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An Inventory Management System Based on Intelligent Agents

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Abstract

An inventory management system of manufacturing industry has a model of different kinds according to the objective and the situation. An inventory management system needs superior system technique in demand forecast, economical efficiency, reliability and application for stable supply of the finished goods, the raw materials and the parts.

This paper proposes a demand forecast method based on fuzzy structured neural network, which uses min-operation and trapezoid membership function of fuzzy rules. So we can construct an intelligent inventory management system that make optimized decision-making for forecasting data with expert's opinion in fuzzy environment. The inventory management system uses intelligence agent and it could be adapted to a system environment change in order.

Key Words : Neural Network, Intelligent, Decision Making, Inventory System, Fuzzy theory

1. Introduction

The inventory properties which has are production raw won material, an part, a process width, a product, a semi-manufactured goods, a stored goods and a facility preservation article etc.

The percentage of the inventory property in the total property is dependent on the type of business. But the korean's is about 20%.

Most enterprise has a lot of the inventory property with inventory expense. This is because to supply in time.

So, the inventory management is adapted quickly in demand and has flexibility in economy.

Namely, it prepares that is setup it adaptable to the production demand trend of market quickly, inventory quantity of the product, and to maintain the product as small as possible[1][2][3].

A inventory management system demands the superiority system technique of demand prediction, economical efficiency, reliability and application. Also, Actuality inventory management system which is under the restricted space of the handled the various item needs the accurate of demand forecast and the expert inventory management ability.

This paper proposes a demand forecast method based on fuzzy structured neural network, which uses min-operation and trapezoid membership function of fuzzy rules. So we can construct an intelligent inventory management system for optimized decision making of forecasting data with expert's opinion in fuzzy environments. This inventory management system using an intelligence agent can adapt to a system environment changing in order.

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2. Fuzzy neural network and Agent

The neural networks are good at recognizing pattern, they are not good at explaining how they reach their decisions. Fuzzy logic systems, which can reason with imprecise information, are good at explaining their decisions but they cannot automatically acquire the rules those use to make decisions. These limitation can be supplemented by intelligent hybrid systems that combine of is combination of two or more techniques[4].

2.1 Fuzzy Rules

Neural network learning techniques can automate this process and substantially reduce development time and cost. For neural networks, the knowledge is automatically acquired by the backpropagation algorithm, but the learning process is relatively slow and the analysis of the trained network is difficult(black box). The neural networks can't extract structural knowledge(rules) from the trained neural network, also can't integrate special information about the problem into the neural network in order to simplify the learning procedure. Fuzzy systems are more favorable in explaining based on fuzzy rules, thus their behavior can be adjusted by turning the rules. But since, in general, knowledge acquisition is difficult and also the universe of discourse of each input variable needs to be divided into several intervals, applications of fuzzy systems are restricted to the fields where expert knowledge is available and the number of input variables is small. To overcome the problem of knowledge acquisition, neural networks are extended to automatically extract fuzzy rules from numerical data.

Cooperative approaches use neural networks to optimize certain parameters of an ordinary fuzzy system, or to preprocess data and extract fuzzy (control) rules from data[4].

We present some methods for implementing fuzzy If-Then rules with trainable neural network architectures.

Consider a block of fuzzy rules

$$R_i: \text{ If } x \text{ is } A_i, \text{ then } y \text{ is } B_i \quad (1)$$

where Ai and Bi are fuzzy number, i=1,...,n

Each rule of (1) can be interpreted as a training pattern for a multilayer neural network, where the antecedent part of the rule is the input and the consequence part of the rule is the desired output of the neural net.

The training set derived from equation (1) can be written in the form

$$\{(A_1, B_1), \ldots, (A_n, B_n)\}$$

If we are given two input and two output (MIMO) fuzzy systems of the form

$$R_i: \text{ If } x \text{ is } A_i \text{ and } y \text{ is } B_i, \text{ then r is } C_i \text{ and } s \text{ is } D_i$$

where Ai,Bi,Ci, and Di are fuzzy number, i=1,...,n

Then the input/output training pairs for the neural net are the follows

$$\{(A_i, B_i), (C_i, D_i)\}, 1 \le i \le n$$

There are two main approaches to implement fuzzy IF-THEN rules(1) by standard error backpropgation network. A fuzzy set is represented by a finite number of it's membership values. let $[\alpha_1, \alpha_2]$ contains the support of all the Ai, plus the support of all the A' we might have as input to the system. Also, let $[\beta_1, \beta_2]$ contains the support of all the Bi we can obtain as output from the system.

i = 1, . . . n

M≥2, and N≥ bepositive integers.

