Information Systems International Conference (ISICO), 2 – 4 December 2013

Design of an Intelligent Warehouse Management System

Reza Pulungan*, Simon Pulung Nugroho, Nova El Maidah***, Tri Bowo Atmojo*, Putut Dewanto Hardo*, Panggih Pawenang***

*Jurusan Ilmu Komputer dan Elektronika, Universitas Gadjah Mada, Yogyakarta, Indonesia
**Department of Informatics, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia
***Department of Informatics, Universitas Teknologi Yogyakarta, Indonesia

Keywords:
WMS
RFID
Neural Network
Bee Colony Optimization
Fuzzy Control
Android
GDSS

ABSTRACT

Warehouse Management System (WMS) is a new paradigm on integrating a set of business processes. The primary goal of WMS is to efficiently control all activities in an organization. However, most of existing WMSs focus mainly on data input, data processing, and report generation. Recent researches attempt to make use of results from the field of intelligent system in parts of the business processes within WMSs.

This paper proposes a new alternative to WMS. It is called intelligent WMS (i-WMS). This system consists of five subsystems: *intelligent logistic system, intelligent warehouse system, real-time transportation monitoring, intelligent sales forecasting system,* and *intelligent executive summary system*. The reported research in this paper integrates state-of-the-art results in the field of intelligent systems—neural network, bee colony optimization, fuzzy control, and decision support system—together with the latest technologies—RFID and Android-based handheld devices—in every part of business processes in WMS.

Corresponding Author:

Reza Pulungan
Jurusan Ilmu Komputer dan Elektronika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Gadjah Mada, Yogyakarta, Indonesia
Email: pulungan@ugm.ac.id

1. INTRODUCTION

Warehouse Management System (WMS) is one of effective strategies to accelerate an organization's development by giving priorities on the reliability of its supply chain. The main purpose of WMS is to efficiently control all processes in the supply chain (the reception and delivery of products, stock facilities management, stock of products, and packing and shipping). However, WMS development paradigm so far is focused only on the classical data management, where input from the end user is the main determinant of output validity or the resulting decisions. This raises many problems, especially in the supply chain management of national-scale retail companies, where high thoroughness, accuracy, and precision are the demands of supply chain managers. Even though a company uses WMS, human characters and cases diversities still cause supply chain managers to be the target of mistakes in every muddle of data processing and product distribution. Is the product expired before sending? Do the products have defects when sent to the reseller? Is there any mistake in stock product demand? Do stock products pile up in the warehouse?

These classic WMS limitations certainly are not advantageous for the organization because WMS typically needs large budget allocation. This problem becomes even more complex because WMS is urgently needed in organizations that handle goods that are easily expired, such as agroindustry businesses. As an agricultural country, the development of agroindustry becomes one of the milestones of food security in Indonesia. Agroindustry has been able to give real contributions for the development of the developed countries because: (1) agroindustry conducts raw material transformation including the transformation of subsistence products into final products for customers; (2) agroindustry is able to create working opportunity; (3) agroindustry processes yield important export commodities; (4) agroindustry saves the cost by reducing the production loss after harvest and creates distribution link [1].

An intelligent warehouse integrates computer systems, material handling equipment, storage equipment, and users into a single integrated work element [2]. The new breakthrough developed to overcome the limitations of the traditional WMS is i-WMS (Intelligent Warehouse Management System). I-WMS is a solution in the supply chain field obtained by applying results from intelligent systems to WMS processes. The i-WMS model gathers several artificial intelligence techniques to support warehouse management activities as shown in Figure 1.

