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FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS

MASC – MODULAR ALGORITHMS FOR SURFACE CONTROL
SYSTEMS FOR SURFACE INSPECTION

The **MASC** product series

MASC-DISQ

DISQ recognizes defects in the surface of coated gaskets having various geometries. Several defects can be found, such as bubbles or foreign bodies and also dents or scratches due to the punching process. Remains of paint and adhesive are considered as defects as well. The inspection system is integrated in the production process without interfering with it.

MASC-FOQUS

In wood and furniture industry, a frequently recurring problem is the sorting of parts according to matching colors, or the control of constant colors. FOQUS allows for such an objective evaluation of colored, structured surfaces.

MASC-TASQ

TASQ is an online inspection system for the quality control of belt-like textiles. The result of the inspection is a defect protocol or a direct action during production, e. g., the marking of defects on the textiles.

MASC-VQC

One of the most important properties of nonwoven is the mechanical firmness, which is correlated to nonwoven homogeneity to a high degree. Applying image processing methods VQC quantitatively determines the nonwoven homogeneity, thus allowing conclusions about the firmness of the nonwoven.

MASC-STEX

In buildings ceilings are being used for fire protection, heat insulation and improvement of the acoustics. To guarantee for these functionalities the Fraunhofer ITWM developed an automatic inspection system for ceilings.

MASC-SPOT

The system SPOT has been developed for the quality control of paper surfaces. Using digital camera images, SPOT detects defects on papers and classifies them according to geometry and intensity. On the basis of the results, measures can be taken during the production process.

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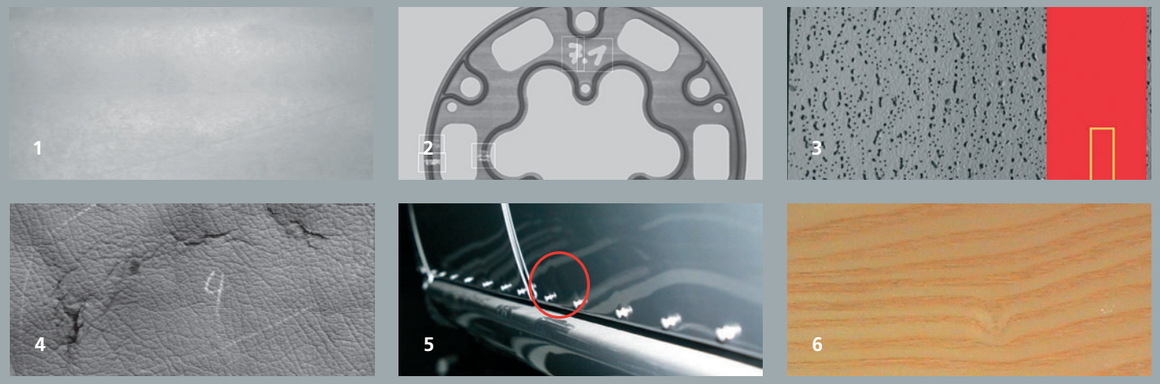


Examples of inspected surfaces

1 *Paper*

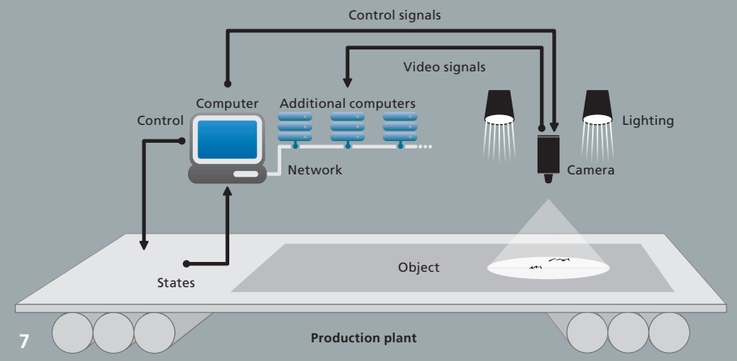
2 *Coated metals*

3 *Ceilings*

4 *Leather*

5 *Free surfaces*

6 *Wood*



7 *General structure of an inspection system*

Surface Inspection – Modular Algorithms for Surface Control

Scope

In many areas, the quality of a product depends on the quality of its surface. A unified approach is difficult due to the variety of possible surfaces. The quality of almost every type of surface is measured individually, depending on very different properties. Very often, the tasks of surface inspection are still carried out by especially-trained controllers. Frequently, this method only allows for the examination of random samples, mostly according to criteria that are not objective. A complete online product control and the guarantee of a constant quality are impossible here.

