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Intelligence decision systems in enterprise information management

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Abstract

Purpose – The purpose of this paper is to show how intelligence techniques have been used in information management systems.

Design/methodology/approach – The results of a literature review on intelligence decision systems used in enterprise information management are analyzed. The intelligence techniques used in enterprise information management are briefly summarized.

Findings – Intelligence techniques are rapidly emerging as new tools in information management systems. Especially, intelligence techniques can be used to utilize the decision process of enterprises information management. These techniques can increase sensitiveness, flexibility and accuracy of information management systems. The hybrid systems that contain two or more intelligence techniques will be more used in the future.

Originality/value – The intelligence decision systems are briefly introduced and then a literature review is given to show how intelligence techniques have been used in information management systems.

Keywords Intelligence techniques, Decision support systems, Enterprise information management, Information management

Paper type Literature review

1. Introduction
Information plays a great role in the enterprise. It is consistently a hot topic for information management, and all the time, evaluating its efficiency is a critical task. For a corporation, there are thousands pieces of vertical and horizontal information flows within it. The information management activities, in fact, can be regarded as the control on those flows (Li et al., 2003). In response to global competition, enterprises are increasingly employing information technology to conduct business electronically. Thus, various information systems, such as enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM), are increasingly used to gather business transaction, supplier and customer data. Those
various operational and transaction data can be transformed into information and then knowledge by using business intelligence (BI) tools. Enterprises decision makers make better business decisions (Wu, 2010). Decision making is one of the most important tasks for enterprise managers, and is generally based on various data sources derived from information systems, such as ERP, SCM, human resource management (HRM), financial management (FM) and CRM. Numerous intelligence decision systems (IDS) have been developed to support decision making for enterprises. A definition of intelligence which is needed to be defined to research in a field termed artificial intelligence and computational intelligence has only rarely been provided, and the definitions in the literature have often been of little operational value. The intelligence was defined as the ability of solving the hard problems. However there are basic questions in this definition, such as how hard the problem is or who decides which problem is hard (Chellapilla, Fogel, 1999).

Intelligent decision support systems (IDSS) is a term that describes decision support systems that make extensive use of artificial intelligence (AI) techniques. Use of AI techniques in management information systems has a long history, indeed terms such as Knowledge-based systems (KBS) and intelligent systems have been used since the early 1980s to describe components of management systems, but the term “Intelligent decision support system” is thought to originate the late 1970s (Holsapple and Whinston, 1987). Flexible manufacturing systems (FMS) (Chan et al., 2000) can also be considered examples of intelligent decision support systems. Ideally, an intelligent decision support system should behave like a human consultant; supporting decision makers by gathering and analysing evidence, identifying and diagnosing problems, proposing possible courses of action and evaluating the proposed actions. The aim of the AI techniques embedded in an intelligent decision support system is to enable these tasks to be performed by a computer, whilst emulating human capabilities as closely as possible. Many IDSS implementations are based on expert systems, a well established type of KBS that encode the cognitive behaviors of human experts using predicate logic rules and have been shown to perform better than the original human experts in some circumstances (Baron, 1998; Turban et al., 2009). Expert systems emerged as practical applications in the 1980s based on research in artificial intelligence performed during the late 1960s and early 1970s. They typically combine knowledge of a particular application domain with an inference capability to enable the system to propose decisions or diagnoses. (Jackson, 1998). Some research in intelligence techniques, focused on enabling systems to respond to novelty and uncertainty in more flexible ways is starting to be used in intelligent decision support systems. For example intelligent agents that perform complex cognitive tasks without any need for human intervention have been used in a range of decision support applications. Capabilities of these intelligent agents include knowledge sharing, machine learning, data mining, and automated inference. A range of intelligence techniques such as case based reasoning, rough sets and fuzzy logic have also been used to enable decision support systems to perform better in uncertain conditions (Sugumaran, 2007; Bui, and Lee, 1999). So they can be used to construct intelligence decision systems in enterprise information management. Enterprise information management systems in many companies have been developed following the needs arising from administration, control, reporting and transaction management.
In this paper, the results of a literature review on intelligence decision systems used in enterprise information management are analyzed. The intelligence techniques used in enterprise information management (EIM) such as fuzzy set theory (FST), multi-agent systems (MAS), neural networks (NNs), genetic algorithms (GAs), ant colony optimization (ACO) and particle swarm optimization (PSO) are briefly summarized in Section 2. The results of the literature review are analyzed in Section 3. The conclusions and future research directions are discussed in Section 4.

