Features of translucent materials and products defects detection with support of optical system

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Abstract. The translucent materials and products defects detection by optical methods are published in the article. The methods are described on quality assessment of sheet glass. There is an application approach based on complex feature. The recognition algorithm is based on three main feature types of defect: brightness, color (primary features) and geometrical or features of shape (secondary). In the document main (algorithmic) and technical sides of creation of machine vision system are described.

1. Introduction

The quality control of items made of glass is often raised. There are several different glass defect classification approaches mainly based on digital image processing (described in documents [1,2,3,4]).

Till now the translucent materials defects detection automation is not widely used on local manufacturing sites. Primarily it is linked to the complexity of classificatory development. This classificatory should recognize objects with sufficient accuracy in line with state standards and additional requirements of clients.

There is a list of main glass defects in [5] which includes about thirty defect types. The defects are divided into the groups by different occurrence. The automated integrated glass defects detection system is not available at the moment. And usage of neural network technology is one of possible ways. An example of such classification is shown in [1,6]. However usage of such method requires massive number of sample standards. And this usage may follow to significant material and time expenditures.

There is an approach of glass defects detection based on wavelet transformation of functions pixel brightness coefficients of rows, columns and diagonals [7]. Therefore, the defects detections is done only on the base of image processing not taking in account physical material properties, lightning system and optical part of machine vision system.

Certain procedures are being carried out depending on defect type. For example, comparison with etalon can be used for classifying of cuts, cracks and chips. For scratches, bubbles and stones the search of defects may be done on a base of filtering with usage of additional solving rules. However, it is necessary to remember the filtration with high mask coefficients may lead to picture noise and interfere to search of linked objects on the picture.

Therefore, two approaches should be used at the same time for complex assessment of objects made of glass. Let us imagine a synchronous model of quality assessment considering all listed above (figure 1).
An important task in the development process of industrial system for translucent objects defects detection is a description of received picture of controlled objects based on its properties [8]. The process of signs selection, like classifying process, still is heuristic procedure and depends on targets and recognizing conditions.

2. Statement of problem
Let us look at signs classification including recognizing features of sheet materials and translucent objects.

![Diagram of synchronous defect control model for translucent objects](image)

**Figure 1.** Synchronous defect control model for translucent objects.

One of the tasks is assignment of defect to certain class and category as state standards [9,10] and additional client demands [11] require various numbers and sizes for different defects. It is enough to use geometrical assessment only for some sheet glass defects as it is linked to defects origin. This group includes those signs, the calculation of which is based on the use of geometric characteristics presented on the image of defects.

The most commonly identified are the following signs [12]:

- geometric dimensions of the depicted defect on vertical or horizontal;
- distance between the most distant points on the depicted defect;
- perimeter and area of the depicted defect;
- compactness of the defect (as the ratio between its area and perimeter);
- numerical characteristics of geometric shapes described or inscribed in the image of the defect, such as circles, polygons, etc.

Geometric features can be used in recognition problems, which are characterized by:

- defects with a pronounced geometric structure (border);
- low noise and dynamic distortion.

The proposed control system for the recognition of defects in sheet glass uses a monochrome image from a digital camera. A certain class of defects can be distinguished using threshold filtering by brightness. The main brightness characteristics can be attributed to: a histogram of the distribution of brightness values in the image, the initial $\nu_k$ and central $\mu_k$ moments of the brightness function...
\[ \nu_k = E(X^k), \quad \mu_k = E\{(X - E(X))^k\} \]

where \( X \) - average value of the brightness function in the image, \( E \) - mathematical expectation.

The signs of defects are presented in more detail in [12, 13]. In the course of the analysis, three main features should be identified on which the recognition algorithm will be based:

- brightness;
- color;
- geometric or shape features (ellipse, line, curve, etc.).

The first two are the primary signs. Based on the information received, primary — geometric — are formed on primary features. Let us highlight an additional feature for transparent internal glass defects (bubble and swirl) - shadow, the methodological essence of which is shown in figure 2.

![Figure 2](image)

**Figure 2.** An additional shadow sign of transparent internal defects of sheet glass: 1- upper illumination of the test object; 2 - sheet glass; 3 - a bubble; 4 - lower illumination of the control object.

Thus, it will be necessary to implement a lighting system with switching upper and lower sources to classify defects in this group

The process of processing a monochrome image can be divided into two stages: pre-processing and image analysis. The analysis uses a matrix device. During processing the image at the output it is possible to get a set of some numbers that can uniquely characterize the picture perceived by a person visually. The selection of image elements do not corresponding to the basic structure of the controlled object (glass defects) is carried out by spatial filtering, by detecting sharp changes in pixel brightness or high spatial frequencies and dividing these frequency components into two-dimensional data. With the help of this process, firstly, the boundary of the control object itself is determined, and secondly, of course, the boundaries of the defects themselves or the defects themselves (for example, scratches).

The spatial frequencies are identified and the frequency components are separated using the convolution algorithm - the weighted averaging of a pixel that undergoes the matrix addition operation and its nearest neighbours.

