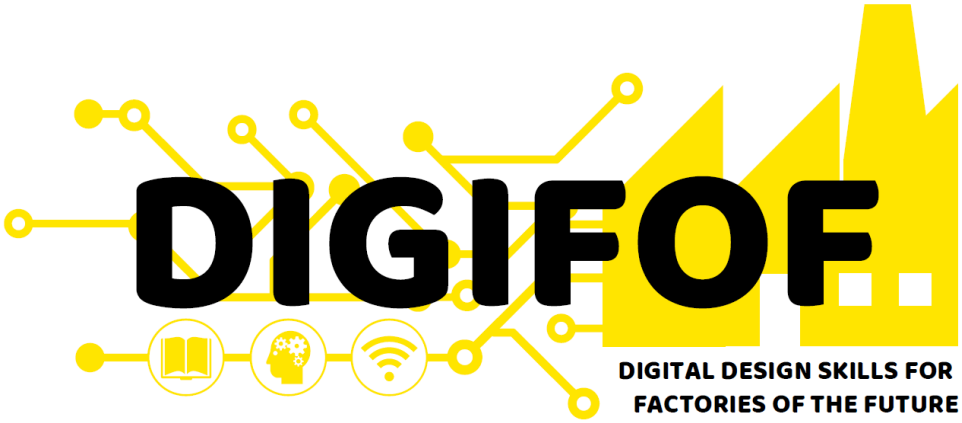
Computer Vision for Manufacturing Industry Application

Case study: textile industry

Remus Brad



Welcome

Remus BRAD

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Research interests

- Remus Brad received an Engineer Diploma degree in Computer Science from the “Lucian Blaga” University of Sibiu (ULBS), Romania in 1993, a M.S. degree from Université “Pierre et Marie Curie” Paris, France in Artificial Intelligence in 1995 and a PhD. from Technical University of Cluj-Napoca Romania in 2003
- Since 1994 he has joined the Department of Computer Science and Automation at the “Lucian Blaga” University of Sibiu, Romania, where he is actually a Professor
- He is a Senior Member of the IEEE
- His current research interests include Image Processing, Motion Estimation and Medical Imaging

Agenda

- Motivation
- Image processing for textile defect detection
  - Texture
  - Gabor filters
  - Texture analysis techniques for fabric defect detection
- Implementing a defect detection system in airbags manufacturing
- Image processing for sewing defect detection
- Computer Vision for Manufacturing Industry Application
  - Conclusions
- Q&A

Motivation

- High productivity and quality by intensive inspection
- High production speed and large flexibility urge to automated defect detection
- In weaving sector, inspection is performed at the end of the manufacturing stage
- In the clothing industry, defect detection is performed between manufacturing stages
- In both cases, carried-out by manual measurements and visual examination of markers and texture

Motivation

- Computer vision systems can offer:
  - robust detection
  - large flexibility
  - does not suffer of human limitations
  - could entirely replace traditional methods

- Automated visual inspection relies on material properties as texture or other features

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Image Processing for Textile Defect Detection

Image Processing for Textile Defect Detection

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- Quality assurance systems have been developed in the aim of providing the client with a high level of trust in the producer's capacity
- Automatic production control is an important phase of quality assurance
- Texture analysis techniques for fabric defect detection
- Image processing for sewing defect detection

Texture

What is texture?

- “Texton” – the texture unit
- Replication of the texton in two directions -> frequencies
- Detect frequencies -> detect the texton

Texture

Texture analysis techniques for fabric defect detection are based on:

- gray-levels texture properties
- texture statistics
- characterization of fabric texture using a Markov random field model
- detection by model-based clustering
- Fourier transforms and Fourier-domain analysis for discriminating texture variations
- multi-resolution approaches by decomposing fabric images in several scales using a bank of Gabor filters

Gabor filters

- Defined as mathematical representation of the receptive cells of the visual cortex
- Applications starting from edge detection, ending by texture classification and image compression
- Feature detection characteristic of the Gabor filters relies on the possibility of tuning the orientation and his frequency selectivity
- A bank of Gabor filters processes the input image
- Choosing the appropriate filter represents the key to correct results

Gabor filters

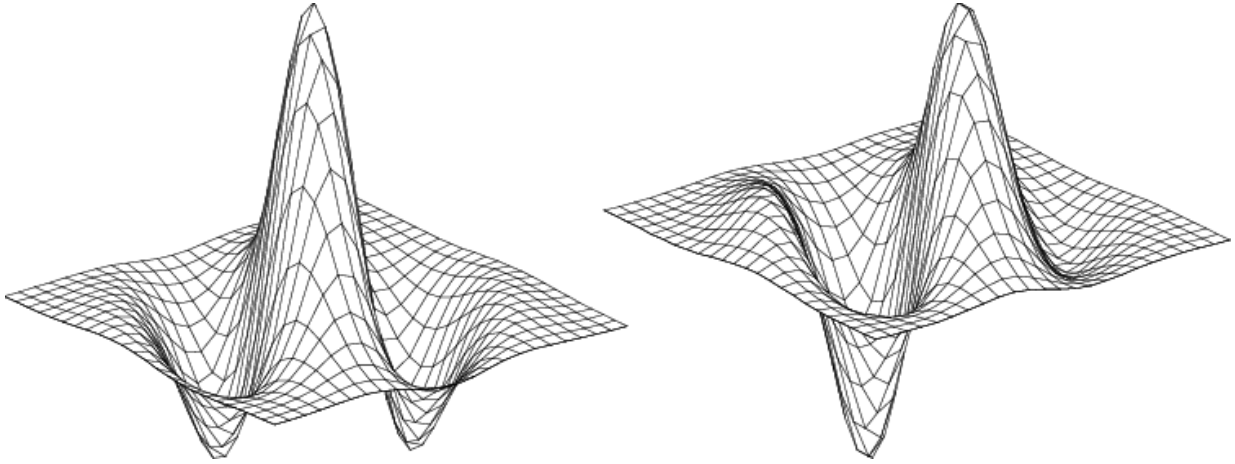
- Gabor function resulted from a modulation product of a gaussian and sinusoidal signals

