Economic interest of a system of vision interns in a planing mill

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Abstract: This presentation is the first phase of a more complete study about the interest of the use of an X-ray scanner in the context of a planing mill. This scanner, placed upstream to edging phases of concerned wood products (unedged timber, square edged timber), allows to make visible not perceptible defect of the material by the human operator eye. These new knowledge in correlation with rough materials has to allow an improvement of the valuation of the end products, but also has to indicate the improvement tracks of the production installation. Our first tries aim at validating this hypothesis.

Keywords: X ray, wood, defect, planing mill, evaluation

1. INTRODUCTION

In wood industry, yield increase and improvement of the qualitative classification represent important financial gains. Various ways of improvement of the industrial environment are followed: automation of jobs, training of production operators, implementation of decision-making tools and means of control. The study presented here joins within the framework of the automation of working posts and implementation of decision-making tools. The application case is one of the SIAT-BRAUN planing mill and aims at the qualitative improvement of a production chain.

2. CONTEXT OF THE STUDY

A planing mill makes wooden products with high added value such as brackets or mouldings. The raw material is in form of unedged timber or of square edged timber in 15 % of relative humidity. This raw material is also said "of choice", i.e., it contains few defects (knots, marrow, compression wood, heart wood, cracks, tints). It is necessary to value at the best this expensive raw material. To do it, two main ways are followed: (1), from a quantitative point of view, reduce the losses to increase the yield and, (2), on a qualitative point of view, estimate the characteristics of every board to maximize the associated financial gain.
To make profitable an industrial installation aiming at these objectives, big volumes must be treated there. Time granted for every product and the decision-making are thus weak.

In the entrance of the planing mill, we find a dryer and an edging chain. This last one consists of:

- A supply post in unedged timber or in square edged timber by variable dimensions,
- A valuation post of the board on the length by a purge and a selection of the standard lengths of finished products stemming from the board and the cuttings into sections which ensue from it,
- A valuation post of the board on the width by a selection of zones of homogeneous quality of variable width.

The edging plans are obtained by means of an optimization taking into account quality zones. They allow to obtain wood pieces of small rectangular sections (pre-cut) being of use as base to finished products. The pre-cut are then sorted out and manufactured on moulding machine to obtain finished products.

One of the key points of the transformation process is in the definition of the zones of homogeneous quality on the width of every board.
The study, presented in this paper, concerns this valuation post in particular. The selection of zones is made by a human operator assisted by technical means. The affectation of the quality bases itself only on the analysis of the external profile of every board according to five quantifiable criteria:

- The presence or not of a defect,
- The defect type,
- The size of the defect,
- Its location on the board,
- The family of finished products susceptible to be made in the thickness of the board.

The evaluation of these criteria for every board is subject, because of the human operator, to errors of judgment [Buehlmann U., on 2002] linked to the hardness and the repetitiveness of the task without counting a very short time of analysis and decision. The study presented here, estimates the qualitative and quantitative impact that a system of internal vision can have in the definition of the zones of homogeneous quality.

So, it is necessary to define the various homogeneous qualities being of use to the zoning as well as the current process. Then, it is necessary to justify the choice of a system of vision internal being able to improve the process, and finally estimate the contribution of this system of vision in the application case.

2.1. Defects taken into account for the qualitative classification

The wood defects are taken into account in specifications appropriate for the planing mill which defines the qualities of the sold finished products only. Every defect must be analyzed and located to predict the quality class which it imposes on the finished product. The qualitative classification (or sorting) bases itself on six different wood defects. These are, in the important order: (1) knots, (2) curly grain wood, (3) compression wood, (4) warmed wood and tints, (5) cracks and (6) resin pockets.

2.1.1. Knots

Knots are branches (of stronger density than the wood of the trunk) which its base only is present. Stemming from buds, knots can be completely situated by the tree. Knots are dead or alive. In the dead knots, it is necessary to distinguish those who are full and members in encircle neighbours (white knots) and those who are altered or susceptible to part from some surrounding wood (knots corks of the conifer, the black knots). Knots are a place of strong withdrawal during the drying of boards where from the appearance of cracks or the total separation of the knot. These cracks contribute, besides the tint, to the unsightly aspect of knots on the finished products of a planing mill. Concerning the influence zone of these knots, peripheral zones of knots where the thread of wood is diverted, they can be the cause of a qualitative displacement but it is about a subjective criterion appropriate for the operator of classification.

