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Research and Implementation of Digital Microscope Image Acquisition System Based on Embedded Linux

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Abstract: With the rapid development of multimedia and Internet in today's society, embedded Linux system also involves many places, and the application of digital microscope is also reused in many industrial manufacturing areas. The main purpose of this paper is to complete the research and implementation of digital microscope image acquisition system based on Embedded Linux, including image acquisition card, logic function, hardware circuit design and image acquisition system. In this paper, the CMOS digital camera is used to connect the CMOS digital camera with the computer through the transmission network, so as to collect the data. In the image preprocessing, the adaptive method based on mean and variance is implemented to correct the gray level of the collected image to avoid high error. In the image registration, the registration algorithm is used to smooth the mosaic place. Then, Sobel algorithm is used to carry out the color transition step by step to eliminate the gap in the image and realize the microscopic image mosaic. The results are as follows: the overall design scheme of the system is designed; the circuit board of digital microscope image acquisition and processing unit based on Embedded Linux is realized; image mosaic is realized by using image preprocessing, registration algorithm and fusion technology, In order to improve the quality of digital microscope image acquisition; through the feasibility test of the system, it is concluded that the performance of the embedded Linux digital microscope image acquisition system proposed in this paper is good, which is worthy of wide application.

1. Introduction

The microscope that can pass through image sensor and digital image processing is called digital microscope [1]. The images obtained can be observed on the monitor and recorded at any time. Digital microscope has changed the traditional manual operation mode of microscope, in which the

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single variable test is out of date. Therefore, the digital microscope control system can realize automatic tracking of multiple feature points, automatic matching of objective lens and lighting, automatic adjustment of focal length, uneven slice thickness, and different objective lens optical axis, focus alignment, automatic compensation, high and low power objective lens conversion, condenser automatic switch and other tasks. When the digital detection equipment was born, the detection optimization process of digital microscope was born. It can adjust and control the equipment, correct the shortcomings of modern microscope, and effectively improve the overall automation function and work efficiency. At the same time, it also improves the accuracy and speed of data acquisition by digital microscope. The advantage of digital microscope lies in abandoning the loopholes of traditional microscope, and breaking through many constraints of confocal microscope, scanning microscope and optical microscope. The advantage of digital microscope is that it can display the collected data to various displays by connecting the host system, which is helpful to study the details and carry out the corresponding image measurement, print and save the data. At present, the prices of digital microscopes vary, and there is no time and energy spent on the sales of digital microscopes in China. In fact, digital microscopes can be widely used in various fields.

The development of digital microscope technology in foreign countries is much earlier than that in China. At present, the research and development of digital microscope is mainly concentrated in foreign countries. The technology of digital microscope is mainly owned by foreign manufacturers. Domestic R & D lags behind. There are few kinds of digital microscope developed and produced by domestic manufacturers. A small part of them are low-end digital microscope products, and the matching image processing system is not perfect. In recent years, ba60omot automatic microscope [2] developed by Motic image technology research and development center of Beihang has the functions of automatic scanning, positioning, recognition, automatic collection of optical slices and three-dimensional reconstruction. Because the digital microscope of the whole system is very large and involves many technologies, it is difficult to develop a complete system. The cost of digital microscope is very high, especially for the foreign companies that initiated the complete system, which is more than one million, and domestic users cannot afford it.

Embedded Linux system [3] has become the new focus of IT industry in the world. It is of great strategic significance for China's IT industry to develop embedded processors and embedded operating systems with independent intellectual property rights to catch up with the level of advanced countries in the world. From a certain point of view, embedded system is a new field full of innovation, just in the mainstream of architecture, and there is no market monopoly. Therefore, the products and technologies in the field of embedded system must be highly dispersed. In addition, with the continuous development of various social application fields, the embedded processor core must also develop synchronously, which is a powerful driving force to promote the development of embedded field. Since the development of Hongqi Linux in China, the Chinese Academy of Sciences has launched the Hopen embedded system and realized its industrialization. Embedded operating system based on Linux technology is very popular. The broad development prospect of embedded technology in China has attracted more and more enterprises, scientific research institutions, training centers and universities to join. The continuous expansion of the demand for embedded talents also stimulates more and more its practitioners to enter the field. Colleges and enterprises pay more and more attention to the cultivation of embedded talents. Excellent embedded development talents are very important for the development of enterprises. For practitioners, the earlier they enter this field, the earlier they gain competitive advantage, which will greatly enhance their whole career. Embedded Linux system is application-oriented and based on computer technology. It can customize software and hardware to meet the strict requirements of application system in function, reliability, cost, volume and power consumption. Embedded system is a kind of

