3D SEGMENTATION OF A MULTI-LAYERED FOREST STRUCTURE USING AIRBORNE LASER SCANNING (ALS) DATA

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Journées de la recherche de l'IGN 2012

IPGP
INSTITUT DE PHYSIQUE DU GLOBE DE PARIS

IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

MATIS

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Outline

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Forest point clouds
Individual tree crown segmentation
Thesis goal

✧ Method

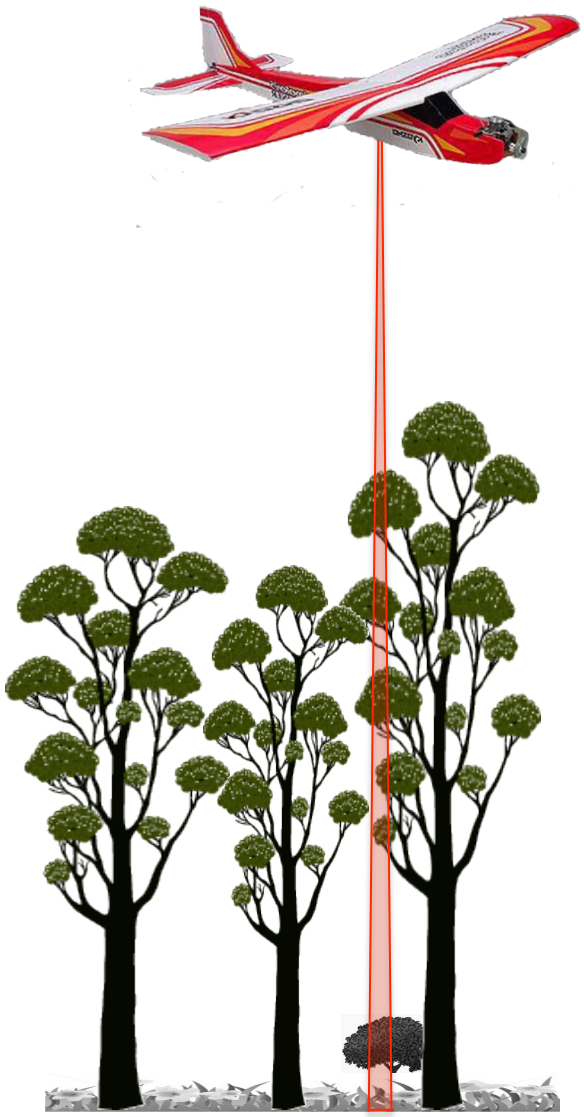
Mean shift algorithm
Adaptive mean shift algorithm
Adaptive mean shift based method

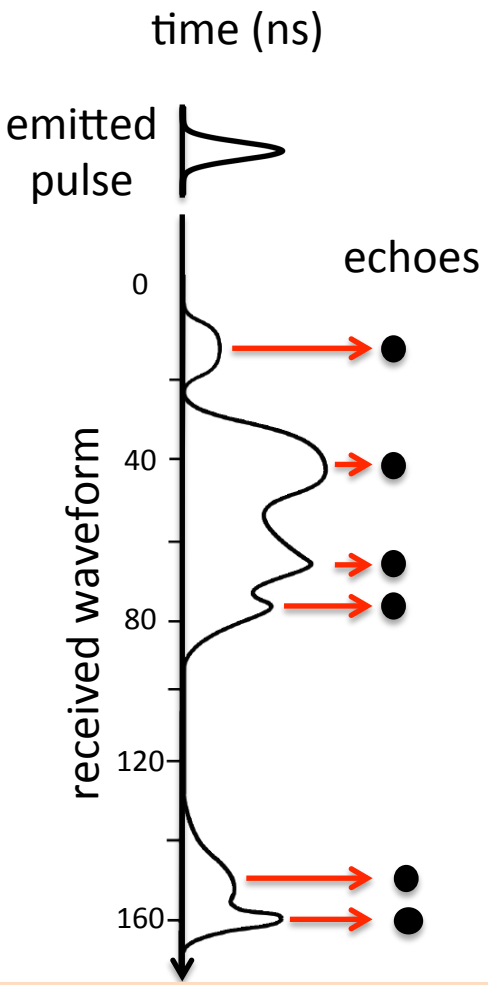
✧ Results

Study area
Forest layers mean height
Individual trees identification
Tree height and crown base height

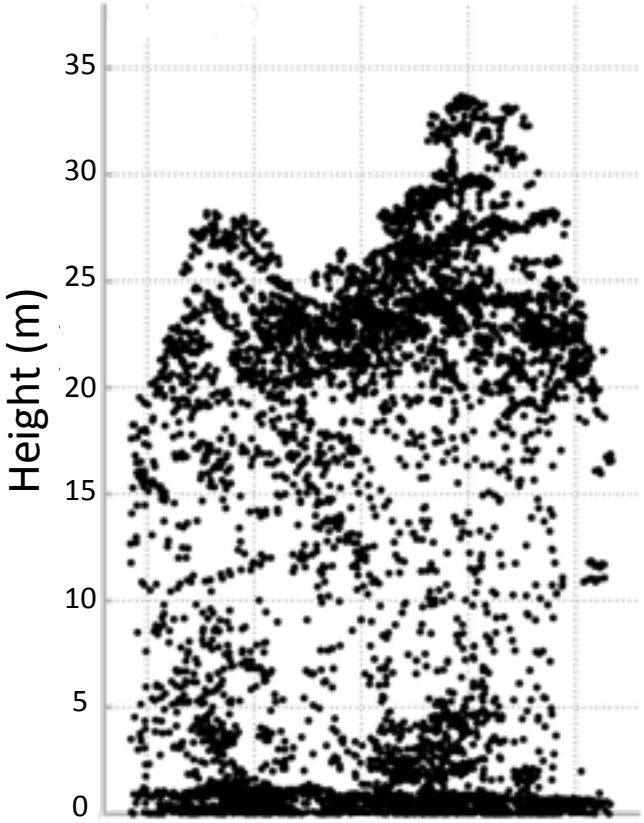
✧ Conclusion

Introduction: forest point clouds

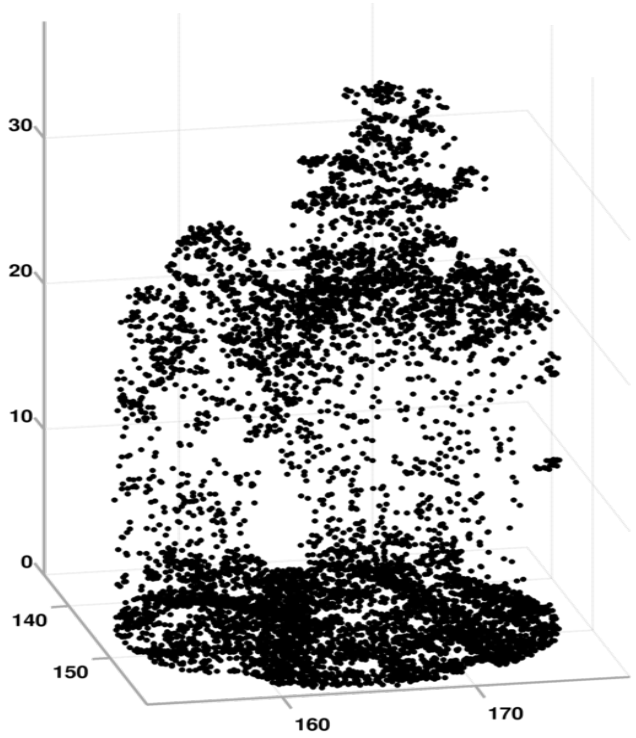


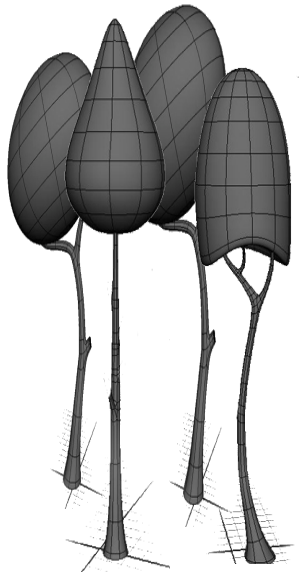


LiDAR point cloud



Introduction: individual tree crown segmentation

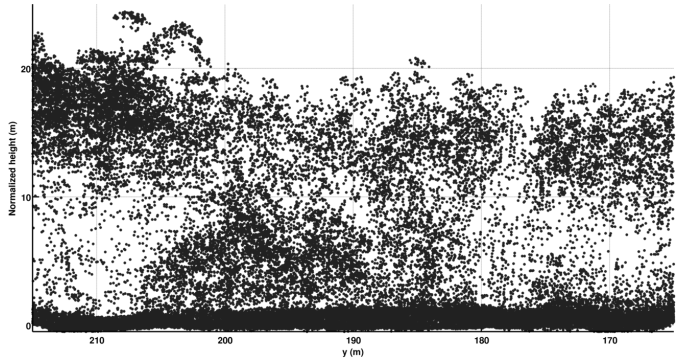




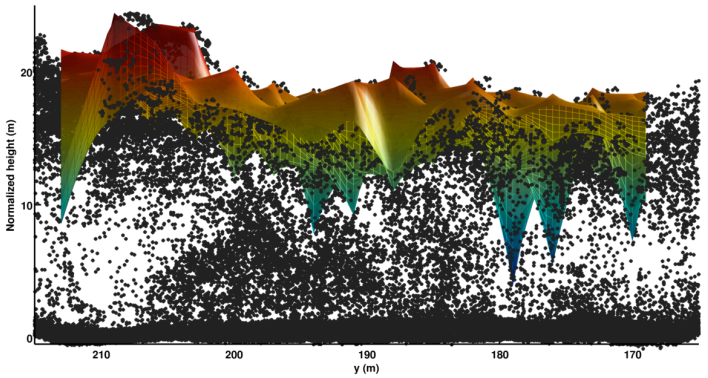
Introduction: individual tree crown segmentation

all approaches rely on a canopy height model (CHM)

LiDAR point cloud



CHM



CHM = image 2.5 D

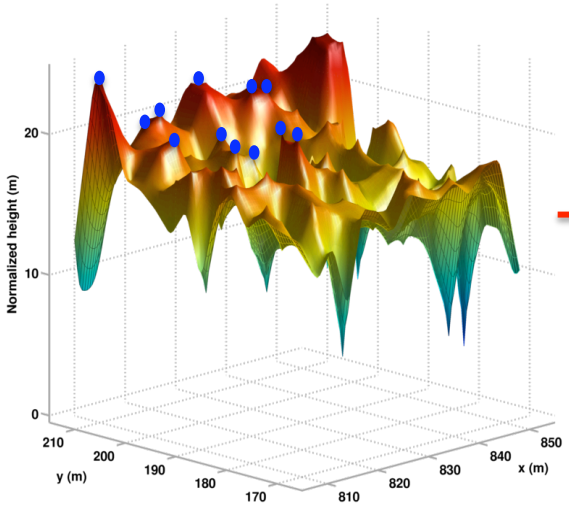
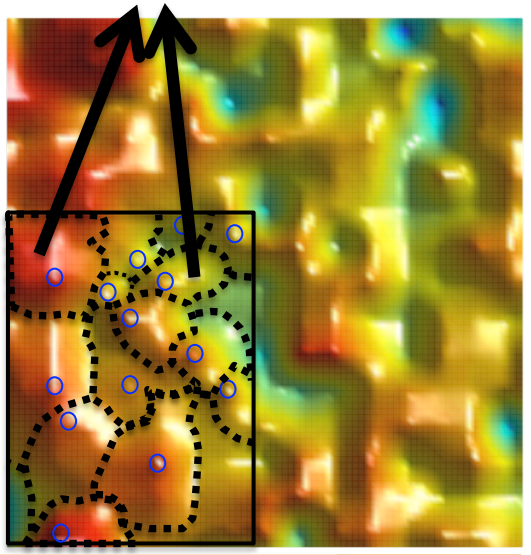


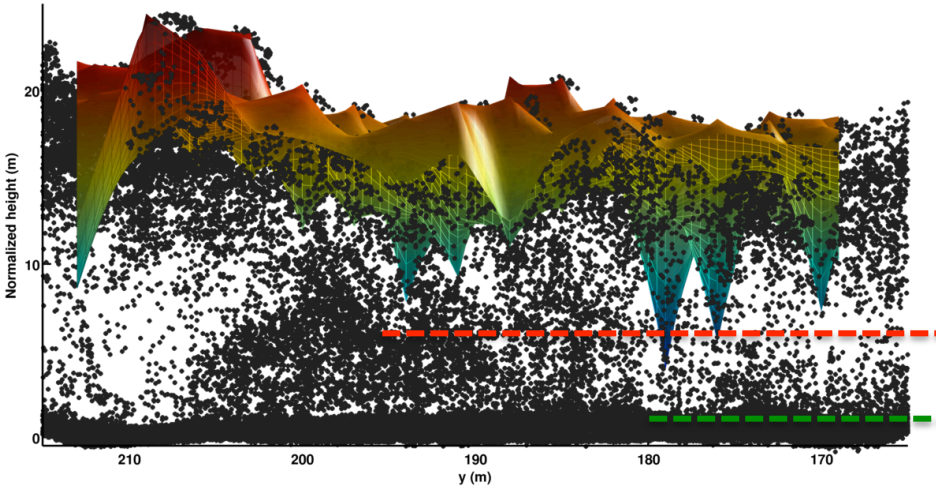
image segmentation techniques

- **Watershed segmentation** [Chen et al., 2009]
- **Edge detection** [Hyyppä & Inkinen, 2009]
- **Region growing** [Erikson, 2009]
- **etc.**

Individual tree crowns



CHM are not appropriated to characterize multi-layered forests



understory

surface vegetation

information loss

Boreal forest biome

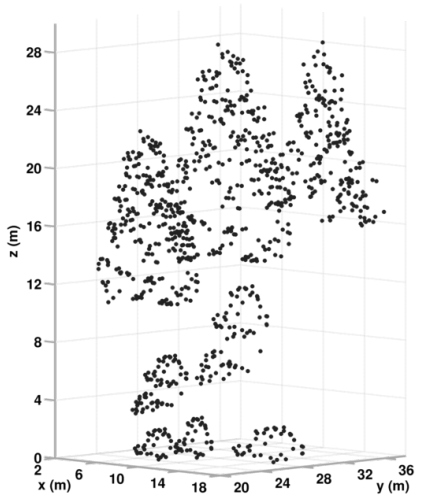
single-layered

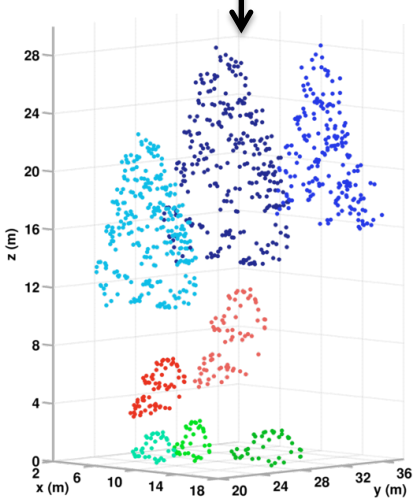
Mediterranean forest biome

multi-layered

- method to fully characterize multi-layered forest environments: overstory, understory and surface vegetation.

