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Operating Efficiency of Software Platform for Machine-Vision-Oriented CNC System

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Abstract. The combination of machine vision and open CNC system contributes to develop various functions of CNC system such as visual inspection, condition diagnosis and machining error compensation. Focusing on the two commonly used software development platforms (Visual Studio, Qt) and three machine vision libraries (OpenCV, Halcon and EmguCV), this paper studies the operating efficiency of software platform for development of open CNC system with machine vision function. The operating efficiency of various schemes is experimentally compared. Finally, the machine-vision-based error compensation efficiency is studied by taking the curve grinding CNC system as an example. The optimization scheme based on operating efficiency is presented, which provides a basis for the selection of software platform for machine vision oriented CNC software.

Keywords. Image processing, open CNC system, machine vision, software development, operating efficiency

1. Introduction

The requirements for portability and flexibility have contributed to the birth and development of open Computerized Numerical Control (CNC) system. The common architecture of open CNC system is a combination of industrial PC and real-time control unit. As the upper computer, PC is responsible for the man-machine interface, complex or massive calculation, while the real-time control unit is responsible for high real-time functions such as servo drive of the lower computer. With the continuous development of machine vision technology, the introduction of digital image processing technology into CNC system has become a developing direction. Many functions such as online visual inspection, diagnosis, machining error compensation can be developed in CNC control system with machine vision. But at the same time, the host computer not only needs to have the function of traditional human-computer interface, but also have the ability of fast real-time image processing and display. It puts forward a high demand on how to choose the right software development language, integrated development environment and vision development tools, in order to improve the operating efficiency of software development platform.

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In the aspect of introducing machine vision into open CNC system, Tian [1] et al. developed a classification system for vegetable grafting machines, and developed image processing and corresponding algorithms using the open source computer vision library (Open CV) on the Visual C++ platform. Zou [2] et al. designed a six-axis robotic arm weld tracking experimental platform based on the Halcon machine vision library. Its control system includes the upper computer software module of Visual Studio Microsoft. The upper computer software module mainly performs image acquisition, image processing and coordinate calculation. Schumacher [3] et al. developed model-based computer vision applications based on Visual C++, which can be used in systems such as industrial robots, but there are still limitations in visual recognition. Hazrat Ali [4] et al. developed an industrial sorting robot manipulator based on image processing by using VB. Yan [5] et al. established an image processing algorithm library through C# program, and added machine vision function to the industrial sorting system. Hou [6] et al. developed an online tool wear monitoring system based on machine vision. With the help of Matlab software, a self-matching algorithm is proposed for monitoring tool wear. The corresponding user-friendly graphical user interface (GUI) of the algorithm is developed, improving the accuracy and reliability of tool wear detection. Rui [7] et al. developed a machine vision system for inspecting the dimensions of flat coil springs. The detection algorithm of the system is written in C++ language. The machine vision system improves the stability of detecting the dimensions of flat coil springs.

In terms of the operating efficiency of software platform, Alnaser [8] et al. compared the efficiency of horizontal algorithms based on C++ and Java, but did not consider the efficiency of the development platform. Elsayed [9] et al. analyzed the speed and efficiency of the algorithm run on Matlab and OpenCV, concluding that Matlab is more convenient in development and data display, and OpenCV is more conducive to improving execution efficiency. For the unmanned aerial vehicles control problem, Parfiryev [10] et al. proposed a correlation filtering target detection algorithm based on two-dimensional discrete Fourier transform, using OpenCV and C++ to realize the software implementation of the detection algorithm. The efficiency of the object detection algorithm is improved.

Commonly used software platforms include Visual Studio (VS) and Qt, etc. As a Microsoft IDE, VS contains almost all the tools in the software development life cycle and the code supports most of the products of the Windows. At present, Visual Studio supports mainstream programming languages such as Visual Basic (VB), C, C++, C#. The programming languages are based on .NET architecture, which greatly facilitate the development of various API (application programming interface); Qt is a C++ based cross-platform graphical user interface application framework. It supports Linux, Windows, iOS platforms, and the rich GUI library can easily be used to develop various kinds of human-computer interaction.

Typical machine vision development libraries include OpenCV, Halcon, EmguCV, etc. OpenCV is an open source machine vision library which provides interfaces with C++, Java, Python, etc. OpenCV focuses on improving the computing efficiency of image processing, that is, efficient processing in real-time application. Halcon is a commercial machine vision library. It has been applied in various fields of medicine, measurement and control, and industrial automation. Halcon provides a convenient hybrid programming mode compared to other visual libraries. EmguCV is a product developed by OpenCV developers to package OpenCV under the .Net framework for the situation that OpenCV cannot be used in Visual Studio's C# and VB.

