Yugoslav Journal of Operations Research
1 (1991), Number 2, 171-177

A CONCEPT OF AN EXPERT SYSTEM FOR SPARE PARTS INVENTORY CLASSIFICATION

Mirko VUJOŠEVIĆ, Milorad ŠUĆUR

Mihailo Pupin Institute, Volgina 15, POB 15, 11000 Beograd, Yugoslavia

Abstract. The problem of inventory classification in spare parts inventory system is considered. The classification is performed prior to determining the inventory review and replenishment policies, and these are a basis for developing and applying mathematical models. A good inventory classification has to take into account the total inventory cost per time period rather than usage value which is used in classical ABC classification. The problem arises from the fact that it is very hard to measure total cost, especially stock-out cost which are of particular importance in a maintenance system. Therefore, the classification is to be made on the basis of attributes describing spare parts. Inference mechanism as a part of proposed expert system uses data about spare parts from an existing data base and heuristic rules from a knowledge base.

Key words and phrases: inventory, classification, spare parts, expert system, decision support

1. INTRODUCTION

Inventory management system can be significantly improved on by simply adopting decision rules that do not treat all items equivalently. Therefore, the inventory classification is one among the first tasks to be solved in designing an inventory management system. It is suggested in books, manuals and papers that the first step to be made is Pareto analysis, i.e. ABC classification [**1**, **2**]. The criterion employed in this classification is the inventory value. The inventory value for each spare part is obtained by multiplying the annual demand by the unit cost. Although simple to perform and efficient, this classification has exhibited serious practical shortcomings. This is why the literature suggests modifications of the ABC classification according to user criteria. However, these criteria are rarely specified, with justification that they depend on a user's actual conditions. This is why some authors find the ABC classification inappropriate for spare parts inventory systems intended for maintenance purposes and give preference to other classification approaches [**3**]. They attach greater importance to the role of a spare part and to the way in which it is used in maintenance processes.

A starting point in this paper is that the classification based on the total inventory cost is the most important for inventory control system design purposes.

Here the total inventory cost is taken to mean, in addition to the cost of spare parts themselves on which ABC classification is based, the order cost, the stock-holding cost, and the stock-out cost. If data on the total cost were available, the classification itself would be a simple procedure, similar to the one employed in the ABC classification. However, the problem lies in the fact that, except for the first, the remaining three types of cost, particularly the stock-out cost, are difficult or impossible to measure, or even estimate. This is why, instead of explicit costs, other attributes of spare parts and heuristic rules leading to a desired classification are considered in this paper.

2. PROBLEM FORMULATION

2.1. Classification problem

Classification, sometimes called categorization in the cognitive science literature, may be considered as information processing task [4]. Then it can be functionally specified by the information it takes as inputs, and information it gives as output. The input to the classification task is a collection of data about some specific entity, in our case about spare part, and the output is the general category (or categories) pertaining to the entity.

The classification task considered in this paper is to classify all spare parts into four groups denoted by α, β, γ, and δ. This classification is to be made by taking into account the total inventory cost as classification criterion. The parts that belong to the class α are the most important in inventory management system, the parts from the class β are very important, those from the class γ are important, and those from the class δ are less important.

Attributes describing each spare part as an entity for classification are:

- A_1 — inventory value obtained by multiplying the annual demand by unit purchase cost
- A_2 — unit purchase cost
- A_3 — repairability
- A_4 — supplier (supply source)
- A_5 — replenishment (lead) time
- A_6 — commercial availability
- A_7 — essentiality in maintenance and operation
- A_8 — perishability, life time
- A_9 — requirements for warehousing space
- A_{10} — attractivity of spare part to be stolen
- A_{11} — consumption dynamics.

Most attributes are qualitative in nature. A characteristic from a finite set of corresponding considered attribute characteristics is associated to each spare part. For the attributes of numerical type, e.g. A_1 and A_2, it is also possible to make a preliminary classification that represents the expert system input or, possibly, a portion of the system. For example, on the basis of the unit purchase cost, it is suitable to classify all parts into five classes: extremely expensive, very expensive, expensive, cheap, and very cheap.

Each of these attributes is a basis for performing special classifications which may be useful for decision making in inventory control process. A desired classification should employ the existing simple classifications and rules that reflect their influence on the total inventory cost.

2.2. Mathematical Formulation

The classification task is stated symbolically as follows.

