Technology Based Training for Radar Image Interpreters

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***Abstract*—This document describes the need of training tools for radar image interpreters. Concepts, methods and solutions for supporting technology based training are presented and demonstrated by means of two examples: SAR-Tutor is a computer based training software for learning the basic principles of radar image interpretation. ViSAR is a simulator for exploring and understanding geometrical effects which occur in radar images. The interaction of these two tools and their use in operational training scenarios are explained.**

***Keywords*— SAR; radar; E-Learning; training; simulation; Serious Games; CBT; WBT**

I. Introduction

In the last decade more and more spaceborne radar sensors have been launched in the orbit and deliver lots of high resolution images to the remote sensing community. Especially Germany has access to high resolution data due to programs like TerraSAR-X, Tandem-X and SAR-Lupe. The benefits of radar images in comparison to optical images are obvious, because you can achieve images at night as well as under cloudy weather conditions.

At a first glance so called SAR images (Synthetic Aperture Radar) look like optical images everybody knows from Google Earth. SAR is a special type of radar where the sensor aperture is artificially enhanced by using complex data processing techniques. But at a closer look you will see differences, which could not be explained with common optical transformation models.

E.g. the top of mountains folds forward and is displayed ahead of the bottom of the mountains. A moving vehicle is not located in the middle of a road but is shifted a couple of meters next to its real position (see Fig. 1). Small objects can outshine their surroundings though they should not be seen due the sensor resolution.

Therefore SAR image interpretation is a challenging task, which requires intensive education and training of remote sensing interpreters to achieve a sufficient SAR interpretation expertise.

Fig. 1. Moving ship misplaced on the shore

Ten years ago only radar courses for scientists with academic background were offered mainly by universities or other research institutes. These lectures were not suitable for remote sensing interpreters who are working in the German armed forces (Bundeswehr). The gap between mathematical theory and daily practice was too big. Therefore special training courses for nonacademic SAR interpreters were developed and established, first at the German armed forces and later also in the civilian sector (e.g. at ASTRIUM GEO-Information Services, Infoterra GmbH). The goal was not to explain radar principles with complex formula for differential and integral calculus but to show the physics in an easy and user adapted way and to familiarize the interpreter with radar image interpretation.

To enhance the effectiveness and efficiency of such training courses it is important to harmonize the course participants, i. e. the more homogeneous the knowledge of the students the more efficient the course could be held. Thus the challenge was to deliver motivating learning materials for the students which ensure an individual user adaptable curriculum for remote radar image interpretation.

II. Approach

To keep in mind the boundary conditions mentioned above, we decided to concentrate on technology based learning (TBL) concepts, which includes also all kinds of E-Learning methods and tools. Here a wide area of concepts like Computer Based Training (CBT), Web Based Training (WBT) and simulations are available and can be adapted to the needs of radar image interpretation training. Combining E-Learning elements with face-to-face seminars leads to so called Blended Learning concepts, where the best of both worlds are used.

TBL concepts allow learning individually, independent of special time and places. Also the order of learning units can be adapted to the knowledge, skills and preferences of the student. Once the learning material is developed it can be duplicated and deployed very easily.

III. RESULTS

In the following we introduce to the concepts of a CBT/WBT tool and a simulation tool for radar image interpretation.

A. *SAR-Tutor*

The E-Learning software SAR-Tutor is developed in order to facilitate and support the training and education of radar image interpreters. We decided to use a textbook metaphor. So the content is arranged in books, chapters and pages. „SAR-Tutor“ consists of four books:

- The first book is called “Radar principles”. Among other things it deals with some physics like electromagnetic waves, the basics of radar technology and basics of the real aperture radar technology.

- The second book is called “SAR principles”. It covers further physics, like the Doppler Effect, synthetic aperture radar technology and principles of radar image processing.

- The third book is named “Procedure of SAR image interpretation”. It describes the procedure of radar image interpretation in detail and trains skills in recognizing and identifying radar effects. It also trains basic skills in segmenting a radar image.

