NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Sawing optimization based on X-ray computed tomography images of internal log attributes

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Université Laval

Canadian Wood Fibre Centre
Working together to optimize wood fibre value – creating forest sector solutions with FPInnovations

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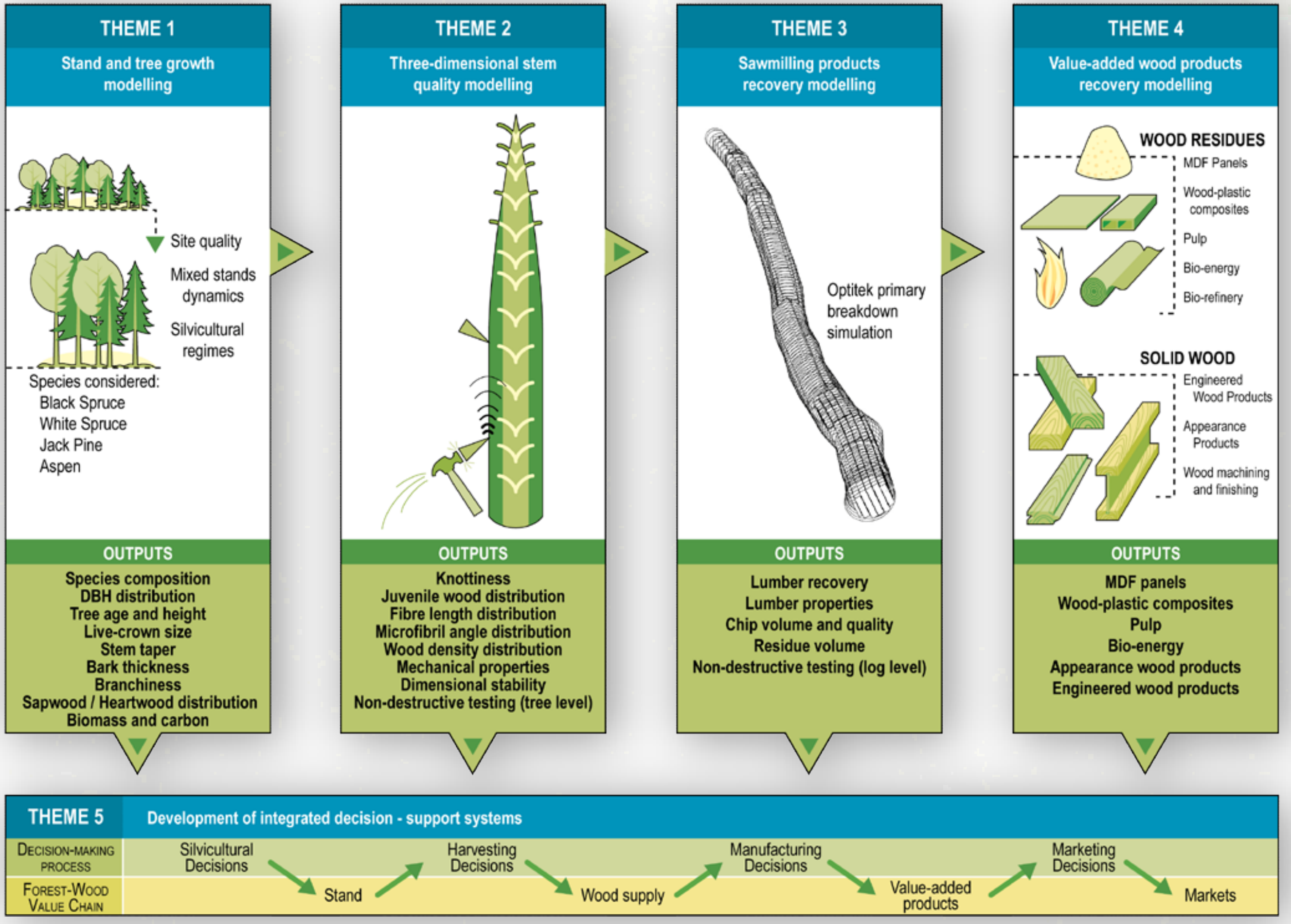

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Outline

1. Introduction and Objectives
2. Approach
3. Knot detection tool for CT images of logs – **CT2Opti**
4. Results - Sawing simulations results in Optitek
5. Conclusions and Next steps

