaptive intelligence as a powerful add-on for ERP software customization. In this paper the SCM system developed is described, whereas the expected benefits of the open source initiative employed are illustrated.

KEYWORDS: Supply Chain Management, Open Source, Multi-Agent Systems, Agent Training, Data Mining

1 INTRODUCTION

In a conventional supply chain, raw materials are procured, items are produced at one or more company sites, shipped to warehouses for intermediate storage, and then sent to retailers or customers. Consequently, effective supply chain strategies are applied at various stages of the supply chain, in order to reduce cost and improve service levels (Levi, Kaminsky & Levi, 2000). In addition, the distributed nature of corporate Supply Chains impose flexible policies that can bridge the digital divide amongst partners, who can have different levels of familiarization with technologies as well as the various underlying business models.

Systems that facilitate Supply Chain primitives can be viewed as networks of collaborative, yet autonomous, units that regulate, control and organize all distributed activities involved in procurement, manufacturing, order processing, order transaction and product distribution. Research literature on intelligent agent system architectures has proven that problems that are inherently distributed or require the synergy of a number of distributed elements for their solution can be efficiently implemented as a multi-agent system (MAS) (Ferber, 1999). Thus, multi-agent technology constitutes a powerful technology for developing Supply Chain systems. It offers unprecedented opportunities for modernization throughout the Supply Chain. Currently we are only at the start of a revolution which is changing the way companies shall do business and the way Supply Chain partners get as many of the services and goods they need.

In a MAS realizing a Supply Chain system, all requirements collected by the end users are thought of being perceived as distinguished roles of separate agents, acting in close collaboration. All agents participating in a MAS communicate with each other by exchanging messages, encoded in a specific agent communication language (ACL). Each agent in the MAS is designated to manipulate the content of the incoming messages and take specific actions/decisions that conform to a particular reasoning mechanism designed by the agent programmer.

Though agent technology is a powerful enabler, the starting point should always be to identify what the customer wants and then look to how we use agents to achieve this.

Inter-enterprise Supply Chains are expected to embrace new ways of thinking, innovative paths for doing business, new alliances and – after all this – novel agent technologies. This is vital in order to give Supply Chain members the services they want, at the time they want them and with the minimum cost and overheads (Lee & Billington, 1992).

In this paper we identify a framework for changes across the Supply Chain, by means of separating its business aspects from those that affect or relate to its technologic ones. In this respect, our aim is to leverage the current attempts for establishing a leading role for agent technologies in the field of Supply Chain Management, something that has till now been treated only as a segment, in which marginal expectations can be supported (Stenross & Sweet, 1991). Our position is that this comes only as a result of deficiencies in the existing infrastructures to support large-scale business projects that will make use of agent technologies.

A strong standing point of this paper is that open source-ness should be regarded as a *sine qua non* for mainstreaming the adoption of agent technologies in the addressed area.

The rest of this paper is organized as follows: Section 2 introduces the need for open source-ness. In section 3 the two representative approaches of our system, the Open Source and Agent Academy approach are presented. Section 4 illustrates the developed system's architecture, whereas section 5 presents our conclusions and ends this paper.

2 THE NEED FOR OPEN SOURCE-NESS

Open Source software is software whose source code is openly published and freely distributed. It is often developed by voluntary efforts (mostly academics and non-profit research institutes) and is usually available at no charge under a license defined by the Open Source Initiative. This initiative permits the redistribution of Open Source software under certain conditions.

Till now, it has leapt to prominence by starting to take a significant market share in some specific parts of the software infrastructure market. It is common knowledge that the software industry is rapidly moving, and frequently produces innovative developments that although promise to make great changes in the marketplace at first, they ultimately fail to live up to their initial press hype in the end.

Open Source software is indeed the start of a fundamental change in the software infrastructure marketplace, critically related to the sources of value and money for this industry.

The European Commission's initiative eEurope2005 addresses the topic of Open Source software and sets the target "to support standardization with a view to wider use of open standards and open source software" (URL1, 2002). Mandating open standards and specifications in the area of Supply Chain Management and allowing market driven products to support these could be a proper response.

One might argue on our approach, since, at the time we were submitting the final manuscript for this paper, it appeared on the press the story of Microsoft "having pulled out of a leading Web services standards group due to growing disagreements with IBM over the direction of technology". In addition, Microsoft dropped out of a W3C working group that focused on establishing rules for how businesses will send and receive data to one another via Web services.

One should notice, however, that in the company's communications to the press, it is stated that Microsoft "aims to sell businesses the tools to set up their own trading networks based on *open Internet standards*, such as XML." (URL02, 2003).

