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A COMPARATIVE ANALYSIS BETWEEN INVESTIGATIVE AND CONVENTIONAL CONTROL TECHNIQUES FOR MOVEMENT CONTROL OF AMPHIBIOUS ROBOTS

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ABSTRACT

Fuzzy Logic is an investigative control system method that contributes to performance in systems. It covers almost every electronic circuit, very large computer networks, process automation to household gadgets. It can be used very effectively to develop a better hardware and software combination. Fuzzy logic provides us the flexibility to jump to an unambiguous result to a blurred input. Its approach enables us to emboss human like thinking which is in certain cases based upon a blurred input; onto a machine. While designing a control system, controller selection and tuning of its parameters must be taken into account. Because of Fuzzy PID control it is now possible to design a control system which is capable of taking decisions faster and certain based on blurred input, just like Humans. In this Paper, a comparison of fuzzy PID, Fuzzy, Adaptive Fuzzy PID controller and Conventional PID controller is done for the most complete case of Robotic Applications. The Adaptive Fuzzy-PID and Fuzzy PID performances is summarized in terms of its input and output variables, which allows us to analyse the responses and to compare it with each other. The tuning has been tested using Matlab Simulation.

Keywords— Amphibious robot, Fuzzy PID, Conventional PID, Problems in Robot control, Control Techniques for Robots.

I INTRODUCTION

The general goal of the research of which this report is part, is 1. To control a robot that can maneuver on land as well as in sea and 2. To take inspiration from animals that can perform these tasks very easily; to design new types of robots and controllers. The main goal of this project is to design a control algorithm that can be used as building blocks for the construction of amphibious spherical robots. An approach involves a mathematical model of controlled object to which the two control techniques are applied using Matlab and Simulink. The figure 1 explains the building blocks of proposed control algorithm.

Taking the trouble in handling an amphibious robot into account, it is tricky to solve the problem to control a robot when a system is complex. In this paper a comparative analysis between Fuzzy PID control technique and a Conventional PID control technique is done. This paper proposes a Fuzzy PID control over a Conventional PID control for the reasons shown in results. From the simulation results we can conclude that a Fuzzy PID can successfully reduce the settling time of a control system, speed up the system response as well as decrease the alteration time, although it has slight overshoot as compare to Conventional PID, this method can improve the performance of Amphibious Robot.

A. Problems in robot control

At any instant human brain control 244 various mechanical degrees of independence which involves greater than 600 various muscles (Nourse 1964, Saziorski 1984) [1]. In fact, abounding various muscles frequently proceed simultaneously. For example, the muscles in both arm and leg manage 30 mechanical degrees of liberty, utilizing quite convoluted muscle combinations (Saziorski 1984) [1]. This control is skilled through feedback control. The feedback is the outcome of the various sensors in the human body such as tactical and sensors of joints. Originally these facilities rest in the brain's enormous, cataleptic power of management of which we are luckily uninformed [1].

The difficulty of the control system is on the cards as soon as any one attempts to prepare a Robot with only a small portion of human agility. Let us consider the simple example of identifying the people trapped inside the destroyed structure. First the robot must see the structure, then it must identify the difference between living and non living things. To do so, the robot must determine the people's position, and then choose an appropriate angle to capture an image. The choice depends on the available space and accessible path, its location inside the

