Solar Prominence Feature Tracking

Jean J. Lorre

Introduction

Many images returned to Earth comprise objects with dynamic surfaces—Jupiter, Saturn, Venus, and the Sun, for examples. Because these objects are constantly in motion, the history of where they move betrays the dynamics of the local atmosphere. From knowledge of atmospheric dynamics, we can reveal the physical processes at work within the atmosphere. In certain cases, it may be acceptable to permit spacecraft to track features and to return only the velocity vectors—arrows that indicates the motion of an atmospheric feature over a period of time. This on-board type of logic has great potential in reducing the overall data transmission load to Earth. Our Sun takes feature tracking to a new level because it consists of a superposition of three-dimensional hot loops—solar flare-types of features—upon a boiling background. However, there is benefit in characterizing solar activity because it directly affects communication on Earth. Great loops erupt from the Sun and eventually arrive here. We have found an autonomous means of modeling them.

Modeling Prominences

One of the most interesting features we have been tracking has been solar hot loops seen in EUV (extended ultra violet) imagery. These features are more difficult to track than features lying on a surface because they appear different when viewed from other perspectives. Thus there is no way to predict feature locations in an image by just positioning the viewer or rotating the sphere. To obtain three-dimensional image structure, therefore we must view the 3-d world via stereo image pairs.

With true (simultaneous) stereo pairs, and knowledge of where and when they were obtained, restriction of feature matching to those coordinates would produce physically realistic solutions. Monocular views alone provide few constraints. In the process of matching features in stereo pairs in order to later track them, we compute the three-dimensional nature of these features, and can tell from their heights whether they are solar hot loops or surface structure. To illustrate, we determine the 3-d structure of hot loops and allude to possible data-compression benefits as follows.

First, solar coordinates, pointing coordinates, and camera parameters permit us to construct a "camera model". A camera model is an algorithm that can convert a 3-d point in space into an image coordinate and, inversely, convert an image coordinate into a view ray from the camera into the 3-d space of the object. A view ray contains all those points in the 3-d object along your line of sight. Given a stereo pair with two camera models, we can construct an epipolar line. This is a line in both images formed by the plane containing both cameras and any 3-d point on or in the object being viewed. Epipolar lines are very useful because, given an image point in one camera, the only place the corresponding point can lie in the other camera is along the epipolar line defined by the first point. We will rely upon this formidable constraint to aid us in rejecting false matchings.

Then we process each image of the stereo pair independently. This involves locating points that are on the bright crest of hot loops, determining the direction of image texture, and then connecting the points together into strings representing individual loops.

We do not yet know the one to one (1:1) association between the strings sets in both images of this example. Therefore, to match the strings of points in both images, we compare each string in one image with the strings in the other image. For a point in one image we look for a string of points in the other image that cross the epipolar line. By comparing the view ray for the first point with the view ray for the epipolar crossing point in the other image, we extract the 3-d location of where these view rays cross. This will be a physical point in solar coordinates. If that point is on the solar surface, it belongs to a surface feature. If it lies within about 100,000 kilometers above the surface, it may be a point along a hot loop. If it is well above this or within the Sun, it is due to a mismatch between strings in both images and can be ignored. Many strings may cross the same epipolar line and result in nonphysical geometry. Eventually, after comparing all strings and tabulating all meaningful associations, matches are made based upon the number of good points in common between strings in both images. The result is a list of loops and their detailed 3-d profile in solar coordinates. This entire process is performed without human intervention.

It is not possible to test this process directly upon solar imagery because of the lack of simultaneous stereo pairs. Images taken close in time provide inadequate baselines and images taken far apart in time are unrelated. To test the software, we created synthetic hot loops using a magnetic solar model. Two such images are shown as Figures 1 and 2. The software locates all the shown hot loops and associates them correctly, producing 3-d values for each point which are close to the true synthetic ones. Only strings that are very close can be confused. We can, however, test the software that locates the strings of points. Figure 3 shows a Trace image with strings superimposed, and in which many of the strongly linear features have been located.

We look forward to eventually tracking hot loops by locating features that look the same and propagate gradually with time.

