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Design and Implementation of ARM-Based Children's Accompanying Robot

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Abstract:

With the development of social economy and the improvement of people's living standards, people's work rhythm is getting faster and faster, and people have more and more work matters to deal with. Many parents need to work outside during the daytime, leaving only minors alone at home. The minor faces the dilemma of "nothing to say" in the family. This kind of growth environment is extremely detrimental to the physical and mental health of minors, so the care and companionship of minors is becoming increasingly important. In view of the situation that minors often stay alone at home, the author of this paper designed an ARM-based minor companion robot to cope with such situations. This system is divided into three parts: ARM robot part, Linux server part, cloud data processing part. This product will be used in family to realize voice chat with minors. The ARM demo board is used as the human-machine interaction carrier. The ARM front end, Linux server and the cloud cooperate with each other to complete the user-specified needs. The ARM robot part includes: user interaction interface design, collection and playback of ALSA voice data, and transmission of voice data and Linux server. The Linux server part includes: real-time monitoring whether the system memory receives audio data uploaded by the ARM robot; use the received audio data to generate text data by adopting iFLY voice recognition, and then uploading the text data to Alibaba Cloud to obtain a response result, converging of cloud computing, big data and artificial intelligence, and finally synthesizing the response content into an audio file by combining with iFLY Cloud voice and passing it to the ARM robot. After receiving the data, the cloud performs data analysis and calculation to obtain the optimal solution and returns it to the server. Through this division of labor and cooperation, the robot can normally "talk" to human. The thesis designed the overall scheme of the design and implementation of ARM-based minor companion robot, and then elaborately introduced the resources used by the system, including the establishment of QT interface, the processing of audio data by ALSA, and the monitoring and processing of data by Linux server, the establishment of NFS service, Linux server and cloud data exchange. Finally, this thesis proved through experiments that the system achieves the purpose of intelligent and efficient connection between machine and human.

***Keywords**: Linux server, Cloud data processing, Voice recognition, Voice synthesis, Voice recognition to text.*

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I. INTRODUCTION

1.1 Background and Significance of the Project Research

With the development of social economy and the improvement of people's living standards, people's work rhythm is getting faster and faster, and people have more and more work matters to deal with. Many parents need to work outside during the daytime, leaving only children alone at home. Nowadays, most children are born in the post-90s and post-00s period [1-3]. The majority of them are from only-child families, in which there is very little communication between parents and child. The child faces the dilemma of "nothing to say" in the family. This kind of growth environment is extremely detrimental to the physical and mental health of children, so the care and companionship of children is becoming increasingly important.

This topic employed a single-chip computer and cloud computing to implement the child companion function. With cloud resources, child companion robot can interact with human and human can tell the robot the problems encountered. The robot can "understand" what human said, and then "speak out" the answer after the received information being processed by loud computing. This product can solve the dilemma of parents working outside and only leaving child alone at home. Cloud technology has begun to be applied in various industries. For example, in the current mainstream Internet of Things, the final data must be delivered to the cloud for processing. Due to the use of cloud technology, there is no need to perform complex processing calculations on the local side, hardware costs can be reduced and product development cycle can also be greatly shortened.

1.2 Research Status of Similar Projects both at Home and Abroad

1.2.1 Development status abroad

Professor Takashi Takino of Waseda University in Japan spent over 7 years in developing a "TWENDY-ONE" escort robot for the elderly. It can not only help the elderly getting out of bed, but also deliver and feed meals. "TWENDY-ONE" is 1.5 meters tall and weighs 110 kilograms. It can move freely by four walking wheels. In addition, this kind of robot can judge and bypass obstacles by itself. The user only needs to say "Help me getting out of bed" before getting up, the robot will lift the person out of the bed with both hands and help the elderly to sit in a wheelchair. Designed with soft silicone finger plus flexible joints inside, the robot can cleverly perform manual tasks like human, from holding raw eggs to taking sliced bread.

In the middle of the 20th century, Japan has been committed to the development of humanoid robots due to lack of labor forces [4]. At first, Japan's robot industry was dominated by industrial robots. Later, due to the serious problem of aging population, Japan's robot industry was gradually expanded to service and entertainment. In 1999, Sony Corporation of Japan launched AIBO, a dog-shaped robot, which was sold out immediately, and henceforth the entertainment robot has successfully entered ordinary families.

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1.2.2 Domestic development status

In recent years, domestic robot industry has ushered in good development opportunities. In the past 5 years, the development of Chinese robot market has maintained an average annual growth rate of over 30%. Under rapid development, policy support is naturally indispensable, and robots have been explicitly written into the 13th Five-Year Plan. In *Made in China 2025*, nine strategic tasks and priorities were clarified by focusing on the strategic goal of achieving a manufacturing power, including ten key fields such as robotics [5].

The "Escort Robot" developed by Robotics Institute, Harbin Institute of Technology has the appearance true to what people think a robot should look like: 1.6-meter high, round heads with big "blinking" eyes, wearing a silver-white "coat" revealing the full modernity, walking steadily and smoothly, be capable of performing many actions with flexible arms. This project named "Research on Key Technologies for the Robots Assisting the Aged and Disabled" was included in the key project of the "863" Program in 2006 and was officially launched in 2007.

1.3 The Research Content and Structure of This Thesis

1.3.1 Research content of this thesis

This research subject uses the ARM demo board as the front-end for data interaction with users, and the Linux server and cloud computing as the main technical support to achieve the purpose of normal communication between human and machine [6]. Because the Linux server supports the features of multi-user, multi-task, multi-thread and multi-CPU, it can support the access of any number of ARM demo boards at the same time, and the demo boards can be used in the operating environment only supporting Linux. Therefore, it has the characteristics of ultra-low cost and user-defined requirements.

