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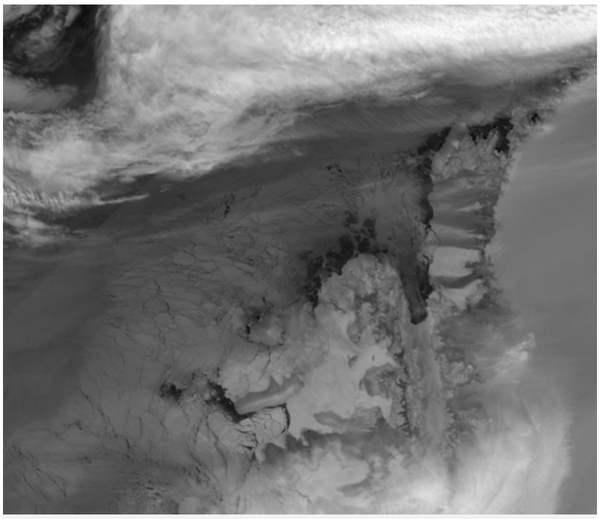
E-learning for radar image interpreters

by **Alexander Streicher**, Fraunhofer IOSB



Charcot Island, Antarctica - NASA Earth Observatory

In peace or war, the fate of millions can depend on the analysis of images gathered by camera, radar or other imaging sensors. These images might reveal the truth, like the 1962 U-2 pictures of Soviet missiles in Cuba, or support an allegation, like the chemical road tanker pictures produced by Colin Powell at the United Nations before the Second Gulf War. Interpretation can be a stunning breakthrough, like 1943 “ski site” pictures of V-1 launching sites in France or a missed opportunity, like the 1944 South African Air Force photographs of Auschwitz-Birkenau. Alexander Streicher reveals how radar image interpreters are now being trained in the German armed forces (Bundeswehr) for crucial work with global importance; supporting scientific research, tackling disaster relief, tracking climate change and sometimes telling the truth about weapons of mass destruction.

In military intelligence and military reconnaissance knowledge is power and one way to get to know your opponent is to watch him from the air, or from space.

But it’s not so simple. Enemy countermeasures, natural atmospheric disturbances and daunting technical challenges complicate the task. Even when you are watching your enemy under the best conditions, you may not understand what you are looking at. When the fate of an army can hang on a small detail being observed or missed, the training of the image interpreter becomes critically important.

And when you have trained your image interpreters, how can you persuade them that the task requires life-long learning to follow bewildering changes in technology and politics?

Figure 1

Image interpretation can range from microscopic images of small organisms to images of our universe, but the Bundeswehr image interpreters are usually concerned with images gathered from aircraft or satellites and have to be able to recognise objects and interpret their meaning from what is known about the location. Target objects are often vehicles (Figure 1), camps or barracks.

The image interpreters often work under heavy time pressure from mobile bases in countries remote countries like Afghanistan, handling varyious sensors and imaging parameters (Figure 2).

Figure 2: Mobile laboratory - ©Fraunhofer ISOB

Analysis of the images of complex infrastructures such as airfields, harbours and industrial installations by Synthetic Aperture Radar (SAR) is a task requiring long periods of training and extensive experience.

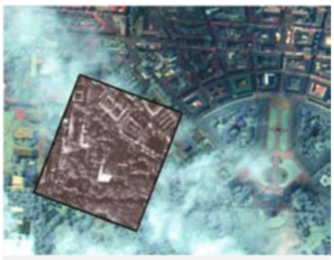


Figure 3: Radar vs. optical image, penetration of clouding - ©Cassidian radar, ©Eurimage, otical

SAR imaging technology is used widely in both civil and military situations. On the civilian side the technology is used for pollution detection, map making, and monitoring of ice layers and vegetation. For the military, radar images have many advantages over optical images, since they indicate what the territory will look like in the dark or below cloud cover. SAR images are largely unaffected by weather effects like heavy cloud. Figure 2Figure 3 shows an optical satellite image of downtown Karlsruhe in Southern Germany. In the optical image some city areas are covered by cloud. But the radar sensor penetrates the cloud and presents a clear view, the sort of view that might be priceless to someone monitoring the nuclear facilities of an unfriendly foreign state.

SAR-Tutor – E-Learning Course for Radar Image Interpreters

New SAR satellite systems like SAR-Lupe and TerraSAR-X offer the great advantages for reconnaissance but demand personnel capable of handling the data.

The SAR-Tutor e-learning course for radar image interpreters was set up with Bundeswehr experts by the Fraunhofer IOSB and is now deployed in the German armed forces. Figure 4 shows a screenshot of the SAR-Tutor's "Introduction to the Doppler Effect". The students get background knowledge from texts and graphics and by interaction with schematic explanatory content (the fire truck in the bottom left).

SAR-Tutor is part of a blended-learning scenario in the German armed forces. The e-learning system is Web-based, to allow students to study before and after their course.

Figure 4:

The training group includes personnel with varying levels of skill and experience, so content is aligned to look like a manual, with books, chapters and sections. In the basic level SAR-Tutor includes four books which covering the principles of radar and how to interpret radar images of airports, harbors or industrial facilities. A later book offers rare information about how to identify of specific types of industrial building objects in radar-based aerial images.

The first book on "Radar Principles" introduces basic physical principles like electromagnetic waves as well as radar basics and basic radar technology. The second book "SAR Principles" covers the Doppler Effect and synthetic aperture radar technology. A small part of this book also covers the principles of radar image processing. The specific SAR effects are covered in the third book, "Procedure of SAR Image Inter¬pretation". Working with this book develops skills in recognizing and identifying the very specific radar effects in SAR. The fourth book "Object Oriented Interpretation" deals with the interpretation of real life objects like civil and military airfields and harbours.

