

REAL-TIME FABRIC DEFECT DETECTION & CONTROL IN WEAVING PROCESSES

Project No. G94-2

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1. Abstract

Project No. G94-2 titled "Real-time Fabric Defect Detection & Control In Weaving Processes" was initiated on March 1, 1994. This brief progress report covers the period from March 1, 1994 to August 15, 1994 and details the major accomplishments during this reporting period. This collaborative research between Georgia Tech and N.C. State addresses the monitoring requirements for performance assessment of a weaving machine under on-line real-time conditions and control of the machine parameters to minimize fabric defects. The report describes the experimental and algorithmic development for this study and presents some preliminary test results.

2. Introduction

The textile industry is continually pressing for higher product quality and improved productivity to meet both customer demands and to reduce the costs associated with off-quality. Higher production speeds make the timely detection of fabric defects more important than ever. Newer weaving technologies also tend to include larger roll sizes and this translates into greater potential for off-quality production before inspection. Many segments of the industry are working toward just-in-time delivery and a poor quality production run can be disastrous. Presently, the inspection is done manually after a significant amount of fabric is produced, removed from the weaving machine, batched into large rolls (1000-2000 yds or more) and then sent to an inspection frame. An optimal solution would be to automatically inspect fabric as it is being produced and to alert maintenance personnel when the machine needs attention to prevent production of defects or to change process parameters automatically to improve product quality. Reducing the number of defects produced by timely maintenance or control would result in obvious savings. Also if inspection is accomplished on the machine, the need for 100% manual inspection is eliminated. Costs to inspect fabric manually range from 1.0 to 1.5 cents/yard. The cost to inspect the annual production of a machine would be \$1250 to \$1900. Other tangible and intangible benefits could be factored into the savings equation. Computer vision systems do not suffer from some of the limitations of humans (such as exhaustion) while offering the potential for robust defect detection with few false alarms.

3. Project Objectives

Development and testing of an on-line real-time monitoring system for defect detection and identification of textile fabrics. The yearly breakdown of goals and milestones is as follows:

YEAR 1

Goal 1:

Categorize fabric defects.

Milestones:

A new fabric defect categorization method prioritizing defects to meet the manufacturers' needs while accommodating the automated inspection and control goals.

Deliverables:

An easy to understand computer code for fabric defect categories to be delivered to NTC and textile manufacturers for their review and comments.

Goal 2:

Design and install prototype lab hardware.

Milestones:

A demonstration of the hardware prototype.

Deliverables:

A laboratory prototype to be reviewed by equipment manufacturers for operational characteristics, cost-effectiveness and manufacturability.

YEAR 2

Goal 3:

Develop recognition and control algorithms.

Milestones:

A computer demonstration of a sequence of algorithms from the pre-processing steps through the final classification and control goals.

Deliverables:

A computer code of all the algorithmic developments with full documentation to be delivered to NTC.

Goal 4:

Combine Goals 2 and 3; System refinements.

Milestones:

This is a major milestone of a full laboratory demonstration of the combined hardware/software capabilities; proof-of-concept to be demonstrated; control routines will be shown in a simulation environment.

YEAR 3

Goal 5:

Install on loom in the laboratory.

Milestones:

A laboratory demonstration of the modified prototype installed on a loom at GT or NCSU and performing under "realistic" conditions.

Deliverables:

A report detailing the performance characteristics of the prototype.

Goal 6:

Technology transfer.

Milestones:

A series of reports, demonstrations and presentations to highlight the findings of the research effort.

Deliverables:

A final report to be accompanied by audio-visual demonstrations and documentation.

4. Relevance to NTC Goals

1. This project will significantly improve the weaving process by integrating on-line inspection and feedback control into the process.
2. Industrial partnership are established at the equipment manufacturer and end-user level.
3. The project requires the collaboration of experts in textiles, optics, video image processing, and software development.
4. It focuses on improving quality and competitiveness in the textile industry.
5. Promotes collaboration between member institutions (GT and NCSU)
6. Addresses basic research concerns whose solutions will benefit the textile industry in the other critical areas.
7. It provides a complementary effort to AMTEX's project by focusing on algorithmic development for real-time monitoring and process control.

