An Optimal Control for Multiple Unmanned Underwater Crawling Vehicles

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Abstract: This paper presents an optimal control methodology to generate a group behavior for Unmanned Underwater Crawling Vehicles (UUCV) having track-style wheels. The group behaviors with leader-follower formation and obstacle avoidance algorithm is developed to maximize multiple objective functions within a goal attainment method for an uncertain environment. This is done by using intelligent control technology based on physical dynamics modeling.

The criteria of optimization are to maximize search and reacquisition efficiency for targets that are on the bottom and to maximize the power management efficiency. Intelligent control technology (Intelligent Agent) provides a learning capability (Neural Network) and a decision making capability (Fuzzy Logic) based on a human-like mapping process for unmanned vehicles.

The motion of UUCV is constrained by environmental uncertainties which are represented by unknown friction coefficients between the tracks and ground surface, and an unknown topography of the operating field.

The leader-follower formation is designed under two trajectory generation modes, centralized and decentralized. The commands of all UUCV of the group in centralized mode are assigned by the central command control board or a designated group leader. In the decentralized mode, each vehicle of the group can be a leader and follower except a designated group leader and the two outmost vehicles. As a follower in this mode, each vehicle generates its own commands autonomously to maintain a constraint mutual distance and a velocity between its leader.

The obstacle avoidance strategy is developed by using sensory information provided by a smart bumper system attached in front of UUCV. The smart bumper system consists of multi-springs, multi-dampers elements, and three sonar distance measure elements. The spring and damper system provides information of solidity of a touched obstacle for UUCV. The sonar system tells the relative coordinate of the obstacle to UUCV by providing an orientation and approximation of distance of the obstacle .

The controller used in each UUCV, a combination of conventional Proportional-Integral-Derivative (PID) and Adaptive Neural Network Fuzzy Logic (ANNFL), is designed by using multi-objective optimization techniques from which the fixed control gains of PID controller and the adjustable control gains of ANNFL are obtained.

In the simulation to implement the formation control of group vehicles, two three-dimensional spline surfaces are used for the topography of the mission area, and the friction coefficient distribution that is taken at random. When the desired command trajectory of a heading with a constant velocity and a constraining mutual distance are given, the behavior of a group of vehicles shows satisfactory results.

KEYWORD: Formation Control; Optimal control; Obstacle Avoidance; Intelligent Control.