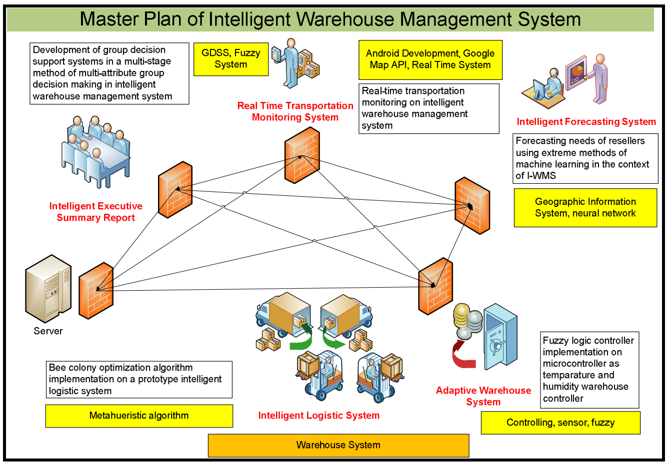

Figure 1. The Master Plan of Intelligent Warehouse Management System

2. RESEARCH METHOD

The research reported in this paper tries to contribute to a new discourse on i-WMS development. Specifically, the contribution consists of (1) providing a brief description on the practical implementation of artificial intelligence in the main WMS processes; (2) providing an explanation on how to the use new technologies, such as bee colony optimization, fuzzy controlling, extreme learning machine, RFID, group decision support system (GDSS), and Android programming, in WMS development; and (3) providing a data integration model in the heterogeneity of applications among subsystems that are going to be built.

The i-WMS system consists in five subsystems, namely: (1) Intelligent Logistics System (ILS), which will use bee-colony optimization algorithm to create effective order schedules; (2) Adaptive Warehouse System (AWS) in order to place goods in the storage based on ideal temperature and its expiration time; (3) Intelligent Forecasting System (IFS), which will use extreme learning-machine algorithm to effectively predict the number and the inventory of products such that reseller's needs can be fulfilled on time; (4) Real-Time Transportation Monitoring System (RTMS) to provide goods delivery information and visualization by using Google maps supported by GPS, GPRS, and RFID; and (5) Intelligent Executive Summary System (IESS) to compile decision recommendations for decision makers using a GDSS (Group Decision Support System). All subsystems work together according to their functionality as depicted in Figure 1.

3. RESULT AND ANALYSIS

In this section, we provide analysis and discussion on the practical implementation of artificial intelligence in each of the i-WMS' subsystems.

3.1 Intelligent Logistic System

Intelligent Logistics System (ILS) is a subsystem that serves as the controller of the logistics process from freight storage to the consumer. Figure 2 shows the ILS work area. Factors that need to be considered in the development of the logistics system are the number of orders to be completed, inventory of goods in the warehouse, the number of fleets required to deliver goods, and payload capacity of each fleet. In addition, consumer needs are not only limited to physical needs (fulfillment of ordered goods) but also non-physical needs, such as satisfaction when booking or purchasing goods or services, delivery timeliness, and completeness of goods [3]. In other words, the core problem in the logistics system is to make the delivery schedules in such a way that it can meet the needs of consumers [4].

The ILS workflow, shown in Figure 3, consists of 4 stages, namely orders collection, orders grouping, determination of eligible orders, and scheduling delivery for eligible orders. The last stage in the workflow is the process of scheduling orders with the aim of optimizing the delivery time of goods. The core issue at this stage is to determine the combination of orders and fleet carriers such that an optimal time distribution of all goods is achieved [5]. ILS uses Bee Colony Optimization (BCO) algorithm as a method to perform scheduling optimizations. BCO algorithm consists of two phases, forward and backward. The forward phase aims at exploring alternative solutions that area available, while the backward phase is performed in order to determine the best solution among alternative solutions resulting from the forward phase [6].