Approach

MASC offers a series of ready-to-use tools and system components for applying objective online quality control. The Fraunhofer ITWM has a wide range of experience with respect to the development of algorithms for automatic surface control. By using this experience in combination with the in-house image processing library the basic system can easily be adapted to almost every problem. For products such as paper, textiles, or metal parts, possible defects occur locally, so that it makes sense to look for local deviations with respect to a global homogeneity. In the case of other products (nonwovens, wood products, carpets) properties are considered that characterize a larger section of the sample or the entire sample.

Inspection process

An inspection process consists of few steps: First, a suitable configuration consisting of cameras and illumination needs to be found. This is being done by testing a set of sample parts, taking into account the production process. This configuration is then being used to acquire images of the surface to be inspected. It is also possible to do an online survey of the quality control via a web interface. Existing defects are being detected by applying the appropriate image processing algorithms. If needed, these defects can then be classified into different types. The resulting data are stored in a protocol and further processed to deliver statistics of the inspection process. At a control station, the inspection process can be observed online. According to the inspection results, necessary action for the production process can be taken. This might be the exchange of a defect tool or in more serious cases even a halt of the production line.

Image analysis

The main competence of the Fraunhofer ITWM is the development of image processing algorithms. The in-house software library MASC-Lib contains a wide variety of mathematically-founded image processing operations such as smoothing filter, edge detectors and multi-scale decomposition. By building an appropriate combination of these operations almost all customer-based tasks can be solved.

Why automatic quality control?

- early detection of product defects
- quality control without affecting the production process
- online defect detection and classification
- long time quality protocols and statistics
- objective quality criteria

Especially tailored instead of standard products

- adaptation to special customer requirements
- mathematical methods for different materials: synthetic material, paper, wood, metal
- interfaces for production machines
- adaptation to local conditions (e. g., lighting)

Selection of available algorithms

- linear filters
- morphological filters
- nonlinear projections
- multiscale decomposition
- variance analysis
- SVM-based classificators
- image registration
- texture-based segmentation

Fields of application

- paper industry
- textile industry
- plastics industry
- wood industry
- nonwoven industry
- metal working industry
- leather industry
- automotive industry
- automotive suppliers

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MASC-FOQUS
COLOR CLASSIFICATION FOR QUALITY CONTROL

Textured, colored surfaces

If finest color shades of structured surfaces are to be evaluated, neither human controllers nor classical color measurement systems can cope with the problem. The color differences determined visually can hardly be reproduced because they strongly depend on the observer and the surroundings. Color measurement tools cannot be applied since they work on the basis of an unstructured homogeneous surface. Especially for the solution of these problems, the software FOQUS has been developed at the Fraunhofer ITWM.

Application examples

- sorting of veneering in the furniture producing industry
- objective: combination of woods with identical color shades and identical grain
- Quality control of leather interior facings in the automobile industry
- objective: Quality control of outgoing goods to avoid bad deliveries

Fields of application

- Textile, paper, fleece industries (dyeing and printing processes)
- wood and furniture industry (veneering, furniture components, facings, ...)
- automotive industry (interior facings, leather, mounting parts, ...)

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1 **2**

1 *unsorted sample*

2 *color classification*

MASC-FOQUS: application

Scope

In many fields of processing industry (e. g., wood, leather, paper, wallpaper, fleece, etc.), the evaluation of the processed materials with respect to their visual features, such as color and contrast, is a decisive quality criterion. Particularly in the wood processing and furniture producing industry, a repeatedly occurring problem is the sorting of components with respect to corresponding colors, or the controlling in order to guarantee color constancy. The grain enormously inhibits the application of classical color measurement systems. The sorting according to color features is mostly carried out by hand, which by nature provokes mistakes.

Solution

The software tool FOQUS is able to extract objective color and structure parameters from structured surfaces by methods of image processing, and to classify them automatically, thus allowing a perfect sorting of materials with relatively homogeneous colors and textured surfaces.

Inspection process

The system is based on a standard CCD color camera and allows the objective detection of finest color differences of structured surfaces. The RGB pixel values provided by the camera are transformed into the HSI colorspace which corresponds better to the human perception of colors. This nonlinear transformation separates the information about color and brightness, resulting in a simple compensation of brightness variations. Based on the HSI images, features are computed which describe the structure and color properties of the actual sample. The system is supposed to decide according to similar criteria as the human controller, therefore it is presented with presorted samples in the training phase. Based on the feature values of these reference samples, optimal separating planes are computed in the feature space, which allow a correct assignment of new, unknown samples.

