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IMAGE AND DATA FUSION - CONCEPT AND IMPLEMENTATION OF A MULTIMEDIA TUTORIAL

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ABSTRACT: Image and data fusion is a fast developing field of research used in a growing number of operational applications but it involves rather complex techniques. Therefore, there is an increasing need for teaching people how to use it in an efficient way. Using a multimedia tutorial is one suitable way of teaching the topic of data fusion in a structured manner and according to the user's needs.

The multimedia tutorial on remote sensing image and data fusion we introduce consists of seven chapters. It describes the concepts and ideas of data fusion and provides the technical background of three different levels of data fusion (pixel-based, feature-based and decision-based). Two case studies are included to show practical applications of the different fusion techniques. A glossary of terms, a list of relevant literature as well as a list of useful links on the Internet are given as appendices.

This paper focuses on two different aspects. One is the concept of the tutorial – how the field of image and data fusion can be introduced by means of background information, case studies and exercises. The other is the use of different multimedia tools such as animation, sound, video, graphics, text, etc. to elucidate these aspects.

1. INTRODUCTION

Image and data fusion is an established technique for the combination of data sets from different sources. Fusing two images, for example, can provide information, which cannot be obtained when the images are processed individually. Thus, the need for the application of image and data fusion techniques increases in the remote sensing data user community. A multimedia tutorial "*A Tutorial on Remote Sensing Image and Data Fusion*" was developed at the International Institute for Aerospace Survey and Earth Sciences (ITC). The Western European Union Satellite Centre (WEUSC) has been established by the Western European Union (WEU) to operationally exploit Earth observation satellite imagery for security and defense purposes. The educational demand occurred in this field at the WEUSC, where hundreds of satellite images are processed and interpreted annually.

The aim of the tutorial is to provide the image analysts at WEUSC with the background knowledge about image and data fusion with emphasis on the radar techniques as they work mainly with optical imagery. The tutorial complements an image fusion software, the Data Fusion Demonstrator, DFD (Pohl *et al.*, 1997), which was developed by Earth Observation Sciences (EOS) Ltd. in the UK. The developments were embedded in a project funded by the WEUSC, which finished in March 1997.

