Robust Tensor-Based Velocity Estimation of Plant Root Growth

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A new computational bioimaging approach has been developed to quantitatively measure biological growth and differentiation at unprecedented spatial and temporal resolutions without using invasive markings or manual tracking methods. This approach is a two-step procedure using the orientation of the structure tensor followed by robust matching. This method computes motion fields for quantitative biophysical studies of cellular processes involving growth or motility, and it was used to measure root growth in *Arabidopsis thaliana* at spatial resolutions of one micron per pixel and time intervals of 10 sec which has not been previously possible. We find that the growth zone of the root can be divided into two regions, an apical region where velocity rises gradually with position and a sub-apical region where velocity rises steeply with position. In both zones, velocity increases almost linearly with position, and the transition between zones is abrupt. We find this pattern for roots of *arabidopsis*, tomato, lettuce, and timothy. The approach can be extended to measure other biological motion or screen for interesting behavior arising from genetic or environmental variation.

References: 1. CM van der Weele, H Jiang, KK Palaniappan, VB Ivanov, K Palaniappan, TI Baskin, 2003, A new algorithm for computational image analysis of deformable motion at high spatial and temporal resolution applied to root growth: Roughly uniform elongation within the meristem and also, after an abrupt acceleration, within the zone of elongation, Submitted *J. Plant Physiology*

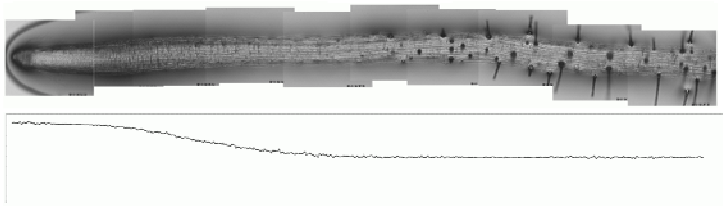
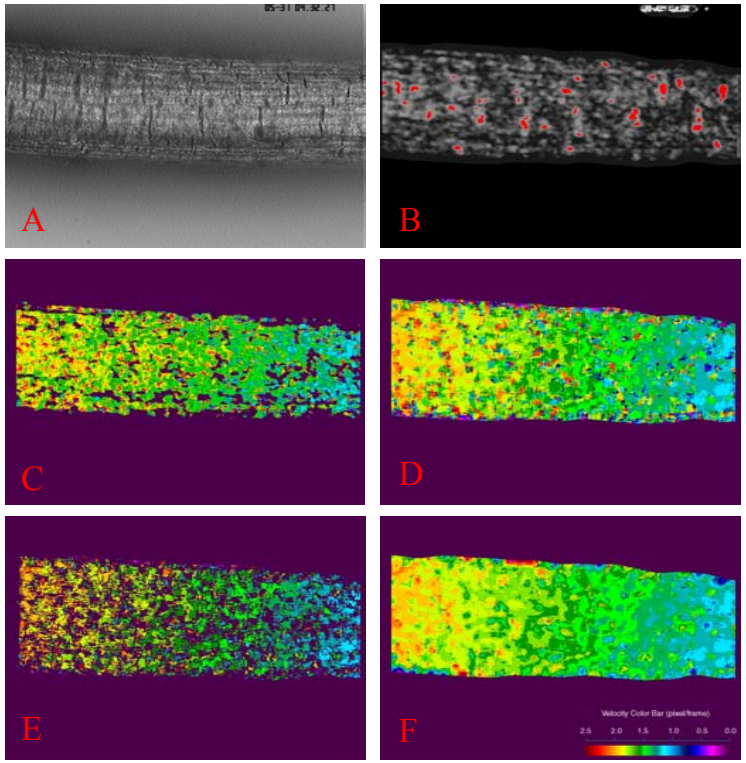


Figure 1. The plant root (upper panel mosaic), velocity field (Fig 2) and velocity profile along its medial axis(lower panel). The velocity is relative to the base of the plant root.



2. H Jiang, 2001 *Robust Tensor-based Velocity Estimation of Plant Root Growth.* MS Thesis, Dept CECS Univ of Missouri-Columbia.

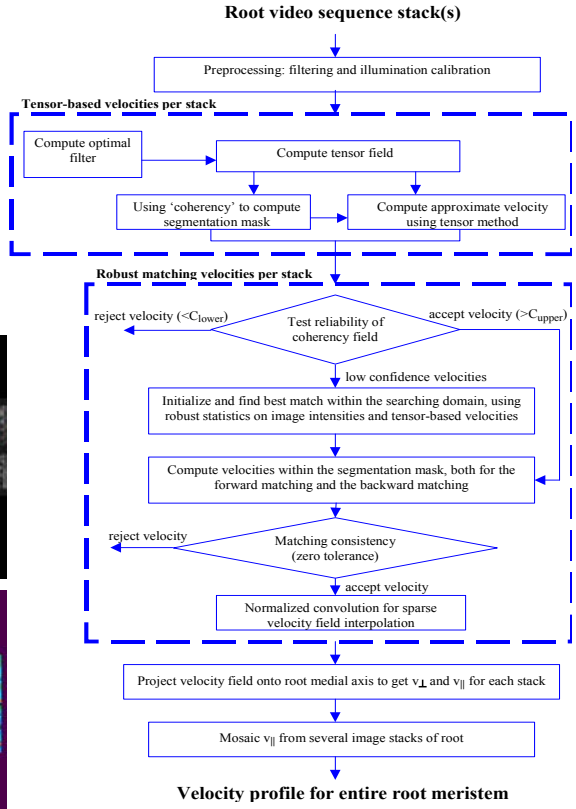


Figure 2. The original image sequence of segment three of a plant root and the motion fields after each specific processing. **A**. The original plant root image in a 9-frame image sequence, only frame 5 is shown; **B**. The motion mask in the tensor motion estimation method. **C, D, E, F**: the motion fields after the tensor method, the robust matching method, forward-backward consistency test, and interpolation. Only the horizontal components of the motion are displayed for each step. The vertical components of the motion are not shown here because they are very small and dominated by the noises.