Product properties

- easy adaptation to certain applications by the specification of color samples
- system calibration for the compensation of varying and inhomogeneous lighting
- sorting according to color shades in the case of textured surfaces
- classification into several categories
  - online/offline classification
  - decision: good/bad
- possibility to separate very similar color classes

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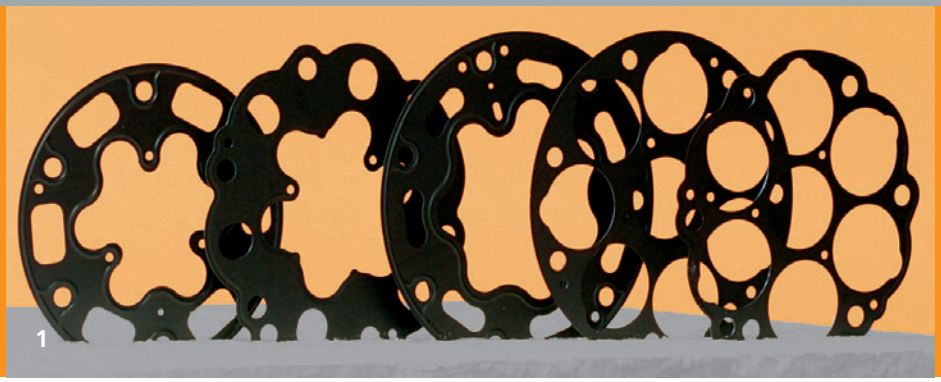

1 *Black rubber coated metal gaskets*

MASC-DISQ
GASKET INSPECTION SYSTEMS FOR QUALITY CONTROL

Gasket quality control

The image processing system DISQ has been developed for the surface inspection of metal gaskets. DISQ is able to detect defects of (coated) gaskets on the basis of digital camera images, classifying these according to geometry, cause, and size.

Product properties

- easy adaptation to specific requirements, such as different gasket shapes or coatings
- classification according to several defect classes (scratches, indentations, blisters, etc.)
- statistical documentation, e. g., for the determination and analysis of defect trends
- feedback within the production process
- user-friendly interface

Service of the Fraunhofer ITWM

- delivery and installation of the control system
- adaptation to customer-based requirements
- evaluation records for the substantiation of production quality
- set-up of the desired defect classes
- communication between control system and production process
- system maintenance
- adaptation to new requirements

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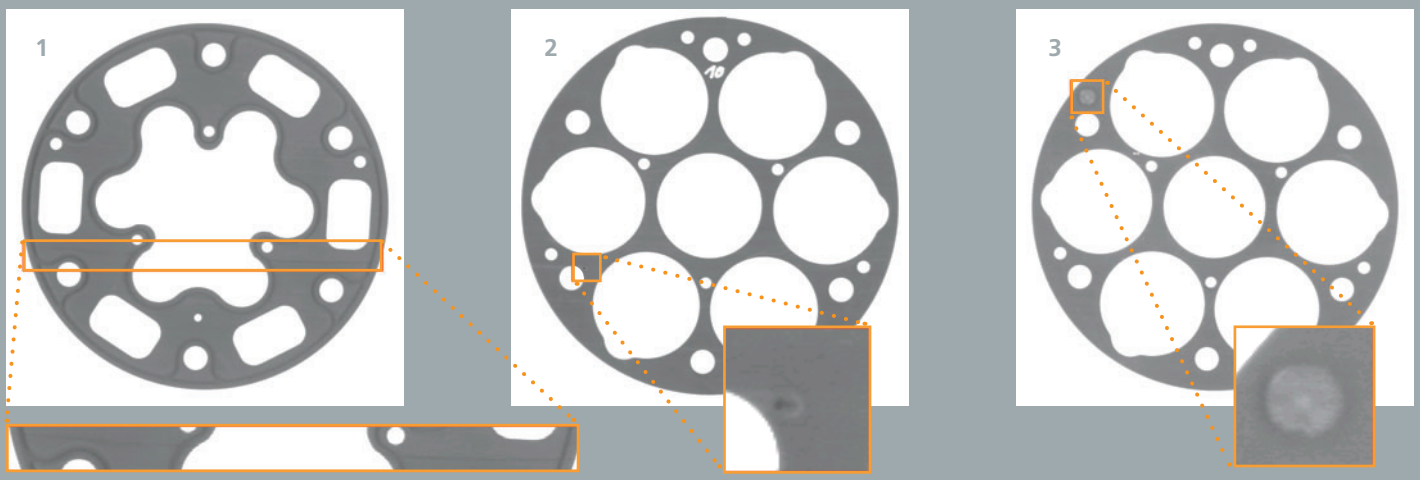

1 - 3 *Scratch, blister, and dent as defect examples; the gaskets are represented at a scale of approximately 1:2.*

MASC-DISQ: Application

Image acquisition

The method consists of several steps observing the top and bottom side of each gasket. Due to the partly very complex shape of the gaskets, which, e. g., show holes and embossments, the method works with samples of the same shape serving as reference for a go-part. After the image acquisition of the part to be inspected, the relevant image section has to be found.