5. Current Detection Approaches

We have initiated a thorough literature review of the current practices in defect detection and identification as the first task of this project.

There are three basic approaches that have been presented recently in the literature. In all cases, measurements are made on non-defective fabric and these measurements are compared with those from the inspection sample. The three methods are:

5.1 Gray Level Matching

The sample to be analyzed is subtracted from a reference signal and all nonzero differences are classified as defects. The limitations to this approach are that one has to ensure that the imaging conditions are always constant and that the (non-defective) fabric samples are all identical. Under such conditions, this approach offers a possible means for locating fabric defects.

5.2 Random Field Models

The fabric texture is modeled as a random field characterized by a certain parameter. These parameters are estimated from good fabric samples. If the corresponding parameters from an inspection sample do not match the "good" parameters, the sample is classified as defective. The performance of this procedure greatly depends on the estimation technique used. This limits the applicability of this method for on-line inspection.

5.3 Convolution Masks

The fabric is convolved with texture energy to obtain a measure of "roughness" of the fabric. Considerable computation is involved in developing the masks for the texture samples.

6 The Technical Approach

6.1 Fuzzy Logic Based Recognition Algorithms

Recognizing the need for on-line fabric inspection systems, commercial vendors are currently field testing several prototypes to demonstrate proof-of-concept feasibility. These attempts borrow technology from other application areas, such as paper machine inspection, and rely heavily upon simple thresholding techniques to provide operator alarms. Unfortunately, such basic parameters as process speed, medium texture and defect categories show little commonality between paper and textile fabric processes. Moreover, textural, structural and color properties of fabric patterns are drastically different from those typically found in paper production. In the weaving process, these properties are "fuzzy" by nature and require, therefore, appropriate fuzzy-based tools.

We propose to address, as part of this project, such basic research questions as: What is the most efficient categorization of fabric defects? What is an optimum sensor configuration needed to capture those features that will provide an accurate and expedient defect classification? What algorithms are best suited to detect and classify fabric defects? Which hardware/software architecture will result in a cost-effective, user-friendly and efficient inspection system? Finally, how can we improve process performance by utilizing the results of an on-line real-time inspection system? We intend to provide answers to these basic research questions by introducing an innovative research agenda: Fabric defect categories will be defined and prioritized first (with assistance from our industrial partners); features will be extracted from typical defect patterns that selectively characterize these defects. A vision-based system will constitute the centerpiece of the hardware configuration. Software developments will next proceed along the following steps: Image pre-processing routines will exploit such techniques as Discrete Wavelet Transform, FFT, morphological filtering and segmentation in order to enhance contrast and highlight the features under investigation. A model-based vision algorithm will be constructed to perform as a "gross filtering mask" and to provide a conservative estimate of candidate fabric defects. In the event that the filtering mask detects a candidate defect, the classification algorithm takes over and executes the following goals: First, a feature extractor calculates a vector of geometrical, structural, statistical and color-related features, and the available evidence is combined using Dempster's

rule of combination. Uncertainty management addresses both missing data and noisy or conflicting information. The innovative feature of our approach is an active perception algorithm which, in a feedback sense, selects the optimum step of an iterative detection process, that minimize time to classification while maximizing the confidence level in