The system scheme of this research subject is as shown in Figure 1.

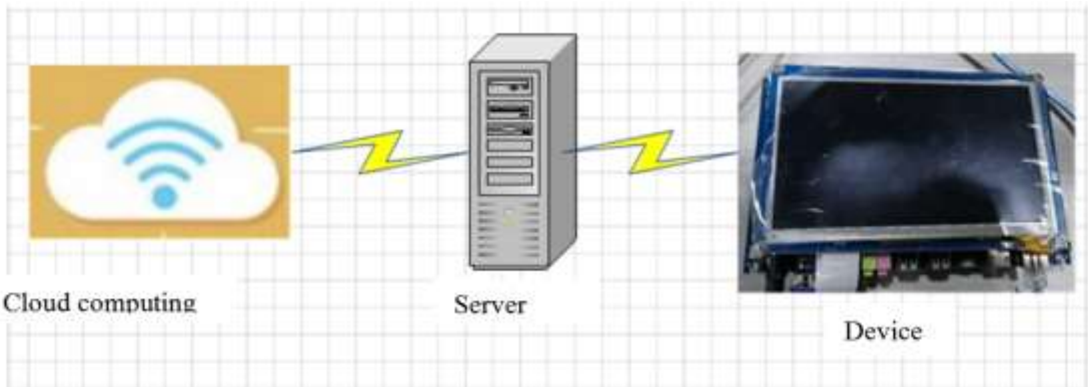

Fig 1: Schematic Diagram of Overall System

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This research subject is intended to be used at home. The user can turn on the timed voice reminder function through the LCD display screen on the ARM, and is able to directly talk to the machine at the same time without the need to manually enter text and other information. TCP / IP and NFS services can be adopted to achieve data interaction between ARM demo board and server, server and cloud [7]. The main control chip of demo board uses S5P6818 of the mainstream Cortex-A53 series. With its powerful performance, many different tasks can be processed synchronously.

This research subject focuses on the following five issues:

(1) The design of the overall system scheme, the establishment of the software and hardware platform of the embedded system;

(2) Development of ARM platform system, machine response system, voice data acquisition system and voice recognition system;

(3) Graphic interface design and program writing of QT operation;

(4) Data communication between cloud computing and Linux server, Linux server and ARM;

(5) Commissioning of the overall system.

A data communication network is built among ARM local end, Linux server and the cloud. Their mutual relationship and the data transmission method are as shown in Figure 2.

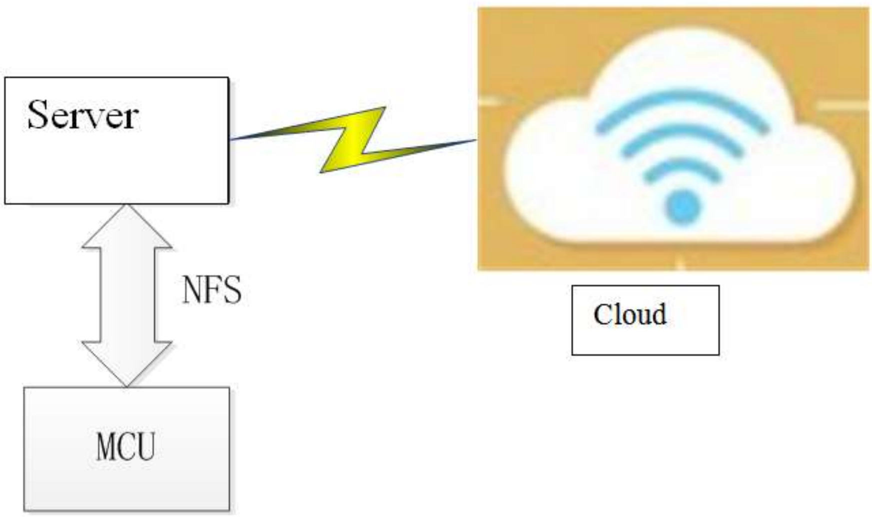

Fig 2: Schematic Diagram of Data Transmission

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The ARM part mainly uses QT to realize the human-machine interaction interface. ALSA data acquires the user's speech information and processes it according to the different requirements of the user. If the user only needs a timed voice reminder, it is done on the ARM local end. If the user needs a voice chat, the collected audio information will be uploaded to the Linux server [8-10]. After receiving the data from the local end, the Linux server uses cloud computing to analyze the data and return the valid data after analysis to the ARM front end. In this way, the intelligent purpose of the machine can be achieved thereby, and the user feels like having a dialogue with a wise man.

II. DESIGN FOR SYSTEM OVERALL SCHEME

2.1 Overall Scheme Design and Function Introduction

2.1.1 General description of the system

This product will be used in family to realize voice chat with children. The ARM demo board is used as the human-machine interaction carrier. The ARM front end, Linux server and the cloud cooperate with each other to complete the user-specified needs.

The research process of this project is divided into the following steps:

(1) Design the overall hardware environment.

(2) Establish an overall software platform.

(3) Design and implement the conversion between analog signals and digital signals of audio data.

(4) Use QT to complete the development and design of human-machine interaction interface.

(5) Design and implement the establishment of NFS services.

(6) Design and implement the mutual conversion of audio data and text data conducted by server.

(7) Design and implement the communication between cloud and server.

(8) Test the system operation stability, analyze and verify the success rate of recognition in the voice communication part and the rationality of the answer content in the answer part.

