Proceedings of the 17th World Congress
The International Federation of Automatic Control
Seoul, Korea, July 6-11, 2008

Robot Detecting System of Burnable Gun Bore Based on Radio Transmission

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Abstract: According to the restriction of wire for flexibility of robot in detection system, a radio transmission and image acquisition system with RF transmission and CCD image sensor that works in short distance was designed and introduced in this paper. It has been applied in the gun bore automatic detecting system. The system has the characteristics of high integration degree, high flexibility, small volume, low power consumption and so on .Through the scene testing of prototype, the intelligent robot is proved with accurate positioning, high survey accuracy, good stability. The robot detecting system with radio transmission and remote/semi-automatic control was achieved, and the automation and accuracy of gun bore detecting was improved.

1. INTRODUCTION

As one of the important parts, barrel seriously affects the performance of gun. The effects resulting from actions of high temperature propellant gas, pressure wave transmission and reflection of power gas and friction between the bullet and gun bore in the firing process of guns result in forms such as erosion and abrasion of gun bore, making the surface contour of gun bore displays arc trace track, crater and particles hanging at the surface of track. These lead to the reduction of muzzle velocity, range and accuracy, shorten the life of guns, limit the performance of guns, and become restrictions to improvements of gun power (Jianping Fu et al, 2000). Taking effective measures to reduce the erosion and abrasion of gun bore is a key factor that must be considered for raising the gun power.

Aiming at the situations mentioned above, a lot of researches have been done, such as pre-acceleration of prime gun, current waveform adjusting by classification power supply and enhancement of track structure (Guijun Tian, 2003). Even so, the erosion and abrasion of gun bore is still difficult to avoid during the beginning stage of projectile motion. The signal transmission and energy supply of traditional image measurement technology of gun bore based on wire. So not only the mechanical structure is complex, the detecting efficient and the measurement resolution are very low, but also the motor dexterity of robot is limited without safety.

The requirements of gun bore robot detecting system can be concluded as follows:

Receipting command for realizing the movement of robot;

Achieving the switching of motion modes and the state control of robot;

Small volume, light weight and easy to operate of control system;

High flexibility, good real-time feature, favourable exploitability and expansibility of system;

Remote/semi-automatic control of working style;

Visual feedback function;

Having sensor-based system with perceiving self-status and environment, and which can provide basis for remote operation and behaviour decision of robot.

So we developed a gun bore robot detecting system that can move automatically toting the bore testing equipments, extract surface contour characteristics of gun bore through optical image detecting technology and transfer images with wireless device. The flow chart of gun bore detecting robot is shown in Fig.1.This paper aims at testing the erosion and abrasion of gun bore in the firing process and providing an effective basis for taking effective measures as shown in Fig.1. This paper aims at testing the erosion and abrasion of gun bore in the firing process and providing an effective basis for taking effective measures.

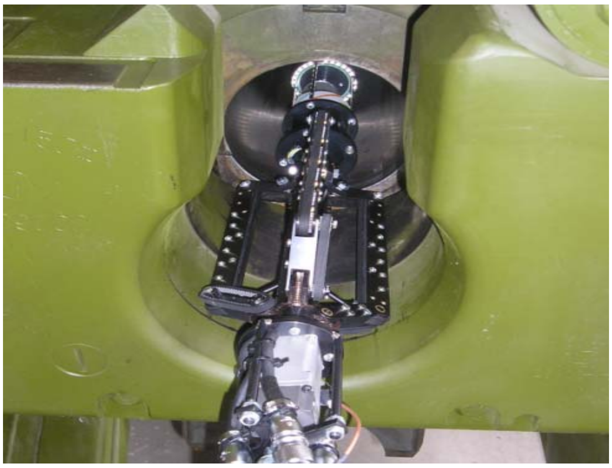

Fig.1.The flow chart of gun bore detecting robot

2. SYSTEM ARCHITECTURE

2.1 System Composition

The mobile robot is composed of operators, mobile robot and detecting environment from the view of system. The sketch map of composition of the whole system is shown in Fig.2.A close relationship is formatted by operators, robot and detecting environment.

