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Interconnection and valorisation of long-term solar datasets via deep learning

DURATION
15/12/2019 - 15/03/2024

BUDGET
556 847 €

PROJECT DESCRIPTION

Context

Sunspots are dark spots appearing in groups on the surface of the Sun as a manifestation of solar magnetism. The magnetic field embedded in sunspots is the driving force behind the solar variability that influences the Earth space environment on a day-to-day basis. Studying sunspots evolution on a long-term basis is a keystone to several areas of Solar Physics, from helioseismology to irradiance modelling and the prediction of space weather.

The Royal Observatory of Belgium (ROB) is a key player in sunspot observations: In 1939, the ROB Solar station (called 'USET', for Uccle Solar Equatorial Table) started up a solar observing program in collaboration with the Zürich Observatory consisting of daily drawings of the sunspot configuration. As of July 2019, this collection counted 23000 sunspot drawings and is still expanded every day. In this project, we will use these sunspot drawings, along with two other datasets produced by the USET facility: White light images, taken since 2002, and CaIIK images, taken since 2012, see Table 1. The co-temporal and co-spatial acquisition of drawings, white light, and CaIIK images makes it favorable to interconnect these datasets using novel image processing techniques, see Figure 1.

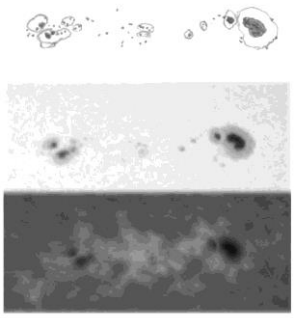

Figure 1 Sunspot group on a drawing (upper panel), a WL image (middle) and a CaIIK image (lower)

Type of images	Available since	Drawings since availability	Observation days since availability	Drawings, images [2002-2007]	Drawings, images [2012-2019]
Drawings	Mars 1940	23831		1987	2080
White light WL	February 2002	5135	3895	3465	14680
Calcium CaIIK	Augustus 2012	1879	1766	0	16034

Table 1: USET data availability as of July 1, 2019. For CCD cameras, multiple images may be recorded on one day. No images are indicated for the [2008-2011] because it was a solar minimum period with few sunspots.

General objectives and underlying science questions

The over-arching goal of this project is to produce high-level data products for science data exploitation and dissemination from the various USET datasets. We want to go back in the past by exploiting the connection between drawings and WL pairs of images on one hand, and WL and CaIIK sequences of images on the other hand. The goal is to reconstruct important information from the past when no direct data, such as magnetic information or solar irradiance measurement, is available. To go back in the past, we will leverage on advancement happening in the signal-processing field. In the process, we will derive algorithms for the:

- Translation of sunspot drawings into white-light (WL) images
- Automated classification of sunspot groups on WL images
- Tracking of sunspot groups on WL images
- Connection between photospheric (WL) and chromospheric (CaIIK) sequences of observation

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Methodology

The wealth of today's information will improve our knowledge of past solar activity as we leverage on advancement happening in signal processing methods, and in particular in image-to-image translation methods based on convolutional neural networks (CNN). This will require a careful preparation of the data, with in particular the precise delimitation of sunspot group boundaries and the tracking of these groups over time. CNN will also be used to devise an automated classification of sunspot groups based on photospheric information.

Potential impact on research

Translating drawings into white light images will allow going as far as 1940 while handling a standard imaging modality. An automated sunspot classification tool will allow independence from the man-made classification and help reduce the forecasting latency, giving us earlier predictions of solar events that could have an impact on our planet.

Tracking of sunspot groups on WL images will allow for long-term studies of sunspots dynamics, with almost 8 solar cycles of observations. Currently such studies are done with only 3 solar cycles of observations. The evolution of sunspots is important e.g. in the context of space weather studies.

Solar irradiance has been directly measured from space since 1978. This quantity is paramount to understand the effect of the Sun on our climate, from the distant past to the future. To go farther in the past researchers today use mostly linear regressions. There are also attempts to better reconstruct irradiance from CaIIK images since these images are available further in the past. However, the quality, consistency, and availability of the historical data greatly varies.

Our CaIIK observations, complemented with same-time WL observations even if only going to 1940 will provide a significant contribution in this irradiance study.

Expected final research results and valorisation perspectives

The output of the developed algorithms will be inserted in a 'consolidated sunspot group database'. Together with the standardized USET images, they constitute new USET data products. We will make these high-level products available via virtual observatories and standard data access protocol, with as primary target groups: colleagues from the scientific community and space weather operators. The goal is for solar physicists to be able to use the derived products, e.g. for sunspot evolution study, or for reconstruction of solar irradiance in the past. Valorisation towards the scientific community will happen through the publication of scientific articles as well as communication at conferences and seminars. As for social valorization, the general public will be encouraged to participate in our efforts, via a citizen-science initiative for assessing the performance of the sunspot group classification task.

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LINKS

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