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OPC Based Automated Three-dimensional Warehouse Management：Key Issues and Design Methodology

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ABSTRACT
Automated three-dimensional warehouses are now more and more widely utilized in logistics industry to enhance efficiency of storage allocation, storage location, assignment, etc. in logistic activities. Increasingly, there is a need to study strenuously to provide assurance that automated three-dimensional warehouses are well managed. Although a large volume of research findings is available on the topic, high efficiency automated three-dimensional warehouse management (ATWM) is always on the way. In this article, theoretical background and key issues related the ATWM are briefly reviewed, and then and OPC (OLE for process control) based ATWM approach is proposed. Also, overall functional architecture, flow-process diagram and functional module implement idea are described in detail. Prototype system of our design is implemented, and it shows a good practicability in storage location assignment, storage allocation and assignment and other critical operations. It is expected that our research set a good example for high-performance ATWM system design and implementation.
Keywords: *OPC; Automated three-dimensional warehouse; PLC*

I. INTRODUCTION

According to the supply chain management principle, modern logistics enterprises, such as FedEx, UPS etc., try to achieve high-volume production and distribution utilizing minimal inventories in the process of product dispatching and shipping. The most challenge point is to make sure the goods to be stored, allocated and delivered within short response times [1, 2]. As the increase of low volumes to be shipped within short response time from a great many stock keeping units, more and more companies incline to amalgamate several relatively small distribution centers into a lager one and managed with the help of information systems.

With the development of automation control, computer science, warehouse and other related technologies give rise to the emersion of automated three-dimensional warehouse. These changes have significantly boosted the existing paradigms in inventory study. However, too much attention has been paid to storage allocation or location algorithm modeling and control. Relatively less scholars spend their effort on theory to the management. It is usually considered warehouse management to be a technical issue, which belongs to the domain of material handling research. In this paper, we think ATWM is a both theoretical and technological issue, the latter usually lend it to a more practical matter.

II. GENERAL REVIEW OF WAREHOUSING SYSTEMS

2.1 Warehouse categories

Warehouse is popularly deemed as an important component in the supply chain of products. According to the purpose of usage, warehouses can be divided into three categories[3, 4]: (1) distribution warehouses, where products from a great number of suppliers are collected, sorted and labeled for shipment to different customers; (2) production warehouses, where raw materials for assembling or processing a commodity, semi-finished products or totally finished goods are stored, and (3) contract warehouses, where warehousing operation on behalf of one or more customers is provided as a facility, and a great deal of expertise for logistics demands are provided. There are still varies of criterions of warehouse division, but they have many features in common.

Material handling[5] is another kind an important activity, which is commonly defined as the movement of materials (raw materials, semi-products, end products, et al.) to, through and from productive processes (as can be shown in Fig 1). It concerns material flow and warehousing in storage or receiving and shipping areas. Typically, many devices, such as conveyors, fork lifts, automated guided vehicles (AGVs), shuttles, overhead cranes and power-and-free conveyors are involved in the process of material handling. In addition, receiving of goods, order-picking, sorting, etc. are all material handling related activities [6, 7].

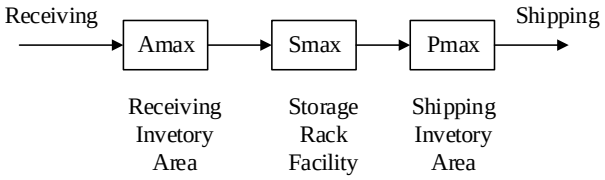

Fig. 1 Overall flow diagram within the warehouse

2.2 Warehousing activities

Here we review the entire process of materials managed in a warehouse. Commodities are shipped to the receiving areas by truck or other vehicles, and then followed by random quality checks and quantities verification of the goods. And then, bar code, magnetic labels or other digital signs are attached to the load. After these operations, the loads may be well prepared for transportation to the storage area of a warehouse. If materials for internal usage is different from that of the new incoming load, then they must be collected and placed in a special location within the storage area.

Order picking begins when a product request is submitted. The request may come from a customer, a distribution center or a production warehouse, with product name and the exact quantalities. If enough storage of the requested products is available, they must be carried to the shipping area and wait to be taken away. But additional accumulation and sorting may be needed if the order contains more than one stock keeping units (SKUs), before they can be carried to the shipped area.

There many processing and operating in warehouse, however basic activities may a fall into four types: receiving, storage, order-picking and shipping. Among these activities, storage take the most capital but use the lest labor, order-picking is the most costly, account up to 60% of all operating costs in a typical warehouse[8], and shipping rank the second.

