Augmenting a magnetic feature tracking code by interpreting interactions between magnetic elements

M. Gošić and L. R. Bellot Rubio

Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain
e-mail: mgosic@iaa.es

Abstract: Automatic feature tracking algorithms have become an indispensable tool for understanding the solar magnetism on a wide range of temporal and spatial scales. They provide an efficient way to analyze the huge amounts of data gathered by ever improving solar instruments, particularly those on space-borne platforms. Despite their usefulness, tracking codes have many shortcomings. Some of them stand out clearly in highly populated regions of the solar surface such as the internetwork, where magnetic elements frequently interact with each other. In those cases tracking codes fail to properly identify interactions between magnetic patches, which may severely bias their results. To overcome this problem, we have implemented additional constraints to an automatic feature tracking code. These improvements have allowed us to evaluate in a direct way the importance of small-scale internetwork fields for the maintenance of the quiet Sun magnetic flux

Motivation

Small-scale magnetic fields have emerged in recent years as an important contributor to the solar magnetism. Therefore, it is crucial to understand their origin and how they are maintained on the solar surface. To decipher these questions, a careful analysis of interactions between magnetic elements is needed.

Problem

Automatic feature tracking codes frequently misinterpret interactions between magnetic patches. Thus, the same magnetic feature may change its label many times during its lifetime, which makes it difficult to determine its history correctly (Figure 1).