The didactic strategy follows a constructivist approach where the students are encouraged to interact with the content by interactive elements to "build up" their knowledge. The students can "play" with the content to increase their motivation and eventually their learning efficiency.

With an e-learning system and course programme like SAR-Tutor the German armed forces are maintaining a high standard of image interpretation skills. New personnel can be quickly and flexible trained and the experienced image interpreters are continuously update their knowledge.

ViSAR – Radar Simulation for Training

ViSAR, Visualisation of Geometric SAR Effects, is a training system to develop an understanding of the specific effects coming from SAR sensors.

Despite its advantages in poor weather and in the dark, SAR imaging technology suffers from its own special and very complicated problems. Depending on the illumination angle by the radar sensor these effects can severely affect the two dimensional representation of the object.

As an example see Figure 5. Displayed on the left is a simplified 3D model of the Stephan's church in Karlsruhe, Germany. On the right a simulated rendering of a radar illumination of this very scene is shown. No change in scale, rotation or position has been done. The rendering on the right exactly reflects the radar signature of the model on the left. The illumination angle is given by the viewing perspective.

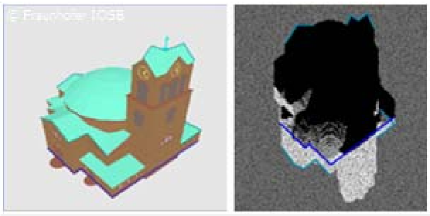


Figure 5: Radar signature example - ©Fraunhofer IOSB

Three main effects, layover, foreshortening and shadows, are prominent in this rendering. The first, layover, is explained in more detail. The layover effect can be seen at the flipped down church tower. As this is the highest point of the church the radar beam is first reflected by the tip of the tower. This reflection returns first at the radar sensor followed by the rest of the tower and then by the rest of the church. BThings reflected first are shown first. The tower is therefore flipped downwards. The black area in the rendering looks like shadow because no radar beam was reflected. Foreshortening can be seen at the dome of the church. In the rendering a somehow shortened representation of the dome is displayed in shaded grey (instead of white as for layover or black for shadows).

The task is to interpret the radar signature and infer its true entity. In image interpretation you only get the radar signature (the grey image) and no image (or 3D model) of the actual building or vehicle. Because of these various radar effects it become gets very hard difficult to identify the objects. Can you tell by just looking at the radar signature (Figure 6, right) what object in reality has produced such an image? One may argue that you always have the ground-truth by looking at the scene first-hand or using the high-quality aerial photos from Google Earth, Microsoft Virtual Earth etc. For Germany, the USA, Great Britain and so on this may be true, but for distant places like Afghanistan or Iraq this can be very complicated. Furthermore, military image interpretation usually involves moving targets like tanks, field guns and temporary encampments.

Tools like ViSAR allow the image interpreters – both students and professionals – to train their comprehension of radar effects in radar signatures. They can simulate how the radar signature of a particular object is rendered. They can manipulate the object to fit the scenery they encounter in the real world.

A screenshot of ViSAR is shown in Figure 5Figure 6. On the right an example for a simulation session is shown. The user has marked some points at the object and the tool displays a schematic visualization of radar beams and their reflections at the house-shaped object plus the resulting radar signature.

For training purposes this is of great interest. Image interpreters can test various scenarios before and after the image interpretation process. In mission planning such tools can help the planners to adjust the position and illumination angles of the radar sensor to deliver the best radar signature of the object or region of interest. In image interpretation the tool can help to verify the interpretation by remodelling the scene or object and then simulating it.

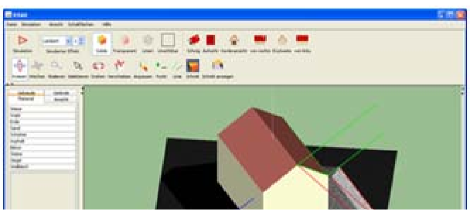
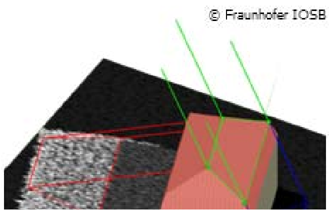
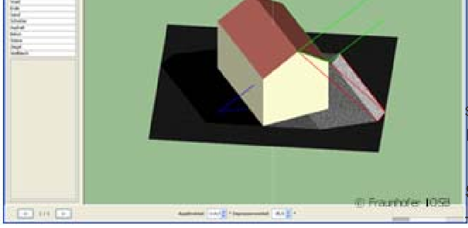
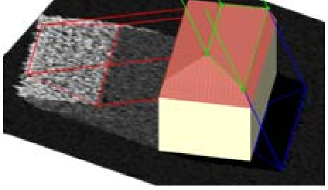


Figure 6: ViSAR – interactive training simulator for radar effects.
Left: user interface. Right: schematic visualisation of radar beams and their reflections at a house-shaped object with the resulting radar







signature (© Fraunhofer IOSB)

Summary

This article presented the motivation for radar image interpretation and how it is applied to military intelligence and military reconnaissance. Two examples of e-learning for radar image interpreters are shown. The first, SAR-Tutor, is an e-learning system with content about radar image interpretation. The second, ViSAR, is a radar signature simulator that allows image interpreters to understand various radar effects.
Since aerial image interpretation can sometimes make the difference between military success or failure, image interpretation personnel must be optimally trained and get access to up-to-date information.

Photograph front page:NASA space radar, false colour image of Kilauea, Hawaii.