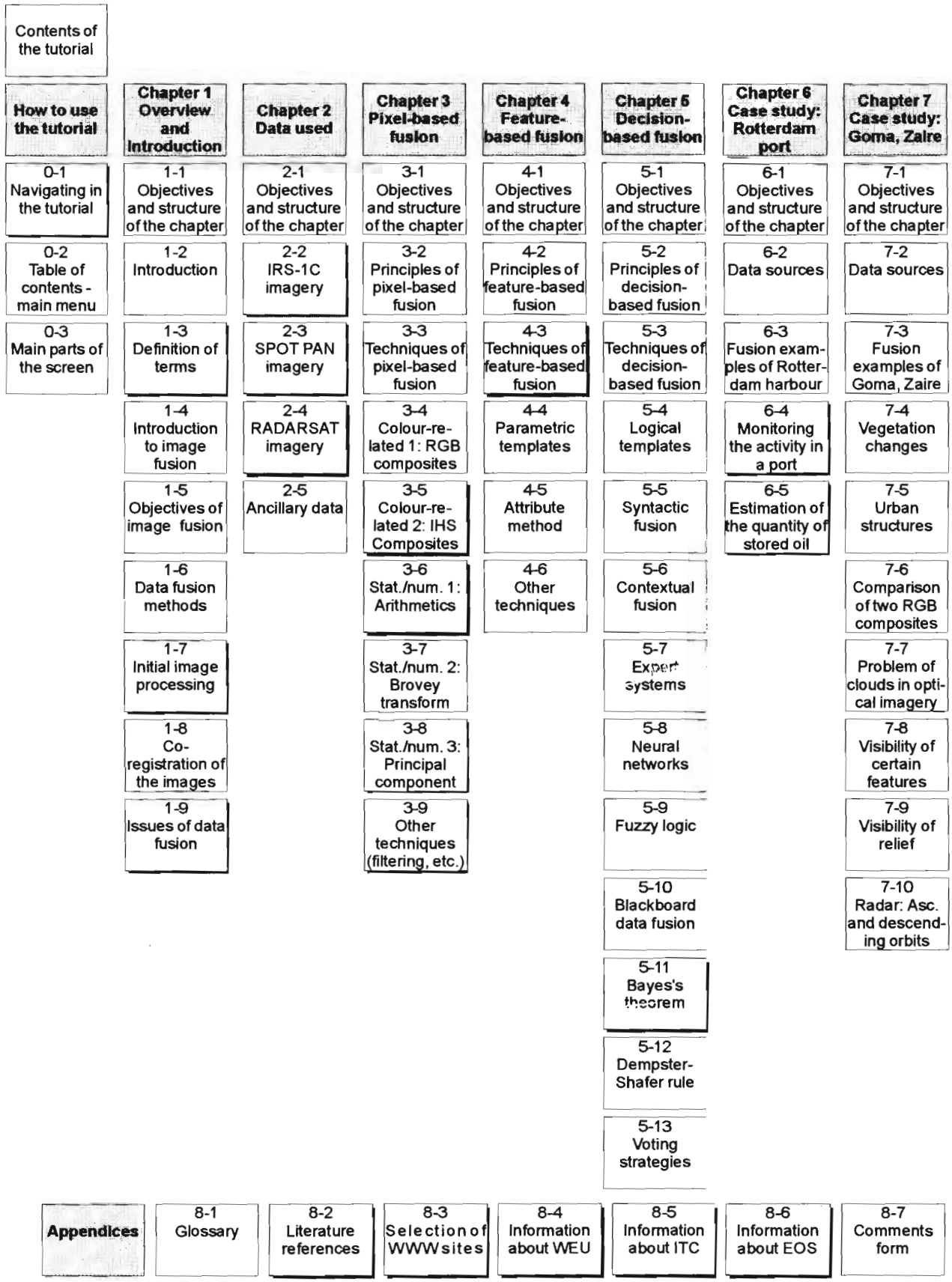

Figure 1 Structure of the multimedia Tutorial on Remote Sensing Image and Data Fusion

2. STRUCTURE AND CONTENT OF THE TUTORIAL

The tutorial is built up from seven chapters and an appendix. *Figure 1* shows the structure of the tutorial where every box in the figure represent one section. The sections shown with a shadow consist of multiple pages.

Although the pieces of information in the chapters are built upon each other didactically, it is possible to navigate according to the personal needs of the user. This can be done from the menu bar (e.g. using the page index) or from the page describing the chapter structure at the beginning of each chapter.

The tutorial summarises the state of the theory in remote sensing image and data fusion (based on works such as Hall, 1992; Waltz and Llinas, 1990) and provides some practical examples.

The first chapter of the tutorial gives a general introduction to the topic, using the definitions of image fusion by Genderen and Pohl (1994) and of data fusion by Hall (1996). The second chapter includes the description of data used in the tutorial. Three chapters discussing the theoretical background of the three levels of remote sensing image and data fusion (Figure 2) follow this.

The last two chapters provide practical examples by case studies in Rotterdam port, The Netherlands and in Goma, Democratic Republic of Congo (at that time called Zaire).

The tutorial is accompanied with a fieldwork dossier containing topographic maps and data collected in the Rotterdam port. This fieldwork was carried out simultaneously with the satellite overpasses when RADARSAT images were taken for the case study.

