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A Novel Nero Fuzzy Controller as Underwater Discoverer

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ABSTRACT

In this paper, a novel Nero-Fuzzy controller based autonomous underwater controller for UN_UND_VHs (unmanned underwater vehicles) is described. The research describes a Nero-fuzzy controller as basic tasks to be accomplished of handling of motion coordination between the vehicle and the discoverer to successfully execute the manipulation task. A numerical case study is developed to demonstrate effectiveness of the proposed technique. The result of chip design is a chip in an area less than 0.56mm^2. The speed is 3420MFILIPS.

KEY WORDS: ANFIS, Underwater Vehicles, Discoverer, FLC.

I. INTRODUCTION

Fuzzy controllers use fuzzy logic that is a nonlinear mapping of the nonlinear systems. Nonlinear systems lack a simple mathematical model and therefore are very complex to implement with classical systems. Fuzzy systems use language terms (words) instead of mathematic variables and rule-based inferences (Word Computing) instead of mathematical model. Using fuzzy logic for the implementation of the controllers used for nonlinear systems with high nonlinearity provides low cost, simple design and the possibility to design without knowing the exact mathematical model of process.

Nowadays, general tendency for implementing the controllers of nonlinear systems is toward using fuzzy logic. The design and simulation of a fuzzy logic controller using MOS circuits is considered in this project.

The state of the art of underwater manipulation is based on remotely operated vehicles carrying a tale-operated discoverer. One or more human operators are in charge of remotely controlling the vehicle actuators and the discoverer by, e.g., a master–slave technique. It is evident that trained and skilled operators are necessary to accomplish such operations and that the achievable performance is quite limited. Moreover, the operators are often required to be physically near to the vehicle-discoverer system, e.g., in a submarine, which raises the risks and costs involved with the mission to be executed. To partly solve the above problems, the ROV can be replaced by an autonomous underwater vehicle (ROV); in this case, however, while the operator can be in a surface vessel and control the sole discoverer, new problem s arise due to the time delays introduced by the vessel–discoverer communication system.

To overcome the above limitations, recent research efforts are gold at developing completely autonomous underwater vehicle–discoverer systems. In this framework, one of the basic tasks to be accomplished is handling of motion coordination of the bodies constituting the UVMS to successfully execute the manipulation.

The ocean has not been fully explored because of the hazardous underwater environment. The recent advancement in various areas such as batteries, materials, wireless communications and computers makes autonomous Information Sciences [1, 2, and 3] underwater vehicles (ROVs) attractive to various underwater applications.

However, ROVs are highly nonlinear, coupled, and time varying and their hydrodynamic parameters are often poorly known [4]. Unlike other terrestrial systems, it is impossible to manually tune control parameters of ROVs, especially in deep water. Therefore, ROVs would require an intelligent control system that would self-tune the controller when the performance degrades during the operation, due to changes in the system and environment. Various advanced ROV control systems have been proposed in the literature, such as sliding control [5, 6], nonlinear control [7], adaptive control [8, 9], neural network [10,11], and fuzzy control [12,13]. Nonlinear control schemes often require an accurate system model. However, it is not easy to derive an accurate model of the ROV system due to parameter uncertainties in hydrodynamics. Conventional fuzzy control schemes require an expert knowledge or many cycles of trial-and-error to achieve the desired performance. In neural network control, training time is unpredictable and neural networks may not be suitable for real-time control [14]. Wang et al. [15] proposed Nero-fuzzy controller, called self–adaptive Nero-fuzzy inference system (SANFIS), for ROVs. The SANFIS controller can make fuzzy rules automatically with self-learning parameters. However, it requires learn the relationship between input and output using off-line learning schemes with input–output data generated by another control system.

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This paper describes a Nero-fuzzy controller that was developed based on the first authors previous work on Fuzzy Membership Function-based Neural Network (FMFNN) [16, 17] and applied to control ROVs. Section 2 describes the FMFNN controller. Effectiveness of the FMFNN controller was investigated and it was also compared with a non-repressor based adaptive controller by computer simulation. The simulation results are discussed in Section 3 before the conclusions in Section 4.A generic manipulation task is usually given in terms of position/orientation motion trajectories for the end effecter. When the robotic system used to perform the manipulation task possesses more degrees of freedom than those strictly required to execute the given motion of the end-effecter it is said to be kinematic redundant. In this sense, an UVMS is always kinematic redundant due to the mobility provided by the vehicle itself in addition to the dots provided by the discoverer arm. However, it is not always efficient to use vehicle thrusters to move the discoverer end effecter because of the difficulty of controlling the vehicle in hovering [18, 19, and 20].

