Using Phyllotaxis for Date Palm Tree 3D Reconstruction from a Single Image

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Presentation by
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Outline

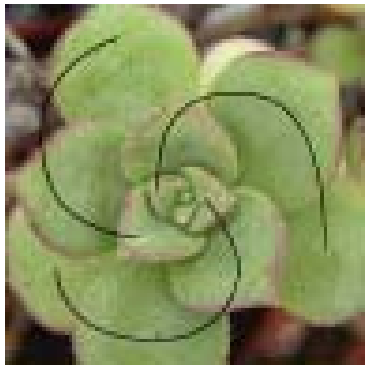
- Phyllotaxis
- 3D construction of Date Palm Tree
- Pineapple form

Phyllotaxis

- The arrangement of plant organs
- Flower lets in Sunflower head
- Scales/eyes in Pine cone and Pineapple
- Leaves on stem

Phyllotaxis

- Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, ...
- Golden Angle: ~ 137.5 degree

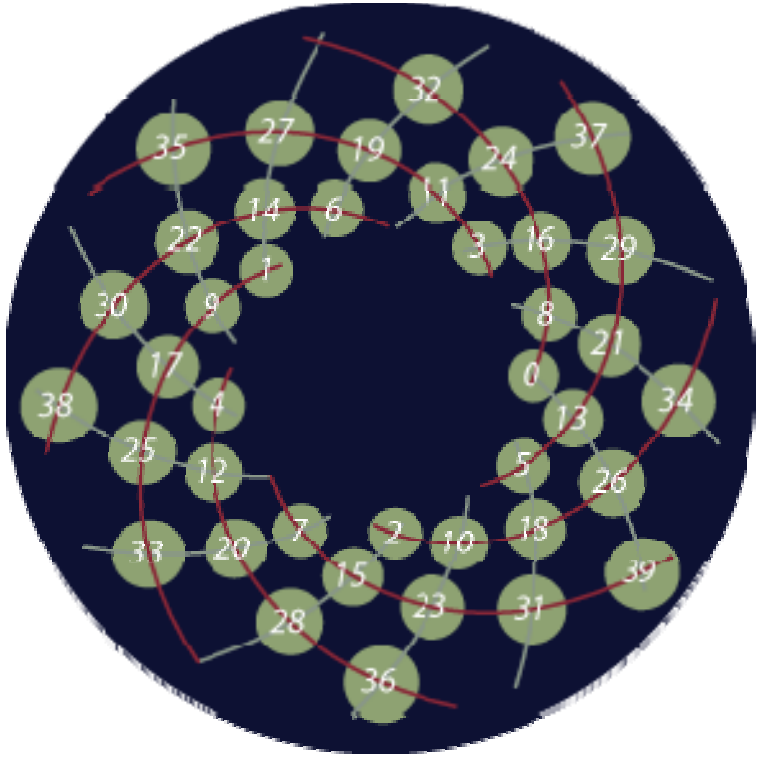


- Taken from http://maven.smith.edu/~phyllo/About/fibogolden.html

Phyllotaxis

- Pine cone 13 clockwise spirals and 8 counter clockwise spirals
- Taken from http://maven.smith.edu/~phyllo/

Phyllotaxis



- parastichy numbers (8, 13)
- Taken from http://maven.smith.edu/~phyllo/

3D reconstruction of date palm tree

- Objective: built a 3D model of a date palm tree tend to use in a maintenance robot