- The forth book is called “Object oriented interpretation”. It deals with the interpretation of objects in detail, for example finding and segmenting an airfield.

The user group of SAR-Tutor we focused on is very heterogeneous with different knowledge background and ages. For our didactic approach we assume that all users have at least the German “Mittlere Reife” degree, which is comparable with the well known “International General Certificate of Secondary Education” (IGCSE).

Therefore we use formulas only if they are simple and absolutely necessary. For complex issues interactive animations were used. With this interactive content the students were able to explore and finally understand the physical principles and the relations between sensor components and the signature representation in the SAR images. Furthermore parts of animations are used in other animations, if they are used in topics which are based on other topics. In Fig. 2 such two related animations are shown: in the first animation the Doppler effect is explained whereas in the second the issues of ground moving target are described. Most of the parts of the first animation are re-used in the second animation. The knowledge learned by studying the first animation could be easily transferred to the second animation.

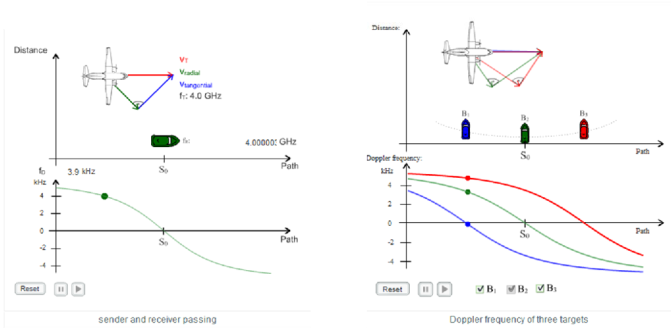

Fig. 2. Left: Doppler effect, Right: Moving targets

To sustain the learning process we followed the constructivist approach, which means that content is not just presented static. Here the student “builds up” his own knowledge. For example different kinds of animations, as shown above, should initiate processes of accommodation and assimilation in which the learners construct new knowledge as their knowledge from their experiences.

For didactical issues the learning content is divided in orientation, explanation, action and source knowledge. There are text components, pictures, audio and video elements as well as interactive animations. To support the learning process the student has to perform exercises. But the exercises should not handicap the learners by exploring new chapters. Sometimes they are not allowed to continue a course until they solved a special test or they got a predefined minimum scoring. To avoid such frustration we decided not to use such restrictions in our software. The exercises we offer are suitable for the students to recognize their knowledge level. They decide to which chapter they will jump after performing an exercise and what they will learn next.

Using always the same type of exercises will easily lower the learning progress of the student [1]. Different types of exercises are inserted like multiple choice (MC), drag and drop, clozes and image exploitation exercises to avoid boredom [2].

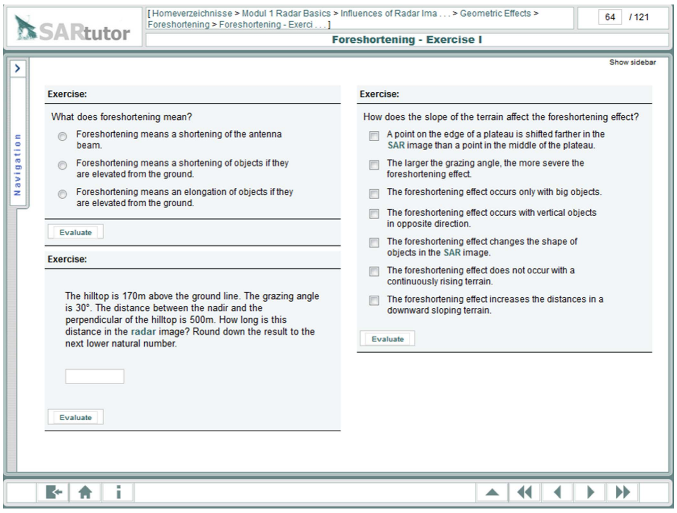

Fig. 3. Multiple choice exercises, cloze exercise

To reduce the probability to guess the right answer we not only use MC single select but also MC multiple select types where more than one offered answer could be right. Also for the drag and drop exercise type, where you have to assign items from one group to items to a second group by dragging there is a chance to solve the task by guessing. In the case of the cloze type the student has to insert a word or a number, therefore the probability to get the right answer by chance is very low (see Fig. 3).