Moreover, due to the different inertia between vehicle and discoverer, movement of the latter is energetically more efficient. On the other hand, reconfiguration of the whole system is required when the discoverer is working at the boundaries of its workspace or close to a kinematic singularity; motion of the sole discoverer, thus, is not always possible or efficient.

When a manipulation task has to be performed with an UVMS, the system is usually kept in a confined space (e.g., underwater structure maintenance). The vehicle is then used to ensure station keeping. However, motion of the vehicle can be required to specific purposes, e.g., inspection of a pipeline, reconfiguration of the system, real-time motion coordination while performing end effecter trajectory tracking.

In this paper the task-priority redundancy resolution technique for kinematic control of UVMSs presented in [21] is integrated with a Nero-fuzzy approach. A Nero-fuzzy inference system (FIS) is in charge of distributing the required end-effecter motion between the vehicle and the discoverer. At the same time, the FIS can activate a secondary task if the corresponding variable is out of a safe range. Notice that several secondary tasks can be defined and handled with this approach. Preliminary work, based on the introduction of fuzzy techniques in kinematic control of UVMSs, has been presented in [22]. The proposed task-priority inverse kinematic approach is based on the work in [23] and thus is robust to the occurrence of algorithmic singularities.

Numerical simulations have been developed on a UVMS constituted by a vehicle carrying a three-link planar discoverer [24]. The obtained results show the advantage of the proposed approach.

II. PROPOSED REDUNDANCY RESOLUTION

To achieve an effective coordinated motion of the vehicle and the discoverer while exploiting the redundant degrees of freedom available, we resort to a task-priority redundancy resolution technique [25, 26] In this framework, a primary task up must be defined which is fulfilled along with a suitably defined secondary task as long as the two tasks do not conflict; when the two tasks conflict, the secondary task is automatically released to allow fulfillment of the primary task. The velocity vector f is then computed as [28] where JP and JS are the primary task and secondary task Jacobeans, respectively. It can be recognized that the secondary task is given lower priority with respect to the primary task by projecting the relative actions through the null space of the primary-task Jacobean.

This would be advantageous for underwater applications in which uncertainty on dynamic parameters is experienced.

In order to stabilize the vehicle for *Autonomous Navigation and penetration* or even human supervisory in semi-autonomous concept, the closed loop control concept is considered. The configuration of thrusters in vector form enables the vehicle for smarter navigating concept, as in figure 3.

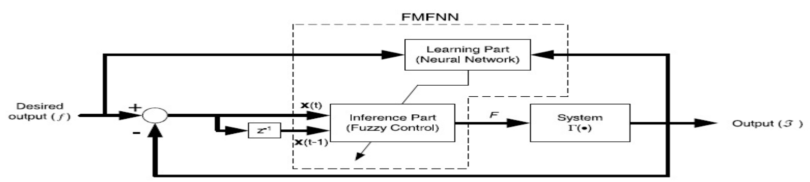

Fig. 1. Sketch of the two-stage Fuzzy controller learnable via Neural Networks control architecture
The block TP (Task Priority) includes the use of Nero-fuzzy techniques.

By employing the fly back diagram of figure 4, the technique of ANFIS logic that is in gear to control the duty cycle (D), can be applied, as drawn by the Block diagram which is shown in figure 2. In the design of the Power management Unit of the vehicle, ANFIS is used for the control and stabilization concept of the voltage and current in output and input sections.

III. ADAPTIVE NERO-FUZZY INFERENCE SYSTEM (ANFIS)

ANFIS is a five layered feed-forward neural network structure, as shown in Fig. 1. The functions of the various layers are well explained in the literature together with its merits over the other types of Nero-fuzzy approaches and therefore will not be dwelled upon here. The only remark that is worth making is the fact that its special architecture based on Sugeno type of inference system enables the use of hybrid learning algorithms (explained below) that are faster and more efficient as compared to the classical algorithms such as the error back propagation technique.

