Proceedings of the International Conference for Agricultural Machinery & Process Engineering
October 19-22, 1993, Seoul, Korea

Development of Intelligently Unmanned Combine Using Fuzzy Logic Control -(Graphic Simulation)-

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<Abstract>

The software for unmanned control of three row typed rice combine has been developed using fuzzy logic. Three fuzzy variables were used: operating status of combine, steering, and speed. Eleven fuzzy rules were constructed and the eleven linguistic variables were used for the fuzzy rules. Six sensors were used to get input values and sensor input values were quantified into 11 levels. The fuzzy output was infered with fuzzy inferrence which uses the correlation product encoding, and it must have been defuzzified by the method of center of gravity to use it for the control. The result of performance test using graphic simulation showed that the intelligently unmanned control of a rice combine was possible using fuzzy logic control.

Key Word : Combine, Artificial Intelligence, Fuzzy Logic Control, Graphic Simulation

I. Introduction

Agricultural population in Korea has rapidly decreased recently and farm labor has been ran short. Therefore, farm mechanization and automation has been in great need. The application of artificial intelligence(AI) in agriculture based on the efficient use of agricultural information has rapidly been done in expert system and computer vision in Europe, US, Japan, and so on. Recently artificial neural network and fuzzy theory are being utilized for the intellegent automatizaton of farm machinery and facilities with the improvement of various sensors. AI application techniques for intellegent control of agricultural machinery and facilities has been getting drawn great attention with the developement of microcomputer.

In 1990's the agricultural application of fuzzy theory has begun to be studied in Japan and US. Ziteraya(1987) showed the pattern recognition of farm products by the linguistic description with fuzzy theory, Brown(1990) explained that the food grade could be determined with the fuzzy sets and fuzzy control, Zhang(1990) developed the fuzzy control system that can control the corn drying, and Yamasita(1990) tested the practical use of unmanned vehicle for a greenhouse with fuzzy control. This study was focused on the intelligent automatization of farm machinery using fuzzy control. Objectives are to develop a fuzzy control software for a unmanned rice combine and to verify the intelligent harvesting process with interactive graphic simulation.

II. Methods and experiments

Firstly the concept of fuzzy controller for the unmanned intelligent combine was designed, secondly to check the operation through the simulation, the fuzzy variable, sensors on combine, fuzzy inference, composition of fuzzy controller, and graphic simulation were discussed.

2.1 Introduction of fuzzy theory

The word "fuzzy" has the meaning of "ambiguous" and "fuzzy" deals with the ambiguous information such as "big" and "fast".

Fuzzy theory quantifies the meaning of language. It represents the degree of membership belonging to the universal set with the real value between 0 and 1. For example, we make a function that numeralizes the linguistic description(linguistic variable), "young", we assign real value 1 to age 20, 0.8 to age 25, 0.6 to age 30, 0.4 to age 35, and 0.2 to age 40(applying real value to age). That is, we say "To be considered to be young in this age is this degree." according to the real values. Here, we can notice that the closer is the value to 1, the younger the age is, and the closer is the value to 0, the older the age is. This is not the two-valued logic but the multi-valued logic. Therefore, fuzzy theory is convenient to handle the ambiguous informations. Fuzzy control is also called fuzzy logic control, which describes the control knowledge which includes expert knowledge and the ambiguity based on the expertise with "if - then" rules.

Fuzzy theory has been established by professor Zadeh in 1965 and its history is very short. Thereafter theoretical basis has been established in US and various applications have been conducted in Japan especially for home electronics.

2.2 Fuzzy variable

The linguistic variables such as "very big", "somewhat small", and "rotated hardly to the right" were used in fuzzy control.

A three row typed rice combine was used and the status of combine was decided by the sensors. Six contact sensors were used. This sensor is on when the crop is in front of it, and off when the crop isn't. The figure 1 showed the location of sensors. Four of them were attached on each devider of cutter bar of rice combine and the other two of them were attached on left and right sides, at about ⅔ portion from the front. It has been proved that side sensors operated best when they were on about ⅔ portion from the front by the trial and error through the simulation harvesting.