Work directly on the 3D point cloud





individual tree crown + vertical stratification

overstory

understory

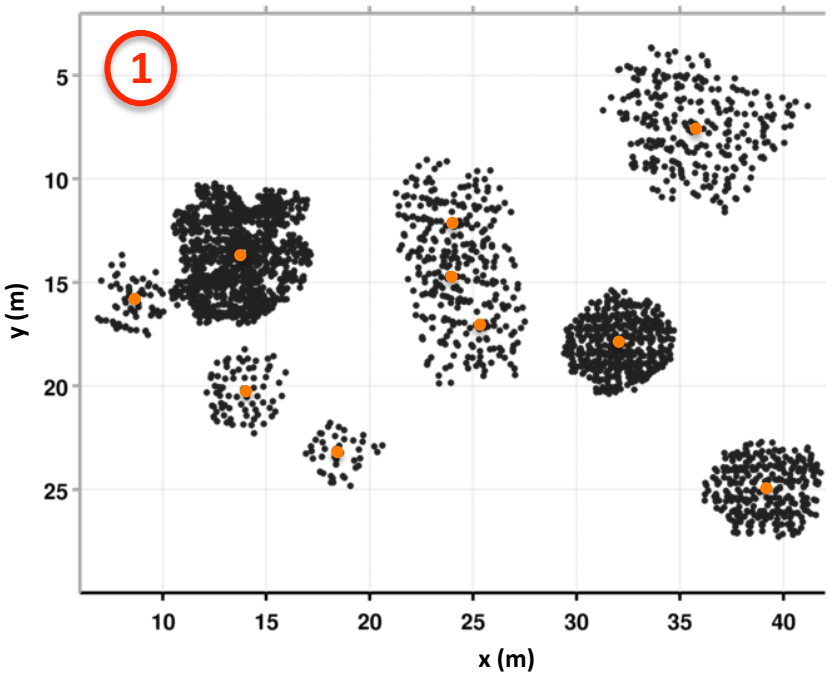
surface vegetation

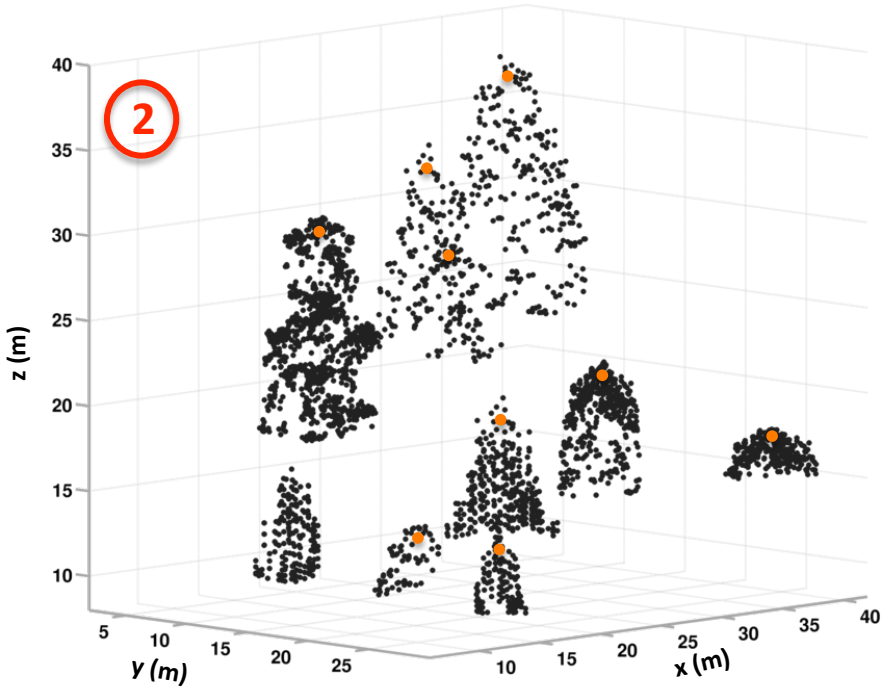
We see the LiDAR point cloud as a multi-modal distribution.

Our approach is based on two experimental evidences. The crowns apexes of the plants are both

① local density maxima and,

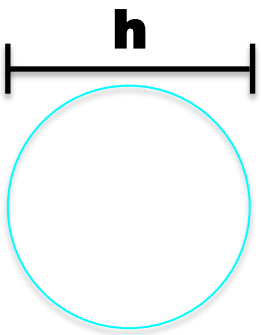
② local height maxima

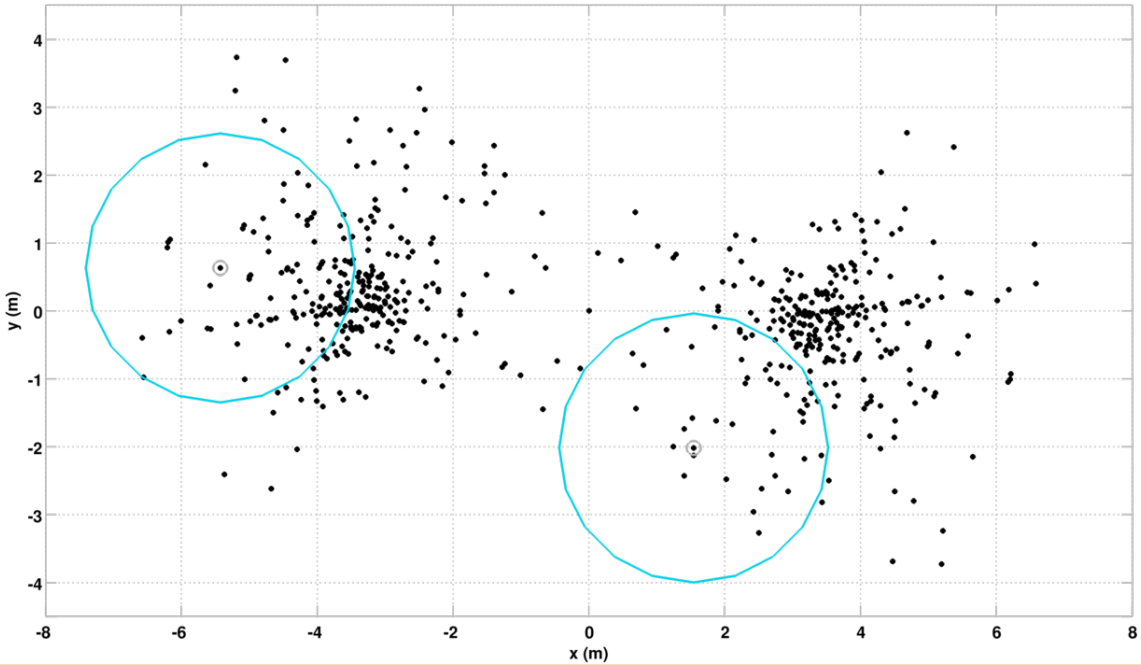




Mean shift algorithm (MS): [Comaniciu & Meer, 2002]

- Tool to calculate the local density maxima (modes) in a data set samples
- The modes are found by means of a kernel bandwidth (**h**) density estimation
- The MS vector is iterated until convergence (reaching the local density maximum)





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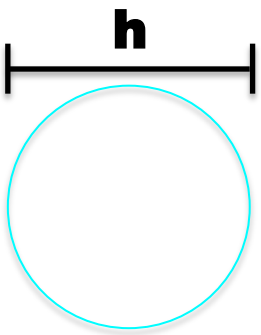

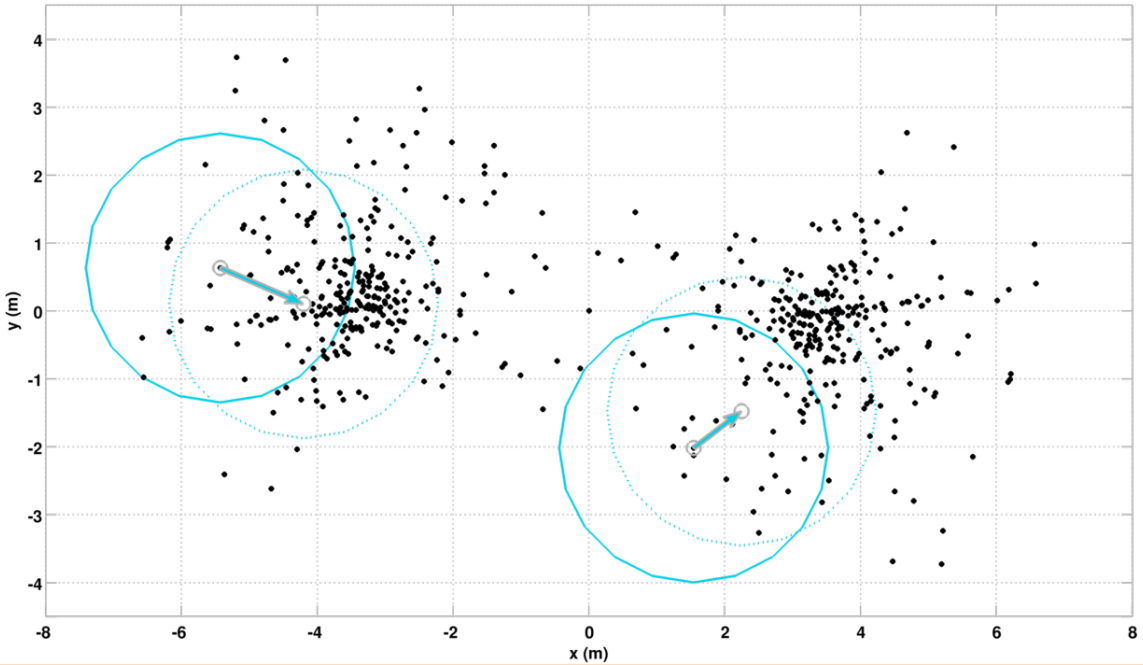

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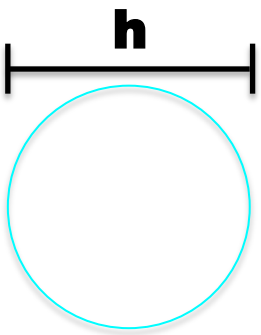

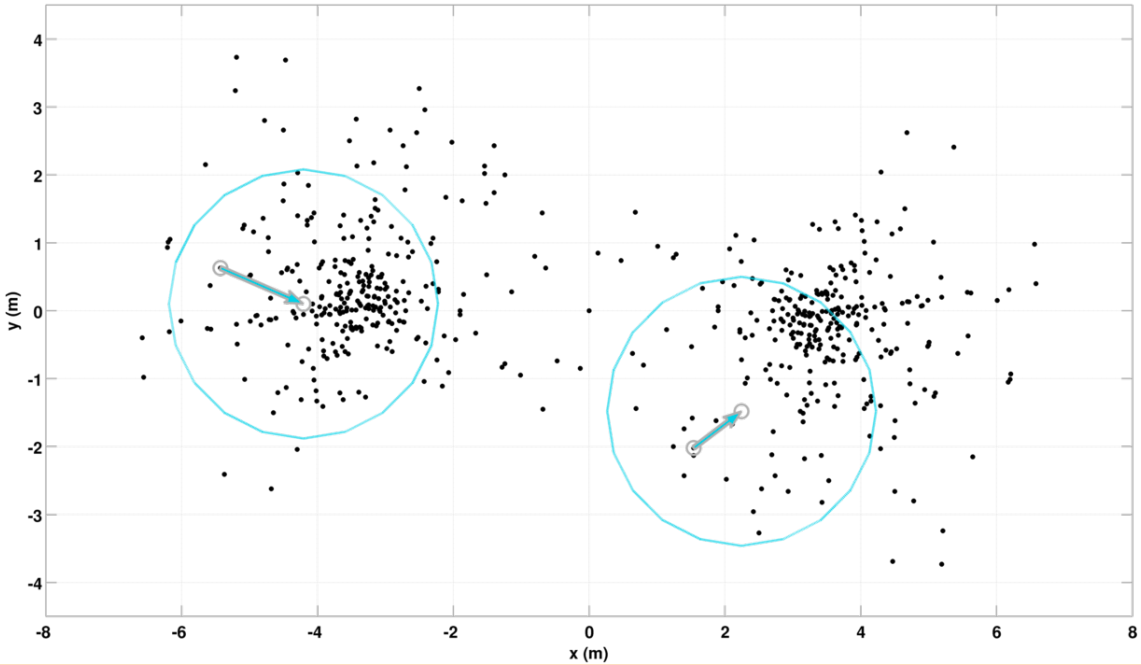

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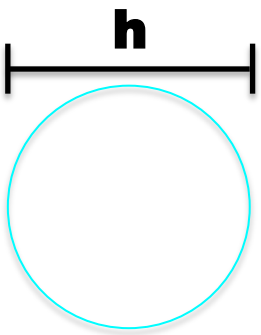