What is also worth a second thought is the deliberate differentiation between open source (code) and open standards. Code is usually regarded by companies as (a main form of their capitalisable) intangible assets, whereas the standards are promoted as the more efficient way to increase share and control over a market, even if they have been driven by work carried out within a single company.

Our opinion is that this is a monolithic approach that has till now lead to sub-optimal utilization of efforts from all sides, and that there is considerable space for organizing the underlying economies in a (much) better way.

3 TWO REPRESENTATIVE APPROACHES

3.1 *The Open Source Supply Chains project*

The Open Source Supply Chains project (in brief: Open Source) (URL2, 2001) concerns the identification of commonalties amongst a set of operational European R&D projects in the IST Programme, that reside in the wider area of E-Commerce, aiming to harmonize efforts for the establishment of common methodological and technological building blocks in the area of smart organizations, taking into consideration relevant Standardized models and methodologies developed by respective bodies and consortia.

The overall objective of the project is the development of a *reference model* for promoting the establishment and lifecycle management of Open Supply Chains and the related technical specifications to enable reusable software components for communication between autonomous Supply Chain nodes scalable according business objectives, by drawing on the base technologies being developed within the context of a number of IST R&D Projects that reside in the area of networked organizations.

By providing common terminology, perspective and measures, the Open Source Reference Model intends to provide Supply Chain players with facilities to first describe and configure their internal

Supply Chain related business processes to reflect current business activities and product manufacturing resources. Then, organisations can establish standard process descriptions and metrics for use with external Supply Chain participants inside and outside their industry segment; determine priority improvement efforts and quantify the anticipated benefits of specific improvements.

The adopted approach for establishing the Open Source Supply Chains reference model within the wider area of e-Commerce and smart/networked organizations, extends the field of "conventional" Supply Chains, enriching them with characteristics from the Open Source paradigm, considering them as unique, open, easily configurable entities that:

- Are composed by independently operating nodes, able to interoperate with supply chain models compliant with different software standards
- Can adopt different technologies and standards (from legacy to open, to specific technologies for information systems) to be an integrated part of the supply chain ensuring this way the open future collaboration
- Are supported by re-usable software components for communications between autonomous supply chain network nodes, scalable according to business operations.

The Open Source Supply Chain reference model was implemented by organizing and extending the corresponding set of already existing commonalties amongst the participating projects that reside in the area of networked/smart organizations, in two different levels taking into consideration the nature of their provided concepts.

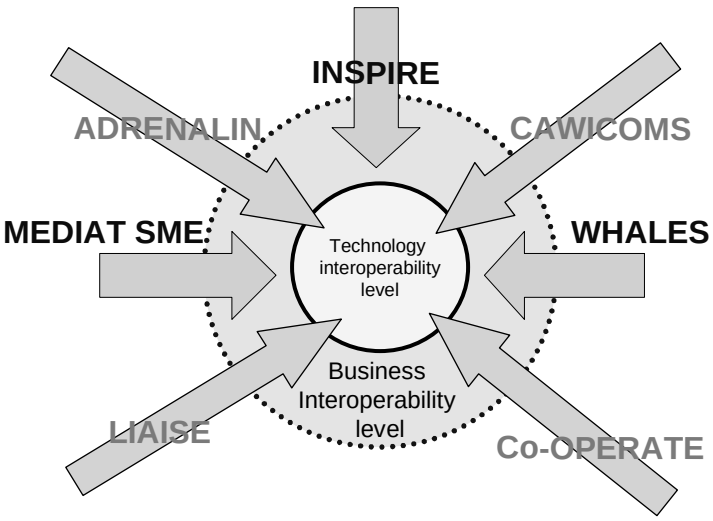

Figure 1. Positioning and contribution of participating projects in the Open Source Reference Model

More specifically, four of the seven participating projects (ADRENALIN, CAWICOMS, LIAISE, Co-OPERATE) formulate the *Technology Interoperability Level* (TIL), by the provision of their relevant to Supply Chain management organizational/ technological results. TIL is responsible for sustaining the development and evolution of the mechanism for supply chain establishment and lifecycle management.

For the successful achievement of the previously described integration, the methodological and business interoperability concepts of the other three (INSPIRE, WHALES, MEDIAT SME) participating projects have been utilized. The framework constituted consisted of their application tools, relevant methodologies and architectural support frameworks and are used for the support and validation of the Open Source Supply Chains reference model.

3.2 *The Agent Academy project*

Agent Academy is an integrated environment for embedding and improving intelligence in newly created agents through the use of Data Mining techniques performed on data derived from monitoring agent data and agent behavior. Its training facility supports:

- the creation of agents with limited initial inferencing capabilities, and
- the training of these agents in order to augment their intelligence efficiently, according to user specifications and preferences.