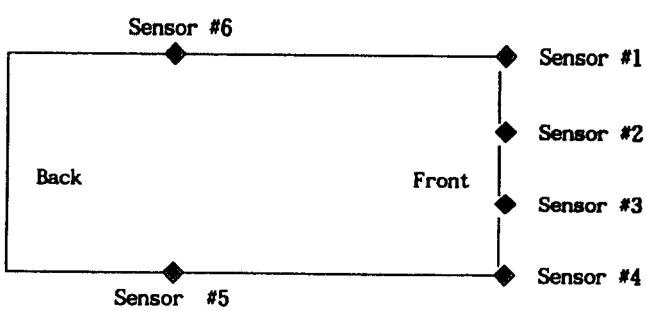

Fig 1. Location of sensors on a combine

The eleven linguistic variables were used in this program shown in figure 2.

LL (Left sensor is on and combine should turn left)
PL (Positive Large, very right)
PM (Politive Medium, medium right)
PS (Positive Small, a little right)
ZP (Positive Zero, almost zero but right)
ZO (Zero)
ZN (Negative Zero, almost zero but left)
NS (Negative Small, a little left)
NM (Negative Medium, medium left)
NL (Negative Large, very left)
RR (Right sensor is on and combine should turn right)

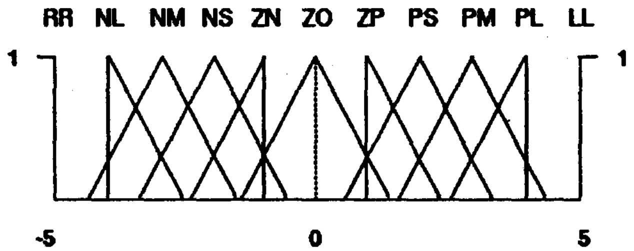

Fig 2. Triangle fuzzy variable

The linguistic variable describing the operating status of combine was assigned as LL when the sensor #6 was on only, PL when the sensor #1 was on only, PM when the sensor #1 and #2 were on, PS when the sensor #1, #2, and #3 were on, ZP when the sensor #1, #2, #3, #4, and #5 were on, and ZO when all the sensor were off. The other cases were vice versa.

The three fuzzy variables using these linguistic variables were used as the operating status of combine in conditional part("if" statement) of fuzzy rule, steering, and speed control in conclusion part("then" statement) of fuzzy rule. The linguistic variable corresponded to the combination of sensor inputs was assigned to the status of combine. Steering and speed control were the results from the status of combine in conditional part.

2.3 Fuzzy inference and control

In fuzzy inference, firstly fuzzification, quantificaion for the sensor inputs must have been done, secondly fuzzy sets were infered with the fuzzy rules, thirdly they were defuzzified to use it in the real control.

The role of fuzzification is to devide the sensor inputs into 11 levels and assign the grade of membership corresponding to each fuzzy variable. The membership grade was assigned to all the input data using the discrete triangle typed fuzzy variables.(Fig 2) The grade of membership can have the integer value between 0 and 10 instead of 0 and 1 of real value for the sake of computation.

Correlation Product Encoding was used for the fuzzy inference. Center Of Gravity(COG) was used for the defuzzificaion. Figure 3 shows the process of a simple inference, when it has 2 inputs and 1 output, and the number of rules are 2.

