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# A Hierarchical Conceptualization for Automatizing Human Expertise

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Abstract:Based on a systematic idea developed for experience-based expertise acquisition systems, a human-oriented methodology for plant operation is described.

Keywords:Expertise, Experience sequence, Human-oriented automatization,

## 1. Introduction

The idea for categorizing obtained data is successfully implemented in a plant controller. Things related to this implementation are described in previous papers.[1,2,3] The ideas utilized in those previous papers plays the fundamental role in building the idea here. Categorizing and finally conceptualizing real events and data, obtained in experiencing the operation of a particular system, is one of the central interests. In other words, the procedure of experiencing is modeled. In the course of organizing experienced objects as knowledge, categories are obtained as the shallow-level understanding of exact data. Such a way of thinking and understanding things is similar to that of a human. That is, for intuitive cognition, conceptual level which deals with things somewhat ambiguously is sufficient enough. And the more detailed information he needs, the deeper level of cognition he employs. This aspect of cognition is already discussed in previous papers, and part of it is also utilized in categorizing figures. The same structure can be seen in organizing experienced objects in the verbal side of cognition. So, described here is how such categorization is deepened in a form of hierarchical structure of concepts. To be concrete, a categorization is made in the most shallow level and it has a single layered structure. Re-categorizing a category in that level yields a partition of that original category; i.e., two extreme categories and their intermediate category which separates the former two categories. This procedure is applied only when the human operator realizes its necessity. And further level deepening may be made on demand which depends on the accuracy of the original pieces of experience and the surrounding of operation. Proofs are given for the validity of this procedure.

Also fundamental descriptions for the present mehodology can be found in [4,5,6]. The basic direction is to make most of a human operator's knowledge. Or it can be said that different from the conventional idea of utilizing a human operator's knowledge in the level of logics or in the level of linguistics, the present idea also utilizes imagery which seems to be essential in a human thinking. It is usually considered to be difficult to elicit a human operator's knowledge sufficiently by hearing with other auxiliary methods. The point is imagery. Consider any skill you attained at a sufficient level such as, for instance, car driving. There are so many things which you can not give concrete ideas in some verbal level, but you may have rich information in some imagerial level.

Vagueness in human's understanding sometimes brings disadvantages. But such a characteristic seems to be natural, because, as is partly described above, the mechanism is conceptual. Catastrophic behavior is one of such disadvantages, as briefly described in the following: Some quantity which takes on continuous values, such as the hopper level here, goes up or down through the boundary of "medium(the ordinary level)" and "high," then the operator must judge when the value passes the boundary value. The boundary may not be clearly defined by himself, at least when he is at the beginning stage of his concern to that particular plant. Suppose that he has to take some regulation action, if the value goes beyond that boundary. In that case, a hysteretic behavior is seen in his judging when to take his action. Some details are described in Reference[7]. This sort of vagueness is partly removed if a human's idea is translated into the structure proposed here, although his idea is followed.

## 2. The System to Be Controlled

A powder conveying system as a part of a plant for cement manufacturing is the objective to be controlled. The system supplies powder (clinker) continually to finish mills. The real system and its control is already described in Reference[2]. Here, instead of the real system, a basic system in Fig.1 is considered. The real system is so complicated and PID control is not available. But the basic system in Fig.1 is simple enough to use PID. Hence the performances were compared between PID control system and the proposed human-oriented control system. The original control system proposed is already described in Reference[1]. Here in this paper, a revised system is proposed for better control, modeling a human operator's characteristics of thinking which can be realized through experiencing the control of the system. The elements of the system a feeder and a hopper. The feeder conveys clinker from the silo to the hopper of a finish mill. Some details are found in Reference [1].

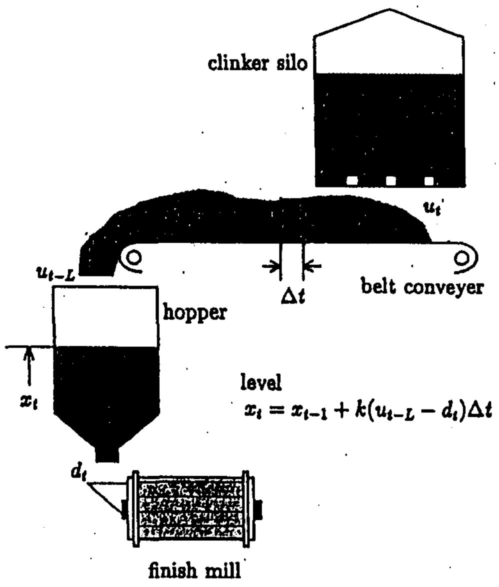


**Fig.1 Schematic of the system**

## 3. A Hierarchical Structure for Control

As was already mentioned, here in this paper, described is a methodology based on the idea which is utilized by a human in everyday life. For an intelligent human interface, this characteristic is desirable, from the viewpoint of human-orientedness of interface, or use-friendliness. An ordered set (A,R), given a certain order relation R, can be written as a sequence:

