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Research on Home Healthcare Management System Based on the Improved Internet of Things Architecture

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Abstract

This paper designs an improved internet of things architecture to redefine the internet of things architecture into the node domain, the network domain and the application domain so as to design and implement a home healthcare management system based on this improved internet of things architecture. In this way, all of the equipments characterized with Zigbee communication function in the blood pressure measuring node, the blood oxygen measuring node and the ECG measuring node can be connected to the internet through the Zigbee-Wifi gateway. Meanwhile data uploaded by the users can be stored and analyzed on the backend server of the internet of things so that the users can review their health data and control the node devices through the intelligent terminals such as cell phone etc. Taking the blood pressure measurement as an instance, the experiment has proved the feasibility and reliability of this system.

Keywords**:** *Improved internet of things architecture, family health, Zigbee, blood pressure measurement*

1. Introduction

On the internet of things, things can be connected to the internet through the following communication modes including the local network or the internet with the support of the technologies of RFID technology, sensor technology and GPS technology etc. to exchange information according to the relevant network protocol for the intelligent management through the internet [1].

Nowadays, it’s widely recognized that the internet of things architecture can be divided into three domains including the sensing domain, the network domain and the application domain. In the sensing domain, RFID and sensors etc. are used to identify things and collect information. In the network domain, information acquired in the sensing domain can be processed and transferred through the mobile communication system and the internet etc, while in the application domain, information will be analyzed and processed to server for the correct control and decision making for the purpose to achieve the intelligent management, application and service [2].

In such an aged tendency of population, the harm done by various chronic diseases becomes increasingly serious [3]. Now in China, the sufferers of chronic disease account for 1/5 of the total population, among which there’re more than 0.2 billion people suffering from hypertension [4]. However with the development of the internet of things technology, the medical internet of things is able to facilitate the patients to transform from the “passive treatment” mode into the “early warning” mode. Actually the medical internet of things, which is the technical extension in smart home, has broad scope of application with a promising market prospect.

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Aiming at the generally acknowledged fact that the sensing domain in the three-tier internet of things architecture has been defined narrowly in scope, this paper proposes an improved internet of things architecture to extend and expand the concept of sensing domain, which is also called as the node device domain. Actually it's based on this improved internet of things architecture that a home healthcare management system is designed, which can then be used to measure the various physical health parameters such as the blood pressure, the blood oxygen and the ECG etc. with the measuring data able to be uploaded to the web server so that the users can review their health data and control the node devices by connecting their smart phones to the server.

2. Improved Internet of Things Architecture

Since the concept of internet of things has extremely extensive connotation and denotation, then in most cases the researchers would like to adopt the USN-based high-level architecture described by the ITU.T in the Y.2002 Proposal as the foundation [5] when they're trying to describe the architecture of the internet of things. In an ITU model, the architecture of internet of things has been divided into three major domains: the sensing domain, the network domain and the application domain. In fact, in the research technology route provided by ITU, there's not a separate research having been made purposely on the internet of things. Therefore the sensing domain in the internet of things architecture has been defined through the extension of the concept of WSN. Currently it's widely recognized that the sensing domain consists of two parts, including the data acquisition and the short-distance data transmission. It means that firstly, data will be acquired from the external physical world through such equipments as sensors and cameras etc. for the collaborative operation or data will be transferred to the gateway equipment [6] through the short-distance wire or wireless transmission technologies including Bluetooth, infrared, ZigBee or industrial field bus etc.

With the rapid development of the internet of things technology, the underlying hardware equipments in the internet of things are able to provide such functions that are far beyond the well-defined scope of the sensing domain, which includes acquisition and transmission. Actually many of the underlying equipments in the internet of things are able to realize various actions under the control command from the backend server. Therefore there're two data transmission modes, including forward transmission and reverse transmission modes. Moreover the increasing diversification of the hardware in the internet of things makes the functions become more and more complicated. Now all of the underlying equipments including the intelligent temperature controllers, the smart sockets and the smart appliances that are available on the market and have been used in the internet of things, are characterized with the features of forward and reverse data transmission, data acquisition and remote control and integration. Under such a circumstance, this paper defines the underlying hardware of the internet of things into the node device domain to extend and expand the original concept of the sensing domain in the internet of things, where the equipments in this domain include but not limit to the acquisition and transmission of the physical data, the forward and reverse data transmission and the remote control. The improved architecture is indicated in Figure 1:

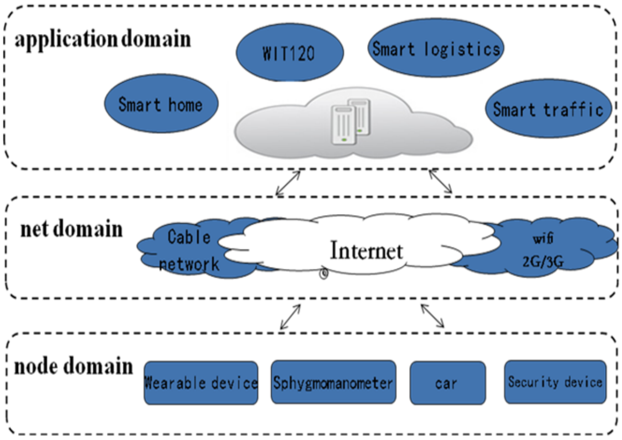


Figure 1 . Improved Architecture Of Internet Of Things

3. The Overall Architecture of Home Healthcare Management System

In this chapter, home healthcare management system is designed based on the improved internet of things architecture described in Chapter 2 with the architecture diagram shown in Figure 2. There're various equipments for the measurement of vital signs in the node device domain including the blood pressure measuring instrument, the blood oxygen measuring device and the body temperature measuring device etc., enabling the user's measuring data to be sent to the Zigbee-wifi gateway for the internet of things via the Zigbee wireless communication. Such a gateway, which can be connected to the home router through wifi for the further access to the internet, is able to upload data to the back-end server.

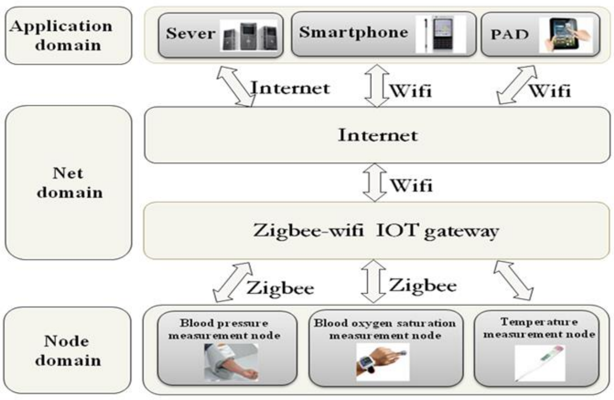


Figure 2. Architecture Diagram of the Home Healthcare Management System

With the advantages of large network capacity, low power consumption, long-distance transmission, low cost, simple architecture and automatic networking [9-10], Zigbee technology enables the various household equipments to be connected to the Zigbee gateway for a reliable data transmission.

Different from those intelligent healthcare devices (such as the bracelet) that are very common in the market and generally adopt the Bluetooth for the connection with cell phone, this system introduces the Zigbee wireless communication technology to the node device domain to enable the users to upload the measuring data without the need of any cell phone. Therefore the users can get access to the server to review their health data at anytime and anywhere. In addition to these, the application of the Zigbee network makes the system featured with strong scalability, which makes it an easy work to expand the functions based on this home healthcare management system. In this way, the system will achieve the other smart-home functions, such as appliance control and monitoring on the family environment etc.

4. System Design and Implementation

This chapter mainly introduces the design and implementation of various function modules in the system, including the building of a back-end server in the application domain, the design of a Zigbee-wifi gateway for the internet of things and the design of the blood pressure measuring node.

4.1. Design and Implementation of Back-End Server

The back-end server, which is home user-oriented, is the data processing and analysis center of the system. The functional units of the server mainly include the user management module, the service response module and the data storage and analysis module. The user management module is designed for the management over the user's registration rights and the user's authentication on all of the devices in the internet of things. The service response module serves for the analysis and statistics of the multi-user data, while the data storage and analysis module is used to provide data support for every function module.

The physical implementation of the server consists of web server and database server. It's through the Http protocol-based communication module that the Zigbee-wifi gateway for the internet of things and the user's smart phone can communicate with the web server, which can be built according to the technology applied in the Apache Tomcat server. JSP technology has been adopted in the web server to feed back the web information, and JavaBean and Servlet technologies have been applied to make response to the user requests and complete the processing of the transactions. Meanwhile access operation can be performed on the web server to access the MySQL database through the JDBC access method. The functional block diagram of the server is shown in Figure 3.