operating system software with small kernel, strong specificity, simple system and high real-time performance. It is widely used in industrial process control, traffic management, information equipment and robot system. The embedded system has the following characteristics [4]: (1) the CPU of embedded system has the characteristics of low power consumption, small size and high integration. Many tasks completed by the motherboard are integrated into the chip, which is conducive to the design of the whole system. (2) Embedded system is organically combined with specific applications, and its upgrading is also synchronized with specific products. Therefore, once the embedded products are put into use, they will have a long market life cycle. (3) In order to improve the execution speed and system reliability, the embedded system software is usually fixed in the memory chip, not in the disk and other carriers. (4) The speed and storage capacity of embedded system are limited. In addition, due to the high real-time requirements of embedded system, the quality of the program, especially the reliability, is required to be higher.

The purpose of this paper is to discuss the design of image acquisition and processing unit in distributed visual inspection system to meet the requirements of small size, low power consumption, low cost and data preprocessing function. This paper uses CMOS digital image sensor and FPGA chip based on embedded system to form image acquisition and processing unit. The solution is put forward and its feasibility is verified. The application of embedded system in image acquisition and processing can integrate signal acquisition and preprocessing, artificial intelligence, system control circuit and network communication to image acquisition and processing unit, which can not only greatly improve the performance of image acquisition and processing unit, but also expand its function. Compared with the traditional image acquisition method, the acquisition method based on CMOS digital image sensor takes less space, lower cost, better expansibility and stronger anti-interference ability. The processed data can also be exchanged with the outside world through the transmission network. Because the transmission signal is digital signal, the anti-interference ability of the measurement system is enhanced. More importantly, this kind of image acquisition and processing unit based on embedded system is easy to expand and reduce the maintenance and development costs. It can effectively overcome the shortcomings of traditional CCD camera image acquisition unit. The research of image acquisition and processing technology based on embedded system is of great significance for the development of image acquisition and processing to miniaturization, networking and intelligence.

2. Research on Image Acquisition System of Digital Microscope Based on Embedded Linux

2.1. Overview of Embedded Linux System

Linux is an open source operating system that follows the GPL protocol and can be used for free. The advantages of the operating system are [5]: support a variety of hardware platforms; arbitrary tailoring of the kernel; source code can be obtained free of charge; network protocol support is extensive; the kernel directly provides network support; there are many available applications (GUI programs, debugging tools, compiler tools); numerous technical forums, large development groups, free and fast question answering. The disadvantage is real-time. The Linux kernel of version 2.6 greatly improves real-time performance. Some Linux distributions greatly improve real-time performance. These Linux versions are available in free and commercial paid versions 3.

Because of the above advantages, Linux system is very popular in the field of embedded development. Embedded Linux is the same source code as Linux kernel on ordinary computer. Although the degree of tailoring is different, most PC Linux software can run directly on the device with embedded Linux operating system after recompiling, which greatly enriches the software resources of embedded devices, such as small games, practical function library, etc.

