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Implementation of Fuzzy for Satellite Attitude Control by Two State Actuator to Reduce Limit Cycle

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***Abstract**: This paper presents an algorithm used to control the attitude of satellites in their orbit with the goal of reducing fuel consumption and increasing operational lifespan. A fuzzifying controller was therefore deployed to save fuel while dealing with the uncertainties and nonlinearities of the satellite control system based on its effective performance and simplicity. The suggested control algorithm displays an extremely high level of reliability in the face of adverse unintended disturbances consistent with the satellite's constraints. Low-frequency limit cycles result from the natural chatter of the on-off controllers. This results in the increase of system error and the greater fuel consumption for the satellite. To minimize the system error, the algorithm of Particle Swarm Optimization (PSO) was used. Simulation results for the satellite show that the fuzzy on-off controller is greatly enhanced once this algorithm is applied.*

***Keywords**: PSO, Limit cycle, Satellite attitude control, Fuzzy on-off control*

I. Introduction

The control systems of satellite attitude ability is to save fuel is very desirable. The control of satellite attitude is based on two-level on-off controllers that are typically utilized in conjunction with the thrust reaction actuator. These controllers are time independent and respond quickly. With or without propulsion power, they quickly adjust the satellite's attitude. The valves in on-off control systems are dependable enough to remain open for a few milliseconds. The actuations effect the discrete angular velocity of the satellite when it is altered then the valves are fully opened for a limited period of time. Consequently, zero residual angular quickness cannot be achieved. A dead band is placed between the on-off control and the controller is turned off in this dead band area to stop thruster engagement. As a result, the controlled system either increases wetness or decreases velocity to attain the equilibrium position. This diminishes the thruster force and produces low frequency limit cycles. Fuzzy logic and other nonlinear control algorithms are advised due to the satellite's intrinsically unpredictable and nonlinear behavior. The accuracy of the microsatellite model has no bearing on this approach. To stabilize a small spacecraft in low earth orbit, Stein used three fuzzy controllers with several inputs and one output [2-4].

By selecting the optimal magnetic moment, polarity, and switching periods, he demonstrated that fuzzy controllers may eliminate control constraints [1]. A satellite control system can improve satellite performance and save fuel. In reference [2], on-off attitude control using on-off and sliding mode was examined. Sliding mode controllers have the drawback of producing a large control signal because of system uncertainty [1].

II. Satellite State Space Model with Three Degrees of Freedom

This issue was resolved by using a fuzzy controller [3]. A fuzzy controller is a suitable option for managing nonlinear systems. A key consideration in the design of fuzzy controllers is minimizing the amount of time needed for the system to reach the steady state. Membership functions are optimally adjusted to do this [4]. Different initial settings are required by the controller studied in reference [5] in order to enhance system performance and reduce response time.

However, ordinary linear controllers are not appropriate for these applications. An on-off controller is a suitable choice in this situation [6,7]. After comparing several controllers, Reference [4] determined that the fuzzy on-off controller is the most effective one in terms of efficiency. A multi-level relay is a fuzzy controller. It defuses using the average least squares approach. In this research, control signals from defuzzification were converted using specialized hardware. In reference [6], the fuzzy on-off controller's minimum control time using a relay was demonstrated [3-5].

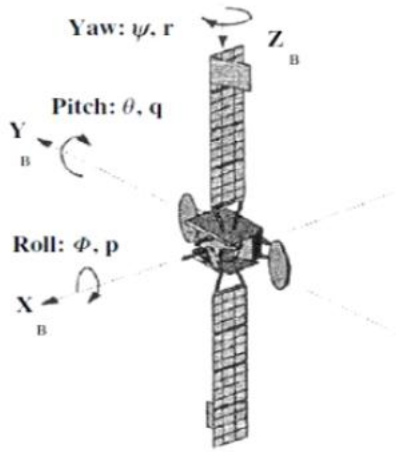

Fig 1: Satellite reference and body coordinates

III. Algorithm Particle Swarm Optimization

A fixed number of particles with a random start value comprised in the particle swarm optimization approach. The values of velocity and attitude of the particles are indicated. A location vector and a velocity vector, in turn, represent the above quantities. Exploring the problem's n-dimensional space and looking for new possibilities, these particles move across the space using the optimality value as the assessment parameter. The number of the useful parameters of the optimization function is equal to the dimension of the problem space. Memory areas are separated for recording the particle with the best conditions and the previous best location of the particle [4].

Particles make future motion decisions based on these memories. Every particle moves in the n-dimensional issue space during the repetitions. The public optimal point has finally been identified. Depending on the best local and public solutions, particles alter their location and velocity.