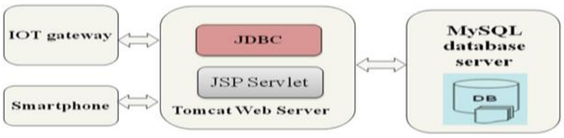


Figure 3. Block Diagram of the Server

The data process flow in the core of the system is indicated in Figure 4. Both of the gateway for the internet of things and the user' smart phone device will work as the client terminal to communicate with the server through the Http protocol. Servlet, JDBC and Model represent separately the part of Tomcat web server and DB is the back-end MySQL database.

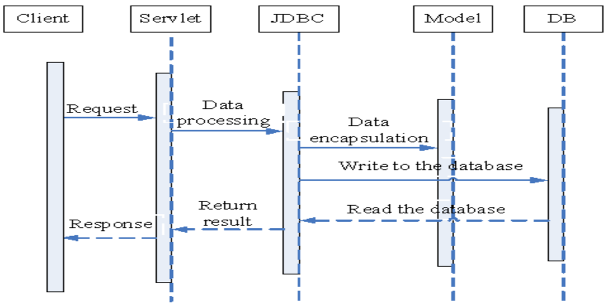


Figure 4. Data Process Flow

After the gateway for the internet of things is powered on, it will automatically establish an HTTP connection with the back-end server and send the registration information to the back-end server so that the users can complete the user registration or the private gateway registration to activate the gateway after the intelligent terminals are connected to the backend server. In the case that the user doesn't take the measurement of the physiological parameters, heartbeat packages will be sent regularly from the gateway to the back-end server to make sure that the back-end server will keep the gateway in an activated state. Also when the measurement on the physiological parameters is completed, the gateway for the internet of things will send automatically the test data to the back-end server.

It's through the HTTP protocol that both of the user's smart terminals and the gateway for the internet of things communicate with the back-end server. Define that an HTTP message consists of message header and message body. The message header is constituted by the following elements including <Total Length, Cmd Type, SequenceId >, where the Total Length is used to record the total length of the message (including the message header and message body) and the Cmd Type indicates the command or response type, consisting of registration, activation and query. The message body that is closely after the message header contains all of the uploaded measuring data consisting of the following elements including < Device Type, GatewayID, Node type, Node ID, Data type, Data Length, Data>, where Device Type is used to indicate if the message is a gateway message or a node message, GatewayID refers to the serial number of the gateway, Node type is the type of the node device (0 represents the sphygmomanometer,1 represents the oximeter and so on), Node ID is the serial number of the node device, Data type is the type of the uploaded data (for example, 0 represents the heart rate value and 1 represents the blood pressure value), Data Length is the length of the data and Data is the specific measuring data. The structure of the HTTP message is indicated in Figure 5:

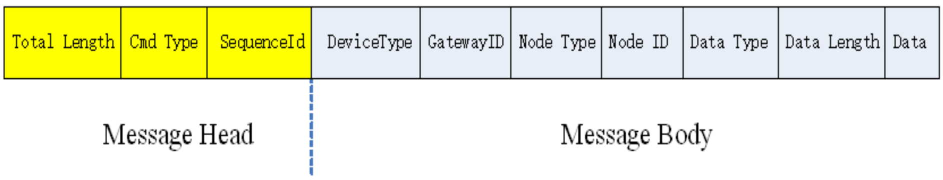


Figure 5. The Structure of the Message

4.2. Design and Implementation of Zigbee-Wifi Gateway

The gateway for the internet of things is able to realize the transformation of the zigbee-wifi protocol in data communication, the unpacking and the repacking of the node device data and the background control command with the structure diagram shown in Figure 6.

Choose Zigbee CC2530 chip produced by TI Company as the Zigbee module. Integrated with the industrial leading RF transceiver and the enhanced industrial 8051MCU, CC2530 chip is designed with abundance resources [11] including the programmable Flash memory, 8KB RAM and the UART communication interface. With the support of the 8051MCU embedded in the CC2530 and the large RAM resource, gateway authentication and data processing can be performed within the CC2530 without the need of any additional microcontroller. In this way, both of the size and the power consumption of the device will be reduced.

