Design and implementation of through wall radar display and control system

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Abstract. Portable through wall radar display and control system is bridge between the radar signal process system and users. On the one hand, radar display and control system receives the origin image signal and present it to users after processed it, on the other hand, the system receives the users' instructions and passes it to the signal process system.

Introduction

As an important part of through wall radar system, the display and control system is a kind of customized embedded system which got the function of radar configuration, integrated display and human-computer interaction [1]. In the early time, due to the technical constraints, the display and control unit is not seem as a single system, and its only function is showing the targets by using analog technology [2]. The unit often use distance monitor, radial scan monitor and rectangular coordinates monitor [3]. Early radar display and control unit is backward in technique, simple function, complex and difficult to maintain.

As the development of microelectronics and computer technology in recent years, radar display and control system is developed to an independent radar subsystem. The independence is reflected in its own hardware platform and operating system and the independent process of software development. Specifically, the system uses the modular embedded microprocessor hardware platform which provides sufficient interfaces and can support operating system, and uses operating system to achieve optimal management of software and hardware resources, and it uses advanced programming language and powerful graphics library to design software.

Compared with MIPS, PowerPC and other embedded hardware, ARM has the advantages of high performance, high reliability, small size, low power, low-price [4]. The Android OS has the stable core and efficient scheduling mechanism, and it is supported by a lot of hardware platform [5]. Based on these, this article designed a portable through wall radar display and control system

Design of hardware platform

Portable through wall radar display and control system is bridge between the bottom signal process system and users. On the one hand, radar display and control system receives the bottom signal and present it to users after processed, on the other hand, the system receives the users' instructions and passes it to bottom signal process system. A well designed radar display and control system's function should contain the following points:

(1) Interact with the signal process system, send and receive instructions and data

(2) Process the original image signal from the signal process system

(3) Send the image data to display screen
(4) Receive instructions from users
(5) Power and battery management

From those five basic function, the hardware design is show in figure.1.

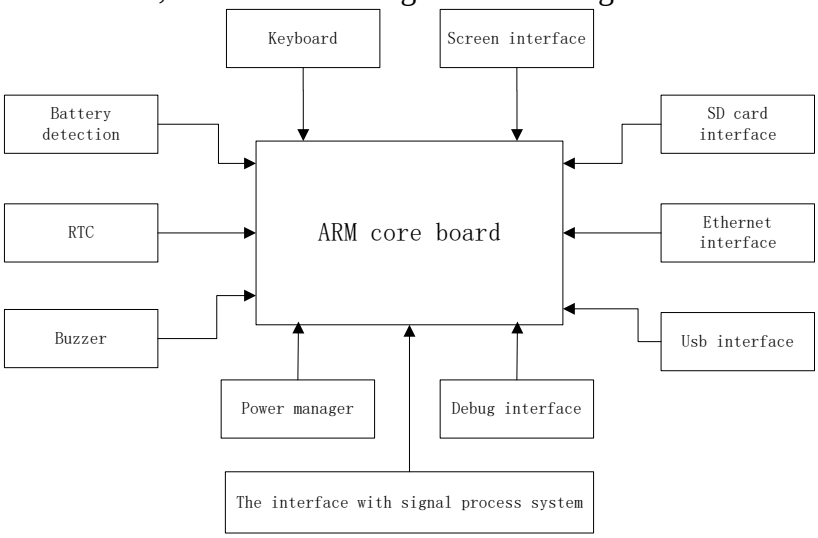

Fig. 1 Hardware design of display and control system

The core is ARM, peripheral circuit contains battery detection chip, RTC, buzzer, power manager, keyboard, data and instructing interface. After the analysis of the radar system, the technical specifications such as image types, image frame rate, image size, data format can be confirmed. Based on these technical specifications, this article choose samsung's tiny210v2 as the core board, this core board takes ARM cortex-A8 as the core chip, SGX as graphics acceleration module.

Transplantation of the operating system

Choose embedded operating system: Portable through wall radar display and control system has complex function, and it need a good operating system to manage the software and hardware resources and process scheduling.