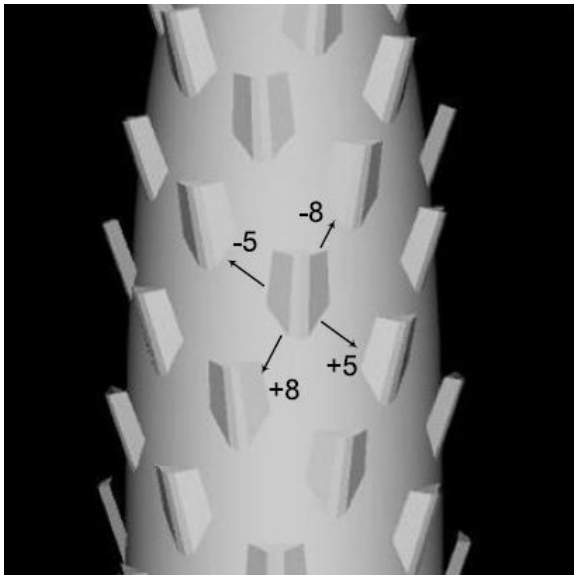
3D reconstruction of date palm tree

Phyllotaxis model for the Date Palm Tree

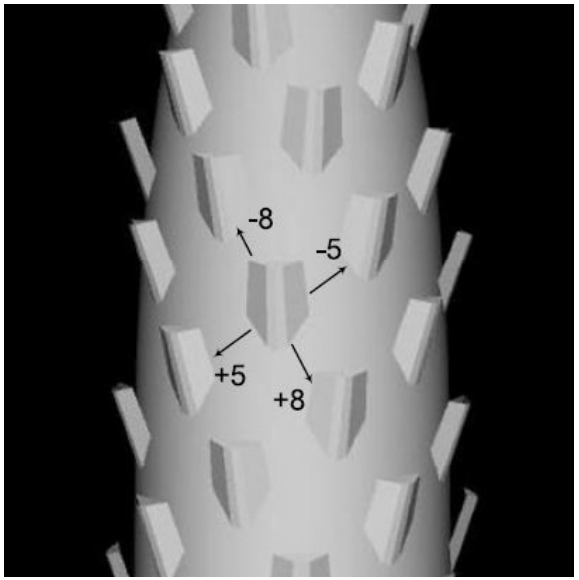
$$\theta_{n+i} = \theta_n + i \cdot h \cdot \psi$$
$$r_{n+i} = R^{table}(n+i) \cdot R$$
$$H_{n+i} = H_n - i \cdot d$$
$$\alpha_{n+i} = \alpha^{table}(n+i)$$

h – The handedness, 1 clockwise, -1 counter clockwise
ψ – The Fibonacci angle 137.5°
$R^{table}(j)$ – A table with the ratio of trunk radius at the growing point of leaf number j to R
R – The widest point of the radius of the trunk
d – The vertical distance
α_{n+i} – Leaf growing angle for leaf number n+i.
α^{table} – A table with leaf growth angles for leaf number j. The data was acquired from a reference tree by measuring images taken from a perpendicular angle to the leaf.

