Non-destructive analysis of Norway spruce (Picea abies (L.) Karst.) logs by means of CT scans

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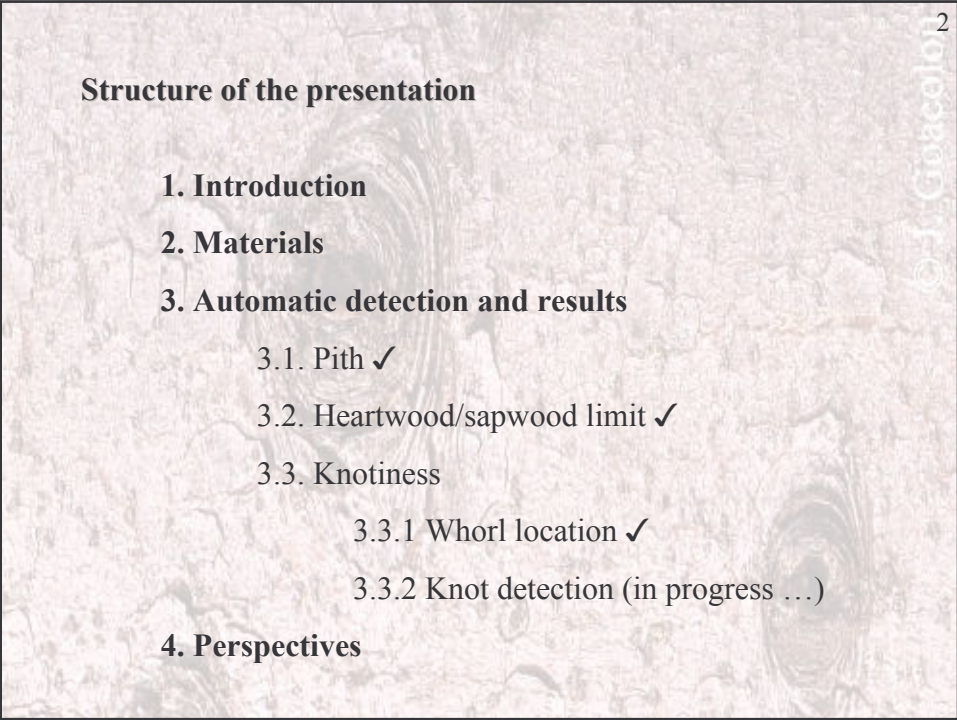
Fleur Longuetaud

9ème rencontre annuelle FOBAWI-LERFoB, INRA Champenoux, 5-6 avril 2005

Structure of the presentation

1. Introduction

2. Materials

3. Automatic detection and results

    3.1. Pith ✓

    3.2. Heartwood/sapwood limit ✓

    3.3. Knotiness

        3.3.1 Whorl location ✓

        3.3.2 Knot detection (in progress …)

4. Perspectives

1. Introduction

In this study spruce logs were scanned with a medical CT scanner.

Objectives:
Automatic detection of wood characteristics (pith, heartwood/sapwood boundary, knots, ...)
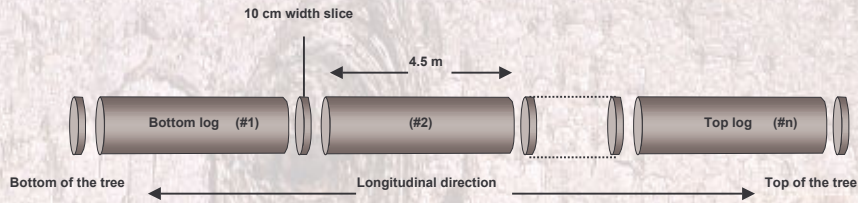
Possible applications:
• Variability analysis of wood properties in a nondestructive way
• Sawing simulation for optimizing the quality of sawn products

2. Materials

24 trees from 4 stands in the north-eastern part of France

Stands	Age	Density (stems/ha)	Fertility class (Décourt)	Dominant height at 100 years (m)	Average diameter (cm)	Average height (m)
31	66	510	4	33	31.4	23.6
32	95	520	2	36.1	39	33.5
33	68	800	2	38.3	32.1	29.4
34	133	520	4	31.1	43.2	31.9

The trees were cut in logs ...

