



DESIGNING ARCHITECTURE OF DEMAND FORECASTING TOOL USING MULTI-AGENT SYSTEM

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Abstract: *Topics in supply chain management have been widely researched and the issue of demand forecasting is getting supplementary concentration in the age when the customer satisfaction is the major concern for the supply chain manager. The accurate demand forecasting is the basis of the efficient production scheduling and inventory control strategies. It plays very important role in smooth running of the supply chain activities. In this paper, the concept of the multi-agent system is being applied in the architecture of the demand forecasting tool. Such tool is capable of handling the complexities and limitations of traditional demand forecasting system used in the real time supply chain management system.*

Key words: *Supply chain management system, demand forecasting, intelligent agent, multi-agent system, Jade*

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1. INTRODUCTION

The intelligent agent is a software computational entity which has the capability of perception, solving problem, self-learning and becoming accustomed to the environment. These agents are being observed as the best option for solving the complex real-time problems with more efficiency. The multi-agent system (MAS) is a system composed of multiple interacting intelligent agents. Multi-agent systems can be used to solve problems which are difficult or impossible for an individual agent or monolithic system to solve. Examples of problems which are appropriate to multi-agent systems research include online trading, disaster response, and modeling social structures. The figure 1 indicates the working of the intelligent agent in the real time environment.

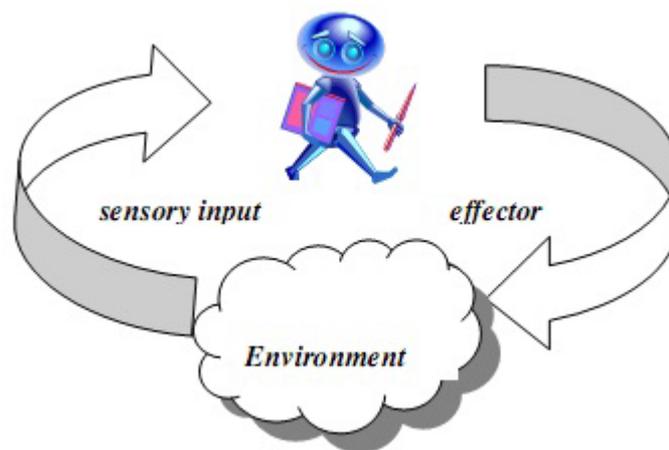


Figure 1: Intelligent agent

The agents in a multi-agent system have several important characteristics:

- **Autonomy:** the agents are at least partially autonomous.
- **Local views:** no agent has a full global view of the system, or the system is too complex for an agent to make practical use of such knowledge
- **Decentralization:** there is no designated controlling agent (or the system is effectively reduced to a monolithic system)

Typically multi-agent systems research refers to software agents. However, the agents in a multi-agent system could equally well be robots, humans or human teams. A multi-agent system may contain combined human-agent teams. The figure 2 indicates the working of multiple intelligent agents in the multi-agent system as given below.

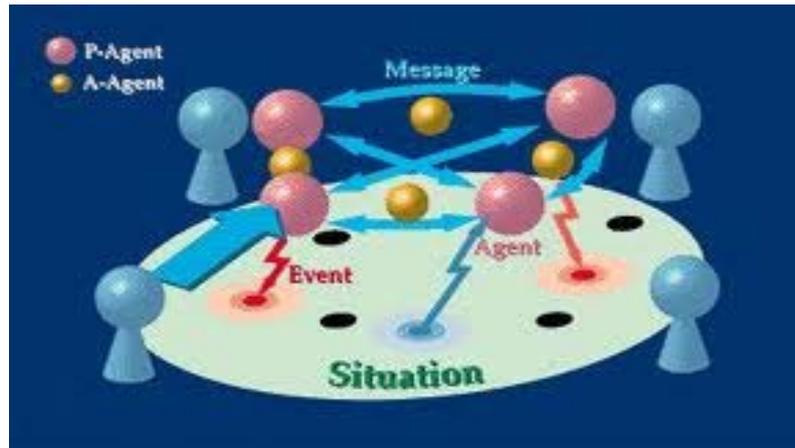


Figure 2: Multi-agent system

Multi-agent systems can manifest self-organization and complex behaviors even when the individual strategies of all their agents are simple. Agents can share knowledge using any agreed language, within the constraints of the system's communication protocols each agent has incomplete information or capabilities for solving the problem and, thus, has a limited viewpoint;

1. there is no system global control;
2. data are decentralized; and
3. computation is asynchronous.