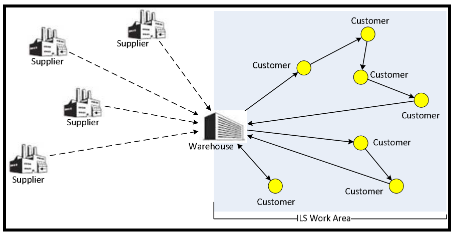

Figure 2. ILS Work Area

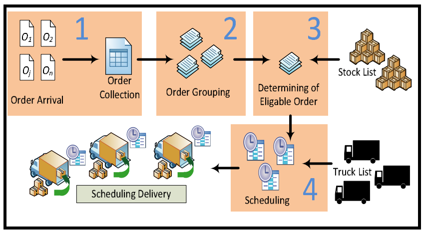

Figure 3. ILS Workflow

3.2 Adaptive Warehouse System

Adaptive Warehouse System (AWS) manages the repository of pending items before they are distributed. The repository is expected to maintain the quality of goods; hence, AWS must be able to determine goods input and output by using FEFO (First Expired First Out) method. AWS must intelligently adjust the operating temperature of the repository using a microcontroller with fuzzy operations. Fuzzy logic operators (Fuzzy Logic Control/FLC) for operating air-conditioning in cars [7] and for controling greenhouse climate [8] have been reported; both, however, are still in the form of simulation in Matlab. In [9] FLC controls electricity consumption for room air conditioners. FCL has also been applied in hardware using CMOS electronic components [10]. In [11] FLC has been applied on an LPC2148 microcontroller. In the current research, FLC is used for handling fuzzy operation to control temperature and humidity in a repository based on readings from RFID signals by using microcontroller ATmega32.

The FLC controls the environment of goods in the warehouse. To detect what kind the goods in the warehouse, RFID CR 013 [12] is used. RFID CR 013 is an active reader, but only transmits data if the main application requests for it. The RFID system provides information about the ideal temperature and humidity to store goods and how long they can be stored. Microcontroller ATmega32 is used at the core of AWS. The microcontroller handles all hardware communications amongst sensor, display, RFID system, actuator, and FCL. The microcontroller also processes data as input to the FCL, as well carries out the computation of the FCL. The output of the FCL is a desired state obtained by manipulating the actuators based on signals sent by the microcontroller.

3.3 Intelligent Forecasting System

Intelligent Forecasting System (IFS) focuses on forecasting demands. Efforts to improve the prediction accuracy rate had been done by complementing conventional forecasting methods with artificial intelligence approaches [13], and this has resulted in an increased forecasting accuracy. One of the methods used is artificial neural network (ANN), such as Extreme Learning Machine (ELM). Therefore, IFS was developed with the aim to improve the accuracy of demand forecasting. Forecasting is done by considering multiple data models, namely time series, seasonal, cyclic, and randomized data [14]. The workflow of the IFS is depicted in Figure 4.

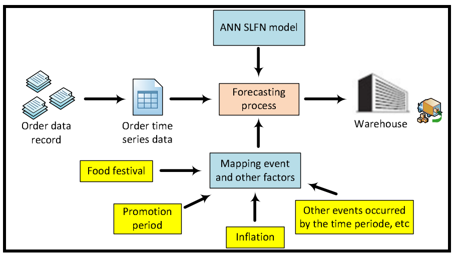

Figure 4. IFS Workflow

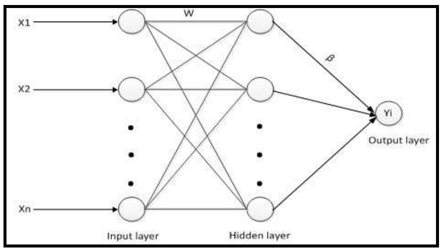

Figure 5. The Model of ANN-SLFN

The ANN model used in this subsystem is the single-hidden layer feed-forward network (SLFN) with ELM as a learning method [15]; the model is depicted in Figure 5. The model consists of 3 layers, namely input, hidden, and output layers. The input layer represents factors that are thought to affect forecasting. The hidden layer represents a computing process, which is carried out by passing values obtained from the input layer using a particular activation function at each neuron in the hidden layer. The output layer produces the forecasting results [16]. ANN models, in general, require a method for learning. The method used, in this case, is ELM. Learning is performed to obtain the ideal weight for each node in the network. The ELM uses Moore-Penrose pseudo-inverse matrix to determine the ideal weights.

3.4 Real-Time Transportation Monitoring

Real-Time Transportation Monitoring System (RTMS) is responsible for monitoring the delivery and the distribution of goods from the warehouse to their destination. This subsystem can help companies reduce unnecessary costs and improve the timeliness of their delivery. Delivery of goods has a mission, namely sending the right stuff at the right place and time.