2.1.2. Curly grain wood

Curly grain wood is mainly situated in the footing of the trunk. The aspect of the grain is tourmented, of a sinuous grain in irregular and muddled curves. Its presence is avoided in the production of brackets or high-quality mouldings because of its aspect. Furthermore, this wood is breakable and can create complications in the manufacturing.

2.1.3. Compression wood

This wood results from a natural reaction of the vegetable to compression strength. The physical properties of this wooden type are such as it results, during the manufacturing, a tearing of fibers, deformations due to the relaxation of the internal tensions, the irreversible collapses in the drying, the bad states of surface, or still cracks of surface. Furthermore, this wood, in species such as the Fir tree or the Spruce, is tinted. All these factors make that a safety margin must be taken during the selection of the zones of homogeneous quality.

2.1.4. Warmed wood and tints

Warmed or tinted wood are mainly owed to changes of fungal origins. Attacks, if they are stopped in time, do not affect the mechanical resistances of the wood but tint the wood. Superficial tints can also be due to a prolonged exposure in the direct sun rays ({UV).

2.1.5. Cracks

Cracks are due to a rough change of temperature (frost cracks, check or star shake), a separation of two encircle with increase (ring shake), in the sun (sunburn or crack of drought) or in an unsticking of fibers (honeycombing). Frost cracks, checks and star cracks develop in the radial direction while ring shake follows one rings of wood. The cracks of drought propagate of the bark up to the sapwood and are characterized by flows of resin leading to a tanning of the wood. Cracks, more at least long and deep, can, besides the unsightly aspect, provoke the breakage of some finished products after or in the course of manufacturing.

2.1.6. Resin pockets

Resin pockets are present only in evergreen wood. Resin pockets are internal cracks fill with resin. These pockets raise problems more aesthetic than structural even if the resin presents complications during the manufacturing (fouling of tools). These pockets can be inside the product finished but must in no case be visible on finished products of high quality.

2.2. Qualitative zoning of the production chain

In production, the zoning is made by a human operator who pilots a measurement station. This station is linked to optimization software which allows establishing the edging plans and in a multi-blades edging machine allowing the manufacturing. The operator selects the zones of homogeneous quality through a laser and through a control panel.

These zones of homogeneous quality are defined at the same time as the direction of the grain and are of width is variable, i.e., for an unedged timber, 2 zonings (several parallel zones) different are necessary as the Figure 1 show it.

In the experimental and application case of the study, there are 5 different qualities:

- The quality "OA", the highest, which contains no defect and outcome exclusively from a straight wood grain on all the length. A little deviation of the grain (subjective criterion) is however accepted,
- The quality "OB", the second, which can contain black knots of diameter lower than 5 millimetres, knots white with diameter lower than 7 millimetres, with tints, with collapses or crack lower than 0,3 millimetres, compression wood with straight grain and some curly grain wood, resin pockets lower than 2 centimetres, bark pocket lower than 3 millimetres. All these criteria are the maximal tolerances of the quality but they cannot be all combined on the same zone because this one would present too much defects. In that case, the zone is downgraded towards the "Relegated" quality. On the other hand, the dimensions of these tolerances decrease according to the dimensions of finished products, or families of products, to which the thickness of the

