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3D plant phenotyping in sunflower using architecture-based organ segmentation from 3D point clouds

William Gélard (a,b), Philippe Burger (b), Pierre Casadebaig (b), Nicolas Langlade (c), Philippe Debaeke (b), Michel Devy (a), Ariane Herbulot(a)

a: LAAS-CNRS, University of Toulouse

b: INRA, UMR AGIR, Toulouse

c: INRA, UMR LIPM, Toulouse

Abstract:

This paper presents a 3D phenotyping method applied to sunflower, allowing to compute the leaf area of an isolated plant. This is a preliminary step towards the automated monitoring of leaf area and plant growth through the plant life cycle.

First, a model-based segmentation method is applied to 3D data derived from RGB images acquired on sunflower plants grown in pots. The RGB image acquisitions are made all around the isolated plant with a single hand-held standard camera (Sony A5100) and a 3D point cloud is computed using Structure from Motion and Multiple-view Stereo techniques [1, 2]. To do that, we used Bundler [3] and PMVS [4], Open Source libraries which can produce an accurate point cloud for plant phenotyping [5].

Then a model-based segmentation method is applied in order to segment and label the plant leaves, i.e. to split up the point cloud in regions, one for the stem, the other ones for the leaves [6, 7, 8]. The leaf label is determined using the elevation of its petiole insertion point on the stem, and the relative orientation with respect to the previous leaf. In sunflower, it is observed that the leaves labeled 5 and 6 have opposite orientations while insertion points of the remaining leaves have relative orientations around 137° with the previous ones [9]. Every leaf is then reconstructed with NURBS, as made in [5] and its area is computed from the triangular mesh. The segmentation method is validated comparing these areas with the ones measured manually using a planimeter.

Results from segmentation and 3D reconstruction are presented on Figure 1; it is shown on Figure 2 that differences between automatic and manual measurements are less than 10%; Figure 3 shows how the extracted sunflower model is consistent with the known phyllotaxic model. The present results open interesting perspectives in direction of high-throughput sunflower phenotyping.



Figure 1. Results on a sunflower plant: (left) point cloud, (middle) leaf segmentation, (right) leaf modelling with NURBS.

Leaves label	Ground truth area (in mm ²)	Computed area (in mm ²)	Difference (in %)
8	30140.0	32520.86	+7.90
9	28768.0	30253.69	+5.16
10	33803.0	36586.41	+8.23
11	32526.0	34452.63	+5.94
12	32065.0	36333.11	+13.31
13	33640.0	36569.42	+8.71
14	28776.0	32142.46	+11.70
15	28432.0	31927.66	+12.29
16	27193.0	29939.45	+10.10
18	21639.0	25440.52	+17.57
			+10.09

Figure2. Comparison of leaf area: ground truth vs computed with NURBS.

Leaves label	Phyllotaxic angles (in °)
8-9	136.5
9-10	137.3
10-11	134.3
11-12	142.6
12-13	140.2
13-14	127.8
14-15	140.2
15-16	147.5
16-17	116.2
17-18	150.3
	137.3

Figure3. Results of computed phyllotaxic angles

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