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ABSTRACT

Architecture and technology of the imaging intrusion detection sensor OPAK are presented. Applications and desired features for IDS and UGS are compared. Started developments of OPAK towards an unattended ground sensor system are described.

Keywords: Image processing, pattern recognition, MMI, unattended ground sensor, intruder detection sensors.

1 INTRODUCTION

In all kinds of conflicts information about enemy dispositions and strategic and tactical motions have been vital to own success. Spies and agents, scouts and other special forces have in all times been important to collect such information. Today many military operations will be even more complex and confused than before, including urban warfare. In some "out-of-area" operations frontlines between enemy and friendly forces will be fuzzy and not well defined. Furthermore, the speed and diversity in operations are also expected to increase. Thus, to achieve "situation awareness" is more challenging today than before, and those possessing the most complete information will have an important advantage.

New technology in sensors, automatic signal analysis and communication has resulted in information superiority to the high tech Western countries, in particular to US forces. However, the sensor platforms are primarily satellites, airplanes and UAVs. The most detailed information from these elevated sensors comes from imaging sensors requiring blue skies. Of this and other reasons the information will not always be available in a timely manner on a tactical level. Moreover, at battalion and company level more detailed information than what can be achieved from these sensors may be required.

Ground sensors are unattended devices for battlefield surveillance. The capability of such sensors is typically automatic detection of vehicles and personnel. The sensors can be deployed into enemy controlled areas or near the front lines to monitor motion of enemy forces and serve as an automatic observation post (OP). Such sensors can also be used as an early warning devise against attacks on camps (i.e. as an intrusion detection sensor) or in close combat.

We will here describe an automatic imaging surveillance system and its applications as ground sensor. Forsvarets forskningsinstitutt (FFI, Norwegian Defence Research Establishment), and Norwegian industries Thales Communication AS and Hernis Scan Systems have developed a video intrusion detection system, OPAK, as a security sensor for large stationary facilities like air bases. FFI has further developed this system to be applied for force protection. We will first briefly describe the applications of Unattended Ground Sensors (UGS) and Intrusion Detection Sensors (IDS), and from this induce which features they should possess. Next we introduce the camera based UGS/IDS concept and describe some technology. At the end status and planned continuation of work are given. The system described here may in some details differ from the off-the-shelf systems delivered from industry.

2 GROUND SENSORS – THEIR OBJECTIVES AND FEATURES

By *ground sensor systems* we here mean either *Unattended Ground Sensors (UGS)* or *Intrusion Detection Sensors (IDS)*. UGS are used to provide tactical information to assist the decision makers at various levels of command, and are thus normally used as a technical aid for battlefield reconnaissance patrols. IDS are used to alert the guard (or security personnel) about intrusions into camps or other facilities, and are normally an aid in security or close combat defense.

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2.1 Unattended Ground Sensors

UGS are surveillance sensors, typically used by reconnaissance troops as a supplement to the personnel to increase the patrolls area of coverage. By deploying sensors in the most exposed positions also vulnerability of personnel is reduced.

A UGS system comprises one or more detectors, signal analysis, communication and a display unit. Some sensors can classify the target, and some can indicate the direction of movement. The sensors are portable, lightweight, battery operated units designed for deployment in the field, and left unattended for up to several weeks. With today's typical detection range of some tens of meters, sensors are usually deployed along roads or tracks within a certain area to monitor the movement of enemy vehicles and personnel. The operator's field terminal, basically a monitor, receives messages transmitted via radio from various remote sensors and presents the sensor information on the display. Most modern ground sensors perform internal signal analysis so that the messages will only contain high-level information.

Communication from sensors to monitor is normally in the VHF frequency band. The sensor to receiver distance may be up to several kilometers, depending on the topography. For longer distances repeaters may be used to extend the range considerably.

In older systems the monitor is a hand held device with a small display for the sensor messages. Modern systems typically employ a portable computer with a more advanced man-machine interface, i.e. a graphic user interface (GUI) connected to a geographical information system (GIS). The sensor information is presented on the computer screen as overlays on a digital terrain map of the area of interest. Various functions for storing, filtering and automatically analysing sensor messages (data fusion) may also be implemented in the computer.

Features that we would appreciate an UGS to provide include:

- Automatic detection, classification and identification of troops at maximum distances (discrimination between the individual objects, i.e. counting of personnel, AFVs, MBTs, SPAs, trucks, etc would be ideal)
- Target position, heading and speed
- Covert surveillance, i.e. passive detectors and low radio communication signature
- Minimum power consumption for maximum unattended life time
- Low weight and size
- Remote delivery

Several ground sensor systems are in use today in various countries, and some prototypes are under development. Often simple magnetic, passive IR and seismic sensors are employed. These sensors typically detect personnel at a distance of 20 – 40 meters and vehicles at a few hundred meters, and to a very little extent they meet the wishes listed above.