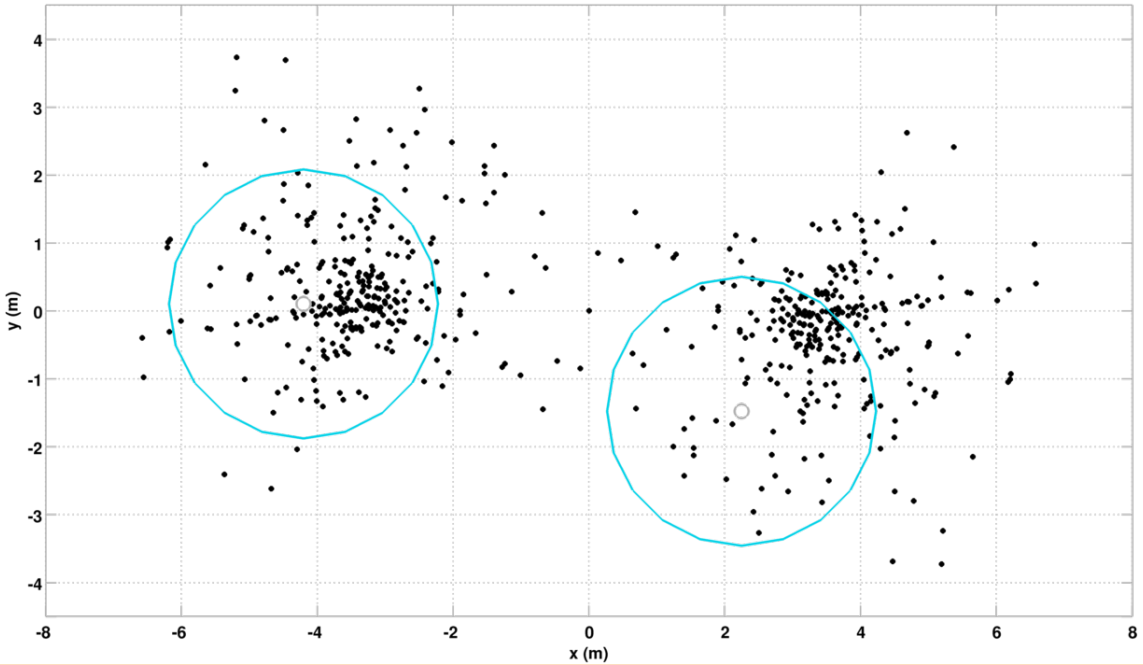

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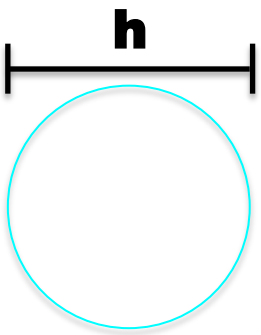

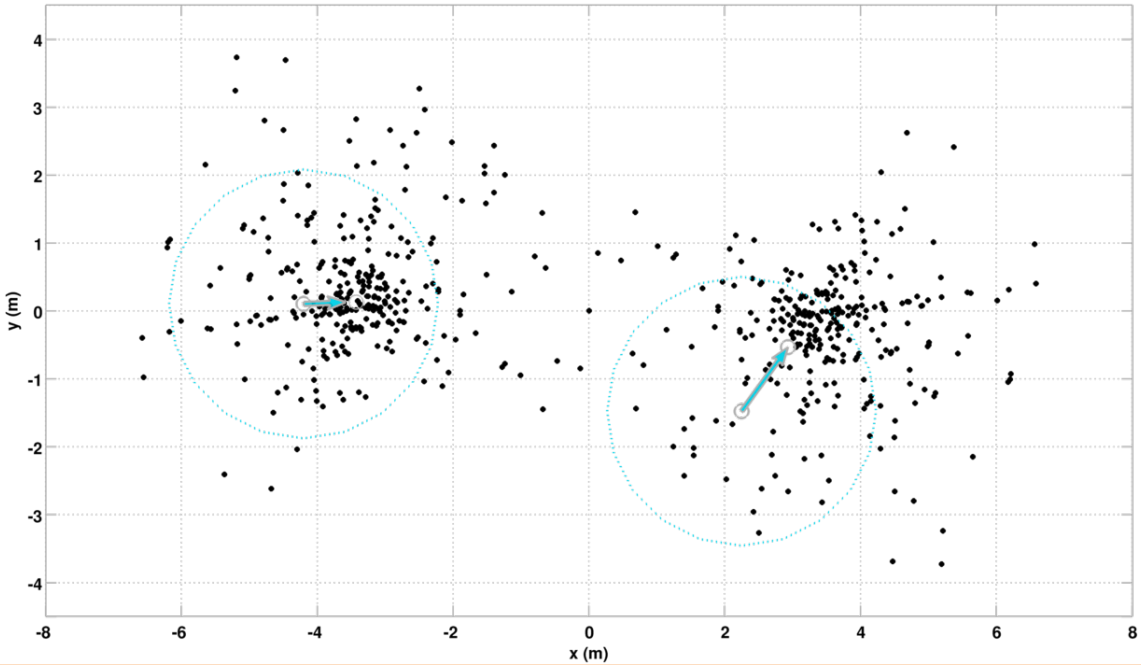

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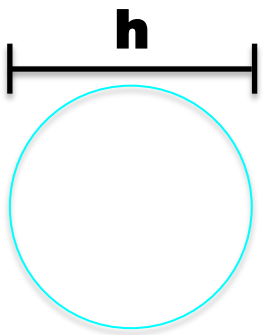

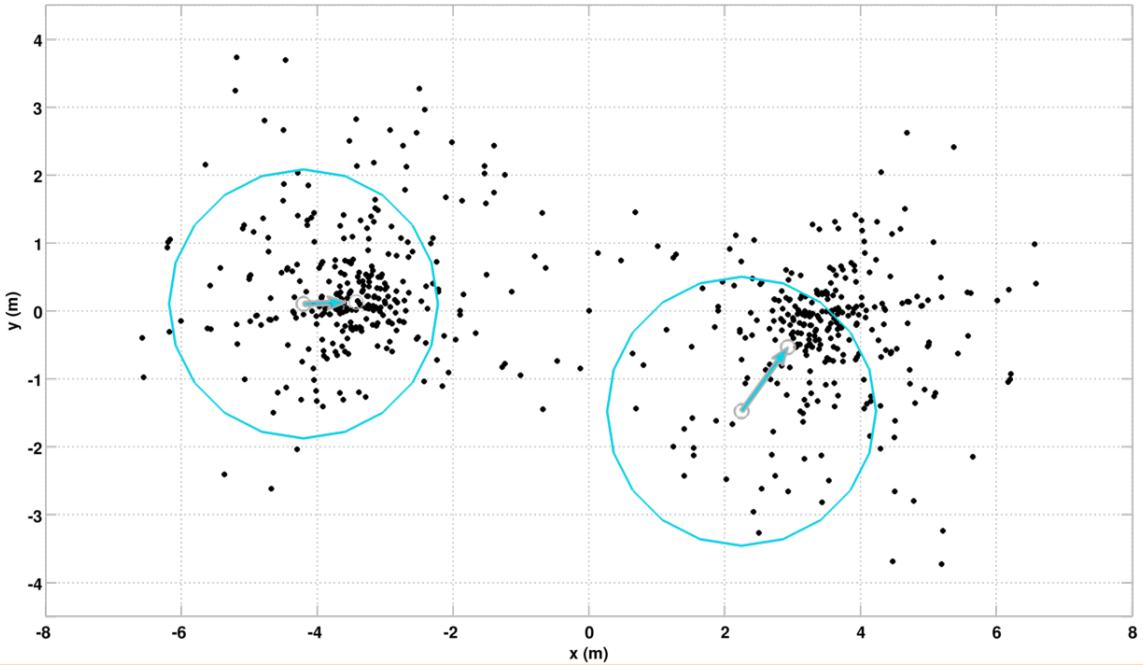

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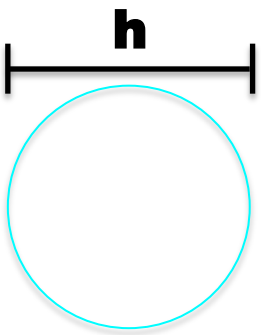

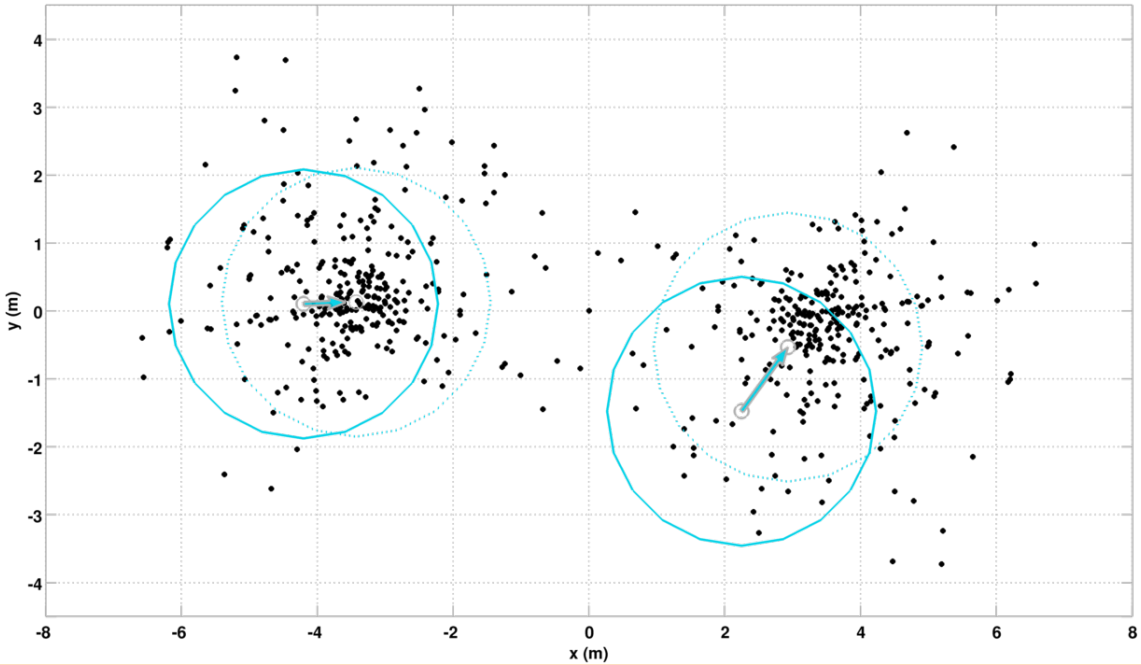

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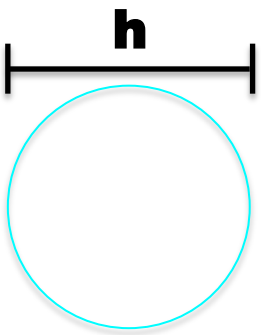

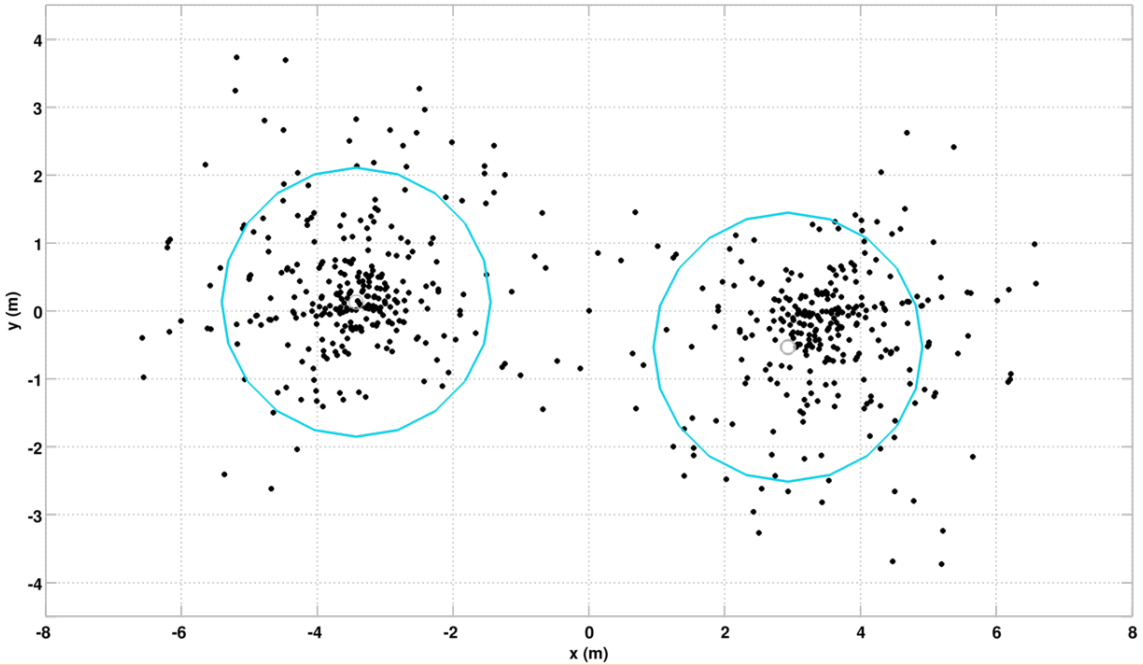

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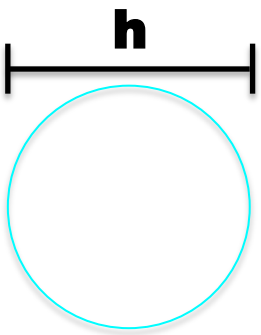

