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Strength training exercises classification with counting the number of repetitions in real time.

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SUMMARY

The paper investigated the problem of detecting strength-training exercises and counting the number of repetitions to automate the process of collecting statistics during strength training. The algorithm for classifying exercises has been improved by analyzing the results based on three different datasets.

INTRODUCTION

Virtual assistants are increasingly being introduced into our lives, as they allow us to solve a wide range of routine tasks, including automatic calendar reminders, smart homes, and mobile banking applications with budget analysis. However, are these applications capable of replacing a live trainer? The first part of the paper discusses issues related to the preparation of the dataset and possible techniques for increasing the number of its examples. Different types of classifiers are considered. The choice of one of them was made by varying their parameters and using different datasets. In the second part of the paper, various approaches to counting the number of repetitions are considered. They are compared based on a video with a predetermined number of exercises and repetitions.

THEORY

In this paper, we will consider three implementations of classical machine learning methods from the sklearn module: the kNN, the SVM, and the SGD classifier. In the future, it is also planned to use neural networks. In this problem, well-structured numerical vectors are the input, so the choice of classical machine learning algorithms is more than justified. It is worth noting that the data submitted to the input of the machine learning algorithm does not relate to personal data since it is impossible to uniquely identify a person using a set of 33 coordinates. The video signal submitted to the input during the operation of the algorithm is used only for coordinate analysis and does not save the images received at the input or any other information about the user.

SCHEME & DATASETS

The dataset of eight types of exercises presented in Table 1 was prepared for training and testing the classifier. The selected dataset can be augmented in several ways. The idea of randomly changing the coordinates of body positions within a small range of values (~2% of the initial state) was proposed, as if a person made a small oscillatory movement with his whole body. A deadlift and a lat pulldown were specially added to the datasets to investigate the possibility of the classifier successfully distinguishing these exercises. For real-time data processing, the Video Capture method from the OpenCV library was used, as well as the Pose method from the MediaPipe library, to determine the coordinates of certain points of the body.

RESULTS

According to the error matrix of the linear support vector classifier (Fig. 1a) and Table 1, the difference in the positions of the bench press is the greatest difficulty for the classifier. As a result of the experiment, based on the f1-score (Table 2), accuracy, and error matrix (Fig. 1b), the kNN with three neighbors was chosen.

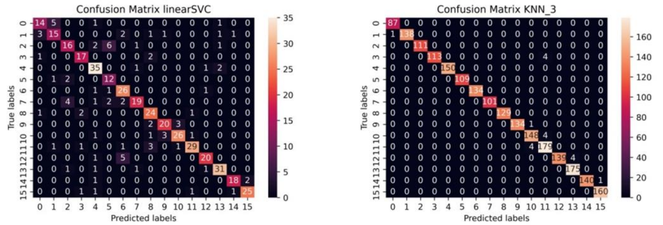

Figure 1. (a) The confusion matrix of the linear SVC for the initial dataset, (b) the confusion matrix of the kNN with 3 neighbors for the augmented dataset with a reduced number of features (66).

Several approaches have been proposed for calculating the number of repetitions. The first approach is that, from the dictionary containing the probability of belonging to a certain class, the class that has the maximum value is selected. Depending on the previous state, there is an increase in the number of repetitions of one of the exercises. The second and third algorithms for counting the number of repetitions were developed based on the first few results obtained from the classifier (the first 2 and 3 matches, respectively).

As we can see in Table 3, all the exercises were repeated, with the exception of situps. According to the assumption, the second and third approaches give the number of repetitions closest to the etalon, and their values differ only for pull-ups and push-ups. It is worth noting the excellent separation of similar exercises, such as lat pulldowns and pull-ups, as well as exercises containing similar positions, such as deadlifts and biceps curls.

Table 1. The types of exercises considered in the datasets and their corresponding numerical designations.

Exercise	state	№	Exercise	state	№
Benchpress	relaxation	0	Lat Pulldown	exertion	8
	exertion	1		relaxation	9
Biceps curl	relaxation	2	Pull-ups	relaxation	10
	exertion	3		exertion	11
Deadlifts	relaxation	4	Push-ups	exertion	12
	exertion	5		relaxation	13
Dips	relaxation	6	Situps	exertion	14
	exertion	7		relaxation	15

Table 2. F1-Score of 5 types of classifiers for 3 types of datasets.

	KNN_3	KNN_5	SGD	SVC	linearSVC
An Initial Data	69.51	68.77	64.06	70.64	**79.06**
Dataset was augmented 5 times (99 features)	99.33	95.43	76.52	87.03	91.88
Dataset was augmented 5 times (66 features)	**99.22**	94.91	76.95	87.06	89.76

Table 3. Test results of 3 types of counters for a video containing a set of 8 exercises with repetitions.

	Exercise name	Etalon	First	Second	Third
1	Benchpress	2/2 (4)	1/2 (3)	3/2 (5)	2/2 (4)
2	Pull-ups	4/4 (8)	3/4 (7)	4/5 (9)	4/3 (7)
3	Situps	2	2	2	2
4	Deadlifts	2/2 (4)	1/0 (1)	2/2 (4)	2/2 (4)
5	Biceps curl	3/2 (5)	3/2 (5)	3/2 (5)	3/2 (5)
6	Push-ups	5/2 (7)	5/2 (7)	5/3 (8)	6/2 (8)
7	Dips	3/2 (5)	2/2 (4)	2/2 (4)	2/2 (4)
8	Lat Pulldown	3/4 (7)	3/3 (6)	3/4 (7)	3/4 (7)

CONCLUSIONS

1. The algorithm for multiclass classification of strength training exercises in real time and counting the number of repetitions was developed based on the Pose solution by a group of researchers from MediaPipe.
2. According to the results obtained for various classifiers, a standard implementation of the kNN with three neighbors and Minkowski distance as a metric was chosen.
3. Based on the etalon video, the third of the three possible counters was selected.