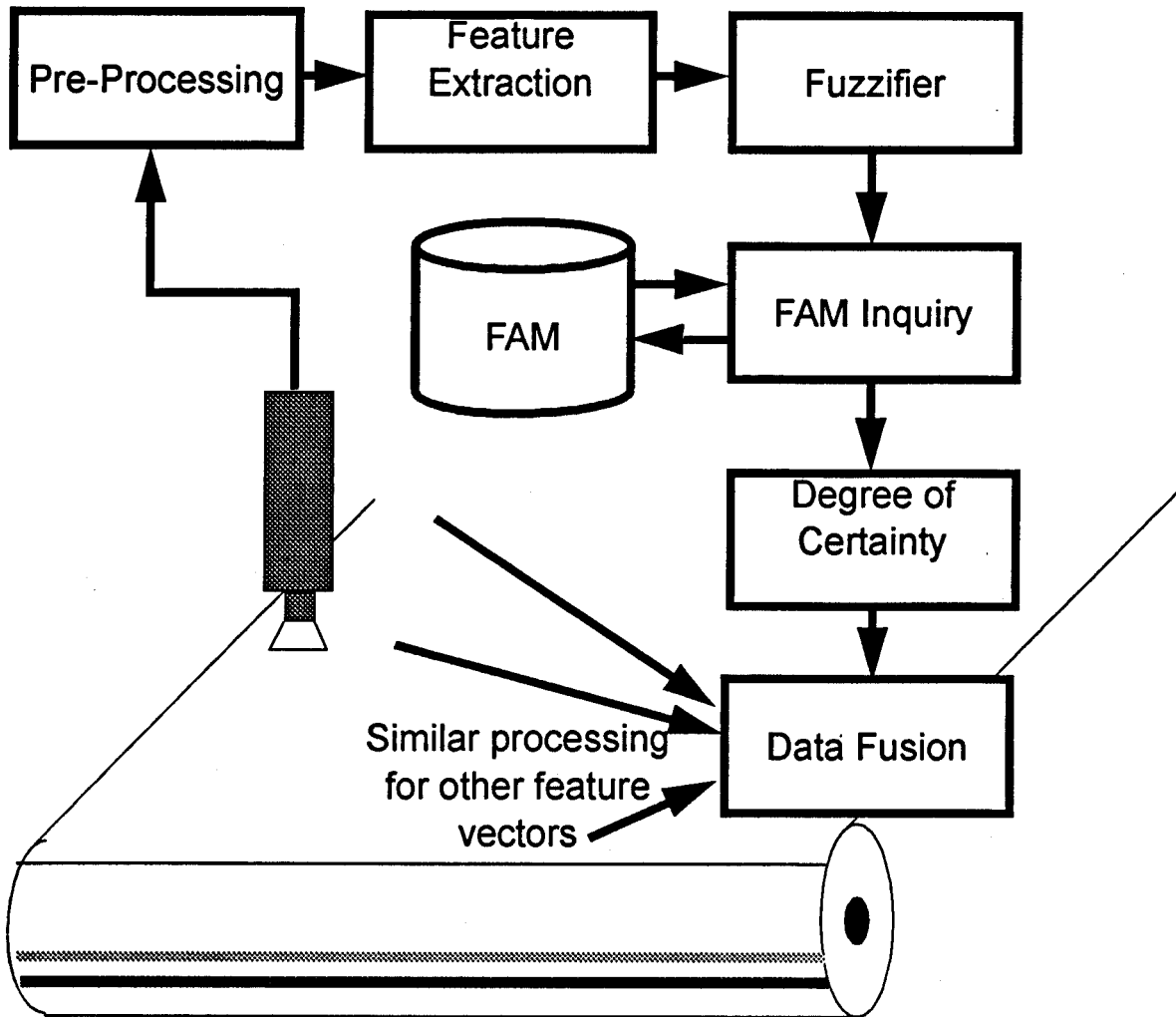


Figure 1. The proposed Fabric Defect Detection and Identification Architecture.

the decision-making process using the measures of detectability and identifiability. A new defect classification algorithm will be developed based upon fuzzy logic and neural network constructs. A neural network architecture will be called upon to perform the fabric defect detection/classification goal. Two alternative architectures will be evaluated as to their applicability in this case:

