Developing a Multi Sensor Scanning System for Hardwood Inspection and Processing

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Abstract

For the last few years the authors as part of the *Center for Automated Processing of Hardwood* have been attempting to develop a multiple sensor hardwood defect detection system. This development activity has been ongoing for approximately 6 years, a very long time in the commercial development world. This paper will report the progress that has been made and will delineate the reasons the effort has taken so long to reach this point in the development effort.

Introduction

For the last few years the authors as part of the *Center for Automated Processing of Hardwoods* 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 employ include color cameras, very high speed laser ranging (profiling) systems, and x-ray scanning technology (figure 1). Roughly speaking the color cameras detect color differences. The profilers 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 lumber grading with NHLA rules used in the USA, 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 marketplace.

A Multisensory Scanning System

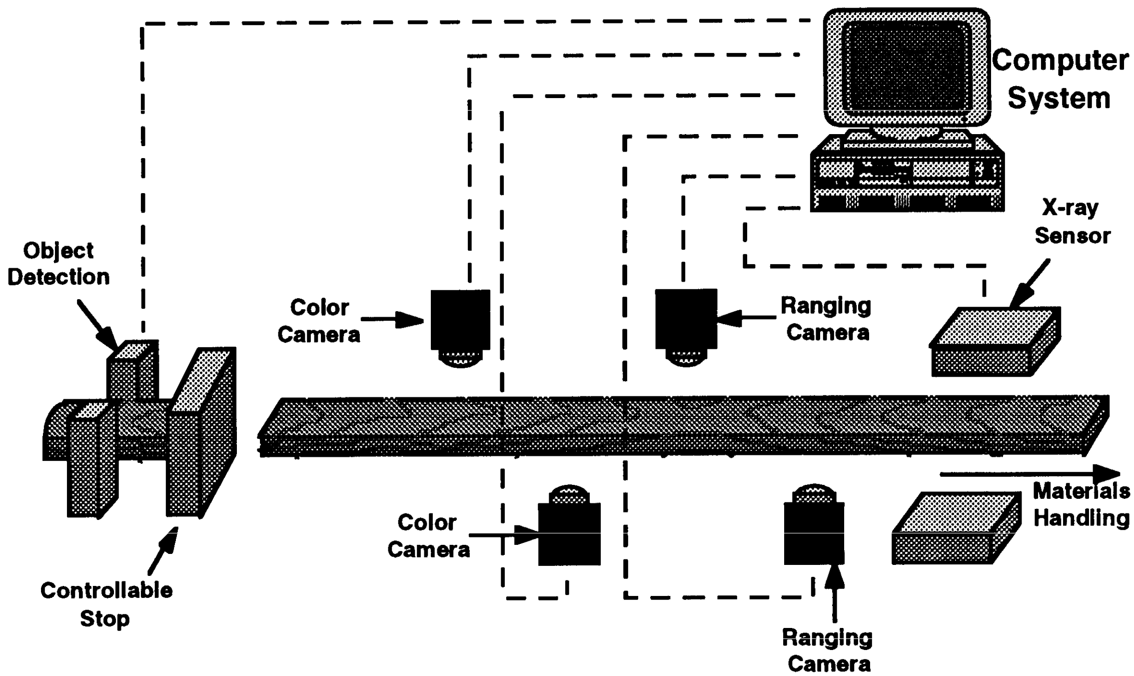

Figure 1. A view of the multiple sensor scanning system at VA Tech.

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. 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 3 years of this funding was provided by a U.S.D.A. 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 funding 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.

From 1987 to about 1992, research collaboration in a team effort and funds to support the activity 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 full 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 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 -- USA provided funds to CAPH that were matched by a Challenger Award from the Southeastern Forest Experiment Station.

In 1994 the U.S. Forest Service merged the Southern Forest Experiment Station and the Southern Forest Experiment Station into a larger unit called the Southern Research Station. The Project in Blacksburg is now apart of the Southern Station. Hence, the research effort has come full circle and is now being primarily supported by the Southern Research Station, albeit a revised Southern Station, once again.

