Predicting internal defects from 3D data: an approach is emerging…

… some results gained in ANR WoodSeer (2019-2024)

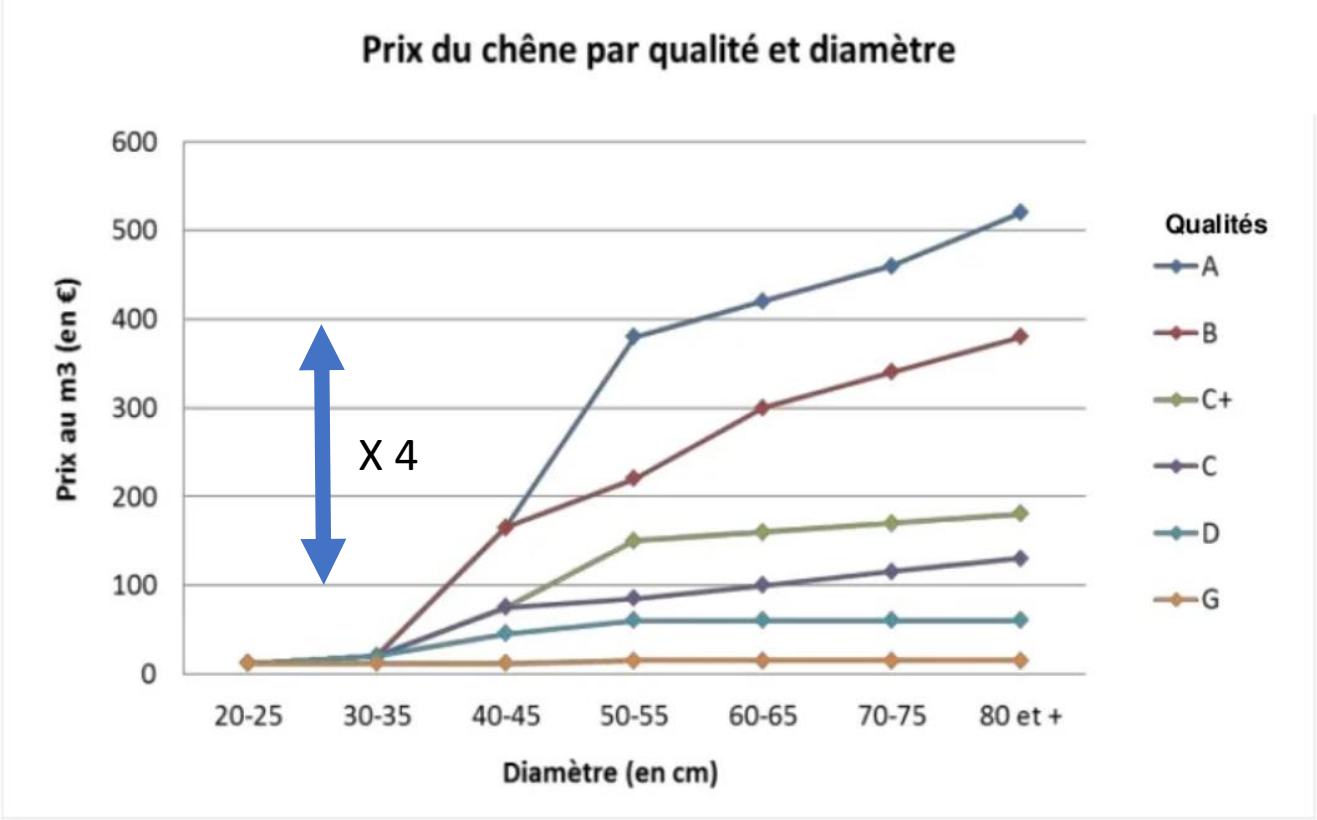
Thiéry Constant - UMR Silva – Project coordinator

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

INRAE

Why be interested in the quality of trees?

- In forestry: a constant financial stake in the hands of experts who combine volume shape and the presence of singularities to grade



D'après revue Forêts-de-France n° 585

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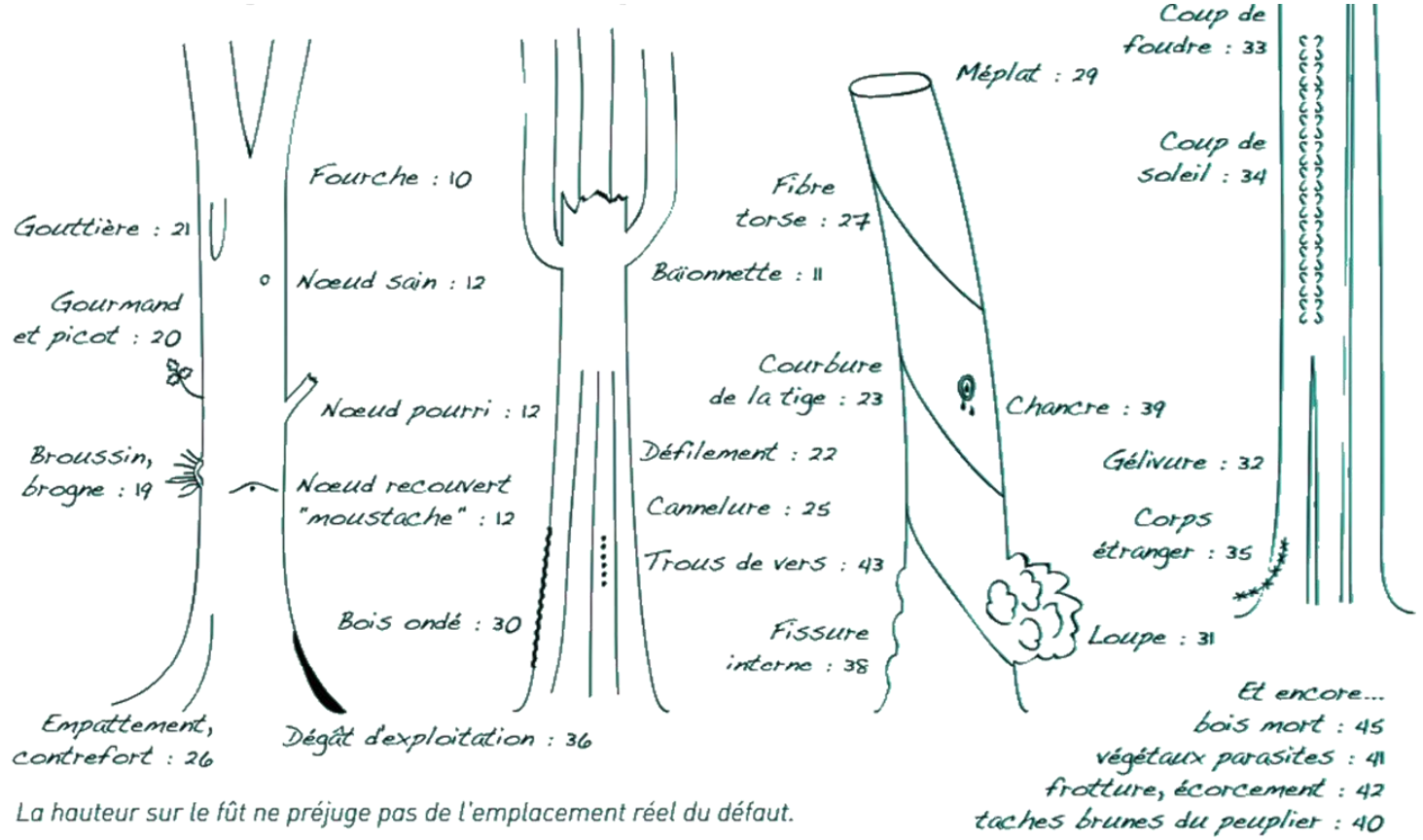
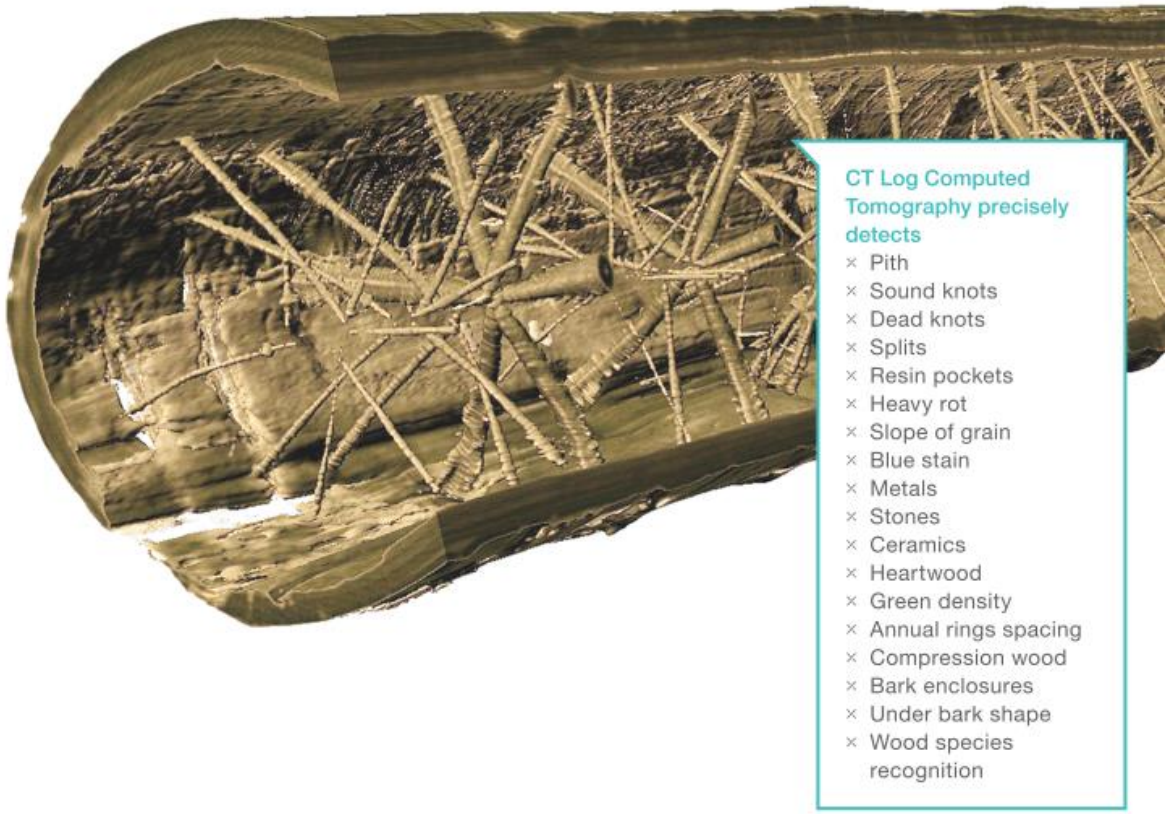


La hauteur sur le fût ne préjuge pas de l'emplacement réel du défaut.