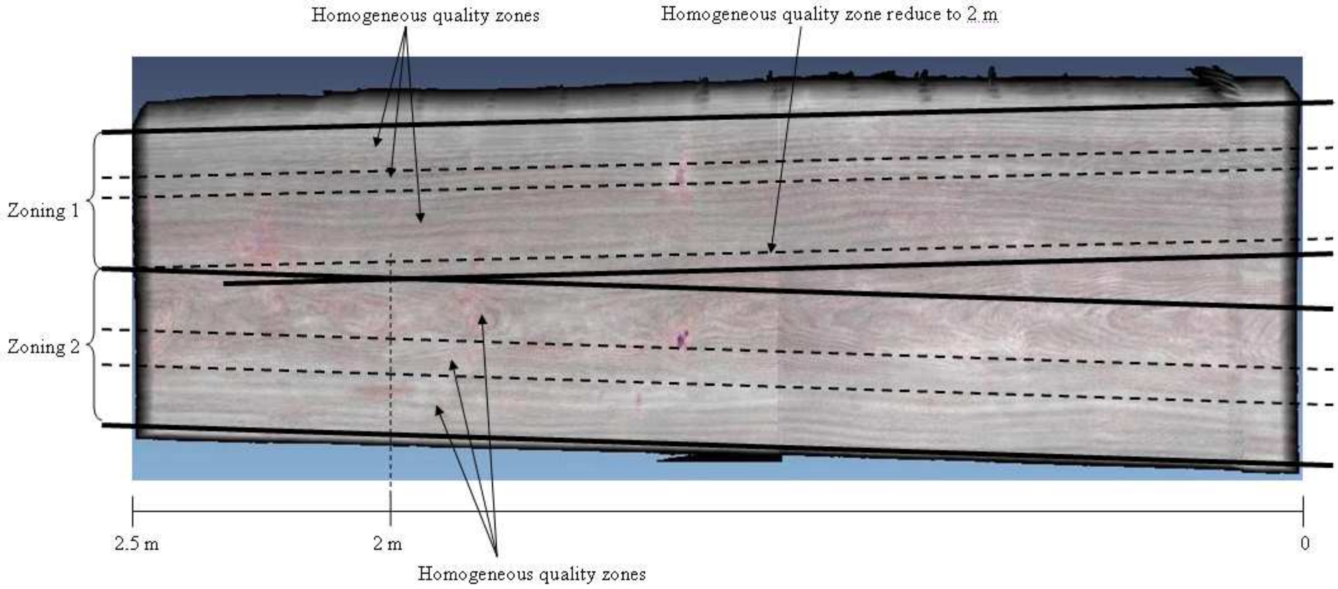

Figure 1 : Zonings and zones définitions

board linked. There is a subjective criterion concerning the general aspect of the zone and the definition of this quality,

- The lowest, "Relegated" quality, which accepts the 6 types of defects about are their dimensions,
- The quality "OA to cut" which allies the criteria of the quality "OA" with a purge in one side (maximum 50 centimetres) allowing to eliminate a penalizing defect,
- The quality "OB to be cut" which allies the criteria of the quality "OB" with a purge in one side (maximum 50 centimetres) allowing to eliminate a penalizing defect.

The qualities "OA to cut" and "OB to cut" are respectively included in the qualities "OA" and "OB" during the analysis of the production.

3. STATE OF ART

3.1. Contribution of the means of visions

Plentiful literatures tries to prove that the use of means of industrial vision during the first transformation of the wood [Thawornwong S., 2003; Rinnhofer A., 2003; Schmoldt D.L., 2000; Lundgren N., 2007] generate financial gains. These studies are applicable to the transformation of boards in pre-cut.

There are two types of industrial vision: (1) the external vision and (2) the internal vision. By misuse of language, the vision initially linked to the sensor "eye" is henceforth said internal when it is a question of obtaining a representation of the internal structure (measure of density, for example) products via a technique of non-destructive control working by transmission in the material.

3.2. External vision

The main means of external vision used in industrial environment are the laser and the digital camera (Manufacturer and designer referents: Microtec-Springer, Luxscan-Weinig, COE Newnes / McGehee). These means of detection allow to obtain an image of external envelope. Afterward, algorithms of detection and, sometimes, interpretations of the defects are applied. The results concerning the detection of defects depend on algorithms which are associated to it but also dimensions of the scanned products. Funck [Funck J.W., 2003] realizes a comparative study where the results of correct detection of the defects extend from 80 % to 99 % according to the algorithms. There are also new techniques as the fuzzy reasoning method [Bombardier V., 2007; 2009] which proposes to translate the subjectivities of the human language in a numerical language by “fuzzy sensor”. This new kind of classification algorithms have better results than the others and, in addition, need less training samples, and finally, calculation times are according to industrial process times. This type of vision requires necessarily the use of algorithms of prediction (interpretation) for the internal analysis of the material. In the case of log, it is possible to interpret the forms of the envelope [Mäkelä A., 2003] to suppose (to predict) the underlying defects. The results remain however little satisfactory because the scanned logs always present defects of envelope which perturb the analysis (missing bark, mistletoe bump). In the case of boards, the interpretation of defect behaviour, visible on the envelope, inside the material is much simpler because the dimensional and geographical variation of the defect is limited by the weak thickness of the product and the defects of envelope are reduced because of the already realized manufacturing.

However, external vision allows on no account to display and to locate the non visible defects on the envelope such as the pockets of resin.

