MECHANICAL COMPONENT SURFACE DEFECT DETECTION DEVICE BASED ON MACHINE VISION

FIELD OF TECHNOLOGY

[0001] The present invention relates to the technical field of machine vision inspection, and specifically to a mechanical component surface defect detection device based on machine vision.

BACKGROUND

[0002] The surface quality of mechanical components (such as automotive bearings, precision gears, hydraulic valve blocks, etc.) directly affects product assembly accuracy, service life, and safety, with surface defects such as scratches, dents, and foreign matter adhesion being among the main causes of component failure. With the intelligent upgrading of the manufacturing industry, machine vision inspection technology, due to its high efficiency and non-contact advantages, has gradually replaced manual visual inspection and become the mainstream solution for surface defect detection.

[0003] Existing machine vision-based surface defect detection systems for mechanical components typically require the use of an acquisition module to capture surface images of mechanical components during inspection, then, after preprocessing (such as denoising and enhancement), the images are directly input into a defect recognition model for judgment, thereby replacing manual determination and identification of whether surface defects exist on the mechanical components.

[0004] However, considering that most systems only use a single viewpoint, such as a fixed top view or a preset-weight multi-view acquisition, they do not take into account the structural complexity of components—for example, the arcuate surface of automotive bearings, the root fillet of gears, or the edge of deep holes in hydraulic valve blocks. In a top view, these areas are prone to missed defect detection due to occlusion or reflection, while 30°/60° oblique views can capture side defects, but the image quality (such as defect clarity and background interference) varies significantly across different angles.

Fusion with fixed weights introduces information from low-quality views into the final result, thereby reducing detection accuracy.

SUMMARY

[0005] To address the deficiencies of the prior art, the present invention provides a machine vision-based surface defect detection device for mechanical components, which solves the problems in existing surface defect detection systems for mechanical components that, due to the use of single-view or fixed-weight multi-view approaches without considering the structural complexity of components, areas such as arcuate surfaces and gear roots are prone to missed detection, and when there are significant differences in image quality between oblique views, fixed-weight fusion introduces low-quality information and reduces detection accuracy.

[0006] To achieve the above objectives, the present invention adopts the following technical solution: A machine vision-based surface defect detection device for mechanical components, comprising a multi-view acquisition module, wherein the multi-view module extracts surface images of mechanical components by deploying multiple viewpoint cameras and transmits the extracted information to a predicted viewpoint weight module;

[0007] The multi-view acquisition module is connected to a predicted viewpoint weight module, which receives image information transmitted from the multi-view acquisition module, predicts the optimal viewpoint module using an improved entropy weight method, allocates different weights to the top-view camera, 30° oblique-view camera, and 60° oblique-view camera, and transmits the final weight values and image information to the multi-view fusion module;

[0008] The predicted viewpoint weight module is connected to a multi-view fusion module, which, based on the weight values and image information provided by the predicted viewpoint weight module, uses a weighted average fusion algorithm for defect confidence values, and finally outputs the fused defect confidence F to the mechanical component surface defect detection module;

[0009] The multi-view fusion module is connected to a mechanical component surface defect detection module, which receives the final fused defect from the multi-view fusion module and compares it with a preset threshold to determine whether there is a defect on the surface of the current mechanical component, and transmits the conclusion to the feedback interaction module;

[0010] The mechanical component surface defect detection module is connected to a feedback interaction module, which receives the result from the mechanical component surface defect detection module, provides feedback, and displays it through a display device.

[0011] Preferably, the deployment of multiple viewpoint cameras includes a top-view camera, a 30° oblique-view camera, and a 60° oblique-view camera.

[0012] Preferably, the determination of whether there is a defect on the surface of the current mechanical component in the mechanical component surface defect detection module is specifically as follows:

[0013] The preset defect determination threshold is 0.6,

[0014] When $F \geq 0.6$, it is determined that a defect exists;

[0015] When $F < 0.6$, it is determined that no defect exists.