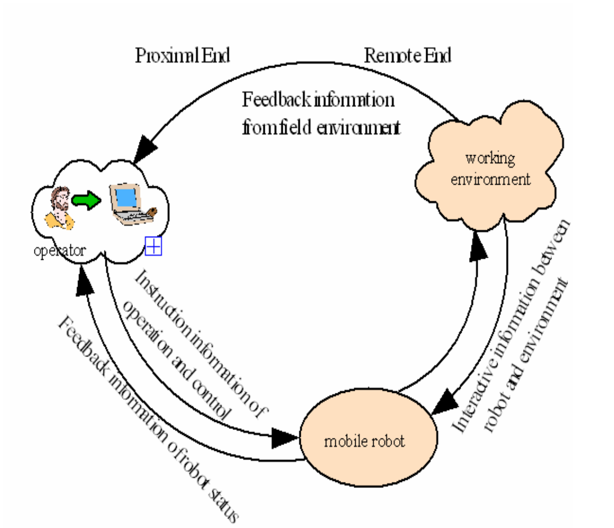

Fig.2. Sketch map of system composition

Based on the task demand from remote operation end, special programs such as image acquisition and motion stopping will be accomplished in virtue of human-computer interactive interface of remote operation platform and feedback information. The feedback information contains the environment information of detecting filed, such as contour feature of bore surface, status of robot and so on. According to the feedback information and the demand of special programs, robot is controlled by operators with control command to start, advance, stop and return and so on.

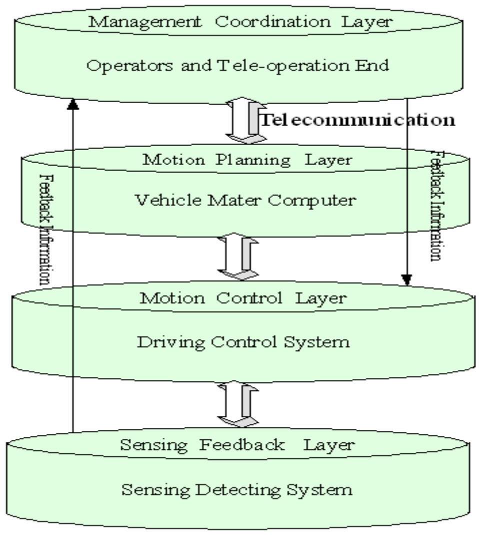

Fig.3.The quantizing structure of robot system

2.2 Quantizing Structure

According to the function characteristics of robot system, quantizing structure is adopted by the system. It was concretely divided into for layers, management coordination layer, motion planning layer, motion control layer and sensing feedback layer, as shown in Fig.3.

With the highest intelligent degree, the management coordination layer is located in the top of the system. Operators are in charge of the management and control of system by remote operation platform. As the central controller, the motion planning layer is used to be responsible for motion planning and format concrete operation command based on the task indicator and the feedback information from sensor-based system. The motion control layer which is constituted by stepper motor and driver is in charge of the motor execution of robot. The driver receives motion control command and achieves the driving of stepper motor. Sensing feedback layer is located in the bottom of the system and is applicable to direct interactive with gun bore environment. So the environment information of gun bore and self-status information can be obtained, and it will be sent to motion planning layer and motion control layer through A/D conversion.

