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APPLICATION OF EXPERIENCE-BASED EXPERTISE ACQUISITION MECHANISM TO HOVERING STABILIZATION OF HELICOPTER

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1. INTRODUCTION

A helicopter is used in a variety of situations because of its usability. Its operation needs human skill. The authors are working on automatization of human skill. Helicopter operation is one of such fields of practicing human skill. This is why the present paper deals with helicopter (model helicopter) operation. Full operation of a helicopter needs more complicated system in both aspects of software and hardware, and also requires more training for operation. From the purpose here that helicopter operation is for checking the applicability of the authors' idea for automatization based on experience, attitude regulation in hovering is the target.

In the present paper, a human operator's operation is recorded as a time series of operation actions, and the record is reorganized as the correspondence between the helicopter's attitude and the proper operation action required in that particular situation.

2. AUTOMATIC HOVERING SYSTEM

Helicopter Operation and the System for Regulation

Operating a helicopter requires inputs for going up and down, forward and backward, sideways, and rotating around the main rotor axis. For a radio controlled toy helicopter in the present paper, a radio controller is equipped with two joysticks which deal with controlling throttle, elevator, aileron, and rudder. Fig. 1 shows a schematic of what change in attitude each operation produces. Fig. 2 shows the whole system for hovering. The system consists of:

(a)Helicopter,
(b), (c), (d)Subsystem for control,
(e)Radio controller.

The helicopter is equipped with a two-dimensional clinometer to detect the change in attitude, as in Fig. 2. The controlling system (b), (c), (d) utilizes the signal from the clinometer to regulate the state of the helicopter. Radio controller sends required changes in operating conditions.

The helicopter is single rotored, and electrically powered. The fuselage is 830mm long, 240mm high, and 90mm wide. The main rotor (diameter=912mm) produces propulsion, and the tail rotor (diameter=175mm) cancels out the reaction torque caused by the main rotor. Using electricity for motor is advantageous for less noisy and hence indoor operation.

Hovering control practice is performed with the helicopter on a safety training board which ties helicopter loosely enough not to hamper hovering. The clinometer (measurable range of banking angle=20° with 0.01° resolution) is attached to the bottom of the fuselage right under the main rotor shaft. Fig. 3 schematically shows the positive directions of rotations about x and y axes.

3. TYPICALITY AND CONTROL METHODOLOGY

A novice operator is likely to use joysticks more often than needed, trying to "control" the helicopter. As he accumulates experience of practicing, his such over reaction for change in helicopter attitude gradually converges to minimum action just required to stabilize the helicopter, in such a manner as "leaving the helicopter fly itself." It is also noteworthy that a skilled operator never uses theoretical knowledge of helicopter dynamics which might force him enormous

