PD-like FLC with Admittance control of Hexapod robot's leg vertical positioning for seabed locomotion

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***Abstract*— This paper presents a proposed Proportional and Derivative (PD)-like Fuzzy Logic Control (FLC) (PD-FLC) on dynamic control for vertical positioning of Hexapod Robot walking on seabed environment. The study has been carried out by modeling the buoyancy force following the restoration force to achieve the drowning level according to the Archimedes' principle. The restoration force need to be positive in order to ensure robot locomotion is not affected by buoyancy factor. As for this force control solution, PD-FLC is used and integrated with admittance control that based on the total of force of foot placement by considering Center of Mass (CoM) of the robot during walking period. This integrated control technique is design and verify on the real-time based 4 degree of freedom (DoF) leg configuration of hexapod robot model. The scope of analysis is focus on walking on the varied stiffness of undersea bottom soil with tripod walking pattern. Moreover the verification is done on the vertical foot motion of the leg and the body mass coordination movement during walking period. The results shows that proposed PD-FLC admittance control able to cater the force restoration factor by making vertical force on each foot bigger enough (sufficient foot placement) if compare to the buoyancy force of the ocean, thus performing stable tripod walking on the seabed with uncertain stiffness.**

Keywords—PD-like FLC; CoM-based impedance model; force restoration; foot motion

I. INTRODUCTION

Researchers have widely studied the seabed or tidal current underwater environment which guided through complex controls and marine vehicle systems to be developed before the mission launch. Therefore it is essential to design an appropriate simulation model that able to perform like the real world autonomous underwater vehicle (AUV) behavior [1]. Hydrodynamic characteristics are very significant factors in research into underwater robotic system. The efficiency and stability of the control algorithms and the most optimum structure of the robot depend on proper hydrodynamic analyses[2].

For the ocean environment, several motion control algorithms have been developed since the past two decades under a range of hypotheses. By adopting a linearized model, various linear control techniques such as PID controller and LQR algorithm have been introduced with acceptable performance in only unusual kinds of manipulation[3]. Indeed, such methods ignore the interactions between the other sub-controllers and simplify the degree of freedom (DOF) model to obtain several subsystems[4]. Considering square integral bounded disturbances into account, linear controller have been furthermore improved in the absence of parameter variations[5]. Numerous modern investigations concern with model uncertainties and current nonlinear-based methods such as sliding mode control in which the upper bound of uncertainties and disturbances is known in advance intelligent control algorithms based on neural networks and fuzzy logic have been also applied to the UVs[6, 7].

Adaptive motion control of a general class of AUVs in the presence of model uncertainties and environmental disturbances is studied as reported in [8]. Both parametric and amorphous disturbances are incorporated into the mathematical model, due to the variations in hydrodynamic and damping coefficients. Firstly, an adaptive based control algorithm is developed to undertake the parametric model disturbances. Then, a robust control law is implemented in order to ensure the robustness of the method with respect to unstructured uncertainties and external disturbances.

In the ocean environments, ocean waves have varying wave periods and height determined by winds and the distance traversed. According to D'Allemberts paradox, in a steady flow there is no force on a body under non-viscous fluid. For tidal current in an unsteady situation with added mass, drag forces, buoyancy, and currents especially in the existence of free surface waves it is required to consider time dependent motions of both the water, robot's body and the system internal as well as external forces adding to the total forces on the system[9]. Thus force control becoming crucial part for the multi-legged robot to crawl on the seabed soil. Common robotics force control for articulated configuration arm and legged system has been practiced in two strategies; force-based and position-based force control.

Therefore this research has taken initiative to propose an integration control technique between intelligent control and dynamics control for hexapod robot foot motion during walking on seabed. The PD-FLC is applied and using two dynamic state of CoM-based impedance model[10] (position and velocity) as crisp inputs to cater the sufficient dynamic