Optimising the Chop Saw Operation.

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SUBJECT KEY WORDS
Independent evaluations of leading chop saw scanners. Comparisons of crayon marker and automatic scanner systems, defect recognition and cutting about the defect position. Updates on new scanning and crosscutting technology.

INTRODUCTION
This paper is based on techniques developed by Forest Research for a multiclient study to evaluate the available scanning systems for use with radiata pine. The procedures were developed using a system developed by the University of British Columbia² as a benchmark.

The main objectives of this paper are to:
- Describe a proven technique for technology evaluation.
- Provide an overview of defect scanning systems for chop saws.
- Provide some benchmark data on defect detection systems.
- Compare the performance of different systems.

Crosscutting saws are available with different levels of automation:

1) Manual:
   a) Cut to length without defect removal. E.g. can use a packet cutter to cut pallet or bin components.
   b) Cutting to grade according to a cutting list without defect removal. E.g. recover two grades of pallet stock. Often done using a manual docking saw with a few selectable stops along a fence.
   c) Cutting according to a cutting list with manual defecting. E.g. can produce a mix of fixed length graded components and finger-jointing stock. Often done using a manual docking saw and few adjustable or programmable stops along a fence.

2) Crayon. Manual defect marking using special crayons with automated cross-cutting:
   a) Automatic defect removal at marked positions. Recovers random length finger-jointing stock.
   b) Automatic defect removal and cutting to length according to a value table or cutting list.
   c) Automatic defect removal and optimised cutting to length according to a value table or cutting list. Can produce a mix of fixed and random length components.

3) Scanner. Automatic defect detection systems use a wide range of grade sensing technologies.
   a) Defect removal and optimised cutting to length according to a value table or a cutting list.

¹ Ensis is a joint venture between CSIRO FFP Pty. Ltd. and Forest Research Australasia Ltd.
² Maness, T. and D. Wong. 2001. A benchmarking system for evaluating the profitability and yield of optimising chop saw systems. Centre for Advanced Wood Processing, University of British Columbia, Vancouver, B.C., Canada.
The main advantage of the crayon system over the manual chop saws is the computerised decision making for optimal component recovery (optimising). Productivity may also be higher.

Sawn timber defect scanners are used in the following situations:
- Board edging or end docking in the green mill (E.g. Catech BoardMaster, Softac, Paul, Industries P.H.L.)
- Trimmer Optimiser for the planer mill. (E.g. Ultimizers Ulti-Vision, COE Manufacturing)
- Grade sorting after the planer (E.g. Gemofor Optifor, Algis, Optimil, Autolog, COE Manufacturing (D*TEC BioScan))
- Grade scan for chop saws (E.g. Lucidyne, Barr-Mullin (Cell Scan), Microtec (Golden Eye), CAE Newnes, Inovative Vision (WoodEye)).

Board scanners are also used for parquet, window and furniture component sorting and component inspection.

Fully automated defect scanning systems may offer the following potential advantages over the other two methods:
- Better grade consistency.
- Higher product recovery (docking closer to defects).
- Higher productivity.
- Better decisions, based on value not volume.
- More products and grades can be handled.
- Flexibility, as product cut may be changed in minutes.

Payback on a fully automated system has been reported to be as short as 12 months; however, it depends on the quality of the resource, how well the system detects and classifies relevant defects and the output product grade and size specification.

The latest generation automated scanners use a range of detectors (sometimes a number of detectors operate together) to ensure more accurate detection occurs. The most common detectors include combinations of; laser (tracheid), laser (grain dive angle), laser time of flight for length (LASAR™), colour vision, X-ray, Gamma-ray (for moisture), microwave, ultrasonics (for stiffness), capacitance for moisture and laser triangulation for geometry. Some include mechanical machine stress grading (MSG). Some modern scanners use up to six channels of scanned information.

Because of the complexity comparing different grading and optimisation routines this report is limited to the evaluation of scanning accuracy, defect detection and defect classification, not grading accuracy and optimisation.

**TYPES OF FEATURES TO BE DETECTED**

**Feature types**
The type of features to be detected depends on the product and varies from customer to customer. To decide if a component is suitable for a specific end use any of the following features may be important:

1) **Stiffness**: As measured by a machine stress grader.
2) **Strength**: Can be based on the correlation between stiffness as a plank and strength, often with knot size limitations. Slope of grain also affects strength.
3) **Appearance**: Appearance blemishes can include loose knots (bark encased), knot holes, stem cone holes, inter-grown knots, bark pockets, resin pockets, resin streaks, needle fleck (also...
known as bird’s eye), wide growth rings, heartwood, pith, splits, stains (blue and brown) rot.