Illustration of singularities taken into account for grading : Brunin, E., Heyninck, C., & Arnal, D. (2012). *Carnet d'assistance pour l'évaluation qualitative des bois sur pied et abattus : Conséquence, tolérance, mesure, normes*. Forêt Wallonne asbl.

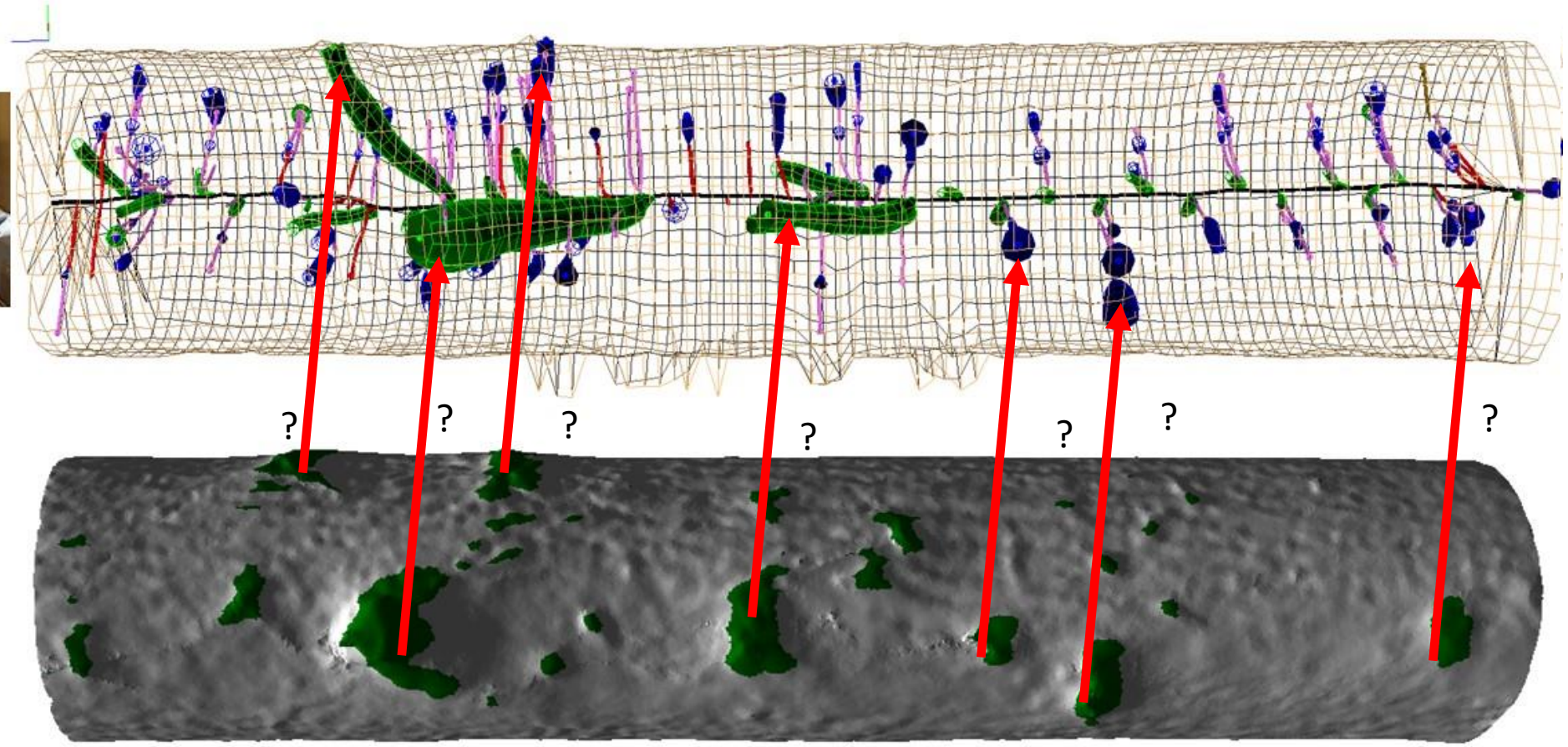
Why be interested in the quality of trees?

In the industry : a financial gain on products of approximately 15% by optimizing the transformation on quality with the use of industrial X-ray scanners (2 in France) but very heavy investments.



ANR WoodSeer :Establishing the link between the external characteristics of a singularity and its internal impact via AI

Geometrical model of branchiness obtained from X-ray CT Scanner



External description and segmented singularities from terrestrial Lidar

The WoodSeer's Team

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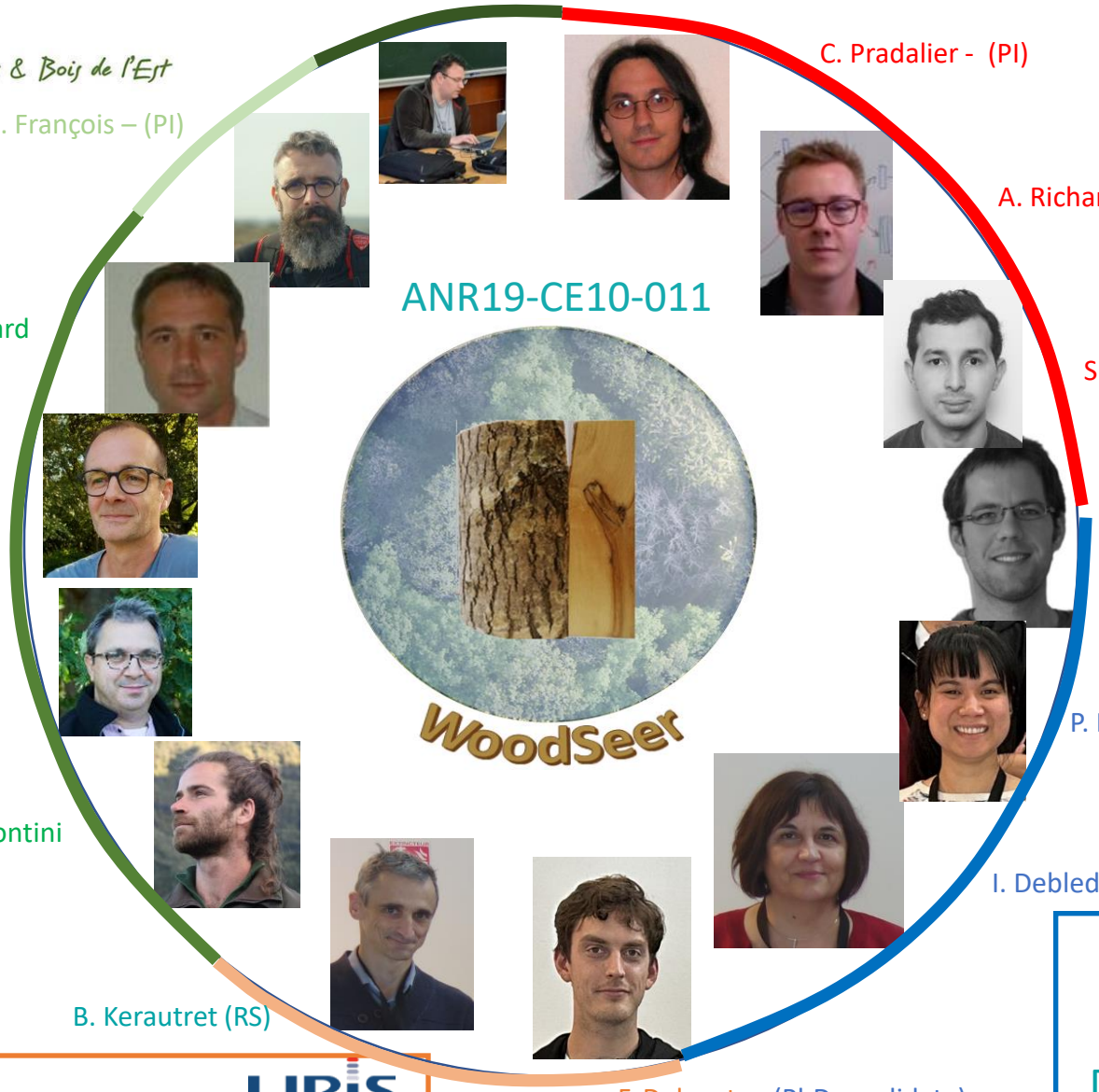
A. Benard

S. Khazem – (PhD Candidate)



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Database

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LIRIS

Discrete Geometry & AI

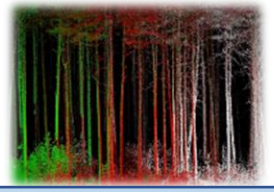
Loria
Laboratoire lorrain de recherche en informatique et ses applications

Discrete Geometry
& AI

ANR WoodSeer : different contexts and acquisition devices along the forest-wood chain

Foresters

Industrials



Terrestrial Lidar (Reference)

Sale of standing trees / Inventory?

Sale of felled trees (roadside)

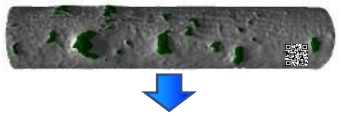
Portable scanner?

