《Research Paper》

Journal of the Human Engineering Society of Korea
Vol. 7 No. 1, June 1988

A Study on Error Recovery Expert System Using a Superimposer and a Digitizer in the Advanced Teleoperator System

S·Y·LEE,† M·NAGAMACHI,†† K·ITO,†† AND C·M·LEE †

Abstract

This paper designs, in the teleoperation task, the world coordinate system by the functional analysis of each of the robot joint so that the human operator performs easily the task. Also, it constructs the heuristic rules of the equal motion line coordinates for the position and the posture control of the robot within the knowledge base so that the robot hand reaches possibly in any position of the robot's work space.

As shown in the result of the experiments, the coordinate reading is easy because the work station is displayed to the high resolution by using the superimposer of the motion analysing computer system. Also, the task burden of the human operator reduces and the error recovery time reduces because the coordinates of the object is obtained just by touch using the digitizer.

Introduction

When a teleoperation task is performed by using a robot in a hostile environment, it is not smoothly performed by the robot if it is not given a situational decision and an appropriate command by a human operator with high knowledge and experience. For this man-robot system of the teleoperation task, it is suggested that the command method by the teleoperation technique performs efficiently the task not performing by each of the human and the robot as the macro decision and the teleoperation of the human operator from the safe remote place greatly using the environment fitness of the robot.

And Lee et al. (ref. 1) are studying, in the advanced teleoperator as a part of the human interface, the research that the world model teleoperator system combining the world model and the master-slave manipulator system makes into the expert system in a side view of the integrated human-robot ergonomics.

† Department of Industrial Engineering, College of Engineering, Korea University, 1, 5-ka, Anam-dong, Sungbuk-ku, Seoul 136-701, Korea

†† Department of INDUSTRIAL & Systems Engineering, Faculty of Engineering, Hiroshima University, Shitami Saijyo, Higashi-Hiroshima 724, Japan

The purpose of the robot ergonomics similar to the human-oriented ergonomics designs the task considering the characteristics and the configuration of the robot for all the tasks of the work station. And the world coordinate system (WCS) (ref.2) is designed by the functional analysis of each of the robot joint and the equal motion line (equal azimuth, altitude, range and posture line) is used so that the human operator performs the task quickly, exactly and easily in the teleoperation task.

In other words, the past coordinate systems of the robot are mostly the coordinate systems by the joint movement of the robot. But, in this paper, the coordinate reading is easy and the robot hand reaches possibly in any position of the work space of the robot because the coordinate is designed by the functional analysis of each of the robot joint and used the equal motion line.

In the real world, although the human operator's reading the coordinate for the task environment in the WCS is easier than the coordinate by the the position of the task object in the remote place and the position of the end point of the robot. The reason for this is as follows. The eye measurement of the human operator for the position is precise to some extent in the line or on the two dimensional surface. But, in the three dimensional surface, it is not easy.

Therefore, the purpose of this paper is to facilitate the coordinate reading using the motion analysing computer system with the superimposer and the digitizer in the error recovery expert system (ERES / WCS), to reduce the task burden of the human operator and to reduce the error recovery time. To do this, the definition of error is that the robot misses the matchstick when igniting of the lamp. The object of the experiment is the error recovery task and the measure of performance is the average error recovery time according to the task difficulties.

MAIN SUBJECT

Knowledge Acguisition and Representation of the ERES / WCS-dig.

Knowledge acquisition is acquired from the ROB-501 robot manual (ref.3), the superimposer, the coordinate information of the object by the digitizer (ref.4), and the knowledge of the human expert on the teleoperation, etc. Figure 1 is the architecture for the ERES / WCS using the superimposer and the digitizer (ERES / WCS-dig.), The three objects of the knowledge base, Parts, Rules, Goals, show their relationship to each other. Figure 2 shows the representation of the knowledge base and the inference engine as the flow chart of the ERES / WCS-dig.

(i) Parts. Parts of the knowledge base are the input entities for this expert system used for the operating of the robot. These parts consist of the module control (MC), the unit control (UC) and the micro motion control (MMC).

In the MC, the error recovery task is controlled intelligently by using the task order within the knowledge base, the position and the posture number of the object on the WCS. And the human operator controls extemporarily. It is an important part of this paper. The position and the posture number of the object are obtained by the superimposer and the digitizer.

