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THE CONCEPT OF THE IMPLEMENTATION OF INVENTOMRY MANAGEMENT BY THE SUPPLIER WITH THE USE OF AGENT TECHNOLOGY

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ABSTRACT. Background: As it is well know, the implementation of instruments of logistics management is only possible with the use of the latest information technology. So-called agent technology is one of the most promising solutions in this area. Its essence consists in an entirely new way of software distribution on the computer network platform, in which computer exchange among themselves not only data, but also software modules, called just agents.

The first aim is to propose the alternative method of the implementation of the concept of the inventory management by the supplier with the use of intelligent software agents, which are able not only to transfer the information but also to make the autonomous decisions based on the privileges given to them. The second aim of this research was to propose a new model of a software agent, which will be both of a high mobility and a high intelligence.

Methods: After a brief discussion of the nature of agent technology, the most important benefits of using it to build platforms to support business are given. Then the original model of polymorphic software agent, called Multi-Dimensionally Versioned Software Agent (MDV) is presented, which is oriented on the specificity of IT applications in business. MDV agent is polymorphic, which allows the transmission through the network only the most relevant parts of its code, and only when necessary. Consequently, the network nodes exchange small amounts of software code, which ensures high mobility of software agents, and thus highly efficient operation of IT platforms built on the proposed model. Next, the adaptation of MDV software agents to implementation of well-known logistics management instrument - VMI (Vendor Managed Inventory) is illustrated.

Results: The key benefits of this approach are identified, among which one can distinguish: reduced costs, higher flexibility and efficiency, new functionality - especially addressed to business negotiation, full automation of work that in practice does not require the involvement of network users, the ability to use new communication channels, etc.

Conclusions: The proposed MDV model significantly enriched the advantages of software agents, which was then practically illustrated by the proposal of their use for the VMI implementation.

Key words: inventory management, VMI, software agents, MDV model.

INTRODUCTION

The Vendor Managed Inventory (VMI) is an instrument of the logistics management, where the responsibility of the management of clients' stock lies within supplier's competence [Manage..., Christopher 2005]. The scope of VMI covers all activities of monitoring and replenishment of client's stocks [Vendor..., Roussel 2005]. Traditionally, one of the following methods implements this process:

- "clean" VMI. The supplier generates orders based on information send by client mainly by EDI (Electronic Data Interchange) or Internet. The information is sent directly to the supplier's computer system, where they are processed and the relevant orders are created based on these data,

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- VMI based on merchandising activities. The sales representative visits regularly the points of sales of clients, controls the stocks levels and places orders on the previously agreed level,
- consignment stock VMI. The consignment stock is established based on the agreement between the supplier and the customer, i.e. the supplier is the owner of the goods, the recipient pays for them when they are taken for the production or sales purposes,
- designated representative of the supplier monitors the stocks levels at the recipient's warehouse and places orders in agreed lead-times.

The implementation of the new information technology, so called agent technology, is undoubtly a challenge for modern business with regard to the implementation of modern instruments of logistics management, especially in the area of the inventory management by the supplier.

In colloquial meaning, the word "agent" means somebody delegated to work in a certain place and there performing a specific task according to previously set agreements. In the information sense, the expression "software agent" is used. It is a computer program, working remotely or locally. It operates according to wishes of the user or other agent, which is able to start it. The software agent has some features, by which it can be distinguished from other traditional programs. They are [Rykowski 2008]:

- Environment – the agent works in a specific environment, which can be an operation system or an application dedicated specially for it,
- Target – the agent tries to achieve it in its activities. Its work is characterized by the high independence, and even isolation,
- Autonomy – the agent requires a certain operation time. It should work effectively and as long as it is needed, aiming to achieve the target set to it, even if the user (who delegates it) disconnects it from the system (which seems to be its biggest advantage),
- Adaptation – the agent has the ability to adjust itself to changes in its environment. Therefore, it manifests some features of the intelligence. It has an ability to learn and to make conclusions,
- Mobility – the agent can move within the environment and (what seems to be even more important) – between various areas, installed on various computers without changing the mission and the operation method.