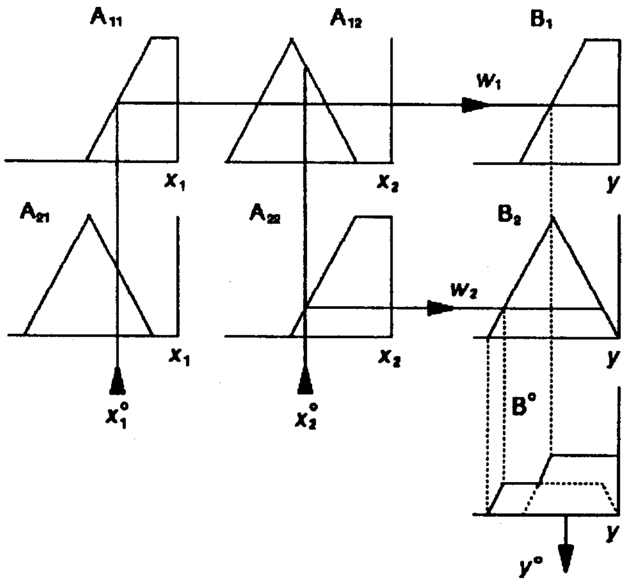

Fig 3. Fuzzy Inference

The final output membership function for each output is the union of the fuzzy sets assigned to that output in a conclusion after cutting their degree of membership values at the degree of membership for the corresponding premise. That is, once we know fuzzified x_1^o and x_2^o, the smaller part(smaller grade of membership) from the two conditional parts of x_1 of A_{11} and x_2 of A_{12} is selected, the shape of output is changed as much as the selected smaller height. B_2 can be obtained by the same way, and B^o is the union of two parts. Then y^o which is the final result is obtained by the COG.

Figure 4 shows the block diagram of fuzzy controller.

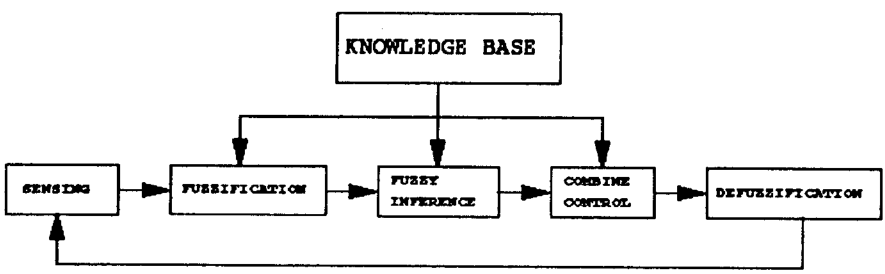

Fig 4. Block diagram of fuzzy controller

The pattern of control rules was "if - then" statments which had one condition on if-statement and two output on then-statement. Control rules were eleven and they were based on the expertise of combine expert.

For example, some rules used in this program are below.

IF COM_STATUS = PL, THEN HANDLE = NM, SPEED = ZO
IF COM_STATUS = NM, THEN HANDLE = PS, SPEED = PM

In the first rule, the status of combine(COM_STATUS) in conditional part tells us that the combine has been rotated hardly to the right(PL), so the handle(HANDLE) has to be directed to the medium left(NM) and the speed(SPEED) has to be controlled to be close to zero(ZO).

2.4 Graphic Simulation

C programming language was used for graphic simulation. The actual program was run on the menu driven style. The menu items that the user can use are : "QUIT"(stopping the program), "RUN"(simulating the operation), "RESET"(reseting the screen to the initial state), "CIRCLE"(making the circular shaped field), "RECTANGLE"(making the rectangular shaped field), "COMBINE"(setting the position of combine).

If the speed was high, the combine moved many pixels per unit time on the screen, if not, just a few pixels. A little space was placed between levee and crop, because the combine could turn when it made a first turn. The rice straws after harvesting was simulated to be thrown from the back of combine.

Figure 5 shows beginning of harvesting. Figure 6 shows the combine is turning the corner of the field. To make a turn, the combine goes back and makes a small turn and goes forward again with several repetitions. Figure 7 is the picture of routine harvesting. Because of the fuzzy control it can't go straight as man or other kinds of controls can do, it makes the locus of rough line as you can see in the picture. Figure 8 is the picture of the end of harvesting. The harvesting is stopped when all the sensors are off for a certain time. No more crop is left for harvesting, all sensors are off. The combine is stopped when the harvesting is through. Figure 9 shows an operation of combine in a circular shaped field. From the view of fuzzy controller all the thing that the combine has to do is to follow the outer line of circle, so there is no diffuculty and works well.