4) Shape: Crook, bow and twist.
5) Size: Thickness, width and length.
6) Finish: Surface finish, skip, tearing of grain, chipped knots, etc.
7) Colour: Natural colour variation, fungal stains (eg. blue stain), process discolouration (eg. kiln brown stain).
8) Grain: Direction (flat or quarter sawn) and grain patterns.
9) Wane.
10) Mechanical damage.
11) Compression wood, which can affect strength and stability.

Some defect scanning machines can detect internal defects such as: Knots, checks, resin pockets, pith and rot.

**Defects to scan for**
When scanning radiata pine it must be accepted that scanners cannot be 100% accurate. Because a number of scanner signals have to be combined in a defect assembler, a two-stage defect detection process may be used. The first stage detects features and classifies them. The second stage assembles the features into defects as described in the grading rules.

The automated grading systems must be designed to minimise errors and the materials handling systems must include inspection points to ensure grading errors are not carried over to the end product. The number of defect types to scan for is important as every additional defect type adds to the complexity of the situation and presents new challenges and increases the potential for errors to be made.

Figure 1 illustrates the importance of external (visual) and internal defects as ranked by over 30 respondents in Australasia based on a survey by the authors.

**Figure 1**

![External and Internal Defects to Scan For](image)
DEFECT DETECTION
Defect detection technologies
A wide range of defect detection technologies have been reported on in technical brochures and published in the literature. Szymani and McDonald (1981) and Szymani (1985) published a good overview of lumber defect detection technologies.

Defect detection technologies include the following:

- Laser triangulation to measure sizes and wane profiles. A wide range of laser triangulation laser sensors is commercially available from companies such as Dynavision. A more recent development is time of flight lasers such as LASAR used by Perception. Used to measure sizes and detect wane, skip, large holes, crook, bow, twist, large splits and grain distortion.

- Tracheid cell scan lasers. When light is focussed to a point on a softwood surface it is scattered preferentially in the grain direction and this is called the “tracheid effect”. Development work was done by Soest and Matthews 1985 (US Patent No 3.976,384 Matthews & Beech 1976). Commercial systems use scatter, specular and retro light (reflective grain) detectors. The defect scanner suppliers use a range of different sensors reading light sources ranging from red, through near infrared, to infrared. Cothrell and Soest (1999, p.24-25) described the laser reflective grain defect system used by Ultimisers. LuxScan and CAE-Newnes uses a laser sensor by Baumer Optronic3. The Barr-Mullin Cell-Scan is described as “a high tech defect sensing device... which bathes the individual wood cells with huge quantities of light using invisible lasers to determine the presence of knots, grain angle and cell content” (Annon, 1998 Buyer’s Guide, p.77). The Barr-Mullin system is very powerful and can detect defects even if a sheet of paper is placed over the scan area. Suitable to detect knots, grain angle, diving grain, pith and compression wood.

- Video camera systems, either gray-scale or color are used by many defect scanners. A wide range of technologies are available with complex variables such as colour channels, colour resolution (number of bits), camera resolution (number of pixel elements) and scan density. Suitable to detect knot type, colour, small holes, stain, checks, small splits, machine surface defects and rot.

- X-Ray. Commercial X-Ray systems are available from a few suppliers. Most of the X-Ray systems are designed to scan face to face (through the thickness) of the boards. The X-Ray systems can detect knots but can be confused by wet spots. X-Rays cannot detect splits unless they are in line with the X-Rays. Internal checks and resin pockets are nearly impossible to detect unless X-Ray computer tomography (CT) is used. The X-Ray computer tomography (CT) method compares well with the destructive method for measuring knot parameters (Oja 1997, p.311-315). Used commercially to machine stress rate lumber, detect knots, pitch, rot, small holes, checks, shake and compression wood.

- Sound wave transmission time. A well-known technique for detecting internal defects in wood (Schad, Schmoldt and Ross, 1996). It is also used to determine the stiffness (Modulus of Elasticity) of wood as used in the Dynagrade and A-Grader4.

- Capacitance: Capacitance is normally used to measure wood-moisture eg Wagner L-600 series moisture meters (Milota 1996, p.39-42).

- Radar. Impulse radar was evaluated for detecting internal wood defects such as decay and voids or knots by Schad, Schmoldt and Ross (1996).

- Microwaves. Have been used to detect internal defects in wood (Martin and Collet, 1984, p.77-122). Microwaves can also be used to measure moisture content, density and grain angle (King, James and Yen, 1985, p. XVI-1).

