Contactless Fall Detection by Means of CW Bioradar

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Abstract— Falls are one of the major risks for seniors living alone at home. This paper presents the results of studies carried out to confirm the possibility of using bioradar for the fall detection. 213 records of various basic movements were recorded by continuous wave radar: BioRASCAN-4 with probing frequencies in range 3.6 to 4.0 GHz. Obtained data was used for the development threshold classifier with the following parameters — length of event and variation of signal amplitude. The results of data analysis by suggested algorithm demonstrated a sufficient level of accuracy.

1. INTRODUCTION

The growing population of senior citizens is a common phenomenon especially in developed and developing countries. Every day about 200 thousand people celebrate their sixtieth birthday, all around the world, and that number will grow [1]. In 2014 every one out of 5 people in Russia was aged 60 years or over, and 24% older adults lived alone [2]. There are many difficulties that senior citizens are facing. In particular, fall incidents are considered to be the most dangerous cause of accidents for elderly people, and represent also the third cause of chronic disability. Immediate help after a fall is a key thing for the successful recovery and returning to the natural life rhythm. Therefore, in time and accurate fall detection is a very important task, especially in case of an elderly who lives alone. So research of an effective fall detection method has become a question of great scientific interest.

There is a variety of wearable devices for motion activity tracking and fall detection based on movement sensors (e.g., accelerometers and gyroscopes) in the market. However, a person using them might simply forget to put it on regularly, and wearable devices are not always comfortable to use. Current approaches for remote fall detection are based on video cameras [3], Kinect system [4], or passive infrared sensors, but walls and fabrics may obscure such systems, and they are sensitive to lighting conditions.

In this paper bioradiolocation method [5] is proposed for fall detection. As known, bioradiolocation is a remote sensing technique allowing to perform noncontact vital signs and motion activity monitoring of living objects including behind optically opaque obstacles. Data set for this research was collected through experiments. 7 different movements were recorded repeatedly. During experiment continuous wave (CW) radar BioRASCAN-4 was used, which specifications and conditions of the recording are given in paragraph 2. Further data processing and development of classification algorithm are presented in paragraph 3 and 4.

2. APPARATUS AND METHODS

We obtained a data set by recording the radiolocation signal from CW radar BioRASCAN-4 designed at Bauman Moscow State Technical University. It operates at 8 probing frequencies in range 3.6 to 4.0 GHz. The technical characteristics are presented in Table 1.

In our experimental studies, the radar data sets were collected in the Remote Sensing Laboratory at the Bauman Moscow State Technical University. Fig. 1 shows the photos of the experiment. Every set of experiments contains a different type of motion, including forward falling, backward falling, turning 90 and 180 degrees, arm motion, going in and out of the location zone, sitting and standing. An initial recording condition depending on the type of motion: persons were located in or out of the location zone. In the first case recording was conducted from a distance of 70–100 cm from the radar, vertical position of the body, primary motor activity was minimized. The general scheme of recording was a periodic repetition of the movement pattern. In the fall recording to ensure the safety and comfort of volunteers was used soft material that is not springy (feather pillows). The duration of records made up of 60–300 seconds with a time sampling rate of 50 Hz.

Table 1: Technical characteristics of bioradar BioRASCAN-4.

Number of frequencies	8
Frequency range	3.6 to 4.0 GHz
Dynamic range of the recording signals	60 dB
Gain constant	20 dB
RF output	< 3 mW
Sensitivity	1 mm

Figure 1: Photo of the experiment.

3. EXPERIMENT RESULTS

During experiments 213 records of following various motion patterns were obtained: 32 motion patterns going in and out of the location zone, 31 motion patterns turning 180 degrees, 23 motion patterns turning 90 degrees, 26 motion pattern sitting down and standing up, 43 patterns of arms movements, 30 forward falling patterns, 28 backward falling patterns. Obtained data records were reviewed at different frequencies (8 operating frequencies, each of them has two quadratures) (Fig. 2). A frequency of 3.8 GHz was chosen for further records processing through the signal to noise ratio.