Let

$$x_j = \alpha_1 + (j-1)(\alpha_2 - \alpha_1)/(N-1)$$

$$y_i = \beta_1 + (i-1)(\beta_2 - \beta_1)/(M-1)$$

for $1 \le i < M$, $1 \le j \le N$.

A discrete version of the continuous set is consists of the input/output pairs

$$\{(A_i(x_i), \ldots, A_i(s_N)), (B_i(y_1), \ldots, B_i(y_M))\} \; i = 1, \ldots, n$$

Representation of a fuzzy number by membership values.

Using the notations

$$a_{ij} = A_i(x_j), b_{ij} = B_i(y_i),$$

Our fuzzy neural network turns into an N input and M output crisp network, which can be trained by the generalized delta rule.

2.2 Max-Min operation network

General error (δ) calculation of differential impossible BP learning of the Min operation and Max operation uses sigmoid function which gradient is large inside function like (2).

Min operation and Max operation compose of the network, Fig. 1.

$$sig\,2(x) = \frac{1}{1+e^{-ax}} \quad (2)$$

$$\doteqdot \begin{cases} 1 & (x>0) \\ 1/2 & (x=0) \\ 0 & (x<0) \end{cases}$$

The network weight, all +1, excepts the place which is indicated with -1.

The general error(δ) from the each network are propagated the following.

.Min operation

The general error of output layer propagates to most small value in input layer value. However, if there are several small value, the result from dividing of general error by minimum input value numbers is propagated.

.Max operation

The general error of output layer propagates to most big value in input layer value. However, if there are several big value, the result from dividing of general error by maximum input value numbers is propagated.

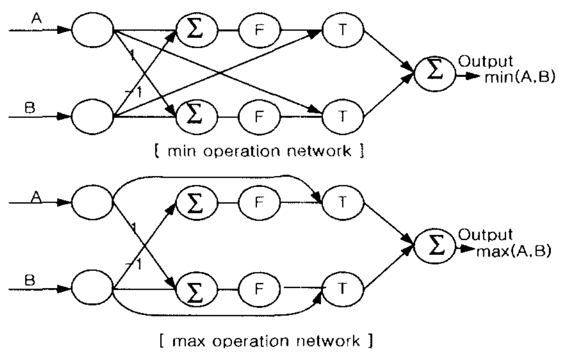


Fig. 1. Min/Max operation network

2.3 Agent

The inventory system using agent can correspond to the production environment change from market trend and the outside factor(demand fluctuation, materials supply delay, production delay, inferiority). There are four agents, Management agent, Account agent, Resource agent, and Production agent, for information processing of each station[11].

The agents distributes the resources, and collects and analyzes information about a production plans and production quantity. Account agent collects, analyzes information of the inventory present condition to minimize inventory management cost(order cost, holding cost, etc) and maximize the profit.

3. I²MS (Intelligent Inventory Management System)

3.1 Structure of I²MS

The agents of the each station exchange relative information, the management agent is able to grasp information in real-time. The agent system composed as Fig. 2.

.Management Agent : It exchanges information which comes in from each agent. collects information. and analyzes information. The management agent manages the system for the demand forecast and the decision -making.

.Business Agent : It manages information about a demand environment change, and decides an order quantity

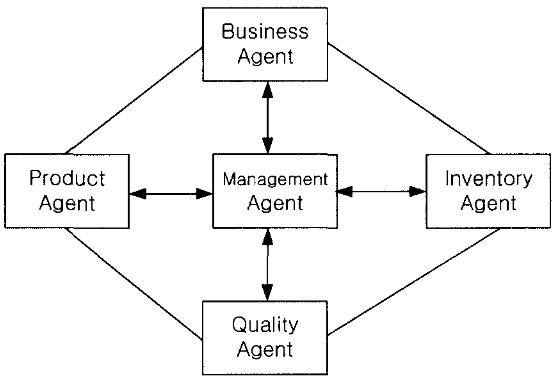


Fig. 2. I²MS

.Product Agent : It makes stand the production plan which follows order quantity. It manages information about a production volume.

.Quality Agent : It manages information regarded as the inferior good and a defective ratio.

.Inventory Agent : It manages information regarded as inventory.

The objective of agent system is to manage a inventory without any failure of production plan from the fluctuation factor. so, it is possible of proper correspondence in uncertain demand forecast.

3.2 Demand Forecast using Fuzzy Structured Neural Network

For a demand forecast, Fig 3.2 consists of input, output and membership. The difference between the general neural network and this system are follows.