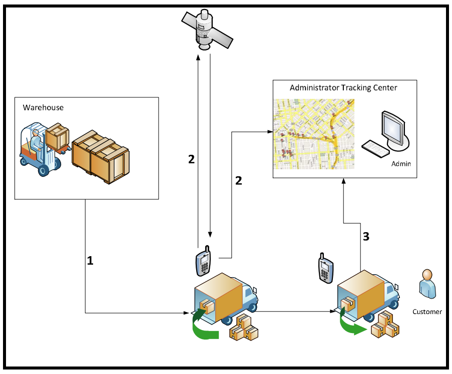

Figure 6. RTMS Workflow

An RFID tag is placed on all goods. This tag functions as an identity of the goods and contains its detailed information. Figure 6 shows the workflow of the RTMS, which can be summarized into three steps. (1) A logistic administrator creates a shipment schedule, containing the details of goods that are going to be shipped based on customer orders. (2) The fleet driver logs into a mobile application to obtain goods shipping list information from the logistic. During shipping, a mobile application periodically sends coordinate data of the current location (obtained from a Global Positioning System/GPS device attached to the fleet) from the shipping fleet to a designated server. The server receives coordinate data from the mobile application and visualizes the coordinates into a digital map so that logistic administrators can monitor the shipping process. (3) When the goods reach costumers, an RFID sensor in the mobile device is used to check the goods that will be received by the customers. The mobile device then sends the obtained data to the server through a GPRS connection to compare it with the logistics' database. Moreover, costumers provide confirmation of delivery using the same mobile application. Marketing can later use data obtained during these shipping processes for forecasting analysis.

3.5 Intelligent Executive Summary System

Intelligent Executive Summary System (IESS) is used to support decision-making process for decision makers. This is because the policy holder in warehouse management is not in the hands of one person alone. Furthermore, important decisions made by managers in organizations or experts take time. They are also constrained by many factors, such as the dominance of a particular member, inter-personal communication, and fears in expressing innovative ideas [17]. Group Decision Support System (GDSS) is designed to overcome the problems of decision-making group members having different perspectives and ideas. Multi-Criteria Decision Making (MCDM) method is developed to solve conflicting preferences between the criteria in making a single decision [18]. However, different alternatives collected at different stages at the decision process may be weighted differently. A Time-Weighted Averaging (TWA) operator can be used to combine the opinion of the group at different stages, such that it can be used to rank the best alternative [19]. The combination of these methods produces Multi-Stage Multi-Attribute Group Decision Making (MS-MAGDM), which is used in IESS as a powerful decision-making tool in the managerial level. The purpose of this GDSS is to help managerial level to get the best assessment of the supply chain performance over a period of time.

Figure 7 depicts the general architecture of MS-MAGDM. It shows that each decision maker provides judgment to every sub-criterion. Then, the values of all sub-criteria are aggregated with certain rules to form the final judgment of the corresponding criteria. Alternate decision is obtained in this step from every decision maker. Furthermore, each decision is accompanied by a scale, set by the team leader. The last step is to join all decisions in every stage by considering the provided scales to produce the final decision. The GDSS model, for instance, is able to give recommendation of suppliers based on many criteria—related to financial, product quality, product regulations, and technical matters—and history (stages) [20][21].

