COMPARATIVE INFORMATION EXTRACTION FROM SAR AND OPTICAL IMAGERY

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ABSTRACT:

Presently EuroSDR, controlled by the Technical University of Berlin, is conducting a test on competitive information extraction from state of the art airborne multi-polarised SAR imagery (C, X and L – band) and high resolution optical imagery of the same area. The test envisages 3 stages, namely visual interpretation and map compilation, automatic object extraction and sensor fusion. Some first results are shown.
The interpretation results of three interpreters will be shown, two of them being skilled photogrammetric operators, the third having only limited experience with SAR images. All interpreters have been given a principal theoretical course on SAR specific imaging features and properties and training possibilities on a separate SAR scene together with map information which was not part of the test.
A common interpretation and - for reasons of comparison - mapping key has been set up and on screen interpretation started using the SAR scenes only, before the optical imagery was interpreted. Object extraction was conducted for linear objects like roads, railways or rivers and area objects like agricultural, forest or residential areas. In some limited areas also single buildings were extracted in order to show the full potential of the imagery. Both interpretations (SAR and optical) have been compared according to accuracy and completeness using the optical data as representative master because of missing reference data. Difficulties in identifying objects by the interpreters will be discussed and compared It can be shown, that in most cases the completeness and correctness of linear and area features as compared to the interpretation of optical data is satisfactory and that discrepancies between both interpretations may be explained.

1. INTRODUCTION

Within an EuroSDR contest, organised by the Technical University of Berlin, a competitive information extraction is performed on both, state of the art airborne multi-polarized SAR imagery (see Table 1) and high resolution optical imagery of different terrain types.

Region	λ	Polarisation	Resolution
Trudering	X	none	1.5 m
Oberpfaffenhofen	L	lexicographic	3.0 m
Copenhagen	C	Pauli	4.0 m
Fjordhundra	C	Pauli	4.0 m

Table 1: SAR images used for the different test areas

The used data sets are described in detail by Hellwich et al. 2002. The true-colour optical data available for each area was resampled to the pixel size of the corresponding SAR images. The optical images have been acquired at different dates than the SAR data, however the exact acquisition times were not provided.
The test is foreseen for three stages namely:

- visual interpretation
- automatic object extraction and
- extraction from sensor fused data

This paper will show some first results of the first stage, in which visual interpretation by on-screen digitizing had been performed. The interpretation achieved with the SAR images will be compared with the results based on optical images. Topographic maps have not been available, by this reason the optical images are used as reference. However each of the 3 interpreters used his own interpretation of the optical data as his own reference.

Region	Landscape Content
Trudering	Fairgrounds
Oberpfaffenhofen	Agriculture & Industry
Copenhagen	Residential & Industry
Fjordhundra	Agriculture & Forest

Table 2: Test sites and their characteristics

The 4 test sites (see Table 2) show a different terrain structure in terms of landscape contents, ranging from agricultural to rural and industrial.
Two of the interpreters do have a long year experience in interpretation of aerial photographs but not with SAR images.

2. INTERPRETATION PROCEDURE

As has been previously shown by Albertz (1970) and Schneider (1974) the quality of image interpretation is very much affected by the experience of the interpreters (Fig. 1). This is especially true for SAR image interpretation because of totally different imaging characteristics.
Because of missing experience with interpretation of SAR images the interpreters were trained for the specialities of SAR by using a tutorial of CCRS and multifrequency SAR images together with topographic maps of an area not being part of this contest.

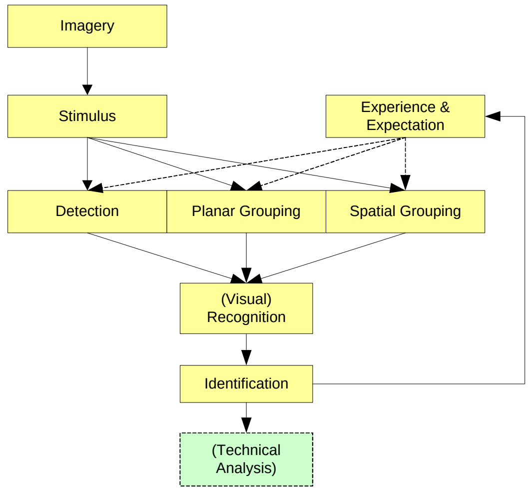

Figure 1: The Image Interpretation Process (Albertz, 1970)