[0016] Preferably, the feedback in the feedback interaction module includes:

[0017] If a defect is present on the surface of the mechanical component, it is determined that the machining of the mechanical component is unqualified, a record is made in a timely manner, and the operator is alerted;

[0018] If no defect is present on the surface of the mechanical component, it is determined that the machining of the mechanical component is qualified, the operator is not alerted, and detection continues for the next mechanical component.

[0019] Preferably, the display device in the feedback interaction module includes: monitor, mobile phone, and tablet.

[0020] The present invention provides a machine vision-based surface defect detection device for mechanical components. It has the following beneficial effects:

[0021] 1. The present invention effectively solves the problem of missed defect detection in complex-structured components by using multi-view acquisition and an improved entropy weight method for dynamic weight allocation. For easily occluded areas such as the arcuate surface of automotive bearings and the root of gear teeth, the complementarity of three viewpoints—top view, 30° oblique view, and 60° oblique view—is utilized. By calculating the information entropy based on three key indicators (gray level difference in the defect area, edge gradient value, and contour integrity), high-quality viewpoints are given higher weights and low-quality viewpoints are given lower weights, thereby avoiding the introduction of invalid information by fixed-weight fusion and significantly improving the coverage and accuracy of defect detection on complex surfaces.

[0022] 2. The present invention improves the reliability of defect determination through a weighted average fusion algorithm and a threshold determination mechanism. The multi-view fusion module performs weighted fusion of defect confidence values from each viewpoint based on dynamic weights, combines defect features from the three viewpoints to generate a final confidence value, and then compares it with the preset threshold of 0.6 for determination. This approach retains effective defect information from each viewpoint, attenuates interference from low-quality images through weight adjustment, and solves the problem of misjudgment or missed judgment caused by occlusion or reflection in single-view detection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is a flowchart of the device according to the present invention.

DESCRIPTION OF THE EMBODIMENTS

[0024] The following describes the technical solutions in the embodiments of the present invention clearly and completely in conjunction with the accompanying drawings of the specification. Obviously, the described embodiments are only part of the embodiments of the present invention, and not all embodiments. Based on the embodiments in the present invention, all other embodiments obtained by those of ordinary skill in the art without creative workshall fall within the scope of protection of the present invention.

[0025] Please refer to Figure 1. The embodiment of the present invention provides a machine vision-based surface defect detection device for mechanical components, comprising a multi-view acquisition module. The multi-view module extracts surface images of mechanical components by deploying multiple viewpoint cameras and transmits the extracted information to a predicted viewpoint weight module. The deployment of multiple viewpoint cameras includes a top-view camera, a 30° oblique-view camera, and a 60° oblique-view camera;

[0026] The multi-view acquisition module is connected to a predicted viewpoint weight module, which receives image information transmitted from the multi-view acquisition module, predicts the optimal viewpoint module using an improved entropy weight method, allocates different weights to the top-view camera, 30° oblique-view camera, and 60° oblique-view camera, and transmits the final weight values and image information to the multi-view fusion module;

[0027] The improved entropy weight method is specifically as follows:

[0028] 1. First, for each viewpoint image of the top-view camera, 30° oblique-view camera, and 60° oblique-view camera, three key indicators are extracted: the gray level difference between the defect area and the background, the gradient value at the defect edge, and the integrity of the defect contour;

[0029] 2. Then, the information entropy of each indicator is calculated as follows:

[0030] $H_j = -k\sum_{i=1}^{3} p_{ij} \ln p_{ij}$|

[0031] Where:

[0032] H_j The information entropy of the kth indicator, j where j k=1, j k=2, j k=3, corresponding to the three indicators above;

[0033] k represents the correction coefficient;

