INFORMATION EXTRACTION TECHNIQUES AND TOOLS TO EXPLOIT STEREO RADAR AND HIGH RESOLUTION OPTICAL SENSORS

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ABSTRACT New sources of image data have become available over the last 3 years, such as higher resolution optical and microwave SAR. Traditional image processing techniques are not always valid with such data types and this paper examines how image processing software tools for geomatics have developed to provide improved exploitation for end users in this new era. The impact of these new data types and new processing tools on earth observation applications is also examined and identifies the need for more streamlined remote sensing and photogrammetry software for non-scientific users.

IN THE BEGINNING

The launch of the ERTS-1 instrument in 1972, later known as Landsat 1, was a credit to the NASA scientists who designed and built it. In those days it was a voyage of greater discovery than today to successfully deploy a satellite into orbit although, as we have seen with the demise of EarthWatch's Early Bird in January 1998, it is a science still yet to be perfected. What has changed during the intervening 26 years however is the recognition that the Holy Grail is not the resulting image, but the information that can be extracted from it. Very early remote sensors took greater delight from the stunning visual effect of a principle components analysis - almost as a testimony to the scientific endeavour, rather than the potential information contained within it.

Information is the key

It is a moot point whether the image itself is now considered a superfluous by-product, but it is certainly of less value than the information that can be extracted from it - exploitation of the image has superseded the image itself. This shift is important, since it is the <u>information</u> derived from the image that provides the necessary insight into understanding important complex processes and for making quantitative predictions (Flasse, 1993). MacDonald (1998) also makes the point that the earth observation business is all about information, 'the tangible result of all the effort that goes into building and operating an Earth observation spacecraft and its associated infrastructure is a set of measurements of the Earth system from space, from which we can derive information of economic, social, strategic, political or environmental value'. The epitome of the thirst for such information is the establishment of programs such as the International Decade for Natural Disaster Recovery in 1989 by the United Nations. Although now coming to a close, the IDNDR has identified the need for more and better environmental information to work towards sustainable development in line with the Rio Conference Agenda 21 (Pisano, 1997).

EXTRACTED IMAGE INFORMATION

The information that is generally required to be extracted from imagery, upon which decisions can be based includes;

Terrain Height

This is usually in the form of gridded height points (DEM), contours or TIN models. This contains height above a specified datum, from which slope (rate of change of height) and breaklines can be derived. This alone can support geomorphological interpretation and is the key input into the orthorectification process which is mandatory if imagery is be used in conjunction with GIS database information.

Land Use

This governs how natural processes interact with the land surface, which is critical for predictive modelling. This is an extension of land cover mapping which only tells us what the material type is, rather than how it is managed and likely to behave.

Feature Delineation

This includes both man-made and natural features, such as infrastructure, buildings, objects and vegetation zones.

NEW DATA, NEW TOOLS

Sensors are continually being developed, enhanced and refined. Unfortunately the benefits of this will not be capitalised unless ground segment processing tools are being developed in-line to ensure that the sensor improvements can be fully exploited. The last 26 years has been characterised by steadily increasing spatial accuracy, the ascendancy of microwave SAR, greater spectral resolution with imaging spectrometers and a wider variety of orbital geometries. The sensors of the future, such as ENVISAT and the nine candidate Earth Explorer missions will in time generate an even wider range of data types such as radiation, steady-state ocean circulation, ozone mapping, cryospheric and magnetometry. New data will inevitably herald new processing tools.

Spatial resolution

By far the most consistent trend has been the improvement in spatial resolution of optical images since the 80 metre Multi Spectral Scanner on-board Landsat 1. These are now as sharp as 85 centimetres in the case of Space Imaging, but this is about as far as the technology will probably be allowed to go, not so much for national security concerns, but because higher resolutions start to invade personal privacy. Higher resolution however is not just about being able to identify objects with impunity, which significantly benefits feature extraction applications, but it is not necessarily so for land cover or land use classification.

SMART CLASSIFICATION

Traditional Bayesian classifiers do not lend themselves well to higher resolution datasets, given the increased amount of heterogeneity between pixels and the problem of collecting suitably representative training areas. Also, since a pixel is not classified solely on its own value but also on its neighbouring pixel values, then contextual information becomes more important in higher resolution situations. The 'mixed pixel' problem confounds traditional classifiers, because the contributions of different material types within the pixel, distort the pixel spectrum from that of the material of interest, often resulting in a loss of discrimination and potential misclassification (Huguenin, 1994). Other techniques for addressing these have been tried in the past, such as neural networks, but with limited success and reliability and is hence used very little commercially. It has therefore been necessary to develop a smarter range of classification techniques to fully exploit this data, based on a number of new techniques being developed by ERDAS Inc.

