Design of Multifunctional Handheld Terminal for EOD Robot

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Abstract. This paper designs a multifunctional handheld terminal for the explosive ordnance disposal robot (EOD robot), which can not only be used for one-to-one remote control of robots, but also be used as a remote monitoring platform for multiple robots. The hardware part of the terminal is based on the four-core processor Exynos4412, including power management, video decoding, data storage, network communication and other functional modules. The software part takes embedded Linux as the operating system platform, including human-computer interaction, network communication and data decoding modules. The system uses multithreading technology and draws the 3d model of the robot through OpenGL. The test results show that the terminal system is stable and reliable, and can meet the application requirements.

1. Introduction
In recent years, with the rapid development of robot technology, EOD robot has become one of the main explosive ordnance disposal methods [1]. It can be used to inspect, grab, transport and destroy suspected explosive items in dangerous environments, so as to avoid injury caused by close contact between EOD personnel and explosive devices [2]. Because of its complicated operating environment and high control precision, it is extremely important to reduce the difficulty of operation. At home and abroad, there have been in-depth studies on related technologies, including remote control technology and multi-robot collaboration technology.

At present, the main remote control equipment is the control box [3], tablet and PC. The control box is controlled by a joystick, which is convenient and direct to operate, but the equipment is bulky and not easy to carry; the tablet uses the existing development platform, which makes the development process convenient, but the touch operation is not intuitive and the operation experience is poor; the PC terminal is mostly used to monitor the status of robot and is not suitable for controlling the robot. In addition, traditional control equipment is mostly used for the control of a single robot, which cannot realize the monitoring of multiple robots, so it cannot be used for multi-robot collaborative research.

In view of the above problems, this paper designs a multifunctional handheld terminal, which can not only be used for one-to-one remote control of robots, but also be used as a remote monitoring platform for multiple robots. The terminal is light to carry and can provide a platform for future multi-robot collaborative research.

2. The Overall Design
2.1. Demand Analysis
The multifunctional handheld terminal mainly has the following functions: multi-robot communication, multi-robot status and video display, and single-robot remote control. Therefore, the following aspects need to be considered in the design process:
- The terminal can be connected to multiple robots stably and receive robot status information and video information in real time, with a delay of less than 100ms.
- The terminal can display the current operation screen of multiple robots, visually display the current state of the robot, and realize the flexible control of a single robot through the joystick.

2.2. Overall Design of Hardware System
The hardware system design is shown in figure 1, including power management module, main controller module, LCD display module, data storage module, joystick module, communication module, etc.

![Figure 1. Hardware system.](image1)

2.3. Overall Design of Software System
The multifunctional handheld terminal software uses embedded Linux as the operating system platform, and uses Live 555 to build a streaming media client to obtain video information. QT is used to design the human-computer interface and OpenGL is used to draw the 3d model of the robot. The network communication uses TCP protocol, establishes the communication connection through the socket. The overall design of the software is shown in the figure 2.

![Figure 2. Software system](image2)

3. Hardware System Design
Some of the hardware modules are described in detail as follows.
3.1. Power Management Module
The terminal is powered by two lithium batteries in series, with a voltage range of 6-8.4V. The operating voltage range required for each functional module in the system is 5V or 3.3V, and the current demand is 1A. Therefore, the system uses MIC44681 chip of Microchip Company to realize 5V voltage output, and uses 74ALVC164245DGG power conversion chip of Neexperia Company to realize mutual conversion between 5V and 3.3V. Since the default output voltage of Exynos4412 is 1.8V, TXS0102DCU chip is used for conversion.

3.2. Main Controller Module
The main controller uses the Exynos4412 processor produced by Samsung Semiconductor. It is a 32-bit RISC cost-effective, low power, performance optimized and Coretex-A9 Quad Core based microprocessor solution [4]. Integrated Multi Format Codec (MFC) supports encoding and decoding of MPEG-2/4, H.263, H.264 and decoding of VC1. It also includes many hardware peripherals, such as TFT 24-bit true colour LCD controller, MIPI DSI and CSI-2 [5]. The design adopts the method of core plate and bottom plate, and four sets of 2.0-mm double row needles are used to connect the core plate and the bottom plate.

