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High-speed Label Inspection System for Textile Industry

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Abstract – In this paper, the current development of a high-speed**,** visual inspection unit for use in the quality assurance of narrow fabric and label weaving will be presented. The aim of the project is to provide full visual defect recognition for the textile industry. Dirt spots and patches, weaving faults, missing or torn fibers, and certain errors of the label patterns are detected. A special experimental setup was prepared for evaluating the algorithm performance. Current phase achieves a very high quality level with low false alarm rate at inspection speed of 4 m/s.

Keywords: high speed textile inspection.

1. INTRODUCTION

In this project, we are currently developing a **high-speed, visual** inspection unit for use in the quality assurance of narrow fabric and label weaving. This project is being developed in cooperation with Jakob-Müller AG, a leader in manufacturing narrow fabric weaving machines. During the manufacturing process up to 15 cm long and 8 cm wide labels are woven into a roll of stripe. Later a machine cuts this roll into labels and the inspection system should detect and identify different kind of faults on the labels and send control messages to the machine.

Fig. 1 shows an example with typical errors containing relatively large size but very low contrast dirty patch, small spots, and torn fibers. The required inspection system should be capable to detect all types of errors at low false alarm rate. Speed of the inspection should achieve 4 m/s.

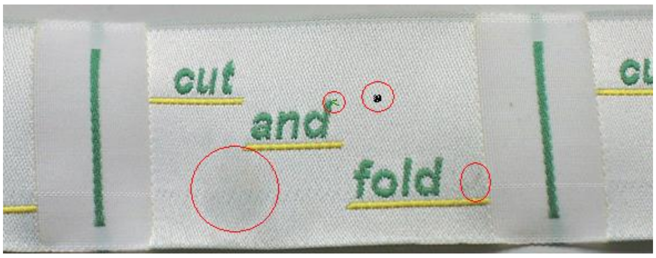

Fig. 1 Sample textile label showing typical errors (dirt spot, a low contrast dirty patch, torn fibers).

Main requirements of the inspection system are the following:

- Continuous inspection of textile-label tapes
- Full and separate inspection of each label
- Stand-alone operation, remote control through network
- Tape speed: up to 4 m/s
- Optical resolution: 3-4 pixel/mm
- Fault types
    - Spot (0,3-1mm, 10% contrast)
    - Patch (>2mm, 5%)
    - Fiber error (thickness: 0,3-1mm, length: 3mm, contrast: 5%)

The inspection task is difficult for a number of reasons. The labels run fast and the inspection should not slow down the overall process. The labels might be distorted which is a normal behavior when they are pulled through the machine. Therefore, there is no straightforward way for constructing reference data for a specific label. The fine texture of the woven label appears as noise on the images. Faults below this noise level must also be detected. A grease spot is a good example as shown in Fig. 1.

2. EXPERIMENTAL SETUP

A special experimental setup was manufactured for test purposes and evaluating the illumination requirements, as well as algorithm performance. The machine can transfer the textile at a maximum speed of 4 m/s. Fig. 2 and Fig. 3 show this developmental setup with some label samples.

Fig. 2 Experimental setup for evaluating algorithm performance and lighting requirements

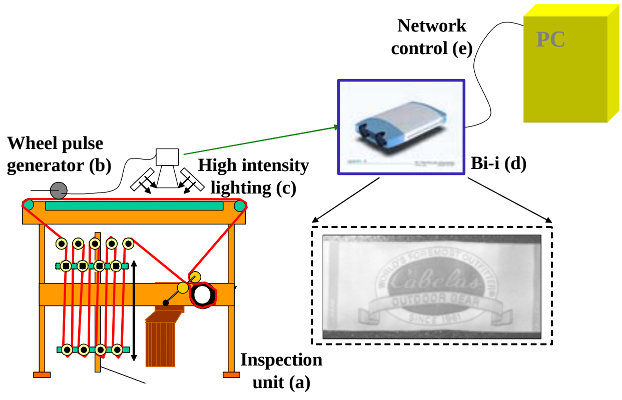

Fig. 3 System components of the visual inspection system. a) manufacturing machine, b) wheel pulse generator, c) LED lighting, d) Bi-i visual inspection unit, e) remote control through network

At a resolution of 0,3 mm/pixel, a typical label with dimension 5 cm by 10 cm can be represented as an image of 55,500,0 pixels. At inspection speed of 4 m/s, 40 images should be processed in a second, i.e. within 25 milliseconds. This image processing capacity fully complies the requirement of narrow fabric textile industry. Since the labels are moving fast, the integration time of the image sensor should be short in order to avoid blurring. Because of the short shutter period and high requirement for even illumination a very strong lighting is fabricated with use of hundred's of LEDs. These LEDs are driven by short current pulses.

2.1. Bi-i system

The full visual inspection (also providing machine control) is carried out on AnaLogic's Bi-i vision system [1,2]. Fig. 4 shows a version hosting two optical sensors.

Fig. 4 Bi-i – a compact, standalone, and high-speed vision system based on the Cellular Visual Microprocessor technology.