3.3. Internal vision

The internal vision of the material is possible by technological means using the properties of gamma rays [Hampel U., 2007] still in the study, of the nuclear magnetic resonance (NMR) for molecular analyses [Maunu, 2002], ultrasounds [Linen C-J, 2008], microwaves for the detection of defects [Yu G., 2009] or X-rays for the localization and the labelling of the defects [Sarigul E., 2003a and 2003b; Longuetaud F., 2005]. These methods of visions have results on macroscopic or microscopic level (analysis of the molecules which constitute some material). Each of these techniques has their advantages and their inconveniences.

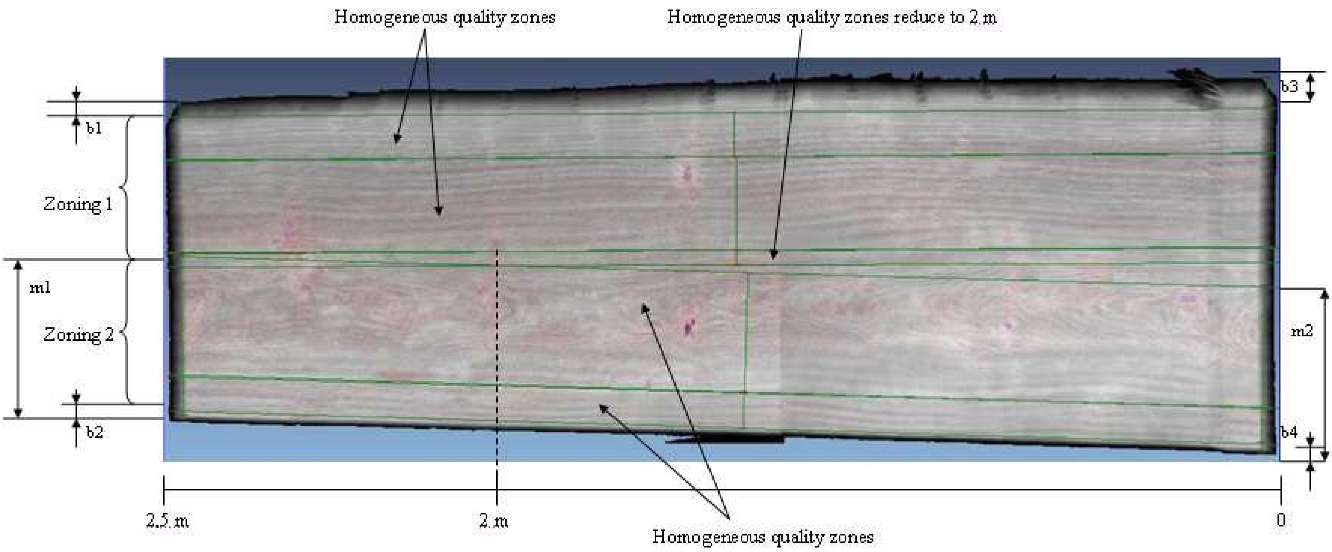

Figure 2 : Zoning localisation

Technique NMR is at present intended for the molecular vision while techniques based on the X-rays, the ultrasounds, the microwaves, although useful in molecular vision, are rather intended for the industrial world for the macroscopic vision.
According to comparative studies, the X-ray imaging is the most successful and the most promising method on an industrial plan [Skatter S., 1998; Wei Q., 2009]. Furthermore, towards the context of the study, this method is compatible with the environment of manufacturing of the wood (dust, vibration, climate).