2.1.2 Overall design scheme of the system

The entire system design is divided into three parts, and the entire product is completed through the coordinated work of each part.

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(1) Human-machine interaction part of ARM front-end

The main control chip uses one Cortex-A53 core chip. A 7-inch capacitive touch screen is used as a human-machine interaction interface. Users can switch between different service modes by operating the screen. The interactive interface is written in QT, which allows users to freely switch between setting a timed voice reminder function and speaking and communicating functions. Under the speaking and communication function, ALSA technology is used to acquire the user's voice data, and the machine can be enabled to "speak" after receiving the response data.

(2) Data processing part of Linux server

After receiving the front-end audio data, Linux uses iFLY Cloud to analyze the audio file into text data, then obtains the response message text through Alibaba Cloud Computing, and finally converts the text into an audio file again through iFLY Cloud.

(3) Data transmission

Since the data processing part of this product is mainly processed on the server and the cloud, it needs stable and reliable data transmission [11]. This system adopts TCP / IP protocol and NFS service to enable data sharing among the ARM front end, Linux server and the cloud. The data communication between the ARM front-end and the Linux server employs the NFS service to ensure timely and accurate data; the communication between Linux server and cloud data uses the TCP / IP protocol to ensure data security and reliability, thereby realizing the Internet of Things technology. The block diagram of the overall system is as shown in Figure 3.

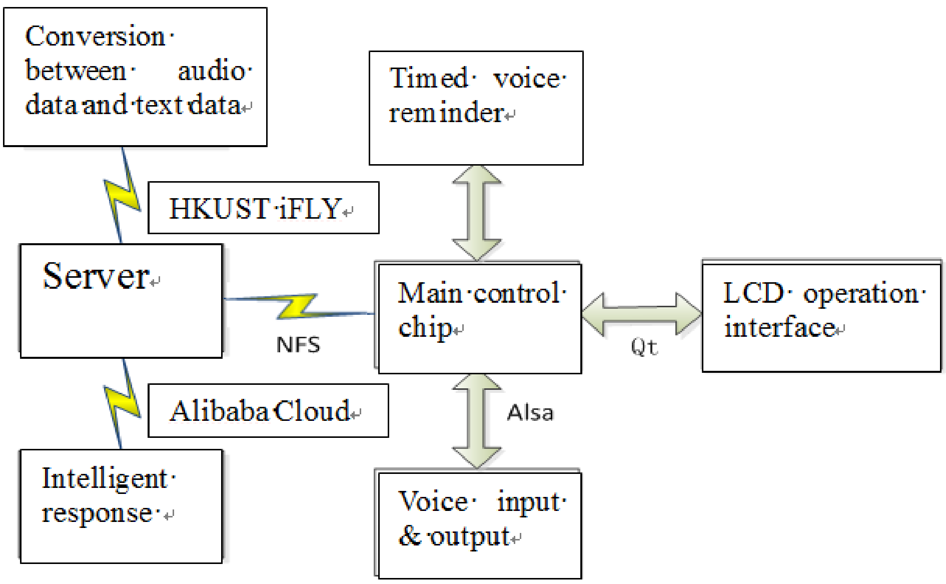

Fig 3 Schematic Diagram of the Overall Structure of the System

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The overall physical picture of the system is as shown in Figure 4 below.

Fig 4: Overall Physical Picture of the System

2.2 Features of the System

Users can turn on the timed voice reminder or communicate with them through the LCD display. Users on the back-end server and the cloud do not need to make any settings, so it is very easy to use.

ARM-based child companion robot products have the following advantages:

(1) It can be used without interruption for 7 * 24 hours, and can work in various environments.

(2) It can judge multiple conversation types such as chat and questioning according to the content of the user's speech.

(3) It can give voice announcement of the events to be reminded at designated time points.

(4) At the age of not knowing how to use the keyboard or input method to find information and solve problems, children can do just by speaking out the problems directly through this product.

(5) The product interface is simple and clear, and it fully implements "0" threshold for use. It is especially suitable for little children to operate, without any need to learn additional methods.

(6) The product is divided into ARM front-end, Linux server-side and cloud, so it supports multiple devices to work independently at the same time.

Based on the system application requirements and characteristics, the author first made a general plan for the system, including system architecture design, QT interface design, acquisition of ALSA audio data, server and cloud data analysis, etc. The project team took the system of ARM-based child companion robot as the research object, established and selected an appropriate object model, and finally designed a physical model of the ARM-based child companion robot through the design of software and hardware.

III. DESIGN AND IMPLEMENTATION OF SYSTEM HARDWARE CIRCUIT

Based on the concept of utility model, the author designed an ARM-based child companion robot system [12]. The system is composed of ARM front end, Linux server and the cloud. The key technologies of the product are mainly focused on the Linux server and the cloud. ARM front end only needs to be equipped with LCD screen and audio acquisition chip for human-computer interaction. This product has low requirements on hardware, which greatly reduces the development threshold. The ARM-based child companion robot system is characterized by highly intelligent and highly integrated.

