Automated Leaf Tracking of Maize Plants for Monitoring Leaf-growth

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Introduction

- Image-based plant phenotyping facilitates the extraction of desirable morphological and biophysical traits by analyzing a large number of plants in short time period non-invasively.
- The health of the plant can be interpreted by the number of leaves emerged, the total number of leaves present at any point of time and growth rate of individual leaves.
- This algorithm tracks each leaf from its emergence during vegetative stage life cycle and measures its length on each day.
- It replaces the manual process of growth stage determination by leaf tracking.
- The algorithm starts with a temporal sequence of images of maize plant and automatically generates a leaf status report.

Method

- To achieve maximum efficiency, the view angle at which line of sight of the camera is perpendicular to the axis of the leaves, is selected.
- The basis of leaf tracking is: (a) leaf emergence strictly alternates in terms of direction; (b) leaves emerge using a bottom-up approach [1].
- The foreground, i.e., the plant, is segmented based on frame differencing technique and color based thresholding.
- The binary plant is skeletonized, i.e., reduced to one-pixel wide lines, using fast marching algorithm [2].
- The skeleton is represented by a graph G={V, E}, where V is the set of vertices and E is the set of edges.
- The vertices with degree 1 are identified as leaf-tips and with degree 3 or more are identified as junctions.
- The stem is formed by iteratively traversing the graph along a connected path of junctions.
- Each leaf is identified by using a graph traversal algorithm from leaf-tip until it meets at the junction.

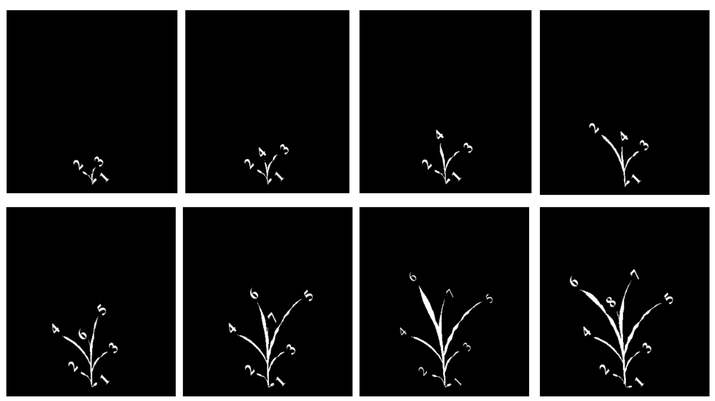

Figure 1: Illustration of leaf tracking (with each leaf numbered in order of emergence) on different days of vegetative stage life cycle

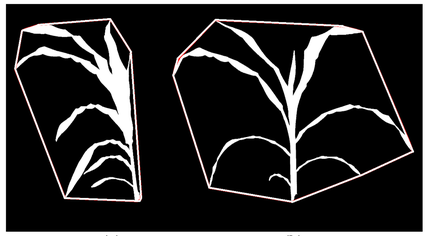

Figure 2: View selection

Figure 2(a) and (b) show the binary images of the same maize plant enclosed by convex-hulls at side view 0° and side view 90°, respectively.
The figures show that the area of the convex-hull at side view 90° is higher than the area of the convex-hull at side view 0°. If the area of the convex-hull at side view 90° is higher than the area of the convex-hull at side view 0°, the image of side view 90° is chosen for that day for subsequent analysis.

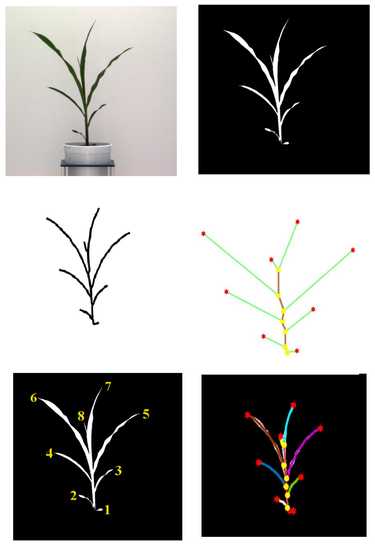

Figure 3: The overall process of leaf detection

Dataset

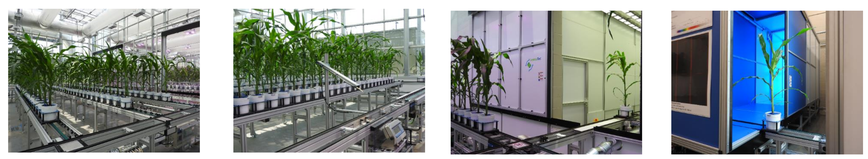

Figure 4: LemnaTec Scanalyzer 3D Plant Phenotyping System

- To evaluate the algorithm, we publicly release a benchmark dataset called University of Nebraska-Lincoln Component Plant Phenotyping Dataset (UNL-CPPD).
- The images of the dataset are captured using LemnaTec Scanalyzer 3D high throughput plant phenotyping facility in the UNL.
- The dataset contains RGB images of 13 maize plants for 27 days.
- We release the following ground-truth information for each original image: (a) the co-ordinates of leaf-tips and leaf-junctions; (b) the total number leaves present (which are numbered in order of emergence).

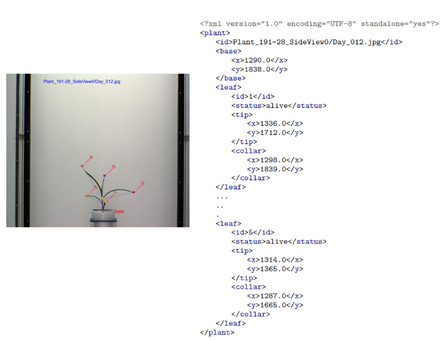

Figure 5: UNL-CPPD ground-truth

Results

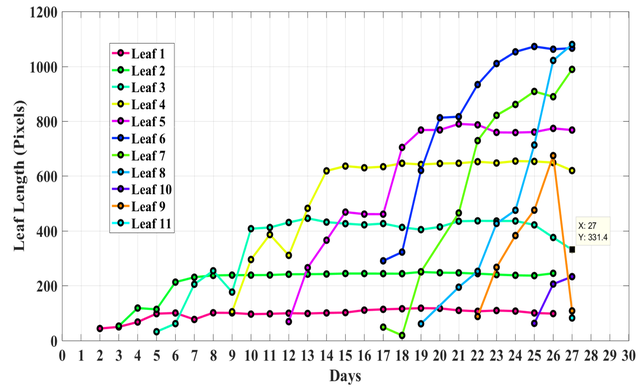

Figure 6: Leaf status report

The graph provides the following phenotyping information with significance in plant science: (1) the total number of leaves emerged during the life cycle; (2) the day on which a particular leaf emerged; (3) the number of leaves present at any point of time; (4) the length of each leaf at any point of time; and (5) the day on which a particular leaf died.

Conclusion

Individual leaves can be tracked providing growth pattern.
A set of rich phenotypes can be automatically computed using computer vision techniques.
A benchmark dataset called UNL-CPPD is released with ground-truth.

Acknowledgement

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References

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[2] M. S. Hassouna, A. A. Farag, MultiStencils Fast Marching Methods: A Highly Accurate Solution to the Eikonal Equation on Cartesian Domains, IEEE Transactions on Pattern Analysis and Machine Intelligence, 29 (9), 1563-1574, 2007.