SOLEV: A Video Generation Framework for Solar Events from Mixed Data Sources (Demo Paper)

Soukaina Filali Boubrahimi, Berkay Aydin, Dustin Kempton, Rafal A. Angryk
 Department of Computer Science
 Georgia State University
 Atlanta, GA 30303, USA
 {sfilaliboubrahimi1, baydin2, dkempton1, rangryk}@cs.gsu.edu

ABSTRACT

One of the main strengths of Geographical Information Systems (GIS) is the analysis of spatial and attributive data. Spatiotemporal interpolation techniques allow the expansion of the collected data to the sites where no samples are available. In the context of GIS, the data, be it interpolated or collected, are visual in nature and hard to understand in raw forms. Visualization of complex evolving region trajectories is often times used as an aid to better understand the data and its underlying patterns. In this work, we created SOLEV, a solar event video generation framework that integrates multiple data sources of solar images. This is the first framework of this kind that not only visualizes spatial solar event boundaries, but also the tracked and interpolated spatiotemporal trajectories they form over time.

Categories and Subject Descriptors

H.2.8 [Information Systems]: Database Management—*Database Applications*

Keywords

Spatiotemporal Visualization, Spatiotemporal Interpolation, Evolving Regions Trajectories, Video Generation

1. INTRODUCTION

Spatiotemporal data sources with rich semantics are being made publically available online for research purposes every day, which fuels the need for data manipulation and analysis. With the cost of storage dropping and the availability of spatiotemporal data sources, data quality and quantity should be maximized. NASA's Solar Dynamics Observatory (SDO), produces eight 4096 by 4096 pixel solar images every ten seconds, which add up to a total of 1.5 TB of daily data [6]. The captured data streams are then fed to different software modules that trace and analyze multiple event classes, including filaments, flares, active regions, coronal holes, coronal mass ejections, coronal dimming, X-ray bright

Figure 1: Solar images taken by the Solar Dynamics Observatory's Atmospheric Imaging Assembly (AIA) instrument with overlaid coronal hole events captured on (a) 2015-11-27T00:13:06, and (b) 2015-11-29T00:12:42 (Both labeled as SPoCA 22264).

points, coronal jets, and coronal oscillations [5]. Metadata about those aforementioned solar events can be queried from the Heliophysics Event Knowledgebase (HEK), which is a massive online solar metadata repository. In [4], a tracking algorithm is proposed to find trajectories of event. This textual metadata includes instances reported by the HEK. The tracking takes individual detections from the HEK, and links them together into trajectories in an iterative fashion. An example of trajectory of two coronal hole events are shown in Fig. 1.a and Fig. 1.b.

One of the main challenges in doing spatiotemporal analysis is the scarcity of accurate event trajectory metadata. Solar images are captured frequently, however; the event detections are not run on all solar images. As a result, the detection modules report solar events metadata less frequently. One way to mitigate the scarcity problem is to interpolate the missing trajectory data with a given cadence based on the originally reported solar events in the HEK. A solar event instance has spatial and temporal attributes. The most prominent spatial attribute of the interpolated event instances is the polygon boundary, which represents the exact location of the event on the surface of the sun. The interpolated polygons form a trajectory over time. Thus, the data is visual in nature and hard to understand without the aid of a proper visualization tool.

All of the SDO data has an open-access policy¹ that states that the use of SDO images for non-commercial purposes and public education and information efforts are strongly encouraged and require no expressed authorization. The data is available to the public via a number of distribution channels. Two visualization tools for the solar and heliospheric images are already available online. The first tool is the iSolSearch² client from the HEK that provides an interface for solar physicists to visualize spatial boundaries on

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¹<http://sdo.gsfc.nasa.gov/data/rules.php>

²<http://lmsal.com/isolsearch>

Figure 2: ISolSearch fixed disk visualization for 2016-06-19T00:00:00-2016-06-19T23:59:59 time span.

a fixed disk that represents the solar disk as illustrated in Fig. 2. The second tool is the Helioviewer³ which is an image viewer that allows the visualization of overlaid spatial boundaries of individual solar events. In addition to the disk and solar image visualization that iSolSearch and Helioviewer provide, the short movies of short movies of fixed regions are also generated, but they do not point out to the spatiotemporal event boundaries primarily because of the lack of trajectory data.