- The Gabor function has the following general form:

$$f(x,y) = \frac{1}{2\pi\sigma_x\sigma_y}\exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)\right]\exp(2\pi j u_0 x)$$

where u_0 - radial frequency of the filter

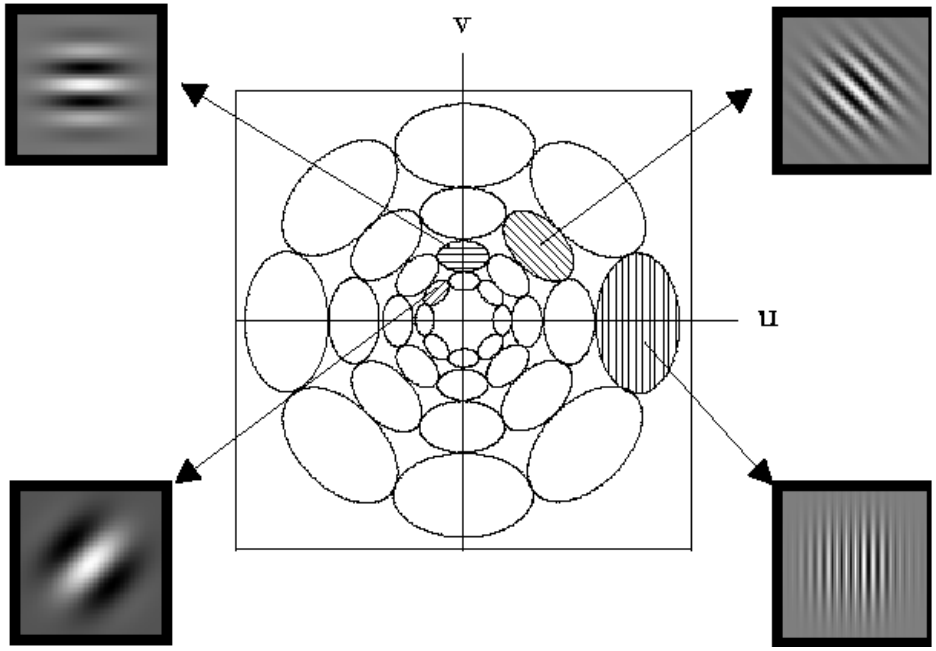
σ_x, σ_y - constants defining the gaussian envelope

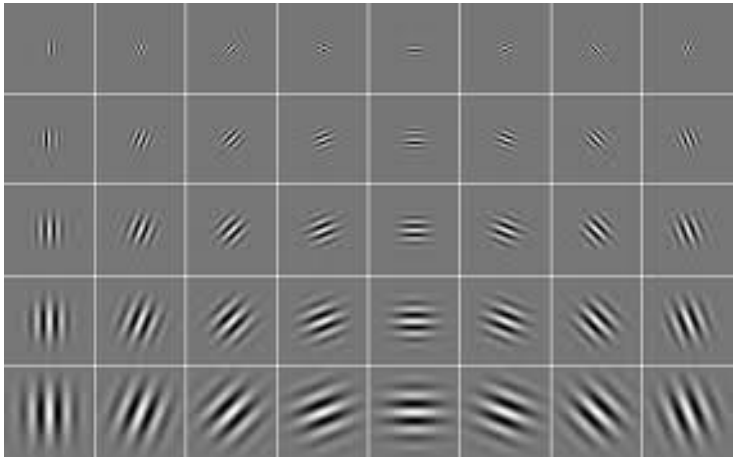


Gabor filters

- Feature detection characteristic of the Gabor filters relies on the possibility of tuning the orientation of his frequency selectivity

- Create a filter bank (variations in orientation and frequency)





Texture analysis techniques for fabric defect detection

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Algorithm

- Choosing the appropriate filter from the bank
- Using an unsupervised algorithm for filter selection
  - The filter with large output for defect texture and small output for defect-free
- A cost function for the discrimination of the filters bank results

Texture analysis techniques for fabric defect detection

Steps:

- Computing S x L filters in a M x M matrix form
- Dividing the original image I(x,y) in N regions of k x k pixels
- Applying each filter in the bank to the each of the N regions
- Computing the average result for every i^{th} filter for region n in N

$$A_n^i = \frac{1}{kxk} \sum_{(x,y)\in n} I_{pq}(x,y)$$

Texture analysis techniques for fabric defect detection

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Steps:

- Retaining maximum and minimum average value for every i^{th} filter among the N regions
- Computing the cost function as the normalized difference between the two values

$$C(i) = \frac{A^i_{\max} - A^i_{\min}}{A^i_{\min}}$$

- Selecting the filter having the highest cost function

- Re-filtering the original image with the selected filter
- Thresholding operation for the final segmentation of texture defects

Texture analysis techniques for fabric defect detection

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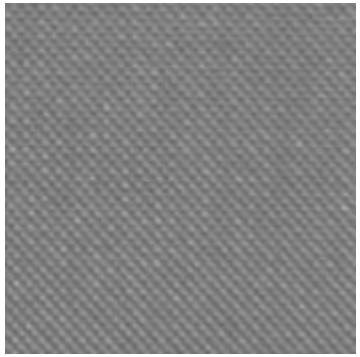
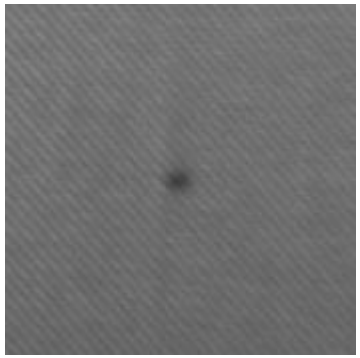
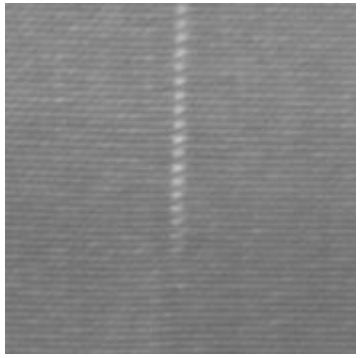
Test images:

- Images from the Brodatz set and acquired in ULBS Vision LAB
- Airbag fabric images from the TAKATA-Petri production site

- Bank of 24 Gabor filters (4 scales and 6 orientations)
- Filter size of 9 x 9 and images partitioned in 32 x 32 regions

Defects considered:

