The Intelligent Nursing House for the Elderly Based on the IoT System

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Abstract. As the problem of the aging population is gradually intensifying, the current nursing house for the elderly cannot meet their living needs. Based on this, this article builds an intelligent nursing house system based on IoT. This article first puts forward the problems existing in today’s elderly care system, and gives detailed solutions from three aspects: health, diet and maintenance. We combine the Indoor health care and auxiliary module and Dining module into the main system network, and list home appliance maintenance solutions, which organically integrate nursing house and the IoT and cater to the intelligent background of the IoT. Finally, we can achieve the goal of intelligent nursing house.

1. Introduction

The Intelligent nursing house system is a combination of different areas. There are many things, devices and subsystems in the actual application which almost covers every area in human’s life. Here we mainly focus on the aspects of improving the quality of the elderly’s life. The smart nursing house system need to realize the health care of the elderly, includes the physical vital sign monitor and customize care appointment; the smart surrounding to protect the convenience and health of the elderly when they are at home. Furthermore, intelligent dining module according to the demand of the elderly, which can deliver food automatically to the elderly and give some diet suggestions according to the electronic records(e-records). Finally, maintenance module can automatically detect whether the electrical appliances in the elderly’s home are abnormal and whether need to be replaced. With only a few nursing house administrators, nurses and doctors could this smart nursing house be realized. The value in this system is extremely reducing the utilization of human resources and greatly improving the quality of life of the elderly. Under this condition, the system focus on the living condition in the nursing house and give the elderly a faster solution to emergencies. At the same time, the elderly can also get better user experience on this intelligent system. The whole structure of the system is shown in figure.

According to the classification criteria established by the United Nations in 1956, when the number of elderly people aged 65 or above exceeds 7% of the total population of a country or region, the country/region enters aging society. According to the data of National Bureau of Statistics in China, there are 176 million people over 65 years old, accounting for 12.6% of total population [1]. According to the World Population Dashboard of the United Nations, in 2019, total population in the world is 7715 million, the proportion of 65 aging and elder reaches 9% all over the world in 2019.
That means there are over 694 million aging people in the world [2]. As a result, the demand of raising elderly is increasing, nursing house is more necessary. However, the traditional nursing house exists some problems. The psychological and spiritual needs of the elderly are not met, if something happens they cannot call for help immediately. If there is no surveillance, the safety of the elderly cannot be guaranteed; the nursing house with surveillance in room will definitely be an invasion of privacy. Based on the situation, an intelligent nursing house system might be the solution to these existing problems in most nursing house.

Figure 1. Structure of the whole system

2. Indoor health care and auxiliary module
For a nursing house, health care is of vital importance. In intelligent nursing house system, the main function is to monitor and keep healthy of the elderly. Indoor health care and auxiliary module could monitor the physical health of the elderly, detect the risk they will occur and allows the elderly to make an appointment with the doctors. For example, this module could monitor the vital signs of the elderly and report once something is wrong; it could do the indoor accident detection, when the elderly fall down and can’t rise again, a distress signal will be sent to the staffs worked in the nursing house; the elderly could use our app “EZcare” to make an appointment with the doctors in the nursing house. In order to realize such functions, many other equipment could be combined and used.

2.1. Devices
Indoor health monitoring and auxiliary module includes blood glucose meter, blood pressure monitor, fall detection monitor, smart mattress and intelligent toilet. The blood glucose meter and the blood pressure monitor could test the blood glucose and blood pressure of the elderly, analyze if the data is out of range.

“EZcare” mobile application (Figure 2) that we would like to design is important in the whole system. Firstly, the elderly could check the personal historical physical data(e-record) like blood pressure at anytime; the elderly can make an appointment with the doctor or nurse and check the suggestions or feedback.

Furthermore, the elderly can order the meal that they like and they can give feedback of the meal.

Finally, it can remind the elderly whether electrical appliances are abnormal and whether need to be replaced.

The elderly need to wear a wristband in daily life. The wristband could monitor the pulse and heartbeat of the elderly and warn when it’s irregular. GPS chip is installed in the wristband, the location of the elderly will be transmitted to the children directly when the children want to know about it. There is a button in the wristband, when the elderly is lost or in danger, press the button for 7 seconds and one SOS message will be sent to call for help.