The AnaLogic's Bi-i system is a high-speed, compact, standalone, industrial vision system utilizing Cellular Visual Microprocessor technology (CVM) [3,4] based on the paradigm of Cellular Neural Network (CNN) [5-7]. The system is extended with state-of-the-art image sensors and digital signal processors (DSPs). The current version of Bi-i used in this experiment hosts two types of sensors: a 1,3 MPixel CMOS image capturing sensor, and the very fast ACE16k focal-plane array processor chip [8]. The ACE16k implementing the Cellular Visual Microprocessor technology can be configured as a co-processor as well, focusing its processing power on selected areas of images captured by the CMOS sensor.

The central processing element of Bi-i is a 600 MHz Digital Signal Processor (DSP) by Texas Instruments. Application programs are executed by this DSP (with the help of an optional 150 MHz floating co-processor) plus the ACE16k sensor-processor. Powerful image processing operations are executed on the ACE16k chip while the DSP is free to run complex algorithms (e.g. feature classification, quality decision).

Architecture of the Bi-i system is shown in Fig. 5. It contains a monochrome high-resolution CMOS sensor array (IBIS-5), a low-resolution but ultra-high frame rate cellular vision sensor-processor (ACE16k), an integer digital signal processor (DSP Texas C6202), and a communication processor (ETRAX 100). The latter version of the Bi-i system has additionally a floating type DSP and in addition to the Ethernet connection, it contains USB and FireWire I/O interfaces as well. Key features can be summarized as follows:

- Standalone operation
- CVM processor (e.g. ACE16k) capable of image capturing and processing up to 10,000,0 fps
- High resolution CMOS sensor (1,3 Mpixel)
- Flexible versions (mono, stereo, combi)
- Embedded Texas Instruments DSP (C6202, 600 MHz)
- Embedded communication processor (EXTRAX 100)
- 100 Mbit Ethernet connection
- C/C++ SDK and Image processing library [9]

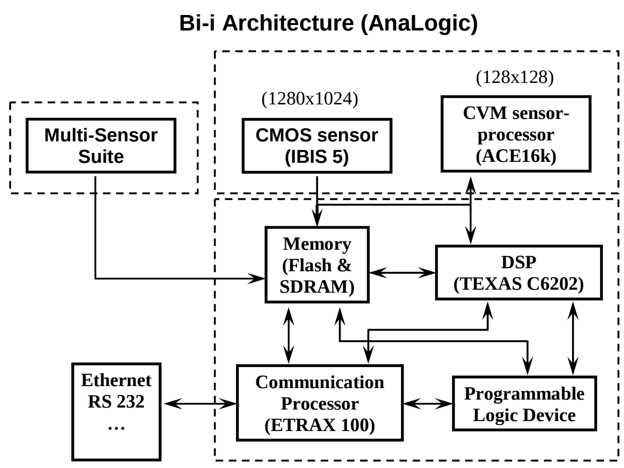

Fig. 5 Hardware architecture of the Bi-i system

From algorithm development and application oriented point of view, the Bi-i system can be attributed as follows:

- Fault-tolerant visual computer (at the topographic cellular processing level, a number of not functioning cells will not affect significantly the overall performance)
- High-speed, compact, standalone system

- Multi-task computing platform (multiple window processing, multi-channel feature analysis and classification, multi-target tracking capability)
- Biologically inspired sensor-computer architecture (hardware support for both topographic and not-topographic computing at various levels)

3. INSPECTION ALGORITHM

The whole inspection algorithm takes place on the Bi-i system. First, there is an automatic calibration phase. The visual inspection system constructs a reference image and its representation by taking images from many good (without errors) labels and calculates different characteristic features of them. As mentioned before, this is a non-trivial task because labels are distorted and there is no such as “perfect” label. Main steps of the calibration are the following:

- Image capturing – determine the optimal lighting, separate background from the label
- Label analysis – determine characteristic points, analyze label features, segmentation into different complexity levels

The whole calibration process takes only few minutes depending on the size of a textile label.

During the inspection process the system takes an image from the label under test and compares it to the reference data. The algorithm comprises different approaches for optimal performance. Both topographic (e.g. edge localization) and statistical (position and distortion invariant feature comparison, like histogram analysis) methods are used. A suitable level of analysis is used for the different areas of the labels, based on the complexity of the area. Thus, simple, robust and fast error detection methods are applied to the plain parts of the label, while intricate patterns are subject to more thorough analysis. This segmentation allows us to optimize the processing speed. Three different regions are distinguished and different analysis’s take place (see Fig. 6).

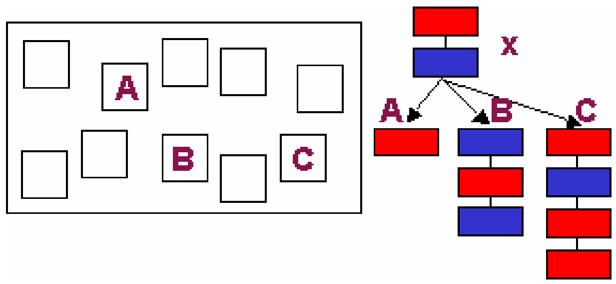

Fig. 6 Optimized processing for different regions of a textile label. The algorithm contains three separate analyzing routines for different complexity levels.

