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Research and Application of Inventory Management System of Foundry ERP Based on Multi-Agent

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Abstract. By analyzing the characteristics of foundry enterprises and the features of multi-agent theory, this paper applies this theory in the management of foundry enterprise. A multi-agent model and a detailed multi-agent model of inventory management are constructed in this study. The KQML is adpoted to meet the requirements of communication between agents. This study set up KQML messages about data manipulation and then map these KQML messages to SQL clause. Based on this model, an inventory management system of ERP for foundry enterprise is developed. The successful application of this system proves that it is applicable to use the multi-agent theory to enhance the management of foundry enterprises

Introduction

In recent years, the foundry industry experienced a rapid development. The casting production grows all the time, however, accompanied with this prosperous sight is a series of problems waiting for solutions, such as high consumption of energy and material, environmental pollutions, low added-value of products, and the ever-changing requirements of customers. For these reasons, foundry enterprises have taken many measures. They bring in new casting methods to reduce pollution, for example, lost-form casting; they also try to transform the rough castings of low added-value to products of high one by building the machining and welding workshops. To some extends, these measures can solve the problems listed above. But they also extend scale of enterprise, which rises from an enterprise with single casting method and single casting workshop to an integrated enterprise. All these improvements also bring changes to the organization, production and product of enterprises. Introducing new casting methods means increasing new enterprise department. There is no fixed manufacturing process for the product of different customers, and the types of products' BOM increase greatly. The communication between departments and people complicates and has a low efficiency; the varieties of raw materials increase, and the inventory management is effected by much more factors. All these changes exert a great challenge for the enterprise management. As the inventory control plays a vital role in the business of foundry enterprises, an efficient inventory management is of great importance to the foundry enterprises in the new situation[1,2].

The concept of Agent stems from Distributed Artificial Intelligent. It is defined as follows: Agent is one kind of entity that exists in an environment, perceives it, receives its message, makes responses, and in turn reacts to the environment. From the perspective of terminal users, Agent is their proxy and assistant, helping them to achieve their tasks; from the perspective of system, as an abstract entity, Agent can be realized as software or hardware which should be controlled by software. Agent has several properties: (1) Autonomy: Agent owns resources (data) and mechanic for behavior control by itself, and it can act on its own without intervention from other people or Agents. (2) Sociability: Agent can interact with others (people included) in a certain language to obtain coordination and cooperation. (3) Reactivity: Agent reacts to its environment (e.g. physical world, graphic world or a series of other Agent, internet, etc.), and then alter environment. (4) Pro-Activity: Agent not only reacts to environment, but collects information and act on its own, showing those goal-oriented behavior. (5) Intelligence: Agent can have intelligent behavior such as

reason and self-study. (6) Communicability: Agents can exchange information with each other and people. The communication mechanism among Agents is: in a multi-agent system, agents understand and communicate with each other through knowledge layer and business layer[3,4].

KQML(Knowledge Query andMani pulati on Language) is a language and protocol for exchanging infromation and knowledge among software agent. It is both a message-handling protocol and can be used as a language for agents interacting with each other in intelligent systems.It is indenpent of network transmission mechanism, content language(SQL,PROLOG) and content entity. KQML predefines a set of performative and can satisfy the requirements of most of the communication between agents[5,6]. A typical KQML message is as follows:

(performative
: sender <word>//sender of the message.
: receiver <word>//receiver of the message.
: in-reply-to <word>//response marks,and former news. Values are the same with the reply with of the former message.
: reply-with <word>//response markers when reply this message.
: language <word>//the language name of content.
: ontology <word>//the set of term definition used in paramter in content.
: content <expression>)//information when this performative is excuted.

In sum, the flexibility of business of enterprise and complexity of production process bring a great challenge to their management. Meanwhile, those popular ERP systems are wide-range but not professional. Wide-range refers to their numerous sub-systems which cannot be fully used by foundry enterprises. It is not professional for foundry enterprise because it cannot fit for the special features of foundry enterprise which includes sale, processing, planning, quality, inventory, delivery, instrument and mold. According to the idea of streamlined management, all these features should be linked together. Among that, inventory management is effected by factors such as orders, processing, planning, quality inspection, etc. In foundry enterprises, all these task should executed all together in a coordinated way, to predict and plan the business for each own. From the perspective of multi-Agent, Inventory Management Agent and Order Agent can work together. Therefore, applying the multi-agent idea in the management of foundry enterprise and developing the ERP inventory management system is of great significance to enhance the foundry enterprise management level.

