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Indoor Navigation using Adaptive Neuro Fuzzy Controller for Servant Robot

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Abstract— **We present our ongoing work on the development of Adaptive Neuro Fuzzy Inference System (ANFIS) Controller for humanoid servant robot designed for navigation based on vision. In this method, black line on the landmark used as a track for robot's navigation using webcam as line sensor. We proposed architecture of ANFIS controller for servant robot based on mapping method, 3 input and 3 output applied to the controller. Only 45 training data used for navigation and best error starting at epoch 62. Each of the components are described in the paper and experimental results are presented. Humanoid servant robot also equipped with 4DOF arm robot, face recognition and text to speech processor. In order to demonstrate and measure the usefulness of such technologies for human-robot interaction, all components have been integrated and have been used for a servant robot named Srikandi I. Based on experiments, ANFIS controller succesfully implemented as controller for robot's navigation.**

Keywords : adaptive neuro fuzzy, robot's navigation, ANFIS Controller, service robot.

I. Introduction

Servant robot are becoming ubiquitous, from domestic uses as robotic vacum cleaners to field applications as cargo, agriculture, military and even interplanetary exploration. Many different technologies are used to achieve the degree of mobility that such robots require, depending on the application. These applications can be typically divided in two main groups: indoor mobile robots are usually designed to operate in a human structured environment, whereas outdoors and field service mobile robots work in a less structured environment[2].

Mobile robot navigation using vision is an essential issue in humanoid robot and artificial intelligent. Vision sensor have good sensing abilities and makes robots able to identify and recognize the objects near them.

Navigation for mobile robot can be classified as indoor and outdoor navigation. Indoor navigation can be using map or without map [1]. In this paper, we proposed ANFIS controller for indoor navigation without map based on line tracking landmark using camera. Navigation using line tracking is one of the solution for dedicated servant robot, because this robot will be implemented to any fast food restaurants that have different landmark and environment.

Fuzzy logic and Neural networks can be used for robot's navigation. Fuzzy logic can be used as a controller for robot's navigation in dynamic unknown environment. Li and Yang [6] proposed an obstracle avoidance approach using fuzzy logic, but the input sensors are separately inferred. On the other hand, neural networks are model-free systems which are organized in a way to simulate the cells of a human brain. They learn from the underlying relationships of data. Neural networks have a self-learning capability, self-tuning capability and can be used to model various systems. Therefore, fuzzy logic and neural networks can be combined to solve the complex robot navigation control problem and improve the performance.

Certain fuzzy systems are universal function approximators. In order to identify a suitable fuzzy system for a given problem, membership functions (parameters) and a rule base (structure) must be specified. This can be done by prior knowledge, by learning, or by combination of both. If a learning algorithm is applied that uses local information and causes local modifications in a fuzzy system, this approach is usually called neuro-fuzzy system[8]. Anmin Zhu et al [3] presented a neuro-fuzzy controller for robot navigation, but the robot uses GPS and many distance sensors (9 sensors) to obtain the obstacle distances of robot that more expensive compared to single webcam.

A. Architecture of Servant Robot

In this paper, we present servant robot implementing ANFIS controller as a navigation controller. The architecture of the servant robot is shown at fig. 1. Robot equipped with arm robot using servo controller, webcam and Laptop for processing the images and coordinating robot movement. Program for processing images and face recognition system using OpenCV[7]. 2 differential wheels used as actuator and compass sensor used for gaining the position of the robot. Text to speech controller used for giving response to the user. Machine vision system used as line sensor because its advantages such as able to detect small objects and accurate measurements. We implementing AVR ATMega16 and

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Basic Stamp microcontrollers to make this robot more robust, fast, easy to connect with general sensors and low cost system.