2.3 Warehouse management systems

A warehousing management system is generally defined as the combination of a set of management police, devices and some computer aided systems that help to improve the efficiency of picking or storage/retrieval. Item picking and pallet-picking are the most commonly used operations in a warehousing system and their efficiency can be greatly enhanced with the aid of computers. According to the automation level, warehousing systems can be simply divided into three types[9]: (a) Manual warehousing systems (picker-to-product systems); (b) Automated warehousing systems (product-to-picker systems), and (c) Automatic warehousing systems.

In an efficient warehouse management system, comprehensive material flow, order picking, receiving, storage and other basics and procedures are all taken into consideration to achieve optimal processes. The basic functions of warehouse management system are discussed in detailed in the following chapter. In addition, the important role of order picking is studied from the whole supply chain management prospect.

2.3.1 Warehouse management

Warehouse management is publicly deemed as the main function of a warehouse management system. Also, location management and inventory management can be operated well with the help of the system.

Warehouse type management. In a manually operated warehouse, the devices, such as conveyor and other storage facility can be rightly chosen based on the knowledge of the stuff's knowledge. And in an automatically operated warehouse, all the facilities are divided into right type according to their characteristics and compatibility. Automatic warehouse management system cannot help doing the labor consuming work, such as loading or unloading, but it can make more scientific workflow to deal with the independent generation of orders, such as optimize the gripping time, and retrieval related operations. From the point view of information science, all the optimizations in warehouse management based on a clear and strict classification of storage related devices and the usage of conveyor technology.

Management of storage bins (Location management) Once a storage bin is registered at the identification point, it must be assigned to a specific location without any change. And the status of any bins is registered in the system for the convenience of control and retrievals. The management of bins usually indicates the whole technical of a warehouse system. It includes storage bins assignment strategy, description loading capacity and position of bins and management of units stored at a certain location. With the help of location management functionality any change of goods-specific data, e.g. number of the unit load can be registered and stored in database.

Quantity management (Inventory management) the main function of the quantity management is to make sure a proper storage supply and avoid excess, according to the predesigned min/max stock number. This function is somewhat like that of in enterprise resource planning system (ERP), however, inventory management focusses on the registration and update

of the quantities of each stored article. Also, status data are required for the control of storages and retrievals. When goods storage excesses the pre-set max number, a goods deliver commend may be sent. Contrarily, a replenishment message can be generated automatically.

2.3.2 Storage allocation and assignment

The storage allocation and assignment problem, concerns reducing both picking time and costs in warehouse management. It is first introduced by Cahn [10], and formalized by Frazelle and Sharp [11] and classified as a non-polynomial (NP) hard problem. At present several storage assignment strategies, include randomized storage strategy and dedicated storage strategy, have been put forward to relieve the storage allocation and assignment challenge.

Although, storage allocation and assignment is a problem that cannot be solved completely in theory, most people approve that order picking related work can be obviously reduced by dividing the warehouse into several functional parts, such as forward area and a reserve area. The forward area is designed for efficient order picking only and reserve area is kept for replenishing the forward area or for picking the loads that are not available in the forward area. All these details can be easily fulfilled in storage allocation and assignment module in a warehouse management system. The forward area and the reserve area can be set in the same pallet or rack, but they should be easily changed and managed.

2.3.3 Conveyor management and control

Conveyors plays a very important role in the whole warehouse system, for its wide usage. Based on these characteristics, automatic conveyors are usually fully manipulated by their control systems, such as material flow controller, MFC, et al. While manual conveyors are usually unsteady and they can be control manually, and sometimes semi-automatic control systems.

Computer-aided conveyor control is usually preferred in warehouse management systems for many reasons, such as system performance (reduction of empty trips, larger handling volumes, higher system load), quick reaction to transport requirements and precise control of runtime of vehicles for instance. Specifically, systems for the deployment and control of vehicles is common implemented by stacker control systems or transport control systems [12-14]. They commonly consist of a server, a radio or infrared as the wireless receiver/sender and a movable device installed on the vehicles. Once an incoming transport order or requests are handled, the completed relevant data can be transmitted to the driver by certain procedures and strategies. In addition, the restrictions of facilities like transfer points, loading capacity and lifting height have to be strictly recorded and followed in operation.

2.3.4 Warehouse Reorganization

To keep a high performance and keep all devices runs well, any active warehouse and the related distribution system should be checked regularly, at an interval of one week or shorter, and necessary steps should be taken for its optimization. The process called reorganization, which ensures an economical interplay between new and old components. The items need to be checked include changed retrievals of certain articles, e.g., lower throughput or change of the typical pick-up unit, beginning or terminated campaigns, changed product range and growing number of partial storage units. If any problems, for instance storage areas are occupied faultily or the utilization of space is reduced, find in the check, the reasons can be inspected carefully and some measures should be carried out with the support of the warehouse management system.

