Enhancing the efficiency of Feature Tracking algorithms to analyze high resolution Solar observations

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Abstract:

Advancements in ground and space instrumentation have led to high-quality observations of the Sun, both in quiet and actively magnetic regions. Analyzing the formation and destruction of magnetic fields on the Sun is crucial for understanding the physical phenomena that drive magnetic activity. To carry out such analysis, feature-tracking codes are employed. In the era of big data generated by various ground and space-based instruments, improving the efficiency of these feature-tracking codes is essential. The primary objective of this work is to streamline the feature-tracking code used in Anusha et al. (2017) that studied small-scale magnetic features on the Sun. To achieve this, we are developing a parallel C++ version of the code and rigorously testing its accuracy and efficiency against the original IDL implementation.

Background[A]

1. Analyzed the evolution of small-scale magnetic features in high-resolution quiet-Sun observations.
2. Centre of Gravity method determined line-of-sight magnetic fields.
3. Distributions:
   - Lifetimes followed power-law and exponential distributions.
   - Flux and area followed power-law distributions, depending on flux thresholds and binning methods.
4. Feature Evolution:
   - Magnetic features predominantly originated from uni-polar appearances (92% of flux).
   - Bi-polar emergence contributed minimally (0.3–0.5%). Disappearance caused the highest flux loss (59%), followed by cancellation (10%).

Data (Sunrise-I / IMaX)[B]

High-Resolution Data

- Quiet-Sun magnetograms with 40 km/pixel spatial sampling.

Noise and Image Size

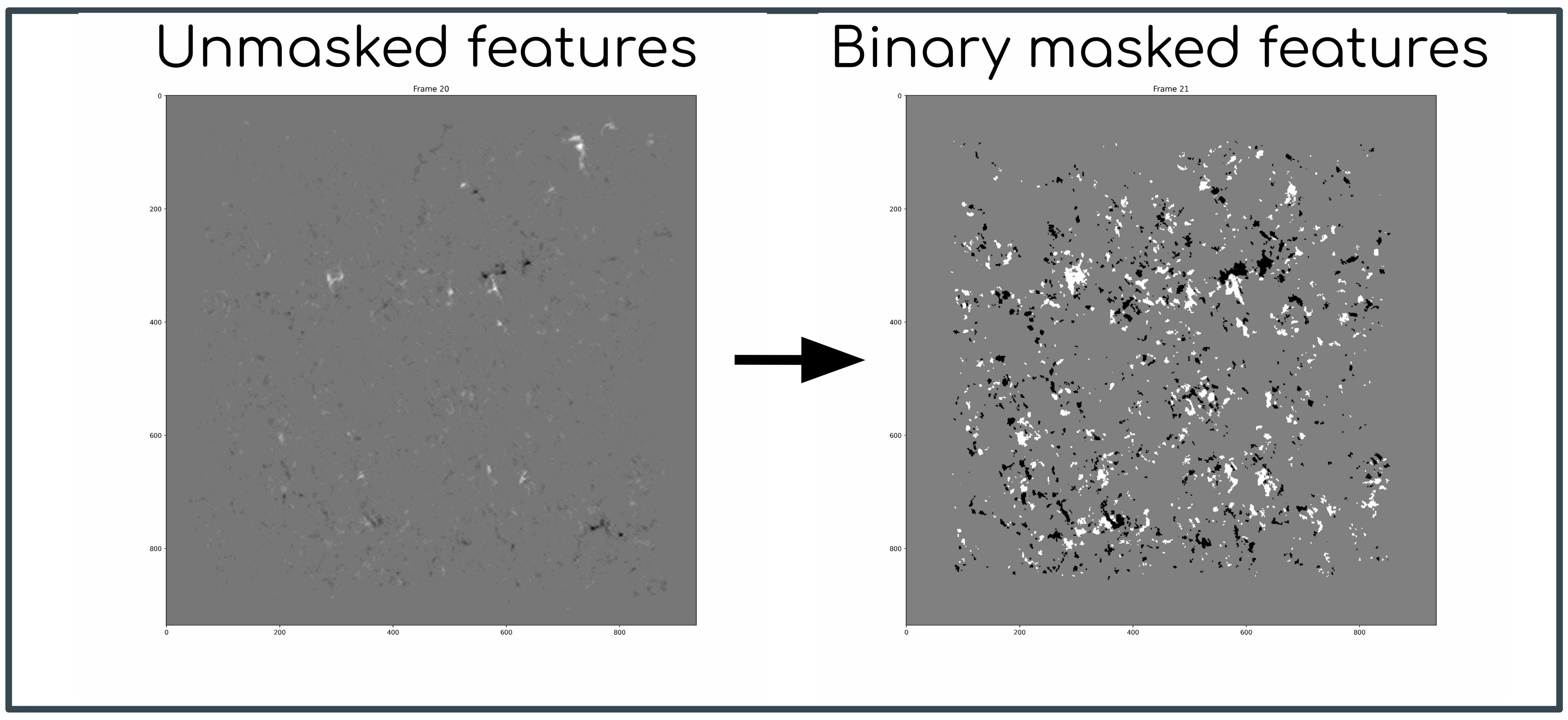
- Reconstructed images had noise level of 3 * 10^{-3} I_c, with an effective size of 43'' × 43''.
- Stokes parameters V and I were normalized using spatially averaged I_c.

