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OPTIMISTIC PREDICTION METHOD FOR VALUE COUNTER OF PHYSICAL EXERCISES REPETITIONS ON THE OUTPUT SIGNAL OF THE NEURAL NETWORK

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Abstract

In recent years, due to the rapid development of artificial intelligence systems and computer vision new neural network architectures appeared, which main function is to assess the three-dimensional posture of a person on one video stream. Posture assessment, signal analysis, and result generation for the end-user inevitably take some time, while in some cases the end-user needs immediate feedback.

The author proposes a method of optimistic prediction of exercise repetitions count before the end of a specific iteration of the exercise during the analysis of the neural network output signal, which estimates the three-dimensional position of a person. An example of the method is given on the basis of the exercise "squats", the calculation of which is performed using a state machine. This method is based on the addition of the exercise iteration counting state machine. This addition increments the counter in the middle of the exercise and performs the decrement if the exercise is declared invalid after the end of the exercise. Application of this method in algorithms of the analysis of exercise will allow emitting number of exercise repetitions without delay as the human coach does.

This method is not specific to any particular neural network and therefore can be used at the output of almost any system that analyzes the sequence of positions of human joints in space using a state machine.

The article also presents the test results of the proposed method. The proposed test method can be applied to any cyclic exercise.

Keywords: optimistic prediction; neural networks; computer vision; biomechanics; Artificial Intelligence; squat; state machine; instant repetition counter.

Introduction. Recent advances in neural network architectures for computer vision (CV) allow recognition of the 3d human posture in space using a single video stream, that is, how a person with one closed eye can do so. A significant limitation of these systems is the high computational complexity, which leads to a delay between receiving the video stream and outputting the processing results to the end-user. The rapid development of specialized computational microchips reduces the delay before the output of the results, but for the best user experience similar to work with a human trainer, the delay should disappear at all.

Optimistic counting of the number of exercise repetitions will allow to develop exercise counters that predict the number of exercises before a specific iteration of the exercise is completed. This will allow the development of methods for analyzing movements with a more positive user experience than those that do not use optimistic counting and increment the counter during the first phase of the next iteration.

Review of publications on the topic. In the twenty-first century, many approaches have been proposed to solve the problem of calculating iterations of exercise by video stream. Classic methods include the results of research that began after the advent of digital video cameras [1, 2, 3]. Methods based on artificial intelligence are being actively studied nowadays [4, 5, 6, 7].

All of these methods can work offline and with some modifications online. In order to apply the offline method in online processing, it is enough to restart it every fixed period of time on all historical data, and update the counter according to the result. But in any case, all these methods take time to calculate, which leads to delayed feedback to the user.

To avoid latency because of the calculation delay, it is recommended to use signal prediction methods.

The sequence of exercises is a quasi-periodic signal, and therefore to predict the end of the iteration, it is logical to use complex tools developed for the analysis of quasi-periodic sequences [9, 10].

But most prediction methods are designed to analyze the input signal with low emissions [9]. In the case of pose sequence analysis, the signal has regular statistically unpredictable emissions, which does not allow the use of these tools without pre-treatment. Pre-treatment, which should filter out anomalies and / or smooth the signal, can be done on the basis of:

1) moving average;

2) Savitzky–Golay filter.

These and most other signal preprocessing methods require an excess of data at the ends of the sequence [11], which excludes the possibility of their use with the above-mentioned methods of prediction, because the need for excess data leads to a delay that is proportional to the length of the excess.

In [12] the author proposed a new method of the neural network output signal analysis, which estimates the position of a person in space, which performs the calculation of repetitions of the exercise "squat". This method is based on the state machine, which adds one to the repetition counter at the end of the exercise cycle. The application of this method in the initial stages of the exercise analysis algorithm will help to further develop systems that test squats and help athletes and coaches during training, as well as scientists in the field of biomechanics during their professional activities. A distinctive feature of this method is durability to both input signal emissions, i.e. incorrect results of recognition of human posture by the neural network, and to human movements that do not belong to the exercise directly. Also, the application of this method to the analysis of the neural network signal allows to combine the positive qualities of neural networks used in computer vision (the admissibility of the high variability of clothing and background), and the positive qualities of analytical and algorithmic methods (easy interpretation of results, easy debugging, possibility use of subject experience of specialists for selection of parameters).