$$a_1, a_2, \ldots, a_n,$$

where $a_{i+1} R a_i$, $a_i \in A$, $i=1,2,\ldots,n-1$. In this sequence, some succesive elements, say $a_i$, and $a_{i+1}$, may be uncomparable. In that case, regarding $\{a_i, a_{i+1}\}$ as an element of the sequence yields a total order. So generally, the above sequence provides a total order. Letting $B_1$=A, pick all the elements b's of $B_1$ which satisfies the property $bRa_1$. And let such elements constitute the set $B_2$. In like manner, let the upper bound of the local minimum $b_i$ of $B_i$ be the elements of $B_{i+1}$. The family of sets thus formed $\{B_i\}$ will be called the filter base of a particular experience sequence concerned, where each element of the above sequence denotes an experienced event or object. It is shown in [6] that the following relation holds:

*[Definition 1]* When the filter base of an experience sequence "big" is given, then the filter base of "small" can be formed by taking the lower bound of each of the elements ($B_i$'s)of the filter base "big," and vice versa.

Using the above definition, "medium" can be defined as follows.

*[Definition 2]* The filter base of "medium" is given as the family of sets each of which is the intersection of particular elements ranked in the same rank choosing one from every filter base.

Let $\{A_K\}$ and $\{B_K\}$, k = 1, 2,..., m, m≦n, be the filter bases of "big" and "small." Then the family of the following sets $C_j$'s, $\{C_j\}$ forms the filter base of "medium":

$$C_j = A_{K-r} \cap B_{K-r}, \quad j = 1,2,\ldots,m-r+1, \quad k = r+1, r+2, \ldots, m,$$

where r is the minimum k which satisfies the condition,

$$A_K \cap B_K \neq \emptyset.$$

For finer categorization, similar procedure can be continued further. That is, for example, to obtain the intermediate category between "big" and "medium," Definition 2 is still available, though the two filter bases must be of "big" and "medium." This means that:

*[Proposition 1]* For the formation of the intermediate concept of "big" and "medium" ("medium" and "small"), elements to be considered are only the upper (lower) bound of the most typical element of "medium."

A similar procedure of Proposition 1 is available in obtaining finer categorization. Thus, a single-layered categorization can be obtained as fine as possible with respect to a specific experience sequence.

By using Proposition 2, hierarchical structure of categorization can be obtained.

*[Proposition 2]* For the intermediate concept of two concepts $C_1$ and $C_2$ which are formed based on an ordered set (A,R) relation R and its inverse relation $R^{-1}$, the elements to be considered are only those each of which satisfies that it is a lower bound of $t_2$ and an upper bound of $t_1$, where $t_1$ and $t_2$ are the

most typical element of $C_1$ and $C_2$, respectively.

## 4. Discussion and Conclusion

Simulations were performed by using the above hierarchical categorization. The mathematical model of the system for building the simulator is described in Fig.1. For comparizon, PID controller was also employed. The simulator was, first, manually controlled to obtain experience for automatic operation. Then two modes of automatic control was performed; i.e., one uses the original single-layered automatic control, and another uses double-layered automatic control introduced here in this paper. Figs.2a to 2d show the comparison among those results. The most swift response is obtained in Fig.2d of double-layered categorization. Figs.3a to 3d show the feeding rate from the silo, denoted as FD extraction rate in % of the full level of the hopper, with time so determined as not to empty the hopper. The frequency of changing the rate is smallest also in the case of double-layered categories. Although the basic system of the real plant used here as the objective of control accepts continuous input as the extraction rate from the feeder, steplike arrangement of extraction rates is also tried. The performance of the single-layered control system was also reported in Reference [1] using the same steplike arrangement (50, 85 125, and 200% of extraction rate). Here, the result of the performance of the double-layered system with that arrangement is observed, and its result is shown in Figs.4a to 4c and inFigs.5a to 5c (in this case, PID control is not available any more). The effectiveness of the double layering is proved also in this figure.