There are two classes of agents: mobile and intelligent ones, the grouping made on the basis of the last from above-mentioned features of agents, which can occur even in very large disproportion to each other. In the context of the technology, the mobile agents are most often not intelligent and vice verse. It means that in practice, these features are usually in the opposition to each other. The reasons for such situation are that, the huge intelligence requires a big sophisticate computer code, which is not convenient to be sent in other locations within the network.

The following advantages of software agents for the implementation of instruments of the logistics management can be distinguished:

- Automation – the autonomous agent can find by himself the information it needs on the appropriate server. It communicates with the user after reaching the aim. It is able also to undertake the further steps, e.g. the negotiation of the cooperation conditions.
- Efficiency – the agent monitors new information 24 hours a day (if the server environment allows it).
- Communication – it is able to use mobile devices (mobile phones, palmtop, on-board computer) for the communication with the user. The communication e.g. in the form of SMS is possible.
- Negotiations. The agent is able to negotiate the conditions with the agent of the service provider. It is able to make the preliminary evaluation of the reliability of the customer as well as to finalize the agreement.

- Reduction of costs. The agent performs the task after sending it to the server and finishing the communication (modem connection). The results of the agent's search are collected in the next session.
- Versatility. The agent can move among various servers. While migrating to the new localisation, it moves together with information already acquired. It is able to compare a few different cooperation offers from different sources.

There are two aims of this study. The first one is to propose the alternative method of the implementation of the concept of the inventory management by the supplier with the use of intelligent software agents, which are able not only to transfer the information but also to make the autonomous decisions based on the privileges given to them. The second aim of this research was to propose a new model of a software agent, which will be both of a high mobility and a high intelligence. The proposed agent is an essential element, which constitutes the success of the implementation of VMI concept using the agent technology.

THE MODEL OF MDV AGENT

The software agent of MDV model consists of two largely autonomous parts. The first one is a kind of agent's head, so called bootstrap agent. It is relatively small and therefore has a high mobility. The main task of this bootstrap agent is to move within the networks and decide whether a newly visited environment is potentially interesting from the standpoint of the agent's mission, defined by the user, who delegated it. In case the environment is interesting, the bootstrap agent communicates with so called proxy agent, located on the parent computer (the computer, where the agent was created by the user) and demands the transfer of appropriate and necessary fragments of the code. These fragments are the additional modules, forming so called agent body [Wieczerzycki 2005]. The bootstrap agent communicates with the proxy agent via messages made in the agent-communication-language (ACL) [FIPA...].

In the situation when the agent's actions bring the assumed effect, the bootstrap agent re-establishes the communication with the proxy agent, demanding next fragments of the code, responsible for its further work. This situation will be described in details shortly.

When the agent's mission is ended in the visited environment (the goals are achieved or not), the agent's body is removed and the bootstrap migrates to another environment or returns to parent computer, where it is merged with the proxy agent.

Due to the versality of the proposed approach, it is assumed that the bootstrap agent is interpreted by the environment into which it goes and therefore it is able to visit any computer. It means, the agent is the source code and not a binary one.

There are four basic functions of the proxy agent:

- it serves as a communication medium between the user and the bootstrap agent. It has information about the current localisation of the bootstrap agent and is able to change both the directions of the agent's migration and the actions undertaken by it.
- it includes all variants of code, which forms the body of the agent and therefore provides the flexibility of its behaviour. Depending on the requests sent by the bootstrap agent, the proxy agent is able to send it the appropriate fragment of the code and therefore to increase its functionality and to enable the fulfilment of the mission given to it by the user.
- it collects and aggregates all data sent it directly by the bootstrap agent. It is very important feature, due to the fact, that redundant data reduce the mobility of the bootstrap agent and are not always useful for the completion of the agent's mission but they can be later useful for the user. The information is collected in so-called knowledge repository.

- it enables the user to monitor the progress of the agent's work. In case it decides that the information collected by the agent is sufficient, the proxy agent is able to finish its operation (together with dynamically broaden agent) and present the results to the user.

