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On the Importance of an Automated and Modular Solar Image Processing Tool

E. Shahamatnia, I. Dorotovič, J. Fonseca and R. Ribeiro
UNINOVA/CA3, Dept. of Computer and Electrical Engineering, New University of Lisbon, Portugal,
{ehs,id,jmf,rar}@UNINOVA.pt

Abstract

Developing sophisticated software tools is essential to support studies of solar activity evolution, climate change understanding and space weather prediction. With new space missions such as SDO, solar images are being produced in unprecedented volumes. To capitalize on that huge data availability, the scientific community needs a new generation of software tools, which enable automatic and efficient data processing and manipulation. In this work, we argue that a modular system design is required to achieve a stable, extendable and comprehensive solar feature tracking tool.

1. Introduction

The Sun is our main source of energy and also the main driver of space weather [5]. The Sun is constantly emitting magnetic field structures, radiations and plasma. The energy of the solar radiation governs a variety of processes in the interplanetary space, in the Earth's atmosphere and at its surface. A better understanding of solar activity processes, such as solar flares, sunspots, filaments and coronal mass ejections will contribute to improve forecasting models of space weather and ultimately to develop better early warning systems.

In the last decades there has been a steady increase of high-resolution data, from ground-based and spaceborne solar instruments, and also of solar data volume. These huge image archives require efficient automatic image processing software tools capable of detecting and tracking various features in the solar atmosphere. Results of applying such tools are essential to support studies of solar activity evolution, climate change understanding and space weather prediction.

1.1 Processing more data faster

In order to find the correlation between the quantity of data and the quality of research is solar studies, Aschwanden [2] created a histogram of peer-reviewed solar physics publications based on NASA's ADS database for the time interval of 1900-2006. According to his results, the publication rate was almost constant before 1950 and suddenly changed afterwards. It has been continuously increasing in a linear scale till now. Taking into account the exponential growth in the data storage capacities and linear growth in science results measured in terms of publication, Aschwanden concludes that science return scales roughly logarithmically with amount of available data. This highlights the need for tools that enable scientists to process large amount of data automatically, thus keeping up with this science return growth rate. This means that without proper automatic tools fully processing and comprehending exponentially growing space weather data will be hampered and hence the scientific productivity will slow down.

In the last decade, profiting from the enormous advances in computer storage availability and processing capabilities, there has been an increasing interest in addressing this problem. Automatic identification of solar features has been studied in the literature from various perspectives, with solar image processing being a popular track of research. Works done in [1–3, 6, 10] are some of them. Maybe the most important data for creating a comprehensive automatic feature-recognition system is put forward by the Solar Dynamics Observatory (SDO) [7]. By providing about 1.5 TB of solar data per day, SDO is pushing the solar image processing scales to the next level. To keep up with the huge quantity and improved quality of the provided solar images in order to produce digestible data for solar physicists, new software tools are required. Efforts of Feature

Finding Team (FFT), reported in [7], aim to address this challenge.

2. Being modular is the key

At CA3-UNINOVA [11], we have been developing a working prototype of a modular framework for solar feature detection, characterization and tracking. To develop an efficient system capable of automatic solar feature tracking and measuring, a hybrid approach, combining specialized image processing, evolutionary optimization and soft computing algorithms is being followed. By using a specialized hybrid tracking algorithm for tracking solar features we can achieve automatic feature tracking while gathering characterization details about the tracked features. The proposed tool was already tested for tracking sunspots and coronal bright points. The results obtained and details about the tool can be found in [4, 8, 9].

The main modules of this tool are: Sunspot detection and tracking, finding solar disk and solar radius, CBP tracking, metadata storage and retrieval, axis and tilt correction, general illumination and contrast corrections, centre to limb darkening corrections, foreshortening effect compensation, solar feature area calculation, classification of Sunspots, input file handling, image dataset navigation, etc. The modular architecture of the proposed framework allows a better reusability and scalability of the system. Several rudimentary preprocessing modules can be chosen to work on various inputs from different sources on an as-needed basis. Common modules such as disk detection, input file handling (i.e. tiff, jpeg, jpeg2000, and FITS file related operations), importing/exporting knowledge bases, visualisation and user interaction, can be shared for different applications of the framework (for instance Sunspot detection and classification or CBP tracking). Modularization produces a structure that integrates the highly dependent tasks with low interdependencies between the modules. By separating the core algorithm modules from pre and post-processing modules, and using metadata repository concept throughout different blocks of the framework we can apply the same algorithms on different solar images from different observatories with minimum efforts.

A brief introduction to the underlying techniques and a use case demonstration will be presented.

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