The ARL Multi-Modal Sensor: A research tool for target signature collection, algorithm validation, and emplacement studies

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Abstract

The U.S. Army Research Laboratory (ARL) has a significant program involving the development of UGS (Unattended Ground Sensors) that addresses a variety of military and government missions. ARL's program involves practically every aspect of sensor development including devices, detection and fusion algorithms, communications, and command and control. One element of the ARL UGS program involves the development of low cost sensing techniques for the urban environment and one embodiment of this effort is the Multi-Modal Sensor (MMS).

The program objectives of this effort were to develop a networked personnel detection sensor with the following major criteria: low cost in volume production, support for MOUT (Military Operations in Urban Terrain) missions, and employ non-imaging sensor diversity techniques. The MMS sensor was an early prototype intended to demonstrate that low cost sensing techniques were suitable for the urban environment and a viable alternative to higher cost and fidelity sensors for some applications. The MMS is used today as a demonstration system and a test bed for many facets of urban sensing.

This chapter will describe many aspects of the MMS design including: hardware, software, and communications. The detection algorithms will also be described including the collection of target signatures and validation of algorithm performance. Finally, MMS usage in a force protection application will be described including issues encountered when integrating into a larger system.

1. A Multi-Modal Sensor

This sensor system is based upon the principles of sensor diversity and simultaneously detects multiple physical parameters emitted by the target. This approach is designed to mitigate the known weaknesses exhibited by single-mode sensors under varying operational settings. The physical parameters sensed are seismic, acoustic, and thermal using an accelerometer, microphone, and passive infrared (PIR) transducers respectively.

The objective of multi-modal sensing is to increase detection accuracy and reduce false alarm rates while operating in a complex and cluttered environment. This early prototype is designed with a path toward low cost, volume production. The MMS is used today as a demonstration system and a test bed for many facets of urban sensing.

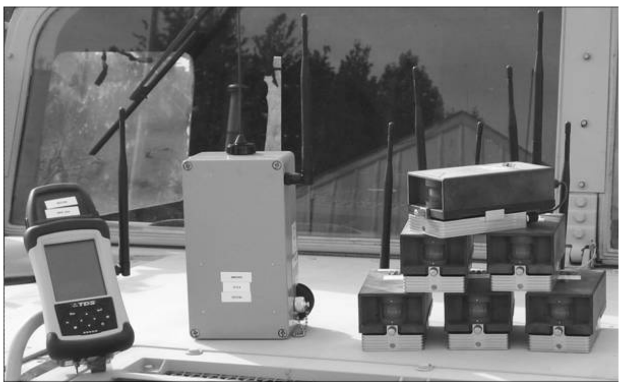
A MMS is composed of three main components: sensing, processing, and communication. The sensing component hosts a microcontroller that interfaces to the selected transducers. The processing component consists of a general-purpose microprocessor for algorithm execution. The communication component is composed of RF components for sending and receiving messages.

The application software executing on a MMS controls the overall functionality. Key components of the software include modules for detection for each modality and for data fusion. A software interface to the sensing component decodes packets, extracts and forwards data streams to the appropriate detection component. When detection occurs, the fusion module calls upon a software interface to the RF component to compose and transmit a detection message. The entire personnel detection algorithm [4] consists of four major parts: detection algorithms for each of the three modalities and an overall data fusion algorithm. Each detection algorithm ingests data from the appropriate transducer channel and processes it in real-time. The data fusion algorithm observes the results from the individual algorithms and decides whether a detection event is to be declared. In this chapter, detailed discussion is provided on the Multi-Modal Sensors. In particular, we will focus on topics such as system architecture, major system components, personnel detection algorithms, and principles of operation.

2. A MMS System

The sensors [5] form an ad hoc wireless mesh network as each node establishes a connection path to a gateway node, either directly or indirectly. If a node is not within one hop of the gateway, it uses other nodes as relay points to communicate with the gateway. All sensor messages flow upstream to the gateway.

The MMS sensors are nominally configured to operate in a centralized network. Neighboring sensors do not share information and all traffic flows upstream to the gateway for any additional processing such as tracking and multi-sensor fusion. ARL is also involved with distributed tracking [6] techniques which could easily be applied by the MMS sensor network.



The gateway is the central processing point of the network. All sensor information flows to the gateway which can respond to an individual sensor or all sensors. The gateway performs many functions but its fundamental task is to act as a communications bridge between the MMS network and higher level entities.

A PDA node is used to view sensor information sent to and from the gateway. The PDA node resides on the same network as Multi-Modal Sensors and can move about anywhere within the network, providing a certain degree of mobility. The PDA provides three basic services: sensor survey, emplacement verification, and tactical display. This chapter will provide detailed description on each of the network-level entities and the behavior of the networked sensors.

3. System Usage

The suggested usage models for the MMS system are missions involving detection of personnel and vehicles. The MMS was designed specifically for urban operations and is effective in detection of personnel and vehicles in urban settings. In addition, testing has shown that they are also effective against personnel and vehicles in rural venues such as trails, woods, and fields.

The basic deployment procedures are organized into five basic steps: mission planning, emplacement, survey and test, operation, and sensor management. This chapter will describe the basic deployment procedures for the MMS system. Particular variations due to change in venue will be discussed when relevant; otherwise the procedures will be somewhat generic.

4. Algorithm Development

The first step in the algorithm development process was to collect personnel signatures in representative urban environments using the MMS waveform capture capabilities. The signatures were then used to identify salient features to be used as a basis for detection algorithms. Candidate algorithms were then implemented and subjected to simulation and operational testing to validate performance. The details of this activity are presented in this chapter.

5. Applications

The MMS is currently used as a research platform for low cost sensing technologies and has been adapted for several particular applications since its creation. This chapter will describe the operation of the MMS in three separate applications, as well as some of the modifications and enhancements required in each case. The three applications of MMS are 1) Cave and Urban Assault ACTD, 2) NATO LG-6 demonstration, and 3) C4ISR OTM experiment.

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