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Optimizing computing time for cloud-tracked winds by template matching: a parallel computing approach

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Abstract

We discuss the implementation of a parallel computing solution to optimize the computing time of an image cross-correlation task for cloud tracking in a planetary atmosphere. This is performed sequentially, at first, within a larger image analysis procedure, by a set of MatLab (ML) scripts. In this context, some insight is given concerning the ML scripts' conversion to a parallel application, PrcImages, written in C and using MPICH2 as portable implementation of MPI, and detailed results are presented that demonstrate the significant optimization achieved, in terms of computing time, with different hardware configurations, namely the Nonius cluster (project GridPT) located at the CAAUL. Also, further insights are provided about the integration of PrcImages' execution and output into the remaining image analysis procedure, and some notes are presented regarding future work, mainly the possibility of optimizing access to Nonius's resources, for a completely autonomous and non-idle execution of PrcImages, when called within a Torque PBS/Maui script. VIRTIS images of the atmosphere of Venus are used here as case-study, since they were used as test basis for this parallel application.

1. Introduction

Here we describe a parallel computing solution for the problem of cross-correlating a pair of images, applied to planetary research. This work led to the creation of PrcImages, a C application, with the aim of optimizing CPU time spent correlating a large set of infrared images taken by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS), onboard ESA's Venus Express spacecraft. We will describe the image analysis procedure and purpose and the correlation task, as well as the context of PrcImages' creation and its parallel implementation.

2. Analysing Planetary Images

With the aim of studying the evolution and dynamics of Venus' Southern Polar atmosphere, we routinely need to process large sets of infrared images obtained by VIRTIS (Piccioni et al., 2006; Drossart et al., 2007). In order to obtain a wind velocity vector map for the region of interest – see Figure 1 –, the adopted solution consisted on correlating pairs of time-displaced images taken from a given area, to determine feature displacement between the images in each pair. The technique is widely used for ground and orbiter-based wind measurements in planetary science (see Sanchez-Lavega et al., 1999; Wang and Ingersoll, 2003; Ogohara et al., 2012)

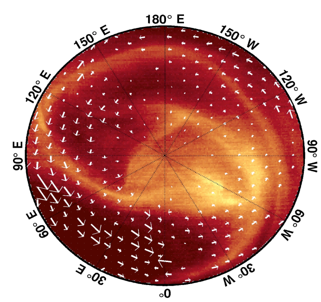

Figure 1. Example of a wind velocity vector map for the Venus polar region, overlaid on a VIRTIS/Venus Express radiance map at 5 μm.

3. Summary and Conclusions

We address the optimization of computing time for image cross-correlation, using a parallel computing approach, with the aim of determining motion of cloud features in a planetary atmosphere (Luz et al., 2008; 2011).

Starting with a set of ML scripts already tested and routinely used in our team for cloud tracking in planetary images, a sequential application, PrcImages, was created, which generated the same results as the former ML scripts.

A master-slave model was adopted, with a partitioning strategy similar to "M-divide and conquer", allowing small communication overhead: after initially distributing a copy of four arrays to each slave, master-to-slave communication consists on transmitting a pair of array coordinates, while slave-to-master communication consists on sending the cross-correlation output. Three distinct hardware profiles were used to test PrcImages, namely the Nonius cluster at the CAAUL.

The results presented in this work show the benefit of employing a parallel solution to optimize image cross-correlation execution: computing times decreased significantly, from around 2700 seconds with ML scripts to approximately 40 seconds with PrcImages' parallel version, executed by 10 processes in Nonius, while maintaining accurate cross-correlation output.

Time results also show that Nonius performance is optimal when executing PrcImages with 10 to 16 processes, corresponding to computing times ranging from 44 to 27 seconds, on average, with an efficiency between 0.56 and 0.57.

PrcImages is interfaced with ML, for further data processing, and communication between them is made through ASCII files, to ensure compatibility.

When executed in configurations like Nonius, with Torque PBS + Maui as resource manager, PrcImages must be called within a PBS script, which, in certain conditions, poses an issue to ML scripts' capability of batch-processing the images. A solution is now being prepared for this, in order to allow a fully autonomous and non-idle execution of PrcImages.

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