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Novel Approach for Inventory Planning Using OPAL and Some Neural Networks

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***Abstract:** One of the major concepts in Enterprise Resource Planning (ERP) or Supply Chain Management (SCM) systems is to identify the similar items in an inventory database. The approach used is called planning and there are different methods to segment/classify the items into different groups. This can be easily done using ABC or XYZ analysis available in most of the ERP systems. However, these approaches are limited to single variable like dollar usage or demand. Ranking the multivariate series to identify the similar units of information can provide additional insights. Similarly, segmentation of the multi Variate data using an unsupervised neural network will help the decision maker to proactively build alternate plans for differing scenarios. In this research, a novel framework along with a case implementation in inventory planning is proposed. The proposed frame work consists of three modules namely – an analytical query tool to provide quick access to data, a ranking module and a segmentation module. A case study of the proposed frame work has been carried out to test the suitability of framework for inventory planning applications and has shown promising results. Work is under progress to develop additional modules for using different approaches to forecast the demand for each category of the inventory.*

***Keywords:** Supply Chain Management, Inventory Planning, Multi Variate Segmentation, Neural Network, ERP Systems.*

I. INTRODUCTION

Inventory planning is one of the major functions in an ERP or SCM framework. Even medium sized organizations, hundreds of stocks keeping units (SKU) are monitored on a regular basis. When the number of SKUs exceeds the limit of manual control, it needs good planning to identify the stocks that need different control procedures.

Traditional ABC analysis has been implemented in many ERP/SCM systems for effective inventory management. However, traditional ABC analysis is hindered by the fact that it uses a single criterion and ignores other important factors. Thus, the inventory control problem becomes a multivariate / multi criteria inventory classification which is studied widely by researchers.

The current research is trending towards the data driven approaches to multivariate/multi attribute classification problem. In this paper, a framework which combines linear and nonlinear paradigms for inventory planning is evaluated.

II. LITERATURE SURVEY

ABC analysis is one of the most commonly employed inventory classification techniques. Conventional ABC classification was developed for use by General Electric during the 1950's. The classification scheme is based on the Pareto principle, or the 80/20 rule, that employs the following rule of thumb: ‘‘vital few and trivial many.”

The process of ABC analysis classifies inventory items into A, B, or C categories based on so-called annual dollar usage. Annual dollar usage is calculated by multiplying the dollar value per unit by the annual usage rate [4].

A. This classification divides the stock into 3 categories:

1) A (very important)
2) B (quite important)
3) C (less important).

A product belongs to one group depending on its annual value. An item’s annual value is obtained by multiplying its unitary cost (value) by its annual rotation. When decreasingly ordering the items’ annual values and at the same time representing their accumulated annual values, a graphic is obtained that shows that a 20% of the items make up to 80% of the annual total value of the warehouse (A Class), next 50% of the items represent 15% of the annual value (B Class) and the last 30% of the items represent only 5% of the annual value (C Class). Although this classification is not always exact, it represents with enough accuracy, the behaviour of items in most warehouses.

The first paper about multi variate ABC analysis was presented by Flores et.al[Flores]. Improving on this study, Chen et al.[7], have presented a case based multi criteria ABC analysis by accounting additional criteria, such as lead time and criticality of SKUs to provide managerial flexibility. Keskin et.al. [6] have presented a solution to multi criteria planning with fuzzy c-means clustering. Authors have found that the soft clustering allows the uncertainty in classification boundaries compared to judgmental rules used in ABC classification.

Simha et.al [2] have reported an SOM based methodology, for multivariate inventory planning. They have demonstrated how SOM preserves the topology, with similar results to fuzzy clustering.

Ng [8], has presented a linear model, which is more comprehensible by managers in inventory control. The model converts all criteria measures of an inventory item into a scalar score. The classification based on the calculated scores using ABC principle is then applied. It was expected that model can be widely applied to inventory managers with minimal backgrounds in optimization.

In this research work a framework which combines the properties of a linear model with that of a nonlinear model like SOM has been proposed. It is assumed that the extension helps in much finer control of inventory, than the linear model alone.

III. CASE STUDY

The proposed framework consists of three major components. They are -

an analytical query system, which provides the data in the standard format from a data mart

a ranking module which ranks the multi Variate series with an adoptive algorithm and

a segmentation module, which provides intelligent grouping of the SKUs based on the scalar value.

A simplified architecture diagram of the proposed system is shown in Fig. 1.