Multi-agent systems are applied in the real world to graphical applications such as computer games. Agent systems have been used in films. They are also used for coordinated defenses systems. Other applications include transportation, logistics, graphics, GIS as well as in many other fields. It is widely being advocated for use in networking and mobile technologies, to achieve automatic and dynamic load balancing, high scalability, and self-healing networks.

2. DEMAND FORECASTING

Forecasting is the estimation of the value of a variable (or set of variables) at some future point in time. In this note we will consider some methods for forecasting. A forecasting exercise is usually carried out in order to provide an aid to decision-making and in planning the future. Typically all such exercises work on the premise that if we can predict what the future will be like we can modify our behavior now to be in a better position, than we otherwise would have been, when the future arrives. Applications for forecasting include:



- inventory control/production planning - forecasting the demand for a product enables us to control the stock of raw materials and finished goods, plan the production schedule, etc
- Investment policy - forecasting financial information such as interest rates, exchange rates, share prices, the price of gold, etc. This is an area in which no one has yet developed a reliable (consistently accurate) forecasting technique (or at least if they have they haven't told anybody!)
- Economic policy - forecasting economic information such as the growth in the economy, unemployment, the inflation rate, etc is vital both to government and business in planning for the future.

One way of classifying forecasting problems is to consider the timescale involved in the forecast i.e. how far forward into the future we are trying to forecast. Short, medium and long-term are the usual categories but the actual meaning of each will vary according to the situation that is being studied, e.g. in forecasting energy demand in order to construct power stations 5-10 years would be short-term and 50 years would be long-term, whilst in forecasting consumer demand in many business situations up to 6 months would be short-term and over a couple of years long-term. The table below shows the timescale associated with business decisions.

Forecasting methods can be classified into several different categories:

- qualitative methods - where there is no formal mathematical model, often because the data available is not thought to be representative of the future (long-term forecasting)
- regression methods - an extension of linear regression where a variable is thought to be linearly related to a number of other independent variables
- multiple equation methods - where there are a number of dependent variables that interact with each other through a series of equations (as in economic models)
- time series methods - where we have a single variable that changes with time and whose future values are related in some way to its past values.

3. RELATED WORK

Handfield and Nichols et al. (1999) argued that integrated supply chain management is becoming recognized as a core competitive strategy. As organizations continuously seek to



provide their products and services to customers faster, cheaper and better than the competition, managers have come to realize that they cannot do it alone; rather, they must work on a cooperative basis with the best organizations in their supply chains in order to succeed.' The success of SCM will depend upon the choice of the specific partners in the supply chain and on the way in which they co-operate efficient and effective with each other.

Gérard P. Cachon et al. (2001) argued that optimal supply chain performance requires the manufacturer to share her initial forecast truthfully, but she has an incentive to inflate her forecast to induce the supplier to build more capacity. The supplier is aware of this bias, and so may not trust the manufacturer's forecast, harming supply chain performance. We study contracts that allow the supply chain to share demand forecasts credibly under either compliance regime.

Gene Flidner et al. (2002) proposed a conceptual framework to forecast supply chain demand in a collaborative manner and ultimately to coordinate and integrate various supply chain partner management activities including purchasing, production planning and inventory replenishment. This paper explains the collaborative forecasting concept and framework, identifies benefits that can be achieved using collaborative supply chain forecasting, and identifies potential obstacles to implementation.

