Multiagent Based Global Enterprise Resource Planning: Conceptual View

DARIUS PLIKYNAS[1]
IT department, Vilnius Management School
J. Basanaviciaus 29a, Vilnius,
LITHUANIA,
Email: darius.plikynas@vva.lt http://neuraleconom.puslapiai.lt/

Abstract. In recent decade, the business of manufacturing and service organizations alike is strongly conditioned by unpredictable changes taking place in a global market. The question is how to provide efficient and cost-effective responses on time. Current systems such as extended enterprise resource planning (EERP) and supply chain management (SCM) do not provide adequate facilities for addressing this problem. This paper addresses multiplatform integration as a key factor for designing a novel kind of global enterprise resource planning (GERP) systems. The main idea is based on merging two separate approaches, i.e integrated agent-based network models of e-manufacturing systems and supply chains (EERP and SCM simulation platforms), and a field-based information network of intelligent agents. We examine each approach separately and give some clues how the merging of both approaches may contribute to the achievement of better simulation results.

Key-words: Multiagent systems, Enterprise resource planning, Global enterprise resource planning, Supply chain management

1 Introduction

In this section, the reader is introduced to the business application side of the project, i.e. integration of extended enterprise resource planning (EERP) and supply chain management (SCM) platforms.

A major problem facing business organizations is how to provide efficient and cost-effective responses to complex and unpredictable changes that take place in a global market, i.e. how to become even more dynamic and adaptive in the ever changing mass customized markets.

Current limitations stem from the fact that the first generation of ERP products has been designed to integrate the various operations of an individual firm. In modern SCM, however, the unit of analysis has become a network of organizations, rendering these ERP products inadequate in the new economy [1].

As a matter of fact, Microsoft and IBM, two of the world's best known software companies, run most of their business on the EERP software neither of them makes, the SAP (AG) R/3 ERP package [2].

In other words, extended ERP reflected the fact that most leading non-manufacturing industries turned to ERP systems for 'backbone' financial transaction processing capabilities [4]. The next ERP iteration was called the enterprise application suite (EAS), as it was tailored for service industries too. The same authors postulate that as enterprises looked to applications that would provide supply-chain management (SCM), customer relationship management (CRM) and e-business functionality would enable them to jump ahead of their competitions [5].

Responding to the growing demand, vendors had to extend ERP from an enterprise-wide domain to the inter-firm collaborating (IFC) approach, which later grew into the ERP II platform. Collaborative structure building does remain an important operational construct for ERP II success [5]. In sum, ERP II is an evolution from ERP that clearly extends business processes, opens application architectures, provides vertical-specific and horizontal functionality as well, and is capable of supporting global enterprise-processing requirements [6].

In the global economy, that means the emergence of collaborative networks of enterprises, "win-win" strategies, efficient mass customization, and sharing of resources, information and supply chains. These

[1] This work is a part of the project Reg. No. BPD2004-ERPF-3.1.7-06-06/0014.

technologies would spare global resources and use them in the more effective way.

More specifically, this paper addresses the above mentioned issues by designing concepts of multi-agent systems (MAS), capable of facilitating integration and communication among ERP and SCM systems. It has long been proven that these domains can be modeled using multi-agent approaches involving interactions amongst manufacturing organizations, their customers, suppliers, etc. with different (possibly conflicting) individual goals and propriety information [7,8]. However, not much research has been undertaken to unite everything under one cohesive multi-agent umbrella.

Of course, there is a lot of research done for SCM and ERP integration, using many of different platforms and methods, as this is an area that has, indeed, received a lot of attention amongst researchers in the past two decades. Specifically, regarding the MAS platform, recent team work lead by Zhang [7] is implementing an agent-based approach for e-manufacturing and supply chain integration. Monteiro [8] and others explore MAS approach for multi-site coordination. A somewhat similar, yet more SCM oriented research is done by, for instance, Turoski [9] and Ghiassi&Spera [10]. They developed agent-based techniques for coordinating activities of e-commerce and internet-based supply chain system for mass customization markets.

Li and Fong [11] and Choy and Lee [12] proposed agent-based architectures to facilitate the formation and organization of virtual enterprises for transactions order management. Bo and Zhiming [13] developed a multi-agent system SCM tool to evaluate various scheduling algorithms for orders allocated to different suppliers. Whereas, Sadeh, Hildum, Kjenstad, and Tseng [14] developed the MASCOT decision-making tool; a reconfigurable, multilevel, agent-based architecture for coordinated supply chain planning and scheduling.

These works, however, did not consider the details of the operations of the individual enterprises' systems and how these operations are affecting the operation of the entire supply chain. Therefore, these approaches are not transparent and reconfigurable from the enterprise internal processes view.