- Ultrasonic. Shows strong promise to detect defects such as splits and knots (Kabir, Sidek, Daud and Khalid, 1997, p.88-96) and some suppliers, such as Barr-Mullin, offer a

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3 www.baumeroptronic.com
4 A-Grader by Forest Research, Rotorua and Falcon Engineering, New Plymouth.
commercial system for detecting internal checks using ultrasonics. The pulse-echo ultrasonic technique can detect large internal knots and splits (Kodama and Akishika, 1993, p.7-12).

- Infrared thermography. This system can accurately differentiate clear wood from knot wood (Quin, Steele and Shmulsky, 1998, p.80-84) but is not used commercially. The knots measured by thermographic methods are larger than the visual knots because it includes the distorted grain region (Sadoh and Murata, 1993, p.13-18).

- Near Infrared Reflectance Spectroscopy (NIR). This method is very versatile in the non-destructive evaluation of wood density, compression strength and chemical and biological degradation (Hoffmeyer and Pedersen1995, p.165-170)

- Light Reflection. Light reflection can be a useful technique when the knot color is the same as clearwood (Sugimori, 1996, p.799-803). Light reflections on a lumber surface can be used to detect slope of grain (Sugimori, 1993, p.1-6).

Figure 2 illustrates some of the signals produced by the different sensors.

**Figure 2**

**SENSOR SIGNALS**

<table>
<thead>
<tr>
<th>Colour</th>
<th>RGB Signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCD Camera</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Laser Scatter (tracheid effect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight Grain</td>
</tr>
<tr>
<td>Sloping Grain</td>
</tr>
<tr>
<td>Pith, knots or compression wood</td>
</tr>
<tr>
<td>Resin Streak</td>
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<table>
<thead>
<tr>
<th>Lasers</th>
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<tbody>
<tr>
<td>3-D Triangulation</td>
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<tr>
<td>Reflectivity</td>
</tr>
<tr>
<td>Tracheid Scatter</td>
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<table>
<thead>
<tr>
<th>X-Ray</th>
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<tbody>
<tr>
<td>Detects Density Change</td>
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</table>

**Defect detection, classification and quantification**

The defect detection sensors provide inputs to a defect assembler as illustrated in Figure 3. The defect assembler processes the inputs to produce a single board model. These single board models can often be viewed with specified transducers turned on or off. Commercial systems use a minimum of two types of sensors, usually triangulation lasers and charge coupled device (CCD) cameras. Systems using four or more types of sensors are available.
The conversion of the scanned signals into wood features is normally done using a range of image processing algorithms. This process enhances the images and produces information about the image that can be further analysed to allow classification into knots, resin pockets, pith etc. The size of the defects can then be calculated from the enhanced images.

The single board model data is normally contained in a computer file and this file is very useful for evaluation purposes. By checking actual defects against the computer listing, missed and ghost (or imaginary) defects can be identified and actual defect locations compared with the scanner generated locations as shown in Table 1. In practice this task can be difficult because most systems will break up complex defects into smaller defects such as pith, resin, intergrown knot and bark-encased knots.

The single board model data is passed to an optimiser that will apply the grading rules and search for components as per the specified value table or cutting list.

**Application of grading rules and optimisation of cross-cut solution**

The required grading rules can be applied to the classified and dimensioned defects to determine the timber grades and optimum cross-cut positions. Some clever programming is required and the performance difference between systems may be due to the optimisation algorithms.

Checking of the optimisation routines can be difficult if the grading and optimisation routines used are complex. The assembled defect data files produced by the defect scanners are used for optimising the cross-cut positions but these routines are often customised to suit the needs of individual operators. The optimisation routines are best checked using a simulator.
Implementing the cross-cut solution
The optimised cut solution, which includes trim and crosscut positions, is passed to the programmable logic controller (PLC) controlling the defecting saws and component sorter.

Reports
A report writer will report on performance measures such as:
- Number of boards processed.
- Total linear length processed.
- Average board length.
- Input length per minute.
- Total number of saw cuts made.
- Average number of cuts per board.
- Unprocessed material. Usually no decision or reject boards.
- Number and value of fixed length components recovered.
- Number and length distribution of finger joint stock recovered.
- Waste percentages.

TECHNOLOGY EVALUATION
Short-listing suitable technology suppliers
A full list of scanner suppliers may be quite long and it is very tempting to pick a few on the basis of satisfactory reports by other users, or some other subjective basis. Another approach may be to classify the systems on the basis of the technologies employed and then evaluate one of each technology. Some may prefer to evaluate only the top three on the basis of current market share.

