Requirements and Specification for High Speed Computing unit for flaw detection in fabrics

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Abstract --
Industrial High Speed units (or High Performance Computing – HPC)are of strategic interest for the textile industry as they could form the basis of a system achieving a high degree of accuracy on textile inspection.

Due to the specific nature of textile, the defects encountered within textile production must be detected and corrected at early stages of the production process. Thus, the visual defect detection is of utmost importance for the product's overall quality and cost.

This paper presents the requirements of the textile companies, in regards to the quality control process by assessing the feasibility of using a HPC based machine vision to substitute human operators.

The prerequisites or the overall system and its software components are also discussed analytically. The evaluation of the first results is also presented in detail, as well as the limitations and the restrictions imposed due to the nature of the problem.

Keywords -- **High Speed Computing, High Performance Computing,Textile Quality Control, Fabric Inspection, Textile Industry.**

I. Introduction

The quality engineers in the textile industry have to retain the high quality standards established for the textile industry [5]. They have to deal with an extensive variety of fabric defects [16] either due to mechanical malfunction of the loom, or due to low quality fibers and spreads. At the present, the quality assessment procedures are generally performed manually by expert quality engineers and technicians. Hence, the detection and classification of these defects is a time consuming and tiring procedure. In addition, the low quality control speed (only few centimeters per second) when compared to the production speed reveals the bottleneck in the work flow [8].

The Textile and Clothing Industry has an estimated turnover of 150 billions ECU's and employs about 2,5 million persons in EUROPE [1]. The majority of the companies in this sector are SME's, which are facing an ever increasing competition by low price imports. Automation and technological development are suggested as key factors for the survival of this industrial sector. Another key factor is the production of new top-of-the-range products, which are less sensitive to price competition [12]. Although the clothing industry has benefited from technological innovations, particularly in CAD, it is still a labor-intensive industry.

- This paper studies in depth the quality control requirements in the vision systems of the textile clothing industries, by analyzing the quality control processes, evaluation of the performance of the vision system and establishing the feasibility analysis of using High Performance Computing (HPC) based vision machine to substitute human operators [14].

The paper is organized as follows:

In section 2 the quality control in the textile industry is presented analytically. The following two section describe the system's architecture and the specifications for the required constituent parts. In section 5 a brief introduction to the software requirements is taking place. Finally, in the last section, the first conclusions are presented and issues such as the interoperability and the system's performance in the Textile Industry are evaluated.

II. Quality Control

Fabric inspection is mainly effectuated in a textile company through fabric inspection machines, where an operator checks fabric quality [8]. Taking into account that the textile industry uses many types of yarns and wave patters, there are many types of visual defects, that affect overall quality. There are several formal systems to evaluate the quality of the fabric, namely the 4-point system, Graniteville [6], [2] 10-point systems etc. The main concept of all these systems is that the operator calculates the numbers of major and minor defects as point values per m^2 and then considers the quality of the fabric as "first" or "second" quality. Each fabric, either woven or knitted, presents specific defects.

III. Overall System Architecture

The HPC-surface inspection system is typically made up of the following main components:

- The inspection bridge (top and bottom side) with cameras and lighting
- The defect analysis computer system including a main computer (server) and a workstation per camera.
- The operator console, and the quality control console for production purposes.
- The archive subsystem for the strip and defect databases.
- The cabling of the system including the interface to the operational database and the rotational encoder to determine the speed.