Nonetheless, a number of works have made some effort to integrate manufacturing activities with supply chain activities. For instance, Peng et al. [15] present the CIIMPLEX framework for integrating manufacturing activities with customer services. In fact, CIIMPLEX uses functional agents with specialized expertise for integration of existing manufacturing scheduling, planning, analysis and execution systems. However, since the use of functional agents does not provide for local autonomy of manufacturing resources in scheduling and decision-making the desirable inductive, distributed and co-operative problem-solving capabilities of agent technology is not fully exploited [9].

In terms of functional frameworks, currently employed MAS approaches (see above) are dealing with 1) hierarchical MAS structures, 2) "point-to-point" relations, 3) contractually based agreements, and 4) if-then rules. In some sense, they are trying to reflect the real business logic in virtual settings.

Meanwhile, complexity of reality at "ground zero" makes such models very hard to develop and even much harder to implement at the agent and system level too. Obviously, one reason is organizational - the poor knowledge of each detail for each deal in the real market (some information is tacit, default or informal etc). Another serious issue is the technical difficulty to simulate a whole net of heterogeneous enterprises, though, there are some very mixed results as a previous survey shows. Subsequently, as numerous studies emphasize, current MAS applications are not well received by the middle and top management levels [1, 7].

Much research is concerned with the appropriateness of traditional research approaches and methodologies. There is a growing suspicion that the main hindrances are hidden in the modern social processes, which are badly modeled using "point-to-point" (mechanistic) approaches. In reality, with the advent of the new information society, we are increasingly dealing with some modern social phenomena like the network economy, globalization, e-commerce, complex social emergence, predominance of intangible (informational) goods etc [17].

Meanwhile, our models are still based on the old fashioned mechanistic approaches, where agents are represented as simple linear systems, without intelligence and self-organized adaptability. Naturally, such artificial systems can not catch up with the today's complexity.

In this sense, this study is a pioneering work, which is not intended to propose ready to go applications, but rather introduces a new concept. It contributes to the development of a conceptually new approach for simulation of network economy represented by linked EERP and SCM networks. In short, the author proposes field-based multi-agent model. Further details are discussed in the next sections.

Concluding this section, let's briefly discuss the content of the paper. The research subject of this paper consists of two frameworks, which are discussed next. The first framework is dealing with business application and another with conceptual modeling. The first and second sections describe the first framework, i.e. MAS based simulation platform for EERP and SCM integration in the network (information) economy. In fact, we are investigating how both EERP and SCM can be integrated in a cohesive whole. Meanwhile, the third and fourth sections describe the second framework, i.e. field-based information network of intelligent agents. Finally, the fifth section ends with discussion and conclusions.

2 Global Enterprise Resource Planning Platform (GERP)

As previous studies have shown, current ERP systems lack a modular, open, and internet-like system architecture, or "web-enabled ERP". Basically, this shortcoming is the reverse side of some of the generic advantages of ERP[2], where ERP was intended originally to replace a multitude of local legacy systems; a great deal of emphasis was therefore placed on its integrated architecture. In the new network economy, this former strength is rapidly becoming a weakness [1], [8].

In modern supply chain management (SCM), however, the unit of analysis has become a network of organizations, rendering these ERP products inadequate in the new information economy. Another reason appears to be the advent of the network economy, which is triggering profound changes in all operational levels of enterprises.

The relevant entity for analyzing potential business success is no longer the individual enterprise, but the chain of delivering and supplying organizations; the individual firm is only a single part of this network, see Fig. 1. An important fact is that in this whole picture each chain is simultaneously a receiver and supplier of goods; even customers are simultaneously receivers of goods and suppliers of work force in the network economy.

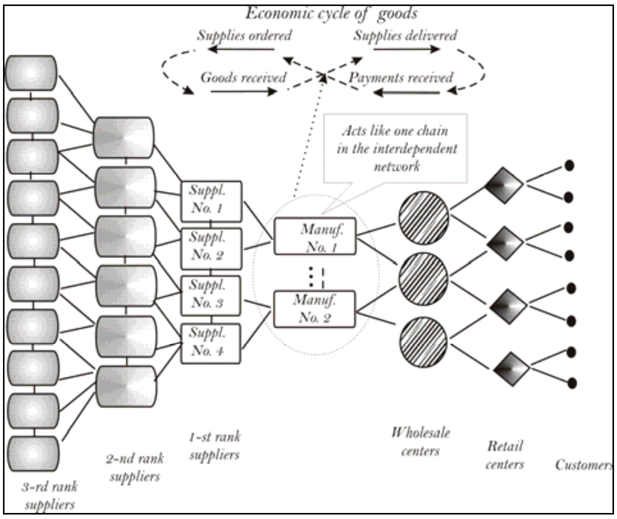

Fig. 1 Modern enterprises embedded in the chain of links in the network economy.

This greatly increases the importance of integration between EERP and SCM for corporate survival. These inferences are confirmed in the number of studies [1], [4], [15], [17]. Besides, markets are becoming more transparent, customer demands are being met in a more customized manner and, in general, the rate of change in the business world keeps increasing.