Log yard

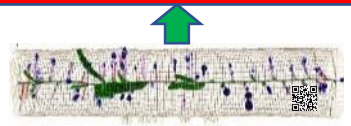
X-Ray CT Scanner

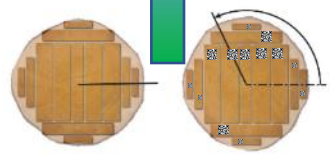
? Detection of external singularities & recognition of their types

3D True Shape scanner



? Links between external singularities and internal defects



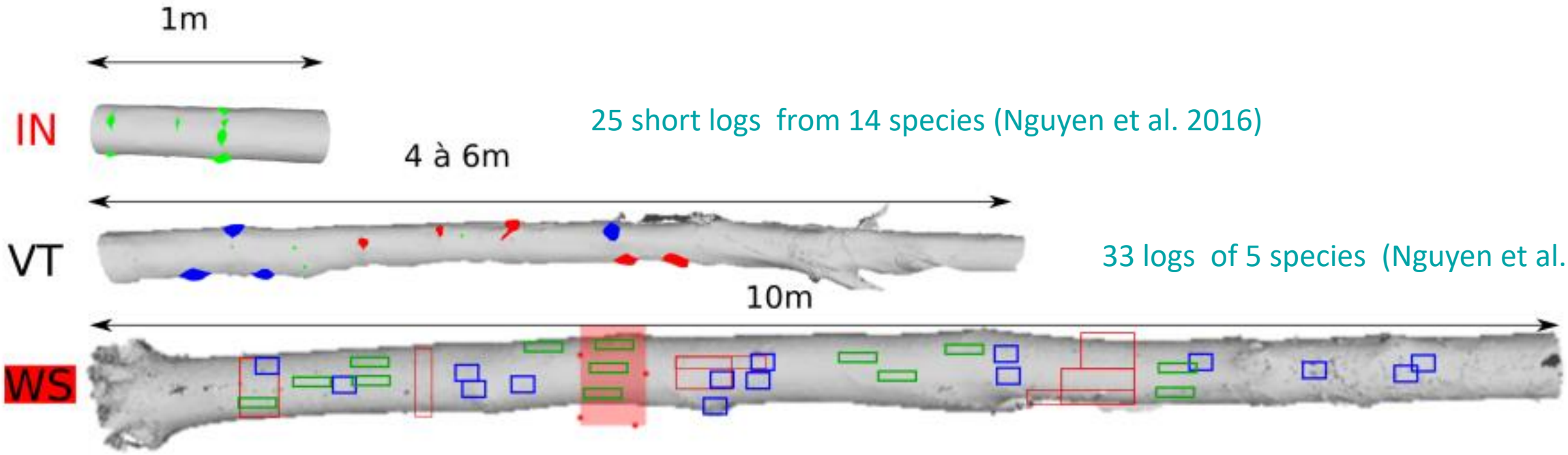


Optimisation of the transformation based on internal quality

Goal: better profitability -> more high value products

1st Challenge : detect singularities on the surface of the bark

- Avalaible data: scans 3D TLS et vérité terrain sur la localisation (voire le type des singularités)



25 short logs from 14 species (Nguyen et al. 2016)

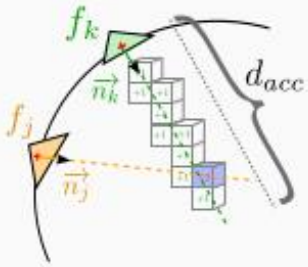
33 logs of 5 species (Nguyen et al. 2020)

40 trunks of six species (WoodSeer)

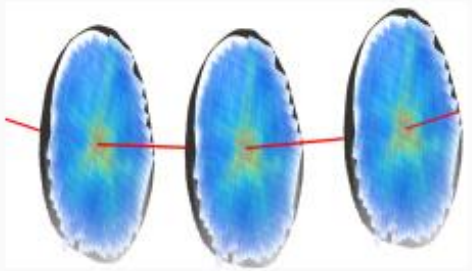
1st Challenge : detect singularities on the surface of the bark

- State-of-art Reference : PhD Van-Tho Nguyen,(2018)
- Geometrical method based on the analysis of the local roughness and automated relief thresholding

- 1st step



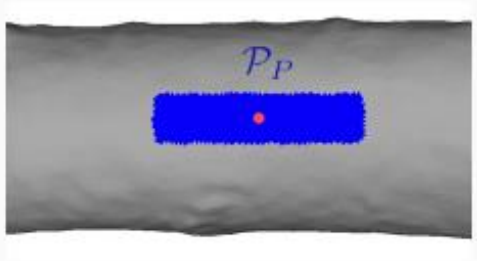
Accumulation



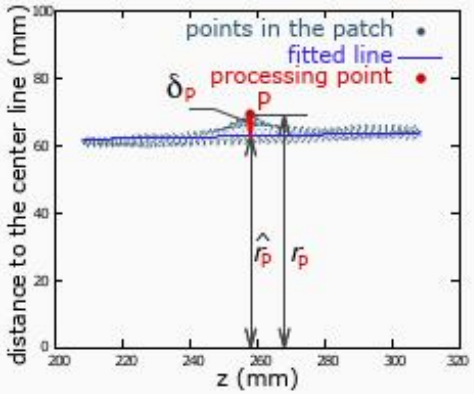
Tracking step

Centerline (red)