Embedded Linux is widely used in embedded systems because the core is stable and efficient and the code source is open. There are lots of third-part software libraries support Linux well. The Android operating system is based on the Linux core. Compared to traditional Linux, Android is born for the mobile terminal's limited resources, it cut the Linux core to a certain degree. Android cut the native window system, removed the support for GNU Libc, imported a more efficient optimized Bionic, and cut some Linux tools. Android also did a lot of optimization for Linux core in time clock, low memory killer, ashmen, core debug system, inter process communication, log, power manager [5]. Based on the advantage of Android, this article choose Android as the operating system for portable through wall radar display and control system.

Transplant Android embedded operating system: The whole structure of Android is shown in figure.2 [6]

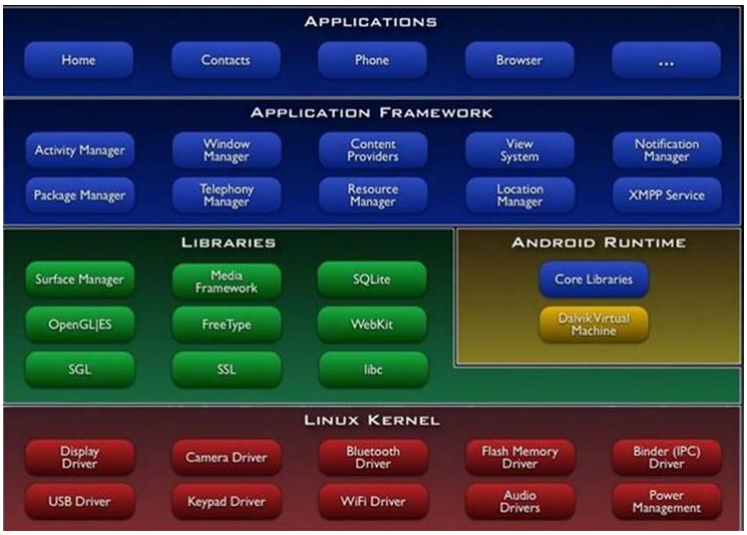

Fig. 2 Android system's structure

The target of transplant Android system is get a stable Android operating system in display and control system, including all module's integrity and stability. Specific transplant steps including modify and transplant the core and the file system, modify and test for some functional module, and the integrity test. The steps of transplantation is shown in figure.3.

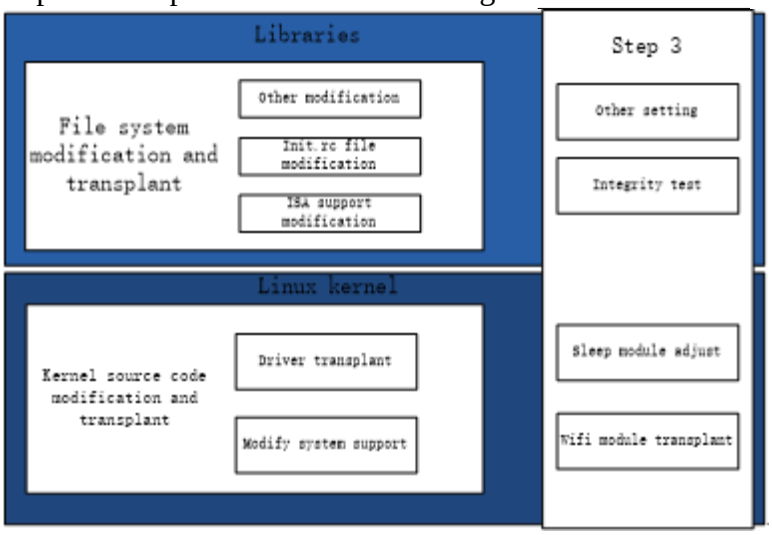

Fig. 3 Steps of Android transplantation

The first step is transplanting core and file system, the core transplantation including source code modify and driver transplant. The core source code can be tested and ran on the target board independently, and the modification and transplantation of file system should be done after the core transplanting. After file system's transplantation, some relevant expansion module can be added, if the display and control system need the function of remote communication, the wifi module should be added. At last is the test of performance.