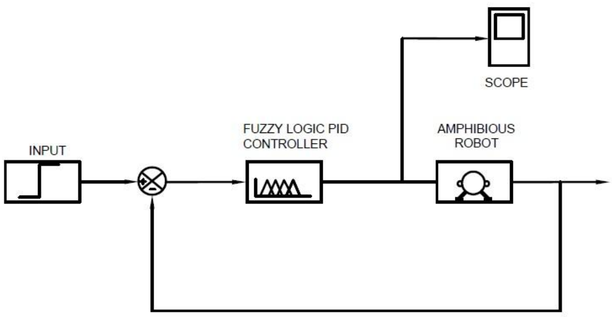

Fig. 1 Proposed Control Technique for Amphibious Robot

building and the presence of other debris which might hinder the robot. The people might, for example, trapped deep inside the derbies. The path of robot is also affected by the destroyed structure: it makes a big difference if the image only needs to be captured, or if people should actually be rescued. As we are able to answer such questions we can plan a path for a robot, once a path is determined a robot can be programmed to follow that path. The direction and any probable obstacles should be considered into the trajectory planning. The shared angles and torques necessary to shift the robot as intended are then planned. The joint angles and torques depend on the geometry and the moments of inertia of the robot. Whereas the progress should be as speedy as feasible, the equivalent shared angles and torques should not go beyond the mechanical restrictions of the robot. If such violation happens, the new trajectory should be planned. After the trajectory planning and after the robot has been brought back to its destination, the image and location must be perfectly identified with a precision in the hundredths of millimetres.

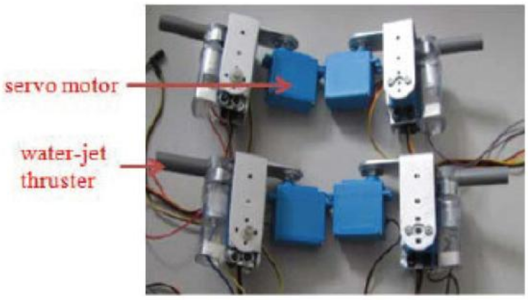

Fig. 4 The Water-Jet Thrusters [4].

This task seems, of course, much easier for human beings; after a rough identification of people trapped, one can make use of visual feedbacks from the eyes in guiding and searching the path into the debris. Robot has to use a similar plan to move along as the very accurate location information is not realizable by cameras alone.

The Paper is ordered as follows. Some research about Robots is introduced in Section I. In Segment II, the construction of amphibious robot is explained. Section III explains the Fuzzy PID and Adaptive Fuzzy PID controllers. In Section IV, the Simulation results are shown. Section V, determines conclusions and future work.

II STRUCTURE OF AMPHIBIOUS SPHERICAL ROBOT

The amphibious robot is the type of robot which can be viable on land as well as on (or under) water. These robots can have the benefit of more degrees of independence with the aid of its actuator units. To analyze and control a system we need to construct the mathematical model. The model is a vital technique and prerequisite. If we want to analyze underwater robot motion control precisely it is important to construct its accurate mathematical model.

2.1 Common Design

The amphibious robot is shown as in figure. 2. This robot comprised of a conserved greater hemispheroid. Two shells (generally spherical). The shells and its actuating units can be open [4]. Inside every unit there is a water-jet propeller along with servo motors [2,3]. They are perpendicular to each other. The control circuits, power supply and sensors are located in the conserved greater casing. The casing is water-defiant. We can alter the motion of the robot by controlling

The propeller thrust [4]. Figure. 2 show the general arrangement of the robot.

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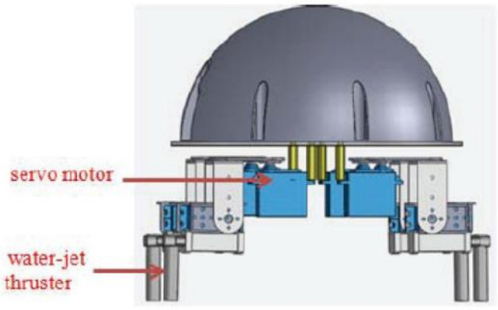

Fig. 2 Structure of Amphibious Spherical Robot [4].

2.2 Actuating System

As shown in Figure 4, the robot has two sets of actuating units. Thrusters are made up of stainless steel [4]. The progress of the robot is inhibited by water jet thrusters. The motor can be operated with the help of PWM signals. The servo motor can rotate 180°. Simultaneously, one more motor is linked to the water-jet thrusters and is focussed to move with its vertical axis [4,5]. Two degrees of freedom movement can be achieved by each actuating unit with the help of servo motors, as the robot manoeuvre on land, actuating units can be used as legs, and each leg has two degrees of freedom [4].