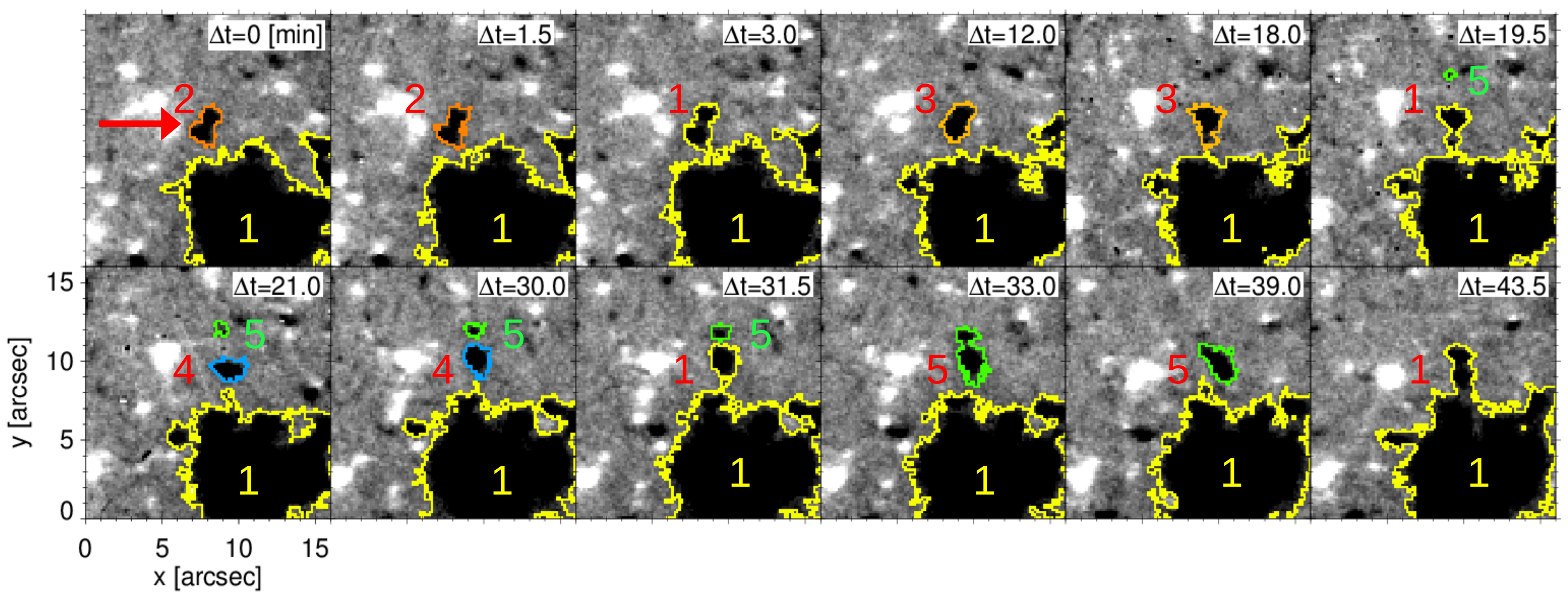

Figure 1. Example of multiple interactions of one magnetic element detected by the YAFTA code (Welsch & Longcope 2003) in Hinode/NFI deep magnetograms. The magnetic element with label 2 at Δt =0 min (orange contour) interacts many times with the stronger flux patch labeled 1 (yellow contours), for example at Δt =3 and 19.5 min. Because of the interactions, element 2 changes its label from 1 to 4 several times, as indicated by the different contour colors. A fragmentation of element 1 at Δt =33 min and merging with element 5 (green contours) of this specific patch is not detected by YAFTA because they occur in the same frame. Thus, the stronger flux patch gets the label 5 from the smaller element.
.

Method

Magnetic elements are in constant motion and often interact with other features. The following processes can occur during their evolution: in-situ appearance, merging, fragmentation, in-situ disappearance and cancellation.

Merging and cancellation processes need to be interpreted and corrected. To this end, we have developed a new module for the YAFTA package:

- Written in IDL
- It uses YAFTA output file as its input
- The output file is the same as the YAFTA output file but with updated labels and information how magnetic elements appear/disappear
- The labels of all magnetic features that truly disappear by cancellation are stored

Merging: Simple cases of merging events in which a small element blends with a stronger patch, can be found directly from the YAFTA output file.

However, more complex scenarios like the one shown in Figure 1 are misinterpreted. Comparing logical masks of consecutive frames our method is able to detect magnetic elements that merge with stronger flux features and fragments from them in the following frame. In these cases, we keep the original label of the merging/fragmenting magnetic patch, instead of the new label assigned to it by YAFTA. We also preserve the information about its origin provided by YAFTA. For instance, magnetic element with label 3 at Δt = 18 min will preserve its label at Δt = 21 min after applying our module (Figure 2).

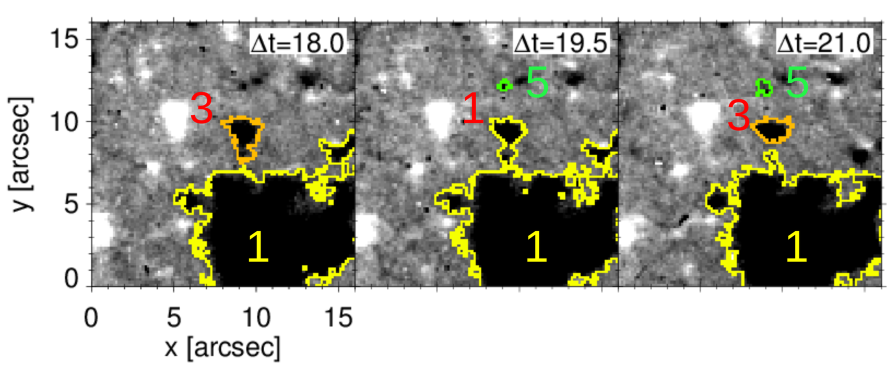

Figure 2. Example of corrected interaction between magnetic elements 3 and 1 from the Figure 1. Magnetic patch 3 merges with patch 1 at Δt =18 min and fragments from it at Δt =21 min.

If an element merges with a fragment from some other element which is not detected by YAFTA as an individual feature because the fragmentation and the merging take place in the same frame, for YAFTA that element continues to be the same element with increased flux and size. If the fragment has more flux than the patch with which it merges, then their common flux-weighted-centre will more likely be located inside the flux feature of the previous frame from which the fragment detached. This case can be seen in Figure 1 at Δt = 33 min where the larger fragment gets the label carried by the smaller element. Our module will recognize such process and appropriately update YAFTA output file (Figure 3).

