Extremely high spatial resolution observations for deriving vegetation characteristics: recent advances

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Extremely high resolution imagery is now available from various vectors and sensors

**Vectors**

- **Plane/ULM**
  - altitude: 150m-3km
  - coverage: 5 – 200 km²/h

- **Drone**
  - altitude: 2m-150m
  - coverage: 0.5 – 500 ha/h

- **Robots**
  - altitude: 0.5m - 5 m
  - coverage: 0.1 - 1 ha/h

- **IoTs**
  - altitude: 0.5m-3m
  - coverage: 1m²-5m²

**Sensors**

- **RGB camera**
  - Resolution: 10 – 100 Mpix

- **Multi-spectral camera**
  - Resolution: 0.5 – 2 Mpix

- **Hyper spectral**
  - Resolution: 0.1 – 0.5 Mpix

- **Thermal camera**
  - Resolution: 0.1 - 1 Mpix

- **LiDAR (scanner)**
  - Resolution: 1 mm – 1 m
The toys we are playing with

Drone
- Throughput: 1000 plot/h
  Almost simultaneous acquisition of the platform
- Sensible to wind
- Passive measurements

Phénomobile
- 150 plot/h
  Several hours between first and last plot sampled
- Little sensitive to wind
- Active measurements
accessing new scales

• **Organ**
  – Leaf
    • Size / orientation
    • Sanitary state
    • Biochemical composition (Chlorophyll / Water contents)
  – Stem
    • Diameter
    • height
  – fruits

• **(Plant)**
  – When not too much overlap between plants:
    • Early stages
    • Low plant density

• **Canopy**
  – Plant/stem density (and sowing pattern)
  – height
  – Green fraction
  – Green area index
  – FIPAR
  – 3D structure
- The stem density and diameter can be measured with an accuracy better than 10%
- When spatial resolution better than 0.2 mm
- Biovolume (basal stem area x crop height) highly correlated to total biomass at harvest

From Jin et al., AFM, 2018
Plant / Canopy: Plant counting & characterization

- Sony α5100
- 60 mm lens
- 3-7 m altitude
- 0.2-0.5 mm resolution

Images quality equivalent to those taken from ground
Processing Method

Automatic classification
- White balance correction, SVM classification

Identifying rows
- Distribution of green pixels

Identifying objects
- Cleaning by erosion/dilatation

Objects metrics
- Length, width, orientation, size, tips...

Classifying objects

- 1 plant
- 2 plants
- 3 plants

Actual density
Sample results

- Good performance if density not too high
- Importance of image quality:
  - Resolution (<0.5mm)
  - Crisp (RAW),
  - Orientation with sun (better facing sun)
- Difficulty to maintain low altitude precisely (sonar)
- Difficulty to geolocate the images (RTK/PPK)

From Liu et al. FPS, 2017
From Jin et al. RSE, 2017
Canopy: plant height (1/2)

**LiDAR/Phenomobile**
- Resolution: 3-5 mm
- Throughput: 150 µplot/h
- Active measurements

**RGB Camera/UAV**
- Resolution: 10 mm
- Throughput: 4000 µplot/h
- Passive measurements

3D point cloud

**Structure From Motion**
plant height: results

Canopy height is a very relevant trait:
- Highly heritable
- Dates the start of the stress
- Synchronism between stop of growth (height increase) and flowering

From Madec et al. PM 2018
Canopy: Leaf Chlorophyll Content

Improved retrieval performances when separating the background from the leaf problems

From Jay et al., RSE 2017
Green fraction and second order functions

Green fraction (first order)

Second order functions

High spatial resolution imagery allows to account for leaf clumping through second order functions

From Baret et al., AFM 2010

From Lopez-Lozano et al., AFM 2014
Combining observations with 3D models

ADEL-Wheat model (20-30 parameters)
GAI estimates from LiDAR combined with ADEL-Wheat

**Adel-Wheat**

**Input parameters**

**3D Structure**

**LiDAR simulator**

**3D Point-cloud**

**Features**

**Neural network**

**Estimated GAI value**

**GAI**

**Problem due to:**
- saturation
- Structure not realistic

**From Liu et al. AFM, 2017**

**Improved performances with the 3rd dimension from LiDAR!**

**Limited saturation effect as compared to that of the Green Fraction**
CONCLUSION

- Much more pertinent information can be derived from extremely high resolution imagery
  - Accessing new scales (organ, plant)
    - Characteristics of specific organ/plant
    - Average characteristics (most often)
  - Better description of the canopy
    - 3D structure (Structure from Motion)
    - Element grouping (clumping)

- Different approaches as compared to the degraded resolution data
  - From Radiative transfer model inversion to machine (deep) learning approaches

- Using 3D models should improve accuracy of retrievals
  - Limits of the realism of the 3D models
  - Develop hybrid learning mixing model and observations

- Spatial extension methods to be developed to cover larger areas
  - Combination with satellite observations
Thanks for your attention

Questions??