Let $\mathcal{R}$ denote the spare parts set, and R_j its elements, $j = 1, \ldots, J$. Let A_i, $i = 1, \ldots, I$, stand for the attributes describing the elements of the set $\mathcal{R}$, and let $\mathcal{A}_i$ denote the set of values that can be taken by attribute A_i, and α_i^k, $i = 1, \ldots, I$; $k = 1, \ldots, K_i$, the corresponding values. The attribute vector of part R_j is $\alpha_j = (a_{1j}, \ldots, a_{ij}, \ldots, a_{Ij})$, with $a_{ij} \in \mathcal{A}_i$, $i = 1, \ldots, I$; $j = 1, \ldots, J$. The set of rules $\mathcal{P}$ should be used to assign, on the basis of the values of a_{ij}'s, to each R_j an additional attribute, $a_{i+1,j}$ that will show whether the part belongs to class α, β, γ or δ.

3. CLASSIFICATION KNOWLEDGE BUILT INTO THE EXPERT SYSTEM

3.1. System Input and Output

As it has already been stated, the values of attributes a_{ij}, $i = 1, \ldots, I$; $j = 1, \ldots, J$, represent system input, and the attributes $a_{i+1,j}$, $j = 1, \ldots, J$ system output.

3.2. Classification Process

The spare parts classification process is presented in Fig. 1. The first step involves the initial classification into four groups based on attribute A_1, i.e. inventory value. This is a kind of classical Pareto analysis. In this case the classification criterion is the ratio of inventory value a_{1j} of particular part to the average inventory value per part. In this sense, we calculate first the average inventory value per part

$$P_{gp} = \frac{1}{J} \sum_{j=1}^{J} a_{1j}$$

and accept the bounds k_A, k_B, and k_C, that will determine the initial classification. This is followed by calculating, for each spare part a coefficient $k_j = a_{1j}/P_{gp}$ on the basis of which the part is classified into one of four initial classes.

The whole first step can be represented by the following procedure:

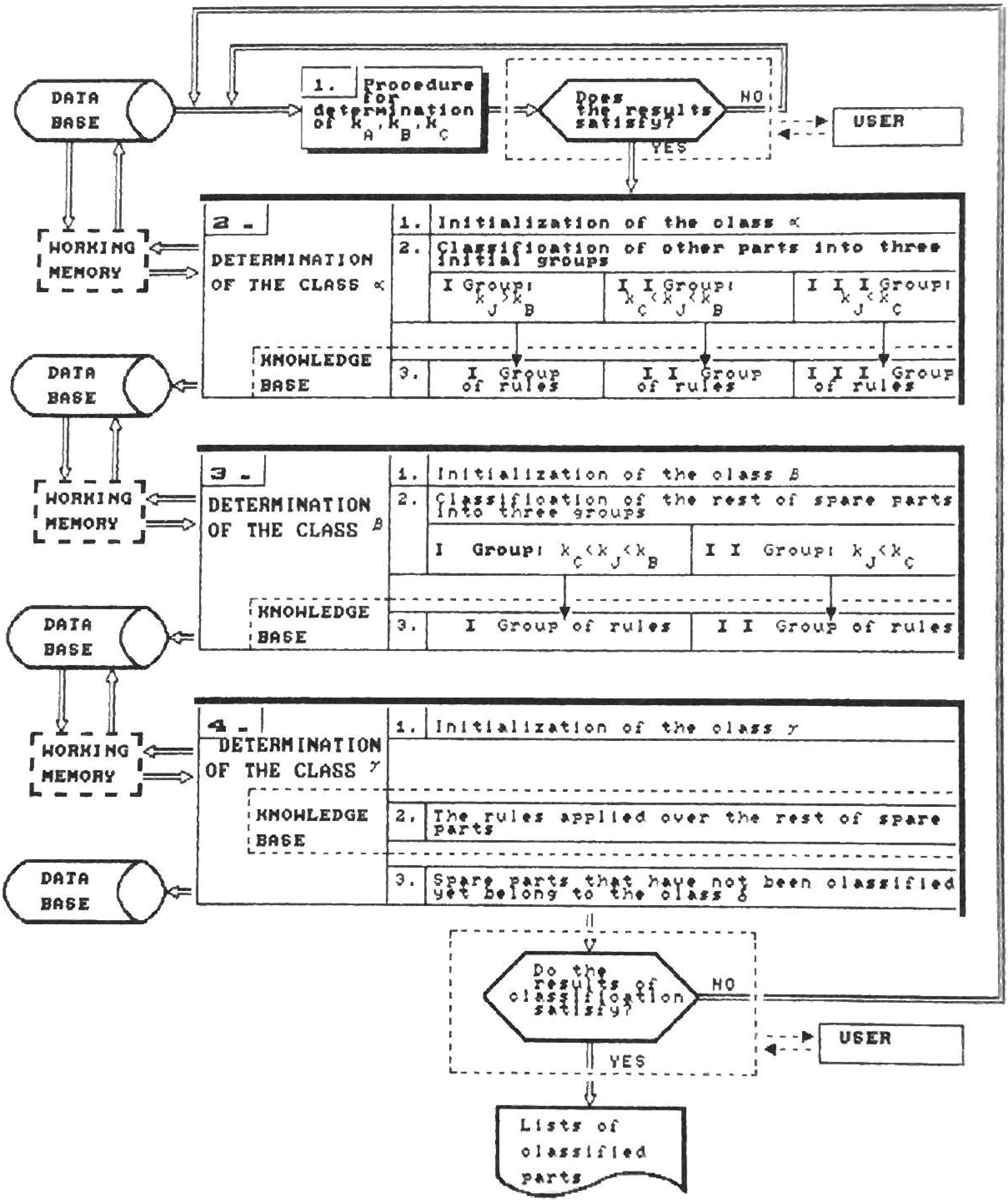
DATA BASE
1. Procedure for determination of k_A, k_B, k_C
Does the results satisfy?
NO
YES
USER
WORKING MEMORY
2. DETERMINATION OF THE CLASS α
1. Initialization of the class α
2. Classification of other parts into three initial groups
I Group: k_J > k_B
I I Group: k_C < k_J < k_B
I I I Group: k_J < k_C
KNOWLEDGE BASE
3. I Group of rules
I I Group of rules
I I I Group of rules
DATA BASE
WORKING MEMORY
3. DETERMINATION OF THE CLASS β
1. Initialization of the class β
2. Classification of the rest of spare parts into three groups
I Group: k_C < k_J < k_B
I I Group: k_J < k_C
KNOWLEDGE BASE
3. I Group of rules
I I Group of rules
DATA BASE
WORKING MEMORY
4. DETERMINATION OF THE CLASS γ
1. Initialization of the class γ
KNOWLEDGE BASE
2. The rules applied over the rest of spare parts
3. Spare parts that have not been classified yet belong to the class δ
DATA BASE
Do the results of classification satisfy?
NO
YES
USER
Lists of classified parts

