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Knot shape assessment on various species through X-ray CT scanning

A. Krähenbühl¹ F. Longuetaud² J-B. Morisset²
F. Colin² I. Debled-Rennesson¹ B. Kerautret¹
F. Mothe²

¹LORIA, Université de Lorraine

²INRA, LERFoB

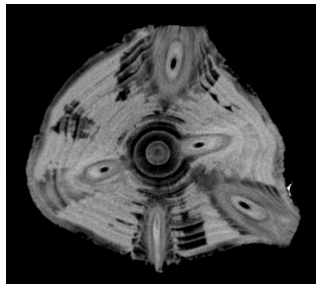
IUFRO
July 9, 2012

Context

Knots are the prolongation of branches inside the stem.
Size and shape of knots / branches directly impact:

- tree growth and physiology
- architectural tree models
- wood quality (structural or aesthetic uses)
- lumber cutting optimisation & grading

X-ray CT scanning is specially well adapted to knot measurements



Plan

Manual measurements of knot features

What can be seen?

The tool

Application to species classification

Automatic algorithm for knot features

3DKnotDM

Measurements

Limits

Work in progress

Conclusion

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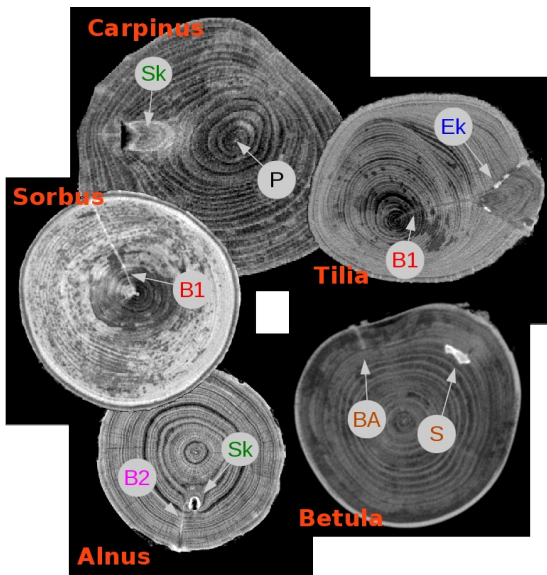
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Sequential knots, epicormic knots and bud traces



P Pith
S Scars

Sk Sequential knot
Ek Epicormic knot

B1 Trace of 1ry bud
B2 Trace of 2ry bud
BA Trace of adv. bud



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Software design

Gourmands: ImageJ plugin to record knot location & shape.



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Outputs

- 3D location
- azimuth
- leaning angle
- length
- diameter



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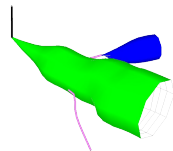
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- azimuth
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- length
- diameter
- + hierarchical organisation
- + pith density & trajectory

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Outputs

- 3D location
- azimuth
- leaning angle
- length
- diameter
- + hierarchical organisation
- + pith density & trajectory
- + 3D view



Utilisation

Processing time

scanning:	10 min / m
measurements:	1 hour / m

Drawbacks

- accuracy 0.2 to 1mm / pixel
- \emptyset not measured in longitudinal direction (circular section assumed)
- low contrast for wet wood
- operator effect unquantified



[1] F. Colin et al, 2010

Tracking rameal traces in sessile oak trunks with X-ray computer tomography: biological bases, preliminary results and perspectives.
Trees-structure and Function.



Fagus

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Objective

Classify log species based on internal knot architecture.

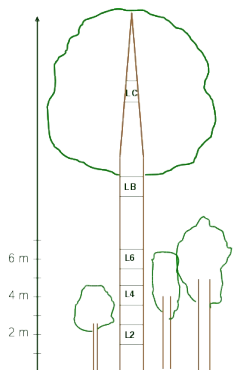


Objective

Classify log species based on internal knot architecture.

