Controlling the Correctness of Physical Exercises Using Microsoft Kinect

Vybornyi A.I., Rozaliev V.L., Orlova Yu.A.
Volgograd State Technical University,
Volgograd, Russia
Email: iamalexvybornyi@gmail.com
Email: vladimir.rozaliev@gmail.com
Email: yulia.orlova@gmail.com

Zaboleeva-Zotova A.V., Petrovsky A.B.
Federal Research Center
«Computer Sciences and Control»,
RAS, Moscow
Email: zabzot@gmail.com
Email: pab@isa.ru

***Abstract*—This document contains the description of the program for controlling the correctness of physical exercises using Microsoft Kinect. The method of the comparison between live motions performed by the user and recorded motions is described. Presented short review of existing systems and description of testing the program.**

***Keywords*—Physical exercises, motions, Microsoft Kinect, motion comparison, production rule system.**

I. Introduction

Nowadays the automation is used in many areas, including sport and physical culture. Most of the modern consoles have motion sensors. It gives developers big opportunities. The application of the new technologies and methods may be interesting and popular among people who care about their health, but do not have time for the gym and gamers who are interested in new experience. It is possible that in the near future people will give up going to the gym and hiring personal trainers and will use a virtual coach instead, doing physicals exercises at home in front of their consoles.

Program that is being developed may be useful both for the people who are recovering from injuries and for the people who just don't have enough time to go to the gym. The main objective of the program is to compare a predetermined sequence of the human movement with actual human movement captured via Kinect. The program should allow user to train at home controlling the way exercises are performed by the user and reporting to user about the mistakes he makes.

II. Existing virtual training systems

A. Nike+ Kinect Training

This system allows user to train at home with the help of the virtual coach using Microsoft Kinect sensor.

The biggest advantage of this system is the diversity of physical exercises and automatic selection of these exercises according to the user's goals. With the first launch of the system the user is tested for his shape and abilities and then he can choose the goal of the training sessions.This system also provides user with the feedback about the performance of the exercises through the voice tips of the virtual coach.

Considering disadvantages it is worth mentioning that the accuracy of the exercises performance tracking is not really that good. System may sometimes ignore quite poor form of the exercise performance by the user or on the contrary may not count repetitions with the good form.

B. The Vera System

The Vera System is a program that is used by the medical institutions to help people in rehabilitation after injuries, surgeries, diseases etc. It is available only for the clinics that ordered it, so it's quite hard to fully review this system.

According to the developers, doctors and patients this system suits perfectly exactly for the rehabilitation. Doctor can track the progress of his patient and for the patient it's a lot easier to do exercises because system demonstrates the technique and tracks the performance of the movement. And the accuracy of exercises performance tracking is the biggest advantage of the system. It reports about any inaccuracy in the user motions.

C. Your Shape: Fitness Evolved

Your Shape: Fitness Evolved is a game for Xbox 360 consoles. It allows user to do usual physical exercises and also to do some different physical activity such as boxing movements, dancing, yoga etc.

The game is quite colourful, interface looks nice and bright. User can move around and have fun. Represented exercises are divided by muscle groups.

Overall, the game looks pretty good, but it's not very accurate at tracking performance of the movements. The repetitions may be counted even in those movements that reminds the standard only remotely. This is the main disadvantage of this system.

D. Conclusion

Three of the most popular and convenient existing virtual training systems are described in the sections above. There are some other similar systems that weren't mentioned, but the majority of them look more like games for entertainment than training systems.

As for the systems that were mentioned above, though they are better than most of the alternatives, each of them has it's disadvantages. Nike+ Kinect Training and Your Shape: Fitness

Evolved aren't accurate enough to detect all the mistakes in the user motions and The Vera System is available only for the medical institutions (most of the people do not have any access to it).

III. Analysis methods of the control of the correct physical exercises performance

The implementation of the program for the control of the correct physical exercises performance was divided into two main phases: recording phase and comparison phase.

A. Recording phase

In the first phase we needed to record the exercise and save it to file for the further use as a movement with a perfect form.

A few approaches have been tried for the recording. Firstly, we were trying to save only the coordinates and types of the joints. But this approach was too inefficient. Another suggested method was serialization and in the end it was decided to use it.

Serialization is the process of converting an object into a stream of bytes in order to store the object or transmit it to memory, a database, or a file. Its main purpose is to save the state of an object in order to be able to recreate it when needed. The process of the serialization is shown on the figure 1.

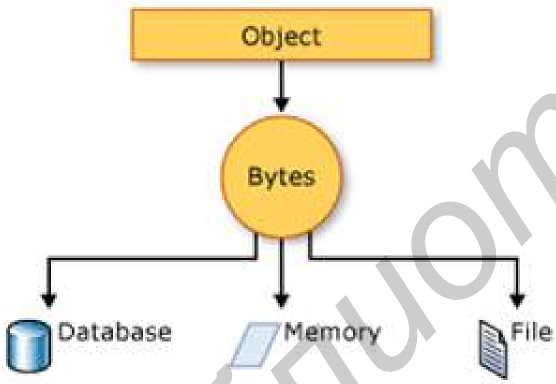

Fig. 1. Overall process of the serialization

The object is serialized to a stream, which carries not just the data, but information about the object's type, such as its version, culture, and assembly name. From that stream, it can be stored in a database, a file, or memory.