3.4. The vision by X-ray scanner

The imaging by X-rays allows the localization of several defects of the wood. Combined with detection algorithms, this method allows to obtain a mapping (labelling) of the material which can, in theory, be reused in every stage of manufacturing of the material.
More specific studies for every type of defect were led. These studies concern mainly the improvement or the creation of algorithms of detection. These algorithms use statistical models, intelligent systems of "on-line" type ("dynamics") or artificial neurones network (ANN), pre-treatments or post-treatments of images, mathematical operators or still, detection results of the defects.
From the X-ray imaging, it is possible to detect and to qualify knots, as concludes it Oh J-K [Oh J-K., 2009] which specifies that a finer determination is not yet possible. The cracks detection, limits of sapwood / hardwood, compression wood, wane, bark pocket or resin pockets is also possible. It is also possible to consider the density of zones particular and located some wood to analyze the causes or the consequences [Leban J.M., 2004]. This type of imaging still allows to estimate the mechanical resistance of the wood from the characteristics of knots [Öhman M., 1999] or from models, as Brännström M. makes by correlating the density, the width of rings, the module of elasticity and the resistance in flexion [Brännström M., 2007].
The reliable and strong algorithms of detection require however long time of calculations and are often useful for a single type of defect at the same time. So, there is a time accumulation for all the detection on every image. On the other hand, the acquisition, in an industrial environment, is generally made with a system linear source / detector (range of X-rays) perpendicular to the scanned piece and not use the reconstruction of the volumes, the tomography, which is much more precise (resolution raised in 3 dimensions). Times of acquisition to realize a tomography are indeed long. The study of Magnusson Seger M. in 2003 encourages the exploitation of the cone of X radiation in the industrial circles by developing, in laboratory, algorithms fast and capable of reconstituting the volume in high production speed [Magnusson Seger M, 2003]: the acquisition is not linear any more. It becomes now possible to use reconstructions in 3 dimensions to detect more easily and more exactly the defects.
However, the imaging by X-rays does not allow to visualize tints (aesthetic criterion in the field of the wood) because these present a tiny difference of density.
In this study, it is the imaging by X-rays that is used for its capacity to detect and to localize the internal and external defects of the wood.

4. EXPERIMENTAL METHOD

4.1. Objectives

The study presented here aims at three objectives: estimate the impact of a X-ray scanner in the identification and the sizing (1) of the visible defects by the operator but also (2) of the non visible defects, and finally, consequences due to its introduction in the edging chain (3). To do it, an experiment was led in a real scale: the following paragraphs describe this one.

4.2. Sampling

We selected randomly and among stocks, one parcel of square edged timber in dry mixed Fir-Picea whose nominal thickness is 24 millimetres and 4 meter length, then one parcel of unedged timber in mixed Fir-Picea 32 millimetres in thickness and 5 meters in length. These two thicknesses represent 50 % of the production of the edging chain.
Boards are cut up in a fixed length of 2.5 meters because it is the length of the most sold finished products, the most representative. Among these boards, a lot of 29 boards is selected for the analysis by X-rays. These boards are chosen

for the defects which they contain; the purpose is to have the biggest proportion of defects in a minimum of samples. In this way, among 29 boards, 14 have a 24 millimetres thickness and 15 have a 32 millimetres thickness. Then, the boards of width superior to 50 centimetres are edged (in two) because their passage is impossible in the X-ray scanner (truncated images). This operation carries the number of products scanned in 32.
Boards not selected for the analysis by X-rays (more than 70) are visually analyzed to evaluate the presence or not from defects and so establish general statistics based on the proportions of every defect according to the thickness of boards. In this way, the results obtained with the samples of the experiment are generalized at 50 % of the planing mill.

4.3. Measure of the samples by X-ray scanner

X-ray scans are acquired by means of a medical scanner Brightspeed 4 of the manufacturer General Electrics. Scans are made in two steps because displacement of the scanner is lower than length of boards. Furthermore, to limit the acquisition time, several boards are scanned at the same time; they are piled and separated by foam of low density.

4.4. Treatment of the measures obtained by X-ray scanner

The measures obtained of the scanner were treated then manually so as to:
- Separate the boards of the same scan of the others,
- Move closer to every half-scan to obtain an image of the board in volume on the total length.

The difficulty of the operation results from variations of orientation and from location due to the manual reversal of piles to scan the second half-length.
Every volume (board) is then handled with manual threshold. Thresholds allow to eliminate or to put in front of the ranges of levels of grey by means of colours or of the luminosity. The method of thresholding bases itself on the spectres of the levels of grey of boards.

4.5. Qualitative zoning from the X-rays imaging

The widths of the zones of homogeneous quality are measured with a tool of the software as the Figure 2 shows it. Furthermore, the beginning of the zonings those are located with regard to the edge of the board in both extremities, are the distances b1, b2, b3 and b4. We also note the distances m1 and m2 for the localization of the end of the first zoning made on the board.

4.6. Qualitative zoning in production

The location of zones is internal in the installation and not accessible by the user, however, the order and the widths of the various quality zones selected in the same zoning are accessible and found by computer.
The location of the zoning, manual and in the course of production, is located in the same way as the zoning makes with the imaging by X-rays: the distances b1, b2, b3, b4, m1 and m2 are found. It is so possible to postpone the zones of qualities selected on the real board to analyze the zoning made by the operator of production.