Introduction

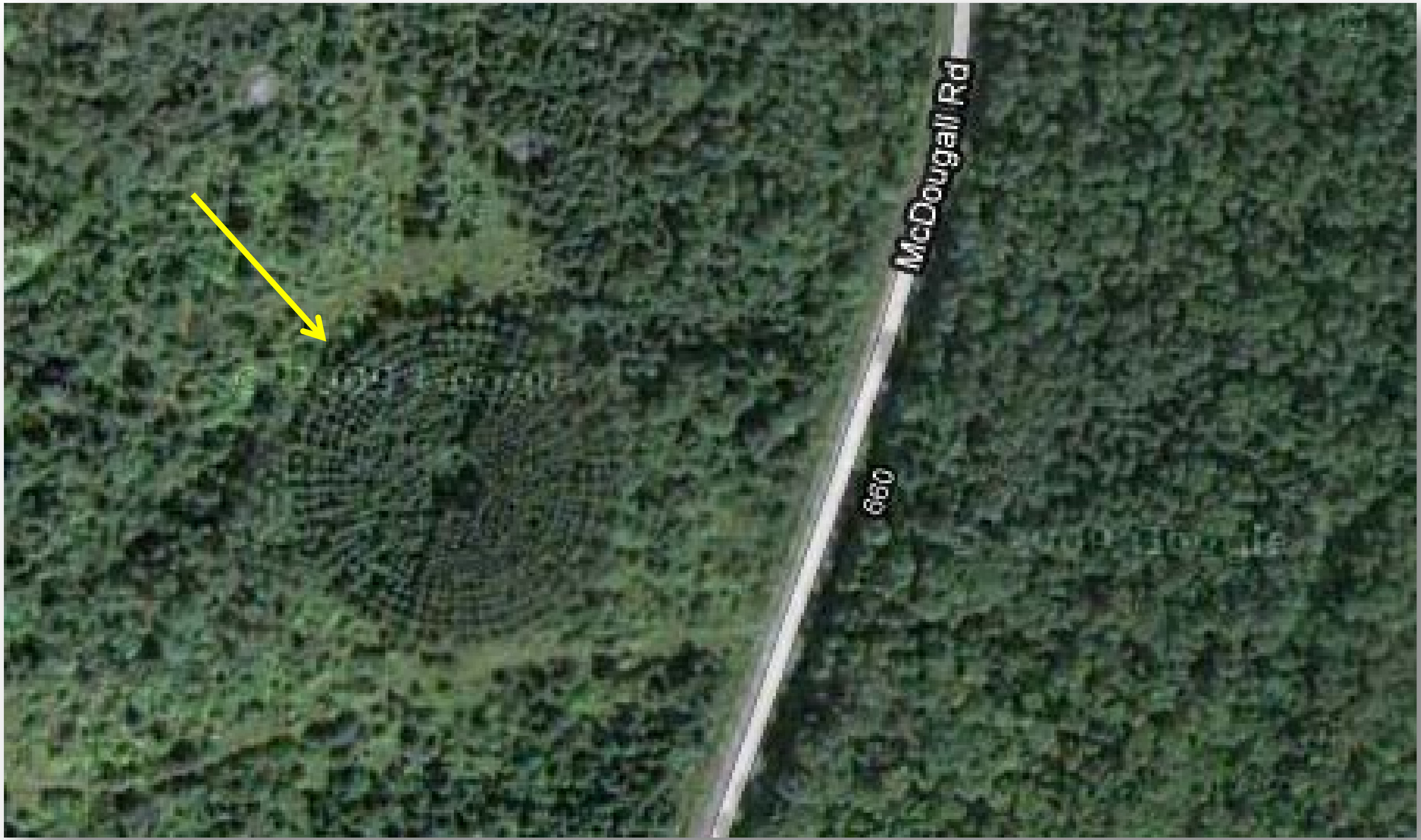
- Current **sawing optimization strategies** in softwood sawmills are mainly based on **external log characteristics.** Yet, **knots** are one of the major defects affecting stem quality and lumber structural performance (e.g. Oyen *et al*. 1999; Longuetaud *et al.* 2012).

- **Knowledge of internal log attributes** is important to adapt sawing patterns to the characteristics of fibre supply and extract more value.

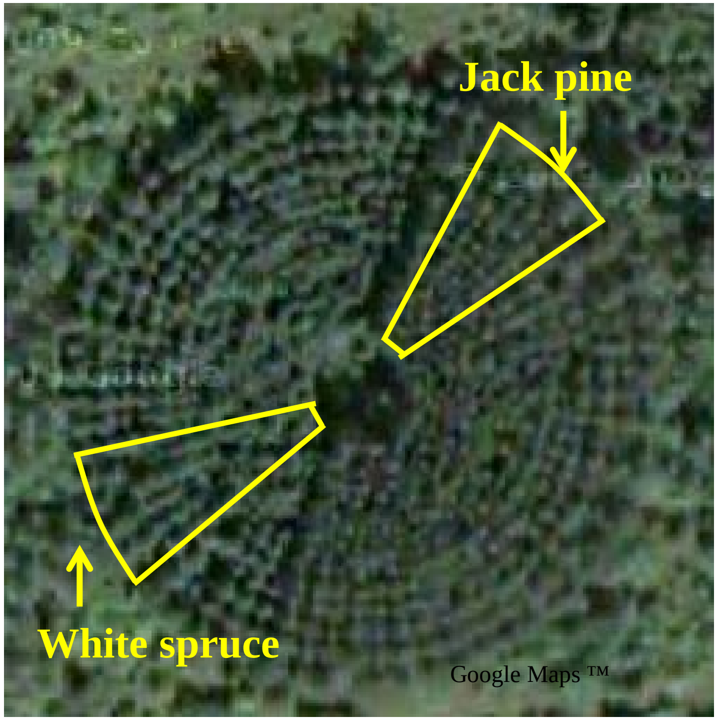
Objectives

- Evaluate whether knowledge of **internal knottiness** combined with **optimized log rotation** could increase **lumber value yields** for white spruce (*Picea glauca* (Moench)) and jack pine (*Pinus banksiana* Lamb.) stems.

Material: 32-year old Nelder type plantation established by the New Brunswick Department of Natural Resources in 1977



Material: 32-year old plantation grown in New Brunswick, Canada



Type Ia Nelder spacing design

Spacing/density range:

