Swarm Formation Control Utilizing Ground and Aerial Unmanned Systems

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***Abstract*—This work addresses the problem of coordinating a swarm of unmanned ground vehicles with an Unmanned Aerial Vehicle (UAV). The UAV is utilized as a leader robot that is intelligently followed by a coordinated group of Unmanned Ground Vehicles (UGVs). The UAV is a completely autonomous agent that is controlled using Sugueno fuzzy logic. The UGVs are organized into formation utilizing artificial potential fields generated from normal and sigmoid functions. These functions are built around the location of the UAV and ultimately construct the surface that swarm members travel on, which inherently controls the overall swarm geometry and the individual member spacing. Nonlinear limiting functions are defined to provide tighter swarm control by modifying and adjusting a set of control variables forcing the swarm to behave according to set constraints, formation and member spacing. The swarm function and limiting functions are combined to control swarm formation, orientation, and swarm movement as a whole. Parameters are chosen based on desired formation as well as user defined constraints. Simulations demonstrate the precision of the approach with up to forty UGVs. Experimental results are presented using a fully autonomous swarm of three UGVs and a single UAV helicopter for coordination.**

***Keywords* – UAV-UGV coordination, swarms, formation control**

I. Proposed Solution

THE use of Unmanned Aerial Vehicles (UAVS) with Unmanned Ground Vehicles (UGVs) provides the ability for cooperation, coordination, and tight or loose collaboration which is directly applicable to a multitude of missions.

A UAV can provide a global perspective of the surrounding environment, obstacles, and possible threats, while simultaneously broadcasting goals, sub-goals and overall mission modifications for the swarm. Further, the presence of the UAV creates a 3-D sensor network increasing communication capabilities.

UAV-UGV cooperation has obvious applicability in military applications due to its inherent ability to increase situational awareness and provide a force multiplier for the soldier.

In this research the UAV oversee and guides a swarm of heterogeneous UGVs thereby controlling their overall formation. The autonomous UAV is equipped with the ability to take-off, land and waypoint navigate via four fuzzy logic controllers. The vehicle is capable of providing wireless relay through it dynamic ad-hoc network as well as multiple forms of sensor and state data. This data includes vision from its onboard camera system with dedicated video transfer, position, orientation, and velocity. Specific details of the UAVs hardware and control system can be found in [1].

The UGVs utilized in the outdoor experiments utilize similar hardware built around an RC truck platform. The entire swarm of UGVs utilizes identical navigation and formation controllers. The proposed solution [2] for the formation control is based on potential fields generated by sigmoid and normal functions that are used to control the swarm geometry and the inter-member spacing. These functions are used to create the vector fields that control the velocity and heading of robot swarm.

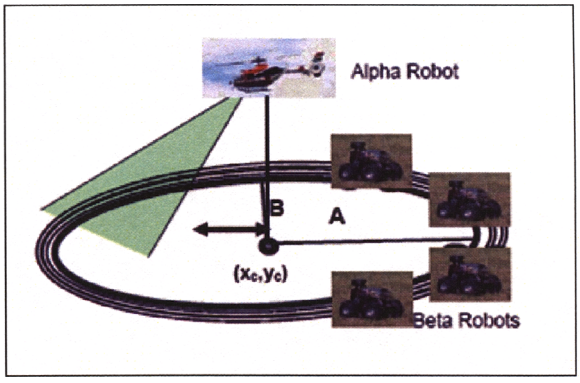

Fig. 1. Framework for UAV-UGV swarm coordination.

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