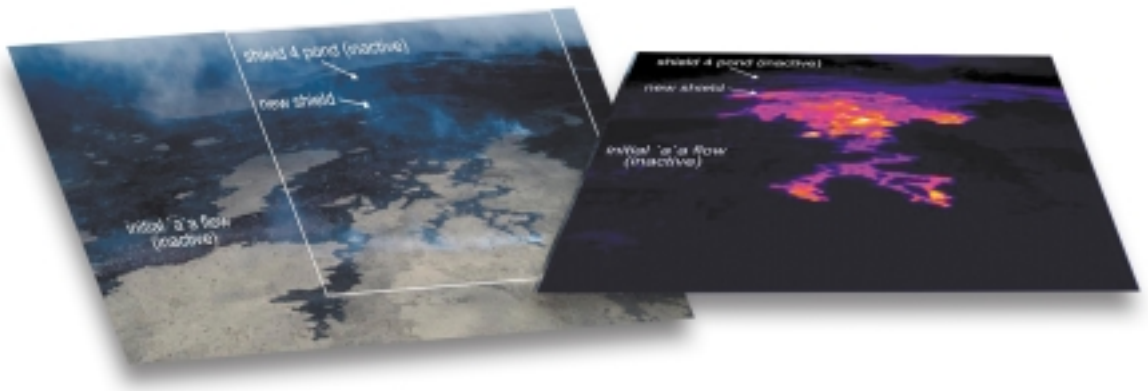
1st Place

Synthetic Aperture Radar and Forward Looking Infrared: Operational Applications



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Introduction

The use of SAR (Synthetic Aperture Radar) and FLIR (Forward Looking Infrared) technologies is extremely important for reconnaissance and combat military missions. The possibility of obtaining images generated by thermal characteristics of the environment and targets (FLIR), as well as high resolution capacity for long distances regardless of the time of acquisition and the environmental conditions (SAR) have led to an expansion of tactical knowledge about theaters of operations, whatever its nature: air, sea or land.

As a result of the possibilities and limitations of each system, the current trend is towards the use of multifunctional systems, i.e. systems that congregate information generated by more than one sensor so as to obtain a hybrid image. Based on the proper algorithms, the system eliminates points without confirmation of ambiguities, generating a more accurate response to field operational problems.

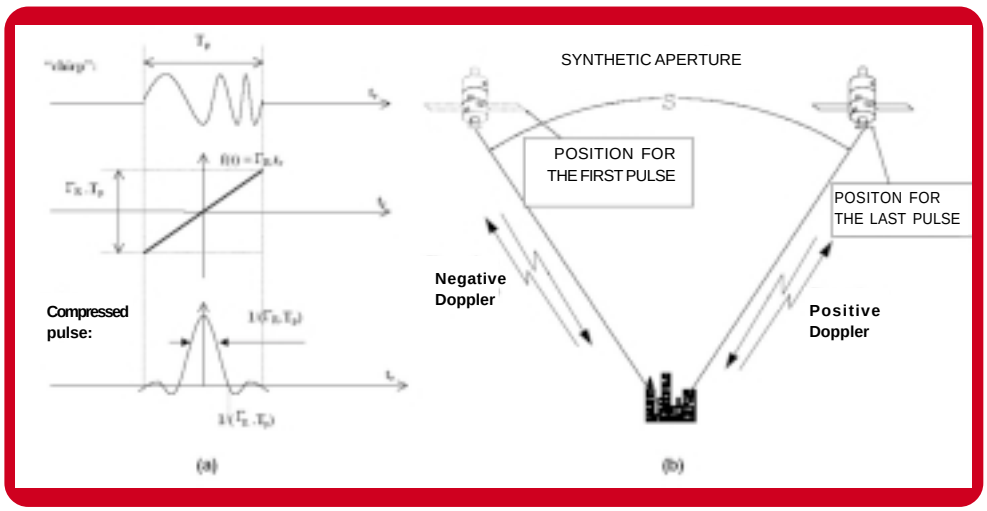
Within the current international scenario, mastering SAR and FLIR technologies grants the independence of design, production and acquisition of these sensors. In order to analyze this trend, let us have a brief review of SAR and FLIR techniques.

