

Strength Grading

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CONTRIBUTION OF SLOPE OF
GRAIN INFORMATION
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WoodNDT – Structural Lumber Grading

Arnaud JEHL, 14 September 2011

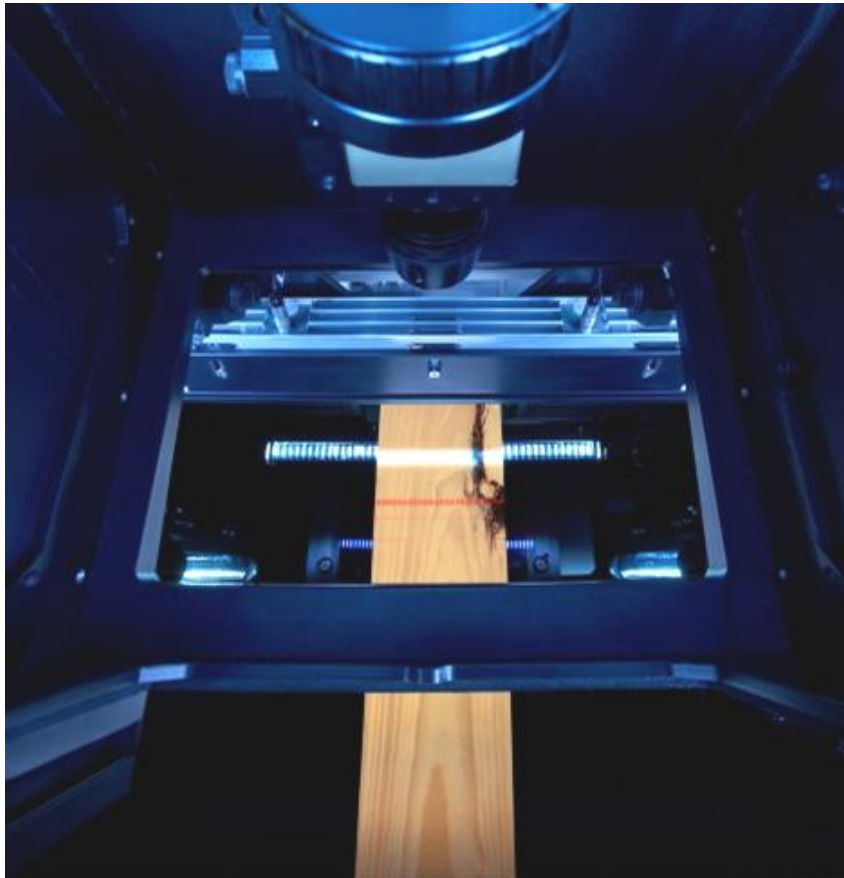
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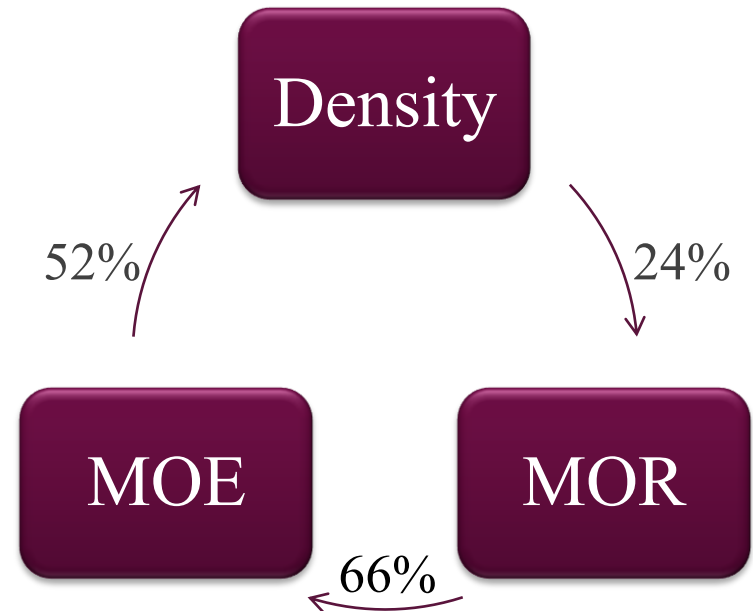
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Introduction