Greater and faster changing demands from customers will lead to faster and more comprehensive information exchanges between all the players in the chain, see Fig. 2. In terms of technology, this will not just mean better ERP systems but, in general, enhanced IT-tools to integrate the different parties in the network (SCM, CRM, MAS etc).

The author further implies that telecommunications and internet technologies are most likely to provide the technological means for emergence of the global ERP (GERP). This will make distributed architectures possible, in which standardization takes place mainly at the level of information definitions and processes, so that local flexibility in information usage can be maintained at high precision. Needless to say, all these developments are already taking place on a global scale. Hence, IT for SCM in general, and ERP systems in particular, will have to be developed on a worldwide basis [10], see Fig. 2.

GERP supports mass customization only if customers can configure their products as a combination of a number of predefined options. The emergence of "configurators" [1], [4] in the ERP ecosystem supports this aspect of mass customization. A configurator in this context is a computer program that translates individual

[2] In general, ERP is transaction management system that integrates many kinds of information processing abilities and places data into a single database. Prior to ERP, this processing and data were typically spread across several separate information systems.

customer demands into feasible product specifications. Using such a configurator, it becomes possible to start an assemble-to-order process. The integration provided by the ERP system would ensure that the unique product ordered by the customer is properly translated into the appropriate production orders [18], [19].

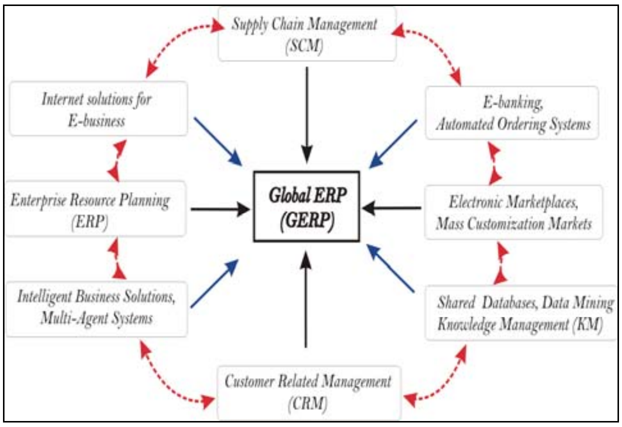

Fig. 2 Global Enterprise Resource Planning (GERP) and related platforms.

There is ongoing process of search, as the ERP industry has become an ecosystem of software vendors, middleware vendors, supply chain experts, specialty-software houses, and hardware vendors. This ecosystem is also evolving fairly rapidly in an effort to provide effective supply chain solutions.

According to the recent GRG findings, the challenge for current ERP systems is to move to a more modular, internet-like system architecture [1], see Fig. 3. This would certainly improve information exchange with all the players in the chain and make the power structures in extended supply chains less dependent on the ERP system of the dominant player in the market segment. Also, it would improve communication with the final customer.

Once EERP is installed (see Fig. 3), there exists a process-oriented enterprise transaction backbone that can support—within a single firm—developments in many business areas, including MES, SCM, DIMS, CRM etc. Though, initial architecture of ERP systems were never designed just to support, e.g. SCM, and certainly not across multiple enterprises. Their architectural advantage of being fully integrated for one firm becomes a strategic disadvantage in this new business environment, where modular, open and flexible IT solutions are required. Therefore, EERP, EAS and GERP are under way to fill the gap [20].

As literature review indicates, so called GERP, is upcoming trend, which is inevitably approaching to substitute EERP, SCM, CRM etc. The main reasons behind this process are very obvious: 1) economy of global resources, 2) mass customization (convenience for customers), 3) unification of information resources (network information economy), 4) standardization of processes, platforms and business models (convenience for B2B, B2C, G2B etc).

After all, the main driving factors are economical, meaning existence of a clear market need for the new GERP technologies.

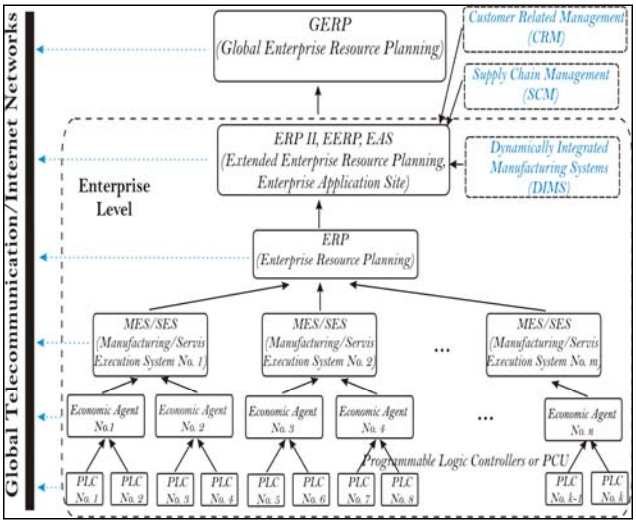

Fig. 3 Hierarchical structure of GERP interlinked by the global telecommunication/internet networks

In reality, the distribution of the enterprise network cannot be managed only by one and unique data-processing and data base application. The main reason is that the exchange of information and the behaviors, which are specific to operations of the network members, are so complex that they require computing paradigms which need to be decentralized and shared. Consequently, it seems that a MAS architecture (as a middleware) can best meet this need [8].