None of these approaches are perfect and with the technologies changing rapidly it is highly recommended that as many suppliers as feasible be listed and a short list be prepared for evaluation. It is often wise to exclude models where less than 5 operational units are offered by suppliers as available for evaluation. An American study found the following were the most important selection criteria for mills producing dimension components:
- Equipment warranty.
- Machine accuracy.
- Technical support.
- Reduction in labour costs.
- Machine durability.

A procedure to evaluate scanning technologies is given in Appendix A.

A list of sawn timber (lumber) scanner suppliers is given in Appendix B.

COMPARING ALTERNATIVE SCANNING SYSTEMS
Each scanning technology study should produce two sets of data. The first set of data relates to the defects detected by the scanner, the defect sizes as measured by the scanner and cut positions as determined by the scanner. The second set of data relates to the manually measured defects and actual cut positions as cut or as scored by the docking saws.

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5 Cumbo, D.W.; Adoption of Scanning Technologies in the Secondary Wood Products Industry, Master of Science, Virginia Polytechnic
Defect size measurements should be accurate but the most important measure is the correlation between scanned and actual size (in both X and Y directions) as illustrated in Figure 4. If the slope of scanned versus actual is slightly slanted it can be corrected for, but if the scatter is too wide (low correlation) the percentage wrongly rejected and wrongly accepted will be high.

It is desirable to set performance targets at the outset of the study. A goal of keeping scanner and crosscut length errors to less than ±5 mm should be initially targeted. A defect find rate on all scanned edges and faces should be at least 95%, depending on the defect type. Keeping ghost defects (defects found which do not exist) and missed defects (actual defects missed by the scanner system) below 5% is also important.

From experience there appears to be a direct correlation between the amount of rework on the one hand and the ratio of missed to ghost defects and trim allowance on the other. By increasing the amount of ghost knots relative to missed knots and increasing the trim allowance the yield and average finger-joint component length will decrease as will the amount of product to be reworked.

**SUMMARY OF FIVE SCANNING SYSTEMS**

**Limitations**
The results in the following section is for illustration purposes only as the study was done a few years ago and at that stage some of the scanners were of different vintages, some had software upgrades, and some machines were operated by mill staff and not the suppliers. The timber samples were matched as well as possible but handling and unpacking by customs affected the surface and appearance. Any one of these factors can influence machine performance. Because of changes in technologies used and software refinements the machines currently on the market may perform very different from the ones tested.

**All Systems: Scanner versus manually marked cut positions**
The key measure of performance in the study by Forest Research was the percentage of leading cuts made within 20-mm of the manually marked cut positions. This is very much an arbitrary rule as the laser tracheid measures the grain direction, while the manually marked cut position is based on the judgement of the operator looking at knots and other defects. The operator marked the cut positions before the timber was scanned. Often, with hindsight, the scanner cut position was found to be a more suitable cut position for finger-jointing than the manually marked cut position (i.e. the scanner removed more of the disturbed grain).

The performance of the scanners is dependent on being tuned to the resource. Because of the wide range of defects scanned for during the trials the systems may perform better than shown in the study results when dealing with a more uniform resource.

Figure 5 illustrates the absolute distance of actual leading cuts, to remove defects, from the manually marked cut positions. The improvement in the cut position by re-gauging the timber
processed by the WoodEye scanner is clearly illustrated in Figure 5. For most of the scanners at least 70% of the leading cuts were made within 20 mm of the manually marked cut positions.

**Figure 5**

![All Scanners Boards 1-50: Percentage of Leading Cuts Near Marked Positions](image)

**Number of Finger-Joint pieces produced**

Figure 6 illustrates the number of finger-joint pieces per linear metre produced by the different scanning systems. The packets were fairly well matched as shown by the manual recovery of 1.5 pieces per linear metre. These results exclude multiple cuts where long length clears were cut into shorter lengths to suit the maximum shook length requirements of the finger-jointers.

**Figure 6**

![All Scanning Systems: Number of FJ Pieces Produced](image)
**Average piece lengths.**

Figure 7 illustrates the average finger-joint piece lengths produced, excluding cuts made to meet maximum shook length limits. The difference between the CAE and Barr-Mullin systems is partly due to the different trim allowance used for the two studies and the ratio of ghost defects to missed defects.

![Figure 7: All Scanning Systems: Average Piece Lengths](image)

**Significant defects missed or ghosted.**

All systems studied missed a few defects or produced ghost (imaginary) defects. The nature of the tuning system allows the scanners to be set to find most defects, but a balance must be found between missing defects and producing ghost defects.

Small grain deviations, often associated with defects that were in the vicinity of the board, can show as ghost defects. Torn grain can also be seen as a ghost knot. Some missed defects are more difficult to explain but the lasers do not necessarily see the images observed by eye.