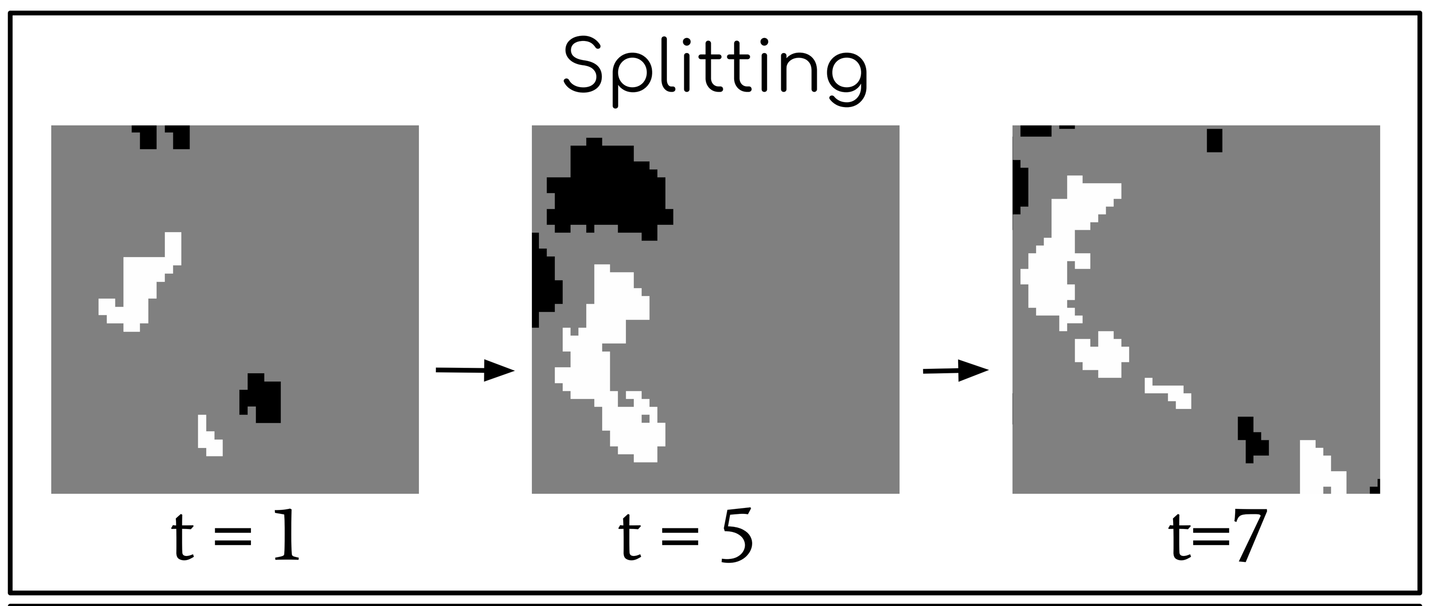
Spectral Observations

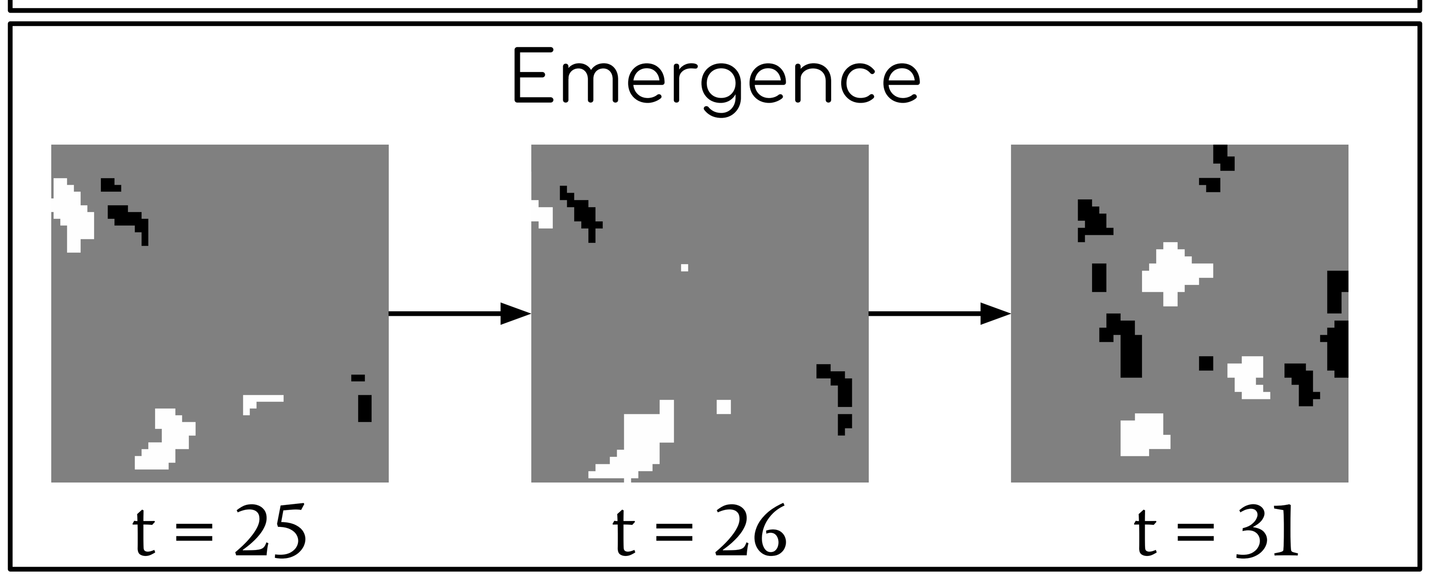
- Time-series observations of 42 magnetograms sampled at five wavelength points
- Fe I 525.02 nm ±40 mÅ, ±80 mÅ, and continuum at 227 mÅ from line center.