Revolving movement on ground can be determined by PWM Signals .And the robot can travel with the help of controlled PWM signal to the servo motors [4]. Multi- degree freedom such as moving forward, rotating, floating up and floating down motions can be achieved.

2.3 Block Diagram of Control System

These robots can have the benefit of more degrees of independence with their actuator units, in order to analyse and control a system it is very important to build a mathematics model, which is a crucial method and also a prerequisite. If we want to understand underwater robot motion control accurately, it is essential to know its model correctly. The block illustration of planned control method is exposed in fig 1. The block illustration of the control scheme for amphibious robot is exposed in Figure 4. An AVR unit is used as the CPU of the system. PWM signal is generated to run the servo motors and thrusters [4]. A PWM signal is used to move the robot underwater.

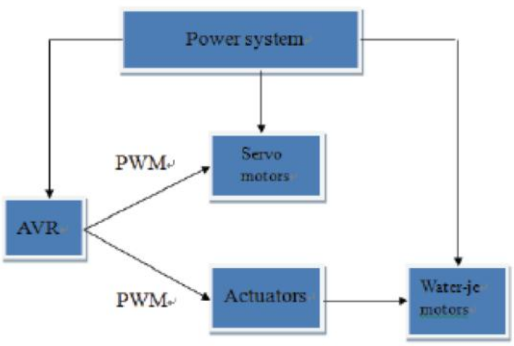

Fig. 3 Block Representation of a Control System [4].

III CONTROL METHODS FOR THE AMPHIBIOUS ROBOT

3.1 PID Control

With the fast progress in science and technology, the requirement of accurate control has increased. Response time of automatic control system and stability also needs to be higher. Traditional PID control is focused on controlling mostly linear process, and almost all industrial processes are of nonlinear in nature. Mathematical model of some processes are almost impossible to obtain. As a consequence general PID control cannot achieve precise control of such processes [4].

Integrated model PID control now days are widely used due to its simple construction and robustness. In actual practice PID control is a dominant technology. The basic of PID control is to execute a control using proportion, integration and differential actions. Then choosing an appropriate combination to control the object.

Control equation for PID Controller is:

$$e(t) = x(t) - y(t) \qquad (1)$$

The control law of a PID controller is:

$$u(t) = k_p e(t) + k_i \int_0^t e(t)dt + k_d \frac{de(t)}{dt} \qquad (2)$$

Where K_p, K_i and K_d are proportional, integral and derivative gains respectively.

3.2 Fuzzy PID Control

The arrangement of the Fuzzy PID control is mainly possessed of the PID of which the parameters can be changed and the fuzzy logic alongside. In Fuzzy an error '*e'* and rate of change error '*ec'* are the inputs to the

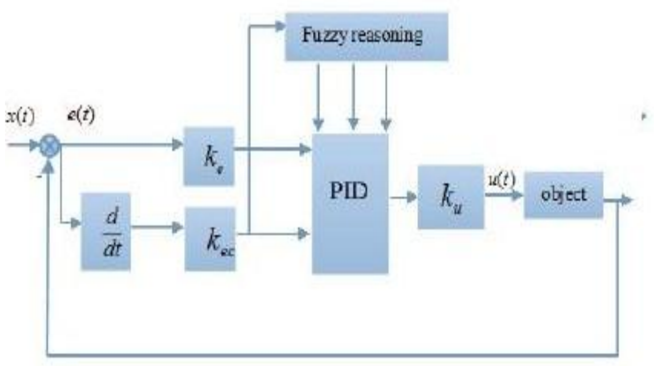

Fig. 5 Block Diagram of a Fuzzy PID Control System [4].

PID. Reason behind fetching an error '*e*' and rate of change of error '*ec*' is to make the controlled object

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delivers a good performance when subjected to dynamic and static conditions. PID parameters *'k_p'*, 'k_i', 'k_d' are used as an output. Error '*e*' and rate of change of error *'ec'* self-tunes the PID. We are using the fuzzy rules to adapt the PID parameters in real time. A Fuzzy PID controller is shown in Figure 5. Fuzzy PID has an enhance control accuracy and flexibility.