- 0.87 × 0.91 m ~ 3.50 × 3.66 m
- 12,000 ~ 600 stems per hectare

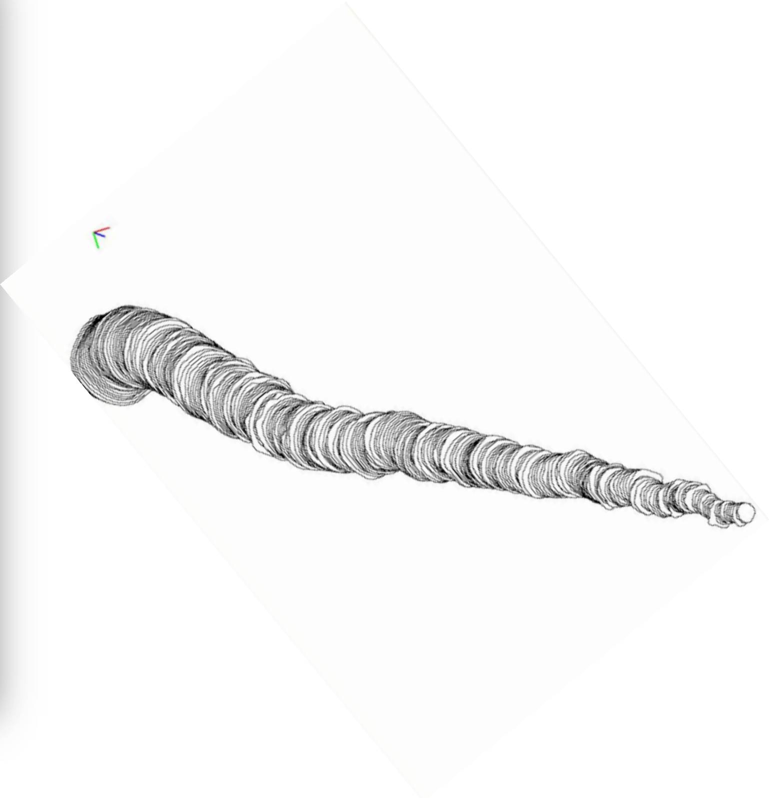
53 trees harvested:

- 31 white spruce *(Picea glauca)*
- 22 jack pine *(Pinus banksiana)*

White spruce

Jack pine

External stem shape assessment using FPInnovations portable laser scanner



Average stem characteristics measured from FPInnovations portable laser scanner and Optitek

Species		Scanned Length (m)	DBH (cm)	Taper (cm/m)	Sweep (cm/m)	Merchantable volume (dm^3)
White spruce	**avg.**	**6.9**	**16.2**	**1.2**	**0.5**	**99.4**
	st. dev.	2.1	3.9	0.3	0.2	59.9
	max.	10.5	25.3	2.0	1.4	270.7
	min.	2.5	9.6	0.6	0.2	11.3
Jack pine	**avg.**	**10.3**	**18.1**	**0.6**	**1.0**	**174.5**
	st. dev.	1.6	4.2	0.2	0.3	85.3
	max.	13.0	27.7	1.6	2.0	357.2
	min.	5.3	10.8	0.3	0.5	27.2

CT scanning of 173 logs

Institut National de la Recherche Scientifique (INRS), Québec (Canada)

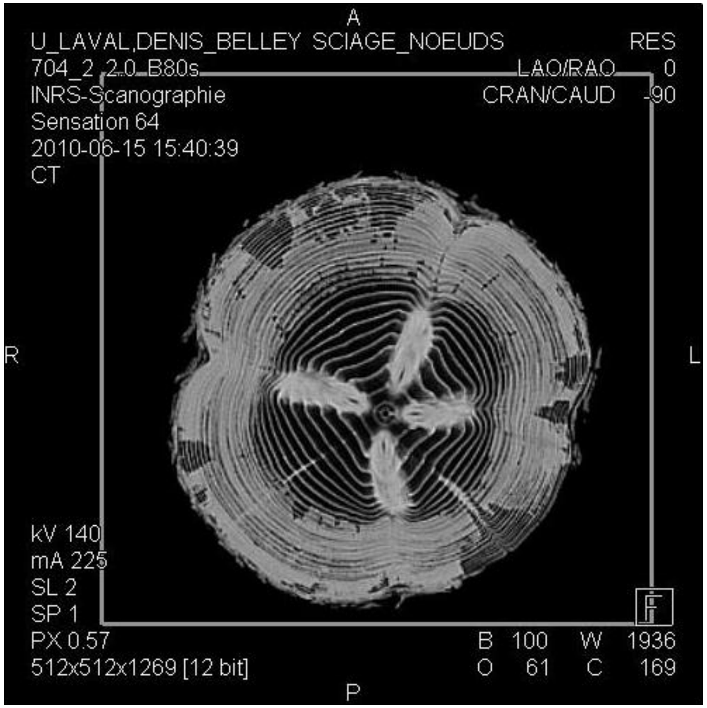
Siemens Somatom Sensation 64 medical scanner

CT-scanner parameters:
a slice every mm
a thickness of 2 mm (creating a superposition of 1 mm)
140 kV
B80s Kernel
150 mA
Pitch of 1.5

