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A Unified Viewpoint of Automatizing Human Expertise

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ABSTRACT

The authors experienced some industrial processes which essentially require human expertise. Human expertise for those processes have characteristics in common, and such human knowledge is described from a unified viewpoint in order to utilize it in automatization.

INTRODUCTION

There are a variety of manufacturing systems which essentialy need human expertise. But the modern industries have the following problems:
1)A human operator's load is growing.
2)Young generations have tendency of avoiding elaborate works.
So, it is necessary to reduce workers' loads and at the same time to draw out their interest of working. This is just the issue which the traditional automation lines suffered from. That is, changing environment gives only a secondary effect on attracting young generations' hearts. Direct effect is required. Some of such trials by it are the authors' research works toward offering a situation which, at the same time, achieves automatization with comfort working environment and offers attractive jobs.[1,2,3,4,5,6] This concept of automatization produced a unique methodology.

The first task to do in the authors' trial for automatization was to observe and learn from experts' ways of performing their jobs, and besides to discuss with them. It often required to analyze the validity of such experts' ideas. This task sometimes involved professional analysts for analyzing materials and products. Observations were directly utilized in acquiring data. Models of their performing jobs were directly built by the authors' learning activities from the experts. This is rather different from the ordinary idea of knowledge engineering. Those results taught us that there is some common ideas between different fields of expertise.

The second task to do is to build a control system for each of the systems dealt with. For the workers' positive working attitudes and prides for working, it is necessary to build a control system so that an operator can learn and evolve his ideas as he accumulates experience for that particular job. An intelligent man-machine interface is required to do this, and some ideas will be described.

EXTRACTING FUNDAMENTALS OF HUMAN EXPERTISE FROM A FEW INSTANCES DEALT WITH BY THE AUTHORS

The authors investigated constitution of human expertise and its acquisition process in the following plants operation.

Process(A) Fish-Drying
The experimental drying process was at first set by the expert at the workshop and gradually his expertise was transferred to the authors' research team. After this, a drying room for commercial use was built in order to implement the authors' ideas. As a model of the human expert's way, the control system consists of three procedures:

Procedure 1)[Human expertise for predicting the required drying time.] The inference process for the determination of the proper drying condition based on the freshness and fatness of the fish to be dried.

Procedure(2)[Basically, the special procedure for the present automatic process.] The on-line weight change monitoring and estimation (mainly prediction) of necessary drying time in order to determine the most proper time for the next Procedure(3). The model for the estimation is given mathematically. A similar action is also taken by the expert, though not continuous action different from the automated case. He sometimes goes into the drying room, if necessary, and checks if drying is progressing as he predicted in Procedure(1).

Procedure(3)[Adjustment] Final regulation of drying time at the end of drying process in order to quarantee the optimal dehydration.

The first procedure, Procedure(1), is essentially the experience accumulation on the fishing place, freshness, fatness, and required drying time, etc. By interviewing the expert, the authors found that the basic knowledge of the expert consists of a few pieces of knowledge, and hence it is really simple. The peripheral knowledge of this basic knowledge will be acquired as experiencing proceeds, to modify the basic knowledge and to make the whole knowledge matured. This knowledge is used in estimating the drying condition including the drying time. As already mentioned, Procedure(2) is not exactly included in the conventional drying process by a human expert. This is for the present automated system, and helps the control system more stable. The change in weight with time which is equal to water loss, i.e., the degree of dehydration, can be measured in process, and can be utilized in on-line checking of the progress in drying. The last procedure, Procedure(3) is also a part of the conventional system, and is necessary to guarantee good products. And this Procedure(3) is constituted by applying the notion of localization proposed by one of the authors.[7]

Procedure(2) is to estimate the drying time required in the fish-drying process employed. A drying process is also used in manufacturing papers and so on. And the authors' analysis found that the fish weight takes a particular type of change with time in the drying process. This process is independent of the individual characteristics of raw fish such as the original weight, fatness, etc. The basic element of predicting drying time is a mathematical model or a set of differential equations which governs change in weight.[8] Drying is to reduce water from fish body. And the weight of fish decreaces as much as the amount (weight) of the water evaporated. Estimating the parameters of that set of linear differential equations provides the prediction of necessary drying time. Procedures(2) and (3) enforce the expertise in Procedure(1) by feeding back the final result from the overall drying process.

Process(B) Fish-Meat-Grinding

This is another traditional process to preserve fish, and the product from this process is called "kamaboko" (boiled fish paste) in Japanese. As is the case in fish-drying, used is raw material or frozen material which needs defrosting as the preprocess. At a proper time in the course of grinding, salt must be added. The timing of doing this requires skill. And then watching how well the change in material to paste is proceeding, the operator decides when to stop grinding which also needs matured sensory inspection.

