

ANN-Based Defects' Diagnosis of Industrial Optical Devices

Matthieu Voiry

University of Paris, France

SAGEM REOSC, France

Véronique Amarger

University of Paris, France

Joel Bernier

SAGEM REOSC, France

Kurosh Madani

University of Paris, France

INTRODUCTION

A major step for high-quality optical devices faults diagnosis concerns scratches and digs defects detection and characterization in products. These kinds of aesthetic flaws, shaped during different manufacturing steps, could provoke harmful effects on optical devices' functional specificities, as well as on their optical performances by generating undesirable scatter light, which could seriously damage the expected optical features. A reliable diagnosis of these defects becomes therefore a crucial task to ensure products' nominal specification. Moreover, such diagnosis is strongly motivated by manufacturing process correction requirements in order to guarantee mass production quality with the aim of maintaining acceptable production yield.

Unfortunately, detecting and measuring such defects is still a challenging problem in production conditions and the few available automatic control solutions remain ineffective. That's why, in most of cases, the diagnosis is performed on the basis of a human expert based visual inspection of the whole production. However, this conventionally used solution suffers from several acute restrictions related to human operator's intrinsic limitations (reduced sensitivity for very small defects, detection exhaustiveness alteration due to attentiveness shrinkage, operator's tiredness and weariness due to repetitive nature of fault detection and fault diagnosis tasks).

To construct an effective automatic diagnosis system, we propose an approach based on four main

operations: defect detection, data extraction, dimensionality reduction and neural classification. The first operation is based on Nomarski microscopy issued imaging. These issued images contain several items which have to be detected and then classified in order to discriminate between "false" defects (correctable defects) and "abiding" (permanent) ones. Indeed, because of industrial environment, a number of correctable defects (like dusts or cleaning marks) are usually present beside the potential "abiding" defects. Relevant features extraction is a key issue to ensure accuracy of neural classification system; first because raw data (images) cannot be exploited and, moreover, because dealing with high dimensional data could affect learning performances of neural network. This article presents the automatic diagnosis system, describing the operations of the different phases. An implementation on real industrial optical devices is carried out and an experiment investigates a MLP artificial neural network based items classification.

BACKGROUND

Today, the only solution which exists to detect and classify optical surfaces' defects is a visual one, carried out by a human expert. The first originality of this work is in the sensor used: Normarski microscopy. Three main advantages distinguishing Normarski microscopy (known also as "Differential Interference Contrast microscopy" (Bouchareine, 1999) (Chatterjee, 2003))

from other microscopy techniques, have motivated our preference for this imaging technique. The first of them is related to the higher sensitivity of this technique comparing to the other classical microscopy techniques (Dark Field, Bright Field) (Flewitt & Wild, 1994). Furthermore, the DIC microscopy is robust regarding lighting non-homogeneity. Finally, this technology provides information relative to depth (3-th dimension) which could be exploited to typify roughness or defect's depth. This last advantage offers precious additional potentiality to characterize scratches and digs flaws in high-tech optical devices. Therefore, Nomarski microscopy seems to be a suitable technique to detect surface imperfections.

On the other hand, since they have shown many attractive features in complex pattern recognition and classification tasks (Zhang, 2000) (Egmont-Petersen, de Ridder, & Handels, 2002), artificial neural network based techniques are used to solve difficult problems. In our particular case, the problem is related to the classification of small defects on a great observation's surface. These promising techniques could however encounter difficulties when dealing with high dimensional data. That's why we are also interested in data dimensionality reducing methods.

DEFECTS' DETECTION AND CLASSIFICATION

The suggested diagnosis process is described in broad outline in the diagram of Figure 1. Every step is presented, first detection and data extraction phases and then classification phase coupled with dimensionality reduction. In a second part, some investigations on real industrial data are carried out and the obtained results are presented.

Detection and Data Extraction

The aim of defect's detection stage is to extract defects images from DIC detector issued digital image. The

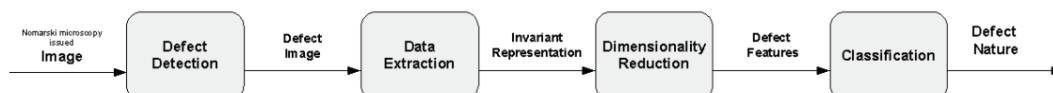
proposed method (Voiry, Houbre, Amarger, & Madani, 2005) includes four phases:

- Pre-processing: DIC issued digital image transformation in order to reduce lighting heterogeneity influence and to enhance the aimed defects' visibility,
- Adaptive matching: adaptive process to match defects,
- Filtering and segmentation: noise removal and defects' outlines characterization.
- Defect image extraction: correct defect representation construction.

Finally, the image associated to a given detected gives an isolated (from other items) representation of the defect (e.g. depicts the defect in its immediate environment), like depicted in Figure 2.

But, information contained in such generated images is highly redundant and these images don't have necessarily the same dimension (typically this dimension can turn out to be hundred times as high). That is why this raw data (images) can not be directly processed and has first to be appropriately encoded, using some transformations. Such ones must naturally be invariant with regard to geometric transformations (translation, rotation and scaling) and robust regarding different perturbations (noise, luminance variation and background variation). Fourier-Mellin transformation is used as it provides invariant descriptors, which are considered to have good coding capacity in classification tasks (Choksuriwong, Laurent, & Emile, 2005) (Derrode, 1999) (Ghorbel, 1994). Finally, the processed features have to be normalized, using the centring-reducing transformation. Providing a set of 13 features using such transform, is a first acceptable compromise between industrial environment real-time processing constraints and defect image representation quality (Voiry, Madani, Amarger, & Houbre, 2006).

Figure 1. Block diagram of the proposed defect diagnosis system



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