The first option is a neural network construct called Fuzzy Associative Memory (FAM). FAM's belong to a class of fuzzy neural networks which combine notions of fuzzy set theory and neural networks. The second alternative involves the utility of a Genetic Algorithm (GA) or a self-organizing neural network. These techniques are both global and robust over a broad spectrum of problems. They combine the adaptive nature of natural genetics with functional optimization procedures. The final choice between a genetic or self-organizing algorithm and the FAM will depend upon the dimensionality of the data base, the volume of data to be manipulated, the type and magnitude of data uncertainty to be dealt with and the performance objectives of the project. Figure 1 depicts the major components of the defect detection and identification architecture. The research agenda combines concepts of image processing, fuzzy logic, neural nets and data fusion to achieve the defect classification goal accurately and expeditiously. The combined expertise of the research team in textile processes, vision systems and detection/classification algorithms will be fully exploited to achieve the project objectives. The algorithmic developments proposed for fabric defect detection/identification are generic and applicable to a wide spectrum of problem areas in the textile industry. Although we propose a specific application focus for this research, results may be transferred to other key processes in the manufacturing cycle.

6.2 Application of Wavelet Transforms

Another method under consideration involves comparison of the spectra of the fabrics. The Fourier Transformation is one way of accomplishing this task. However, even fast implementations (FFT) are not suitable for on-line inspection process.

We are currently investigating the applicability of wavelets. Wavelets are highly compact signals which are localized in both time and frequency. Wavelets have been used with considerable success in image compression. In our approach, we compute wavelet coefficients for the given fabric sample and compare them (in a statistical sense) with those obtained from good fabric. The difference will be used to detect defects.

7 Major Accomplishments

7.1 Categorize Fabric Defects

Towards establishment of a new fabric defect categorization method, we have pursued the following strategy:

1. We have reviewed the available literature that addresses fabric defect categorization.
2. We have formed a group of industry experts who have agreed to assist us in the categorization process. They will provide us with defect statistical data and will participate in the categorization and prioritization process.
3. We have begun by considering some obvious defects (i.e. broken picks, start-marks, etc.) that will probably rank high on our final list.

This task will be completed in the first year of the R&D effort.

7.2 Defect Detection and Identification

We have initiated research activities in two directions: The first one refers to the design and construction of a laboratory scale test facility while the second is concerned the development of appropriate detection/identification algorithms.

1. Laboratory Test Unit

A test fixture has been designed and built at Georgia Tech that will simulate fabric conditions at the output of the loom while supporting the imaging sensor and associated lighting and transport apparatus. The test unit is capable of simulating the mechanical noise (vibrations) and will provide variable speed operation normally encountered in modern looms. A schematic design of the test unit is shown in figure 2. The imaging hardware, support and tracking devices are on order. A computer is currently being purchased to be interfaced with the test system and to house all the recognition/control software. The unit will be used to test and validate the software routines under real-time environment. Actual defective sample from various sources (Greenwood Mills, GT and NCSU) will be employed for testing and verification process.