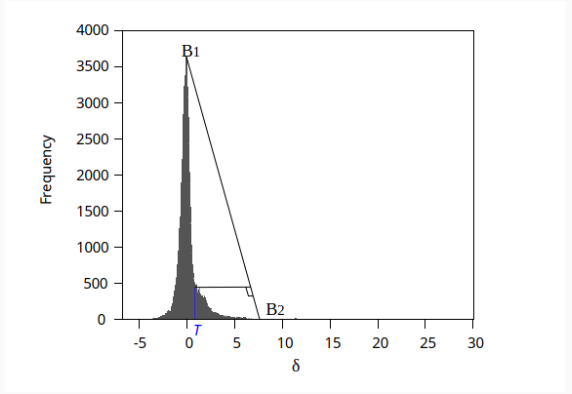
- 2d step



Patch

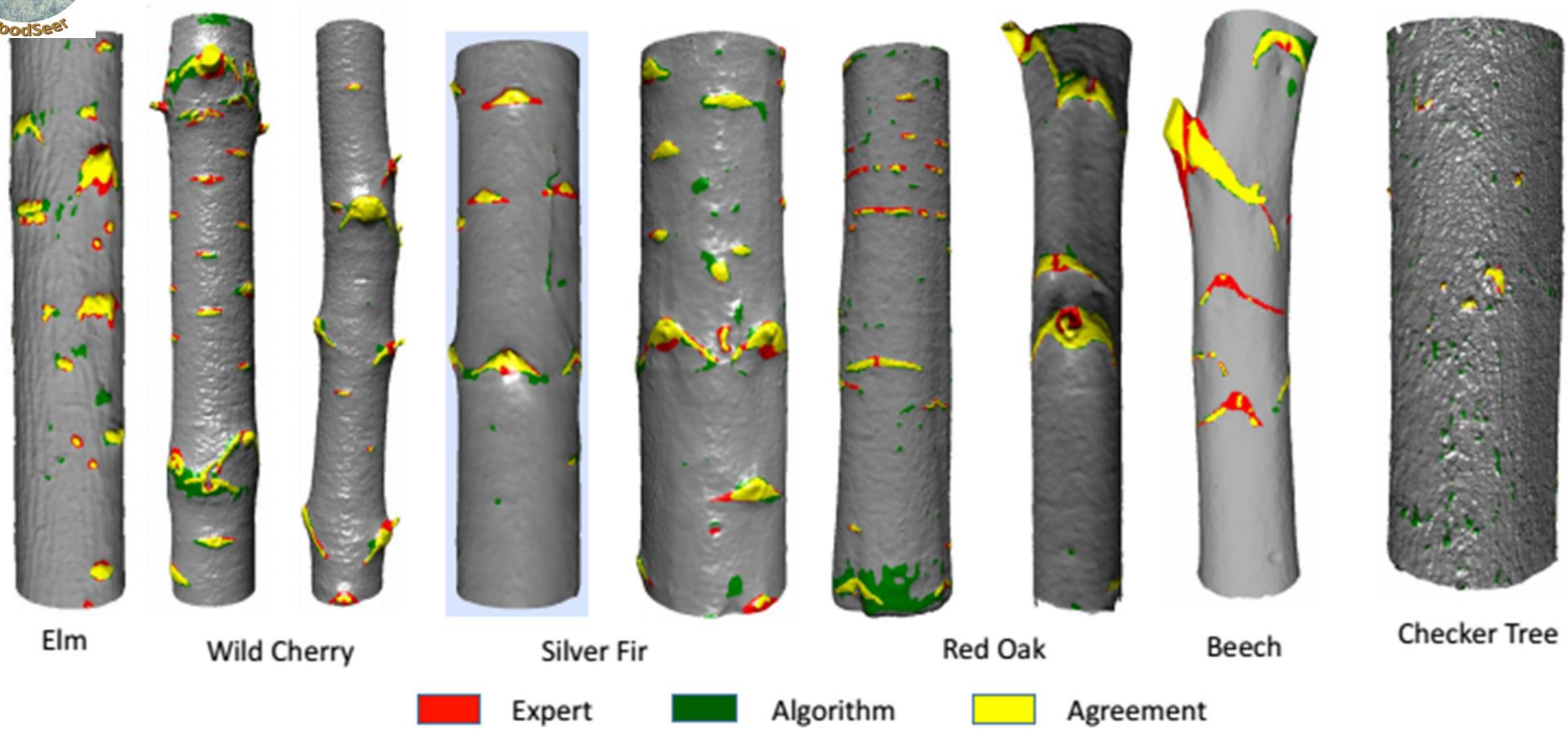


Delta distance

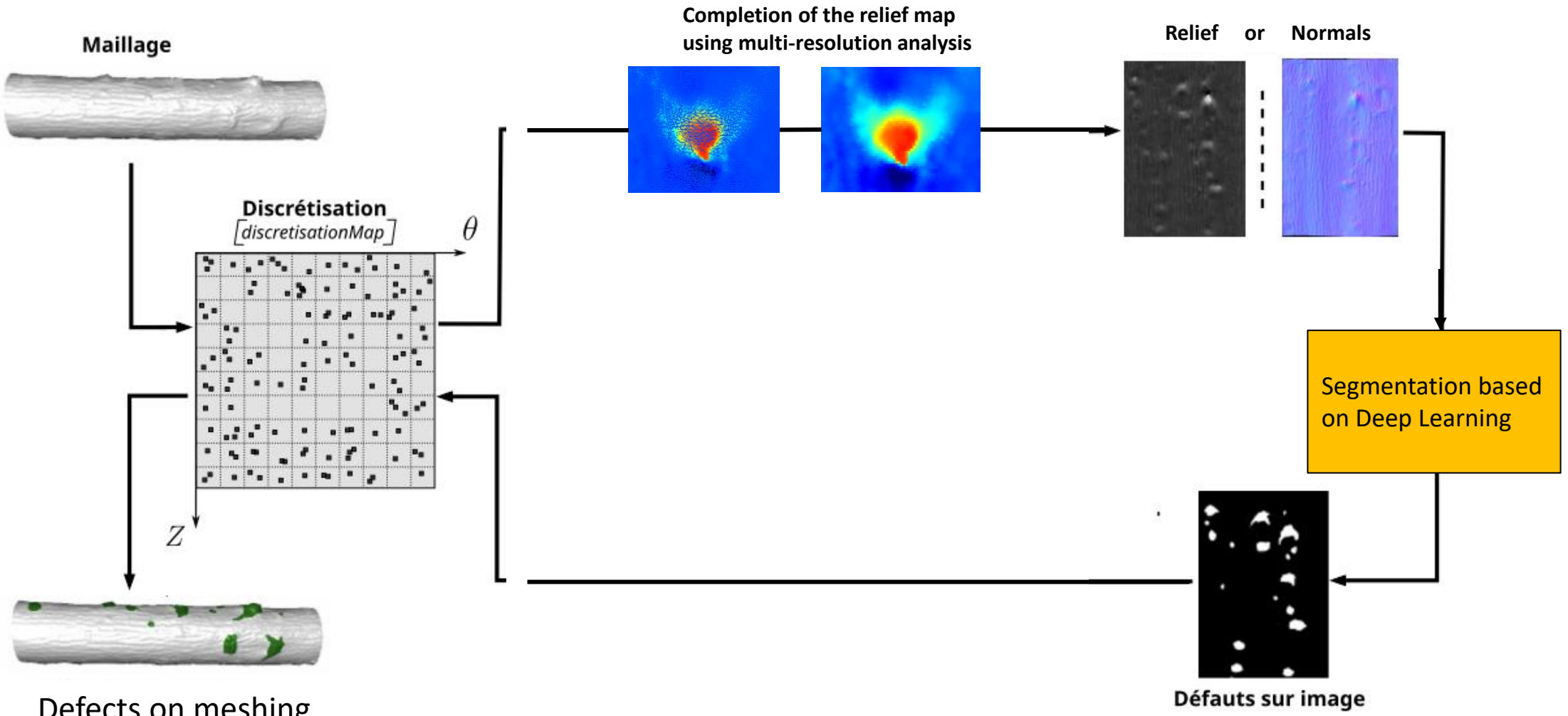


Delta distance thresholding

Detection of singularities par Nguyen et al. 2017

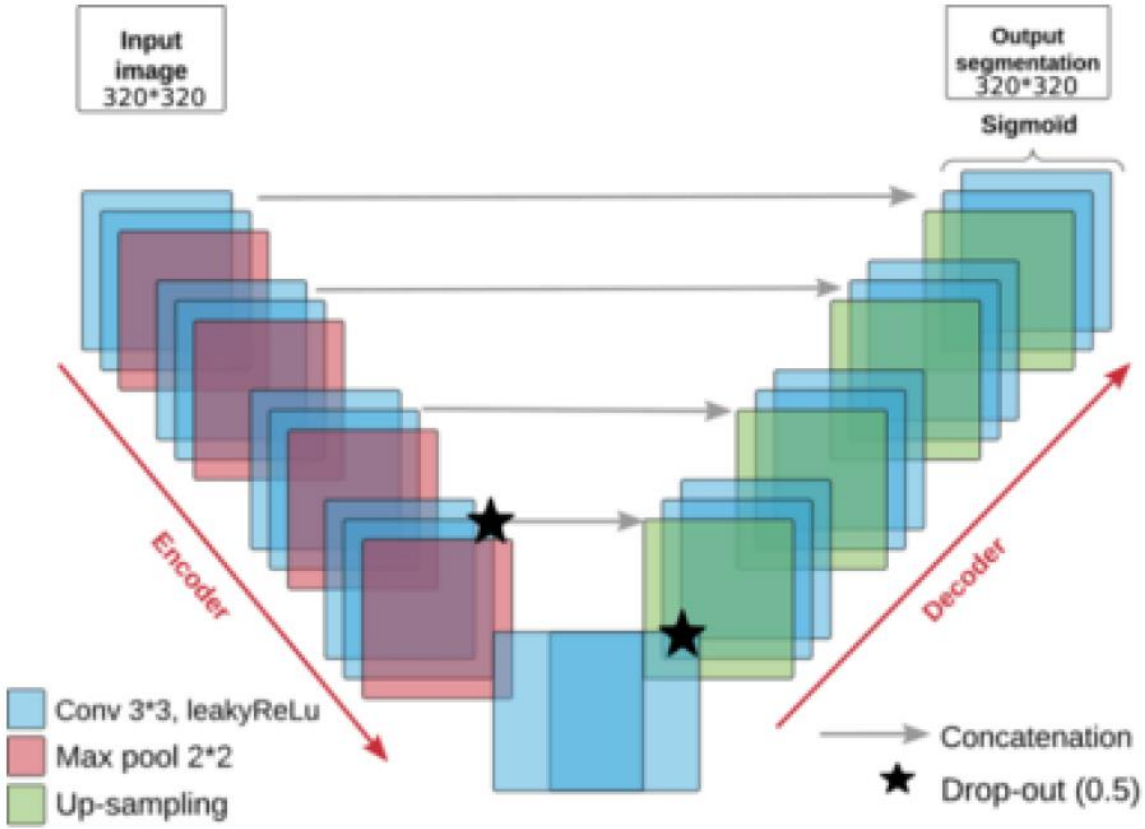


New method proposed by F. Delconte (PhD Candidate) based on Deep Learning

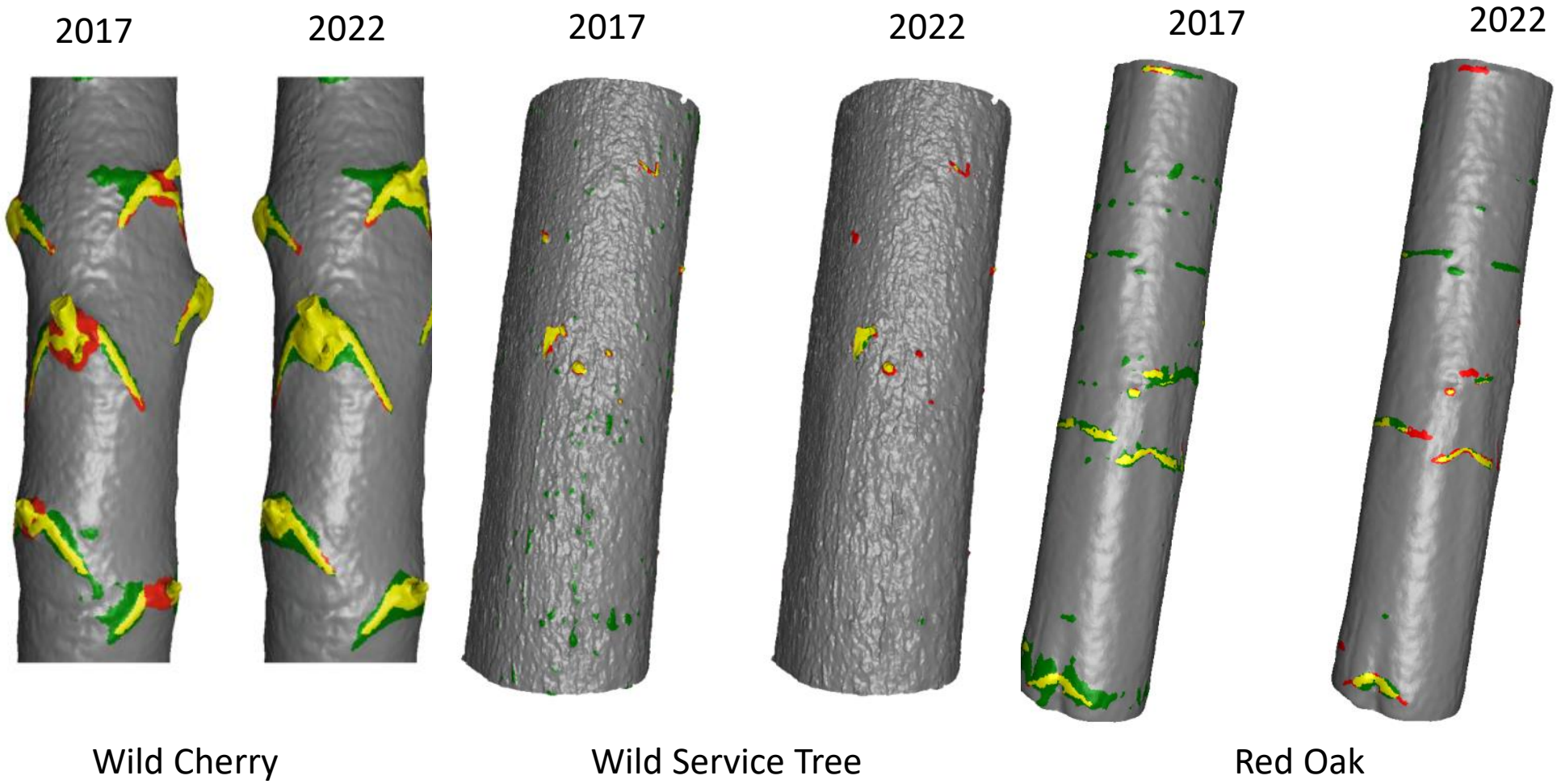


New method proposed by F. Delconte (PhD Candidate) based on Deep Learning

- Via CNN architecture U-Net slighty modified



Visual comparison of both methods from Nguyen (2017) and Delconte (2022)



