DEVELOPMENT OF LAB MODEL OF AUTOMATED VISUAL LUMBER GRADING SYSTEM

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DISCLAIMER

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2.0 PROJECT BACKGROUND

2.1 State of the Art

Although research has been conducted for many years into various aspects of grading lumber, no comprehensive system currently exists. Of the fragmentary systems that do exist, none have been implemented in a commercial machine.

In the course of examining the concept of a Grader-Optimizer System, VisionSmart conducted searches of both patents and published literature. A number of references to such a system were discovered. However, the technology for a working system had not yet been developed.

One of the most successful attempts was documented in U.S. patent number 4,606,645 entitled "Method for Determining Localized Fiber Angle in a Three Dimensional Fibrous Material", which described a specific detector technology that can be applied to the grading of lumber.

Additionally, four reports from the Forintek Canada Corp. conference "Scanning Technology for the Eighties" were of use in providing background information. Particularly the report by J. Soest, Weyerhaeuser Technical Center, Tacoma, WA, entitled Optical Scanning Techniques for Defect Detection, showed how people wished to apply certain scanning technology to the grading of lumber. All four reports are listed in section 7.0 ("REFERENCES") of this report.

A Trip Report prepared for The National Research Council (Project No. 1251K621) by Forintek Canada Corp. was also of note. The report, entitled Sawmill Applications of Machine Vision in Europe, gave an actual survey of systems in Europe, where automation of lumber grading is more advanced than in North America. The report indicated that the type of technology VisionSmart is developing was expected to come from a North American firm within five years.

2.2 Background of Principals

The development of the lab model is a direct offshoot of previous industry work of Carl Flatman (P. Eng.), one of the principals. He was directly responsible for the engineering design of a lumber grade mark reader, and a computer vision based headrig optimization system.

In discussion with two of the other principals, Daniel Kenway (P. Eng.) and Will Bauer (P. Eng.), it became apparent from their experience in the engineering development and implementation of real-time high-speed signal processing systems, that there was a major technological opportunity in the forest industry. The opportunity lay in the application of digital signal processing techniques to the real-time recognition of features required for visual lumber grading.

3.0 DESIGN BASIS AND ADVANTAGES

3.1 Design Basis for Grader-Optimizer System

The basis for the design of the Grader-Optimizer System is the linear scanning of all four sides of planed lumber as it moves on a belt between the planer and the trimmer. This is accomplished by creating a gap in the belt and passing the lumber through a ring containing twelve camera sensors (three for each side of the board). The twelve images, each of more than a million pixels, are collected, and processed for features by a proprietary computer featuring an array of 300 autonomous processors capable in total of 3,000 MIPS (million instructions per second) of 16 bit wide computation. By way of comparison, the super-computer at the University of Calgary operates at "only" 450 MIPS. This 3,000 MIPS capability has become possible through advances in high reliability semiconductors, resulting in signal processing chips which have only become available in the last year.

3.2 Design Basis for the Lab Model

The lab model was developed to implement a one-sided version of the Grader-Optimizer System. In the lab model, the wide face of a piece of lumber is scanned, the features present on that side are detected, and the features for each board are passed in a list to a high level processor programmed directly in accordance with the NLGA grading rules.

The lab model is designed so as to have a straightforward implementation of relevant grading rules. Because of this, it is possible to implement other rules and grading standards. For example, a different market standard which could be met would be the requirement of the Japanese market for "J Grade" wood.

When all board feature information has been digitized, it is possible for the lab model to evaluate in real time all possible trim solutions for a board and achieve the optimum dollar return and volume utilization. In making its decision, the lab model is designed to weigh the features, grading rules, and current market price for different grades and lengths.

4.0 SYSTEM DEVELOPMENT

The production of the lab model required the development and testing of a number of subsystems. These are as follows:

4.1 Development of NLGA Based Grading Software

Before software development could begin, an NLGA software specification document was required. The document needed to specify what species, board dimensions, grades of lumber, and features would initially be graded and trim-optimized by the software. The A.F.P.A. was consulted for input on grading issues during the development of this document.