The embedded system has the following important characteristics [6]: (1) the system kernel is very small. Because the embedded system is usually used for small electronic devices, the system resources are relatively limited, so the kernel is much smaller than the traditional operating system. For example, ENEA's OSE distributed system only has a 5KB kernel, while the windows kernel is much larger. (2) Strong specificity. Embedded system has strong personalization, and the combination of software and hardware is very close. Generally speaking, it is necessary to transplant the hardware of the system. Even products of the same brand and series also need to be modified according to the changes and changes of system hardware. At the same time, for different tasks, the system often needs to be changed greatly; the programming and downloading should be combined with the system, which is completely different from the "upgrade" of general software. (3) The system is simplified. In the embedded system, there is no obvious difference between the system software and the application software, and the design and implementation of its functions do not need to be too complicated. This is conducive to control system cost and realize system security. (4) High real-time operating system software is the basic requirement of embedded software. Software needs to solidify storage to improve speed. Software code requires high quality and reliability. (5) In order to standardize the development of embedded software, it is necessary to use multitask operating system. Embedded system applications can run directly on the chip without operating system; however, in order to arrange multi tasks and reasonably use system resources, system functions and expert library function interface, users must choose RTOS (real-time operating system) development platform to ensure real-time and reliability of program execution, reduce development time and ensure software quality. (6) The development of embedded system needs special development tools and environment. Because the embedded system itself does not have the ability of independent development, even after the completion of the design, users can not modify the program function. Therefore, it is necessary to have a set of development tools and development environment. These tools and environments are generally based on the software and hardware equipment of general-purpose computers and various logic analyzers. In program development, the concepts of host and target machine are often used. As the last execution machine, the target machine needs to be combined alternately.

2.2. Cmos Digital Camera

CCD [7] or CMOS [8] image sensors are usually used to obtain and extract feature images. The inherent non-uniform response of these two sensors will cause obvious fringe noise in image acquisition. Compared with CCD, CMOS sensor has the characteristics of low cost, high integration and low power consumption. The design of light and small imaging system is realized. Therefore, it is more and more widely used, but its working noise is relatively large.

2.3. Establishment of Software Development Environment

(1) Build host software platform: dual system (non-virtual machine) is installed on the host. For Linux system, select Ubuntu Linux 11.23, for Windows system, select Windows XP. Compile all software on the Linux platform of the host, and record DNW or HyperTerminal under the windows system of the host. When installing Ubuntu Linux, you must be connected to the network, otherwise the above packages cannot be installed. Because the campus network of Xi'an University of architecture and technology is adopted in this paper, the network configuration should be carried out according to the campus network mode of the University. This paper uses Huawei 802.1 client for networking. First, install the standard library files required by the client, and then configure the network. Using shell script to network, the script successfully solves the problem of frequent

disconnection and networking difficulties.

(2) Install cross compilation tools: cross compilation is a compiler that runs in one computer environment and compiles code that runs in another environment. In short, it is to generate executable code on one platform on another. In this paper, one platform is the PC using the Ubuntu Linux operating system, and the other is the development board used in the experiment. On the Ubuntu Linux operating system, the compiler tool is used to generate the executable file, and then the executable file is written into the flash of the development board through USB or serial port. At this point, the new development board can execute the file. The cross-compiler tool used in this paper is crosstool-4.5.2 tar.bz3.

(3) Debugging tools: debugging is generally divided into software simulation debugging and hardware debugging. For hardware debugging, JTAG is usually used for debugging. The debugger on the host communicates with the target board system by calling related interfaces. At present, the commonly used hardware debugging tools are H-JTAG [9], ULINK [10] and JLINK. The method of software debugging: the debugged program runs on a specific hardware platform, the cross debugger runs on the host, and connects to the target board through JTAG, parallel port, serial port, network, etc. The general approach is to use GDB and GDB server to debug applications. GDB server runs on the target board, while GDB runs on the host.

(4) Interactive control terminal: the default terminal of Linux system is serial port. After the operating system is started, the information is printed on the serial port terminal, so that developers can realize the interaction between the host computer and the target computer. In the host's windows system, we can use HyperTerminal or serial port operation tool DNW as the interactive terminal; in the host's Linux system, we can use minicom as the interactive terminal; we can also make the target machine start remote login when starting the Linux of the target machine, and the developer can realize the interaction with the target machine and log in the target machine through the host.