The reorganization of warehouses plays an important role in the success of a company, as markets are constantly changing and the demands on material flow are increasing continuously. For example, batches are becoming smaller and smaller, whereas product ranges are ever larger and more complex. To remain competitive in the long term, you need a warehouse that adapts to such requirements and can respond to changes as quickly as possible. This gives you the opportunity to get the most out of your warehouse. Powerful intralogistics is a crucial factor in this regard.

III. DESIGN OPC TECHNOLOGY BASED AUTOMATED THREE-DIMENSIONAL WAREHOUSE MANAGEMENT ARCHITECTURE

3.1 OPC Technology

Traditional field device data fetching methods include driver based query and dynamic data exchange, however both measures need pay much effect on dealing with a great many different kind of interfaces. In addition, much extra work is needed to cope with problems caused by upgrading of software or interface for many different devices. Under this background, OPC comes into being.

OPC is an OLE & COM (The Component Object Model) interface specification between data source (OPC server) and user (OPC application). It provides a mechanism to get data from device data source and send it to any client applications in a standardized way and hence deemed as a practical bridge between Windows based applications and field process control applications. OPC normalizes APIs between field devices and client users, so that any device supplier can develop reusable and highly optimized sever side application to communicate with

a great many devices. Generally, an OPC server consists of three objects: server, group and item, and the overall structure can be shown in Figure 1. The server object response for information services in server side, meanwhile, it acts as container for group objects. Group object provides a data aggregation method for client application, and it can set safe area, refresh frequency, items et al. Item object represents a physic link between server object and data source. It can be a register in PLC (Programmable Logic Controller), or a bit in the PLC register. Item object is a minimum read or write unit, but cannot be accessed by client application directly. There is no COM interface in OPC specification, and all the item object related operation can be completed by indirect group object, contain the right item object, call.

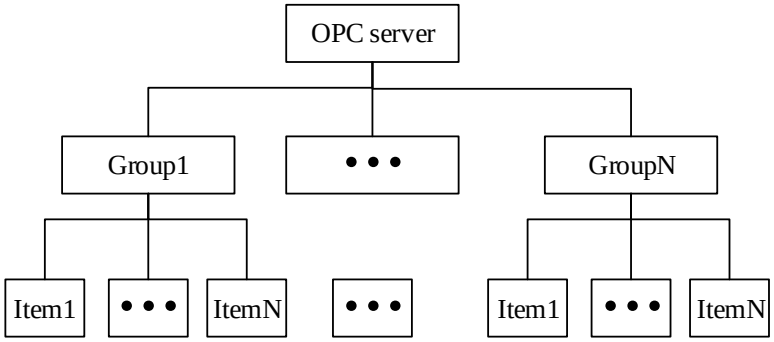

Fig. 2 Structure of OPC server

It can be seen from Fig. 2 that DCOM (Distributed Component Object Model) is the basis of OPC specification. DCOM support TCP/IP, so a system can be divided into several subsystems and locate in physically separated nodes. In addition, OPC server-side applications are encapsulated according to object oriented principle and clients can invoke them related to a set unique interface functions transparently. Follow OPC specification, software development cycle can be obviously shorted, system complexity and maintain cost can be greatly reduced.

3.2 Overall Function Architecture

The automate three-dimensional warehouse management system consist of four parts: dispatching system, storage management system, stockers, high shelves and buffer platform. Storage management system plays an important role in the warehouse management system. It controls the stockers to conduct in and out operation of loads. At the same time, storage management system indicates the real-time status of high shelves and buffer platforms. Top scheduling system and storage management system are connected by CORBA. When a load in commend is received, storage management system will communicate with or PCL by OPC, and the stacker will be further manipulated for real-time in/out operations. Under automatically execute status, loads in commend can be sent automatically if in storage material are detected on stock platform. Additionally, loads out operation can be conducted with the help of stackers if spare space is detected on loads out buffer platform. The whole function of the system is shown in figure 3.