The REMBAS, now replaced by IREMBAS (Improved Remotely Monitored Battlefield Sensor System), has been in service in US Army since 1987. CLASSIC (Covert Local Area Sensor System for Intrusion Classification) entered service with the British Army in 1982, and has since been introduced in most NATO and some non-NATO forces. IREMBAS and CLASSIC both use magnetic, seismic and passive IR as the basic detectors. Due to the limited range of these detectors, these systems are more or less restricted to surveillance of roads and possible avenues of enemy approach. Acoustic UGS systems have a potential of longer detection range. Such systems are now being developed, but have still not got into service.

2.2 Intrusion detection systems

Traditionally the security of military facilities has relied on human guards. Usually this is achieved by patrols, often accompanied by dogs, and a post at the gate. The same tradition also goes for the security at camps out-of-area. However, reduced defense budgets, less personnel and increased focus on cost/effective solutions argue for the introduction of technical aids. Automatic perimeter intrusion detection sensors are now available and are in some countries used to alert the guard/security at civilian and military facilities including major Navy and Air Force bases. The Norwegian Army and FFI have started testing IDS systems also at the main Norwegian camp in Kosovo, and WEAG conducts an R&D project on perimeter surveillance for employment during the construction phase of new camps out-of-area. The threat against (military) camps out-of-area will to some extent depend on kind of operation, whether it is peace keeping or peace enforcing operations. However, the major threats will be crime, terrorism, espionage and sabotage. Other applications of IDS are border control and even as an aid in close combat defense.

An IDS system, like an UGS, includes the detectors themselves, signal processing, data communication and the operator's terminal. Also IDS may fuse information from different detectors. The signal analysis may be local, close to the detectors, or in a central computer (for instance a PC) typically directly connected to the operator's terminal. Data transmission between detectors and the central computer usually goes by wire.

Features that we would appreciate an IDS to provide include:

- Automatic detection, classification and identification of intruders
- Target position and heading
- Instantaneous display of alarm situations for visual inspection, preferably in form of on-line video
- Covert surveillance at users choice
- Easy to deploy with no need for special heavy machinery

IDS have been used in security for some time. However, these sensors have not been able to discriminate between different alarm situations in any detail, and they have been hampered by many false/unwanted alarms. Most systems also need a rigid infrastructure for power and data distribution, some detectors are supposed to be buried into the ground, some are supposed to be mounted on a fence, etc. Therefore these sensors only to a little extent are suited for deployment to out-of-area operations. It is a need for an easily deployable system that automatically detects and informs the operator (the guard) about any alarm situation, its character and location.

3 IMAGING GROUND SENSORS

Except for short detection ranges, the main deficiency of today's ground sensor systems is a too low detection-to-false alarm ratio. Target signatures vary a lot, and non-target signatures vary even more. The measurements available from the rather simple detector suites of in-service UGS systems cannot discriminate between all these signatures, i.e. overlap between signatures is large. Complex sensors provide more information, thus increase the probability that the various measured signatures differ.

Imaging (i.e. multi dimensional) sensors extract more information than 1-D sensors, and therefore have the potential of providing more information about most scenarios. Unfortunately, more complex sensors also require more complex data processing to extract the information. However, the electronic revolution and resulting cost reduction in computation power now permits the introduction of intelligent imaging sensor systems as ground sensors. Video intrusion detection systems already exist, a few of quite good quality.

3.1 Basic architecture

Figure 1 defines the basic components in an imaging ground sensor system. Images from the camera are input to a low level processing unit. This unit processes on pixel level, i.e. it captures and digitizes images, extracts moving objects in the scene and characterizes each object/movement. It thus has to handle large amount of data in each time interval, and typically it consists of digital signal processors (DSPs) and/or field programmable gate arrays (FPGAs). Also this unit provides camera control signals, e.g. for camera regulation. The information extracted from the low level processing unit is in turn input to a high level processing unit. This unit is utilizing this information for object tracking and classification. Based on the tracking and classification, this unit also checks if objects from specific classes behave according to some user specified alarm criteria. If so, an alarm is sent to the Man Machine Interface unit (MMI) along with an image or image sequence of the alarm (for verification purpose). The high level processing unit may also send control signals back to the low level processing unit. An example of such signals may be commands to make the object extraction more sensible in areas where moving objects are detected. The MMI is in general basically a graphical user interface (GUI). The GUI consists of the alarm information overlaying a map, it can show alarm sequences, and also the user may give commands to the processing units, look at previous and new alarms, define alarm criteria, etc.