Destructive properties relationships (R^2)

- For \approx 1400 spruce boards
- High MOE – MOR correlation
- Final accuracy limited
- No board optimization

→ Approach : taking local singularities in account



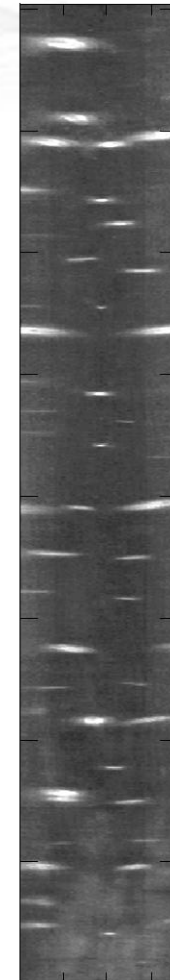


Introduction

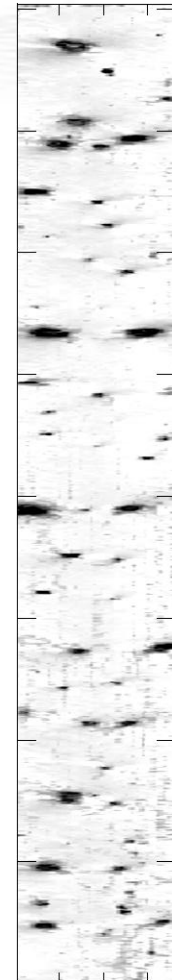
Macroscopic heterogeneities

- Most critical : knots
- Slope of grain around knots
- Compression wood areas
- Juvenile wood areas

→ Need to be detected and mechanically modeled



Local Density



Slope of grain

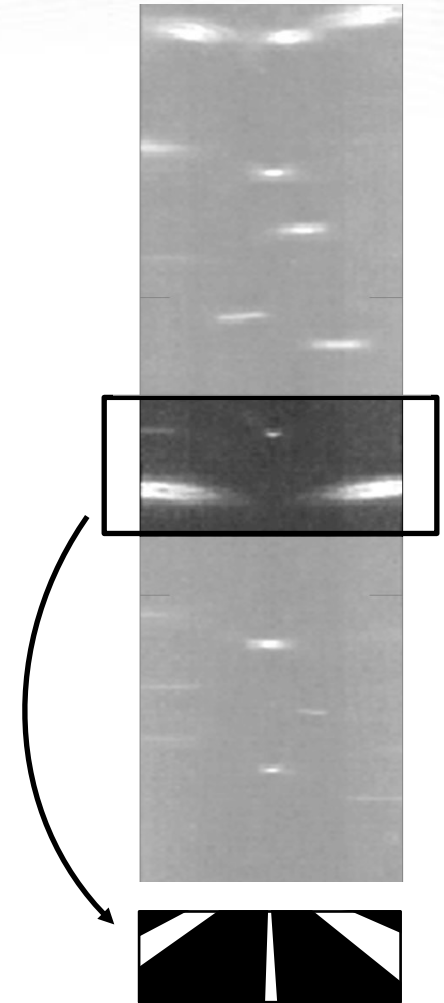


State of the Art

KAR-like models

- Measures max local knots proportion
- knots detected by X-Rays...
- ... or on faces, then matched (Roblot, 2010)
- Works well, gives good results