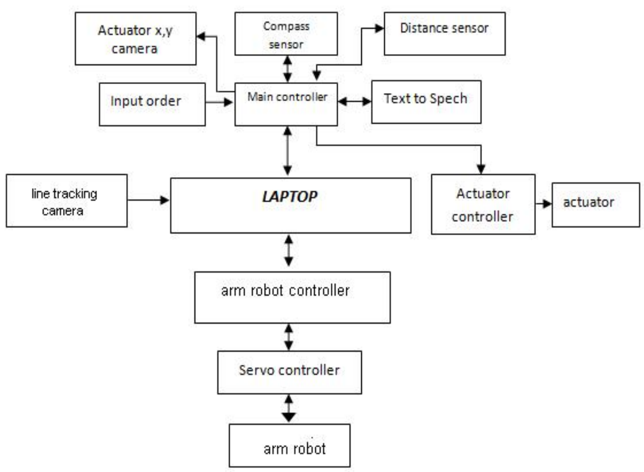

Figure 1. Architecture of Servant Robot Srikandi I, it contain controllers for controlling robot and Laptop for processing images form the camera.

B. Model of Servant Robot

The model of servant robot called Srikandi I shown at Fig. 2. Webcam used as line sensor and detecting face using face recognition system. Cup sensor used to detects whether a cup already loaded to the robot. When a cup already loaded to the robot, the robot starting to run following the line, until the end of the line and the camera looking for people's face. When people's face detected, arm robot will give the cup to that people, and then robot return back to the home.

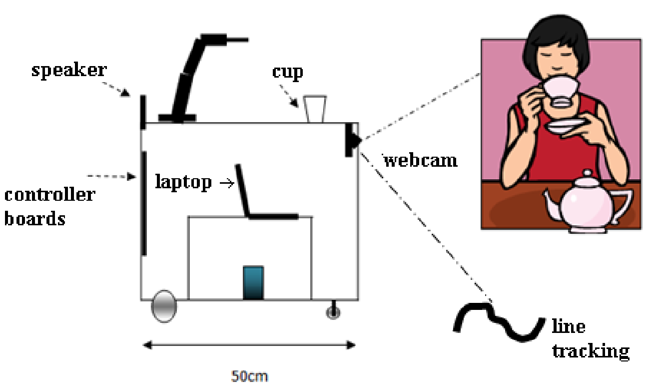

Figure 2. Model of servant robot Srikandi I, here camera used as line following sensor and detects faces.

II. ADAPTIVE NEURO FUZZY INFERENCE SYSTEM

Fuzzy Logic Controllers (FLC) has played an important role in the design and enhancement of a vast number of applications. ANFIS are fuzzy Sugeno models put in the framework of adaptive systems to facilitate learning and adaptation. Such framework makes FLC more systematic and less relying on expert knowledge. ANFIS is a fuzzy inference system formulated as a feed-forward neural network. Hence, the advantages of fuzzy system can be combined with a learning algorithm. Let us consider two-fuzzy rules based on a first order Sugeno model to present the ANFIS architecture:

Rule 1 :

- If x is A_1 and y is B_1 then

  $z_1 = p_1*x + q1*y + r_1$

- If x is A_2 and y is B_2 then

  $z_2 = p_2*x + q_2*y + r_2$

ANFIS architecture to implement these two rules is shown in Fig. 3. Note that a circle indicates a fixed node whereas a square indicates an adaptive node (the parameters are changed during training). In the following presentation O_{Li} denotes the output of node i in a layer L.

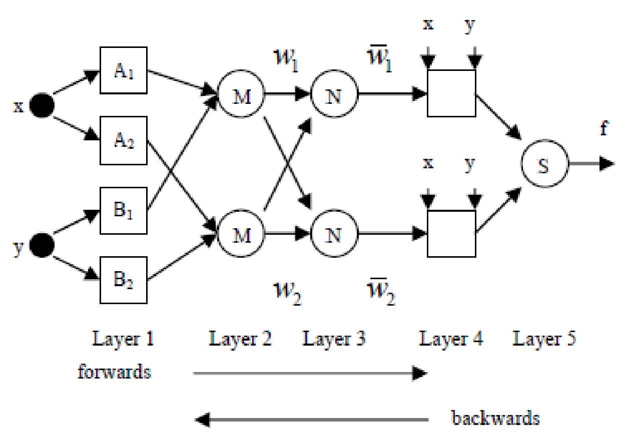

Figure 3. ANFIS architecture using 2 input x and y[4].

