Assessing Canine Emotional States Using an Accelerometer

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Abstract: The estimation of emotional states is important to maximize the performances of rescue dogs. Although such physiological data as heart rate and its variability are effective for estimation tasks, they are difficult to measure in noisy environments. In this paper, we proposed a method for emotional state estimation from acceleration data. The method classified positive, negative, and neutral emotions with 92% accuracy within one subject and 72% over all subjects. These accuracies are high enough for practical use in rescue dogs.

Keywords—**Rescue Dogs, Emotion Estimation, Machine Learning**

1. Introduction

Emotion, which is critical for working and learning, affects a person's performance both mentally and physically. For example, a strong motivation in rehabilitation improves performance [1]. This effect can even be applied to dogs. Some handlers of rescue dogs say rescue dogs show a lower performance during the task of finding injured people after disasters when they have negative emotions. In such cases, the handlers have to find a substitute. Thus, they need to recognize the animal's emotional state to maximize the performances of rescue dogs.

Canine emotional states in dogs are estimated from physiological data since emotion induces such changes as oxcytocin secretion, cortisol concentration, heart rate and heart rate variability [2], [3], [4], [5]. However, since physiological data are difficult to measure and easily corrupted by environmental noises in practical situations, simpler sensors are more convenient and preferable.

In this paper, we proposed a method to estimate emotional states using acceleration data. The acceleration data are easy to measure robustly and rich enough to estimate the action states of humans, horses and dogs [6], [7], [8]. Since emotional states also affect actions, they would be estimated from acceleration data.

2. Materials and Methods

Our estimation system consists of three parts: measurement, preprocessing, and classification. The second extracts effective features for classification and the last discriminates a given condition into one state, positive, negative, or neutral. The classifier was trained by the labeled data from experiments (see data collection). The data were also used to evaluate our system's performance using the cross validation [9].

2.1 Data Collection

The acceleration data in this study were collected in the experiment in [5] and [10]. The experiment was approved by the ethical committee of Azabu University.

Subjects

39 healthy dogs and their owners in Azabu University were recruited (Age, mean $\pm$ SE $= 4.56 \pm 0.56$ years).

Procedure

In the beginning, the owner stayed with his/her dog for five minutes (neutral condition). Next, the owner called the dog's name and gently petted it for five minutes (positive condition) and then returned to the neutral condition for five minutes. Next the owner departed from the experiment room and left the dog alone for five minutes (negative condition) before returning to the room. During the experiment, the dog's acceleration data were recorded (Fig. 1).

2.2 Measurement

The three-dimensional acceleration data were collected by a three-dimensional accelerometer (TSND 121, ATR Promotions, Japan) at a sampling frequency of 50 Hz (Fig. 2). ECG data were simultaneously collected in the experiments (TS-EMG01, ATR Promotions, Japan) but they were not used in the following analysis.

2.3 Preprocessing

To make features that are robust to the device-orientation, we calculated the acceleration's magnitude, which is invariant against device direction [6]. The features of our system are the powers of the short-time Fourier transform (STFT) with a window-size of 10.24 sec. and a shift-time of 1.28 sec.

2.4 Classification

Our system can employ any classifier in machine learning and signal processing [11]. In our study, we tested Support Vector Machine (SVM) [12] and Random Forest [15] since both of them are well-known and high generalization performance classifiers in the machine learning community.

Figure 1. Procedure of the experiment.

Figure 2. Accelerometer equipped to a dog.

SVM in our system was implemented using the R package ‘e1071’ [13]. The package provides an interface to `libsvm` which is a fast and easy-to-use implementation of the most popular SVM formulations and includes the most common kernels (linear, polynomial, RBF, and sigmoid). In our study, we used linear and RBF kernels. Since the problem was a multiclass classification, we employed one-versus-one strategy.

Random forest in our system was implemented using the R package ‘randomForest’ [14]. Random Forest is an ensemble learning method for both classification and regression that constructs a number of decision trees at training time and chooses its output class by voting.

The SVM and Random Forest parameters were chosen by grid search to maximize their performances using the cross validation [9].

2.5 Evaluation

We used 70% of the collected data for training and the remainder to evaluate the estimation ability.

The estimation was done in two ways: Estimation within a subject and estimation over all subjects. In the former, each classifier was trained using the dataset from one dog and evaluated using the same dataset. In the latter, the data from all the dogs were mixed for training and evaluation.

3. Results

Nine of 39 dogs were excluded from the analysis because three dogs did not lie down within an hour, three failed in recording their RRI due to equipment trouble, and three showed unusual behavior during the positive condition [5].

In both estimation cases within a subject and over subjects, Random Forest showed better accuracy (92% and 71%, respectively) than SVM with the linear kernel (70% and 41%, respectively) or the radial basis kernel (50% and 41%, respectively). in classify ing positive, negative, and neutral emotions (Fig. 3).

4. Discussion

Although the accuracy of 71% over all subjects of Random Forest was not high, because the rescue dogs were registered in advance and were collected data to make a tailored classifier. Hence, the classifier is practical for rescue dogs since the accuracy of 92% within a dog was surprisingly high.

Compared to the estimation accuracy of 92% of Random Forest, those of SVMs with linear and radial basis kernels were much lower. This tendency was seen in other applications [16].

5. Conclusions

We proposed a method for emotional state estimation from acceleration data. The method, which consisted of the STFT based preprocessing and a Random Forest classifier, classified each dog’s emotional state with 92% accuracy on average when trained with the dog’s data. The accuracy is high enough for practical use in rescue dogs.

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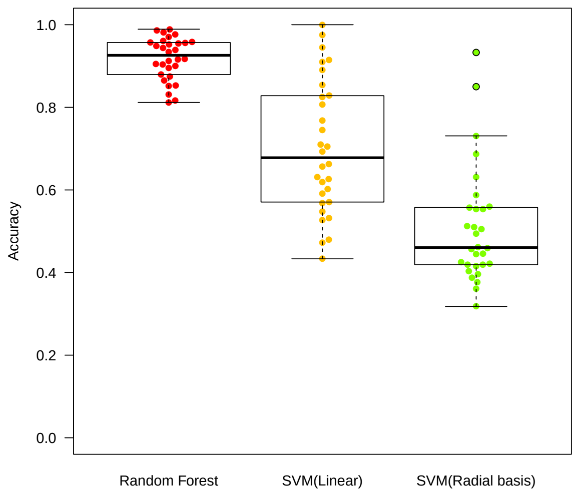
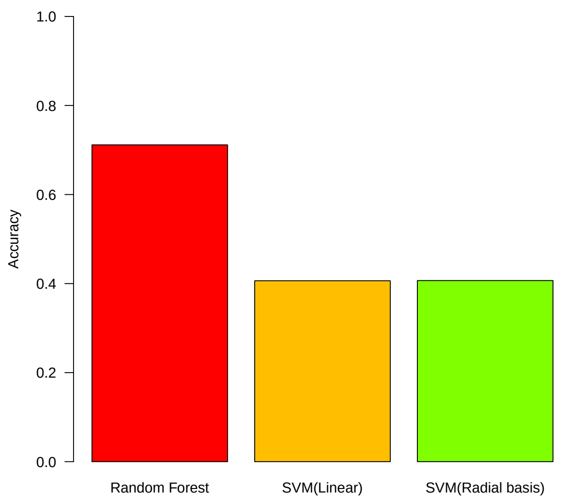


(a) estimation within a subject



(b) estimation over subjects

Figure 3. Estimation accuracy of our system.

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