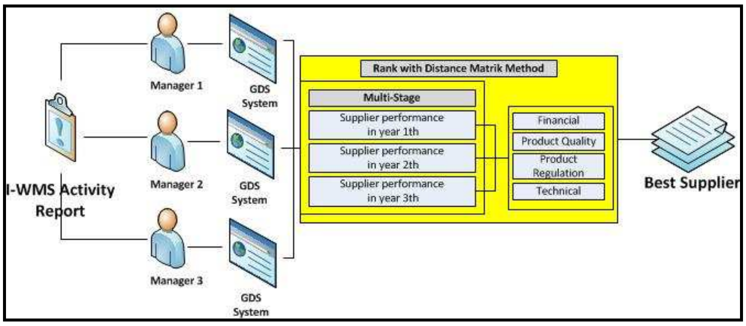

Figure 7. MS-MAGDM Architecture

The IESS uses multi-stage GDSS architecture model. Based on IWMS report, a firm manager provides a performance appraisal to the suppliers for a certain period. The preferences assessment is given in the form of fuzzy logic. At every stage, assessment is coupled by multiplying it with the agreed interest weight. After obtaining decision aggregations from every stage, they are combined again using the Time Weight Averaging [19]. Finally, a decision is reached by comparing the distance matrices of the spread fuzzy and the mean fuzzy for every prospective supplier [22]. The prospective supplier with the highest distance-matrix average value is the recommended supplier.

4. CONCLUSION

We have reported on our effort to incorporate several state-of-the-art results in the artificial intelligence research community into warehouse management system. Due to space limitation, we provided only brief discussions on the practical implementation of artificial intelligence in the main WMS processes and on how to the use new technologies—bee colony optimization, fuzzy controlling, extreme learning machine, RFID, group decision support system (GDSS, and Android programming—in WMS development. All subsystems of the i-WMS are available right now in the form of a software prototype. Together with an industrial partner, we are currently planning to deploy the prototype and to carry out further studies on the impact of the “intelligence” on the Warehouse Management System.

REFERENCES

[1] J.E. Austin, “Agroindustrial Project Analysis”, The John Hopkins University Press, Baltimore, Maryland, 1981.
[2] J.A. Tompkins, “Warehouse Management Systems Technology”, Tompkins Associations, New York, 2002.
[3] C.A. Silva, J.M.C. Sousa and T.A. Runkler, “Optimization of logistics system using fuzzy weighted aggregation”. Elsevier: Fuzzyset and Systems 158, pp.1947–1960, 2007.
[4] S. Carrera, W. Ramdane-Cherif and M. Portman, “Scheduling problem for logistic platform with fixed stair case component arrivals and various deliveries hypotheses”. 2nd International Conference on Applied Operational Research, pp. 517 – 528, 2010.
[5] P. Lucic and D. Teodorovic, “Bee system: modeling combinatorial optimization transportation engineering problems by swarm intelligence”. Preprints of the TRISTAN IV Triennial Symp. On Transportation Analysis, Sao Miguel, Azores Island, Portugal. Page 441 – 445, 2001.
[6] V. Arabnejad, A. Moeini and N. Moghadam, “Using Bee Colony Optimization to Solve the Task Scheduling Problem in Homogenous Systems”. International Journal of Computer Science (IJCS) Volume 8 Issue 5 No 3 September 2011. Page 348 – 353, 2011.
[7] X. Zhao, J. Zhang and D. Chen, “Simulation Analysis of Automobile Air Conditioner Based on Fuzzy Logic Control”, International Conference on Automation Engineering, pp. 169-173, 2009.
[8] P. Javadikia, A. Tabatabaeefar, M. Omid, R. Alimardani, and M. Fathi, “Evaluation of Intelligent Greenhouse Climate Control System”, Based Fuzzy Logic in Relation to Conventional Systems, International Conference on Artificial Intelligence and Computational Intelligence, pp. 145-150, 2009.
[9] T.M. Wang, P.C. Lin, H.L. Chan, J.C. Lia, T.W. Sun and T.U. Wu, “Energy Saving of Air Condition using Fuzzy Control over ZigBee Temperature Sensor”, International Conference on Advanced Information Networking and Application Workshop 4, pp. 1005-1010, 2010.
[10] V. Varshavsky, V. Marakhovsky, I. Levin and H. Saito, “Hardware Implementation of Fuzzy Controller", Fuzzy Controller, Theory and Applications, pp. 3-44, InTech, Croatia, 2011.
[11] S.B. Patil and S.D. Dhamakale, “Fuzzy Logic Approach with Microcontroller for Climate Controlling in Green House”, International Journal on Emerging Technologies, Vol. 2, pp. 17-19, 2011.
[12] User Manual CR 013 Serial Reader Protocol, 2013.
[13] S. Rampal and S. Balasundaram, “Application of Extreme Learning Machine Method for Time Series Analysis”, International Journal of Electrical and Computer Engineering 2:8 2007, pp 549-555, 2007.