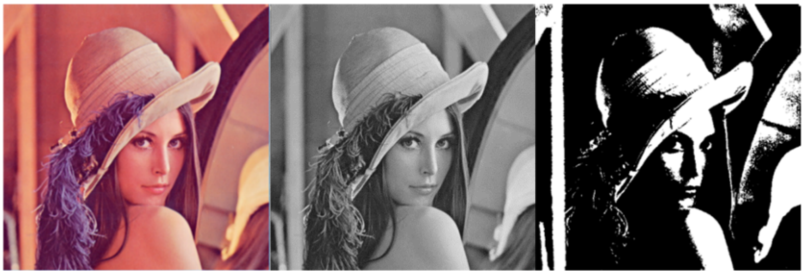
This study selects the commonly used software platforms and machine vision development libraries, conducts a time-consuming test of typical image processing algorithms, studies the operating efficiency of different software platforms, and provides data support for the selection of open CNC system development platforms.

2. Operating efficiency of software development platform

In order to explore the impact of various development platforms, languages and visual library on the processing efficiency, two algorithms of image processing, gray-scale and thresholding are selected to test the processing efficiency. The Lena image (resolution 512×512, RGB image) is chosen as original image and the processing results are shown in Figure 1.

To ensure the accuracy of the test time, the QueryPerformanceCounter function of WindowsAPI is selected as the timer, which can provide 64-bit timing accuracy. The average running time is taken as the result after 1000 times operation of each algorithm on each platform.

The test computer configuration is: The CPU is i5-6300HQ, GPU is NVIDIA GeForce GTX 960M, the memory is 4G, and the system is Windows 10 Home Edition (64-bit), the software is Qt 5.7.0, Visual Studio 2013, Halcon 10.0, OpenCV 2.4.13 and EmguCV 3.0. The test results are shown in Table 1 and Figure 2.



（a） Original drawing （b） Grayscale （c） Thresholding

Figure 1. Test picture and result after algorithm processing.

Table 1. Execution efficiency test using different vision libraries and development platforms (unit: ms)

Time Platform Algorithm	Halcon + Qt	Halcon + (C++)	Halcon + (C#)	OpenCV +Qt	OpenCV + (C++)	EmguCV + （C#)
Grayscale	0.357	2.231	8.147	0.626	2.193	3.375
Thresholding	0.194	1.561	5.776	0.124	2.530	2.857

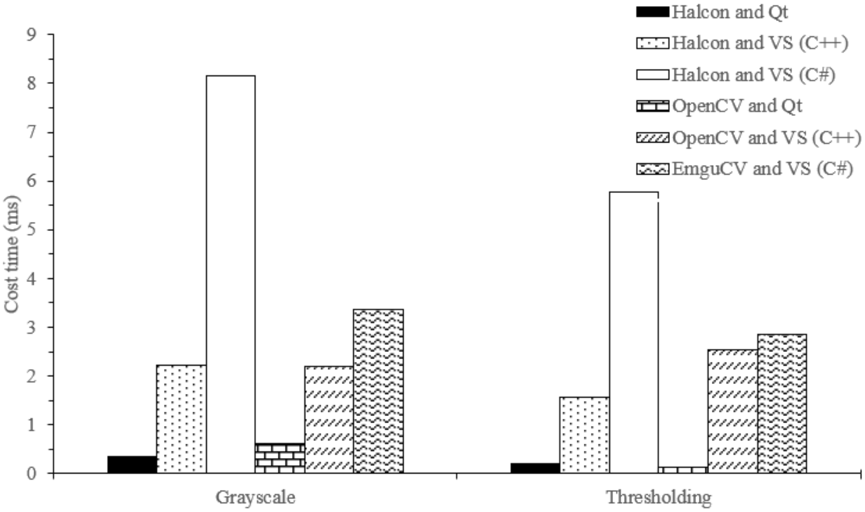


Figure 2. Comparison of execution speed of image algorithms based on different software platforms.

It can be seen from Figure 2 that the efficiency of C++ related platforms is generally better than that of C# related platforms, especially in the comparison of C++, Halcon with C#, Halcon. However, Qt has the best effect on the C++ platform. OpenCV has better performance than Halcon on Qt platform, but is close to Halcon on VS (C++) platform.