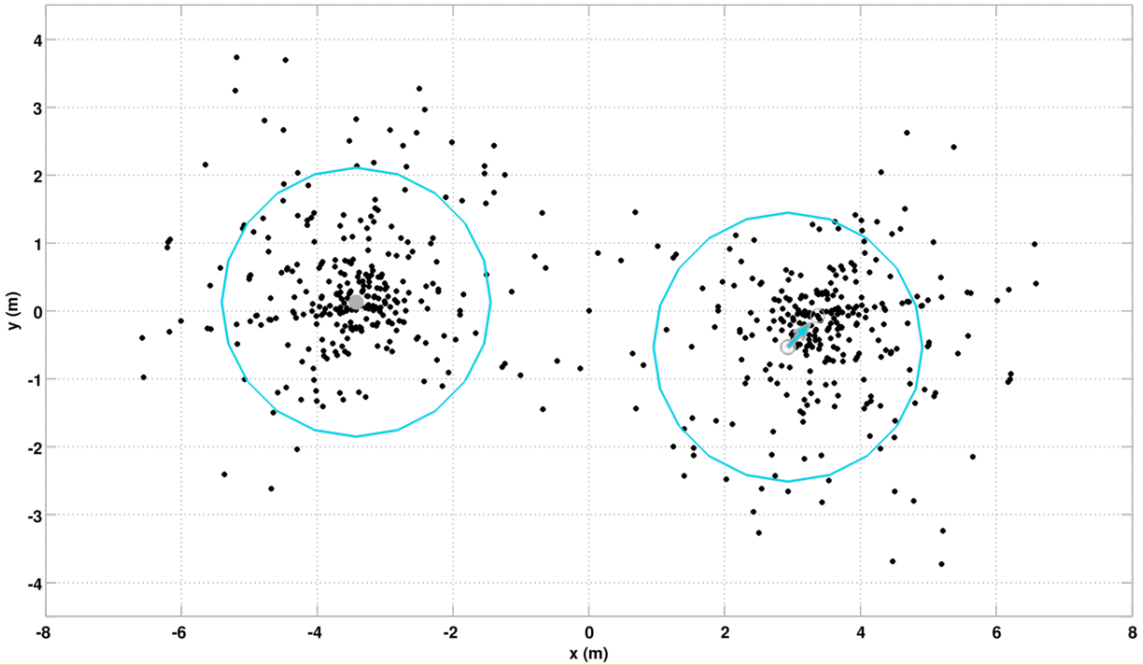

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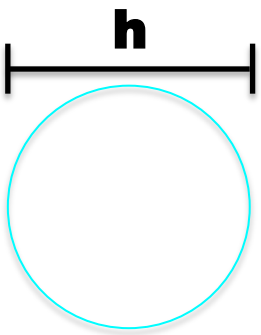

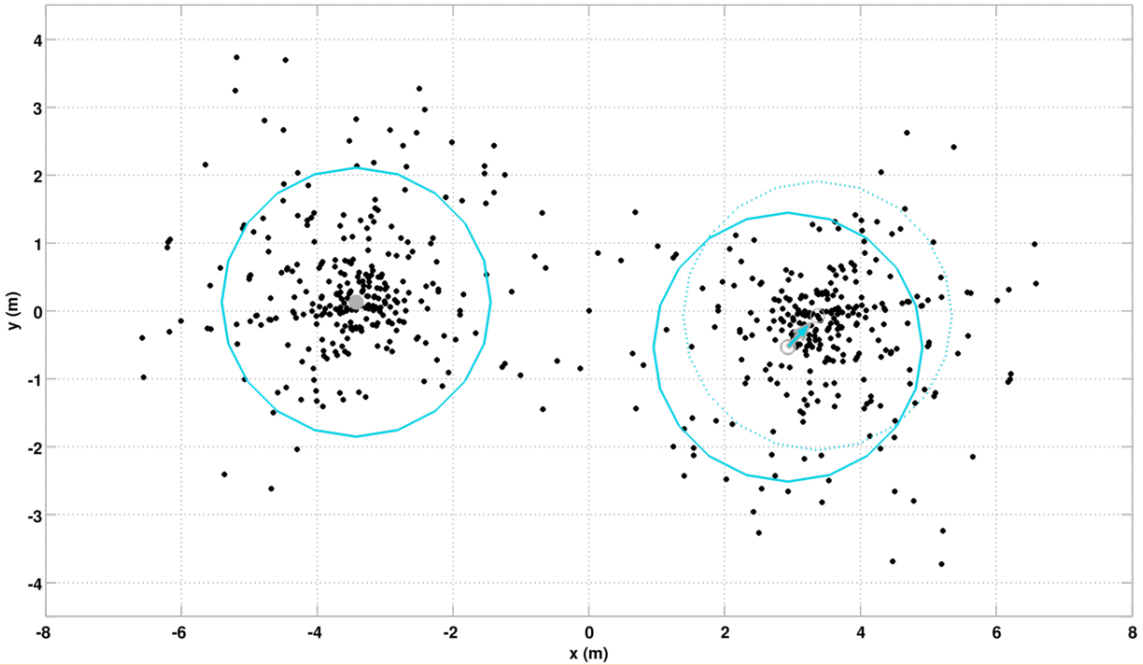

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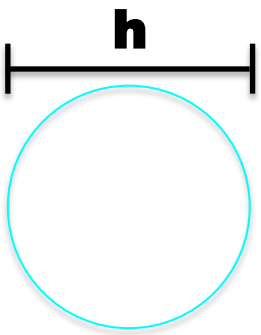

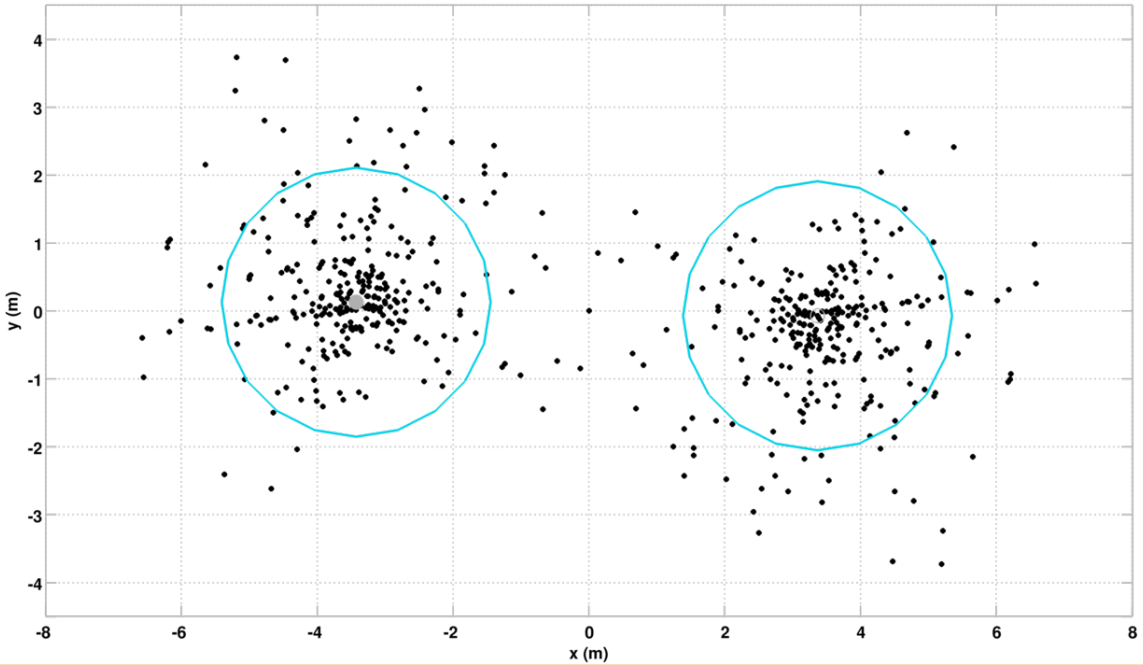

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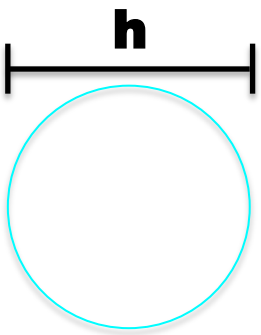

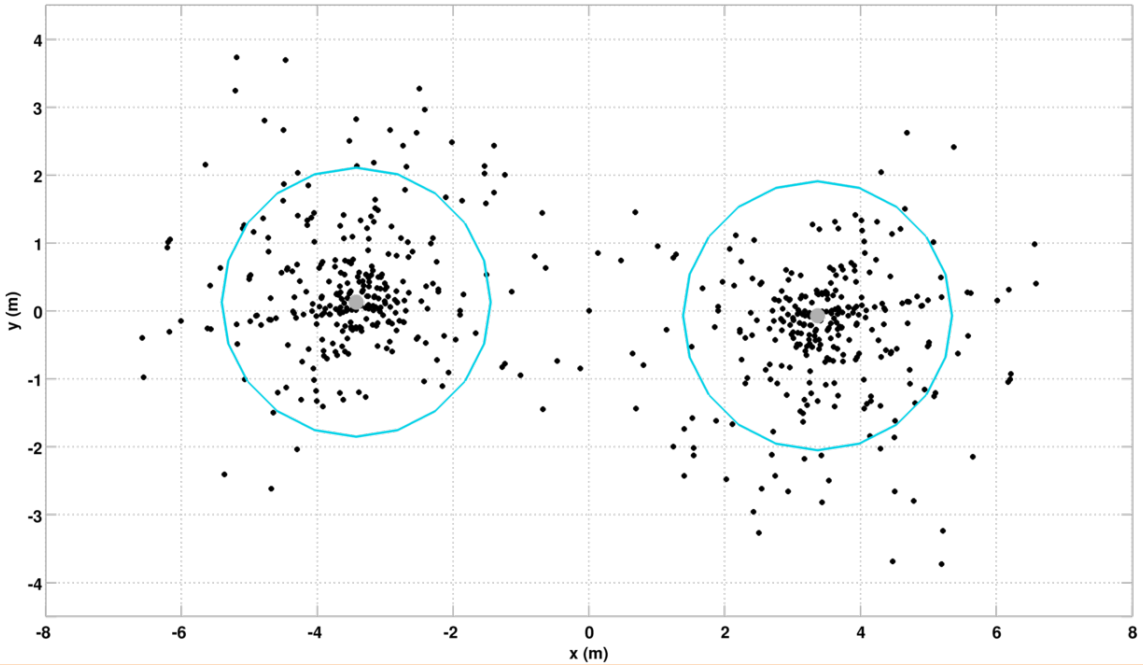

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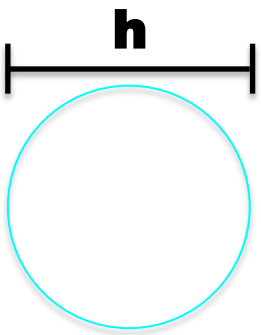
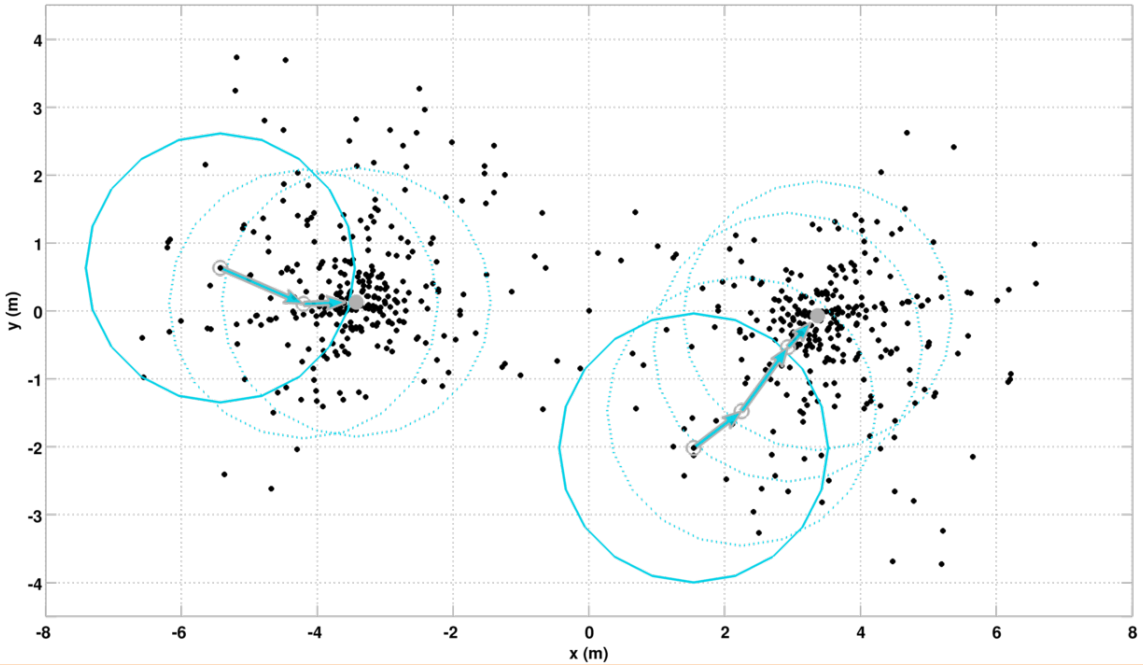
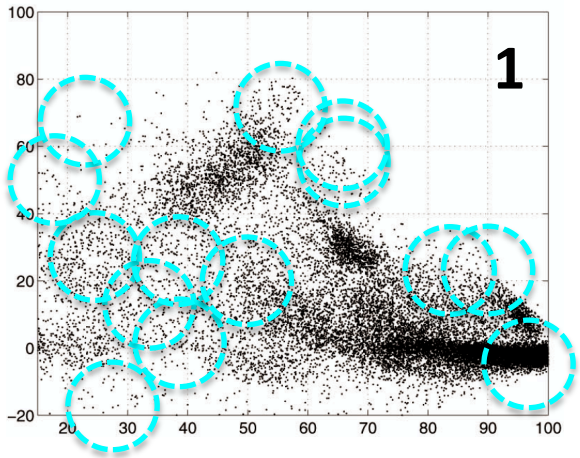
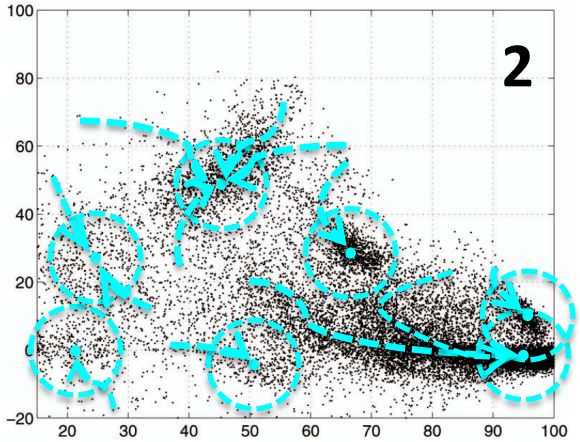