Layer 1: All the nodes in this lyer are adaptive nodes, i is the degree of the membership of the input to the fuzzy membership function (MF) represented by the node :

$$O_{1,i} = \mu_{Ai}(x) \qquad i=1,2 \qquad (1)$$

$$O_{1,i} = \mu_{Bi-2}(y) \qquad i=3,4$$

A_i and B_i can be any appropriate fuzzy sets in parameter form. For example, if bell MF is used then :

$$\mu_{Ai}(x) = \frac{1}{1 + \left| \frac{x - c_i}{a_i} \right|^{2b_i}} \qquad i=1,2 \qquad (2)$$

Where a_i, b_i and c_i are the parameters for the MF.

Layer 2: the nodes in this layer are fixed (not adaptive). These re labeled M to indicate that they play the role of a simple multiplier. The outputs of these nodes ar e given by:

$$O_{2,i} = w_i = \mu_{Ai}(x)\,\mu_{Bi}(y) \quad i=1,2 \qquad (3)$$

The output of each node in this layer represents the firing strength of the rule.

Layer 3: Nodes in this layer are also fixed nodes. These are labeled N to indicate that these perform a normalization of the firing strength from previous layer. The output of each node in this layer is given by :

$$O_{3,1} = \overline{w_i} = \frac{w_i}{w_1 + w_2} \quad i=1,2 \qquad (4)$$

Layer 4 : All the nodes in this layer are adaptive nodes. The output of each node is simply the product of the normalized firing strength and a first order polynomial :

$$O_{4,i} = \overline{w_i} \cdot f_i = \overline{w_i}\left(p_i x_1 + q_i y_1 + r_i\right) \qquad (5)$$

Where p_i, q_i and r_i are design parameters (consequent parameter since they deal with the then-part of the fuzzy rule).

Layer 5: This layer has only one node labelled S to performs a simple summer. The output of this single node is given by :

$$O_5 = \sum \overline{w_i f_i} = \frac{\sum_i w_i f_i}{\sum_i w_i} \qquad (6)$$

The ANFIS architecture is not unique. Some layers can be combined and still produce the same output. In this ANFIS architecture, there are two adaptive layers. Layer 1 has three modifiable parameters (a_i, b_i and c_i) pertaining to the input MFs [4]. These parameters are called premise parameters. Layer 4 has also three modifiable parameters (p_i, q_i and r_i) pertaining to the first order polynomial. These parameters are called consequent parameters. The task of training algorithm for this architecture is tuning all the modifiable parameters to make the ANFIS output match the training data [5].

III. ANFIS CONTROLLER FOR ROBOT'S NAVIGATION

Block diagram of the proposed controler using mapping method is shown in figure 4. In this method, at training phase, ANFIS will compute and compare training data with test data, if error approach to 0, then ANFIS equal to the navigation rules.

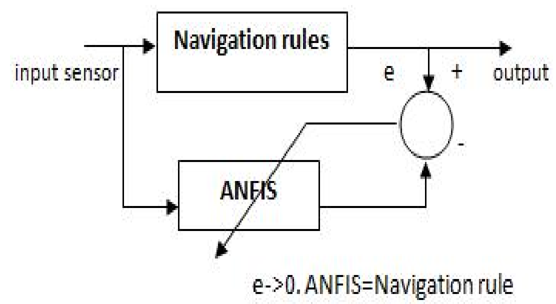

Figure 4. Block diagram for the mapping method in training phase

Fig. 5 is ANFIS architecture proposed for servant robot. We give training data for ANFIS controller using mapping method. We designed 3 input for servant robot; x for robot position, y for face recognition and z for cup status sensor. The training data contain 45 possible input (x,y,z) and appropriate output (V_R, V_L, Arm), we only create 15 rules where each rule consist of 3 training data.