2.4. Image Acquisition Mode of Digital Microscope

Digital microscope is a kind of microscope based on the principle of optics [11]. It can place and image tiny objects that cannot be distinguished by human eyes. The structure includes three parts: mechanical part, optical part and lighting part. The optical system includes eyepiece and objective lens; the lighting part is installed under the stage, including light source, reflector and concentrator. The scanned images can be directly displayed on the computer screen, stored on the computer, and can be printed or transmitted through the network at any time. The principle is to use CMOS camera technology to amplify the objective lens or eyepiece of the microscope, convert the optical signal into electrical signal through photoelectricity, and then import it into the computer for display.

Digital microscope image acquisition scheme design: ordinary microscope stage moving, lens focusing, objective lens conversion, light source control was all completed by hand, which cannot realize the intelligent processing of microscopic image, let alone remote control. The digital image acquisition system of microscope is composed of computer, single chip microcomputer system, stepping motor, microscope and automatic stage, camera, etc. Its working principle is that the computer sends instructions to the platform controller through RS232 serial port. After receiving the instruction, MCU controller analyzes and judges the instruction, and sets the step number, moving speed, corresponding built-in field of vision and direction. The corresponding X-Y-Z level and physical environment converter can move accurately and complete the control operation through its precise mechanical transmission mechanism according to the instructions. The controller sends a return signal to the computer through RS232 interface of MCU to inform the computer that the work has been completed and wait for the next command to be received. In this way, the controller successively executes the control instructions of the computer to complete the continuous control of

the x-y-z scanning platform and the focusing mechanism.

3. Realization of Digital Microscope Image Acquisition System Based on Embedded Linux

3.1 Registration Algorithm

Image registration algorithm [12] is developed for the integration of multi-source image information. The main purpose of image registration algorithm is to find the spatial transformation mapping relationship between two or more images at the same location to obtain the maximum image information. These images can come from different times, different imaging devices or different angles. After registration, the spatial pose and texture information are consistent. Taking two images as an example, the image that needs registration through spatial transformation is called floating image, and the standard image without transformation is called reference image. Spatial transformation can be linear or nonlinear. The process of image registration algorithm is an iterative optimization process. Firstly, the spatial transformation model is applied to the floating image, and then the similarity between the transformed floating image and the reference image is calculated. Then, the space transformation parameters are optimized by using the optimization algorithm. The similarity between the transformed floating image and the reference image is maximized by continuously adjusting the spatial transformation parameters.

3.2. Image Fusion Technology Based on Sobel Algorithm

Compared with smart algorithm, although Sobel operator [13] is not the best algorithm in image display. It doesn't look like a smart algorithm, but smart algorithms are very complex. According to the real-time requirements and system display requirements of this paper, smart algorithm is obviously not a suitable choice, although Laplace algorithm is rarely used alone in projects due to noise. Obviously, Sobel algorithm is the most suitable, Sobel operator has smooth filtering effect, and the algorithm is relatively simple, so it is widely used in digital image processing.

According to Sobel algorithm, there are many forms of image fusion. Different image sources and different image transformation fusion methods are used. Due to the poor ability of human eyes to distinguish gray hues, it is necessary to achieve image edge fusion.

Sobel algorithm is to calculate the highly discrete function again. Firstly, it moves from two directions to make the detected image coincide with a position of the central image. Secondly, the detected template coefficient value is multiplied by the pixel value. Then add all the multiplied values. Finally, the maximum value is assigned to the center pixel value of the image. The image fusion technology based on Sobel algorithm is realized.

3.3. Realization of System Page Software Layout

Client software is usually graphical software, which needs to interact with users directly. The development methods of graphical interface software and embedded device terminal software have their own characteristics. There are many commonly used graphical interface software development environments, but there are two kinds of graphical software design environments: QT and MFC.

MFC is a class library for developing Windows GUI. MFC uses some object-oriented methods to package win64 API. For this reason, these APIs are sometimes C + +, sometimes C, or even a mixture of C and C + +.

The QT graphic library was developed around 1994 and is constantly updated and maintained. The latest version is qt5.7. It can run on windows, Mac OS, x, UNIX and other operating systems. QT is completely object-oriented.