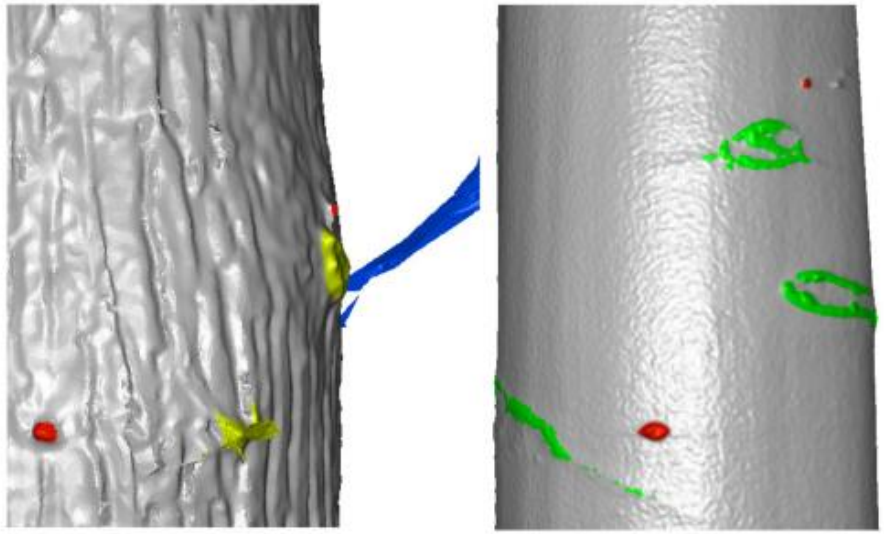
Comparison of three methods

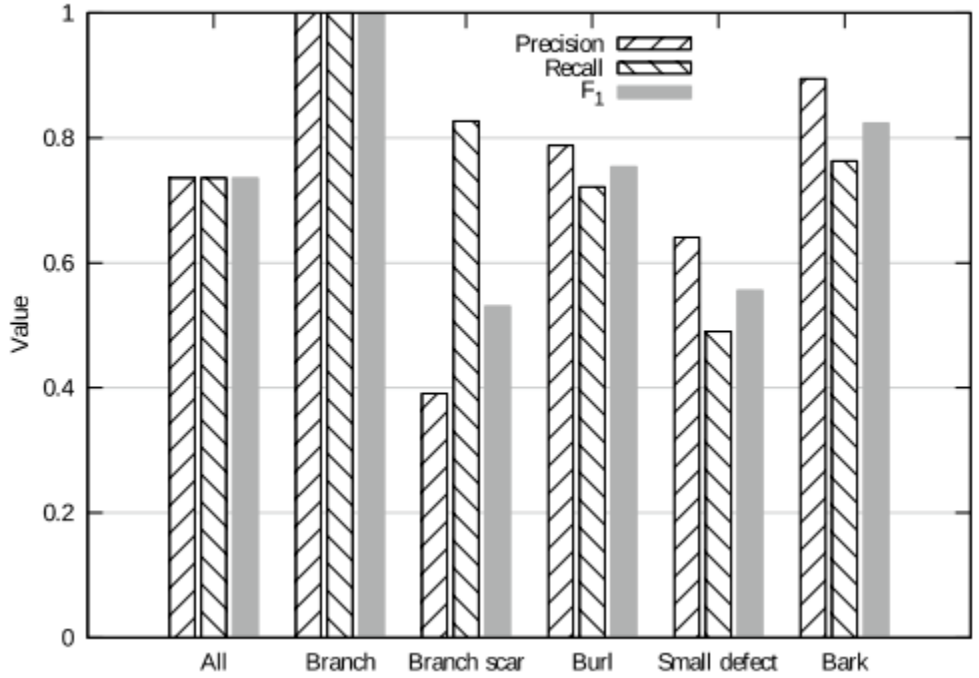
	Nguyen (2017)			log as a cylinder*			Delconte (2022)		
Data IN	**Method 2017**			**Methode Cylinder**			**Methode 2022**		
	precision	**recall**	**F1**	**precision**	**recall**	**F1**	**precision**	**recall**	**F1**
Fir1	**0.747**	0.769	0.757	0.137	**0.937**	0.238	0.746	0.857	**0.797**
Fir2	0.673	0.775	0.719	0.353	0.452	0.395	**0.792**	**0.801**	**0.795**
WildCherry1	0.696	0.765	0.728	0.683	0.512	0.584	**0.757**	**0.881**	**0.813**
WildCherry2	**0.846**	0.711	0.771	0.661	0.822	0.732	0.799	**0.955**	**0.870**
Redoak1	0.749	**0.742**	0.744	0.479	0.444	0.459	**0.866**	0.696	**0.770**
Redoak2	0.428	**0.833**	**0.564**	0.061	0.400	0.104	**0.730**	0.428	0.538
Beech	0.670	**0.604**	0.634	0.360	0.289	0.320	**0.863**	0.591	0.701
Birch	0.733	**0.756**	0.744	0.607	0.421	0.496	**0.774**	0.726	0.748
Elm	0.694	**0.755**	0.721	0.494	0.309	0.378	**0.881**	0.642	0.741
WildServiceTree	0.247	**0.741**	0.370	0.057	0.463	0.100	**0.856**	0.504	0.633
Total	0.685	0.740	0.710	0.289	0.563	0.380	**0.793**	**0.789**	**0.790**

* Cylinder fitting from 3D points -> 1 unique reference radius for computation of delta-distances

2d challenge : identify the type of singularity

- State-of-art method based on classification by Random Forest osf shape descriptors (Nguyen et al. 2021)

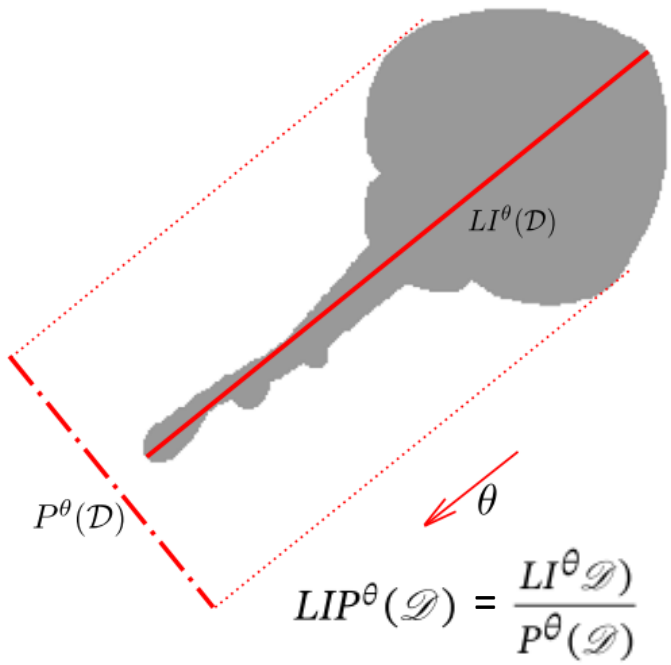




- Branch
- Branch scar
- Burl
- Small defects (picot, cluster fo buds, sphaeroblast…)
- Bark

2d challenge : identify the type of singularity

From Nguyen and Nguyen (2018)



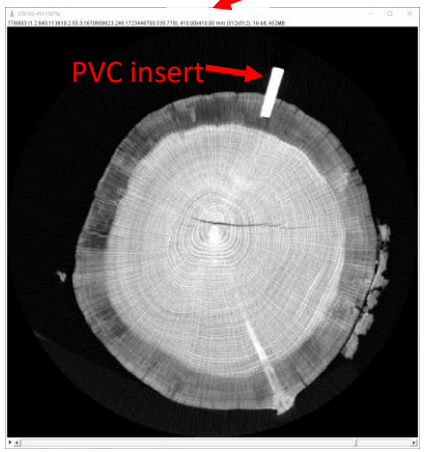
- New method proposed by F. Delconte et al. (2024)
  - Addition of a shape descriptor the LIP signature generalised in 3D (i.e. Largest Interception and Projection[Nguyen et Nguyen, 2018])
  - Resultts

	Ec (11)	Bra (23)	Cic (48)	Bro (28)	pDef (23)	w.AVG
V-T[38] (17)	0.76	0.77	**0.83**	0.64	0.84	0.78
V-T (3) + LIP (11)	**0.81**	**0.85**	0.82	**0.66**	**0.89**	**0.80**

→ Gain in identification of types with less descriptors

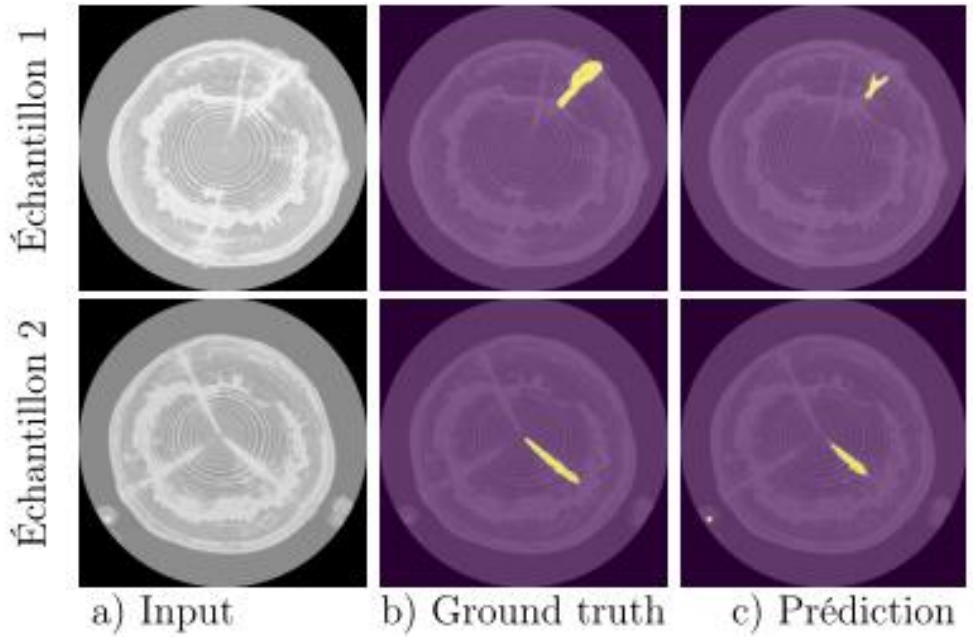
3rd challenge : segmentation of internal defects in X-ray images to establish a ground truth

- More than 600 logs (~160 « Oaks » ~70 conifers,…)
- Moisture alters the contrast of density between structural elements and normal wood
- Good results with room for improvement for conifers (Architecture CNN U-Net -> F1 = 0,698)
- Difficulty for broadleaves with very low contrast



