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Holography, Radar Data and Interpretor Performance

A test of the Synthetic Aperture Radar Interpretation System showed significant improvement in the completeness and accuracy of detection performance.

Introduction

Recent advances in the state-of-the-art of side-looking radar systems have surpassed the capabilities for processing and displaying the data from these systems. Currently the image quality of radar maps is limited by the correlation and recording methods utilized to produce the final radar output map. These limitations prevent the image interpreter (I.I.) from observing the full signal content of the radar data. Until recently the interpreter had no choice but to accept the correlated map film no matter how poor the image quality and radar information.

Abstract: *The objective of this study was to determine if an experimental radar viewing technique, the Synthetic Aperture Radar Interpretation System (SARIS), could improve the performance of image interpreters detecting tactical targets from selected radar imagery. Six radar image interpreters performed a radar exploitation task using both the SARIS Viewer and conventional image interpretation techniques. Comparative performance measures of detection accuracy and detection completeness scores as a function of speed were calculated. The test imagery consisted of multiple radar passes from different radar systems over an Army exercise in Fort Hood, Texas. The results indicated that for viewing the imagery with the SARIS technique, interpretation performance was significantly superior to that using conventional interpretation techniques.*

In attempting to solve this information transfer problem, the AF has demonstrated the feasibility of extracting from synthetic aperture radar data, the total signal content. This concept is a unique technique for presenting and displaying all the image information recorded by a synthetic aperture radar system. Its main attributes are that it overcomes the dynamic range and focusing problems which plague conventional radar image interpretation and enables the I.I. to manipulate the radar information to obtain the optimum display of the target situation.

Detailed information on the SARIS (Synthetic Aperture Radar Interpretation System) concept is documented elsewhere and is available from the author upon request. However, the basic concepts are presented below. Fundamentally the standard complicated format of the doppler phase history of the Synthetic Aperture Radar (SAR) data is converted into a simple holographic format. The holographic record upon illumination with a coherent light source projects an aerial image. If this holographic record is viewed through a special viewer, it allows the photo interpreter to perform operations on the aerial image which cannot be done today or which require the generation and evaluation of many output maps.

With the viewer the interpreter can manipulate the aerial image to perform aspect-angle viewing (which provides different look angles of the target), incoherent integration (which provides a higher signal-to-noise ratio), and spatial frequency filtering. The

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interpreter need not be knowledgeable in optical data processing to operate the viewer. Also, the final map output is independent of the parameters chosen by the correlator technician in processing the radar imagery.

Although the SARIS concept theoretically, and under subjective experimentation, provided more information to the interpreter than conventional exploitation systems, a qualitative evaluation of the SARIS concept was necessary to determine if the additional information provided by this unique viewing system could actually improve interpreter performance. This paper compares experimentally the image interpreter performance of a controlled group of radar interpreters utilizing conventional and SARIS viewing devices as a function of time.

Test Design

In order to determine if the SARIS concept does, in fact, improve the extraction of information of tactical-sized targets in radar imagery, it was first necessary to obtain test imagery which fulfilled the following requirements:

- It had to contain a sufficient sample of tactical size targets along with reliable ground truth information, and
- It also had to be in the holographic format compatible for viewing in the SARIS viewer.

To satisfy this criteria, test imagery was selected of a combined Army-AF exercise conducted in a remote area of Ft. Hood, Texas. Seven different passes were flown over the nine-square-nautical-mile test area with three different radar systems. Each pass contained 44 tactical targets in three main target areas.

Radar image maps were recorded as were holograms of each scene. The radar maps were recorded in the usual manner, i.e., in a tilted plane radar correlator. The holographic records were fabricated by introducing a reference beam in the image plane of the correlator during the correlation process.

Six of the seven image scenes available were chosen to be viewed by six test subjects. Each subject viewed each of the six different image scenes. Each of the two viewing methods (*SV*-Saris Viewer, *LT*-Light Table) was utilized by each subject three times. This resulted in six trials per subject. Each subject viewed the designated photograph in a randomly assigned order and by the method *(SV/LT)* also randomly assigned.

