Investigation of Dirty Area Recognition for Coin

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Abstract
Coin can be destroyed during the usage if there are some dirty, corrosion, deformity and abrasion areas on the coin surface which can impact the continuous usage of coin. Some key technologies for dirty area recognition are especially investigated in this paper. Firstly, the dirty area recognition and quantitative algorithm are developed according to the statistic results of different material coin. The algorithms which are based on fuzzy intent judgment algorithm can automatically calculate the disfigurement area. Secondly, in order to prove the effectiveness and robustness of the algorithm, repeated test of relevant algorithm is researched. The experiment results prove the validity and practicability of the related algorithms.

Keywords: Coin, Disfigurement, Fuzzy Intent Judgment, Dirty Recognition

1. Introduction

At present, the study of current coin is mainly in the coin sorting, identification and detection of forgeries at home and abroad. Such as the common coin sorter [1-4], the coin sorting of the common coin sorter is completed by the quality, size, materials and other physical characteristics of the coins based on the eddy current sensor, which does not only have capabilities of the coins identifying, incomplete discrimination and detection of forgeries, but also can detect the total nominal value of the coins and face value of various types of the coin. But image processing technology can not be used in coin sorter mostly. The study of coins based on the image processing technology is mainly reflected in the coin recognition [5-12]. The function of coin recognition is achieved by Bi Xiaojun etc based on clustering ability of the ant colony algorithm which classify data of the input image [13]. The different denominations of coins are recognized based on the improved BP neural network based on the study of neural networks by Liu Meijia etc [14]. Distinguishing processing is achieved based on the surface pattern of coins detected by image processing technology by Zhang Chi etc [15]. Coins are identified based on characteristic parameters of rotation invariance of coin image combining neural networks and genetic algorithms abroad [16-19].

At present, image processing techniques to detect the quality of coin surface at home and abroad are still in its infancy. The design of comprehensive evaluation system of coins surface quality is posted by Zou Guangfu etc [20]. First, numerical indicators of the degree of surface defects are obtained based on image processing techniques. Then, coins are grading processed by the analytic hierarchy process and fuzzy comprehensive evaluation method. Finished coin surface quality detection system is invented to detect the coin surface quality of the production line by Shanghai Mint Co., Ltd [21]. In short, the technology and theory of the coin surface quality inspection based on image processing technology is not perfect and mature, and it still has a wide range of prospects, important value and significance.

Coin surface will be inevitably destroyed by the external environment including human or non-human because of all circulation of coins in circulation. This damage often includes dirt, corrosion, defects and wear and tear. Identification and quantification algorithm of dirt which is one of the difficult type of defects is researched. Dirty identification and quantification algorithm based on fuzzy intent judgment is researched. The experiment results show that the algorithm proposed is effective and practical.
2. Dirty processing technology

The dirt of coin surface can be divided into two types. One is that the color of the dirt is close to the color of the coin surface itself; the other is that the color of the dirt varies the color of the coin surface itself greatly. Colors of surfaces of a dime, five cents and a dollar coin are different because of their material. Color of dirt, which is different from the surface color of coin, can be extracted based on the RGB relations in the RGB color space. The color of five cents coin, whose RGB relations is $R > G > B$ is golden. The pixel can be thought as dirty, whose RGB relations is $G > R > B$ or $B > G > R$.

A reasonable classifier is needed in extracting dirty whatever its material is, which influences the accuracy of the dirty region extraction. The design of classifier is combined with fuzzy decision making method in fuzzy mathematics. The design of classifier in the dirt extraction of non-copper coins is set as an example. Color of coin surface without serious wear and tear and dirty is bluish, whose RGB relations is $B > G & G > R$ in the RGB color space. The a area in Figure 1 shows that RGB relations coins with obvious dirty presenting is $R > G & G > B$, or Gray $< T$ (gray value is less than a threshold). The b area in Figure 1 shows that the relationship between $R$ and $B$ is the key to the design of the classifier of coins whose surface color is close to dirt and RGB relationship is $G > R & G > B$. Fuzzy intent judgment method in fuzzy mathematics is adopted.