Before choosing whether to use MFC or QT [14] to design graphic page software, the following comparison and thinking are made. First, QT uses the signal slot mechanism as the message mechanism. In the QT application program interface, various operations of the control are taken as signals, and then the slot functions are bound by code or interface settings. In the use process, the slot function is directly triggered by the signal, the logic is very simple. On the other hand, message management on MFC is a bit confusing.

QT has a very simple and powerful layout mechanism for interface design. In addition, powerful QT can be used to build the interface directly by dragging and dropping controls, and what you see is what you get. The generated code is placed in a separate file, which can be viewed during programming. In addition, you can use code to build interfaces, which is very flexible. In terms of control flexibility, QT is slightly better than MFC.

The whole interface includes the public layout in the upper left corner, which is used to manage the sub windows. There are also various controls below, including buttons, commonly used input and output controls, etc. Then in the middle is the operation platform of interface design. You can drag and drop the control directly to this location. This is QT design mode. In the upper right corner, you can simply control the layout and dependencies, as well as the object name and class name of the control. You can further set the control in the lower right corner, including the size, position, font, and color of the control. The following is a brief introduction to the functions and features of some common layouts and controls. Common layout includes horizontal layout, vertical layout, grid layout and so on. Controls in the horizontal layout are displayed horizontally. If the size of a control in a layout is not fixed, its size is automatically stretched with the size of the layout. You can adjust the edges of internal controls relative to the layout by setting the left, top, right, and bottom edges. In the same direction, vertical layout is different from horizontal layout. Grid layout places controls in a grid layout. It takes up as much interface space as possible in the parent window or layout, divides its own space into rows and columns, and then inserts each control into one or more set cells.

3.4. Design and Implementation of Each Module

The remote embedded device collects all kinds of field data and transmits it to the host through the network. The main function and function of the host is to visualize the received data. That is to display a column of received displacement information reflecting the bridge deflection change on the coordinate axis and observe the data change clearly. In addition, the host sends remote control commands to embedded devices through the interface. In addition to the above main functions, the host also has some auxiliary functions to help the remote monitoring of the whole system more convenient and practical. For example, when installing the camera, it is necessary to observe the scene video captured by the camera to view the scene accident situation, so there is also a video receiving function window. In addition, in order to analyze some data more intuitively, the maximum and minimum offset values of a function, the maximum and minimum offset values of x-axis and y-axis are also the configuration interface set. Also need to configure the IP and port number of remote embedded device network, need to save and connect.

3.5. Interface Display

After pressing the "interface display" button, the video receiving window will be opened. This window contains a control for displaying the received JPEG compressed image. Transport network protocol uses UDP transmission. Due to the use of JEPG compression format, the amount of data is greatly reduced. The embedded device can send once through the sending function, and the client

can receive the complete picture at one time.

3.6. Deficiencies

In the whole system operation process, the displacement data and video data cannot be timely fed back to the system by pressing the button to close and start receiving displacement data and video data. The emergency out of band data is later used to send and receive commands. In addition, segmentation failure (core dump) error often occurs during runtime, which causes the whole program to be forced to exit. Errors are located and vulnerabilities are corrected.

4. Results and Discussion

4.1. Comparison of Edge Detection Algorithms

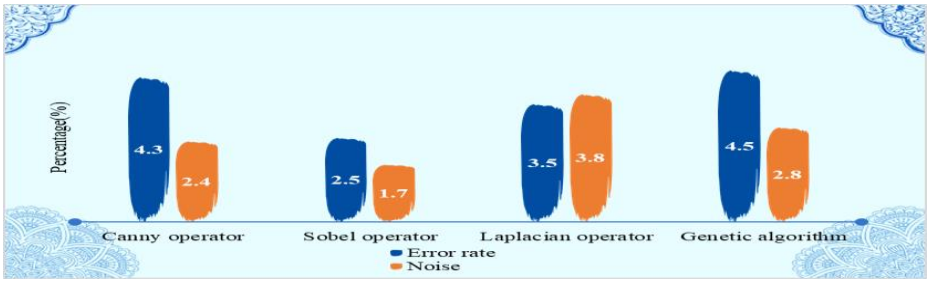

Figure 1. Comparison of edge detection algorithms

Shown as Figure 1, compared with the four algorithms, the error rate and noise interference rate of Sobel algorithm are lower than those of other algorithms. The genetic algorithm has the highest error rate of 4.5%, while Sobel algorithm has the lowest error rate of 1.7%. Compared with other algorithms, Sobel algorithm has higher accuracy, so it presents more detailed image edge detection. In the process of various algorithms affected by noise and vibration, Sobel algorithm has the lowest noise generation, which can effectively avoid the impact of noise in the process of command execution.