10 cm width slice

4.5 m

| Bottom log (#1) | (#2) | Top log (#n) |

Bottom of the tree   **Longitudinal direction**   **Top of the tree**

Then, each log was scanned in a **medical CT scanner**

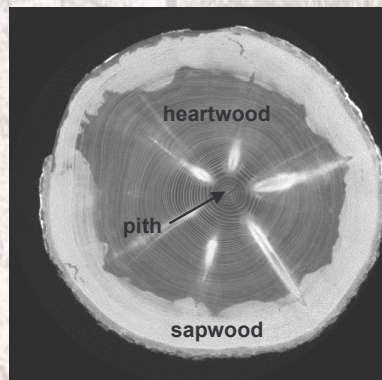(European Research Project STUD)

512 pixels

512 pixels

… resulting in a **stack of CT slices**

Size of a pixel: between 0.68 and 0.88 mm

1 cm
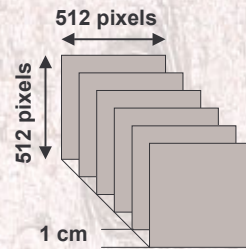
Some examples of CT slices

heartwood

pith

sapwood

knot
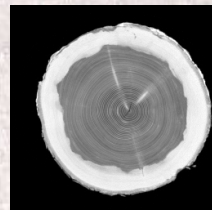
Bottom log (34-4-1)
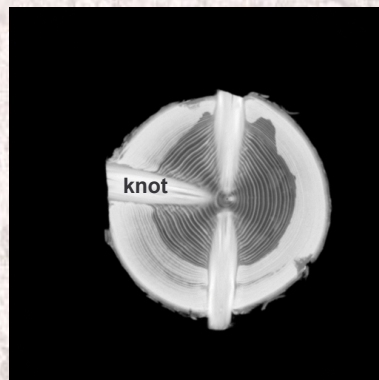
Top log (34-3-5)

Some examples of particular CT slices
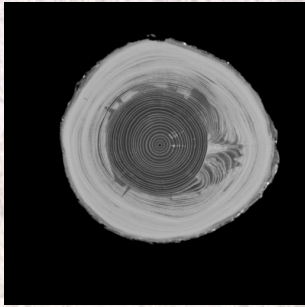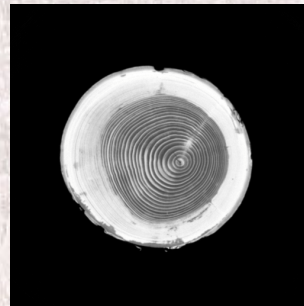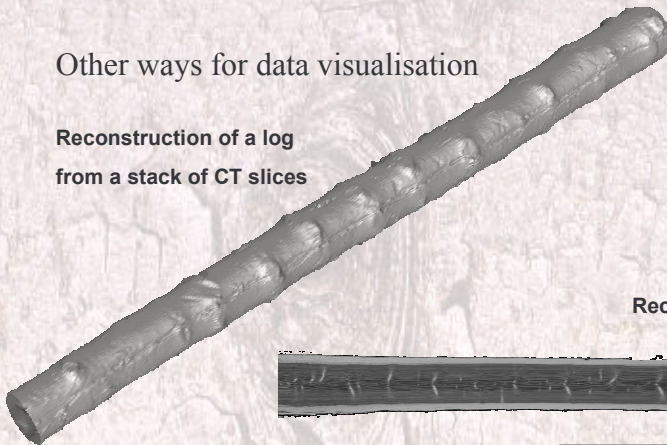
Compression wood
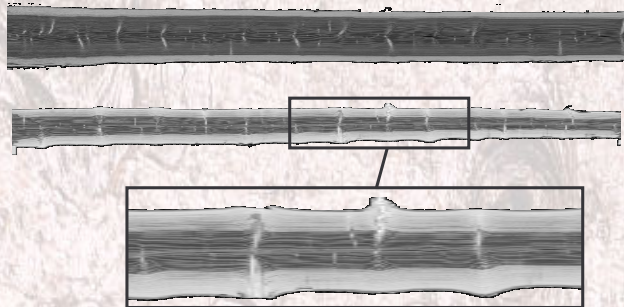
Wound ?
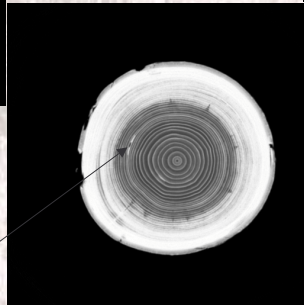
Resin pocket