Sampling

Species	Common name	# trees	# logs
<i>Robinia pseudo-acacia</i>	Black locust	2	5+5
<i>Sorbus torminalis</i>	Wild	2	4+5
<i>Alnus glutinosa</i>	Alder	2	5+5
<i>Betula pendula</i>	Birch	2	5+5 LC</td
<i>Carpinus betulus</i>	Hornbeam	1	0+5
<i>Quercus rubra</i>	Red oak	2	2+5
<i>Acer platanoides</i>	Norway maple	2	3+1
<i>Fraxinus excelsior</i>	European ash	2	2+4
<i>Fagus sylvatica</i>	European beech	2	5+5
<i>Prunus avium</i>	Wild cherry	2	5+3
<i>Ulmus minor</i>	Field elm	2	5+5
<i>Abies alba</i>	Silver fir	2	3+3
<i>Tilia platyphyllos</i>	Lime	2	5+5
<i>Populus tremula</i>	Aspen	2	5+5
Total	14 species	27	115



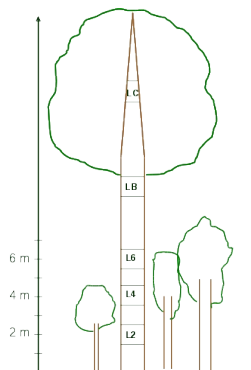
14 species, 2 trees per species, 2-5 logs per tree
(thanks to InterReg European Project CoForKo)

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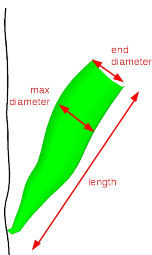
13 angiosperms vs. 1 gymnosperm.

Data used in classification

20 variables computed from *Gourmands* outputs:

Considered variables

sequential branches	length relative length (/ log radius) sd relative length inclination sd inclination initial inclination (median) diameter relative diameter (/ log diameter) sd relative diameter diameter / length min diameter (1st decile) max diameter (last decile) diameter decrease (end diam. / max diam.)
number / m of	sequential knots epicormic knots all buds primary buds secondary buds adventive buds
angle between 2 successive buds/branches (phyllotaxic angle)	

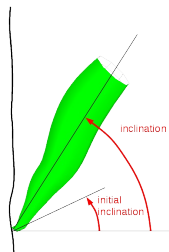


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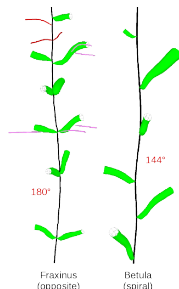


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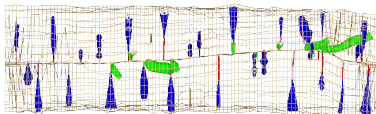
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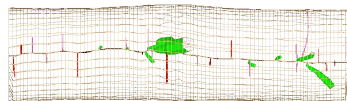
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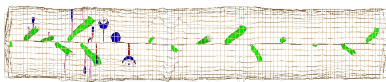
Visualisation 1/2



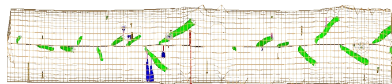
Robinia pseudo-acacia



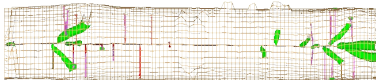
Sorbus torminalis



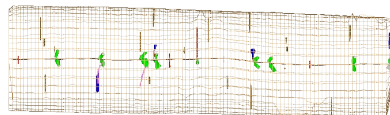
Alnus glutinosa



Betula pendula



Quercus rubra



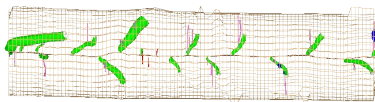
Acer platanooides

Tree #1 – log #2 (4m height) for each species,

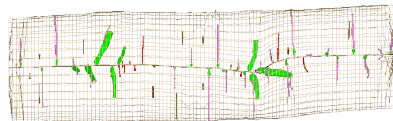
Knot shape assessment through X-ray CT scanning – A. Krähenbühl et al.



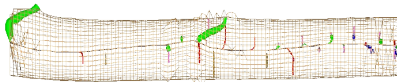
Visualisation 2/2



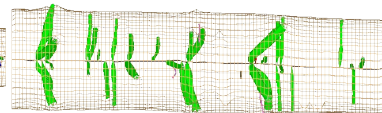
Fagus sylvatica



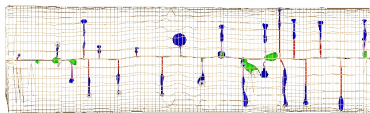
Prunus avium



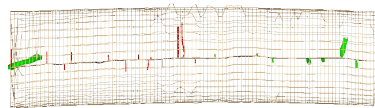
Ulmus minor



Abies alba



Tilia platyphyllos



Populus tremula

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Classification methods

2 methods tested

- 1 Regression Tree (*R package rpart*)

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- 2 Score based method (*R script*)