The process of image signal

Due to the specialty of portable through wall radar, its range, azimuth and altitude are different, and the number of pixels in different dimensions is also different. For example, the pixel of the original 2D image data from signal process system is 256*64 in polar coordinates. In order to obtain a good visual effect, the azimuth resolution and range resolution of the display area should be the same, such as 600*600 pixels in rectangular coordinates. Therefore, it is necessary to carry out the polar coordinate transformation, and the distance and direction of the interpolation and other operations.

The two methods of transformation for polar to rectangular coordinates are real-time calculation and table look-up. The real-time calculation takes more CPU resources while the look-up table

occupies more RAM. Before choosing method of transformation for coordinates, analyzing the overall situation of the software resources is necessary.

For the image interpolation, there are three algorithm widely used which are Nearest neighbor element, Bilinear interpolation, Three times interpolation [7]. The Nearest neighbor's computation is the smallest, but it may cause the image gray not continuous. The Bilinear interpolation's computation is much bigger, the discontinuous pixels are less, but it has low pass filtering property which cause the high frequency component is damaged, the image outline will appear fuzzy. The Three times interpolation's computation is the biggest which occupies much more software and hardware resources but the visual effect of image is the best after three times interpolation.

The original image from the signal process is shown in figure.4, the image is 256*64 in polar coordinates. The visual effect is bad.

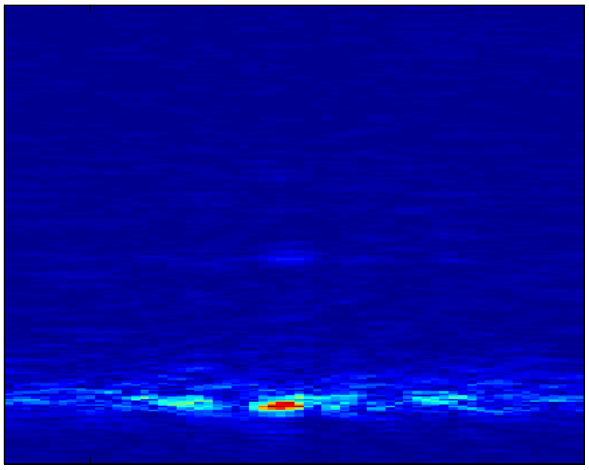

Fig. 4 Original image

Figure.5 is the image after the processes of coordinate transformation and the Nearest neighbor interpolation. The image after Bilinear interpolation and coordinate transformation is shown in figure.6. It can be seem that the image after Bilinear interpolation is much more clearly in details, and the middle computation fit the hardware and software in display and control system well.

