Beam Transport System using Fuzzy Controller in the KCCH Cyclotron

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The KCCH Cyclotron beam transport system consists of a neutron gantry line and a radioisotope production line. Designed controller using Fuzzy algorithm for the neutron gantry line. The correlation inference method was used for inference of Fuzzy algorithm. Defuzzification was done by a center of gravity method. The result of the Fuzzy controller could reduce beam tunning time and supply the good quality beam to patients at neutron therapy and also get optimum beam status for neutron gantry.

1 Introduction

The KCCH cyclotron has been working in Korea Cancer Center Hospital is isochronous, multi-particle variable cyclotron . It has been utilized to production of isotopes, cancer therapy with neutron beam, nuclear physical research and research of the biology and material science.[1,2] The control system consists of a main computer PDP-11/23+ and I/O system.[3] But the operation of cyclotron is deeply depend on the experience of the operator and the computer system only used for the memory of the changed parameters. Even though the extraction energy and ions is same, the control parameter always required tuning by the operator for the for better extraction efficiency. In particular the proton beam transported through the beam line need not only the tuning for beam extraction but also beam line tuning on the basis of the beam optical process. We monitored and control in concentration for the beam extraction and transportation status in RI production and neutron therapy. In the case of neutron therapy the change of the gantry angle required the many input control parameters involved in gantry system and which are main portion of therapy. Therefore, the automation of this system can save treatment time and supply the better beam quality due to the minimization of the dose rate for treatment angles. In present study we tried to control the beam position in therapy unit automatically. To realize such nonlinear properties we adapted the artificial intelligential method which treats in process similar to human being. The representative methods of artificial intelligence are the analysis on the basis of neural network technique in potential field[4], temporal difference technique[5] and neural network based technique. But the neural network based technique needs much time and complex for cognition and also requires much care for the case of supervised training. Another technique is based on the fuzzy theory. Fuzzy theory treats input data as like human and includes fuzzy set , fuzzy logic and so on.[6] Almost mathematical logic and technique are well constructed.[7] Our control unit based on fuzzy theory is consisted of five units: ADC of 4 channels as input, fuzzification unit for transformation from input to fuzzy data, decision unit to decide output for fuzzy data, unit for transformation from fuzzy data to common data and DAC. We used nonlinear method for beam line control and inference unit adopted the correlation minimum method[8] with some change and defuzzification method with center of gravity method [9] commonly used.

2 Hardware structure of controller

In the neutron gantry line there are 23 parameters included quadrapole lens values. It needs 23 analog outputs for the control. Gantry bending magnets and X steering magnet are most changeable parameters depending on gantry rotation angle. They are the most important parameters for getting the beams in the target. Fuzzy beam line control system is composed of quadrant (sensor of four directions, east, west, north, south), AD converter, Fuzzy controller, and DA converter.

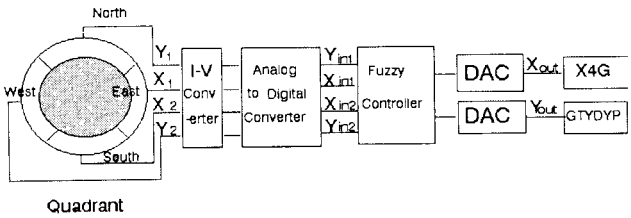

Figure 1: Fuzzy controller for the beam line

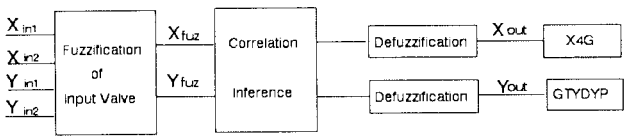

Figure 2: Structure of Fuzzy Controller

Fuzzy controller is composed of the part of fuzzification of input data, the part of determine by fuzzy logic, and defuzzificative part. In this system output of fuzzy logic is divided to X axis and Y axis of beam directions. The methods of each parts are used triangular method for fuzzification, correlation minimum method for inference, and centering gravity method for defuzzification.

Fuzzy controller requires digital input values so every input data should be changed to digital input data by A-D converter. The A-D converter is needed to get high speed and accuracy. In this system HADC547Z which has 12 bits resolution and 16 sing ended is used for A-D converter. AD7541AKN which has 12 bits resolution is used as a D-A converter

3 Software structure of Fuzzy controller

Fuzzification of input and output values are determined by linguistic expression of fuzzy set, range of set, membership function, and discrimination level.

3.1 Fuzzification

Nonlinear method is used for quantization in this controller. Table is comparing input values range with linguistic expression. Correction range is from -1 μA to 1 μA whose resolution is 1/100. Actually input values are current values which should be voltage values by I-V converter.

After determine of linguistic expression and range membership function should be determined with general method as like as triangular type or trapezoid type. In this controller we used mixed type with triangular and trapezoid type.

We used correlation-minimum method for inference. The control rule should have some correlation between x and y axis control, which is weighted within some voltage range on the basis of operator experience. We took the maximum value under OR concept since the inputs for x and y axis are connected under OR concept.