Convolution is performed using a 3x3 matrix, such as:

\[
\begin{bmatrix}
a_1 & a_2 & a_3 \\
a_4 & a_5 & a_6 \\
a_7 & a_8 & a_9
\end{bmatrix}
\]

3. **Research results**

Investigations of the recognition processes were carried out on a device for automated detection of defects of sheet glass (ADPS) where a vision camera with a short-focus lens mounted on used as an image receiver. A detailed description of this setup is presented in [14, 15].
The optical scheme of the control device taking into account the above requirements is presented in figure 3. Lighting system 5 is shown conditionally: the number and type of sources are specified in [14]. The distance L from the control object 3 to the background (screen) 6 is determined experimentally. The optical scheme is presented taking into account the technical characteristics of the Computar M0814-MP2 lens and the NI 1722 camera.

Figure 4 presents images of the main glass defects obtained using the ADPS system. First of all, the lighting system affects the recognition process. Studies have shown that LED lighting is optimal. Examples of the implementation of the lighting system of the ADPS device are considered in [16].

The choice of control conditions should be reduced to ensuring normal lighting conditions of the controlled sample, setting the required operating mode and the relative position of the control object and equipment. The parameters of the light source should be chosen so as to ensure maximum image contrast [17]. To develop a system for monitoring glass defects, the most acceptable method is the use of diffused lighting, since it allows monitoring of diffuse-reflective products, detecting inclusions by the dark field method, and analyzing the color and brightness of controlled objects.

![Figure 3. Optical design of a glass defect monitoring system: 1 - camera vision; 2 - short-focus lens; 3 - object of control; 4 - glass defect; 5 - lighting system; 6 - background (screen).](image)

![Figure 4. Defects of translucent materials: (a) scratch; (b) stone; (c) bubble.](image)

Consider the analysis of a monochrome image of a double-glazed window (figure 5) in the NI Vision Builder software environment.

Let us use the Laplace operator to highlight possible defects in the image. At the initial stage, let us determine the overlap region of the filter matrix (figure 6). Next let us apply matrix masks (horizontal, vertical, diagonal) which, in accordance with the algorithm, show possible “linear” defects.

\[
\begin{pmatrix}
-a1 & -a1 & -a1 \\
0 & 0 & 0 \\
a1 & a1 & a1
\end{pmatrix}, \quad \begin{pmatrix}
-a1 & 0 & a1 \\
-a1 & 0 & a1 \\
-a1 & 0 & a1
\end{pmatrix}, \quad \begin{pmatrix}
0 & a1 & a1 \\
-a1 & 0 & a1 \\
-a1 & -a1 & 0
\end{pmatrix}, \quad \begin{pmatrix}
-a1 & 0 & 0 \\
-a1 & 0 & a1 \\
0 & a1 & a1
\end{pmatrix}
\]

| horizontal | vertical | diagonal \ | diagonal / |
|-----------------|-----------|------------|-------------|
| \begin{pmatrix}
-a1 & -a1 & -a1 \\
0 & 0 & 0 \\
a1 & a1 & a1
\end{pmatrix} | \begin{pmatrix}
-a1 & 0 & a1 \\
-a1 & 0 & a1 \\
-a1 & 0 & a1
\end{pmatrix} | \begin{pmatrix}
0 & a1 & a1 \\
-a1 & 0 & a1 \\
-a1 & -a1 & 0
\end{pmatrix} | \begin{pmatrix}
-a1 & 0 & 0 \\
-a1 & 0 & a1 \\
0 & a1 & a1
\end{pmatrix} |
The matrix of the form most suitable for the diagnosis of defects (as studies show) in transparent media is:

\[
A = \begin{bmatrix}
-3 & -3 & -3 \\
0 & 0 & 0 \\
3 & 3 & 3
\end{bmatrix}
\]

The converted monochrome image contains a white line on a black background (figure 7). Upon applying a matrix filter with higher upper and lower row coefficients (for example, “10” and “-10”) the appearance of additional white linear noise structures that are not physically defects but represent the glass structure itself (figure 8).

To control the surface and internal scratches of double-glazed windows, an algorithm is required taking into account the probabilistic process of the appearance of the defect, the probabilistic distribution and direction. As studies have shown, for this it is necessary to include in the control program a certain
number of filters of the integrated Laplace transform that will convolve the image at 0, 45, 90, 135, 180, 225, 270, 315 degrees, which will give a reliable system for detecting defects.

In the case of detecting glass scratches, a monochrome image contains interesting controlled defects of one brightness against a background of a different brightness.

Therefore, the primary control task is to establish a threshold limit between two maximum brightness values. In addition to using the shadow feature and image filtering, the classification of defects can be carried out according to statistical criteria. In [18], a technique is presented for distinguishing linear and ellipsoidal objects in an image based on the calculation of the correlation coefficient, which may be applicable for such defects as a scratch, chip, bubble, pin, stone.

4. Conclusions
The considered methodology for the recognition of glass defects can be applied both in laboratory research and at manufacturers of glass and glass products (double-glazed windows).

Of the unsolved problems, the determination of the depth of occurrence of defects remains open. Despite the fact that this parameter is not standardized by national standards, it is important in assessing the criticality of a defect and affecting the performance of glass products. It is necessary to pay attention to the metrological characteristics of image filtering which can bring both a positive (removal of objects that are not defects in the image) and a negative result (removal of the desired objects) in the classification of defects.

Comparison of the results of determining the number of defects and the assessment of their geometric parameters of the proposed installation with the results of visual inspection by a person showed the advantage of the developed installation. None of the control samples during visual inspection revealed all of its defects, the detection rate of defects varies from 0.62 to 1.2 (the last value indicates the identification of non-essential defects, i.e., rejection). Upon using the ADPS system, the probability of detecting defects varies from 0.92 to 0.99, there are no cases of rejection.

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