The aim of this study is the presentation of an optimistic prediction method for the number of exercise iterations based on the neural network output signal, which evaluates the 3d position of a person by one video stream, on the example of the exercise "squat". This method can be used to implement systems with instant feedback for the end-user.

Results and discussion. *Input signal.* At the input of the system that implements the method described in the article, a sequence of three-dimensional coordinates of each human joint is expected. An example of modern neural networks that emit this type of signal is described in the articles [13, 14, 15]. Also, such a signal can be obtained from classic systems such as MoCAP systems based on gyroscopes (Xsens), or on the analysis of the state of labels from several cameras (Vicon), as well as RGB-D sensors (Kinect) [16].

Signal analysis (counting repetitions of exercises) of a modern neural network is a more difficult task than signal analysis of the classical system, due to the fact that at the moment such a signal is less accurate, and the statistical characteristics of emissions of such a signal do not have a mathematical model.

To analyze such a multidimensional signal as a sequence of human poses, it is necessary to develop a system that leads to a visual representation of the signal. Visual representation of human poses in space at different angles was made using the Python3 programming language and the matplotlib package (Fig. 1) [17].

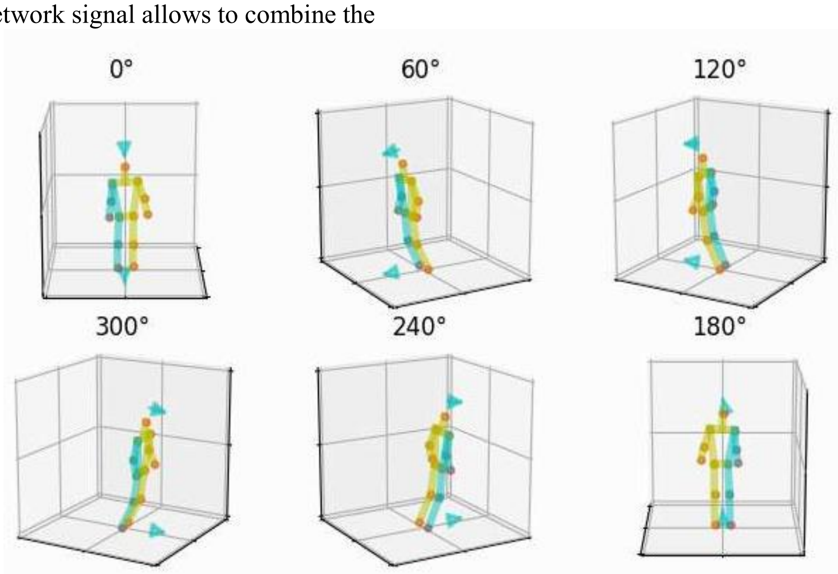

Fig. 1. Visual representation of the signal

Preprocessing of the input signal.

Preprocessing of the input signal is not performed.

Input signal processing.

The proposed state machine is shown in Fig. 2.