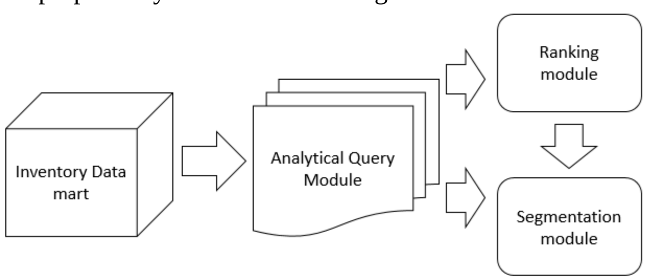

Fig. 1 Architecture of the proposed system

A. Analytical Query Module

The analytical query module will provide the data in appropriate format for the other two nodules. This system gets the data from inventory data mart by executing an appropriate cross tab query. It is based on well-known Online Analytical Processing (OLAP).It is assumed that the data model for the analytical data mart follows the star schema due to several reasons stated by Kimball et. al [5]. This type of schema de-normalizes the dimension tables to facilitate the faster joins on the queries, reducing the latency. The major function in the query module is the SQL query model for a cross tab. This function will be executed by the DBMS and provide the result set for further analysis.A typical cross tab provides aggregated factual values for selected dimensions in the required format. Generally, the cross tab is a tuple (X_i, Y_j, F_k) where X_i are dimensional values plotted on rows of a spread sheet, Y_j are the dimensional values plotted on columns of a spread sheet and F_k are aggregated / functional factual values constituting the row column interaction i.e. the shells several commercial systems provide some means of generating cross tabs from the data Simha et. al [2]. In this research X_i is allowed to take theoretically unlimited number of dimensions (practically limited to six). User selected facts are aggregated as F_k values.

B. Ranking module

Once the multivariate series data for the user defined criteria is extracted from the query system, it will be processed by the ranking module.

A simple pattern based approach has been developed in this research work to compare the multivariate series data. The proposed solution extends the time series ranking, proposed in Simha et.al [1]. The ranking of records is done through automated sorting of patterns. In order to sort the multivariate values, the spread of each series is computed and compared with the spread of all the series.

Large variances suggest a very different development, while small variances indicate a similar development pattern.Since the values for each series are very different, it is not possible to compare the series values directly. In order to make the series comparable, the series will be normalized, by dividing the individual values of the series by series mean. Once the data is normalized, square of a sum of differences of individual values in the time series with that of the overall mean vector values is computed, which results in scalar values for each series. Ranking of these series of scalars will provide statistically valid ranks for the original multivariate series. The algorithm for computing the ranking of multivariate series is shown in Fig. 3

1. For each series
   i. Compute the mean value of series.
      $X_{im} = \sum x_{in}/n$
      Where X_{im} = mean of the series X_i
      X_{in} = n^{th} value of the series X_i
   ii. Compute the normalized series
2. Compute the average for the set of series
   $X_{ij} = X_{in} / X_{im}$
   Where X_{ij} is the normalized value of series I such that j = n for all n (0, n)
   X_{in} = actual value of index n of series i
   X_{im} = mean value of series i
3. For each series compute the squared difference with the overall averages
   $\Delta_i = \Sigma\, (xim - x_m)^2$
   Where Δ_i = squared distance of series i with overall average
   Xim value of series i (normalized)
   Xm = m^{th} value of overall average
4. Sort the series based on the difference δ computed in step 3.

Fig. 3: Algorithm to Compute the Ranking

C. SOM module

SOM imitates the function of ‘grouping by categories’ operated by human brain and every output processing element would affect each other. It includes a set of neurons usually arranged in a two dimensional structure, in such a way that there exist neighbourhood relations among the neurons, which dictates the topology, or structure. The neurons are well connected to each other from input to output layers but they are not connected to themselves.

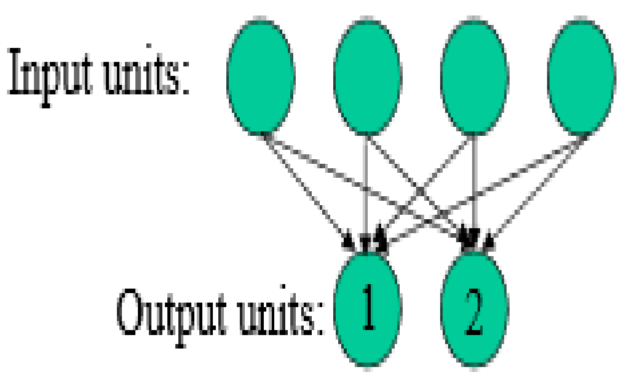

Fig. 4: Self Organizing Map

It uses unsupervised learning which is known as self-organization to visualize topologies and hierarchical structures of high dimensional input spaces. The algorithm of SOM is initialized by assigning the values of weight vectors of each output neuron linearly or randomly. Training process of SOM starts by representing a data point randomly in the network. The distances between these data points and the weight vectors of all neurons are computed by using distance measures such as Euclidean distance. The nearest neuron wins and is thus updated to move closer to the data point.