The fall detection monitor contains the Witrack module and a LoRa terminal. Witrack is the technology which is developed by the team in MIT to do the indoor detection, which contains fall detection. It could send and receive the FMCW radar, as FMCW could do the speed detection as well.
as distance detection even through the wall, Witrack monitor could analyze the elevation of the elderly or his/her gesture without wearing other equipment, which can be used in indoor fall detection.

The bedroom is equipped with a smart bed, which can measure some data of the elderly when they sleep, reflect the sleep quality of the elderly, and provide some functions to help get out of bed. Equipped with an intelligent toilet in the bathroom, it can realize automatic flushing and deodorization, and assist the elderly to sit down or get up to avoid falling. The floor below the smart toilet is equipped with sensors that can sense the weight of the elderly, the amount of excretion and the number of excretion. Every device is shown in Figure 3.

2.2. Network Structure
In indoor health monitoring and auxiliary module, the devices are mainly connected by WIFI, Bluetooth and Zigbee. The blood pressure monitor and the blood glucose meter uses WIFI to connect to the app “EZcare” as the data should be recorded in the “e-record” of the smart phone. Bluetooth is also a good choice, which consumes less energy. The wristband need to upload the irregular and abnormal heartbeat and pulse in case of the heart disease, so it should be connected to “EZcare” by Bluetooth. WIFI is not a good choice because the wristband maybe carried by the elderly out of the room, so the connection might not be so stable. WIFI also consumes much power compared to
Bluetooth. But if the elderly carries the phone and wears the wristband at the same time, the connection is stable.

The Witrack monitor need to do the indoor fall detection and report when fall happens, so it needs to connect to the centre system installed in the central control room directly to save time. One room will have one monitor, so there are many nodes. The centre control room maybe a bit far from home, so WIFI, Bluetooth and Zigbee are not suitable. LoRa(Figure.4) is a good choice which could connect thousands nodes and transmit for 2-5km. The speed maybe a bit slow, but all the things fall detection monitor need to transmit is the warning information which is very small.

![Figure 4. LoRa networking of fall detector](image)

The smart medicine box can use Bluetooth to connect with the mobile phone, transmit data to "EZcare", and store the elderly's medication data in the "e-record". Devices in bedrooms and bathrooms, including smart bed and smart toilets, have more data to measure and transmit, and more sensor types are used, so microprocessors are required to integrate each data. The ZigBee network's low power consumption, close range, and multi-node characteristics are very suitable for smart home appliances. We can use the ZigBee SoC module to effectively integrate various microprocessors, and then connect the WiFi module through the network coordinator and connect with the mobile application "EZcare". Then we can transfer data to mobile phone.

![Figure 5. ZigBee networking of smart surrounding devices](image)
2.3. Functions

2.3.1. Intelligent vital sign monitor.

The vital signs of the elderly, like blood pressure, pulse, will be monitored and reported when something is wrong. To realize such function, an electronic health record (e-record) for the elderly should be built. It could be the electronic file of the hospital or just do the physical examination in the hospital of the nursing house. The e-record should record the medical history, family medical history, physical examination results, etc. To monitor the body condition of the elderly, smart vital signs detection equipment system should be built. It consists of the blood pressure monitor, blood glucose meter and a wristband to monitor the pulse and heartbeat. Everyday the elderly should use the blood pressure monitor and blood glucose meter to test and the wristband should be worn all the time. However, the pulse and heartbeat monitor happens in the night in case the sudden heart disease happens in the night. If it happens when the elderly is conscious, he will fall, which will be detected by indoor fall detection module, or press the SOS button on the wristband. Here it only do the pulse and heartbeat detection when the elderly is unconscious, like fall asleep.

The blood pressure and glucose data could be acquired by the monitors and transmitted to the app “EZcare” in the smart phone of old people, then the app will analyze whether the data is of the normal range. If so, store the data in the local e-record. If there is something wrong, upload the data and a “warning” message to the cloud server, then the data with the warning message and the e-record of the elderly will be distributed to the doctor. Doctor will analyze the reasons according to the e-record of the elderly and the data and give a suggestion back which will be shown to the elderly and his/her children. If it’s the symbol of a disease, the doctor will suggest the elderly to do the related test. The elderly could use the app “EZcare” to make an appointment with the doctors or nurses of the nursing house.