5. RESULTS ET ANALYSES

5.1. Comparison of both zonings

A dimensional characterization and a geographical localization of all visible defects are made out of production. This statement is confronted with the zoning made in production and with that made by the imaging by X-rays.
This confrontation allows to advance:
- Not visible defects from the outside but visible with the X-ray imaging ,
- Visible defects from the outside but not seen by the operator,
- Visible defects from the outside but not visible with the imaging by X-rays,
- Visible defects from the outside, seen by the operator and visible with the imaging by X-rays.

The comparison, between quality zones selected in production and with the imaging by X-rays, is made according to two criteria: (1) the selected quality and (2) the dimensions and the location of zones.

The analysis of the made zonings, the one in production and the other one on the basis of the imaging by X-rays allows to obtain the Table 1 and the Table 2.

	Surface (m²)	Percentage /Zoned surface visually in production	Percentage /Zoned surface by X-rays imaging
Zoned surface visually in production			
OA Quality	2.07	16%	
OB Quality	8.51	66%	
Relegated Quality	2.39	18%	
Total surface	12.96	100%	
Zoned surface by X-rays imaging			
OA Quality	2.37		18%
OB Quality	7.92		59%
Relegated Quality	3.04		23%
Total surface	13.32		100%
Difference between zoned surfaces by X-rays imaging and visually in production			
OA Quality	0.30	2%	2%
OB Quality	-0.59	-5%	-4%
OA/OB addition	-0,29	-2%	-2%
Relegated Quality	0.65	5%	5%
Total surface	0.36	3%	3%

Table 1 : Global results of the comparison of both zonings

We notice a 3 % distance between the total surface zoned in production and that zoned by means of the imaging by X-rays (See Table 1). This distance is due to the various locations of zonings (slopes to follow the straight grain) make either visually and or with the imaging by X-rays. Indeed, some degrees of slope furthermore or at least echo on the zoned total surface. Furthermore, this table shows a distribution of the similar qualities with both used means of vision.

The Table 2 informs the causes of the displacements made during the passage from one to another means of vision : visual and by X-rays. We notice that 45 % of the zoned total surface undergoes a change of quality class according to the used means of vision, the means of visions do not thus influence the qualitative choice of the operator on the rest of the surface.

		Visual zoning (m²)		
		OA	OB	Relegated
X-rays imaging zoning (m²)	OA	0.9850	1.2000	0.1900
		8%	9%	2%
	OB	1.1350	5.3025	1.4300
		8%	41%	11%
	Relegated	0.1125	1.8375	0.8150
		1%	14%	6%

Table 2 : Detailed results of the comparison of both zoning

The operator changes 32 % quality on the 45 % of the total surface displaced in spite of visible elements with both means. The causes of these changes of class are mainly : diverted grain (9.7 %), the brown spots of strong density (8 %), compression wood (2.8 %), curly grain (1.5 %) and a grouping of isolated defects of the image or the material not identified under the other categories (8.4 %). We also notice a distance from total 1.6 % of the surface due to the accumulation of several variations, from some millimeters, from the location of the borders of zones. We explain all these changes of classes by the aspect different from the material according to the used means of vision. Indeed, certain defects are more contrasted with the X-ray imaging than visually and conversely.

With imaging by X-rays, operator has access to the internal characteristics of the material; so he downgrades 23 % of the total surface towards qualities lower than that zoned visually in production. Among these 23 %, displacements are of:

- 8 % are a displacement of quality OA (visual) towards quality OB (by imaging X-rays),

- 14 % of quality OB towards Relegated quality and,

- 1 % of quality OA towards Relegated quality.

Besides the displacements due to factors explained previously, 4.7 % of the total surface is downgraded by the presence of resin pockets (2.4 % of total zoned surface) and of crossing or little visible knots (2.3 %) detectable only by X-rays imaging.

Conversely, by basing itself on the visual aspect, the operator downgrades 22 % of the total surface zoned from X-rays imaging. The main cause of the visual displacement is the tint of wood (8.9 % of the total zoned surface) because the X-rays imaging does not allow to visualize characteristics, as tints, which do not affect material density.

Experimentally, the X-ray scanner allows to improve the qualitative classification on approximately 4.7 % of the total surface but it also implies loss of information about the tint which is the cause of the displacement of 8.9 % of surface zoned.