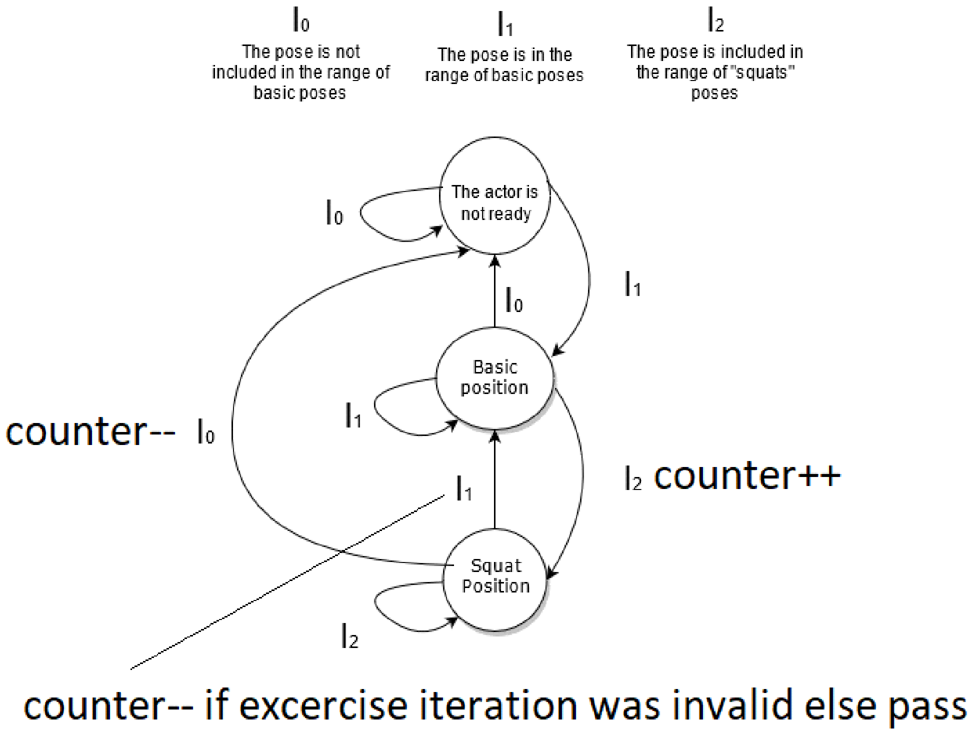

Fig. 2. Representation of the state machine

To calculate squats, a state machine from a previous study is used [12]. State machine transactions occur when the posture class is changed.

Classes of poses:

1) I_0 – the pose cannot be part of the exercise (not included in the range of base exercise poses).

The position is reached if the camera was installed by these person, who moves from the camera to the place of exercise. Also, a person may find himself in this position if the exercise is interrupted, the person has stopped performing the exercise, and for example, turned around and went somewhere.

2) I_1 – posture is the basic position of the exercise (for squats it is a pose when the person is standing straight, with the face directed to the camera, with outstretched knees)

3) I_2 – the pose enters the space of poses, which can be called as "squat".

Mathematical criteria by which it becomes possible to determine the affiliation of a pose to a particular class:

1. Pose I_0. Any pose at which the angle between:

the perpendicular to the plane "left hip-right hip-starting point of the neck", projected on the floor plane

and

the line connecting the point of the camera and the human head, projected on the plane of the floor

is more than 30 degrees.

2. Pose I_1. Any pose, which:

1) is not I_0;

2) in which the sum of knee angles divided by two is less than 90 degrees;

3) to which 2 previous poses met conditions 1 and 2.

3. Pose I_2. Any pose, which:

1) is not I_0;

2) in which the sum of knee angles divided by two is less than 80 degrees;

3) to which 2 previous poses met conditions 1 and 2.

Intersection of the second requirement to poses I_1 and I_2 is in the space of poses in which the sum of knee angles divided by two is more than 80 degrees and less than 90. When the pose is found in this space, it is classified according to requirement 3 (2 previous poses class).

Optimistic prediction of the number of iterations:

When moving from the "Basic position" to the "Squat position" state, the increment of the counter is performed.

When moving from the "Squat Position" state to the "Actor is not ready" state, the counter decrements.

When moving from the state "Squat Position" to the state "Basic position" the validity of the squat is checked in the background and in case it was not valid - the decrement of the counter is performed (Fig. 3).

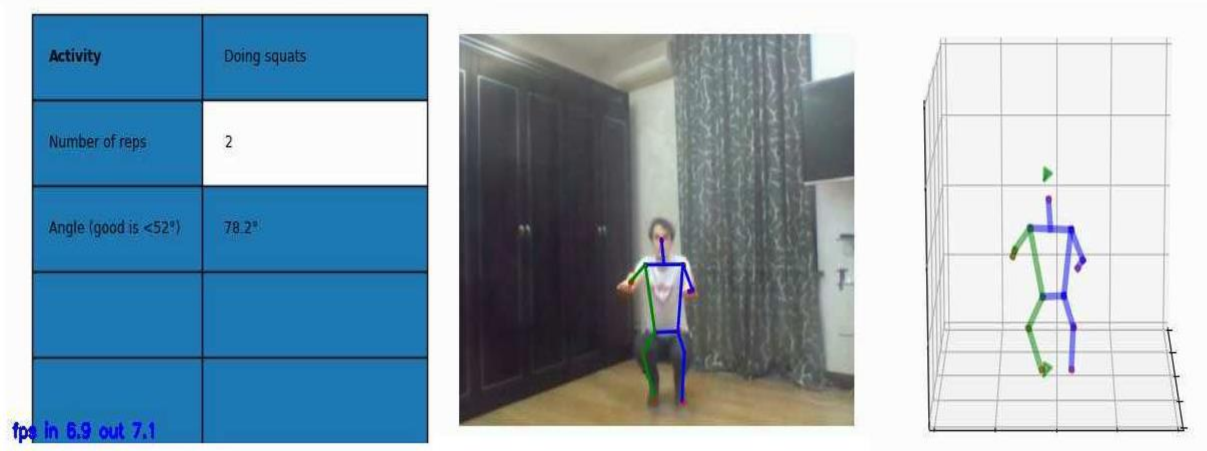

Fig. 3. Pose with a squat of 19 degrees (I_1)

Testing and problem analysis.