In this system, the object of the work station through the camera is inputted to the computer via the VTR as the picture information. This information is displayed very brightly by the superimposer. After piling up the plus mark of the function strip of the digitizer on the displayed object in the monitor using the inputted picture information and the digitizer program, it is able to read

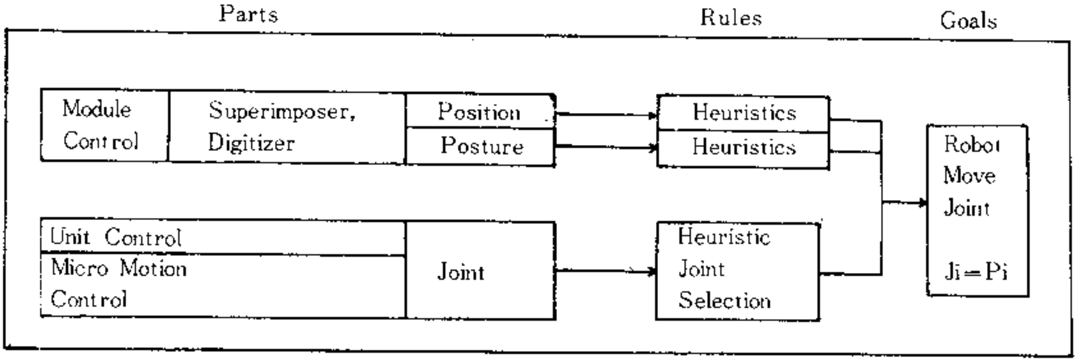

Fig. 1. Architecture of the ERES/WCS-dig.

the X, Y coordinate among the position in informations. The coordinates reading are automatically inputted to the HIS computer. The Z coordinate among the position informations and the posture information of the end point by the eye measurement is inputted to the computer key board. The X, Y, Z coordinates are converted to the azimuth (WC1), the altitude (WC2) and the range (WC3). The relational equations are shown in the figure 2.

The UC and the MMC imply the method in which operates the robot directly. The increasing and decreasing unit method is applied. Each has 10 function keys and if a key is pressed, the corresponding robot joint moves a certain length. However, the MMC operates ten times as precise as the UC does.

(ii) Rules. The values of the azimuth, the altitude and the range for the control of the position are inputted to the heuristic position rules and the posture of the robot hand is inputted to the heuristic posture rules.

The knowledge base of the ERES / WCS-dig. stores the rules for the equal azimuth line coordinate (WC1), the equal altitude line coordinate (WC2) and the equal range line coordinate (WC3) for the position control of the robot hand. If the calculated values of WC1, WC2, WC3 in the parts are inputted to the rules, the motor values for the robot joints 1, 2, 3 are inferred by the heuristic method like figure 2.

Also, the knowledge base of the ERES / WCS-dig. stores the heuristic posture rules of the equal posture line coordinate (WC4) to control the posture of the robot hand efficiently by using the joints 4, 5 of the robot wrist. If the posture informations in the parts are inputted to the rules, the motor values for the robot joints 4, 5 are inferred by the heuristic method like figure 2.

The joint selection rules in this knowledge base, by the random selection among the 10 function keys, infer the corresponding joint value Ui when the robot is operated by a human, directly.

(iii) Goals. In the goals, the position and the posture of the robot are simultaneously controlled by using the motion data of the robot joint inferred in the rules. In other words, the position and the posture control of the ROB-501 robot are performed by inferring the Pi (i=1, 2, 3) of joints 1, 2, 3, of the robot according to the heuristic position rules and the Pi(i=4, 5) of joints 4, 5 of the robot joint according to the heuristic posture rules. The Pi (i=1, 2, 3, 4, 5) for the goals of the UC and the MMC is used by the heuristic joint selection rules.