3.1 Introduction to Core Board Chip

This system uses S5P6818 as the core control chip, with the highest frequency up to 1.4GHz. S5P6818 has eight ARM processors with Cortex-A53 architecture inside, so it supports almost full-format video decoding in terms of multimedia performance. At the same time, integrated with Gigabit Ethernet controller in the interior, S5P6818 is convenient for users to expand the development. The physical picture of main control core chip is as shown in Figure 5 (front side) and Figure 6 (reverse side):

Fig 5: Front Side of Physical Picture of S5P6818 Core Chip

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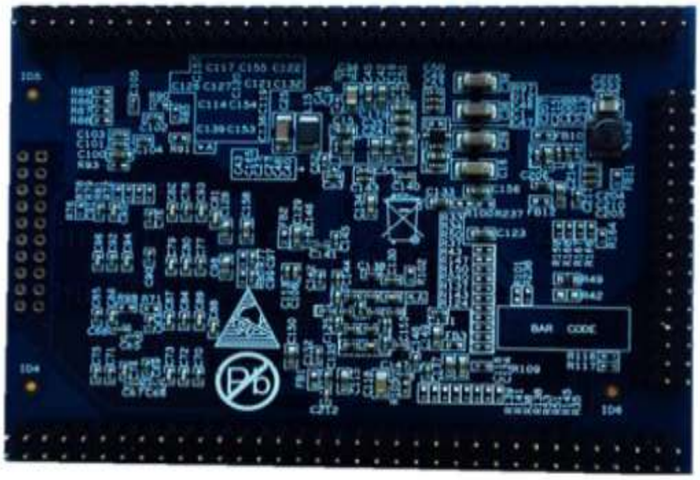

Fig 6: Reverse Side of Physical Picture of S5P6818 Core Chip

3.2 Motherboard of Demo Board

Due to the powerful performance and complicated functions, the S5P6818 needs to be equipped with a motherboard with abundant peripherals to achieve the maximum utilization of the S5P6818. The physical object of the motherboard used in this system is as shown in Figure 7 below. It is designed with Gigabit Ethernet interface, audio interface and other resource interfaces, which are convenient for product debugging and development.

Fig 7: Physical Picture of S5P6818 Demo Board

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3.3 LCD Capacitive Screen

At present, the LCD capacitive screens used by mainstream electronic products are actually divided into two screens, one is a TFT LCD screen for content display, and the other is a capacitive touch screen which is used to detect the specific coordinates of the user's screen operation. The two screens are stacked together. The TFT screen is responsible for display, and the capacitive screen is responsible for sensing user's operations. This product adopts AT070TN92 LCD, which employs a general LCD display controller method based on CPLD or FPGA, so that the LCD display control is applied in a variety of embedded devices in a modular manner.

Schematic diagram of the connection between LCD capacitive screen and S5P6818 hardware is as shown in Figure 8 Schematic Diagram of LCD Capacitive Screen:

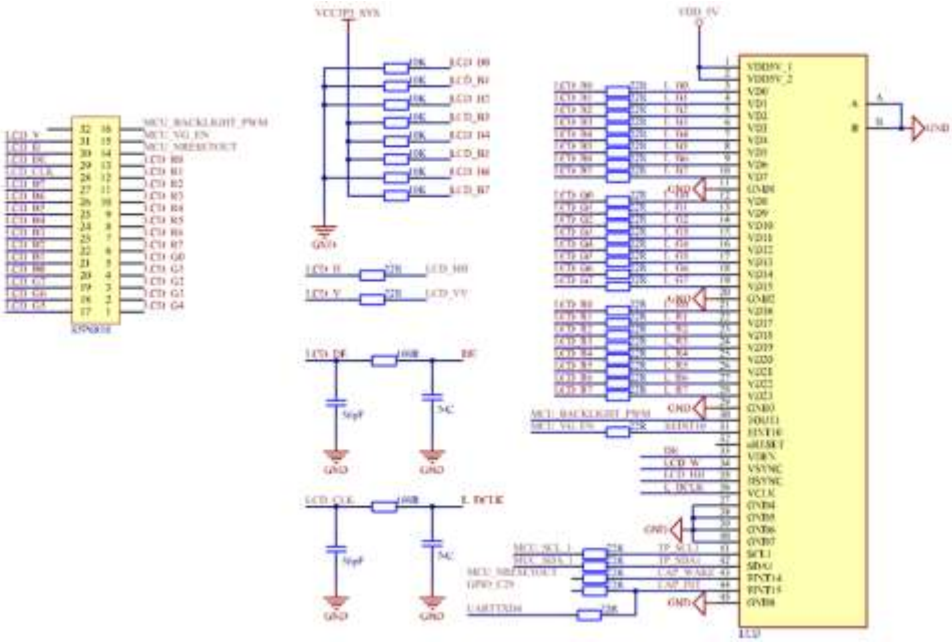

Fig 8: Schematic Diagram of LCD Capacitive Screen

The physical picture is as shown in the following Figure 9 Physical Picture of LCD Capacitive Screen:

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Fig 9: Physical Picture of LCD Capacitive Screen

3.4 Audio Chip

The audio chip uses the highly integrated I'S/PCM interface audio codec ALC5621 produced by Realtek Semiconductor Corp. ALC5621 has multiple output ports and is a high-performance audio chip dedicatedly designed for mobile communications and computing, converging of cloud computing, big data and artificial intelligence.