The document defined a "working set" of features, dimensions, etc., which were considered essential in the development of the lab model grading system. Other features required by mills with specific grading problems or desires (eg. "J Grade" requirements) were left to be added in the future as these needs are more clearly defined. Once the software specification was written, the software was designed. One of the design considerations was to allow for the addition of extra features and grades. To this end a stack-based allocation of major data structures was adopted and care was taken to select processing algorithims fast enough so that the total processing time was well under what was required. Enough margin exists in the software design (current program execution time is estimated at sixty percent of the processing time limit) that the inclusion of more features or grades into the design will be possible.

Once the specification document and software design were formulated, development of the grading software proceeded smoothly. The resulting finished program evaluates a list of roughly twenty feature categories, each containing between 16 and 40 features, in conjunction with tables specifying grade and price parameters. A grade for each of the 120 "virtual" boards (boards that could be created depending on where the trim saws are dropped) is produced for each of the standard NLGA grading categories. The value of all possible boards having these grades is then calculated, and the best selection made on the basis of value and volume. This computation is performed in less than half a second.

4.2 Design & Fabrication of Vision Processing Hardware

The vision processsing hardware required for the lab model consisted of three cameras, seven custom computer boards designed and built by VisionSmart, and four IBM AT computers.

In order to transfer the camera data into the vision processing boards, two other boards were required. The first of these processed the analog camera signals from three cameras into a form that could be input to the second board, which converted the signals into digital form readable by the vision processing board. The speed of the cameras required that roughly one million digitizations per second be performed on each of the three camera channels.

The design and fabrication of the vision processing board proceeded after the development of the analog camera and digitization boards. After the circuits were designed, the schematics were drawn using OR-CAD (PC software). This generated a wiring netlist which was used with PADS, a printed circuit board design package. The traces were routed and photoplots generated. The 6 layer board was produced and tested.

The vision processing board is a custom 90 MIPS 16 bit wide board with 35 nanosecond memory. These boards were incorporated into a four board, 360 MIPS, system which was built and tested.

The three cameras used in the lab model were connected to the analog and digitization boards mentioned above. The digitized output from each channel was directed to one of the 90 MIPS boards. The output from the 90 MIPS board was fed into an IBM AT computer where it was stored to disk. For the complete lab model, one analog processing board, two digitization boards, four 90 MIPS boards and four IBM AT's were required. This allowed the three cameras plus the knot sensor to acquire data. A diagram of this data flow can be found in Appendix 8, entitled "Lab Model Data Flow".

4.3 **Camera and Lighting Requirements**

In order to acquire data for the VisionSmart computer boards to process, it was necessary to develop a camera imaging system capable of the high speeds required. It was decided that a high-speed line scan camera capable of about 2000 scans per second would be sufficient. The EG&G model 1902 was selected. Three of these cameras were used in the lab model.

VisionSmart's lab model was designed to use two different types of lighting: direct and edge. Direct light shone at a high angle of incidence to the wood tended to highlight shakes, checks and holes. Edge light shone at a low angle of incidence tended to enhance board edges and surface textural features.

The lighting requirements for the high-speed imaging system required presented a difficult challenge. For the direct light cameras, in order to provide proper lighting, high intensity lighting such as that used in the film industry was required. After a significant search effort, lights were found with the prerequisite intensity and spectral distribution qualities. However, to make them suitable, the lights had to be modified by VisionSmart to eliminate low frequency ripple from their power systems.

The requirements for the edge lighting were not as stringent and were fulfilled after only a few weeks of searching among different light manufacturers.

4.4 Optical Measurements of Unsound Wood and Stain

As part of the lab model design, a program of research was undertaken in conjunction with the University of Alberta Physics Department under the direction of Dr. Frank Weichmann. This program measured the optical qualities of unsound wood and stain as a function of light frequency compared to normal "clear" wood. Analysis and reduction of data indicate that it is possible to detect both of these features optically.

