OPERATIONS MANAGEMENT BASED ON RFID-IMSII

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ABSTRACT

In order to improve the operations management of a distribution center, this paper proposes a management system based on Multi-Agent Systems (MAS) enhanced with Radio-Frequency Identification (RFID) or RFID-IMSII. An experimental platform composed of a simulation combined with a physical platform is used to study a company situated in Spain. It has been necessary because of the company's complexity. The simulation software WITNESS has been used to study different scenarios. It leads to control the main parameters of the company, for example the schedule of orders. It has been demonstrated that the RFID-IMSII system improves the system utilized by the company.

INTRODUCTION

Distribution centers operate in a competitive environment, which forces them to constantly improve in terms of quality, response, agility and flexibility (Leitao *et al.*, 2008). It could be evaluated in terms of costs by the Life Cycle Cost (LCC); which can be defined as the overall estimated cost for a particular solution considered over its life span. LCC should include direct and indirect initial costs plus any periodic or continuing costs for operation and maintenance (García Márquez *et al.,* 2008). The LCC of a system can simply be considered as the total incurred cost between requirement specification and disposal.

This paper presents a new operations management for a real production company with a distribution center in order to reduce the LCC. It has been necessary to build a physical platform connected to a simulated real facility created by the software GRASP. Web technologies and a network provide communication and actuation in the experimental platform. Modern Programmable Logic Controllers (PLCs) and PCs support the multi-agent systems. Using this platform makes it possible to experiment different techniques without interfering with the company. The traceability has been employed for studying variables of the products, for example its production history. It leads to the creation of a database of the variables (Morel *et al.*, 2007). The identification using radiofrequencies (RFID) leads the traceability control (Finkenzeller, 2004).

The modeling of the movements of parts is at a very detailed level, and it is therefore suited for the analysis of operations which have been carried out in this paper employing discrete simulation (e.g. Law and Kelton, 1991; Pidd, 1998, 2003). The introduction of Visual Interactive Simulation, or VIS, in the late 1970's (Hurrion, 1978) and the move to menudriven model building in the 1980's (Bell, 1989) had a big contribution to the discrete simulation. However, in fairly general terms, most simulationists might agree with a definition of the type: "the use of a model to predict the behaviour of a stochastic system", and perhaps "involving experimentation and statistical analysis of the results".

Indeed the major challenge for the developers of discrete simulation software is to balance flexibility against ease of use: historically the balance was in favour of the former, but the modern emphasis is increasingly on the latter. Surveys appear regularly in the literature (e.g. Swain, 1999) and the choice is exceptionally wide e.g. Arena, Extend, Promodel, Simul8 and Witness. Discrete simulation is now used widely in industry, commerce and the public sector to model the behaviour of systems such as production lines, hospital departments and transport systems. The modeling in a real enterprise case is needed because of its complexity. By using a model, it is possible to manage part of the enterprise, and by some models to manager some parts of the enterprise or to manage all of it.

The model should consider the description, prediction and explanation of the enterprise's work (Flood and Carson, 1993). The description is based on a real case, which is simulated in a laboratory, based on observation. The complexity of the system makes it so that the system cannot be considered to be matched by the predictions obtained through mathematical models. The software Witness will be employed to analyse the data obtained in the laboratory. The analysis is based on past observations for deducing future behavior and it considers the stochastic charasteristic of the system (Casti, 1994). The results obtained by the model should help to obtain an explanation depending on the purpose of the study (Rivett, 1972).

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Therefore, it is necessary to analyze some key parameters of the business. In this paper a platform is analysed which simulates a real case. It allows design, experiments and evaluates different cases. That is achieved by the Flexible Manufacturing System presented in this work.

FLEXIBLE MANUFACTURING SYSTEM

A Flexible Manufacturing System (FMS) is defined as a manufacturing system that uses extensive automation to integrate the following characteristics (Barros, 2003):

- Processing equipment comprising numerical control machines and robots with the ability to change pieces and tools rapidly.
- Material Handling Systems (MHS), including conveyor belts, fork lifts, elevators, automatic guide vehicles (AGVs) and automatic storage and retrieval systems (ASRSs).
- Sophisticated computerized control and communication systems.
- Efficient management and maintenance structures that can tackle situations such as malfunction.