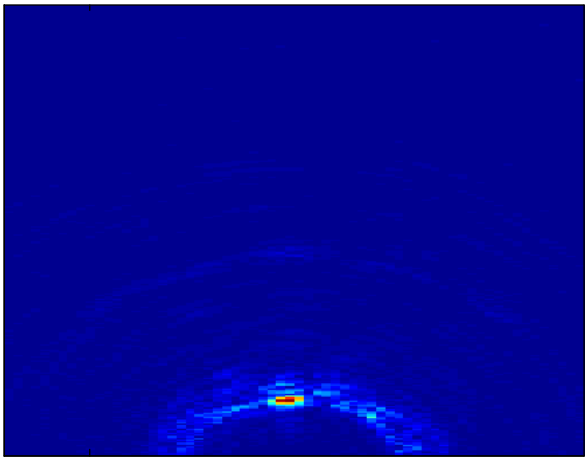

Fig. 5 Image after nearest neighbor transform

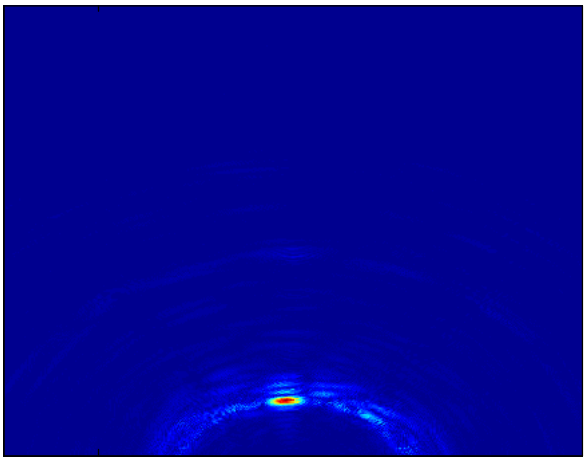

Fig. 6 Image after bilinear interpolation

Design and implementation of radar display and control software

Interaction protocol with the signal process system: In this paper, the display control system is designed to receive three kinds of image data, the original 2-D image data, the 2-D image data after target detection and the 3-D image data after target detection. Meanwhile, the display and control system receives user's instructions and transmits the instructions to the signal process system to switch three kinds of image data mode. Based on the requirement of real-time display, the portable

through wall radar's display and control system uses UDP protocol to exchange data and instruction with the signal process system. The design of the protocol is following:

(1) handshake during the initial time

For display and control system: Due to the different initial speed of display and control system and signal process system, this could lead to one is in initial state while the other is in initial finish state. Therefore, the protocol set that after the display and control system send the first handshake instruction. The first initial handshake instruction include the messages of image mode, grid size. If the display and control system don't receive the response from the signal process system after 10 seconds, it will send the instruction again. The process is shown in figure.7:

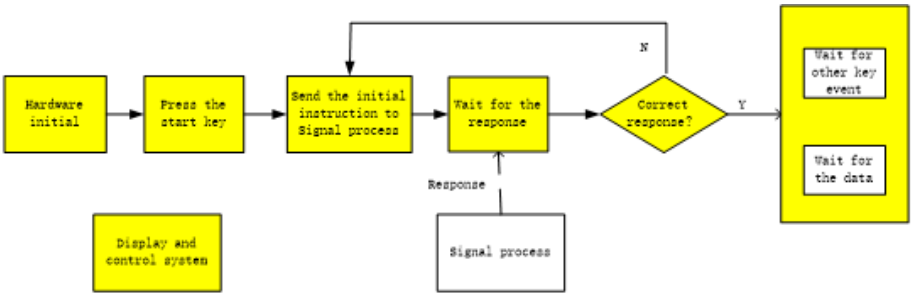

Fig. 7 Display and control system's process during initial time

For signal process system: After its own initialization, the signal process system wait for the instruction from the display and control system. When it receives the instruction, the signal process system will send the confirm instruction back to complete 2-way handshake. The process is shown in figure.8:

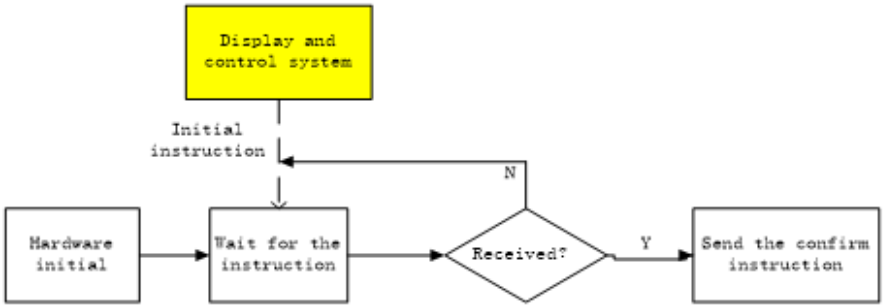

Fig. 8 Signal process system's process during initial time

(2) Interaction of instruction and data

For display and control system: This protocol uses a simple structure to separate the instruction and the data. The display and control system's detail is shown in figure.9