The term significant is used to denote that the presence or absence of these defects affected the defecting decision of the scanner. The actual number of individual missed and ghost defects may be higher. It is interesting to note that the two experienced graders missed a few defects when crayon marking the boards and the crayon mark reader missed reading a few crayon marks.

Figure 8 illustrates the significant missed and ghost defects produced by the different scanning systems.
Average product yields
Table 2 lists the clear finger-joint recovery as a percentage of the volume of lumber scanned. The small samples used cannot reflect actual commercial recoveries but are given as an indication of the small amount of variation between the systems. An interesting aspect of the study was the importance of the trim allowance setting. For the CAE study the trim allowance ranged from 12-mm to 25-mm depending on the defect size, while for the Barr-Mullin study the trim allowance was the width of the saw kerf (4-mm).

Table 2

<table>
<thead>
<tr>
<th>Clear FJ Recovery as a Percentage of Lumber Scanned</th>
</tr>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>As Scanned</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Dimter crayon mark reader(^7)</td>
</tr>
<tr>
<td>Innovative Vision: As supplied</td>
</tr>
<tr>
<td>Innovative Vision: Re-gauged</td>
</tr>
<tr>
<td>CAE Newnes AddVantage</td>
</tr>
<tr>
<td>Bar Mullin CellScan(^8)</td>
</tr>
<tr>
<td>LuxScan</td>
</tr>
</tbody>
</table>

SUMMARY
The key measure of scanner performance was the percentage of leading cuts made within 20mm of the manually marked cut positions. This is very much an arbitrary method as the laser trachied systems can measure grain angle, while the manually marked cut position is based on the judgement of the operator looking at knots and other defects.

The scanner performance was basically determined by the scanning technology used with laser power being important if dealing with rough or dirty timber. Defect detection was a trade-off\(^6\)

\(^6\) Ghost defects will decrease the scanner recovery and missed defects will increase scanner recovery. The trim allowance was slightly different for the various studies.

\(^7\) The operator missed marking a few defects and the scanner missed reading a few crayon marks. Average measured trim allowance about 20-mm.

\(^8\) The higher scanner recovery is mainly due to the fact that the only trim allowance specified by Barr-Mullin was the width of the saw kerf and that the system produced very few ghost defects. This clearly illustrated the ability of the scanner to detect the defect position accurately and the positioning accuracy of the Brute crosscut saw.
between missing some defects and finding too many ghost defects. Defect classification was based on computer code interpreting the defect information collected by the scanner heads and was prone to error on all systems.

**ACKNOWLEDGEMENTS**

We wish to thank the sponsors of the multi-client project for funding the technology evaluation part of this report. The results in this paper were subject to a two-year embargo period and may not be applicable to current models.
APPENDIX A

TECHNOLOGY EVALUATION STUDY PROCEDURES

The details of a study program will depend on the objectives of the study and the following study procedures were developed to provide useful and reliable information to base a purchasing decision on.

Selecting the right technology for a specific task can be difficult. Often the range of systems on the market can be confusing and a system that works well for one user may be unsuitable for another. Most car buyers will study test results and evaluation reports before making a purchasing decision. Unfortunately the buyer of specialised equipment usually does not have access to this level of objective information and has to make a large purchasing decision on the basis of sparse information.

Technology evaluation can be done at different stages:

- Before a purchasing decision is made. An essential ingredient of any Capital Expenditure Proposal (CAPEX).
- On commissioning of a new system. A commissioning audit can provide valuable information as to the performance of the system as supplied, and can identify problems to be rectified before acceptance.
- After a period of operation. The acceptance study can provide a useful benchmark to compare current performance.
- To get information for dispute resolution.

Technology evaluation requires expertise, time and money. Often the amount of work involved can be quite daunting but the question to be answered is: *Can I afford not to do it well?*

Unfortunately there are many examples of technologies not performing to expectation and many of these problems can be linked to inadequate technology evaluation before the purchasing decision was made or not keeping suitable records documenting performance at different times.

**Selecting timber samples**

Selecting timber samples for any study is critical; the samples should be representative of the material to be processed by the system. For radiata pine it may be desirable to select samples to cover different kiln schedules (high temperature versus conventional or accelerated conventional to ensure a range of kiln brown-stain is included), compression wood (to ensure the system will not be confused when the laser scatter sensors sense compression wood) and heart versus sapwood if applicable.

**Figure A1**

To select the timber it is recommended that boards be selected by taking a vertical column from each packet as illustrated in Figure A1. This will ensure that the boards are selected at random.

