Towards Automated Analysis of Minirhizotron Images

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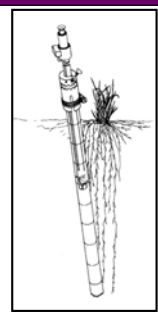
Introduction: The scientific and technical challenges

Background

- **What is a minirhizotron?**
  A clear tube with graduated markings buried in soil with a camera that slides inside.
- **Scientific goal:**
  - Determine plant growth patterns by analyzing changes in soil structures over time
  - Image analysis currently performed manually (trained subjects count roots and other structures).



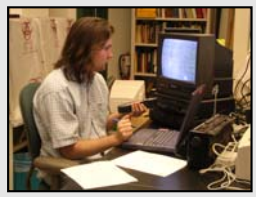
Technical challenges

- **Can analysis of minirhizotron images be automated?**
  - Need registration of multiple images in space (mosaics) and time (motion estimation for deforming structures).
  - Need a classification system to detect, localize and count various structures (roots, hyphae)
  - Bottom up analysis of the images may not be appropriate; may need a model based approach.

Problem Description: Automate the process of finding roots in images from a minirhizotron.

The Case For Automation

- **Why should an automated system be created?**
  - The ability to do robust, meaningful research with *minirhizotron* images is currently limited by the amount of time that can be spent by a human expert classifying the data.
  - Automating some or all of this process could speed it up dramatically, allowing more data to be collected from more locations.



- **What are the problems faced by an automated system?**
  - Classifying the images is challenging even for trained humans
  - There is large within-class variability of the scale, appearance, and color of the objects in the images.
  - The images are low resolution and noisy.
  - The texture of the background is complex and varied, and in some cases exhibits statistics similar to the structures of interest.

Towards Automation: Preprocessing minirhizotron images

Developing Tools to Aid in Image Analysis

- **Minirhizotron Software:**
  - Will be used to speed up manual analysis, and to provide training data for automatic (supervised) classification.
  - Native, cross platform image analysis program.
    - Written in QT / OpenCV, compiles on Windows / Mac / Linux
  - Portable / reusable filter architecture applicable to many other problems
    - Allows new filters to be written in OpenCV with minimal effort.
    - Leverages existing OpenCV functionality.
  - XML database of known images and labeled data based on filename
    - Will aid in training supervised learning algorithms.
  - Allows forward and reverse navigation in time or location.

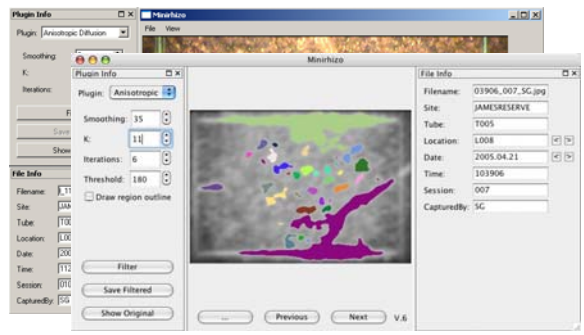


Figure 1: The minirhizotron image analysis software, running on Windows and on OS-X.

- **Filters**
  - Gaussian Smoothing + Anisotropic Diffusion: Smooth the noise from an image while preserving edge-like structures.
    - Images with complex textures have many "edge-like" structures.
    - Pre-smooth with a Gaussian that is appropriate for the scale of the feature we are trying to detect.
  - Intensity Thresholding: Simple first pass approach for segmentation
    - Yields surprisingly good results on filtered images.
    - Tube markers (in green on Figure 2) are very strong features and are often grouped with roots. Potentially use color information to disambiguate tube markings and structures of interest

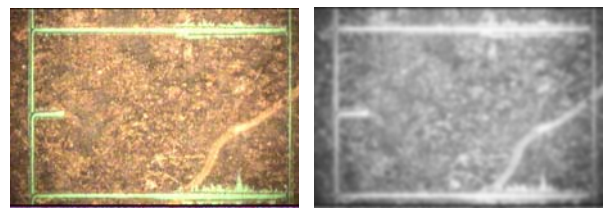


Figure 2: An example image containing a root in the lower right corner (left). The same image after Gaussian smoothing (right).

- **Current Research**
  - Segmentation via normalized cuts or kernel k-means.
  - Exploring model based approaches such as those found in modern satellite road tracking algorithms.
  - Developing supervised learning algorithms to move toward automatic classification of the data using:
    - Multi-scale representations based on the response of filter banks (wavelets, ridgelets, curvelets) or super-pixels based on segmentation from local statistics (textures and color).
    - Adaboost and other methods involving banks of weak classifiers to represent the data.

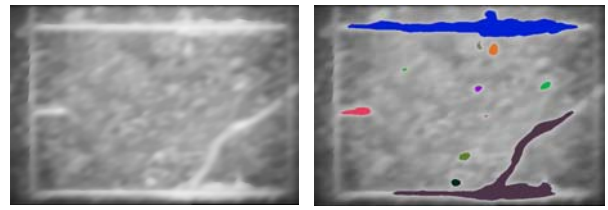


Figure 3: Anisotropic diffusion blurs the background texture while preserving the root (left). After thresholding, the resulting regions correspond to the root and the tube markings (right).