Invited Paper

REVIEW OF INFRARED TECHNOLOGY IN THE NETHERLANDS

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ABSTRACT

The use of infrared sensors in The Netherlands is substantial. Users can be found in a variety of disciplines, military as well as civil. This need for IR sensors implied a long history on IR technology and development. The result was a large technological-capability allowing the realization of IR hardware: specialized measuring equipment, engineering development models, prototype and production sensors for different applications.

These applications range from small size, local radiometry up to large space-borne imaging. Large scale production of IR sensors has been realized for army vehicles. IR sensors have been introduced now in all of the armed forces. Facilities have been built to test the performance of these sensors. Models have been developed to predict the performance of a new sensor. A great effort has been spent on atmospheric research, leading to knowledge upon atmospheric- and background limitations of IR sensors.

Whereas a few decades ago the main thrust in the Netherlands was the introduction of the IR technology, in more recent years the new components, becoming available on the market, have led to drastrical improvement of the performance of the IR sensors. New focal plane arrays and faster processors mean a breakthrough in IR sensors, leading to more applications for lower cost.

A topic, on which The Netherlands are historically strong is the knowledge on target- and background signatures. Cooperation between research institutes like NLR, TNO and the Universities has led to large databases, which are used in the interpretation of IR (and optical) imagery. On the other hand this information leads to requirements for single sensors or fused sensors to be built. A lot of effort is spent on signature modelling, leading to knowledge upon operational aspects, when to fly with a sensor or how to conceal.

1. INTRODUCTION

The work on Infrared in the Netherlands has been presented on an earlier SPIE conference.[1] The activities are concentrated on all phases of detection chain as shown in Fig. 1. Each block in this diagram represents a group of activities. The targets and backgrounds may be military as well as civil: tanks as well as corn fields. The interpreter will have a different task. The civil interpreter is looking for phenomena of agricultural, geological or environmental interest; the military interpreter has to decide if he can observe the target or not.

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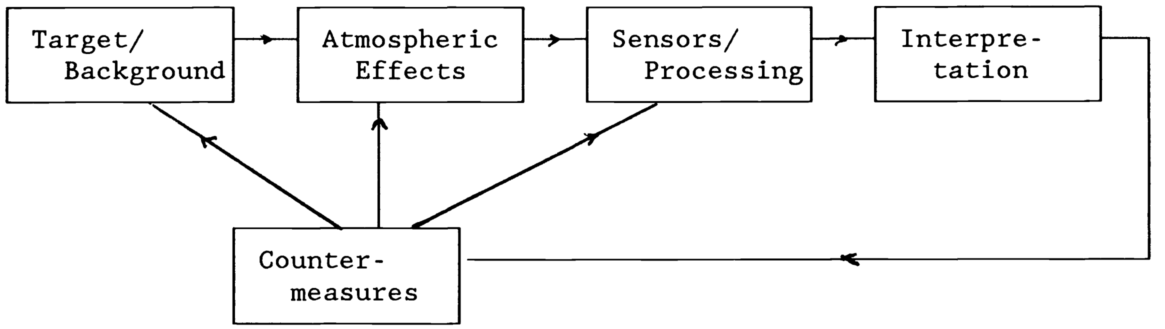

Fig. 1 Block diagram of Detection/Countermeasure Chain.

The scientific and technological competence, required to carry out this work is based upon the following topics:

- physics of the phenomena
- modelling and measurement
- signal processing (algorithms)
- sensor design (measurement equipment, demonstrators, production)
- evaluation (performance, effectiveness end to end)
- simulation techniques.

The driving forces behind our activities can be summarized as follows:

- increased threat (military); may not be the number but the quality of enemy sensors
- increased threat (civil); worry about pollution, energy consumption, food supply, traffic, etc.
- technological breakthroughs; new EO/IR components becoming available
- computation power; leading to better models, simulations, data analysis systems, etc.
- increased number of users, enlarging the market, the production, reducting the cost, etc.

Customers of our work are primarily national, although the large number of international contacts is still growing. Of these contacts can be mentioned NATO, WEU, EEC, ESA, bilateral contacts with many nations (governments as well as industries). They help to create new markets, because a small nation as the Netherlands has its limitations in capabilities and users. In this review, due to the limited space, a limited number of examples will be given of each group of activities.

2. PHYSICS OF THE PHENOMENA

This type of work concerns the constrast-forming around the target to be detected and the way how the atmospheric effects influence this contrast. A number of projects are currently going on, of which the next list contains some examples:

- variations of temperature-contrasts; heat balance equations (dynamic)[2]

. bi-directional reflection properties; contrast dependence upon irradiance distribution and respect angle
. temperature effects in vegetation, soil, water, etc. leading to natural land-clutter
. atmospheric turbulence effects on MTF and Point Spread Fuction
. formation of aerosols above the sea; dependence of size distribution on sea state, height, etc.
. spectral emission and -reflection of selective sources and atmospheric propagation.