Specific results were obtained relating to spectral reflectance characteristics of unsound wood and stained wood as compared to normal samples of SPF lumber. Measurements were taken with the spectrophotometer, and on the basis of those measurements, specific filtering schemes tested, and an optimum scheme selected. Test results indicate that it is possible to reliably detect, with greater then 95% accuracy, the presence of normal blue stain, heart stain and brown stain in SPF wood. This detection capability is adequate for the lab model to identify these features.

4.5 Feature Recognition Software

Software was developed to detect several different categories of features. Among these were pitch pockets, shakes and checks, wane, knots, holes, heart stain, blue stain and brown stain. Each feature could be specified in terms of a few orthogonal parameters such as brightness, length, width, area, shape, and color. Since the parameters did not interact to any great extent, each feature occupied a particular position in a multi-dimensional parameter space. Identification of the features was done by finding its position in this space. To do this, it relied heavily on weighing the input from several different sensors and based its decisions on a comparison of the different inputs. Data gathered under several different types of lighting tended to highlight certain specific features, depending on the type of lighting.

Additionally, the shape of objects helped in their identification. For example, checks tend to be long and thin, whereas knots tend to be short and fat. A great deal of experimentation and testing went into the development of the feature recognition software.

4.6 Testing of Feature Recognition

Following the integration of the prototype vision processing boards, cameras and their associated hardware, the feature recognition software was installed. A period of experimentation ensued, during which time the design concept outlining the camera/light/sensor arrangment was finalized. Testing of the lab model was performed for each of the basic features being detected. This testing was successful. Analysis of data gathered during the Boucher Bros. field test and at VisionSmart shows that all features important to grade determination were detected and none were confused with others in any meaningful way. Some small objects were not identified i.e. knots or holes smaller than 1/4 of an inch and shakes/checks smaller than two or three inches were often missed, as were small (2 square inches or less) patches of stain. However, none of these objects were large enough to affect the grade. The lab model as designed is capable of meeting grading requirements.

An example of the feature detection data processing is included in Appendix 8. It shows detection of checks by the lab model in a series of displays of computer output from various levels of the feature recognition programs. The "Raw Data" picture shows the raw (unprocessed) data as digitized from the camera. The "Processed Output" page shows output from the processing algorithims. Here the shapes have been correctly identified as checks and are represented by straight lines.

The length of the lines corresponds to the length of the checks. The last display, "Graded Output", shows output from the grading software itself. Again, the checks are represented by straight lines. The positioning of the checks are sorted in order of length with the longest one appearing at the top edge of the board. Up to 16 successively shorter checks are displayed across the wide face with the shortest being displayed closest to the board's bottom edge. The display indiates the trim solution (in this case, the trim is set to six feet) via vertical dotted lines. The untrimmed board length is given along with the nominal width. The trimmed board's value is also given along with the grade and downgrading feature (if any). In our example, none of the checks are long enough to affect the grade. The one dollar board value is a nominal figure used in testing.

4.7 **Development and Integration of Knot Detector**

The final requirement for completion of the lab model was the development and integration of a knot detection sensor. This device had to detect all types of knots, both narrow and wide faced. Additionally, it had to detect "white" knots which traditionally have proven difficult to identify. Following experiments with various types of knot detection technology, a solution was found which fulfilled these design goals. Since the solution is currently part of a patent application, we cannot discuss its technology at this time.

The integration of this new sensor required the modification of some of the sensor's electronics in order to interface with VisionSmart's high-speed computer boards. This was accomplished and testing was done to verify the system functionally. This completed the lab model.

