A Stereoscopic Warehouse Stocktaking Method Based on Machine Vision

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Abstract. In order to solve the problem of high security risk, low efficiency and low accuracy of the manual stocktaking during stocktaking of stereoscopic warehouse, the image processing method of python+OpenCV visual library software was adopted. Firstly, the sampling camera is controlled by the stacker PLC to traverse all cargo positions and obtain physical images of the goods. Then, OpenCV platform is used to provide operators for image preprocessing, image segmentation and one-dimensional barcode recognition, so as to identify the barcode information and determine the material type. Finally, the inventory report is generated by comparing with WMS system. The research shows that the OpenCV-based method can quickly and accurately identify the one-dimensional barcode, and realize the automatic unmanned intelligent inventory, effectively reduce the workload of staff, improve the production efficiency, avoid the potential risk of manual inventory, and achieve the expected goal.

1. Introduction

With the development of machine vision technology, especially the continuous emergence of cross-platform computer vision library technology based on BSD license (open source) such as OpenCV, machine vision technology has been more and more widely used in various industries, and there have been many excellent products. For example, text recognition [1], license plate recognition [2], face recognition and unmanned supermarket, etc. In the future, under the new situation of the continuous advancement of intelligent manufacturing 2025, in order to solve the pressure caused by the rising labor cost, the industrial field is gradually developing towards the direction of unmanned workshop, which puts forward higher requirements for the automation degree of production equipment. In the aspect of warehouse management with a higher degree of automation, due to the existence of machine failure or human processing error, resulting in the inventory information and the real object is not consistent, the need for regular or irregular inventory operation. The original operation mode is that the staff take the printed cargo location information list and then take a stacker to the cargo location for on-site verification. This operation method has several problems:

First, safety risk: at present, the vast majority of stacker are designed for cargo. The safety measures are not included in the design, and the safety level of the design is not up to the requirements of human beings. Personnel travelling by stacker to inspect the cargo will face great risk of falling from high places.

Second, the workload is large: there are more than one thousand positions in a roadway of the stacker, if the personnel come close to check one by one, it will consume a great deal of time and energy.
Third, low production efficiency: the application scenarios of automatic warehouse are generally in the production site storage or logistics hub storage with high turnover rate, which requires very high efficiency of warehousing. If manual inventory is adopted, the existing warehousing operation must be stopped, and the whole production process stops before the inventory is completed.

In order to solve the above problems, the use of digital image processing method, combined with the stacker PLC technology to control the industrial camera to collect the face of the physical picture of the cargo location, identify the one-dimensional bar code information on the physical box, the realization of the automatic detection and proofreading of the material on the cargo location, will greatly improve the production efficiency and the degree of automation of the production equipment[3].

2. Methods
We processed the physical case photos using OpenCV, which was developed under the BSD license (open source).This is a cross-platform computer vision library. It can realize many general algorithms in computer vision concisely and efficiently.

OpenCV's visual processing algorithms, written in C, are well handled and can be fully compiled and linked to generate executable programs without adding new external support. The code can run in DSP and ARM embedded system after appropriate rewriting, which is helpful for integrating related software such as VisualStudio, and the interface is friendly and easy to use. [4].

This paper mainly introduces the identification of one-dimensional bar code of goods by OpenCV image processing software. Firstly, the software used in this project is introduced. Then, the process of experiment, the steps of image preprocessing, the selection of areas of interest, the identification of one-dimensional bar code and comparison with WMS system information are introduced, and the inventory report is generated.

The flow of this method is shown in Figure 1.

**Figure 1.** The overall stocktaking process

2.1. WMS issues stocktaking instructions
The warehouse management system (WMS) issues stocktaking instructions at appropriate times according to business requirements. The choice of this time point can be considered when the equipment is idle and the entry and exit tasks are relatively few. If the loading and unloading task is more and the production pressure is always higher, WMS management function can be considered to distribute the loading and unloading task of the roadways to other roadways to balance the pressure. Instructions are transmitted to the stacker PLC through the equipment scheduling system (TDCS). Generally speaking, the upper management system (WMS and TDCS) is far away from the stacker, so Ethernet communication is appropriate. Common communication methods include Nport, Opc technology and Rslnix software.