The pulse and heartbeat will be detected by the wristband. As the wristband will be worn all the time, the real-time pulse and heartbeat data will be detected and analyzed inside the wristband. If the data is out of normal range for a regular time, like 20 seconds, shake to warn the elderly, if it reaches 40 seconds, transmit the warning to the app “EZcare” in the smart phone. Then the app just upload a distress signal to the cloud server, the nurse in nursing house will come and help.
2.3.2. Indoor fall detection.

The accident happens inside the room, like fall to the ground, which causes 300,000 death of the elderly, will be detected and prevented. Among the accident happened indoor, the most important one is fall. Although the wristband has the function to call for help, fall down is sudden and sometimes the elderly could forget to wear the wristband. So an indoor fall down detection system is necessary.

There are many technologies to realize the indoor fall detection, however most of these technologies have disadvantages. Current solutions to this problem include inertial sensors which old people tend to forget to wear, or cameras which infringe on privacy, particularly in bedrooms and bathrooms. In contrast, “Witrack” developed by MIT is a good solution. WiTrack can detect falls with 96.9% accuracy, even through walls and simply by using reflections off a person's body. It does not require the user to wear any device and protects her privacy much better than a camera. However, simply looking at the change in elevation cannot allow us to distinguish a fall from sitting on the floor. WiTrack builds on the 3D localization primitive to enable new functionalities. Specifically, WiTrack can detect a fall by monitoring fast changes in the elevation of a human and the final elevation after the change. WiTrack uses FMCW(Frequency Modulated Continuous Wave) to do the fall down detection. Different from other waves, FMCW could do the speed detection as well as distance detection even through the wall. WiTrack uses a human body to reflect radio signals to track a user's three-dimensional movements. Using the reflection of waves, WiTrack is more convenient [3].

The fall detection monitor contains Witrack module and LoRa terminal. When the Witrack module senses that the elderly falls and cannot rise again for 20 seconds, the monitor will send a warning message to the centre system in the centre control room to ask for help through LoRa.
2.3.3. Smart surrounding.

The smart surrounding we understand is very similar to the environment, and it can be understood as the indoor living environment of the elderly. The range of indoor living environment is very large, we can think of many aspects, there is no way to list and explain clearly. But for the elderly, we believe that health monitoring and equipment assistance are the most important. Therefore, we selected the two areas of the bedroom and the bathroom, because sleep and toilet are problems for many elderly people, and it is also an urgent problem to be solved. We cite a few examples, hoping to explain the function of smart surrounding, as well as the monitoring and auxiliary functions it plays.

Old people sometimes cannot guarantee the health and quality of sleep due to physical reasons, so it is necessary to design smart beds to meet the sleep needs of old people. The problems faced by the elderly during sleep are: not warm enough when sleeping, and it is inconvenient to get up, especially when getting up at night, or even falling. In order to solve these problems, we increased the functions of the mattress and bed. First add a thermistor to the mattress to form a temperature measurement module on the bed. It can sense the temperature of the human body surface and is connected to the heating module. If the elderly's body temperature is slightly lower than the normal body temperature, he will automatically turn on the heating module and maintain a moderate constant temperature to help the elderly warm up [4]. If the elderly's body temperature is higher than normal, the mattress will respond to the abnormal situation and remind the elderly through the mobile phone app "EZcare". If the situation is serious, you can directly notify the elderly children and nursing home staff to quickly ensure the safety of the elderly. At the same time, the bed body is equipped with a pressure sensor, and the bed head is equipped with a night light and a light sensor, which are used to sense the elderly go to bed and get up, automatically adjust the angle of the bed board, and help the elderly. If the light is dim at night, the night light will turn on and adjust the brightness according to the light condition to improve the lighting condition, thereby reducing the risk of the elderly falling [5]. It is recommended to place a smart pill box next to the bed to remind the elderly to take medicine sooner or later. The medicine box can use the pressure sensor to know the amount of medicine in the medicine box, so as to know whether the old man takes the medicine on time and in quantity [6].