3.2 The basic architecture of OPAK video intrusion detection system

In the mid 1990s FFI developed the principle solution for a video intrusion detection (VID) system, along with the basic image analysis. The OPAK system was then developed in cooperation with Norwegian industry (Thales Communication and Hernis Scan Systems).

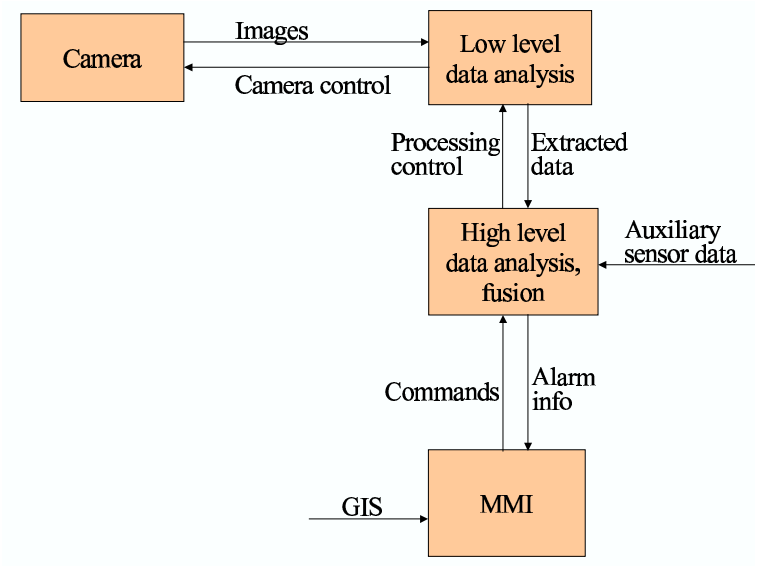

Figure 1 Main components of an imaging ground sensor system.

The prime application of our first video intrusion detection system has been as part of the security of large military and civilian facilities (i.e. as a stationary system). Cameras and auxiliary sensors are mounted along the perimeter of the actual site/installation. The frames from each camera are sent to data analysis through optical fibers. Also commands for camera control as well as communication between the MMI and the high level data processing are done through optical fibers.

The system automatically detects illegal activity in the surveyed area and alarms the operator/guard, so that proper reactions can be initiated. Combined with sufficient physical protection of the sensitive objects, our system can provide the reaction forces with the time needed to meet the required security level at the facility. The applications of the OPAK Video Intrusion Detection System are depicted by the Norwegian acronym OPAK, meaning Object and Perimeter security by means of Automatic surveillance by Cameras (in Norwegian spelled with a K) .

The OPAK system comprises:

- A number of cameras covering the surveyed area by their field of views. The cameras are mounted in weather protective housings on top of 4 m high posts.
- Electric lighting in cases where CCDTV cameras are used. (So far we have prefered CCDTV cameras, because we believe use of electrical lighting has a preventive effect.)
- A number of auxiliary (e.g. acoustic) sensors deployed to cover (part of) the surveyed area.
- A central computer, which automatically detects activities in the cameras' field of view, extracts information about the detected activities, classifies objects to categories (human, car, etc.) and compares the detected activity descriptions with user specified alarm criteria. It also fuses information from auxiliary sensors. Alarm information, including an image sequence, is stored.
- Operator's work station for presentation of alarm information, and the man-machine interface (MMI) for system configuration, service and everyday operations. Included are also acoustic and optical alarm indicators (siren and flashlight).
- Cabling for power distribution and data and control signal communication between modules.

OPAK performs high detection probability combined with low false alarm rate (FAR) by use of advanced image analysis techniques, including temporal and spatial adaptive detection processes, scene modeling and fuzzy logic classification. Use of 3D terrain model and pattern recognition techniques permit automatic comparison between extracted information about activity in the surveyed area and alarm criteria specified by the user in terms of object category, motion parameters and sequence of events. To further improve the performance, OPAK permits the inclusion of additional sensors, and fuses information extracted from these with what is extracted from the image data.

The main hardware modules of OPAK and their interconnections are given in Figure 2.

OPAK Processor hosts all data analysis and storage including image processing, scene analysis and system configuration, control and management. The processor includes a PC running Linux and an in-house developed real time image processor (special HW), see Section 4.4.