The calibration study will require a sample of about 50 boards, about 3-m long, to teach the system. The 3-m length limit is important when air-freighting timber because many freighter planes use 3-m pallets.

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**RECOMMENDED SAMPLING PROCEDURE**

Select Timber in Columns, not Rows

Number Pieces on Ends
This sample must contain a range of all the defect types to be scanned for. One scanner manufacturer recommends a minimum of 50 examples of each defect type. This means if the scanner is to be used to scan for bark encased and intergrown knots, pith, resin pockets, splits and holes the study sample will have to contain at least 50 of each defect, which may be difficult to achieve with only 50 boards.

As it is not desirable to use the same pieces used for teaching the system to evaluate its performance, a second set of a further 50 boards may be required. From a practical point of view it may be possible to split the test packet into two. Use one half for teaching and the full packet for testing. If the packet of timber contains a wide range of defects it may not be necessary to split the packet in two for teaching and evaluation.

Numbering and photographing timber samples
All sample pieces should be numbered on the ends using permanent marker pens. It recommended that all samples be numbered in the packet in a similar way so that tops and bottoms are differentiated.

It is recommended that all boards be photographed. For this purpose a special camera frame is useful as 5 to 10 boards can be photographed in one frame. At least one set of photographs must have the board numbers on them. A camera and frame is available from Forest Research.

Photographic records are valuable for the following reasons:
- It is easy to make a mistake when handling a large number of pieces and a photographic record can help sort out problems.
- Reassembly of components back into boards is a lot quicker with a photograph of the board to check against.
- Errors are better illustrated using photographs than just statistics and graphs.
- Cut positions can be illustrated on the photographs.

Check to ensure all systems have been set up correctly
Before doing any teaching, or tests, the scanning system must be set up to the manufacturers specifications. Make sure you keep a master copy of the manufacturers set-up parameters.

Teaching scanners to recognise defects
System manufacturers have set protocols for teaching their scanners to recognise defects. It is important to understand how the scanning system works and try and match defect boundaries to the detector boundaries. If a detector sees the raised grain of the branch collar around a knot as part of the knot it may be best to teach it that the collar is part of the knot.

PERFORMANCE TEST
Performance expectations
Before evaluating a new technology it is a good idea to have realistic expectations about the technology. It is not realistic to think that a scanning system will be 100% correct. It is however important to know how well the current technology is performing before setting objectives for the new technologies being evaluated.

Wong and Maness (1999) evaluated six manual crayon marker type optimising crosscutting systems in British Columbia, Canada. Defect detection accuracies ranged from 68%-95% with a median of 85%. Average defect mark placement errors ranged from 27-mm to 51-mm with significant variation. The systems missed 1%-11% of the crayon grade marks (median 6%) and
found 0%-11% ghost crayon grade marks (median 3%). The average crosscut positioning accuracy ranged from –4-mm to +1.6-mm.

The results show that defect density, the grading rules and the time pressure on the graders had a dramatic effect on defect identification and mark placement accuracy. Potential value gains of up to 15% were reported by Wong and Maness (1999, p.68).

It is recommended that potential purchasers set realistic performance targets and do the necessary tests to quantify the performance of available systems.

Table A1 illustrates an example of a performance matrix for an automated defect scanner and defecting system:

### Table A1
**PERFORMANCE MATRIX FOR AN AUTOMATED DEFECT SCANNER**

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>% Found Not less than</th>
<th>% Missed Not more than</th>
<th>% Ghost Not more than</th>
<th>Wrong Defect Type: Max</th>
<th>Found Defects Acceptable Size Range9: Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>All knots</td>
<td>95%</td>
<td>8%</td>
<td>8%</td>
<td>10%</td>
<td>95% ± 15-mm</td>
</tr>
<tr>
<td>Holes</td>
<td>95%</td>
<td>8%</td>
<td>8%</td>
<td>10%</td>
<td>95% ± 15-mm</td>
</tr>
<tr>
<td>Bark and resin pockets</td>
<td>95%</td>
<td>8%</td>
<td>8%</td>
<td>20%</td>
<td>95% ± 20-mm</td>
</tr>
<tr>
<td>Pith (exterior)</td>
<td>90%</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td>95% ± 20-mm</td>
</tr>
<tr>
<td>Dimensional errors exceeding 2-mm</td>
<td>98%</td>
<td></td>
<td></td>
<td></td>
<td>95% ± 30-mm</td>
</tr>
<tr>
<td>Wane over 3-mm</td>
<td>98%</td>
<td>2%</td>
<td>2%</td>
<td>0%</td>
<td>95% ± 20-mm</td>
</tr>
</tbody>
</table>

At first glance the performance standards in Table A1 may look very high but these levels of accuracies are required to ensure the system works well. Some scanner based defect detection systems have defect found percentages in the range 70%-90%, not 90%-95%. The acceptance percentages are based on a minimum sample size of 100 defects of each defect type. The problem with an acceptance table as illustrated in Table A1 is that it applies to the scanned defects after being assembled into defect types for grading purposes. Messy clusters of defects can influence the accuracy rate and therefore the acceptance criteria.