Oak X-ray slice


Pine X-ray slice



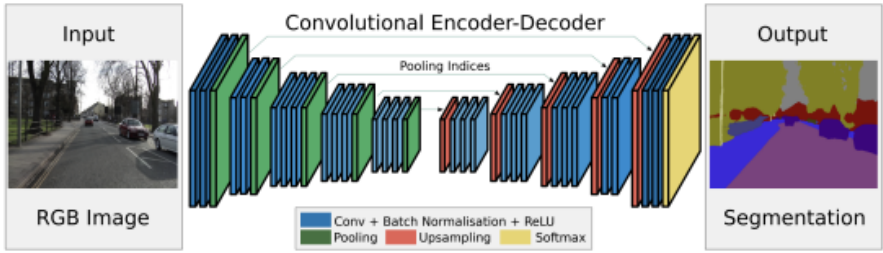
Khazem et al. 2023

4th Challenge : Moving from surface detection to internal defect quantification

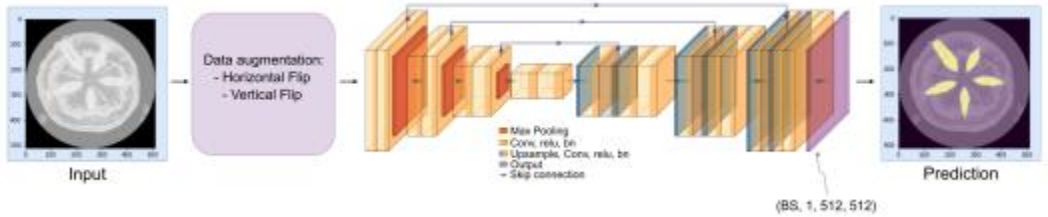
- ⚠ Due to segmentation difficulties, just for Fir and Spruce, and contours from X-Ray data

Khazem et al. 2023

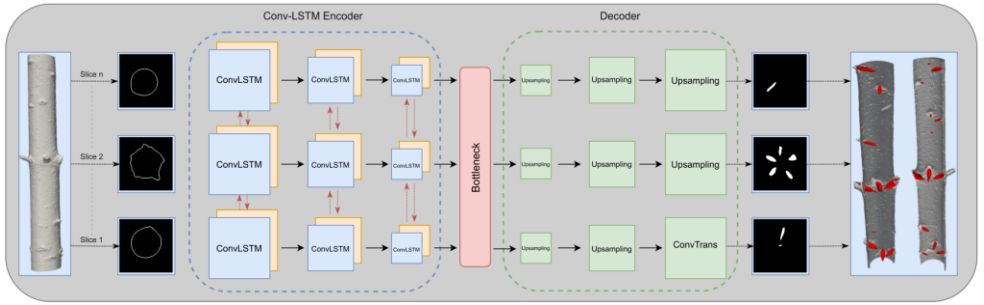
- Trial of three types of neural networks
  - SegNet : Reference network for segmentation



  - U-Net : Reference network for segmentation



  - ConvLSTM (recurrent convolutional network)
    - Travaille sur une série d'images
    - Allows the introduction of a spatial dependence between the slices when linking the surface irregularities to the defect



4th Challenge : Moving from surface detection to internal defect quantification

- Metrics of performence of the different neural networks on the validation set

Similarity [0;1] ↑ | Dissimilarity [mm] ↓ | Fiability [-1;1] ↑

Recurrent Connections	Methode	Espèce	Dice ↑	HD ↓	Kappa ↑
Without	SegNet	Sapin	0.68	17.04	0.12
	SegNet	Épicéa	0.67	33.14	0.06
	U-Net	Sapin	0.69	37.95	0.10
	U-Net	Épicéa	0.68	56.62	0.05
With	ConvLSTM	Sapin	**0.74**	**12.68**	**0.41**
	ConvLSTM	Épicéa	**0.70**	**22.11**	**0.21**

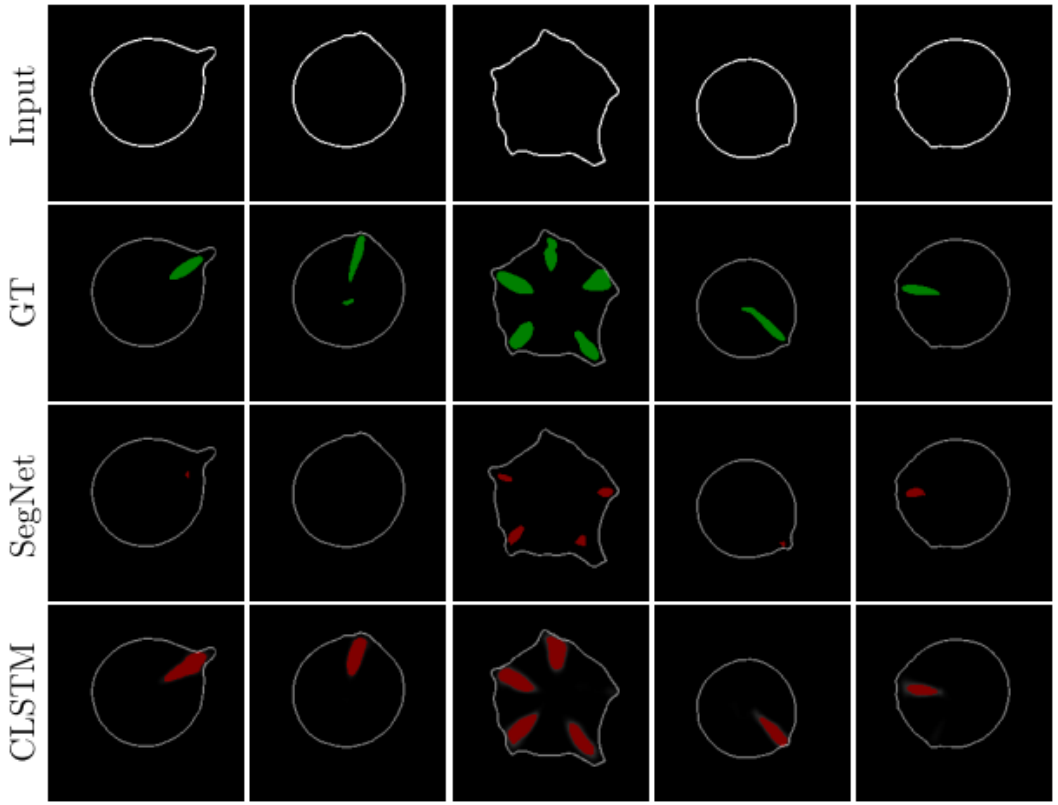
Whatever the metrics, the recurrent convolutional network performs better

Khazem et al. 2023

4th Challenge : Moving from surface detection to internal defect quantification

- Performence of the different neural networks on the validation set

Fir



Input : Contour (extracted from X-ray data)

→ Ground truth: knots segmented by AI in X-ray data

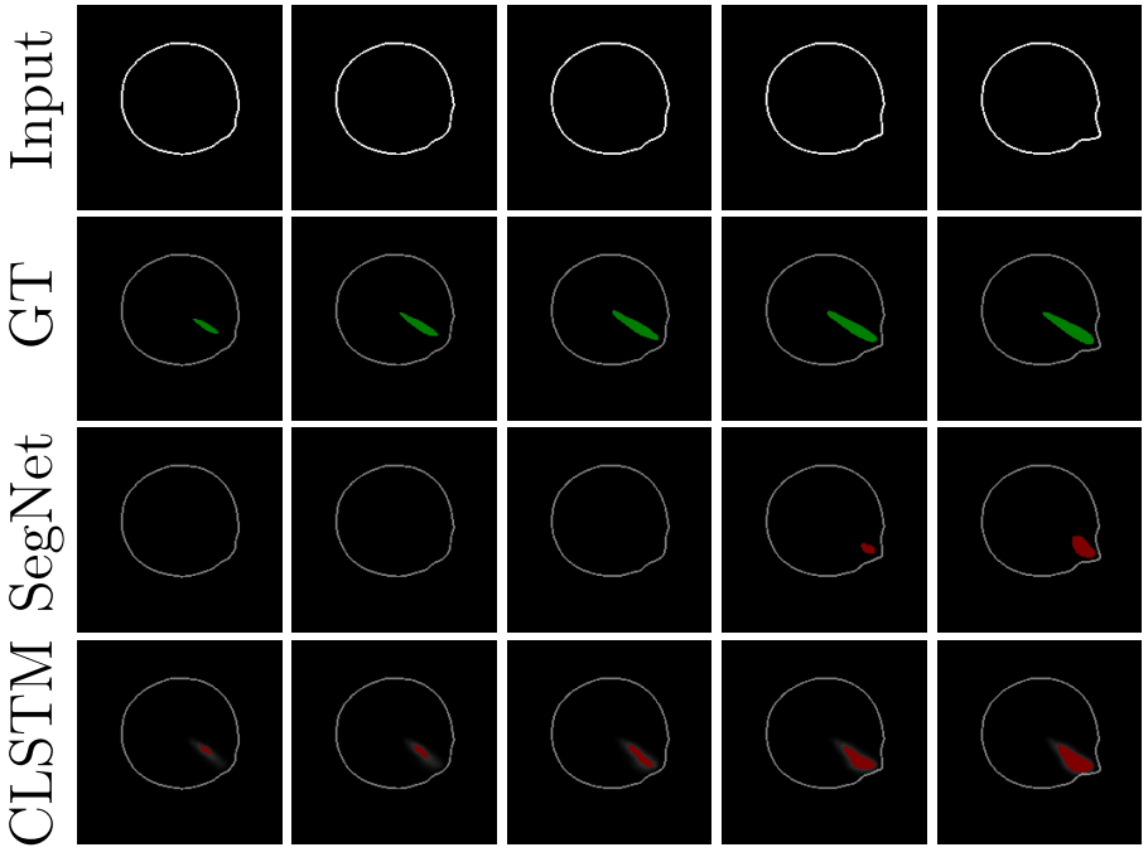
→ SEG-NET : Underestimation, even omission of some knots

→ ConvLSTM : some slight differences with ground truth but satisfactory for roundwood quality assessment.