The image exploitation exercise is particularly adapted to the special need of a learning tool for image interpreters. Basic image manipulation functions like zoom, rotation, contrast and brightness are available to enable the student to detect, recognize and analyze signatures in the radar image. One of the main tasks of the student is to mark objects in the image. Therefore he is able to set marks on the images. If these marks are inside the invisible polygons which are set by the author of the exercise, the task is solved correctly. After performing a task, the student can verify the results. All correct marks are colored in green whereas the incorrect are colored in red. Furthermore the polygons are shown to the student during the verification phase. (see Fig. 4)

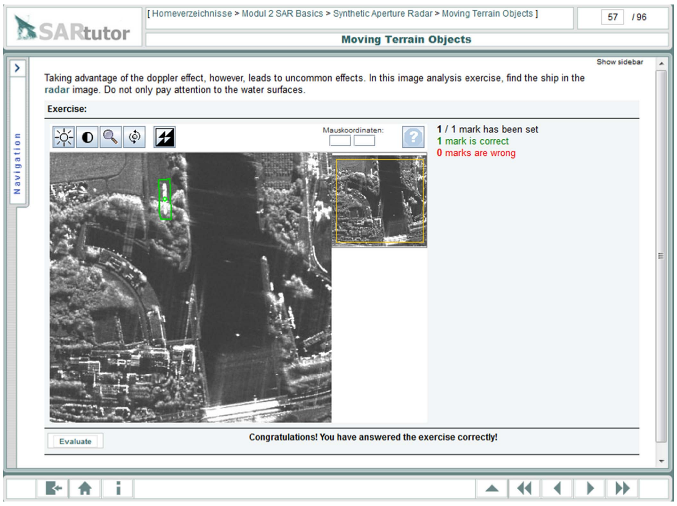

Fig. 4. Image interpretation component

B. ViSAR (Visualization of Geometrical SAR-Effects)

ViSAR is an easy to use simulation software tool to explore the basic geometrical effects which occur when generating images with radar sensors. Especially radar characteristics like foreshortening, layover, layback and shadow can be examined. Similar to ray tracing algorithms the linear propagation of the radar beam is traced, by considering single and multiple reflections. In Fig. 5 the ViSAR user interface showing an urban scenario with an underlying simulated radar image is displayed.

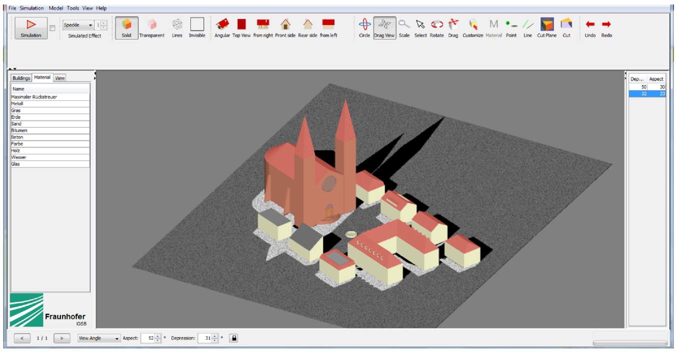

Fig. 5. Simulated urban scenario

Basic 3D objects like cubes, pyramids and cylinders are provided by the system. The student can move, rotate and expand the basic objects and combine them to complex 3D models. I addition it is possible to assign a material type e. g. concrete, metal, wood etc. to each surface of the 3D object. After constructing the 3D model the student can inspect the results by looking around the scenario. Here the student's perspective corresponds to the angle of view of the radar sensor, i.e. with this inspection tool aspect and depression angle of the sensor relative to the whole scenario can be adjusted. Now the simulation process can be activated. Different kind of areas like shadows, ambiguities etc. are calculated and displayed. The most important thing is that this calculation needs only a couple of seconds for moderate sized scenarios. The student can store the simulation results and continue with a new adjustment of the sensor or scenario parameters. Afterwards the various simulated images can be displayed simultaneously and the influence of parameter adjustments to the radar signatures can be compared.