3 GERP: operational framework

The MAS are regarded as one of the most promising technologies in EERP management. Usually we model such systems with functional agents, which are responsible of several activities such as order acquisition, logistics, transport, or scheduling. The specificity of the agents is to support distributed decision making in the network economy [7], [8], [9].

In the GERP, each agent acts like the mediator, e. g. for the local ERP or SCM platforms. The goal of the mediator is to 1) find optimal solutions for the represented entities, 2) to solve conflicts by relaxing constraints, where relaxation is based on a global cost. In general, the main objective of an enterprise network is to minimize the purchase and the production costs as well as to ensure a positive benefit. The global benefit of the effective network of mediators is then a function of the total selling and the total cost, such as:

$$Global\_benefit = \sum_{m} incomes - \sum_{m} \exp enses \geq 0, \quad (1)$$

$$\max(Global\_benefit), \quad (2)$$

where optimization function, see Eq. (2), is to be maximized throughout all virtual nodes *m*. Evaluation of the GERP efficiency should, therefore, measure performance of the total integrated network and not only performance of an individual member.

In a sense, the basic components of the GERP are creating virtual reality, composed by so called virtual enterprise nodes (VEN) or mediators, see Fig. 4. The clarity of the “virtual game” is determined by the business ethics and norms, but, in principal, it should lead to “win–win” principle on the long run. This principle prevents always benefiting the same company and allows preserving collaborative network [8], [10].

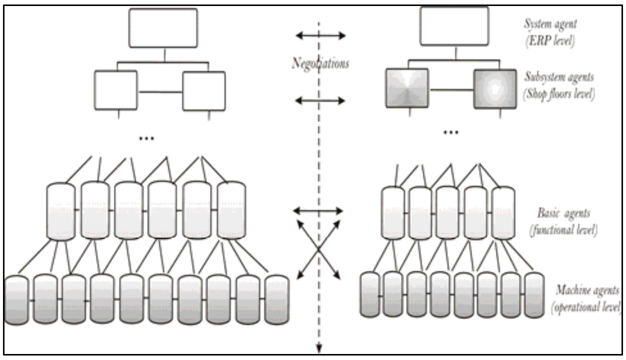

Fig. 4 Negotiating and collaborating agents’ network architecture in the GERP model

Even when such relationships exist, the technologies and techniques that would enable such relationships to be explored fully for maximum benefits on all sides need to be developed and thoroughly understood. In this paper, MAS is used in order to coordinate a multi site network chain with a distributed decision and distributed information network (see Fig. 3). As a result, the potentials of the combination of agent technology and the internet in facilitating all chains integration in the GERP model, forming dynamic partnerships, require our earnest study.

As with most new information technologies, the major problem that faces agent-based e-enterprise is the skepticisms that the manufacturing industry shows towards new technologies [7]. In the case of EERP systems, such skeptical attitudes can be attributed to their reputation of being expensive and difficult to implement [3], [4], [7], which in turn may be a result of lack of understanding.

The work presented in this paper represents a step forward in this direction, as it not only gives overall vision for the management level, but also some conceptually new ideas and platforms, which, as the author believes, will take place in the near future.

Sure, the path to GERP will be more complicated and involved than that for EERP. It will require deploying internal processes and enterprise systems that are capable of connecting with other virtual enterprise participants in a seamless, near real time manner. Enterprises will have to combine a business intelligence framework with their transactional systems to manage and monitor various levels of corporate performance [6].

Besides, GERP ought to be though of as a dynamic process of assembling chains of capabilities and not just collaborating organizations. The configuration of the GERP as a network of cooperating business units will evolve continually: with a high frequency business units entering and leaving the network. This is in high contrast to the current ERP implementations, which have monolithic structure.

At the top level the most important is efficient collaboration of managerial and informational processes using corporate business intelligence systems. The level of sophistication provided by these solutions should elaborate on intelligent decision support systems, rule-based expert system functionality etc. Artificial intelligence (AI) techniques are especially welcome with their flexibility, adaptability and self-organizing capabilities.

In the next section, are given some possible conceptual GERP solutions using field-based approach. It aims to give a novel understanding how information exchange between networks could be efficiently represented.

4 GERP: field-based MAS simulation concept

This section deals with a novel concept of how to represent communications and operations in the complex MAS network. Instead of the pair-to-pair communication model, the author proposes to adapt a field-based model, where synchronous and asynchronous communication can take place.

As a matter of fact, effective communication stands among the top most important issues in GERP and EERP implementations [7], [10]. However, we are not going to delve deep into the technological details, as this is not our main task. Instead, our goal is to understand the relevance and potential benefits of the new approach in general terms.