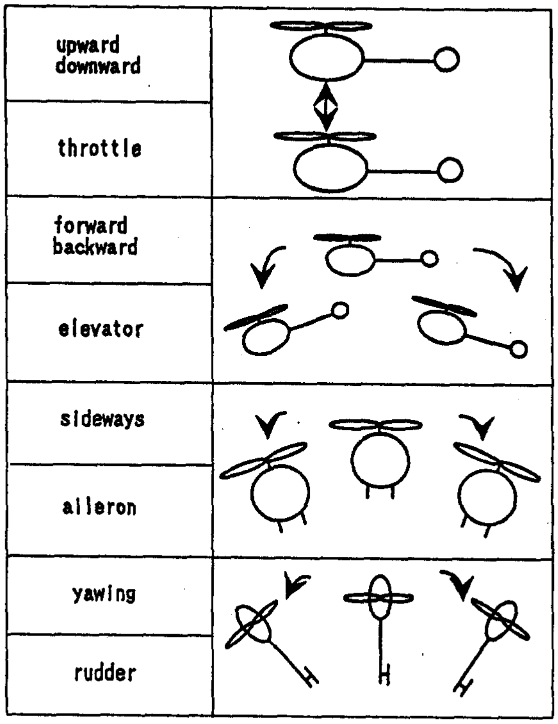

Fig.1 Movement and Operation of Helicopter

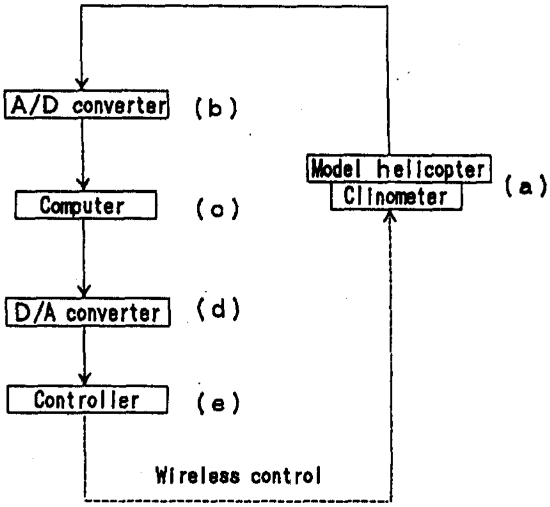

Fig.2 Schematic of Control System

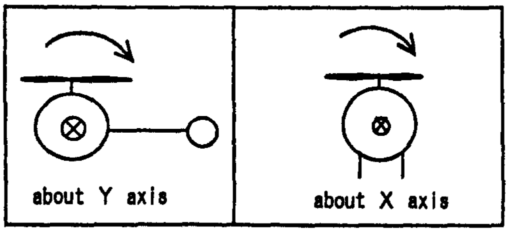

Fig.3 Positive directions of angle in inclination about X axis and Y axis

amount of calculation if he tries to apply. His knowledge is acquired only from practicing. And it is true that such human idea of operation is really applicable in a variety of regulation activities. In the present paper, control is performed taking advantage of this fact. A human operator´s idea seems to be rather conceptualized in order to use it in a flexible manner. Change in attitude from level flight is sensed visually in some linguistic manner, knowing "Helicopter is banking." and evaluating "in what direction," and "how big." Banking has two freedom; i.e., forward and backward, and right and left as in Fig.1. The operator has to respond the occurring change. If he is rather skilled, then he can include the effect of time delay on attitude regulation in his reacting. This fact causes the already mentioned difference in response between a novice and an expert. The relevance of using linguistic expressions can be found, for instance, in that the idea of "big" for the operator may change with his accumulation of experience. A "big" change for an expert may just be a "small" change for a novice who allows the helicopter "swinging-like" hovering. Here in the present paper, such a linguistic manner for grasping change in attitude and the corresponding necessary reaction is utilized. General ideas behind typicality application to the problems of vehicle control can be found in Reference[1].

It can be said that it takes more than 0.2s for a human operator to take necessary action when he awares change in helicopter´s attitude. The present system employs timed operation. So, the timing can be 0.2s. But a human operator can respond any time, and such flexibility may also be necessary for the present system. Thus, the timing of sending operation signal is taken to be 0.1s as a compromise. Existence of noise in the clinometer output must also be taken into account. Hence, observation of attitude of the helicopter is made at every 0.01s, and the change in attitude is evaluated by checking the average of successive 10 such samples of observation.

To obtain proper change in operating condition from a flight record by a human operator, the idea of experience sequence is applied. For the basics on experience sequence, refer to References[2,3]. An operator´s operation in flight experiment is recorded with flying time. Then, the correspondence between the occurrence of some attitude change and the operator´s reaction against it is automatically described in that record. Interviewing for hearing his technique is basically unnecessary. The procedure for doing this by using the smoothed record as a time series sampled at every 0.1s is as follows:

(1) List the elements in the time series as a numerical sequence by applying the order relation, R, "bigger than or equal to."

(2) Then inversing the order of listing gives a sequence applying the order relation, R^{-1}, "smaller than or equal to."

(3)The above two sequences provide the conceptual ideas of "big," and "small" with typicality by constituting a filter base for each of the concepts.[3] Now, the third concept of "neither big nor small" can be obtained from those ideas by taking the intersection of the lower bounds of elements of the above filter bases, picking one from each of the filter bases. And this procedure gives another filter base for the typicality of "neither big nor small."[2]

The above algorithm gives "big," "small," and "medium." "Medium big" and "medium small" can be obtained by a similar processing.

Table.1 The meanings of symbols for fuselage attitude description in the case of applying 5 divisions.

[Inclination about X axis]
B = Banking to the left
MB= Banking to the left slightly
M = Level
MS= Banking to the right slightly
S = Banking to the right

[Inclination about Y axis]
B = Nose up
MB= Nose up slightly
M = Level
MS= Nose down slightly
S = Nose down

Table2 Proper operating condition change for change in helicopter attitude. Attitude is denoted (Change about X axis, Change about Y axis)

aileron: S	aileron: MS	aileron: M	aileron: MB	aileron: B	elevator
B, S	MB, S	M, S	MS, S	S, S	S
B, MS	MB, MS	M, MS	MS,MS	S, MS	MS
B, M	MB, M	M, M	MS, M	S, M	M
B, MB	MB, MB	M, MB	MS,MB	S, MB	MB
B, B	MB, B	M, B	MS, B	S, B	B

4. HOVERING EXPERIMENT

Throttle is manually operated for safety. Rudder is fixed at a preset value. A control method by direct application of typicality is mainly described. Operation was executed in a calm condition to prevent disturbance.