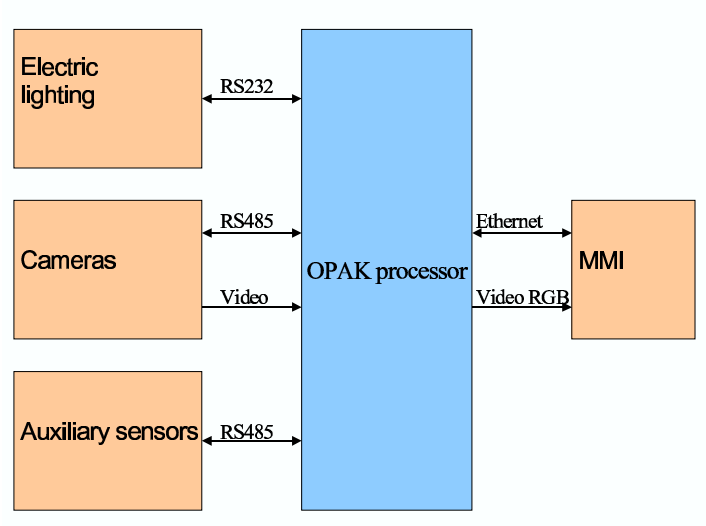

Figure 2 Main components of OPAK Video Intrusion Detection System.

3.3 OPAK based ground sensor architecture

The original OPAK system, as an IDS for major homeland defense facilities, needed some changes to permit deployment to camps "out-of-area". The infrastructure composed of buried cables and heavy masts for the cameras, does not support temporal applications, and the installation procedures require experts. FFI has evolved OPAK into a transportable and reusable system.

In order to reduce installation time, we have developed a methodology for quick generation of 3D terrain models. This is based on first estimating the distance between the camera and objects with known geometry for given positions in a scene. Next, these positions are used as input to a triangulation algorithm, and finally the resulting planes are used for determining a "distance image", i.e. an image where the "intensity" of each pixel is the estimated distance between the camera and the corresponding position of the pixel in the scene.

For reducing the complexity of infrastructure, standard components are used. For example the optical fibers and electrical power cables have standard length (and connectors on both ends). This makes the installation much easier, and the installation time is significantly reduced.

Using CCDTV-cameras implies that electrical lighting must be available in order to obtain night capability. However, we have tested OPAK using a thermal IR camera (TIR), and the system performs very well using such cameras. When TIR-cameras are used, electrical lighting is not necessary, and thus the infrastructure is simplified.

4 TECHNOLOGY

4.1 The detection process

An overview of the detection process in OPAK is shown in Figure 3.

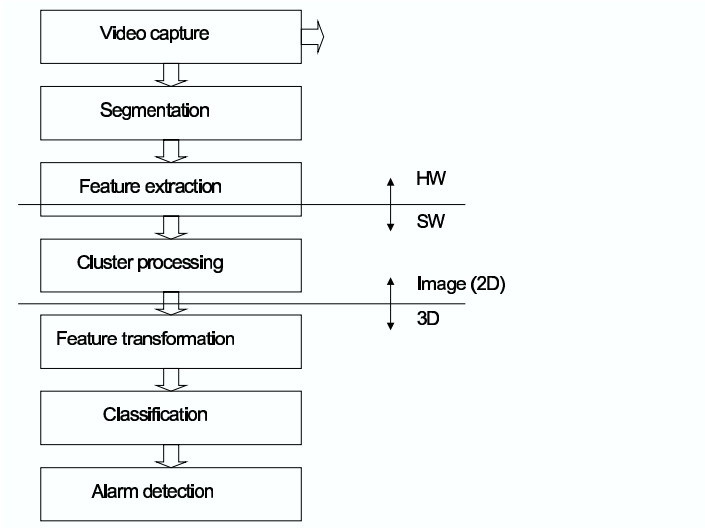

Figure 3 An overview of the detection process. The upper horizontal division-line separates those processes which are mainly implemented in HW and those mainly implemented in SW. The lower division line separates those processes where only image plane (2 dimensional) features are available and those where also 3 dimensional features are available.

4.1.1 Video capture

The system accepts European video format with 50 fields per second. Image noise is reduced at the input by means of both analog and digital filtering. The digital image format is 512 x 256 pixels. Each input card time-multiplexes video from up to 8 cameras, i.e. during normal operation the system processes 6.25 images per second from each camera. The multiplexing sequence can be changed on the fly. This can be used to increase the priority of a camera as soon as the system detects a potentially interesting activity in that camera.