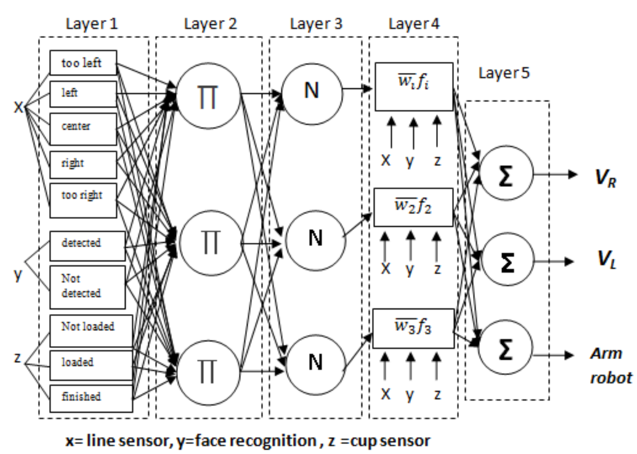

Figure 5. Proposed ANFIS controller for servant robot's navigation

Robot position gained by reading line track on the landmark that separate into 5 region as shown in figure 6. This region used to adjust motor's speed. Each region having pixel range to indicate robot's position. After camera detected line and obtaining robot's position, it used as input sensor to ANFIS controller to be processed. First, morphological operation (erosion following by dilation) applied to original image to eliminate noises. Then, we determine threshold value for black color. Final image is an image with the information about the center position, and robot position to be an input test data for controller . 3 output of this controller for controlling speed of motors and arm robot.

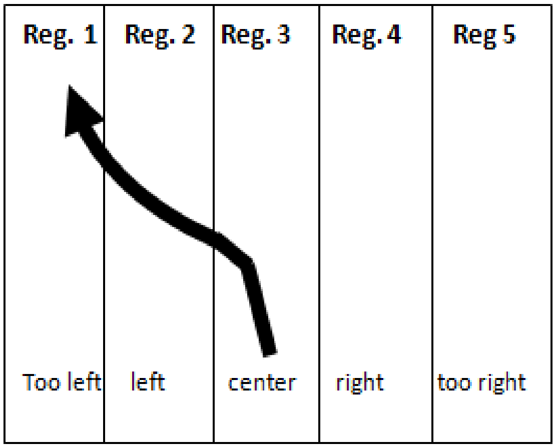

Figure 6. Mapping area for line tracking consisting of 5 regions.

We created rules for controller shown at Table 1. These rules determined how robot's bevahiour. Target seeking is action by robot to still running until it found end line.

TABLE 1. THE RULE BASE OF THE PROPOSED FUZZY CONTROLLER. C: CENTER; L:LEFT; TL: TOO LEFT; R:RIGHT; TR: TOO RIGHT; S:STOP; ND: FACE NOT DETECTED;D: FACE DETECTED; L=LOADED; NL: NOT LOADED; F: FINISHED; PS:POSITIVE SMALL; PB: POSITIVE BIG; NA: NO ACTION; A:ACTION.
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Rule no.	Input			Output			Behaviour
	x	y	z	V_L	V_R	Arm	
1	C	ND	NL	0	0	NA	stop
2	C	ND	L	PS	PS	NA	Target seeking
3	L	ND	L	PS	0	NA	Target seeking
4	TL	ND	L	PB	0	NA	Target seeking
5	R	ND	L	0	PS	NA	Target seeking
6	TR	ND	L	0	PB	NA	Target seeking
7	S	ND	L	0	0	NA	Target seeking
8	S	D	L	0	0	A	Giving order
9	S	D	NL	PB	0	NA	Return back
10	C	ND	F	PS	PS	NA	Going home
11	L	ND	F	PS	0	NA	Going home
12	TL	ND	F	PB	0	NA	Going home
13	R	ND	F	0	PS	NA	Going home
14	TR	ND	F	0	PB	NA	Going home
15	S	ND	F	0	0	NA	Available

IV. EXPERIMENTAL RESULTS

ANFIS controller has been tested for navigating servant robot to delivers a cup in a lab as simulation of indoor environment. Line sensor succesfully detects track and controller produced output with expected response. Fig. 7 shown below display the track and the center position (indicated by yellow circle) as reference, and the robot's position for input data to controller.