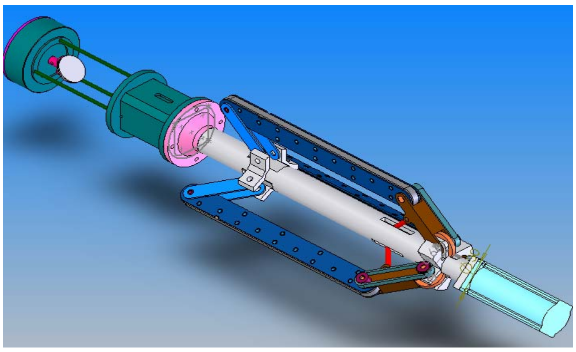

Fig.4. Assembly drawing of robot system whole system is composed of stepping

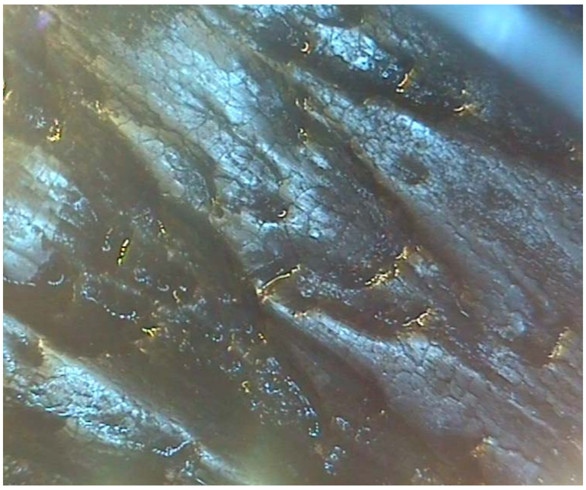

Fig.5. Amplifying digital image contains information of gun bore

3. SYSTEM STRUCTURE AND DESIGN

3.1 Robot System Architecture

An assembly drawing of robot system drawn by CA×A electronic board is shown in Fig.4. The whole system is composed of stepping motor, driver, semiconductor laser, optical lens, CCD (Charge Coupled Device) camera and RF (Radio Frequency) chips and other components. The surface of gun bore is irradiated by Parallel light beams from semiconductor laser. Transmission beam irradiates to the CCD device through a group of optical lens. With A/D converters and image data registers and other devices, the images will be input to the computer for processing and analysis by wireless devices. Consequently, the detection of erosion and abrasion of gun bore is implemented. An amplifying digital image contains information of gun bore is shown in Fig.5.

3.2 Hardware Architecture

Fig.6 shows the system schematic diagram. In order to monitor the robot status and information of gun bore, the communication between remote operation and robot microcontroller can be achieved by radio transmission at remote operation end. Microcontroller MSP430F149 chip is used as processor of motion control layer, and ASIC （Application Specific Integrated Circuits） RF transceiver chips are used for communicating between PC and controller. The propulsion device is mainly composed of stepper motor and driver. The driver controls starting, forward, stopping and return of propulsion device based on pulse signal emitted by microcontroller.

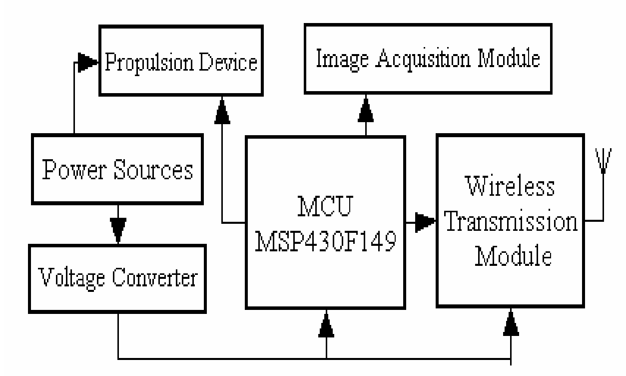

Fig.6. Schematic diagram of system

3.2.1 Microcontroller

Because of the size and weight restriction of gun bore detecting robot and the requirements of low power consumption, high performance and real-time, the suitable control system must be adopted for gun bore detecting system. According to the hardware and information processing methods, the robot control system can be divided into single machine centralized control, dual-machine master-slave control; multi-spindle motion control and multi-machine master-slave distribution control at present.

According to the implementation models and the characteristics of controller and the requirements of size, weight, and power consumption and real-time, a gun bore detecting system based on MCU MSP430F149 is introduced in this paper. Due to its high speed, low power consumption, high performance and small size, it is widely applied in various products.