SAR and FLIR techniques: A Comparative Picture

SAR Technique

The conventional radar presents a very poor spatial resolution, both in bearing and distance. As a result, the use of signal processing techniques that increase this resolution capacity has been considered for imaging systems. This system has been known as Synthetic Aperture Radar or SAR. It is based on the following principles:

- It is a coherent radar, that is, the acquisition covers the phase and range of the echo signal.
- To get a much shorter pulse at very high power, its width must be increased, which results in resolution degradation with the distance. To lengthen the pulse and obtain a better resolution, the pulse compression technique is used, modulating it in either frequency or phase, with variation of the chosen parameter for modulation, which may be linear or not.
- To generate a synthetic aperture, i.e., to simulate an antenna with a wider beamwidth, Doppler is used, generated by the movement of the antenna in relation



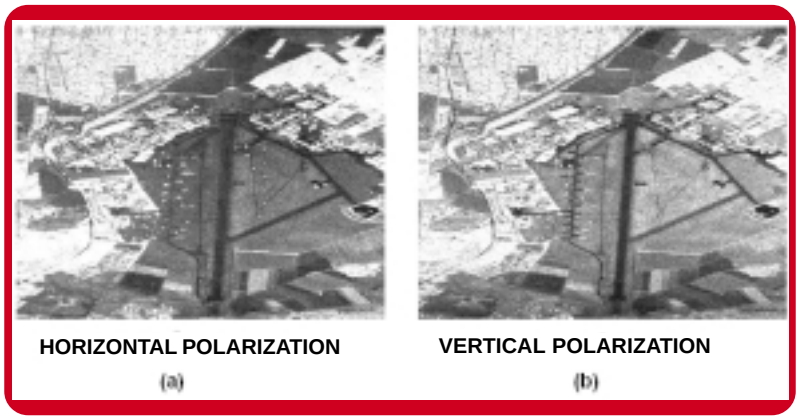
SAR Technique:
a) Pulse Compression
b) Synthetic Aperture

to the target, from the coherent compensation of each echo, from its respective phase resulting from the antenna-target distance. As the resolution is approximately the ratio between the wave length (l) and the distance covered by SAR while the object is still in the field of view (S), the more S is synthetically increased, the better the resolution.

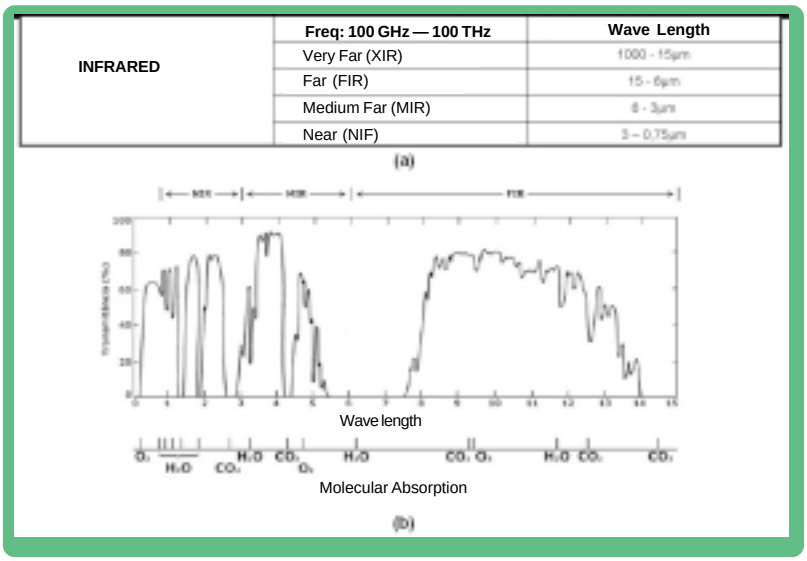
The SAR system is renowned for the fact that it uses a radio-frequency source as radiation generator. This radiation source is active and may have its parameters of frequency, polarization and angle of incidence previously chosen by the operator. SAR's echo signal depends on electromagnetic properties; on geometrical shape (relief); on roughness of dimensions similar to wavelength of the wave carrier; on frequency; on polarization; and on angle of incidence. In this way, the calibrated image represents the scene or its backscatter coefficient (s_o).