- break-out
- thick-yarn
- mispick
- dirty-yarn
- stains

Texture analysis techniques for fabric defect detection

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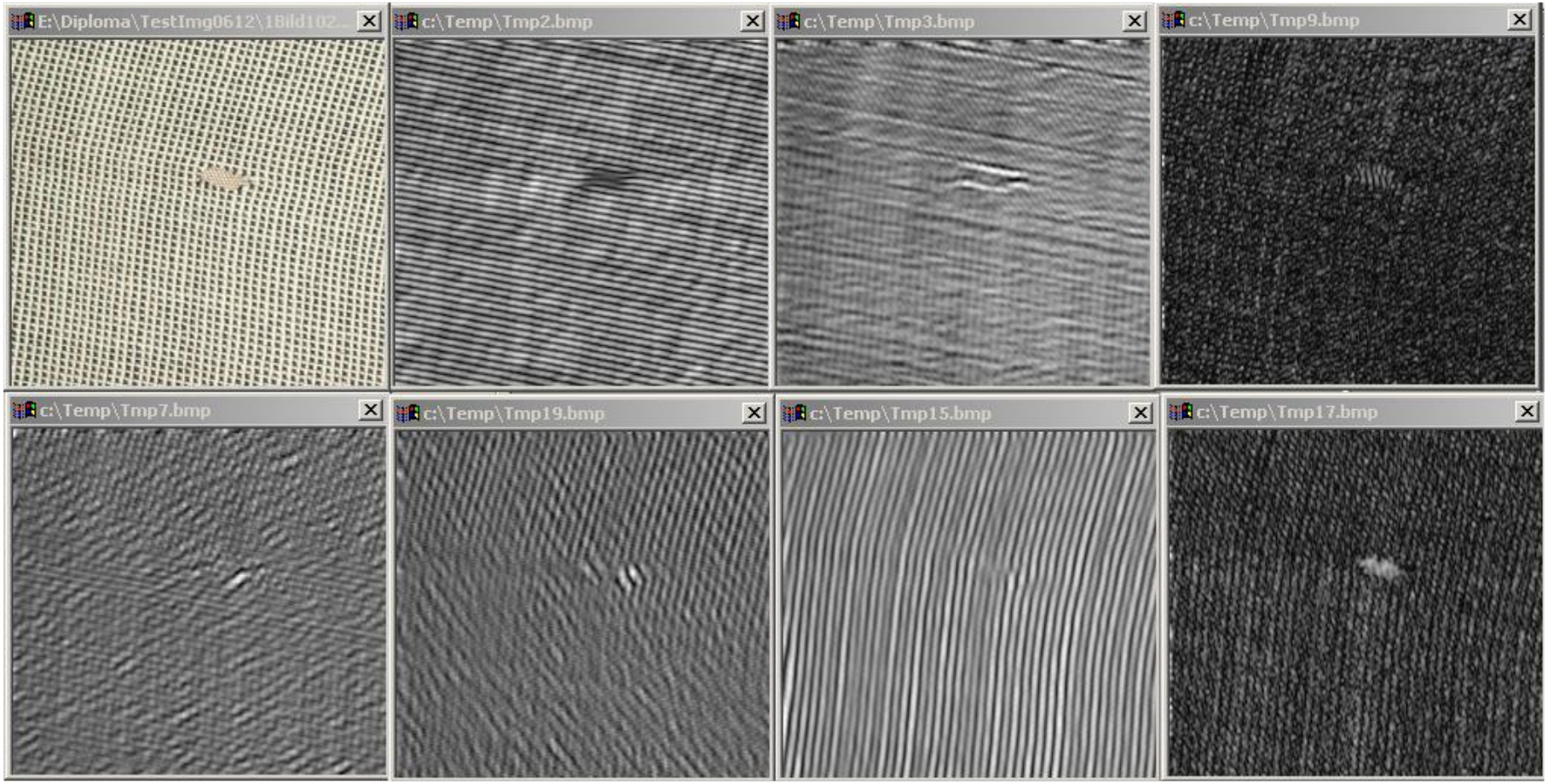
Results:



Texture analysis techniques for fabric defect detection

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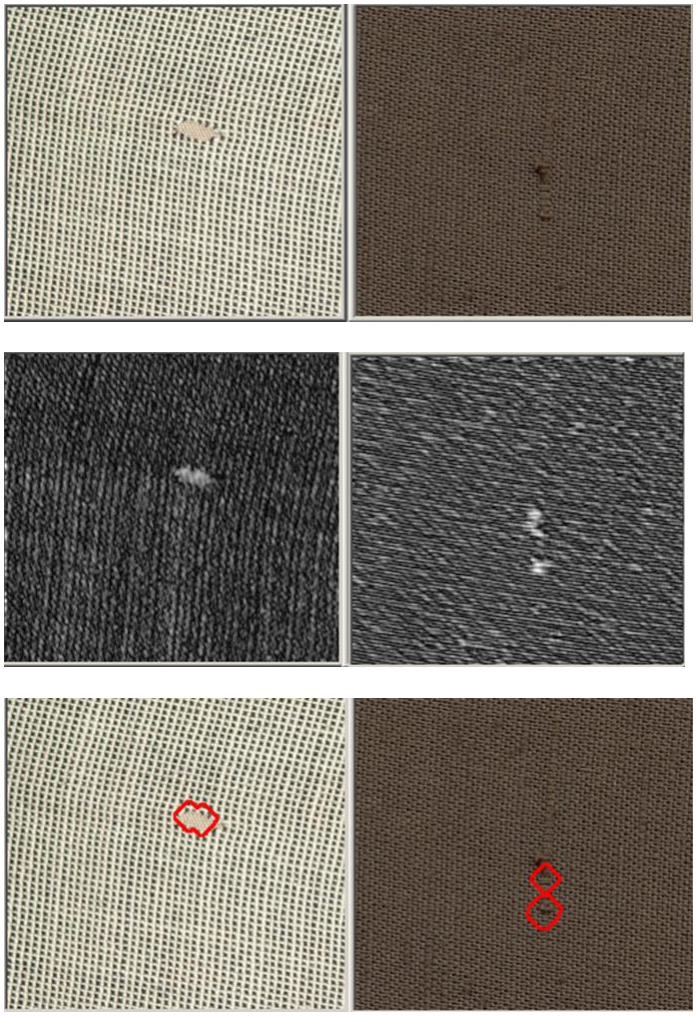

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Implementing a defect detection system in airbags manufacturing

Implementing a defect detection system in airbags manufacturing

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Research Grant from Takata Petri Sibiu

TAKATA

- Improvement of quality assurance techniques
- Weaving is one of the most important stages in airbags manufacturing process
- Quality of fabrics must be higher and provide a low air permeability in order to prevent structure tear or hot gas leak in the inflation process