3D reconstruction of date palm tree

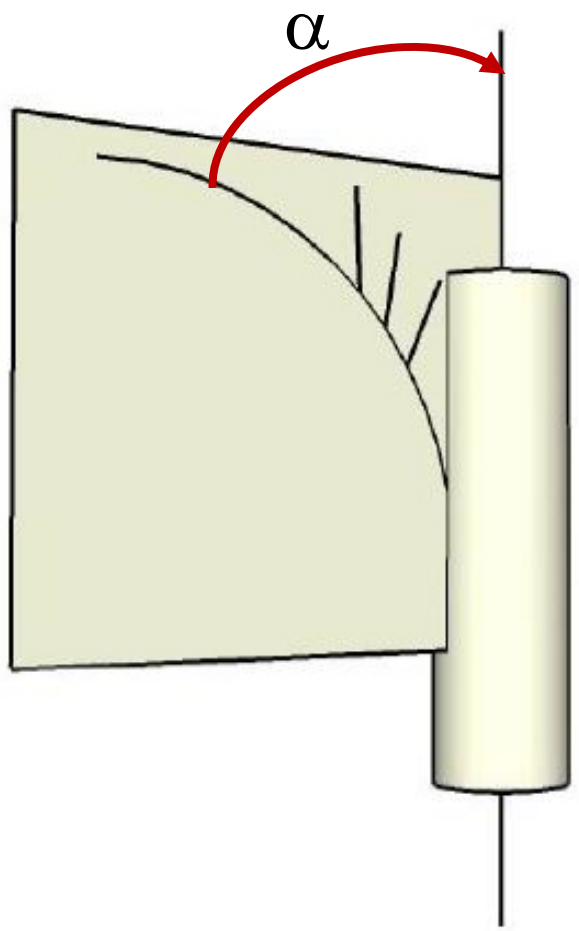


Right handed tree



Left handed tree

3D reconstruction of date palm tree



Leaves grow outward from the axis of the trunk

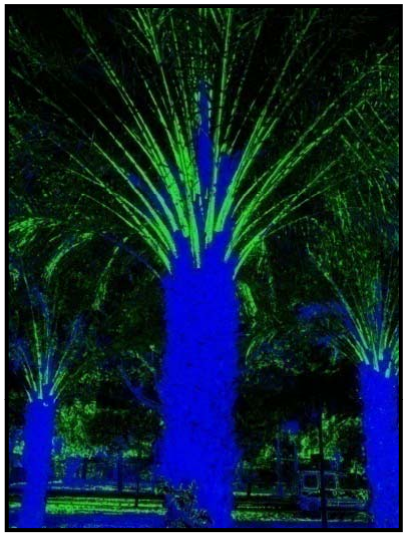
3D reconstruction of date palm tree

Algorithm

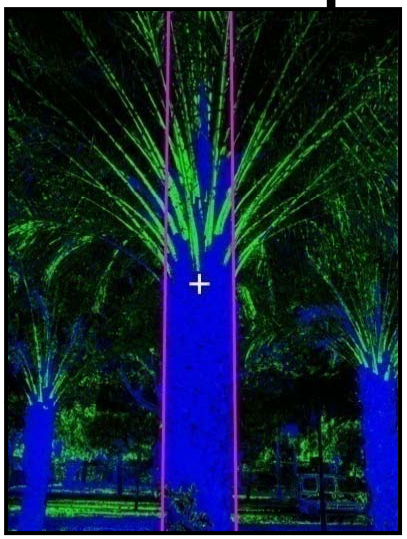
1. Calculating Probability Image of the Leaves and Trunk
2. Search for Trunk Location and “Tree Center”
3. Creating the Leaf Clues Image
4. Search for Prominent Leaves
5. Estimating Model Parameters
6. Search for More Leaves
7. 3D Reconstruction

3D reconstruction of date palm tree

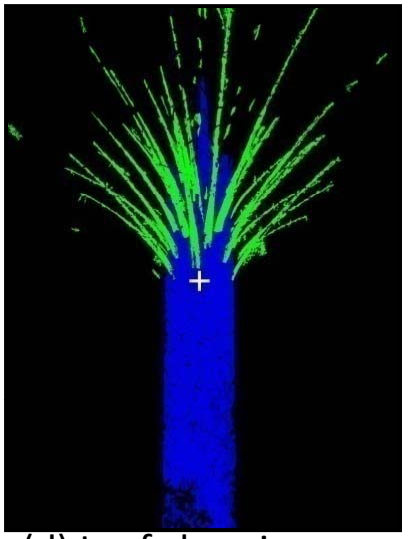
(a) Original image.



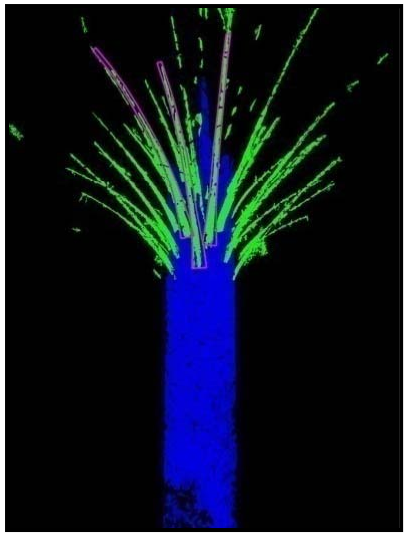
(b) leaves and trunk probability images.



(c) Trunk location and “tree center”.



(d) Leaf clues image.



(e) Prominent leaves search.

(f) Model prediction.

(g) Search for more leaves.

(h) VRML 3D model.