Data compression benefits

One potential benefit is in the area of data compression. If two satellites obtained stereo data then it would not be necessary to transmit the imagery to Earth. They could, on board the spacecraft, locate the strings of points lying along hot loops and downlink the strings. This would result in a data compression of about 1000 to 1 (1000:1).

Conclusion

There are many benefits to feature tracking in imagery of objects with gas atmospheres. These include autonomous feature recognition and modeling, and data compression based upon the specific topic of interest.

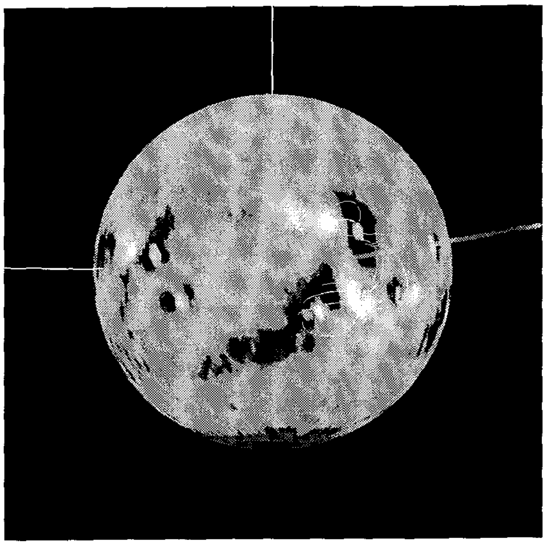

Figure 1. Synthetic hot loops using a magnetic solar model, Exhibit A

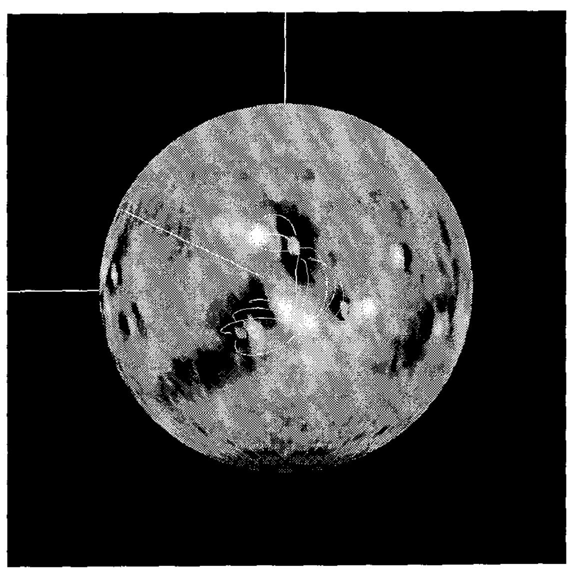

Figure 2. Synthetic hot loops using a magnetic solar model, Exhibit B

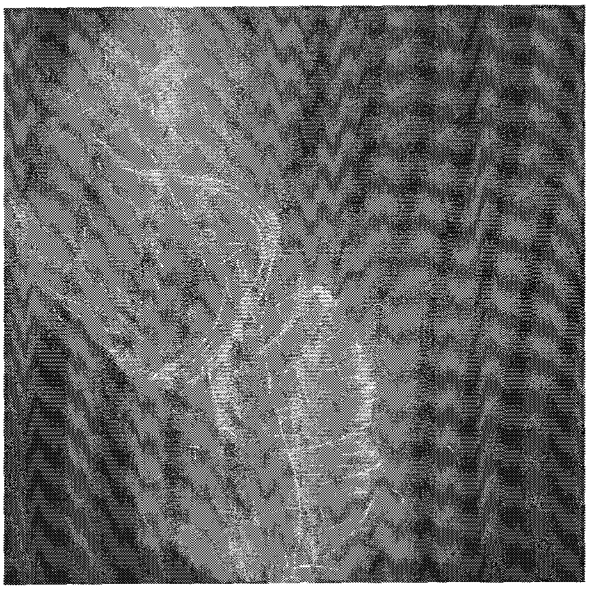

Figure 3. Trace image with strings superimposed