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A Compact and High Performance Wood Inspection System Using Smart Sensor Technique and Real-Time Parallel Processing

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Abstract

This paper shows the power of the combination of smart sensor technique and real-time parallel processing. This implementation results in a very compact system which consists only of four cameras and an extension board to a PC.

1 Introduction

Today, industrial inspection systems often employ standard line or matrix cameras connected to some processing unit, typically a PC. By using smart sensor technology together with a real-time parallel processing array, we are capable of acquiring new types of images which can be processed more efficiently. The price of this type of system is expected to be significantly lower since it requires no special purpose hardware and all algorithms are implemented in software.

The wood industry is one of the fields where machine vision has found practical use. There exist a number of systems, commercial as well as research for automatic wood inspection and quality sorting. The basic task for a wood inspection system is the detection of various defects, such as knots and checks. Other measuring principles, such as range imaging, must also be added to the system in order to detect all relevant properties of the wood surface. This will significantly increase the total cost of the system. However, if the different measuring principles are integrated into one single sensor, the total system cost can be reduced. An other advantage of this type of sensor is the exact geometrical correlation of, for example, grayscale and range data and we will thus avoid the problem of spatial sensor fusion of data from different sensors. By combining this type of sensor with a highly parallel architecture for image processing, the total system cost can be very low and thus be used in many different applications.

The real-time parallel processing system used in this paper is called WVIP (Wood Video Image Processor). WVIP is a modified version of the 1-D SIMD array processor RVIP [8][6]. RVIP, Radar Video Image Processor, has been designed at Linköping University and it is used by Ericsson Microwave Systems in Sweden, in their new ground based surveillance radar system. There are plans to build a general purpose VIP. This paper is a part of a preliminary study to investigate the feasibility of a VIP in industrial inspection. The implementation of the algorithms in this paper has been done on a WVIP simulator using data from smart image sensors.

2 WVIP

A WVIP chip consists of 512 processor elements, PEs, as shown in Figure 1. Several chips can easily be joined together to form a larger array. Each PE is bit-serial with a common 1-bit bus to which all units are connected. The WVIP is clocked at 100 MHz.

Each of these chips contains 512 PEs. Each PE, which is bit-serial, consists of four 32-bit I/O registers, a 16-bit shift register, 2048 bits of memory, a 16-bit serial parallel multiplier, an ALU, a Global Logic Unit, and a 32-bit accumulator. A floor plan of a chip is shown in Figure 1.

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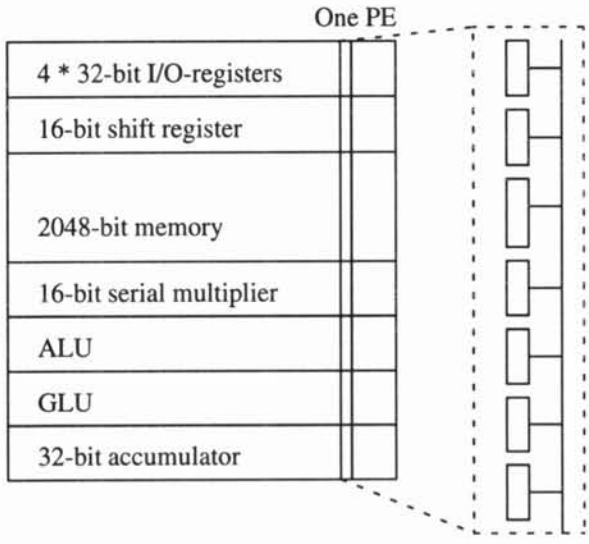

Figure 1, Layout of the WVIP.

3 Global Logic Unit, GLU

The GLU in combination with a WVIP has proven to be a powerful combination [7]. The idea is to perform operation along the array at a much higher speed than shift register would permit. In this application we will use the GLU for fast feature extraction.

There are four GLU operations in WVIP. They are Global-OR, LFILL, COUNT, and MARK. The Global-OR, or GOR, operation can be found in most of the SIMD arrays. In a linear array GOR is set to one if there is at least one PE which is one. The LFILL operation sets all PE to one which are to the right of the leftmost PE, see Figure 2.

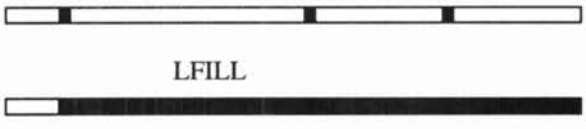

Figure 2, LFILL

The COUNT operation returns a value which is the number of set PEs along the array. In Figure 3 COUNT delivers three as a result.

