A Multiple Sensor Machine Vision System Technology for the Hardwood Secondary Remanufacturing Industry

Richard W. Conners, Professor
The Bradley Department of Electrical Engineering
Virginia Tech, Blacksburg, Virginia, U.S.A.

D. Earl Kline, Associate Professor
Wood Science and Forest Products Department
Virginia Tech, Blacksburg, Virginia, U.S.A.

Philip A. Araman, Project Leader
Southeastern Forest Experiment Station
Virginia Tech, Blacksburg, Virginia, U.S.A.

Abstract

For the last few years the authors have been extolling the virtues of a multiple sensor approach to hardwood defect detection. Since 1989 the authors have actively been trying to develop such a system. This paper details some of the successes and failures that have been experienced to date. It also discusses what remains to be done and gives time lines for the completion of the tasks that remain to be performed.

Introduction

For the last few years the authors have been extolling the virtues of a multiple sensor approach to hardwood defect detection. The authors were certainly not the first to point out the efficacy of using multiple sensing modalities (1), nor are we the first to create a multiple sensor system for locating defects in lumber (2). However we were the first to actively pursue this approach for defect detection in hardwoods.

The sensing technologies we are going to employ include color cameras, very high speed laser ranging (profiling) systems, and x-ray scanning technology. Roughly speaking the color cameras are to detect discolorations. The profilers are to' detect voids and anything that makes a piece too thick or too thin. The x-ray scanner is to locate internal defects that might show themselves after further processing. This array of technology seems capable of addressing the varied inspection tasks associated with the manufacturing of hardwood products. The tasks could include automated grading lumber with NHLA rules, automatically controlling the conversion of lumber to parts, matching of parts, and the inspection of parts.

Since 1989 the authors have been actively pursuing the development of this technology for commercial applications. A significant amount of effort has gone into both our research and development activities and in raising funds to support these activities. We believe that we have come a long way. And while there is still more that must be done, we feel that within the next two years systems employing these technologies will be available in the market place.

In this paper we would like to discuss the progress that has been made, the problems that have been encountered, and what remains to be accomplished. We will outline the approaches we have taken and are going to take to solve the remaining problems. We would also like to point out the many sponsors who have contributed to this project since its beginning in 1982. We owe these people a good deal of thanks for supporting us.

Brief History

Over the years a number of people and corporations have been involved in developing machine vision systems for forest products applications. However, this conference is not addressed to university researchers but, rather, to industrial people interested in assessing the current status of this technology. Hence, the purpose of this paper will not be to recount the contributions that have been made by people around the world. Readers interested in following the historical development should refer to references (3-7) which document much of the development that has taken place. Missing from these conference proceedings is any mention of the pioneering efforts by Kent McDonald in the mid- 1970s at the U.S. Forest Products Laboratory in Madison, Wisconsin (8). He used ultrasound methods for detecting wood defects. Unfortunately this required that the parts being inspected be immersed in water albeit for a very short period of time. Another notable exception is Lakatosh (9), a Russian who did the earliest work in the area of anyone the authors have yet discovered.

The authors' involvement in this area dates back to 1981 when Drs. Charles W. McMillin of the Southern Forest Experiment Station, U.S. Forest Service, and Hank Huber of Michigan State University came to Louisiana State University to discuss the possibility of using computer vision techniques to find defects in hardwoods. The Southern Station funded the early development work from about 1982-1987. The last three years of this funding was provided by a USDA competitive grant award. This early work concentrated on determining the relative capabilities of black and white imagery versus color imagery.

Around 1987, a number of events occurred. First Charles McMillin retired from the U.S. Forest Service. At this time the Southern Station decided to shift its interest away from forest products automation. Fortunately, a new U.S. Forest Service project was formed in Blacksburg by the Southeastern Forest Experiment Station whose primary thrust was in the field of forest products automation. Also, the Northeastern Forest Experiment Station became interested through its project in Princeton, West Virginia. It was during this period of time that the research moved from LSU to Virginia Tech.

It was also during this period of time that technology had matured to a point where it was clear that a vehicle for conducting full-scale tests was needed. Hence, we aimed the thrust of the research at developing a full-scale prototype. It was also during this period of time that it became clear to the investigators that multiple sensors were required in order to address the complex nature of the inspection of hardwood lumber.