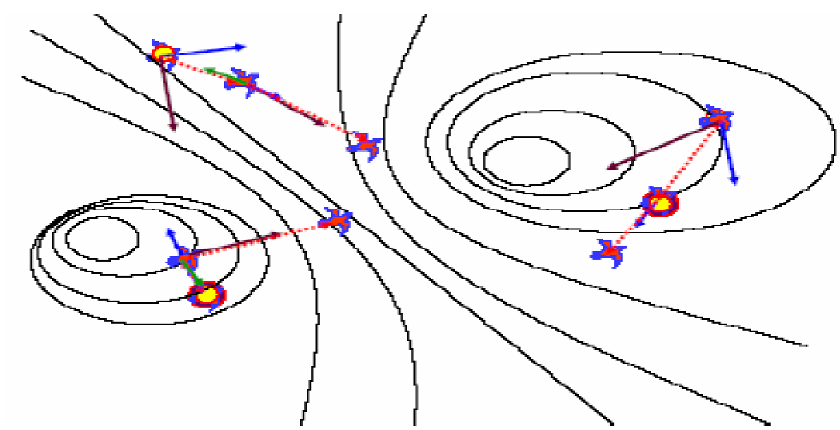

Fig 2: General structure of particle swarm algorithm

IV. Simulation

This section analyzed the response of this system to initial conditions, or the zero input response. The roll angle oscillates for the rolling fuzzy on-off controller in Figures 3 and 4 after 18 seconds, with amplitude 0.04 radians (3.2 degrees) and a frequency of 0.014 hertz. The phase plane trajectory shows that the time response decays towards the origin where rate and location are both zero as rate feedback attenuates the system.

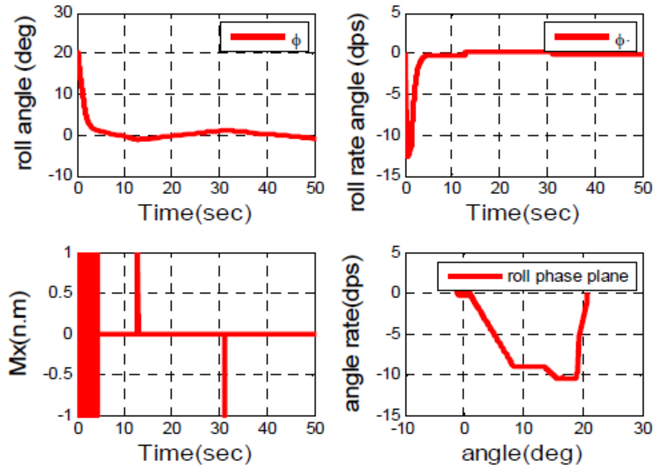

Fig 6: Roll angle operation of fuzzy on-off controller with dead band (nonlinear model)

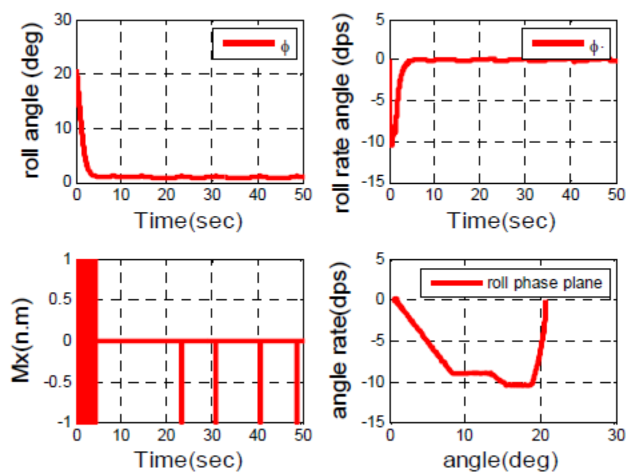

Fig 7: Roll angle operation of fuzzy on-off controller (T-S model)

V. Conclusion

A simulation of the fuzzy on-off controller algorithm was demonstrated. This controller was installed on a three-degree of freedom satellite model nonlinear system. From the simulation results, the current fuzzy on-off control makes the system refractory, resistant and stable with good disturbance rejection.

The fuzzy system was optimized and the limit cycle's oscillation amplitude was decreased using the particle swarm approach, which was derived from the absolute error integral. As a result, satellite longevity decreases and fuel consumption rises. The method requires fewer parameters for tuning and has a high rate of convergence. The controller used the optimization approach to complete the tracing without steady-state error based on the results. The amplitude of the output oscillations was significantly lower than that of the other controllers. This approach was also used to lower the power consumption of the thrusters and the temporal damping system.

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