System Design and Implementation

Multi-Agent Model Design for Foundry Enterprise. The basic business flow of a foundry enterprise is: order, preparation, planning, manufacture, quality inspection, and finally delivery. In these stages, we can encapsulate agents with different roles and sections. Every agent has its own authority, and can communicate with other agent by a certain protocol. Driven by information, every agent can accomplish its own work, receive information and instructions from upper stage and based on these information it can independently make smart policies. Meanwhile, they all serve for the global target, cooperating to finish the whole business.

Centered by inventory agent, the enterprise business can be divided into several agents shown in Fig. 1.

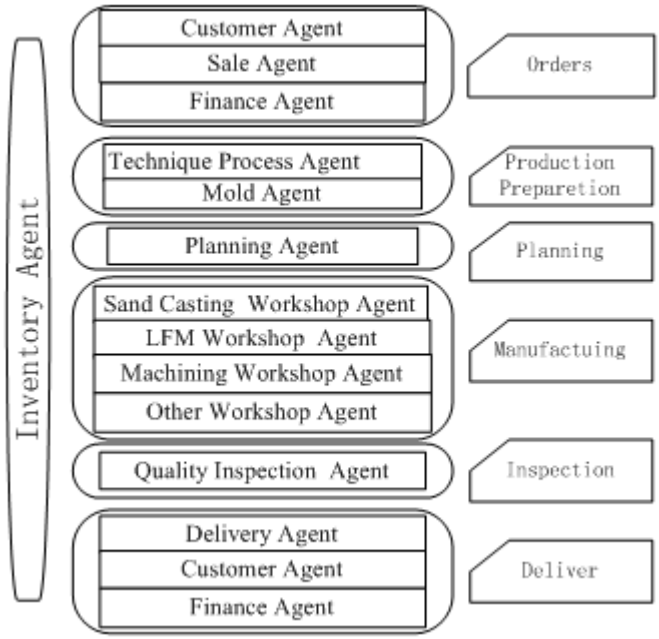


Fig. 1 Multi-Agent of foundry enterprise business

Each agent and its cooperation relation are defined as follows:

1) Customer Agent (CA): It belongs to the outer agent of enterprise, cooperating with sale agent and finance agent. It is the source of the business and production of foundry enterprise.

2) Sale Agent (SA): Cooperating with customer agent and finance agent, it takes responsible for signing of orders. After the orders are signed, it provides material requirement prediction for inventory agent.

3) Finance Agent (FA): Driven by sale agent, and controlling the delivery agent, this agent control the enterprise business from the start to the end. Cooperate with inventory agent to control the purchase and storage of inventory material.

4) Technique Process Agent (TPA): Driven by sale agent and customer agent, cooperate with mold agent, this agent establishes the process and bill of material (BOM) of products based on customer blueprint and mold. It decides the techniques for workshop agent, and provides inventory agent with initial material requirement.

5) Production Plan Agent (PPA): Driven by sale agent, cooperating with technique process agent, inventory agent, and workshop agent, this agent arranges the production plans, providing the inventory agent with detailed material requirement.

6) Workshop Agent (WA): It demands material from inventory agent, and returns the excess material; it offers products for quality inspection agent for inspecting; it undertakes production according to schedule which is established by Production Plan Agent.

7) Quality Inspection Agent (QIA): Driven by workshop agent, inspecting the quality of products, and submit the report to customer agent; It cooperates with inventory agent to control the quality of purchased material.

8) Inventory Agent (IA): Receiving the orders from sale agent, combined with the pre-orders to predict the material requirements. Then it receives the process card and BOM from technique process agent, again combined with orders to make out the material requirement of the whole enterprise.