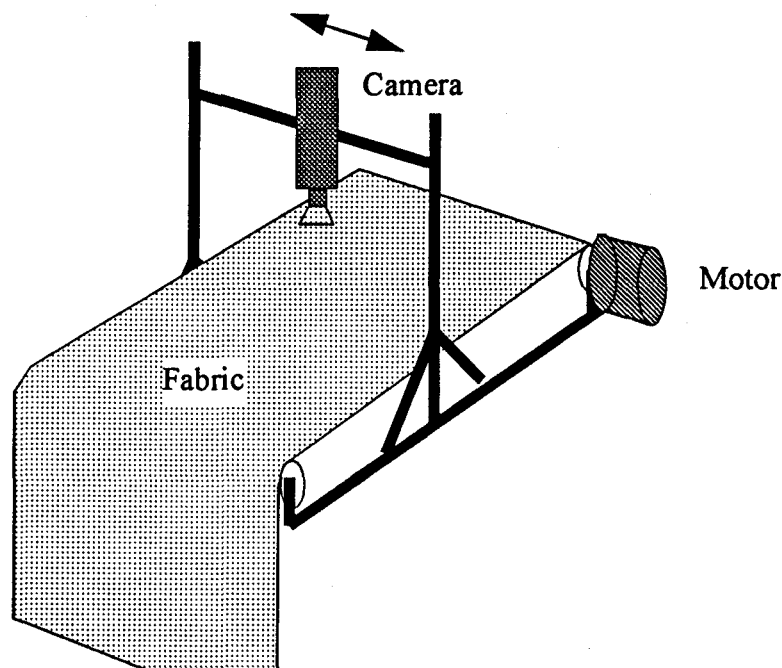


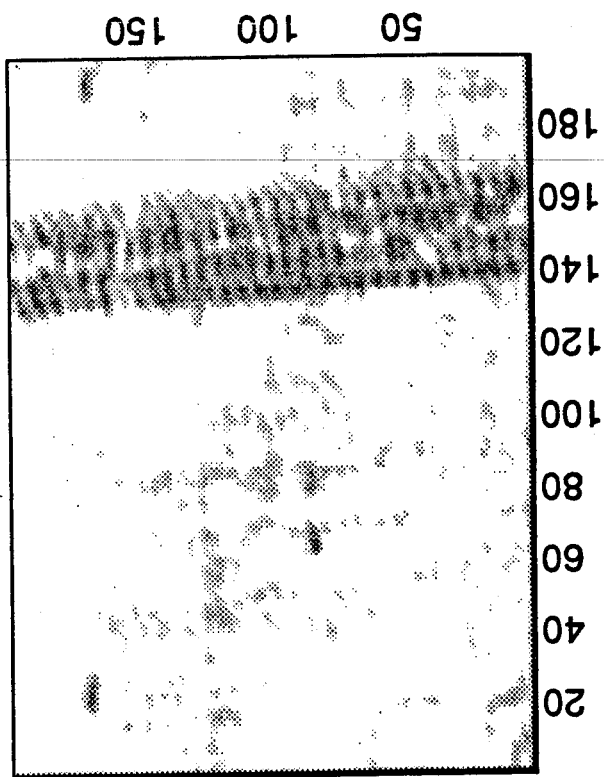
Figure 2. Schematic design of the laboratory test unit.

2. Recognition Algorithm

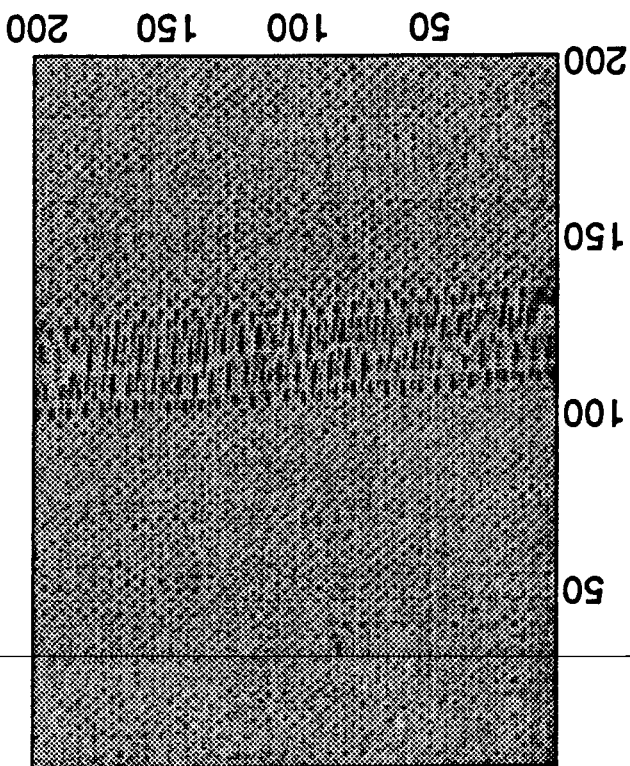
The defect recognition task is delegated to two software algorithms: The first one undertakes the role of a conservative gross filter. Its objective is to detect all possible defects. The intent here is to provide a reliable means of identifying rapidly suspect regions in the woven fabric that may or may not be finally classified as defective. Several approaches are considered in the design of the gross filter that build upon a measure of detectability and take into account the textural and

Figure 3. Application of a gross filter on an actual textile fabric sample.