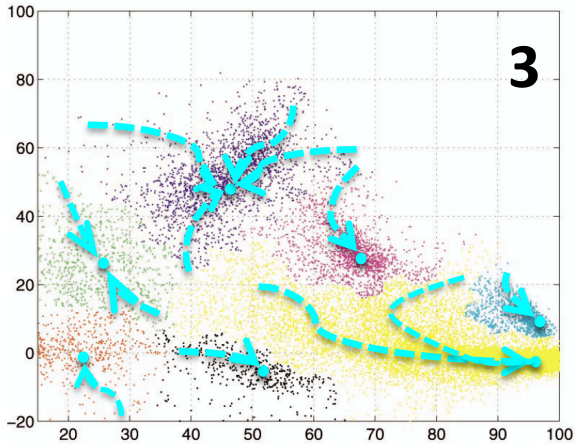


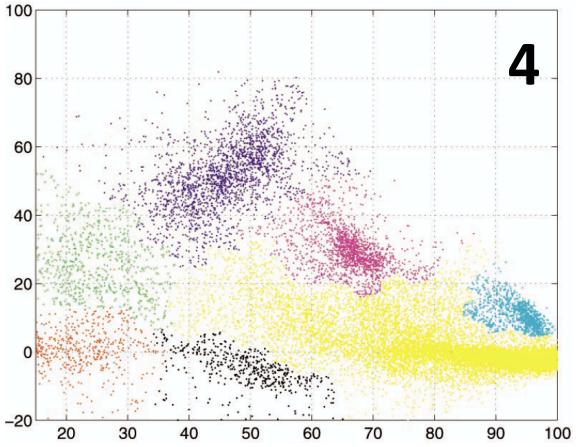
Mean shift segmentation:

1. One kernel bandwidth for every single point
2. Kernel bandwidths iterated until convergence
3. All points that converged to the same mode are gathered together
4. Mean shift segmentation



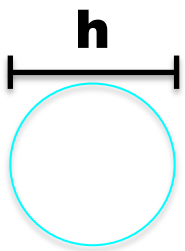
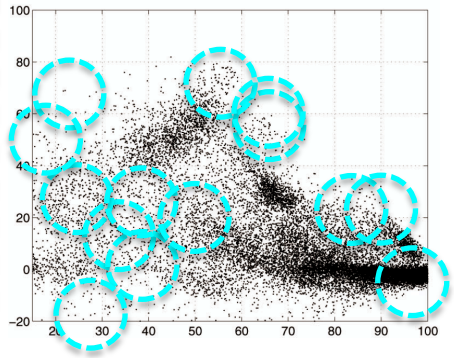
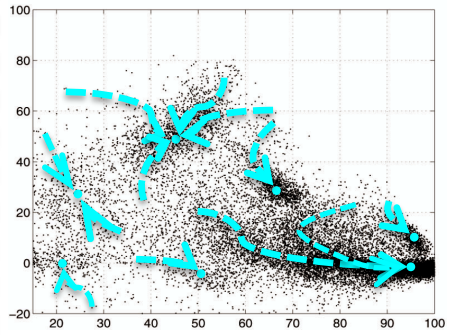
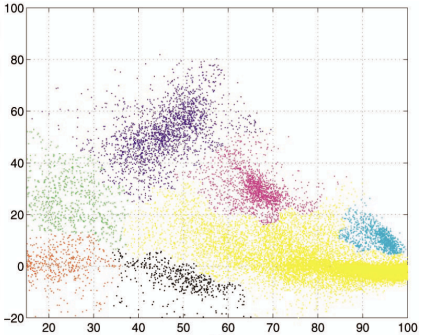
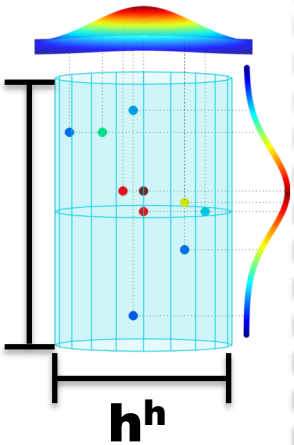
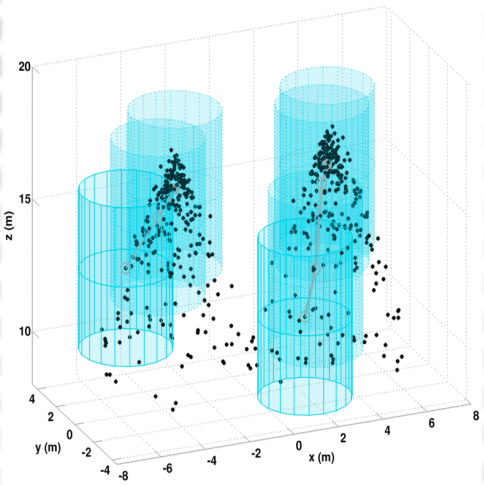
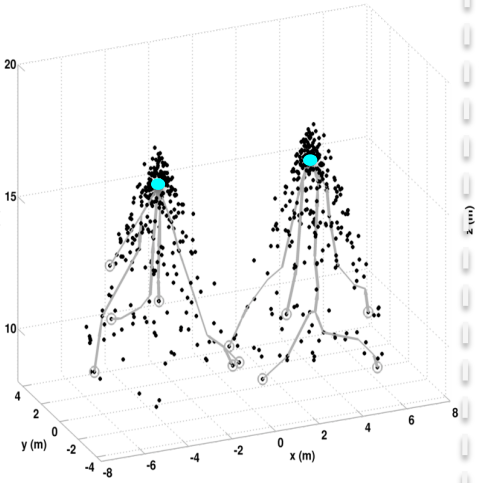
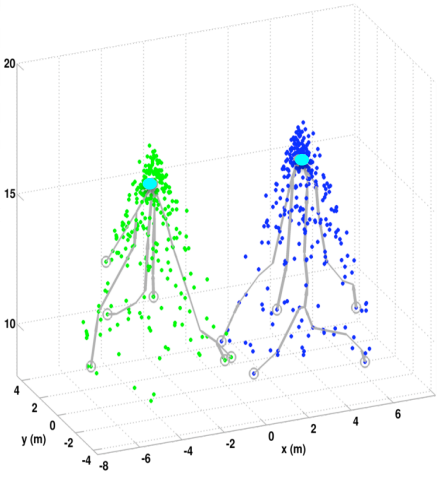






3D mean shift segmentation to apply for ALS point clouds:

Ferraz et al. (2012). 3-D mapping of a multi-layered Mediterranean forest using ALS data. *Remote Sensing of Environment*, 121, 210-213.

	kernel	mean shift	search modes	segmentation
2D				
3D				

Method: mean shift algorithm

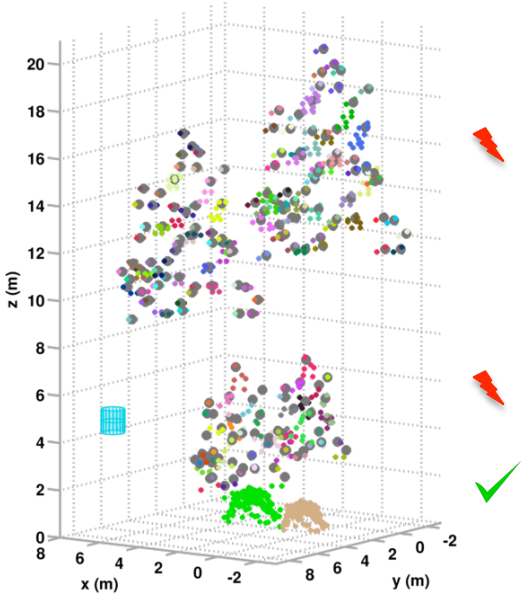
Strengths:

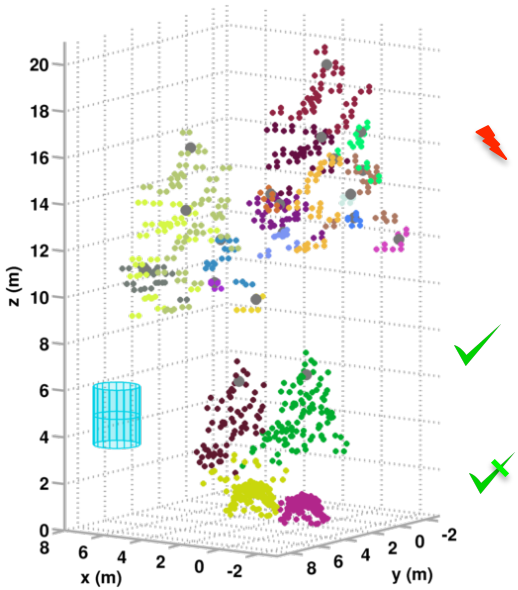
- ✧ Non-parametric approach (does not assume any prior shape on data segments)
- ✧ Does not need a-priori knowledge about the number of the final segments
- ✧ Only one parameters to choose, **h** (kernel bandwidth).

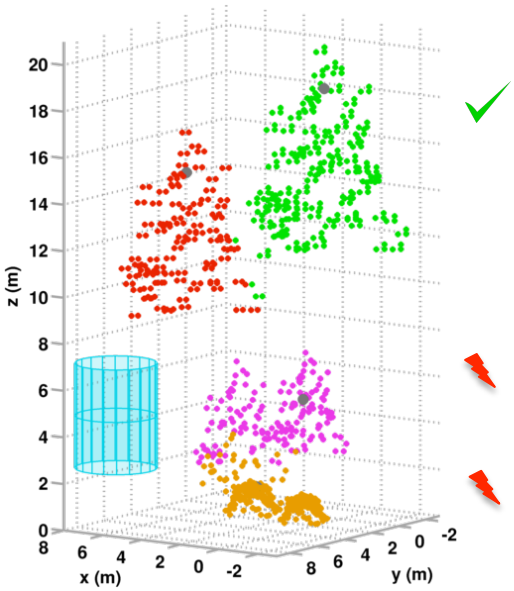
Weaknesses:

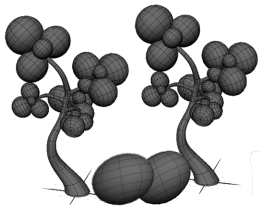
- ✧ The bandwidth selection is not trivial
- ✧ The bandwidth strongly impacts on the results

