Проект РФФИ № 17-07-00166а

Разработка новых бесконтактных многоканальных методов для выявления потенциально опасных лиц в местах массового скопления людей.

Материал в научно-популярной форме (отчет за 2018 г.)

За период второго этапа по проекту была разработана методология проведения экспериментов в случае одновременной регистрации биорадиолокационного и видеосигнала с целью оценки поведения и двигательной активности людей. Для разработки методологии были проведены эксперименты, схема проведения которых представлена на рис. 1.

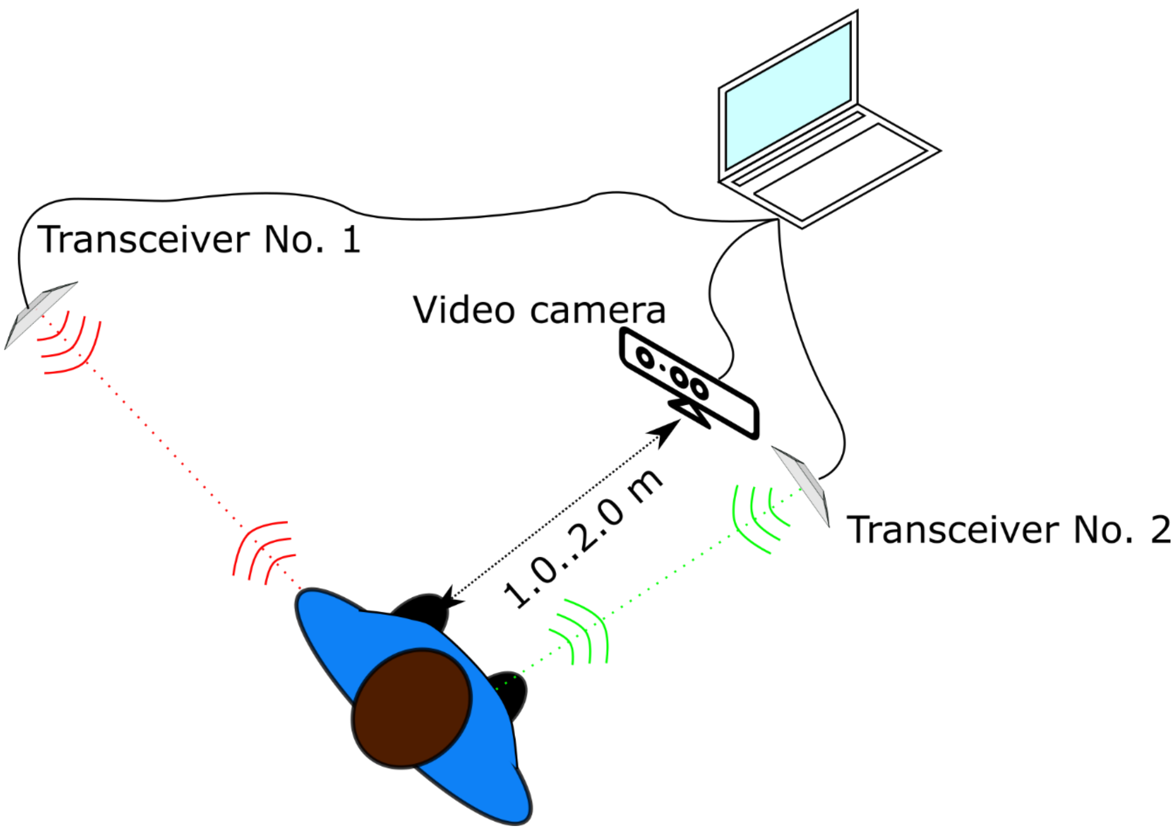

Рис. 1 Схема проведения эксперимента

Осуществлен сбор базы экспериментальных данных, соответствующих различным типам повседневной двигательной активности человека, которая в дальнейшем была использована для разработки алгоритмов распознавания различных типов двигательной активности человека по совокупности данных, регистрируемых многоканальным комплексом.

С использованием методов машинного обучения разработан специализированный алгоритмы распознавания различных типов двигательной активности человека по биорадиолокационным данным. Точность, чувствительность и специфичность разработанного алгоритма для классификации спокойное/агрессивное поведение на экспериментальной выборке составили 0,86, 0,86, 0,87, соответственно. Предложен алгоритм распознавания различных типов двигательной активности человека по видеоданным. В основе алгоритма лежат методы машинного обучения и глубокого обучения. Проведено теоретико-экспериментальное исследование целесообразности использования системы из нескольких биорадиолокаторов для повышения качества регистрации паттернов дыхания и двигательной активности. Доказано, что использование системы, состоящей из нескольких биорадилокаторов, предпочтительней использования одиночного биорадиолокатора для случаев, когда положение испытуемого в ходе проведения эксперимента может изменяться. В это случае использование системы из двух радиолокаторов характеризуется приростом точности более 10 %, что обусловлено нивелированием влияния неоптимальности расположения испытуемого по отношению к радиолокатору.