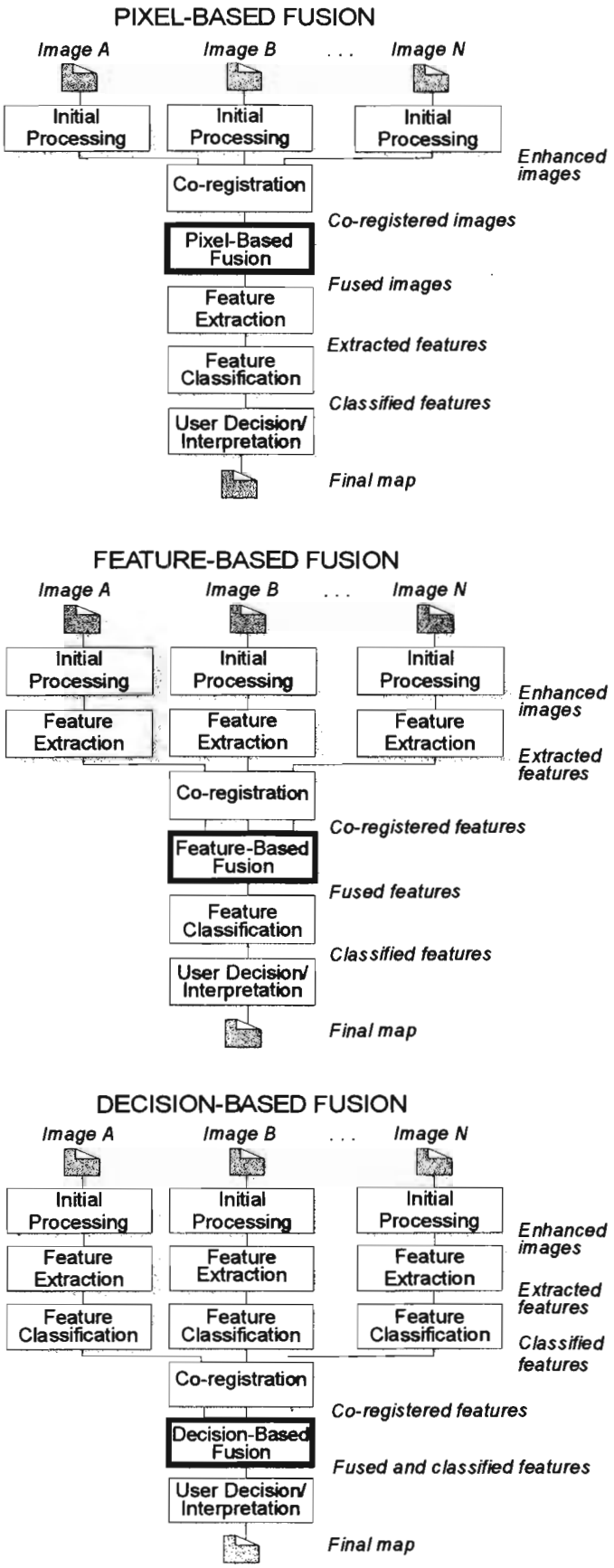

Figure 2 Levels of data fusion

3. MULTIMEDIA FOR TRAINING IN IMAGE AND DATA FUSION

The multimedia technique has proved to be useful in the field of data fusion for different purposes. It is interesting to mention that multimedia itself is a kind of data fusion technology. One of the widest application fields of multimedia is teaching and training. Compared to textbooks, the navigation through a multimedia tutorial is more flexible, i.e. hot links providing faster access to references than turning the pages of a book. These links are widely used throughout the tutorial. The tutorial can be used as a kind of reference "book" as well as a guide introducing the basics of image and data fusion.

Multimedia software can provide the user with an interface to start other applications. Using this technique the user can make notes during his work through the *Tutorial on Remote Sensing Image and Data Fusion*.

Using multimedia technique different kinds of digital data can be visualised. Satellite imagery and maps are displayed at various scales in the tutorial. Videos and photographs from the fieldwork are additional information sources in the explanation of the image and data fusion techniques. These data are also assembled in the fieldwork dossier, which is an appendix of the software package. This enables the image analysts at WEUSC to check the interpretations explained in the tutorial.

In multimedia sound can support visual information. In the present version of the tutorial these tools are used only sparingly, but the feedback from the users showed that there is a need for using it more extensively in future versions and upgrades to the tutorial.

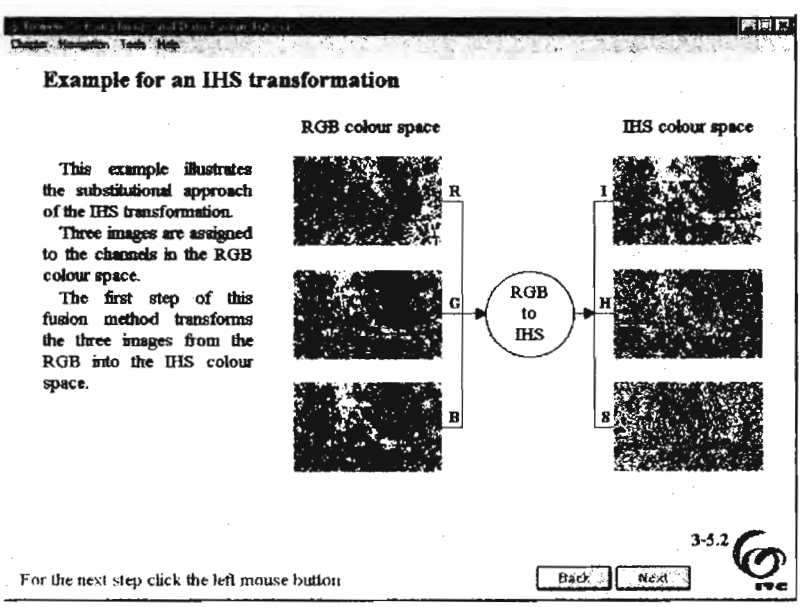

Figure 3 Example for an IHS transformation

The most powerful multimedia tool is certainly the interactive animation. It can be used to describe each single step of a processing chain. In the tutorial it combines a descriptive component (text) with an illustration part (imagery) as shown in *Figure 3*. The animation is interactive since the user can invoke any step of it according to his needs and repeat the animation as many times as needed for the full understanding.

Animation combined with oral explanation is frequently more efficient than texts in introducing complex techniques.

4. CASE STUDIES

The case studies targeted two different tasks. The Rotterdam port is a fully built up, artificial environment where many metal structures can be found. The main task of this study was to show how image fusion techniques might help the mapping and monitoring of such a complex environment. In the Goma case study the monitoring of the refugee crisis was the focus of interest. Here, the environment is mainly natural except the large refugee camp outside the town Goma. The speed of the processes (e.g. the movement of ships in the harbour versus the increase of the area of the refugee camp) in these two cases differ from each other.

