

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

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

<u>A. Krähenbühl</u>¹ F. Longuetaud² J-B. Morisset² F. Colin² I. Debled-Rennesson¹ B. Kerautret¹ <u>F. Mothe</u>²

¹LORIA, Université de Lorraine

²INRA, LERFoB

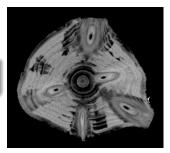
IUFRO July 9, 2012

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





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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



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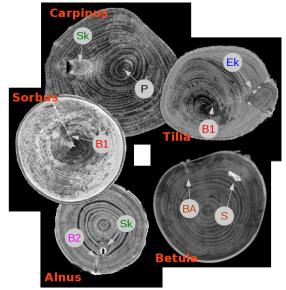
Automatic algorithm for knot features 3DKnotDM Measurements Limits Work in progress

Manual measurements of knot features

What can be seen?



Sequential knots, epicormic knots and bud traces





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sk Sequential knot Ek Epicormic knot

BI Trace of 1ry bud BI Trace of 2ry bud A Trace of adv. bud

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



Manual measurements of knot features

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Conclusion

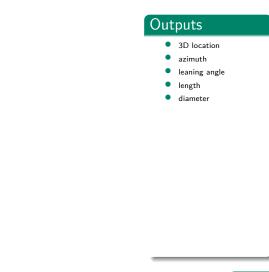


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Gourmands: ImageJ plugin to record knot location & shape.

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Gourmands: ImageJ plugin to record knot location & shape.





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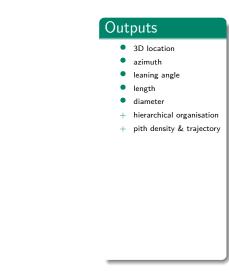
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Gourmands: ImageJ plugin to record knot location & shape.





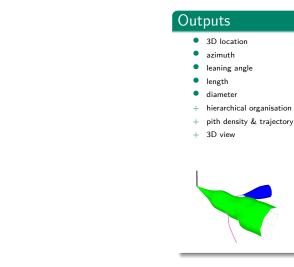
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Gourmands: ImageJ plugin to record knot location & shape.





Utilisation

Processing time

scanning: measurements: $\begin{array}{l} 10 \hspace{0.1 cm} \text{min} \hspace{0.1 cm} / \hspace{0.1 cm} \text{m} \\ 1 \hspace{0.1 cm} \text{hour} \hspace{0.1 cm} / \hspace{0.1 cm} \text{m} \end{array}$

Drawbacks

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- 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.







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



Objective

Classify log species based on internal knot architecture.



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Objective

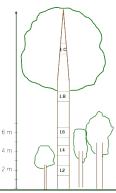
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Classify log species based on internal knot architecture.

mpling			
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)

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

Objective

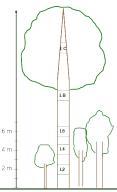
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13 angiosperms vs. 1 gymnosperm.

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



Data used in classification

20 variables computed from *Gourmands* outputs:

sequential	length	
branches	relative length (/ log radius)	
branctics	sd relative length	
	inclination	
	sd inclination	diameter
	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	



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Data used in classification

20 variables computed from *Gourmands* outputs:

sequential	length	1
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	

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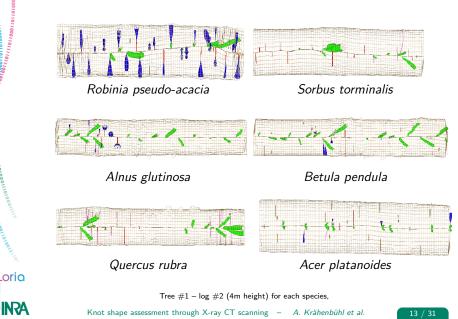
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sequential	length	
branches	relative length (/ log radius)	
	sd relative length	
	inclination	
	sd inclination	
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	diameter	
	relative diameter (/ log diameter)	
	sd relative diameter	
	diameter /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

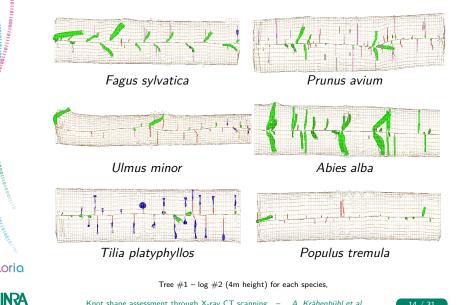
Visualisation 1/2



Visualisation 2/2

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2 methods tested

1 Regression Tree (*R package rpart*)

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1999 Helena hellen

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Classification methods

2 methods tested

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

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

minimal score \Rightarrow predicted species

Classification methods

2 methods tested

1 Regression Tree (*R package rpart*)

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minimal score \Rightarrow predicted species

In both cases

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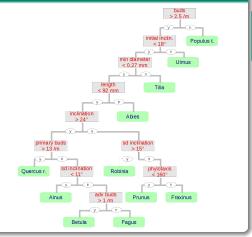
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- calibration using the full data-set
- cross-validation for each log using other logs as training data