Experiments and Result Analysis

(i) Experimental Apparatus. Figure 3 shows the conceptual diagram of the experimental ap-

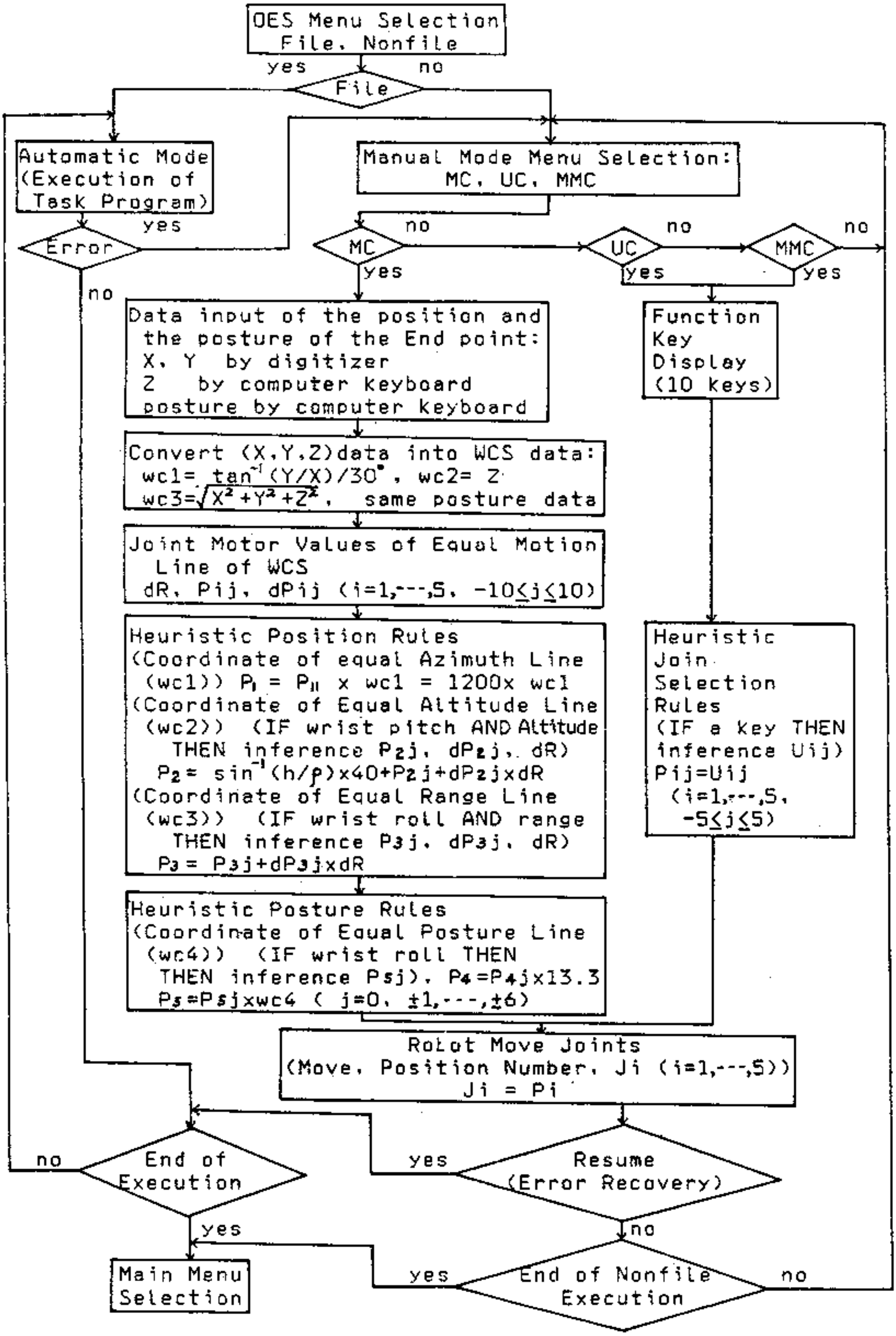

Fig. 2. Flow chart of the ERES/WCS-dig.

paratus. As shown in the figure 3, the experimental apparatus consists of the ROB-501 robot as the slave manipulator, the robot drive unit as the TIS, the IBM-PC as the HIS and the motion analysing computer system consists of the digitizer, the VTR and the camera. The output part consists of the monitor and the printer. And the micro computer part consists of the micro computer, the superimposer and the disk drive.