It is important to remember that defect detection accuracy is only one aspect of scanner performance. The ability to handle complex grading rules, speed, consistency and ease of use are other important factors to be considered.

### Scanning and defecting test
Before starting the defecting test, the scanner must be checked for consistency. This is best done by passing the same board through twice and record the defect data files. Turn the board upside down and pass it through and record the defect data files. Turn the board around tail first and pass it through again and record the defect data files. Turn the board over to get the original face back on top, and pass it through and record the defect data files. The 5 data sets should be essentially the same. If there are significant differences between the data files it means the system is not consistent and this can make it very difficult to obtain reliable data from

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9 It was assumed that the distribution will be normal and that 95% of the dimensions will be within 2 standard deviations of the mean. A tolerance of ±30 mm requires a standard deviation $\sigma < 15$mm.
performance tests. This test is important because the different scanner heads may have small manufacturing differences that can influence performance.

For the performance tests, all timber must be passed through the scanner and the defect data files saved. To prevent the handling of a large number of cut components the boards can be scored at the cut positions using a small diameter saw blade or by limiting the stroke of the docking saw.

**Reconstruction of components into boards**
If a scoring saw was not used the cut components must be reassembled into boards using the defects and kerf-sized spacers, such as cut to size hardboard, to get back to the original boards. The photographs are useful to ensure all the components are in the correct positions. The scanner generated defect file and intended cut positions can then be compared with the defect positions on the reconstructed boards.

**Evaluating scanner performance**

**Scanned length accuracy**
The first check is to ensure that the system got the lengths right. If the board slips while being scanned the defect images might look good but the crosscut positions will be wrong. The scanned board lengths can be compared against the actual board lengths as shown in Figure A2.

**Figure A2**
Figure A2 shows the scanner length error on a range of boards. As the weight of the boards can affect the scanner cutting accuracy it may be desirable to ensure some of the boards are long and heavy but still within the expected product range to be produced.

**Figure A3**
The difference between the optimiser cut positions and the actual cut positions indicates the cross-cut positioning error as shown in Figure A3.

To cut down on the amount of measurements it is possible to record only the last cut position. If the boards have been scored and not cut into components the drive system must be able to come with a full-length board when making the last cut. This can be a big ask as most defecting saws have a large number of in-feed rollers but only a few out-feed rollers.

This error must be added to the scanner error to know where the scanned defects will be relative to the actual cut positions.
Scanning defect detection accuracy
Defect detection accuracy is best expressed in terms of percentage found, missed and ghost defects. Often changing the settings to increase the percentage of found knots would also increase the percentage of ghost knots.

Figure A4
Figure A4 illustrates the correlation between scanned and actual defect sizes. Often the scanner systems miss or split large knots found in radiata pine, underestimating the size of large defects. The defect errors can be different in the different directions.

The splitting of large defects may, or may not, be important depending on how the grading rules interpret defect clusters.

Defect detection on the edges can be significantly different to the faces because the edges are narrow and do not have knot clusters. If the defect detection rate on one face is significantly better than the other face the difference in the amount of wood removed by the top and bottom planer heads may be a cause.

It must be accepted that most systems will have some blind spots where it finds it nearly impossible to reliably detect defects. Knowing these scanner blind spots can be important when comparing systems.

Scanner grading accuracy
To check grading accuracy the individual boards must be cut up into graded components. A suitably qualified grader must then grade the pieces and compare the visual grades with the scanner grades. By sticking to simple clear cuttings this task can be greatly simplified.

Solution implementation
Comparisons should be made of scanner component cut positions compared to the manually identified cut positions. It can be difficult checking cut positions if the solutions are market demand or price driven. It is more practical to check cut positions without optimising to ensure the mechanical feed systems do not slip.

To check the optimiser it is best to use actual data and simulate different solutions scenarios.
SCANNER SUPPLIERS
A list of scanner suppliers was obtained from the internet and buyers guides. The list includes scanners for chop saws as well as other board defect scanners. The A-Grader was included because it is a technology which could be used to stiffness sort defected components for finger-jointing into structural timber.