It provides Hi-Fi-level audio playback and recording. The physical picture of ALC5621 chip is as shown in Figure 10:

Fig 10: Physical Picture of ALC5621 Chip

The ALC5621 chip uses an interface to connect with the main control chip. The audio chip connection section is as shown in Figure 11, and the core board connection section is as shown in Figure 12:

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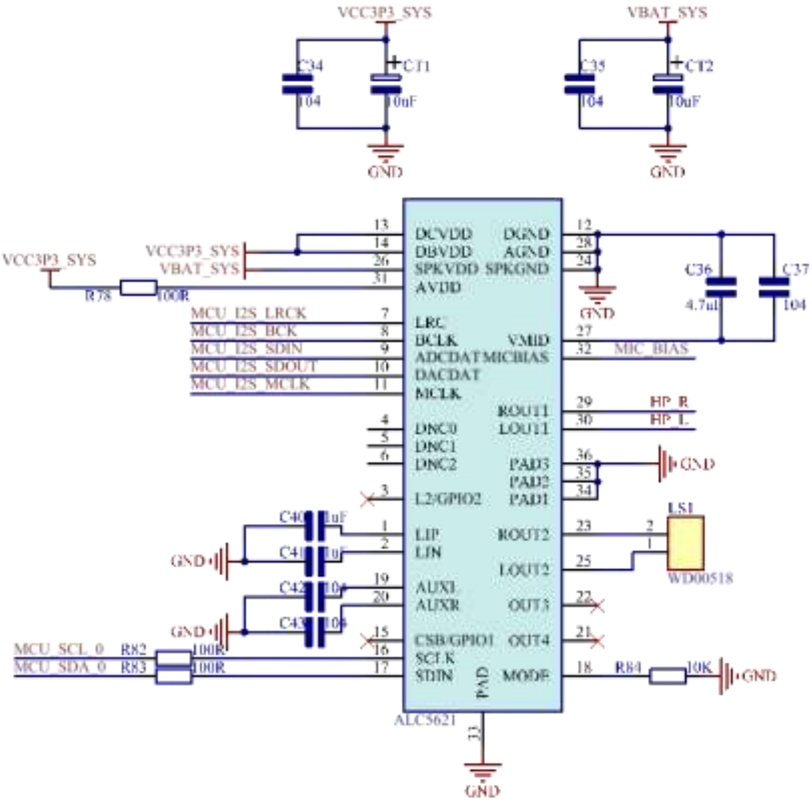

Fig 11: Connection Section of ALC5621 Chip

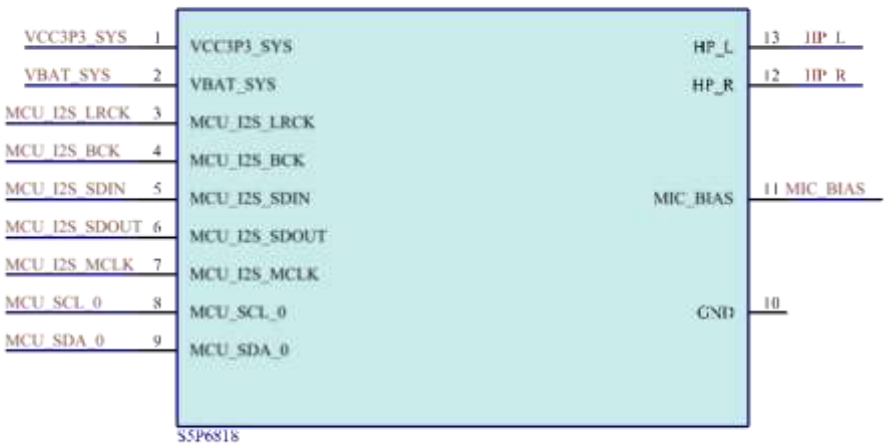

Fig 12: S5P6818 Connection Section

IV. DESIGN AND IMPLEMENTATION OF SYSTEM SOFTWARE

Hardware serves the main body of the entire system, while software acts as the soul of the entire system, so the quality of the software design directly determines the operation of the entire system [13]. The software development of ARM-based child companion robot system is divided into three parts: design

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and implementation of ARM front-end software, design and implementation of data processing software, and design and implementation of data transmission software. The system software structure is as shown in Figure 13.

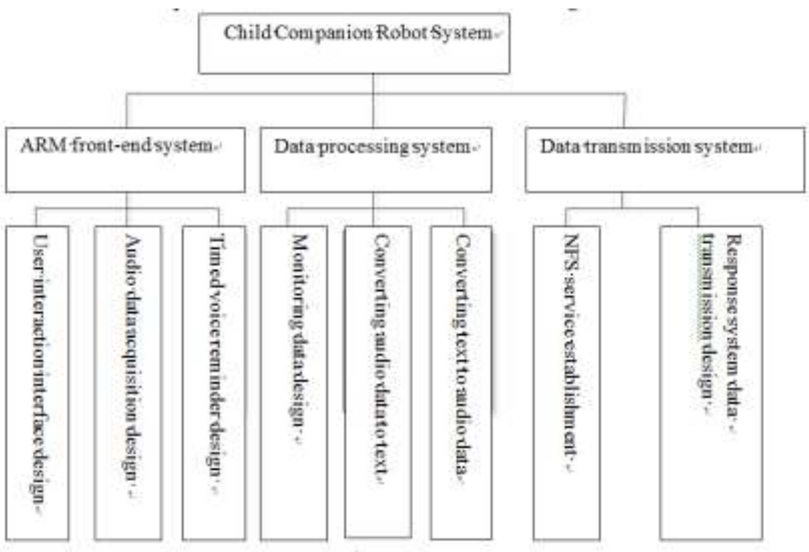

Fig 13: Schematic Diagram of System Software Structure

ARM front-end: The user interaction interface is written in QT; audio data collection is completed by using ALSA; timed voice reminder function means that the user can let the ARM demo board announce the event to be reminded at a specified point of time;

Data processing: The ARM front-end uploads the collected data of the user to the server. Then the server uses the inotify mechanism for file monitoring to determine whether the uploaded data has been received; the audio data and text data are mutually converted by using HKUST iFLY Cloud;

Data transmission: Data communication between the ARM front-end and the server is realized through the NFS service; the response mechanism means that the server uploads the text data to the Alibaba Cloud by using TCP / IP and HTTP for cloud computing after obtaining the text data through audio data, and thereby obtains the JSON format packet and carries out analysis of JSON.