Each subject was trained as a SARIS viewer operator and given test procedure instructions before participating. All six subjects were operational image interpreters chosen from as homogeneous a group as practical to eliminate as much subject deviation as possible. Each subject was instructed to search each image scene, working as quickly and accurately as possible, and to detect and locate all visible imaged targets which appeared in the test area only.

The original test design called for six image scenes. However, it was found that the ground truth for Image 5 was incomplete, making it impossible to score that scene correctly. Therefore, only five image scenes (1 through 4 and 6) were used in the evaluation. Each interpreter was tested in a secluded work area. Test equipment included the SARIS viewer, a light table and 8× magnifier, and a standard response sheet.

It should be noted that the liquid-crystal screen which was installed in the SARIS viewer was not utilized. The liquid-crystal screen eliminates the speckle effect inherent in laser viewing devices by utilizing molecular scattering to destroy the coherence of the laser beam. However, in this application, it also reduced the illumination level. As the screen illumination level of the viewer was already low, it was decided to sacrifice the reduction in speckling for the additional screen brightness. In order to eliminate the speckle effect, the interpreters then had to translate the imagery on the viewer screen or move their heads back and forth. In either instance, it increased the time required to detect the targets viewed on the SARIS viewer.

The imagery displayed on the SARIS screen also had another drawback. The illumination was monochromatic at 6238Å which results in a red and black display. The test subjects were disturbed by the red display but no measure was recorded of its effect on image interpretation performance.

Analysis of Data

The data were analyzed using the detection-completeness and detection-accuracy scores as a function of time. The completeness measure was defined as the total correct detections divided by the total possible targets whereas the accuracy score was defined as the total correct detections divided by the total correct detections plus the incorrect detections. These values were com-

TABLE I. COMPLETENESS DATA AS A FUNCTION OF TIME

Cumulative Time Interval	SV	LT
15 sec.	5.9	0.9
30 sec.	11.2	2.3
45 sec.	17.7	3.4
1 min.	21.8	7.8
2 min.	29.4	16.0
3 min.	32.6	25.9
4 min.	33.5	26.8
5 min.	35.5	31.2

puted for specific time intervals during the five-minute testing period. Table I shows the cumulative completeness values as a function of fifteen-second intervals for the first minute and one-minute intervals thereafter.

Figure 1 portrays this data graphically. The curves are expressed as logrithmic equations that have been fitted by the method of least squares to the data points. The curves indicate that the completeness values for the SARIS viewer up to and including the first two minutes are overwhelmingly superior to those values obtained using the light table. For the first fifteen-second interval, more than six times as many targets were found employing the SARIS viewer. Even at the one-minute mark, approximately three times the number of targets were detected with the Viewer than with the light table.

The completeness ratio of the two curves diminishes thereafter until the five-minute mark. The number of targets detected using each viewing method and the ratio of targets detected utilizing the SARIS viewer to the number of targets detected utilizing the light table *(SV/LT)* as a function of time are shown in Table II.

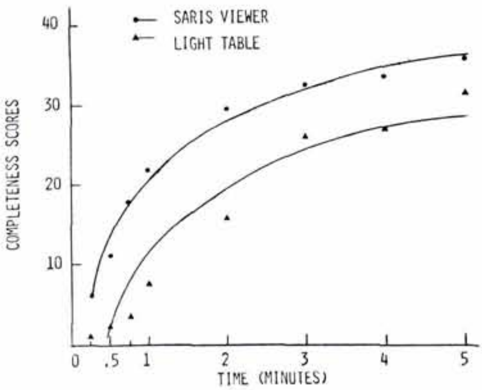

FIG. 1. Completeness scores as a function of time.

TABLE II. TARGET DETECTIONS AS A FUNCTION OF TIME

Number of Targets Detected			
Time Interval	*SARIS*	*Light Table*	*SV/LT*
15 sec.	39	6	6.5×
30 sec.	74	15	4.9×
45 sec.	117	21	5.5×
1 min.	144	51	2.8×
2 min.	194	106	1.8×
3 min.	215	171	1.3×
4 min.	220	177	1.2×
5 min.	234	206	1.1×

TABLE III. ACCURACY DATA AS A FUNCTION OF TIME

	Method of Viewing	
Time	SV	*LT*
15 sec.	56.4	28.6
30 sec.	58.7	32.6
45 sec.	57.4	34.4
1 min.	59.2	35.7
2 min.	58.0	38.0
3 min.	57.8	42.8
4 min.	56.7	40.8
5 min.	56.0	45.4

A similar time analysis was conducted for the accuracy data which are summarized in Table III.