[0034] p_{ij} represents the normalized probability of the ith viewpoint for the kth indicator, calculated as$j p_{ij} = x_{ij}/\sum_{i=1}^{3} x_{ij}$, where$x_{ij}$ is the original value of the ith viewpoint for the kth indicator, including the absolute value of the gray level difference and the magnitude of the gradient value;

[0035] $\sum_{i=1}^{3}$ represents the summation of the same indicator across the three viewpoints;

[0036] 3. Then, based on the information entropy of each indicator, finally calculate the different weights for each viewpoint, specifically as follows:

[0037] $w_i = \frac{\sum_{j=1}^{3}(1-H_j)\cdot r_{ij}}{\sum_{i=1}^{3}\sum_{j=1}^{3}(1-H_j)\cdot r_{ij}}$|

[0038] Where:

[0039] w_i represents the weight of the ith viewpoint (i=1 for top view, i=2 for 30° oblique view, i=3 for 60° oblique view);

[0040] The numerator represents the total utility value of the ith viewpoint across all indicators;

[0041] The denominator represents the sum of the total utility values of the three viewpoints, ensuring that the sum of the weights is 1, $\sum_{i=1}^{3} w_i = 1$;

[0042] $1 - H_j$ represents the information utility value of the kth indicator, where the smaller the information entropy, the greater the utility value, and the more significant the impact on the weight; j

[0043] r_{ij} represents the normalized score of the ith viewpoint for the kth indicator, $j 0 \leq r_{ij} \leq 1$, obtained by normalizing x_{ij}, reflecting the performance of the viewpoint on the indicator;

[0044] 4. Finally, output the top-view weight w_1, 30° oblique-view weight w_2, and 60° oblique-view weightw_3;

[0045] The predicted viewpoint weight module is connected to a multi-view fusion module, which, based on the weight values and image information provided by the predicted viewpoint weight module, uses a weighted average fusion algorithm for defect confidence values. The weighted average fusion algorithm is specifically as follows:

[0046] $F = w_1 \cdot C_1 + w_2 \cdot C_2 + w_3 \cdot C_3$

[0047] Where:

[0048] F represents the final fused defect confidence, with a larger value indicating a higher probability of defect presence;

[0049] w_1, w_2, w_3 represent the top-view, 30° oblique-view, and 60° oblique-view weights output by the predicted viewpoint weight module;

[0050] C_1, C_2, C_3 represent the defect confidence detected in the images of each viewpoint, calculated using edge detection and threshold segmentation from each viewpoint image, which are common prior art and will not be described in detail here;

[0051] Finally, output the fused defect confidence F, which integrates the defect features from the three viewpoints and is used for subsequent comparison with the preset threshold for judgment;

[0052] The multi-view fusion module is connected to a mechanical component surface defect detection module, which receives the final fused defect from the multi-view fusion module and compares it with a preset threshold to determine whether there is a defect on the surface of the current mechanical component, and transmits the conclusion to the feedback interaction module, specifically as follows:

[0053] The preset defect determination threshold is 0.6,

[0054] When $F \geq 0.6$, it is determined as "defect present";

[0055] When $F < 0.6$, it is determined as "no defect present";

[0056] The mechanical component surface defect detection module is connected to a feedback interaction module, which receives the result from the mechanical component surface defect detection module, provides feedback, and displays it through a display device for easy viewing by the operator. The display device includes a monitor, mobile phone, and tablet;

[0057] Feedback includes:

[0058] If the surface of the mechanical component has a defect, it is determined that the machining of the mechanical component is unqualified, a record is made in a timely manner, and the operator is alerted;

[0059] If no defects are present on the surface of the mechanical component, it is determined that the mechanical component has passed the processing inspection, no notification is sent to the operator, and the inspection proceeds to the next mechanical component.

[0060] Although embodiments of the present invention have been shown and described, it will be understood by those skilled in the art that various changes, modifications, substitutions, and alterations can be made to these embodiments without departing from the principles and spirit of the present invention, and the scope of the present invention is defined by the appended claims and their equivalents.