The model and system design of Inventory Agent. In order to obtain a deep and lean management, foundry enterprise should build the multi-agent mode described above, and should make a detailed regulation on each agent's business, when to execute and which agent to cooperate with. Among this, the inventory agent can be divided into different sub-agents (see Fig. 2). The warehouse material agent is the core agent, and others include purchase material agent, raw material agent, semi-processed product agent, product agent, mold agent, and material agent with different types, etc.

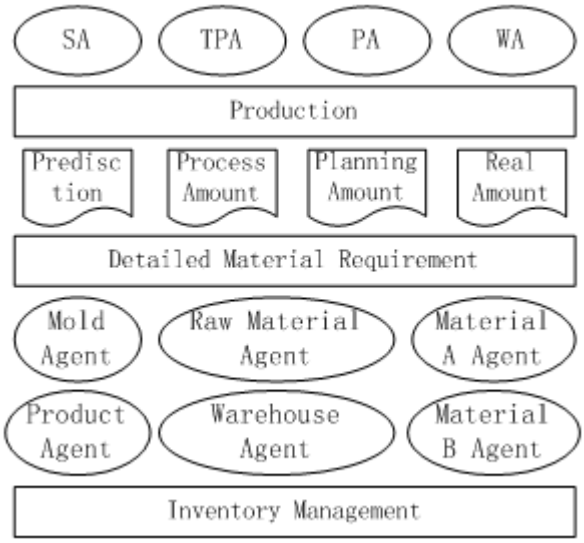


Fig. 2 Multi-Agent of inventory business for Foundry enterprise

Communication and Cooperation model among different Agents. After setting up multi-agent model for foundry enterprise according to its bussiness, a communication and cooperation mechanism must be establish which can reflect the sociability, intelligence and communicability. This research proposes a KQML-TO-SQL communication model. By means of the independence of KQML, it can express complex business in foundty enterprise, and then it can map the content of KQML to SQL clause to operate the database of enterprise.

This model has used these performative as follows:

1) ask all, sender wants receiver to know all item which meet to the content

2) delete all, sender wants receiver to delete all item which meet to the content

3) delete one, sender wants receiver to delete one item which meet to the content;

4) insert, sender wants receiver to insert : content;

5) tell, sender show receiver that content;

6) forward, sender send to receiver the message which is from A and its goal is to B

In the process of communication, the communication between agents is aim to read and write data. Thereforce this describe the map principle from KQML to SQL as follows:

1) (insert … : content (tableNameX (? field1 v1) (? field2 v2) … (? fieldn vn))). This message shows that sender wants receiver to insert one ite. The corresponding SQL clause is: INSERT INTO TableNamex(field1, field2, *, fieldn) VALUES (v1, v2, *, vn).

2) (ask one or ask all ... : content (tableNameX(condition))). This message shows that sender wants receiver to get one or all item. The corresponding SQL clause is: SELECT field1, *, fieldn FROM tableNameX WHERE condtion.

3) (delete one or delete all … : content (tableNameX(condition))). This message shows that sender wants receiver to delete one or all item. The corresponding SQL clause is: DELETE FROM tableNameX WHERE condition.

Take purchase and storage management as an example, the table 2-1 show the communication content which adopt the KQLM-TO-SQL model.

Table 1 Communication content of purchase and storage management

Communication Goal	KQML Description
Workshop agent need some special material	(insert ... :content (requisitions(?field1 v1)(?field2 v2) ... (?fieldn vn)))
Purchase agent sum the requirement of material	(ask all or ask one ... : content (requisitionssum(condition)))
Purchase agent inquire price for the material	(insert ... :content (inquiry-price(?field1 v1)(?field2 v2) ... (?fieldn vn)))
Innovatory agent in-stock material	(insert ... :content (in-stock(?field1 v1)(?field2 v2) ... (?fieldn vn)))
Workshop agent recipt material	(insert ... :content (out-stock(?field1 v1)(?field2 v2) ... (?fieldn vn)))

Application

Starting from a sand casting enterprise, enterprise A developed into a united enterprise including casting, machining and welding. It owns both sand casting and lost foam casting production line. Most of the rough casts it produced are machined to finished goods and then sent to customers. Because of the expansion of enterprise scale and the change of business model, the former management method can no longer fit for current one. For the inventory management, purchase, raw material, semi-processed products and finished products become even more complicated. This paper introduces the multi-agent idea into the demand analysis and the development of ERP system. By implementing this system, management level has been promoted, solved the inconsistency between the management and enterprise scale. The interface of the system can be seen in Fig. 4, Fig. 5, Fig. 6, Fig. 7 and Fig. 8.