2.2. Industrial camera traverses the position
One of the following two methods can be used for industrial camera traverses the position.
Method 1, The pallet of the stacker with an industrial camera traverses the cargo position. The PLC controls the stacker to send the camera of the platform to the correct position. The physical position of each side of each row and each floor is planned in advance. The initial position of the stacker, namely the 0th row and 0th floor of each roadway, is taken as the origin of coordinates. The PLC of the stacker issues instructions, and the motor is driven by the inverter to drive the stacker horizontally and vertically to the exact position, and then the encoder synchronously with the motor is used for numerical verification to achieve the precise control purpose. The rule of taking photos is to traverse in the shape of "S", which can make the traversal distance shortest and the operation efficiency highest.

Method 2, the use of unmanned aerial vehicles (UAV) with a cargo of industrial cameras traversed. UAV technology is used. UAV autonomous flight path planning is used to traverse each cargo location to take pictures and samples under the premise of safe flight. Then, the sample pictures and location information are transmitted to the computer for analysis via wireless Ethernet [5-7].

2.3. Trigger industrial camera to take pictures
The position triggers the photographing. The camera is installed here through experiments to ensure accurate focusing [6,8]. In this application environment, the goods placed in the warehouse are required to be pasted with barcodes at relatively fixed positions.

2.4. Transfer photos and location information to the computer
Photos taken by industrial cameras are sent to the upper computer in real time. The method of transmitting photos can choose the existing communication channel of the stacker or through the field wireless Ethernet. The upper computer saves the received pictures and location information into the database.

2.5. Process photo identification barcode
This step is the most core part of the whole process. Machine vision is the difficulty and innovation point of new type of stocktaking technology. This method is implemented by Python + OpenCV + PyZbar platform, visual resource library and barcode decoder.

2.5.1. Image preprocessing. Due to the unstable light environment in the warehouse, the operation vibration of the stacker and other factors, the image quality will inevitably be affected during the image acquisition process, and the unstable image quality will interfere with the recognition process, resulting in a decrease in the recognition accuracy. Image preprocessing includes the following steps:

2.5.1.1. Image blur. On the premise of preserving crack features, the image noise is removed as far as possible. Image convolution operation is one of the common denoising methods. Because the gray value changes rapidly at the image noise point, it belongs to high frequency noise, so low pass filtering can be used for processing. This process is also known as image blur processing. Gaussian filter generates filter template based on two-dimensional Gaussian distribution [9].

2.5.1.2. Image enhancement. Compared with the background pixels in the image, the number of pixels in the crack is relatively small, and the image blur operation will cause the loss of some edge pixels. Due to the non-uniformity of external light, the overall brightness of the obtained crack image is not uniform. The image enhancement algorithm highlights the brightness and edge features of the image. Contrast limited adaptive histogram equalization (CLAHE) was used for image enhancement [10]. When the number of pixels exceeds a certain threshold, it is randomly assigned to other gray values to increase the image contrast.

2.5.1.3. Threshold segmentation. The process of distinguishing the crack features and background of an image is called threshold segmentation. Global binary segmentation is a relatively simple
processing formula, which converts pixel points greater than a certain threshold into white points, and pixel points less than the threshold into black points [11].

2.5.1.4. **Morphological operation.** Morphological operations can be divided into expansion operations and corrosion operations. By mathematical set operations of image pixels and customized structural elements, feature areas in the image can be enlarged or reduced. In actual operation, the expansion operation and the corrosion operation need to be used in combination.

2.5.2. **Bar code region extraction.** The image transmitted from the industrial camera to the computer is generally centered on a specific area and contains an area other than the barcode. To locate the barcode region, a process of selecting the region of interest is also required. This process requires the use of OpenCV's RIO (Region of Interest) [3]. In the application of machine vision or image processing, the region to be processed is outlined from the processed image in the form of boxes, circles, ellipses, irregular polygons, etc., which is called the region of interest. Then extract the barcode area as follows [12]:

   a. Construct the horizontal and vertical gradient amplitude representation of the grayscale image using the `Schar` operation (specifying ksize = -1). The image region containing high horizontal gradient and low vertical gradient was obtained by subtracting y-gradient from x-gradient.

   b. Use a 9 * 9 kernel to average the gradient map, which will help smooth the high-frequency noise in the graphs represented by the gradient. Binarize the blurred image, set any pixels less than or equal to 255 in the gradient image to 0 (black), and the rest to 255 (white).

   c. Perform morphological operations and apply the obtained kernel to the binary graph to eliminate the gap between the vertical bars.

   d. Perform 4 erosions, and then perform 4 dilations.

   e. Obtain the rectangular border of the barcode area through `findContours`, find the largest contour in the image, determine the smallest border for the largest contour, and display the detected barcode.