Scores computed for each species i using n variables x_j :

$$Score_i = \frac{1}{n} \sum_{j=1}^n \frac{|x_j - \bar{x}_{ij}|}{\sigma_{ij}}$$

minimal score \Rightarrow predicted species

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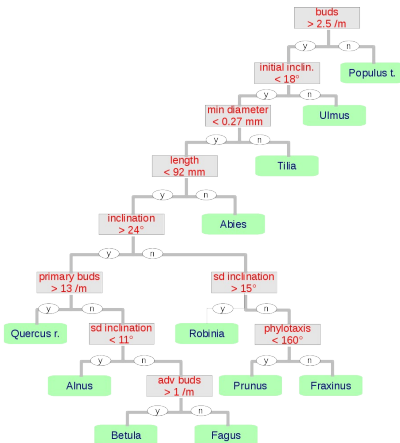
minimal score \Rightarrow predicted species

In both cases

- calibration using the full data-set
- cross-validation for each log using other logs as training data

Results: Regression Tree

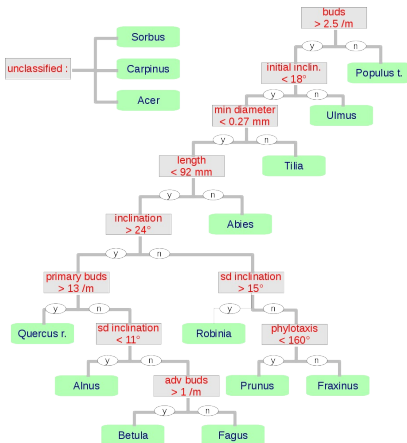
Calibration tree after pruning



Unstable nodes pruned based on internal cross-validation

Results: Regression Tree

Calibration tree after pruning

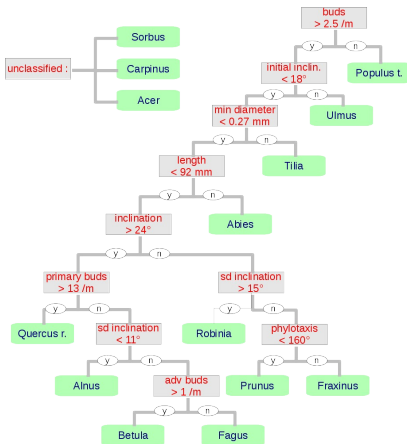


Unstable nodes pruned based on internal cross-validation

3 misclassified species

Results: Regression Tree

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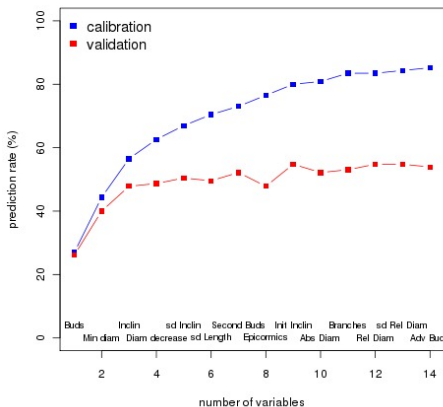
Detection rates

calibration	70.4 %
validation	33.0 %

Results: Score based method

Step by step method to select the best variables

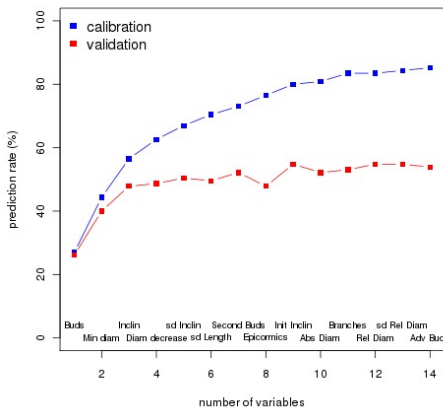
Same variables applied in validation



Results: Score based method

Step by step method to select the best variables

Same variables applied in validation



Detection rates

calibration	82.6 %
validation	53.9 %

Results: Score based method

Detection rates per species (validation)