Ground pixel size of SAR images is considered to be of greater importance than different polarisation shown as colour. The pixel size differs for the test areas from 1.5 to 4.0m (Table 1). In the Trudering area no polarisation has been used, leading only to black and white SAR images. Some authors (Ohlhof et al., 2000) refer to the NATO Standard (STANAG 3769), recommending the appropriate ground pixel size for the detection, recognition, identification in some cases also technical analysis of image objects (Table 3), whereby the following definitions are used:

Object	Detection	Recognition	Identification	Technical Analysis
Terrain Features	~800m	90m	3m	0.75m
Urban Areas	60m	15m	3m	0.75m
Roads	6m	4.5m	1.5m	0.38m
Railroad	15m	4.5m	1.5m	0.38m
Bridges	6m	4.5m	1.5m	0.3m
Airfield Fascility	6m	4,5m	3m	0,15m

Table 3: Required ground pixel size for optical image interpretation (STANAG 3769)

Detection: In image interpretation, the discovering of the existence of an object without its recognition.

Recognition: The ability to fix the identity of a feature or object in images within a group.

Identification: The ability to place the identity of a feature or object on imagery as a precise type.

Technical Analysis: The ability to describe precisely a feature, object or component imaged.

Although STANAG 3769 does not discriminate colour or black and white imagery as well as contrast, it gives an indication of the expected details which may be extracted from imagery. The work being carried out in this investigation can be allocated to the detection, recognition and sometimes also identification tasks in image interpretation, while the technical analysis is something of more military nature.

Considering these facts and the experiences of the interpreters a list of common objects was set up prior to the interpretation in order to ensure comparable results. Altogether 45 object types have been defined as common features although each interpreter also had some personal features. Some of these features have been selected for a detailed analysis separated for linear and planar (area) object types.
At first the interpretation was made just with the SAR images to avoid an influence of the higher information contents of the optical images. Then the optical imagery was interpreted using the same object types as for SAR. In some cases this was leading to totally different results. For example the radar image of Trudering showed a historical site which was considered a specified object type but could not be detected at all within the optical imagery (Figure 2). The reason is not known but might be caused by the different acquisition times.

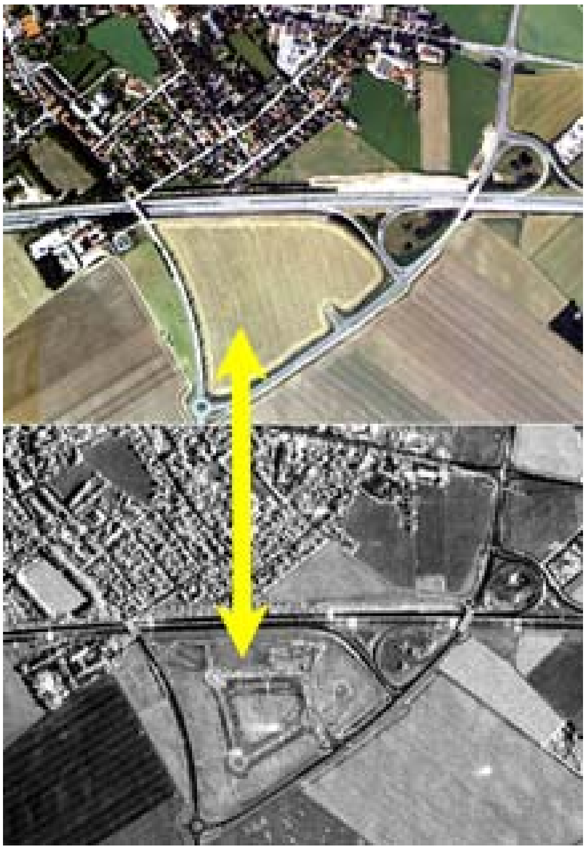
Figure 2: Comparison of optical and SAR images

The analysis was carried out for all 4 test sites and resulted in a data set for each of the operators as shown in Figure 3.