	Defects					
	Knots < 5 mm (crosiing or less visible)	Tinits	Compression wood	Resin pockets	Curly grain wood	Diverted grain
Defects by studied board by RX sampling	0.59	0.38	0.53	0.16	0.09	0.09
Defects by studied board by total sampling	0.37	0.36	0.43	0.06	0.11	0.09
Relation between total sampling and RX sampling	0.62	0.96	0.80	0.36	1.19	0.99

Table 3 : Relation between total sampling and X-rays sampling

Statistical analysis on the presence of defects gives the Table 3. It allows generalize the experimental results in 50 % of the production of the planing mill. The displacements due to tints are thus worn in 8.57 % of half production, and those due to internal defects in 2.29 %.

5.2. Additional result: threshold characteristic

As show in example Figure 3, every spectre consists of a strong presence of low levels of grey (black: 0) which represents the background of X-rays images. The spectre shows two central peaks representing all the levels of grey of the studied board. After analysis, we noticed that the levels of grey correspond to 4 defects of the wood decomposed into 4 ranges: wood without visible defect by scanning, compression wood, knots and resin pockets. Thresholds are defined by the intersection between the curve and the maximal value of peaks multiplied by a coefficient function of the defect ($C_{compression\ wood}$, C_{knot}, $C_{resin\ pocket}$). These 3 coefficients are defined in an empirical way by comparison between the human perception and the result obtained by threshold.

The range of "wood without defect" begins when the spectre is minimal between the levels of grey of background of the image and the first central peak; the abscissa of this point is named $x_{wood\ without\ defect}$. Other ranges begin in the points of abscissa $x_{compression\ wood}$, x_{knot}, $x_{resin\ pocket}$ according to the following mathematical definitions:

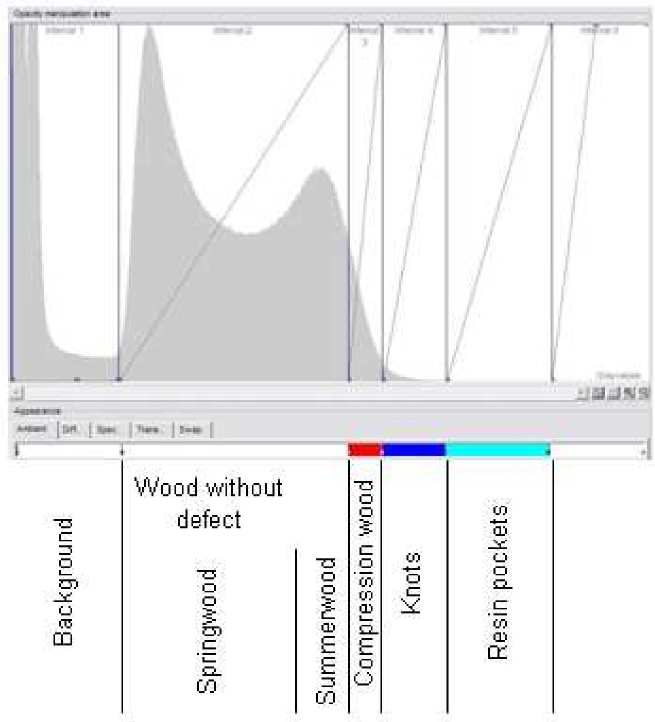

Figure 3 : Board grey level spectre

If f is function of the grey levels spectre and M the maximal value of the central peak,

$$M = \max (f(x)) = f(x_{max}), \text{ with } x > x_{wood\ without\ defect}$$

$$f(x_{compression\ wood}) = C_{compression\ wood}.\ M, \text{ with } x > x_{max}$$

$$f(x_{knot}) = C_{knot}.\ M, \text{ with } x > x_{max}$$

$$f(x_{resin\ pocket}) = C_{resin\ pocket}.\ M, \text{ with } x > x_{max}$$

The thresholding analysis showed that the spectres of levels of grey have a similar profile and that the threshold coefficients are equivalent from a sample to another one. The analysis allows determining an empirical value for every coefficient:

$C_{compression\ wood} = 0{,}363$, $C_{knot} = 0{,}036$ and $C_{resin\ pocket} = 0{,}009$

However, abscissas of the thresholds of every defect are different and become confused from a sample to another one as the Figure 4 shows. Thresholds representing the knots are included in those representing the compression wood. We obtain better result, as shows in Figure 5, by deducting the appropriate threshold of the wood without defect in three thresholds representatives of the defects. The ranges of thresholds are reduced but there is always a strong inclusion between ranges.

