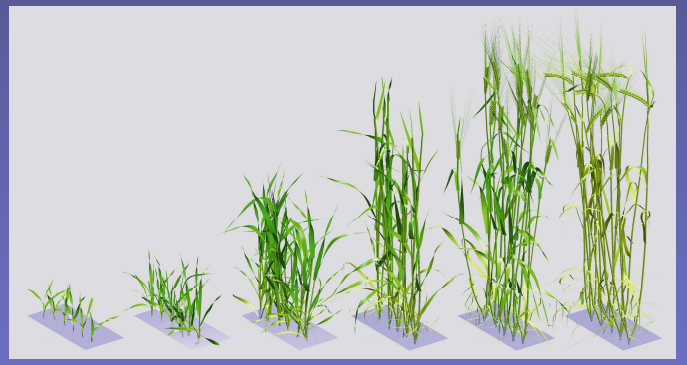
Digitization techniques to measure the architecture of crop plants

Tino Dornbusch



Presently post doc at
UMR INRA-AgroParisTech
Environnement et Grandes Cultures

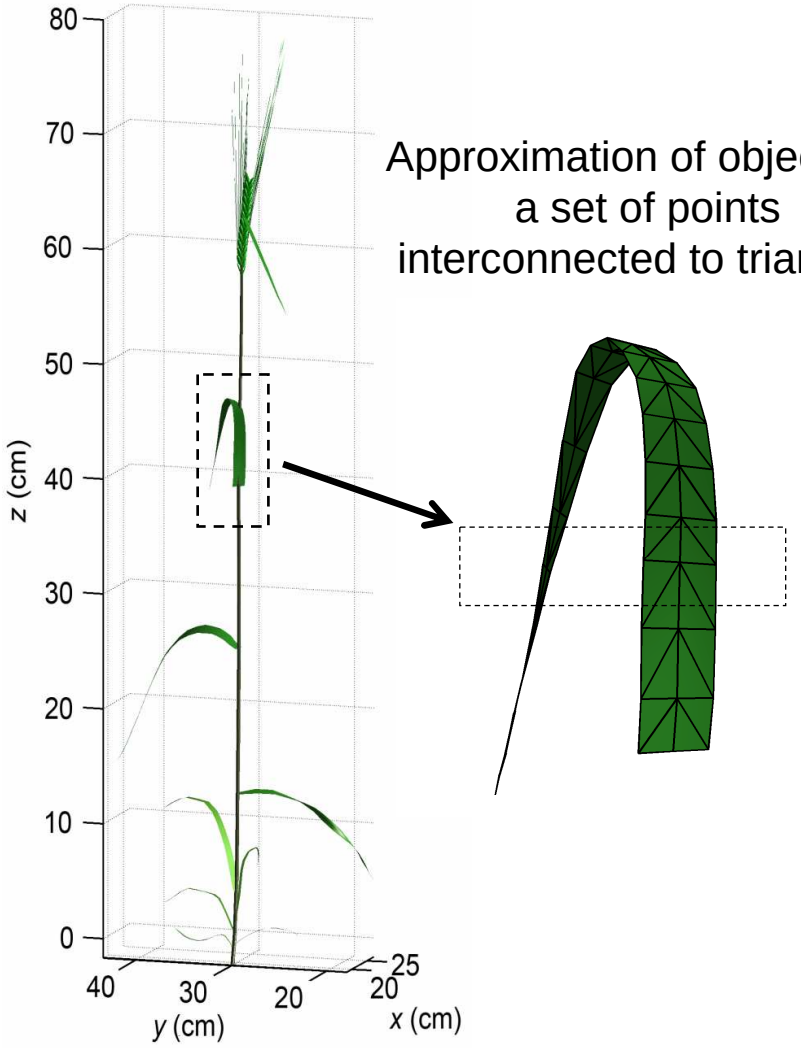
Introduction

- Computers, virtual worlds and reality has become part of our modern society
- Demand to ‚transfer real world objects‘ into the computer

Virtual worlds – „Second Life“
(source: www.welt.de)