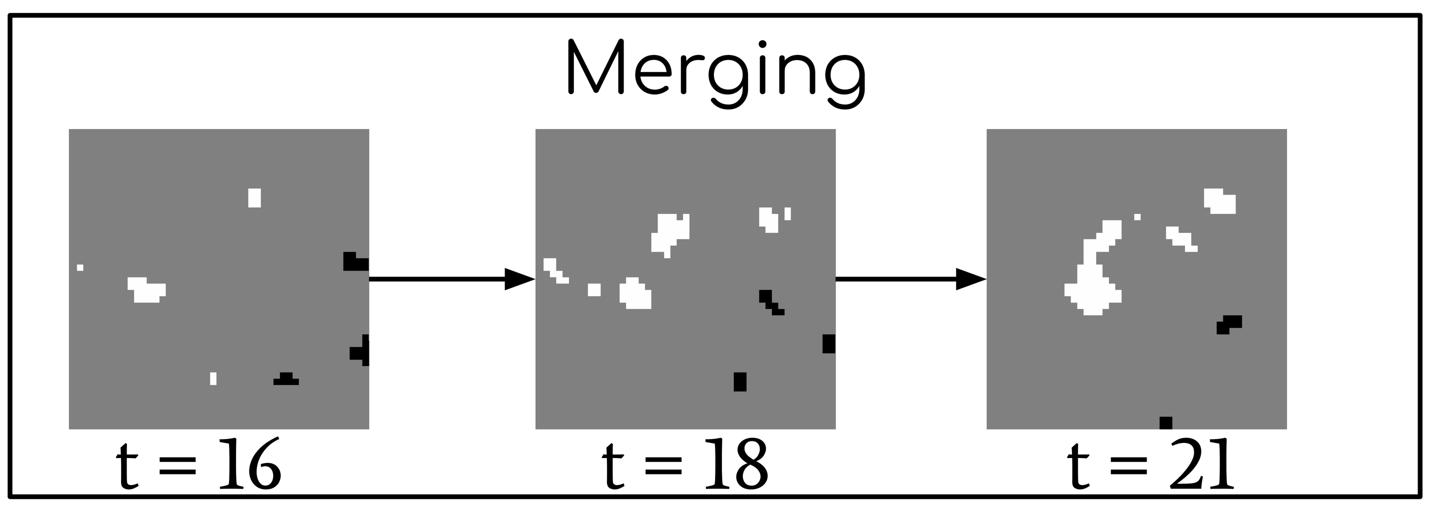
Feature Identification

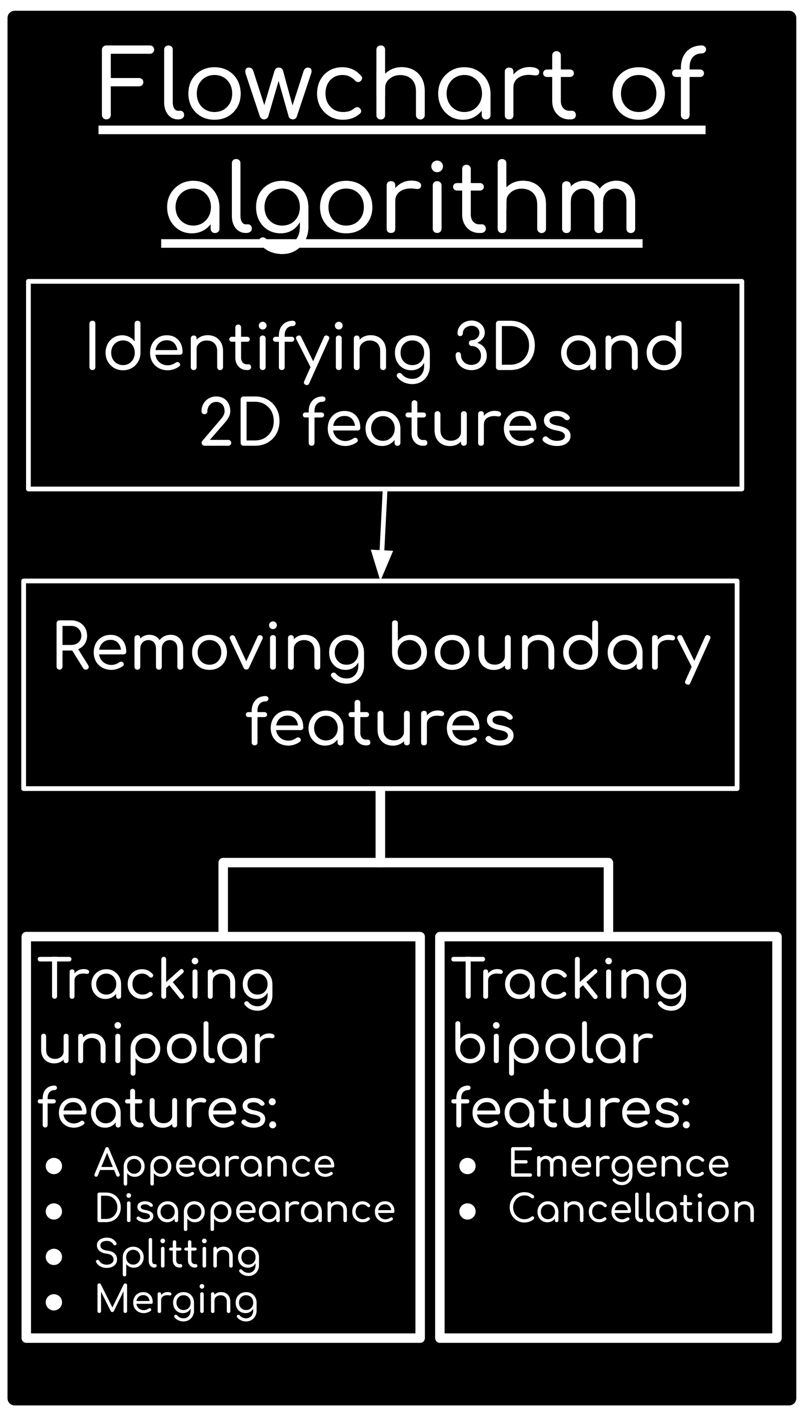
- Wavelength-averaged V/I_c identified features.











Optimization steps

1. Code Reorganization: Several loop were optimized for efficiency.
2. Parallel Processing: Significant restructuring enabled parallel processing, reducing runtime from 1 hour to 4–5 minutes.
3. HDF5 Storage: 3D vectors were converted to 1D for storage, as direct 3D storage was unsupported.
4. Image and GIF Generation: Python scripts replaced C++ libraries for creating images and GIFs efficiently.

Table for time comparison

	IDL	CPP		IDL	CPP
Identifying 3D features	~30 mins	~5 mins	Identifying 2D features	~20 mins	<5 mins

References:

A. Anusha, L. S., et al. (2017). Evolution of small-scale magnetic features in high-resolution quiet-Sun observations from Sunrise/IMaX.
B. S. K. Solanki et al. (2010). SUNRISE: INSTRUMENT, MISSION, DATA AND FIRST RESULTS

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