Abstract – Novel concept of sensor fusion algorithms implementation are proposed. While the algorithmic design is tested and implemented in generic software on a Windows PC, a first single ASIC implementation of the sensor fusion is being readied for the marketplace. A novel optical approach is suggested for a hand-held or goggle sensor fusion implementation. Together with a fusion ASIC, the proposed approach will yield new class of devices ultimately replacing existing NVG and similar platforms. New concepts in sensor fusion of visible, near and far IR sensors coupled with target tracking algorithms are also proposed and implemented in a single ASIC system.

Keywords: Visible, Night Vision, FLIR, Sensor Fusion, target tracking.

1 The Fusion Problem

The ultimate goal of the sensor fusion algorithm development is not only in creating an advanced software platform, but a development of a software/hardware implementation on the basis of programmable gate array. The single chip implementation will usher a new era of fusion products – devices that can be hand held or helmet mounted. In order to implement a system in a chip we have developed a sophisticated system on a PC that allows quick analysis and algorithm modification. We are at present in final stages of development for a first single chip sensor fusion for embedded applications of cameras and scopes. The system will perform the following tasks in real time operating on video streams:

- Monitor the same space in several (two or more) spectral ranges – visible, near to far IR
- Unify the information from several spectral ranges and present the information in operator requested form.
- Automatically segment the background from objects
- Extract moving objects and contour them
- Remove all vibration from the optical sensors
- Detect new objects and separate them from the background
- Track the separated objects within the field of view
- Control the orientation of the sensor to allow the tracking of moving objects
- Estimate the parameters of objects and classify them
- Increase the resolution of the video imagery and improve the video of tracked objects
- Show the results of tracking/enhancements and offer adequate operator control

1.1 Novel Optical Implementation

The actual novel concept for the fusion of multiple sensors in real time is being implemented in a binocular/ goggle/ gun scope platform. There are existing development projects working on the same goals, such as ITT ENVG project. Their current effort concentrates mainly on optical fusion of images. This approach has some clear advantages, namely:

- Resolution of the intensifier is still significantly superior to any digital display/CCD, thus at least intensifier channel will be high enough resolution
- Operators at present are quite familiar with NVG issues and will be able to perform better with intensifier component of the system working rather than with pure digital system and display
• Optical fusion certainly provides lower power consumption and smaller packaging

However, optical fusion implemented by ITT Night Vision Systems at present (see above) has a severe shortcoming: the overlay of FLIR imagery over the optical channel is an open-loop system. I.e. ENVG tries to match the images based on mechanical design and collimation of three optical channels – intensifier, FLIR sensor and IR FPD display. If any one of the optical channels is slightly out of alignment, images are no longer matching. This misalignment can occur from shock, or various standard occurrences in the field. Furthermore, if repair in the field replaces any one of the components, for example, an intensifier, the system can be badly out of alignment. Nobody in the field has a sophisticated collimator. In addition to the above problem, there is a persistent delay to the FLIR channel which makes image difficult to use when ENVG moves rapidly. The rubber-banding effect, when FLIR image is somewhat delayed with respect to the fast response of the intensifier, makes the unit hard to use in the field.

All of these issues can be corrected considering a closed-loop system with optical/electronic feedback. We are developing a modified combiner/splitter coupled with a CCD. CDD will provide sufficient feedback information to perfectly match FLIR output to an optical channel and will resolve misplacement, rubber banding and recoil issues. We have been developing the advanced proposed combiner/splitter specifically for the sensor fusion application and has already achieved great results. The combiner/splitter allows optical path of intensifier to go directly through, coupled with IR FPD from one side, while retaining a splitting capability of coupling a CCD with optical path and calibrating each frame of FLIR with perfect registration onto intensifier image. Main features of the proposed ENVG design are:

• An ability to perfectly match thermal and intensified channels
• No dependency on collimation of the channels
• An ability to substitute lenses (different FOVs) on either channel while maintaining perfect fusion
• Additional digital processing benefits, including resolution doubling for the thermal channel

