Research on the aged fall detection and alarming based on Doppler radar technology

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Abstract. Accidental fall among the aged is the "number one killer" which destroys their physical and mental health. Therefore, the realization of the aged fall detection and alarming system to judge the situation of the aged is imperative. In this paper, the platform of fall detection for the aged based on doppler radar is designed and implemented. When the aged falls down, the platform of fall detection will sound alarm. The effectiveness of this method is proved by the experiment results.

1. Introduction
At present, China's population aging situation is increasingly severe, and the artificial intelligence has been an important technical way to promote the medical construction, which will drive the aged care equipment into a period of rapid development[1]. Accidental fall among the aged is the "number one killer" which destroys their physical and mental health. The world health organization points out that the annual probability of falls among people over the age of 65 is 28%-35%, and the probability of falls over the age of 70 is 32%-42%[2]. The function condition of the aged decreases gradually along with the age. When the aged suddenly fall down, if they cannot get timely assistance, it is easy to cause a series of complications, such as fracture, soft tissue contusion, heart shock, cerebral thrombosis and psychological trauma[3].According to statistics, 25% of the deaths among the aged are caused by accidental falls[4].Despite the fall detection method based on wearable device is the research hotspot of the medical institutions and scientific research institutions at present, the method still has disadvantages of the difficulty of cleaning equipment and poor wearing comfort[5,6]. The fall detection based on video method can not protect privacy in the place such as the bathroom and bedroom[7]. Based on the biological signal monitoring technology of Doppler radar, this method has the advantages of non-contact, low cost, strong penetration, strong anti-jamming ability, etc., and is widely used in monitoring [8]. In this paper, the platform of fall detection for the aged based on doppler radar is designed and implemented. When the aged falls down, the platform of fall detection will sound alarm.

2. Architecture of the platform for the fall detection and alarming
Figure 1 shows the architecture of the platform for the fall detection and alarming. The fall monitoring terminals according to the different activates are divided into three categories. They are the fall monitoring terminal in the bathroom, the fall monitoring terminal in the bedroom and the fall monitoring terminal in the living room. The three categories monitoring terminals have the same hardware, but they have different algorithms to detect aged fall.
The fall monitoring terminal with a wireless communication module, can facilitate the connection of the wireless network of the family and update the aged vital signs data to the fall monitoring system server through wireless network. The authorized mobile phone users through GPRS/GSM network and the network computer users (IPAD&PC) through the INTERNET view the real-time status of the old man as well as just viewing historical data. When the old man falls down the fall monitoring terminal can sound the alarm and at the same time send alarm data to the fall monitoring system server for informing his family and the doctor in the first time. The fall monitoring system server receives the real-time data which is sent by the fall monitoring terminal and identifies the alarm data according to the user-defined communication protocols and saves them to the database. When the alarm event happens, The fall monitoring system server can display specific failure messages, activate sound and light alarm to warn the staff. According to the failure code, the staff can easily find which old man falls down at where.

3. Implementation of the Fall Monitoring System

The fall monitoring terminal is made up with the radar module and the controller module. The radar module adopts the structure of non-intermediate-frequency receiver which directly mixes RF signals with local oscillator signals, as shown in figure 2. The LFM source outputs a wideband LFM signal, which is transmitted as a transmitting signal through a transmitting antenna array. When the transmitting signal meets the target, it is reflected and the reflected signal is received by the receiving antenna array. After receiving the radar echo signal, the LNA of non-intermediate-frequency receiver amplifies the signal to the desired power which can be allowed through the bandpass filter and mixed with the local signal. The mixed signal is dived into two groups which are named I and Q. The phase angle difference between two groups signal is 90 which can avoid zero point problem and phase demodulation with high linearity can be achieved by combining with effective demodulation and calibration technology.