A skilled operator's operation is used to extract the correspondence between change in attitude (change in state) and required stick control (change in operating conditions) to keep hovering. To be concrete, voltages are measured for two clinometer outputs, elevator output and aileron output. Sampling is made in every 0.01s, as already mentioned, and 3000 samples are sampled in 30s flight. As was also mentioned, every successive 10 samples are averaged, with respect to clinometer outputs, to obtain the attitude to couple with necessary reaction. Ten sets of this sort of typicality extraction experiment were performed, and typicality was extracted. Typicality thus obtained is used in hovering control for 30s, and attitude is evaluated through the same procedure as in the case of extracting human technique.

Fig.4a shows the flight record with respect to attitude change in forward and backward direction. This kind of regulation is to be made by elevator's up and down. Fig.4b is the result of "typicality control." Fig.4c shows an additional control outcome by using fuzzy control. Typicality was used as basic data in generating the fuzzy rules. It may also be one of the advantages of the present idea to be able to produce production rules for knowledge engineering without directly consulting human operator.

5. DISCUSSION AND CONCLUSION

A human operator´s record of flight tells that degree of shifting stick reduces to 1/3 of his own beginning data to guarantee rather stable hovering.

A tendency of giving the helicopter a state being a little banked to the left (-2° . on average) rather than giving it just level flight is seen in the case of human data in Fig.4a. This tendency still remains in the flight using typicality, because typicality utilizes his idea directly. In the case of fuzzy control, the most stable result is obtained, showing frequent application of rules, while "typicality control" shows a flight record rather similar to the human operation, although the human operator´s tendency seems to be almost canceled. Frequent regulation seen in the case of fuzzy control comes from the fact that the number of rules are 4 times larger than in the case of "typicality control."

Although not cited in the present paper, the records with respect to the attitude change in the sideways direction (aileron application) shows almost the same tendency as in the cases of Figs.4;i.e., The range of banking angle is almost in the same range as in the case of forward and backward.

To conclude, as suggested in the preceding sections, the present system can be improved by applying more skilled operator´s records, and also by incorporating automatically the automatic operation data themselves in continual revision of typicality with experience accumulation.

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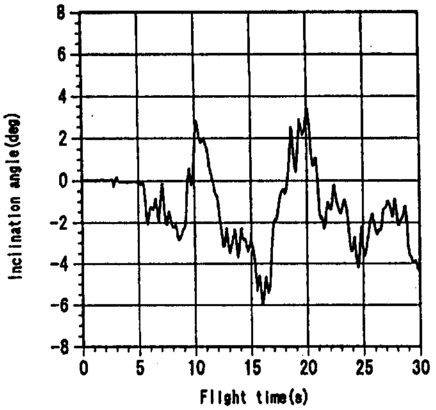

Fig.4a In the case of operation by a human

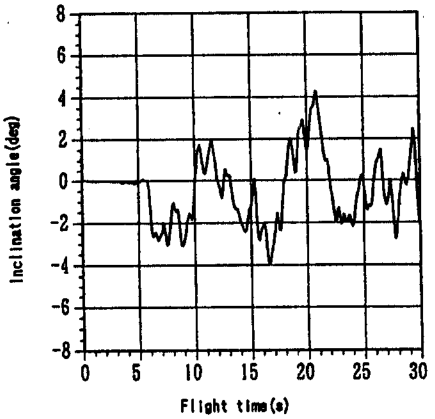

Fig.4b In the case of "typicality control"

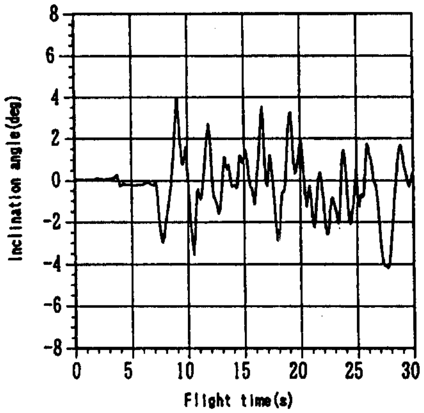

Fig.4c In the case of fuzzy control

Fig.4 Real examples of change in attitude in hovering in human operation, in "typicality control," and in fuzzy control, as change in inclination angle about Y axis.

6. REFERENCES

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