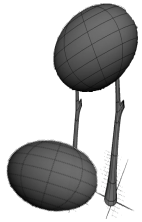
Method: mean shift algorithm



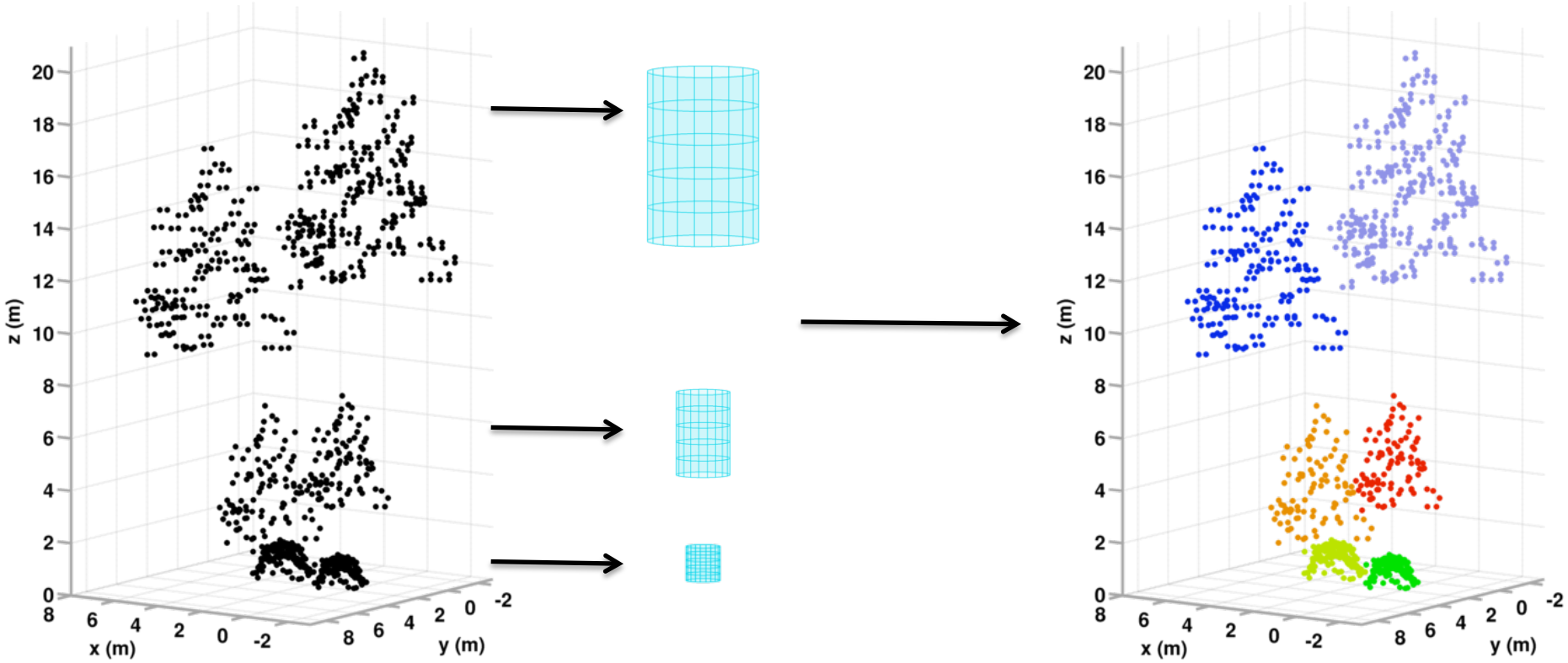




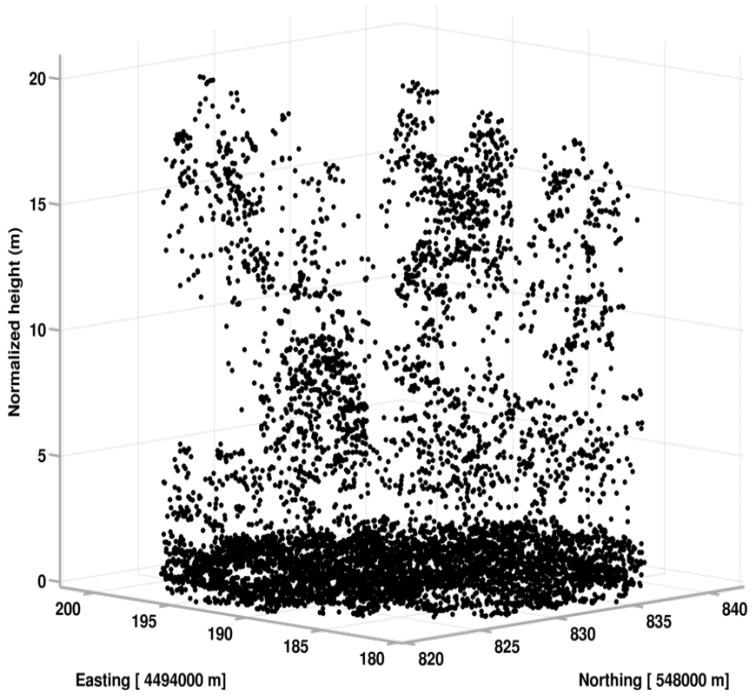




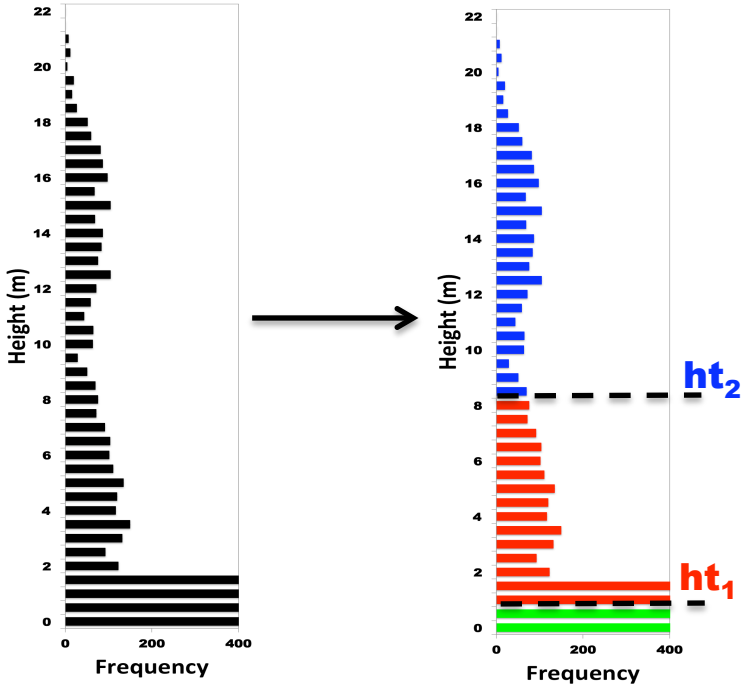
Adaptive kernel bandwidth



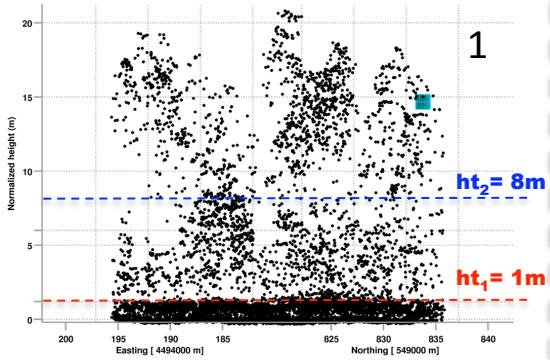
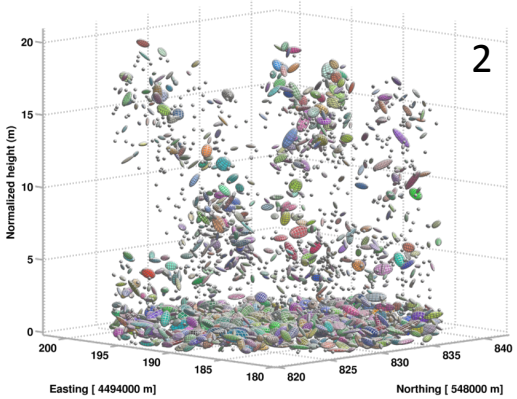
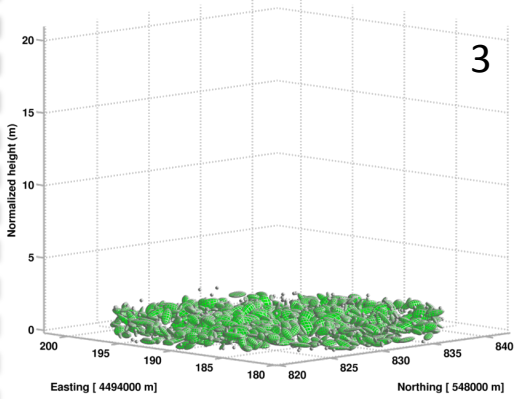
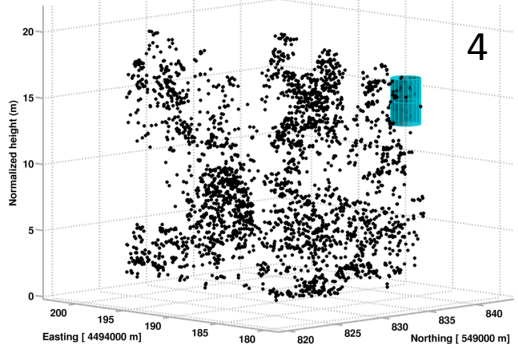
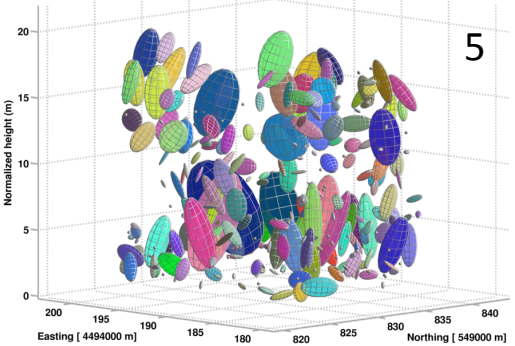
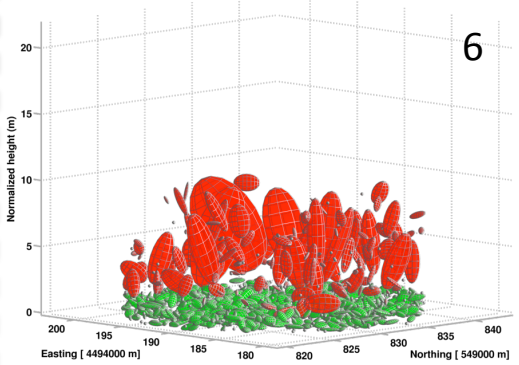
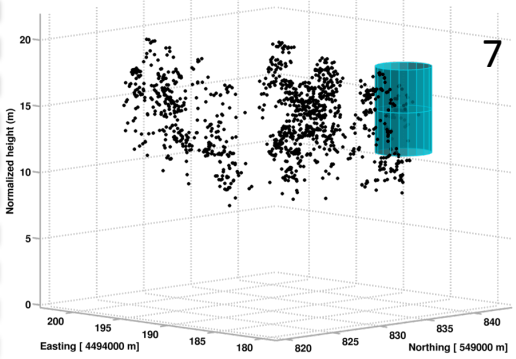
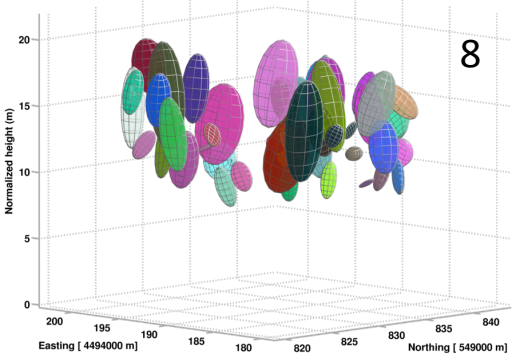
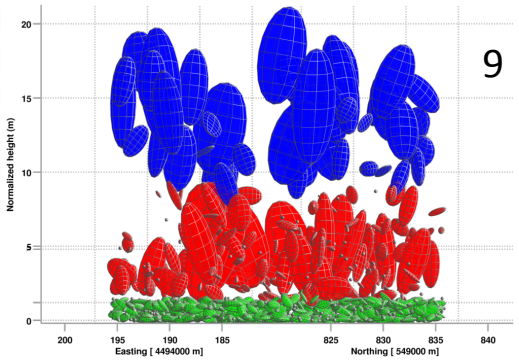
Method: adaptive mean shift based algorithm



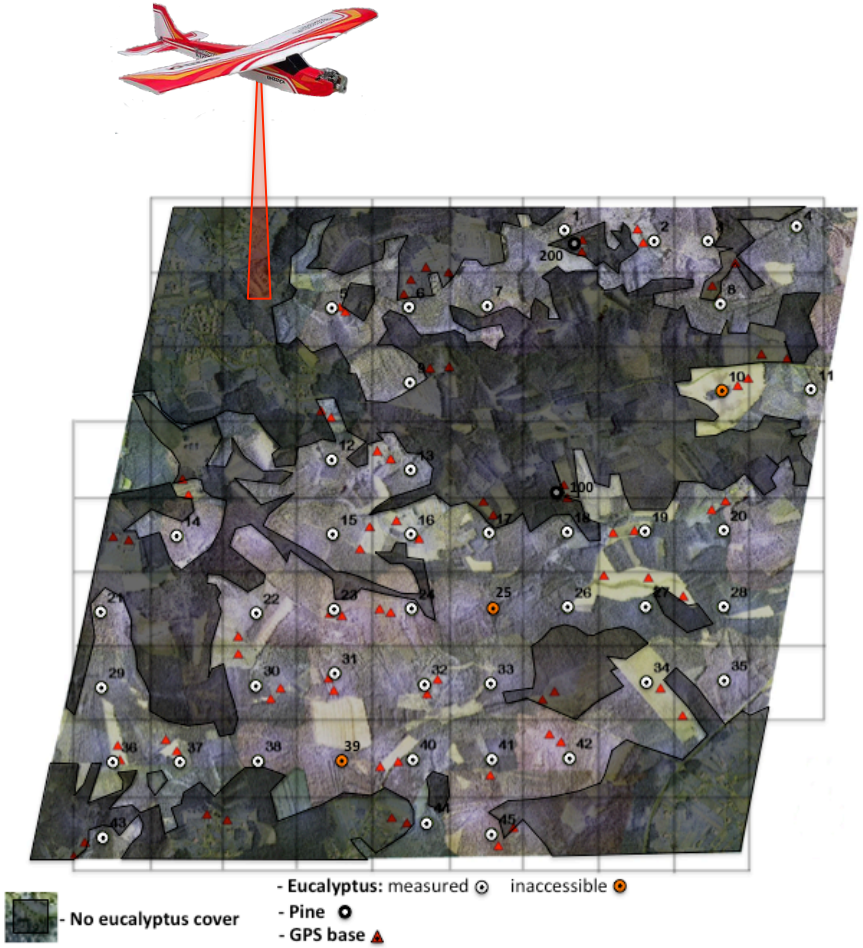
histogram segmentation

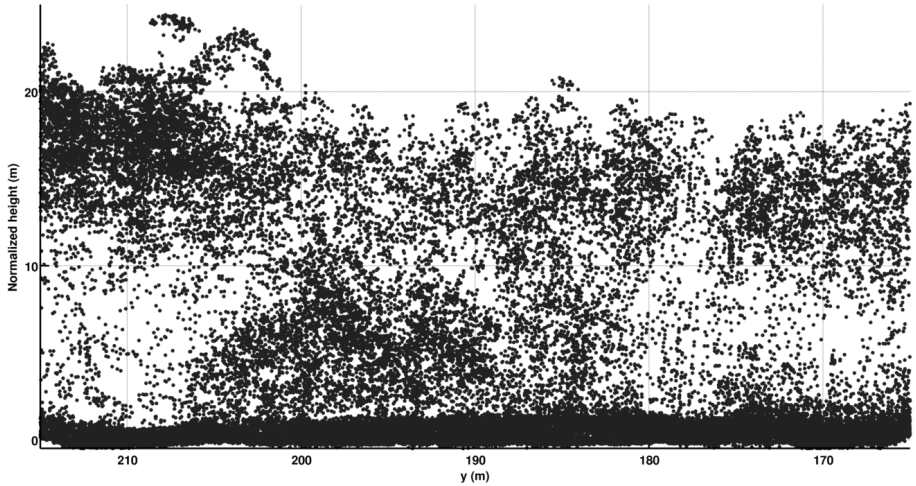


Method: adaptive mean shift based algorithm

	modes search	segmentation	segments selection
1st iteration			
2nd iteration			
3rd iteration			

Results : study area





Forest inventory:

- North-west Portugal (40°36' N, 8°25' W)
- 900 ha
- 70 m < Altitude < 220 m
- 0 % < Slope < 30 %

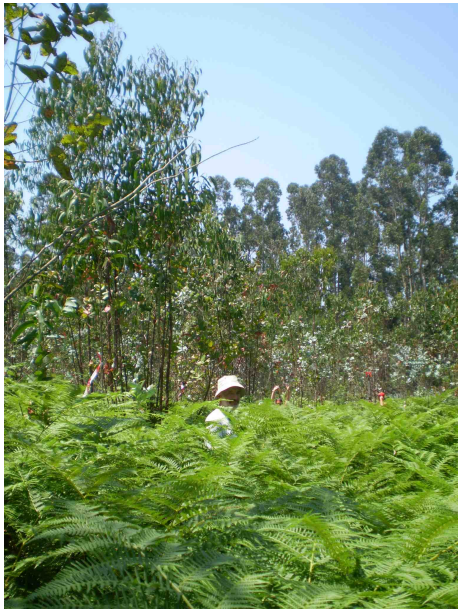
LiDAR data:

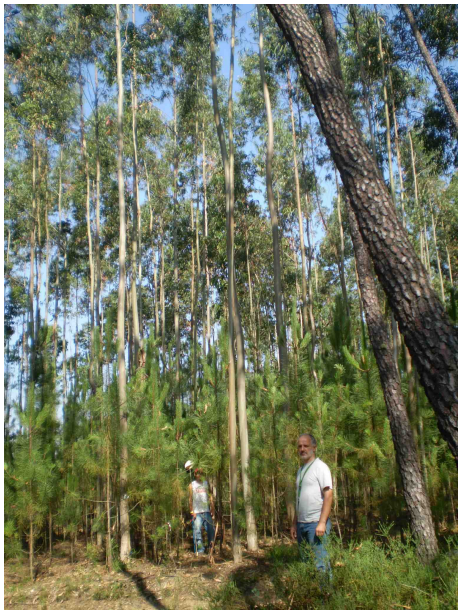
- RIEGL LMS-Q560
- Wavelength = 1064 nm
- Footprint = 30 cm
- Density = 10 pt/m^2

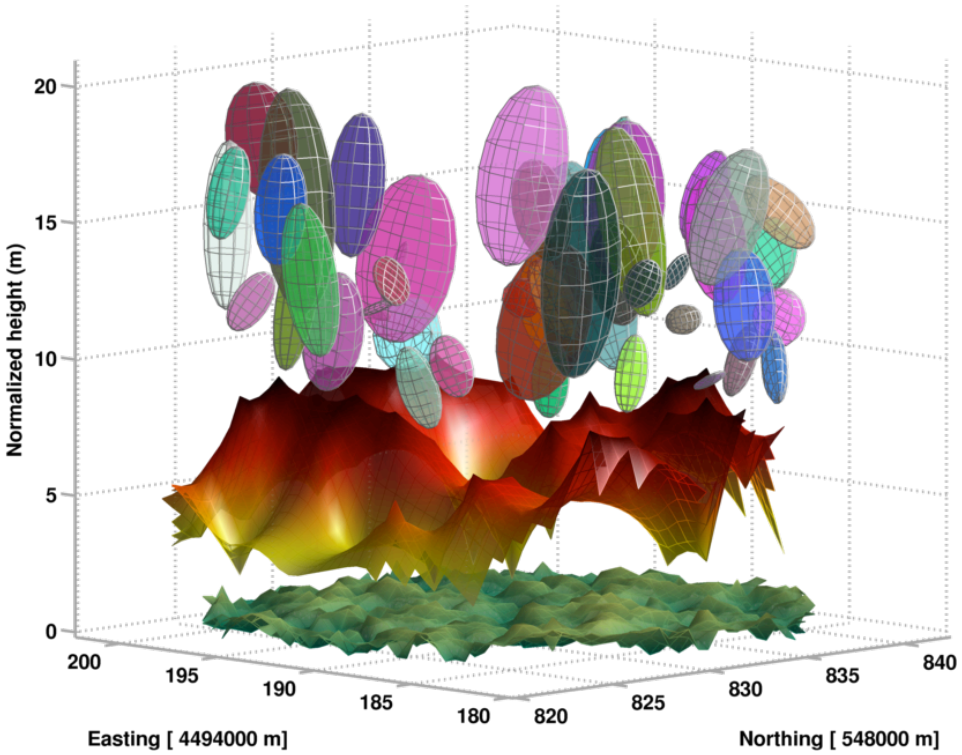
Results : study area

method applied to 44 forest plots:

- **42 mainly composed of eucalyptus (*Eucalyptus globulus*)**
- **2 composed of pines (*Pinus pinaster*)**
- **many plots strongly populated by understory and surface vegetation**



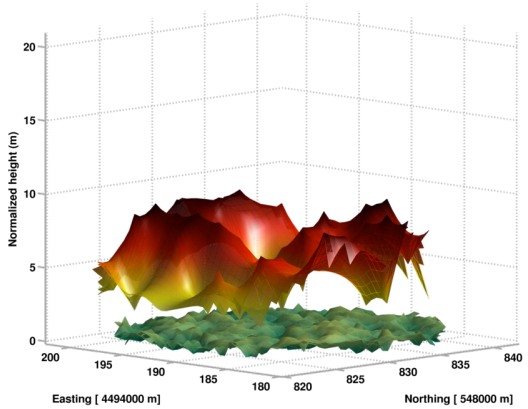




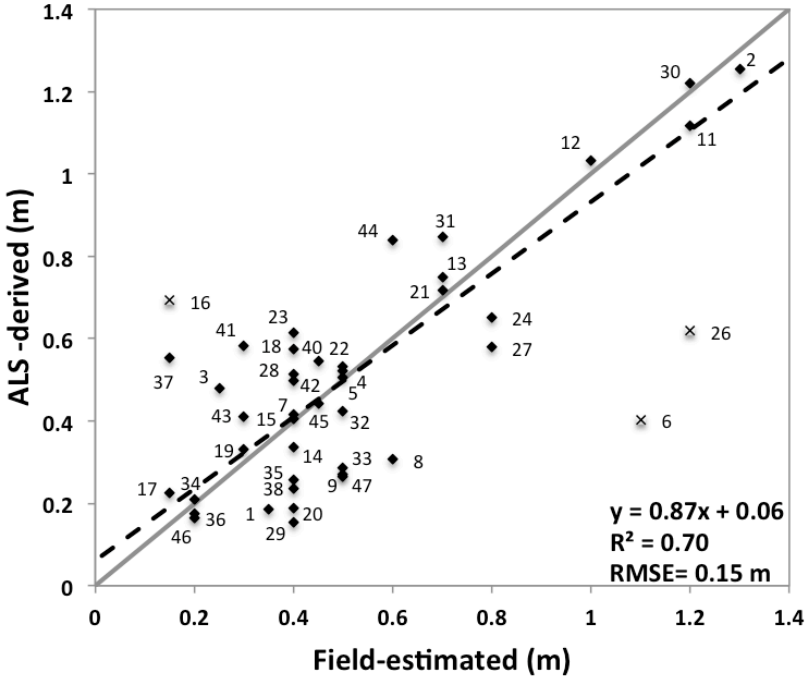
validation of forest cartography :

- **individual trees**
  - number of trees
  - tree height
  - crown base height
- **forest layers mean height**
  - understory
  - surface vegetation

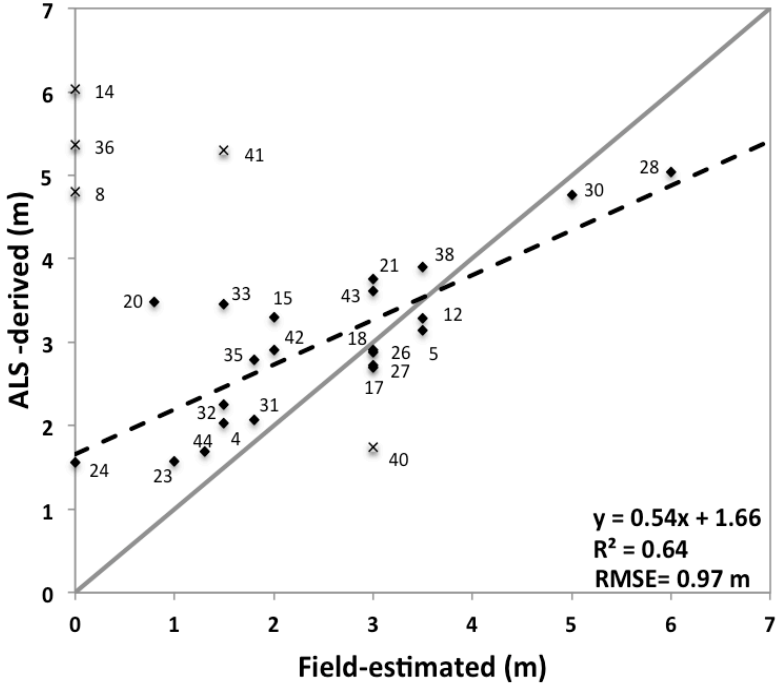
Results : layers mean height



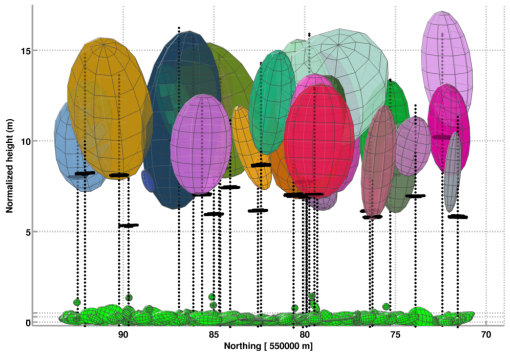
surface vegetation



understory vegetation



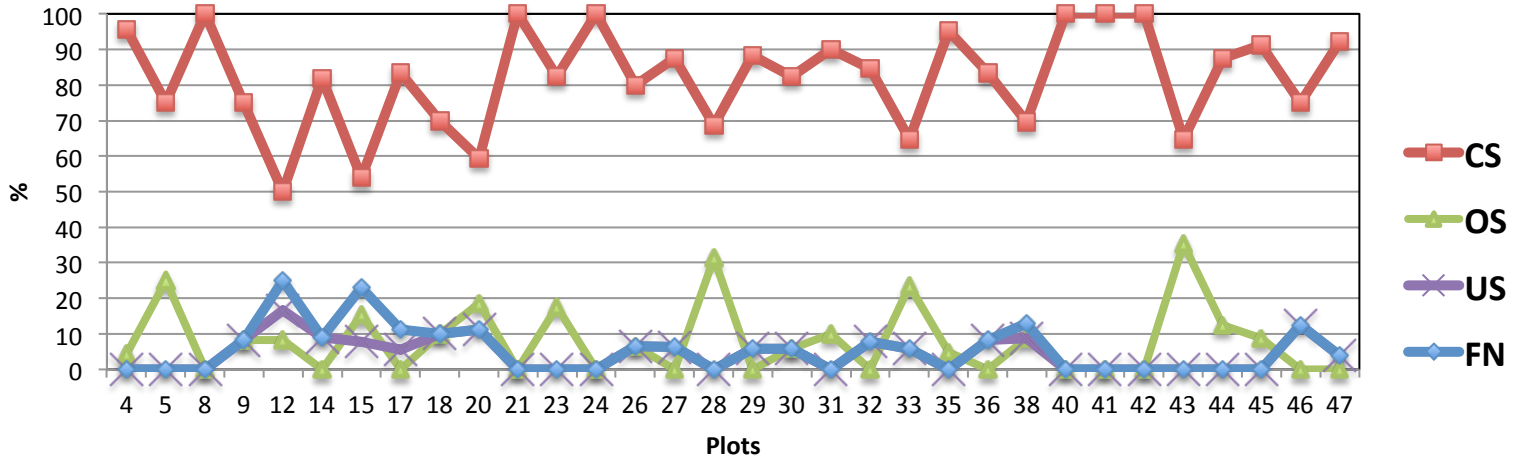
Results : individual trees identification



Segmentation results (%)

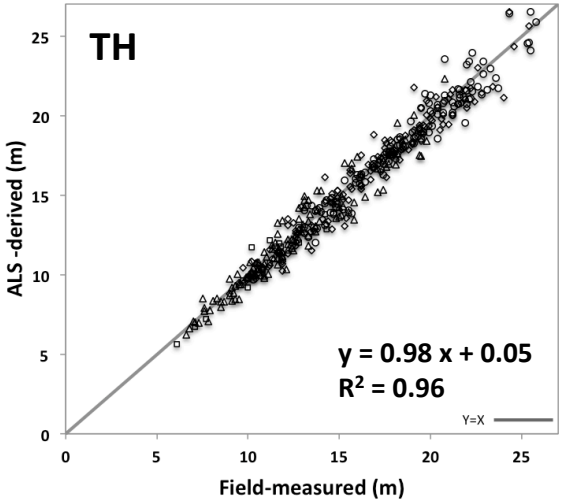
correctly segmented (CS)	**81**
oversegmented (OS)	**9.3**
undersegmented (US)	**5.0**
false negatives (FN)	**4.8**