Составлен план работ на заключительный этап выполнения проекта.

Two-channel Bioradar for Stress Monitoring

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Abstract— In present work, we propose a two-channel bioradar for non-contact everyday monitoring of mental stress level. The bioradar was designed by using two single-chip transceivers KLC-5 (RFbeam), a customized amplifier, and 16-bit precision ADC. As a microcontroller board we used an Arduino UNO board. Usage of two transceivers allows more accurate detection of respiration and heartbeat pattern compared to a single transceiver architecture. A total of 42 subjects (18 males and 24 females) in the age group between 20 and 21 years participated in the study. All subjects gave their informed consent prior to the start of the experiments. The information about respiration and heartbeat variability derived from the bioradar signal is used to classify the stress state of the subject. Processing of the experimental results showed that the designed two-channel bioradar can be used as a simple and relatively easy to implement a non-contact method for the stress monitoring.

1. INTRODUCTION

Stress is a normal organism response to changing environmental conditions. It helps deal with everyday challenges. In the short term stress may results in fatigue, fit to work decreasing, anxiety, etc. However, a chronic stress, which is one of the fundamental problems of todays society, may result in irreversible physiological and psychological shifts, which in the long term increase the risk of such socially significant health problems as cardiovascular diseases [1],[2], obesity [3], diabetes [4], sleep disorders [5],[6] and depression [7].

Although there are numerous psychological questionnaires to estimate stress, their results need to be interpreted by an expert. Moreover, there are stress detection techniques based on measuring some physiological parameters, such as level of cortisol [8],[9], skin conductance [10],[11], blood pressure [12], heart rate variability (HRV) [13], pupil diameter [14] and facial expression [15], etc. The main drawback of these methods is their need of contact with the human body or even taking blood samples (in case of measuring cortisol level), which may cause a discomfort to the patient and makes these methods inappropriate for everyday usage.

There are mobile apps, e.g. [16], stated to be able to monitor mental stress, but the majority of them were not verified in realistic conditions. Moreover, they take into account only heart rate variability, which limits the informative value of such methods.

In the present paper we propose to use bioradar technique [17] for the detection of mental stress allowing noncontact unobtrusive detection of mental stress, which makes it suitable for everyday stress level estimation and even prolonged monitoring, which may be used for distinguishing hidden stress factors. One of the main advantages of the approach is its non-contact nature since the signals are taken by a bioradar that does not require any direct physical contact with the user. Non-contact methods have experienced a growing interest by the scientific community thanks to the high acceptance of patients [18].

2. METHODS

In present work, we propose a two-channel bioradar to solve this problem. Its architecture is depicted in Fig. 1. The bioradar was designed by using two single-chip high sensitivity dual channel transceivers KLC-5 (RFbeam) [19]. The transceiver operates at a frequency of 24 GHz, which may be varied by VCO input, and provides as an output signals two quadratures (I and Q). As the KLC-5 sensors do not have an integrated amplifier we designed amplifier adapted to monitor human vital signs by limiting bandwidth around 0.1 to 3 Hz. As analog-to-digital converter (ADC) we used a higher-precision ADC ADS1115, which provides 16-bit precision at 860 samples/second over I2C and can be configured as 4 single-ended input channels. As a micro-controller board, an Arduino UNO board was used.

Usage of two transceivers allows more accurate detection of respiration and heartbeat patterns compared to a single transceiver architecture. Moreover, such architecture allows separating vital

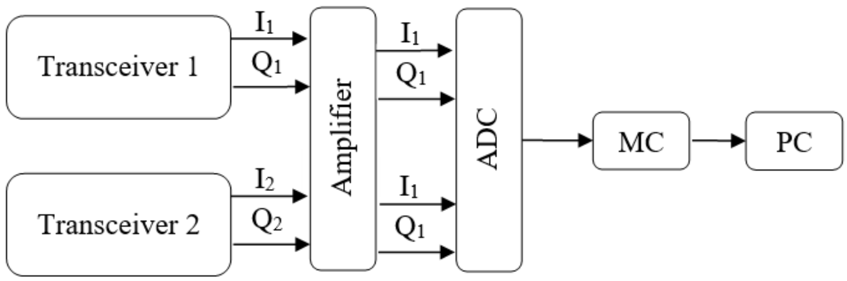

Figure 1: The scheme of the bioradar

signs patters of two different simultaneously observed humans, which is described in [20]. The technical characteristics of a two-channel bioradar designed at Bauman Moscow State Technical University, are as follows:

- operating frequency of transceiver No.1: 24.0 GHz;
- operating frequency of transceiver No.2: 24.2 GHz;
- radiated power density: 0.3 μW/cm^2;
- analog bandwidth: 0.1..3 Hz;
- sampling rate: 40 Hz.