Definition: Digitizing is measuring the object surface and representing it by a discrete set of surface points

3D Models



Approximation of objects by
a set of points
interconnected to triangles

3D Model of Barley (Tino Dornbusch)

Fields of application

- Industry (Reverse Engineering, Quality control of tires)
- Medicine (Production of dental implants)
- Geography (Surface topology, City planning)
- Archeology (Measurement and reconstruction of sites and artifacts)

- Our Interest: Description of 3D Morphology of plants

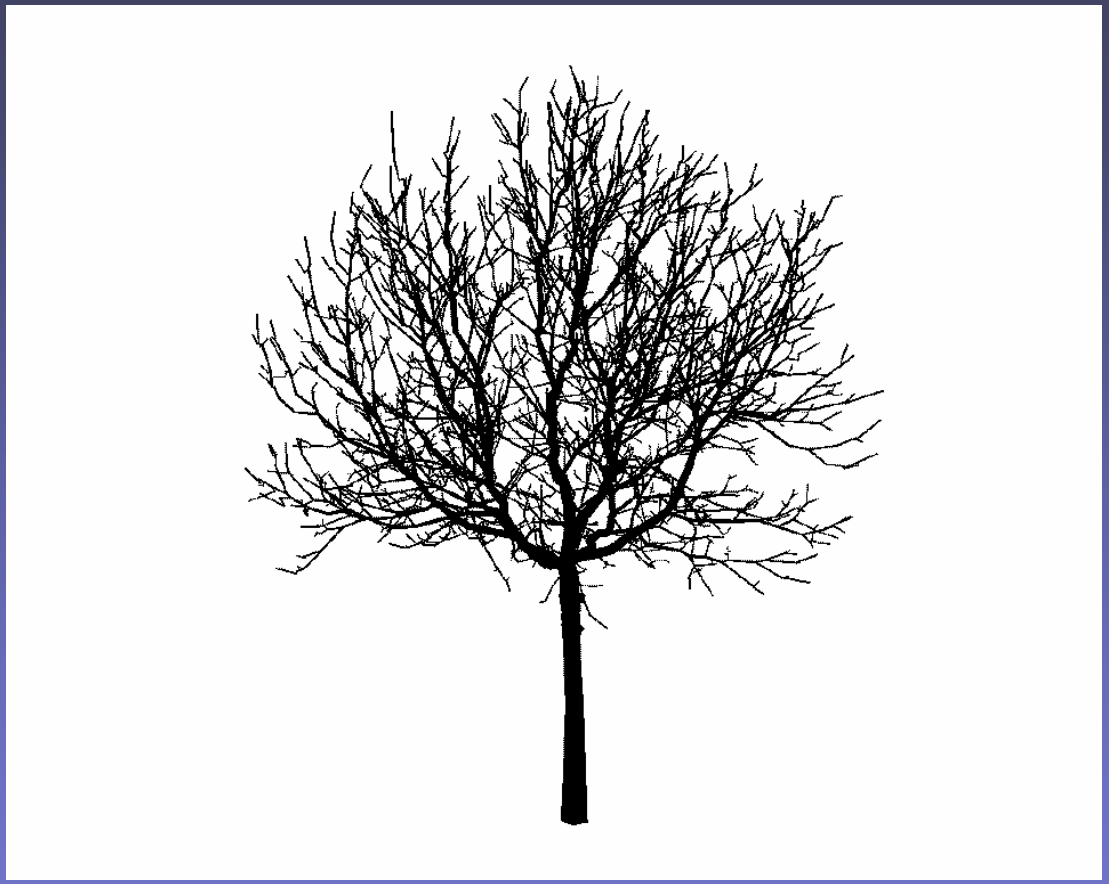
Approach

- Current knowledges are unsufficient to build deterministic models of organ shape (eg midrib curvature)
- Measurements can be used to calculate parameters of empirical models of organ shape
- Estimated parameters are used to simulate the measured plants and/or to derive statistical distribution of values from which a large number of “plausible” organ shapes are generated
- This uses softwares such as presented in the talk by Christian Fournier