As the data trends for the two viewing devices differ substantially (Figure 2), the data were not curve fitted. The accuracy scores for the SARIS viewer are approximately equal for the entire five-minute period. However, the values are slightly lower at and

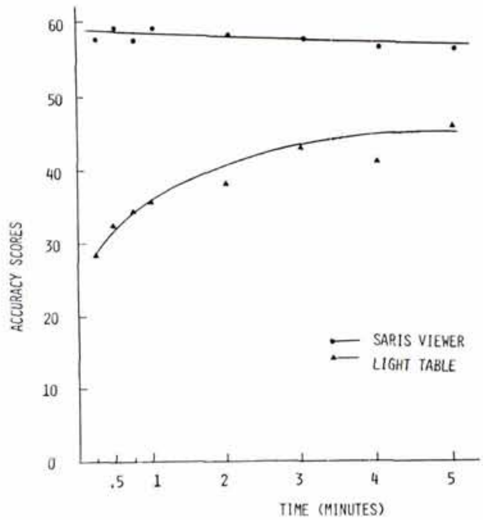

FIG. 2. Accuracy scores as a function of time.

TABLE IV. FALSE ALARMS AS A FUNCTION OF TIME

Time Interval	*No. of False Alarms* *SARIS*	*Light Table*
15 sec.	29	15
30 sec.	52	31
45 sec.	87	40
1 min.	99	92
2 min.	141	173
3 min.	157	229
4 min.	168	257
5 min.	184	293

near the five-minute mark. This was expected as the obvious targets are detected quickly, leaving the less obvious targets to be detected at the longer time intervals which increases the interpreter's chances of detecting a false target. The light table values, however, increase with time. Because the targets are not as obvious utilizing the light table, the accuracy levels for the first time intervals are lower. With increased examining time, the accuracy values increase until the maximum number of targets are detected. Still, the SARIS viewer is superior to the light table for all time intervals.

The number of false alarms for both viewing techniques as a function of time are shown in Table IV.

RESULTS

Using SLR conventionally to detect tactical targets that are reasonably subtle has previously proved to be a very difficult task for the image interpreter. Consequently, the most recent emphasis in radar image exploitation has been placed on automatic change detection techniques. However, with the SARIS viewer the most subtle targets appear to *pop out*, thus enhancing quick and accurate detection and reducing the search time.

Obviously, the optimum use of the SARIS viewer would be as a complementary manual over-ride system which would confirm military targets detected in an automated radar change detection system prior to their presentation to the strike commander to reduce the overall probability of false alarms.

This test evaluation proved conclusively that the SARIS viewer did, in fact, improve detection performance significantly from the standpoint of completeness and accuracy. Post-test oral critiques with each subject also substantiated the original hypotheses. However, it must be remembered that the data are based on a small number of image scenes (six) with a limited number of targets in each scene (44). Therefore, the following conclusions are somewhat fewer and more tenuous than they would otherwise be, but they still seem to be warranted by the data.

★ During the shorter time intervals—15 seconds to 2 minutes—the number of targets detected utilizing the SARIS viewer are approximately 6 to 2 times as many as using the light table.

★ The completeness performance for both viewing methods as a function of time can be expressed as a logarithmic function.

★ The accuracy performance for the SARIS viewer decreases slightly as the time interval exceeds three minutes. This is due to the fact that the obvious targets are quickly detected and the less obvious targets (which have a higher false alarm rate) are detected at the longer time intervals. The accuracy performance values for the light table still behave logarithmically with respect to time. However, its performance was still significantly below that of the SARIS viewer.

★ For all the applications examined, both completeness and accuracy performance values for the SARIS viewer were significantly higher than their respective performance values for the light table.

Although the data presented are extracted from a limited number of experimental samples, it is hoped the data presented herein will substantiate the need for the continual development of unique interpretation systems for the optimum extraction of information from remotely sensed data.

Two Meetings in October—see pages 616 and 629.