2 Fusion Software Implementation

2.1 New Optical System

Figure below illustrates this concept applied to a monocular system such as the one ITT currently uses. In such a system a high quality image relay lens has been replaced with a lower quality and resolution tap camera system which only needs to be good enough to capture and resolve edges of the scene. A significant source of misalignment in the original unit has been the image relay lens which is now out of the system. The two displays are brought up to the combiner / splitter directly. In addition to eliminating this source of problems, this technique would be fairly immune to lateral misalignment of the two displays since it will always rely on the electronics to adjust images rather than physical display positioning. While the image is laterally adjusted using signal processing, the use of a relatively long depth of field eyepiece will allow for axial misalignment without detrimental effects on the resulting combined image.

One issue that needs to be continuously monitored is power consumption. While we are introducing two elements that will consume power, we need to note that CCD that is intended for the proposed design is not high resolution. It will be from the same family of products as

CCDs currently present in mobile phones. They are extremely low power and will be used only to align images. The second component is a video processing unit. While the name itself implies power usage, its only task is to align edges and stretch the image if needed. Those operations are performed by number of products in 44-pin packages with extra low power consumption and most of them are parts of standard camcorder designs. Both component will create some drain on the batteries, however, it will not be significant and can be completely characterized and developed. We should also note here the unusual splitter combiner designed (We are currently in the process of filing a patent on the splitter/combiner).
In concert with electro-mechanical considerations of the goggle/binocular platform in development, we have pixel matched sensor fusion. Originally created as a purely software implementation on a generic PC platform, algorithm has been successfully ported to an FPGA. The images below show various modes of the fusion system, including: geometric correction of IR channel to the visible image; fusion of two images according to different rules and “hot areas” indication in fused images. The approach presented is specifically geared toward target detection and subsequent tracking of moving targets in the video sequences. The set of rules developed in the decision making module allows an operator to key in or automatically detect moving “hot” objects and subsequently track them in fused imagery. Multiple display modes aid the operator in classification of the targets of interest.

Decision making process in sensor fusion and target detection and tracking is a major consideration when creating instruments for a wide audience of operators. Not only the system has to be easy to use, but major functions and components have to be field replaceable and easy to adjust, maintain and control. Dr. Volfson will present all key considerations, steps and decisions that had to be incorporated in the system before it is ready for the field use.

Images below show examples of tracking multiple targets in the environments where targets are moving and can be variable size – from minimum of 3 pixels across. There are interesting effects coming into play here, as some targets are people and some targets are birds. From the position of the camera, the birds targets turned out to be much larger than other desirable targets. It is important to note that fusion code together with target tracking is running on a laptop PC with Pentium-M at 2.13Ghz in real time (30fps).

2.2 Target Tracking

In addition to the standard sensor fusion algorithms the FPGA can carry target tracking components. At present we have implemented several application specific tracking cases. For example, we extract the target based on the heat signature being over the background temperature. This approach works well in temperate climes where the temperature of the observed background is generally lower than the heat produced by the individual.

We will be able to present the demo system at the conference for the hand-on use and testing.
3 Sensor Fusion Platform

Sensor fusion platform as described was implemented on the basis of the following hardware:

- Sony 1.5Mpixel 3 CCD color camera with 20x zoom
- DRS HMIC microbolometer sensor
- IR defocused (eye safe) laser for low light imaging
- Quickset PTZ all weather platform for 360 degree continuous move and track operation
- Embedded Pentium-M PC/104 computer or single FPGA board containing the same software
- Software for sensor fusion, tracking multiple targets, resolution and image enhancement

Hardware platform is shown below and will be offered commercially in fall of 2006.

4 Conclusions

In the paper we have presented generic sensor fusion and target tracking approaches and algorithms. Their implementation in a single Xilinx platform is being tested at present with market availability in the fall of 2006.

References