The MHS can be defined as "A group composed of all of the standard features that make possible the physical movement within the supply chain– including the chain of production and warehouse – of raw materials, work in progress, and finished products" (García *et al.*, 2003). The experimental environment is focused particularly on the operations of materials handling. This is assembled in the facilities of the Autolog Group at the University of Castilla-La Mancha (UCLM, Spain).

MHS has some problems such as: stock control, discrepancies in inventory and complicated processes of picking. It is necessary to apply new technologies in order to minimize these errors in large distribution centers. RFID can manage a lot of information, and it is possible to detect, identify, and verify the nature of the coming products; which allows storing them according to the different rotation levels (Abarca et al., 2007). It is permissible to update the products contained on each pallet at any moment and thus being able to control the quality of operations. RFID allows the products to be marked and inventoried while on conveyor lines, during the loading/unloading of trucks at the docks, or while handling the loads in warehouses or distribution centres (Xiao *et al.*, 2007). It corrects errors in each phase of the supply chain and determines rapidly and precisely the errors produced.

RFID together with Information Management System (RFID-IMS) is understood when an information management system is added to the RFID technology. It can manage every data processed that is being generated in the dynamic systems and to provide that information to the management system (Encinas *et al*., 2008).

RFID provides the information to the agents. They describe the change in situations in industrial environments, and have the capacity to negotiate and coordinate to achieve a common goal (Franklin and Graesser, 1996). It leads to the adaptation of new technologies that should be able to supply the system with the current information necessary to make decisions online. An agent is also capable of carrying out different objectives through an information exchange in the environment with other human agents or software agents (Garijo, 2002). The decisions made by agents using reasoning are based on their internal knowledge and their experience (Cheeseman *et al*., 2005).

George *et al*. (1998) proposed an agent model based on beliefs, desires, and intentions (BDI). To characterize these types of agents, the following characteristics are added to the initial definition: beliefs (what it believes to be true), desires (the objective that the agent is trying to reach) and intentions (what it plans to do based on its beliefs to reach its desires).

These properties make the agent applicable to highly dynamic situations, which turn them into promising candidates in providing a management solution. Moreover, software agent technology can monitor and coordinate events, meetings and disseminate information (Balasubramanian *et al*., 2001) improve Knowledge Management Systems (Soto *et al.*, 2008) and build and maintain organizational memories (Abecker *et al.*, 2003). Other applications have been made in order to improve the manufacturing control and supply network coordination using models of behavior such as the one in ant colonies (Valckenaers *et al.*, 2007).

A multi-agent system (MAS) can be defined as a set of agents that represent the objects of a system, capable of interacting, in order to achieve their individual goals, when they do not have enough knowledge and/or skills to achieve individually their objectives (Leitao *et al.*, 2008).

The MAS model depends on the information available from the elements of the system. Therefore it is necessary to get accurate data to the MAS by a flexible management system. RFID-IMS applied to MASs provide flexibility and intelligent control for its application in production, distribution, storage, etc. The MAS controls the system on-line. The designer only has to determine the design characteristics and implementation. RFID-IMS together with MAS can be defined as an intelligent management system enhanced with radiofrequency identification (RFID-IMSII) (Garcia et al., 2007).

CASE STUDY

The platform is divided into two parts, which together simulate the real system. One is assimilated by a physical platform and other by the 3D visualization environment GRASP. The physical platform simulates the loading/unloading processes. RFID-IMSII technologies have been employed together in a storage and distribution system (see Fig. 1). The program simulates the processes of storage and distribution.