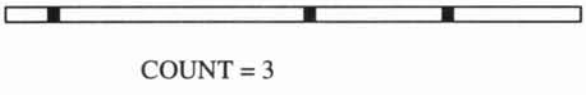

Figure 3, COUNT

The MARK operation takes two binary vector, i.e. each PE has two bit, one is called Mask and the other is called Image. The result is that objects in Image which has at least one corresponding Mask bit is kept and the rest of the array is set to zero. An object is defined as a number of set PE which are connected. The MARK operation is shown in Figure 4.

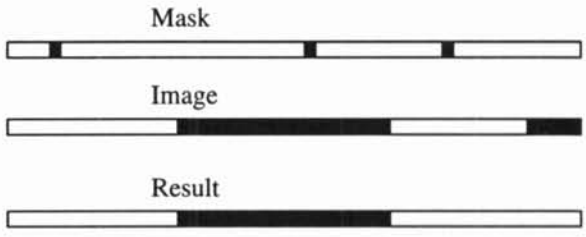

Figure 4, MARK

4 The system

The object for a wood inspection system is to detect and classify defects on a wooden board. Typical defects are splits, knots, and deformation of the board. There are different approaches to find these different defects [1]. Our system is based on the principals described in [2]. The system setup for one side is shown in Figure 5. A line projector (a) located in the same plane as the camera illuminates the board for the split and knot detection. The other line projector (b) illuminates the board at a certain angle to the camera which results in a sheet-of-light range image system, where the height of the board is acquired by triangulation. The sensor view is shown in Figure 6. The line (1) is used for greyscale (split) measurement, the areas (2) for the scattered light detection, and the line (3) is the range image of the line in the scene.

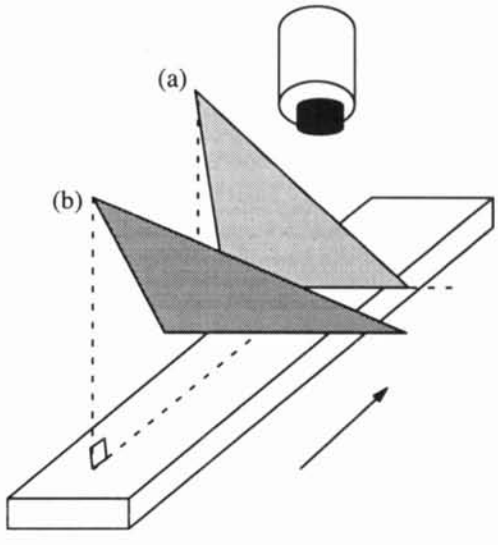

Figure 5, The set-up for a one sided system

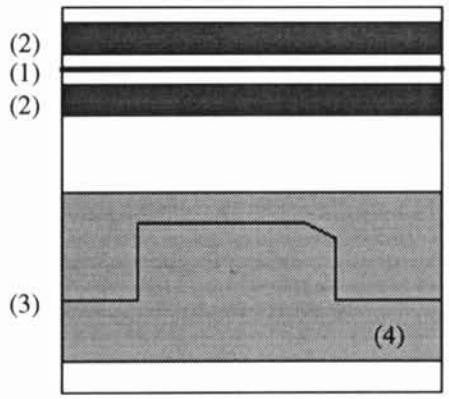

Figure 6, Sensor view

The splits are narrow in the crosswise direction and elongated in the lengthwise direction. In order to find the splits we will use convolution filters with a typical size of 5x5. A typical convolution kernel for splits is shown in Figure 7.

1	3	–8	3	1
1	3	–8	3	1
1	3	–8	3	1
1	3	–8	3	1
1	3	–8	3	1

Figure 7, Split detection kernel

The knots are larger objects. However, many knots have very little contrast to the rest of the board. A new method has been developed which solves these problems [2]. The method requires smart sensor technique since it collects the light which has been scattered within the board by performing a columnwise analog summation of the pixels surrounding the actual illumination line. The deformation of the board is measured by range imaging using sheet-of-light technique [5][3].

The view of the sensor for each line scan, shown in Figure 6, are the greyscale line (1), the scattered light (2), and the range from line (3). The range is acquired by twice reading the columnwise summation of the content of the area (4). This procedure is described in [3][5]. Thus, for each line scan we need to read 4 lines of data. To be able to detect splits, the crosswise resolution needs to be about 2000 pixels. The smart image sensors used in this project have been MAPP2200 and CIVIS [4][5] which both have a resolution of only 256. However, there are currently on going projects to meet the demands of larger sensors. In order to have a sufficient lengthwise resolution we need to scan with a line frequency of 6 kHz. Before data is read from the array we perform, typically, 10 different thresholds on the image giving 10 binary images. Normally, a system consists of 4 cameras which is illustrated in Figure 8. Table 1 summarizes the parameters.