5.0 **TESTING**

The lab model was tested at VisionSmart's plant facility in Edmonton. Once functional, the lab model was taken to the Boucher Bros. mill in Peace River for an insitu test. A lay-out diagram showing equipment placement in the mill is included in Appendix 8 entitled "Lab Model Mill Test Layout". A drawing of the actual lab model itself is also included in Appendix 8 entitled "Lab Model Layout". Post-analysis of data acquired during the test indicates that the system performed as expected. No unexpected problems were encountered in either the detection of features or in the lab model's ability to cope with the field environment, even though temperatures dipped below -30 degress Centigrade.

6.0 **CONCLUSIONS**

In this report we have discussed the development and testing of the lab model of VisionSmart's Grader-Optimizer System. The fact that the lab model works as expected enables VisionSmart to proceed with confidence on the development of the full system. This development will aid Alberta's attempts to diversify its economy into the forestry sector and will increase Canada's competitiveness in world lumber markets.

7.0 REFERENCES

1. U.S. patent number 4,606,645 entitled "Method for Determining Localized Fiber Angle in a Three Dimensional Fibrous Material".

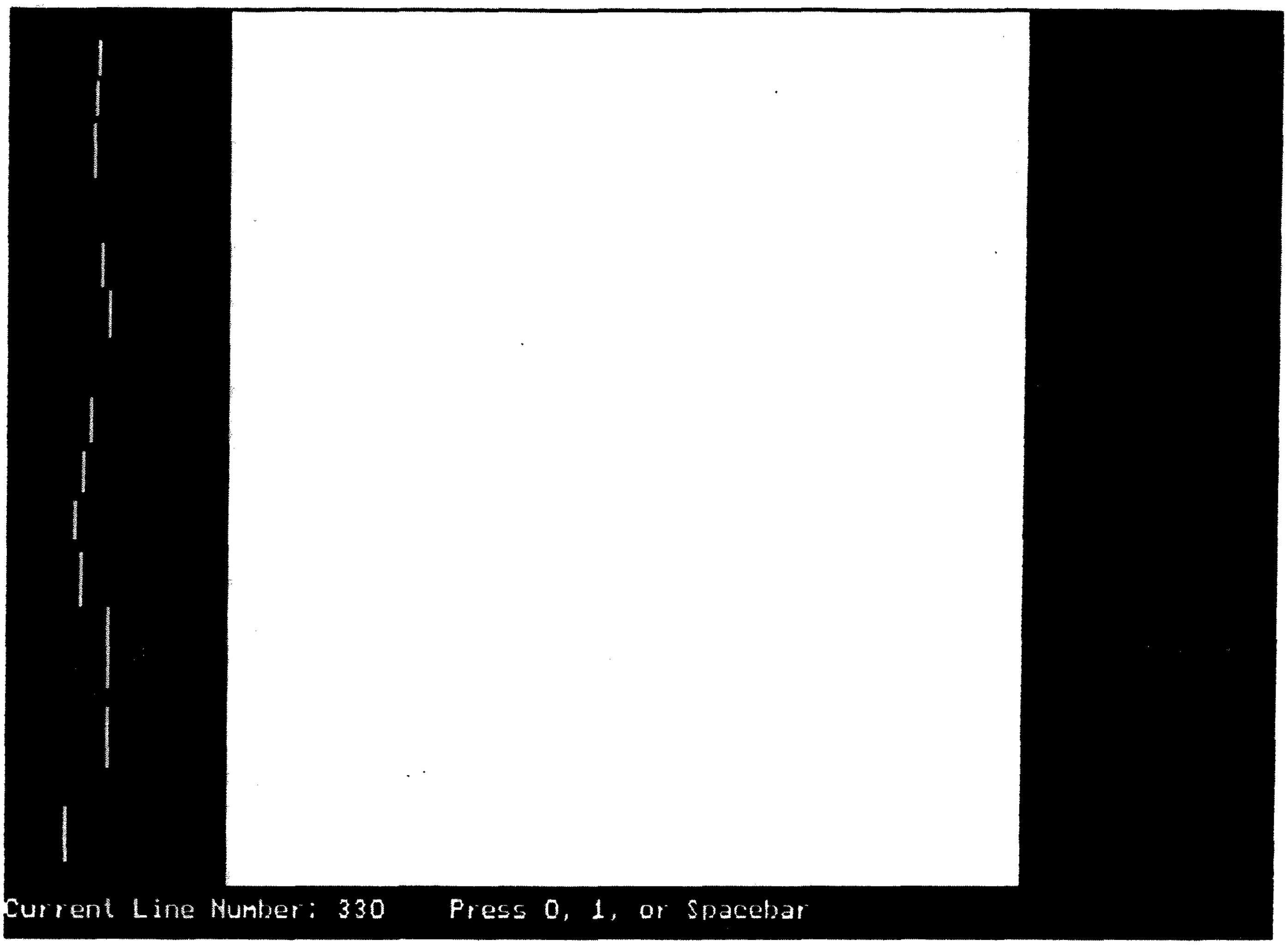
2. Optical Scanning Techniques for Defect Detection by J. Soest, Weyerhaeuser Technical Center, Tacoma, WA.