- Select output layer network topology
  - Initialize current neighborhood distance, D(0), to a positive value
- Initialize weights from inputs to outputs to small random values
- Let t = 1
- While computational bounds are not exceeded do
  1) Select an input sample i_l
  2) Compute the square of the Euclidean distance of i_l from weight vectors (w_j) associated with each output node
  $$\sum_{k=1}^{n} (i_{l,k} - w_{j,k}(t))^2$$
  3) Select output node j^* that has weight vector with minimum value from step 2)
  4) Update weights to all nodes within a topological distance given by D(t) from j^*, using the weight update rule:
  $$w_j(t+1) = w_j(t) + \eta(t)(i_l - w_j(t))$$
  5) Increment t
- Endwhile

Fig. 5: Self Organizing Map Algorithm

Fig.5 shows the SOM algorithm proposed in the literature by Mehrotra et. al[9] and is used in the current study. SOM converges into a stable structure and represents information that is learned. SOM reflects an input value onto a point of plane, and the points around neighbouring area have similar functions, thus providing a homogeneous group.A case study on publicly available bench mark data and decision support requirement is discussed in the next section

IV. CASE STUDY

In our research, the proposed framework is implemented to classify inventory items. In order to study the effectiveness of the framework, the classification results were compared with the results obtaining using traditional ABC analysis.

Four classification criteria, initially utilized by Flores et al. [3], were selected as inputs: average unit cost (AUC), Demand, Critical factor, and Lead-time. Though additional variables can be added, from literature survey, these four have been identified as the most important variables. In addition, the proposed framework, is suitable, when the number of variables are less, due to computational complexities.

The evaluation methodology is based on comparison of the classification results from two approaches – ABC classification and proposed classification. Though direct comparison is not possible on a single measure, due to dissimilarity in number of segments formed by each approach, a general metric of the variance, is used to measure the better fit.The data is cleaned and prepared in standard format in the data mart. The data required for data is evaluated and modified to suit the analysis. Later the proposed frame work is used to classify the SKUs and assessed for the effectiveness of classification based on the reduction of inventory. The best one is suggested for adoption.

The data used comes from the available literature Simha et. al [2]. The data is transformed to standard form and the ranking algorithm was applied on it. The ranked series are further segmented using SOM module.

The Pareto analysis, prior to ABC analysis is shown in Fig 8. It can be seen that 25% of the products cover 60% of demand, which are categorized as Class A items. Similarly, class B and class C items are extracted.

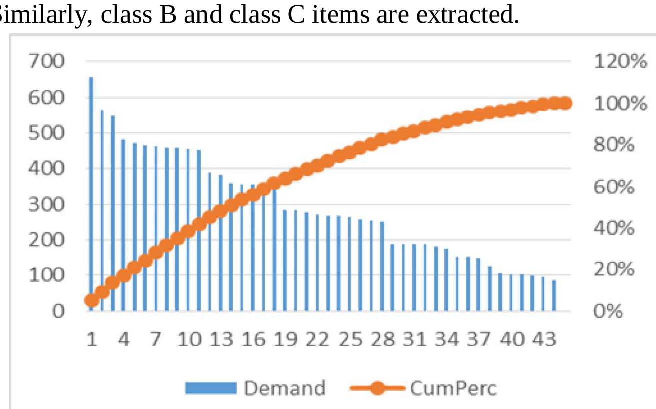

Fig 6. Pareto Analysis for the data

The ranking based on the proposed algorithm and classification of items based on the SOM segmentation has been compared with the average variability with ABC analysis.

Table 1, shows the results of that comparison. It can be observed that the proposed approach results in 5 classes, instead of 3 classes. The average variability with the proposed approach compared to ABC analysis has been reduced by a considerable 17%. This helps managers to identify the critical components that need management control, which in turn will reduce the complexity in demand forecasting.

TABLE 1.
RESULTS OF ANALYSIS

Segment	Variance % compared to ABC classification
High Value	18
Medium value	12
Medium value – medium usage	30
Low value – high usage	20
Low value – low usage	22

V. CONCLUSIONS

ABC analysis is most widely used inventory classification technique in commercial ERP systems. Since it has a limitation of being based on single criteria for classification, different multi criteria approaches have been suggested in the literature. n this research, an attempt has been made to develop an analytics framework to provide these features.

The proposed framework is built using pivot able data model with multivariate series ranking using pattern recognition and segmentation using SOM model. A case study on a publicly available inventory planning data set has been carried out. The results are promising. The research is under progress to provide additional capabilities for forecasting for different segments within the proposed framework

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