Tests of this method were performed by comparing the moment of increment of the counter by a coach, and the proposed method. It turned out that the moment of increment of the counter by the proposed method of optimistic prediction of the number of iterations almost coincides with the human-coach.

Differences with humans were found in the final step of the method. People did not correct the counter in case of incorrect exercise. Instead, the person repeated the value of the counter during the next increment.

Results and discussion. According to the results of the study, it can be concluded that the presented method of optimistic prediction for exercise repetitions count can be used to simulate the instantaneous signal processing from the neural network. This approach can also be used to predict the number of other iterative exercise repetitions, the iteration of which lasts more than a second (in the case of short iterations - the prediction makes little practical sense).

In the future, it is planned to conduct research on expanding the class of exercises under analysis, in particular, such as the exercise "Lunges" and the exercise "Knee lifting".

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АНАЛИЗ ВЛИЯНИЯ КОЛИЧЕСТВА УРОВНЕЙ ДЕТАЛИЗАЦИИ НА ПРОИЗВОДИТЕЛЬНОСТЬ В UNREAL ENGINE 4

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ANALYSIS OF THE EFFECT OF THE NUMBER OF LEVELS OF DETAIL FOR PERFORMANCE IN UNREAL ENGINE 4

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Аннотация

Проведен сравнительный анализ производительности рендеринга игровой локации в зависимости от количества уровней детализации. В качестве исследуемых объектов использованы трехмерные модели из бесплатно распространяемого для Unreal Engine 4 пакета Open World Demo Collection. Результаты исследований обеспечивают возможность выбора оптимального количества уровней детализации объектов на сцене.

Abstract

A comparative analysis of the performance of rendering of the game location is carried out depending on the number of levels of detail. Three-dimensional models from the Open World Demo Collection are used as the objects under study. The results of the research provide the ability to select the optimal number of levels of detail objects on the scene.

Ключевые слова: Level of detail, производительность, Frame per second, трехмерная графика, Unreal Engine 4.

Keywords: Level of Details, Performance, Frame Per Second, Three-dimensional graphics, Unreal Engine 4.

Введение. Система уровней детализации (level of details) давно успешно используется в качестве метода оптимизации графики. Например, уровни детализации применялись в игре 1998 года «Spyro the Dragon». Суть этого метода заключается в том, что с увеличением расстояния игровой движок вместо оригинальной высоко детализированной модели будет подгружать упрощенную модель, снижая нагрузку на вычислительную систему [1], но при этом пользователь не должен видеть внешней разницы между ними. Однако у этого подхода есть существенный недостаток. Поскольку теперь к одной оригинальной модели добавляется одна или несколько упрощенных моделей то возрастает требования к объему и скорости накопителя, объему оперативной памяти и памяти видеокарты. В 2000х годах из-за ограничений на объем памяти и скорость доступа к накопителю многие разработчики были вынуждены ограничивать и количество уровней детализации. Например, рекомендовалось не использовать количество уровней детализации больше трех, т.е. больше одной оригинальной модели и двух упрощенных.[2] Однако сегодня в условиях взрывного роста характеристик потребительского качества персональных компьютеров стала очевидной необходимость выполнения исследований, связанных с выбором оптимального количества уровней детализации объектов на сцене для достижения требуемого быстродействия и плавности переходов между уровнями детализации.

В статье показана возможность выбора оптимального количества уровней детализации объектов на сцене для повышения производительности рендеринга игровой локации.

Экспериментальное исследование влияния на производительность (FPS) различных факторов. В процессе экспериментирования необходимо определить оптимальное количество уровней детализации трехмерных объектов. Основными характеристиками для анализа будут: количество кадров в секунду, время построения одного кадра в миллисекундах, потребление оперативной памяти, занимаемое моделью место на диске.

Эксперимент 1. Для снижения трудозатрат разработчика-исследователя сформирована тесто-