3. Optimizing Lumber Recovery Using Board Profile and Defect Detection Scanning Techniques by M.V. Maleta, SAAB Systems Inc., Seattle, WA.

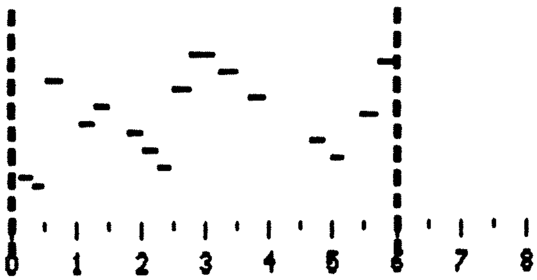
4. A Prototype Software System for Locating and Identifying Surface Defects in Wood, by R.W. Connors, Louisiana State University, Baton Roughe, LA; C.W. McMillin, Southern Forest Experiment Station, USDA, Forest Service Pineville, LA; and R. Vasquex-Espinosa, Louisiana State University, Baton Rouge, LA.

5. Use of Computers for an Automated Lumber Processing System by R.W. Connors, K. Lin and D. Middleton of Louisiana State University, Baton Rouge, LA.

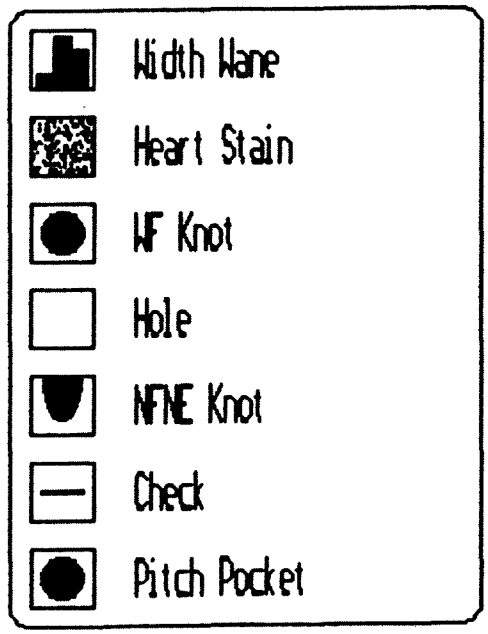
6. Sawmill Applications of Machine Vision in Europe, a trip report prepared for The National Research Council (Project No. 1251K621) by Forintek Canada Corp.