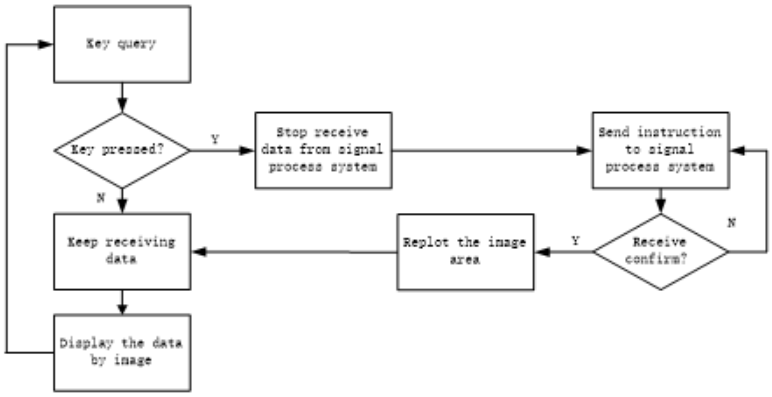

Fig. 9 Display and control system's process during interaction

For signal process system: the signal process's is shown in figure.10.

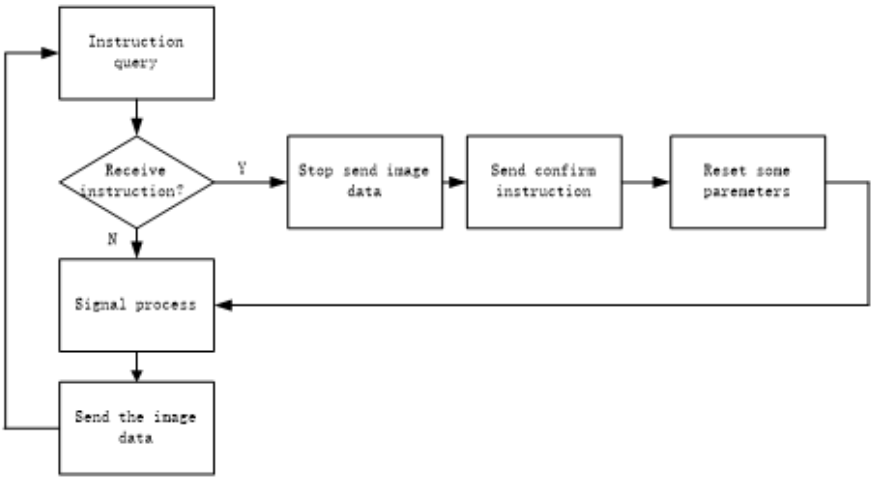

Fig. 10 Signal process system's process during interaction

Design of UI and interaction: As a very important part of through wall radar system, the display and control system got a vital function of human-computer interaction. The design of the basic UI is shown in figure.11

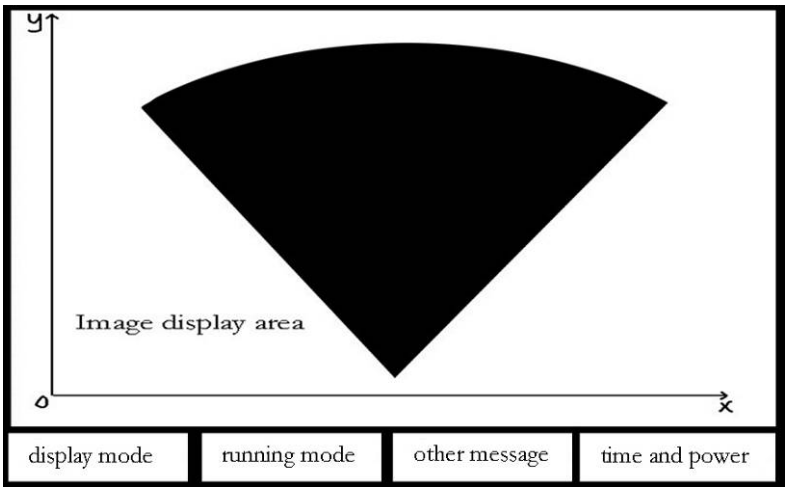

Fig. 11 Design of the user interface

Image display area: According to the characteristic of radar's azimuth scanning area, the image display area uses sector to display the image.