4.1.2 Activity detection

The next step is to separate potentially interesting activity (objects) from the background. In OPAK cameras and background are stationary, and any activity is detected by extracting changes in the images. The challenge is to ignore natural or normal noise while at the same time detect changes inflicted by intruders and other activity that should trigger an alarm. There are also parameters for global sensitivity adjustment (for each camera). The global sensitivity can be adapted to the security level and relevant threats by specifying a range of legal values for these parameters. The system automatically adjusts the global parameters inside the current legal range.

The output of the comparison between the current image and the reference image is a binary image, where non-zero pixels indicate significant differences between the two. The binary image is spatially filtered to fill in gaps and to remove small noisy areas. The resulting image is labeled in a Connected Component Analysis. A segment is defined as the set of pixels having the same label, i.e. a connected set of non-zero pixels.

In the next process features are computed for each segment. Some features are computed in full resolution. Other features (e.g. some shape descriptive features) are computed after sub-sampling the picture.

Even though OPAK's instantaneous segmentation is very sensitive, low contrast or noisy background may result in fragmented segments, i.e. that one real world activity is represented by several segments. The cluster processing remedies this by grouping segments judged to depict the same activity into one cluster. The system uses two different clustering processes. In the instantaneous clustering only static features (e.g. size and position) are used. The dynamic clustering also uses dynamic features (e.g. velocity).

4.1.3 Feature transformation

In this process the system transforms some of the features from image plane (i.e. 2D coordinates) to global 3D coordinates). Using the assumption that all activity touches the ground, the system employs a digital terrain model and camera models (including position and orientation) to estimate where in the scene the activity is located. It is then a straightfor-

ward computation to transform for instance 2D width, height and area to 3D. This enables the operator to communicate with the system using familiar units like "meters", "meters per second" etc.

4.1.4 Classification

The OPAK system uses fuzzy logic classification to assign detected activities to defined classes. The individual feature values of an activity are matched to the corresponding feature ranges of each class. The possibility that an activity belongs to this class can then be computed by combining the match-values. The activity is assumed to belong to the class with the highest possibility, if the possibility is above a certain threshold value. If no class has a possibility above the threshold, the activity is assigned to an "Outlier" class.

An alternative is to assume that the activity may belong to all classes with a possibility above a certain threshold value. This enables the alarm detection to use a combination of class possibilities and weights to determine if an alarm should be triggered.

4.1.5 Alarm detection

In the final alarm detection, the activity's features and class are compared to user defined alarm criteria. Specification of activity class (e.g. small car) and ranges for selected features (e.g. speed less than 5 m/s) are included in the alarm criteria. The surveyed area is partitioned into several zones. An alarm criterion can refer to these zones both for defining its valid area, and for defining a pattern of movement an activity must match in order to trigger an alarm. It is possible to have different criteria sets for different times of the day, for different seasons, or for different security levels.

A priority is assigned to each alarm criterion. This priority is passed along with other information about the alarm situation to the MMI. All alarm information is also stored on hard disk.

4.2 Man Machine Interface (MMI)

The MMI is the user's interface to the system. The MMI is meant to be easy to understand and use, and should require only a minimum of training. The MMI includes two types of displays.

A Graphical User Interface (GUI) is employed for general user interaction, including display and configuration of system status and miscellaneous parameters. When an alarm is triggered acoustic and visual indicators (siren and flashlight) are activated. The alarm priority is used to determine the order in which several simultaneous alarms are presented. An image of the alarm situation (including a cue indicating the activity causing the alarm) is displayed in the GUI together with a text describing the systems interpretation of the situation. The textual description includes activity class and selected features (e.g. size and speed). Instructions for the operator are also available. A map of the surveyed area may be used both for parameter setting and for overlaying information about alarms.

An additional high-resolution display is used to present alarm sequences and live video. This display is capable of displaying up to four alarm sequences or live videos simultaneously. An alarm sequence may be up to 8 seconds (divided between pre- and post-alarm sequences as configured by the user).

OPAK is prepared for sending the alarm information through standard communication channels to a remote security central / operation center, thus OPAK may be used for surveillance of an unmanned facility.

Three main categories of users are defined. The set of available information and functions is adapted for each user category.

- The *operator* category is intended for everyday user. When an alarm is triggered, information about the alarm (including the alarm sequence) is automatically presented for the operator. The operator uses this information to determine whether this was a false or real alarm. The operator may watch several cameras in order to better verify the alarm situation. When correct response to the alarm has been initiated, the operator enters a short report.
  The operator may at any time choose to inspect earlier alarms and appurtenant alarm sequences. The operator may also inspect individual cameras or groups of cameras at his own choice.
- The *security manager* is responsible for definition and maintenance of security aspects of the system (alarm zones, alarm criteria etc.).
- The *service personnel* category is intended for personnel performing technical maintenance of the system.