4.1 Converting Audio Data into Text Data

This system uses the SDK provided by HKUST iFLY to complete the conversion between audio data and text data. It implements voice recognition mainly by employing machine-aided self-learning mode.[14] In the recognition process, the self-learning system will summarize the user's using habits and recognition methods, and then summarize the data to the database, so that the recognition system can be more and more intelligent for the users.

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Voice recognition technology process of HKUST iFLY machine-aided self-learning system is as shown in Figure 14:

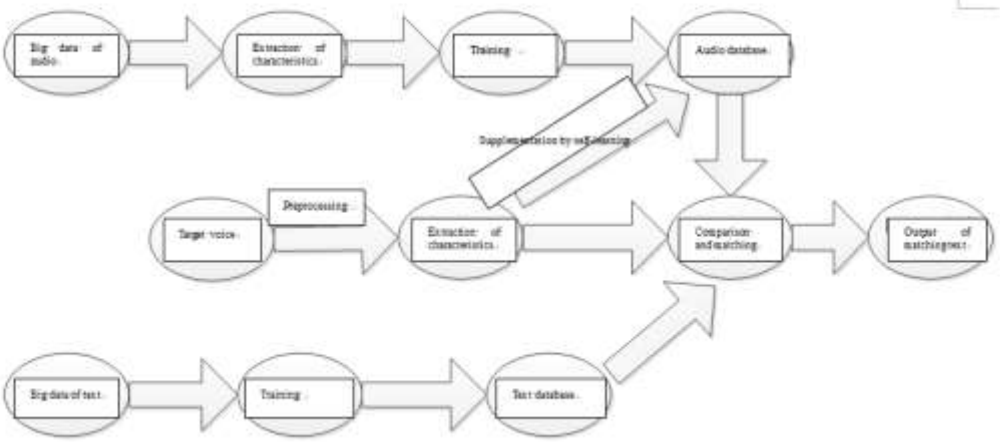

Fig 14: Voice Recognition Technology Process Flowchart of Machine-aided Self-learning System

Before using the HKUST iFLY SDK, the user needs to apply for the unique appid, which is used to log on iFLY Cloud. After successfully logon, the user is required to read the audio file data and configure the basic parameters of the current voice recognition, such as language settings (Simplified Chinese, English, etc.), region and language settings (Mandarin, Cantonese, etc.), audio sampling frequency, etc. It is required to use iFLY Cloud API: QISRAudioWrite to perform voice recognition once, because the audio signal is classified by frame and obtained from multiple experimental tests, therefore the best effect can be achieved in once recognition every ten frames [15-17]. The recognition result string can be obtained from the result returned by using the iFLY Cloud API: QISRGetResult. It is required to repeat the above steps until all audio recognition is completed. Finally, the text file corresponding to the audio file can be got just by writing the string into the file in order.

The specific implementation steps are as follows:

(1) Log on HKUST iFLY Cloud Service and obtain all SDK access rights

(2) Read the audio file data and configure the basic parameters of the current voice recognition

(3) Converting audio data into text data with every ten frames as once recognition operation

(4) If the voice recognition is successful, it is required to use strncat function to save the current recognition result after the last string

Through the above operations, the user's speech content in the audio file can be converted into corresponding text data. The information desired by the user can be obtained just by means of the server uploading the text data to Alibaba Cloud for performing cloud computing.

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4.2 Converting Text Data to Audio Data

After the server obtains the information requested by the user, this information is saved in the form of text. As a result, if the machine is required to "speak out" the answer like a human, the text data needs to be converted into audio data for the machine to "speak out" [18].

The general process flow of converting audio data into HKUST iFLY text information is as shown in Figure 15 TTS Conversion Process:

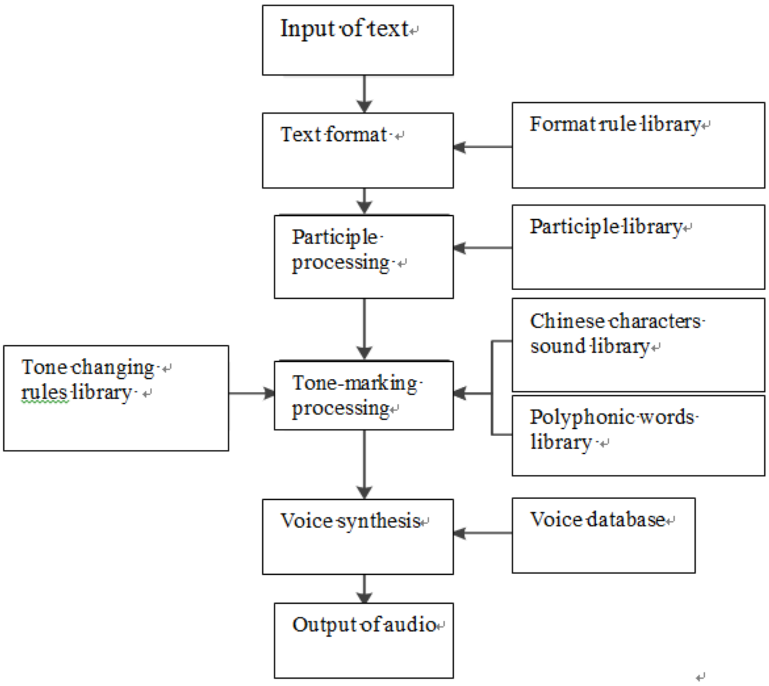

Fig 15: TTS Conversion Process

Before using HKUST iFLY SDK, the user needs to apply for the unique appid which will be used to log on iFLY Cloud. After successful logon, the system starts to configure the basic parameters of the voice synthesis, such as encoding format of the synthesized text (GB2312, UTF8, etc.), speech rate of the synthesized audio and sampling rate of the synthesized audio. The system will further record the text string to be synthesized through iFLY Cloud API QTTSTextPut [19]. As the audio signal is classified by frames, the system needs to repeatedly call the API: QTTSAudioGet to obtain the audio data synthesized each time. Upon the completion of successfully acquiring all data, the audio data is written into the file. The system unified the audio used to be saved in WAV format, as shown in Figure 15 WAV Format Header. The corresponding WAV format header is generated according to the audio data obtained from the current voice synthesis, it is written into the audio file header.

With the support of HKUST iFLY, this system completes the conversion between audio data and text data. The server only needs to transmit the last converted audio file to the ARM front end through NFS service.

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V. SYSTEM FUNCTION DEBUGGING AND SUMMARY

The system is tested from the following three aspects:

(1) ARM front-end; (2) Data processing; (3) Data transmission;

Test conditions: Connect the ARM demo board to the PC through a serial port to simulate the user's operations and test whether the ARM demo board accurately captures user's instructions and responds accordingly; and observe whether the server can receive the demo board data and whether the data is normally processed; test whether the data transmission channel is normal [20].

5.1 ARM Front End

Simulate the user to set a timed voice reminder function. First set the timer to 19: 07 on June 3, and then use the "recording hint" button to enter the voice content that needs to be reminded later "It's time to do homework". Use the serial port to print and display the data captured by the demo board.

Fig 16: The User Setting Timed Voice Reminder

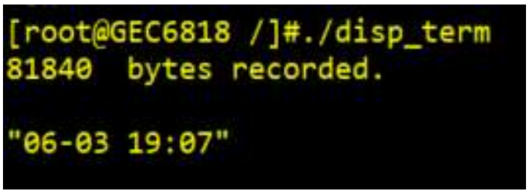

Fig: 17: Data Captured by the Demo Board

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From the comparison between Figure 16 and Figure 17, it can be concluded that the demo board can correctly capture the timing time set by the user as "06-03 19:07" and the audio information to be reminded entered by the user, which occupies 81840 bytes of data size.

Simulate the user talking, press and hold the "talk" button on the main interface, and ask "Who is Zhu Yuanzhang?" Then use serial port to print the audio data information collected by ALSA.

Fig 18: Simulation of User Talking

```
[root@GEC6818 /]#./disp_term
126852  bytes recorded.
```

Fig 19: Serial Port Printing the Collected Audio Information

By comparing Figures 18 and 19, it can be concluded that ALSA can normally capture the audio content of the question just now, and the space occupied by the demo board is 126852 bytes.

The ARM front end will automatically play after receiving the response data transmitted from the server. As can be known from section 4.2.4, the server saves the response audio file at 16000 sampling rate, 16-bit recording and in single track format. Serial port is adopted to print the basic information of the audio file being played.

```
Playing WAVE 'talking1.wav' : Signed 16 bit Little Endian, Rate 1600
0 Hz, Mono
```

Fig 20: Print Response Audio Message through Serial Port

As shown in Figure 20, the ARM demo board can normally play the audio files in WAV format.

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5.2 Data Processing

After receiving the audio file transmitted from the ARM front end, the server converts the audio data into text data. After the audio information is converted into text information "Who is Zhu Yuanzhang?", the system will print out the converted text content through serial port printing, and observe whether the conversion is correct.

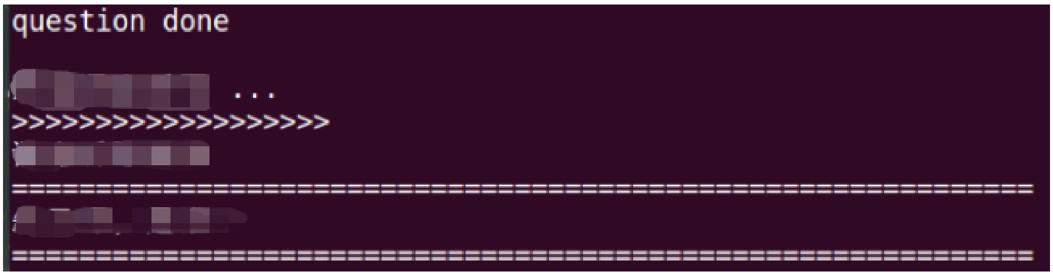

Fig 21: Text Converted from Audio Data

As can be seen from Figure 21, the server correctly converts the audio file into the corresponding text information.

The text information is uploaded to Alibaba Cloud server via TCP / IP, the system will wait for the end of cloud computing, and then print the information transmitted from the cloud through the serial port for observation.