Implementing a defect detection system in airbags manufacturing

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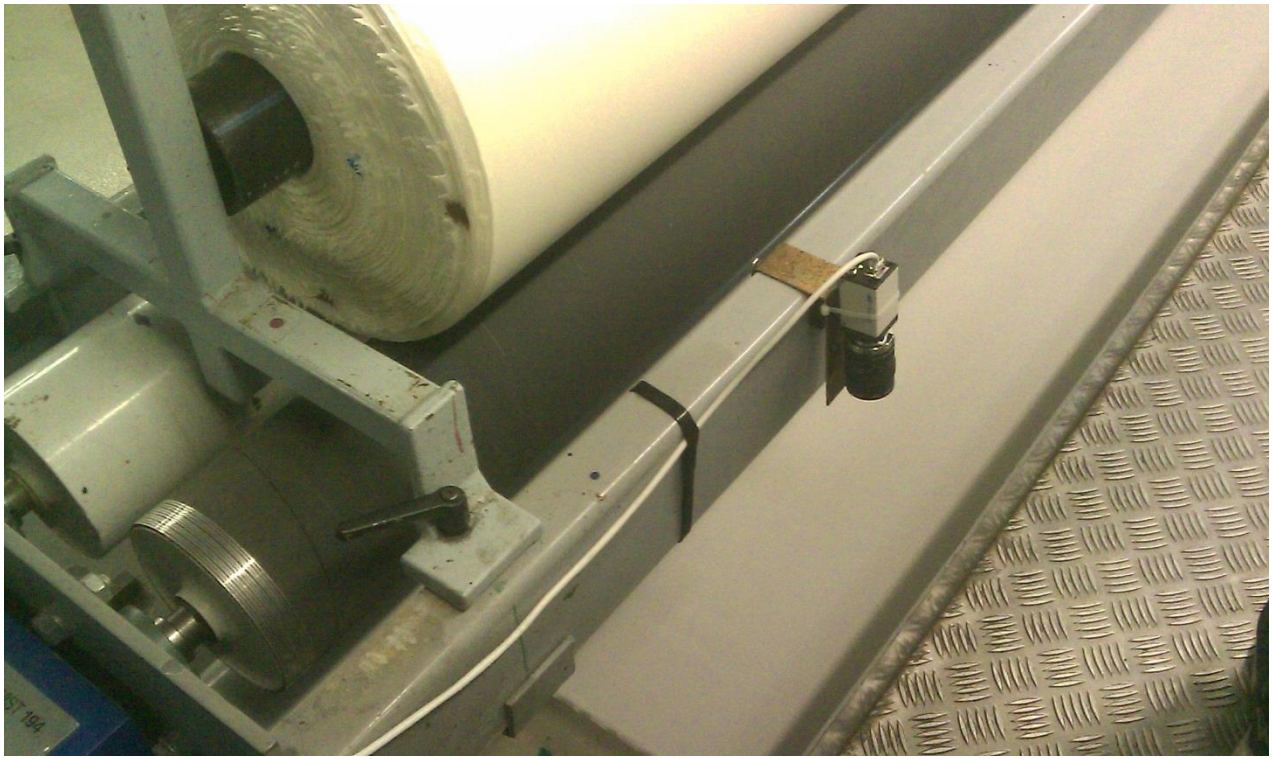
- Started with one camera on Toyota water jet loom
- 5MP Gibabit PoE Industrial camera



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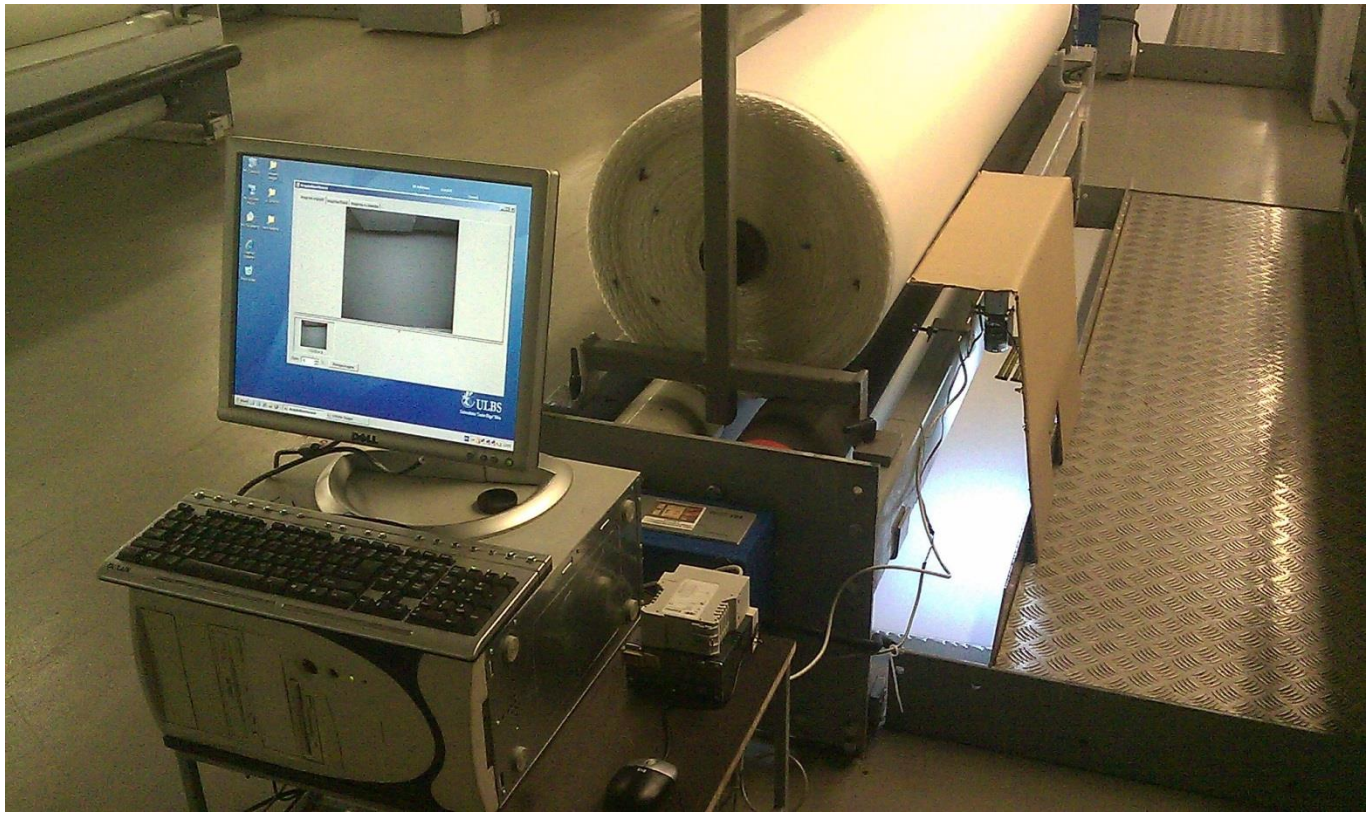
- Adding local illumination and lighting immunity