4.2. Comparison of MFC and QT Graphic Software Design Environments

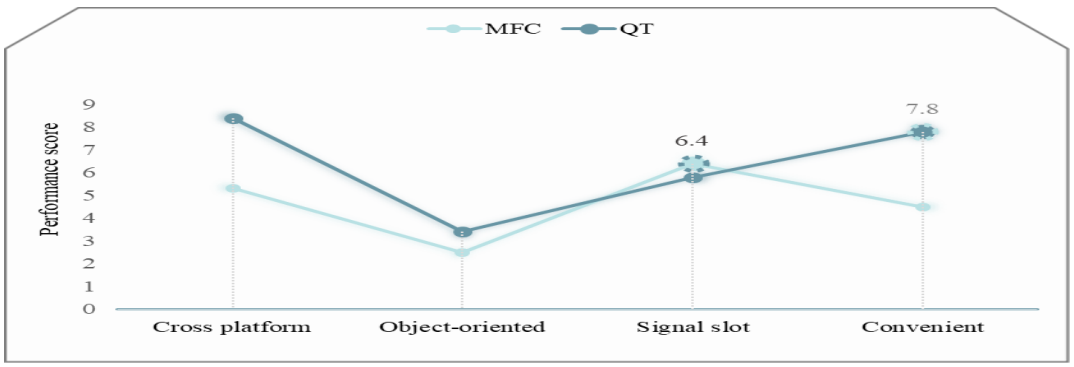

Figure 2. Performance comparison of MFC and QT graphic software design environment

Shown as Figure 2, we compare the excellent characteristics of the two graphic software design environments, and analyze the scores from cross platform capability, object-oriented editing, signal slot design function, and port design convenience. QT's cross platform capability, object-oriented

editing and port design convenience scores are higher than MFC, but signal slot design is inferior to MFC. Comprehensive score comparison results show that QT good cross platform ability makes score block processing ability strong and stable. The high-strength processing power plays a unique role in object-oriented editing, so the graphical interface designed in this environment is more clear and real.

4.3. Test Results in All Directions of the System

Table 1. Performance test content

Content	Methods
Unit test	In the process of testing, from whether the software needs to be executed, it can be divided into static testing and dynamic testing: static testing refers to checking the syntax, structural branches and processes of program source code; dynamic testing refers to running the program directly and observing the input and output of the program.
Integration test	
System test	
Performance test	
Specific structure	Firstly, the input and output tests are carried out for each unit module to check whether the output meets the expected results. In the test process, a large number of data sets are used as input, including some special critical values and error values, to test the correctness and robustness of the program. Then, the function of the whole software is tested to check whether it meets the requirements at the beginning of the design and whether the performance parameters meet the design requirements. For example, whether the operation or response was completed within a specified time.
Logic flow chart	
Program branch	

Shown as Table 1, the contents and methods of system test are listed, and the test direction is clear.