(ii) Experimental Procedure. The experiment in this paper is the task of the ignition of a lamp. The occurence of an error is defined as a matchstick missed during the movement to the matchbox. The task difficulties are 0, 1, 2, 3, 4, 5 according to the condition of the object laid (the angle of twist 0°, 15°, 30°, 45°, 60°, 90° between the extension line of the robot base and the object). The experiments are performaed five times repeatedly. The measure of performance is the average error recovery time corresponding to the task difficulties and the difference of the average error recovery time corresponding to the difficulties between the ERES / WCS and the ERES / WCS-dig.,

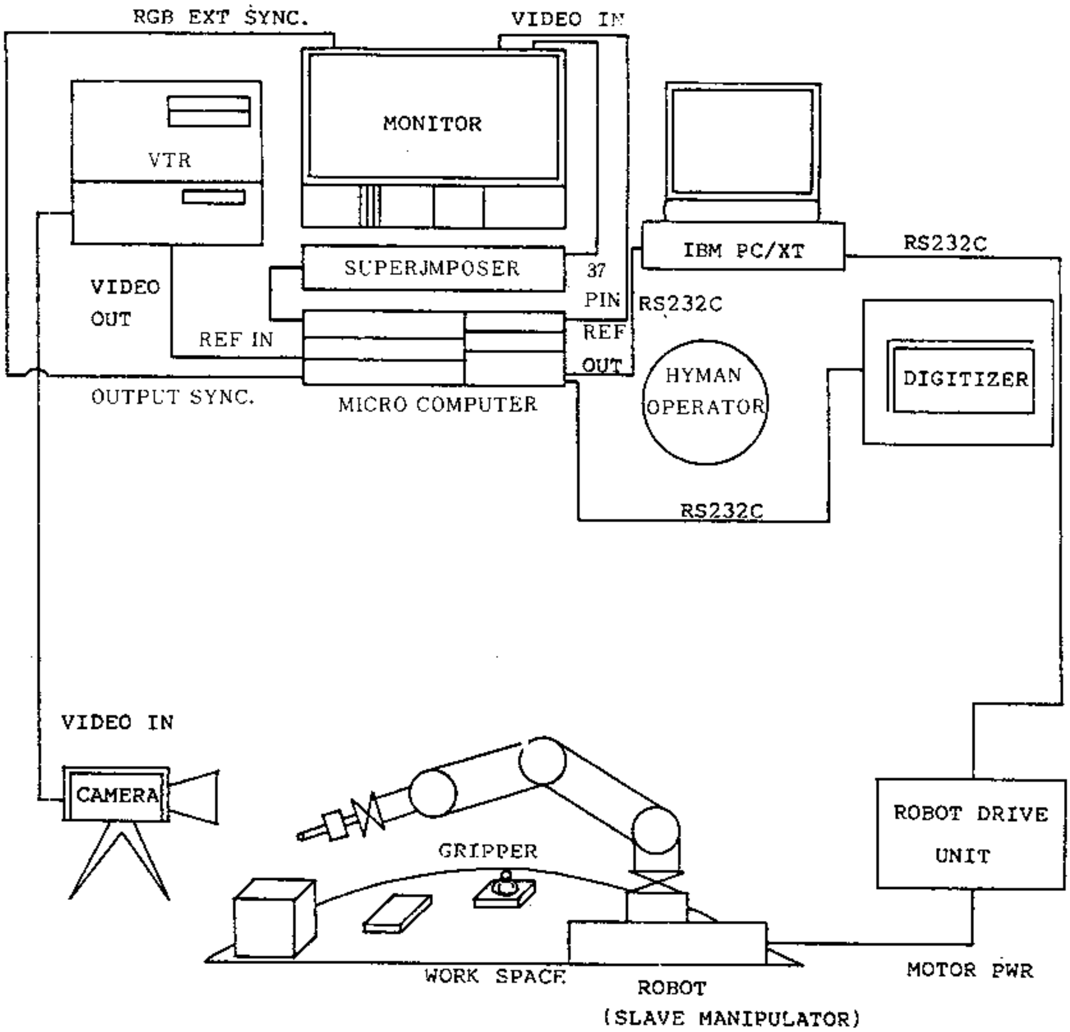

Fig. 3. Conceptual diagram of the experimental apparatus.