Vickery et al. (2003) demonstrated that no statistically significant relationship exists between supply chain integration and financial performance and that the effect of supply chain integration on financial performance occurs through customer service. Demand forecast accuracy drives customer service performance. Demand forecast is already a difficult task for a supermarket, but it gets much more complex for the other agents since variability of demand increases backward the supply chain.

Minghui XU et al. (2003) addressed the problem of handling the uncertainty of demand in a one-supplier-one-retailer supply chain system. Demand variation often makes the real production different from what is originally planned, causing a deviation cost from the production plan. Assume the market demand is sensitive to the retail price in a nonlinear form, we show how to effectively handle the demand uncertainty in a supply chain, both for the case of centralized-decision-making system and the case of decentralized-decision-making system with perfect coordination.



In their comprehensive review of logistics journals, Fabbe-Costes and Jahre et al. (2008) found only one article focused exclusively on this limited dyadic upstream scope. Researchers also question the benefit of supply chain integration and recommend more research pertaining to the link between supply chain integration and performance. According to empirical evidence, supply chain integration affects financial performance by improving operational performance (Germain and Iyer 2006); we consider how one type of integration, namely, demand information sharing, may affect operational performance.

Azzam ul ASAR et al. (2005) applied the approach of using ANN methodology alone is limited which has generated interest to explore hybrid solutions for a better alternative. This paper presents a brief review of the recent work focusing on the STLF solution based on combining ANN approach with other techniques. An intelligent multi-agent based solution of STLF is proposed that provides a better framework for building a more realistic solution

Fu-ren Lin and Shyh-ming Lin et al. (2006) used a supply chain that produces digital still cameras as an example to demonstrate how the SPA works. In this example, individual information systems of the involved companies equip with the SPA and the entire supply chain is modeled as a hierarchical object oriented Petri nets. The SPA here applies the modified AGNES data clustering technique and the moving average approach to help each firm generalize customers' past demand patterns and forecast their future demands. The amplitude of forecasting errors caused by bullwhip effects is used as a metric to evaluate the degree that the SPA affects the supply chain performance. The experimental results show that the SPA benefits the entire supply chain by reducing the bullwhip effects and forecasting errors in a dynamic environment.

Hakan TOZAN et al. (2009) emphasized the response of demand variability to the proposed hybrid system; which consists of fuzzy time series forecasting model and ANFIS based decision process, in supply chain networks is analyzed using a near beer game simulation model under relatively medium variate demand data.

Réal Carbonneau et al. (2009) investigated the applicability of machine learning (ML) techniques and compares their performances with the more traditional methods in order to improve demand forecast accuracy in supply chains. To this end we used two data sets from particular companies (chocolate manufacturer and toner cartridge manufacturer), as well as data from the Statistics Canada manufacturing survey. A representative set of traditional



and ML-based forecasting techniques have been applied to the demand data and the accuracy of the methods was compared. As a group, Machine Nazia Sultana et al. (2010) showed demand planning methodology and few applications have been shown here. The potential of this Demand Planning Methodology is to improve the certainty of demand planning decision making of a FMCG company. This methodology helps to maintain less excess and shortage quantity over the supply chain. Hence save the value lost and improve the Supply Chain Efficiency.

4. CAUSES OF BAD FORECASTING

Predictions are notoriously inaccurate. Some have gone so far as to suggest that a chimpanzee with a dart board could provide a credible forecast. While forecasting has become more technical and statistical in recent years, it is still checked by the limitations of the forecaster and the methodology used. If these shortcomings can be identified, then compensation can be made, but recognizing them is not always easy.