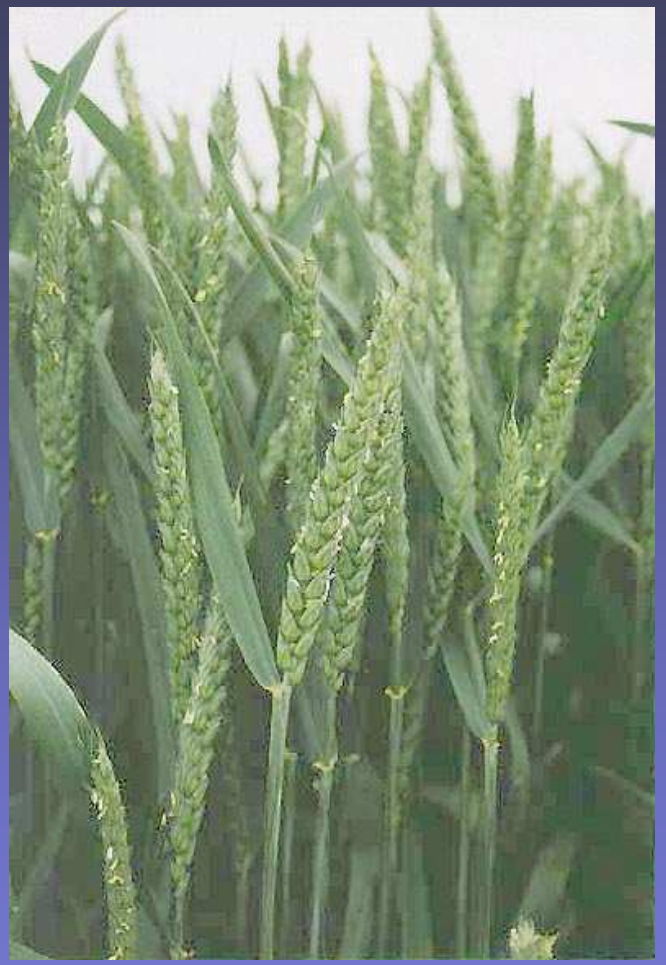
Challenges

Some plants are easy to digitize but,

Challenges



Most plants are more complex.



And usually grow in dense populations

Challenges

- Complex plant architecture
- Numerous and generally small objects (leaves, petioles, branches)
- Frequently overlapping
- No stable architecture – e.g. fluttering leaves (changes due to growth and external forces)

What is the digitizing strategy to tackle this difficulties?

Classification

Active digitization techniques

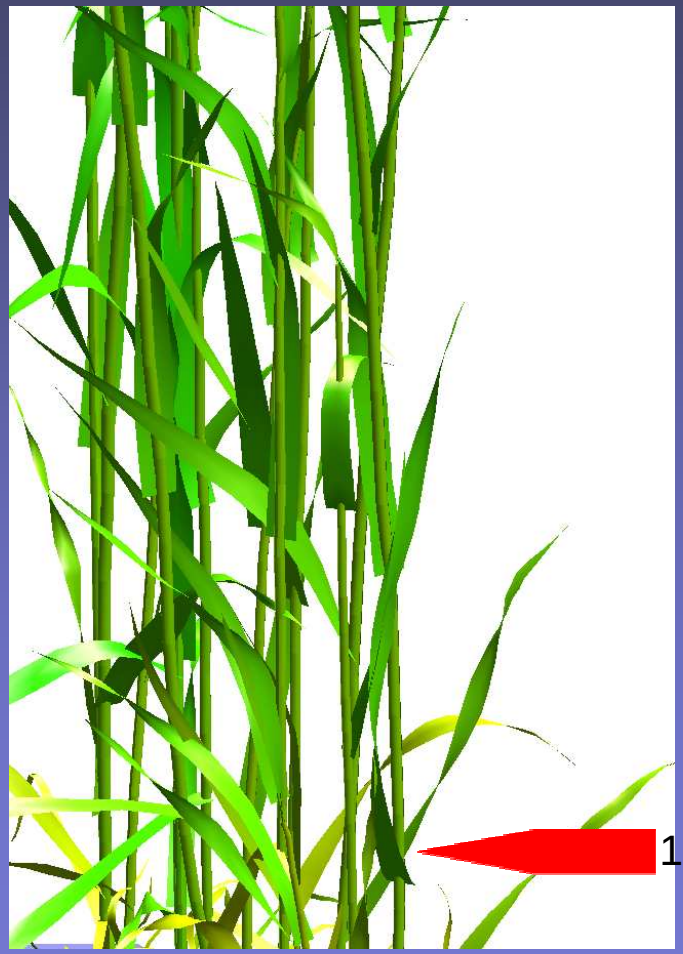
- direct measurement of object position and dimension