2. Intelligence techniques
In this section, the intelligence techniques used in EIM are summarized briefly.

2.1 Multi-agent system
Multi-agents systems (MAS) theory can be viewed as an evolution of artificial intelligence, in order to achieve autonomous computational systems. Although the agent definition has been argued into the researcher’s community of the distributed artificial intelligence, it is accorded that the autonomy is the main characteristic describing an agent, the autonomy being the ability to accomplish a task and reach its objectives without human, or any other, assistance. Particularly, each agent has got properties as autonomy, mobility, rationality, sociability and reactivity. Furthermore, they may have built-in reasoning mechanism permitting to propose intelligent solutions and to evolve by experiences. Thus, intelligent agents have attributes and methods, like the object-oriented programming, and also they have built-in beliefs, desires and intentions, which are linked with their environment and provide them of the states that determine their behavior. The most important agent’s characteristics are:

- autonomy;
- communication;
- reactivity;
- intelligence; and
- mobility (Cerrada et al., 2007).

2.2 Fuzzy set theory
Zadeh published the first paper, called “fuzzy sets”, on the theory of fuzzy logic in 1965. He characterized non-probabilistic uncertainties and provides a methodology, fuzzy set theory, for representing and computing data and information that are uncertain and imprecise. Zadeh (1996) defined the main contribution of fuzzy logic as “a methodology for computing with words” and pointed out two major necessities for computing with words: “First, computing with words is a necessity when the available information is too imprecise to justify the use of numbers, and second, when there is a tolerance for imprecision which can be exploited to achieve tractability, robustness, low solution cost, and better rapport with reality”. While the complexity arise and the precision is receded, linguistic variables has been used to modeling. Linguistic variables are variables which are defined by words or sentences instead of numbers (Zadeh, 1975). Many problems in the real world deal with uncertain and imprecise data so conventional approaches cannot be effective in finding the best solution. To cope with this uncertainty, fuzzy set theory has been developed as an effective mathematical algebra under vague environment. Although humans are comparatively efficient in
qualitative forecasting, they are unsuccessful in making quantitative predictions. Since fuzzy linguistic models permit the translation of verbal expressions into numerical ones, thereby dealing quantitatively with imprecision in the expression of the importance of each criterion, some methods based on fuzzy relations are used. When the system involves human subjectivity, fuzzy algebra provides a mathematical framework for integrating imprecision and vagueness into the models (Kaya and Çınar, 2008). Uncertainties can be reflected in mathematical background by fuzzy sets. Fuzzy sets have reasonable differences with crisp (classical) sets. Crisp set A in a universe U can be defined by listing all of its elements denoted x. Unlike crisp sets, a fuzzy set $\tilde{A}$ in universe of U is defined by a membership function $\mu_{\tilde{A}}(x)$ which takes on values in the interval $[0, 1]$. The definition of a fuzzy set is the extended version of a crisp set. While the membership function can take the value of 0 or 1 in crisp sets, it takes a value in interval $[0, 1]$ in fuzzy sets. A fuzzy set, $\tilde{A}$, is completely characterized by the set of ordered pairs (Jahanshahloo et al., 2006):

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in X\} \quad (1)$$

There is a huge amount of literature on fuzzy logic and fuzzy set theory. In recent studies, the fuzzy set theory has been concerned with engineering applications. Certain types of uncertainties are encountered in a variety of areas and the fuzzy set theory has pointed out to be very efficient to consider these (Kaya and Çınar, 2008).

2.3 Artificial neural networks
Artificial neural networks (ANN) are optimization algorithms which are recently being used in variety of applications with great success. Artificial neural network (ANN) models take inspiration from the basic framework of the brain. The main parts of a neuron are cell body, axon and dendrites. A signal transport from axon to dendrites and passing through other neurons by synapses (Fu, 1994). ANN consists of many nodes and connecting synapses. Nodes operate in parallel and communicate with each other through connecting synapses. ANN is used effectively for pattern recognition and regression. In recent years, experts prefer ANN over classical statistical methods as a forecasting model. This increasing interest can be explained by some basic properties of ANN. Extrapolating from historical data to generate forecasts, solving the complex nonlinear problems successively and high computation rate are features that are the reasons for many experts to prefer ANN. Moreover, there is no requirement for any assumptions in ANN (Pal and Mitra, 1992). Neural networks can be classified according to their architectures as single layer feed-forward networks, multilayer feed-forward networks and recurrent neural network. The most important section of ANN is training. Training is another name of seeking the correct weight values. While classical statistical techniques only estimate the coefficient of independent variables, ANN selects proper weights during training and keeps them for further use to predict the output (Cheng and Titterington, 1994). There are three types of learning processes; supervised, unsupervised and reinforcement learning.