Image registration

In the next step, the image of the gasket to be examined is adjusted to the reference image with respect to displacement as well as rotation, in order to allow for a comparison with the reference parts. In such a way, boundaries and structures are to be recognized as far as possible, so that they are not accounted for during defect detection.

Defect detection

Different methods have been implemented for different types of defects (mainly with respect to their size) in order to bring them out in the best possible way and to allow for a comparison with the reference part. When the comparison is concluded, the relevant positions are marked and can be displayed graphically. The examined gaskets are sorted with respect to go and no-go parts, and detected defects are classified. Finally, type and frequency of the occurring defects are documented statistically.

Teach-in

If the respective reference parts are available, a fast and automatic learning of new types of gaskets with a similar surface structure is also possible.

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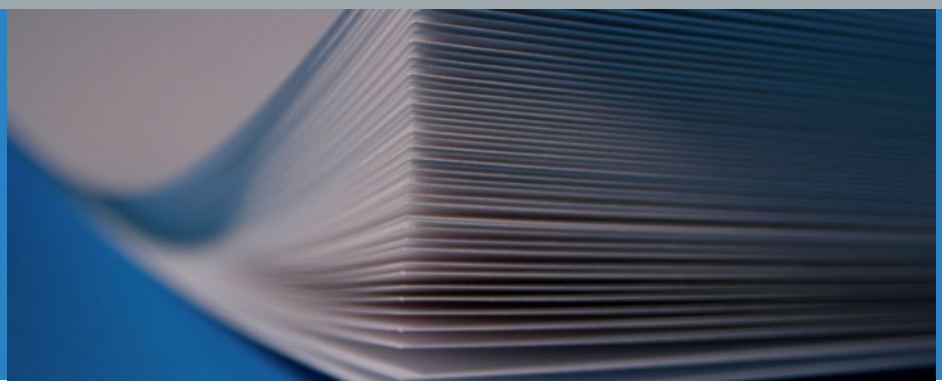

MASC-SPOT
SYSTEM FOR THE INSPECTION OF PAPER SURFACES

The image processing system SPOT has been developed for the quality control of paper surfaces. SPOT detects defects in papers and laminations by using digital camera images, classifying them according to geometry, size, and intensity.

Product properties

- online detection of defects
- visualization of defects
- classification of defects according to size, geometry, and intensity (dots, stains, bends/scratches)
- feedback with respect to production by sorting orders or system halts
- flexible adaptation to customer requirements (parameter adaptation, different configurations, extension of production plants)
- defect protocols
- storage of defect images

Service of the Fraunhofer ITWM

- delivery and installation of the control system
- adaptation to customer-based requirements
- evaluation records for the substantiation of production quality
- set-up of the desired defect classes
- communication between control system and production process
- system maintenance
- adaptation to new requirements

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Examples of typical paper defects

1 *fold*

2 *coating error*

3 *spot*

MASC-SPOT: System for the inspection of paper surfaces

Up to now, defects on paper surfaces could only be detected by the human eye. However, this kind of quality control is laborious and time-consuming; furthermore the human eye needs recovery.

Inspection of paper surfaces

The image processing system SPOT provides online quality control which can be integrated into the production process. In the center of the system is a fast image processing algorithm which detects and simultaneously classifies defects, e. g., stains and scratches, on the homogeneous paper surface. Input data of the algorithm are digital images of paper sheets. The results of the image evaluation can be used as sorting orders for the next process steps; a direct feedback with respect to production is also possible (e. g., system halts if defects accumulate). A defect protocol is written automatically and can be retrieved at any time. If necessary, the images on which SPOT has detected defects can be stored and viewed offline.

Image processing

As a first step of the image processing algorithm, the camera image is reduced to the relevant region, i. e. the section of the image showing only the paper sheet. After this recognition of boundaries, defects are detected in the image and marked by so-called ROIs (Regions of Interest). On the basis of the features provided by the ROIs, the algorithm classifies the defects.

Structure of the entire system

The SPOT system is directly integrated into a paper sorting machine. Above the transport belt, several cameras are installed which observe the entire width of the paper sheets. Each of these cameras is connected to one of the clients of the SPOT system. These clients run the image processing algorithms. Each client consists of a double processor system where several image algorithms run simultaneously. This parallelization is finally responsible for the high performance of the SPOT system.