    **The key source code** (Shared from open source web site [4] https://opencv.org/):
    ```python
    gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
cv2.imshow("Gray",gray)
gradX = cv2.Sobel(gray, ddepth = cv2.CV_32F, dx = 1, dy = 0, ksize = -1)
gradY = cv2.Sobel(gray, ddepth = cv2.CV_32F, dx = 0, dy = 1, ksize = -1)
gradient = cv2.subtract(gradX, gradY)
gradient = cv2.convertScaleAbs(gradient)
cv2.imshow("Gradient",gradient)
blurred = cv2.blur(gradient, (9, 9))
(_, thresh) = cv2.threshold(blurred, 225, 255, cv2.THRESH_BINARY)
cv2.imshow("Bin",thresh)
kern = cv2.getStructuringElement(cv2.MORPH_RECT, (21, 7))
closed = cv2.morphologyEx(thresh, cv2.MORPH_CLOSE, kernel)
cv2.imshow("Closed",closed)
closed = cv2.erode(closed, None, iterations = 4)
closed = cv2.dilate(closed, None, iterations = 4)
cv2.imshow("erode-closed",closed)
cnts = cv2.findContours(closed.copy(), cv2.RETR_EXTERNAL,cv2.CHAIN_APPROX_SIMPLE)
c = sorted(cnts, key = cv2.contourArea, reverse = True)[0]
rect = cv2.minAreaRect(c)
box = np.int0(cv2.cv.BoxPoints(rect))
cv2.drawContours(image, [box], -1, (0, 255, 0), 3)
```

    Bar code area extraction process is shown in Figure 2.
2.5.3. **Bar code recognition.** Using python's third-party module *pyZBar* can easily identify the extracted barcode. The ZBar algorithm is an open source barcode and two-dimensional code detection algorithm on the Internet. The algorithm can identify most types of one-dimensional codes (barcodes), such as I25, CODE39, and CODE128.

The key source code (Shared from open source web site [13] [https://github.com/zplab/zbar-py.html](https://github.com/zplab/zbar-py.html)):

```python
import pyzbar.pyzbar as pyzbar
from PIL import Image, ImageEnhance
image = "yuxi.jpg"
img = Image.open(image)
img = ImageEnhance.Contrast(img).enhance(4.0)
img.show()
barcodes = pyzbar.decode(img)
for barcode in barcodes:
yuxibarcode = barcode.data.decode("utf-8")
print(' Bar code: ', yuxibarcode)
```

After the program runs, bar code recognition results are displayed on the interface as follows:

```
Bar code: 9131591312530402200104092893619.
```

3. **Compare with WMS inventory information and generate inventory report**

The information identified by machine vision consists of two parts: One part is the barcode and the material information it represents, and the other is the location information. The two parts of information are also available in the WMS system, but the two sets of information sources are not the same. The information identified by machine vision is the physical information, which actually reflects the current physical goods. The information in WMS is the information formed in the process of managing the stereoscopic warehouse. It is the result of a series of handling tasks. It is a logical level of inventory information. The information from the two sources is compared to generate an inventory report. The contents of the report include: machine vision information, WMS information, and consistency. Consistent information indicates that the inventory is accurate. Inconsistent information indicates that the WMS logic is incorrect or the machine vision recognition is incorrect.
Under normal circumstances, the possibility of inconsistency is small, and the occupied space is not much. It can be verified by manual final confirmation. After the entire process is completed, the inventory can be 100% accurate.

The inventory information comparison table is shown in Table 1.

| location | material code | material | location | material code | material | match or not |
|----------|---------------|----------|----------|---------------|----------|--------------|
| L001     | MC001         | M001     | L001     | MC001         | M001     | yes          |
| L002     | MC002         | M002     | L002     | MC002         | None     | no           |
| L003     | MC003         | M003     | L003     | MC003         | M011     | no           |
| ...      | ...           | ...      | ...      | ...           | ...      | ...          |

4. Conclusion

Through a variety of bar code repeated experiments, the application of OpenCV digital image processing method based on machine vision stereoscopic warehouse stocktaking mode can effectively identify the box bar code information, has the advantages of high speed, high accuracy. It can identify the barcode of different varieties and different specifications, locate the stacker and UAV accurately, and generate reports from the upper WMS to integrate the information of the two sources, so as to obtain the accurate information of the inventory. However, this scheme has a high requirement for storage material stacking in the cargo location, and the barcode location must be in the designated location, which is suitable for the scene with standard appearance size and unified barcode location, so the untidy and irregular cargo identification cannot be effectively realized. How to improve the scope of machine vision recognition and realize the recognition of general materials is the future research direction of this program.

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