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The present achievements of the EARSeL - SIG "Data Fusion"

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ABSTRACT: Data fusion is becoming of paramount importance in Earth observation. A Special Interest Group "data fusion" has been created within EARSeL and SEE to better understand data fusion for a better exploitation of the synergy between all instruments observing and measuring our environment. The SIG also intends to make recommendations to agencies, industries and the scientific community. The communication presents the SIG and its objectives. The achievements already accomplished are: *i)* statement of the importance of data fusion in Earth observation, *ii)* dissemination of the fundamentals and properties of data fusion, *iii)* concept, definition and terms of reference, and *iv)* assessment of methods for the synthesis of images at higher spatial resolution. Further tracks are indicated. Several publications have been made, resulting from the SIG meetings. The SIG has a wide audience world-wide, benefiting from the use of Internet. It has also launched a series of high-quality international conferences in Côte d'Azur.

1 INTRODUCTION

Data fusion is a recent term. It means an approach to information extraction spontaneously adopted in several domains before this was expressed as "data fusion". This approach is based upon the exploitation of the synergy offered by the information originating from various sources. Combination of additional independent and/or redundant data usually results into an improvement of the results. The example of human vision is often given to illustrate the advantages and benefits of data fusion. Because they have slightly different viewing angle, the two eyes of a man make possible stereo vision and hence depth perception, thus extending the capability of a single eye. Another advantage of having two eyes is redundancy; if one is disabled, we can still see.

Using recent words such as "data fusion", or "information fusion" translates the recent understanding that whatever the application domain, these synergistic approaches share common problems and common properties. The objective of data fusion is to express these problems and properties. Hence the properties of the data and their interactions will be better described and analysed; it will be easier to develop the most appropriate methods and algorithms, to monitor the quality throughout a process etc.

Data fusion is exploited by a large number of biological systems. An illustration is given by the human system, which calls upon its different senses to perceive its environment. Human sensors acquire information on view, smell, touch, sound, and taste. The acquired data are processed within the brain. To do so, the brain will use other sources of information: its memory, its experience and its *a priori* knowledge. Calling upon its reasoning capabilities, the brain "fuses" all this available information to perform deductions, produce a representation of the environment and order action.

Data fusion is not limited to biology. It originates in Defence activities, and such applications are still very vivid. Nevertheless, fusion applies to many other domains.

The exploitation of satellite images and more generally of observations of the Earth and our environment is presently one of the most productive in data fusion. Observation of the Earth is performed by means of satellites, planes, ships, and ground-based instruments. It results into a great variety of measurements, partly redundant, partly complementary. These measurements may be punctual and time-integrated, bi-dimensional and instantaneous (images), vertical profiles with time-integration or not, three-dimensional information (oceanic / atmospheric profiler / sounder at ground level, or satellite-borne, or ship-borne). Adding the large amount of archives and numerical models representing the geophysical / biological processes, one should conclude that the quantity of information available to describe and model the Earth and our

environment increases rapidly. Data fusion is a subject becoming increasingly relevant because it efficiently helps scientists to extract increasingly precise and relevant knowledge from the available information.

The operation of data fusion by itself is not new in environment. For example, meteorologists predict weather for several tens of years. In remote sensing (i.e. Earth observation from spacecraft or aircraft), classification procedures are performed since long and are obviously relevant to data fusion. Data fusion allows formalising the combination of these measurements, as well as to monitor the quality of information in the course of the fusion process.

The European Association of Remote Sensing Laboratories (EARSeL) and the French society for Electricity and Electronics (SEE, the French affiliate of the IEEE) are fully aware of the importance of data fusion in remote sensing. They jointly organised a conference in 1996, called 'Fusion of Earth Data - merging point measurements, raster maps and remotely sensed images', which was the first of a series with a venue every 2 years. During the round table of that initial meeting, the need for a working group, called special interest group (SIG) in the EARSeL jargon, was expressed, and it was created later this year.

2 OBJECTIVES

The SIG 'data fusion' contributes to a better understanding and use of data fusion by tackling the fundamentals in remote sensing underlying data fusion. Further the SIG will certainly be helpful in designing and engineering tools and methods for assessing *a priori* or *a posteriori* the quality of a fusion product, that is answering the following questions: is it worth performing a fusion process ? was it worth doing it ?

It has been proposed to restrict the SIG to the so-called radiometric aspects. The so-called geometrical aspects are already tackled by several working groups at national and international levels. The exact meaning of these words (radiometric, geometrical) is delicate to define precisely but every one can understand this share in problems. In other words, the present SIG does not handle matter related to any pure geometrical use of the data, e.g. image matching for geo-referencing, or geo-referencing, accurate positioning, assessment of digital terrain models, ... unless it appears necessary for the wealth of the studies and if information cannot be obtained from elsewhere.

All applications are accepted, none is excluded. The work tasks initially set are:

- list and better understand the fundamentals in data fusion
- list and better understand tools and methods in data fusion, develop new ones
- develop and provide instruments for the assessment of the quality of the fusion
- prepare application cases exhibiting several processes and levels of fusion. These cases will help in illustrating data fusion and in students training. Several domains (urban domain, meteorology, ...) should be handled.
- prepare sets of data for well-documented sites which may be useful for testing algorithms. This should be performed with the help of the space agencies and other data providers.

The SIG also makes recommendations to agencies, industries and the scientific community.