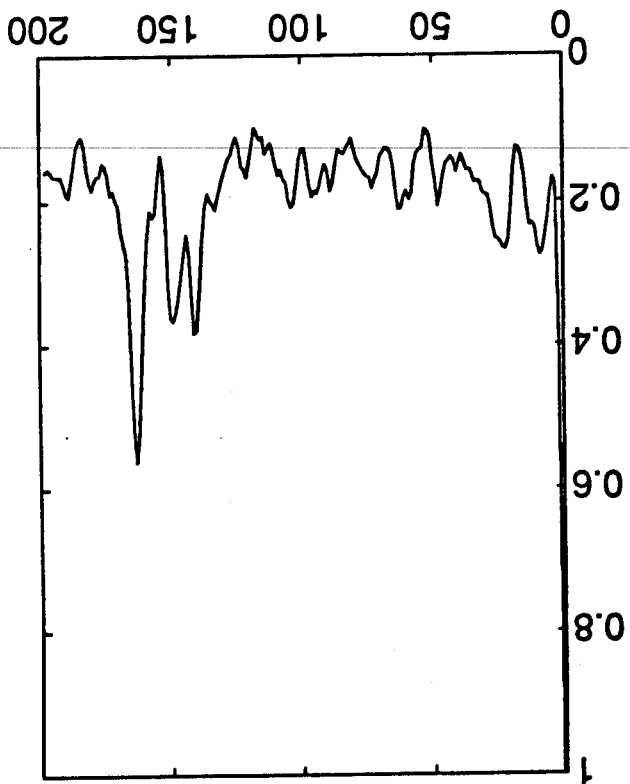
3 (c) Low Pass Filtering.



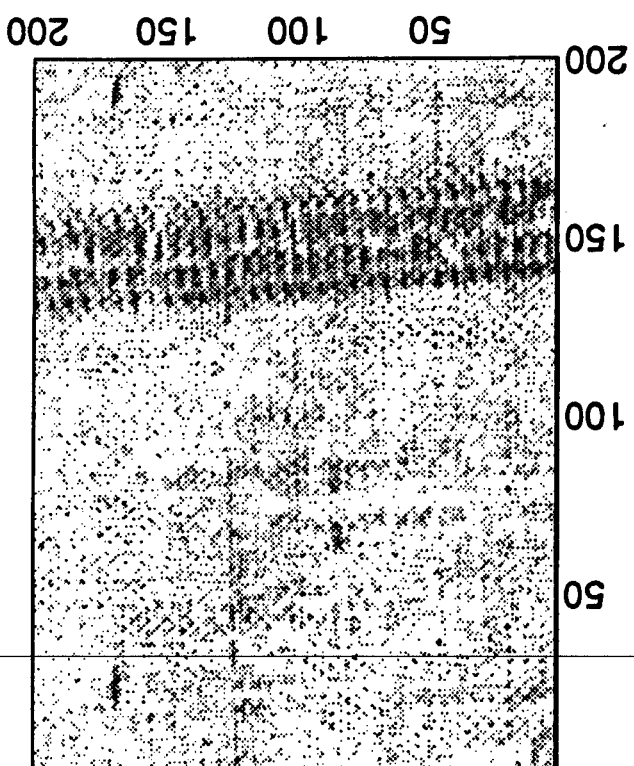
3 (a) Original Image.



3 (d) Typical variation of signal in the warp direction.