It builds on the idea of employing data mining for training intelligent agents; the reverse path has been successfully walked down: in many data mining applications, intelligent agents are used for carrying out specific tasks. However, the project aims to prove both the feasibility – from a technological perspective – and the marketability – from a business perspective of the previous hypothesis.

In this respect, our work in the project concerned the following hypotheses:

- Agents show considerable promise as a new paradigm for software development as they provide a natural way to define high level abstractions;
- A distributed application can be modeled in terms of autonomous agents;
- There are several agent platforms such as Jade providing several functionalities, yet low level programming is required to code agent behaviors;
- Agent design and development tools should empower software developers:
  - to cater more efficient agent development solutions
  - to provide software solutions at lower cost for their customers

– to cope with rapidly changing requirements and differing application specifications.

3.3 *The Open Source-Agent Academy coalition*

In an attempt to provide an Open Source Supply Chain paradigm, we developed a system with the use of Agent Academy. The technologies employed from Agent Academy follow the Open Source initiative and that results to an open source SCM system.

More specifically, the operational framework for the SCM system relates to the specification of communication, co-ordination and information management procedures for each entity within a Supply Chain to be realized as a networked structure. In this respect we have classified this system (which is one of the Agent Academy project test cases) as being in the field of Supply Chain Management.

All the agents of the system are developed over the Java Agent Development Framework (JADE) (URL03, 1999), which conforms to the FIPA specifications (URL04, 1997), while the required ontologies have been developed through the Agent Factory module (AF) of AA. Data mining has been performed on ERP data through the Data Miner (DM) of AA, which expands the Waikato Environment for Knowledge Analysis (WEKA) tool (Witten & Frank, 2000). The extracted knowledge structures are represented in PMML (Predictive Model Markup Language) (URL05, 1998), a language that efficiently describes clustering, classification and association rule knowledge models. The resulting knowledge has been incorporated into the agents by the use of the Agent Training Module (ATM) of AA. Retraining issues are also easily met with the use of Agent Academy. The MAS is described in the following section.

4 THE SCM SYSTEM

4.1 *System schemes and agent types*

For supporting the desired class of SCM business applications in ALTEC's ATLANTIS ERP system, we have identified three different types of agents that are needed to be built, monitored and maintained inside the AA platform. These are:

– **Communication agents,** which ensure interconnectivity of the MAS with the ERP.
– **Pattern identification agents**, which are responsible for identifying patterns related to a specific scheme according to a set which will be initially provided and which has to be dynamically fine-tuned and improved (also change in the cardinality and granularity aspects).
– **Recommendation agents**, which provide customized suggestions to different types of enterprise users from the Sales, Supplies, Production and Accounting Depts, e.t.c. related to proposed alterations of the existing policies for the different schemes under consideration.

From the above, one can see that the main medium that is used for building the community of intelligent agents is this of a *scheme*. A scheme can be regarded as the placeholder of information entities, which will be used and shared by the different categories of Agents (see also information provided below). The main advantages of a scheme are that the issue of semantic representation is successfully met and that the affected entity *types* (customer, product, supply) are represented / managed and can be easily modified.

Three *schemes*, namely the *Sales scheme*, the *Inventory scheme* and the *Supplies scheme* have been identified:

– *Sales schemes* concern how a specific *customer* or *customer type* behaves in terms of requests for specific *products* or *product types*.
– *Inventory scheme* relate to the correlations between products and product types and how these correlations can be exploited efficiently
– *Supplies schemes* concern how a specific *supply* or *supply type* behaves (i.e. how it is demanded) in terms of requests for specific *products* or *product types* and/or specific *customers* or *customer types*

A further point that is satisfied by the developed system relates to the tracking of user activities in regard to providing improvements for:

– better recognizing patterns with respect to the adoption of recommendations given to the users (this concerns the operation of the pattern identification agents)
– reduction of the recommendations that are not undertaken by the users (this concerns the operation of both the pattern identification and the recommendation agents)
– discovery and identification of the number of the most suitable recipients on corresponding recommendations (this concerns the operation of the recommendation agents).