Figure 3: (1) - optical image
(2) - Interpretation of optical image
(3) - SAR-image
(4) - Interpretation of SAR image

In addition to these interpretations the interpreters were asked to appraise the SAR data quality for interpretation. The result for the main categories is summarized in the following:

Roads: In open areas recognised in general well while it was difficult in the built up areas.
Highways: Recognition and in most cases also identification (number of lanes etc.) is possible.
Railroad: Detection and recognition was possible, but sometimes confusion with roads occurred.
Development: Built up areas could be recognized well (identification of large buildings is possible, but small buildings only could be recognised).
Agricultural areas*:* Appear in unusual colours (as compared to optical data). A good identification or separation between arable and grass land was impossible.
Ponds: Good identification was given in most cases but difficulties with smaller ones.
Forest: Good detection and recognition, but clear identification of forest type is not possible.

Figure 4 (see annex) shows as an example the 3 different interpretation results (SAR and optical data) for the Copenhagen region obtained by the 3 operators.
It is remarkable that only one interpreter was able to identify the golf course, while the other marked this area as undefined. It can be seen also, that the amount of roads and the areas identified as developed differ quite remarkable.
For this reason an investigation on the completeness and correctness of the interpreted features was performed.

3. EVALUATION OF INTERPRETATION RESULTS

As already mentioned in section 1 neither ground truth nor reference data was available to check the quality and completeness of the interpretation results. Because of the extensive know-how and experience of the 3 interpreters with aerial imagery and also the higher information contents, the optical images have been used as reference. The interpretation of the SAR imagery was checked against the interpretation of the optical imagery for each interpreter individually. The use of a single interpretation of optical imagery alone was thought not to be sufficient, since the way an operators address image objects is varying individually.

For each of the 4 regions and for each operator the interpreted SAR imagery was checked against the interpretation of the optical data (see Figure 5 in annex).
As the interpretation was done by on-screen digitizing using the Arc/View software, the length and area of objects could be computed.
The analysis was done exemplarily for linear objects like highways, roads and railways and planar objects like development, agricultural, pond and forest areas. The SAR interpretation has been compared with the optical interpretation. For linear objects both were compared (buffered) visually (i.e. checked if the lineaments belong to the same object) and the length of the objects was computed for the optical and the SAR data in the common buffer area. In addition the length computation has been done separately for objects appearing in either the optical data or SAR data only. A similar approach was used for planar features, which were intersected. Buildings however were very often found at a position, where intersection would yield wrong results, because of the different geometric behaviour of the data sets. Therefore instead of the building areas only the "building position" was used, which means that the compliance of buildings in the optical and SAR interpretations was checked.
For each object type the completeness and correctness of the interpretation was computed following an approach presented by Wiedemann (2003).
This approach is illustrated in Figure 6.

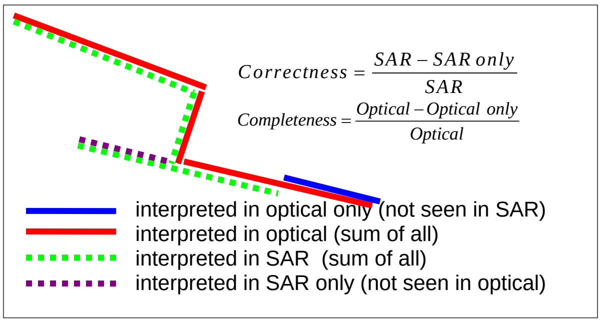

Figure 6: Definition of Completeness & Correctness for linear objects

The correctness (range 0.0 up to 1.0) is the percentage of correctly interpreted line / planar features i.e. the percentage of the interpretation of the SAR images, which is in accordance with the reference (interpretation of the optical data).
The completeness (range 0.0 up to 1.0) represents the percentage of the reference data which is explained by the interpreted SAR data, i.e. the percentage of the optical interpretation which could be interpreted from the SAR data. The computation according to Figure 6 is done by using the length in case of linear objects and the area in case of planar object.
The results of selected object types together with the range of the computed values for the 3 interpreters and the 4 test sites are shown in figures 7 to 10.