Display mode: Show the display mode, 2-D image mode, 2-D result mode, 3-D result mode.

Running state: Show the state of the system, state like running state, stop state or pause state.

Other message: Show the number of targets in result mode.

Time and power: Show the battery level, WiFi icon, and the time message.

About the interaction with the users, this article designed four physical key: start\stop, image mode\result mode, 2D mode\3D mode, local\remote switch.

Result and Summary

Real object display: Figure.12 figure.13 and figure.14 are the real Object of the display and control system's UI. There are three mode to display the radar image, figure.12 for 2-D image mode, figure.13 for 2-D result mode, figure.14 for 3-D result mode.

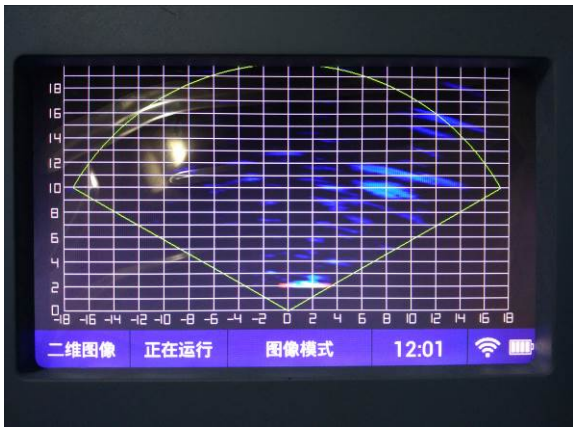

Fig. 12 UI for 2-D image mode

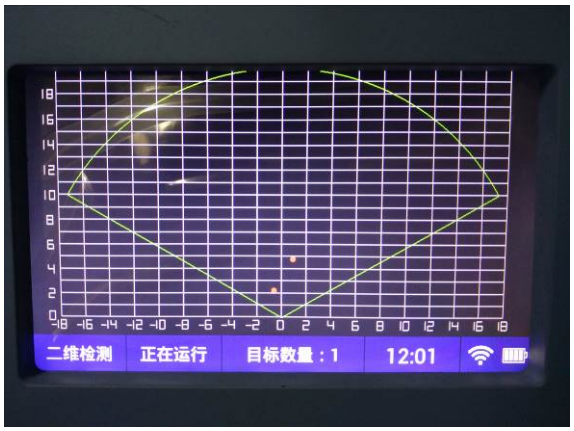

Fig. 13 UI for 2-D result mode

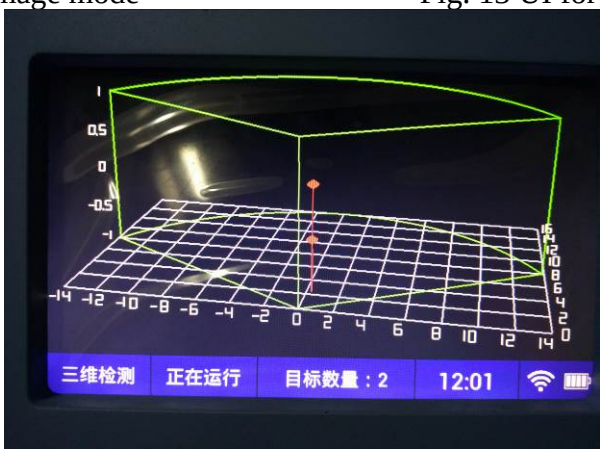

Fig. 14 UI for 3-D result mode

Summary: This article designed a portable through wall radar display and control system based on the ARM cortex-A8 and Android system. This article uses two methods of transformation for polar to rectangular coordinates, and bilinear interpolation to process the image data. In the software design, this article designed a two-handshake interaction protocol to realize the communication between signal process system and display and control system, meanwhile, the article designed a user-friendly UI to make the system interacting with users.

Acknowledgements

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