Table 1.Analog Input Values for the Controller

	North	South	East	West
0.01 μA	-0.0752 V	0.1063 V	0.5009 V	0.2178 V
0.1 μA	0.0869 V	0.1900 V	0.5766 V	0.3802 V
0.3 μA	0.1889 V	0.4280 V	0.8303 V	0.6040 V
0.5 μA	0.3964 V	0.5721 V	1.0417 V	0.7900 V

3.2 Defuzzification

We used the center of gravity method which are one of defuzzification method. This method is known to have good output characteristics and relatively small calculation quantity. Input parameter defined x axis for west-east and y axis for north-south, and after inference of input and fuzzification of result each output unit produced outputs. As the x axis steering magnet of output range current defined from -50 A to +50 A and voltage from -2.2041 to 2.112 V. Gantry dipole as y axis fixed 302 A with remote control voltage 3.102 V. Our control unit produced remote control voltage as output which used to control the gantry bending magnet and gantry quadrapole magnet. In consequence we controlled the beam orbit by control of magnet. We used output from -2.041 to 2.112 V, so we made circuit satisfy the input requirements because common ADC works from 0 to 5 V.

3.3 Control Program

Control software programed C language and assembler language, and consisted A/D, D/A control unit and graphic unit. A/D and D/A unit are responsible for input and output for controlled signals, and for interface with computer. The core part of main program are consisted of fuzzification, defuzzification and inference parts.

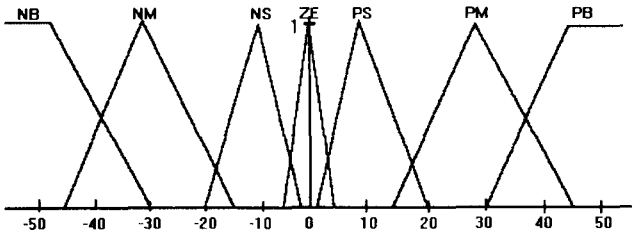

Figure 3: Membership Function of X and Y Axis

Table 2. Rule base of x axis

Y \ X	LB	LM	LS	ZE	RS	RM	RB
LB	PM	PS	ZE	ZE	ZE	NS	NM
LM	PM	PS	ZE	ZE	ZE	NS	NM
LS	PB	PM	PS	ZE	NS	NM	NB
ZE	PB	PM	PS	ZE	NS	NM	NB
RS	PB	PM	PS	ZE	NS	NM	NB
RM	PM	PS	ZE	ZE	ZE	NS	NM
RB	PM	PS	ZE	ZE	ZE	NS	NM

Table 3. Rule base of y axis

Y \ X	LB	LM	LS	ZE	RS	RM	RB
LB	PM	PM	PB	PB	PB	PM	PM
LM	PS	PS	PM	PM	PM	PS	PS
LS	ZE	ZE	PS	PS	PS	ZE	ZE
ZE	ZE	ZE	ZE	ZE	ZE	ZE	ZE
RS	ZE	ZE	NS	NS	NS	ZE	ZE
RM	NS	NS	NM	NM	NM	NS	NS
RB	NM	NM	NB	NB	NB	NM	NM

4 Experiment and Discussion

We have performed fuzzy control for x axis steering magnet and gantry dipole maget. The control speed was 500 msec on account of magnet power change speed. Ar-

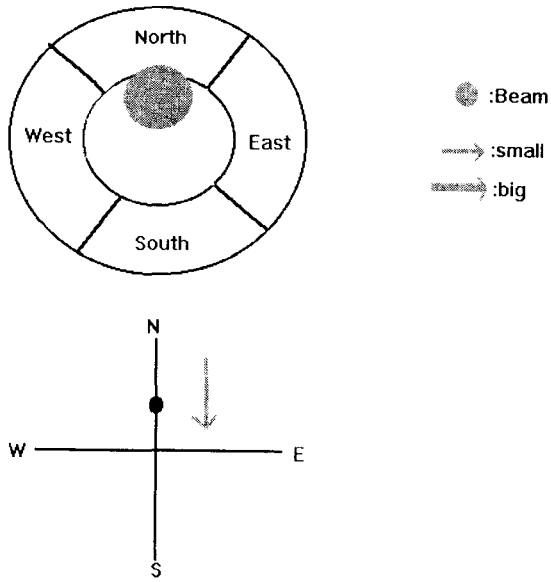

Figure 4: Result of Fuzzy Control for Case 1

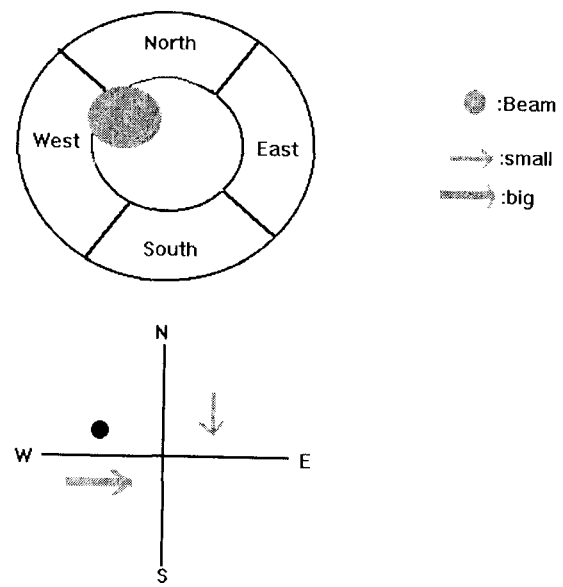

Figure 5: Result of Fuzzy Control for Case 2

tificially we produced proton beam deviation from well turned state, so we check the fuzzy control outputs and speed to reproduced the well tuned state.

5 Conclusion

We tried to beam line control based fuzzy concept Such system showed to have good response to produced well tuned state , therefore, we can reduce the loss of beam current. The suggested system is appropriate to reduced the mistake compared to human based system, is able to supply the good quality beam to patients at neutron therapy and give possibility to control arc therapy which is impossible of previous method. On the basis of this study we are planning to propagate automation for overall cyclotron control system

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