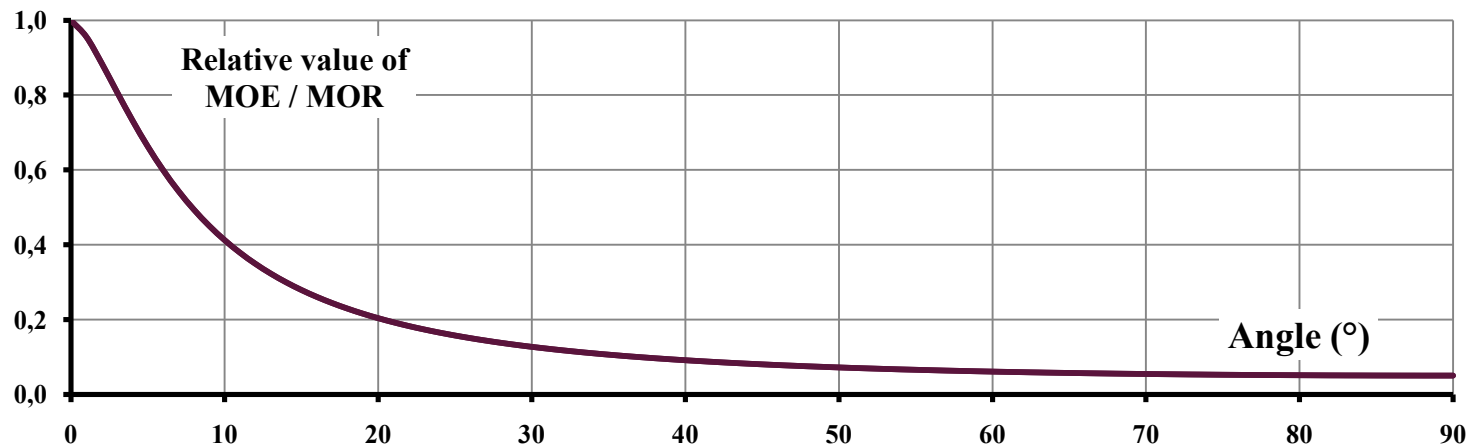
→ Reference for further analysis





State of the Art

Slope of grain's mechanical influence



- Well-known in case of small wood samples, see Hankinson formula
- Mainly located around knots

→ **What is its influence on a full-size board ?**



Materials & Methods

Objective

- Define a method to estimate fibers diving angle
- Adapt the KAR model in order to take in account slope of grain
- 2 cases : projected angle & projected + diving angles
- 2 machines : optical scanner & optical scanner + vibration analysis
- Compare to a “basic” KAR model

Materials & Methods

Materials

- 350 boards of European spruce, 4m, various cross-sections
- E-Scan → vibration analysis
- CombiScan+ → images
- Matlab processing
- IPs compared to tension tests



Materials & Methods

Local knots depth measurement

- Hypothesis : homogeneous CW and knots density (2 phases material)
- ...knots density $\approx 2x$ CW density

Relative knot depth (KDR)