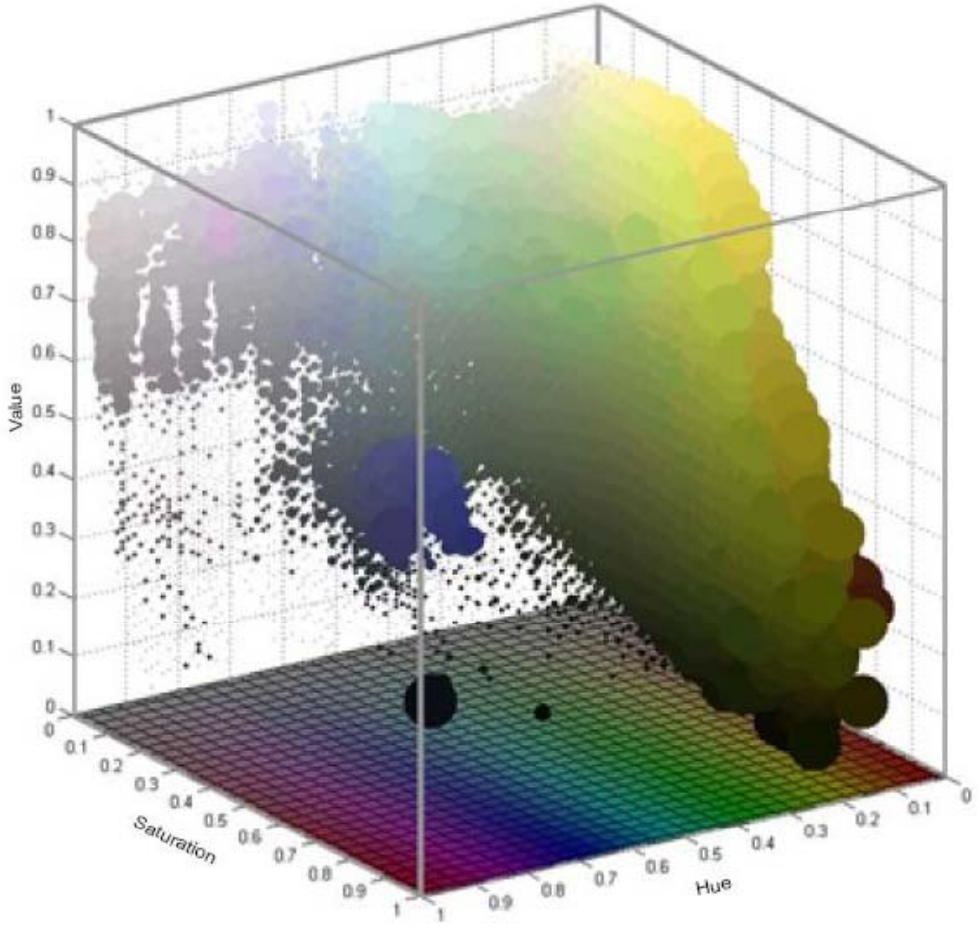
3D reconstruction of date palm tree

1. Calculating Probability Image of the Leaves and Trunk

Leaf probability table

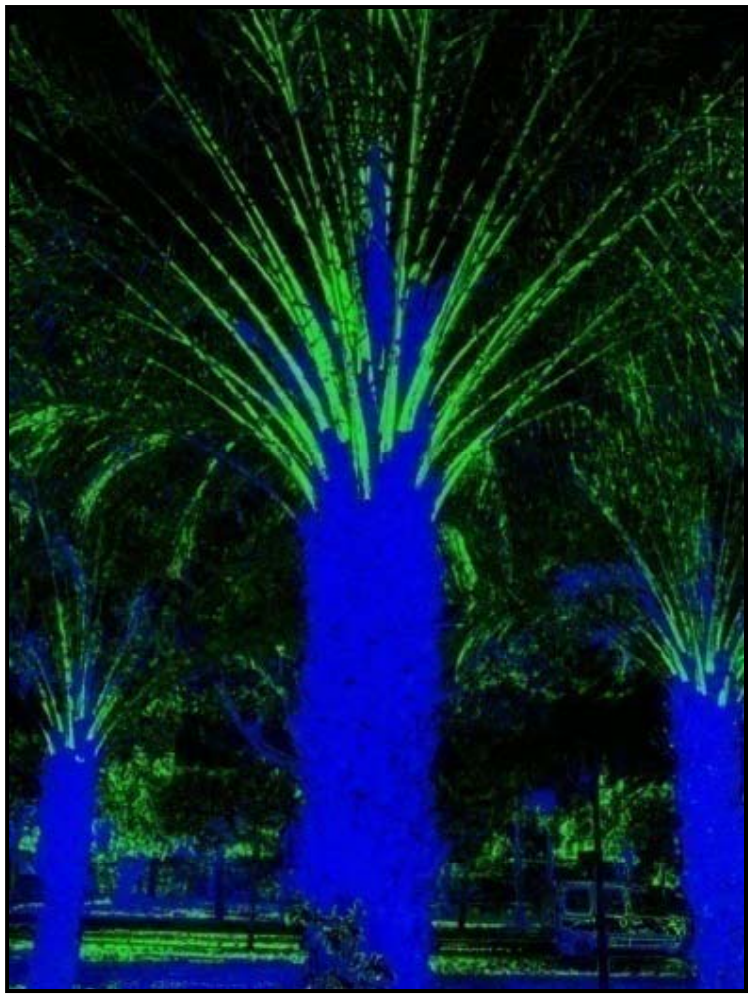
- Defines by given color and gradient
- Big ball = high probability to be leaf
- Small ball = low probability to be leaf