3 MEANS OF COMMUNICATION AND DISSEMINATION

The activities of the SIG are organised around the organisation of the series of international conferences "Fusion of Earth Data", co-organised every 2 years jointly with SEE and the Ecole des Mines de Paris. These conferences are conceived as a forum and intend to help in understanding what "data fusion" means by providing a clear description of concepts, applications, tools and benefits of data fusion. This series is characterised by a strong interactivity between participants, authors and exhibitors in a warm and friendly atmosphere. The Scientific Committee selects the communications on an anonymous basis and only keeps extended abstracts of good to excellent quality. Accordingly the presentations given during each Conference represent the latest methodologies and advanced applications. They are all of high quality, contributing to lively discussions and to the success of the conference. The "Fusion of Earth Data" Prize of 200 euros is awarded by the Scientific Committee and rewards the best paper appearing in the Proceedings.

An average of approximately 60 scientists attended each of the three Conferences. During each Conference, a plenary debate is organised on a major subject. After the closing of the Conference, half a day is devoted to an in-depth discussion of this subject. The outcomes are the inputs of the following working meeting and Conference. Usually, there is one working meeting per year. Once a consensus reached and most of the hot questions answered, the outcomes are published, and a new subject is proposed.

The SIG has a wide audience worldwide, benefiting from the use of Internet. Approximately 400 persons are registered in the mailing list. A web site has been established:

http://www-datafusion.cma.fr.

It contains information on the fundamentals in data fusion, the series of Conferences and the other meetings. Together with the mailing list, it is an

efficient way to disseminate the outcomes of the SIG, or to launch a discussion on a particular topic.

Nevertheless, traditional means of dissemination are not neglected such as the EARSeL Newsletter and reports to the general assemblies of EARSeL and SEE.

Several publications have been made in ISPRS meetings or in IEEE journals. These publications result from the outcomes of the SIG meetings.

4 DEFINITIONS, TERMS OF REFERENCE

The concept of data fusion is easy to understand. However, its exact meaning varies from one scientist to another. Several words have appeared, such as merging, combination, synergy, integration, ... All of them appeal more or less to the same concept but are however felt differently. There is also a fashion. Several times, the word « fusion » is used while « classification » would be more appropriate, given the contents of the publication.

During several meetings, the debate focused on the formalisation of the data fusion in remote sensing which is sorely needed and would shape the domain. The main outcomes of the debate were on definitions and terms of reference. The following definitions were finally agreed upon in January 1998.

Data fusion: *data fusion is a formal framework in which are expressed means and tools for the alliance of data originating from different sources*. It aims at obtaining information of greater quality; the exact definition of 'greater quality' will depend upon the application. Here quality has not a very specific meaning. It is a generic word denoting that the resulting information is more satisfactory for the "customer" when performing the fusion process than without it. For example, a better quality may be an increase in accuracy, or in the production of a more relevant information. In this definition, spectral channels of a same sensor are to be considered as different sources, as well as images taken at different instants.

It then has been suggested to use the terms merging, combination in a much broader sense than fusion, with combination being even broader than merging. These two terms define any process that implies a mathematical operation performed on at least two sets of information. These definitions are very loose intentionally and offer space for various interpretations. Merging or combination are not defined with an opposition to fusion. They are simply more general, also because we often need such terms to describe processes and methods in a general way, without entering details. Integration may play a similar role though it implicitly refers more to concatenation (*i.e.* increasing the state vector) than to the extraction of relevant information.

Other definitions were accepted, such as attributes, features, rules, decisions, etc., which actually follow international standards and terms of reference (information science, ISO/DIS 12651).

More information is available on the Data Fusion Web server.

5 FUTURE TRACKS

Quality is of paramount importance nowadays. There is no discussion of this point. This is especially critical for fusion processes given the amount of additional work to be performed for fusing different sources. Accordingly, ways of answering simple questions such as: what is the benefit of fusing this source and this one, are greatly welcome.

Some debates were already hold on the particular problem of the assessment of the quality of fused products, which are a synthesis of multispectral images but at a higher spatial resolution. Typical examples are the fusion of SPOT multispectral images XS with a resolution of 20 m with panchromatic images P having a 10 m resolution. The objectives of such processes are to obtain synthesised XS images having a resolution of 10 m, and close to what should be observed by a SPOT multispectral sensor having this resolution.

Beyond the arguments about methods, the protocol proposed by Wald *et al.* (1997) seems to be accepted. Parameters to quantify the quality are various. Their use depends upon the application.

A more general discussion on quality in data fusion was the subject of the last Conference and of the following working meeting. The European (CEN) and international (ISO) standards in geographical data quality were discussed with respect to the fusion aspects and were proposed as a basis for further work. Some progress has been made that will be presented on the data fusion Web server, and will be further discussed.

6 CONCLUSION

Needs expressed by the remote sensing community in Europe have led to the creation of a SIG on data fusion. The SIG has issued statements that identify the degree of importance of data fusion in Earth observation. It has tackled the problems of terms of reference. A new definition of the data fusion is now proposed which emphasises the concepts and the fundamentals in remote sensing.

Several other terms are also proposed which for most of them are already widely used in the scientific community, especially that dealing with information. These terms of reference are published on the Web site of the SIG. They foster exchanges within and between scientific and application communities.

The SIG is contributing to establish a sound understanding of data fusion fundamentals. Means have been set up to disseminate the outcomes of the SIG for the benefit of the Earth observation community and others. These outcomes are regularly reported to the spatial agencies, the European Commission, EARSeL and SEE. A series of high-quality Conferences is the flagship of the SIG. They permit to present the latest methodologies and advanced applications, but also to discuss a major topic, which will be debated in-depth during the following SIG meetings.

The SIG has now undertaken an inventory of methods, tools, and instruments for the assessment of the quality in data fusion.

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