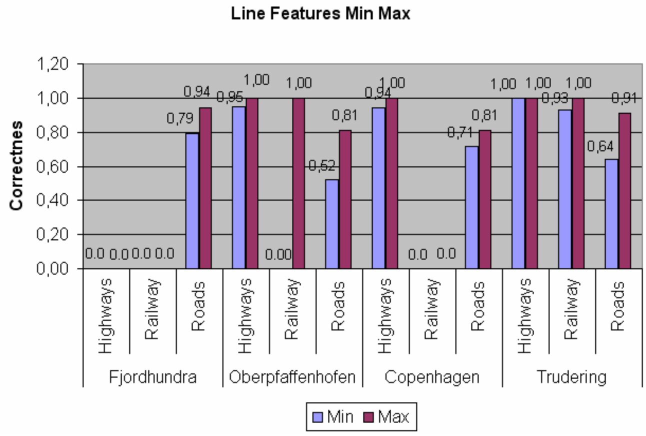

Figure 7: Correctness of line features highways, railways and roads

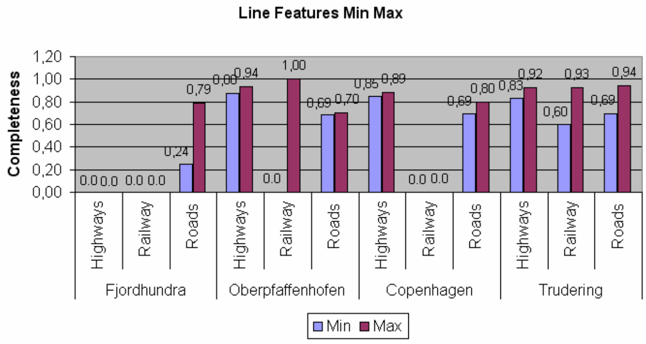

Figure 8: Completeness of line features highways, railways and roads

Fjordhundra is a region of agricultural structure. Therefore no highways or railroads (as in the Copenhagen scene) exist in this image. In case of roads the difference between the minimum and maximum value of completeness for roads in this area is quite big. Again at a ground pixel size of 4m in an agricultural area it is not easy to differentiate between a land use boundary and a small road. However the correctness value of the found roads is satisfactory.
The completeness and correctness of linear objects like highways and roads in the other areas is quite high and also the variation of the interpreted results is moderate. Only one interpreter detected the railroad in the Oberpfaffenhofen area, while the others recognized it as road.