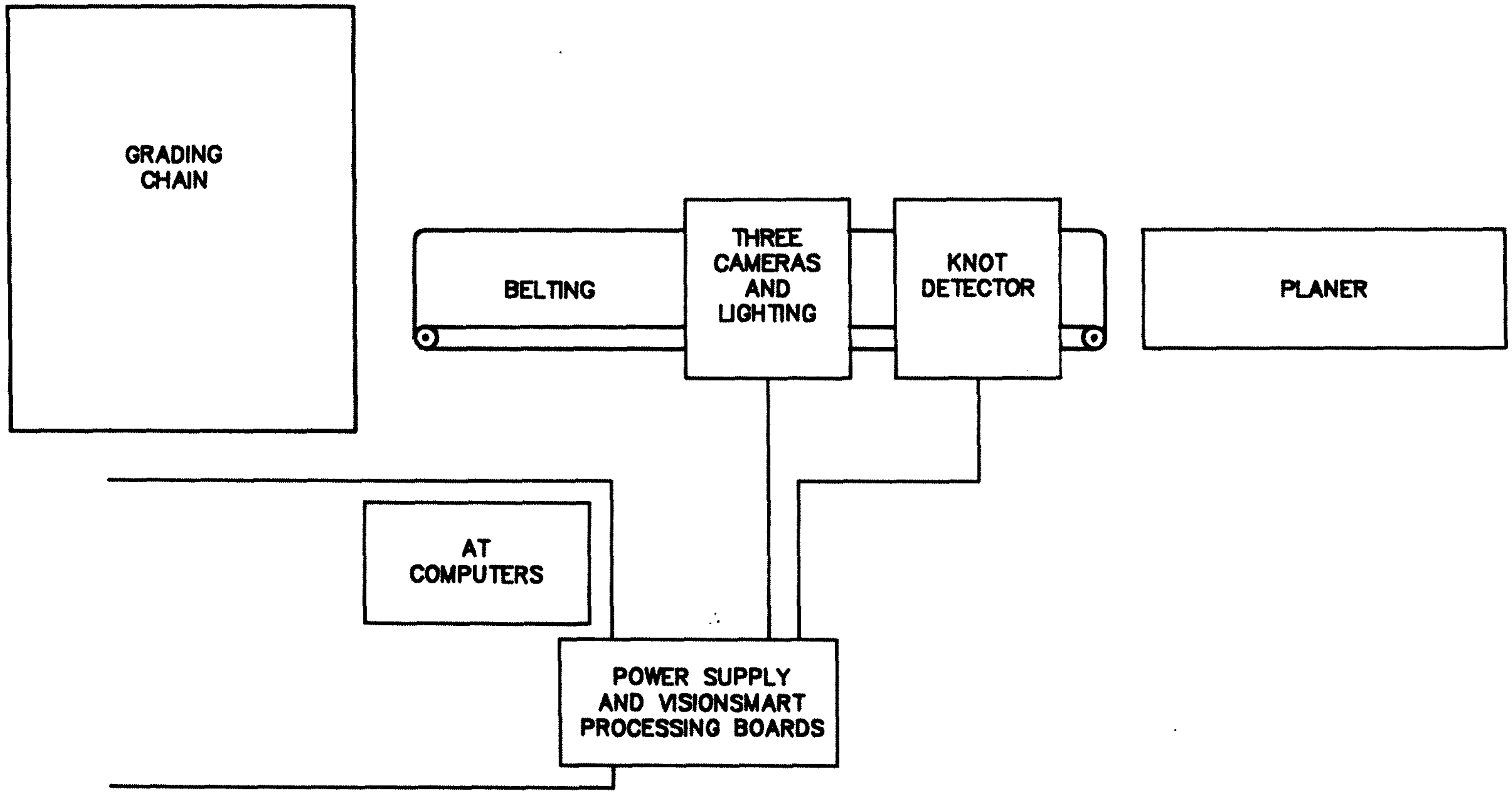
Processed Output



Nominal Board Width:	4 inches
Board Length:	7.7 feet
Trimmed Board Length:	6 feet
Board Value:	$1.00
Board Grade:	construction
Downgrading Feature:	No Feature



Graded Output



Lab Model Mill Test Layout at
Boucher Brothers Mill in Nampa Alberta