Summarizing the above considerations, the behaviour of the mobile component (code) can be described as follows. Only the bootstrap agent is sent during the migration to the following node of the network. All variants and additional modules, which constitute the agent, are removed from the preceding node. There is no need to send the whole code together with the agent, because the following environment, where the agent will be, will probably require a completely different code's variants. After finishing the migration, the agent checks the specific character of the new localisation and sends a request of the transfer of the most relevant fragments of the code to the proxy agent and then it continues its run.

During the analysis of individual network nodes, only information, which enriches the intelligence of a mobile agent, is integrated with the bootstrap agent (therefore the agent becomes slightly bigger over time). The information, which does not affect the agent's intelligence, is sent directly to its stationary part, where is stored in the knowledge repository. This property of rejecting the unnecessary data is called agent self-slimming.

The variability of an agent in the MDV model has two dimensions – horizontal and vertical one:

- agent segmentation,
- platform versioning.

Agent segmentation. The agent's mission can be usually achieved by performing a sequence of relatively autonomous activities (action steps). In order to increase the efficiency of the agent's activities, the whole its code is divided into so-called segments, each of them is responsible for a specific task. When the specific task is finished, the following segment of MDV agent's code is taken from the proxy agent and then it is of course executed. Depending on whether the agent's behaviour is of sequential or interactive nature, the previous code fragment is deleted (in first case) or kept during the following task (the second case).

For example, the first agent's segment can be responsible for checking offers on e-markets (e-marketplaces). If there is a potentially interesting offer for a client, the second segment (responsible for negotiations of cooperation conditions) is sent on the request of the bootstrap agent. If the negotiations are completed and the agreement is achieved, then the third segment is sent, which is responsible for signing the agreement, etc. In case one of steps of the procedure fails, there is no need to send the following segment of the code.

In this example, the recommended form of the agent's behaviour would be its sequentiality, which is able to reduce the number of transmitted segments of the code. It means, the first segment should analyze all available offers on e-market, flag the potentially interesting ones (worth to be negotiated) and then switch to the second segment. Similarly, negotiations should be conducted with all agents representing the flagged offers. If they are successfully finished, MDV agent should flag all these agents, to which the procedure of the third segment should be applied.

In the summary, the above-described dimension of variability of MDV agent (i.e. segmentation) is an attempt of modelling of multi-stage of the nature of software agents.

Platform versioning. Each segment of an agent is available in many variants, each responsible for specific configuration of any remote platform, where the agent will work (i.e. hardware configuration, operative system configuration, network communication protocols). Additionally, there is one special variant of each segment, stored in the form of a source code (and therefore platform-independed). It is sent to computers, which do not accept the binary code due to security reasons. It means, the agent can be interpreted by the environment instead of executing the fixed compiled code. Except this one particular variant, the proxy agent is able to store potentially unlimited number of binary variants.

If the target environment accepts the executable code, the proxy agent sents a variant of desired segment, corresponding to specific hardware requirements of the environment.

It is clear, that the executable (binary) variants of agent segments increase its productivity, while the stored source variant guarantees the fulfilment of all restrictive security requirements.

In summary, the above-described dimension of variability of MDV agent (i.e. platform versioning) is an attempt of modelling of platform independence of software agents, while maintaining their high efficiency of the work.

THE USE OF MDV AGENTS FOR VMI IMPLEMENTATION

The alternative method of the implementation of VMI concept (in relation to those presented in the first chapter) is the use of intelligent software agents as managers of stocks levels of customers. Due to the complexity of operations performed and the responsibility, the agents must have a high intelligence, which automatically reduces their mobility. Therefore, the ideal model of the software agent suitable for the implementation of VMI concept seems to be the MDV agent, described in the previous chapter.

The necessary condition, which has to be fulfilled for the proper work of the solution, is the preparation of reports by the customer. These reports include stocks levels, moves, forecasts and must be in the electronic form as a file or complex databases. The recipient must also provide the access to information to the supplier's agents. Based on this information, they are able to make right decisions on orders of goods and materials. The process of the implementation and the work of VMI concept by the use of MDV software agents is presented below.