.The node function of each node is as follows.
- (Σ) : output of input total
- (T): output of input the product
- (1/x): output the an inverse number of input
- ( ) : output the min of input
- [1] : output of 1

.(F) and (N) Max-Min operation network
- (F): output the f(x) of input
- (N) : output the min of input
- (S): sigmoid function

.The Wa, Wc, and Wδ only weight it changes.

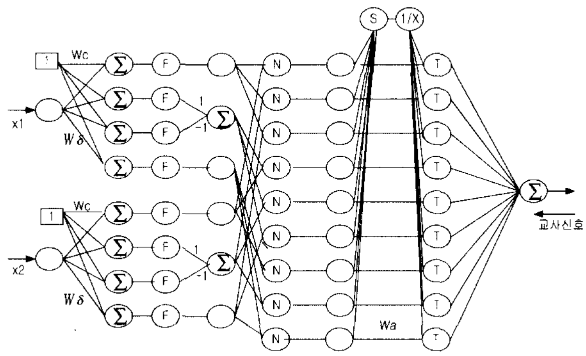


Fig. 3. FSNDF Structure

3.3 Fuzzy Reasoning

If the membership function is $Ar_1, Ar_2, \ldots, Arm$ for rule r(r=1,...,N), the output y for input x1, x2, ..., xm is obtained as follows[10].

$$\mu = \min(Ar_1(x_1), Ar_2(x_2), \ldots, Ar_m(x_m))$$

$$y = \frac{\sum_{r=1}^{N} \mu r \cdot W_r}{\sum_{r=1}^{N} \mu r}$$

Arj is liner function f(x).

$$\begin{cases} y = arj \cdot X + brj \\ Arj(x) = F(y) \\ F(y) = \min(\max(y, 0.0), 1.0) \end{cases}$$

Also, "the middle value" is difference between the min and max.

3.4 Demand Forecast Method

For demand forecast, quantitative element and the quantitative element should be considered[10]. The input data have the sale data of 7 days(weekend) unit and the rapid changes in society (holiday, discount). Using a sale result data, we update for predictive model and new data.

The feature of the data for a demand forecast are as follows.
1. It has a systematic cycle(day, weekend, month.).
2. It receives a holiday effect or a sale.
3. Learning for a forecast does sequential order of the little data.

Input data has the information of holiday and sale. In weekly it classifies a pattern especially, and learns independently. Though is a periodic feature but in order to apply a small-scale data, it is in sequential order.

The forecast have three inputs (demand quantity, discount ratio and holiday effect, demand quantity) and one output (demand forecast quantity).

3.5 Economic Order Quantity

The inventory management is to minimize a inventory relation expense[11]. It is expressed as follows.

$$\text{Total cost}: TIC = \frac{DCp}{Q} + \frac{QPi}{2} \tag{1}$$

Order cost(Cp)=

$$\frac{\text{yearquantity(Q)}}{\text{quantity(D)}} \text{ X order cost(Ch))} \tag{2}$$

Holding cost(Pi)=

$$\text{(average inventory quantity(}\frac{Q}{2}\text{)) X units holding cost(Ch))} \tag{3}$$

$$\text{Economic order quantity } Q_0 = \sqrt{\frac{2DCp}{Ch}} \tag{4}$$

Forecast quantity(T), one day's average portion(M), Day number(K), inventory quantity(X), order quantity(N),

$$K = T/M \tag{5}$$

$$N = T - Q \tag{6}$$

Optimization Economic order quantity(Q_1)

$$Q_1 = \sqrt{\frac{2DCp}{Ch}} - (T - Q) = \sqrt{\frac{2DCp}{Ch}} - N \tag{7}$$

The order day(Dy) is decided by considering with the inventory quantity of present and the quantity ordered.

3.5 Order Quantity Decision-making

The final order quantity decision is become accomplished from the situation uncertain. Therefore, the optimum decision of inventory manager must be satisfactory regarding demand forecast quantity and an order quantity. Here, the optimum decision of the inventory manager apply to the fuzzy integral of Sugeno. The fuzzy integral of Sugeno confronts and the what kind of object multiple item (viewpoint) when evaluating, the purge scale and with the method which it does evaluation against a field each item(evaluation value) it uses synthesis (aggregation) it uses [5][7]. The Fuzzy integral of Sugeno is uses for evaluating about the multiple item (viewpoint) to the object item[5][7]. The set X is the evaluation item about the object item.