![Figure 1. Schematic of coins face dirty](image)

**Determination of classifier of RB relationship:**

RB relationship is a total of three cases, namely, ① $R > B$; ② $R = B$; ③ $R < B$. Analyzed theoretically, $R$ more tends to $G$ in the condition of $R > B & G > B$. It is obviously dirty as Figure 1 shown because color is yellow from the color. $\Delta d$ ($\Delta d = R - B$) is the key in the design of classifier.

RB relationship is judged according to the fuzzy intention. Firstly, the means of collection, fuzzy goals and fuzzy constraints are needed to be determined. Then, the membership functions of fuzzy goals and fuzzy constraints are needed to be determined. Finally, the fuzzy decision is determined.

Collection of means is established as follows: $X = \{ \Delta d \} = \{0, 1, \cdots, 255\}$, the fuzzy objective $G$ and fuzzy constraint $C$ are expressed as follows:

- $G$: “$\Delta d = 0$ is more larger than 0” and $C$: “$\Delta d = 0$ should be lower than G-B”.

The corresponding membership function is:
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\[
u_c(\Delta d) = \begin{cases} \frac{1}{1 + 1/(\Delta d)^2}, & \Delta d \geq 0 \\ 0, & \Delta d < 0 \end{cases}
\]

(1)

\[
u_c(\Delta d) = \begin{cases} \frac{1}{1 + 1/(G-B - \Delta d)^2}, & \Delta d \leq (G-B) \\ 0, & \Delta d > (G-B) \end{cases}
\]

(2)

Fuzzy objective G and fuzzy constraint C can be expressed as the intersection of G and C in the choice of means, because G and C are connected with conjunctions “and”.

\[u_{G\cap C}(\Delta d) = u_G(\Delta d) \land u_C(\Delta d)\]

(3)

Detail is expressed as:

\[u_{G\cap C}(\Delta d) = \begin{cases} \min\left[1, \frac{1}{1 + 1/(\Delta d)^2}, \frac{1}{1 + 1/(G-B - \Delta d)^2}\right], & \Delta d \geq 0 \\ 0, & \Delta d < 0 \end{cases}
\]

(4)

The so-called fuzzy decision D can be indicated as the intersection of fuzzy objective G and fuzzy constraint C, because the so-called fuzzy decision basically is choosing an effective means or indicating selected collection.

\[D = G \cap C\]

(5)

In other words:

\[u_D = u_G \cap u_C\]

(6)

This is expressed in Figure 2.

**Figure 2.** Relationships between fuzzy goals, the fuzzy constraint and fuzzy decision

Variable G-B is presented in the membership function of fuzzy constraints from observational. A total of 256 fuzzy constraints are got based on \(X = G-B\) and \(X\) is range from 0 to 255.

\[D = G \cap C_0 \cap C_1 \cap \cdots \cap C_{255}\]

(7)

\[u_D = u_G \land u_{C_0} \land u_{C_1} \land \cdots \land u_{C_{255}}\]

(8)

Fuzzy objective G and fuzzy constraint \(C_0, \cdots, C_{255}\) are in Table 1.
Table 1. Fuzzy objective $G$ and fuzzy constraint $C_0, \ldots, C_{255}$

<table>
<thead>
<tr>
<th>$\Delta d$</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>$\ldots$</th>
<th>255</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u_G$</td>
<td>0</td>
<td>0.5</td>
<td>0.8</td>
<td>0.9</td>
<td>$\ldots$</td>
<td>1</td>
</tr>
<tr>
<td>$u_{C0}$</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$u_{C1}$</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$u_{C2}$</td>
<td>0.8</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
</tr>
<tr>
<td>$u_{C_{255}}$</td>
<td>1</td>
<td>$\ldots$</td>
<td>$\ldots$</td>
<td>$\ldots$</td>
<td>$\ldots$</td>
<td>0</td>
</tr>
</tbody>
</table>

Fuzzy decision $u_D$ is given in Table 2 if $u_G, u_{C_0}, \ldots, u_{C_{255}}$ take the minimum in Table 2.