3 (b) Normal fabric template subtracted from the sample



topological architecture on the woven fabric. Masking techniques have been widely exploited in other applications and they constitute a potential alternative in our case. An example for gross filter using template matching and basic filtering is shown in figure 3. Sobel edge operators are powerful tools in detecting image edges. Such a technique has been tested on a simulated fabric structure using zero mean uniform random noise as shown in figure 4. The dark line indicates a defect (missing pick). The goal of the recognition system is to detect this defect. The image shown in the figure has a resolution of 72 x 72 dpi. The Sobel operator detects all edges in the texture as shown on figure 5. An additional step is, therefore, required to identify the defect from the rest of edges. This simple demonstration points out the limitations of the low level image processing when applied to the textured fabrics. We are currently exploring approaches that will consider the fabric structure, the defect characteristics, as well as computing requirements in the optimum design of the gross filter.

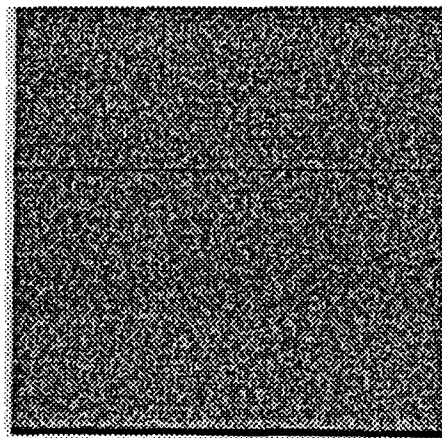


Figure 4. Simulated Textile Fabric with defect.

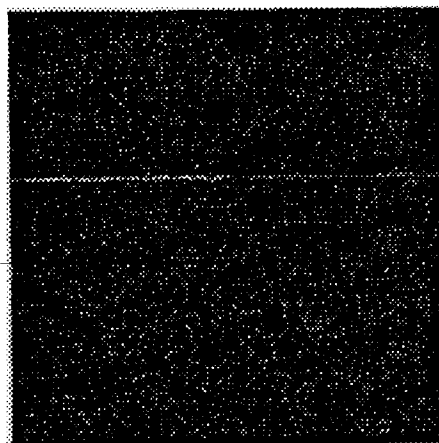


Figure 5. Filtered Image : The Sobel transform of the simulated defect.

The second algorithm is aimed at verifying the findings of the gross filter and identifying the type and severity of the defect. Here, characteristic feature of the image at hand will be extracted and compared with templates stored in a neural network structure. The basic tools: feature extraction and neural network, are already available in our laboratory and they will be employed towards this objective in subsequent phases of the project.

8. Tasks to be Performed During the Next Reporting Period

1. The experimental setup will be completed and installed. This includes the mechanical fixture, imaging sensors, interfacing and computer hardware.
2. Collection of defective fabric samples will continue and testing will be initiated.
3. Gross and fine filtering algorithms will be developed and tested.
4. Collaboration with equipment manufacturers, textile mills and AMTEX will be expanded.

The Resource Base

A team of experts has been assembled to define and carry out the research agenda. Their combined expertise in textile engineering, inspection processes and computer hardware/software systems provides the synergism required to accomplish the complex research goals and to integrate effectively the diverse elements of the inspection process. Participating faculty and students from GT and NCSU will work to promote textile research by collaborating closely with several industrial partners. Honeywell and ABB will contribute personnel and laboratory resources to this project. Greenwood Mills has expressed an interest in actively participating in the research effort. GT and NCSU will make available vision systems, computer processing equipment, weaving machines and loom monitoring systems that are needed to carry out the research. Experienced support personnel is also available to assist in the conduct of the experimental work.

We have made several attempts to communicate with the colleagues involved in the AMTEX CAFE project on fabric defect detection. Our objective is to interact as closely as possible with parallel efforts in this direction. We anticipate exchanging views and discussing progress reports in the near future, once a channel of communication is provided to us with our AMTEX colleagues.