ADVENTED IMAGE PROCESSING FOR STEREO

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We are developing advanced image processing methods to extract the evolving morphology and kinematics of CMEs and to compare these results with as yet unconfirmed predictions of theory.
OVERVIEW

• Motivation
• CME models
• Multiscale methods
  Background Subtraction
  Edge Detection
• CME Morphology & Kinematics
• Current Work

LASCO/C2 & SECCHI/COR1-A
24-Jan-07
**CME MODELS**

- Magnetic Flux-Rope:
  - Forbes & Priest, 1990
  - Chen & Krall, 2003

- Magnetic Break-out:
  - Antiochos et al. 1999
  - Lynch et al. 2004
Break-out Simulation:

-Lynch et al. 2006
WHY MULTISCALE?

- Computational analysis seeks representations of signals as linear combinations of basis, frame, dictionary, element (i.e. sines, cosines, wavelets, etc.):

\[ f = \sum_{k} a_k b_k \]

coefficients basis, frame

- Analysis of the signal is through the statistical properties of the coefficients.

- The analyzing functions (basis, frame elements) should extract features of interest.

- Approximation theory wants to exploit the sparsity of the coefficients.

Why do we need sparsity?

- Data compression
- Feature extraction
- Feature detection
- Image restoration (e.g., deconvolution)
BACKGROUND
SUBTRACTION
Wavelet transform at scales 1, 2, 4, 8

Coefficients
MULTISCALE EDGE DETECTION

Described in “Multiscale Edge Detection in the Corona, Young and Gallagher, Solar Physics, 2008.”

(a) LASCO C2
(b) Running Difference
(c) Raw Image
(d) Roberts
(e) Sobel
(f) MS edge detector

Gradient edge detection
Multiscale Decomposition

Horizontal Direction:
- Scale 1
- Scale 3
- Scale 5

Vertical Direction:
- Scale 1
- Scale 3
- Scale 5
Gradient Space Information

• The gradient of an image:

\[ \nabla f = \left[ \frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right] \]

• The gradient points in the direction of most rapid change in intensity

• The gradient direction is given by:

\[ \theta = \tan^{-1} \left( \frac{\frac{\partial f}{\partial y}}{\frac{\partial f}{\partial x}} \right) \]

• The *edge strength* is given by the gradient magnitude:

\[ \| \nabla f \| = \sqrt{\left( \frac{\partial f}{\partial x} \right)^2 + \left( \frac{\partial f}{\partial y} \right)^2} \]
Gradient Space Information
Gradient Space Information

Vector-Arrow Field

Vectors with magnitude: $|\nabla f|$ and inclination angle $\theta$

C2 01-Apr-04
Vector-arrows corresponding to the magnitude and inclination angle of the Scale 5 decomposition of a LASCO/C2 CME on 01-Apr-04.
Spatio-Temporal Filter

Degrees of Freedom: Scale, Magnitude & Angle … in Space & Time

LASCO/C2 18-Jan-00
Non-Maxima Suppression

1) Nearest-neighbour info.

2) Criteria of angle and magnitude from gradients.

3) Pixels chained along edges.
CME FRONT CHARACTERIZATION

• Ellipse fit
• Height, Width, Curvature, Orientation

\[
\frac{\rho^2 \cos^2 \theta}{a^2} + \frac{\rho^2 \sin^2 \theta}{b^2} = 1
\]

\[
\rho^2 = \frac{a^2 b^2}{\left(\frac{a^2 + b^2}{2}\right) - \left(\frac{a^2 - b^2}{2}\right) \cos(2\theta' - 2\alpha)}
\]
Kinematics & Morphology

SECCHI 08-Oct-07
CURRENT WORK

• testing a basic toolkit for IDL - 1D and 2D wavelets

• developing additional multiscale transforms - e.g. ridglets and curvelets

• developing improved fitting methods for height-time, velocity and acceleration