Process(C) Granulation Plant

This is a granulating process which is used for giving a particular shape to medicines and so on. Material for granulation is called "C-cake" and is supplied from the preceding process It is fed continuously to the kneader. Adding some additives(two kinds of additives are used in the present case), the material is kneaded and then granulated by pressing material out of small apertures on the wall of the granulating machine. Finally it is dried. An operator decides the initial kneading condition (flow rates of the additives to the continuous kneader, etc.) from the information about the material. Then the process is started, and how well granulation is performed is observed by the operator in the monitoring room. Basically he pays attention to the state of material just pressed out of the machine. Based on his observation, he makes decision on the necessary change in the flow rates of the additives. Here in this case, human vision also plays an important role. There exists a time delay before the change in additives' flow rates starts to have effect on the state of granulation.

HUMAN MENTAL PROCEDURES

Concept Formation and Knowledge Acquisition

A piece of knowledge consists of concepts like in a proposition:

"Less fat fish dries fast."

This proposition includes concepts "less fat," "fish," "dry," and "fast." The noun "fish" and the verb " dry" are concepts acquired in daily life. The concepts which need special feeling for fish-drying are "less fat," and "fast." As this example shows, concepts are divided into:

Concept(1) Known concept in one's daily life.

Concept(2) Concept which needs worker's special effort to understand as professional feeling.

In considering the case of Concept(2), it requires to notice the two aspects of concept:

Aspect(1) Intension of concept

Aspect(2) Extension of concept

Aspect(1) of Concept(2) must also be known by the worker. Only the Aspect(2) is the objective of acquisition here. For instance, "fast" means "short in time compared with the average time required in achieving something," and without knowing this fact, the extension of "fast" can not be acquired.

Typicality

Typicality is regarded as a predominance (or priority) relation R on the extension E of a concept so that aRb means " a is more typical than b," for any two elements a, b of E. [9,10,11 and for general discussion on typicality, for example, see 12] The subset T of E which consists of (tentatively) the most typical elements; i.e., each element a of T satisfies aRb for any element b of E. T is formed by real instances which were already experienced, as an element of E can be evaluated only by being experienced.

Evaluation of Objects

A human operator's evaluation basically uses, for a case in which rating is required:

1)High, 2)Low, and 3)Proper, ...(1)

These expressions can be equivalently broken down into the following two, disregarding the aspect of rating:

1)Good (proper), and 2)Not good (high or low). ...(2)

And Classification(2) is based on the idea that an object is allowable in a certain sense or not. From this viewpoint, it can be said that Classification(1) is a vectorized (or directed) Classification(2). And also a third value exists sometimes as an intermediate evaluation around the boundary between (1) and (2). For the case of classification(1), two intermediate evaluation exist; i.e.,

a)"neither high nor proper,"

and

b)"neither proper nor low."

And if necessary, further evaluation may be employed around the boundaries of the above third evaluation(s).[9,10,11] But in that case, human idea is often blurred and sometimes unreproducibility in evaluation increases. But it is also true that the cause of such further evaluation is the existence of nonlinearity which is not negligible.[8]

Context for Thinking

As described in [13], a small surrounding of an operating condition (vector) in the case of plant or machine tool operation is a region of alternative operating conditions when change in condition is required due to failure or something. In the process of human thinking (inference), a similar idea is used. In this case, a context can be considered to be a superordinate concept, but at the same time it produces any alternative available. In this sense, a context in thinking can be considered to be equivalent in that of system operation: i.e., experiencing real instances.

STRUCTURE OF EXPERT'S KNOWLEDGE FROM A UNIFIED VIEWPOINT

From the above descriptions on manufacturings and human conceptual functions, a human operator's way of making decision can be said to take the following procedures in general:

Procedure(1)Know a context.

A context, as defined in the above, is narrowing the circumstance to the one just available. (Getting information about general characteristics of the particular kind of material)

Procedure(2)Choose one element of the above available choice (extension of context obtained through experiencing), taking into account the real material to be processed, imagining its finish. Procedures(1) and (2) are those before starting manufacturing.

Procedure(3)Observe the real progress under the condition chosen in the above procedure(2), and regulate the condition if necessary. This process is processed during manufacturing.

Procedure(4)Check the appropriateness of the determination given in Procedure(3) as the final check, and memorize the result for later decision making.The result of Procedure(4) is added to the extension of context employed in Procedure(1).

DISCUSSIONS AND CONCLUSION

As mentioned in Introduction, automatization needs a human supervisor. He is not just for watching. He has many things to do as an auxiliary operator; starting the process, intervening if necessary, dealing with regulation, troubles, and so on. In doing any of his job, one attempts to progress. And this is an important point in automatization. By incorporating the human operator's experience to the automated process, he gains in his interest of working, and the product is also improved. Based on the present idea and utilizing fuzzy control method, an automated fish-drying room for commercial use has already built successfully.[4,5]

There are a variety of fields of engineering which unavoidably use human skill. Although a conventional methodology for automatization uses a good amount of rules in order to avoid unexpected failure, a human way of regulation uses just a small number of pieces of knowledge very succesfully, as described here. This is an important point. And in the case of human idea, sometimes the best system state is not known beforehand, and instead he can acquire it only through experiencing by Procedures(1) to (4) in the preceding section. This aspect of human idea is usable in unmanning a system as a hierarchical man-machine system as mentioned in the beginning of this section.

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