These inclusions are essentially due to the fact that the grey levels spectres associated to every part have dimensions which extend from 647 to 3745 levels of grey. On the other hand, a light overlapping is accepted between thresholds because defects have closed densities (grey levels) or even confused in certain cases.

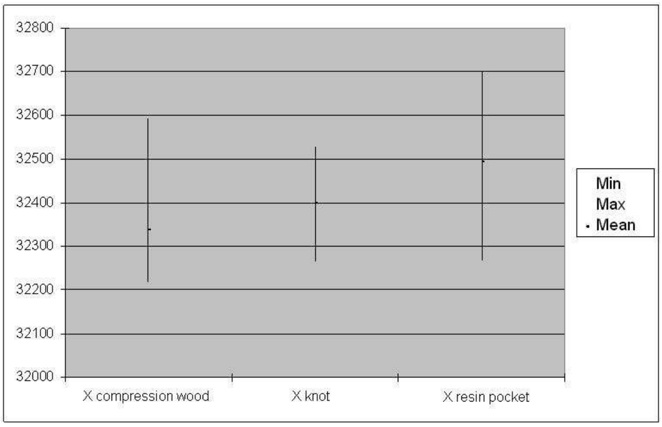

Figure 4 : Inclusions of defect's grey level

The thresholding can be improved by calibrating all the spectres on the same range of grey levels and by improving definition method of the characteristic coefficients in thresholds.

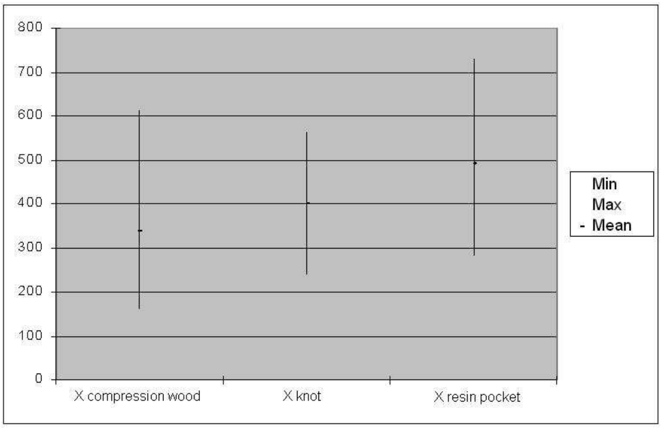

Figure 5 : Inclusions of defect's grey level after correction

6. CONCLUSION AND DISCUSSION

The comparative analysis of the qualitative zonings of 32 wooden boards made from two various means of vision allowed advancing that 45 % of the zoned surface undergoes a change of class according to used means of vision, either human eye or a X-ray scanner. The experiment demonstrated that the use of a single X-ray scanner in the production chain is penalizing. Indeed, X-ray scanner does not allow the detection of wood tints which are the cause of 8.9 % of the visual displacements. Therefore, if the scanner is combined to a colorimetric vision system, such as digital cameras or human eye, then it allows to improve the qualitative classification on 4.7 % of the surface zoned experimentally. The analysis also showed that visible defects by both means of visions do not lead obviously to the same affectation of quality (32 % of the surface zoned experimentally) because of the contrasts of the material are not the same visually and by X-rays imaging. Interpolation of the experimental results shows that contribution of the X-ray scanner concerns 2.29 % of the surface of 50 % of the production of Siat-Braun planing mill. So, it is necessary to pursue a statistical study concerning the totality of the production, more than 9 thicknesses, to know real contribution of the X-ray scanner.

Characteristic thresholds of every defect tried to be unsuccessfully updated; it surely is necessary to add a work of calibration of spectres to succeed. It should be possible, after this stage of calibration, to establish fixed average thresholds which allow generalizing thresholding according to specie and to board thickness. The first calculations, not presented here, realized on the thresholds of a single thickness of board show a decrease of the inclusion of the threshold ranges between them (especially for the 24 mm thickness). However, to conclude on the generalization of thresholding, it is necessary to diversify the widths and the types of boards of the sampling because that experiment deals with the same type of product of small width.

7. THANKS

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