The aforementioned tools are designed to visualize the spatiotemporal boundary data; however, they are limited to untracked spatial event boundaries that have been reported by their respective detection modules. In this paper, we describe our video generator framework (SOLEV) that is, to our knowledge, the first attempt to visualize spatiotemporal trajectories of tracked and interpolated solar data combined.

2. SOLEV OVERVIEW

The results of event detection process generated from the different detection software modules are textual metadata related to the event instance including the event instance location, spatial boundaries in helioprojective-cartesian and heliocentric coordinates (HPC), minimum bounding box, and centroid. The data is then passed on to our tracking module [4] that relates event instances across images and creates evolving regions trajectories. The trajectories of events textual metadata are used as an input to our interpolation module, which interpolates the event shapes at times where no detection was recorded. The last step, which is the focus of this paper is the video generation step that takes the SDO images and combines them with the tracked and interpolated metadata. The video generation process consists of overlaying the polygon geometries at their locations in our SDO images, and encode them into a video format. The whole process is summarized in Fig. 3. We give a detailed description of our framework’s components in the following parts of the section.

³<http://Helioviewer.org>

Figure 3: Solar events metadata generation and processing steps

2.1 Data Sources

The SDO takes 10 solar images every 10 seconds daily. The observatory carries three independent instruments: The Helioseismic and Magnetic Imager (MKI), the Extreme Ultraviolet Variability Experiment (EVE), and the Atmospheric Imaging Assembly (AIA). In this work, we only focus on using images from the AIA instrument as the majority of the events we use are detected in these images and therefore are most visible in these images. The AIA instrument captures full-disk solar images in 10 different electromagnetic wavelength bands across the ultra-violet and visual spectrum. In fig. 4, an illustration of how the different wavelengths show different layers of the sun is presented.

With the large volume of images being produced, an automated system was needed to process and detect solar events on these images. So, NASA funded the formation of an international consortium of independent groups called the Feature Finding Team (FFT) to develop several modules for this task.

For example, the Spatial Possibilistic Clustering Algorithm [7], has been implemented to deliver modules detecting active regions and coronal holes, while the Advanced Automated Filament Detection and Characterization Code module [2], is the module used to detect filaments. All modules have access to the raw data pipeline for near-real-time event detection and data analysis. The metadata about the solar events is then reported and hosted in online repositories, such as the HEK, ready for querying.

2.2 Tracking Event Instances

The tracking module previously appeared in [4] takes individual detections from the HEK, and links them together into trajectories in an iterative fashion. The tracking algorithm firstly links the individual detections by projecting a detected object forward using the known differential rotation of the solar surface, and searches for the potential detections that overlap with the search area at the next time step. If there is one and only one possible detection to be linked

Figure 4: The sun in different wavelengths from left to right: 94, 131, 171, 193, 211, 304, 335 Å. The images were captured by SDO within a 3 minute period.

to, the algorithm links them together. The results from this step are then fed as the input for subsequent processing steps. After the initial step of linking detections together, the algorithm repeats the search for possible detections to link to. In these later steps, the algorithm considers detections that had multiple paths in their search region. To determine which path a tracked object takes, several aspects of visual and motion similarity are compared to produce a probable path for the object. The resultant paths are again fed into another iteration of the algorithm with larger and larger gaps between detections allowed to account for missed detections in the original metadata.