Log species	Detected species													Detect. rate (%)	
	Rob	Sor	Aln	Bet	Car	Que	Ace	Fra	Fag	Pru	Ulm	Abi	Til		Pop
Robinia	7	0	0	0	0	0	0	0	1	0	1	0	1	0	70
Sorbus	0	0	0	0	1	3	0	0	4	1	0	0	0	0	0
Alnus	0	0	6	0	2	0	0	0	2	0	0	0	0	0	60
Betula	0	0	2	6	1	0	0	0	1	0	0	0	0	0	60
Carpinus	1	0	0	0	1	1	0	0	2	0	0	0	0	0	20
Quercus	0	2	1	0	0	3	0	0	0	0	1	0	0	0	43
Acer	0	0	0	0	0	0	1	0	1	1	1	0	0	0	25
Fraxinus	0	0	0	0	0	0	0	1	3	1	0	0	0	1	50
Fagus	0	0	3	0	0	0	1	0	4	0	2	0	0	0	40
Prunus	0	0	0	0	1	0	1	0	0	6	0	0	0	0	75
Ulmus	0	1	0	0	0	0	1	0	0	0	8	0	0	0	80
Abies	0	0	0	0	0	0	0	0	0	2	0	3	0	1	50
Tilia	0	0	2	0	0	0	0	0	0	0	1	0	7	0	70
Populus	0	0	0	0	0	0	0	0	1	2	0	0	0	7	70

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Fagus	0	0	3	0	0	0	1	0	4	0	2	0	0	0	40
Prunus	0	0	0	0	1	0	1	0	0	6	0	0	0	0	75
Ulmus	0	1	0	0	0	0	1	0	0	0	8	0	0	0	80
Abies	0	0	0	0	0	0	0	0	0	2	0	3	0	1	50
Tilia	0	0	2	0	0	0	0	0	0	0	1	0	7	0	70
Populus	0	0	0	0	0	0	0	0	1	2	0	0	0	7	70

Very low detection rates for Sorbus, Carpinus & Acer

Applications of the manual measurement tool

For species classification:

- Two classification methods gave similar results
- Detection failed for 3 species
 - ⇒ find more species-specific architectural variables?
 - ⇒ include other CT measurements (bark, density...)?
 - ⇒ larger sampling?
 - ⇒ grouping species based on knot architecture?

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- Knot shape modelling & epicormics ontogeny
(see presentations by E. Duchâteau & J-B. Morisset)

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- Validation of automatic algorithms
 - ⇒ **A. Krähenbühl**

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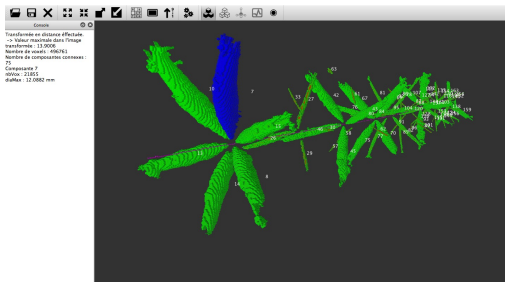
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Automatic knot segmentation



3DKnotDM software developed in [1].

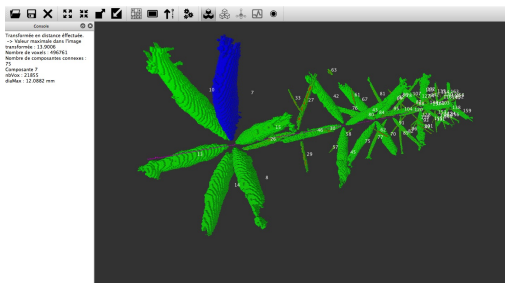


[1] F. Longuetaud and al., 2012

Automatic knot detection and measurements from X-ray CT images of wood: A review and validation of an improved algorithm on softwood samples., Computers and Electronics in Agriculture.



Automatic knot segmentation



3DKnotDM software developed in [1].

1 Thresholding based on knot density

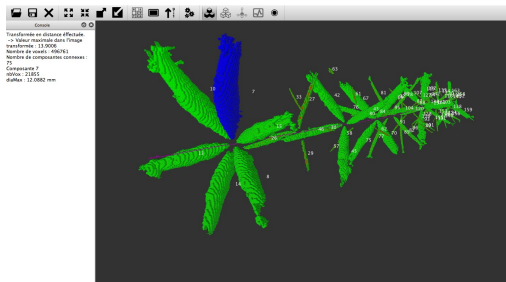


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- ① Thresholding based on knot density
- ② Extraction of connected components

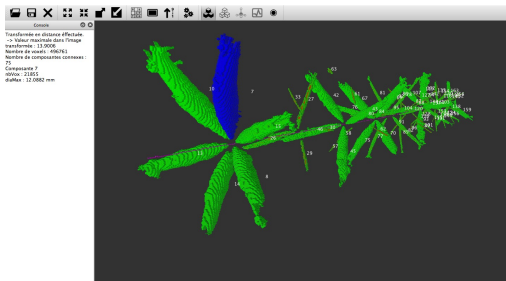


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Automatic knot segmentation



3DKnotDM software developed in [1].