Other ways for data visualisation

Reconstruction of a log
from a stack of CT slices

Reconstruction of boards
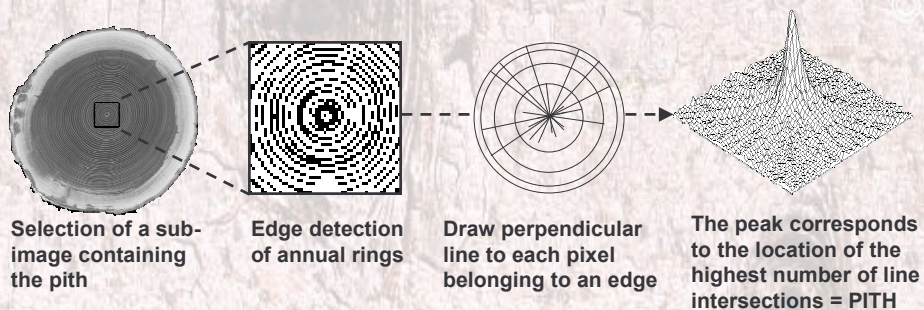
3. Automatic detection (AD) and results

Structure of the work done during the thesis

AD of the **pith** — Pith density (in progress)
Eccentricity

AD of the **heartwood/sapwood limit** — Analysis on the amount of heartwood and sapwood

Knotiness

•AD of **whorl location** inside logs

•AD of **individual knots** (in progress)
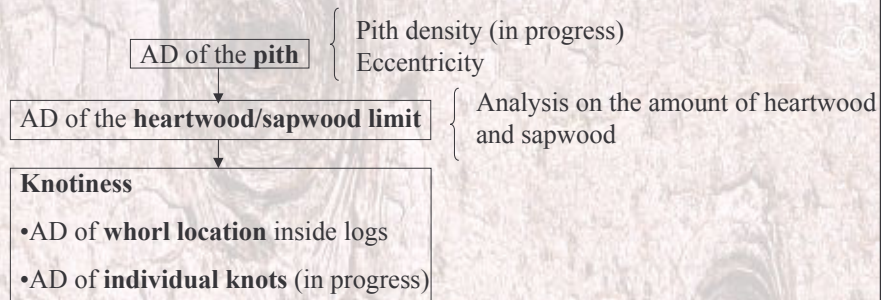
3.1. Pith detection

Completely automatic detection of the pith location inside logs.
A Hough transform was used based on the annual ring pattern.

Example of a slice without knots:

Selection of a sub-image containing the pith

Edge detection of annual rings

Draw perpendicular line to each pixel belonging to an edge

The peak corresponds to the location of the highest number of line intersections = PITH
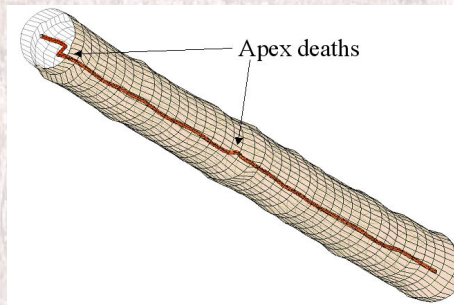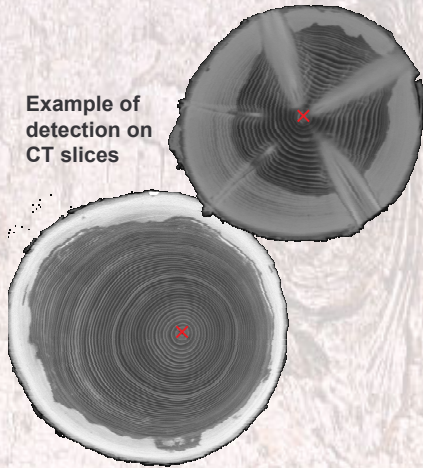
The algorithm also deals with slices containing knots but this more complicated case will not be presented here.