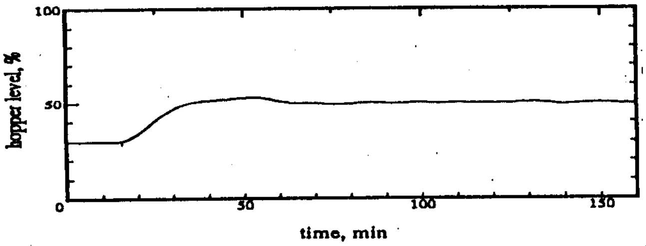


Fig.2a PID control

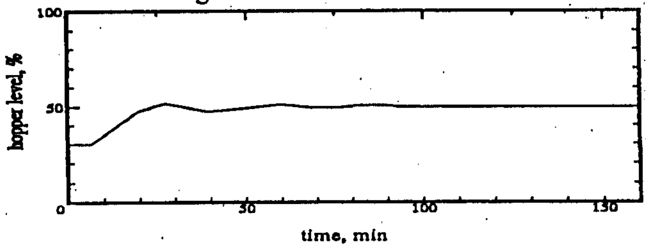


Fig.2b manual control

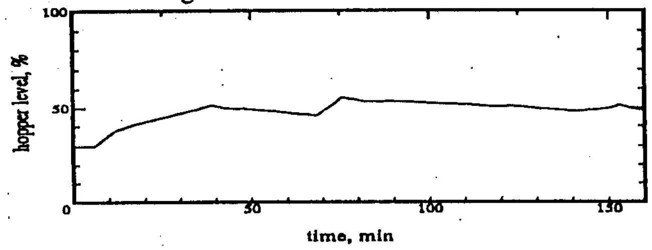


Fig.2c automatic control (layer1)

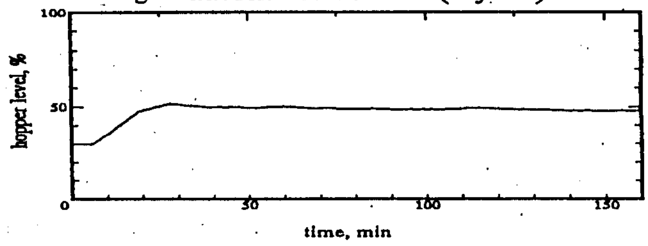


Fig.2d automatic control (layer2)

**Fig.2 Responses**

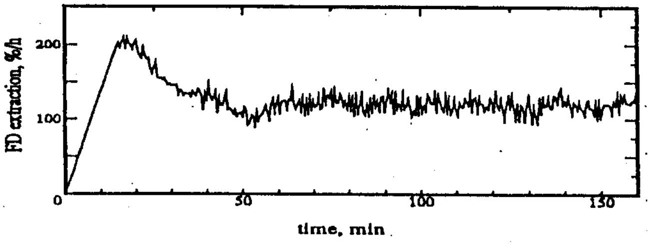


Fig.3a PID control

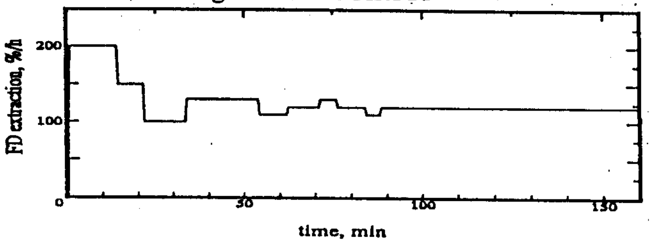


Fig.3b manual control

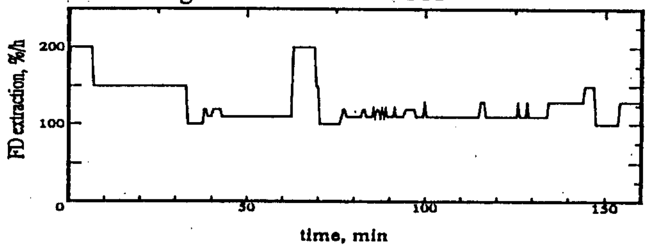


Fig.3c automatic control (layer1)