4.3 Sensors, sensor control and electric lighting

Both CCDTV cameras and TIR cameras have been tested with the system. (The image processing unit accepts standard 50 Hz black and white signals.) For stationary applications, CCDTV cameras (and electrical lighting) have been applied because it is believed that the electrical light has a preventive effect against intruders.

The system detects activity by determining changes in the camera images. Any kind of camera internal automatic exposure control (Automatic Gain Control, Auto-Iris etc.) introduces unwanted changes in the images and should not be used. Therefore the image processing system continuously monitors several small regions in each camera image in order to detect illumination changes. When significant illumination changes are detected, image information from sub areas of the surveyed areas is used to compute correct camera settings, e.g. iris setting and CCD integration time. Internal data (e.g. the reference images in the segmentation process) are modified according to the changes in the camera settings, and the new camera settings are transmitted to the camera. During manual inspection of the cameras (e.g. after an alarm was detected), authorized personnel may override the computed camera settings.

Current CCDTV-cameras are not sensitive enough to allow around the clock surveillance without the use of artificial illumination. A special illumination system has been developed for use with the surveillance system. The lighting produces a nearly horizontal illumination with low and uniform illumination level. The image processing system detects when the artificial illumination is needed, and the system automatically switches the illumination on or off.

4.4 Computer architecture

An overview of the computer architecture of the OPAK Processor is shown in Figure 4. The OPAK Processor consists of custom developed HW and a PC running Linux. The system is powerful enough to simultaneously handle multiple alarm and non-alarm activities, and cannot easily be jammed by imposing activity in the surveyed area.

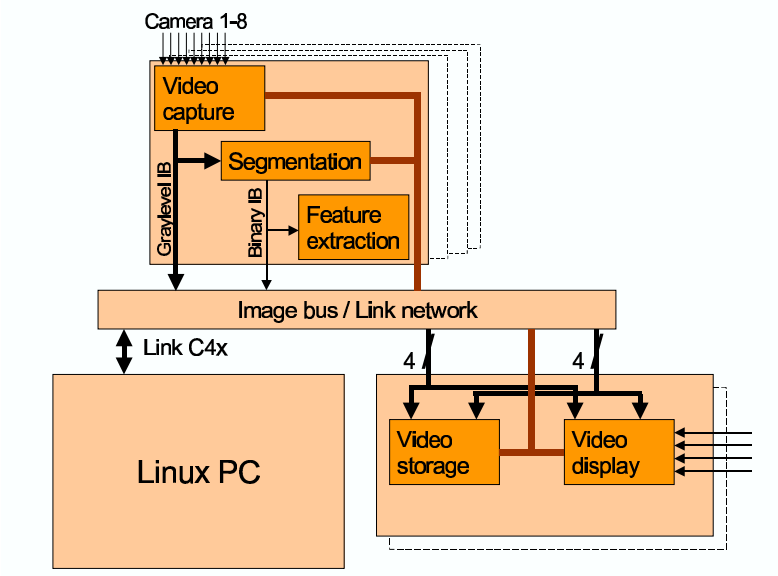

Figure 4 The OPAK Processor consists of a PC running Linux and custom developed HW. All image processing, and storage, retrieval and display of digital video is implemented in custom developed HW. High level detection processing (e.g. feature transformation, activity classification, alarm detection), as well as MMI, camera communication, database etc. is implemented on the Linux-based PC.

The custom HW is primarily implemented through extensive use of Field Programmable Gate Arrays (FPGA) from Xilinx. In addition to custom HW, each card contains one or more TIM-modules, each with one or two TMS320C4x (C40 or C44) signal processors from Texas Instruments. The C4x processors are used for configuration (e.g. FPGA programming) and control of the HW, and for (post) processing of data generated by the HW.

The following cards have been developed:

- *OLIVIA (Opak LIve Video input and Instantaneous Analysis)* implements video capture including camera multiplexing and A/D, HW for illumination change detection and camera control, instantaneous segmentation and feature extraction. Each OLIVIA card processes 50 fields per second, and can process data from up to 8 cameras. Digital video and binary images are transmitted on proprietary image busses to other cards. During testing and debugging image data can be received from the image busses.
- *OVS (Opak Video and Storage)* continuously stores digital video (received from the image busses) in circular RAM buffers (for the pre-alarm sequences). When an alarm is triggered the OVS stores an alarm sequence on a harddisk connected to the card. The OVS includes a system for displaying alarm sequences from the RAM-buffers or from the harddisk. The OVS is also able to digitize and display live sequences from up to 4 cameras. During testing the OVS can read a digital test sequence from disk and output it to an image bus, while at the same time receiving data processed on other cards (from another image bus) and storing them on disk.