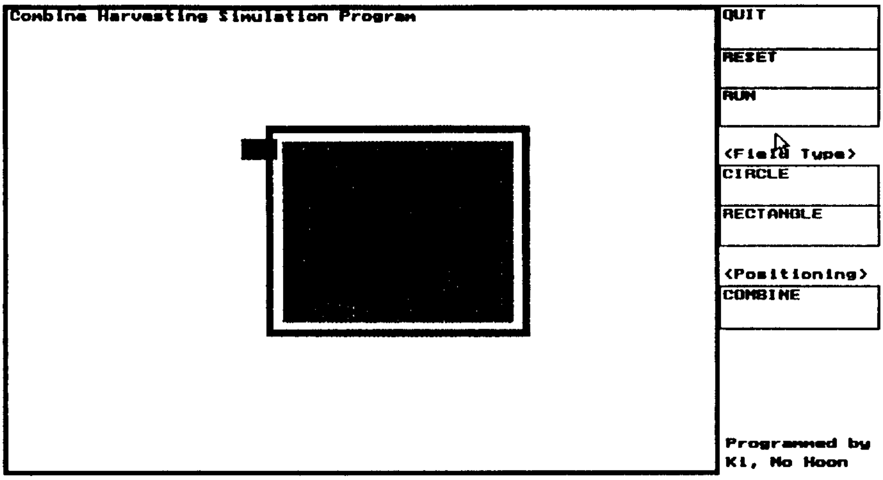

Fig 5. At the beginning of harvesting

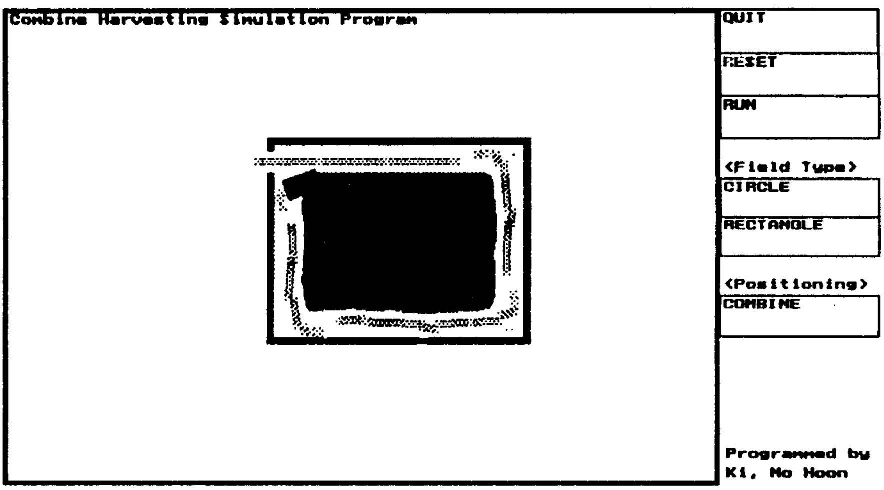

Fig 6. Turning the cornor of the field

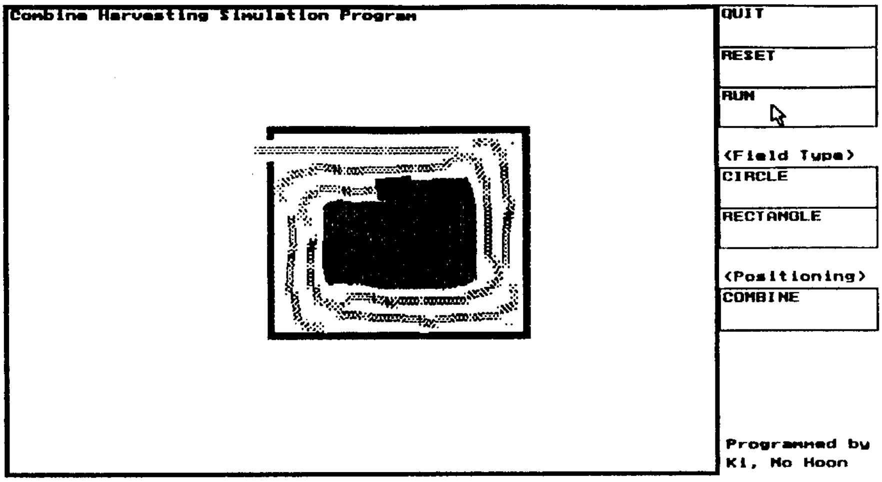

Fig 7. Routine harvesting

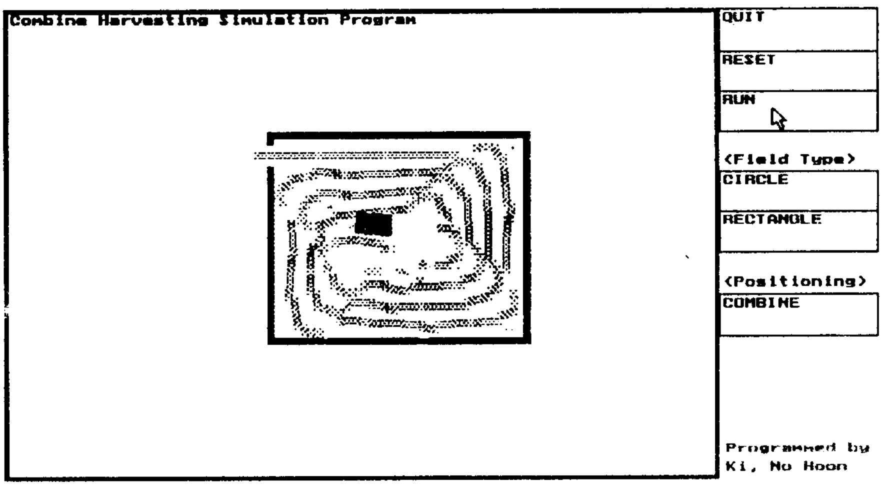

Fig 8. At the end of harvesting

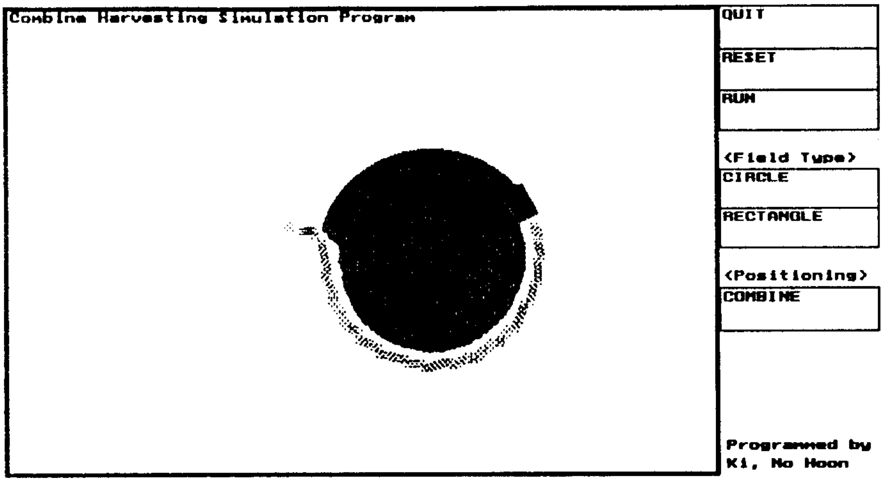

Fig 9. Harvesting on a circular field

III. Results

Harvesting with the fuzzy controller was graphically simulated and compared with the man's operation of combine. When the man operated the combine it could be operated on a straight lines, but the unmanned operation with the fuzzy controller it couldn't make the straight line but a somewhat rough line.

In most rice farming the crops are cultivated in the readjusted field and rectangular fields were tested in the simulation. Especially supposing that the crops are cultivated in the circular shaped field, the combine worked well without any problem. But, when the corner had an acute angle like the triangular shaped field, the unmanned harvesting did't work well. However, on the readjusted fields, there would be no triangular or acute angled fields. The harvesting simulation worked well on the rectangular fields.

In addition, the speed of combine had an effect on the simulation. If the speed was too high or too low, the unmanned harvesting wasn't good. Appropriate speed was related to the number of sensors on the combine and the location of them. The adjustment of sensors was needed to get it.

IV. Conclusion

The graphic simulation showed that the unmanned automatization of rice combine is possible with the FLC(Fuzzy Logic Controller) which was operated by fuzzy rules. The control method of FLC is relatively simpler than any other controllers. Fuzzy control is not following the exactness itself but the effort to be close to the exactness. Because of this, as long as the input data isn't crooked heavily, it works well even though certain rules are missing and not adequate. Besides the unmanned rice combine, fuzzy control can be used for an unmanned pest control machine in the orchard or unmanned tillage operation with the tractor.

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