Implementing a defect detection system in airbags manufacturing

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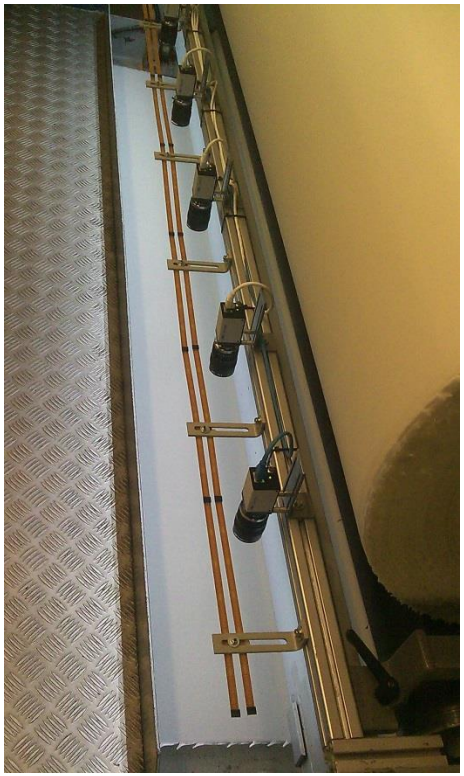
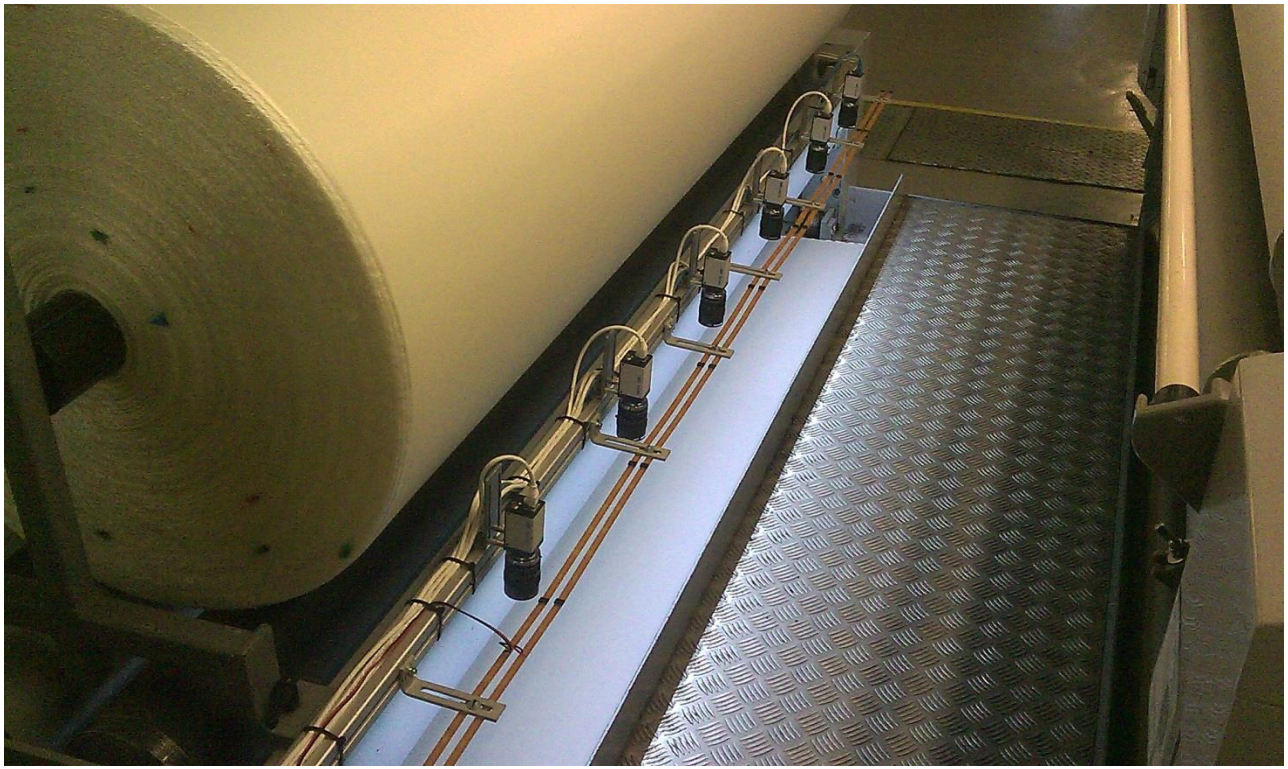
- One more step ahead
- 6 GigE cameras and double LED illumination





Implementing a defect detection system in airbags manufacturing

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- Improved application for defect detection and touch screen operation
- Dedicated server for data analytics