Fuzzy Classification

Useful for mixed pixels, boundary conditions, and hard to discriminate classes giving rise to greater generalisation in heterogeneous areas. Pixels are not assigned a single spectral class but an array of possible classes. The classifier also produces an associated set of probabilities, distances and confidence values, giving rise to greater post-processing analysis.

Sub Pixel Classification

This technique isolates the contribution of the specific material of interest within the mixed pixel. Traditional classifiers identify pixels in the scene that have the same spectral properties as the signature. The Sub Pixel classifier locates pixels that contain the signature as a fractional component of the overall pixel spectrum. A background estimation and removal process, called linear spectral unmixing, is used to produce a residual spectrum. This technique is regarded as being more sophisticated than neural networks and as well as providing greater spectral discrimination, it is also able to classify objects smaller than the spatial resolution of the sensor, down to 20% of the pixel.

Expert Classification

This uses a series of rules, stored as a Knowledge Engine, to determine land use from non-spectral information such as adjacency, texture, pattern, shape. High resolution imagery can cause higher errors of commission (false identification) using spectral information alone, but using other cues, the Knowledge Engine refines the initial land cover classification using the rule sets to identify land use. One advantage of this technique is that it allows for complex relationships and interdependencies between variables, which better models natural world processes.

SAR IMAGING

The launch of ERS-1 in 1991 was the trigger for rapid developments in radar mapping techniques. With the subsequent launching of ERS tandem missions and SIR-C, so the demand for SAR information extraction techniques has grown. With either conventional dual-pass or single-pass (with dual antenna) SAR, a main thrust has been the development of techniques for the creation of Digital Elevation Models (DEMs), either by interferometry or stereo correlation.

Radar interferometry

This technique in particular has matured from science and engineering and is now a complementary technique for height measurement, although the dual-pass technique does have some quite severe data limitations. Principally this is the need for a very small baseline - less than 600 metres for ERS, and in the case of RADARSAT, baseline is not easy to control at this accuracy (Cordey, 1997). But there is another significant problem - the areas presently needing satellite-derived DEMs are the same areas where interferometry performs worst, which is cloud-covered highly vegetated regions. This is due to vegetation induced de-correlation. Indeed, many experts, including NASA, conclude that interferometry will only meet its potential when dual antennae systems are launched. The earliest such system, due to be launched in 1999, is the NASA developed Shuttle Radar Topography Mission (SRTM), an across- track single pass radar instrument. This is designed to collect sufficient data in a single 11- day Shuttle flight, to produce a rectified terrain-corrected C-band mosaic of 80% of the Earth land surface at 30-meter resolution. Until and unless single-pass data becomes commercially available however, wide acceptance of interferometry may well be hindered. At present interferometrically-derived DEMs have accuracies similar to those of optically derived DEMs and underlines the fact that the benefits of INSAR are not immediately apparent. Indeed the exuberance for interferometry stems from the potential capability more than the reality at present.

Stereo Intersection

At present, an attractive alternative to interferometric DEM generation is stereo intersection technique of SAR scenes which is being currently developed commercially by ERDAS as a plug-in module to IMAGINE. The design philosophy for this is autonomy for the end user, a feature that is explicitly identified by MacDonald (1998) in filling what he describes as the knowledge gap. Users of earth observation derived information are 'a diverse lot and who, in general, are not well versed or even knowledgeable in the technologies of measurement of the Earth from space.' He goes onto to say that 'Furthermore operational users have little, if any, interest in how the information is derived. They only care that it be accurate, timely and appropriate to their needs'. To this end, ERDAS has developed 'smart' data autoloaders which utilise all the available ephemeris data to pre-determine satellite geometry as accurately as possible, using ground control points to perform 2nd order rectification (minimum of 6 GCPs) to a ground co-ordinate system. In built automation such as this allow users to fill MacDonald's knowledge gap and provides users with a rapid and autonomous exploitation tool for SAR.

NEW APPLICATIONS, NEW TOOLS

In 1995 the European Association for Remote Sensing Companies (EARSC) ran the first symposium on 'The Expansion of the Remote Sensing Market' in response to the then general belief that the overall market appeared very limited. Kamoun (1995) made the analogy between this and astronomy's 'big bang' theory of the universe, which is followed by a period of chaos. The Big Bang for remote sensing was the announcement of new privately owned spaceborne systems and the ensuing chaos was the emergence new data handling techniques, like the Internet, as they found their footing.

