Holistic and Component Plant Phenotyping Analysis using Visible Light Image Sequences

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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.
- It is broadly classified into: holistic and component phenotypes.
- Holistic phenotypes consider the whole plant as a single object, whereas component phenotypes are computed by considering individual components of a plant, i.e., leaves and stem.
- An algorithm is proposed to track each leaf from its emergence during vegetative stage life cycle and measure its length on each day.

Holistic Phenotypes:

\[ \text{Plant Aspect Ratio} = \frac{\text{Height of BR at side view}}{\text{Diameter of MEC at top view}} \]

\[ \text{Bi-angular Convex-hull Area Ratio} = \frac{\text{Area}_{\text{convex-hull}} \text{ at side view } 0^\circ}{\text{Area}_{\text{convex-hull}} \text{ at side view } 90^\circ} \]

where, BR: Bounding Rectangle, MEC: Minimum Enclosing Circle

Component Phenotypes:

- 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 3 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.

Results

Figure 3: Bi-angular Convex-hull Area Ratio (provides information on phyllotaxy)

Figure 4: Plant Aspect Ratio (provides information on canopy architecture)

Figure 5: The overall process of leaf detection

Dataset

- 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 6: LemnaTec Scanalyzer 3D Plant Phenotyping System

Figure 7: UNL-CPPD ground-truth

References


Conclusion

A set of new holistic and component phenotypes are proposed using computer vision techniques. Individual leaves can be tracked providing growth pattern of leaves. A benchmark dataset called UNL-CPPD is released with ground-truth.

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