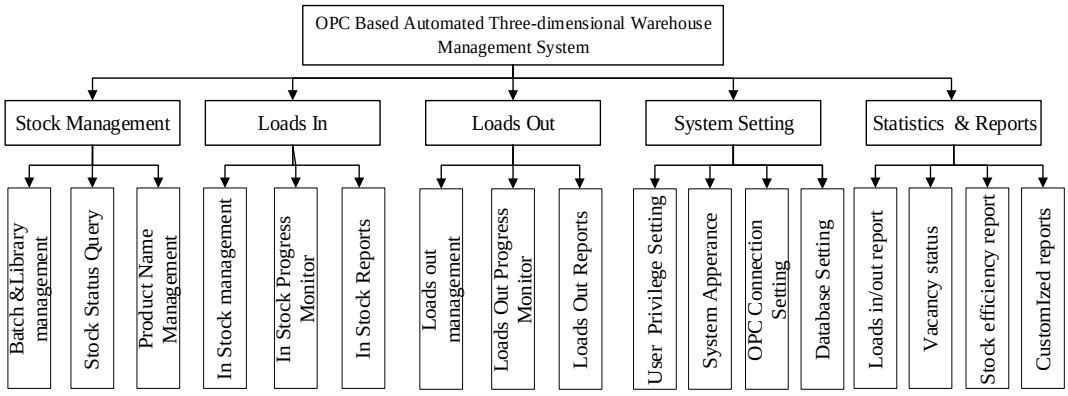

Fig. 3 Functions of OPC based automated three-dimensional warehouse management system

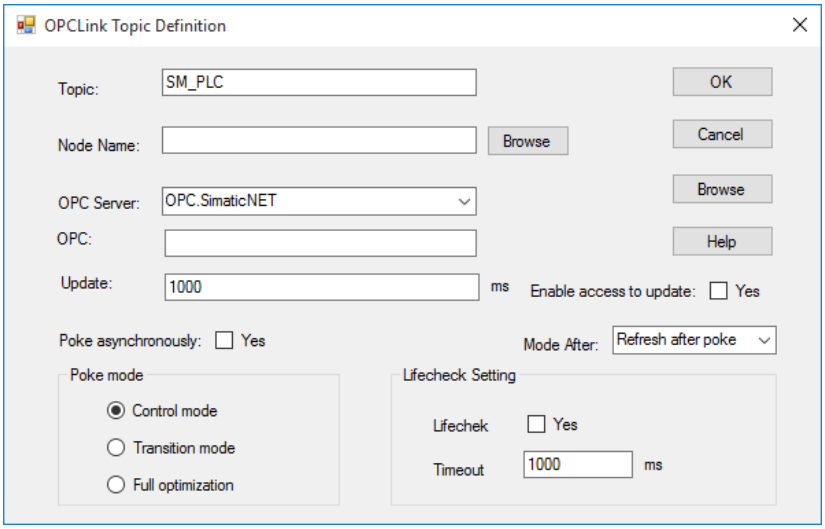

Fig. 4 OPC connection interface

3.4 System Development Environment

The automate three-dimensional warehouse management system involve many devices in warehouse, and software development related hardware and software. Here we just list the latter in brief as below:

(1) PLC: Siemens S7-300 CPU 313
(2) Computer: Huayan Industrial control computer (IPC-610H), with Core i3 3.3G processor, 4G memory and 1TB Hard disk capacity.
(3) Operating System: Microsoft Windows 7 Ultimate 64 bit.
(4) Development Platform: Microsoft Visual Studio 2012
(5) Database: Microsoft SQL Server 2008
(6) Development Language: C++

In the system, as is shown in figure 2, OPC plays a key role in message transferring between devices. By simply two commends, #include “OPC.h” and # include “OPC_IC”, in C++ IDE, the whole function of OPC can be utilized to create an OPC server or OPC groups. Figure 4 shows the form of OPC connection in our system and Figure 5 is the main interface of the OPC technology based automated three-dimensional warehouse management system.