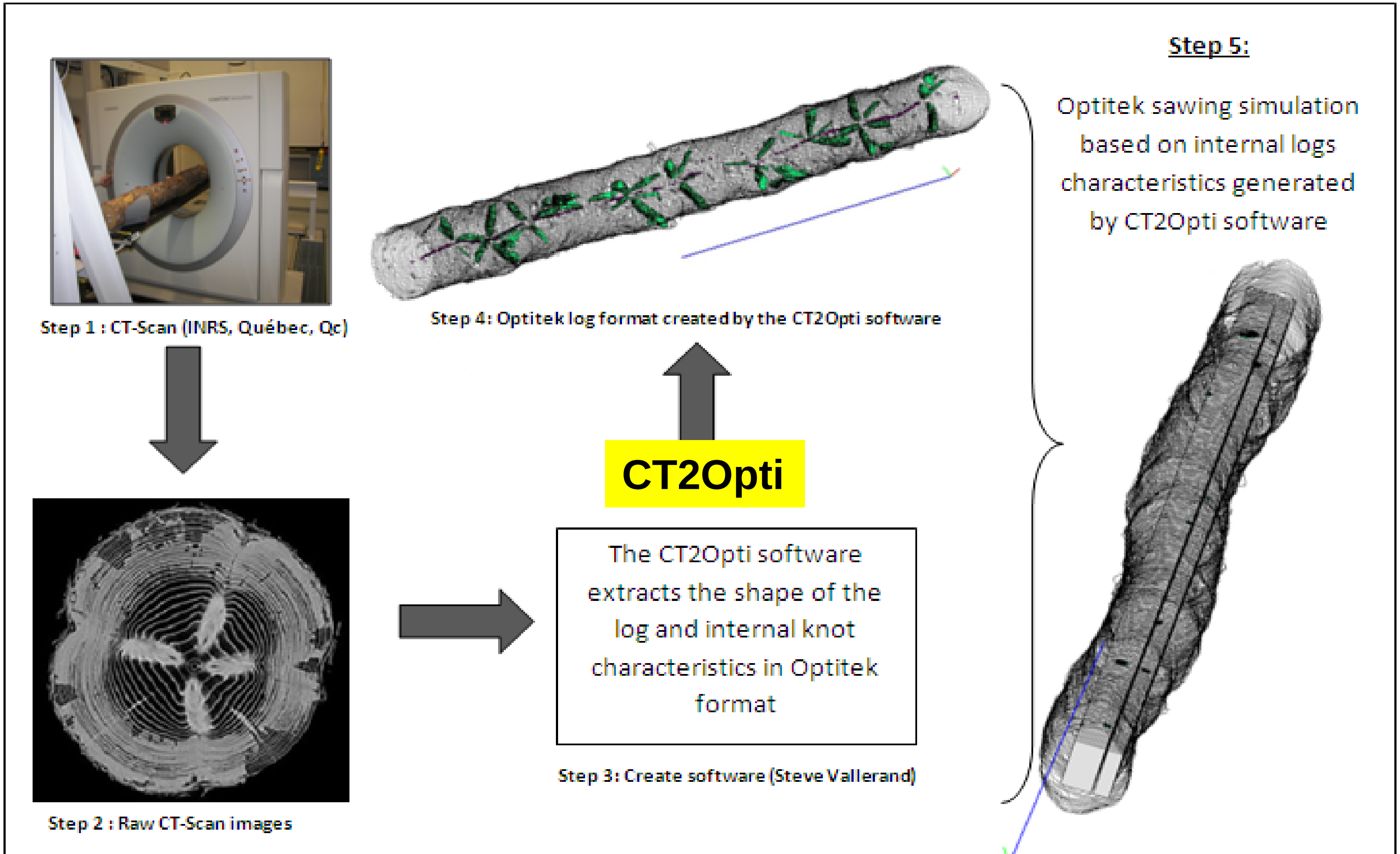
Log length: 2.5 m

2500 CT-images per log

CT images – Jack pine

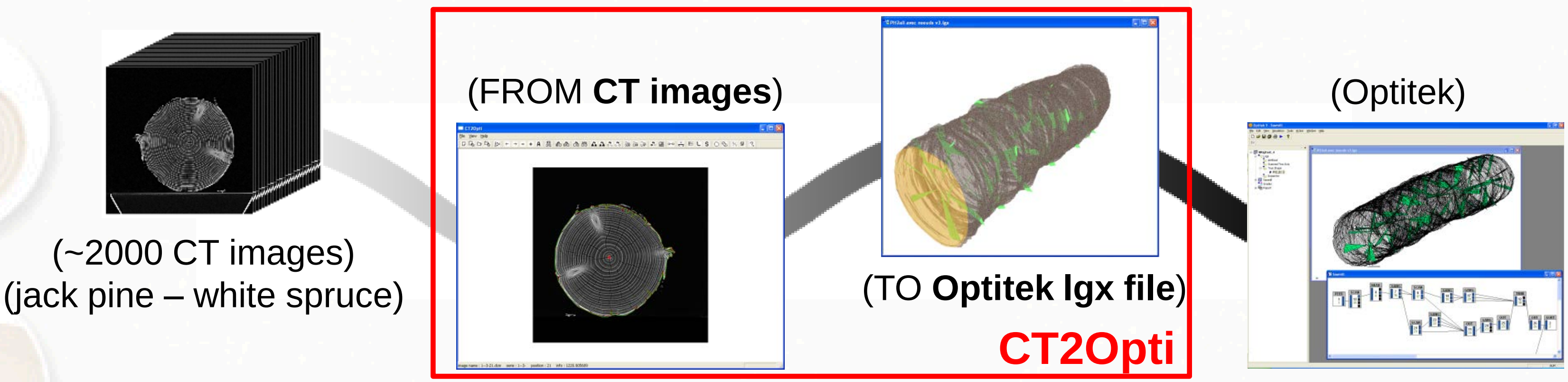


Development of a knot recognition tool based on CT images: CT2Opti



CT2Opti

- **Extracts log shape, pith point and knots from a set of CT images**
- **Merges the data into an Optitek formatted log**



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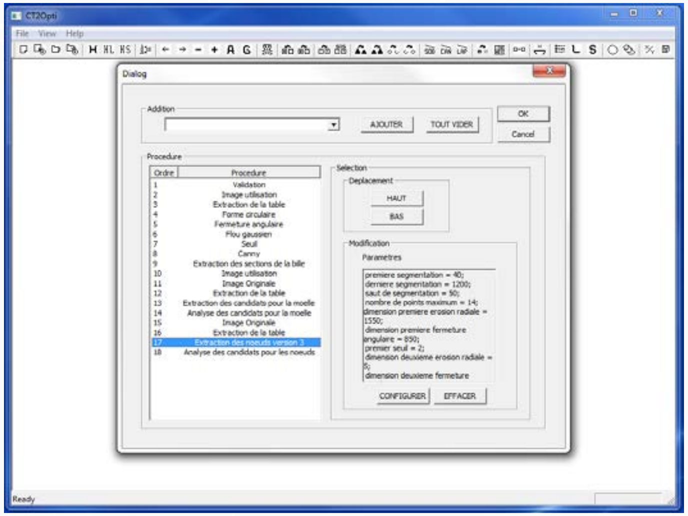
CT2Opti software

More than 50 image processing functions

- Morphological operations (erosion, dilatation, opening, closing, …)
- Edge detector (Sobel, Canny, Laplacian, …)
- Threshold (basic, simple image statistics, step threshold, …)
- Filter (Gaussian, custom, …)
- Multiframe (substraction, binary operators, …)
- Complex processes (table, shape, pith and knot extractions, …)