Figure 1.

1. DETERMINE P_{gp}
2. REPEAT

   Read: k_A, k_B and k_C;

   Make a preliminary classification using the following rules:

   If $k_j > k_A$, then R_j belongs to class I;

   If $k_B < k_j < k_A$, then R_j belongs to class II;

   If $k_C < k_j < k_B$, then R_j belongs to class III;

   If $k_j < k_C$, then R_j belongs to class IV.

   Calculate the percentage of the total number of parts that accounts for respective classes and the percentage of the total inventory value that accounts for parts of a certain class.

   Display the results to the user.
3. UNTIL

   the values displayed satisfy user's requirements.
4. EXIT: k_A, k_B, k_C.

Block 2. in Fig. 1 illustrates the determination of class α, i.e. the class of the most significant (important) parts. All the parts from previously determined first class, i.e. the parts for which $k_j > k_A$ holds, block 2.1, are firstly classified into α. After that, block 2.2., we start from the already performed division of the remaining parts into 3 groups. Particular rules and facts from the knowledge base corresponding to a certain group are applied to each part from that group. The classification of these rules results in classifying all the parts that satisfy the required conditions into class α. The remaining part are then subject to the further classification procedure.

The procedure for determining classes β and γ is practically the same, with a relatively smaller number of groups of rules. Class δ will include the parts that haven't previously been classified into any class.

3.3. Classification Rules

The classification rules from the knowledge base are simple rules of IF-THEN form, whose general structure in this ES is recognizable from the following examples that are contained in the first group of rules in block 2 of Fig. 1:

1. If the part is extremely expensive, then classify it into class α;
2. If the part is expensive and attractive to be stolen, then classify it into class α.

4. EXPERT SYSTEM ARCHITECTURE

The ES proposed has a classical architecture [5, 6] comprising the following subsystems, Fig. 2:

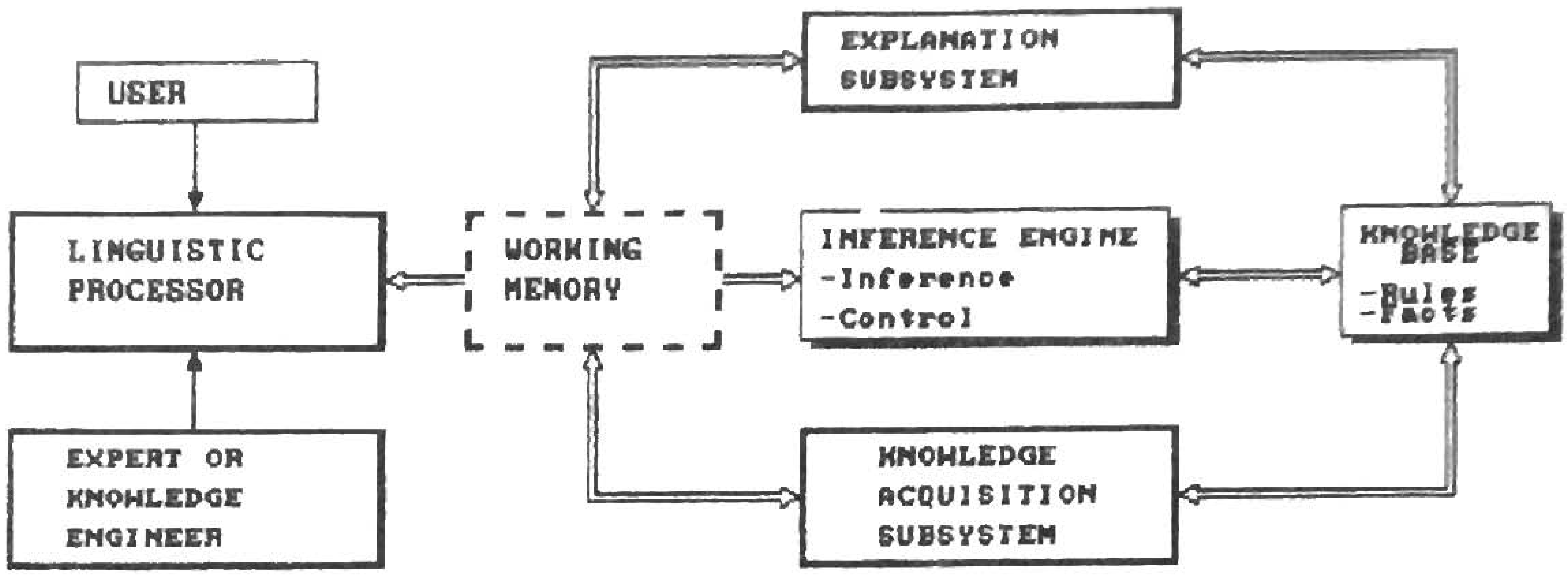

Figure 2.

1. A KNOWLEDGE BASE containing rules and facts.

2. A WORKING MEMORY storing current data that should be modified according to the rules from the knowledge base.

3. An INFERENCING MECHANISM or an interpreter in which the given problem is solved on the basis of the strategy for applying the rules and facts from the knowledge base. This means that the interpreter controls the sequence in which certain rules are applied to the data currently stored in the working memory.

4. A USER INTERFACE or a linguistic processor for establishing a contact with the user or expert.

5. A KNOWLEDGE ACQUISITION SUBSYSTEM that allows adding and changing the rules and facts from the knowledge base and changing the rule selection strategy.

6. An EXPLANATION SUBSYSTEM intended to explain the conclusion reached.

The mode in which the interpreter controls the classification process is illustrated in Figure 1. In certain classification steps the interpreter selects, on the basis of its metaknowledge, the rules that correspond to a particular data item.

5. CONCLUDING REMARKS

A concept of an expert system for spare parts classification was presented in this paper. This classification is a first step in the design and implementation of an effective inventory management system. The selection of an appropriate control system as a set of rules and procedures which give instructions when and how much to order is the task of the next step. This requires further research on extension of the knowledge base by algorithms for computing control variables as well as by rules for the selection of appropriate algorithm for each part.

REFERENCES

[1] J. Lawrenson, *Effective spares management*, International Journal of Physical Distribution & Materials Management **16** (5) (1986).

[2] B. Shorrock, *A cost-effective approach to stock control*, OR Insight **2** (1), January–March 1989.

[3] M. A. Cohen, R. Ernst, *Multi-item classification and generic inventory stock control policies*, Production and Inventory Management Journal, Third Quarter, 1988.

[4] B. Chandrasekaran, A. Goel, *From Numbers to Symbols to Knowledge Structures: Artificial Intelligence Perspectives on the Classification Task*, IEEE Transactions on Systems, Man, and Cybernetics **18** (3) (1988), 415–424.

[5] P. Harmon, D. King, *Expert Systems, Artificial Intelligence in Business*, John Wiley & Sons, 1985.

[6] F. Hayes-Roth, D. A. Waterman, D. B. Lenat, *Building Expert Systems*, Addison-Wesley, 1983.