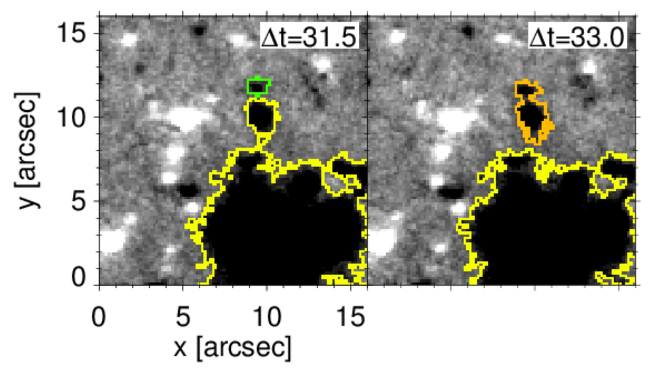

Figure 3. Example of merging event that is not recognized by the YAFTA code. The evolution of the smaller flux patch (green contour) is updated to reflect that it is a feature that disappears in a merging process. The label of the stronger flux patch (orange contour) which fragments from the yellow contoured element is corrected by the module.

This method is very useful when one wants to know how much flux an element gains from merging with surrounding flux patches. All patches that contribute to a certain element are adequately tagged using comparison of logical masks to avoid calculating their contribution more than once, as shown in Figure 4.

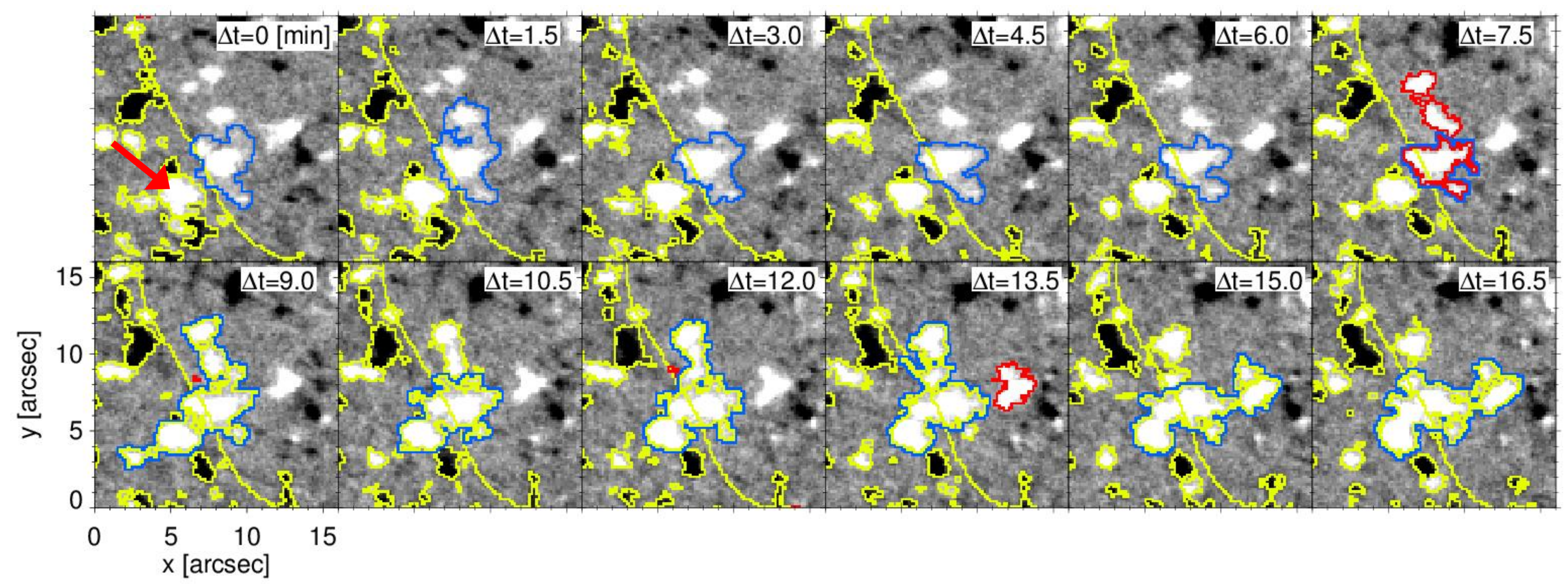

Figure 4. Example of merging events. An internetwork element detected by YAFTA as a single feature (blue contours) merges with a network patch (yellow contours) and becomes a network feature itself. This specific IN patch undergoes several mergings with other IN patches, revealing the full complexity of interactions between magnetic elements. The red contours mark the boundaries of the IN patches that merge with the NE. The flux they enclose is taken to be the contribution of the IN patches to the NE patch.