A mix of these cards can be inserted in a custom developed backplane containing the image busses. In addition the backplane contains a C4x link network which connects C4x processors on the different cards. All communication between the Linux PC and the link network is routed through the backplane. One Linux PC may be connected to more than one backplane.

The SW is implemented using multi processing and multi threading both on the Linux PC and on the C4x processors. Communication libraries have been created which allow message passing across the two architectures. This permits a flexible and scalable system architecture. Communication on the Linux PC is implemented using TCP/IP, while in the C4x network it is implemented using Virtual Channel Router (VCR). Large systems (with more than hundred cameras) may be controlled from one MMI by connecting it to several OPAK Processors. It is also possible to connect several MMIs to one OPAK Processor.

5 DEVELOPMENTS TOWARDS A TIR UGS

In Section 2 the appreciated features of IDS and UGS systems are listed. OPAK meets the IDS list. We now want to address the UGS list.

The two first features listed are covered by OPAK image processing and pattern recognition algorithms. However, the system hardware and infrastructure do not accommodate the kind of covert surveillance one would like an UGS system to perform, and operation in enemy controlled areas will not be possible with today's implementation. To approach this application we would like to change the system architecture.

With reference to Figure 1, we would like to perform both low level and high level data analysis close to the cameras, so that long distance communication could be limited to a minimum. Restructuring the system to have separate processing units at each camera has started. Algorithms that currently are implemented in hardware are now being transferred into software. Thus when our aim is fulfilled, only extracted information (types and numbers of various objects, their speed and heading, kind of activity etc.) and alarm sequences are transmitted wirelessly to an OP. The alarm sequences are used for verification of the extracted information. Battery operation is a requirement, and low power consumption is extremely important for long unattended lifetime. This will be a major challenge.

Development of a new concept for generation of terrain models by use of LADAR has started. This will reduce the time needed to deploy the system in a given position to a minimum.

Figure 5 illustrates a concept using OPAK as an unattended ground sensor.

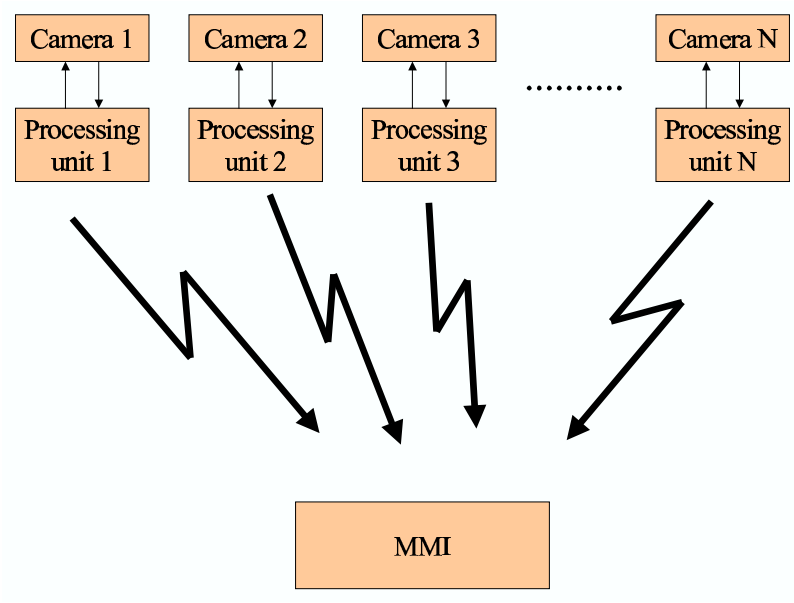

Figure 5 Concept of using OPAK as a ground sensor.

6 DISCUSSION AND CONCLUDING REMARKS

We have in this paper described the OPAK Video Intrusion Detection System, which also accommodates thermal IR. The system is supposed to serve as an aid both in peacetime security and wartime close defense. So far two variants are developed, one that serves the needs of "homeland security" for protection of properties/facilities and defense capabilities, and one transportable variant that can go with the armed force in international operations, and can be deployed fast and easy at the base abroad. Both systems are being tested this year (2003), one at an Air Force base in Norway, one at a Norwegian camp in Kosovo. Tactics for security, force protection and close combat taking advantage of such aids are being developed.

