IMPLEMENTING AN IMAGE PROCESSING SYSTEM FOR THE NEXT GENERATION EARTH OBSERVATION SENSORS FOR THE SUNSAT 2 MICRO-SATELLITE PROGRAMME
Sias Mostert and Eduard Kriegler
University of Stellenbosch
Mostert@sun.ac.za

ABSTRACT

The next generation of microsatellite earth observation sensors will generate more data than can be downloaded in real-time by a ground-station. Managing the data volume is thus crucial to the regular access to data (operational success) of these missions. For the Sunsat 2 programme a combination of image processing and lossy image compression will be used. This paper will give an overview of the considerations and solutions for next generation microsatellite imagers.

1. INTRODUCTION

The next generation of earth observation sensors for the Sunsat 2 programme will generate more data than can be downloaded in real-time by a ground-station. Due to the limited download bandwidth and the limited contact time between the low earth orbit satellite and the ground-station network, it becomes important to reduce the data by some means.

Two alternatives exist: The first is to perform data processing and information extraction onboard the satellite and then only transmit the results. The second is to perform lossy data compression on the raw data and transmit the compressed result. Many compression options are possible, with Wavelet-based lossy image compression algorithms presently being preferred.

This paper will explore the viability of the two image processing options and the hardware implementation options.

2. THE SUNSAT 2 MULTI-SENSOR IMAGER DATA REQUIREMENTS

The data requirements considered for SUNSAT 2 include more than 3 multi-spectral bands with between 6000 and 12000 pixels each, a panchromatic sensor and a hyperspectral sensor with up to 200 channels.

3. THE DATA PROCESSING SOLUTION

By doing all the processing onboard the satellite, it is possible to obtain significant levels of data reduction. This section looks into the processing required to extract the necessary information from the images.

3.1 System Corrections
Satellite images often have to be obtained in non-clear conditions, so atmospheric corrections have to be applied. These entail stretching the contrast of the original image, which increases the visibility and level of any instrument non-homogenieties.

Image compression schemes attempt to only transmit a number of bits representing the true information in the scene, and are able to compress low information areas because there is little detail present. Instrument defects producing high spatial information should thus be removed prior to compression to avoid keeping the compression busy encoding instrument defects.

Both area and linear sensors have fixed pattern noise. One component of the noise is independent of the illumination level of the pixel, and is related to dark current differences and other offsets between pixels. A second component is proportional to signal level (PRNU – photo-response non-uniformity) and results from variation in the photo-response of pixels arising from small geometric differences from masks, lithography, and etching.

The first image correction is thus a per-pixel offset and gain correction. The offset correction also normally removes any clock feed-thru artifacts from the data.

On area arrays, it is possible to develop line dropouts due to failure of one of the transfer cells. To avoid the effects of such a line being spread further by a compression algorithm, the line should be replaced by the nearest valid line prior to compression.

To avoid transmitting large cloud-covered areas, the final sensible function to perform on-board the satellite is to delete large cloud covered areas before passing data to the downlink encoders.

3.2 Atmospheric Corrections

The atmosphere and particles contained in the atmosphere, reflects, refracts and absorbs electromagnetic waves. These effects are not uniform and vary as temperature, pressure, particle distribution and ground level changes. Effective correction of these effects requires a detailed model of the atmosphere and some knowledge of the atmospheric condition at the time of image acquisition.

Some good models do exist (like the 6S-model), but to obtain the best results, the model needs to be very accurate. This may require a high level of human control. Also, the algorithm does require significant processor time, and is best implemented on the ground.

3.3 Geometric Correction and Referencing

Geometric correction removes the effects of optic viewing geometry, satellite orientation, land slope and shadows in images while geometric referencing is the process of mapping the pixels of an image to actual earth coordinates. The level of processing that is appropriate depends greatly on the purpose of the imagery.
Geo-referencing is done by identifying ground control points (GCP’s) in the images, and warping the image to match the known locations of the points. By identifying enough GCP’s, polynomial equations can be generated that will transform the image. The image is then resampled in the new coordinate system.

3.4 Extracting the Required Information

After all appropriate corrections above had been completed the information extraction process can start. Some processes, such as looking for unauthorized fishing activities is potentially implementable on-board, but most information extraction is best performed on the ground where human access is feasible.

3.5 Conclusion

The amount of human control necessary to obtain good information extraction results means that most processing will remain to be done on the ground, and the main purpose of on-board processing is to prepare data for efficient compression and downlinking.

4. THE LOSSY IMAGE COMPRESSION SOLUTION

Lossy image compression offers significantly higher compression ratios than lossless compression algorithms. The algorithms cannot guarantee the perfect reconstruction of the original data, and many maximise the visual appeal by exploiting known insensitivities of the human visual system. Care must be exercised that the radiometric information (or scientific data) in the images is not damaged as a consequence of the processing, including effects such as data drop-outs, that may be absent in terrestrial applications.

In addition to adversely affecting the useful information contained in the images, lossy compression may also make some image corrections, described in the previous section, more difficult to perform successfully on the ground.

Although an initial implementation of Shapiro’s Embedded Zerotree Wavelet (EZW) image compression algorithm [1] has shown attractive results, the Sunsat 2 programme presently prefers a guaranteed maximum distortion level which is not possible with the original EZW algorithm.

5. A COMPROMISE SOLUTION

Both previous has some shortcomings. By combining the two solutions, some of these shortcomings can be by-passed. The idea is to perform some parts of the image processing chain onboard the satellite before using the lossy compression to compress the resulting image. However, this will require an understanding of how each step in the processing chain will affect the science data in order to better judge which steps to place onboard the satellite.

5.1 The Impact of the Processing Chain on the Science Quality of Images
The two steps of the image processing chain that can have the greatest impact on the science quality of data are the system corrections and the atmospheric corrections. Both of these phases remove artifacts from the image and it is this removal of the artifacts that improves the science quality.

Due to the reasons outlined in section 3, the atmospheric corrections will not be considered for implementation onboard the satellite at this time. Therefore only the system corrections are done onboard.

The EZW algorithm used in evaluation tests is not very good in dealing with noise in the images. Noise added into the satellite image before compression could not be extracted as easily from uncompressed images, even when it could be readily removed from the original images.

5.2 Alternative Error Functions for Lossy Compression Algorithms

The compression algorithm needs an error function to tell it when to end the compression process. Usually this error function will monitor the current compression rate and stop as soon as a preset minimum ratio has been reached.

By replacing this error function with one that can monitor the quality of the data the compression process can be stopped when a certain level of quality is reached.

6. HARDWARE IMPLEMENTATION OPTIONS

The Sunsat 2 programme requires a platform with reconfigurable hardware and software to allow for better upgradeability. Furthermore, to meet the real-time requirement, it must be a high performance platform.

Reconfigurable hardware will require the use of a FPGA. Both Altera and Xilinx offer FPGA’s with built-in high performance microprocessors. Another option would be to use multiple smaller soft-core microprocessors in conjunction to more dedicated hardware in the FPGA to achieve high performance.

7. CONCLUSION

Future camera payloads produce data rates far exceeding downlink capability, making it essential to compress data on-board the satellite. Care has to be excercised in the processing to remove artifacts at the correct location, and also to ensure that while maintaining good visual appearances of imagery, the radiometric values are not allowed to drift – an effect to which the eye is not sensitive.