- A: Plain, homogeneous - simple region checking based on statistics
- B: Patterned - Neighboring pixel scan method and sophisticated morphological filtering
- C: Fine and Complex structures –Thorough analysis with sophisticated distortion compensation.

The label inspection algorithm consists of the following steps:

- After taking an image the position of the label is determined by correlating of characteristic points to the reference data.
- The distortion of the label is calculated and image is corrected based on these characteristic points
- An error image is computed using different analyzing routines.
- Only few active pixels with error level above the noise can produce fault signal indicating fabrication error.
- For errors below the noise, several active pixels must be grouped together indicating a fault.
- Specific routine to determine missing or broken fibers by means of grouping long but thin horizontal (or vertical) active pixels.

Fig. 7 shows the flowchart of the inspection algorithm.

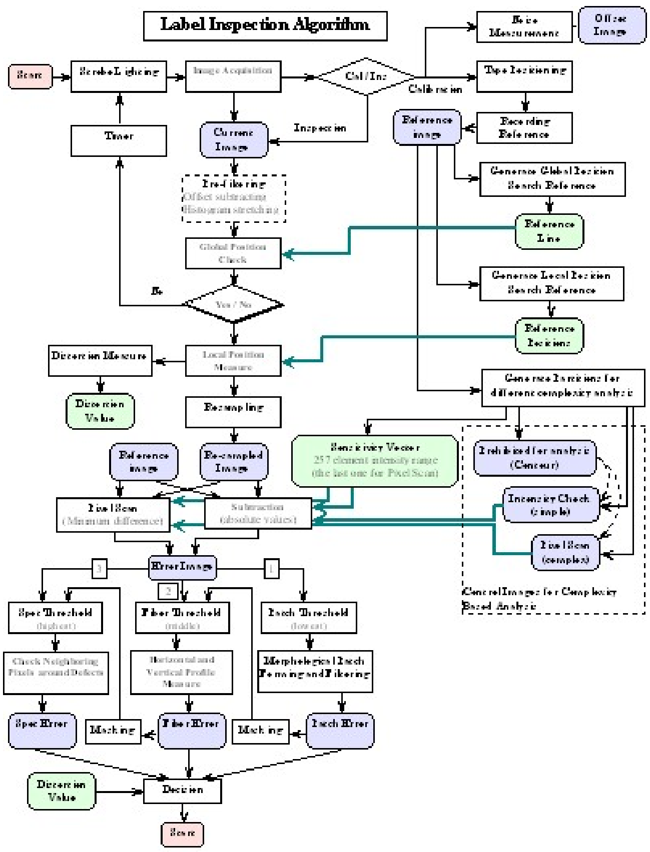

Fig. 7 Flowchart of the inspection algorithm

The current implementation of the label inspection algorithm runs completely on the Bi-i system. For extensive morphological and convolution type operations, the high-speed ACE16k Cellular Visual Microprocessor is used, while feature evaluation and classification take place on the

DSP. At the resolution of 0,3 mm/pixel, a typical 5 cm by 10 cm label can be analyzed in 25 milliseconds. Thus 40 images are analyzed in a second giving an outstanding 4 m/s textile-tape speed.

4. EXPERIMENTAL RESULTS

Several textile-label tapes have been analyzed during the algorithm development. For each label, errors and their types have been determined and these reference data were compared to the algorithm response. Both *false positive* (a good label is classified as a wrong one) and *false negative* (a wrong label is classified as a good one) classification errors were evaluated. Fig. 8 shows a typical result for a specific label tape.

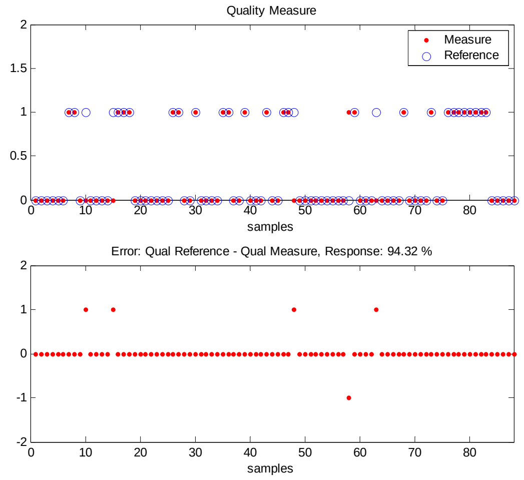

Fig. 8 Quality assessment of label inspection algorithm

At this stage, the system achieves a very low false alarm rate (i.e. indicating errors incorrectly). This means that there are only a few false stops in an hour, i.e. up to 5 at 144,000,0 samples.

5. CONCLUSION

A high-peed, visual inspection system is presented for quality control of narrow fabric textile label production. Full and independent visual inspection is carried out on each label separately while the roll of labels is moving at a continuous speed up to 4 m/s. Detailed and complex analysis of every label (while accounting for various distortions) is carried out using Cellular Neural Network technology implemented on Analogic's Bi-i system. The system is capable of detection of dirt spots and patches, weaving faults, missing, warped or torn fibers, and errors in the patterns on the label.

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