Contractual based handshaking between two business parties shapes "pair-to-pair" communication in today's ERP systems. Currently, "pair-to-pair" type of communication between agents is prevalent in all applications [6], [8], [11]. "Pair-to-pair" communication occurs when the connection between sender and receiver is bonded in time and space. This is obsolete, though, as agents' direct and coupled communication model is badly justified in the real markets. The main reasoning behind this argument is based on the analogy with other extremely complex networks, e.g. telecommunication networks, where "pair-to-pair" connections are not efficient for the multitasking, parallel processing, congested traffic, conflict resolution etc [1].

The striking parallel between modern telecommunications network systems and GERP model is obvious – the main information traffic between businesses is flowing through telecommunications networks, which act as a backbone for the modern network-based GERP, see Fig. 3. In fact, the internet era has shaped efficient protocols for the complex information traffic in the telecommunication networks, where 1) each agent has capability to send and receive information simultaneously through multiple channels, 2) information flows are selectively managed by the agents' internal filters etc. Agents themselves have become only nodes ("black boxes") in the telecommunication networks. Therefore, it is not surprising, that telecommunication protocols lay sound foundations for the GERP simulation platform.

Following modern telecommunications standards, instead of a single communication channel per session, our simulated agents adapt multitasking, parallel processing, congested traffic control, conflict resolutions etc. Additionally, the information is spreading with the speed of light via multitude of channels. This is not a simple "pair-to-pair" approach.

Consider, though, that there is another way to represent communication in the complex hierarchical GERP network. The author argues that field-based approach works very well for the multi-agent GERP simulation. The information in a form of fields is emitted and absorbed by the environment and the agents themselves.

In fact, for efficient functioning, agents have to possess a sensor type of receptive mechanism to be attuned to the specific information emitted from the sources they are interested in. In fact, there is no other way to deal with the large amount of different information flowing currently in the information networks. In some sense, agents are using filters to be senseless for some information and very sensitive to other information.

According to the above discussion, the novelty of this work is to simulate a multi-agent environment immersed in the fields of heterogeneous information. The frequency domain, indeed, is the only suitable media for the representation of the infinite information flow. Specific small pieces of information can be represented as a single band in the frequency spectrum whereas more sophisticated information can be represented as a set of bands (unique composition of frequencies).

Most importantly, the spectrum can track energy associated with the possessed information (spectrum bands are prioritized according to the frequency scale). Consequently, relatively simple rules may help to organize agents' internal states, oriented to optimize the total internal energy. Whereas, the simulation's objective could determine the form of functional relation between the type of information and it's energy representation on the frequency scale (there is a direct relation between frequency and energy).

Using Fourier transformation, we can translate agents' time dependent behavioral patterns (which is nothing else but information) to the frequency domain. In this case, each agent's characteristic behavior set is represented by his unique spectrum pattern.

Following this line of reasoning, we could imagine each agent as a set of internal frequencies, which resonate if triggered by the external fields with the coherent frequencies. The resonating frequencies are then transferred to other frequencies following agent's internal "production rules", see Fig. 5. These rules are nothing else but frequency transformation laws, which govern agent's dynamic behavior [2]. In order to understand the underlying "production rules" context we have to uncover the whole layer of principles and ideas coming from a multitude of other interdisciplinary studies.

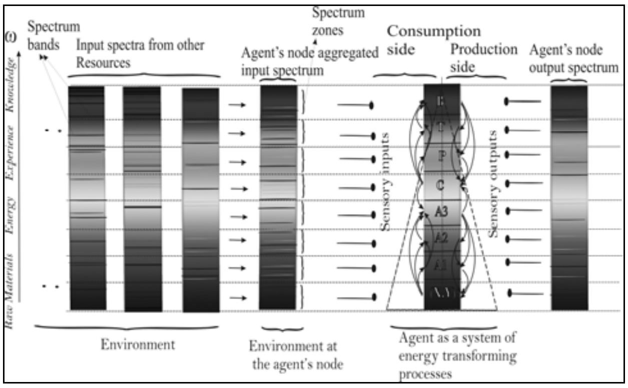

Fig. 5 Production rules based on the transformation of internal states, which are represented as energy spectra

Undoubtedly, GERP is essentially a business oriented model. Therefore, we are going to employ some ideas from interdisciplinary studies, which are mostly related to the social domain.

The study of coordinated models goes beyond computer science, in that also evolutionary computation, behavioral sciences, social sciences, business management, artificial intelligence, and logistics somewhat strictly deal with how social agents can properly coordinate with each other and emerge as globally coherent behaviors from local interactions.

Being inspired from the natural systems, we are starting to understand that in order to construct self-organizing and adaptive systems in the social domain, it may be more appropriate focusing on the engineering of the proper interaction mechanisms for the components of the system, rather than on the engineering of their overall system behavior [3].