2.3 Interpolating Event Instances for Better Accuracy

Our interpolation algorithm takes a trajectory segment composed of two polygons as input, and generates one or more interpolated polygons depending on the user-defined time cadence. The interpolation algorithm aligns the start points of two polygons' vertices to capture rotation based on shape similarity [3]. The two input polygons are firstly transformed into two time series, where the values of the time series are the distance between the centroid of the respective polygon and the point coordinates of polygons' vertices. Dynamic time warping technique is used to link and align two input polygons represented as time series. The result of this step is a many-to-many point matching. Next, linear interpolation is used between all the matched pair of points to generate a set of interpolated polygon objects. An example of interpolated trajectory between two polygons with a cadence of 1 hour is shown in Fig. 5. The black polygons represent the tracked event types and the three blue polygons are the interpolated ones.

2.4 Trajectory Video Generation

The video generator takes two inputs as shown in Fig. 3. The first input is the interpolated trajectories from the previous modules. The second input is the thumbnail images from the SDO. The video generation process consists of two major steps. The first step retrieves individual trajectories consisting of two input polygon geometries of the tracked and interpolated events. The second step consists of

Figure 5: Input filament event type polygons that happened respectively on 2012-01-06T18:05:45 and 2012-01-07T09:33:12 with the dashed interpolated polygons at 2012-01-06T21:50:45, 2012-01-07T01:35:45 and 2012-01-07T05:20:45

Figure 6: SOLEV System behavior (1) SOLEV issues a pull request for the track metadata (2) SOLEV issues a pull request for the image thumbnail to the GSU DMLab server (3) if step (2) is unsuccessful, SOLEV issues a pull request for the image thumbnail to the Helioviewer

requesting the image thumbnails of the sun at the time of occurrence of the individual reports in the trajectory from the DMLab server at Georgia State University. If the retrieval is successful, the thumbnail is directly retrieved from the data store for further processing. In the case of non-existence the thumbnail in our database, a request is sent to the Helioviewer online repository to retrieve the corresponding image, and stores it in our database. Fig. 6 illustrates SOLEV system behavior for the two previous scenarios. After the solar image containing the event is retrieved, information about the event is added to it. The information consists of the event class, the trajectory start and end dates, the event centroid, and exact time of occurrence.

There is a range of 10 wavelengths that the user can choose from to generate the video. Seven out of the ten wavelengths are illustrated in Fig. 4. The three other wavelengths that are not shown in the aforementioned figure are 1400, 1700 and 4500 Ångström. An example of 304 and 4500 Ångström wavelengths thumbnails is shown in Fig. 7. This latter illustrates an example of a series of input images of an active region and a coronal hole trajectories with the spatial boundaries overlaid on top of the images.

The polygon geometry representing the event instance is reported in HPC, a coordinate system used for solar image data. The HPC coordinates are then converted to pixel-based coordinates based on the thumbnail image specific

Figure 7: (a) Trajectory segment of an active region (AR) event boundary from 2013-10-14T04:01:36 to 2013-10-14T08:01:36 overlaid on the corresponding 306 Ångström wavelength images (b) Trajectory segment of a coronal hole (CH) event boundary from 2013-08-15T11:02:55 to 2013-08-15T15:02:55 overlaid on a 4500 Ångström wavelength image

meta-data. This process removes the need for any further spatial positioning transformations. After the events meta-data and spatial boundaries are drawn in their corresponding thumbnails, the images are fed to the video encoder that generates a complete video of tracked and interpolated trajectories combined.

The demonstration will highlight the visualization capability of our implemented video generator. Readers are invited to access our public video generator webpage⁴ and explore our framework.

3. CONCLUSION AND FUTURE WORK

In this paper, we presented SOLEV framework that provides visualizations of spatiotemporal event trajectories that are visual in nature. SOLEV is the first framework that integrates multiple data sources of solar images to generate videos of tracked and interpolated solar events in different wavelengths. While our framework provided to be useful for visualizing event trajectories from data sets with evolving regions, there are a couple of areas in which it could be improved. SOLEV works by retrieving single trajectories one by one and overlaying the trajectory segments on the corresponding image thumbnails. the framework will benefit from the addition of all trajectory segments that happened at the same time in a single thumbnail, which is useful for spatiotemporal co-occurrence pattern analysis [1].

4. ACKNOWLEDGMENT

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⁴<http://solev.dmlab.cs.gsu.edu>

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