Results

Example of
detection on
CT slices

Apex deaths

3D pith profile inside a log

An example of direct application

Tree #31-1-2 slice #50

Tree #32-5-1 slice #130

Bark —— Bark ellipse fit ● Pith ☐ G Cross-section

Bark —— Bark ellipse fit ● Pith ☐ G Cross-section
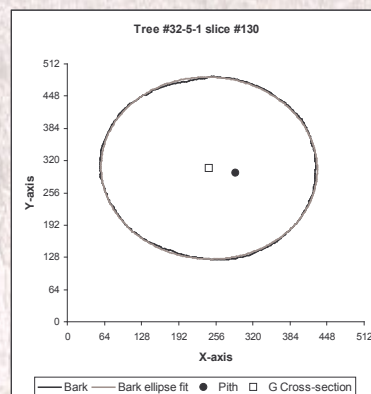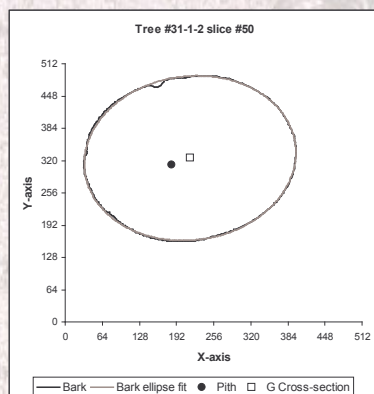
Eccentricity measurements
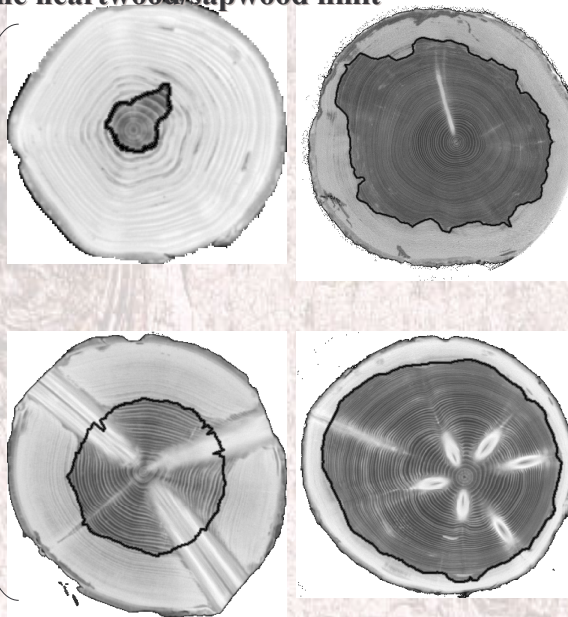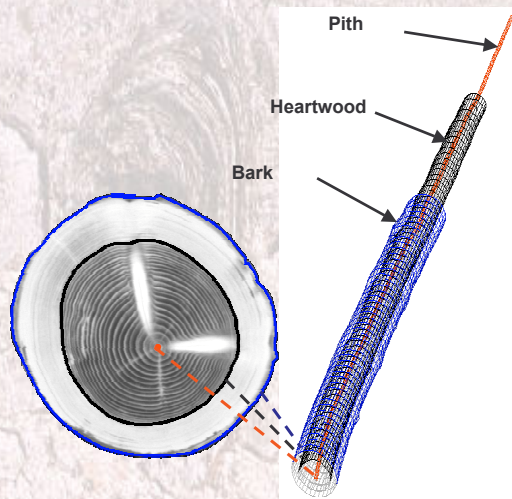
Other applications ...