According to Tesfatsion [4], economies are complex dynamic systems, where large numbers of micro agents engage repeatedly in local interactions, giving rise to global regularities which in turn feed back into the determination of local interactions. The result is an intricate system of interdependent feedback loops connecting micro behaviors, interaction patterns, and global regularities. As elaborated by numerous commentators, the modeler must now come to grips with challenging issues such as asymmetric information, strategic interaction, expectation formation on the basis of limited information, mutual learning, social norms, transaction costs, externalities, market power, predation, collusion etc.

This is a highly heterogeneous information network with many links and complex interrelations. Uncoupled and indirect interactions among agents require the capability of affecting and perceiving the context. The context is modeled here as virtual data fields, where each spatial or logical node stores the pervasive field values. The model promotes mediated interactions by exploiting some sort of distributed information that can be used as a means to enforce indirect and uncoupled interactions among agents and that can also be expressive enough to represent contextual information in a form locally accessible and immediately usable by agents.

One of the closest examples in this area is amorphous computing [5]. Another interesting proposal in that direction is the Multilayered Multi Agent Situated System (MMASS), defining a formal and computational framework relying on a layered environmental abstraction [6]. MMASS were related to the simulation of artificial societies and social phenomena, for which the physical layers of the environment were also virtual spatial abstractions. In the last decade, a number of other field-based approaches were introduced like Gradient Routing (GRAd), Directed Diffusion, "Co-Fields" at TOTA Programming Model, CONRO, etc [3].

In fact, almost all proposed systems are either employed for various technological or robotics applications and very few of them like MMASS, Agent-Based Computational Demography (ABCD) or Agent-Based Computational Economics (ACE Trading World application: simulation of economic phenomena as complex dynamic systems using large numbers of economic agents involved in distributed local interactions [4]) are suitable for programmable simulations of GERP.

For the effective implementation of spectra as a universal energy-information warehouse, we first have to transform all tangible objects-resources to their energy equivalents and then to interrelate different types of energy as intangible information stored in the form of corresponding sets of spectral bands (see Fig. 6). The deep meaning of it is based on the principle of reductionism and universality as we are looking for the most universal means to reduce multiplicity of forms into the singularity of content.

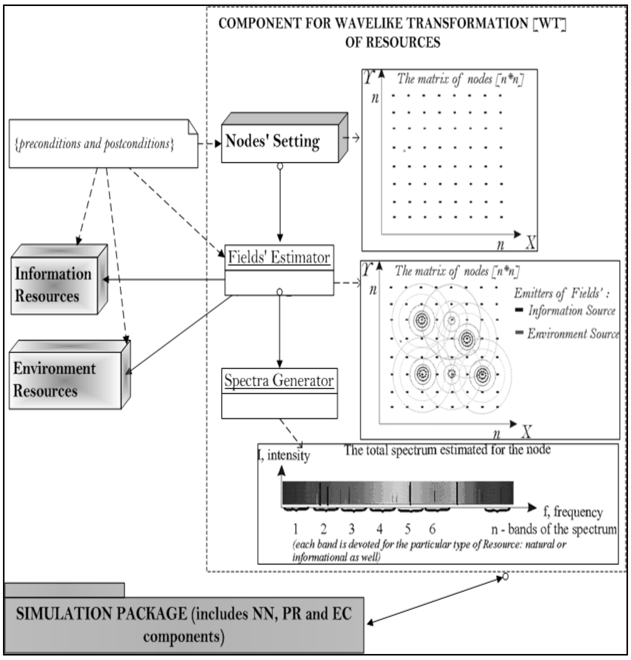

Fig. 6 Component for wavelike transformation of resources (the major recourse is information).

The prospective implementation model could adapt a discontinuous rectangular grid of spatial nodes. All natural and information resources (e. g. agents) could be distributed only on those nodes, see Fig. 2. For the larger grids, field intensities could be calculated only for the nonempty nodes, i.e. where we have an agent or we are interested to know the superimposed field intensities. Field intensities and resulting combinations of frequencies may be easily calculated using standard approaches from the physics of potential fields. The biggest advantage of such a model is its simplicity, reductionism and universality.

Another module is needed to attune agents for a proper functioning in the frequency domain, e.g. internal algorithmic calculation of transmission and superposition of waves (calculation of phases, intensities, frequency modes, interference etc). We have to bear in mind, that the sources of waves are not only environmental (natural) resources (which are initially distributed randomly) but also agents, who transmit some information about their capital, location, behavioral patterns they posses etc. A fields' intensity decreases according to the $1/R^2$ law.

So, a fields' estimator (see Fig. 2) calculates the aggregates at each node for various waves coming from different resources. This module produces spectra for the nodes. Each spectrum zone is devoted to the particular type of resource: natural or informational. In qualitative terms different resources have their own dedicated spectrum zones where each resource has a unique composition of spectrum bands (waves). In this way all agents' resources, including even location (X, Y), have their own separate spectral zones, where they are appropriately represented.