Figure 1. Architecture of the platform for the fall detection and alarming

Figure 2. The structure of the non-intermediate-frequency receiver

Figure 3. The schematic diagram of the fall monitoring terminal controller module
As shown in figure 3, the FPGA which is the data preprocessor, completes the data preprocessing tasks such as the conversion from parallel data to serial data. DSP reads the data processed by FPGA and completes the tasks of FFT operation and algorithm implementation. ARM, as the central processing controller, mainly reads the operation result data from the DSP and completes the real-time communication with the server through WIFI module and Ethernet.

4. intelligent program of remote assistance system

The fall monitoring terminals collect the original echo signals I and Q, and when the conversion times of AD get to N which is the number of Fourier transform points, the fall monitoring terminals get into different algorithms according to their classification.

4.1. The fall monitoring terminal in the bathroom

\[ A(t) = \sqrt{(I(t) - 2^n)^2 + (Q(t) - 2^n)^2} \]  
\[ \hat{A} = \sum_{f=f_1}^{f_2} A(f) \]  

the fall monitoring terminal in the bathroom processes the original data collected by AD according to the formula (1) and then the fast Fourier transform is done to get the frequency domain data of N/2; According to the formula(2) calculates the accumulated results from frequency thresholds f₁ to f₂. If the results meet conditions \( A_1 \leq \hat{A} \leq A_2 \) for continuity of three times, the elder fall in the bathroom will be determined.

4.2. The fall monitoring terminal in the bedroom

\[ \theta(t) = \tan^{-1}\left(\frac{I(t)}{Q(t)} + 1\right) \]  
\[ \hat{\theta} = \sum_{f=f_3}^{f_4} \theta(f) \]  

the fall monitoring terminal in the bedroom processes the original data collected by AD according to the formula (3) and then the fast Fourier transform is done to get the frequency domain data of N/2; According to the formula (4) calculates the accumulated results from frequency thresholds f₃ to f₄. If the results meet conditions \( \theta_1 \leq \hat{\theta} \leq \theta_2 \) for continuity of three times, the elder fall in the bedroom will be determined.

4.3. The fall monitoring terminal in the living room

\[ a(t) = I(t) + iQ(t) \]  
\[ \hat{a} = \sum_{f=f_5}^{f_6} a(f) \]  

the fall monitoring terminal in the living room processes the original data collected by AD according to the formula (5) and then the fast Fourier transform is done to get the frequency domain data of N/2; According to the formula (6) calculates the accumulated results from frequency thresholds f₅ to f₆. If the results meet conditions \( a_1 \leq \hat{a} \leq a_2 \) for continuity of three times, the elder fall in the bedroom will be determined.

As shown in Figure 4, the steps of fall detection and alarming system based on the wireless network and Ethernet security communication are as follows:
1) system initialization, assign ID and corresponding IP address to all the fall monitoring terminals, and calibrate the bathroom fall terminal, bedroom fall terminal and living room fall terminal according to the installation location;

2) FPGA acquires radar sensor echo signal for processing, and DSP computes and processes data from FPGA by adding Windows, filtering operation and phase and amplitude FFT calculation to determines whether the elder fall, and sends the result of data processing and analysis to ARM module which ensures high speed data communication;

3) The data processing and saving

The server receives data from the fall monitoring terminals. When the fall monitoring terminals have detected aged fall, according to smart algorithms which the terminal in the bedroom gets into bedroom algorithm, the terminal in the bathroom gets into bathroom algorithm, the terminal in the living room gets into living room algorithm. If the results meet conditions for continuity of three times, the aged fall will be determined.

5. Conclusion and future work

This research has presented the architecture of fall detection and alarming system based on doppler radar. When the aged falls down, the platform of fall detection will sound alarm. The effectiveness of this method is proved by the experiment results. By using fall detection and alarming system, the medical staffs or family members of the aged can obtain more accurate information of location and condition of the aged. Future work will be carried out to test different algorithms for learning and making decision for the aged behavior anticipation.

Acknowledgments

This work was supported by Key research and development program of Shandong Province(2019GGX104064), Research and development of multi-shaped 3D laser marking system (ZR2017BF024). The authors would like to thank our fund providers.

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