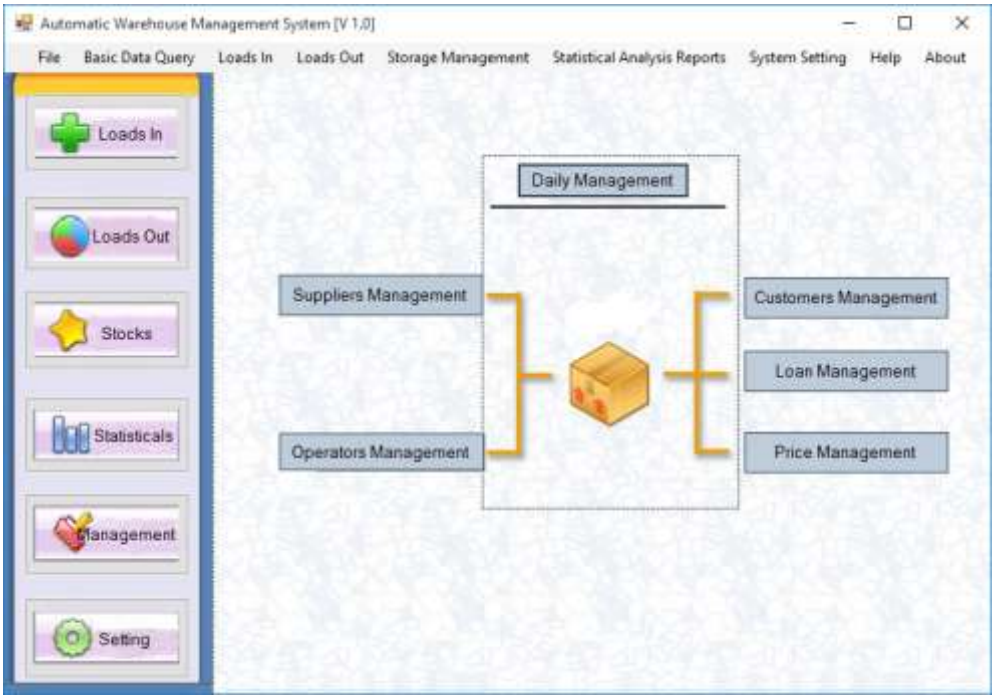

Fig. 5 OPC technology based automated three-dimensional warehouse management system main interface

IV. CONCLUSIONS

This paper studies the functions and characteristics of warehouse systems, include warehouse categories, warehouse activities, features in warehouse management system and key points in automated three-dimensional warehouse management. Especially, we introduce the OPC technology and functional flow chart of the self-developed system. The OPC based automated three-dimensional warehouse management system is based on an applicational project from the Wuxi Institute of Technology, and application in more than one year indicates its high efficiency in storage location assignment, storage allocation other critical operation. OPC technology has an obvious advantage in enhance the performance of database access, and the stability of data transmission. With the help of the system, both commends execute efficiency and real-time monitoring performance are greatly improved. However, there are still many modules need to be perfected.

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REFERENCES

[1] Cormier G, Gunn E A. A review of warehouse models [J]. European Journal of Operational Research, 1992, vol. 58, no. 1, pp. 3-13.

[2] Park Y H, Webster D B. Design of class-based storage racks for minimizing travel time in a three-dimensional storage system [J]. International Journal of Production Research, 1989, vol. 27, no. 9, pp. 1589-1601.

[3] Novák V, Krajčovič M. Warehouse Management System [J]. TRANSCOM 2011, 2011, vol. no. pp. 23-26.

[4] Al-Shakarchy N D K. Warehouse Management System [J]. Int J Sci Res, 2015, vol. 4, no. 10, pp. 1253-1260.

[5] Park Y H, Webster D B. Modelling of three-dimensional warehouse systems [J]. International Journal of Production Research, 1989, vol. 27, no. 6, pp. 985.

[6] E.H. Frazelle. Material Handling Systems and Terminology [M]. Atlanta, GA: Lionheart Publishing Inc, 1992.

[7] Rakesh V, Adil G K. Layout Optimization of a Three Dimensional Order Picking Warehouse [J]. IFAC-PapersOnLine, 2015, vol. 48, no. 3, pp. 1155-1160.

[8] Drury J. Towards more efficient order picking [M]. IMM monograph. Cranpeld, U.K.; The Institute of Materials Management, 1988.

[9] van den Berg J P, Zijm W. Models for warehouse management: Classification and examples [J]. International Journal of Production Economics, 1999, vol. 59, no. 1, pp. 519-528.

[10] Cahn A. The warehouse problem [C]; proceedings of the Bulletin of the American Mathematical Society. American Mathematical Society, 1948.

[11] Frazelle E. H., Sharp G P. Correlated assignment strategy can improve any order picking operation [J]. Industrial Engineering, 1989, vol. 21, no. 4, pp. 33-37.

[12] Groover M P. Automation, production systems and computer-integrated manufacturing [M]. Prentice Hall Press, 2007.

[13] De Koster R, Le-Duc T, Roodbergen K J. Design and control of warehouse order picking: A literature review [J]. European Journal of Operational Research, 2007, vol. 182, no. 2, pp. 481-501.

[14] Faber N, de Koster R B, van de VELDE S L. Linking warehouse complexity to warehouse planning and control structure: an exploratory study of the use of warehouse management information systems [J]. International Journal of Physical Distribution & Logistics Management, 2002, vol. 32, no. 5, pp. 381-395.

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