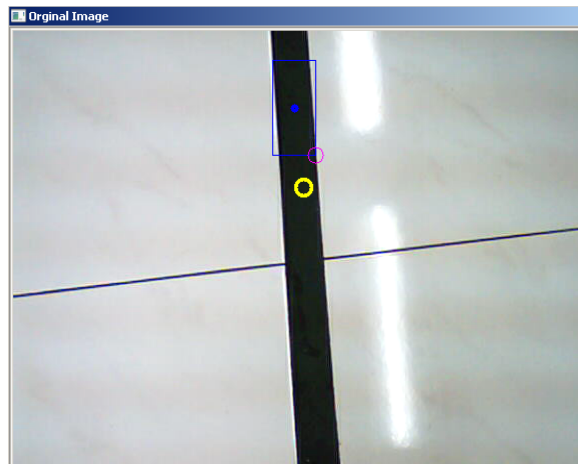

Figure 7. Original image and points for input data, yellow circle is center posi.tion.

Original images then procesed using morphological operation for reducing the noises and then we got the region of interest as shown at Figure 8.

Figure 8. Region of interest from the black line.

Robot automatically running when a cup loaded to the robot, after that camera detect the line to give information to the robot about its position. Table 2 shows the expected response of the robot's navigation after ANFIS controller implemented to the robot.

TABLE 2. THE EXPEDTED RESPONSE OF THE ROBOT'S NAVIGATION AFTER ANFIS CONTROLLER IMPLEMENTED TO THE ROBOT.

Input			Output			Behaviour
x	y	z	V_L	V_R	Arm	
C	ND	NL	0	0	NA	stop
C	ND	L	PS	PS	NA	Target seeking
L	ND	L	PS	0	NA	Target seeking
TL	ND	L	PB	0	NA	Target seeking
R	ND	L	0	PS	NA	Target seeking
TR	ND	L	0	PB	NA	Target seeking
S	ND	L	0	0	NA	Target seeking
S	D	L	0	0	A	Giving order
S	D	NL	PB	0	NA	Return back
C	ND	F	PS	PS	NA	Going home
L	ND	F	PS	0	NA	Going home
TL	ND	F	PB	0	NA	Going home
R	ND	F	0	PS	NA	Going home
TR	ND	F	0	PB	NA	Going home
S	ND	F	0	0	NA	Available

We developed program for ANFIS controller using C++ based on Adaptive Neuro Approximation method[8]. Based on results that displayed using Gplot, after training process, we get the best error after epoch 62 as shown in Fig. 9.

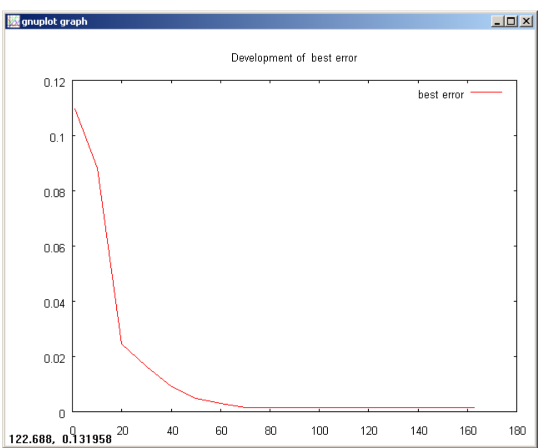

Figure 9. Development of best error starting at epoch 62.

V. CONCLUSION

In this paper, adaptive neuro fuzzy controller for navigation of robot already proposed and implemented for servant robot. ANFIS controller with mapping method can be used as controller and only using 15 rules and epoch requried for training the controller very small (62 epochs). Line sensor using camera can be used in servant robot. For future work, we will implementing ANFIS controller for Arm robot movement and docking system

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