'e' stands for an error and *'ec'* stands for rate of change of error, therefore *'k_e'* is a quantitative factor for *'e'* and *'k_{ec}'* is quantitative factor for *'ec'*. *'k_u'* is the scaling factor.

The error *'e'* and *'ec'* are the input variables of fuzzy PID. *'k_p', 'k_i', 'k_d'* are the output variables and their range is defined as follows: *e, ec,* K_p, K_i, K_d = {-4, -3, -2, -1, 0, 1, 2, 3, 4} The fuzzy subset is *e, ec ={NB, NS, ZE, PS, PB}* which means negative large, negative small, zero, large, small. The membership functions we have considered are of symmetric triangular type [4]. Because the shape of its is only associated with its straight slope. Hence the process is straightforward and the engaged memory space is minute. The method of symmetric triangular is more appropriate for the Fuzzy PID control [4]. Symmetric triangular membership functions are shown in Figure.6-7.

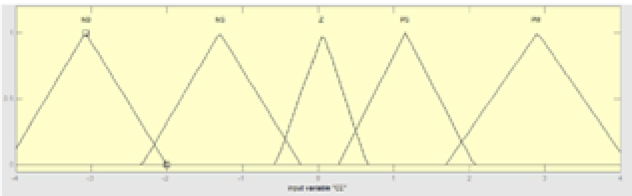

Fig. 6 Input variable change in error "ce"

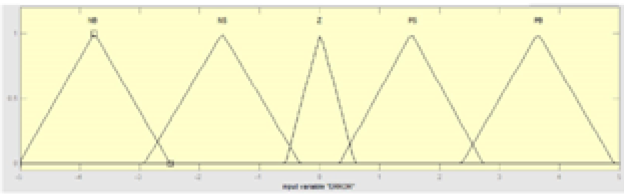

Fig. 7 Input variable error "e"

The blow of the shape of the membership function on the control is not big; the blow of the size of each on fuzzy set is huge. Generally, the consequence in width of each fuzzy subset control will alter, if the width is little. Selected parts do not have rules, so the union is bad, on the contrary, if there have the overlapping rules, the shared weight between rules make the response sluggish. Therefore, *'e'* and *'ec'* adopting same membership function. Simultaneously *'k_p', 'k_i'*, 'k_d' also use the same membership function. In order to establish *'e'*, *'ec'* and the membership project table of *'k_p'*, *'k_i'*, *'k_d'*. The control law is the main part of Fuzzy PID controller. In usual practice and a sensitive analysis we use input and output variables to explain a huge number of flourishing control strategies in daily life. Fuzzy state therefore gains lot of attention. Fuzzy PID control rules developed are shown in Table 1

Table 2 Fuzzy PID Rules for output variables 'K_p','K_i', 'K_d'

e / *ec*	**NB**	**NS**	**ZE**	**PS**	**PB**
NB	PB,VB,VB	PB,VB,VB	PB,B,B	B,M,M	B,M,M
NS	PB,VB,B	B,B,B	B,B,B	B,M,M	B,M,M
ZE	B,B,B	B,B,B	B,M,M	M,S,S	M,S,S
PS	B,B,B	B,M,M	M,S,S	M,S,S	M,S,S
PM	B,M,M	M,S,S	M,S,S	M,S,S	M,S,S

Table 1 Rules for Adaptive Fuzzy PID Control

ec *e*	**NB**	**NS**	**Z**	**PS**	**PB**
NB	C1	C1	C2	C2	C3
NS	C1	C2	C2	C3	C4
Z	C2	C2	C3	C4	C4
PS	C2	C3	C4	C4	C5
PB	C3	C4	C4	C5	C5

