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RADAR SCANNING ON GREEN PRUNED LOGS

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ABSTRACT

Radar scanning offers the potential to non-destructively collect commercially valuable information about the internal structure of a log. This information can then be used to make cutting decisions. Low powered radar does not have health and safety dangers and is fully portable.

INTRODUCTION

The name “radar” is an acronym derived from the initial letters of the phrase “RAdio Detection And Ranging”. Radar is a method of scanning using high-frequency radio signals which are broadcast from a transmitter and reflected off objects. The reflected signal is detected by a receiver and provides information on distance and size of objects in the path of the signal.

Most radar systems use pulse radar. The transmitter sends out short intense bursts of energy with a relatively long interval between pulses. After a brief pause of the order of nanoseconds, returning signal is picked up by the receiver.

Conventional radar is used to detect objects at a distance such as aircraft and mountains. The radar used in scanning logs is constructed to detect objects at much closer distances, less than one metre.

Radar relies on the differences in dielectric permittivity of materials being detected. In this application, radar is detecting the differences in dielectric properties between different regions of the log. For example, air has a dielectric constant (relative permittivity) of 1 and water 81. Hence the velocity of propagation of electromagnetic waves is 81 times slower in water than air.

Features inside the log have differing dielectric properties due to their moisture content, physical structure and chemical composition of the material they are made of. The presence of water has a huge effect on dielectric properties. These are typified in radiata where sapwood wood has 150% (or more) moisture content and heart wood has around 50% moisture content. These differences in moisture are reflected in relative permittivity values of 20-25 for radiata sapwood and 5-10 for heart wood respectively. These estimates were obtained using freshly cut wood from radiata pine logs-with the Percometer V.3 by Adek. Fortunately, knotty material forming pruned branch stubs typically gives some dielectric contrast with surrounding sapwood and heartwood, and hence is visible in the scans. The electromagnetic propagation velocity is different in sapwood and heartwood parts of the log, so to get an accurate depth calculation for the features of interest, this must take into account the relative permittivity of the medium above the target feature.

SCANNING STUDIES

Scanning studies have been undertaken to determine the capabilities of radar to reliably identify internal features, particularly the occluded knotty core, of pruned radiata logs. A US patent was granted to Parker & Todoroki at Forest Research in 2004. Various antenna configurations and signal processing algorithms have been trialed. As an illustration of the radar research being undertaken, the results of a recent scanning trial will be described below.
Method

Log Selection
Three fresh pruned logs were obtained directly from Kaingaroa forest. The stand was planted in 1979 and at the time of felling in 2004 was 25 years old. Each pruned log was cut to 4.5 m long with a short section of about 1.2 m long nearest the stump wasted. This was because of transport limitations and the fact that we were mainly interested in the medium and high pruned sections of the stem. The logs were all 43 to 44 cm large end diameter (being roughly breast height after deducting stump height and wasted butt section of log), and 37 to 37.5 cm small end diameter. The logs were transported to Scion, where the bark was removed by debarking with a spade.

Radar scanning
The logs were scanned on the long axis with a Subsurface Interface Radar (SIR) system, manufactured by Geophysical Survey System Inc (GSSI) consisting of a hand-held antenna moved to maintain surface contact with the log, a cable connection to the base unit, and the hardware associated with the base unit mounted in a 4WD vehicle. The logs were scanned linearly along their length at 10° intervals in a clockwise direction resulting in a total of 36 length-wise scans of each log (Figure 1). Scan speed was approximately 10 m/min, but as it was hand driven, it was subject to considerable variation. Distance encoding was also done manually at one meter intervals with a click device attached to the scanner handle. There is some inaccuracy of distance along the log, as the clicks must be performed in real time whilst moving the scanner. In addition, considerable difficulty was experienced in coping with the surface topography of the logs while scanning as the surface bumps caused the pitch of the scanner head to alter frequently. This contributes to scan data variability.

Figure 1 – Manual scanning of logs
GPR data processing and analysis was carried out using RADAN 6.5 software. The initial step involved frequency analysis using fast fourier transform (FFT) which was used to determine the optimum frequencies for bandpass filtering using finite impulse response (FIR) triangular filters. This step removed all noise components above and below the required frequency range covering reflections from within the log. Signal stacking was used to increase signal to noise ratio of reflections. A background removal filter was used to eliminate horizontal noise bands on the data set and highlight the signal diffractions from knots. Constant velocity Kirchoff migration was used to collapse signal diffraction events.

**Sawing of logs.**

Once scanned, the logs were sealed with Mobilcer waxy emulsion painted on to try to prevent excessive water loss, as some delay was expected before the non-orthogonal bandsaw was ready to segment the logs. In the event, the logs were quartered at TiTC sawmill (Rotorua) and sawing the logs into 10 degree radial segments subsequently took place on Campus at Scion. The resulting boards were then laid out in a manner which matched the orientation of the radar scan images created by the Radan software. Location of knots and depth of the heartwood / sapwood boundary was recorded on coding sheets for later correlation with radar scanning images.