4.2 *System architecture and use case description*

The implemented system has six different types of agents:

1 The Database Agent type
2 The Customer Order Agent type
3 The Customer Profile Agent type
4 The Inventory Pattern Identification Agent type
5 The Supplier Profile Agent type
6 The Recommendation Agent type

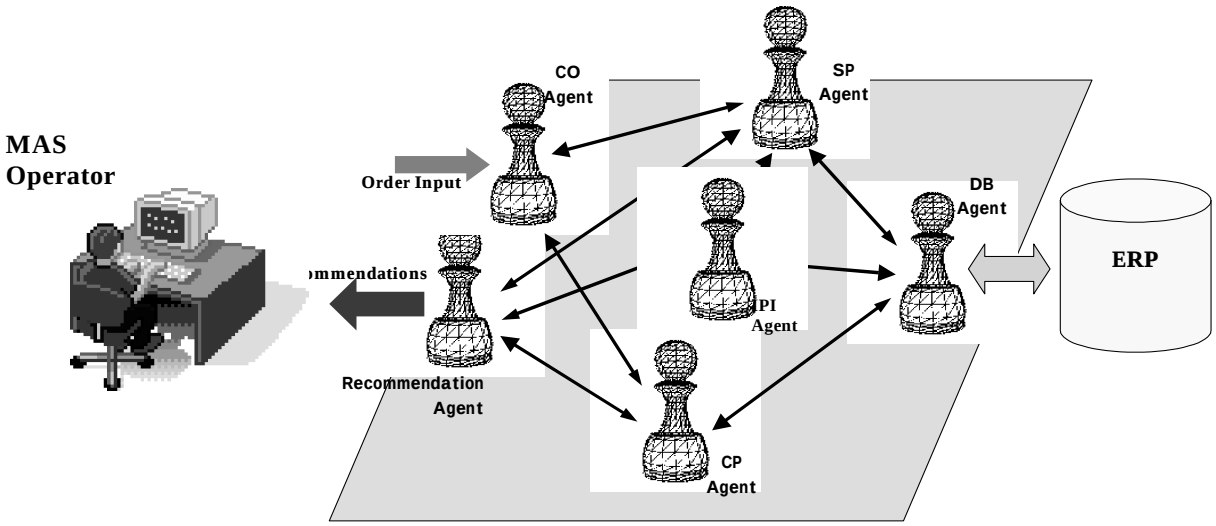

Figure 2. The Functional diagram of the proposed MAS

Upon receiving an order, the Customer Order Agent (COA) collects all the necessary information, in order to provide the other IPRA agents with input. The collected data include the Customer id, the list of items ordered and the corresponding quantity, as well as the customer's preferred payment terms, ie. cash, by check, by credit card etc. The Customer id is then sent to the Customer Profile Agent (CPA), that decides on the discount to be made to the particular customer. Even more, CPA provides a customer priority metric, depending on customer "quality", i.e. the added value of the customer's behavior, as it is extracted from historical data stored in the ERP. These two attributes that the CPA outputs are estimated with the help of data mining techniques.

The Inventory Pattern Identification Agent (IPIA) gets also input from COA. According to the items that the end user has ordered, IPIA recommends additional items that could be also bought in the same order invoice. The recommendations that IPIA makes, are derived from data mining on transactional data of the ERP.

The Supplier Profile Agent (SPA), in an analogous to the CPA manner, performs data mining on supplier data and outputs Supplier credibility, therefore providing a reliable estimation of products due time.

Finally, the Recommendation Agent (RA) gets input from the CPA, the IPIA and the SPA, and provides the final recommendation, on order discount, estimated time of order processing and delivery time, as well as a splitting policy, depending on customer priority, available product stock, and order turnover.

The implemented MAS is illustrated in Figure 2. Thin arrows represent messages exchanged between agents, while thick arrows correspond to data transfer from/to the MAS

5 CONCLUSIONS

Till recently, ERP developers and business software solution providers have been regarding open source software as a sub-optimal approach for treating potential or existing markets. We have made an attempt to stratify the field in terms of separating technology aspects from business ones, and regarding the latter to provide the means for approaching needs for addressing interoperability problems that exist across Supply Chains with a framework that recognizes two distinct levels, namely:

– technology interoperability, and
– business interoperability.

Though open source-ness has been thought as leverage for the first one, corporate dispositions may change with respect to it if they re-consider it as an approach to increase efficiencies and support wider adoption of their value propositions for the second level.

Our belief is that for the field of Supply Chain Management where agent technology proliferation has been rather low and fragmentary, there is an open challenge to seize for organising communities of both demand-side and supply-side representatives. This way we expect to foster a spirit of pluralism in the underlying (sub)cultures, which will have a very specific target, namely to successfully bring on the central stage the utilisation of agent technologies in the field of Supply Chain Management. After all, SCM actually represents a considerable part of all business-to-business transactions and processes.

From our own experiences we foresee that allowing more stakeholders of the Value Chain to have access to the source code, as it is the case in open source applications, it is more of an advantage

than a threat. Especially, in the Supply Chain field where IT companies and solution providers are investing in both code and competencies (rather cashing in from the latter, though) open source-ness minimizes the time for reporting defects and suggesting appropriate fixes.

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