5 Discussion and Conclusions

This paper sheds new light on the conceptually novel platform for transformation of EERP systems to the GERP (Global Enterprise Resource Planning), which would operate in the local and global level as well. In the global economy, that means emergence of collaborative networks of enterprises, "win-win" strategies, efficient mass customization, and sharing of resources, information and supply chains. These technologies would spare global resources and use them in more effective ways.

In fact, current research provides more evidence that successful implementation of any mass-customized strategy requires a collaborative environment that follows a build-to-order production strategy. In such an environment, customers can configure their orders online and monitor any order's status at any time, suppliers can view demand streams dynamically in real-time, and the manufacturers can react to changing orders efficiently and expediently.

The new approach is no longer enterprise-oriented, but rather information flow and processes-oriented. In conceptual terms, this paper is presenting a pioneering approach that would enable simulation of dynamic interaction of e-manufacturing network of organizations and supply chains, which together compose a kernel of the complex modern information economy.

The main novelty is based on merging two separate approaches 1) integrated agent-based network models of e-manufacturing systems and supply chains (EERP and SCM simulation platforms), and 2) a field-based information network of intelligent agents.

The author further implies that telecommunications and internet technologies are most likely to provide the technological means for emergence of the global ERP (GERP). This will make distributed architectures possible, in which standardization takes place mainly at the level of information definitions and processes, so that local flexibility in information usage can be maintained at high precision. Needless to say, all these developments are already establishing themselves on a global scale. Hence, telecommunications and internet solutions for integrated SCM, ERP and CRM systems will have to be developed on a worldwide basis.

In reality, the distribution of the enterprise network cannot be managed by only one unique data-processing and data base application. The main reason is that the exchange of information and the behaviors, which are specific to operations of the network members, are so complex that they require computing paradigms which need to be decentralized and shared. Consequently, it seems that a MAS (Multi-Agent System) architecture (as a middleware) can best meet this need. Artificial intelligence (AI) techniques are especially welcome with their flexibility, adaptability and self-organizing capabilities.

As a result, the potentials of the combination of agent technology and the internet in facilitating all of the integration of chains in the GERP model, forming dynamic partnerships, require our earnest study. Enterprises will have to combine a business intelligence framework and their transactional systems with global ERP solutions.

Additionally, GERP ought to be thought of as a dynamic process of assembling chains of capabilities and not just collaborating organizations. The configuration of the GERP as a network of cooperating business units will evolve continually with a high frequency of business units entering and leaving the network. This is in high contrast to the current ERP implementations, which have a monolithic structure.

A number of theoretical and empirical studies have suggested that agents' direct and coupled communication model is badly justified in the real markets. The main reasons for this are the extremely complex communication protocols and networks. Currently dominating "pair-to-pair" coupled communications are not efficient enough for e-markets transactions, multitasking, parallel processing, congested traffic, conflict resolutions etc.

As the study shows, the study of coordinated models goes beyond computer science, in that also evolutionary computation, behavioral sciences, social sciences, business management, artificial intelligence, and logistics somewhat strictly deal with how social agents can properly coordinate with each other and emerge as globally coherent behaviors from local interactions.

Inspired from natural systems, we are starting to understand that to construct self-organizing and adaptive systems in a social domain, it may be more appropriate to focus on the engineering of the proper interaction mechanisms for the components of the system, rather than on the engineering of their overall system behavior.

Uncoupled and indirect interactions among agents require the capability of affecting the context and of perceiving it. The context is modeled here as virtual data fields, where each spatial or logical node stores the pervasive field values. The model promotes mediated interactions by exploiting a type of distributed information that can be used as a means to enforce indirect and uncoupled interactions among agents and that can also be expressive enough to represent contextual information in a form locally accessible and immediately usable by agents.

In the second part of this paper, the author introduces a novel concept: how to represent communications and operations in the complex MAS network. Instead of the "pair-to-pair" communication model, the author proposes to adapt a field-based model, where synchronous and asynchronous communication can take place.

In sum, the novelty of the proposed approach adaptation for GERP lays in the nonstandard simulation concept: mapping the entire time dependent multi-agent communication model into frequency domain, which is a very powerful media for the effective representation of the complex information flows. The sound meaning of the proposed approach is based on the principle of reductionism and universality.

Using Fourier transformation, we can translate agents' time dependent behavioral patterns (which are nothing more than information) to the frequency domain. In this case, each agent's characteristic behavior set is represented by his unique spectrum pattern. In fact, for efficient functioning, agents need some sensor-like receptive mechanism ("radio tuning") to be attuned to the specific frequencies emitted from the different sources.

The author assumes that, following this line, we could imagine each agent as a set of internal frequencies, which resonate if triggered by the external fields with the coherent frequencies. The resonating frequencies are then transferred to other frequencies following agent's internal "production rules". These rules are nothing else but energy transformation laws, which govern agent's dynamic behavior.