Features

- Quick reload using historic files
- Batch process
- Inverse log (small or big end first)
- Generate Optitek log



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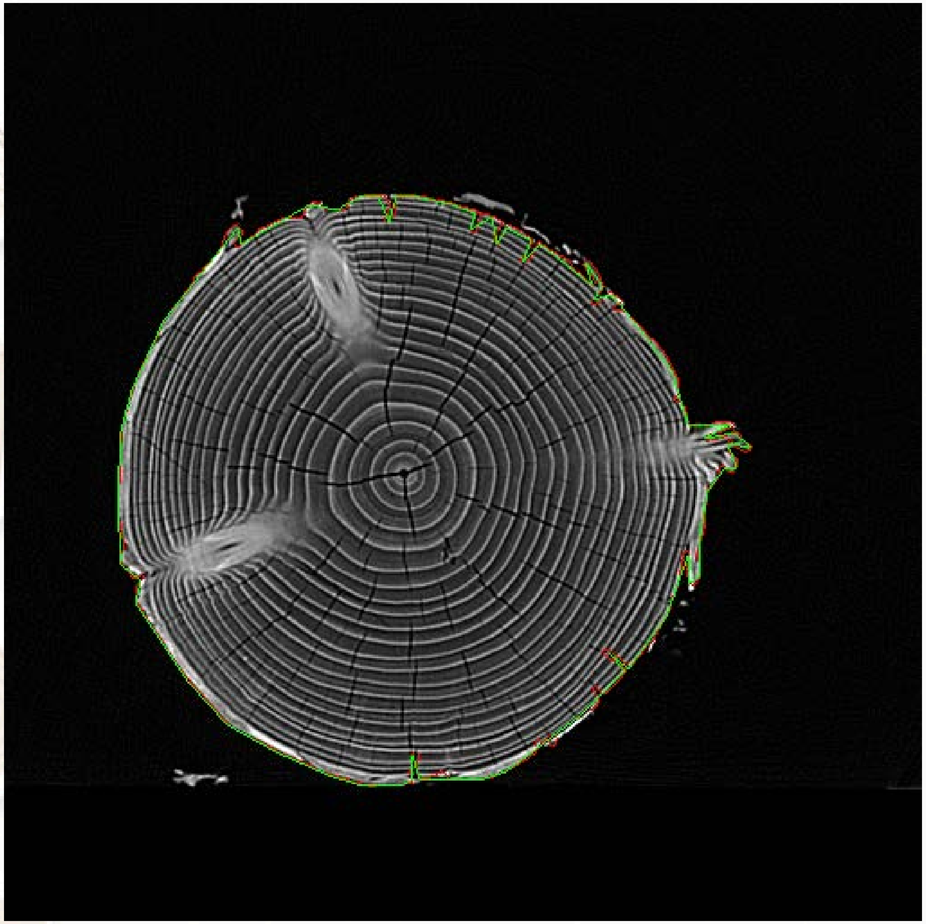
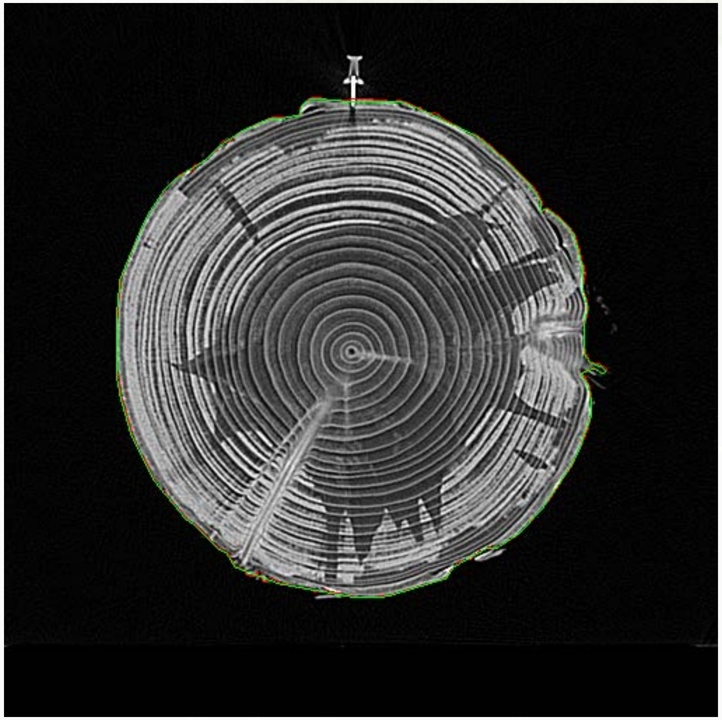
Shape