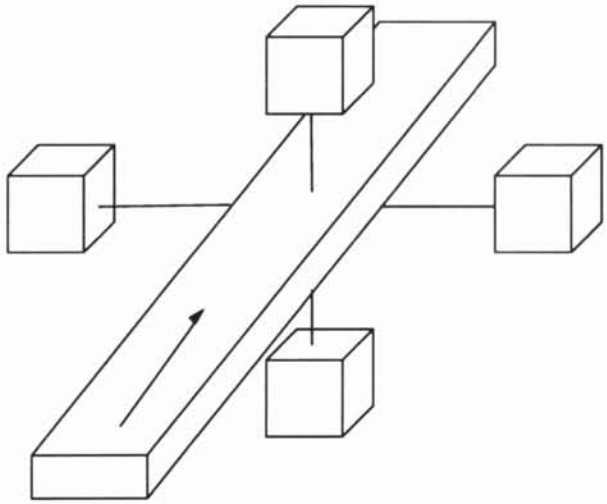

Figure 8, A four camera set-up

Number of measurements	$m_1=4$
Resolution	N=2048
Line frequency	f_{line}=6kHz
Kernel size	k=25
Number of thresholds	$m_2=10$
Number of sensors	C=4

Table 1, Different system parameters

The operations we perform in the WVIP, for each sensor, is shown in Table 2.

Operation	# of cycles	Type of cycle
Shading correction	m_1Nf_{line}	MAC
Split detection	kNf_{line}	MAC
Range calculation	Nf_{line}	DIV (=3 MAC)
Thresholding	m_2Nf_{line}	ADD

Table 2, Computational demand

Combining Table 1 and 2 gives 468 MMAC + 122 MADD per sensor. For a four camera system this is 1.9 GMAC + 490 MADD. Both the ADD and the MAC operations take 16 cycles for a 8 bit value. A 512 WVIP array can be clocked at 100 MHz. This means that we can execute 3.2 GMAC/s on the array. The total complexity of the computation is 2.4 GMAC which means that we utilize the array at a ratio of 75%.

We could now just output the result for further processing outside the system. However, to make full use of the WVIP we will use the GLU to output relevant features.

The major part of the wood surface consists of clear wood while the interesting defects only occupy limited regions.

Therefore, the only data output from the system are objects, i.e. regions within the image which are potential defects because of deviating grayscale, grain direction etc. This is done on a line by line basis. For each line, the position and width of each object is output together with property data depending on the different sensors. This is done using the GLU.

At the next level a host computer, in our case an ordinary PC, merges the line objects and establishes a list of two-dimensional objects. For each such object a number of property functions are calculated including geometrical properties such as size and elongation and properties based on darkness, scattering etc. Each object is then classified as a particular defect, e.g. a knot or a check.

5 Conclusions

To conclude, smart sensor technique is powerful in acquiring several different measurements on a single sensor. This reduces the price of the system and broadens the area of application. To be able to process these data it is important to have a powerful processor onto which the data can be mapped efficiently. The WVIP is ideal in the sense that it can handles very large amount of data and that the linewise input data maps well to the linear processing array. The combination of smart sensor technique and linear processing arrays like WVIP seems to be the right solution to many industrial problems.

6 Acknowledgements

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7 References

[1] Åstrand E., *Automatic Inspection of Sawn Wood*, Ph.D. thesis, Linköping University, 1996.

[2] Åstrand E., Åström A, *A Single Chip Multi-Function Sensor System for Wood Inspection*, Proc of ICPR94, Jerusalem, Israel.

[3] Åstrand E., Johannesson M., Åström A., *Two Novel Methods for Range Imaging using the MAPP2200 Smart Sensor.* Proc of SPIE95, Vol. 2423, San Jose, USA.

[4] Åström A., *Smart Image Sensors.*, PhD Thesis, Linköpings University 1993.

[5] Åström A., Åstrand E., *Very high speed and multi resolution sheet-of-light range imaging*, Proc. of MVA96, Japan.

[6] Åström A., Isaksson F., *Geometrical distortion correction on the 1D SIMD architecture IVIP*, Proc of Machine Vision and Applications 94, Tokyo Japan

[7] Hall Michael, *A Study of Parallel Image Processing on the VIP Architecture*, Lic. Thesis, Linköpings University, 1995.

[8] Johanneson M., Åström A, Ingelhag P., *The RVIP Image Processing Array*, Proc of CAMP93, New Orleans, USA.