2.4 Evolutionary computation
Evolutionary computation concept based on Darwin’s evolution theory by applying the biological principle of natural evolution to artificial systems for the solution of optimization problems has received significant attention during the last two decades,
although the origins were introduced in the late 1950s with works of Bremermann in 1962, Friedberg in 1958 and 1959, and Box in 1957, and others (Back et al., 1997). The domain of evolutionary computation involves the study of the foundations and the applications of computational techniques based on the principles of natural evolution. Evolutionary algorithms employ this powerful design philosophy to find solutions to hard problems from different domains, including optimization, automatic programming, circuit design, machine learning, economics, ecology, and population genetics, to mention but a few. Evolutionary computation for solving optimization and other problems has considerable advantages. The first and important advantage is adaptability for fluxional situations. Unlike many traditional optimization procedures where the calculation must be restarted from the beginning if any variable in the problem changes, evolutionary computation does not need to restart from beginning since the current population serves as a memoir of stored knowledge that can be applied on the fly to a dynamic environment. Therefore, traditional optimization methods are more computationally expensive than the evolutionary computation. Another advantage of an evolutionary computation to problem solving comes in being able to generate good enough solutions quickly enough for them to be of use (Kahraman et al., 2010). There are several techniques of evolutionary computations, among which the best known ones are genetic algorithms, genetic programming, evolution strategies, classifier systems and evolutionary programming; though different in the specifics they are all based on the same general principles (Back et al., 1997; Dimopoulos and Zalzala, 2000; Pena-Reyes and Sipper, 2000).

2.4.1 Genetic algorithms. Genetic algorithms (GAs) which were first developed by Holland in 1975 are based on mechanics of natural selection and genetics to search through decision space for optimal solutions. The metaphor underlying GAs is natural selection. Genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. GAs can be categorized as global search heuristics. GAs are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination). GAs are stochastic search methods based on the genetic process of biological organisms. Unlike conventional optimization methods, GAs maintain a set of potential solutions (populations) in each generation. A GA is encoding the factors of a problem by chromosomes, where each gene represents a feature of problem. In evolution, the problem that each species faces is to search for beneficial adaptations to the complicated and changing environment. In other words, each species has to change its chromosome combination to survive in the living world. In GA, a string represents a set of decisions (chromosome combination), that is a potential solution to a problem. Each string is evaluated on its performance with respect to the fitness function (objective function). The ones with better performance (fitness value) are more likely to survive than the ones with worse performance. Then the genetic information is exchanged between strings by crossover and perturbed by mutation. The result is a new generation with (usually) better survival abilities. This process is repeated until the strings in the new generation are identical, or certain termination conditions are met. This algorithm is continued until the stopping criterion is reached. GAs are different from other search procedures in the following ways:
• GAs consider many points in the search space simultaneously, rather than a single point;
• GAs work directly with strings of characters representing the parameter set, not the parameters themselves;
• GAs use probabilistic rules to guide their search, not deterministic rules.

Because GAs consider many points in the search space simultaneously there is a reduced chance of converging to local optima. In a conventional search, based on a decision rule, a single point is considered and that is unreliable in multimodal space. GAs consist of four main sections as: Encoding, Selection, Reproduction, and Termination (Kaya and Engin, 2007; Engin et al., 2008; Kaya, 2009a, 2009b).

2.4.2 Genetic programming. Genetic programming (GP) developed by Koza (1990, 1992) is an evolutionary algorithm-based methodology inspired by biological evolution to find computer programs that perform a user-defined task. It is defined by Koza (1990) as “... genetic programming paradigm, populations of computer programs are genetically bred using the Darwinian principle of survival of the fittest and using a genetic crossover (recombination) operator appropriate for genetically mating computer programs”. In GP, instead of encoding possible solutions to a problem as a fixed-length character string, they are encoded as computer programs. The individuals in the population are programs that – when executed – are the candidate solutions to the problem. It is a specialization of genetic algorithms where each individual is a computer program. Therefore, it is a machine learning technique used to optimize a population of computer programs according to a fitness landscape determined by a program’s ability to perform a given computational task (Kahraman et al., 2010).