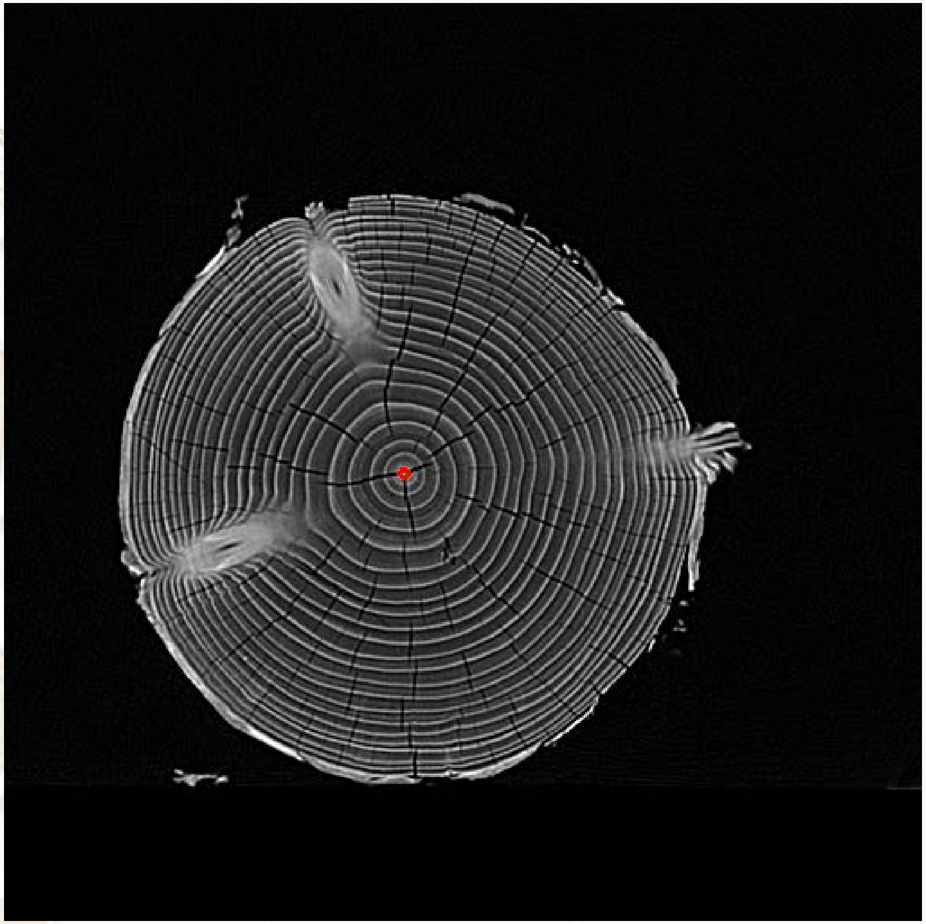




Contour points (> 2000 points)

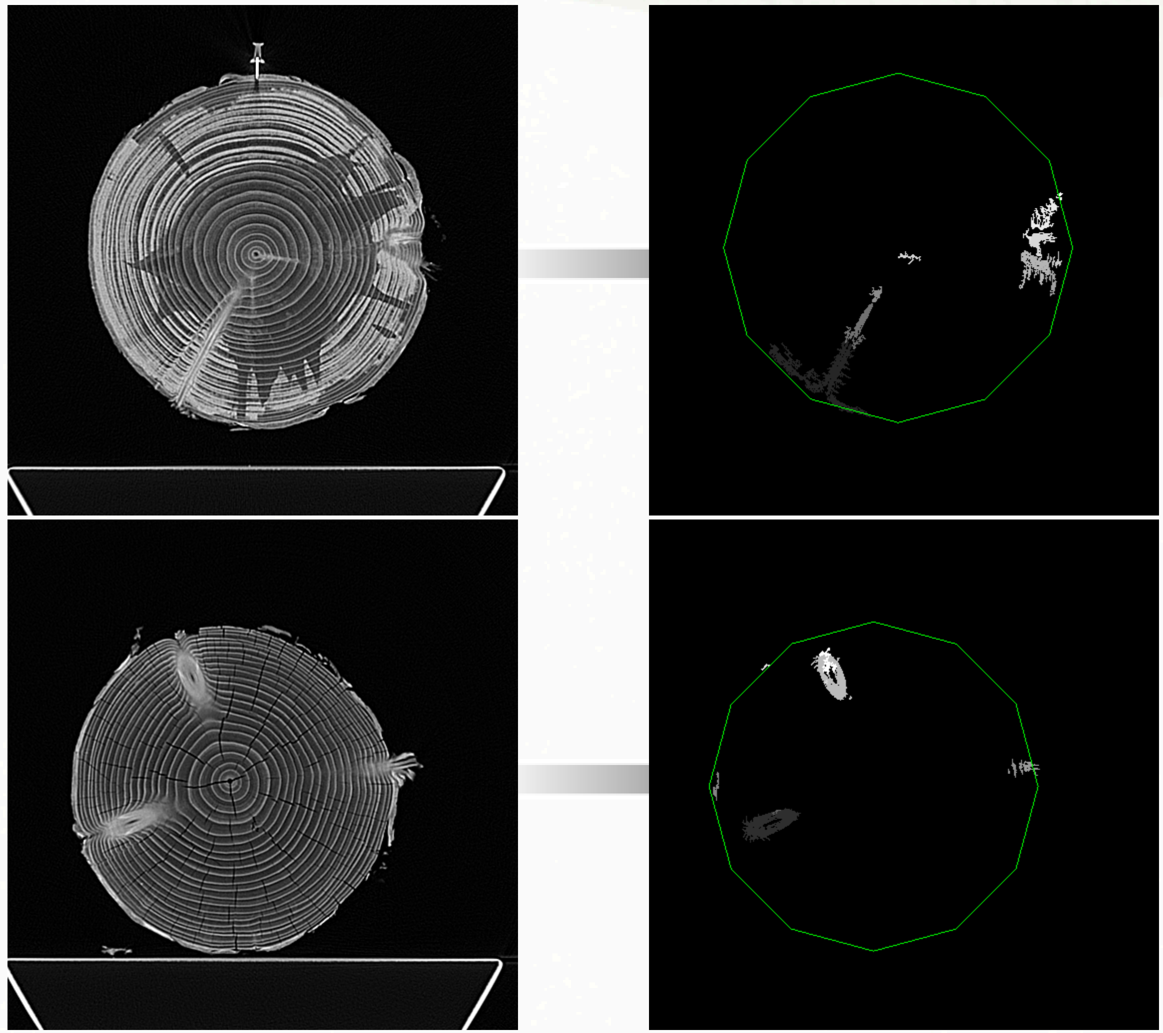
Model points (= 60 points)