The development of the two case studies for the tutorial demonstrated the advantages of data fusion but also indicated some problems. Working with satellite imagery, a major concern is the availability of suitable data sets. This includes aspects such as data type, acquisition date and spatial resolution. Depending on the weather conditions, the acquisition of optical imagery is not always possible. For some interpretation tasks, it is necessary to have data sets from a particular date or time period, with a particular spatial resolution or from a specific sensor. These acquisition requirements cannot be fulfilled completely in each case, since the satellites' orbits determine the viewing geometry, and allow a limited repeat cycle.

In both studies the tutorial focuses on mostly how optical and radar images can be fused. In the case study of the Rotterdam port colour and black-and-white aerial photos and IRS-1C panchromatic images were fused with RADARSAT fine-beam images. In the case study of Goma SPOT panchromatic images were fused with RADARSAT ScanSAR and fine-beam data.

The quality of radar data depends on the radiometric calibration. The Rotterdam port case study demonstrated that images with a large number of metal constructions acting as corner reflectors are very difficult to calibrate radiometrically. Pixel-based fusion products of these inhomogeneous images with optical ones (e.g. colour composites) were not easy to interpret. It is easier to overcome these difficulties using feature-based and decision-based fusion techniques. Radar images played an important role in this case study due to the frequent cloud coverage in this region.

Figure 4 shows an example of the case study in the Rotterdam port. By using a logical template, a decision-based fusion technique, the activity in a petroleum port was monitored. The possibility of radar imagery to penetrate clouds ensures the data acquisition independently from the weather conditions. In this case an IRS-1C image was combined with three temporal RADARSAT images acquired in the fine-beam mode. This approach focuses on the temporal aspect of data fusion.

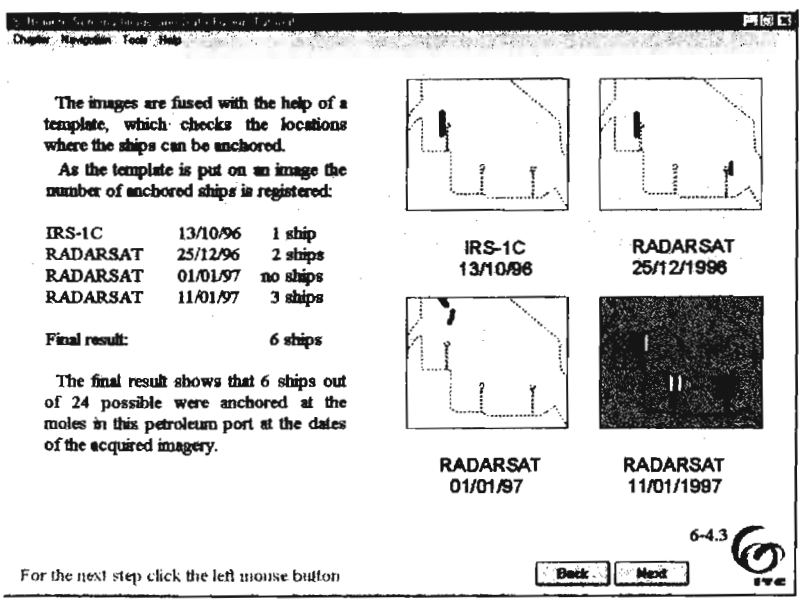

Figure 4 Monitoring of the activity in a petroleum port

The Goma case study highlighted the applicability of pixel-based fusion techniques in the identification of urban structures. Radar imagery showed its limitations in mapping mountainous areas due to the special geometry.

5. RECOMMENDATIONS

In the introductory phase of the application of image fusion the multimedia tutorial "*A Tutorial on Remote Sensing Image and Data Fusion*" serves as teaching material to introduce the background and capabilities of this technique. For the operational use of data fusion in an environment such as WEUSC, the role of a multimedia tutorial has to be newly defined (Pohl and Munro, 1998). An extended version of the tutorial could be used as a training tool, further improved by introducing interactive exercises. Standard procedures developed for predefined situations and repeatedly occurring scenarios could be demonstrated by various case studies. Finally, the multimedia tutorial could be integrated in data fusion software as a 'guided tour' as part of the online help.

In the next version of this tutorial, various enhancements will be made, based on the experiences of the first version. These include:

- using of other satellite data types (e.g. Landsat TM, ERS SAR, or high resolution optical data),
- expanding of the case studies,
- adding more multimedia techniques (e.g. sound, animation, video),
- including interactive exercises and self-tests, and
- including a more detailed explanation of image enhancement techniques.

6. ACKNOWLEDGEMENTS

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