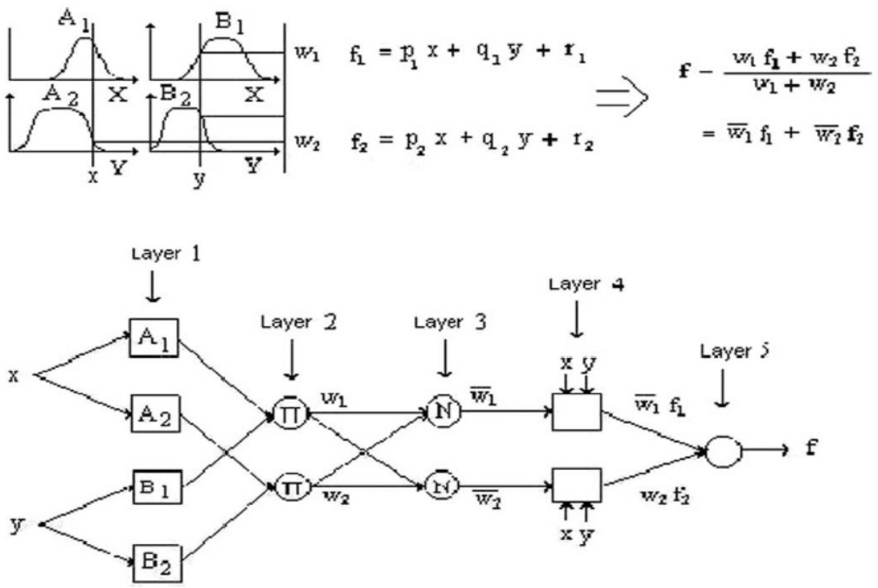

Fig.2: ANFIS architecture proposed in literature

The approach used in this work for updating the ANFIS network parameters is a hybrid learning algorithm which is a two level learning algorithm. In this approach, the parameters of ANFIS network are evaluated in two parts as input and output parameters.

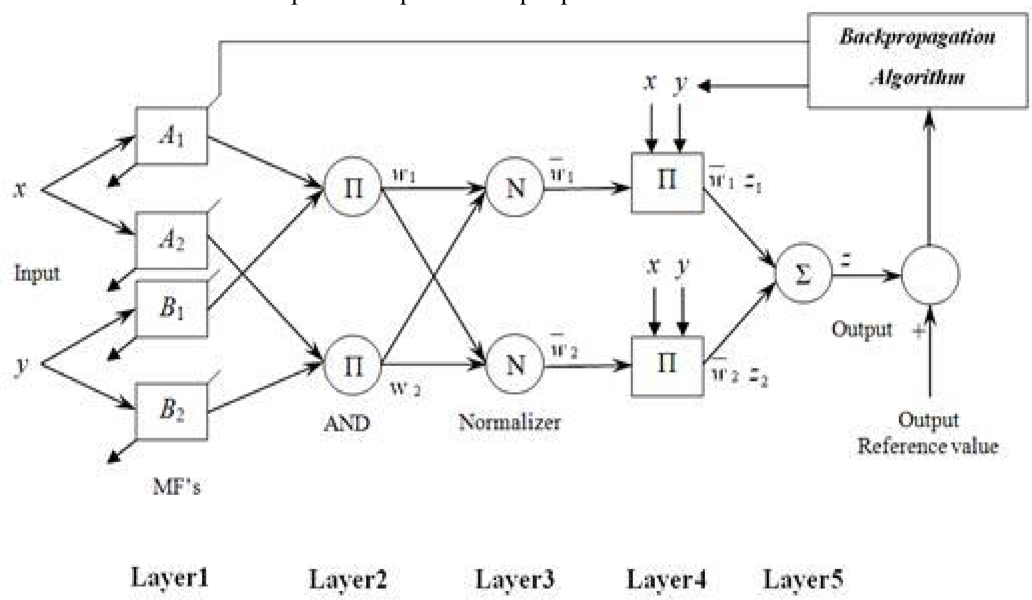

Fig.3: The structure of proposed two-input one-output ANFIS system

Let us express the total parameter set as S = S1 + S2, where S1 is the set of input parameters (the parameters of the membership functions) and S2 is the set of output parameters (weights). During the forward pass of the hybrid learning algorithm, the parameters of the membership functions in the input stage (S1) are kept constant.