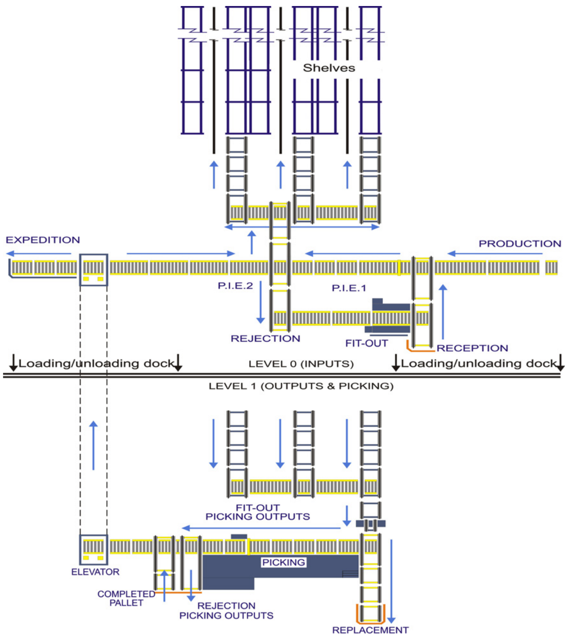

Figure 1: Case study

Platform

The physical platform is shown in Fig. 2. The platform is controlled by the sixth PLC type SIMATIC S7 200. The platform represents the area of the entrance/exit of the products. Tagged pallets arrive to the merchandise loading/unloading zone (loading docks) colored and tagged with RFID. They use different colors to indicate the rotation grade of the products, where red indicates high rotation, yellow medium rotation, green low rotation and blue picking.

Petri nets were used in order to create a generic experimental platform capable of adapting itself to a different distribution center. Petri nets are used for modeling due to their ability to represent small sections of a complex system and it is not need to exert such force trying to model the system. Petri nets are also employed for programming the PLCs.

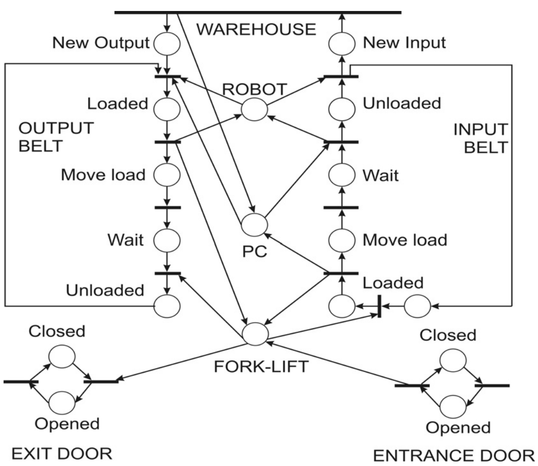

Fig. 4. Petri net diagram of the processes at the platform

The loading and unloading docks are based on two conveyor belts for the entrance and exit of products. An RFID reader has been installed in the entrance conveyor belt to read the tags of the incoming pallets. It identifies the entering pallet and indicates to the robot arm, Motoman HP3 the position where the pallet should be in the warehouse. The pallets with higher rotation occupy the lowest and closest part to the exit of the automatic warehouse. When the robot has located a pallet, it then connects with the simulation. The pallet will have a route within the automatic warehouse corresponding with the rotation grade of the product and its destination.

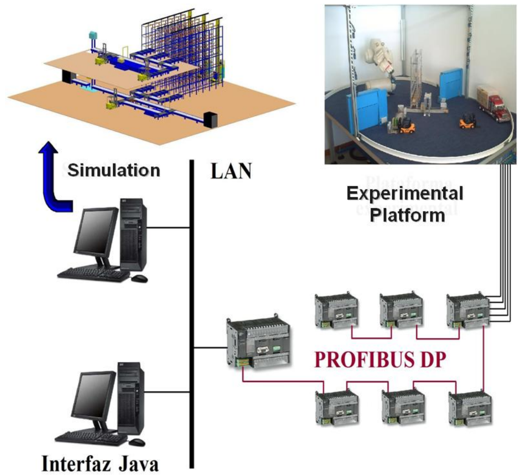

Figure 2: Experimental Platform

As as pallet leaves the automated warehouse, the simulation provides the robot with the pallet information. Then the robot transfers the pallet to the exit conveyor belt. After that, the fork-lift takes it to the loading docks. Another RFID reader is located in the exit door in the loading/unloading zone. It verifies the products that are leaving to reduce errors in the entrance and exit of products.

MASs allows the agents to resolve any type of conflict by themselves (Wooldridge, 2002). RFID-IMS II manages the decisions at different places such as: conveyor belt crossing points, entrance and location in the warehouse, and the priority of the orders.

One of the most representative hybrid architectures is the 3-Tiered (3T). It has been develop by NASA (Bonasso, 1997), and it is designed of a multi-agent architecture composed of three levels (Fig. 3): reactive, deliberative and interface.