2.4.3 Evolution strategies. Evolution strategies use natural problem-dependent representations, and primarily mutation and selection as search operators were introduced by Ingo Rechenberg and Hans Paul Schwefel in the 1960s (Pena-Reyes and Sipper, 2000) as a method for solving parameter-optimization problems. Mutation is the major genetic operator in evolution strategies. It also plays the role of a reproduction operator given that the mutated individual is viewed as an offspring for the selection operator to work on. One of the commonly proposed advantages of evolution strategies (ESs) is that they can be easily parallelized. ESs with \( \lambda \) offspring per generation (population size \( \lambda \)) are usually parallelized by distributing the function evaluation for each of the offspring on a different processor. However, when the number of offspring is smaller than the number of available processors, the advantage of using evolution strategies in parallel cannot be fully exploited. Consequently, when large numbers of processors are available, it is desirable to develop an algorithm that can handle a large population efficiently (Hansen et al., 2003).

2.4.4 Evolutionary programming. Evolutionary programming (EP) was first used by Lawrence J. Fogel in the 1960s in order to use simulated evolution as a learning process aiming to generate artificial intelligence. Fogel used finite state machines as predictors and evolved them. It has been applied with success to many numerical and combinatorial optimization problems in recent years. Like with evolution strategies, evolutionary programming first generates offspring and then selects the next generation. It is becoming harder to distinguish it from evolutionary strategies. Some of its original variants are quite similar to the later
genetic programming, except that the program structure is fixed and its numerical parameters are allowed to evolve. Formulating EP as a special case of the generate-and-test method establishes a bridge between EP and other search algorithms, such as evolution strategies, GAs, simulated annealing, tabu search, and others, and thus facilitates cross-fertilization among different research areas (Yao, 1999; Kahraman et al., 2010).

2.4.5 Classifier systems. Classifier systems (CSs), presented by J.H. Holland in the 1970s, are evolution-based learning systems, rather than a “pure” evolutionary algorithm. They can be thought of as restricted versions of classical rule-based systems, with the addition of input and output interfaces. A classifier system consists of three main components:

(1) the rule and message system, which performs the inference and defines the behavior of the whole system;

(2) the apportionment of credit system, which adapts the behavior by credit assignment; and

(3) the GAs, which adapt the system’s knowledge by rule discovery (Pena-Reyes and Sipper, 2000).

CSs exploit evolutionary computation and reinforcement learning to develop a set of condition-action rules (i.e., the classifiers) which represent a target task that the system has learned from on-line experience. There are many models of CSs and therefore also many ways of defining what a learning classifier system is. Nevertheless, all CS models, more or less, comprise four main components:

(1) a finite population of condition action rules, called classifiers, that represents the current knowledge of the system;

(2) the performance component, which governs the interaction with the environment;

(3) the reinforcement component, which distributes the reward received from the environment to the classifiers accountable for the rewards obtained; and

(4) the discovery component, which is responsible for discovering better rules and improving existing ones through a GA (Holmes et al., 2002).

2.4.6 Ant colony optimization. In the early 1990s, ant colony optimization (ACO) which is a class of optimization algorithms modeled on the actions of a real ant colony was introduced by M. Dorigo and colleagues as a novel nature-inspired metaheuristic for the solution of hard combinatorial optimization problems. The inspiring source of ACO is the foraging behavior of real ants (Dorigo and Gambardella, 1997). In general, the ACO approach attempts to solve an optimization problem by repeating the following two steps (Dorigo and Blum, 2005):

(1) Candidate solutions are constructed using a pheromone model, that is, a parameterized probability distribution over the solution space.

(2) The candidate solutions are used to modify the pheromone values in a way that is deemed to bias future sampling toward high quality solutions.
2.4.7 Particle swarm optimization. Particle swarm optimization (PSO) which is population based stochastic optimization technique developed by Kennedy and Eberhart (1995), inspired by social behavior of bird flocking or fish schooling is a global optimization algorithm for dealing with problems in which a best solution can be represented as a point or surface in an $n$-dimensional space. PSO shares many similarities with evolutionary computation techniques such as genetic algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles (Kahraman et al., 2010).