In this manner, the output of the network becomes a linear combination of output parameters of the parameter set S2 and the well known Least Square Error (LSE) based training can be used.

During the backward pass of the hybrid learning algorithm, the parameter set S2 is kept constant and the error is back propagated.

The parameter set S1 can now be updated using the well known gradient descent method. The efficacy of the ANFIS controllers is evaluated by demanding the Water spondee UN-UD-VH to execute some defusing in water manoeuvres autonomously.

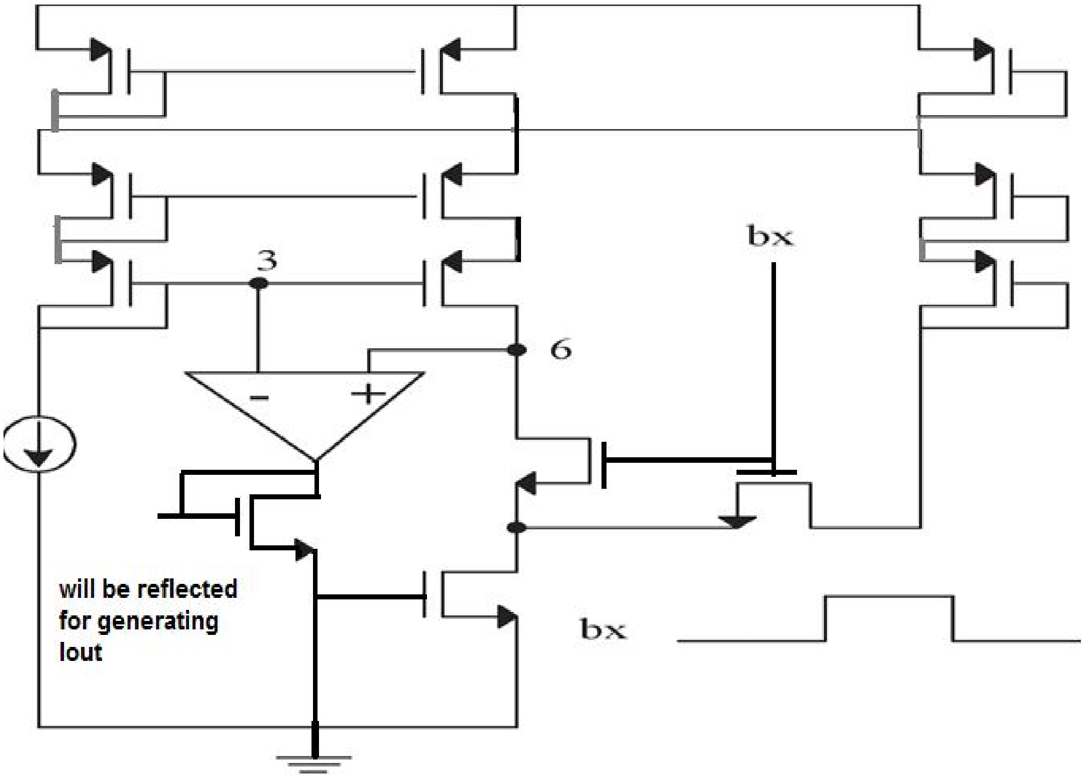

Fig. 4 The proposed circuit for normaliser block of ANFIS

There are some basic manoeuvres described in the aviation literature. One of them is steep turns. Steep turns goal to see the domination of the pilot over the control surfaces of the plane in basic training. There are several types of steep turn manoeuvres. The one that is used here is a 270_ turn which starts at a particular heading angle. A steep turn at lower altitudes need more skills and can be dangerous because it is more difficult to keep the altitude level.

If the controller can manage to complete the described turn with the same speed and the altitude values as at the start of the turn, this would indicate that the control surfaces of the UN-UD-VH are effectively controlled by the BARGIN system and that the UN-UD-VH can accomplish any other kind of manoeuvre demanded (turns, dives and climbs) with the same success as long as the manoeuvre is within its defusing in water envelop.

It should here be noted that while in steep turn UN-UD-VH must have maximum 30 bargain bank angle. If the nose of the UN-UD-VH comes under the square horizon line, it starts to lose altitude and the water speed is increased.