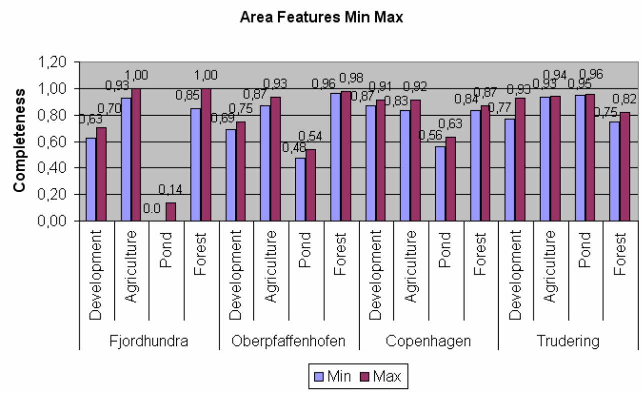

Figure 9: Completeness of area features development, agriculture, pond, forest

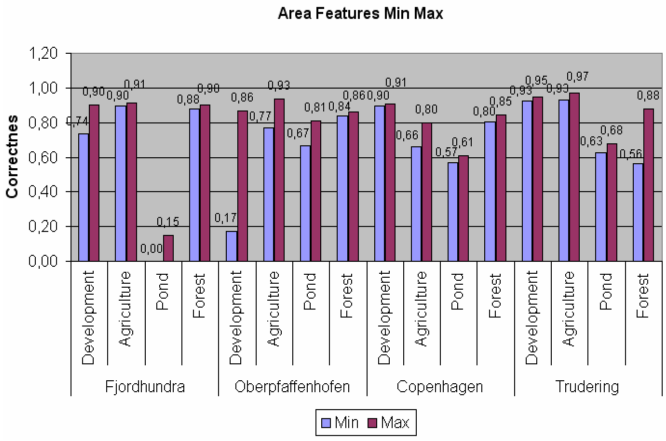

Figure 10: Correctness of area features development, agriculture, pond, forest

Figure 9 and 10 show the completeness and correctness of the interpretation of planar features. The interpretation within the 4 regions shows more or less a comparable quality. However for the feature “developed areas” within the Oberpfaffenhofen region a remarkable difference between the minimum and maximum value of correctness can be observed. This is due to a wrong feature declaration within the SAR image interpretation. Some areas of the airport have been declared as developed in the optical image and as airfield area in the SAR image. In the test area Fjordhundra ponds do show a small value for completeness and correctness due to the fact that the existing ponds are very small, and within the optical data their colour does not allow a good recognition and identification. The development areas in that region are difficult to be identified because of insufficient spatial resolution.

4. CONCLUSIONS

In general all of the line and area features could be interpreted quite well. Difficulties could be observed with small objects like ponds in agricultural / forest type areas and in the recognition of railways in one of the investigated regions. Although the presented results seem to be quite satisfactory, the major drawback of this investigation is that no exact reference (topographic map or equivalent) was available for the analysis. Therefore one has to consider uncertainties which originate from facts like multiple meaning of some found features in the interpretations. In this way the same linear object may have been interpreted as a boundary or a creek or a path. Without having a correct reference it is impossible to identify such objects as of the correct type or not.
The analysis of the interpretation results against map data will be part of the function of the organizer of this test. In the next stage of this contest automatic methods of image analysis and interpretation will be used.

5. ACKNOWLEDGEMENTS

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- DLR-IHR for the Oberpfaffenhofen data

- DDRE, Copenhagen and Lantmäteriet, Sweden for the Fjordhundra data set
- DDRE, Copenhagen and Kampsax A/S, Hvidovre for the data over Copenhagen city

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CCRS:
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6. ANNEX