To really understand the radar effects like foreshortening and shadow it isn't enough to see the resulting radar image corresponding to a 3D scenario. Often the interpreter cannot explain where a special signature in the image comes from. Therefore the explanation tool "point" permits the student to select an arbitrary point of the 3D model and visualize the corresponding rays in the scenarios. So the whole propagation way from the sensor to the ground object and back again to the sensor can be traced. With the "line" tool every edge of the 3D model can be selected and the corresponding line in the simulated radar image is highlighted (see Fig. 6). Besides also the border of the shadow is displayed.

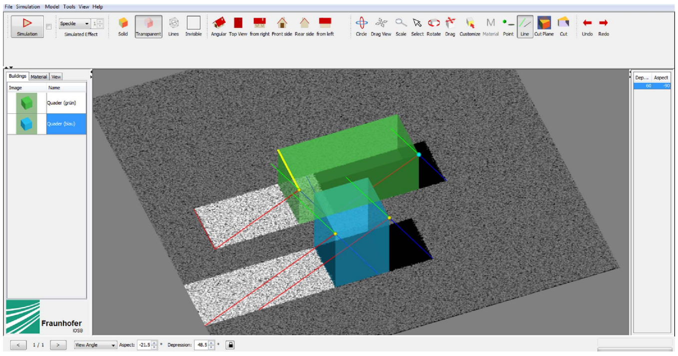

Fig. 6. Explanation tool "point" and "line"

Sometimes signatures of objects are repeatedly displayed in radar images. The reason is that the radar signal is reflected not only at the object itself but also at the ground (especially if it is water). Then the distance the radar signal has to cover is extended and the object signature is displayed at a range position farther from the right position. To examine those phenomena the student can display all rays occurring from multiple reflections, which correspond to a preselected point of the 3D model. (see Fig. 7)

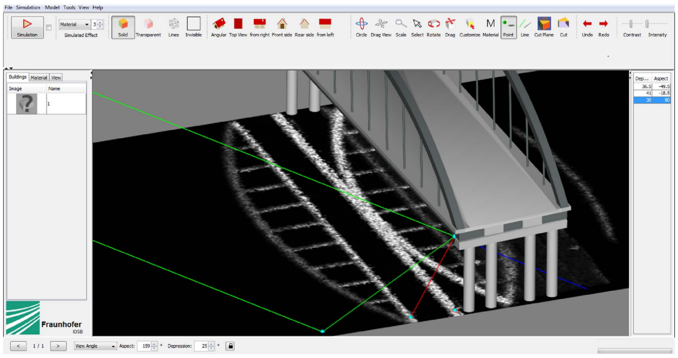

Fig. 7. Multi reflection ray tracing

C. *E-Learning and Simulation*

Simulation tools alone are not sufficient for a learning setting. Often sophisticated simulation tools, developed for sensor development are provided to the image interpreter without a pedagogical or didactical concept. The interpreter is overcharged with the big functionality and the complex user interfaces. The student does not know how to use the simulator and what the tasks the simulator is good for are. An instructor is needed to guide the learner and to tell what to do with the present simulator.