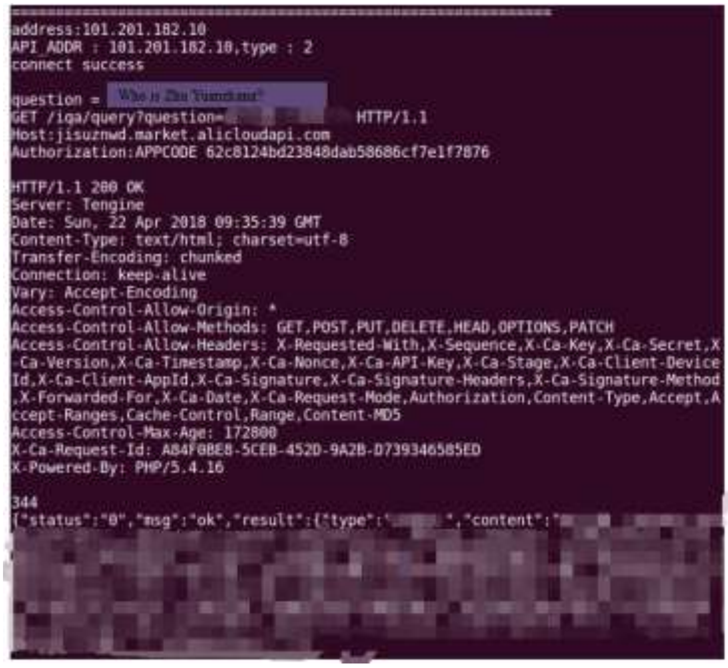

Fig 22: Alibaba Cloud Response Information

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As can be seen from Figure 22, the answer is completely correct when the question is "who is Zhu Yuanzhang?”.

After receiving the information transmitted from the cloud, the server will conduct data analysis for JSON to extract the key content for voice synthesis, and print out the synthesis result through the serial port.

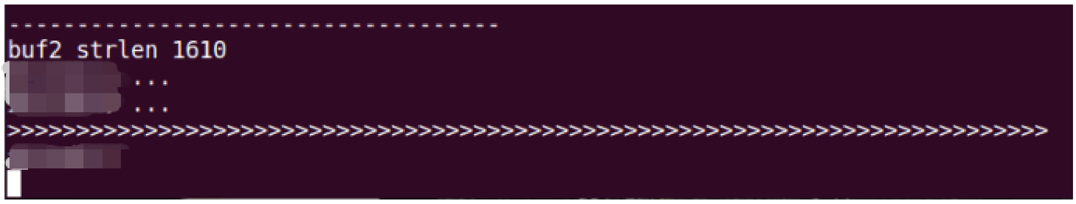

Fig 23: Speech Synthesis Process Display

From the answer in Figure 22 and Figure 23, we can see that, for the question "Who is Zhu Yuanzhang?", the answer has been correctly synthesized into the corresponding audio file for the use on the ARM front end.

5.3 Data Transmission

The server uses the NFS service to achieve the purpose of data transferring and sharing with the ARM front end.

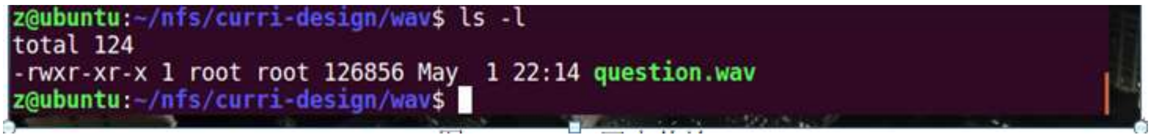

Fig 24: Audio File Saved on the Server

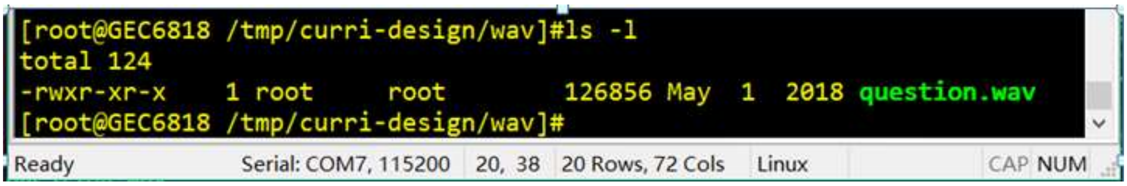

Fig 25: Audio File Saved on the ARM front end

As can be seen from the comparison between Figure 24 and Figure 25, when a file question.wav with a size of 126856 bytes was generated on the server on May 1, the ARM front-end demo board can also receive this file in real time. Therefore, it can be proved that the NFS service can normally realize the data transfer and sharing between the Linux server and the ARM front-end [21].

5.4 Summary

With the improvement of people's quality of life, the pace of life is getting faster and faster, people need to work outside for longer and longer time, and their working places are getting farther and farther from their home. As a result, their children have to be left alone at home, and may feel helpless and lonely when they have problems and want to have a companion to talk. It is easy to cause a huge psychological shadow on the children who are still in growth period and affect their lives for the entire lifetime [22-25].

In order to solve the above problems, this research subject keeps pace with the development of "Internet +", and ingeniously combines today's popular cloud computing with demo boards used in traditional industries to make products intelligent and anthropomorphic to a certain degree.

Functions currently available on this research subject:

(1) Realize the function of timed voice reminder set by users.

(2) Realize the communication between the user and the machine, but since the virtual machine is adopted to simulate the server, and the server can utilize cloud computing to obtain the response data only after the front-end data having been uploaded to the server, so the ARM front-end needs a relatively long time to give response.

The innovations are as follows:

(1) Use cloud computing to place complex computing in the cloud, reduce hardware requirements and improve response accuracy.

(2) The use of cloud computing, big data and artificial intelligence for speech recognition processing and speech conversion word processing improves the recognition rate and conversion efficiency.

(3) S5P6818 with high cost performance and high frequency is used as the core processing chip. Compared with traditional robot and ARM-based child companion robot has the characteristics of high practicality, high efficiency and automation.

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