3. EXPERIMENTS

Experiments were conducted in 2018 in Bauman Moscow State Technical University. A total of 42 practically healthy subjects (18 males and 24 females) in the age group between 20 and 21 years participated in the study as volunteers. All subjects gave their informed consent prior to the start of the experiments. Data of 7 examinees were excluded from the analysis because of bag signal quality. Information about the 35 examinees, which data were used for further analysis is given in Table 1.

Table 1: Information about the studied subjects

Male/Female	14/21
Age (Years)	20–21
Body Mass Index (kg/m^2)	21.6± 3.9(16.5–28.5)

During the experiment, an examinee sat in front of the bioradar at the distance of 0.5 m from each of two transceivers of the bioradar. The test procedure includes two staged (steady state and stress state) with the duration of 3 minutes each. During the first stage, the examinee was asked to relax and breathe normally. To imitate stress at the second stage, we used simple mental load test. Each volunteer was asked to solve a mathematical problem. We avoid using standard laboratory procedures used to reliably induce stress (e.g. the Trier social stress test) because they require taking blood and saliva samples to measure cortisol level. That is why we cannot tell the level of the stress, which was caused by used mental load test for each examinee, but only that the mental stress took place.

4. DATA PROCESSING AND FEATURES EXTRACTION

As it is known in realistic conditions phase demodulation of quadratures not always provide good results due to clutter caused by reflections from surrounding objects and walls of the room, where the examination takes place. That is why in present work we did not use phase demodulation. Instead, all 4 recorded bioradar signals (I and Q quadratures for each of two transceivers) was

Table 2: Classification results

		SVM classifier	
		Steady state	**Mental stress**
True Class	**Steady state**	29	6
	Mental stress	12	23
Accuracy, %		74.3	
Cohens kappa, %		48.6	

analyzed by using ICA method to subtract a single signal containing respiration and heartbeat patterns of the examinee.

After that extracted pattern processing had been made as follows.

- The baseline trend was suppressed by using a highpass Butterworth filter with a cut-off frequency of 0.05 Hz.
- Movement artifacts (if presented) were detected and removed from the analyzed signal by the algorithm proposed in [21].
- To extract respiration pattern of the examinee from the bioradar signal we used a 6th order lowpass Butterworth filter with a cut-off frequency of 0.7 Hz, which cleared respiration pattern from noise and clutter.
- To extract heartbeat pattern of the examinee from the bioradar signal we used a 6th order Butterworth filter with bandwidth [0.7, 3.0] Hz.
- For each free from movement artifacts period peaks and troughs were detected as a turning point. For better performance we used two additional threshold parameters: minimum peak height is equal to a 0.25 level of the average values of the local peaks for the analyzed interval, and a minimum distance between the peaks is 1 s, which was three times less than average respiration period of a human.

After filtration the following features were extracted from each record:

- In time domain: the average and standard deviation of respiration and heartbeat rate, distance between peaks, peaks and troughs, and between troughs.
- In frequency domain: the average, very low frequency (VLF 0,01-0,05 Hz), low frequency (LF 0,05-0,15 Hz) and high frequency (HF 0,15-0,5 Hz) powers, the LF/HF ratio, LF/average power (LFnu) and HF/average power (HFnu).

These features were used to discriminate steady state from the mental stress state while analyzing bioradar signal. Data processing and classification were done utilizing MATLAB 2017b.

5. RESULTS AND DISCUSSION

To discriminate steady state from mental stress in bioradar records we tried different classification techniques realized in ClassificationLearner in MATLAB, and chose the Medium Gaussian SVM classifier, which showed the best performance for the current problem. To evaluate the implemented classifiers and prevent overfitting, we apply the cross-validation k-folds technique with $k = 5$.

The confusion matrix, accuracy, and Cohens kappa coefficients, for proposed classifier are listed in Table 2.

While analyzing bioradar signals we have noticed that estimates of vital signs are less accurate for overweight people than for people with normal weight. It is reasonable because the movements of the examinee thorax caused by respiration and heartbeat are damped by subcutaneous fat layer. Considering this fact the classifier performance may be improved by excluding the data for overweight examinees (BMI $\geqslant$25). Only 22 out of 35 examinees had BMI<25. Classifier performance estimates for this group of examinees are given in Table 3.

Table 3: Classification results (examinees with BMI<25)

		SVM classifier	
		Steady state	**Mental stress**
True Class	**Steady state**	19	3
	Mental stress	4	18
Accuracy, %		84.1	
Cohens kappa, %		68.2	

6. CONCLUSION

In present work, we propose a two-channel bioradar which may be used for non-contact everyday monitoring of mental stress level. The proposed method allows detecting mental stress with the accuracy of 74%, which may be increased to 84 % if using only data for not overweighted volunteers.

However, the achieved results should be accepted with caution because the experimental data used for the classifier training are only for young practically healthy examinees.

The future activity will consider enriching the dataset. Moreover, we are planning to investigate the possibility of estimating stress level by means of bioradar.

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