3.3. LCD Display Module
The display module has two parts. The main part adopts a 7-inch IPS high-definition capacitive screen with a resolution of 1280*800. It is connected with HDMI interface to realize remote control, status display and video playback of the robot. The other part uses a 2.4-inch TFT LCD screen to display the power and running time of the terminal itself.

3.4. Joystick Module
The terminal is equipped with a physical joystick and buttons for remote control of the robot. The joystick adopts a two-axis joystick, whose output is the partial voltage value of the potentiometer on the two axes. The joystick position can be obtained through the A/D conversion module of Exynos4412. The buttons are connected to the GPIO ports of Exynos4412.

4. Software System Design
Since the terminal needs to be connected with multiple robots at the same time and receive data from the robots, the system uses multithreaded technology to avoid task congestion. This system has two parts: the main thread and the robot thread group. The thread group includes the data receiving thread, the control command sending thread, the streaming media data receiving thread and the video decoding thread. The communication between the threads is realized by combining the Shared memory and the signal-slot mechanism. Part of the software design is introduced as follows.

4.1. The Main Thread
The main thread runs as shown in the figure 3. The main thread is mainly used for interface display and robot thread group management. After the software starts to run, it will enter monitoring mode by default. In this mode, robot joystick, button, screen button and other control operations are invalid. Operators can monitor the robot through multiple screens and status bar. By clicking the "control" button, the software enters the control mode and can control the selected robot remotely.
The process of main thread.

The video display module in the interface can switch between 4 and 6 screens flexibly according to the number selected by the robot (default 4 screens), and can display the selected video in full screen by double-clicking, as shown in the figure 4, figure 5 and figure 6.

In order to ensure a good user experience, the system uses OpenGL to draw the 3d model of the robot. Modular design is adopted in the design process. The robot crawler, chassis, swing arm and robot arm are respectively encapsulated and finally combined into a complete robot, as shown in the
Each parameter can be adjusted flexibly to facilitate subsequent debugging and development.

Figure 7. 3D model of each part of EOD robot, (a) chassis (b) swing arm (c) robot arm.

Figure 8. 3D model of the EOD robot.

4.2. The Robot Thread Group
In order to realize network communication and data transmission, the robot thread group is designed. It contains four threads and is divided into two modules according to functions. The video module receives and processes video data, and the network communication module processes robot feedback data and sends control commands. Part of the design is as follows.

4.2.1. The video module. Since the EOD robot uses the Live555 server for video data transmission, the terminal system builds the Live555 client to receive video data. The received raw data is video stream in h.264 compression format, so the system uses the MFC unit of Exynos4412 to decode the video. The decoding process is shown in the figure 9.
4.2.2. The network communication module. In order to ensure the reliable connection between the remote terminal and the robot, the system chooses TCP as the transmission protocol between the robot and the terminal system. Due to the small amount of control command data sent by the terminal system and the high real-time performance, and the large amount of feedback information data received, the data receiving and data sending are conducted in parallel, that is, two threads are established to complete the data sending and receiving tasks respectively. In order to preventing mistakenly touching, the data sending thread is closed in the monitoring mode, while runs normally in the control mode.

5. Experiments
The physical pictures of the multifunctional handheld terminal are shown in figure 10. We have done many experiments to test the performance of the terminal, such as communication connection, data transmission and video display, as shown in figure 11. Experimental results show that the terminal can establish a stable connection, real-time display of video and accurate feedback of robot status, and basically complete the work requirements.

![Figure 9. The process of video decoding.](image)

![Figure 10. Multifunctional handheld terminal, (a) front (b) back](image)
6. Conclusion
In this paper, a multifunctional handheld terminal is designed for EOD robot. The terminal can not only realize one-to-one remote control operation with robots, but also be used as a monitoring platform for multiple robots. The system is designed from two aspects of hardware and software, realizing the functions of multi-robot connection, video monitoring and remote operation. Experimental results show that the terminal can establish a stable connection, real-time display of video and accurate feedback of robot status, and basically complete the work requirements. This terminal is capable of operating and monitoring multiple robots, so it can be used as a hardware platform for the research of multi-robot technology. In the following research, this platform can be used for further research on related technologies of multi-robot.

7. References
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