Fuzzy measure g(E) to defined about element E ∈ P (X) of the power set of sugeno, it is contribution value of the evaluation of item E about the whole evaluation. Namely, the degree of importance of evaluation item sub set E and Domain x of the function h(X), x ∈ X are evaluation value about an evaluation item X. This time, the Sugeno fuzzy integral of evaluation function h (the importance confronted to a function g) from whole evaluation item X is follow.

$$\int_X h(x) \circ g(.) = \sup_{E \subseteq X} \text{Min}[\min_{x \in E} h(x_i), g(E)]$$

And, X is finite set, the Fuzzy integral of Sugeno is follow.

$$x_i \in X(i = 1,2,\ldots,n),\ h(x_i) \le h(x_{i+1})$$

$$E = \{x_i | k = 1,2,\ldots,n\}$$

$$\int_X h(x) \circ g(.) = \max_{i=1,n} \text{Min}[\text{Min } h(x_i),\ g(E_i)]$$

$$\int_X h(x) \circ g(.) = \text{Min}[\text{Min } h(xk),\ g(Ek)]$$

It exists the k of satisfaction.

if fuzzy set A is domain, then the Fuzzy integral of Sugeno is follow.

$$\int_X h(x) \circ g(.) = \int_A \text{Min}[\mu_A(x) \circ h(.)] \circ g(.)$$

The fuzzy integral is useful from the evaluation problem where the subjective judgement[5].

IV. System Construction and Analysis

We apply this inventory management of medium and small-sized enterprises, and make it sure by simulation. This system will be able to be applied on window NT 4.0. The database we uses to MS-SQL, and the Program language uses Visual Basic.

4.1 Agent information Transmission

The expression of basic information of agent is following.

.Management Agent
- Agent name : a
- Safety stock : 0
- Logistics pattern : a → b
- PSI information : omission

.Inventory Agent
- Agent name : b
- Safety stock : 100
- Purchase lead time : 6 day

- Logistics pattern : b → c
- PSI information :
  Bucket : .., -2, -1, 0, 1, 2, ...
  P plan : .., 100, 100, 100, 100, 100, ...
  P result : .., 90, 120, 0, 0, 0, ...
  S plan : .., 70, 70, 70, 60, 90, ...
  S result : .., 60, 140, 0, 0, 0, ...
  I : .., 100, 80, 110, 150, 160, ...

.Product Agent
- Agent name : c
- Safety stock : 100
- Purchase lead time : 1 day
- Logistics pattern : c → d
- PSI information : omission

PSI information has P(Purchase), S(Sales), I(inventory). The Bucket one day, week, shows the month at the hour unit which will manage the PSI. The PSI information is the time series data to bucket to plans and results. Safety stock is Safety inventory quantity. Purchase lead time is the days number. Logistics pattern express of the next position.

The sale plan of business agent bucket 1 was changed from 60 to 100. This case, the information change of each agent is following.

1. The S plan of inventory agent bucket 1 is changed from 60 to 100 , and the P plan increases as 40.
2. Purchase lead time of production agent is one days. So, the product plan of S plan from bucket 1 of product agent is changed to 100 from 60.This information was not reflected from bucket 5 by 6 days purchase lead time of to inventory agent from product agent. The difference 40 of the product plan is reflected to bucket 6. Also, the P and S plan of product agent are decided for in Safety stock.
3. The value of a bucket six of product agent reflect to a S plan in bucket 0, and the value of the P plan does change.

Consequently, the plan information of agent is changed by the fluctuation of demand quantity. The management agent from information change predicts a new demand quantity. The quantity order and ordering date calculate use of information of demand forecast quantity.

4.2 Order Quantity Forecast

The simulation of the demand quantity forecast implements the 3 item from the data of 2000's year. There are three inputs(a average seven days of sale quantity, Discount rate and holiday effect, sale quantity) and one output. The discount ratio shows table 4.1 The fuzzy rules are the rule of sale quantity average 8 (level 2) and the rule of sale quantity 8 (level 2), 27(level 3). The learning is the data of May, and the forecast is the data of June. The forecast error does at one day unit, This calculation is following.

$$Error(\varepsilon) = \left(\frac{\Sigma(\text{demand quantity} - \text{demand forecast quantity})}{\Sigma \text{ demand quantity}}\right) / \text{Day numbers(30 day)}$$

Evaluation value is computed with one month average of absolute error value. Fig 4.2 shows the forecast error average of one day unit for each level and learning times.