MCU MSP430F149 produced by TI is an ultra low power consumption mixed signal microcontroller, with a lot of on-chip external components, it can be widely used. The lowest power consumption of devices can be achieved by flexible CLK sources which is unexampled by other microcontrollers at the present time. With low operation voltage and 5 power saving models, the working current is only 0.8 μ A under dormancy model. The maximum code conversion efficiency of MSP430 can be achieved by 16 registers and constant generators in CPU. The devices can be awaken rapidly from low power consumption model and activated to active working mode within 6 μ s by DCO (Digital Controlled Oscillator). The maximum working frequency is 8MHz.The command cycle is only 150ns.All these are out of range of 51 series single chip computer. The strong data processing ability can reach 2MIPS that is very suitable for embedded system which request very high processing ability. 60KB FLASH ROM and 2 KB RAM provide a great convenience for operation processing (Xiaolong Wei, 2002).

3.2.2 Radio Transmission

Network communication is a very important aspect in mobile robot system. The communication must have high performance to meet the requirement of a large amount of information of robot. In order to ensure all the information can be accurately transferred in time, the choice of communication tools is very important.

Wireless image transmission can be achieved by IR (Infrared) or RF in short distance. The transmission directivity of IR is very strong, but IR can not through barriers. The penetrative of RF transmission is wonderful, especially in Ultra High Frequency (UHF) band (Guoqiang Fu et al, 2002). To effectively raise the quality of wireless image transmission in short distance, ASIC RF transceiver is adopted.

ASIC RF transceiver chip almost can integrate a whole RF transceiver functio*n unit.* With PLL (Posterior Longitudinal Ligament), LPF (Low Pass Filter), FS (Frequency Synthesizer), VCO (Voltage Controlled Oscillator) and PA (Power Amplifier) included in its internal functional module, ASIC RF transceiver chip can work with a few external elements connected. So it can decrease the size of module and is quite suitable for image detection of gun bore. The input of RF transceiver chip can be data or voltage signal. The signal is emitted by the FSK, PSK, ASK, OOK or FM after internal electric circuit treatment. It operates at ISM (Industrial, Scientific and Medical) band which band is open, without any licenses for its use. Because of transmission in short distance, the transmit power is very small, and corresponding the bad effects on workers are also very small.

4. IMAGE PROCESSING

Investigations show that the edges and internal features in an image, particularly the edges and internal features in a microscopic image occur at random, and the regularity of random distribution is unique (Congfeng Zhu et al, 2003). We use this randomness and uniqueness of edge contour in microscopic images for recognizing image characteristics.

4.1 Smoothness of Image

Image will be difficult to escape from noise interference, so noise elimination becomes basic details of image processing. Details of image register as radio-frequency component in frequency domain, and easily mutual interference with high-frequency component of noise. In order to maintain details of image and suppress interference from noise, constrained least square method was employed for filtering (W.J.Staszewski., 2000).

The heart of this algorithmic is sensitive question from linear operator H to noise. We expect that a minimum criterion function C **c**an be found and defined as follows:

$$C=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[\nabla^2 f(x,y)]^2 \tag{1}$$

It is restricted by

$$\| g-H\hat{f}\|^2=\|\eta\|^2 \tag{2}$$

Where ∇^2 is Laplacian, $f(x,y)$ is input image, g is the answer of input f , $\hat{f}$ is estimate of un-degraded image and η is random noise.

The resolving of optimization problem in frequency domain is given as follows:

$$\hat{F}(u,v)=[\frac{H^*(u,v)}{|H(u,v)|^2+\gamma|P(u,v)|^2}]G(u,v)] \tag{3}$$

Where γ is a parameter that must be adjusted to satisfy (2), and function $P(u,v)$ is Fourier transform of function $p(x,y)$,

$$p(x,y)=\begin{bmatrix}0&-1&0\\-1&4&-1\\0&-1&0\end{bmatrix} \tag{4}$$

The function $p(x,y)$ and other related functions must be properly continued with zero before Fourier transform.

This algorithmic has outstanding feature that can produce best results for every processed image. Certainly, these optimality criterions in theory have nothing to do with dynamic visual sensation (Rafael C.Gonzalez et al, 2003).

