Commission II, Working Group II.5
INSTRUMENTATION FOR SAR PROCESSING
ACTIVITIES AND CRITICAL AREAS

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1. INTRODUCTION

The working group II.5 (Instrumentation for Synthetic Radar Aperture (SAR) Processing) was created in 1979, at the previous ISPRS Congress (in Hamburg). The activities of this working group are aimed at assessing the on-going developments and/or identifying the required developments of the instrumentation related to end-to-end SAR systems.

Four years ago, the main difficulties were related to the pre-processing of SAR data, i.e. the production of a SAR image in a reasonable time (between 10 and 20 hours typically at this time). Since the algorithms and other technical difficulties have been solved and very fast SAR processors are under development (typically less than one hour per scene). Nowadays, the challenge is two fold:

- how to optimally extract thematic information from SAR data
- how to optimally use this information as part of a multi-sensor remote sensing approach. This paper is aimed at reflecting this evolution.

2. FUNCTIONING OF THE WORKING GROUP

The first meeting, held on December 1981 at Frascati (ESRIN, EPO) has been devoted to identifying orientations for the work to be completed during the 1981-1984 period. Based on the presented papers and on a particular discussion, six topics have been selected and a task coordinator nominated:

- On-board processing (R. Okkes)
- Ground preprocessing (J. Gredel)
- Algorithms for preprocessing (J. Bennett)
- Acquisition, validation, simulation and Calibration (R. Brooks)
- SAR processing and image interpretation (A. Goldfinger)
- Radiogrammetry and merging of multi-sensor data (F. Leberl).

The role of the tasks coordinator consists of ensuring that the tutorial papers presented do reflect the opinions of the working group members. The members are from Europe, Canada, U.S.A and Japan and this explains the locations of the various meetings held so far:

Frascati (Italy) December 1981
Ottawa (Canada) September 1982
and Tokyo (Japan) November 1983

apart from Hamburg (1979) and Rio de Janeiro (1984) during the ISPRS Congresses.

Proceedings of the Frascati and Ottawa meetings have been published while the data package of the Tokyo has been made available to all members.

The activities in Canada and U.S.A have been coordinated by K. Raney (Co-chairman) while in Europe, Japan and, more recently, India, activities were stimulated by J.P. Guignard (Chairman).

The team members have been invited in an informal way to follow the evolution of the various topics.

3. THE EVOLUTION OF THE MAIN TOPICS

It is not intended here to mention all presentations nor to give detailed references as Proceedings of the various meetings are all available. Rather, it is attempted to synthetise the evolution in view of identifying those topics which deserve today's attention.

3.1 On-Board SAR Preprocessing

This topic was most discussed in Frascati (1981); at this time it has been emphasised that:

- the technical feasibility of a complete spaceborne SAR preprocessing unit is far from being established (e.g. reliability)

- moreover, the technical feasibility would not solve the difficulties involved in the image interpretation step.

In fact, it is more realistic to put into perspective the various functions possibly implemented on-board and their potential utility realising that technical feasibility does not mean benefit from a mission viewpoint.

For this very reason, on-board preprocessing is likely to be limited to data handling and signal conditioning functions (e.g. data time stretching, formatting), in particular to preserve the integrity of the raw data.

After reviewing the technical aspects of the candidate implementation concepts (in particular in Ottawa), it turns out that the major objectives raised in Frascati are still valid.

It is likely that on-board preprocessing of SAR data will remain a technological issue during the next four years but no actual instrumentation is under consideration in that respect.

3.2 Ground Preprocessing

This is the area where most work was necessary and where most progresses have been accomplished.

In the 1979-80 period, the first SAR processors to exist were extremely slow in producing a Seasat image (typically 20 hours computing time per scene). These experimental facilities were mainly devoted to develop and validate the various algorithms, using modest computer facilities. The use of array processors (mainly the AP 120 B by Floating Point Systems) allowed for achieving a reasonable production on an operational basis (e.g. at JPL and DFVLR).

However, the achieved throughput (typically a few hours per scene) was still far from corresponding to the requirements of the next SAR missions (e.g. SIR-B, Japanese ERS-1 in L-band, European ERS-1 in C-band, etc...).

It is not possible here to report all endeavours to develop efficient SAR ground processors. Diversity is the keyword: from mini-computer plus multi-array processors to data flow systems, from dedicated facilities to general purpose super computers, all solutions are under detailed assessment.

This diversity corresponds to various trade-off on technological level (e.g. dedicated operational facility as opposed to experimental (i.e. flexible) facilities) and also reflects the speed of the evolution in the computer industry.

Without being a driving market, SAR processing is a good theme for testing novel computer architectures and to follow all these developments, a survey of all existing and/or under development SAR processors is continuously maintained (thanks to Mr. Gredel) and an updated version is distributed at every working group meeting.

From this survey, it seems that "current" processors under development will produce a SAR image in the 20-30 mn, range.

There is still a significant gap to reach real time operations (i.e. 15 sec. per scene).

From the meetings held at Frascati and Ottawa, it was clear that Japan is particularly active in this field. A meeting in Tokyo (November 1983) was mainly devoted to reviewing the diversity of the Japanese developments: dedicated processes (Mitsubishi), data flow machine (NEC), super computer (Fujitsu) etc...

It should be noted that the tendency towards using super computers (as mentioned in the minutes of the Tokyo meeting) was based on an incorrect appreciation and that more recent information confirms that the diversity of the approaches in to be maintained.

In Europe and Canada the tendency seems to consist of replacing the usual array processors (AP 120 B) by recent and efficient array and/or signal processors. Two typical examples of such machines are the ST-100 by STAR Technologies and the T-ASP by ESE.

