

Volume Sensor – Multi-sensor, Multicriteria Event Detection

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Abstract—A multi-sensory, data fusion approach is being used to develop new detection capabilities for improved damage control and real-time situational awareness on U.S. Navy ships. Various spectral and acoustic signatures, new video imaging techniques, and image recognition methods have been investigated and integrated into a multi-sensory prototype system known as the Volume Sensor that is able to detect event signatures within a space. Intelligent data fusion is used to improve detection while reducing false positives. Two prototype systems were built and assessed in full scale testing in a shipboard environment side-by-side with two commercial video-based systems and several spot-type fire detection systems. The prototype systems were shown to outperform the commercial systems for flaming and smoldering fires with a high immunity to nuisance sources. In addition, the prototypes accurately identified pipe ruptures and flooding events.

Topic: 10. Sensor Systems

1. INTRODUCTION

The U.S. Naval Research Laboratory (NRL) is developing a real-time, remote detection system for shipboard situational awareness known as the Volume Sensor. The objective is to develop an affordable detection system that will identify shipboard damage control conditions and provide an alarm for events such as flaming and smoldering fires, explosions, pipe ruptures, and flooding. The project uses multi-sensory approach that takes advantage of existing and emerging technology in the rapidly growing fields of optics, acoustics, image analysis and computer processing. In addition, this technology utilizes conventional surveillance cameras, which are currently being incorporated into new ship designs, and therefore will provide multiple system functions with minimal new hardware.

The multi-sensory, data fusion detection system is the result of a five-year, five-phase program. The first phase consisted of a literature review and an industry review of current and emerging technologies for video,

optical, and acoustic methods for the detection of smoke and fire [1]. Based on the study, several technologies were identified as having potential for meeting some of the objectives of the detection system development effort. Work performed during the second year provided a basis for moving forward with the use of video image detection (VID) for shipboard applications [2]. A full-scale laboratory evaluation of three VID systems using a variety of fire and nuisance sources indicated that the smoke alarm algorithms of these systems could provide fire detection capabilities equivalent to spot-type smoke detectors for most of the conditions evaluated. In the third phase, potential technologies were assessed for the detection system, which included video image detection [3,4], spectral sensors [5], acoustic signatures [6], and long wavelength imaging [7,8], as well as the development of advanced algorithms [9,10]. Each of the sensing technologies was evaluated using damage control events including fire, flooding and pipe ruptures, and against a variety of typical shipboard nuisance sources. The results indicated that each sensing technology provides unique information for use in the multi-sensory prototype. The VID systems were found to be effective for detecting smoke, while long wavelength video detection and spectral sensors were successful at detection flame emission over the entire space without requiring a large number of cameras. In addition, the acoustic detection was useful for identifying pipe ruptures and flooding as well as for discriminating against nuisance sources, such as grinding. In the fourth phase, the sensor methods were integrated into a prototype which was evaluated. The initial prototype was evaluated in two shipboard test series on the ex-USS *Shadwell*, NRL's advanced damage control research ship. The first test series successfully demonstrated the integration of the detection systems of the prototype system [11]. The second test series demonstrated improved fire detection with very high nuisance source immunity and the ability to detect pipe ruptures and flooding events [12,13].

This paper describes the results in the fifth year of development [14]. The detection system has been enhanced and was evaluated in multiple compartments on the ex-USS *Shadwell* using a variety of damage control events.

2. EXPERIMENTAL

The tests presented were conducted in six different test compartments. The test spaces allowed for a performance assessment of the prototype systems in varying light levels and unique space configurations. A variety of events were conducted including flaming and smoldering fires, gas and water releases (pipe ruptures), and nuisance sources. The performance of Volume Sensor Prototypes was compared to commercial smoke detectors and VID systems.

3. RESULTS

Two volume sensor prototype (VSP) systems were successfully evaluated in multiple compartments while being exposed to multiple sources simultaneously. This work expanded the database of test scenarios and compartment conditions from which continuing prototype development and revisions can be based. The performance of the VSPs was compared to the performance of state-of-the-art spot-type smoke detection systems and VID systems (SFA and SigniFire) as shown in Table I. Analysis of these test results led to the following conclusions:

The VSP systems demonstrated the ability to function in multiple compartments, specifically discriminating between multiple types of events in multiple compartments.

The VSP systems demonstrated the ability to discriminate between source types by detecting flaming and smoldering fire sources, water releases, and gas releases while rejecting nuisance sources.

The VSP systems generally performed better than VID and spot-type smoke detection systems relative to the range of detection capabilities, ability to detect fires, ability to reject nuisance sources, and speed of response.

Table I. Comparison of Correct Classifications for Event Tests

Event Type	VSP1	VSP2	SFA	SigniFire	Ionization	Photoelectric	Multi-criteria
Flaming	95% (38)	97% (38)	91% (33)	95% (37)	88% (32)	75% (32)	88% (32)
Smoldering	71% (28)	75% (28)	65% (26)	89% (27)	63% (27)	93% (27)	78% (27)
Fire Sources	85% (66)	88% (66)	80% (59)	92% (64)	76% (59)	83% (59)	83% (59)
Nuisance	80% (40)	85% (40)	49% (43)	57% (45)	71% (38)	92% (32)	83% (36)
Pipe Rupture	88% (16)	88% (16)	NA	NA	NA	NA	NA
Gas Release	53% (17)	53% (17)	NA	NA	NA	NA	NA

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