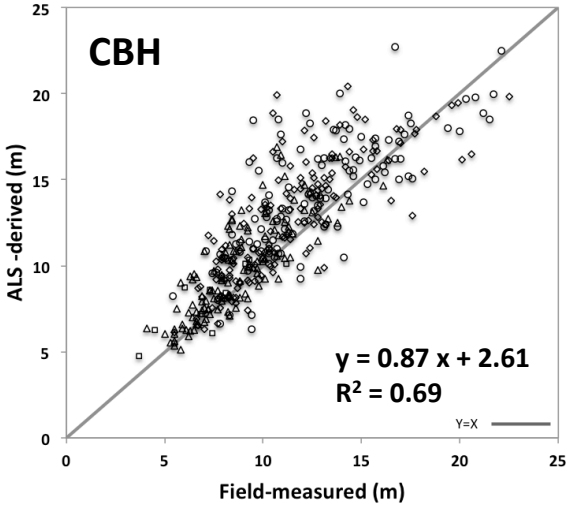
Segmentation accuracy by plot

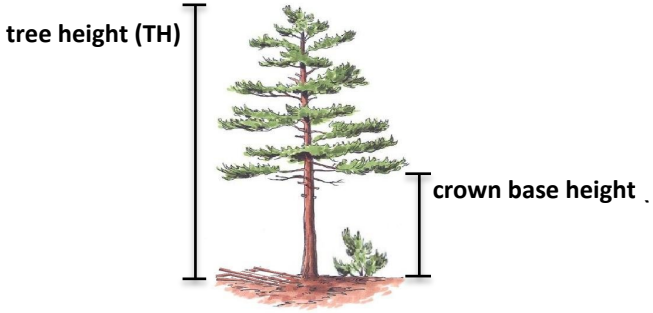


Results : tree height and crown base height

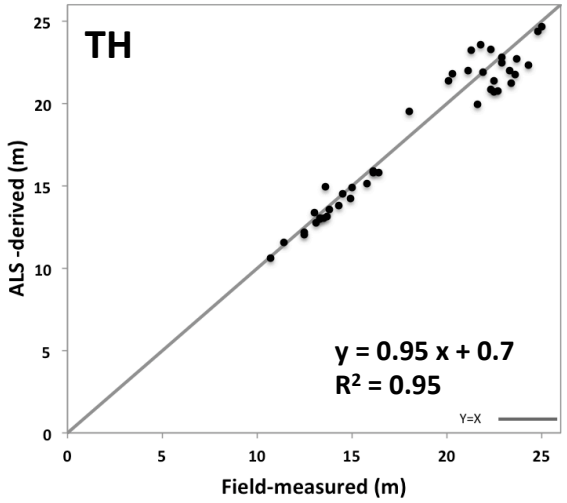
eucalyptus

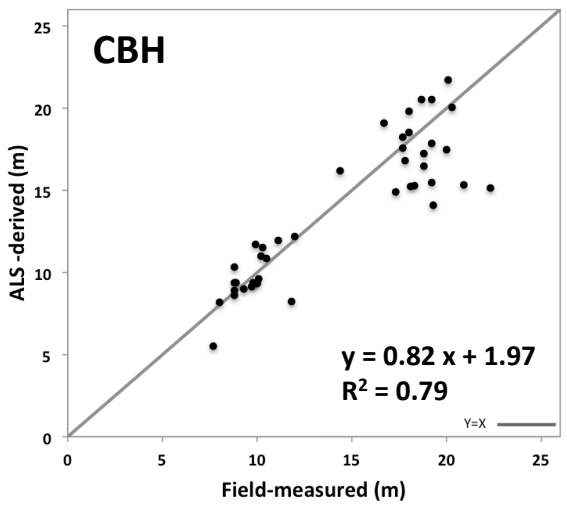






pine

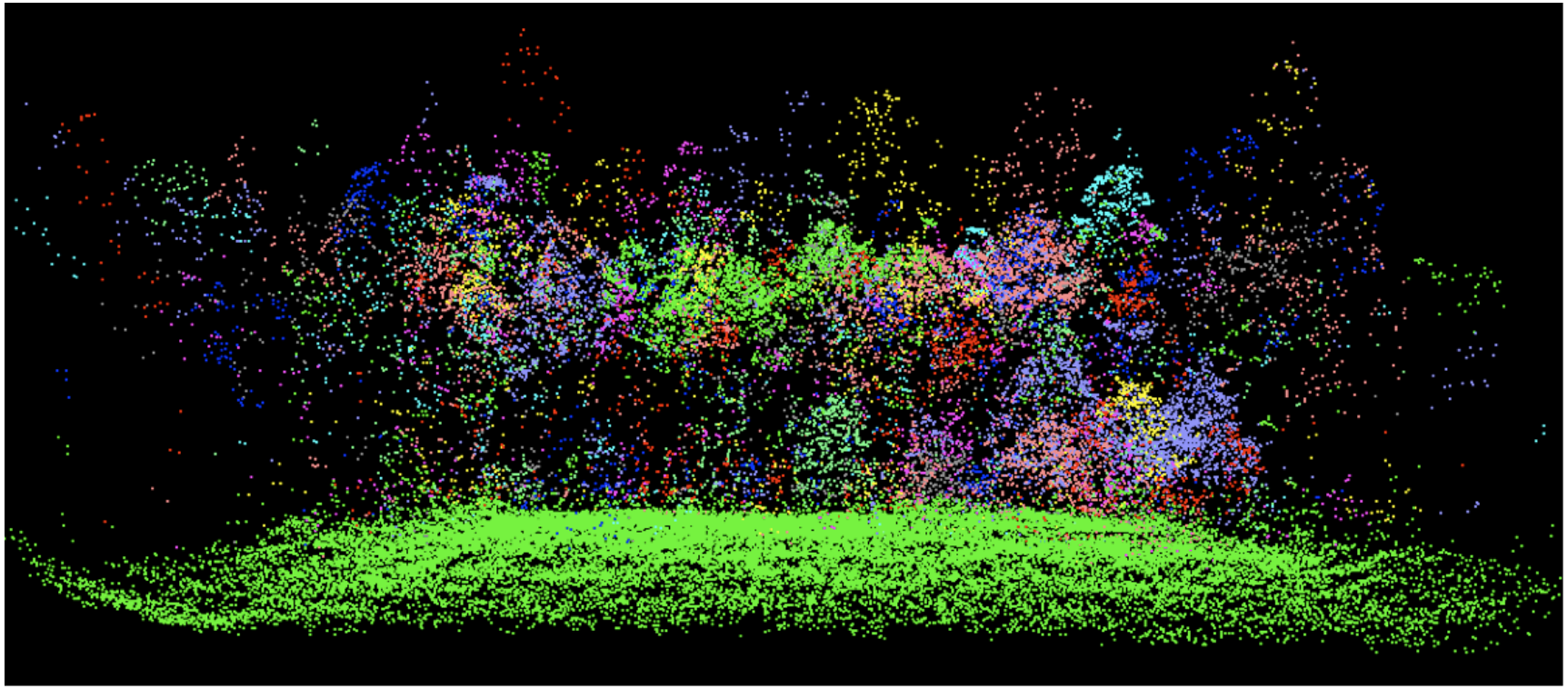




Conclusions

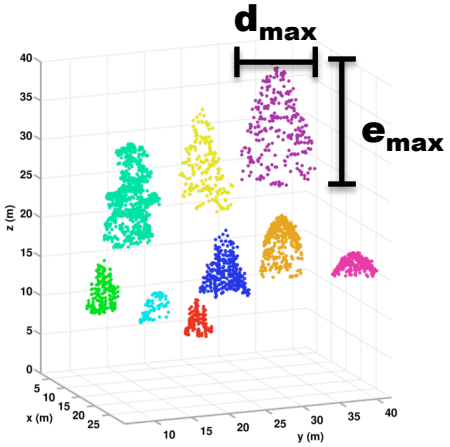
- The mean shift algorithm (MS) is a non-parametric and unsupervised approach able to find the modes of a forest multi-modal distribution.
- Results carried on over simulated data show that the MS is able to apply for tree crown with different architectures.
- Our approach is the first method that does not rely on a CHM
- It produces genuine 3D segments that correspond to plants crowns.
- However, it demands dense ALS points clouds
- The results depends on the forest characteristics

Thank you for your attention



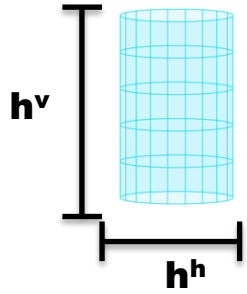
tree class	# trees	identified trees	False positives
dominants	146	144 (98.6%)	24 (16.4%)
codominants	176	150 (85.2%)	15 (8.5%)
dominants	210	129 (61.4%)	3 (1.4%)
suppressed	167	65 (39.0%)	1 (0.8%)
pines	52	46 (88.4%)	0 (0%)
Total	751	534 (71.1%)	60 (8.6%)

Method: adaptive mean shift based algorithm

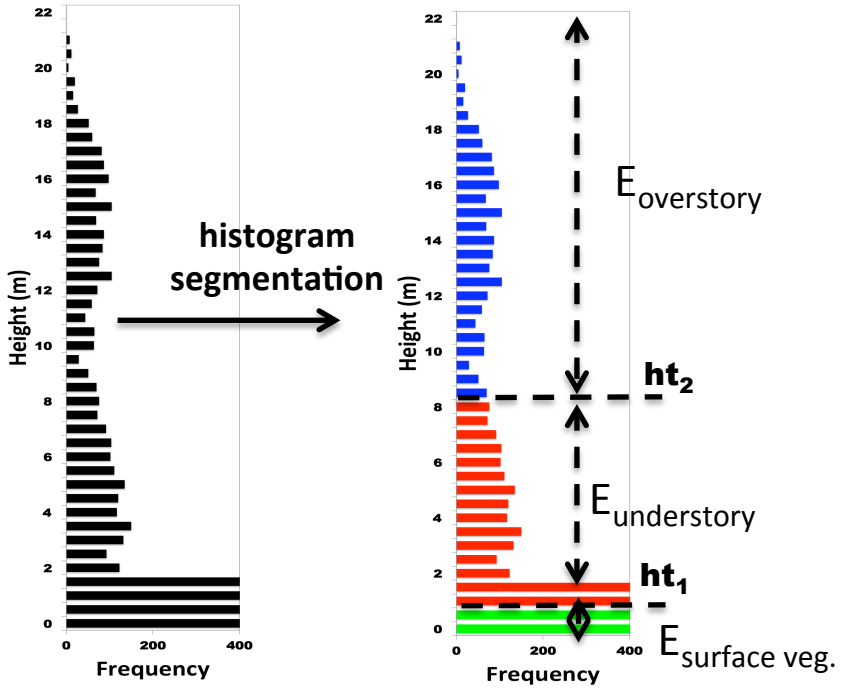


Equation 1:

$$\begin{cases} h^h = -0.05\, e_{max} + 0.65\, d_{max} \\ h^v = 0.23\, e_{max} + 0.42\, d_{max} \end{cases}$$



Optimal kernel bandwidth to segment a stratum is a function of the biggest tree within the forest layer.



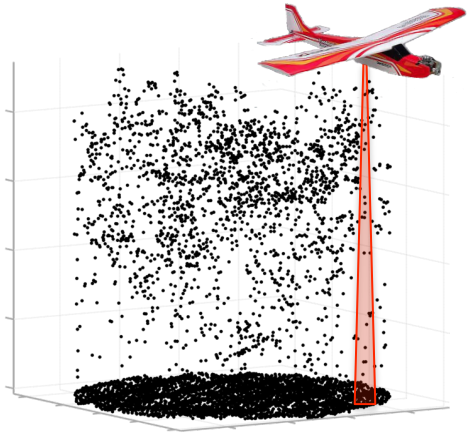
$e^3_{max} \approx E_{overstory}$ ∧ $d^3_{max} = 0.6\times(e^3_{max})$ → **Equation 1** →

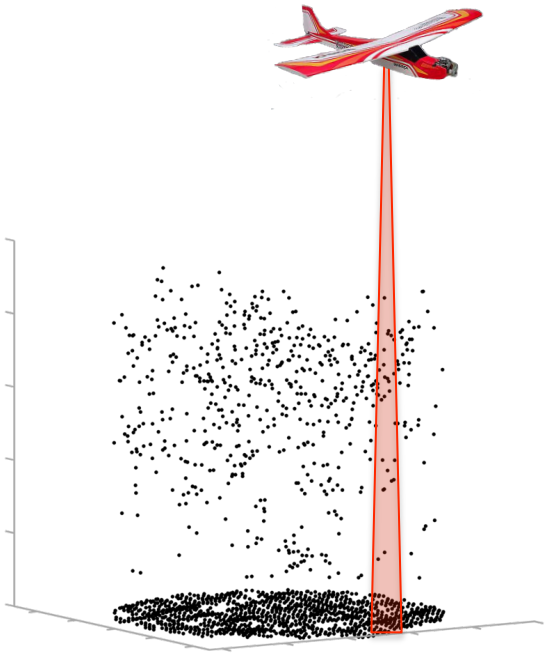
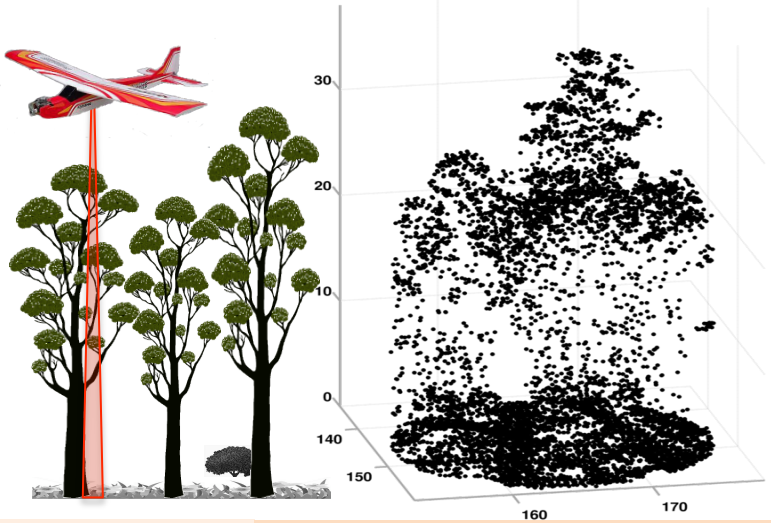
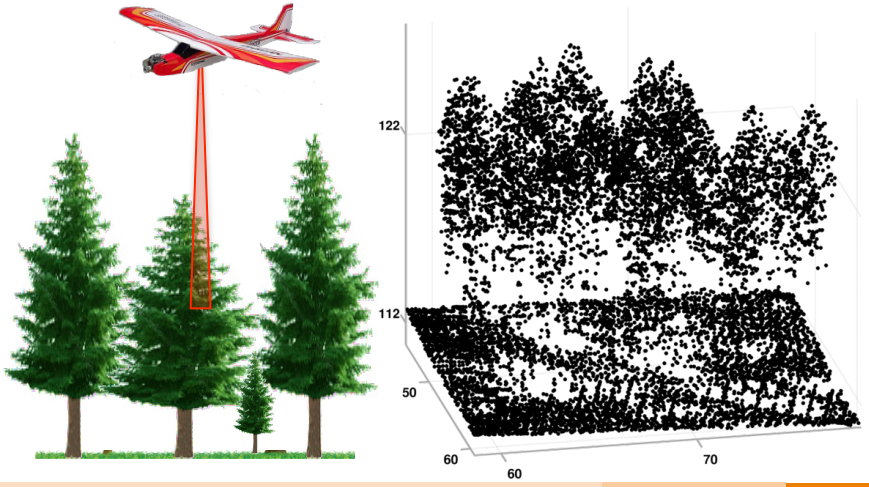
$e^2_{max} \approx E_{understory}$ ∧ $d^2_{max} = 0.6\times(e^2_{max})$ → **Equation 1** →

$e^1_{max} \approx E_{surface\ veg.}$ ∧ $d^1_{max} = (e^1_{max})$ → **Equation 1** →

the point cloud resolution depends on:

① Flight configuration





② Forest structure