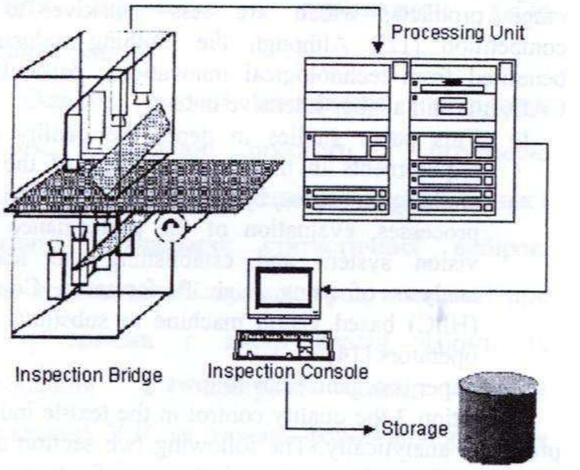

Fig.1 Overall System Architecture

IV. System Specifications

The HPC system specification addresses the overall architecture and detailed data for the required constituent parts like, cameras (number, resolution, spectral sensitivity, etc), illumination and flashing sources and their triggering, mechanical construction, number of processing nodes, configuration and memory, operating and programming software environment, functional specification of algorithms developed, non functional requirements based on production environment and ergonomics. The HPC system based on a prototype developed for the textile industry includes an inspection bridge, illumination modules, image acquisition technology [12] (cameras, objectives, filters, frame grabbers, cables etc) with corresponding peripherals, as well as a high performance computer, which enables the scalability concerning speed and width of material. The system also includes the necessary development environment such as the parallel framework and the software modules [14].

The HPC inspection system consists of three main components [15]:

- the **inspection bridge** with cameras and lighting,
- the **inspection computer system**, consisting of networked industrial PC's, and
- the **inspection console** with the **System Management Interface**.

An extensive requirement analysis took place for all of the mentioned components of the HPC System.

A. *Inspection bridge installation requirements*

The inspection bridge is installed above and below the strip. The images acquired with the cameras have to be transmitted via cable to the analysis computer.

The bridge can be installed anywhere in the production process where a straight strip is available. If a specific application requires the concurrent use of two different image capturing and lighting methods, two inspection bridges may be installed one after the other.

Due to the fact that the quality and resolution of the taken images of the strip surface have a big influence on the quality of the inspection, the determination of the acquisition system (camera and illumination) is the first important step. Generally one needs several pixels in order to detect a defect. On non-structured surfaces (or pre-processed images), the minimal number of pixels needed for a safe detection of a defect is 4 pixels. For a classification of various defect types more pixels are necessary. A minimum for each classification is 12 pixels and for a more precise classification about 30 pixels is necessary.

B. *Inspection computer system requirements*

The computer unit for the evaluation of surface images can be located remotely. The connection to the consoles can be done via standard Ethernet. Access to the inspection results can be provided throughout the mill over an already existing local area network.

C. *Online inspection console requirements*

The online inspection console is usually placed next to the production line at some distance after the inspection bridge. This enables inspection personnel to intervene in the production process when necessary.

D. *System Management - Graphical user Interface*

A Graphical User Interface has been developed in order to control, monitor and manage all the components of the HPC System.

This GUI (System Management Console) enables the operator to perform the following actions:

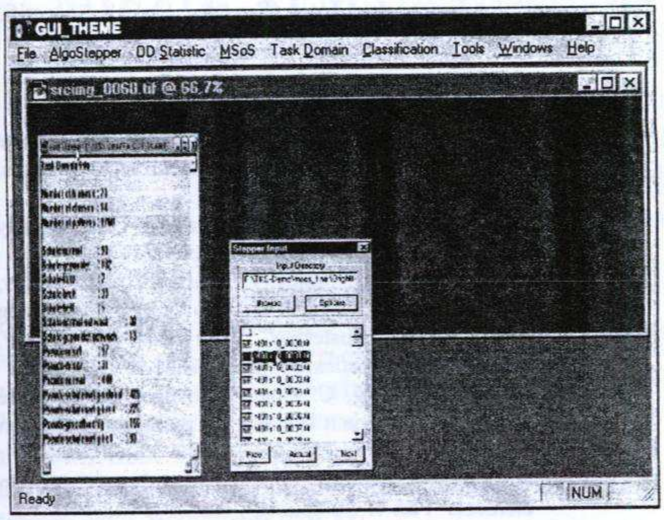

Fig.2 The GUI of the HPC System

- **Load the database**
- **Select the feature space**
- **Select and calibrate cameras**
- **Select the classifier type**
- **Training the classifier**
- **Fabric selection**