The first step to begin the cooperation on VMI principles with use of agents must be the traditional negotiations between the supplier and recipient, during which the agreement on the admission of supplier's agents to data located on recipient's servers (especially in compiled binary form) is finalized. These arrangements are necessary from the security point of view, while the agent technologies have some potential risks (the access to business data by stranger agents can lead to data loss, leakage or modification, which in turn can threaten the future business activities, e.g. inaccurate forecasts due to the distortion of data). When the initial negotiations end in mutual agreement to use the agent technology, it is possible to start the procedure of monitoring of stocks and placing orders by software agents according to VMI rules.

The proper process of monitoring and replenishment of stocks is as follows. At the beginning the supplier sends its representative – an automatic bootstrap agent to each of his recipients (working on VMI principles) in order to obtain information on individual stocks levels. After reaching the contractor's server, the agent starts to look for the client's representative (also a software agent), with which it will be able to make electronic negotiations. This operation can be finished in two ways: the digital representative of the client is found or the client has no representative, which prevents the initiation of negotiations by the supplier's agent.

In the first case, the negotiations can be started. The bootstrap agent sends to the server, where its modules are stored (i.e. proxy agent) the request to send the fragment of the code, responsible for the negotiations. After joining this communication module, the agent is able to start the communication with the client's agent and receive information on actual stocks levels, current consumption and forecasts. The obtained information is compared to the client's data (required stocks levels, etc.), which are received in the form of the separate module downloaded from its server. If the stocks level is optimal, the agent finishes the procedure, removes downloaded modules and migrates to the computer of the next client. In other case, the agent sends next request for an additional module (exactly – the appropriate variant of the next segment), responsible for the analysis of the external factors (a module enables e.g. to get the information on the weather and after the analysis, it calculates its potential impact on the punctuality of deliveries). Knowing the impact of external factors on the complementary process, the agent is ready to start the proper negotiations with the representative of the recipient. The agent generates the proposal of the order, based on initial agreements with a client concerning the size and the punctuality of deliveries and taking into account the influence of the external factors. If the client's representative accepts the proposal, the supplier's agent sends a ready order to the information system of the supplier. In other case, the negotiations continue until both sides reach an agreement. If the conditions imposed by agents are so divergent, that there is no possibility for an agreement, the negotiations end in failure and both the supplier and the recipient will be informed of the failure of negotiations and the need to solve the problem.

In the second analyzed cases, the agent does not find any client's agent and therefore there is no possibility of above described negotiations. It looks data on the client's server, to which it has an access. The data can occur in any digit format, e.g. XML files or entries in the database, to which the agent has an access by using the appropriate API (Application Programming Interface – the method of communication between the application and other programs, in this case it concerns the possibilities of the communication between the agent and ERP application of a client, which in turn has an access to databases. Due to security reasons, the agent has never an access directly to client's database). If the agent does not find any data, which could be analyzed, it sends a notification of a failed operation to both business partners and starts the migration procedure. If it can find data and is able to interpret them, it sends a request (to the proxy agent) to send it the appropriate module, which enables the interpretation of data. This module may allow to use interfaces, defined by a client or to facilitate the analysis of a file of a predefined structure. After downloading the desired fragment of a code, the found data are analyzed and the obtained results (present stocks levels) are compared to predefined norms. If the agent identifies the need of additional order of goods as a result of this analysis, it checks whether it has enough authorization to make a decision. If the agent's authorization is sufficient, it generates an order and sends it to information system of a supplier. In other case, it sends a requirement for the confirmation of the decision to the party, which is authorized to do it (supplier or recipient) and waits for a response. If it does not receive it in the specific time, it interrupts the procedure, removes redundant modules, sends a notification about the status of the operation to both business partners and migrates to the nest recipient.

When the order is generated or there is a failure of the operation, the agent always starts "self-slimming" (consisting in removing all additionally downloaded software modules and already redundant information) in order to return to the original level of the mobility. After removing all redundant components, the agent migrates to the next client, where the whole procedure is repeated.