2.5 Hybrid systems
Although the sufficient results found by computational intelligence techniques, more effective solutions can be obtained when used combination of these techniques. Each combination has an aim to decrease the limitation of one method. For example, genetic algorithm has been used to improve the performance of artificial neural networks in literature. Usage of genetic algorithms in artificial neural networks for training or finding the appropriate architecture can keep from getting trapped at local minima. Another example is using fuzzy inference with other computational intelligence techniques. A fuzzy inference system can take linguistic information (linguistic rules) from human experts and also adapt itself using numerical data to achieve better performance. Generally, using hybrid systems provides synergy to the resulting system in the advantages of the constituent techniques and avoids their shortcomings (Jang and Sun, 1995).

3. Literature review
In Table I, the frequency of the papers including the keywords “enterprise information management (EIM)” and “intelligence techniques” are given for the years 2007-2011. When a search was made with respect to the keywords “EIM” and “fuzzy set theory (FST)” as an intelligence technique, totally 200 articles were viewed. When it was made with respect to the keywords “EIM” and “intelligence techniques”, totally 531 articles were viewed. At the same time, these papers were classified based on their keywords. For example, the number of the papers using the “multi-agent systems (MAS)” and “neural networks (NNs)” are 147 and 108, respectively.

A pie chart which summarizes the distribution of the papers on intelligence decision systems in enterprise information management is given in Figure 1. As it is seen from

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Table I. The results based on publication years
Figure 1, the papers have taken more attention from year to year. Of these papers, 25 percent have been published in the last two years. It can be concluded that intelligence decision systems in enterprise information management will take more and more attention in the next years.

The percentages of the published papers on intelligence techniques in EIM are shown in Figure 2. As can be seen from this pie chart, the FST is the most used technique for EIM with 38 percent whereas the MAS and NN are the successors with 28 percent and 20 percent, respectively. PSO and ACO are the least used two intelligence techniques for this aim with 2 percent.

The papers related to the FST in EIM are also classified based on their subject areas and the frequency distribution of these papers as in Figure 3. As it is seen from Figure 3, the most of these papers are related to “computer science” and totally 155 papers have been published in this area. The next areas are “engineering” and “decision sciences” with 154 and 61 papers, respectively.

Chang et al. (2011) list the criteria that influence supplier selection, and constructs the strategy map among these criteria using the fuzzy set theory. The strategy map revealed interdependencies among these criteria and their strengths. Chen et al. (2010)
introduced fuzzy trust evaluation method for sharing knowledge derived from the activities of a virtual enterprise (VE) and the interactions among allied enterprises, including collaborative relations and the period of collaboration, is developed. Consisting of the evaluation of the correlation among activities, current trust and of integral trust, the method assessed current trust via fuzzy rule based system having the inputs of collaborative time, activity correlation and collaborative relation. The study had a potential of not only enhancing information sharing, but also increasing the efficiency and competitiveness of VEs. Chen and Lin (2009) proposed a fuzzy linguistic performance index based on flow network model to evaluate the performance of an ERP system depending upon the linguistic grades of an ERP examination of the company users involved. The study contributed to ERP pre-implementing for making decision. Tai and Chen (2009) proposed a suitable model for intellectual capital performance evaluation by combining 2-tuple fuzzy linguistic approach with multiple criteria decision-making (MCDM) method. Karsak and Ozogul (2009) used QFD, fuzzy linear regression and 0–1 goal programming by integrating them in the ERP selection problem. ERP characteristics were obtained from vendors in the market and customer requirements by regarding the company profile and strategic selection criteria. ERP system selection was performed with respect to weighted sum of deviations from the maximum achievable values for company needs. Xirogiannis et al. (2008) discussed a novel approach of designing a decision-modeling tool, which assesses the impact of contemporary human resource management (HRM) practices to the shareholder value and satisfaction. The proposed methodology utilized the fuzzy causal characteristics of fuzzy cognitive maps (FCMs) to generate a hierarchical and dynamic network of interconnected HR performance drivers. The intelligent computing characteristics of FCMs were also employed to establish a dynamic feedback and bi-directional alignment of HRM practices and strategic improvement. Zhang and Lu (2007) proposed a fuzzy bilevel decision making model for a general logistics planning problem and develops a fuzzy number based $K$th-best approach to find an optimal solution for the proposed fuzzy bilevel decision problem. The proposed approach illustrated an optimal solution in logistics management, which meets maximally/minimally the objectives of
both supplier and distributor (or other parts of the logistics chain). Kulak et al. (2005) employed information axiom to technology project selection problem. Return on investment, user satisfaction, operational agility, and strategic competitiveness were considered under both crisp and fuzzy environment. Liu et al. (2005) presented a competence appraisement model of human resource in an enterprise. The paper put forward the appraisement index architecture of enterprise human resource competence on the foundation of adopting the concept and models of competence, and establishes a general model of the enterprise human resource competence appraisement. Li et al. (2003) developed an analytical formwork which captures the process of information flowing, and then established a practical method on fuzzy set theory to assess effectiveness of information flow control. With result of study, the enterprise could conduct itself to have cognizance of enterprise information management comprehensively. Harigopal (2001) proposed cognizant enterprise maturity model is a unique five-level maturity model that provides a roadmap for businesses/organizations to evolve their capabilities for realizing immediate value. The application could be meaningful for standardization and stimulate more cross-disciplinary research and development in cognizant enterprise. Chan et al. (2000) proposed an integrated approach for the automatic design of flexible manufacturing systems (FMS), which uses simulation and fuzzy multi-criteria decision-making techniques. The design process consists of constructing and testing the alternative designs using simulation methods. The selection of the most suitable design based on a multi-criteria decision-making technique, the fuzzy analytic hierarchy process, was employed to analyze the output from the FMS simulation models.