4.2 Image Enhancement

According to edge detection, edge enhancement technique strengthens boundary element taking advantage of domain information of pixel spot; or converge edge pixel spot along edge taking advantage of parameter space (Jiaguang S et al,1995).

Differential method was adapted to do edge enhancement in this paper.

Scalar function $G(f(x,y))$ of two dimensional images $f(x,y)$ is defined as follows:

$$G(f(x,y))=[(\frac{\partial f}{\partial x})^2+(\frac{\partial f}{\partial y})^2]^{\frac{1}{2}} \tag{5}$$

Where $G(f(x,y))$ is grad of $f(x,y)$ and responses the variance ratio between x and y direction. Image border is where grad is comparatively large, and the smoother region of image is where grad is smaller. The grad is zero where greyscale is constant, that is to say, image holds the line in this region.

However, even though the grey value of the region is comparatively large, the region will turn into dark space in gradient image. In order to work it out, we can define as follows:

$$g(x,y)=\begin{cases} G(f(x,y)), & f(x,y) \geq T \\ f(x,y), & others \end{cases} \qquad (6)$$

Where T is a nonnegative threshold. With appropriate T, the image border can be enhanced and the feature of smooth background can not be destroyed.

4.3 Contour Tracking

For the purpose of expanding contrast of image, Fig.5 is changed into Fig.7 with partial enlargement and grey processing for image.

Every column of data is searched along scanning direction by computer. The boundary point (contour) is coming in the event of greyscale from $f(x,y)$ to $G(f(x,y))$. The boundary point of every column and the differences of Y coordinate between fluctuate boundary point of every column can be gained, and the maximum differences is the length of erosion and abrasion. In the similar way, the width of damage position can be gained by scanning image along row direction.

4.4 The Judgement of Erosion and Abrasion

To realize full automatic detection of erosion and abrasion of bore, all the images of bore must be collected continuously and no image is missed（Qingben,B et al,2002）.Depend on the stepper motor driven, CCD realized an image acquisition when the stepper motor stepped a certain distance.

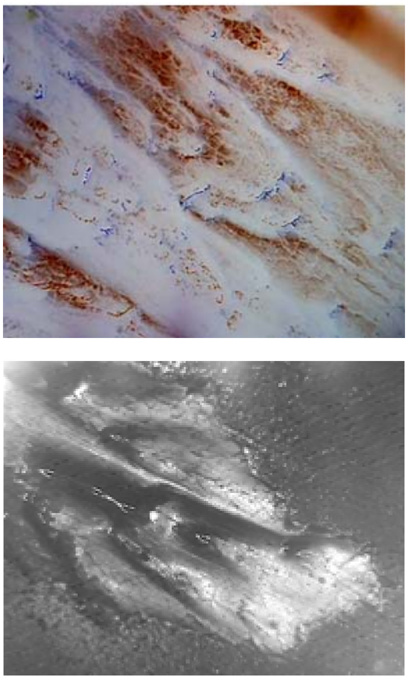

Fig.7.The grey image with partial enlargement

Fig.8.Monitoring interface of terminal operation

Because of the length of gun tube, a lot of images need to be collected in the testing process of bore and that will require a large memory in the actual application. Therefore, HC2004 automatic inspection instrument of bore surface defects was used for observing the erosion and abrasion of damage location, as Fig.8 shown. Then images were collected through acquisition button in the display interface. It is proved that the method can save had disk space and shorten detecting time effetely.

5. CONCLUSIONS

In order to meet the challenge of gun bore detecting system, the robot detecting system with remote/semi-automatic control was designed. The wireless transmission and image acquisition system with RF transmission and CCD image sensor based on the microcontroller MSP430F149 has ensured high flexibility, small volume and low power consumption of robot system and met the demand of small size, light weight and high performance. The automatic detection ability has been improved by the using of HC2004 automatic inspection instrument of bore surface defects. It also has a great advantage to use and repair gun for military. Image recognition technology, neural network and genetic algorithm theory will be used to promote decision making ability of robot system in future. The development of fuel cells and new type motors will be also promote the motion performance of robot.

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