For trunk probability table is consider on color



3D reconstruction of date palm tree

1. Calculating Probability Image of the Leaves and Trunk



(1) leaves and trunk probability images.

3D reconstruction of date palm tree

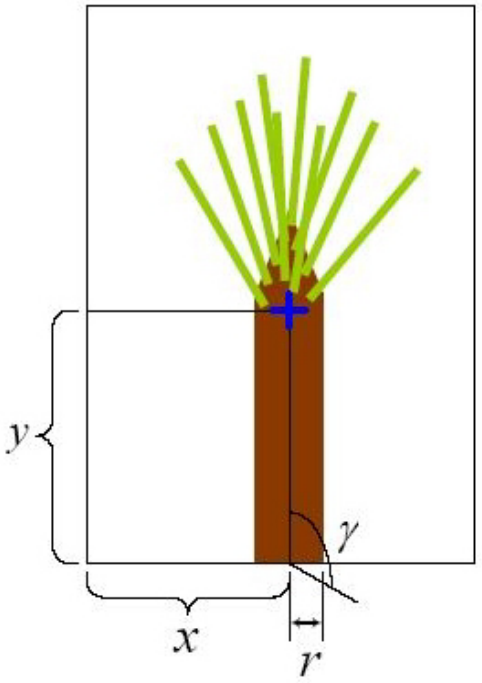
2. Search for Trunk Location and “Tree Center”

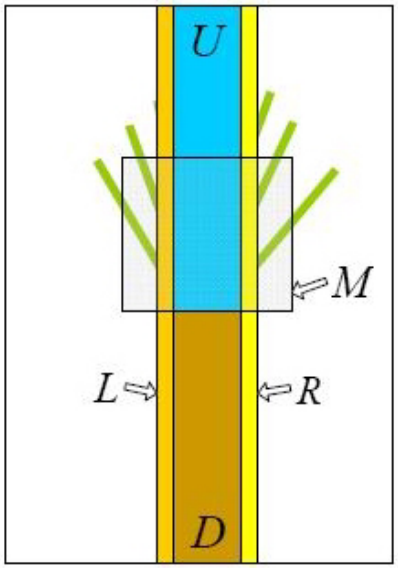
x - the horizontal location on the image

r - trunk radius

γ - the learning angle of the trunk toward the camera

y - the vertical location on the image (the oldest leaf location)





D - descending trunk rectangle

U - ascending trunk rectangle

R - right outer border of the trunk

L - left outer border of the trunk

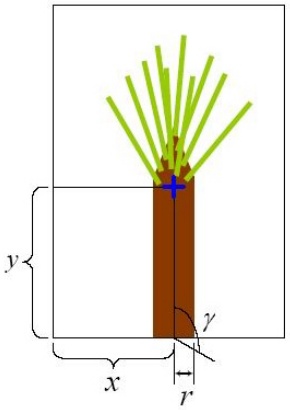
M- a leafy area

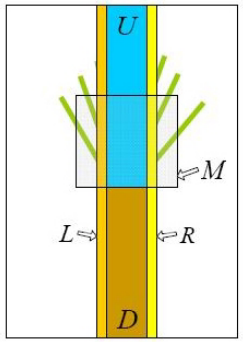
3D reconstruction of date palm tree

2. Search for Trunk Location and “Tree Center”

Searching for x and r using “Integral Image” algorithm (Viola and Jones, 2001)