Finally, at about this period of time the Department of Forestry at Michigan State University received tiding from the USDA CSRS to form the Eastern Hardwoods Utilization Program. Professor Hank Huber heads the part of this program involved in forest products automation.

Since 1987, research cooperation in a team effort and funds to support this research have come primarily from three sources: the Southeastern Forest Experiment Station, the Northeastern Forest Experiment Station, and the Eastern Hardwoods Utilization Program at Michigan State University.

By 1989 all the steps needed to produce a full-scale prototype were in place. Obviously, creating a fill-scale prototype was going to be a hardware-extensive exercise requiring thousands of dollars for just the equipment, let alone the personnel money needed to integrate the various technologies. Fortunately, the Virginia Center for Innovative Technology stepped forward and provided the support needed for the design and fabrication of the materials handling component of the full-scale prototype.

As the development effort continued, it became clear that a focal point for these and other forest products-related research was needed. The Southeastern Forest Experiment Station in cooperation with the Northeastern Forest Experiment Station, the Bradley Department of Electrical Engineering, and the Department of Wood Science and Forest Products at Virginia Tech formed the Center for the Automated Processing of Hardwoods (CAPH). This occurred in 1992.

By 1993 the integration had progressed to the point that the focus turned to putting together the x-ray scanning components. Fortunately, the International Woodworking Fair provided funds to CAPH that were matched by a Challenger Award from the Southeastern Forest Experiment Station.

Development Methodology

As the brief history presented above might suggest, 1987 marked a turning point in the research effort. For the first time this research effort had a number of collaborators in near proximity to one another and finding levels that allowed the effort to turn from a paper study to one aimed at developing and then demonstrating the technology to industry. The goal became one of trying to develop a technology that would find its way into the market place. We fully understood that it was going to take some number of years to accomplish this objective. It also meant that the product of this research was not just going to be some algorithms but some hardware as well.

With regard to the hardware development we understood that creating a full-scale prototype was going to be expensive. We also understood that the development of machine vision technology for the forest products industry was evolutionary rather than revolutionary with different types of inspection tasks being solved at direct times during the maturation period for this technology. Hence, it seemed clear that the prototype should be rather general purpose to attack a range of problems. Hence it was designed to scan anything from rough green hardwood lumber flitches to shaped wood parts. Even small parts can be put through the system with the aid of an appliance. The disadvantage to creating a general purpose system is that it typically takes much longer to get this type of system operational than one aimed at a particular scanning problem, say the inspection of strips.

The creation of the prototype involved and continues to involve two types of hardware design, mechanical and electrical/electronic. The core expertise of the research team is not in the mechanical area. Therefore, we decided to subcontract out as much of the mechanical design as we could. For example the materials handling system was designed and built by Automated Lumber Handling of Lenoir, North Carolina, and the mounting hardware was all designed by MTD Automation in Christiansburg, Virginia. To whatever extent is possible we attempt to employ off-the-shelf hardware, e.g., components designed for an optical bench.

The electrical/electronic components of the system fall into two different categories. One category is imaging components. Another category involves computer interfaces. We chose quite obviously to buy off-the-shelf imaging components. However, with regard to the interfaces we chose to design and build our own systems. This decision is one that could easily be criticized, hence, a word of explanation seems in order.

A primary reason we have built our own interfaces is that at the time that these interfaces were initially needed there was simply no commercially available device that would do the job these interfaces had to do. However, over time we have continued to update the original designs rather than migrate to commercially available components. There are two reasons for doing this. First we are able to hire capable digital designers (experienced computer engineering research assistants) very inexpensively. Second, many of the commercially available machine vision components do not work robustly. Many of these components have been hastily designed and fabricated for a fairly small market. Machine vision technology has not matured to the point where there is a good infrastructure of equipment vendors. Hence, we decided to build our own systems.

Current Status

Currently the full-scale prototype is capable of collecting color imagery from both board faces at a scanning speed of two linear feet per second. We are adding the laser profiling system to the prototype and hopefully this system will be operational within two to three months. The x-ray components have all been ordered. Also, to help augment the research team’s experience in the x-ray scanning area a visiting scholar from the People’s Republic of China has been hired to assist in the integration of this technology onto the full-scale prototype. This individual, Ms. Yuhua Cui, has approximately 12 years experience in designing airport luggage inspection systems.