For the elderly, excretion can also reflect the health of the elderly, which is an aspect that cannot be ignored. If the old man's body is not very convenient, to improve the independence of the old man's life, the bathroom equipment should be as smart as possible to help the old man. The existing
bathroom products are difficult for the elderly to operate and use [7]. Older people will have more difficulty in completing bends, squats, etc [8]. Muscle atrophy reduces the power to support the body, resulting in a decline in their balance ability, which causes many elderly people to sit on the toilet unsteadily and fail to use the toilet properly. Therefore, smart toilets should be equipped with handrails to help the elderly sit down and get up. The handrails are equipped with buttons, including functions such as washing, drying, self-cleaning and deodorization, which are best achieved by one-click to reduce the learning cost of the elderly. At the same time, a pressure sensor should be installed on the toilet and the platform below the toilet, so that it can record the number of toileting times and toilet time of the elderly, and also record the weight of the elderly and the weight of excrement [9]. If the elderly have a disorder in the toilet, such as diarrhea or constipation for several days, the data will be returned to "EZcare" after the abnormality is detected, and the elderly will be prompted. The toilet is equipped with a light sensor, which has the same function as above and can be automatically illuminated to reduce the risk of the elderly falling. More importantly, it can record the number of times the elderly get up at night and reflect the physical health of the elderly.

3. Dining Module

3.1. The structure of dining module

3.1.1. Diet suggestion.
Through the WiFi of the nursing home, e-record in the Cloud can be sent to the elderly's mobile phone, which will provide some suggestions about what food the elderly should eat. (Figure 9) For example, the elderly with diabetes will be suggested to eat low or none sugar food.

3.1.2. Dining methods.
Firstly, the elderly can eat in the dining hall. They order the food they like through “EZcare” but some food that are negative for their health are forbidden. When they finish ordering, the food can be sent to their seats automatically by the dining robot. (Figure 10)

Besides that, the elderly also can order take-way meals through the “EZcare”. After the chef prepares the meal, the dining robot can automatically reach the door of each old man's room (Figure 11) and wait for a certain time. At the same time, the dining car sends the information to “EZcare”. Finally, the elderly take meals away by using their mobile phone to scan the QR code. (Figure 12)
3.1.3. Feedback.
When the elderly finish the meal, they can give feedback of the meal through “EZcare” on their mobile phone. Furthermore, their feedback will be sent to the Cloud, which can help us know what food the elderly like.

3.2. Realization of the dining robot
The system consists of PC (running state monitoring), data analysis, feeding robot and image recognition module. The workflow of the system: when the target location of the intelligent vehicle is set, the intelligent vehicle starts to run from the start and stop area. During the operation, the coordinates of the intelligent vehicle are sent to the PC in real time through the image processing module; the PC algorithm will automatically plan the path required for the operation of the dining
robot according to the principle of the shortest and available path. When the dining robot reaches the
target point independently, the intelligent robot will automatically return to the start stop area to
complete a running task. The structure of the whole system is shown like Figure 13.

3.2.1. **Hardware structure.**

3.2.1.1. **The dining robot module.**
The dining robot is mainly composed of control module, drive module, WIFI communication module,
buzzer, wheel and body mechanical structure. The control module is STM32f407 microprocessor. The
WIFI communication module is ESP8266ex. L9110 is selected as the driving module. The voice
module is LD3320. The application of these three modules in delivery robots is very popular, which
will not be introduced in detail here. (Figure 14).
3.2.1.2. **Image recognition and processing module.**

The processor of image processing module also selects STM32f407, and its hardware connection mainly includes three parts: STM32f407, esp8266ex and ov7725 cameras. STM32f407 is the control unit and esp8266ex is used for network communication. According to the requirements of image processing on embedded processor, micro Python is transplanted to STM32f407 chip in the development process, and on this basis, Python is used to efficiently implement core machine vision algorithms such as color tracking, mark tracking, target detection and tracking, edge detection. Through the above image processing algorithm, the image processing module can identify the moving path of intelligent vehicle and the position of obstacles in real time, and send the position information to PC through esp8266ex for algorithm processing.