Passive digitization techniques

- Holistic measurement of object surface

Active digitization techniques

- Principle:



- Operator is directly pointing on a specific object point
- Conversion of pointer position into x,y,z coordinates

  x_1,y_1,z_1

Active digitization techniques

- Principle:

- Operator is directly pointing on a specific object point
- Conversion of pointer position into x,y,z coordinates

x_1,y_1,z_1
x_2,y_2,z_2

Active digitization techniques

- Principle:

- Operator is directly pointing on a specific object point
- Conversion of pointer position into x,y,z coordinates

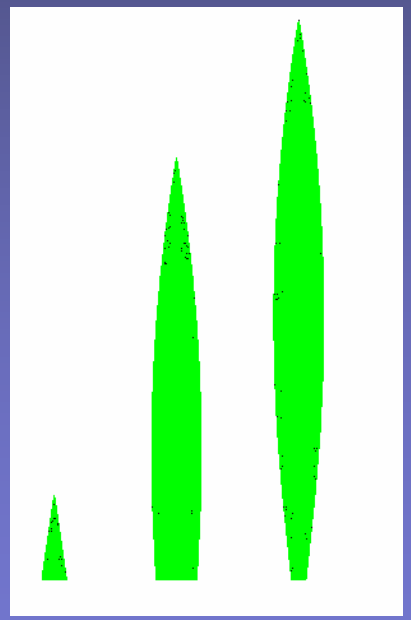
x_1,y_1,z_1
x_2,y_2,z_2
x_3,y_3,z_3

Active digitization techniques

- Principle:

- Operator is directly pointing on a specific object point
- Conversion of pointer position into x,y,z coordinates

x_1,y_1,z_1
x_2,y_2,z_2
x_3,y_3,z_3
⋮
x_n,y_n,z_n



Only midrib curvature is digitized
2D leaf shape is given by a model

Active digitization techniques

- Conversion of real coordinates into Cartesian coordinates by:

1. Articulated arms
   (Microscribe 3D, Ghost 3D,LLC., USA)

2. Ultrasound impulses
   (no more devices in sale)

3. Magnetic fields
   (FASTRAK, Polhemus,
   Colchester, USA)

www.microscribe.com

Active digitization techniques

- Conversion of real coordinates into Carthesian coordinates by:

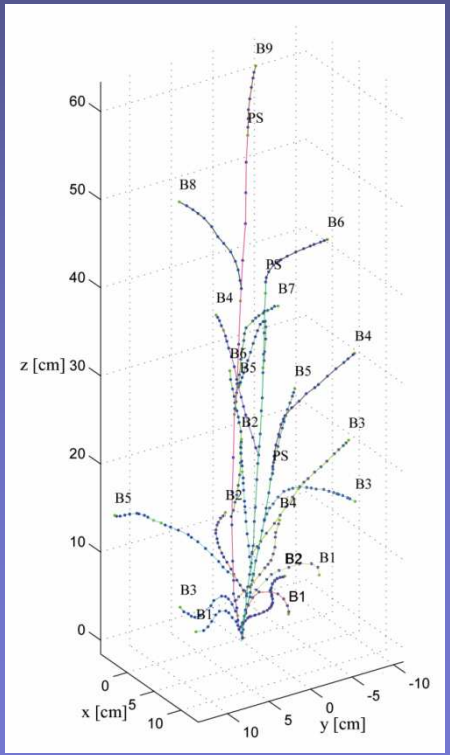
4. Image Processing (Silhouette Method)