Due to the penetration characteristics of the electromagnetic wave, the system can generate images in the presence of clouds, fog, and rain, and regardless of the time of day. With the correct choice of wave frequency and polarization, one may obtain images of tree tops or of a forest floor.

However, a drawback is its low capacity of detection of moving targets due to the need to compensate an aircraft or satellite's "pitch", "roll" and "yaw" movements, in addition to the noise produced by the coherent processing of the backscattering and reflected signal known as



Images generated by the SAR-580/DLR radar from the variation of polarization of the transmitted signal

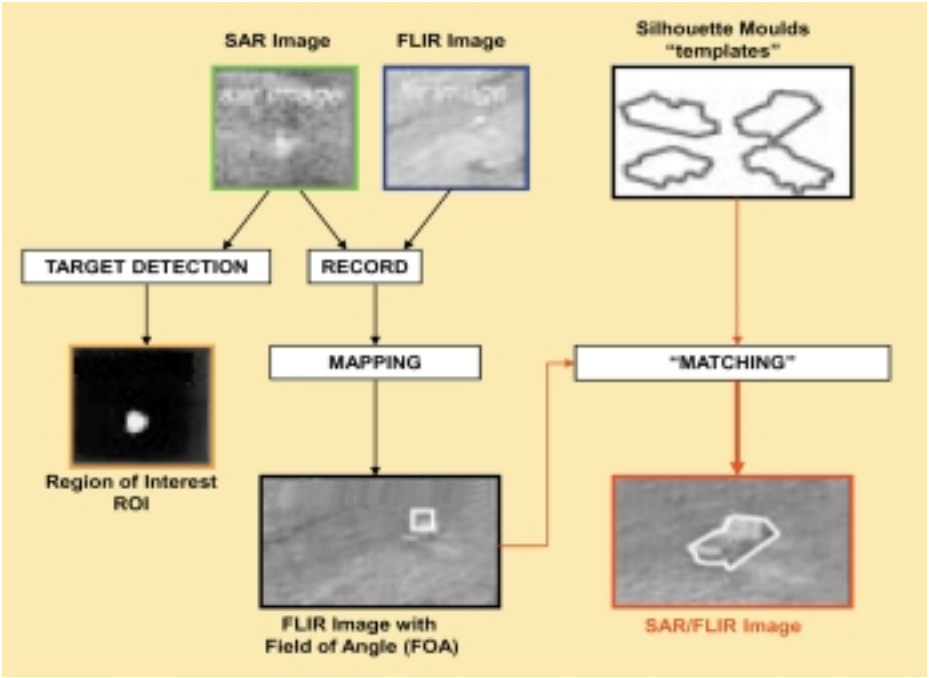


a) Division of the infrared
b) Absorption windows of infrared signals in the atmosphere

"speckle". These factors reduce the automatic distinction and classification of the image.

Owing to these characteristics, the SAR radars are militarily employed in the following missions:

- Satellite or airborne reconnaissance of enemy territory.
- ATR (Automatic Target Recognition).
- Identification of oil spills at the sea, indicating the passage of non-authorized ships.