Khazem et al. 2023

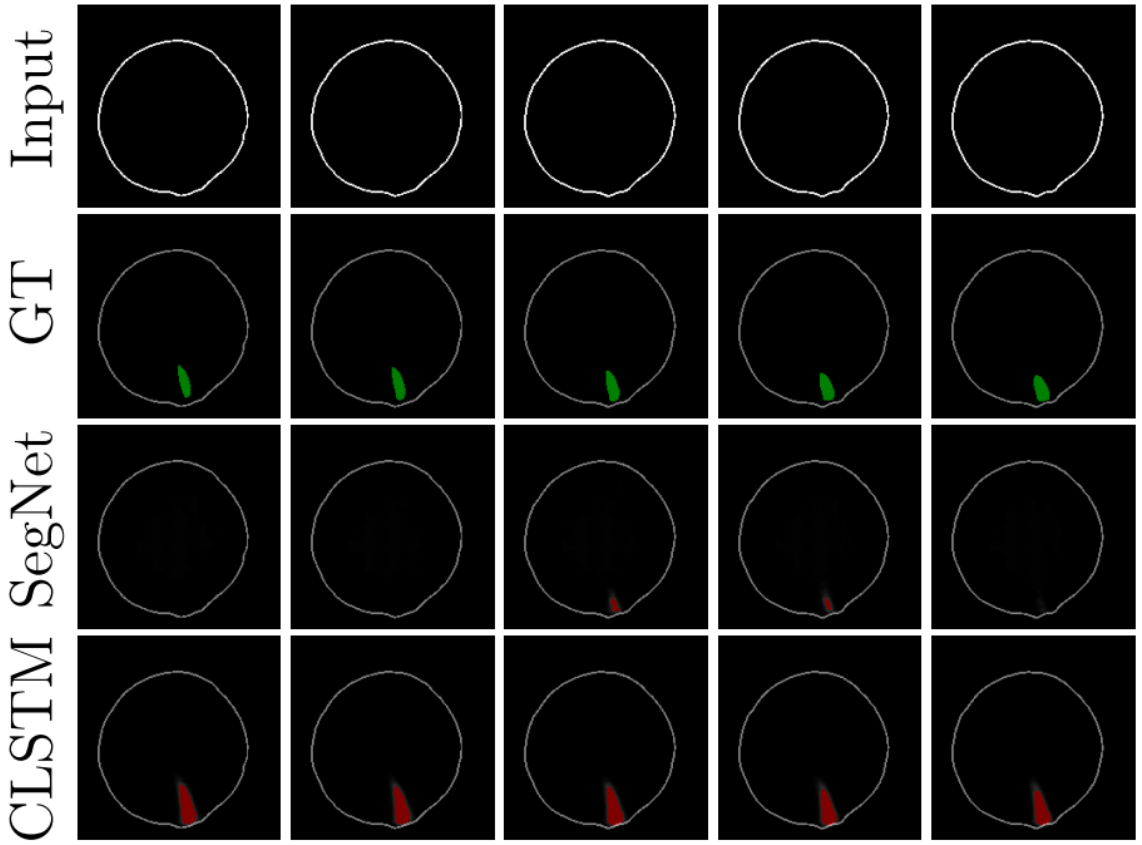
4th Challenge : Moving from surface detection to internal defect quantification

Fir



Consecutive slices

Spruce

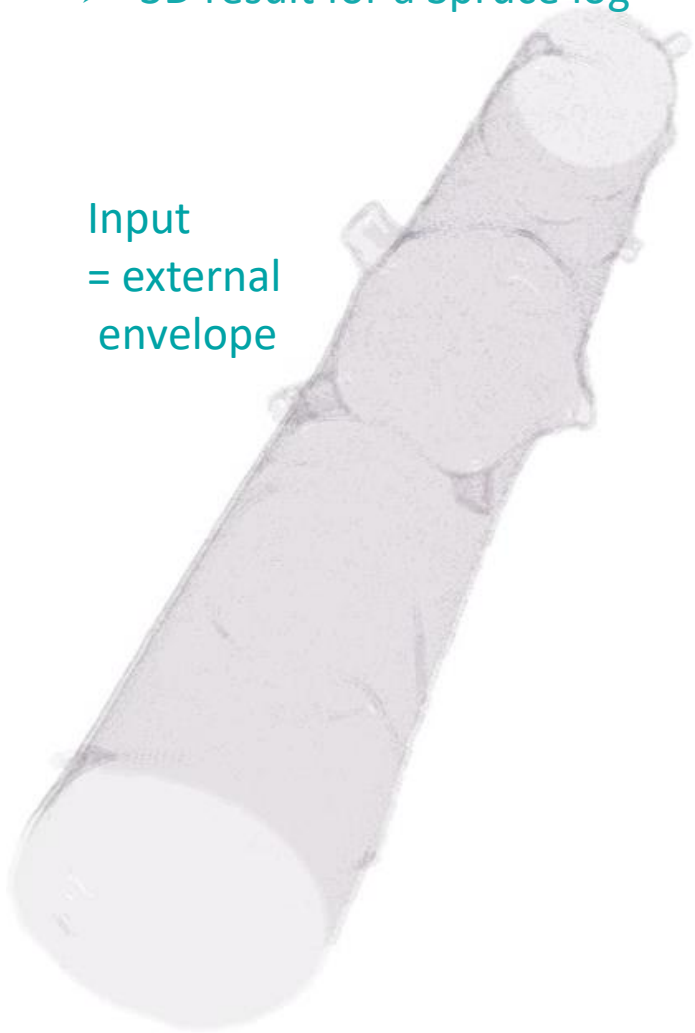


Consecutive slices

4th Challenge : Moving from surface detection to internal defect quantification

- 3D result for a Spruce log

Input
= external
envelope



+ Predicted knots
by Conv-LSTM

Ground Truth
from X-Ray

Khazem et al. 2023

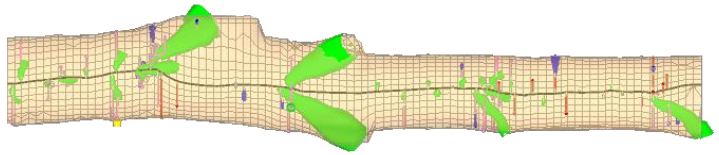
Conclusions and Perspectives (→ AAP PEPR Forestt : EQUALIA Project)

❑ Prediction of the internal defects from outside

- Proof of concept for conifers is established, but needs to be strengthened
- Many questions remain about the suitability of 3D capture
- For broadleaves, a bottleneck is the segmentation of defects in X-ray data

❑ Need for suitable data to continue…

- Ground truth for segmentation of internal defects from X-Ray CT scanned logs
  - By digging in old data → 350 short oak logs (3D Model + X-Ray data)



- A database combining external descriptions and X-Ray CT-scans (40 trees from 6 species) planned during WoodSeer but still under construction…

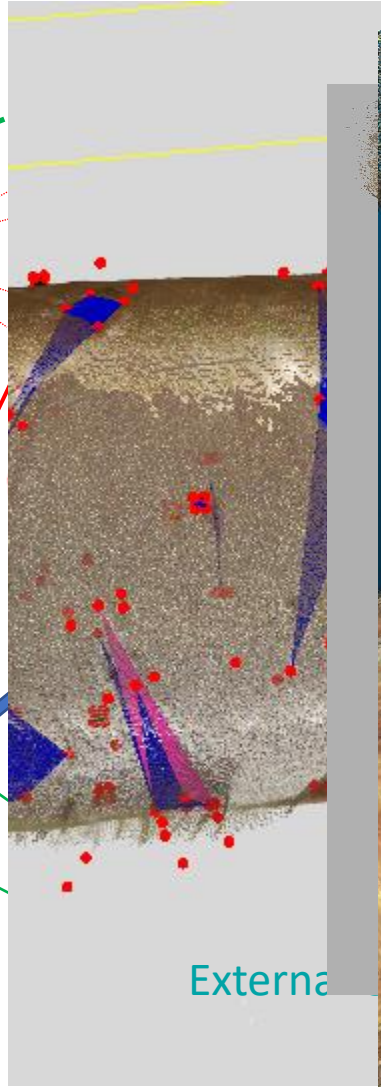
WoodSeer Database: 40 logs (6 species)