Cancellation: These events are found by searching for all closely located, opposite-polarity elements that disappear in the current frame. To determine how much flux disappears from the photosphere, we go back in time and take the total flux of the canceling element at the moment when the cancellation process started (Figure 3). This flux is corrected for all the changes caused by the merging and fragmentation processes that might happen during the cancellation event. We also update the information by which process magnetic elements disappear.

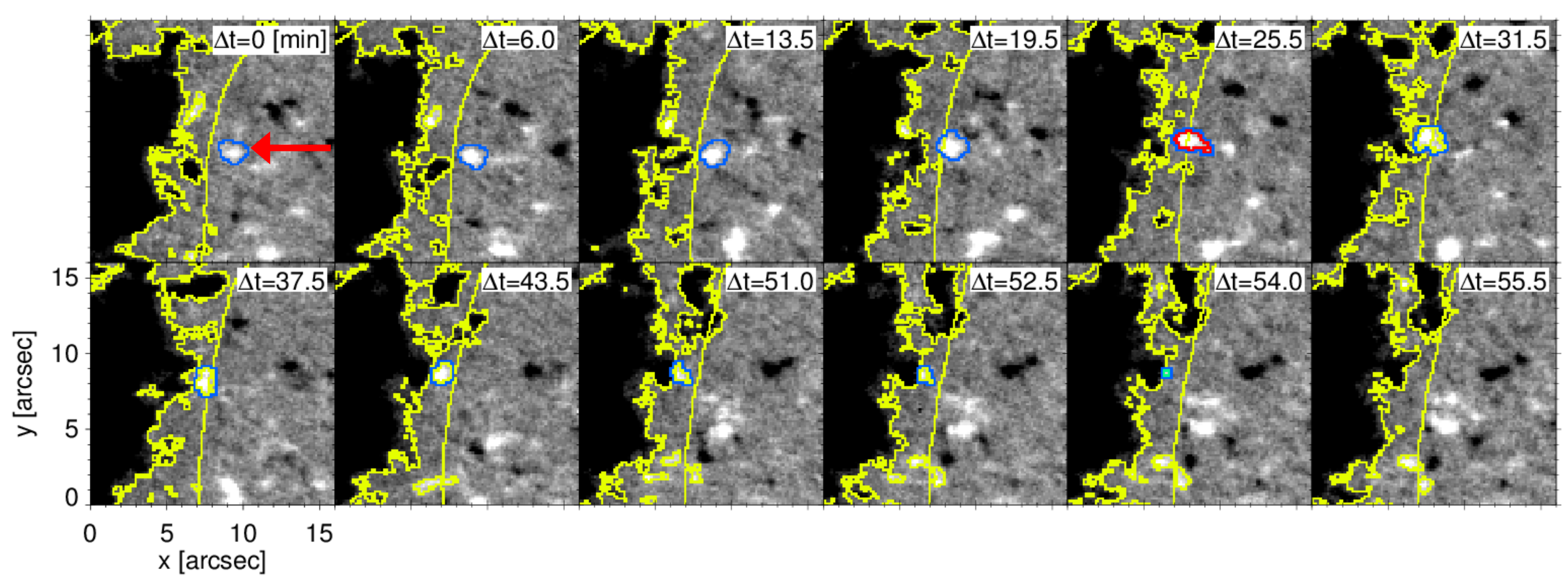

Figure 5. Example of an element (blue contours) canceling with a strong flux structure (yellow contours). The contours are those provided by YAFTA, except that the blue ones have been expanded by 1 pixel for visualization purposes. The red contours mark the patch used to evaluate how much flux has been removed from the solar surface. The green contour at Δt = 54 min outlines the canceling element in the last frame where it is visible.

Future plan

To make this IDL module available to the solar community

References

1. Gošić, M. et al. 2014, ApJ, September 20 issue
2. Welsch, B. T., & Longcope, D. W. 2003, ApJ, 588, 620