SUMMARY

The aims assumed at the beginning of this work were achieved by the consistent presentation of proposed alternative implementation of stocks management by the supplier. The advantages of software agents, presented in the first chapter, are significantly enriched in case of the proposed MDV model, which was then practically illustrated by the proposal of their use for the VMI implementation.

Firstly, the MDV agent carries in the network not only necessary fragments of the code but simultaneously it conducts "self-slimming", sending back the already unnecessary parts of the code to the proxy agent. Therefore, it cancels the restriction, mentioned in first chapter, that a mobile agent is not mobile in practice. It can move effectively among the servers of the supplier's clients.

Secondly, the MDV agent is polymorphic – depending on the peculiarity of visited clients, the information platform used by them (type of ERP or WMS system), preferred scenarios of the cooperation, it requests from the proxy agent the necessary software modules, which fully respond to client's requirements.

Thirdly, in most of the case the MDV agent has a compiled form, matched to the information platform of a client, which efficiently increases the speed of its actions. The authors believe, it does not decrease the safety of the proposed approach, because the VMI implementation has to rely on mutual confidence of the supplier and clients, and thereby it should exclude the suspicion of the possibility of the transfer of a destructive code, in particular computer viruses.

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KONCEPCJA IMPLEMENTACJI ZARZĄDZANIA ZAPASAMI PRZEZ DOSTAWCĘ Z ZASTOSOWANIEM TECHNOLOGII AGENTOWEJ

STRESZCZENIE. **Wstęp**: Jak powszechnie wiadomo, wdrożenie instrumentów zarządzania logistycznego jest możliwe jedynie dzięki zastosowaniu najnowszych technologii informacyjnych. Jednym z najbardziej obiecujących rozwiązań w tym zakresie jest tzw. technologia agentowa. Jej istota polega na zupełnie nowym sposobie rozpraszania oprogramowania na platformie sieci komputerowej, w której komputery wymieniają między sobą nie tylko dane, ale również moduły programowe, zwane właśnie agentami.

Pierwszym celem pracy było zaproponowanie alternatywnej metody implementacji koncepcji zarządzania zapasami przez dostawcę, przez wykorzystanie inteligentnych agentów programowych spełniających rolę nie tylko medium przenoszenia informacji, ale także podejmujących autonomiczne decyzje w oparciu o nadane im przywileje. Drugim celem było zaproponowanie nowego modelu agenta programowego, który charakteryzowałby się zarówno mobilnością jak i wysoką inteligencją.

Metody: Po krótkim przybliżeniu istoty technologii agentowej przedstawiono najważniejsze korzyści wynikające z jej wykorzystania do budowy platform informatycznych do wspomagania biznesu. Następnie zaproponowano oryginalny model polimorficznego agenta programowego o nazwie MDV (ang. Multi-Dimensionally Versioned software agent), zorientowanego na specyfikę zastosowań IT w biznesie. Agent MDV jest wielopłaszczyznowo wersjonowany, co umożliwia przekazywanie przez sieć komputerową jedynie najbardziej odpowiednich fragmentów jego kodu i tylko wtedy, gdy jest to niezbędne. W konsekwencji, między komputerami transmitowane są niewielkie ilości kodu programowego, co gwarantuje dużą mobilność agentów, a tym samym wysoką efektywność funkcjonowania platform informatycznych zbudowanych w oparciu o proponowany model. Dalej przedstawiono propozycję adaptacji agentów programowych, funkcjonujących zgodnie za modelem MDV, do implementacji znanego instrumentu zarządzania logistycznego - VMI (zarządzanie zapasami przez dostawcę, ang. Vendor Managed Inventory).

Wyniki: Najważniejsze korzyści takiego podejścia to: obniżone koszty, większa uniwersalność i efektywność działania, nowe możliwości funkcjonalne, zwłaszcza w odniesieniu do prowadzenia negocjacji biznesowych, pełna automatyzacja pracy, niewymagająca w praktyce zaangażowania użytkowników sieci, możliwość wykorzystania nowych kanałów komunikacyjnych.