In the reactive level the agents have the ability to perceive changes in the environment and respond at the same time that the change occurs. The orders are executed without any reasoning, in other words, the agent must decide quickly in critical situations. The simulation that is in this level provides the products' identification and positioning to the system by the interface control level. The reactive level is composed by the following elements: I/O Doors, AGV, Conveyors, Sensors, and Robot.

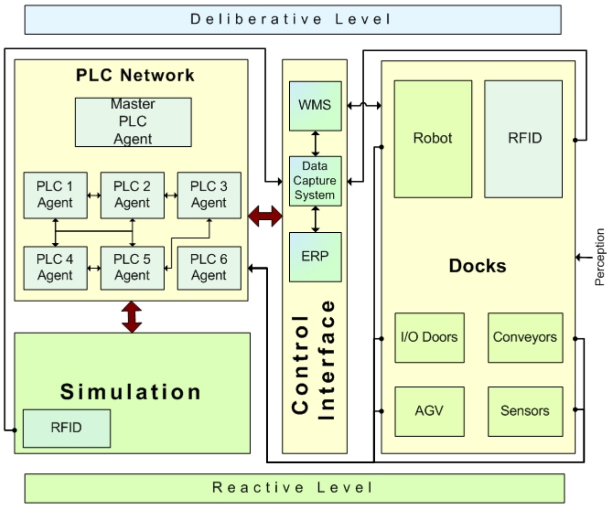

Figure 3: Multi-Agent Architecture

In the deliberative level, the agents receive the information about their environment and according to their beliefs and intentions, they decide the best way to reach the objectives.

The RFID module assigns one identification code to each pallet and it saves this information in the data capture system, which is a part of the control interface. In addition, it supplies the information to verify the outgoing orders.

The control interface module represents the interface level in the architecture and is composed mainly by Warehouse Management System (WMS), Enterprise Resource Planning (ERP) and the Data Capture System (DCS). Every data generated by the system is stored, decoded, and managed.

The management system's effectiveness depends on accurate and timely information from the data capture system. The control interface transfers data from the reactive level to the deliberative level in both directions. The WMS assigns the position that the pallets will occupy in the warehouse, depending on the level of rotation of the product.

Simulation

The software GRASP 10 has been employed for analyzing the facilities of the biggest Spanish bottling companies. It has been done employing simulations because the investments that should be made in order to correctly automate a production plant or a distribution center are lofty (Coyle *et al.,* 2002). The main investment costs are in the transport equipment made of conveyor belts or cranes, the information systems that control the movement of materials, the software and hardware systems, the formation of human resources, and the most important cost is the design work of the storage process (Otamendi, 2004).

The simulation is based on distributed control theory, in other words, it uses the division of a complete system into subsystems with the ability to interact with others and with the intention of achieving a collective objective. It employs a network of Siemens PLCs connected with PROFIBUS DP. It is composed of six PLCs SIMATIC S7 200 (CPU 224) that work as slaves, and a SIMATIC S7 300 (CPU 313C-2DP) that works as master (Fig. 2).

The system is divided into the ground level (inputs), second floor (picking and outputs) and the management of the automatic warehouse (3 S/R Machines). Each part of the system is controlled by a S7 200 PLC and is represented by an agent.

In order to obtain the connection from the PLC network to Ethernet network, a communications processor CP343-1 *Advanced* (Siemens) is added to the master PLC. A computer connected to the network works controlling the interface for the simulation. This interface, programmed in java, serves as a bridge between the decisions made by the PLC network and the simulation. One of the advantages of Ethernet is that it is not necessary that the interface control and simulation are found in the same computer. This makes it possible for a person to supervise the operations that are carried out from any place and control the simulation.