Important success criteria will be high intrusion detection probability (almost 100%) and low false alarm rate. There is, however, a trade-off between the two. During wartime and crises high detection probability is a must, whereas very low FAR is not so important. On the other hand, in peacetime low FAR is very important, whereas the requirement to detection probability may be slightly relaxed.

The most advanced Video Motion Detection systems on marked today seem to produce a FAR in the order of 2 - 10 false alarms per camera per day according to reports. At large installations 50 - 100 cameras may be employed. The FAR then sums up to several hundreds per day, which is not acceptable. In contrast, OPAK has in system acceptance tests demonstrated a FAR below 0.5 false alarms per camera per day. The system's FAR will of course depend on parameter settings and test conditions, and must, when taken as an evaluation measure, also be connected to its detection capability. OPAK was tested as part of an operative security system under difficult conditions at Gardermoen Air Force Base. In these tests, an experimental system has demonstrated very good detection capability. Under ideal conditions (acceptable visibility and light and no occlusion in the surveyed area) a near 100% detection probability is achieved, even with very small object to background contrasts. In our opinion OPAK meets all the needs listed for an IDS in section 2.2. Of course, there will be situations where optic sensors do not work well, but then OPAK also accommodates complementary sensors and data fusion.

We have also reported on a further development towards a thermal imaging UGS. We are already close to have such system for applications not requiring battery operation. By integration of some of the special electronics and conversion of some functions into SW as computer power permits, a much more compact processor could be made, and a portable system would be possible. This opens up for applications by mobile units, both for close defense, and as a ground sensor for early warning and tactical surveillance.

In a study performed by SAS-023*, Norway suggested OPAK combined with remotely fired Directional Fragmentation Charges (sector charges) as a possible alternative for anti-personnel mines (APM-A); see Figure 6. Simulations demonstrated that this kind of solution was the most effective alternative to APMs in infantry close combat defense, and was even better than the banned APMs themselves.

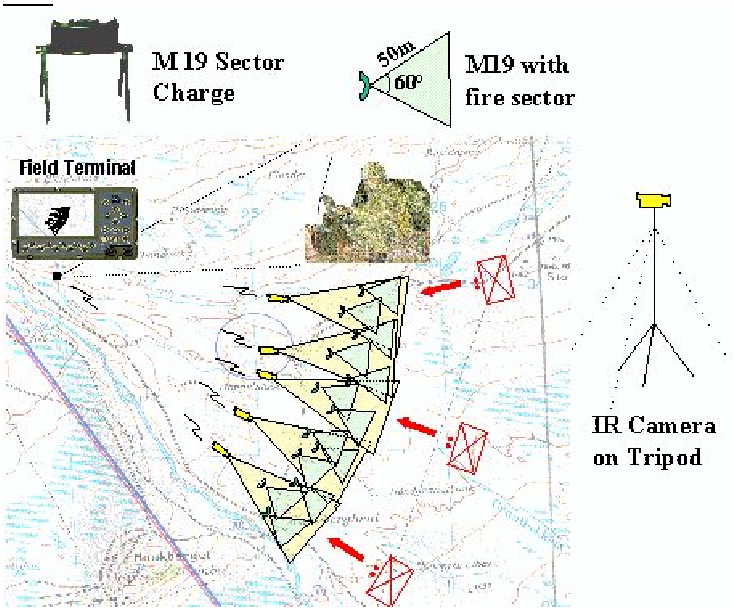

Figure 6 TIR-UGS combined with directional fragmentation charges as an alternative for anti personnel mines. Cameras are surveying the scene. All image processing (both low and high level) is done at the camera, and alarm information including alarm sequences is sent back to an operator wirelessly. The position and orientation of the charges are known to the system. When an operator acknowledges an alarm and hence arm the charges, a charge fires when the image processing system determines an intruder to be inside the charges' fire sector.

To get a TIR UGS that in a broad sense is applicable in surveillance, reconnaissance and target acquisition, and as an APM-A component, the system needs to be powered from batteries with a lifetime of at least a week. This is still very challenging and will not be included in the on-going development. With reference to the desired features of UGS, as listed in section 2.1, we also refuse to address the problems of remote delivery (no other UGS offer this ability either).

Despite the deficiencies of a first TIR UGS, as indicated here, such system will provide superior performance in many applications, not least as an aid in force protection and as an IDS, and the growth potential is enormous.

* SAS-023: NATO/RTO/SAS-023 – Alternatives to Anti-Personnel Mines.
RTO: Research and Technology Organization.
SAS: Studies, Analysis and Simulations.