Wnioski: Zaproponowano alternatywną implementację zarządzania zapasami przez dostawcę. Przedstawione zalety zastosowania agentów programowych są istotnie wzbogacone w przypadku proponowanego modelu MDV, co zilustrowano praktycznie proponując zastosowanie takich agentów do wdrożenia instrumentu VMI.

Słowa kluczowe: zarządzanie zapasami, VMI, agenty programowe, model MDV.

EIN KONZEPT FÜR DIE IMPLEMENTIERUNG DES BESTANDSMANAGEMENTS VON LIEFERANTEN UNTER NUTZUNG EINES AGENTEN-VERFAHRENS

ZUSAMMENFASSUNG. Einleitung: Die Nutzung der Instrumente für das Logistik-Management ist heutzutage nur mit Anwendung der modernsten Informationstechnologien möglich. Eine der erfolgversprechenden Lösungen in diesem Bereich stellt ein sog. Agenten-Verfahren dar. Das Wesen der Lösung beruht auf einer ganz neuen Methode mittels Streuung von Software auf der Plattform des Werknetzes, auf welcher die einzelnen Rechner nicht nur gegenseitig Daten austauschen, sondern auch Programm-Module, die eben als Agenten bezeichnet werden.

Das vorrangige Ziel der Arbeit war es, eine alternative Methode für die Implementierung des durch den Lieferanten betätigten Bestandsmanagements-Konzeptes unter Anwendung intelligenter Programm-Agenten vorzuschlagen, welche nicht nur als Medium für den Datentransfer ihre Funktion ausüben, sondern auch anhand der ihnen eingeräumten Privilegien autonomische Entscheidungen treffen können. Die andere Zielsetzung stellte die Ausarbeitung eines neuen Modells für den Programm-Agenten, welcher sich sowohl durch große Mobilität, als auch durch hohe Intelligenz auszeichnen würde, dar.

Methoden: Nach einer einleitenden Projizierung des Agenten-Verfahrens wurden die wichtigsten Vorteile für den Aufbau von informationstechnischen, Business unterstützenden Plattformen vorgestellt. Des weiteren wurde das originelle Modell eines polymorphischen, auf die Eigenart der IT-Anwendung im Businness orientierten Software-Agenten namens MDV (eng. Multi-Dimensionally Versioned software agent) vorgeschlagen. Der MDV-Agent ist in Mehrflächen-Versionen konfiguriert, was ihn für die Übertragung innerhalb des Werknetzes nur der am meisten brauchbaren Fragmente seines Codes und dies nur dann, wenn das unentbehrlich ist, prädestiniert. Im Endeffekt werden zwischen den einzelnen Rechnern fragmentarische Teile des Programm-Codes transferiert, was eine große Mobilität der Agenten und dadurch eine hohe Effektivität der Funktionstüchtigkeit des vorgeschlagenen Modells gewährleistet. Ferner wurde ein Vorschlag für die Anpassung der gemäß dem MDV-Modells funktionierenden Programm-Agenten an die Implementierung des VMI-Modells (eng. Vendor Managed Inventory - Bestandsmanagement durch den Lieferanten) als bekanntes Instrument für das Logistik-Management dargestellt.

Ergebnisse: Die wichtigsten Vorteile eines solchen Herangehens sind wie folgt: gesenkte Kosten, größere Universalität und Effektivität des Handelns, neue funktionale Möglichkeiten, insbesondere in Hinsicht auf die Durchführung von Handelsnegotiationen, volle Automatisierung der Arbeit, die in der Praxis gegebenenfalls kaum Engagement seitens der Netzwerk-Nutzer mehr bedarf, sowie die Möglichkeit einer Inanspruchnahme von neuen Kommunikationskanälen.

Fazit: Es wurde eine alternative Implementierung des durch den Lieferanten betätigten Bestandsmanagements vorgeschlagen. Die aufgezeigten Vorteile der Anwendung von Programm-Agenten beim vorgeschlagenen MDV-Modell sind ausschlaggebend, was mit dem Vorschlag zur Anwendung solcher Agenten für die Einführung des VMI-Instruments praktisch projiziert wurde.

Codewörter: Bestandsmanagement, VMI-Modell, Programm-Agenten, MDV-Modell.

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