Material requisitions

Number	Production Task	Process Number	Product name	Order Quantity
100727001	RW10071103		gear shaft	10
Material Number	Material	Specification	Model	Unit
riser		Yφ200*300	Yφ200*300	
Planned Quantity	Actual Quantity	Unit Price	Amount	Use
6.000	6.000	50.000	300.000	for production
Notes				

Preparer: Songjian Warehouse Managers:Tangtao 2010-07-27 Workshop Director: cyctui

Fig. 4 Material requisitions

Total Quantity 15

Inquiry Sheet

Number 110115001 Vendor One vendor one
Appraisal Group approved Vendor Two vendor two
Signature wang ms Vendor Three vendor three
Confirm ☑ Confirmed Vendor vendor two
Purchaser Jian Song 2011/1/15 Supervisor Tang Tao Manager

Terms Number	Material	Specification	Material Quality	Requirements	Unit	Quantity	Unit price 1	Manufacturer	amounts
p115001-2	riserφ300*350	riserφ300*350		good thermal protect		5.000	50.000	one	250.000000
110115001-1	riserφ200*300	φ200*300		qualified		10.000	30.000	one	300.000000

Fig. 5 Inquiry Sheet

Number	Type NO.	Raw Material	Standard	Sum	Requirement	Stock	Purchase Quantity
100716001	Electricity	Material B	45	30.000	30.000	0	31.000
100716002	Assistant	Cup#70	45	10.000	10.000	0	12.000
100716003	Electricity	cs	40	10.000	10.000	0	9.000
100717001	Assistant	Cup#100	45	30.000	30.000	0	36.000
p0717005	Waste	Ribbed steel	45	30.000	30.000	0	35.000

Fig. 6 Purchase request

Sum 11.000 Amount 11

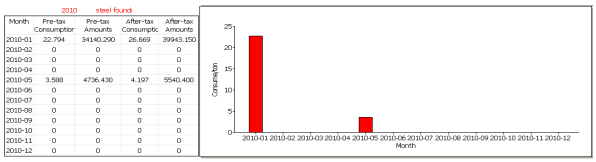
Purchase Receiving Report

NO. CG10070002

Material NO.	Standard	Supplier	Unit Price	Quantity	Amount
Material 4	15	WH Inc.	1.000	11.000	11
Remarks	11				

Recorder Wang MH 2010-07-16 Keeper Zhang WQ Preparer Tangtao Checker Wang MH

Fig. 7 Purchase Receiving Report



2010 steel found

Month	Pre-tax Consumptior	Pre-tax Amounts	After-tax Consumptic	After-tax Amounts
2010-01	22.794	34140.290	26.669	39943.150
2010-02	0	0	0	0
2010-03	0	0	0	0
2010-04	0	0	0	0
2010-05	3.588	4736.430	4.197	5540.400
2010-06	0	0	0	0
2010-07	0	0	0	0
2010-08	0	0	0	0
2010-09	0	0	0	0
2010-10	0	0	0	0
2010-11	0	0	0	0
2010-12	0	0	0	0

Fig 8. Statistical graph of materials consumption classified by department

Conclusions

From this paper, we can have these conclusions:

1) This paper introduced the multi-Agent idea into the management of foundry enterprise, studied the mode of foundry enterprise based on multi-agent technology, and made a detailed study on multi-agent mode for inventory management. This offered effective method to better management of foundry enterprises.

2) According to the multi-agent model for inventory management, an inventory management system for foundry enterprise has been developed, in which the intelligence and coordination of inventory agent have been fully considered. And this system has been in use for one enterprise, and has obtained a favorable effect.

Acknowledgement

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