3.2.2. **Software structure**

3.2.2.1. **Path planning algorithm design.**

The path planning algorithm based on width first search algorithm to realize the path planning of the dining robot. For multiple dining robot, according to the location information of intelligent vehicles and obstacles provided by the image recognition module, the algorithm can automatically plan the shortest path without collision, so that multiple dining robots can work together. The software flow is shown in Figure 15 [10].

3.2.2.2. **Embedded software design of the dining robot.**

After the smart car starts, it initializes esp8266, establishes the TCP connection with the PC, and waits for the command to start running. After receiving the running command, the smart car starts running according to the path instructions sent by the PC. The software flow is shown in Figure 16.

3.2.2.3. **Image recognition software design.**

After the ov7725 camera collects the image of the simulated scene in real time, it sends the data to stm32f407 and runs Python program to process the image. After the camera collects the real-time image data, it uses the image recognition algorithm to identify the intelligent vehicle and obstacles, and track the moving path of the intelligent vehicle. Next, the obtained coordinate, direction data and the position information of the obstacles in the simulation scene are fed back to the path planning algorithm of the PC, which is used to plan the moving path of the intelligent vehicle and update the map information. The software flow is shown in Figure 17.
Figure 15. Software flowchart of planning path
Figure 16. Software flowchart of embedded system
4. Maintain Module
It is difficult for the elderly to detect whether their home appliances are damaged: such as abnormal heating of the water heater, the temperature of the air conditioner cannot reach the preset value, flickering or increased resistance of the light bulb, and abnormal power of the microwave oven. Here you can use the non-intrusive power load detection and decomposition method (abbreviation: NILMD), only install a sensor outside the elderly room, by collecting and analyzing the user's total current and terminal voltage to monitor each or every type of indoor power consumption and working status of electrical appliances (such as air conditioners have four different working statuses: cooling, heating, standby and shutdown) [4], so as to know the power consumption status and power consumption rules of each or every type of electrical appliances in the residents' homes Statistics and analysis, through the accumulation of data over a period of time to get the user's electricity habits, and use this as a judgment to determine whether the appliance is working properly.

Compared with NILMD, intrusive power load detection (abbreviation: ILMD) has the following problems:
1. ILMD sensor is affected by many conditions and cannot work normally.
2. Sensors may affect the normal operation of electrical equipment.
3. Difficult maintenance after the sensor in the electrical equipment is damaged.
NILMD functional block diagram shown in Figure 18[11].

![NILMD Functional Block Diagram](image)

**Figure 18. NILMD Functional Block Diagram**

Delivery and maintenance:
After the old man submits the purchase order from EZcare, the purchasing department will send the relevant delivery personnel to deliver.

If the electrical equipment is damaged, the sensor will automatically report the data and send a repair application to the elderly through EZcare. After the application is approved, relevant maintenance personnel will come to the door for repair.

5. Concluding
This article describes an intelligent nursing house system which combines smart health-care system, smart home system and other Internet of Things systems and technologies. Here we mainly focus on the aspects of improving the quality of the elderly’s life. We combined the existing technologies and IOT systems, like smart health-care system, smart home system together to build a new intelligent nursing house system. The system is divided into three modules. Networks, functions and devices of each module are discussed.

The intelligent nursing house system we designed are far superior to traditional nursing houses in all aspects. For example, it greatly reduces the cost of human resources and provides a safer and more comfortable environment for the elderly. As far as the current technology situation is concerned, the various technologies used in the article have been very mature, whereas there is a lack of a company or team willing to integrate the various technologies. Therefore, the smart pension system has not been popularized all over the world. We believe that in the near future, this system will definitely conform to the development of the intelligent era.

As the development of the network, 5th generation mobile networks will become the new trend of cellular mobile communication. Compared to the current network used in our IOT system, 5G has faster speed and could connect more nodes. In the future, the network we used in different modules, for example, LoRa in Indoor fall detection module, could be replaced by 5G. Furthermore, the efficiency of route planning has always been dependent on the efficiency of the algorithm, which can be optimized continuously. In other words, this intelligent system also can be optimized continuously.
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