3.2. Detection of the heartwood/sapwood limit

Completely automatic
detection inside
logs

**Few examples on
CT slices**

Pith

Heartwood

Bark

2D and 3D visualisation of pith (red), heartwood (black) and bark (blue)

The detection of the heartwood/sapwood boundary makes it possible variability analysis

Within-tree variations

Stand #31 *Stand #34*

A young tree   **An old tree**   *Growth unit*
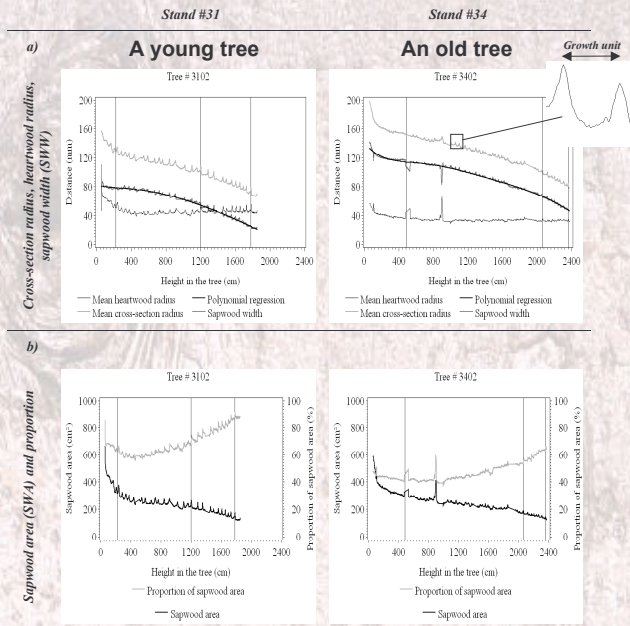
Example of between-tree variations and relationship with the crown size

Stand #31: y = 0.0034x + 2.8477
Stand #32: y = 0.0038x + 1.2952
Stand #33: y = 0.0032x + 2.2284
Stand #34: y = 0.0019x + 2.0815

3.3. Knotiness
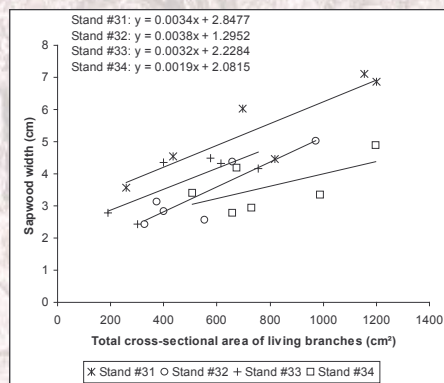
3.3.1 Whorl location
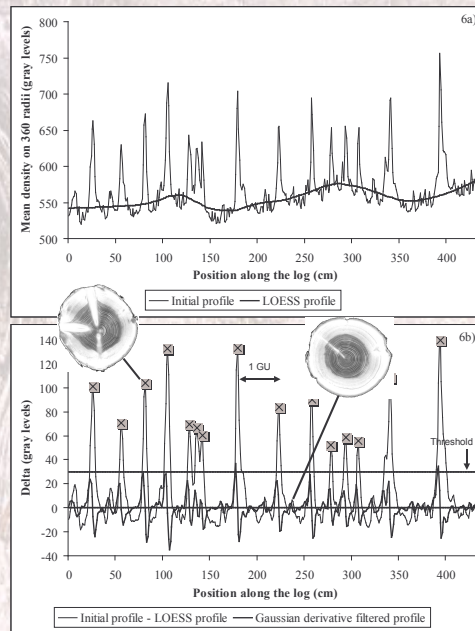
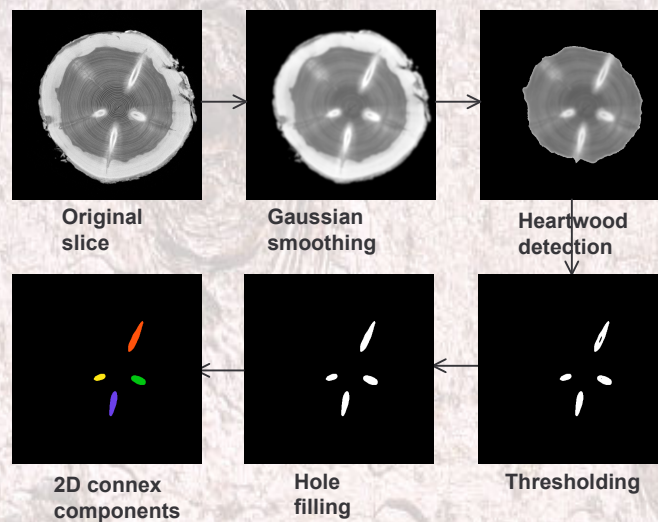Possibility to detect the whorls and to measure the length of annual growth units.