Pith point



- Pith point candidates
- Pith point

Knot detection



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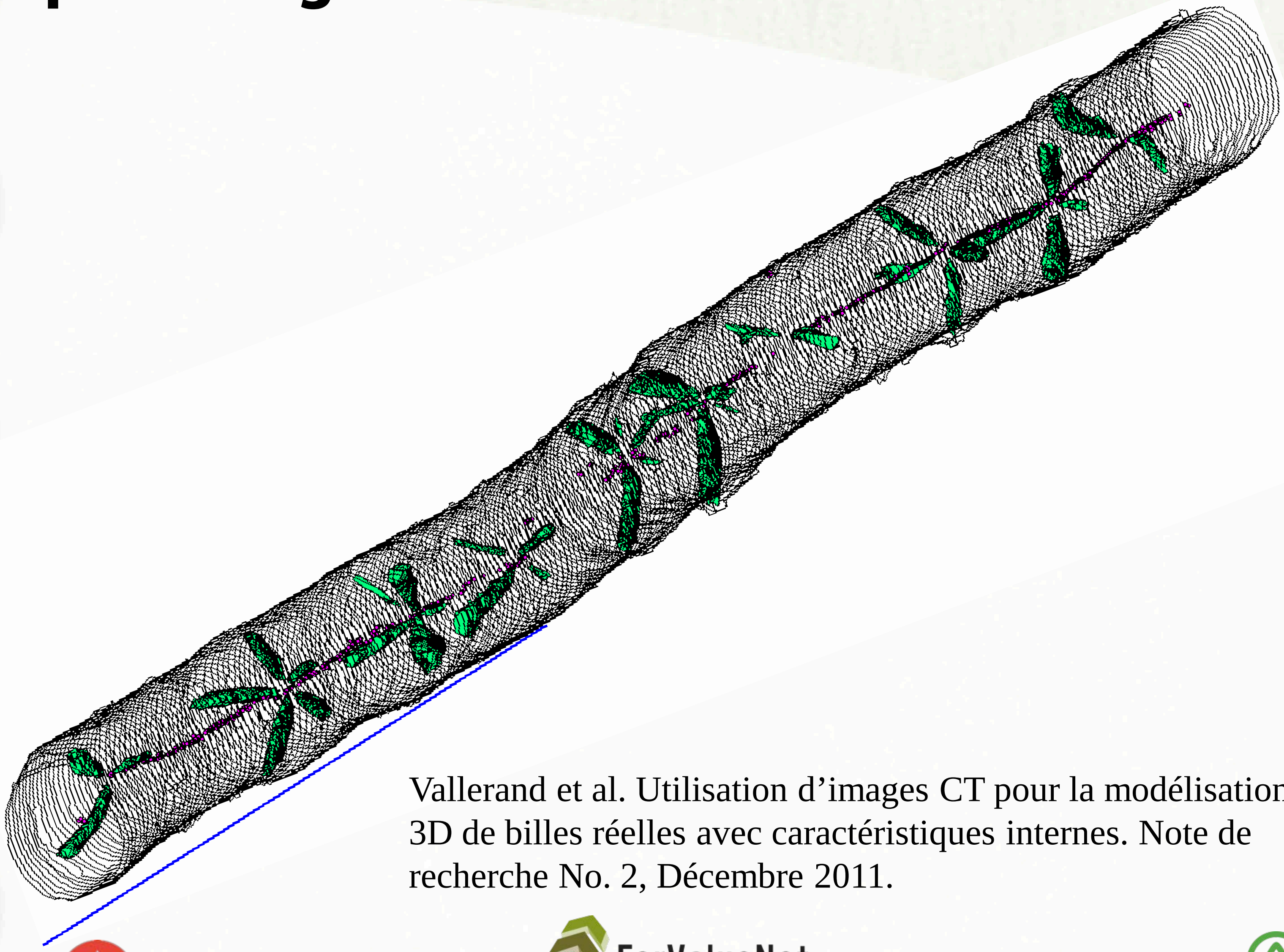
Optitek log model with internal knots



Vallerand et al. Utilisation d'images CT pour la modélisation 3D de billes réelles avec caractéristiques internes. Note de recherche No. 2, Décembre 2011.

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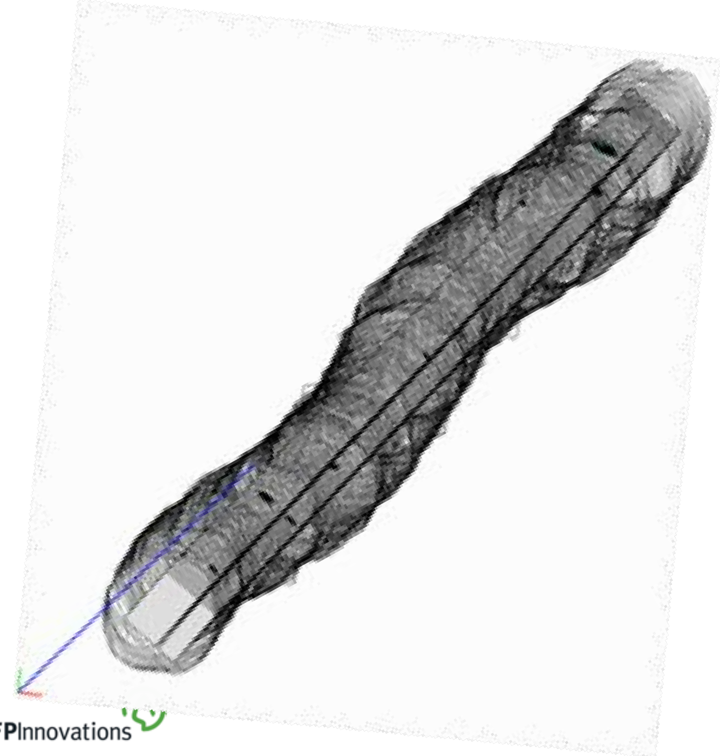
Approach