(iii) Analyses of Experimental Results. Table 1 shows the analyses of the experimental results acquired by the ANOVA on the experiments. In both ERES / WCS and ERES / WCS-dig., 'The average error recovery time varies as the task difficuties.' is used to the null hypothesis(Ho). As shown in the table 1, we can know that there is no difference of the average error recovery time according to the task difficulties in the two systems. This result is for the reason that it is unnecessary the additional task of the human operator because the posture of the robot hand is inferred by the heuristic posture rules through the task difficulties increases.

ANOVA					
Analysis of the task difficulty in two systems			Analysis of two systems in the task difficulty		
1	significance level	5 %	1	significance level	5 %
2	acceptance region	[0,2.38]	2	acceptance region	[0,4.02]
3	F-value of the ERES/WCS	0.4978	3	F-value	823.1789
4	F-value of the ERES/WCS-dig				
5	Ho'	1.2056	4	Ho	rejected
6	Ho'	accepted			accepted

But, by testing the significance of the two systems in each task difficulty, under the hypothesis that the average error recovery time of the experiment of the ERES / WCS equals to that of the experiment of the ERES/WCS-dig.,we can know that there is a differnce between the two systems. This reason is as follows. In the ERES / WCS, the human operator obtains the position information of the object by the eye measurement. But, in the ERES / WCS-dig., it is able to omit the additional task by the human operator because the position information is otained by the motion analysing computer system. Figure 4 shows these results well.

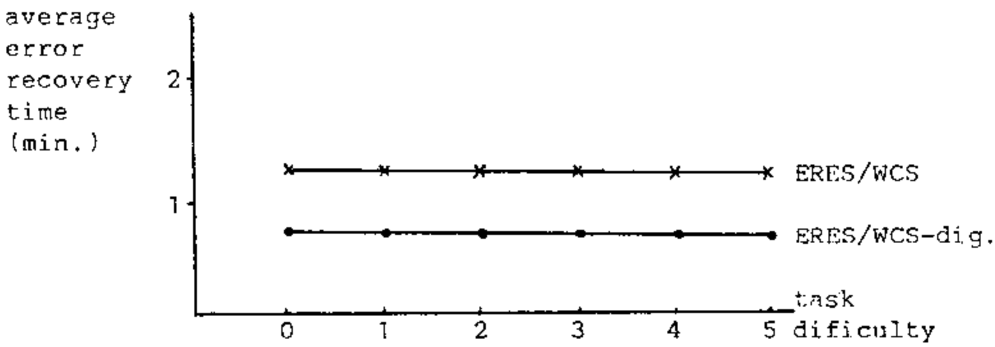

Fig. 4. Comparison of the ERES/WCS and the ERES/WCS-dig.

CONCLUSION

In this paper, it is executed the research that the world model teleopertor system makes into expert system by using the motion analysing computer system with the superimposer and the digitizer in the integrated human-robot ergonomics. It is able to obtain higher resolution than that of the ERES / WCS. And this fact plays an efficient role in the coordinate reading of the human operator. Because the human operator inputs the coordinates of the object just by the touch using the digitizer, it is more accurate and easier than the inputting method by the computer key board and it reduces the operation time. From these results, the ERES / WCS-dig. suggested in this paper reduces the error recovery time by the human operator.

In addition, the study of the three dimensional perception equipment of the work space and the hybrid control by the computer graphic simulation will be continued.

REFERENCES

〔1〕 S. Y. Lee, M. Nagamachi and K. Ito, A study on an comparison between the ERES / WCS and the ERES / CCS in the advanced teleoperator system, in : International Workshop on Artificial ntellingence for Industrial Applications, in press, Hitachi, Japan, 1988, May 25-27.

〔2〕 S. Y. Lee, M, Nagamachi, K. Ito and C. S. Oh, A study on a teaching and operating expert system in the advanced teleoperator system, in : Symposium for International Cooperation on Industrial Robots '87 Tokyo, Japan, 1987, pp, 278-280.

〔3〕 Samsung, ROB-501 Robot Manual, Samsung Electronic Institutes of Technology Co. Ltd., 1986.

〔4〕 Sony, Motion analysing computer system manual, Sony Co. Ltd., 1984.