3.3 Adaptive Fuzzy PID Control

In Adaptive Fuzzy PID controlling technique the two controller outputs are virtually separated, output from a Fuzzy controller then summed up with the output from a PID controller. In this control technique PID parameters are tuned separately according to the transfer function of a Robot and Fuzzy parameters are tuned using Takagi- Sugeno method; which is a liner function of input variables. The schematic of a model is shown in the Figure 8

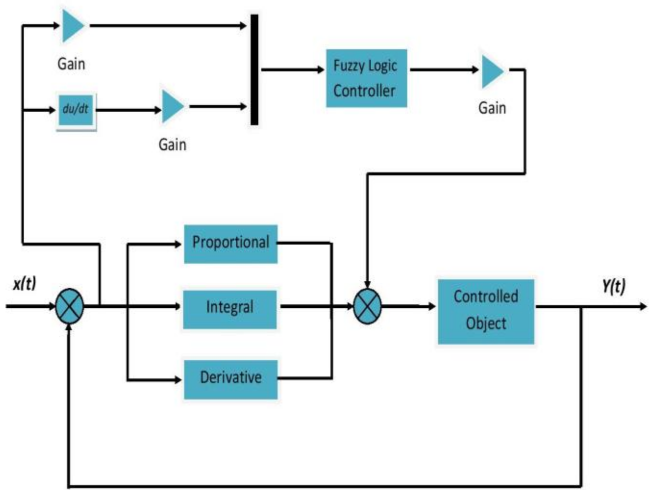

Fig. 8 Schematic of a Adaptive Fuzzy PID Model

The Simulation is carried out in a Matlab and Simulink environment to observe and compare the output response. The rules for the Adaptive Fuzzy PID model are shown in Table 2

IV SIMULATION AND RESULTS

The simulation is conceded this paper to confirm the projected method. Hydrodynamic forces and moments are