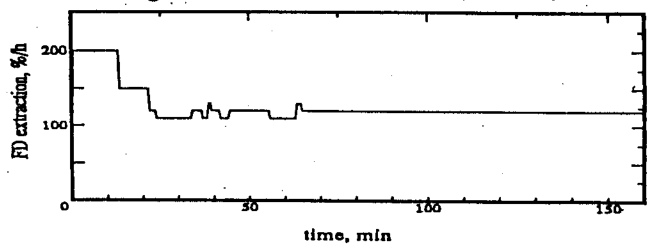


Fig.3d automatic control (layer2)

**Fig.3 Feeding rates corresponding to Fig.2**

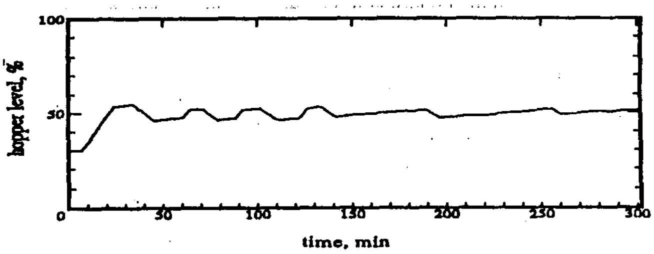

Fig.4a manual control

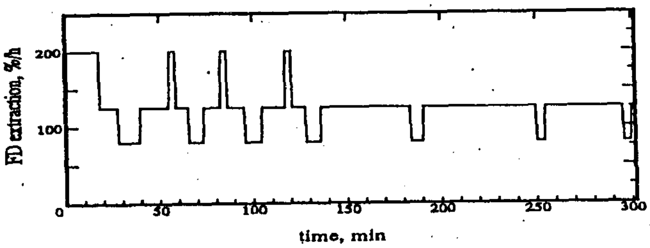

Fig.5a manual control

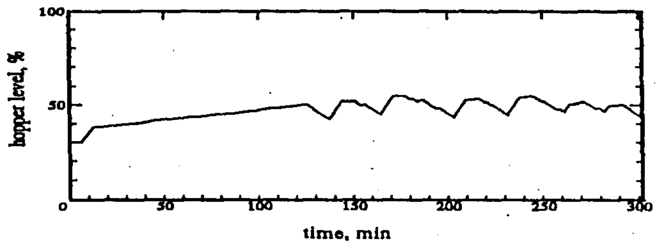

Fig.4b automatic control (layer1)

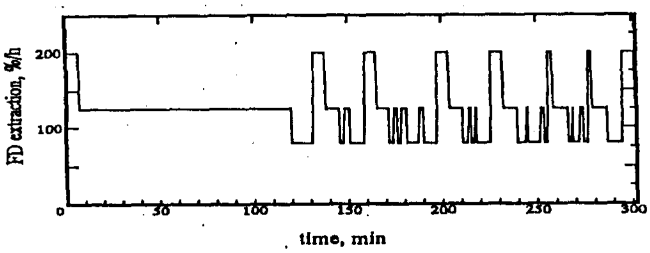

Fig.5b automatic control (layer1)

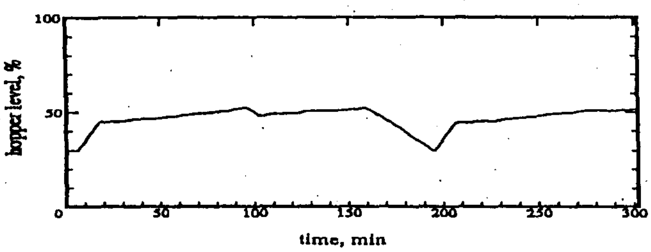

Fig.4c automatic control (layer2)

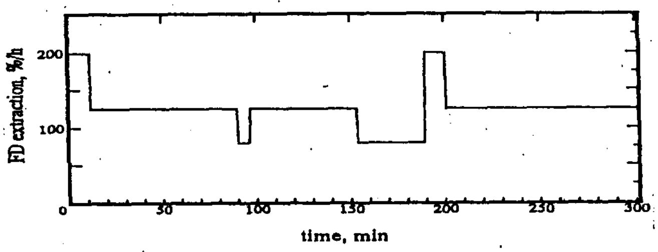

Fig.5c automatic control (layer2)

**Fig.4 Responses in the case of steplike feeding rates**

**Fig.5 Feeding rates corresponding to Fig.4**

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