Choose XLW002S module as the wifi module, which is equipped with the onboard TCP/IP protocol stack and a light-weight WEB server. Therefore the availability of a UART serial port will complete the integration of this module into the user system.

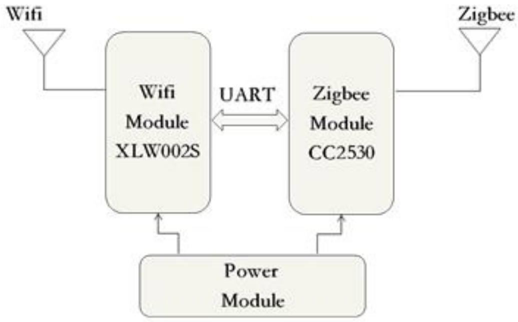


Figure 6. Block Diagram of the Gateway

4.3. Design and Implementation of Blood Pressure Measuring Node

To be specific, the node device domain contains various healthcare monitoring equipments including the blood pressure measuring node, the blood oxygen measuring node and the body temperature measuring node in the internet of things based home healthcare management system. In this section, it introduces the design and the implementation methods for the blood pressure measuring node in the node device domain of the system.

1. Measuring Method

Medically, many methods have been proposed to measure the blood pressure. Compared with the Korotkoff-Souna method and the other methods, the oscillometric method that is able to eliminate the influence of the subjective factors from the operators is extremely suitable for the implementation of SCM. Therefore in this paper, oscillometric method is adopted for the blood pressure measurement.

The oscillometric method has been used to estimate the pressure value according to the variation trend of the pulse wave if there're changes in the cuff pressure. A_s indicated in Figure 7, As represents the SBP of the testee, P_s is the corresponding amplitude of the pulse wave, A_d represents the amplitude of the pulse wave corresponding to P_d, the diastolic blood pressure and A_{max} is the maximum amplitude of the pulse wave with the x-coordinate indicating the various pressure values during the deflating of the cuff. The A_d / A_{max} ratio, K_d is the normalized diastolic blood pressure and the A_s / A_{max} ratio K_s is the normalized systolic pressure. Both of K_d and K_s are the constants. As long as the maximum amplitude of the pulse wave is obtained, it's possible to work out the amplitudes of A_s and A_d that correspond separately to the systolic blood pressure and the diastolic blood pressure. Then through the query, it would be easy to obtain the values of the static cuff pressure which are actually the testee's systolic blood pressure and the diastolic blood pressure when the amplitudes are separately A_s and A_d. According to the conclusions made based on the Mauro mathematical model, the normalized coefficient, K_s is between 0.46 and 0.64 and the normalized coefficient, K_d is between 0.43 and 0.73[12]. In this paper, it adopts such amplitude coefficients that are widely adopted in the clinical medicine, say K_s=0.46, K_d=0.59[13].

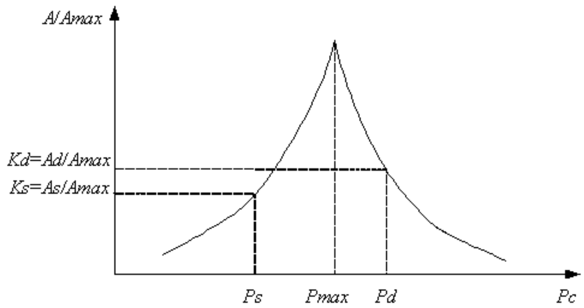


Figure 7. Oscillometric Method for the Blood Pressure Measurement

Assume that the static pressure sequence is $\{P_{sta}[i], i = 0, 1, \ldots, n-1\}$ and the amplitude sequence is $\{A[i], i = 0, 1, \ldots, n-1\}$, thus according to measurement principle of amplitude coefficient method, the corresponding $P_{sta}[i]$ will be systolic pressure when there is i for $A[i]/A_{max} = K_s$. It is difficult to find out a appropriate $A[i]$ to meet the relationship due to the discreteness of measurement sequence, so there will be two nodes of i and $i+1$ to meet $A[i]/A_{max} < K_s$ and $A[i+1]/A_{max} > K_s$, and the systolic pressure is between $P_{sta}[i]$ and $P_{sta}[i+1]$. Assume k as a coefficient, here is:

$$k = \frac{A_{max} \cdot K_S - A[i]}{A[i+1] - A[i]}$$

The relatively accurate systolic pressure is :

$$P_S = P_{sta}[i] + k(P_{sta}[i+1] - P_{sta}[i])$$

2. Hardware Implementation

In the blood pressure measuring node, it's necessary to implement the measurement on the amplitude of the pulse wave and the static cuff pressure, controlling the inflation and deflation of the air pump for the cuff and calculating the testee's systolic blood pressure and diastolic blood pressure based on the amplitude coefficient method and then send the measuring results to the gateway of the internet of things through the Zigbee wireless communication method. The hardware block diagram of the blood pressure measuring node is shown in Figure 8, where the hardware circuit consists of three parts: the power circuit, the sensing signal conditioning circuit and the host control circuit. The power circuit is used to supply power for the whole system, the sensing signal conditioning circuit is used to process the amplitude of the pulse wave and the static cuff pressure signal, and the host control circuit is designed for such functions including data processing, air pump control and data transmission etc.

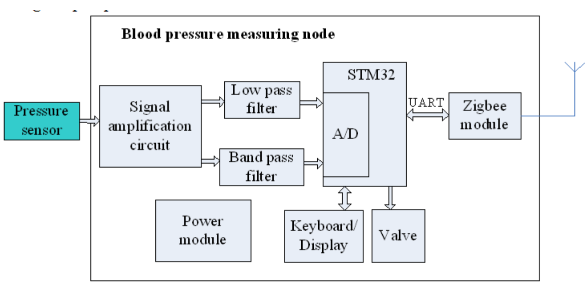


Figure 8. Block Diagram of the Blood Pressure Measuring Node

The model number of the pressure sensor is MPX2050. In the small signal amplification circuit, it adopts the integrated instrumentation amplifier AD620, which is user-friendly with high precision and low noise coefficient. The application of a resistance is able to realize the adjustment on the amplification factor of the differential signal. In this design, the amplification factor of the amplification circuit is 200.

After the amplification, the pressure signal will receive a static pressure value when it passes through the low-pass filter circuit, which is actually an active second-order low-pass filter with the cut-off frequency set to be 0.5Hz to remove the alternating component in the pressure signal.

Acquire the pulse wave after the amplified pressure signal is filtrated in the band-pass filter, which is a an active second-order low-pass filter constructed with LM324 with the centre frequency at 1.5Hz, the bandwidth at 2Hz and the amplification coefficient set to be 2.

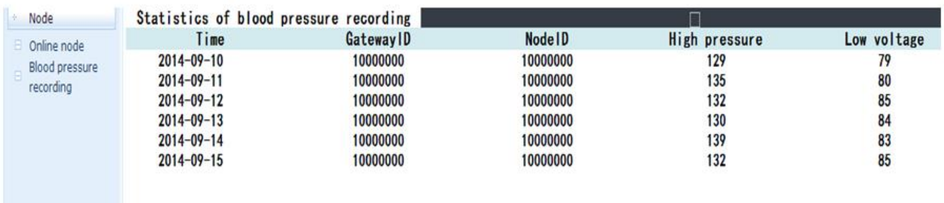
Choose the STM32F103 chip produced by ST Company as the master controller. This chip that adopts the ARM Cortex-M3 CPU core is provided with a multichannel 12-bit AD converter. The static cuff pressure signal and the pulse wave signal will be sent directly to the STM32 chip for AD conversion and data processing after they're conditioned for amplification and filtration. Then the testee's SBP and DBP that have been worked out will be displayed on the LCD and send finally to the gateway of the internet of things after they're transmitted to the Zigbee module through the serial port.

5. Experimental Verification

5.1. Experiment on the System Functions

The experiment on the system functions will be conducted based on the server software design, the design of the wifi-Zigbee gateway and the design of the software for the terminal node and the smart phone for the purpose to verify the feasibility of the system. This experiment is conducted mainly to verify if the measuring data can be uploaded correctly from the equipments in the node device domain to the back-end server and if the gateway and the equipments in the node device domain can be displayed correctly in the background software and even if the software for the smart phone is able to receive the measuring data from the back-end server correctly.