In the U.S.A, the most recent approach is not known at the time of writing this report (March 1984), but will be the subject of a JPL presentation during the working group session in Rio de Janeiro.

3.3 Algorithms for Preprocessing

The evolution in the field of algorithms has been threefold:

- first, the preprocessing algorithms (i.e. for image production) have been refined either to offer more operational flexibility (e.g. autofocus, automatic chirp extraction etc.) and/or more efficiency for a dedicated mission (e.g. SPECAN for C-band processing)

- second, the relationship between algorithms and product quality has been considered (e.g. refined comparison of algorithms including quality considerations) in particular in view of new SAR products (e.g. wave spectra)

- third, the most recent efforts consist of rewriting proven algorithms to optimally map them on new array processors. The trade-off flexibility (e.g. algorithm for L-, X- and C-band) and computer efficiency becomes of particular importance. The mapping of the generalised SAR processor (GSAR by MDA) on a ST-100 machine (at DFVLR) is a typical example of such an evolution.

3.4 Acquisition/Validation/Calibration/Simulation

Side issue in 1979, this topic emerges as of peculiar importance today, to allow for a proper use of the SAR data (see next paragraphs).

The acquisition of the Convair 580 SAR data offered the first opportunity (Frascati meeting) to raise the validation and calibration issues, not only for usual scenes (e.g. using corner reflectors) but also in case of dynamic scenes (i.e. sea surface). The tutorial paper presented in Ottawa did confirm that all these issues are just in their infancy. They are today limited to using corner reflectors for calibration and to developing tools (e.g. at ESA, JPL and in Japan) for assessing the quality of actual SAR image products in terms of resolution (spatial and radiometric) and geometry (e.g. spatial distortions).

More efficient tools are known to be under consideration for calibration (e.g. transponder), and validation, in view of the next spaceborne SAR's.

So far simulation activities have been limited to system definitions (e.g. SARSIM at ESA). New pieces of software (e.g. simulations from Kansas University) indicate that in view of simulating SAR scenes, a significant effort has to be developed, in terms of instrumentation:

- at the level of setting up reliable microwave data banks (e.g. scattering coefficients versus frequency, polarisation, incidence angle, etc...)
- at the level of computing time, to produce a simulated scene in a practical time.

It is clear that this point is a key issue for the near future.

3.5 Extraction of Information

Resulting from a coherent process, SAR images feature multiplicative noise (speckle). This speckle prevents one from using filtering techniques developed for other sources of imagery (e.g. Landsat).

Two trends have been identified, in particular during the Frascati and Ottawa meetings:

- the development of general tools (e.g. segmentation techniques) for images featuring speckle
- the development of specific, application oriented filtering techniques (e.g. adaptive filtering at CCRS, wave spectrum extraction at MRC and APL etc...)

These long term developments, based on theoretical studies and modelling by (amongst others), V.S. Frost, R.K. Raney and Steve Rotheram, are not only aimed at a better understanding of the information content of SAR images but also subject of practical investigations (e.g. tracking of spectral peaks at APL, image spectrum to wave spectrum algorithm facility at ESRIN-EPO Frascati, etc...). Up to date information in that respect will be reported during the sessions of Rio de Janeiro.

3.6 Radargrammetry and Merging of Multi-Sensor Data

Radargrammetry deserves particular attention. Although specific equipment for radargrammetric work does not exist, it has been shown (Ottawa meeting) that existing analytical plotters, orthophoto instruments and digital image processing systems can be successfully employed for work with radar images. Work in this field is also subject of continuous updating at every meeting.

Although they constitute two different areas, we use to relate radargrammetry and use of multi-sensor data as the latter imposes more constraints on geometrical aspects (e.g. use of digital terrain models).

There is an emerging interest for multi-sensor high resolution image data: combinations of active and passive images spanning the electromagnetic spectrum are likely to be used for thematic applications. In turn, the problem is to include methods from integrating multi-sensor data so that users gain an expanded knowledge of the scene content.

Bearing in mind such a purpose, the instrumentation for SAR image processing has to be reviewed (production of so-called SAR precision products).

The actual consequences are computerwise not trivial (e.g. required rotation of a very high resolution SAR image to get vertical north, use of accurate digital elevation models etc.) and its practical feasibility is not yet demonstrated.

4. CRITICAL AREAS AND CONCLUSIONS

The two WG.II.5 technical sessions during the Rio de Janeiro Congress will be devoted to update the previous considerations and finalise the findings and recommendations of the working group.

However, and to conclude this report, we would like to suggest some areas which are felt today as critical and therefore which are likely concerns for the future activities.

We see the necessity of developing practical activities along the following lines:

- the ground preprocessing activities are now becoming processing activities: the SAR image is no longer the only product

- as the instrumentation for SAR processing becomes computerwise extremely efficient, the possibility of developing precision products will have to be considered

- in turn, these possible precision products require additional instrumentation (e.g. data banks including digital terrain models)

- the ultimate goal is to consider SAR data as part of a multi-sensor approach. The required instrumentation is far from existing: validation and calibration of SAR data requires more than corner reflectors but a careful end-to-end system design and the development of specific items (e.g. active transponders for calibration)

- simulation is an effective tool for approaching the information content of SAR data and therefore develop application oriented processing algorithms. However, it requires the setting up (on a long term basis) of radar data bases

- the instrumentation required for SAR thematic products (e.g. wave spectra) implies signficant efforts be devoted to devise optimal algorithms and collect all necessary auxiliary information

- last but not least, the fact that new sources of SAR data (e.g. SIR-B, ERS-1, SIR-C etc.) will soon exist imply a suitable instrumentation for cross-referencing of data (apart from the archiving problem) and easy access of multi-source data for the users.

It is anticipated that these trends will be confirmed in the next few years and it is proposed to develop the future activities of the working group along these lines.

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