The work on these topics concerns a variety of objects and backgrounds, of which some may be mentioned.

. sea- and sky background; variation of radiance in the spatial, spectral and temporal domain
. atmospheric refraction effects close to the horizon; effects of ducting, scintillation, mirages on point source detection
. detectability of environmental pollution and natural hazards; forest fire detection; heat pollution at power plants
. multispectral contrasts; increase in detection probability by spectral combinations; sensor fusion.

It is found that this basic knowledge, baring in mind the capabilities of new sensor technology, is fundamental for studies on new detection methods. The data bases, available in the Netherlands allow these types of studies. It has to be kept in mind however, that updating of this knowledge is of great importance. Background- and target signature data, measured in the past with measurement equipment of course resolution (spatially, spectrally, temporably) have to be upgraded when new detectors like focal plane arrays become available.

3. MODELLING AND MEASUREMENT

Here we mean the modelling and measurement of the IR signatures of targets and backgrounds. One of the more recent activities was the development of the NIRATAM model in cooperation with a number of NATO nations. The integration of the subroutines was done in the Netherlands. The model has been validated for aircraft and is available on the market (ONTAR).[3] The model has been modified since that time for other targets like missiles, ships and vehicles. Special feature of this model is the plume model, complicated due to exhaust gastemperature and concentration-variations over its dimensions.

A realistic eye has been kept in the Netherlands on the relative value of models, the accuracy that they produce the limitations of their input parameters and the approximations made. Therefore we endeavour a good balance between modelling and measurement. Thanks to good workshop and a long history of fine-mechanical and electronical specialism, unique measurement equipment could be realized. Examples of this type of equipment:

. space borne imaging radiometers
. airborne and ground based radiometric scanners
. spectrometers for all spectral bands (UV-IR)
. LIDAR equipment
. multi path, multi spectral transmissometry radiometry

. reflectometers.

The latter sensor has been developed for measuring the screening properties of smokes and other obscurants. In fig. 2, a schematic view of this device has been given.

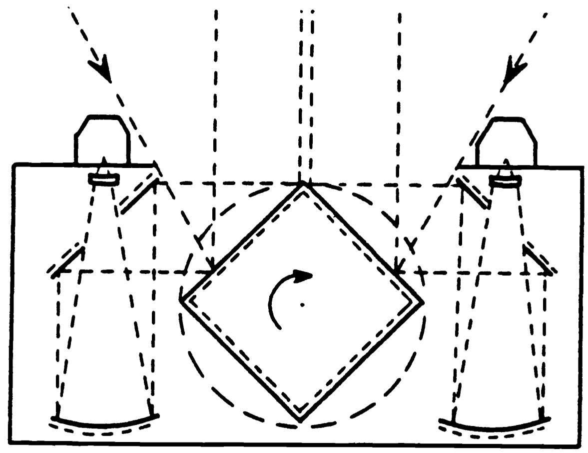

Fig. 2 Schematic view of MPTR system.

The device measures in 6 spectral bands and up to 16 lines of sight transmission and path radiance.[4] The sensor has direct output and evaluation of the performance of the obscurant. The system has been sold to other nations. A derivative of the sensor has been realized with internal calibrations in the object space. This is done to eliminate radiance of the optical components. This scanner is called DUDA scanner and is produced in small series.

Another valuable instrument for measurements is the BOMEM fourier transform spectrometer for the spectral region between 1 and 14 micrometer. Of course additional facilities allow for special measurements e.g.

- data recording systems; digital fast, large dynamic range
- steerable platforms
- tracking units
- rotating table for large targets to allow signature measurements for all aspect angles
- calibrated sources from small, high temperature up to large, low temperature
- global positioning sensors.

4. SIGNAL PROCESSING

The driving force behind signal processing is the need for false alarm reduction. In many cases the IR contrast of targets is embedded in background clutter. In some occasions, like nighttime, wetty weather background clutter may be wiped out and even tiny contractrasts of the targets make them visible. Even if the contrast is below the Noise Equivalent Temperature Difference (NETD) of the sensor, the target may be detectable. But as soon as sunrise is happening, clutter appears and targets may disappear. Sometimes human observers may discern the target due to the pattern recognition of his brain or due to the eventual motions of the target. Most of the time observers send to loose their concentration and their observation performance. Therefore the goal our research concerning signal processing is to reduce the workload of the observer or even to eliminate him, to be replaced by an Automatic Target Recognizer.