Active digitization techniques

- Conversion of real coordinates into Carthesian coordinates by:

4. Image Processing (Silhouette Method)

Transformation of pixel coordinates into Cartesian coordinates



Active digitization techniques

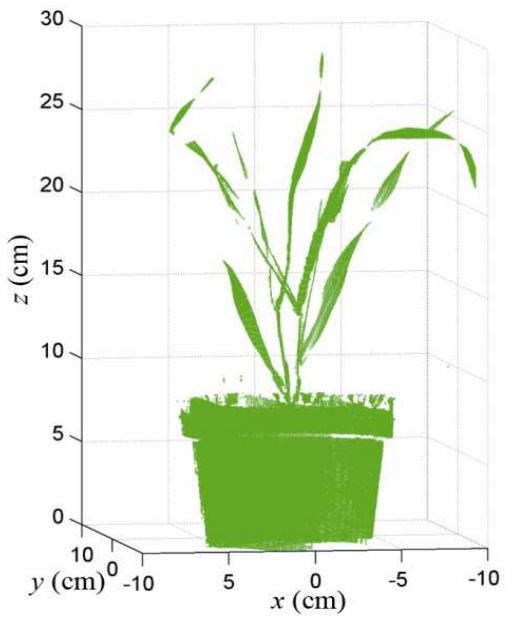
- Advantages:
  - Robust technique usually applicable under field conditions
  - Identification of organs (Topology, e.g. leaf number)
  - Reasonably cheap (especially Silhouette Method)
- Disadvantages
  - Time consuming measurements (therefore this method is usually applied to measure organ orientation - midrib)
  - Applicability may be limited due to wind, obstruction or metal elements
  - Lower Precision due to active interaction with plants
  - Sometimes destructive sampling (Silhouette)

Passive digitization techniques

- Holistic measurement of object surface

Description of the object surface by a discrete set of points

Real Object



3D point cloud

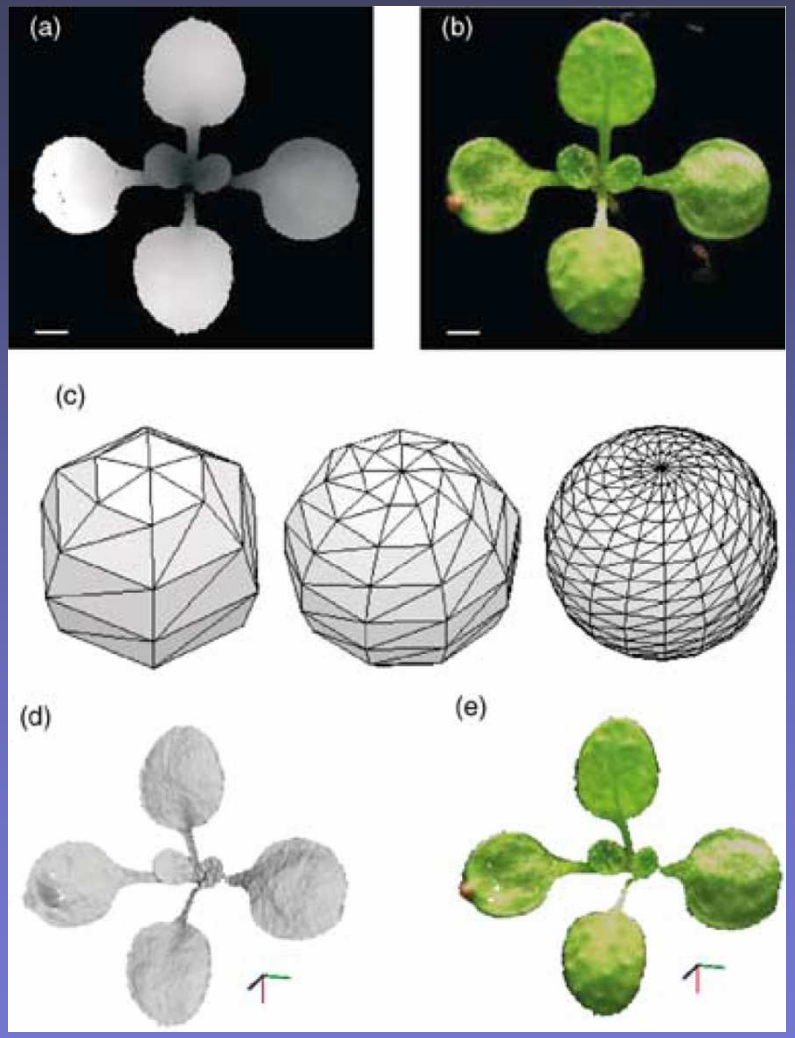
Dornbusch et al. 2007 Ecol Mod 200:119:129