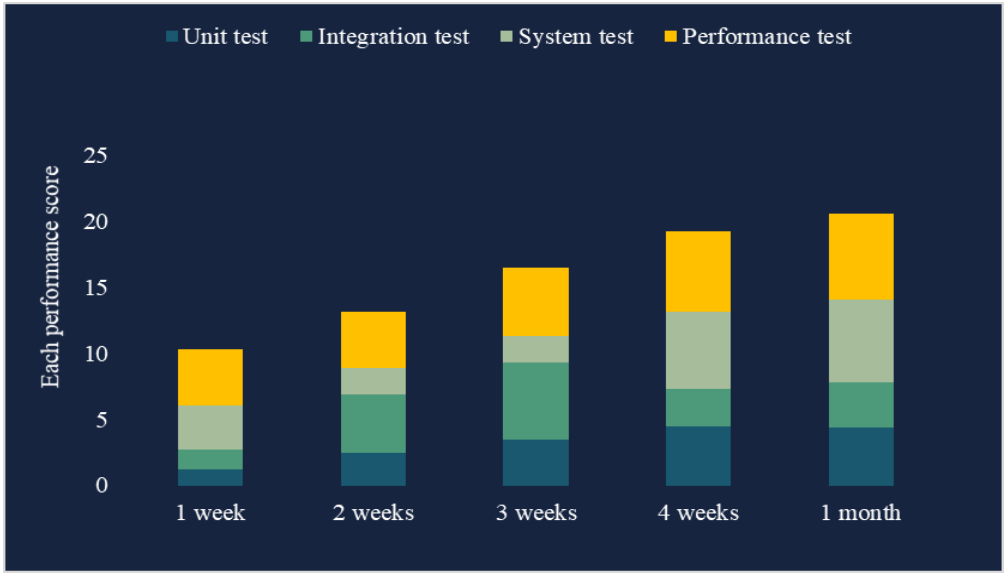

Figure 3. Comparison of system performance test scores

Shown as Figure 3, with the continuous maintenance and improvement of the system, the scores of all aspects show an upward trend over time. In the first week, the highest score was obtained in the performance test, followed by the system test. Although the unit test and integration test scores were low, they were mainly corrected in the following system improvement, and the scores increased a lot after one month. The integration test and performance test reached the peak after one month, while the unit test reached the peak in the fourth week. The integration test reached its peak in the third week, but its stability was affected by the follow-up operation process, which led to the decrease of the score.

4.4. Image Processing Effect Comparison

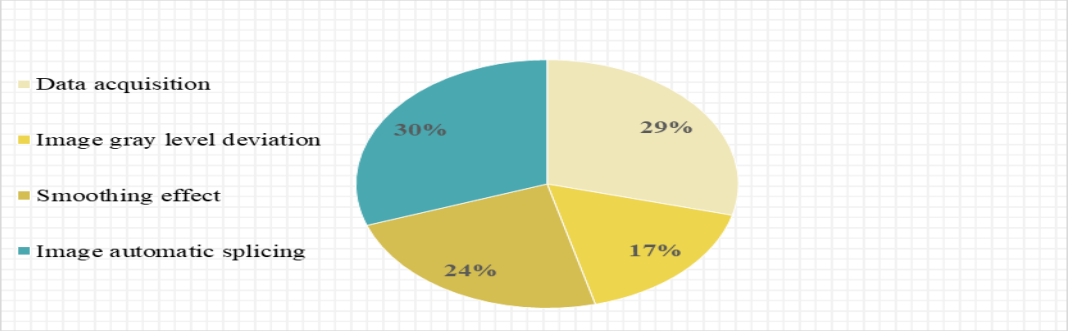

Figure 4. Data acquisition, image gray level deviation, smoothing effect and image automatic mosaic performance score

Shown as Figure 4, from the data acquisition, image gray level deviation, smoothing effect and image automatic mosaic performance score, the image automatic mosaic performance is the strongest, accounting for 30% of the total. The second is the accuracy of data acquisition, accounting for 29% of the total. The gray level deviation score of the image is the lowest, and the effect is also the worst, accounting for 17% of the total.