<table>
<thead>
<tr>
<th>Product</th>
<th>Web Site www.</th>
<th>Company &amp; Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Grader. (Stiffness grading only)</td>
<td><a href="http://www.falcon-eng.co.nz">www.falcon-eng.co.nz</a></td>
<td>Falcon Engineering Limited. P.O. Box 32, Inglewood, New Zealand</td>
</tr>
<tr>
<td>AOK</td>
<td><a href="http://www.hilgefortmachinery.com">www.hilgefortmachinery.com</a></td>
<td>Mereen Johnson Machine Company</td>
</tr>
<tr>
<td>Linear planer optimizer</td>
<td><a href="http://www.autolog.com">www.autolog.com</a></td>
<td>Autolog, 1240, Michèle-Bohec, Blainville (Québec) J7C 5S4, Canada</td>
</tr>
<tr>
<td>CellScan, Brute X-Cut, RipIt, Rough Mill Command center.</td>
<td><a href="http://www.barr-mullin.com">www.barr-mullin.com</a></td>
<td>Barr-Mullin, Inc, 2506, Yonkers Road, Raleigh, North Carolina, 27604, USA</td>
</tr>
<tr>
<td>Linear High Grader (LHG), DataFusion</td>
<td><a href="http://www.coemfg.com">www.coemfg.com</a></td>
<td>Coe Newness/McGehee, 3550-45th Street SE, Salmon Arm, BC, V1E 4N2 Canada</td>
</tr>
<tr>
<td>Eyetech</td>
<td><a href="http://www.eyetec.com">www.eyetec.com</a></td>
<td>CTBA, Pôle Productique, Rue de Blénod, Maidières, 54700 Pont-à-Mousson, France</td>
</tr>
<tr>
<td>Superscan</td>
<td><a href="http://www.grecon.de">www.grecon.de</a></td>
<td><a href="http://www.scanware.biz">www.scanware.biz</a></td>
</tr>
<tr>
<td>OptiGrader Edger Optimiser</td>
<td><a href="http://www.inxsystems.com">www.inxsystems.com</a></td>
<td><a href="mailto:info@inxsystems.com">info@inxsystems.com</a></td>
</tr>
<tr>
<td>OptiScan, RipScan, GradeScan, ChopScan</td>
<td><a href="http://www.lucidyne.com">www.lucidyne.com</a></td>
<td>Lucidyne, 155 SW Madison Ave, Corvallis, OR 97333, USA</td>
</tr>
<tr>
<td>LASERSCAN, COMBISCAN, XSCAN-COMBI, Front End Scan, Shape Scan, COLORSSCAN</td>
<td><a href="http://www.luxscan.lu">www.luxscan.lu</a></td>
<td>LuxScan Technologies, Technoport Schlussgoart, 66 route de Luxembourg, BP 144, L-4002 Esch-sur-Alzette, Luxembourg</td>
</tr>
<tr>
<td>Lumber Grading Optimiser. ex planer.</td>
<td><a href="http://www.gemofor.qc.ca">www.gemofor.qc.ca</a></td>
<td>Optifor. 1442, avenue du Rocher Normandin (Québec) G8M 3Y1 CANADA</td>
</tr>
<tr>
<td>Intelliwood based on SOLITON patent.</td>
<td><a href="http://www.sensotech.at">www.sensotech.at</a></td>
<td><a href="http://www.soliton.se">www.soliton.se</a></td>
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<tr>
<td>Lineal Grade Scanner</td>
<td><a href="http://www.softacsys.com">www.softacsys.com</a></td>
<td>SOFTAC, Based on Finish INX technology</td>
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<tr>
<td>Optimat</td>
<td><a href="http://www.cordis.lu">www.cordis.lu</a></td>
<td><a href="http://www.stn-atlas.de">www.stn-atlas.de</a></td>
</tr>
<tr>
<td>Ultivision Ripping and cross cutting systems</td>
<td><a href="http://www.ultimizers.com">www.ultimizers.com</a></td>
<td>Ultimizers Inc. 28380 SE Stone Road, Boring, OR 97009, USA</td>
</tr>
<tr>
<td>UltraSense™</td>
<td><a href="http://www.perceptron.com/trident@tridentsystems.com">http://www.perceptron.com/trident@tridentsystems.com</a></td>
<td>USNR/Perceptron, PO Box 310 Woodland, WA, 98674, USA</td>
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Annon, Buyer’s Guide & Directory, Wood Machinery Manufacturers of America, 1900 Arch Street, Philadelphia, USA.


Szymani, R., 1985: An overview of scanning technology in sawmilling, 1st International Conference on Scanning Technology in Sawmilling, Wood Machining Institute, Berkeley, California.


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