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 funding 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 device so that it could be used 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 lineals or strips.

The creation of the prototype involved and continues to involve two types of hardware design, mechanical and electrical/electronic. Therefore 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 attempted to use off-the-shelf hardware, e.g., components designed for an optical bench rather than having each part designed and manufactured just for use on the prototype.

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 commercial y 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.

While the initial digital hardware design activities just involved creating the appropriate interfaces, the current thrust of the activity has been to create rather robust designs aimed at real-time processing the data.

Current Status

We have for sometime be able to collect color image data from both board faces at scanning speeds of two linear feet per second. To this capability we have recently added the capability of obtaining x-ray image data as well. And lastly, just very recently we added the capability to obtain laser profile imagery as well. Hence all three imaging modalities are operational. The effort is now turning to optimizing the quality of image data that is obtaining from all three imaging modalities and for developing means for registering the data from the various imaging sensors, and for combining the data to arrive at an accurate analysis. Reaching this stage of the effort has frankly taken about nine months longer than we initially thought that it would. In what follows we will attempt to explain the causes for the nine month delay.

With regard to the x-ray scanning system, a number of problems had to be overcome. While we were aware of the steps that needed to be accomplished, some of the steps took longer to accomplish than we thought. One task took much longer than expected was selecting the x-ray source and detector. These are rather costly components. Hence we had to be very careful in our selection efforts. Once, these components had been identified, the mounting and shielding components for attaching these devices to the full scale prototype had to be designed and fabricated. Methods for meeting the U.S. safety requirements had to be formulated. Lastly, all the electronics needed to collect data from the detector had to be designed and integrated with the other electronic components we had designed.

To address the safety issues a consultant had to be hired. He recommended shielding that was substantially thicker than we thought would be necessary. This markedly increased the cost of the mounting and shielding hardware not to mention increasing the time in took to design and build these mechanical components. The electronic components that needed to be designed was a multiplexer board that can multiplex x-ray data and laser profiling data onto one high speed channel for entry into the computer. While the design of the board was rather straightforward, a number of noise problems had to be addressed. These problems were unexpected and they took longer to solve than We initially thought they would. Their were and continue to be some timing issues involved in collecting data from the detector and in controlling the x-ray source from the prototype's control computer. Timing diagrams were not provided with the detector and the manufacturer of the x-ray source has not been completely forth coming about giving us detailed design information. We are still addressing some issues with regard to controlling the source from the prototype's control computer.

The research team is much indebted to a visiting scholar from the People's Republic of China hired to assist our integration of x-ray technology onto the full scale prototype. This individual, Ms. Yuhua Cui, has approximately 12 years experience in designing airport luggage inspection systems. Without her we would not be as far along as we are.

The remaining issues that need be addressed, to get the x-ray technology fully integrated onto the prototype is improving the quality of image data that can be obtained. The goal is to get the highest contrast image data available. As with any scanning technology, one must gain experience with it to get the best possible image quality. We are currently gaining this experience.

With regard to the high speed laser profiling system, we experienced an unfortunate turn over in personnel in 1994. The individual that designed the very complicated data collection board left in June. Shortly after he left we experienced some problems with this data collection board. It took sometime for us to understand the seriousness of the problem. By December of 1994 most of the problems with the electronics had been found and corrected. However, even today we are still experiencing some timing problems. The board is not collecting data at the speed it is supposed to run. We are in the process of redesigning this board. The new design will extensively use field programmable gate arrays. It will also get rid of much of the unnecessary asynchronous design elements.

As was stated above we are able to collect laser profiling data but not at the down board resolutions we had hoped. The above mentioned redesign will cure this problem. We are now in the process of improving the range solution we can get from this imaging system. This involves minor changes in the imaging geometry that is employed and in changing some of the system optics.

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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