MAS are the second most used technique for EIM. The papers related to MAS for EIM are classified based on their subject areas. A pie chart for this analysis is illustrated in Figure 4. As it is seen from Figure 4, the area “Computer Science” is the most popular area for the application of MAS with 41 percent whereas the areas
“Engineering” and “Decision Sciences” are the following areas with the percentages 38 and 9, respectively.

Liu et al. (2011) concerned with unexpected events (i.e. inventory failure, increased demand fluctuations, and delivery delay) in e-procurement by using multi-agent system. Having a hierarchical framework, the system was simulated within a restaurant e-procurement. The study of Fu et al. (2008) addressed the problems, such as sharing of information, the ability to extend and re-engineer, and the reusable ability of legacy systems in distributed and heterogeneous environments. A method based on agent and ontology was proposed to design knowledge management system, which includes two agencies, namely knowledge and application agencies. The effectiveness of the system for small and medium-size enterprises was tested. Cerrada et al. (2007) described a model for managing faults in industrial processes. The model had a generic framework that uses multi agent system (MAS) for distributed control systems. The system managed faults with feedback control process and decides about the scheduling of the preventive maintenance tasks, also running preventive and corrective specific maintenance tasks. Monteiro et al. (2007) addressed a hierarchical architecture to integrate individual planner agent, negotiator agent, and mediator agent with a decentralized control for achieving robustness and flexibility of the supply chain network. The negotiator agent was responsible for limiting the negotiation process and facilitating cooperation between production centers. Qiu et al. (2006) argued that workflow management technology promotes the automation of enterprise business processes. Multi-agents were utilized in the decomposed material flow management instances that directly interact with enterprise workflow systems. That information on material usage and movement can be reflected to planning department in a timely manner was provided. Kishore et al. (2006) synthesized literature in the areas of integrated business information systems (IBIS) systems and multi-agent systems with the intent of developing comprehensive foundation ontology for the universe of Multiagent-based Integrative Business Information Systems (MIBIS). Based on this review and synthesis, they identified a set of eight ontological constructs (i.e. goal, role, interaction, task, information, knowledge, resource, and agent) for MIBIS modeling that are minimally required to model a system efficiently, precisely, and unambiguously in the MIBIS universe. Caridi et al. (2006) conduct the analysis of the multi-agent system to automate and optimize collaboration along the supply chain via introducing two consecutive multi-agent systems. They focused on Collaborative Planning Forecasting and Replenishment (CPFR), a nine-step approach which provide volunteer standards, protocols, guidelines, etc. required to exchange sales and order forecasts between trading partners. The system had the potential of including inventory management, sales management and production management, along all the supply chain. Providing a comprehensive review of studies about intelligent agents applications for supply chain, Mangina and Vlachos (2005) focused on the effects of MAS on beverage supply chains. It was argued that the efficiency might be increased through the elimination of unexpected mistakes, information visibility and information quality improves, excessive inventory and severe delays will be reduced, capacities will be balanced and customer service will be improved by pre-processing and filtering of information. While discussing hybrid multi-agent system architecture for enterprise integration using a computer network, Nahm and Ishikawa (2005) described that the discrete real-world was dynamic because of a diverse, frequently changing situation,
and there will be no obligation for a person or computerized agent to remain with a network for a certain period. They proposed a hybrid multi-agent architecture for enterprise that updates internal and external states regularly. In the research of Li et al. (2004), an agent that incorporates the working mechanism of expert systems was designed to assist a designer with the aim of shortening the product design cycle. Symeonidis et al. (2003) proposed an intelligent policy recommendation multi-agent system (that introduces adaptive intelligence as an add-on for ERP software customization). They combined multi-agent and data mining technologies to provide intelligent decision support to supply chain management. A flexible multi-agent system for supply chains that can adapt to transaction changes brought about by new products or trading partners was presented in Ahn et al. (2003). The system contributed to the flexibility of adapting to new products or new trading partners that involve changes in transactions. Anumba et al. (2001) emphasized the potential of multi-agents systems (MAS) for collaborate design the characteristics of which were interdisciplinary interaction and negotiation in design. Agent coordination issues for decision support applications was addressed by Bui and Lee (1999) and taxonomy of agent characteristics was proposed. A development lifecycle that looks at agent-based DSS as being a design of coordinated agents to optimally support a problem-solving process was also presented.