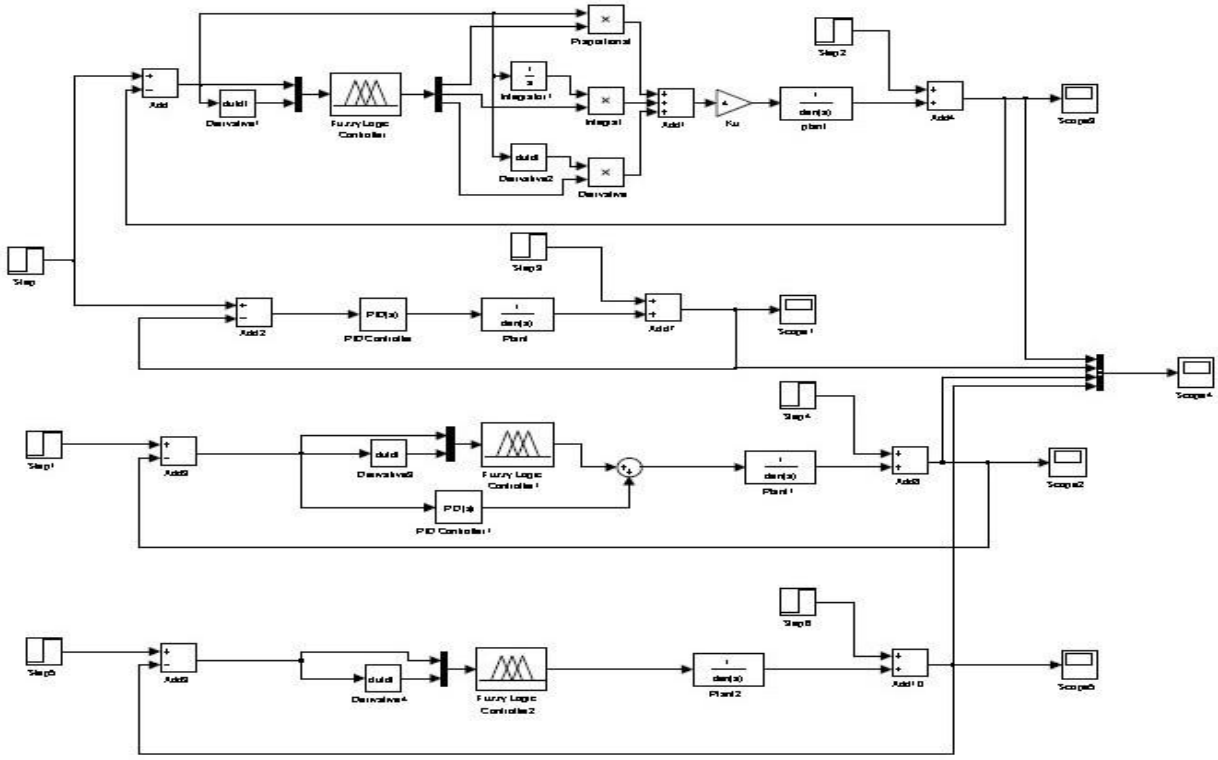

Fig. 9 Simulation Diagram of a Control Systems

one of the main causes of damping [4]. We can articulate the hydrodynamic forces and moments in equation:

$$M\dot{V} + (d(v)v) + g(\theta) = \tau \quad (3)$$

Where '*M*' stands for mass of body. *D(v)* is the damping. *g(θ)* is the elasticity torque vector. *'θ'* is the position vector. *'τ'* is the control vector. To describe the position and velocities of the amphibious robot, the analogues numerical value given by the following transfer function and is:

$$G(s) = \frac{1}{61.4S^2 + 6.128S + 3.265} \quad (4)$$

A Simulink model of a control System

V ANALYSIS OF RESULT

The graph of a Results obtained is shown in the Figure 10

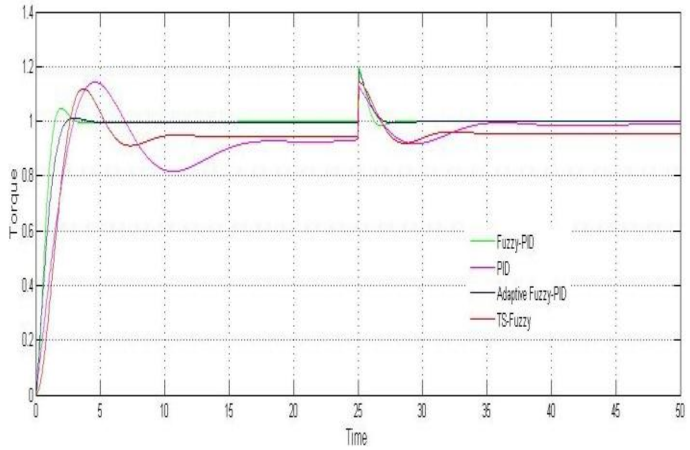

Fig. 10 Simulation Result.

To observe the control systems behavior furthermore, a disturbance is added after 25 seconds. The comparisons between controller outputs is shown in the Table 3

	% Overshoot	Rise Time (Sec)	Settling Time (Sec.)
PID	19.1	3.4	18.2
TS-Fuzzy	11.9	2.5	15.6
Fuzzy-PID	4.8	1.3	4.6
Adaptive Fuzzy PID	1.3	2	4.5

Table 3 Transient Parameter Comparison

This Paper presented the design and comparison of control system for the amphibious robot using the two different algorithms namely Fuzzy PID and Conventional PID. After comparison with a Conventional PID, Fuzzy PID, TS- Fuzzy and Adaptive Fuzzy; the controller which is an amalgamation of fuzzy logic and a PID had a superior performance. Even though it has a small amount of overshoot its settling time is much lesser than Conventional PID. Adaptive Fuzzy PID control algorithm has better performance as it has the obvious effect in shorting the Settling time. It also has a positive law of nature. The Adaptive Fuzzy PID controller has a better ability to control.

Considering the disturbance in the controlled object. If we look at the behaviour of a system it is observed that despite of a sudden disturbance the Adaptive Fuzzy controller achieves its set point in least possible time as compare to Fuzzy-PID, TS-Fuzzy, and PID controlling techniques.

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