MODEL APPROACH

The agents located at PLCs control the areas of the company simulated by GRASP. The decision of sending a pallet to anyplace is done according to priority. If a pallet k_{ji} from an order $\mathbf{K}_j$ and a pallet k_{r1} from order $\mathbf{K}_r$ arrive to a crossing point in the conveyor belt at the same time, it will selected the pallet that has more priority (Fig. 4).

$$\mathbf{K} = \begin{bmatrix} \mathbf{K}_1 \\ \vdots \\ \mathbf{K}_m \end{bmatrix} = \begin{bmatrix} k_{11} \cdots k_{1n} \\ \vdots \qquad \vdots \\ k_{m1} \cdots k_{mn} \end{bmatrix}$$

ERP provides the priority level relating to the orders that it has in its data base and its current priority considering the pallets that are coming. The priority is determined by the equation (1)

$$P_{k_{ji}} = w_c C_{\mathbf{K}_j} + w_d D_{\mathbf{K}_j} + w_t \mathcal{T}_{\mathbf{K}_j} + \frac{\sum_{i=1}^{n} S_{k_{ji}}}{n}, \quad (1)$$

where $P_{k_{ji}}$ denotes the priority. $C_{\mathbf{K}_j}$ is the importance degree of a consumer provided by the company, where $0 \le C_{\mathbf{K}_j} \le 1$. $D_{\mathbf{K}_j}$ is the value assigned to the delivery date that is defined by the company, where $0 \le D_{\mathbf{K}_j} \le 1$. $\mathcal{T}_{\mathbf{K}_j}$ denotes the value assigned to the arriving date that is defined by the company, where

$0 \le \mathcal{T}_{\mathbf{K}_j} \le 1$. $S_{k_{ji}}$ is a binary variable that is 0 when the pallet k_{ji} has been not shipped, and in order cases is 1. w_c, w_d and w_t are weights assigned to $C_{\mathbf{K}_j}$, $D_{\mathbf{K}_j}$ and $\mathcal{T}_{\mathbf{K}_j}$ respectively. For example, if a company considers that all the costumers are in the same category, then w_c = 0.

The virtual mark V_x that activates the orders to allow pallet k_{ji} to move on to the next process is given by equation (1).

$$V_x \begin{cases} P_{k_{ji}} \ge P_{k_{rl}} \Rightarrow V_x = 1 \\ P_{k_{ji}} < P_{k_{rl}} \Rightarrow V_x = 0 \end{cases} \qquad (2)$$

Therefore, according to the above example, the agent, based on the V_x, carries out the decision of which pallet will cross the intersection first.

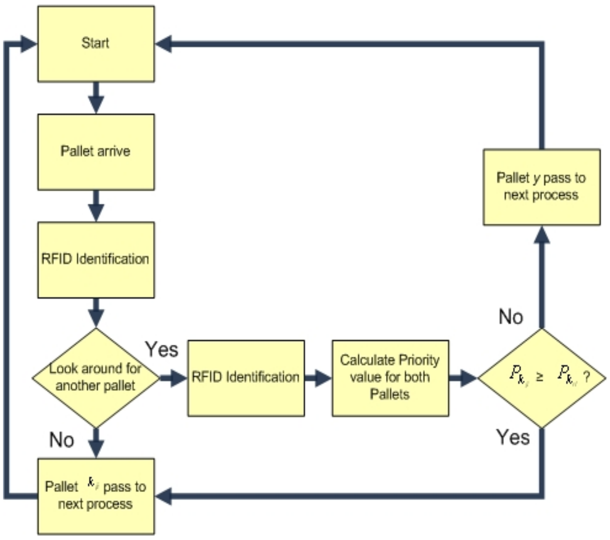

Figure 4: Prioritization Flowchart

RESULTS

The software Witness has been employed in order to analyse different experiments. A visual interface is shown in Fig. 5.

Witness is a simulation package capable of modeling a variety of discrete (e.g., part-based) and continuous (e.g., fluids and high-volume, fast moving goods) elements. It can be used to simulate the actual production process and provide further information on the operation of the system, such as location of possible bottlenecks and buffer size requirements (Markt and Mayer, 1997).

The company is employing for the order preparations the criteria First Input First Output (FIFO), or First Come First Served (FCFS). To get a flexible system, the criterium employed by the company is not good enough.

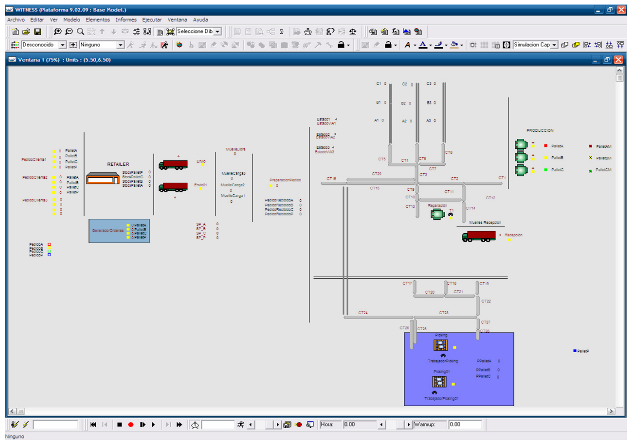

Figure 5: Simulation on Witness.