E. Illumination and Camera Technology

The dark field illumination has a great significance for surface damage detection, due to the fact that it reacts very sensitively to any changes of the surface smoothness. For this purpose infrared LED's (as used e.g. for remote control for various audio and video systems) are combined into a condensed packaged light deal. Through methods that have been patented the angle of the beam has been so reduced that the total light beam is close to parallel. The overlapping of the beam area is desired and allows the lighting module to be used even if some LED's are not functioning. A pulsed light is used for the lighting of the surface rather than a regular light, allowing a dense packaging of the LED's and a high light intensity without dissipating too much power (i.e. heat). These flashes are extremely short (4 µs up to 100 µs, in the standard mode 38 µs). The use of infrared technologies (wave length 800 to 950 nm) has the additional advantage that the employees, who work in the area of the inspection system, are not bothered by the flashing and through the use of infrared filters in front of the cameras, interfering light can be suppressed. Defects that don't have an edgy kind of surface damage can be detected with the extra use of a diffused bright field light. This lighting is based on fluorescent lights and is implemented in the flash (photo) technology. The bright field images are taken by separate cameras. It is also possible if desired, for these defects to have a different resolution than in the dark field. Color cameras can be used for special recognition projects.

In order to capture the entire width without gaps the HPC-System has several cameras positioned in a row. For the complete configuration the following parameters are relevant: image sequence frequency (50 Hz per row of cameras) and brightness area of the lighting. The uses of a second row of cameras can double the web speed. On special request, systems can be provided with more rows of cameras. The cameras are delivered in a closed housing and are being securely mounted.

F. Mechanical Configuration of the cameras

The camera row is installed in a vertical position over the web with the determined spacing (based on the chosen resolution). The LED infrared dark field lighting can be set at angles between 0 and 70 degrees depending on the amount of reflection of the inspected material. Camera/lighting unit is delivered in a stable frame with covering. The housing also contains modules for the synchronization of the cameras and lighting as well as video signal adapters for the fiber optic transfer.

TABLE I

STRIP SPEED AND CAMERA RESOLUTION

CCD Camera Resolution (square mm)	**Max. Strip Speed** (m/sec)
0.10 x 0.20	2.4
0.15 x 0.30	3.7
0.20 x 0.40	4.9
0.25 x 0.50	6.2

V. SOFTWARE REQUIREMENTS

The software core for an automatic Inspection system should be robust and flexible in order to detect the defected region on the inspected fabric. Due to the complexity of the problem and the extensive variety of the possible defects, the software modules must incorporate the most advanced image processing techniques[14]. In short terms, the software requirements includes the following operation:

- **Correction of Non-Uniform Illumination**

The goal of this step is the correction of local varying mean grey values and variances [11]. This way the illumination irregularities within the image are corrected.

- **Detection of possible defect**

On the basis of this observation a simple operation was developed in order to describe the "local" regularity of the underlying fabric. This operation was motivated by the fact that the standard deviation value of a processing block should not vary with the ones in the neighboring blocks. Hence, the standard deviation difference between neighbor blocks should be near zero or at least should vary smoothly across the texture plane. The scope of this step is the detection of possible defects in the fabric. Defects manifest themselves by irregularities in the texture of the image [15]. The algorithm should be able to identify possible irregularities performing appropriate measurements in the inspected image [10].

Threshold values are chosen according to the specific type of the fabric. Pixels, whose measurements exceed the above thresholds, are considered to be candidates for a possible location of a defect in the fabric [13].

- **Regions of Interest (ROI)**

During this step, the candidate pixels are clustered, in order to form rectangular Regions Of Interest (ROI), roughly describing the shape of detected defects [4]. As additional information, further statistics of the features in the respective regions should be computed and evaluated [7].

G. Defect Classification

The last step classifies the detected defects according their shape or other criteria into macro classes. The classification into micro classes requires further specific knowledge provided by texture features and 2nd order statistics [3].

The complete inspection results can be archived in a database. The data of all defects can also be made available (archived) for statistical evaluation. This is useful in order to establish long term trends or occurrences of individual time periods [9].

VI. Conclusions

The objective of this paper is to present the requirements of an automatic system for the textile companies, in regards to the quality control process by assessing the feasibility of using machine vision to substitute human operators. The requirements and specification of such as a system, are studied in depth, and a technical approach is given very briefly (due to words limitation).

The emerging technologies in the field of Information Technologies integrated with available relatively low cost high quality vision machines, can be the most appropriate solution for the Textile Industry. It is anticipated that IT technology can render feasible advanced quality solutions, thus providing an important competitive advantage.

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