AN ACOUSTIC SENSOR FOR THE VIPER INFRARED SNIPER DETECTION SYSTEM

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ABSTRACT

An acoustic muzzle blast sensor has been developed and integrated with the Viper sniper detection system. The system uses an infrared (IR) camera and digital signal processing to detect the muzzle flash of a sniper's weapon. The IR detection is essentially instantaneous and gives the bearing to the target within 70 milliseconds of the shot. However, a single camera IR method can not reliably give a range to target. An acoustic sensor and associated signal processing algorithms have been developed to act as a simple filter to detect the acoustic signature of a rifle shot. The difference in the time of arrival between the infrared and the acoustic signatures is used for range determination. In addition to the ranging function, acoustic detections can be used to reject false IR muzzle flash detections caused by phenomena such as sun glints. A verification method is used where each IR detection opens a range gate and if there is an acoustic detection before the gate closes the IR detection is verified.

1.0 INTRODUCTION

The VIPER infrared sniper detection system was developed by MADL for the Naval Research Laboratory[1]. It uses a midwave infrared staring focal plane array sensor to detect the muzzle flash from a sniper's weapon. The detection occurs within 70 milliseconds of the weapon firing and can be localized in azimuth and elevation to within one fifth of a degree. The weapon

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[1] S. A. Moroz, R.B. Pierson, M. C. Ertem, D. A. Burchick, Sr., T. Ippolito, *"Airborne Deployment of and Recent Improvements to the Viper Counter Sniper System"*, IRIS Passive Sensors Symposium, March 1999

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does not have to be aimed at or near the VIPER system to be detected, the only requirement is that a line of sight exist between the VIPER sensor and the fired weapon. Even if there are small obstructions in the line of sight, (such as when firing from behind bushes) the system is able to detect sniper class weapons fire to beyond their effective range.

In field tests the VIPER system has demonstrated very high detection rates (consistently above 95%) at ranges up to and beyond the effective range of the weapons used. Tests have been conducted with various firearms, including .223, .300, and up to .50 caliber rifles. False alarm rates are very much dependent on the background and the weather conditions. In benign environments, such as in overcast conditions, false alarm rates as low as one per hour have been observed. False alarms that were seen in earlier versions of the system, due to objects such as traffic in the sensor field of view or aircraft transitioning the image have been reduced by implementing a track filter which eliminates these detections. However, on bright sunny days, especially when there is high wind present, the false alarm rate is unacceptably high.

Although the VIPER system provides exceptionally accurate bearings to the detected muzzle flash, the single IR sensor approach does not give an indication of the range to the detected weapon. The variance which has been observed in ammunition in terms of their infrared intensity signature, and varying atmospheric effects makes it difficult to use intensity information to estimate the range to target.

One possible solution to the range estimation problem would be to use two imaging sensors in a stereo vision type system to triangulate the location of a detected event. The feasibility of this approach is limited by two factors, the high ranges where detection is possible means that a large baseline would be needed to separate the two cameras, and more importantly, the high cost of two infrared sensors can not be justified, especially since a lower cost approach is available.

Using a simple acoustic sensor and very simple processing algorithms has allowed the two problems: reducing false alarm rates and estimating target ranges, to be addressed at a very low cost and with little additional complexity in system design.

2.0 FALSE ALARM REDUCTION

Using an acoustic detector allows the reduction of false alarms while the system is being used in a harsh background environment. If the background clutter is so high that false alarms are being generated (typically due to solar reflections from leaves, etc.) then acoustic verification is used before an infrared detection is declared. In this mode all infrared detections are buffered and a range gate is opened for each. The length of the rangegate can be varied if desired. In field testing performed at the Fort Meade rifle range (where the longest range available is 630 meters) this was set to one kilometer. If an acoustic detection occurs then the infrared detection is declared to be verified and is displayed on screen. If no acoustic detection occurs the infrared detection is discarded.

In cases of benign backgrounds the use of the acoustic verification feature is not desired. This is because with the IR only detection the system is able to declare a detection within about

70 mS of the shot, or before a supersonic round has traveled about 100 feet. At the longer ranges with higher caliber rifles this could potentially give up to two seconds warning that a bullet is incoming. If acoustic verification is turned on, there is no chance to provide this warning. A simple solution around this problem has been devised. It consists of displaying a yellow diamond on screen as soon as an IR detection is declared and then either changing its color to red if it is acoustically verified or erasing it if it is unverified.