Market Expansion

Now 3 years on and out of the chaos he refers to, is the expansion he was seeking. If market predictions are to be believed, then future looks very rosy. PlanGraphics, a market research firm that specialises in graphics applications, estimates the imaging market at some $550 million in 1995, which will grow to $2.65 billion by 2000, most of which will come from the use of imagery in GIS applications. And those figures, say the companies, are well on the conservative side. With improvements in supply and potential demand, they think the growth could be much bigger. Such reliance on unspecified GIS applications is like the film 'Field of Dreams': if you build it, they will come. Only time will tell. These figures should be used with caution, since one has to bear in mind the time it will take for the high resolution sensors to build a global database and the, as yet, unresolved problems of purchasing over the Internet will more than likely dampen these predictions.

New Applications

With new applications, come new tools. Since the new burgeoning markets are characterised by non-traditional earth observation users, these tools have to gulf the chasm between technology and user requirements. This means the streamlining of existing process work-flows using simplified software operation and a reduction in pre-requisite knowledge. Candidates for this include optical DEM creation, 3D feature extraction and 3D visualisation, since all of these are in high demand as more applications use more imagery.

New photogrammetric tools.

ERDAS is committed to the integration of these GIS, remote sensing and digital photogrammetry tools by creating a clean and smooth data transfer between the different technologies. The aim is to bridge the gap between each technology and integrate them into a 2D/3D spatial and non-spatial database of information. For these reasons, ERDAS is currently developing a range of standalone tools for 3D visualisation, block adjustment and digital photogrammetric stereo-viewing technology for feature extraction and compilation for use by non-specialists on PC and UNIX platforms.

Streamlining the work flow

To address the non-specialist whilst still preserving a rich set of 3D tools, ERDAS has had to develop smarter techniques that either require less operation or less data. A good example of this is a self-calibrating bundle adjustment capability which will simultaneously recover parameters associated with the interior orientation of a camera and sensor, whilst also estimating the unknown parameters associated with exterior orientation. It was also felt important to provide a robust sensor modelling environment to give users a wider choice of sensor including satellite imagery (i.e. SPOT, IRS), videography, digital cameras employing CCDs, non-metric amateur photography, oblique photography and close range photographs. Above all, it is important to maximise the amount of information which can be extracted from imagery.

Application Enrichment

One only has to look at the number of pages devoted to earth observation applications to see that there has been considerable growth in earth observation applications, reinforcing the belief that there is a market for streamlined remote sensing and photogrammetry tools.. The 1997 International Airborne Remote Sensing Conference for example featured a few newcomers, such as, humanitarian operations, emergency response and peace keeping (e.g Cleminson, 1997). Other new candidates include insurance, telecommunications, civil engineering, tourism) which all now feature along side the old favourites like forestry, agriculture and geology. This has been encouraged to some extent by organisations like the CEO and the BNSC who provide funding for the development of new markets and techniques., but it also a function of decreasing image costs, increasing spatial resolution and streamlined imaging software..

INDUSTRY CO-ORDINATION

If we have learnt anything over the last 26 years, it is that data and data processing software have developed at varying rates. Unless both are of sufficient maturity and reliability at a given time, then new applications will not be forthcoming. Since most software development is market, not technology led, then developments in new data formats tend to drive software development. There is inevitably a lag, whereby the release of a new data format is rarely followed immediately by software loaders that can <u>fully</u> utilise it. Ideally data vendors and software developers would co-ordinate efforts more to ensure that this lag is minimised, as this would serve the best interests of application developers. That applications have developed, is testimony to the fact that this might be less of a problem than originally envisaged.

References

Cleminson, F. R.,1997. Airborne remote Sensing: Practical Application to On-Going Monitoring and Verification (OMV) of Multilateral Arms Control Treaties and Peacekeeping Activities. In: Proceedings of the 3rd International Airborne Remote Sensing Conference and

Exhibition, Copenhagen, Denmark, Vol 1, pp 1- 8.

Cordey, R., 1997 Report of the community meeting on Single Pass Satellite Interferometry, London.

Flasse, S., 1993 Extracting Quantitative Information from Satellite Data: Empirical and Physical Approaches. JRC Report EUR 15409.Huguenin, R., 1994 Sub Pixel Analysis: Process Improves Accuracy of Multispectral Classification Earth Observation Magazine, July 1994

Kamoun, P., 1995 The Expansion of the Remote Sensing Market, EOMARK'95 Proceedings, EARSC.

MacDonald, J.S., 1998 Remote Sensing from Space and its Economic Impact. In Future Trends in Remote Sensing, Preben Gudmandsen (ed), pp3 - 7.

Pisano, F., 1997 The International Decade for Natural Disaster Recovery (IDNR): A Safer World for the Twenty-First Century. In Remote Sensing'96: Integrated Applications for Risk Assessment and Disaster Prevention for the Mediterranean, Anna Spiteri (ed), pp 3 -7.