Figure 9 is the screenshots for the data display in the backend server software. It reveals that the gateway ID and the Node ID can be displayed normally. Also the measuring data from the blood pressure measuring node can be displayed correctly and saved in the system.



Time	GatewayID	NodeID	High pressure	Low voltage
2014-09-10	10000000	10000000	129	79
2014-09-11	10000000	10000000	135	80
2014-09-12	10000000	10000000	132	85
2014-09-13	10000000	10000000	130	84
2014-09-14	10000000	10000000	139	83
2014-09-15	10000000	10000000	132	85

Figure 8. Data Display in the Server Software

Figure 10 and 11 are the pictures of the mobile phone screen acquired when the APP software is running on the smart phone. Figure 10 shows the main interface for the running of software. In this interface, it's optional to choose review or control the node types. Figure 11 shows the data display of the blood pressure measuring node, indicating that the history of the blood pressure measurement can be reviewed by sliding the screen. Furthermore, the APP installed in the cell phone makes it possible to display intuitively the changes in the historical blood pressure measurement data through the following methods such as graph or histogram etc.

Figure 10. Main APP Interface

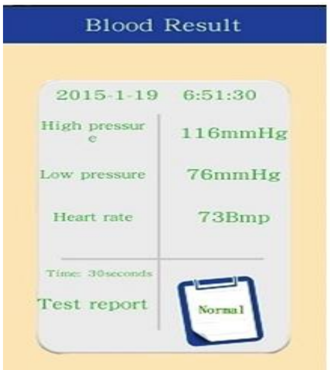


Figure 11. Display of Blood Pressure Data Fit

5.2. Experiment on the Precision of Blood Pressure Measuring Node

In order to verify the measuring accuracy and the stability of the blood pressure measuring node, conduct comparison validation according to such a test method, based on which the same tester will be measured with the medical electronic sphygmomanometer and the blood pressure measuring node at the same time. In the contrast experiment, the Omron automatic electronic sphygmomanometer HEM-7052 is adopted with the verification result provided in Table 2. The test result shows that there's a certain deviation between the measuring results through the blood pressure measuring node and the Omron electronic sphygmomanometer. It's because that through the characteristic coefficient method, the pressure value is calculated based on the abundant sample data acquired in the A/D conversion. However such a sample in itself is featured with the characteristics of discretization. Moreover, the determination of the characteristic coefficient is subject to the further adjustment based on the measuring result. It won't come to an end until the measuring result is within the permissible range of error. What's more, the test result also shows that the blood pressure measuring node that is able to run stably, guarantees a good data consistency.

Table 2. Test Results

	HEM-7052			Blood pressure measuring node		
	Systolic pressure mmHg	Diastolic pressure mmHg	Heart rate	Systolic pressure mmHg	Diastolic pressure mmHg	Heart rate

Subject A	**122**	**76**	**67**	**118**	**74**	**68**
	120	**79**	**70**	**117**	**80**	**72**
	119	**80**	**71**	**121**	**84**	**72**
Subject B	**136**	**89**	**75**	**131**	**85**	**75**
	139	**87**	**77**	**133**	**85**	**78**
	140	**89**	**77**	**137**	**88**	**77**
Subject C	**120**	**69**	**64**	**113**	**63**	**65**
	116	**72**	**66**	**112**	**60**	**65**
	112	**70**	**68**	**115**	**68**	**69**

6. Conclusions

On the basis of the optimization of the layered architecture of the existing internet of things, this paper designs an internet of things-based home healthcare manage system, building a backend server for the system, designing a wifi-Zigbee gateway for the internet of things and determining the communication flows and data packet format for the different domains of the system. Also this paper has designed a prototype for the blood pressure measuring node, which is covered in the node device domain and has been successfully connected to the internet of things system in addition to the programming of APP software for smart phones. The experiment on the system functions has verified the feasibility and reliability of this system. Moreover, since this system is with open architecture, then both of the communication protocol and the hardware platform are featured with strong scalability, based on which such smart home applications that are more user-friendly and able to provide more functions, can be developed.

Acknowledgements

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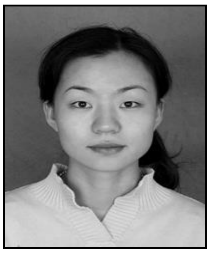

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