The other technique used in EIM is NNs. As it is seen from Figure 5, NNs have generally been used in the area “Computer Science” for EIM and the percentage of this area is 40. The second most popular area for the using of NNs is the area “Engineering” with 29 percent.

Lee et al. (2011) focused on demand and supply chain management and examined how artificial intelligence techniques and RFID technology could enhance the responsiveness of the logistics workflow. The proposed system determined the correct replenishment strategy by automatically classifying the distribution patterns within the complex demand and supply chain. In a recent study, Zhao and Yu (2011)

![Figure 5. A pie chart for papers related to NNS for EIM](image-url)
introduced a case based reasoning framework for supplier selection in petroleum enterprises. The method based on data mining techniques which solves three key problems of case reasoning system, includes calculating the weights of the attributes with information entropy in case warehouse organizing process objectively, evaluating the similarities with $k$-prototype clustering between the original and target cases in case retrieving process exactly, and extracting the potential rules with back propagation neural networks from conclusions in maintenance and revising process efficiently. Addressing how to coordinate a rule-based system and supervised learning for making more flexible the production planning activity, López-Ortega and Villar-Medina (2009) utilized a feed-forward neural network (FANN), which was embedded in a machine agent with the aim of determining the appropriate machine in order to fulfill clients’ requirements. Also, an expert system was provided to a tool agent, which in turn was in charge of inferring the right tooling. Chen and Du (2009) aimed at the financial and the non-financial ratios in the financial statement, and used the back-propagation network (BPN), a neural network that used a supervised learning method and feed-forward architecture, and the clustering model to compare the performance of the financial distress predictions, in order to find a better early-warning method. The authors concluded that the artificial neural network (ANN) approach obtains better prediction accuracy than the data mining clustering approach by developing a financial distress prediction model. Chang et al. (2008) proposed a neural network evaluation model for Enterprise Resource planning (ERP) performance from Supply Chain Management (SCM) perspective. The survey data were gathered from a transnational textile firm in Taiwan. The authors indicated that while the external environments and alliance partnerships facing an enterprise were becoming more complex, executive should enhance efficiency and performance of supply chain management as well as to gain potential competitive advantages. Considering price, quality, reputation, service and improvement culture of suppliers, Choy et al. (2002) used an artificial neural network to design an intelligent supplier relationship management system in order to benchmark suppliers’ performance and shorten the cycle time of outsourcing. Moreover, the model was applied for new product development process in a company in Hong Kong.