$$E_h(x,r) = (f(U \cup D, P_t) - f(L, P_t) - f(R, P_t)) \cdot r^{\frac{1}{3}}$$





Average probability of the pixels in the rectangle A

$$f(A,P) = \frac{\sum_{i,j}^{(i,j)\in A} P(i,j)}{\|A\|}$$

x - the horizontal location on the image

r - trunk radius

D - descending trunk rectangle

U - ascending trunk rectangle

R - right outer border of the trunk

Ll - left outer border of the trunk

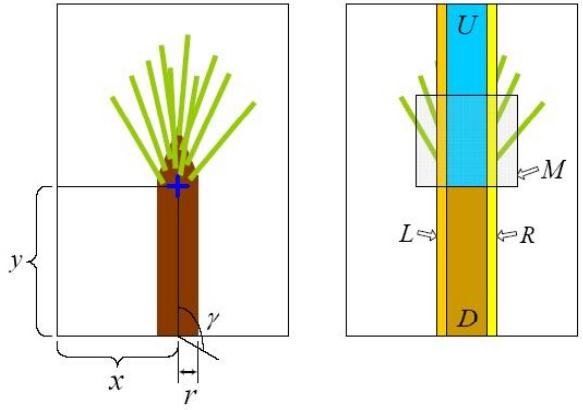
P_l - probability of leaf P_t - probability of trunk

A - area

(i,j) - pixel coordinate

3D reconstruction of date palm tree

2. Search for Trunk Location and “Tree Center”



Search for y using local search

(Lewis and Torczon, 2000) by maximizing

$$E_v(x,r,y) = (f(M,P_l) + f(D,P_t) - f(U,P_t))$$

The best (x,r,y) combination

is chosen by maximizing

$$E(x,r,y) = E_v(x,r) \cdot E_h(x,r,y)$$

E - energy function

x - the horizontal location on the image

r - trunk radius

y - the vertical location on the image (the oldest leaf location)