And if the nose comes over the horizon line, UN-UD-VH starts to gain altitude and the water speed is decreased. To see the nose position and the bank angle, an artificial horizon indicator is used. The controller changes the throttle position and the bank angle to preserve the initial defusing in water values while going through the turn. Throughout the manoeuvre, the basic objective is to keep the nose in horizon line and to control the altitude and the water speed.

IV. SIMULATION STUDIES

While simulating the ANFIS controllers, standard MATLAB/Simulink interface and Water Simulation Block Set are used. Water UUV model is prepared in Water simulation block set and then the ANFIS based controller is adapted to the system.

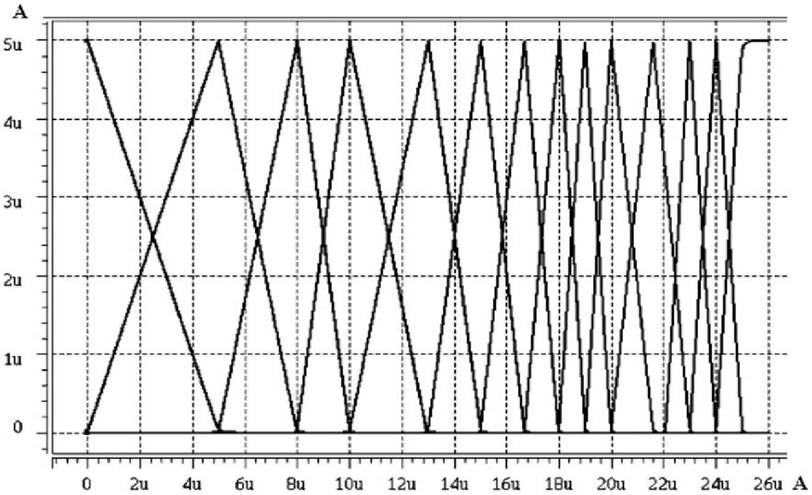

Fig.5: simulation results of one directions

ANFIS controller simulation is shown in Fig. 5. There are three Fuzzy Logic Controller (FLC) blocks in the architecture.

These fuzzy logic controllers' works together to achieve the altitude, the speed and the bank angle values as demanded by the reference trajectory.

Main subsystems in controller as one of the inputs to this subsystem are the altitude error, which is the difference between the desired altitude and current altitude, the derivative of the altitude error, the water speed error, which is the different between the desired water speed and the current water speed, and the last input is the derivative of water speed error. The function of the Altitude Controller subsystem is to reach the desired altitude and the desired water speed and therefore it controls the throttle and the elevator position as outputs. The second subsystem is the Latitude–Longitude Controller subsystem. The inputs of this subsystem are the bank angle error and its derivative. The duty of the subsystem is to reach and hold the desired bank angle to achieve the desired heading angle. In this way, the UUV can be guided through the desired latitude and the longitude. hem is the Altitude Controller.

Summarizing what is described above; the outputs of the two ANFIS controllers enable the water speed, the altitude and the heading to be controlled. That is to say, the attributes of the UUV is kept under control so the system guides the platform to the desired position in three dimensional spaces. To test how successful the designed controllers are, a test pattern is needed that changes the altitude and the heading of the UUV. It is described in the next section.

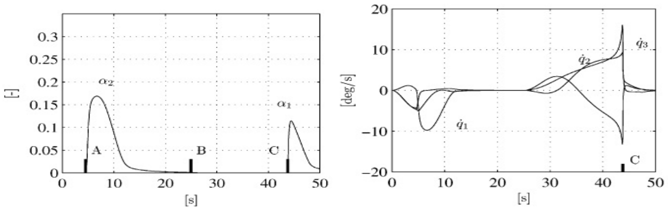

Fig6. Shows simulation results of Discoverer system

V. CONCLUSION

The problem of redundancy resolution and motion coordination between the vehicle and the discoverer in underwater vehicle discoverer systems is addressed in this paper. In this paper, a task-priority inverse kinematics approach to redundancy resolution is merged with a Nero-fuzzy technique to manage the vehicle-arm coordination. The Nero-fuzzy technique is used both to distribute the motion between vehicle and discoverer and to handle multiple secondary tasks. A numerical case study is developed to demonstrate effectiveness of the proposed technique.

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