Table 2. Fuzzy decision $u_D$

<table>
<thead>
<tr>
<th>$\Delta d$</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>$\ldots$</th>
<th>254</th>
<th>255</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u_D$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$\ldots$</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Therefore, the fuzzy decision $D$ is given as the following fuzzy sets.

$$D = [(0,0),(1,0),(2,0)\ldots(254,0),(255,0)]$$  \hspace{1cm} (9)

$\Delta d = 0$ is achieved in order to meet all the constraints. RGB relations of classifier is $G > R$ & $(R-B) > 0$.

Other types of coins classifier are available similarly. The influence of dirt on the coin surface which is a foreign body attached to the surface of the coin and affects the degree of clarity whatever shades of color depend on the dirty area.

The following formula is available:

$$D_{\text{area}} = \frac{S_d}{S}$$  \hspace{1cm} (10)

$S_d$: total area of the dirt on coin surface;
$S$: total area of the coin.
Degree of dirt on the coin surface is heavier as $D$ is greater.

3. The experimental results and analysis

In order to prove the effectiveness and robustness of the algorithm, repeated test of relevant algorithm is researched. To begin with, rotate the coins which have different defects. The rotating angles are 0 degree, 120 degree and 240 degree. Then, take photos and do image processing and the recognition and quantification results of defects can be got. Here, we mainly research the coins which have defects such as dirty.

According to material of circulation coin surface, two processing methods, which are processing method of copper coin and processing method of nickeling coin, are designed for the recognition and quantification of dirty. In the test, 1 jiao coin and 5 jiao coin are used and the original image and
rotating images are shown from Figure 3 to Figure 5. It is obvious that smudginess area exists on the coin surface.

![Figure 3](image)

(a) dirty of 1 jiao  
(b) dirty of 5 jiao

**Figure 3.** The results of rotating 0 degree

Table 3 is the detection results of dirty. In Figure 5 (a), the results in different degrees are stable at 198 pixels. When attention comes to Figure 5 (b), the dirty area occupies 75 to 76 pixels. So it is obvious that the standard deviation of copper coin is bigger. This is determined by the contrast between dirty and background. From the whole results, differences which detected under different degrees are small and standard deviations meet requirements. So the classification method based on fuzzy decision is efficient to recognize dirty on this two kinds of material.

![Figure 4](image)

(a) dirty of 1 jiao  
(b) dirty of 5 jiao

**Figure 4.** The results of rotating 120 degree
Table 3. The results of repeatability test of dirty

<table>
<thead>
<tr>
<th>Name</th>
<th>Angle of rotation</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dirty area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)Dirty of 1 jiao</td>
<td>198.5967, 198.5638, 198.5800</td>
<td>0.0165</td>
</tr>
<tr>
<td>(b)Dirty of 5 jiao</td>
<td>75.3021, 76.0757, 76.2818</td>
<td>0.5165</td>
</tr>
</tbody>
</table>

From Figure 6 to Figure 8, the detected results are shown and the grey black area represents dirty area. So, it is similar with the results which made out by human eye and has little relation with material of coins which are shot in different degrees and marked location.

To sum up, the measured results of the same coin in different rotation angle have little changes and the error includes the rotation error. Therefore, it can be judged that the system actual error is less than or equal to the error. Because the actual error is in scope, the algorithm proposed in this paper has better repeatable accuracy and robustness.

4. Conclusion

This paper focuses on a common defect which is dirty current coin and does further research. The recognition and quantification algorithm of dirty based on fuzzy intent judgment method and the recognition and quantification algorithm of corrosion based on color clustering are expounded. In experiment, the dirty disfigurement on the surface of circulation coin is extracted. Thus, the results acquired in this paper can provide damage level of coin surface and further evaluation with data support.
5. Acknowledgment

This work is supported by the Open Subject of State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, and also supported by the Liaoning Province Educational Office Foundation of China (Grant No. L2011038).
6. References