- ① Thresholding based on knot density
- ② Extraction of connected components
- ③ Computation of several knot's features.



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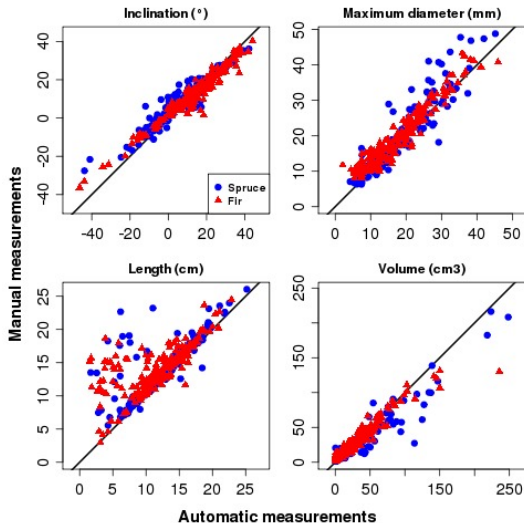
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Automatic vs. manual



Great correlation between feature measures.



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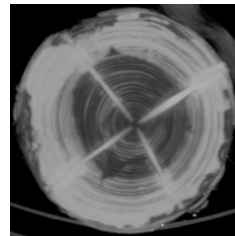
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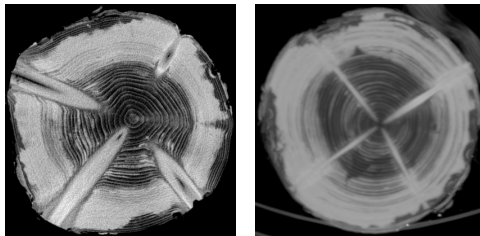
Work in progress

Conclusion

Segmentation of knots with sapwood



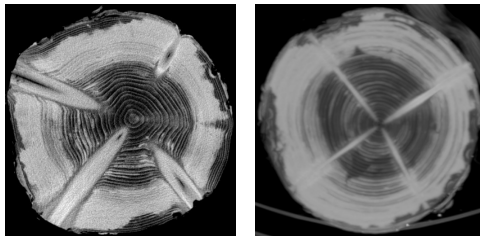
Segmentation of knots with sapwood



Problem

Density/intensity of sapwood and knots are similar.

Segmentation of knots with sapwood



Problem

Density/intensity of sapwood and knots are similar.

Consequences

- ⇒ Unefficient thresholding
- ⇒ Knots merged after connected component extraction

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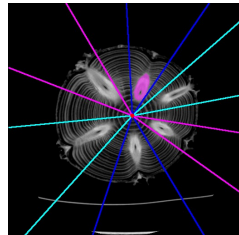
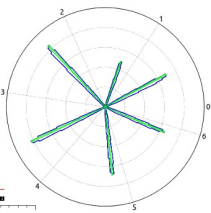
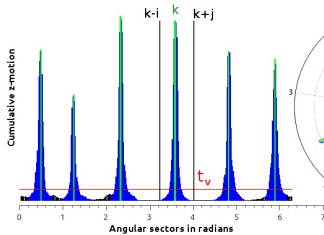
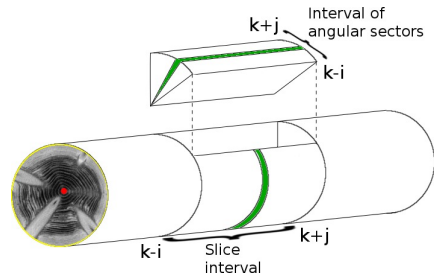
Measurements

Limits

Work in progress

Conclusion

Knot area detection



Plan

Manual measurements of knot features

What can be seen?

The tool

Application to species classification

Automatic algorithm for knot features

3DKnotDM

Measurements

Limits

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Conclusion

Conclusion

Tools for analysing knots on CT scan of wood are available:

- A manual tool for detailed knot architecture measurements, designed for research studies

Gourmands plugin

https://www.nancy.inra.fr/foret_bois_lerfob_eng/boite_a_outils/tomographie_x

Contact: *frederic.mothe@nancy.inra.fr*

Conclusion

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- An automatic tool for fast detection of knots, oriented toward industry (in development)

3DKnotDM

<http://www.loria.fr/equipes/adage/3DKnotDM>

Contact: *adrien.krahenbuhl@loria.fr*



Thanks for your attention !