3. Experiment on error compensation efficiency based on machine vision

In the machining process, open CNC system is responsible for image shooting, image transmission and capture, image processing, compensation value calculation, etc., as shown in Figure 3. Therefore, higher requirements are put forward for real-time performance of CNC system. In addition, in order to avoid the running stuck of man-machine interaction, the CNC system with visual compensation function must be a multi-threaded system. The main thread is only responsible for man-machine interaction and some low-demand processing processes. The complex and massive computing real-time processing tasks should be placed in the secondary thread. In order to evaluate the efficiency of machining error compensation based on visual images, the complete online compensation process of CNC system was analyzed.

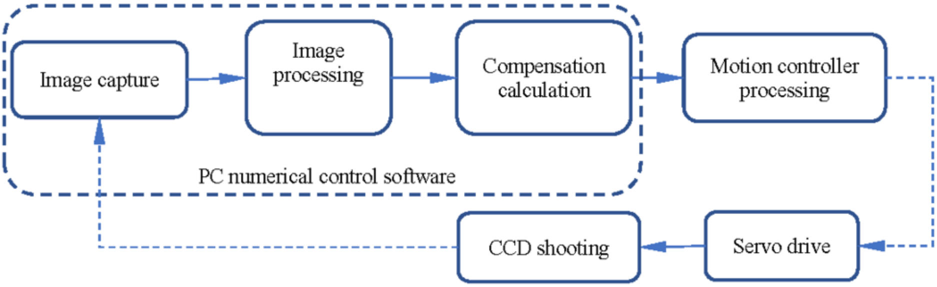


Figure 3. Online CNC machining error compensation process based on visual image.

The experimental platform is the machine vision oriented CNC curve grinding testbed. The PC configuration is the same as the previous experiment, the software platform is Qt 5.7.0, the visual library is OpenCV 2.4.13, and a black and white camera is model GC2441M with 5 mega-pixel global shutter CCD. The Motion controller is MC664-X from Trio Motion company, and the servo motion system is PD series linear motor from Parker and A6N series servo motor from Panasonic.

The experiment mainly tests the time-consuming of each function module in Figure 3 except the servo motion. Figure 4 (a) is the actual CCD image, and the image in Figure 4 (b) can be obtained after operations such as Blur filtering and findContours in OpenCV library. The edge of the black area of the image is the contour of the tool edge and the workpiece edge. The contour is compared with the ideal contour, and the tool motion compensation amount can be obtained by algorithm processing. The amount of compensation will be transferred to the motion controller to complete the compensation process. Table 2 shows the time cost of each process item.

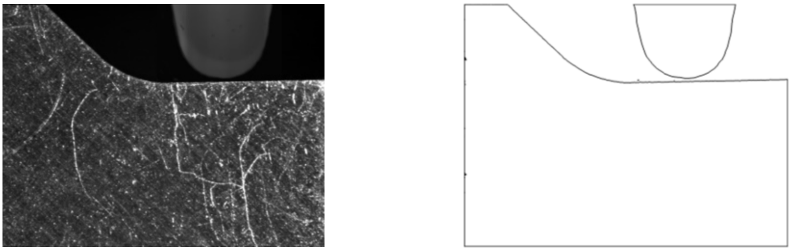

(a) Original image (b) Image after edge extraction

Figure 4. The original image and the image after edge extraction in curve grinding.

Table 2. Consuming time analysis of error compensation in CNC curve grinding

Process item	Consuming time（ms）	Time proportion
CCD shooting and image capture	101.013	83.4%
image processing	16.284	13.4%
compensation calculation	3.617	2.99%
motion controller processing	0.250	0.02%
total	121.164	100%

As can be seen from Table 2, CCD image shooting and image capture occupy most of the time in the online compensation process, while image processing occupies the highest proportion of the remaining time. The running time of first two items should be reduced in order to improve the response speed of the online compensation of CNC system.

4. Conclusions

The operating efficiency of software platform for machine-vision-oriented CNC system is studied, and the conclusions are as follows:

(1) The platform operating efficiency is directly affected by the combination selection of development software and vision library. The efficiency of C++ related software platforms is higher than C# related software platforms with the same vision library. Qt is slightly more efficient than VS under the same vision library. Halcon

library and OpenCV library are basically close in operating efficiency under the same development environment.

(2) CCD shooting and image capture account for more than half of the whole operation time. Image processing occupies the largest proportion in the remaining time and its efficiency directly affects the operation efficiency of the CNC system.

(3) Software development platform for vision oriented CNC system should be selected considering both the operation efficiency and development cost. For example, in order to improve operating efficiency, Qt or VS (C++) can be selected to use with Halcon library or OpenCV library.

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