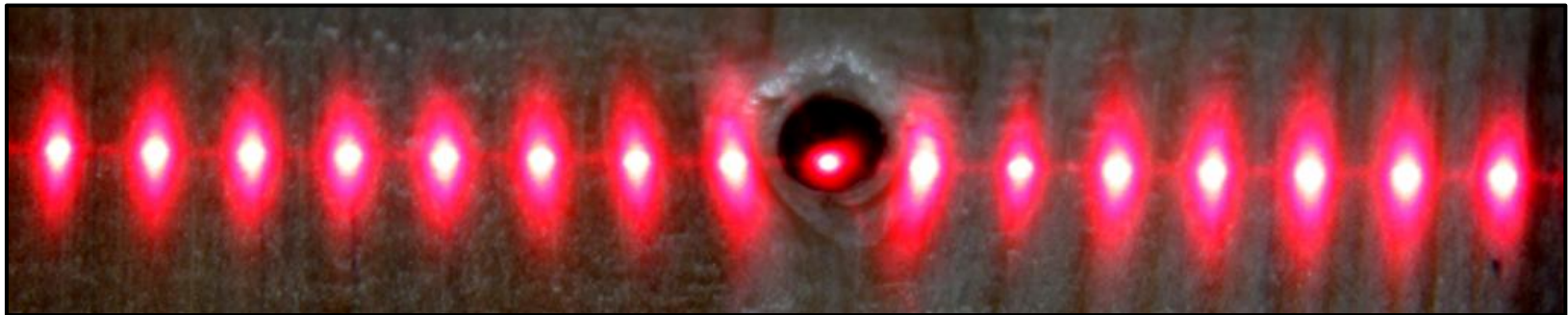




Materials & Methods

Projected angle measurement

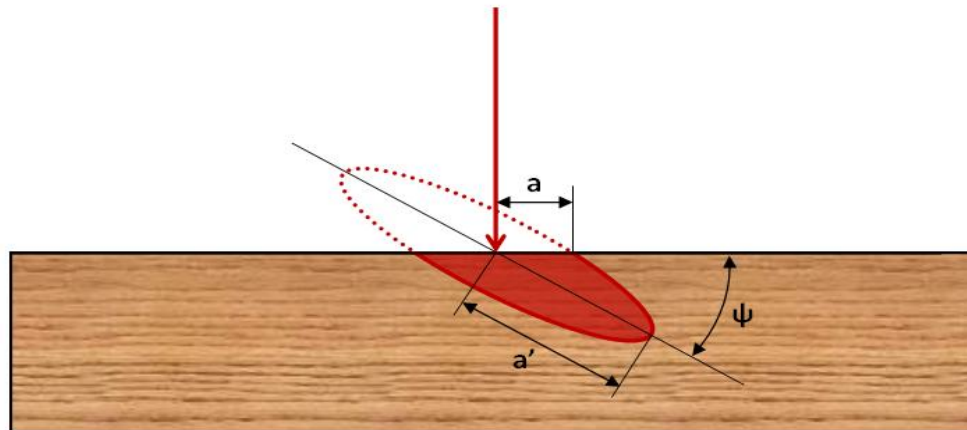
- Based on tracheid effect
- Measured on top & bottom faces



Materials & Methods

Diving angle measurement

- Uses the ellipses shape factor
- Hypothesis : orthotropic light scattering
- High sensitivity around 0°
- Statistical estimation of the 0° shape factor \rightarrow may lead to high noise

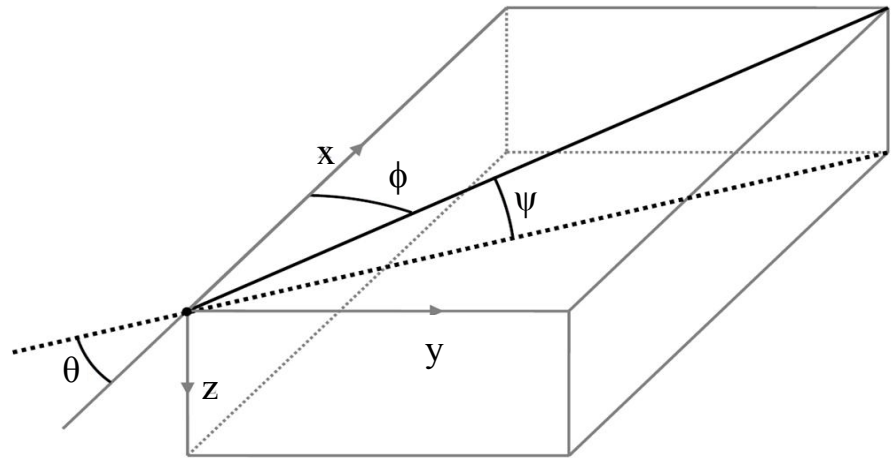


Materials & Methods

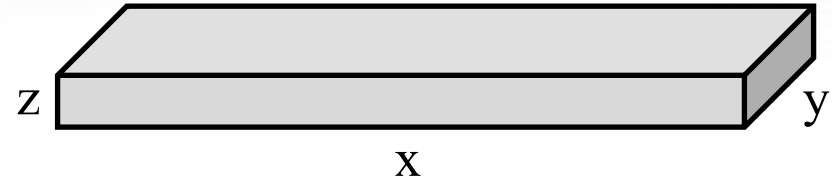
SoG estimation “inside” wood

- Combine projected and diving angle (see below)
- **Strong hypothesis : linear distribution between top & bottom**
- Apply Hankinson formula each 1 mm

$$\cos(\theta) = \cos(\psi) \times \cos(\phi)$$



Materials & Methods



Data processing

(Mitsuhashi, 2008)