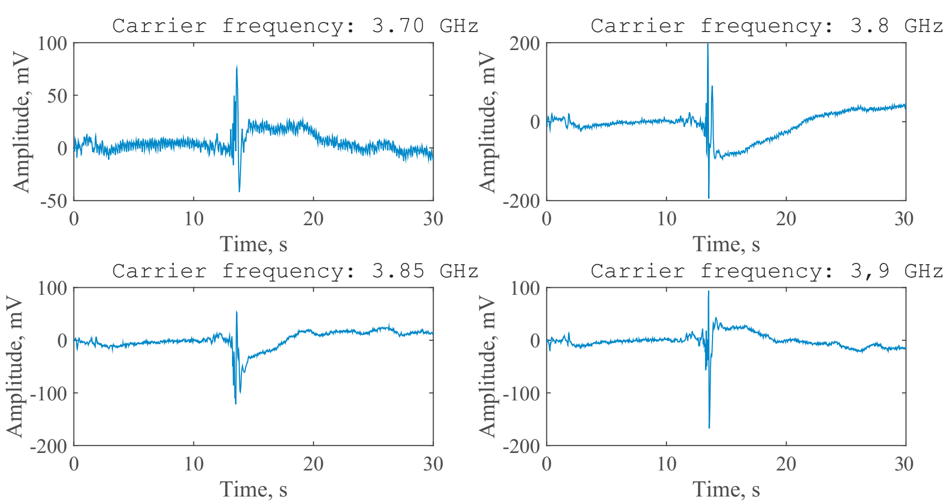

Figure 2: Charts of signal records of backward falling pattern at 4 different carrier frequencies (I quadrature).

The obtained data was divided into training and test samples. To identify characteristic indicators of class "fall" among the training data the following parameters were calculated: **M** — average value of the signal amplitude, $\mathbf{A}_{\max}$ and $\mathbf{A}_{\min}$ — maximum and minimum value of signal amplitude, **t** is length of event, **S** is standard deviation of an amplitude over the entire signal duration. Maximum variation of signal amplitude $\mathbf{\Delta A}_{\max}$ was calculated from the data minimum and maximum values. Averaged results of the calculations are shown in Table 2.

Table 2: Averaged evaluations of experimental results.

Motion patterns	$\mathbf{\Delta A} = \mathbf{\Delta}(\mathbf{A}_{\max} - \mathbf{A}_{\min})$ mV	**S** mV	**t** s
Going in and out of the location zone	1262.61	152.95	2.69
Turning 180 degrees	2130.62	423.13	2.87
Turning 90 degrees	1495.41	233.72	2.17
Arm movements	1516.07	295.8	3.57
Sitting down and standing up	2456.36	404.65	2.39
Fall	601.68	73.91	1.45

4. CLASSIFICATION

Preliminary data analysis showed that the following parameters were useful for fall event classification — length of event and variation of signal amplitude. Considering the length of training data set threshold classification method was chosen. The following ratio for combined assessment of selected signal parameters was introduced:

$$F = \mathbf{10} - \mathbf{t} - \frac{\mathbf{\Delta A}}{\mathbf{1000}} \tag{1}$$

The threshold value of the coefficient F based on the training sample was calculated. Observations of calculated results revealed that coefficient F is greater than 7 for the class "fall". To build the above classifier in Matlab language the following algorithm was implemented (Fig. 3)

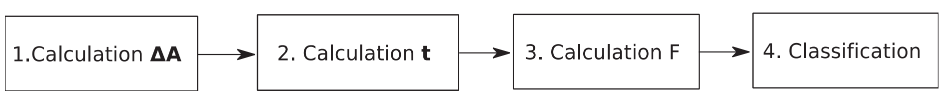

Figure 3: Scheme of the proposed algorithm for radar based fall detection.

1. Calculating maximum signal energy and maximum variation of the signal amplitude $\mathbf{\Delta A}$.
2. Dividing the signal into segments of duration 0.1 s. Calculate signal energy values in the segments. Finding significant changes in signal energy. If energy value of the next segment more than 2 times larger than the value of the previous segment and current energy value is more than 20 percent of maximum energy, fixing the start of event. Similarly finding end times of events. Computing the length of event **t**.
3. Calculating F coefficient and classifying event **t**.

The developed algorithm was validated on a test sample. Table 3 summarizes the resulting confusion matrix.

Table 3: Confusion matrix.

		Actual Class	
		Fall	**Not fall**
Predicted Class	**Fall**	47	2
	Not fall	0	75

5. CONCLUSION

In the present paper we proposed a contactless method for fall detection for elderly based on the CW radar usage. Moreover, the algorithm for radar data processing was designed. Data of more than 213 experiments were used for the development threshold classifier with the following parameters — length of event and variation of signal amplitude. The results of data analysis by suggested algorithm demonstrated the absence of false positive errors and false negative rate was equal to 2.7%.

Some limitations of the study should be noted. The experimental dataset contains radar data for only young volunteers (20–21 years old), which falling movement patterns may differ from the ones for the elderly. Thus, the results should be accepted with caution.

Although the results are preliminary, it was proved that bioradiolocation method can be used for fall detection.

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