Results: Regression Tree

Calibration tree after pruning

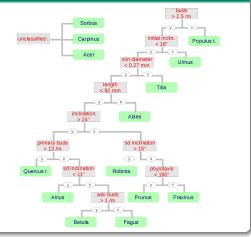


Unstable nodes pruned based on internal cross-validation

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Results: Regression Tree

Calibration tree after pruning



Unstable nodes pruned based on internal cross-validation

3 misclassified species

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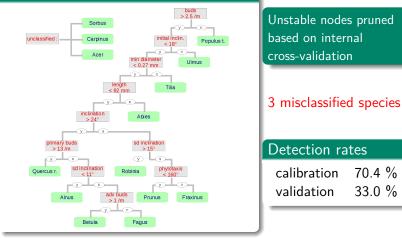
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Results: Regression Tree

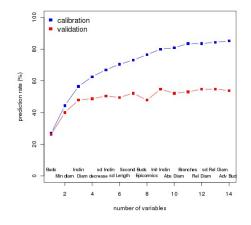
Calibration tree after pruning

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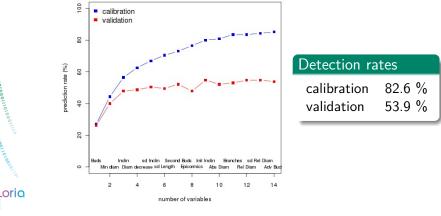


Step by step method to select the best variables Same variables applied in validation



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



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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	Рор	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



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Alnus	0	0	6	0	2	0	0	0	2	0	0	0	0	0	60
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Carpinus	1	0	0	0	1	1	0	0	2	0	0	0	0	0	20
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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

Very low detection rates for Sorbus, Carpinus & Acer

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Applications of the manual measurement tool

For species classification:

- Two classification methods gave similar results
- Detection failed for 3 species
 - \Rightarrow find more species-specific architectural variables?
 - \Rightarrow include other CT measurements (bark, density...)?
 - \Rightarrow larger sampling?

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 \Rightarrow 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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Other applications

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



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





Manual measurements of knot features

- What can be seen?
- The too
- Application to species classification

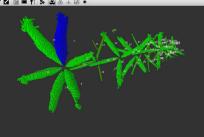
Automatic algorithm for knot features 3DKnotDM

Measurements Limits Work in progress



Automatic knot segmentation

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3DKnotDM software developped in [1].



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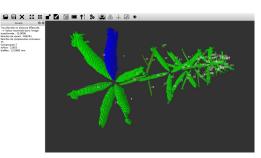
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[1] F. Longuetaud and al., 2012

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.

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

Automatic knot segmentation



3DKnotDM software developped in [1].

1 Thresholding based on knot density



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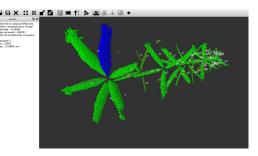
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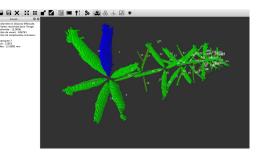
- Thresholding based on knot density
- 2 Extraction of connected components

[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.

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Automatic knot segmentation



3DKnotDM software developped in [1].

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



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.



Manual measurements of knot features

- What can be seen?
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Automatic algorithm for knot features 3DKnotDM

Measurements

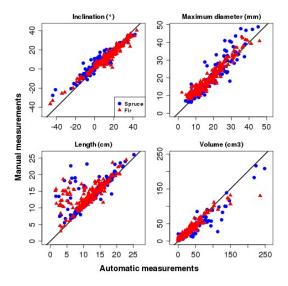
Limits Work in progress



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Automatic vs. manual



Great correlation between feature measures.



Manual measurements of knot features

What can be seen?

The too

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Automatic algorithm for knot features

3DKnotDM Measurements

Limits

Work in progress

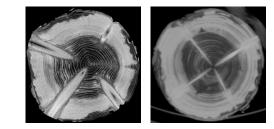


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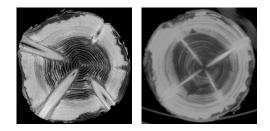
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Segmentation of knots with sapwood



Segmentation of knots with sapwood



Problem

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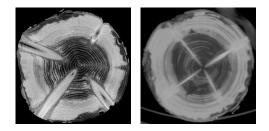
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Density/intensity of sapwood and knots are similar.

Segmentation of knots with sapwood



Problem

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Density/intensity of sapwood and knots are similar.

Consequences

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



Manual measurements of knot features

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Automatic algorithm for knot features

3DKnotDM Measurements Limits Work in progress

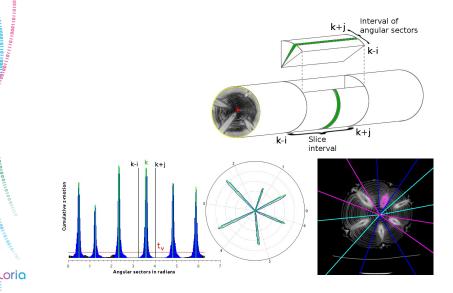


Knot area detection

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

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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

Conclusion

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https://www.nancy.inra.fr/foret_bois_lerfob_eng/ boite_a_outils/tomographie_x Contact: frederic.mothe@nancy.inra.fr

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

3DKnotDM

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http://www.loria.fr/equipes/adage/3DKnotDM
Contact: adrien.krahenbuhl@loria.fr





Thanks for your attention !