[14] G. Ghiani, G. Laporte and R. Musmanno, "Introduction to Logistic System Planning and Control", John Wiley & Sons, London, England, 2004.
[15] M.A.A Hasin, S, Ghosh and M.A Shareef, "An ANN Approach to Demand Forecasting in Retail trade in Bangladesh", International Journal of Trade Economics and Finance, Vol. 2 No. 2 April 2011, Page 154-160, 2011.
[16] H. Guang-Bin, D. Xiaojian and Z. Hongming, "Optimization Method Based Extreme Learning Machine for Classification", Neurocomputing, Vol. 74 (2010), pp. 155-163, 2010.
[17] G.P Huber, "Issues in the Design of Group Decision Support Systems". Management Information Systems Quarterly, Vol. 8, 195-204, 1984.
[18] J.L. Corner and C.W. Kirkwood, "Decision Analysis Applications in the Operations Research Literature". Operation Research, Vol. 39(2), pp. 206-219, 1991.
[19] Z. Xu, "Approaches To Multi-Stage Multi-Attribute Group Decision Making". International Journal of Information Technology & Decision Making World Scientific, Vol. 10, pp. 121-146, 2011.
[20] C.A. Weber, J.R. Current and W.C. Benton, "Vendor Selection Criteria and Methods", European Journal of Operational Research, Vol. 50, 2-18, 1991.
[21] A. Tas, "A fuzzy AHP Approach for Selecting a Global Supplier in Pharmaceutical Industry", African Journal of Business Management, Vol. 6, 5073-5084, 2012.
[22] L.-S. Chen and C.-H. Cheng, "Selecting IS Personal use Fuzzy GDSS based on Metric Distance Method", European Journal of Operational Research, Elsevier, 803-820, 2005.

BIBLIOGRAPHY OF AUTHORS

	Reza Pulungan received his bachelor's degree in 1999 from Universitas Gadjah Mada, Indonesia; his master's degree in 2004 from the University of Twente, the Netherlands; and his doctoral degree in computer science in 2009 from Saarland University, Germany. Since 2009 he has been a lecturer and a researcher at the department of Computer Science and Electronics, Universitas Gadjah Mada. His research interests lie in the field of stochastic processes, especially Markov processes and phase-type distributions. He is also interested in modeling and analysis of networked systems.
	Simon Pulung Nugroho received his bachelor's degree in 2008 from STMIK AKAKOM Yogyakarta, Indonesia. He is completing his master's degree in computer science at Universitas Gajah Mada, Indonesia. Since 2010 he has been a lecturer and a researcher at the department of informatics, Universitas Pembangunan Nasional "Veteran" Yogyakarta. His research interests are in enterprise and network systems.
	Nova El Maidah received her bachelor's degree in 2008 from Universitas Gadjah Mada Yogyakarta, Indonesia. She is completing her master's degree in computer science at Universitas Gajah Mada, Indonesia. Since 2013 she has been a lecturer in the department of science and technology, Universitas Teknologi Yogyakarta. Her research interests are in control and fuzzy systems.
	Tri Bowo Atmojo received his bachelor's degree in electrical engineering from Universitas Tanjungpura in 2007. He is currently studying for his master's degree in computer science at Universitas Gadjah Mada, Indonesia. His research interests are in microcontroller and neural networks.
	Putut Dewanto Hardo received his bachelor's degree in 2004 from Sekolah Tinggi Ilmu Komunikasi Massa Surabaya, Indonesia. He is currently studying for his master's degree in computer science at Universitas Gadjah Mada, Indonesia. Since 2004 he has been working on telecomunication industry as a professional installer for network products such as CISCO network and JUNIPER. His research interests are in enterprise and network systems.
	Panggih Pawenang received his bachelor's degree in mathematics from Yogyakarta State University, Indonesia in 2009. He is currently studying for his master's degree in computer science at Universitas Gadjah Mada, Indonesia. His research interests are in the fields of scheduling and logistics systems.