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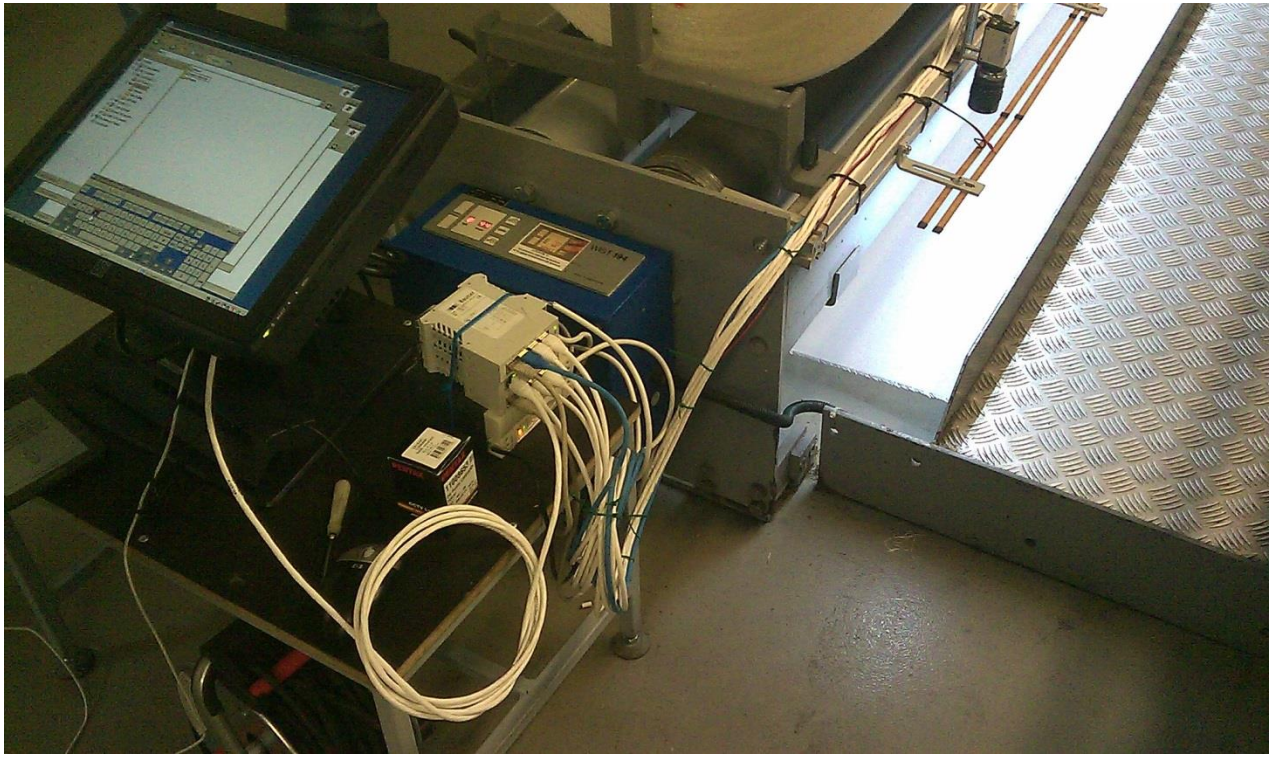
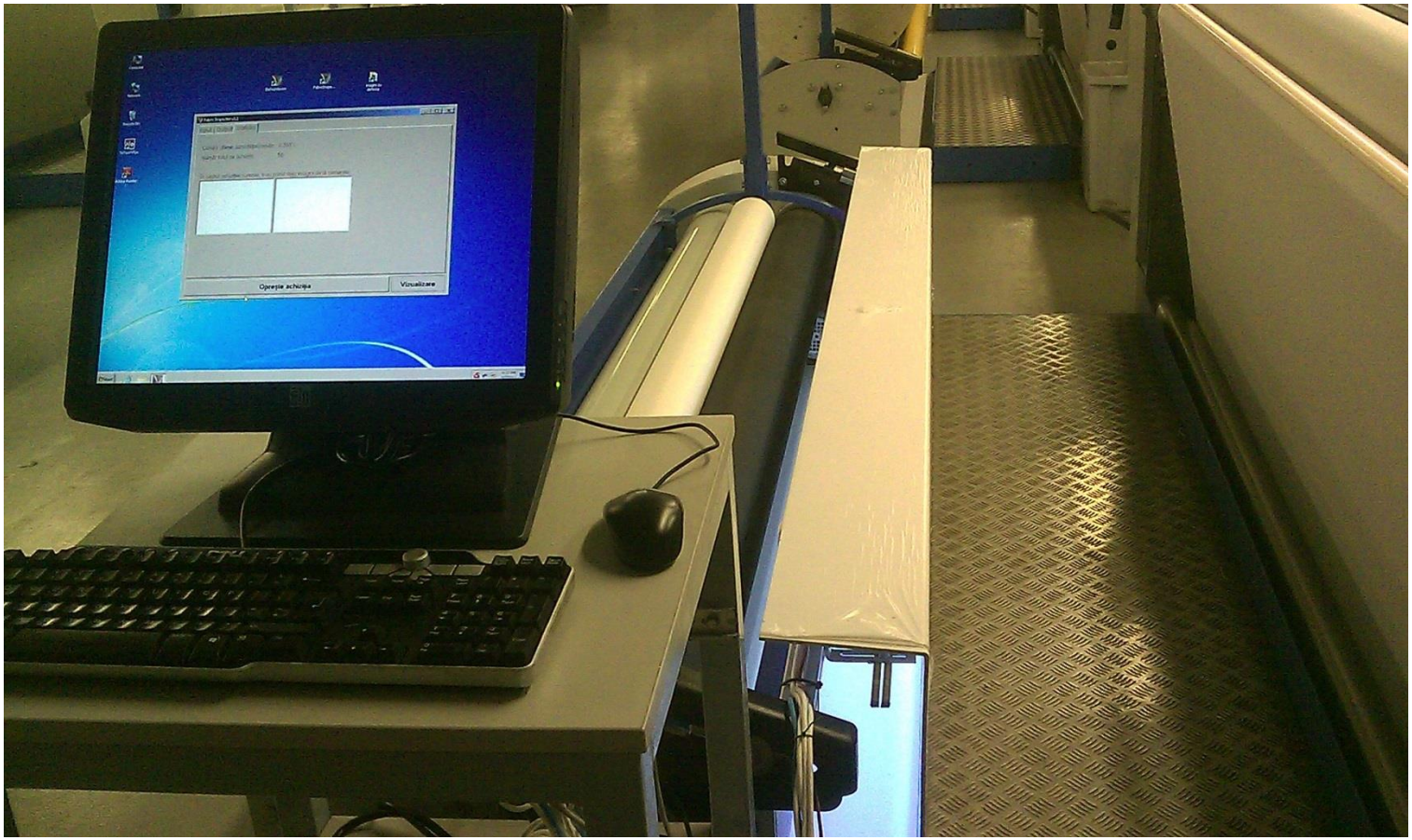


Implementing a defect detection system in airbags manufacturing

- Final implementation

Implementing a defect detection system in airbags manufacturing

- Final implementation



Implementing a defect detection system in airbags manufacturing

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Conclusions

- The system was not implemented on all 60 looms for on-line defect detection (!)
- It was used for an analytical study on the defect causes -> loom maintenance
- A reduction of less than 0.5% defects by applying customized and scheduled loom maintenance
- Better results and less costs!!!