**RESULTS**

Interpretation of radar images takes experience and significant computer based image processing (Figure 2).

![Figure 2 - Radar image of the internal structure of a radiata log and actual location of knots (marked as circles)](image)

*Actual knot location vs radar estimate*
Aggregate measures for the three logs indicated that 36% of knots which occurred inside the logs were ‘seen’ easily on the scans. These scan images related directly to the physical location of knots in the logs. However another 31% of knots were ‘seen offset’ on the radar scan in locations offset from the expected location in the log. Therefore in total, 67% of knots were actually identified in the log. Another 28% of knots were not seen (unseen) by the radar at all.

There were 90 occasions on the three logs where the radar ‘saw’ a feature (ghost) but no feature was visible on the corresponding sawn board. However further examination of up to two adjacent boards to the left or right of the scan line indicated 59 (70%) of ghost features actually existed on adjacent boards (valid ghosts).

Table 1 – Occluded knots present in logs and number seen on radar

<table>
<thead>
<tr>
<th>Log</th>
<th>Total knots</th>
<th>Seen</th>
<th>Seen offset</th>
<th>Unseen</th>
<th>Ghost</th>
<th>Valid Ghost</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>58</td>
<td>24</td>
<td>21</td>
<td>13</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>112</td>
<td>100</td>
<td>48</td>
<td>28</td>
<td>16</td>
<td>31</td>
<td>10</td>
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<tr>
<td>113</td>
<td>89</td>
<td>18</td>
<td>27</td>
<td>39</td>
<td>24</td>
<td>17</td>
</tr>
<tr>
<td>SUM</td>
<td>247</td>
<td>90</td>
<td>76</td>
<td>69</td>
<td>90</td>
<td>59</td>
</tr>
<tr>
<td>Proportion</td>
<td>36%</td>
<td>31%</td>
<td>28%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Definitions:
- Total knots: Knot seen on board
- Seen: Knot seen on radar trace
- Seen offset: Radar sees knot but in wrong place
- Unseen: Radar doesn't see knot
- Ghost: Radar sees something but no knot on board
- Valid ghost: Radar sees something and knot on near (x2) board

Seen vs unseen features
The proportion of occluded knots seen and not seen varied between logs (Figure 3). Log 111 and log 112 had a very low proportion of unseen occluded knots. However, log 113 had a higher proportion of unseen knots and most occurred between 350° and 60°.

Ghost features
On further examination most ghost features related to an occluded knot in an adjacent board.
Figure 3 – Total number of occluded knots in the log vs number of unseen knots by radial location in logs 111, 112 and 113 respectively
5. DISCUSSION

Actual knot location vs radar estimate

Thirty-six percent of the knots were seen and located accurately by the radar. However a further 31% were registered by the radar as being in a slightly different location compared with their actual location. These “offset” knot registrations were most probably the result of pitching and yawing of the radar antenna as it was moving along the surface of the log. A subsequent study will use a mechanism to keep the antenna steady (with less pitching and yawing) while it is moving along the log. Also a rotary encoder will be used to continuously and accurately record the distance along the log.

As yet we do not know why the radar failed to register the remaining 28% of knots. This is the subject of further research.

The radar was able to locate the longitudinal position of 67% of all occluded knots present in the logs. The information would of use for log-bucking of pruned stems where inter-node length is required. Radar, at this stage, cannot determine the depth of occluded knots to the accuracy which is required for sawmilling, without destructive sampling to correlate back to the scan data. For this to occur, more accurate determination of dielectric constant of the wood (specific permittivity) has to be made to calibrate the scan depth.

Devaru et al. (2005), used a similar GPR system to scan yellow poplar logs for hidden defects such as rot and knots. The moisture content of yellow poplar is considerably less than that of Radiata pine (especially the sapwood), and they determined dielectric constant values of 12 to 15.5 for moisture content values varying from 11 to 36% (it is not clear from their article whether moisture content was determined on a wet or oven dried basis).

CONCLUSIONS

Radar scanning of fresh radiata logs appears to be a promising technology to locate internal features. The equipment is relatively portable and lightweight, comparatively inexpensive, and has no known health and safety occupational risks associated with its use. The first challenge is to improve the scanning head accuracy of movement by employing a rotary encoder, in addition to eliminating yaw and pitch as the head is moved along the log. The second challenge is to improve the human factors of the system by making the signal processing and feature depth detection more easily interpreted by non specialist users before wider field application to log scanning can be contemplated.

REFERENCES