Passive digitization techniques

Techniques with applications on plants reported

- Laser scanning
- Photogrammetry (Stereo images)
- Structured light (Projected fringe profilometry)
- 3D Micro Computed tomography

Laser Scanning - Example



Laser Scanning of Arabidopsis
(Kaminuma et al. 2004 Plant J 38:358:365)

Direct digitization techniques

- Advantages:
  - very detailed description of object orientation and form
  - non-destructive
  - fast scanning process
- Disadvantages
  - Only parts visible for the scanner can be measured
  - small, concave and flexible leaves of cereal plants difficult to measure
  - sometimes scans from multiple view angles required
  - measurements usually restricted to laboratory – field application for laser scanner possible

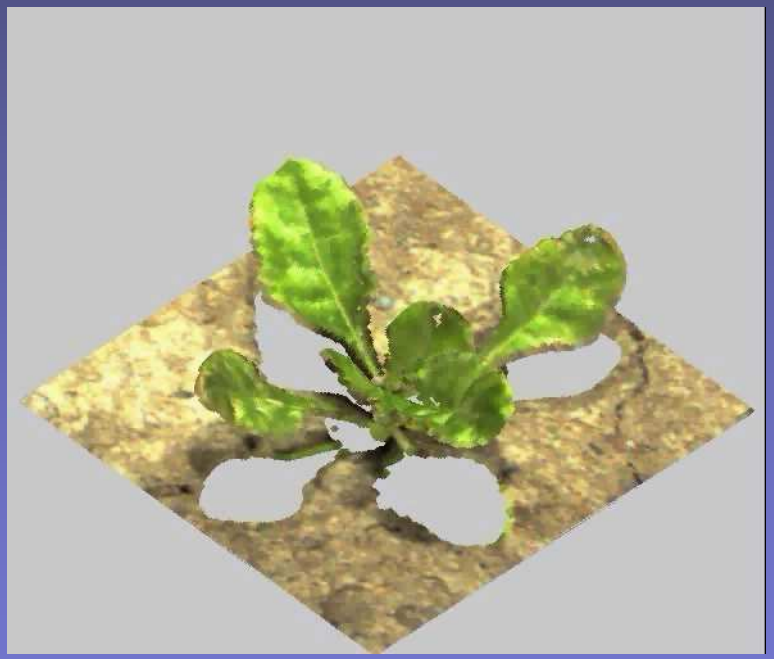
Conclusion

- Complex and filigree architecture is difficult to measure
- Active digitization techniques available, but usually time-consuming and less precise
- From a technical point of view: Application of passive digitizing techniques to digitize plants is no problem
- Efficient methodology (real → virtual plant) yet to develop

Future work

- Project University Halle and Fraunhofer Institut Erlangen to establish a laser scanner for cereals applicable under field conditions

Laser scanner under field conditions
(Source: Fraunhofer Institut, Erlangen)



Scanned and processed sugar beet plant
(Source: Fraunhofer Institut, Erlangen)
http://www.iis.fraunhofer.de/EN/index.jsp