HETEROGENEOUS BATTLEFIELD SENSOR NETWORKS: A BIO-INSPIRED OVERLAY ARCHITECTURE

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Army Impact Sensor networks are an integral part of the Future Combat System (FCS) and need to provide timely and accurate information about events on the ground to the dismounted soldier and upper echelons in support of the mission. Current unattended ground sensors (UGS) provide accurate temporal detection of events, but do not provide adequate performance in identifying objects from multiple sensors via the fusion of disparate sensor data. The Army needs timely dissemination of relevant information in the form of classification of terrestrial events (human activity, truck, lightning, gun shot, mortar launch, etc.), occurrence times, their trajectories and direction of movement of potential threats.

The Army currently employs heterogeneous UGSs using a sparse deployment to maximize coverage, minimize pilferage and to monitor terrain bottlenecks. The Army Research Lab (ARL) is moving towards an architecture (Family of UGSs) that will standardize communications (e.g. Blue Radio) and this will help to mitigate the heterogeneous UGS network problem. The Institute for Collaborative Biotechnologies (ICB) program is developing and will demonstrate a new system of bio-inspired software algorithms for autonomous operations that will leverage proven research to monitor heterogeneous UGS networks from extended ranges, that will collect data in a timely fashion, that will collaboratively control the motion of a sparse network of collectors (e.g. UAV's) using bio-inspired strategies, that will localize and synchronize communications, that will accurately detect and localize field events and will fuse and classify sensed data from UGSs using methods from Evolutionary Computing. The program will also provide both laboratory and field demonstrations of these capabilities supported by ARL by leveraging available resources. The team will develop a plan to move the technologies into Army operations by working with ARL.

Technical Research Objectives Teledyne Scientific & Imaging (TS&I) in cooperation with the Army Research Laboratory (ARL) and the University of California at Santa Barbara (UCSB) have formed a team (UCSB-TS&I-ARL) and have identified specific problem areas associated with automated data exfiltration and the generation of intelligence from multiple unattended ground sensors (UGS) using a sparse network of collectors (e.g. Uninhabited Air Vehicles or UAVs, see Figure 1).

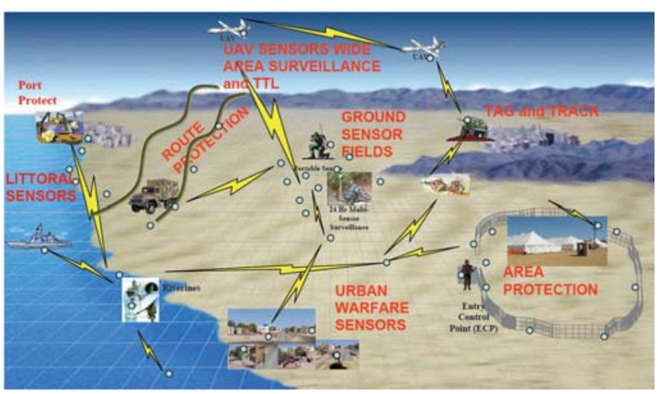

Figure 1: High level depiction of the deployment and interaction of unattended ground sensors and sparse UxV (Uninhabited Air/Ground/Sea Vehicles) resources in joint military operations.

The presentation will provide an overview and preliminary technical results from the following areas of research being conducted on the project:

Bio-Inspired Methods for UAV Planning and Event Detection: This project will feature three bio-inspired technologies developed by the Institute for Collaborative Biotechnologies (ICB) at UCSB in collaboration with the ARL and by TS&I: (1) The navigation algorithms used by the team of collector UAVs to move among the UGS collection sites is based on data-driven stochastic search algorithms that were design based on the principles behind bacterial chemotaxis. Such algorithms exhibit low computational requirements and are able to avoid traps caused by local minima that arise often with data driven navigation. (2) The timing synchronization algorithms (discussed in more detail below) are inspired by swarming behavior observed in bird flocks ad fish schools. These algorithms make optimal use of local information (peer-to-peer clock offsets) in estimating global parameters (absolute clock) in the same fashion that school of fish achieve coherent motion based on interactions between individuals. (3) Evolutionary algorithms are used to fuse sensor data from the multiple UGS.

UAV/UGS Time Synchronization and Localization: The UGSs monitoring a given area of interest may not be synchronized in time, and may not be in communication with each other. However, correlating sensor observations across space and time are crucial to fusing their data. We are therefore exploring *implicit* collector-based timing synchronization: UGSs report time-stamped data as well as their current time when reporting to the UAV, and the UAV uses its own clock as a reference when fusing data from multiple UGSs. We are also exploring scenarios where the UGSs' locations (again crucial for sensor fusion to localize events of interest) may be *a priori* unknown: we are exploring methods for using multiple UAV collectors flying in a closed-loop controlled formation to form virtual arrays to provide such localization. The notion of `time synchronization' here should be interpreted as a metaphor for network parameters or functions of parameters on which there is sensors agreement.

Event Localization and Classification: algorithms for fusing data from multiple UGSs to estimate bearing and location of field events are being developed for 3,4 and more sensors; in addition, Evolutionary Computing techniques are being investigated to identify events from data collected by a sparse set of heterogeneous sensors; field data provided by ARL is being used to test algorithm performance. Results from the evaluation of an Evolutionary Computing algorithm for event classification against real data will be shown. We are also exploring methods of mining data gathered from the sensor field for new, yet-unmodeled events, by exploiting the correlation between the readings from different UGSs. A critical issue is to model and understand the impact of the *network* on the data / information collected / processed by sensors and nodes.

Simulation Environment: The team will leverage a DoD based simulation package (MultiUAV) that models multiple UAV's flight dynamics, communications and planning using bio-inspired algorithms; system performance and sensitivities will be assessed against predefined metrics for mission success; the simulation also provides a visualization capability.

Student Summer Research: UCSB will send two students to ARL this summer to obtain hands on experience in working with real sensor hardware in the laboratory and field.

Lab and Field Testing: The program plan includes laboratory testing of the system capabilities in 2009 and a field test in 2010 all supported by ARL.