A central server collects all the results of the clients and tells the sorting machine whether a sheet is „good" or „bad". Besides, it writes a protocol of all the occurring defects, so that an overall statistics can be provided at the end of an inspection cycle.

SPOT can easily be adapted to customer-based requirements or changing conditions (e. g., lighting differences). The system is flexible with respect to extensions due to the use of PC-based technology.

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MASC-VQC
HOMOGENEITY OF NON-WOVENS

What is VQC?

One of the most important properties of fleece is its mechanical firmness, which is to a high degree correlated to fleece homogeneity. VQC determines the fleece homogeneity quantitatively by methods of image processing, thus allowing conclusions about the fleece firmness.

Product properties

- 100 % automatic control of the fleece homogeneity ("cloudiness") at high belt velocity
- calibration in order to compensate inhomogeneous lighting
- robustness with respect to disturbances, such as displacement of the image section or variations of lighting
- integration into the production process
- easy adaptation of the configuration, e. g., with respect to the desired resolution and inspection severity
- generation of test statistics, e. g., for the determination and analysis of trends
- evaluation protocols in order to guarantee production quality
- user-friendly interface

Applications

- hygienic sector (e. g., diapers)
- medicine (e. g., bandage materials)
- filters (e. g., in the automobile sector)
- textile industry (e. g., technical textiles, padded garments)
- agriculture (e. g., field coverings)

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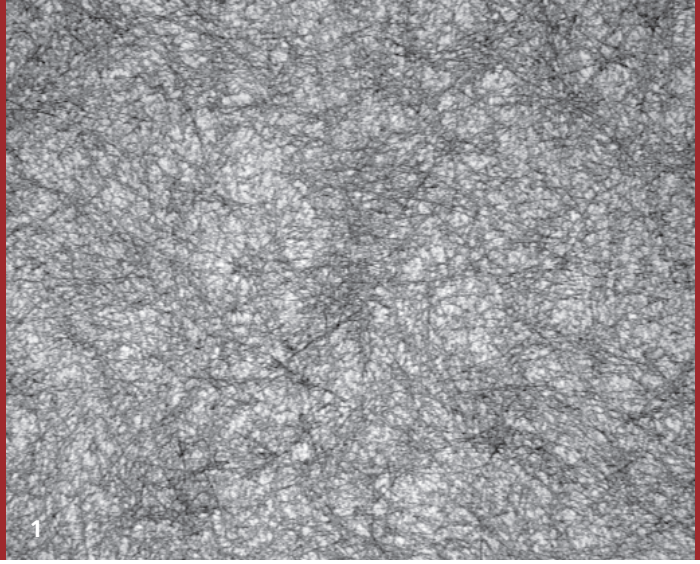

Laboratory determination of fleece quality

1 *Inhomogeneous fleece with some fiber defects and agglomerations*

2 *Relatively homogeneous fleece*

MASC-VQC: Application

Fleece firmness

Fleeces are subject to increasing quality requirements. One of the most important properties is the mechanical firmness, where an essential criterion is the uniform fiber distribution, which is disturbed by inhomogeneities such as fiber agglomerations and fiber defects. During fleece production, the homogeneity is used as an indirect indicator for the rating of the fleece firmness. At a very high resolution scale – if the fleece is observed from a very small distance –, the individual fibers of which the fleece consists are still visible; the fleece seems inhomogeneous. At rough scales – observing from a far distance –, the fleece appears very homogeneous if it does not show extremely distinctive defects. Thus, the fleece "homogeneity" refers to several scales.

Defect detection

Apart from its firmness, the surface quality of the fleece is also an important criterion for the fleece quality. At the Fraunhofer ITWM, the systems MASC-SPOT and MASC-TASQ have been developed for defect detection within the product series MASC. The modular structure of these systems allows a simple combination of several products, resulting in a complete quality control.

Software tool for homogeneity rating

The Fraunhofer ITWM has succeeded in developing an algorithm for a qualitative and quantitative rating of fleece homogeneity. The software tool VQC allows the secure and robust evaluation of fleece homogeneity (the so-called "cloudiness") by methods of image processing. It can be applied to laboratory examinations, as well as for the online determination of product quality during the production process.

Image processing

The original image is subjected to a multiscale analysis according to the Laplace pyramid, a method which suggests itself since fleece homogeneity is a multiscale phenomenon by nature. As a measure of homogeneity, the variance of the images is computed on each scale. The variances of the individual scales are added up to a homo-geneity index in a weighted sum. The scale gradations can be customized, enabling the user to adapt the system easily to very different types of fabrics.