CLEMEmTINE: ON-BOARD IMAGE COMPRESSION
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In spaceborne remote sensing, the amount of image data collected always increases and the ability to store or to transmit it does not increase so fast. There is then a growing interest in developing on-board compression that could provide both high compression ratios and low degradation.
Real-time on board compression is nowadays possible thanks to the progress of both electronic and data processing: a compression module has been successfully used in 1994 during Clementine mission.
We describe first in this paper typical image compression algorithms and present a flexible hardware implementation of a JPEG based compressor. We point then out that the more the compression is optimized according to the mission, the more image quality will be preserved.
We conclude this paper with some Clementine compression results and analysis and with future prospects in on-board compression.

1 - Introduction: Image compression algorithms
Image compression aims to reduce the number of bits required to represent an image by removing the redundancies and the non-pertinent information. They are many approaches to image compression but they can be categorized in two fundamental groups: lossless and lossy.
In lossless compression, the reconstructed image after compression is numerically identical to the original image on a pixel-by-pixel basis. Only a modest amount of compression is however achieved.
In lossy compression, the reconstructed image contains degradations relative to the original one. As a result much higher compression can be achieved as compared to lossless compression. If the compression has been well defined, these degradations may not be visually apparent or not be relevant for the use and post-processing of the data.
The compression ratio (CR) is defined to be the ratio of the number of bits for the original image to the number of bits for the compressed image.
Every compression system consists in three main parts: decorrelation, quantization and encoding. Only the quantization operation is irreversible but the amount of lossy information can be controlled.

2 - Image Compression Module development
For applications in the MARS exploration mission, Matra Marconi Space [3] developed under CNES contract an Image Module Compression (ICM) between 1989 and 1991. The ISO standard JPEG algorithm [2] for still picture compression has been adapted and implemented with up to date rad-tolerant ASIC technology. The first step of the algorithm is a Discrete Cosinus Transform performed on 8*8 blocks of pixels. The transform removes the redundancy and produces decorrelated spectral coefficients with 11 bits precision. The second step is the quantization: a division by a quantization step with rounding to the nearest integer. The quantization step is defined by two parameters: a scale factor, which is constant for all spectral coefficients and a weighting factor which allows to set different quantizers for each spectral coefficient. The third step is entropic coding. The quantized 8*8 block is scanned in zig-zag order, then searched for runs of zero values. Each non-zero value produces an event which is Huffman coded using a predefined variable length code table.
The ICM is very flexible: the transmission format is programmable and the compressor uses a 2k*8 PROM to store 4 sets of algorithmic and formatting parameters (an algorithmic set consists in 16 scales factors, one weighting 8*8 matrix and one code table).
The compressor fits in 6000 mm² and is able to process up to 4 Mpixels/s with a maximum power consumption of 700 mW/Mpixels/s.
3 - Use of the Image Compression Module in Clementine mission:
Compression parameters optimization

In order to optimize the compression, the whole image chain has to be considered from the on-board sensor to the on-ground image post-processings. The optimization of compression parameters consists in two steps: the first step before launch has been devoted to the simulation of images and to the working-out of image quality criteria (as specific as possible to the Clementine mission [1]) and to the development of an optimization tool (cf. figure). The first step is necessary to define a preliminary set of optimum compression parameters.

The second step during the first orbits around the moon has been devoted to the compression parameter estimation from Clementine lunar images (and no more simulated images) since uncompressed images have been transmitted. This second step has allowed the production of still more optimum parameters, which have been up-loaded to Clementine. Compression results are the following ones:

<table>
<thead>
<tr>
<th>SENSOR</th>
<th>Averaged Compression Ratio</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UVVIS</td>
<td>6</td>
<td>1.1</td>
</tr>
<tr>
<td>NIR</td>
<td>2.2</td>
<td>1.4</td>
</tr>
<tr>
<td>LWIR</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>HIRES</td>
<td>10</td>
<td>2.3</td>
</tr>
<tr>
<td>Star Tracker</td>
<td>30</td>
<td>1</td>
</tr>
</tbody>
</table>

Compression results for each Clementine sensor will be further detailed and analysed during the presentation.

4 - Conclusion

On-board compression may be considered as a way to optimize both on-board storage and transmission without any degradation of the mission insofar as all the characteristics of the image chain (from the sensor to the on-ground post-processings) have been studied. CNES further compression activities are focused on on-board processings before compression and on better decorrelation methods such as multiresolution compression.

References