The most important techniques, used in Automatic Target Recognition (ATR) are mentioned in the following list:

. All EO/IR spectral discrimination; reflection and/or emission
. Spatial discrimination; patterns shapes, contours (edges)
. Temporal discrimination; signal growth curve, cloud drifting; sea wave motion
. Active sources for irradiation (3D, lasers)
. Motion detection in stationary background
. Sensor fusion (acoustic, mm wave, IR, etc.).

These signal processing techniques have been applied in several projects e.g.

. forest fire detection (multispectral, temporal)
. agricultural, environmental work (multispectral)
. Infrared Search and Track (IRST) sensors (shape, signal growth)
. Infrared Detection Set for ORION-P_3 (spatial, temporal)
. Laser vibration detection (CO_2 laser, temporal)
. Missile Approach Warning (spectral, temporal).

The status of these activities is not yet at the end of the possibilities. Thanks to the development of fast computers, parallel processing and possibly optical computing, there is still a long way to go. Criterium for the success of the ATR will be the increase of the hit-probability in relation to the cost aspect. Preferably new systems should be smaller and cheaper with higher performance (end-to-end). This will create new applications and markets as mentioned in the introduction.

5. SENSOR DESIGN

In chapter 3 a number of measurement sensors has been mentioned already. Sometimes these devices are very similar to demonstrators, a type of sensors built to demonstrate new principles or new techniques. In most cases these demonstrators are built in the Laboratory, shown to users and manufacturers, sometimes followed by engeneering development models or prototypes. Some examples of demonstrators, realized in the past or more recently are:

. FLIR technology with linear detector arrays
. Multi-element airborne line scanner
. IR tracking sensors with rosette scan pattern
. IR surveillance sensor for ships
. Missile Approach Warning for airborne use
. Airborne IR detection system for point targets at sea
. CO_2 laser BIFF sensor

. Focal Plane Array (1D + TDI and 2D) technology
. Spaceborne IR sensors (for astronomy and/or ground survey)

The Netherlands has a long history on optics design and as a consequence well equipped electro-optical industries:
. Delft Instruments Electro Optics
. Thomson USFA
. Hollandse Signaal Apparaten.
These industries have been active in developing IR sensors for the national and international market. The biggest market has been the military, for which a staff requirement has been set up for many applications e.g.
. IR Sensor for Armoured Personel Carrier
. IR Sensor for TOW system
. IR Sensor for Leopard II
. IR Sensor for Marines
. IR Line Scanner for F16 recce pod
. IR Sensor for Lynx helicopters
. IR Search and Track Sensor for Goalkeeper system.
Unfortunately not all of these products were made by the national industry due to the large competition.
Thanks to National Technology Projects however, the industry is trying to keep track of the new developments in order to compete in the future with other companies (or to cooperate in consortia). The main aim for the near future will be the realization of cheaper systems without loosing performance. Cost is a driving factor, being the major challenge for the industry. International cooperation and standardization will be a key issue.

One aspect of sensor design is the modelling of the sensors. Thanks to modern fast computers, it is becoming more and more common to simulate sensors before they are really built. The advantage is that for low cost easily parameters can be varied. Images can be produced of a synthetic scenario through a synthetic atmosphere by a simulated sensor. This capability is presently being created at FEL-TNO. One step further leads to Tactical Decision Aids, informing the user upon the range, his sensor might have under certain operational conditions. Or at what range his platform (ship, vehicle, aircraft) can be detected by other sensors of certain type.

6. EVALUATION

Evaluation, performance testing and effectiveness studies are major items at FEL-TNO. In these situations we choose the side of the user and carry out studies and or measurements upon candidate systems. In most cases we have given assistance in the phase of setting up requirements so we are familiar with the wishes of the user. A very important aspect in this world of procurement and assessment is our knowledge of the way how sensors are used, what the feelings of the user are and what the user needs.

In all the sensor-applications mentioned before we have played a role in the evaluation. For this purpose a set of test equipments have been bought or built:
. 30 cm collimator; 3 m focal length
. calibrated sources:

- 900 k, 500 k; variable size
- extended with bar patterns; 0,005 k accuracy

. noise measurement equipment
. spectrometers
. zoomcollimator
. data recording equipment.

With this equipment we can measure all kinds of sensor parameters such as:
. Noise Equivalent Temperature Difference
. Noise Equivalent Irradiance
. Minimum Resolvable Temperature Difference
. Line- and Point Spread Function
. Signal Transfer Function
. Spectral Response
. Responsivity; variation of responsivity over field of view.

Besides these standard parameters, special effects can be measures such as response to high intensity sources, battle effects, retro-reflection etc. In a number of cases the sensor evaluation takes place by comparison. It is important that all sensors observe simultaneously the same target in the same condition, preferably in the terrain. For this purpose we developed 2 large test sources of 2 x 2 m which can be heated or cooled down around ambient temperature. We also can use a 4 bar pattern of 2,3 x 2,3 m with a temperature difference between 2° and 10°C, comparable to the standard used in the requirements of many users.