Our goal is to have all three imaging technologies fully integrated on the prototype by December 1994. The purpose of the prototype is to collect image data at industrially useful speeds, two linear feet per second. The purpose of the data collection is to establish the proof of concept for using these technologies to solve various lumber and/or wood part inspection problems.

The development effort includes creating a new, inexpensive, very high-speed laser profiler, integrating all the technologies on one device, registering the images from the different systems, and developing the computer algorithms for analyzing the data. While real-time processing is of concern to us, the major part of the effort is aimed at developing robust algorithms. Once the algorithms are fully developed, the major thrust will then be the real-time implementation. Please note that we have started a low-level effort aimed at real-time implementation of the low level vision operations. We know that increased processing speed will have to be part of any final system.

We have experienced a number of problems during this development activity, most of them coming during this last year. Many of the problems that have slowed our development relate to the inability of getting useful technical information from IBM. The image processing computer chosen for the prototype is an IBM RS 6000 workstation. We purchased this computer approximately two years ago. It was selected because it had a Micro Channel, because it supports a large main memory, and because it provided the capability of displaying 24 bits of color information. Its operating system is AIX, IBM’s version of Unix. The Unix operating system provides for excellent software development. It is a much better software development environment than is provided by, say MS-DOS. Graphics on the RS 6000 is provided by X-Windows.

To connect an imaging system to the RS 6000 requires a hardware interface to the machine’s Micro Channel and a software driver to the Unix operating system. To fully use the system the device driver must be able to run under both AIX and X-Windows. It took us approximately two months to generate a device driver. The driver meets all the requirements delineated in the AIX documentation. Yet it will not run with X-Windows. We then spent approximately four months trying to find someone at IBM who could determine our problem. In four months of effort we never found anyone knowledgeable enough to be of help.

Since we absolutely wanted X-Windows graphics capabilities, we took another approach. We bought an IBM PS/2. This computer collects the data. The data is then transferred over to the RS 6000.

We have also experienced an unfortunate turnover in personnel. This has slowed our laser profiler development somewhat.

We have addressed the safety issues associated with the x-ray scanning system. We have also addressed the safety issues associated with the laser profiling system.

Tasks Remaining

The remaining tasks to accomplish can be broken down into electronic (digital) circuit design, mechanical component design, equipment integration, and algorithm development. With regard to the digital circuit design, only one circuit needs to be finished to complete the prototype. This circuit pulls data from four high-speed cameras, digitizes it, locates the position of the laser line, determines the range, and transfers the resulting range information to the computer. This circuit has been designed and fabricated. One small timing problem remains. We believe that this problem can be solved by developing a new program for the field-programmable gate array used in this circuit.

With regard to mechanical component design, all that remains to be accomplished are to design and fabricate the mounting and shielding components for the x-ray scanning system. We are going to hire a consultant to determine what the shielding requirements are and a local firm to design and fabricate the mounting hardware and shielding based on the specifications provided by the consultant.

With regard to equipment integration, the lasers and cameras associated with the laser profiler must be placed on the existing mounting hardware on the prototype. Lenses must be selected. Then, once we start collecting data, the system must be fine tuned. The x-ray scanning system must mount to the prototype together with the required shielding. Software must be written to control the x-ray source. The detector array chosen has an existing Micro Channel interface. Therefore no digital design work is required.

Please note that while the design team has not had much experience with x-ray equipment, we have also been awarded a Federal Aviation Administration grant that will allow us to develop a good deal of experience very quickly in this area.

Finally, with regard to algorithm development we have formulated an analysis strategy that we believe will be robust. To see if this strategy will work we are going to begin collecting laser profile data from a laboratory version of the system that will be used on the full-scale prototype. We will also use a recently acquired airport security x-ray scanning system to collect x-ray images of wood parts. Using these “laboratory” systems will allow algorithm development to proceed in parallel with the development of the full-scale prototype.

As the development continues we are and will continue to turn the full-scale prototype into a user friendly device so that it can easily be used to collect data.

Conclusions

We feel that we are getting very close to commercializable products based on the technology that has been developed during the course of this research effort. Our hope is that within at least two years, equipment based on the multiple sensor approach will be available. While, as should be clear from the above discussion, there is much remaining to be done, we believe that we have a good basic strategy for completing the required tasks. We also believe that we understand basically how the analysis algorithms must work. This comes from the experience we have gained over the years that we have been involved in the forest products related machine vision system development.

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