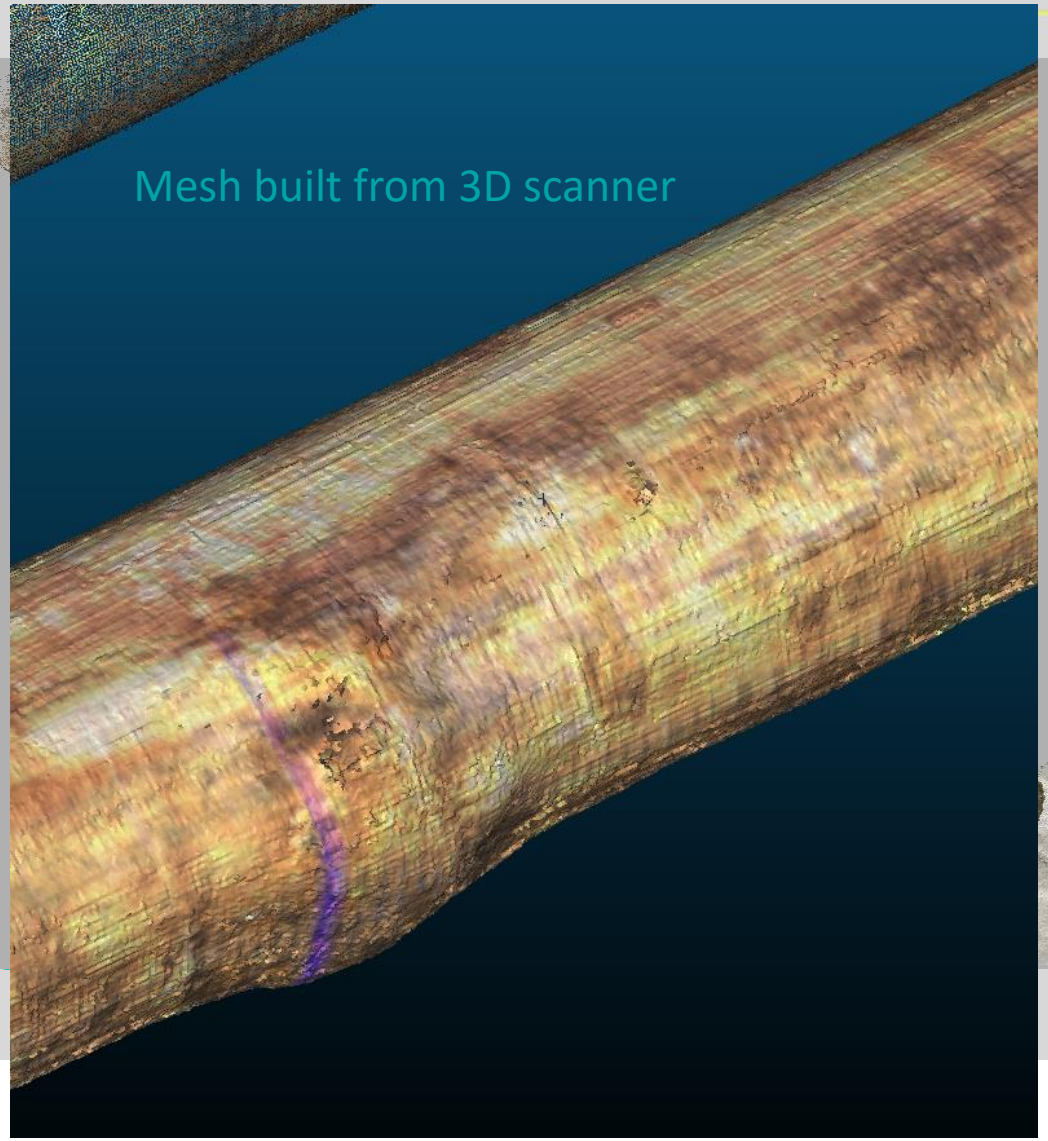
Acquisitions

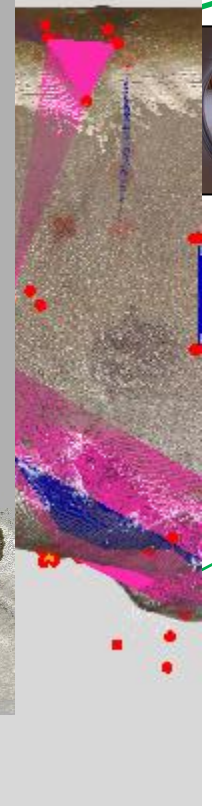
Database

Standing trees

External
Ground Truth

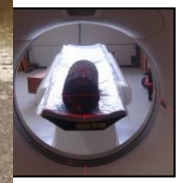


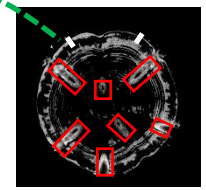




X-Ray CT Scanner
SilvaTech

~500 logs





Segmentation of defects
via density difference

Internal
ground truth

Data Illustration for 1 pine

Standing Tree
Trunk Surface
3D + RGB

T-Lidar

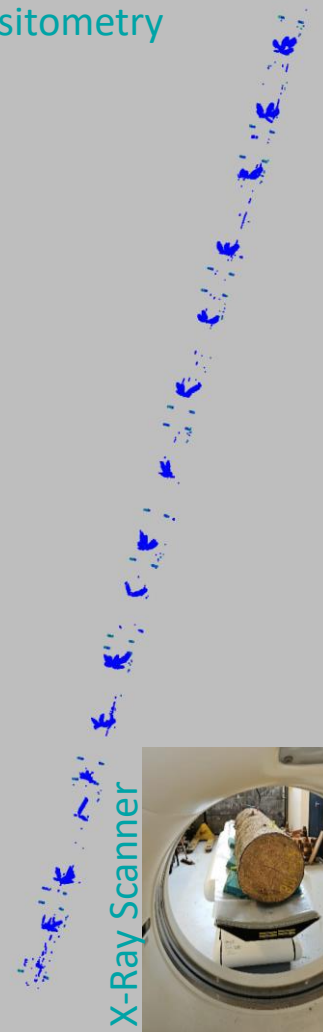
Standing Tree
3D Characterisation
of singularities
-> Ground Truth
(Type and Size)

Tacheometer

Debarked (or not)
Log surface
3D + RGB

3D Scanner

Short logs
Volumetric
Densitometry



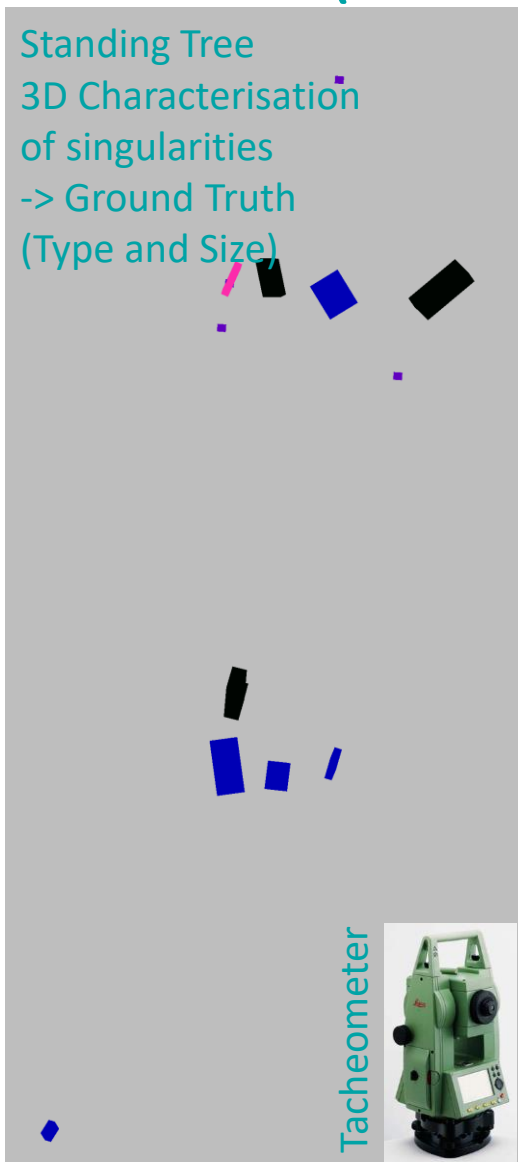
X-Ray Scanner

Data illustration for 1 Pine (Zoom)

Standing Tree
Trunk Surface
3D + RGB

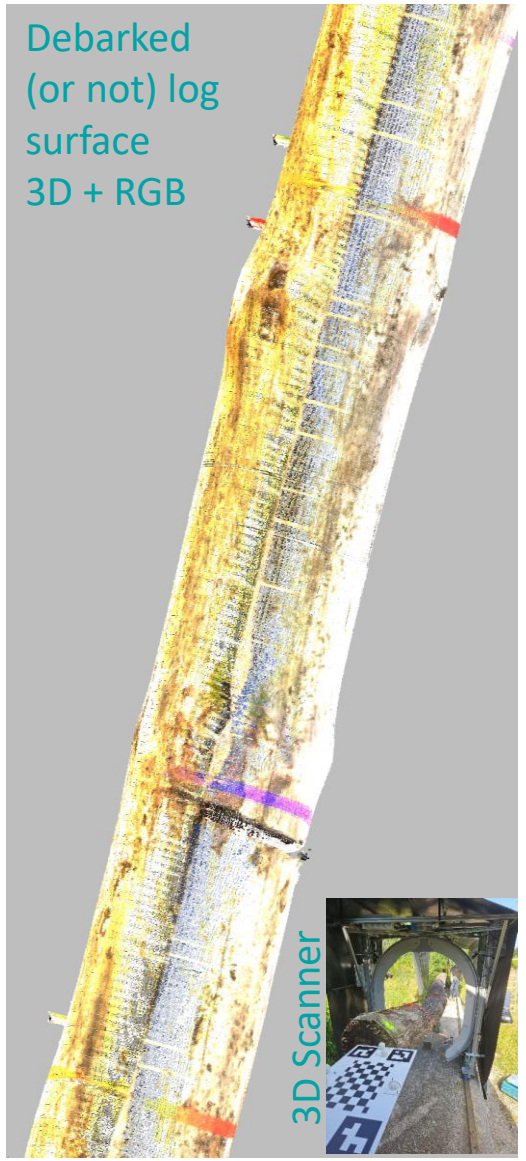
T-Lidar

Standing Tree
3D Characterisation
of singularities
-> Ground Truth
(Type and Size)



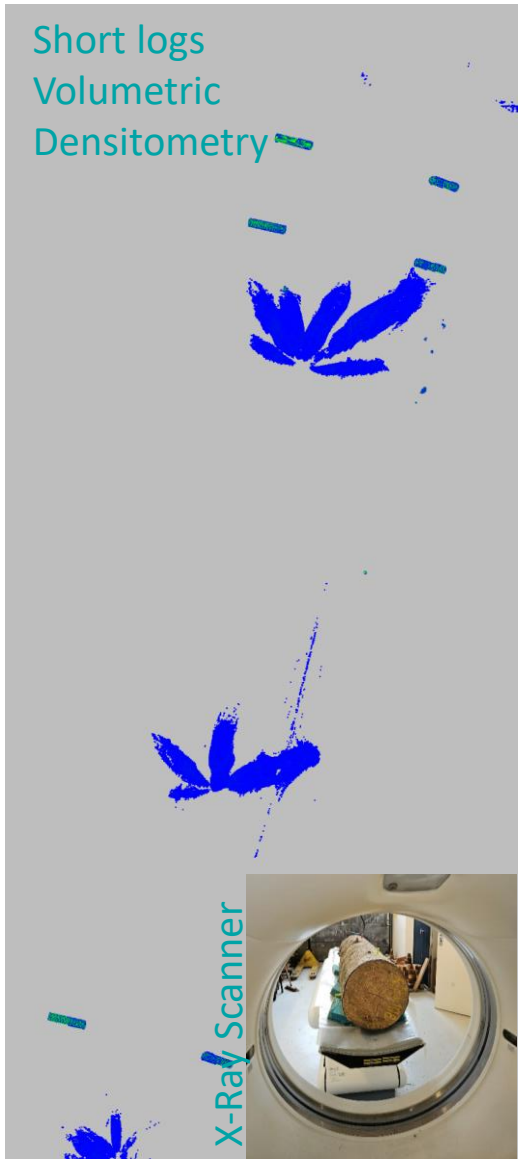
Tacheometer

Debarked
(or not) log
surface
3D + RGB



3D Scanner

Short logs
Volumetric
Densitometry



X-Ray Scanner

Thank you to WoodSeer's partners…

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Thank you for your attention. Any questions ?

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