Recently we developed a system for objective MRTD testing[5] based upon a simple line spread function measurement and measurement of responsivity and noise. Using a standard eye - Noise/MTF behaviour, MRTD is measured within a few minutes. In order to create more test capability, a zoomcollimator was designed and successfully tested in a test with 14 thermal imagers in the Netherlands. In fig. 3 a schematic view of this device is shown.

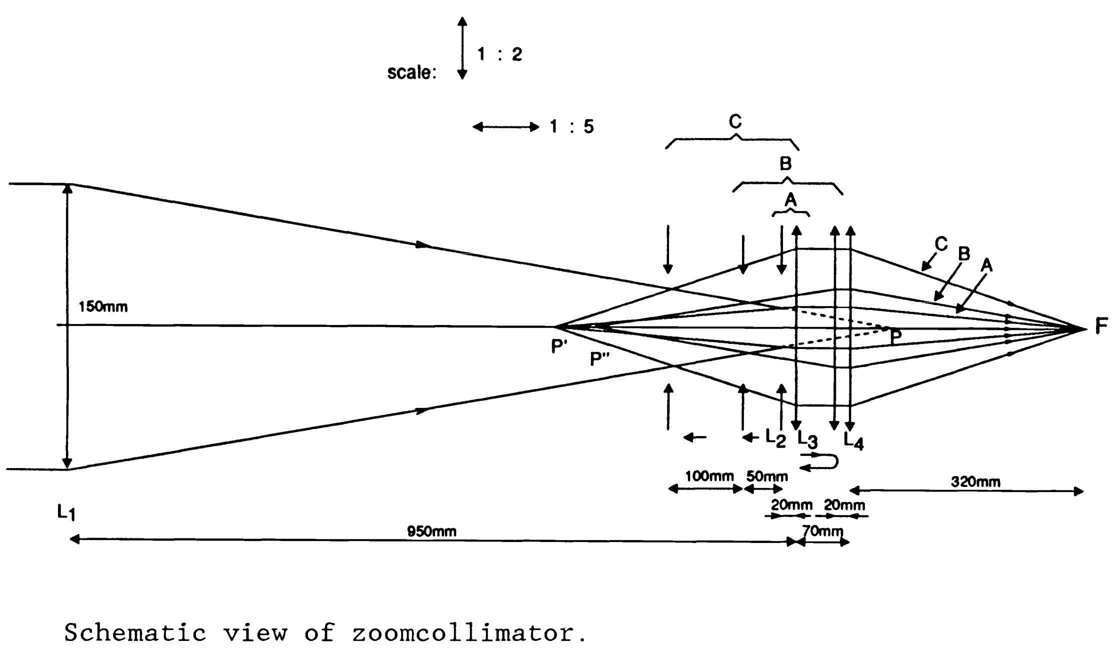

Fig. 3 Schematic view of zoomcollimator.

Whereas in normal MRTD measurement sets the temperature is varied at each bar pattern, we keep the temperature here constant and vary the focal length (equivalent to range) and immediately read out the recognition range for a given temperature difference.

7. COUNTERMEASURES

The work on countermeasure, by its nature is meant to reduce the threat of being hit. At FEL-TNO we have a long history on countermeasure techniques. By means of techniques, developed at TNO or elsewhere, experience has been obtained in most of the areas:

. signature reduction by:
  - shielding (constructive, insulation)
  - cooling (water, air)
  - reflectance changing (paints, structures)
. screening (by smokes, obscurants)
. use of camouflage materials
. use of concealment:
  - decoys for ships
  - flares for aircraft
. jamming sources.

A great difficulty in this work is the establishment of the effectiveness. Simultaneous testing of treated and non-treated equipment is not always possible. The user wants to know the reduction in detection- or identification range or probability, but for what sensor. And if the sensor is made more clever, the observer may still be able to detect the target. For this purpose simulations are under development with algorithms with some level of sophistication. It is too time consuming to call for each experiment groups of observers to evaluate the effectiveness of a certain countermeasure.

The sensors used for evaluation of countermeasure techniques are similar to those mentioned in chapters 3 and 5. Special difficulties arise in measurement of decoy signatures due to the generally high temperature and radiant intensity. Radiometers have been built to measure simultaneously in a large dynamic range the radiant intensity in 10 spectral bands from the UV up to 14 μm.

8. CONCLUSION

In this presentation it was shown that the Netherlands is rather allround in the field of IR technology. Beside some basic components like detectors, a lot of know how exists to realize sensors. Strongest topic remains the knowledge about what you can see with these sensor.

9. REFERENCES

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