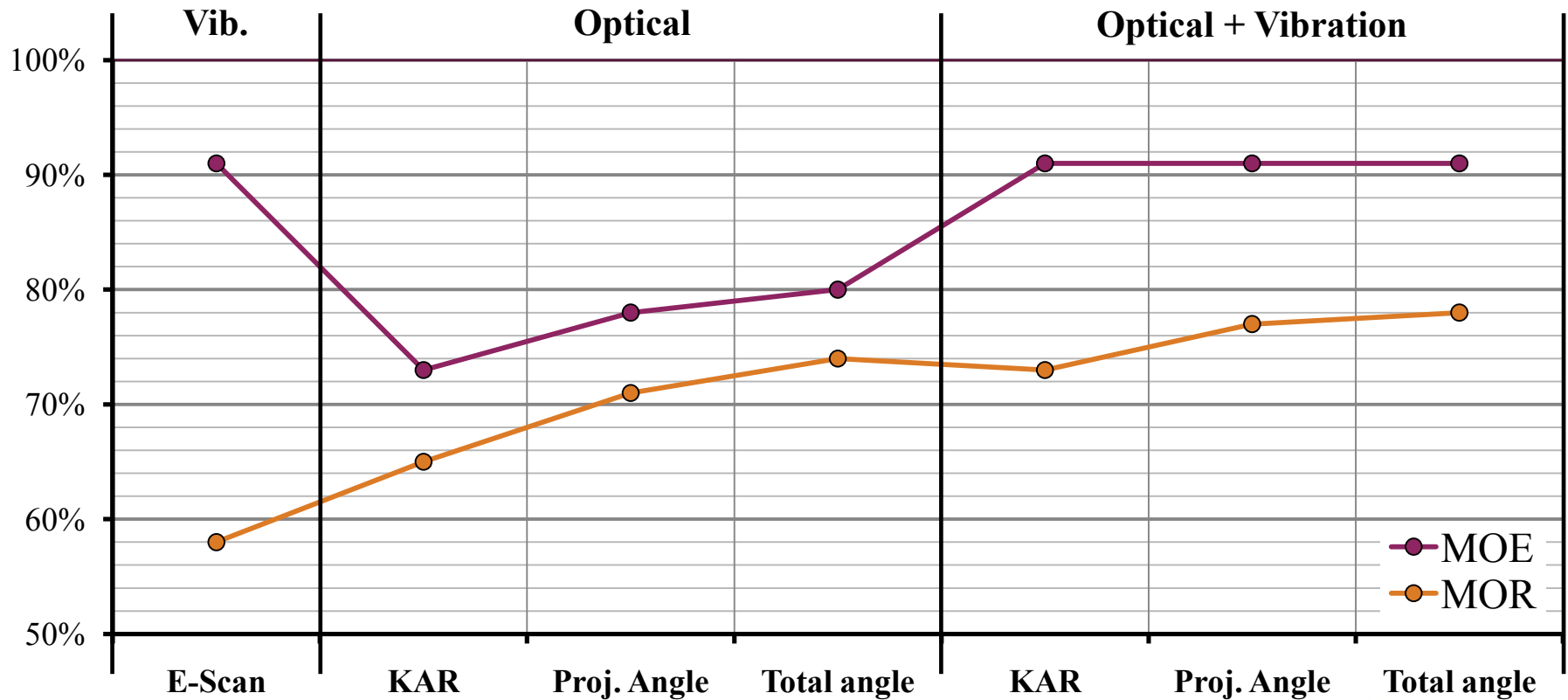
$$CWAR(x) = \frac{1}{w} \int [1 - KDR(x, y)] \cdot H(\theta_1, \theta_2) dy$$

Knots influence
Slope of grain
(linear regression+ Hankinson)

- Mean * clear wood Elast. = MOE
= λ x CW strength
- Minimum * CW strength = MOR

Résultats

Results obtained (R²)





Discussion / Conclusions

Discussion

- Nb of samples sufficient to highlight a tendency
- Diving angle measurement → sensitive to roughness
- SoG linear variation hypothesis currently studied

Conclusions

- MOE + MOR estimation strongly improved
- Efficient data processing method, might be improved
- Will be implemented in scanners, repeatability & robustness OK



Thanks for your attention

Do you have any question?



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