The author is at pain to emphasize that these findings represent an initial first "take" on the simulation of such complex social systems like proposed GERP. This work, though, gives some clear outlines and their explanatory sources. Moreover, the author has spent a considerable amount of this paper examining the methodological novelty of proposed approaches. Subsequent papers will focus more on the empirical aspects of the current research, which already show the feasibility and validity of the presented ideas.

Acknowledgments
The author is very grateful to Jsc "„Alna Business Solutions", referees, and associated editor, whose constructive comments have significantly improved the paper. This work is a part of the project "Designing and Implementation of an Extended Production Planning Algorithm while Creating a Production Management Information System", project identification No. BPD2004-ERPF-3.1.7-06-06/0014.

References

[1] Akkermans H. A., Bogerd P., Yücesan P. E., Wassenhove L. N., 2003. The impact of ERP on supply chain management: Exploratory findings from a European Delphi study. European Journal of Operational Research, Volume 146, Issue 2, Pages 284-301.

[2] O'Leary, D., 2000. Enterprise Resource Planning Systems: Systems, Life Cycle, Electronic Commerce, and Risk. Cambridge University Press, New York.

[3] Wallace, T.F., Kremzar, M.H., 2001. ERP: Making it Happen (The Implementers' Guide to Success with Enterprise Resource Planning). Wiley, New York.

[4] Gartner Research Group, 2000. ERP Is Dead—Long Live ERP II. Gartner Research (SPA-12-0420).

[5] Koh S.C.L., Gunasekaran A., Rajkumar D., 2007. ERP II: The involment, benefits and impediments of collaborative information sharing. International Journal of Production Economics. Published by Elsevier.

[6] Zrimsek, B., 2003. ERP II Vision. US Symposium/ITxpo, 23–27 March 2003, Gartner Research (25C, SPG5, 3/03), San Diego.

[7] Zhang D. Z., Anosike A. I., Lim M. K., Akanle O. M., 2006. An agent-based approach for e-manufacturing and supply chain integration. Computers & Industrial Engineering, Volume 51, Issue 2, Pages 343-360.

[8] Monteiro T., Roy D., Anciaux D., 2007. Multi-site coordination using a multi-agent system. Computers in Industry, Volume 58, Issue 4, Pages 367-377.

[9] Turoski K., 2002. Agent-based e-commerce in case of mass customization. International Journal of Production Economics, 75 (1–2), pp. 69–81.

[10] Ghiassi M. and Spera C., 2003. Defining the internet-based supply chain system for mass customized markets. Computers and Industrial Engineering, 45(1), pp. 17–41.

[11] Li, T., Fong, Z., 2003. A system architecture for agent based supply chain management platform. In Proceedings of the 2003 Canadian conference on electrical and computer engineering (CCECE): Toward a caring and humane technology, Montreal, Canada.

[12] Choy K.L., Lee W.B., 2002. Multi-agent based virtual enterprise supply chain network for order management. In Portland international conference on management of engineering and technology (PICMET), Portland, USA.

[13] Bo, X., Zhiming W., 2003. Modeling of supply chain: a multi-agent approach. In 2003 American control conference. Denver, CO, United States.

[14] Sadeh, N.M., Hildum, D.W., Kjenstad, D., Tseng, A., 1999. MASCOT: an agent-based architecture for coordinated mixed-initiative supply chain planning and scheduling. In Workshop on agent-based decision support in managing the internet-enabled supply-chain, pp. 133–138.

[15] Peng Y., Finin T., Labrou Y., Cost R.S., 1999. An agent-based approach for manufacturing integration – The CIIMPLEX experience. Applied Artificial Intelligence 13 (1999), pp. 39–63.

[16] Shen W., Norrie D.H., 1998. An agent-based approach for manufacturing enterprise integration and supply chain management. Globalization of Manufacturing in the Digital Communications Era of the 21st Century: Innovation, Agility, and the Virtual Enterprise, Kluwer Academic Publishers, Dordrecht (1998), pp. 579–590.

[17] Hendricks K B., Singhal V. R., Stratman J. K., 2007. The impact of enterprise systems on corporate performance: A study of ERP, SCM, and CRM system implementations. Journal of Operations Management 25, pp. 65-82.

[18] Ciufudean C. I., 2008. Risk and Reliability Analysis of Flexible Manufacturing Systems. 10th WSEAS Int. Conf. on Automatic Control, Modelling & Simulation (ACMOS'08), Istanbul, Turkey.

[19] Revetria R. 2008, Scenario and Risk Management Simulation for Supporting Strategical Operational Management in

Process and Manufacturing Industry. 10th WSEAS Int. Conf. on Automatic Control, Modelling & Simulation (ACMOS'08), Istanbul, Turkey.

[20] Jesus M. J. D., Pedro H. G., 2008. Real Time Flexible Manufacturing System. 10th WSEAS Int. Conf. on Automatic Control, Modelling & Simulation (ACMOS'08), Istanbul, Turkey.