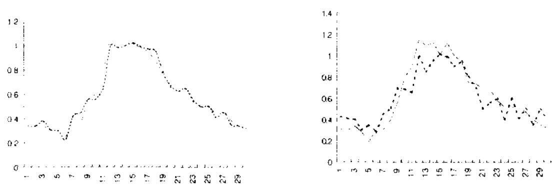
Table 1. Discount rate & holiday effect

Discount rate	Numerical value	Discount rate	Numerical value
0	0.99	21-30%	0.3
1-5%	0.8	31-40%	0.2
5-10%	0.6	41-50%	0.1
11-15%	0.5	50% over	0.01
16-20%	0.4	holiday	0.3

Table 2. Average forecast error of one day units

Item	Learning times	Level 2 Rule 8	Level 3 Rule 27
A item	500	6.14	8.78
	2000	6.64	8.92
B item	500	5.43	5.57
	2000	5.55	5.81
C item	500	5.45	5.98
	2000	5.76	6.17

To the case of leaning 500 times, the error has approximately 6% forecast efficiency. It does not improve from learning 2000 times over. To the case of 2 levels has a good result. The A item has change of demand quantity, and the B , C items are the stable.



(A) (B)

Fig. 4. Result of demand forecast

After 500 learning, Fig 4.1 shows (a) good result (1.11%), (b) bad result (10.87%) each other. The thread line is sale quantity and the dotted line is demand forecast quantity.

4.2 EOQ & Order date

There are structural elements for an economic demand forecast in Table 3. In Table 4. We get a result from applying the algorithm (see, 3.3 Economic Order Quantity) for optimum of the economic order quantity and a order date. The economic order quantity is calculated on base of one day. For item A, the demand forecast quantity 140, so it is less the inventory quantity. So, The order date does not appear.

Table 3. The amount of items used

Item Name	Item A	Item B	Item C
Average quantity of a day	20	30	50
Warehouse quantity	500	500	500
Inventory quantity	321	250	155
Holding cost	30	3	35
Order cost	20	15	32

The demand forecast quantity of the item B is 210, therefore the inventory quantity is exhausted after 7 days. The economic order quantity is 322 in this algorithm. The item C is order after 3 days with 100 economic order quantity, Because it will be exhausted after 3 days, demand forecasts quantity is 350 and inventory quantity 155 .

Table 4. Economic order quantity and date

Item Name	Item A	Item B	Item C
Demand forecast	140	210	245
Economic order quantity	14	46	25
Order quantity	0	322	100
Date of order	0	7	3

This system produces automatically the economic order quantity and date of optimum.

4.3 The Decision-making of Order Quantity Forecast

The demand quantity is predicted by the neural network which executes with uncertain and innocent data. It is desirable to the demand forecast quantity with expert opinion. The fuzzy set about the reliability of the past data, the present condition of inventory quantity, ordering cost, operating cost, the present condition of ordering, the present condition of warehouse, and the present condition of market environment is as follows.

Fuzzy Set x = {Reliability, Inventory quantity, Funds, Environment, Warehouse}

Important of evaluation item is represented in Fuzzy scale g() as Table 5.

Table 5. Importance of evaluation item

	g(.)
Reliability(R)	0.45
Inventory quantity(I)	0.02
Funds(F)	0.15
Environment(V)	0.1
Warehouse(S)	0.1

The Evaluation by the managers is as Table 6. The total evaluation is calculated with the value of the importance of the evaluation (g) and evaluation of the managers (h_A).

The case of manger A

$(h_A(V) \wedge g(\{R, I, F, V, S\})) \vee (h_A(I) \wedge g(\{I, F, V, S\})) \vee (h_A(F) \wedge g(\{I, F, S\})) \vee (h_A(S) \wedge g(\{ I, S\})) \vee (h_A(R) \wedge g(\{R\})) = (0.95 \wedge 1) \vee (0.95 \wedge 0.55) \vee (0.8 \wedge 0.45) \vee (0.85 \wedge 0.3) \vee (0.7 \wedge 0.45) = 0.95$

Table 6. Evaluation of managers

	A	B	C
Reliability	0.7	0.85	0.87
Inventory quantity	0.95	0.86	0.95
Funds	0.8	0.57	0.76
Environment	0.95	0.85	0.6
Warehouse	0.85	0.75	0.8

B manager is 0.85, C manager is 0.6.

If the average of the manager is over 0.75, it can be trust. Because the average of the three managers is 0.8.

V. Conclusion

We should have the safety inventory against the change of production environment. If there are too much inventory, it take much holding cost, the case of less makes a financial loss from absence of inventory. So inventory quantity prediction is not easy.

In this paper, we propose a system which is able to correspondence with in system environment change, and execute automatically the exchange of information. and also using fuzzy structure neural network, it make high system reliability through the demand forecast. This system make automatically a decision of the economic order quantity and a date using expert's opinion. In the future, we will study about the stability of system and the information quantity for the multiple branch against the change.

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