



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

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F. Mothe²

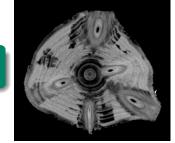
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IUFRO July 9, 2012 Knots are the prolongation of branches inside the stem. Size and shape of knots / branches directly impact:

- 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







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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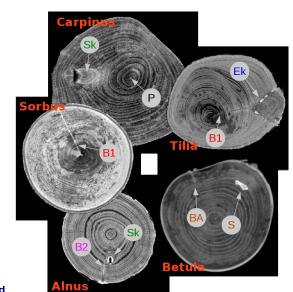
Work in progress





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Sequential knots, epicormic knots and bud traces



- Pith
- Scars
- **Sk** Sequential knot
- **E** Epicormic knot
- B1 Trace of 1ry bud
- 12 Trace of 2ry bud
 - Trace of adv. bud



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Gourmands: ImageJ plugin to record knot location & shape.

Software design

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Outputs

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





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- leaning angle
- length
 - diameter
- hierarchical organisation
- pith density & trajectory





Software design

Gourmands: ImageJ plugin to record knot location & shape.

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
- O 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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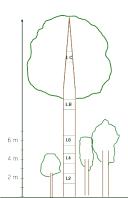
Classify log species based on internal knot architecture.

Objective

Classify log species based on internal knot architecture.

Sampling

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



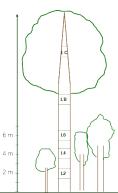
14 species, 2 trees per species, 2-5 logs per tree (thanks to InterReg European Project CoForKo)



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13 angiosperms vs. 1 gymnosperm.

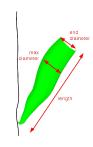
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Data used in classification

20 variables computed from Gourmands outputs:

Considered	l variables
sequential	length
branches	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)



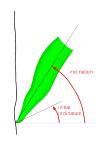




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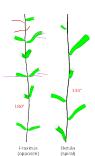
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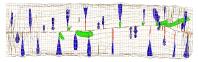
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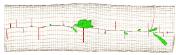






Visualisation 1/2

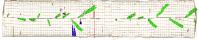




Robinia pseudo-acacia

Sorbus torminalis





Alnus glutinosa

Betula pendula





Quercus rubra

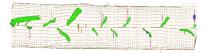
Acer platanoides

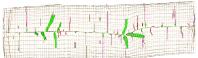


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Tree #1 – log #2 (4m height) for each species,

Visualisation 2/2

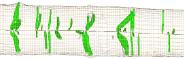




Fagus sylvatica

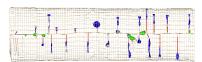
Prunus avium





Ulmus minor

Abies alba





Tilia platyphyllos

Populus tremula

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

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Classification methods

2 methods tested

Regression Tree (R package rpart)



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- Regression Tree (R package rpart)
- 2 Score based method (R script) Scores computed for each species i using n variables x_i :

$$Score_{i} = \frac{1}{n} \sum_{j=1}^{n} \frac{|x_{j} - \overline{x}_{ij}|}{\sigma_{ij}}$$

minimal score \Rightarrow predicted species



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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 Populus t. Tilia Abies Fraxinus

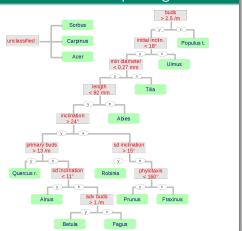
Fagus

Unstable nodes pruned based on internal cross-validation





Calibration tree after pruning



Unstable nodes pruned based on internal cross-validation

3 misclassified species





Results: Regression Tree

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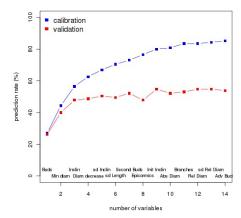
Detection rates

calibration 70.4 % validation 33.0 %



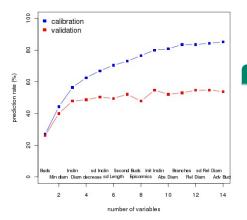


Step by step method to select the best variables Same variables applied in validation



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Step by step method to select the best variables Same variables applied in validation



Detection rates

calibration 82.6 % validation 53.9 %



Detection rates per species (validation)

Log						Det	ected	speci	es						Detect.
species	Rob	Sor	Aln	Bet	Car	Que	Ace	Fra	Fag	Pru	Ulm	Abi	Til	Pop	rate (%)
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	1	3	1	0	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





Results: Score based method

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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
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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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Other applications

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





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- Knot shape modelling & epicormics ontogeny (see presentations by E. Duchâteau & J-B. Morisset)
- Validation of automatic algorithms
 - ⇒ A. Krähenbühl





Automatic algorithm for knot features 3DKnotDM Measurements Limits Work in progress





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What can be seen

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Measurements

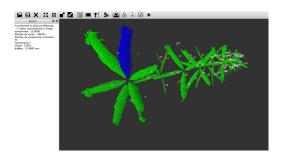
Work in progress

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Automatic knot segmentation



3DKnotDM software developped in [1].





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.

The state of the s

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Thresholding based on knot density

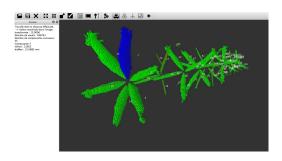


[1] F. Longuetaud and al., 2012

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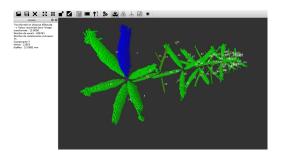
- 1 Thresholding based on knot density
- Extraction of connected components



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3DKnotDM software developped in [1].

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



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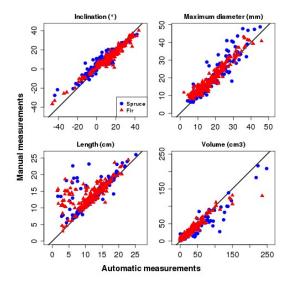
Limits

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Automatic vs. manual







Automatic algorithm for knot features

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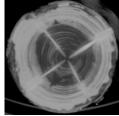
Work in progress





Segmentation of knots with sapwood

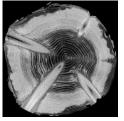


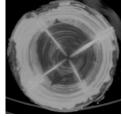






Segmentation of knots with sapwood





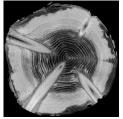
Problem

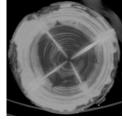
Density/intensity of sapwood and knots are similar.





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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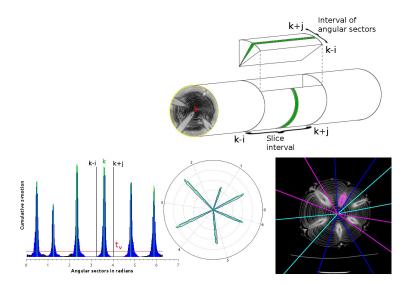
Work in progress

Conclusion





Knot area detection







Manual measurements of knot features

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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



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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!