3.0 RANGE ESTIMATION

It is very easy to estimate the range to target if the time difference between the IR detection and the acoustic detection are used. The 'flash-bang' time difference is a reliable range estimator as long as the direct path signals are used in both the IR and acoustic sensors. In the IR since an imaging sensor is being used, this is inherently the case. In the case of the acoustic sensor the direct path is the shortest, therefore the earliest signal should be used for ranging. This can be accomplished by having an acoustic sensor that is sensitive enough that the direct wave will trigger the detector, and by ensuring that the detection algorithms recognize only the front edge of the signal.

4.0 USER INTERFACE

Upon acoustic verification and range estimation the system overlays a red diamond symbol and the estimated range on the display. The VIPER user interface has been implemented so that using the acoustic verification system does not change the user interface in any way. A user trained with the original VIPER can use the new feature with minimal training.

A situation that has to be addressed is what happens when there are multiple infrared rangegates open. That is, what to do if (due to either bona fide detections or to false alarms) there are two or more IR detections that are pending? This has been resolved by having any acoustic detection validate all IR detections that are pending. In these cases, if the IR detections are real then the range calculated to some will be less than the actual ranges. It is possible to come up with ways to correlate IR and acoustic detections, but since these would involve adding complexity to the user interface they have not been implemented.

5.0 ACOUSTIC DETECTION

The design goals for the acoustic sensor system were that it be low cost, that it not impact the operation of the infrared detection system significantly, and that it be implemented in a relatively fast development time. It was also decided to use commercial off the shelf components throughout this process

The development process was started by collecting acoustic data. An Audio Technica ATR-55 microphone was purchased and connected to an 8-bit analog to digital converted on a personal computer. Existing video tape recordings that had been used during the infrared system development and on which the audio tracks had been used for test documentation were now used to see if the muzzle blasts were recorded. These recordings proved very useful in developing the original acoustic detection algorithms.

The early algorithms consisted of a very simple instantaneous energy estimate, (calculated by adjacent sample differences), and a slow varying adaptive background energy estimator (calculated using a first order infinite impulse response filter). The difference between the instantaneous energy and the estimated background served as the discriminant and a threshold was chosen empirically.

This algorithm was coded to run under the Windows NT operating system on a Pentium processor computer and taken to the field for evaluation. It was connected to the alarm output of the VIPER system and the performance in false alarm reduction and range estimation was evaluated. Based on these tests it was decided that the development of a small acoustic attachment to the Viper using these algorithms would be a significant improvement.

For the deployable version an Analog Devices 2181 development board (the AD EZ-Kit Lite) was chosen, mainly because of its ease of use and built in audio interface. The acoustic detection algorithm was coded in assembly language and burned into EPROM, so that a small, self contained acoustic unit was the result. The ATR-55 microphone which had been used during the algorithm development was mounted alongside the Inframetrics MilCam sensor of the Viper.

6.0 RESULTS

It should be noted that the acoustic verification system described here was meant specifically as a verification sensor for the VIPER system. Thus, it was never a design goal to minimize acoustic false alarms. The acoustic system will readily detect a handclap, car door closing, or other impulsive noises. It is not sensitive to other types of noise, including traffic noise, engines, aircraft, etc.

The high false alarm rate for the acoustic system is acceptable, since its plays the verification sensor role, and the goal is to have as high a detection rate as possible; and because the verification sensor output is of consequence only if the primary (IR) sensor has a pending detection.

In field tests the acoustic sensor has reduced the false alarm rate significantly. On sunny bright days, with high winds, the acoustically verified false alarm rate has been measured at about 2 false alarms per hour, whereas without the acoustic sensor the false alarm rate would have been in the tens, or even hundreds per hour. The acoustic ranging accuracy has been measured to be within 5 meters at distances of about 300 meters.

7.0 CONCLUSION

A secondary acoustic verification sensor using a small DSP processor and an inexpensive COTS microphone has been shown to significantly enhance the VIPER infrared sniper detection system.