5. Conclusion

With the rapid development of modern embedded technology, sensor transmission and intelligent wireless system, most of them have been applied in various fields. Most of the technologies are applied to industrial manufacturing. Data collection technology is used to control the operation in the production process and record relevant information. In this way, the output is greatly enhanced while the quality is guaranteed. This paper presents the research and implementation of digital microscope image acquisition system based on Embedded Linux. It is also applied to the data collection technology. Through the image data collection, with the help of digital microscope, the Sobel algorithm is used to perfectly splice and smooth the edge, presenting a high-resolution image. The experimental results are as follows: first of all, compared with the four algorithms, the error rate and noise interference rate of Sobel algorithm are lower than other algorithms; secondly, the comprehensive score comparison results show that QT's good cross platform ability makes the score block processing ability strong and stable. High intensity processing power plays a unique role in object-oriented editing, and the graphical interface designed under this environment has high resolution. In the process of continuous maintenance and correction of the system, the performance score of each system shows an upward trend; the automatic image mosaic performance is the strongest, accounting for 30% of the total. The ability of image fusion is great, so the image collected by digital microscope can be displayed better. Therefore, on the basis of embedded Linux system and QT software design environment, the image acquisition index of digital microscope has been improved, and the image presented has more reference value.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this

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Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] *Eldahshan, K., Youssef, M., Masameer, E., & Hassan, M. (2015). Comparison of segmentation framework on digital microscope images for acute lymphoblastic leukemia diagnosis using rgb and hsv color spaces. Biotechnology & Bioengineering, 2(2), 142-5.*

[2] *Nguyen, T., Bui, V., Lam, V., Raub, C. B., & Nehmetallah, G. (2017). Automatic phase aberration compensation for digital holographic microscopy based on deep learning background detection. Optics Express, 25(13), 15043-15057. DOI: 10.1364/OE.25.015043*

[3] *Delgado, R., Hong, C. H., Shin, W. C., & Choi, B. W. (2015). Implementation and performance analysis of an ethercat master on the latest real-time embedded linux. International Journal of Applied Engineering Research, 10(24), 44603-44609. DOI: 10.1002/1097-0142(196302)16:2<205::AID-CNCR2820160210>3.0.CO;2-#*

[4] *Olivier, P., Boukhobza, J., & Senn, E. (2015). Read-ahead efficiency for raw nand flash storage in embedded linux. Acm Sigbed Review, 11(4), 43-48.*

[5] *Fu, W., & Narayan, D. (2019). Optimization algorithm for embedded linux remote video monitoring system oriented to the internet of things (iot). Discrete & Continuous Dynamical Systems, 12(4&5), 1341-1354.*

[6] *Lin, X., Wang, Y., Chang, N., & Pedram, M. (2016). Concurrent task scheduling and dynamic voltage and frequency scaling in a real-time embedded system with energy harvesting. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 35(11), 1890-1902. DOI: 10.1109/TCAD.2016.2523450*

[7] *Rüdiger R. Meyer, & Kirkland, A. I. (2015). Characterisation of the signal and noise transfer of ccd cameras for electron detection. Microsc Res Tech, 49(3), 269-280.*

[8] *Takahashi, K., Ozawa, K., & Mizunuma, M. (2015). Adiabatic dynamic cmos logic circuit. ICE technical report. Electron devices, 97(5), 50-58.*

[9] *Deng, B., Liu, C., Chen, J., Chen, K., Gong, D., & Guo, D., et al. (2015). Jtag-based remote configuration of fpgas over optical fibers. Journal of Instrumentation, 10(01), C01050-C01050.*

[10] *Azim, T., Riva, O., & Nath, S. (2017). Ulink. Getmobile Mobile Computing & Communications, 20(4), 34-38.*

[11] *Li, Y., Li, L., Cheng, X., & Zhao, X. (2017). Microscopic properties of mg in li and nb sites of linbo3 by first-principle hybrid functional: formation and related optical properties. Journal of Physical Chemistry C, 121(16), 8968-8975.*

[12] *Nguyen, A. H., Pickering, M. R., & Lambert, A. (2016). The fpga implementation of a one-bit-per-pixel image registration algorithm. Journal of Real-Time Image Processing, 11(4), 799-815. DOI: 10.1007/s11554-014-0420-3*

[13] *Huang, L. J., Liu, Q. H., Tang, J., & Li, P. (2015). Scratch line detection and restoration based on sobel operator. International Journal of Grid & Utility Computing, 6(2), 67-73.*

[14] *Zareba, W., & Bayes, d. L. A. (2015). Qt dynamics and variability. Annals of Noninvasive Electrocardiology, 10(2), 256-262.*