Here we tread a new path and combine CBT/WBT tools with simulation tools. As an extension we developed a new SAR-Tutor module which was combined with the ViSAR simulator. In the first chapters the goals and usage of the simulator is explained. The learning objectives of the following chapters are to get accustomed with the geometrical radar effect mentioned above by using the ViSAR. In various sub chapters the student will be encouraged to solve radar typical questions by using the simulator. To solve the tasks which are assigned in the SAR-Tutor chapters the student can jump to the preconfigured ViSAR simulation environment. The environment is already adapted to the task i.e. the suitable 3D models are prepared and other configuration parameters of ViSAR are adjusted. After using ViSAR simulation the student is able to answer the questions in SAR-Tutor. He inserts the answers into the exercise and checks the correctness of the results.

Thereby SAR-Tutor overtakes the role of an instructor or teacher and helps the student to use the ViSAR simulator correctly. Furthermore the learner is animated to use simulation. According to predefined learning objectives the interpreter is guided through a tutorial with focus on exploring and investigating the influence of scenario and sensor parameters on geometrical radar effects.

IV. OPERATIONAL SCENARIO

Due to the system architecture SAR-Tutor and ViSAR can be used as self learning software as well as a tutor guided tool.

In the first scenario it was delivered as CBT on a CD-ROM or DVD to the learners for preparation to a face to face course at the German armed forces. New image interpreters have to work through the first two books to enhance their knowledge to the required level necessary for attending the course.

During the second scenario all students in the lecture room are connected with a server running SAR-Tutor and ViSAR. Complementary to the face to face tutorial the teacher can individually assign exercises to the students, adapted to their knowledge and skills. Dependant on the current subject suitable chapters of SAR-Tutor also in combination to ViSAR can be chosen.

Since several years the German armed forces deploy their new setting called "Fernausbildung" of a blended learning scenario assisted by human "Teletutors". We also support this third scenario with the WBT version of SAR-Tutor. The teacher (Teletutor) is connected with the students and controls the learning process by unlocking new chapters and exercises. The students use SAR-Tutor and ViSAR as reference for refreshing their knowledge (see Fig. 8).

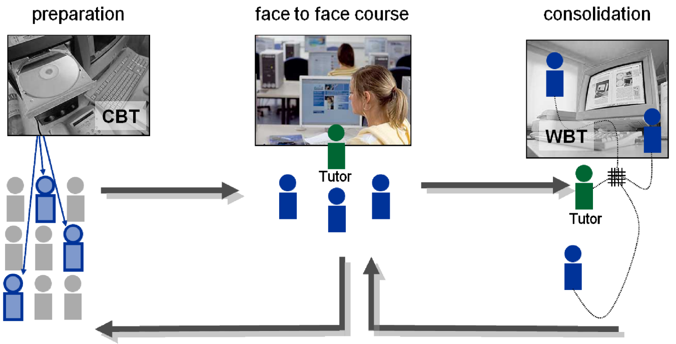

Fig. 8. Operational scenario for CBT and WBT

Fig. 9. Sketch of a Serious Game for image interpretation training

V. OUTLOOK

One of the biggest challenges for the future is how to motivate learners for learning. Especially intrinsic motivation which comes from the learner itself and not from constraints of his environment helps to enhance the learning process.

Much effort will be done in the adaption of learning systems to the learner. The challenge is to monitor the user behavior and to conclude to his status based on his actions. For this purpose user models will be developed which describes long-term properties, e. g. sex, age, language, native country, as well as short-term properties like mood, skills and knowledge. In combination with didactical models the learning system proposes suitable learning units optimized to the current user and the current situation [3].

Contests are also good concepts to motivate learners. Particularly for WBTs, which are connected via internet or intranet, scoring and ranking mechanisms deliver possibilities to compare the performance of the students and serve for stimulating learning processes.

Finally to keep in mind the new generation of interpreters who grow up with game consoles, smart phones and tablet computers are accustomed with games and ask for easy learning environments. Here new developments focus on game based learning, so called “Serious Games” (see Fig. 9). The idea is to use the flow channel gamblers are caught in to learning processes. Studies show that with these concepts intrinsic motivation and sustainability of learning can be improved considerably.

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