SAR/FLIR Fusion for automatic target recognition (ATR) systems

FLIR Technique

The Imaging Sensor FLIR (Forward Looking Infrared) uses a matrix (array) of passive photosensitive infrared detectors that scan a scene to provide a visible image of the thermal radiant standard detected in it, discriminating the levels of irradiation emitted and reflected by natural and artificial objects, without the need of the platform movement to compose the image.

They usually operate in an 8 to 14 mm (microns) wavelength range, where there is also a good transmission window in the atmosphere. In tropical environments, they can use the 3 to 5 mm range, with less absorption by water vapor.

The major advantage of the FLIR sensors is that there is no need to light up the object and, in ideal conditions, they present a resolution that may be three to six times greater than the visual, allowing for a better discrimination of elements of a scene.

However, the system has drawbacks in the presence of unfavorable atmospheric conditions such as rain, clouds, humidity or fog because the absorption curve is altered and there is more spreading of infrared energy due to the mixture of higher concentration of some gases. This considerably reduces the FLIR's sensors resolution when compared with the SAR.

Due to these characteristics, they are militarily employed in:

- Amplification of human vision capacity.
- ATR (Automatic Target Recognition).
- Guidance of weapons and alarms.

SAR and FLIR Fusion: Future Perspective

The current trend to improve target recognition and acquisition is the use of multisensor systems. From the fusion of data from sensors that cover more than one frequency band, it is possible to verify redundancies that can correct errors of discrimination of the images generated by a single sensor. One of the options that

SOME EXAMPLES OF THE USE OF THE FUSION TECHNIQUE OF SAR/FLIR IMAGES

(a) (b) (a) (b)

a) ROI detection by the SAR system
b) "Rendered" image, with the distinction of the target's silhouette

may considerably increase the reliability of associated systems for ATR missions would be the fusion of the SAR and FLIR systems. Actually, this technology has already been patented in the USA and shows how useful and important it may be after its military and commercial implementation.

In general terms, SAR and FLIR systems coexist in the same platform. Each sensor's signals are processed separately and, through the adequate selection of algorithms and parameters, data is merged into a hybrid image with more distinct and precise information. The systems use a sensor as a filter for the other.

While target detection is easier to be achieved in a SAR image due to its higher dynamic band and its better response to artificial objects, most of the ATR algorithms are more stable in a FLIR-like sensor. Therefore, the advantages of both sensors can be combined using the detection of the Region of Interest (ROI) in the SAR image as part of a focus of the warning mechanism to identify the corresponding ROI in a FLIR co-registered image. In this way, the ATR can be executed within those regions of the FLIR image.

As a result, the complete system has a low rate of false alarms, high probability of detection (SAR) and high level of recognition (FLIR).

Conclusion

As it can be observed, the use of the SAR and FLIR techniques is extremely important for the modern detection systems. Occasional deficiencies in sea, air and border surveillance could be reduced if we could rely on orbital or airborne platforms with SAR, FLIR or hybrid systems. Moreover, military tasks such as target recognition, threat identification of, generation of patterns of thermal signatures and SAR, in addition to the civilian use such as deforestation, fire and oil spill control on rivers and seas can have their effectiveness greatly increased with the use of these technologies described.

REFERENCES

– FERNANDES, David. Processamento Radar do Curso de Especialização em Análise de Ambiente Eletromagnético (CEAAE). 2006.

– JACOB, Alexsandro Machado. SAR Image Classification using supervised neural Classifiers. 2003.

– BASTOS, Antônio Frederico. Sistema Imageador Infravermelho Termal: Características, Descrição e Resultados, Anais do X SBSR. INPE, Sessão Técnica Oral. 2001.

– BOSCHETTI, Cesar. Detectores de infravermelho – Princípios e Caracterização. 2006.

– SHAFIQUE, Alper Yilmaz, Khurram. Target tracking in airborne Forward Looking Infrared imagery, Image and Vision Computing. 2003.

– CHEN, Yangl. SAR and FLIR image registration method, United States Patent 6795590. 2004.