Table 1 shows the characteristics of the reference scheduling and RFID-IMS II are summarized.

Table 1: Reference scheduling *vs*. RFID-IMSII.

	Reference Scheduling	**RFID-IMSII Scheduling**
Order Criterium	FIFO	According to priorities
Flexibility	limited	high
Capacity	Fixed	Variable

In order to illustrate the above management system the following case study is presented.

Three incoming orders in the same day have different priority levels:

- 1st Order arrives at 08:00 with low priority.
- 2nd Order arrives at 08:30 with intermediate priority.
- 3rd Order arrives at 09:30 with high priority.

The orders are composed by different amounts of A, B, C and Q products. The last one represents the picking pallets which consist of A, B and C goods. Table 2 shows the description of these orders.

The elaboration times for each order are:

– Order 1: 2h 31’ 37’’
– Order 2: 2h 16’ 36’’
– Order 3: 2h 10’ 9’’

Table 2: Orders’ description.

	Order 1	**Order 2**	**Order 3**
Units	11A, 7B, 5C, 10Q	10A, 8B, 7C, 8Q	12A, 9B, 5C, 7Q
Incoming date	13/01/09	13/01/09	13/01/09
Incoming hour	08:00	08:30	09:30
Delivery date	13/01/09	13/01/09	13/01/09
Delivery hour	----	----	13:30

Figure 6 shows the Grant diagram for the three orders, where the third order it is not completed on time.

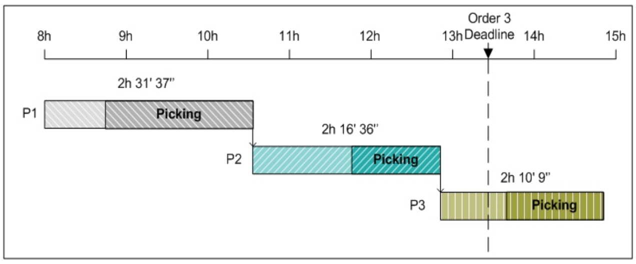

Figure 6. Reference schedule.

Using the management system described in this paper, the total elaboration time obtained is reduced from 6 hours and 51 minutes to 5 hours and 31 minutes. It is reduced by 18.3% of the preparation time. It is possible to fulfill the third order within the delivery time (see Fig. 7).

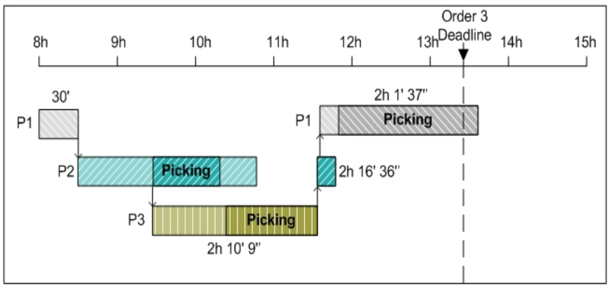

Figure 7. Schedule obtained by RFID-IMSII.

CONCLUSIONS

A new operations management system has been put to test at a real production company with a distribution center. The company has been analysed by using a physical platform connected with a simulation of a real distribution center. Modern Programmable Logic Controllers (PLCs) and PCs support the deployment of multi-agent systems. They are connected by a network and web technologies provide communication and actuation in the system. The main parameters of the products have been analysed by their traceability. The traceability control has been implemented with RFID.

With the platform design in this paper it is possible to generate, experiment and evaluate different situations of the company. Multi Agent System together RFID-IMS has been used as an intelligent management system (RFID-IMSII).

Discrete simulation is concerned in this paper with modeling the movements of parts at a very detailed level, and it is therefore suited to the analysis of operations. It demonstrates that the RFID-IMSII provides the flexibility necessary to the system to deal with different work orders at the same time. A considerable improvement in the use of the resources is also achieved.

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