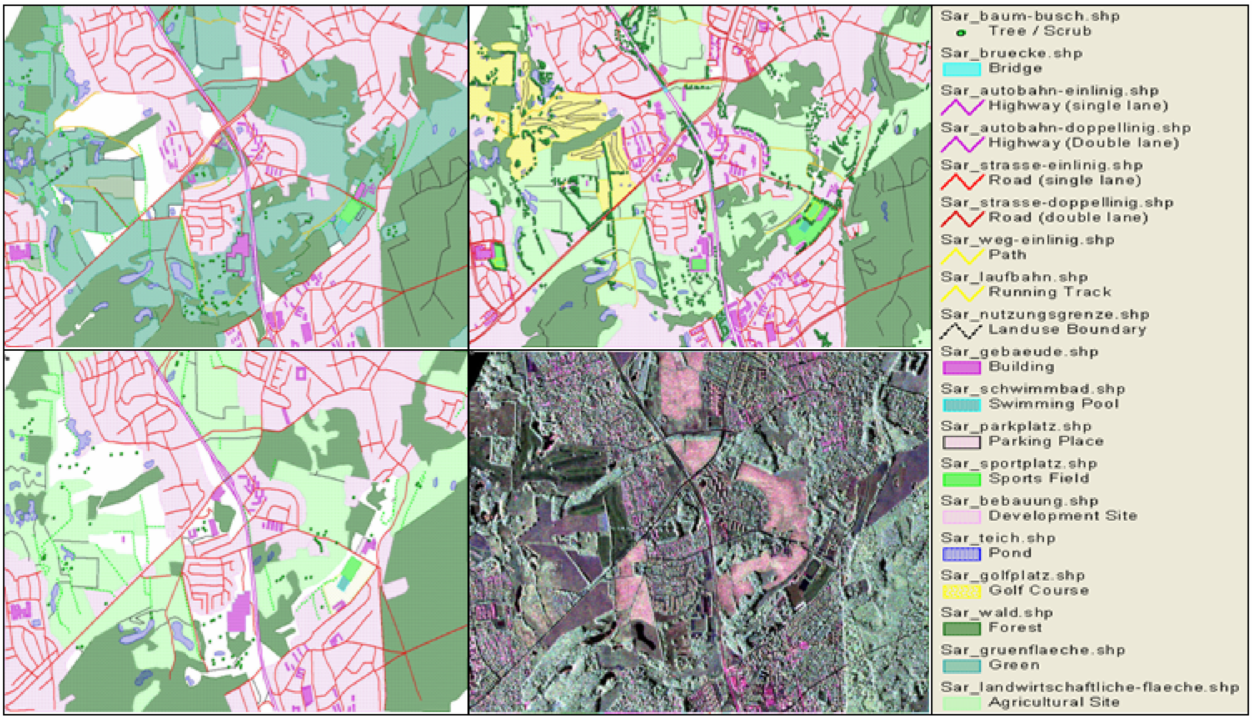

Figure 4: SAR interpretation Copenhagen

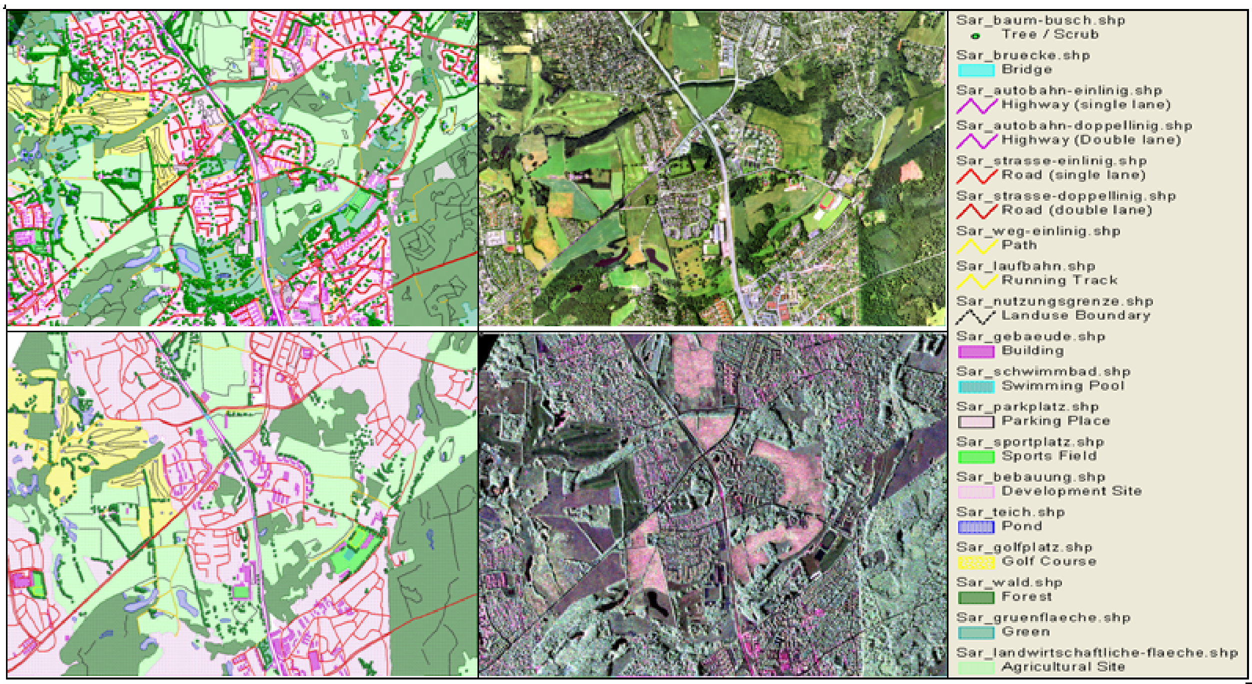

Figure 5: Comparison of interpretations
Top: Optical image
Bottom: SAR image