The main difficulty was the presence of lamma shoots (more than one annual growth unit in one year) ...
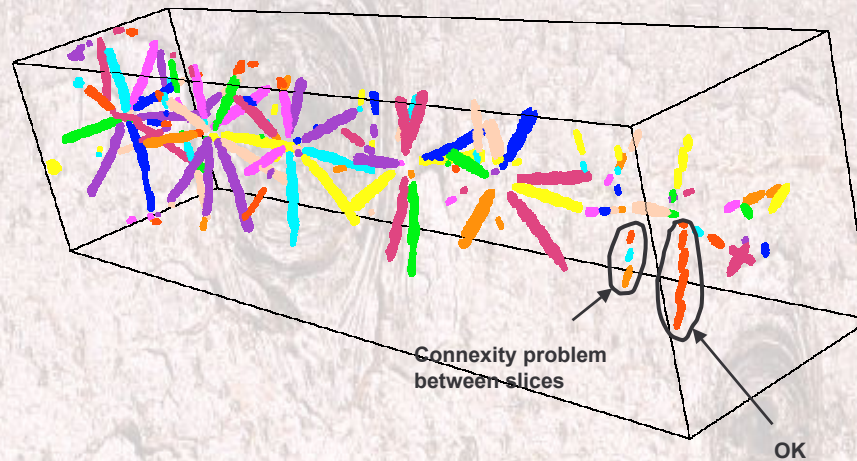
3.3.2 Knot detection (in progress …)

Preliminary results: knot detection in 2D in the heartwood

Original slice → Gaussian smoothing → Heartwood detection

2D connex components ← Hole filling ← Thresholding

Previous obtained results for the 3D reconstruction of knots using 3D connex components.

Connexity problem between slices

OK

Modifications and improvements are in progress ...

4. Perspectives

Before the end of the Ph.D:
- Finalizing the knot detection in the heartwood:
    3D reconstruction and parameter measurements
    (diameter, azimuth, inclination)

Post-doc:
- Knot detection in sapwood
- Annual ring detection (I already obtained interesting results)
- Compression wood detection
...

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THANK YOU

References:

Longuetaud, F., Mothe, F., Leban, J.-M., Mäkelä, A. 2005. Analysis of *Picea Abies* Sapwood by Means of CT Images: Within-tree variations and Relationships with Tree Measurements. Submitted in Scandinavian Journal of Forest Research.

Longuetaud, F., Mothe, F.& Leban, J.-M. 2005. Automatic Detection of the Heartwood/Sapwood Boundary on Series of CT Images of Norway Spruce (*Picea abies*) Logs. Submitted in Computers and electronics in agriculture.

Longuetaud, F., Saint-André, L., Leban, J.-M. 2005. Automatic detection of annual growth units on *Picea abies* logs using optical and X-ray techniques. Journal of Nondestructive evaluation 24(2), in press.

Longuetaud, F., Leban, J.-M., Mothe, F., Kerrien, E., Berger, M.-O. 2004. Automatic detection of pith on CT images of Spruce logs. Computers and Electronics in Agriculture 44, 107-119.