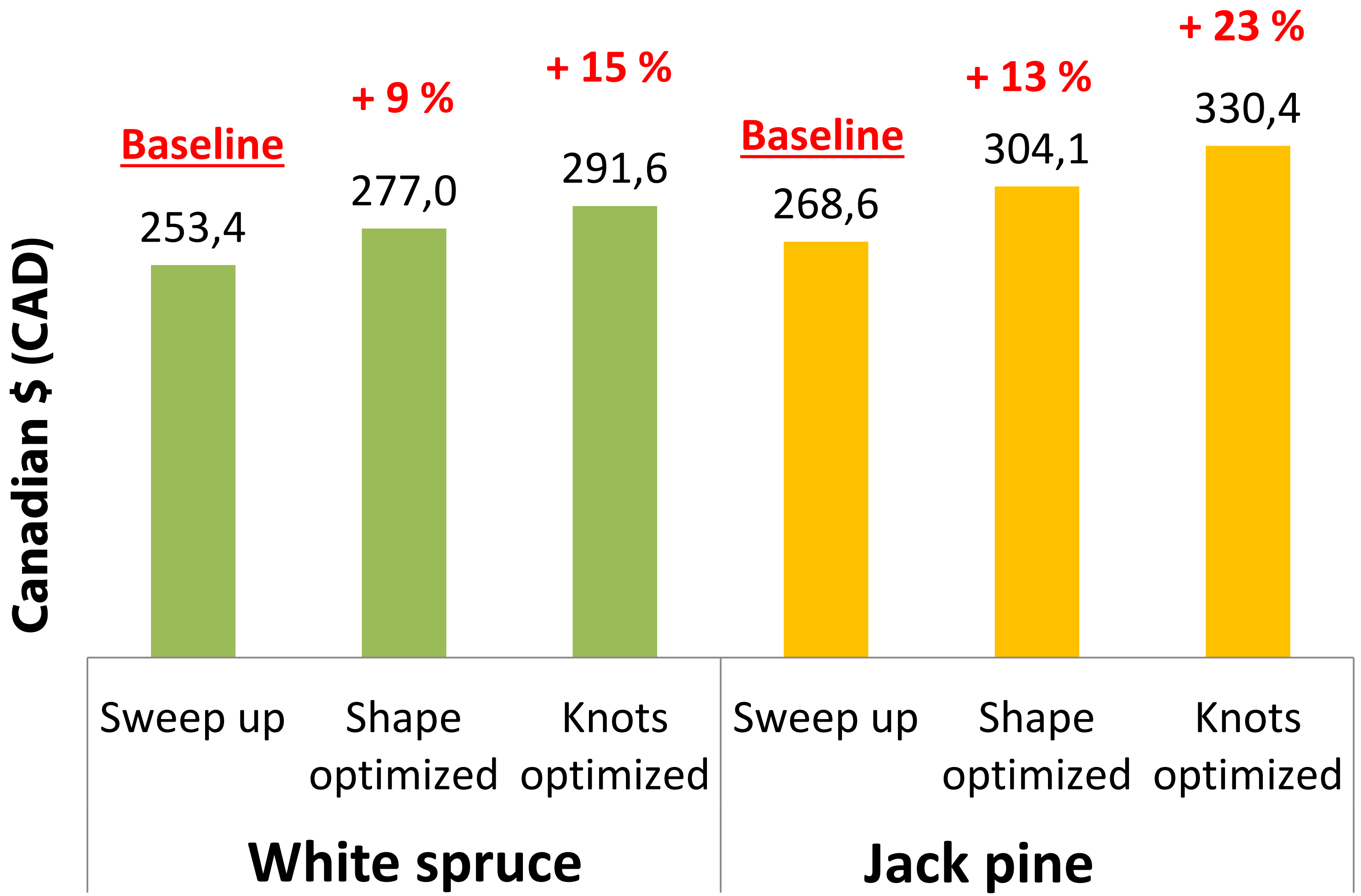
- Three different sawing optimization strategies were used to compare **lumber value yields** in spruce and pine stems.
  1. Sweep up
  2. Shape optimized
  3. Knot optimized



Optitek curve sawing simulations in lumber value

1. **Sweep up** (base case scenario): logs are positioned with the maximum deflection in the vertical axis
2. **Shape optimized**: logs are rotated every 12 degrees (30 positions) to find the rotation where lumber value recovery is maximized (i.e. where wane is minimal)
3. **Knot optimized**: logs are rotated every 12 degrees and sawn in the position minimizing lumber downgrades due to knots.

Lumber value increased with optimized log rotation and when considering internal knots



Sawing simulations in lumber value

Table 2b: Protected LSD multiple comparisons of lumber value ($) among the three levels of sawing optimization strategies for each species.
LS-means with the same letter are not significantly different.

Slice	Sawing optimization strategies	LS-means	Std Error	Grouping
Species (WS)	*Knot optimized*	2.1335	0.1482	**A**
	Shape optimized	2.1116	0.1482	**A**
	Sweep up	2.0473	0.1481	**B**
Species (JP)	*Knot optimized*	2.5377	0.1694	**A**
	Shape optimized	2.4202	0.1694	**B**
	Sweep up	2.3125	0.1694	**C**

Each sawing optimization strategy was significantly different from one another in jack pine and both *knot optimized* and *shape optimized* were significantly different from the *sweep up* position in spruce (Table 2b). **However, no significant difference arose between the *knot optimized* and *shape optimized* strategies in white spruce.**

Lumber value recovery in relation to sawing optimization level

White spruce :

Sweep up < Shape optimized = Knot optimized

Jack pine :

Sweep up < Shape optimized < Knot optimized

Conclusions

- By considering internal knots before log sawing, **23% more lumber value was generated for jack pine and 15% for white spruce** compared with the *sweep up* sawing strategy.

- There is a good potential to increase mill profitability by implementation of the CT-scan technology.

- However, robust algorithms are needed for industrial applications.

Next steps

- Link terrestrial LiDAR information on branchiness with CT images of internal knottiness (and products)
- Collaboration with Prof. Richard Fournier U. de Sherbrooke

LiDAR (tree shape) + CT Scan (knots)