D - descending trunk rectangle

U - ascending trunk rectangle

R - right outer border of the trunk

L - left outer border of the trunk

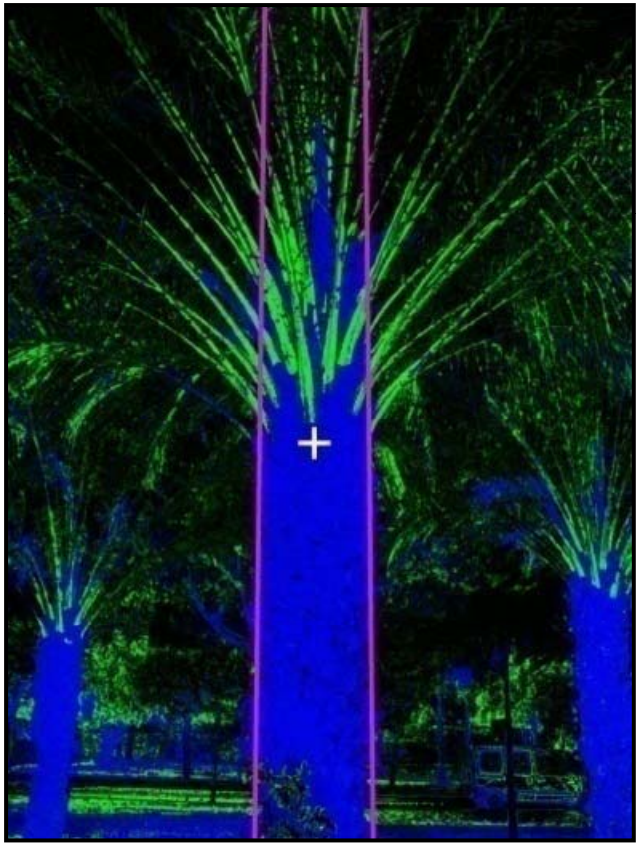
M- a leafy area

P_l - probability of leaf

P_t - probability of trunk

3D reconstruction of date palm tree

2. Search for Trunk Location and “Tree Center”

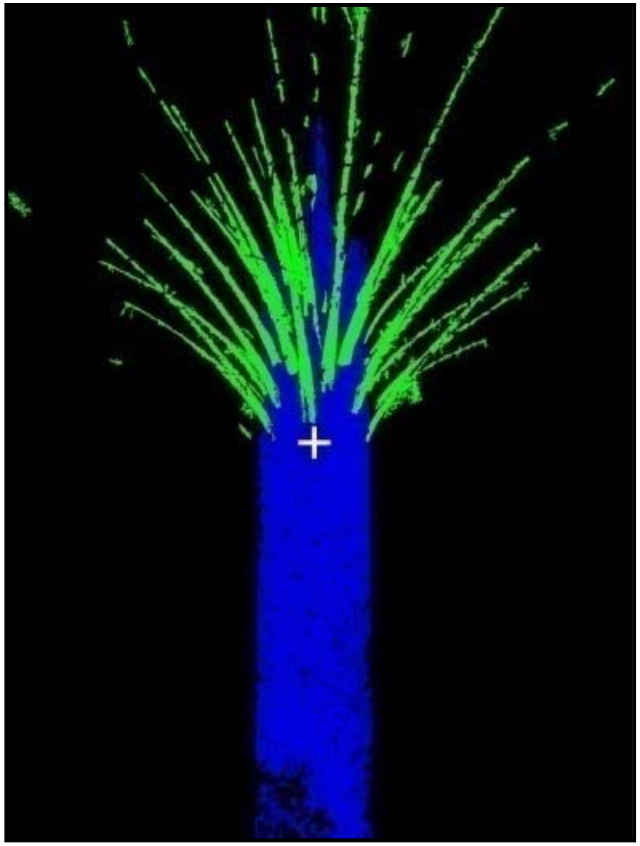


(2) Trunk location and “tree center”.

3D reconstruction of date palm tree

3. Creating the Leaf Clues Image

- the leaf probability image
- Thresholding
- PCA: the dominant clue direction
- Keep the leaves in radius (3/2)r



(3) Leaf clues image.

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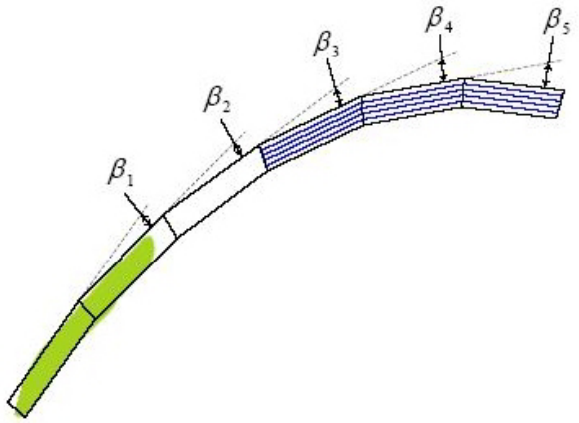
4. Search for Prominent Leaves