- **Horizons:** Forecasts become less accurate the farther into the future one predicts. Events of the next month or quarter are easily predicted. Just as the weather forecast is based on a probability -- 20 percent chance of rain -- a good business forecast should include a range of probabilities.
- **Biases:** Everyone has a world view that is influenced by upbringing, culture and business environment. While one can make every effort to be objective, it is an impossible task. A business owner starting a new venture will naturally be optimistic about growth opportunities. In this instance, the optimism must be reined in. Biases can work from the opposite side as well.
- **Changing Patterns:** The easiest prediction is the one based on past trends and the assumption that they will continue into the future. This may be a valid assumption for a short interval, but eventually the trend line will change. Identifying and predicting turning points is one of the most difficult aspects of forecasting.
- **Bad Data:** A quantitative forecast that is based on historical data can be skewed if the data is insufficient or bad. As an extreme example, one cannot make an accurate five year prediction if it is based on only one year's worth of data. And even then the forecast may be flawed. Another data problem may arise if the forecast is based on

faulty assumptions. In this situation good data are misused to produce a bad forecast. Only critical evaluation can insure that a forecast is as accurate as it can be. These facts shows the main problems faced in the current demand forecasting system used in the supply chain management system.

5. MULTI-AGENT BASED DEMAND FORECASTING SYSTEM

To resolve the problems discussed in the last section, we are proposing the multi-agent based demand forecasting tool. This tool consists multiple intelligent agents working together to provide the accurate product demand during the supply chain activities.

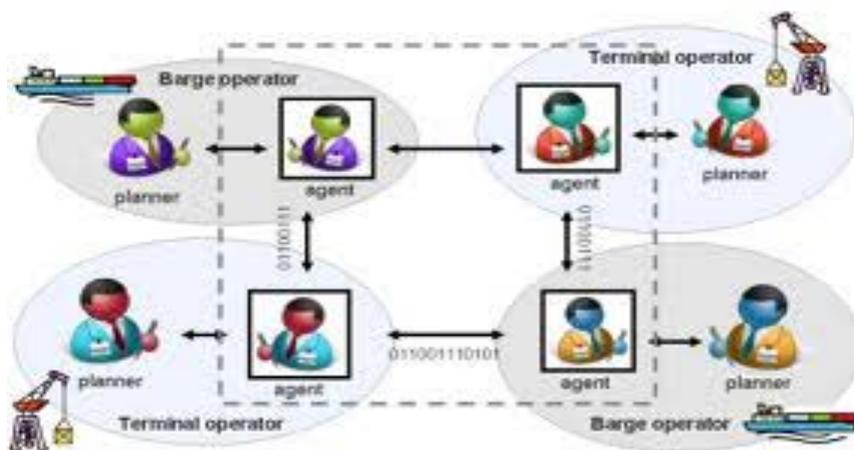


Figure 3: Multi-agent based Demand forecasting system

The agent which performs the task of demand forecasting is known as the demand forecasting agent. The control agent plays a liaison role between a supply chain manager and the system. It collects historical demand data and strategies from managers and aims at building a rule-base for supply chain management. The demand forecast agent, who communicates with control agents, plays a role in transforming managers' experience. In addition, it provides a forecast mechanism, which tries to minimize the total cost for the entire supply chain.

The agent system is autonomous because it allows any manager to change the ordering quantity of that echelon in real time according to recalculation results when the demand of a certain echelon is changed. After being enabled by the control agent, the demand forecast agent automatically calculates the supply chain's total cost, determines the optimal ordering quantity for period $t + 1$, and delivers the message back to each control agent at each echelon. In addition, this agent analyzes historical demands and sends the analytical results to all managers periodically in the supply chain.



6. CONCLUSIONS

In this paper, the multi-agent based demand forecasting system has been proposed which generate the demand forecasts values on basis of the data gathered by the multiple agents. they can forecast the ordering quantity for period $t + 1$ in a multi-echelon supply chain, where every entity was allowed to use different inventory systems. This approach provides following benefits as given below:

- Allowing for various entities at different echelons using different inventory systems and forecasting the ordering quantity accurately as well as minimizing shortage of inventory; consequently, the total cost of a supply chain is reduced;
- Sharing information between entities of a supply chain and coordinating every entity of SC; consequently, optimization can be achieved more effectively and the bullwhip effect is reduced.
- Exploring and transforming managers' experience into rules, this leads to a more accurate and effective inventory control by reusing the explicit rules.

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