The other intelligence techniques such as GA, ACO and PSO have been used in EIM. In this subsection, some papers using GA, ACO and PSO in EIM in the literature are briefly summarized. MeiLin et al. (2010) addressed the problem of dynamic job shop scheduling. Introducing a new ant moving strategy, the methodology utilized the real-time feedback from the Manufacturing Execution System Intelligent Data Terminal was in the new pheromone updating rule. Its application in the production process in a mould and Die enterprise lead to 23 percent decrease in the manufacturing cycle of products. In addition to the achievements about scheduling performance, the methodology enhanced management control in workshops via reducing the workload of the workshop manager by 80 percent. Irani et al. (2009) presented a model that defines a relationship between knowledge management and organizational learning, and highlights factors that can lead a firm to develop itself towards a learning organization via fuzzy cognitive mapping. The study revealed that the model developed showed that a relationship does exist between knowledge management and organizational learning and each knowledge concept engenders/fosters realization of the other. Xiaobing et al. (2008) proposed an ACO model for the minimization of costs
in alloy management. In the proposed model, the usage of each element was tried to be kept close to the pre-determined target value. When compared to linear programming model, the effectiveness of ACO model was demonstrated in terms of computational burden and solution quality by means of the application in Enterprise Resource Planning (ERP) integrated information system of a special steel enterprise. Sun and Li (2007) developed a multi-classification model for the evaluation of a customer service center of a power supply enterprise which adopts Customer Relationship Management (CRM). Considering economic performance, social performance and business quality of the system, the model utilizes principal component for assigning weights to indicators. As an original feature, evaluation classes are determined via decision tree. The evaluation result shows that the model has better accuracy of the classification and practicality. In the research of classifying and segmentation with RFM (recency, frequency and monetary) field, Cheng and Chen (2009) employed RFM attributes and K-means algorithm into Rough set theory to mind accuracy classification rules which can be used for driving an CRM in an enterprise. Within the model, after continuous attributes are discretized for rough set theory, costumers are clustured. Then, the characteristic of customer is determined via extracting rules. The methodology outperforms decision tree, neural network and naíve bayes in terms of accuracy rate regardless of the number of generated classes on output, and yields understandable decision rules. Providing a classification of artificial and computational intelligence techniques, Wu (2010) presented a business intelligence system including optimizer, predictor and classifier. The author suggested that real-coded genetic algorithm (RGA) or artificial immune system (AIS) should be used to optimize the parameter settings of the intelligent business intelligence system. Kuo et al. (2010) introduced a genetic programming-based knowledge-evolution framework to search for a good integrated classification tree with different evolving time points. In the proposed model, each member was represented as a classification tree (CT), and each CT represents a rule set, which is randomly generated, completely by the identical random function and not limited for original knowledge. Herrera et al. (2001) utilized a genetic algorithm that considered the requirements of positions and the relationships among candidates, and solved personnel assignment problem with verbal information. Both personnel skills and position requirements are expressed via fuzzy numbers. Emphasizing the importance of both geographical information systems and internet on bridge maintenance management, Liu and Itoh (2001) applied genetic algorithm for the rehabilitation plan of bridge decks with the aim of minimizing rehabilitation cost and deterioration degree simultaneously. Lu et al. (2009, 2010) presented a novel risk management model for Virtual Enterprise (VE), a Constructional Distributed Decision Making (CDDM) model where the situation of information symmetry between owner and partners is considered. They considered various risks for VE, due to VE’s agility and diversity of its members and its distributed characteristics and proposed a Multi-swarm Particle Swarm Optimization (MPSO) to solve the resulting optimization problem. In the hybrid method of Gao et al. (2009) the wide range of mapping capabilities of artificial neural network (ANN) and the global search ability of particle swarm optimization were combined to find the global optimal solution during ANN training process. The method was applied to evaluate business efficiency in terms of financial statements. Niu and Gu (2007) established a hybrid genetic particle swarm optimization algorithm for a material purchase and storage optimization for electric
power plants to minimize the cost based on its characteristic of raw material stock. The algorithm combined the evolution idea of genetic algorithm (GA) with population intellectual technique of particle swarm optimization (PSO) algorithm.

4. Conclusions
In this paper, the roles of intelligence techniques in EIM are discussed to obtain a successful business strategy. EIM systems in many companies have been developed following the needs arising from administration, control, reporting and transaction management. EIM focus must be shifted from general management and control to a development of the means and solutions to enable integration of cross-functional teams, key business processes, performance management, information and knowledge to increase profitable market share.

Intelligence techniques are rapidly emerging as new tools in information management systems. Especially, intelligence techniques can be used to utilize decision process of EIM. These techniques can increase sensitiveness, flexibility and accuracy of information management systems. Creation and implementation of EIM strategy and investment decisions needs to be guided by not only intelligence techniques but also business strategy and needs. If it successes, the intelligence decision systems arrive its best benefit.

The hybrid systems that contain two of more intelligence techniques will be more used in the future. So, the hybrid intelligence systems in enterprise information management should get the necessary importance from practitioners and academicians.

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