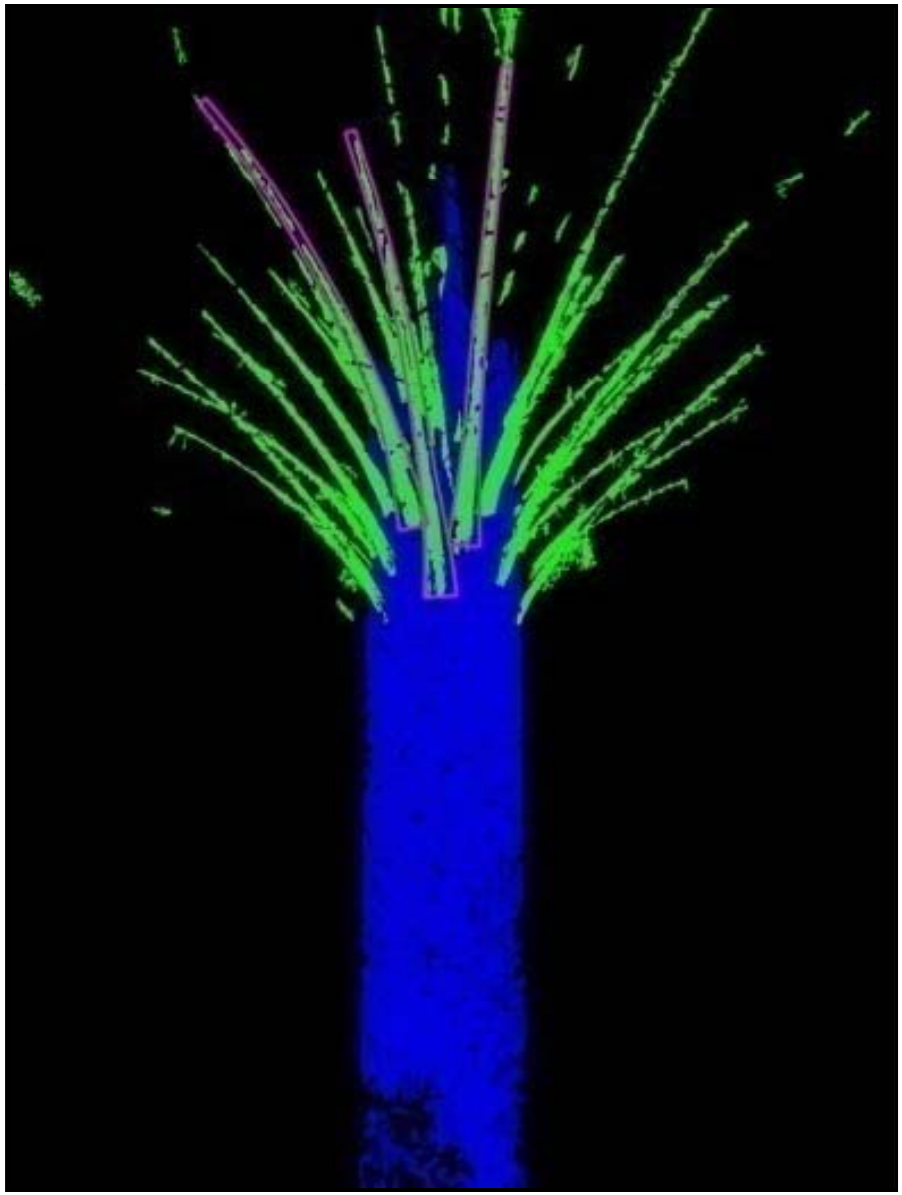
- Removing the leaf start point
- Tracking the leaf
- Removing the leaf



Particle filter tracking model

3D reconstruction of date palm tree

4. Search for Prominent Leaves



(4) Prominent leaves search.

3D reconstruction of date palm tree

5. Estimating Model Parameters

- Parastichy pattern
- Test both: right and left handedness -> select the right one
- d (The vertical distance) = the mean of the inliers
- The relative age index -> the relative location and handedness

Prominent leaves

Predicted leaves

(5) Model prediction.

3D reconstruction of date palm tree

6. Search for More Leaves

(6) Search for more leaves.

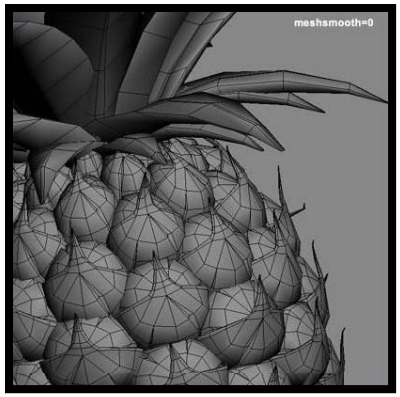
3D reconstruction of date palm tree

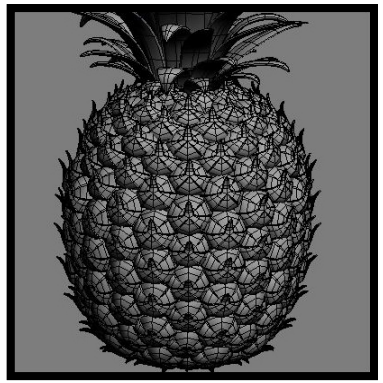
7. 3D Reconstruction

3D VRML model

(7) VRML 3D model.

Interesting Work: 3D reconstruction of Pineapple





Taken from http://www.turbosquid.com/3d-models/3d-pineapple-model/411689
https://www.fallingpixel.com/3d-models/11259

References

- http://maven.smith.edu/~phyllo/
- Dror, R., & Shimshoni, I. (2009). *Using phyllotaxis for date palm tree 3d reconstruction from a single image*. In Vissapp (2) (pp. 288-296).