Image processing for sewing defect detection

Image processing for sewing defect detection

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- Airbags are subject to strict quality control in order to ensure passengers safety
- The quality of sewing influence the final product
- Sewing defects must be early and accurately detected
- Airbag seams assembly can take various forms, linear and circle primitives, with threads of different colors and length densities, creating lockstitch or double threads chainstitch
- A framework for the automatic detection of defects occurring during the airbag sewing stage
- Types of defects as skipped stitch, missed stitch or superimposed seam for lockstitch and two threads chainstitch

Image processing for sewing defect detection

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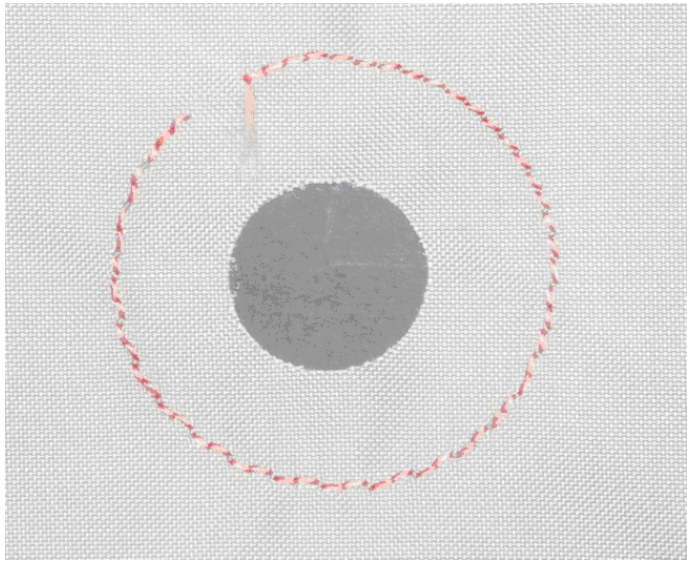
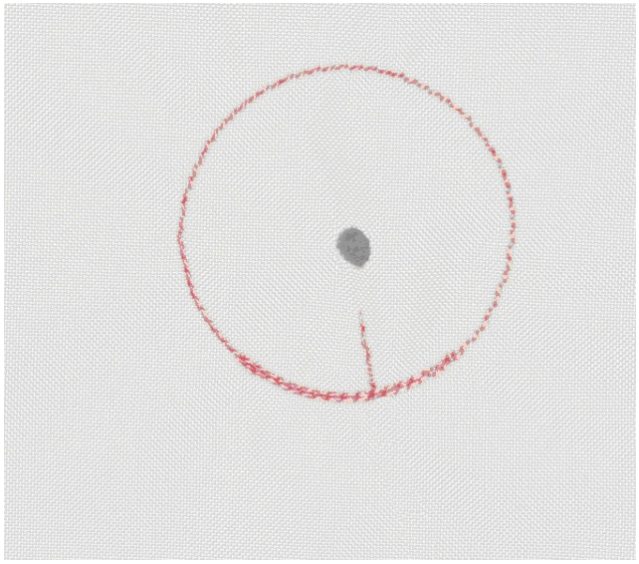
Examples





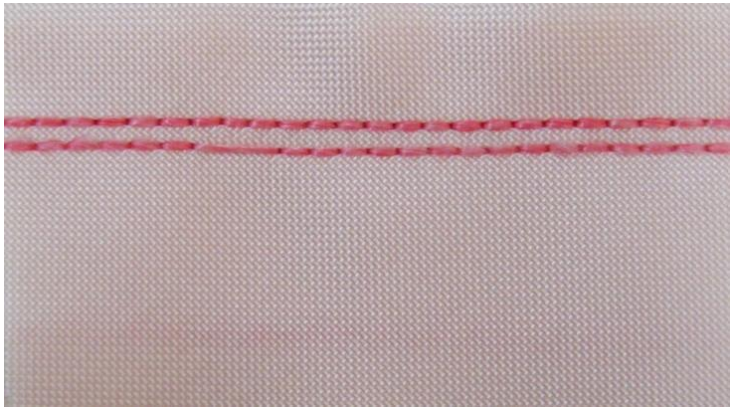


Image processing for sewing defect detection

Steps

- In view of linear or circular path recognition, the image is converted from color to a grayscale format and smoothed for noise attenuation
- The image binarization was performed using an unsupervised adaptive Otsu algorithm
- The detection of linear seams is made using the Hough transform by assessing the pixels position and their co-linearity
- The detection of circular contour seams was made using the Hough transform for circles, employing an accumulator structure to retain information regarding the detected circle center
- Using morphological information, the algorithm for linear or circular seams control is analyzing the colors being present in the acquired image along with the recognized lines or arcs

Image processing for sewing defect detection

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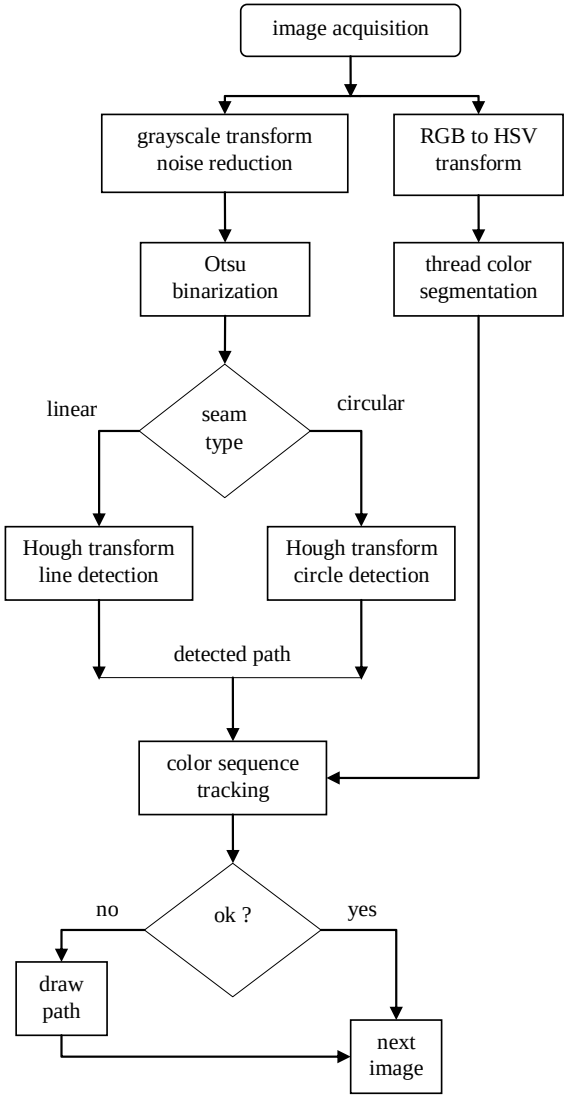
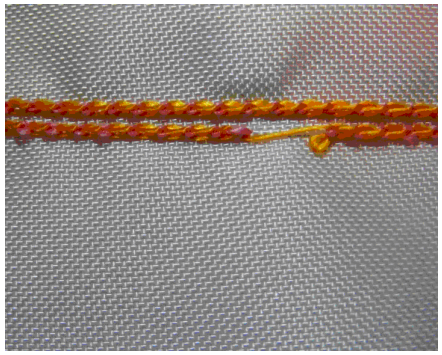
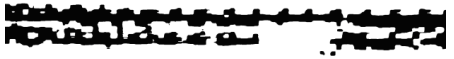
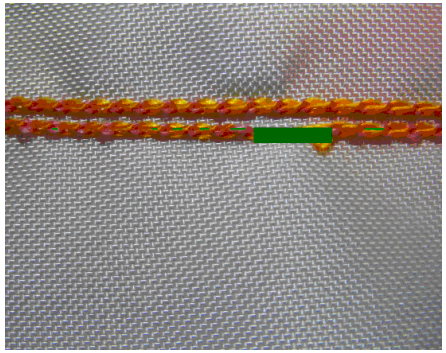
Steps









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Results

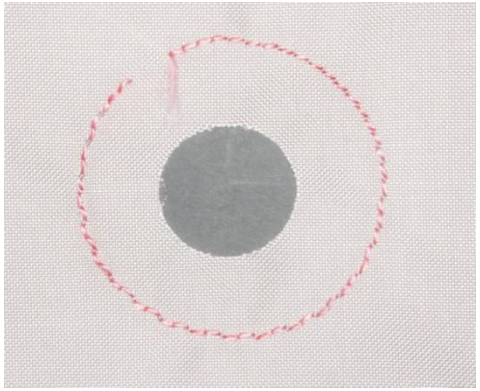
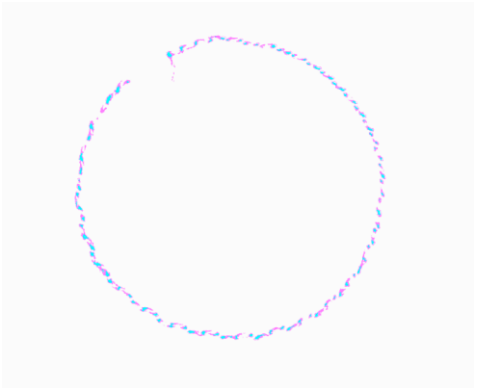
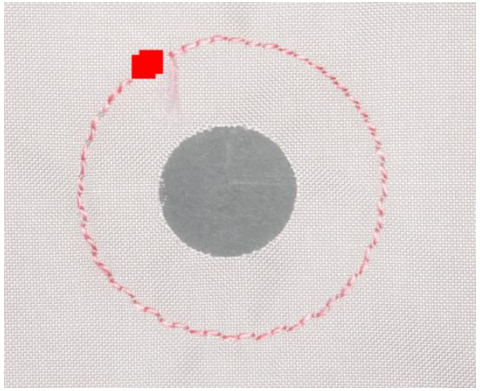
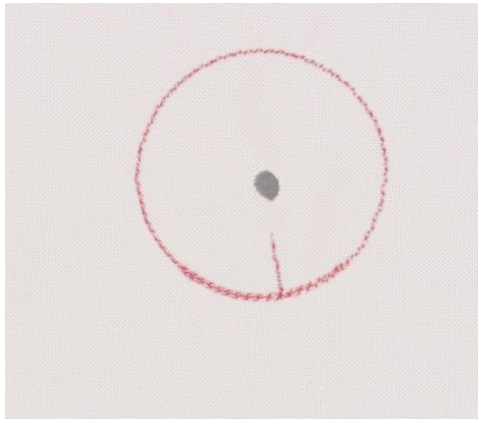
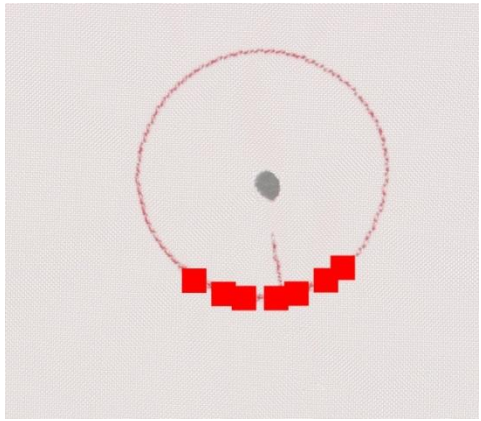
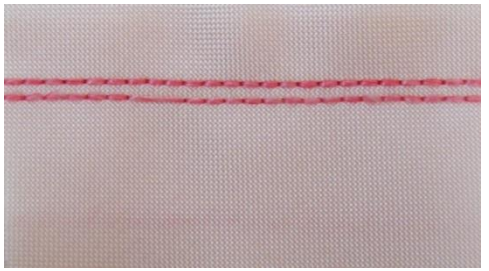
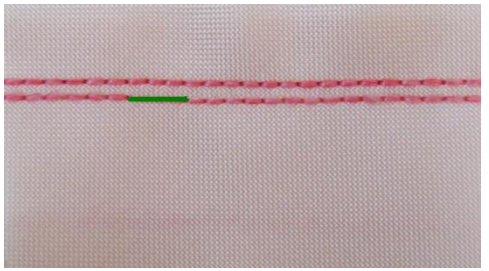

Image processing for sewing defect detection

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Conclusions

- Besides the properties of fabric, the assembly seams play an important role in airbag functionality

- Due to the fact that the seams cannot be repaired during the production process, any stitching defect will cause a nonconforming product. Intermediate inspection of stitches before the final closure of the airbag is an important stage, since it prevents non-compliant subassembly to pass on the next production step

- Automatic defects detection of seams keeps the sewing process in control and makes the final product comply with the client requirements

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Other developed systems for textile manufacturing quality control

- Seam puckering evaluation for sewing process

- The assessment of knitted fabric pilling

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Conclusions

- The textile industry is one of the traditional and dynamic sectors
- The customer quality requirements are constantly changing as a result of trends in fashion and the development of production tools
- In order to satisfy clients' demands, the variables that affect product quality must be kept under control during the production cycle: design, manufacturing, delivery and maintenance

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Conclusions

- The evaluation process of a product relating to appearance and performance have to rely on a holistic perspective
- Both fabrics and sewing threads assessment, but also consider their interactions during sewing, wearing and maintenance of the product
- Due to long reaction time and fatigue of the human operator, an automatic inspection would be able to verify and classify with a much higher speed and would eliminate the subjective factor

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Conclusions

- Computer vision systems can be used both in the pre-production stage, for machines adjustment, and also in product inspection
- The ability to recognize flaws and stop production immediately after the occurrence of the defect is important for clothing manufacturers
- The automatic control system may use different technologies for image acquisition, containing mechanical components, computer software, video cameras, lighting and video equipment

Questions?

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