Thus, with the use of the serialization the collection of frames with the data about the skeleton is saved to the file. This approach is good because we don't need to divide skeleton data and take only particular parts of it. Instead, the collection of frames is saved and each frame contains the whole information about the skeleton including coordinates, joints, type of joints, positions, orientation etc.

After we got the file with the information about the exercise we needed to read this file and process the data. To do it we used deserialization (the reverse process to the serialization).

B. Comparison phase

Now that we have saved motion data about the exercise that will be considered as a standard, we need to compare the standard with the user motion.

The basic idea is to compare the angles of the joints in the recorded motion standard with angles of the joints in the user motion. So, everything comes down to the calculation of the angles between vectors and comparison of these angles. In our case parts of the human body may be considered as vectors. Thus we need to know the values of the angles of the joints in the recorded motion standard and in the user motion. These angles are calculated with the use of the same method.

Method takes 4 arguments: skeleton data and 3 arguments which represent the types of the joints. For example, in addition to the skeleton data it could be three joint types - JointType.ShoulderCenter, JointType.ShoulderLeft, JointType.ElbowLeft. If we pass these arguments in our method the angle will be calculated in the left shoulder joint (JointType.ShoulderLeft). Combining the joints, we can get two vectors that have one common point, and this point will be the joint in which we are calculating the angle. Coordinates of vectors are obtained, vectors are normalized, cross product and dot product are calculated and then the angle between vectors is calculated using Atan2 method. This method returns the angle whose tangent is the quotient of two specified numbers.

The angles of the joints in the user motion are calculated every frame. For the motion standard angles are calculated in advance and stored in list.

Because it's almost impossible to repeat the motion standard with 100 percent accuracy program takes into account little errors in the user motion. At this point the error is 15 degrees in the value of the angles. Also, program compares current frame of the user motion not only with the one frame of the motion standard but with the 16 closest frames (8 previous and 8 subsequent) because user may do exercise a little faster or a little slower than standard motion demands. Angles of the joints in the recorded motion standard and angles of the joints in the user motion are compared in the loop. If the difference between angles is less than 15 degrees it means that user is doing motion correctly.

To calculate the accuracy of the particular repetition in a particular exercise using described above algorithm the result of the comparison (whether the motion has been done correctly or not) is saved and stored. And the results of the comparison are stored for every joint involved in the exercise. When motion standard "ends" (all the frames of the recorded motion has been played) the analysis of the results starts. For the analysis the percent of the exercise performance correctness is calculated. The amount of frames in which the motions of the user were correct is divided by the total amount of frames in this exercise. It is done for every joint involved in the exercise. And after this the conclusion is made about whether this repetition may be considered as the correct or not. If the percent of correctness for each joint is above 85 and the arithmetic mean of all the percents is above 90 then this repetition may be considered as a correctly performed.

To analyze whether the motion is done by the user correctly or not we also used production rule system. All the exercises were divided into groups by the joints that are used in the exercises. And the production rules were set for each group. The example of the production rules for one of the exercises (overhead squats) is described below.

The next joints are used in this exercise:

- Shoulders
- Elbows
- Spine
- Hips
- Knees

Production rules for this exercise:

- Rule 1: IF (exercise = jumping jack) OR (exercise = squats) OR (exercise = overhead squats) OR (exercise = hip raises) THEN (compare angles in shoulder joints = yes) AND (compare angles in elbow joints = yes) AND (compare angles in spine = yes) AND (compare angles in hips = yes) AND (compare angles in knees = yes)
- Rule 2: IF (difference between angles in shoulder joints < 15) THEN (result of the shoulder joints comparison in the current frame = true)
- Rule 3: IF (difference between angles in shoulder joints >= 15) THEN (result of the shoulder joints comparison in the current frame = false)
- Rule 4: IF (difference between angles in elbow joints < 15) THEN (result of the elbow joints comparison in the current frame = true)
- Rule 5: IF (difference between angles in elbow joints >= 15) THEN (result of the elbow joints comparison in the current frame = false)
- Rule 6: IF (difference between angles in spine < 15) THEN (result of the comparison in spine in the current frame = true)
- Rule 7: IF (difference between angles in spine >= 15) THEN (result of the comparison in spine in the current frame = false)
- Rule 8: IF (difference between angles in hips < 15) THEN (result of the comparison in hips in the current frame = true)
- Rule 9: IF (difference between angles in hips >= 15) THEN (result of the comparison in hips in the current frame = false)
- Rule 10: IF (difference between angles in knee joints < 15) THEN (result of the knee joints comparison in the current frame = true)
- Rule 11: IF (difference between angles in knee joints >= 15) THEN (result of the knee joints comparison in the current frame = false)
- Rule 12: IF (percent of correctness in each joint >= 85) AND (average percent of correctness >= 90) THEN (repetition is counted = true)
- Rule 13: IF (percent of correctness in each joint < 85) AND (average percent of correctness < 90) THEN (repetition is counted = false)

The screenshots of the program while user is doing the exercise are shown on the figures 2 and 3.

Fig. 2. Exercise is performed correctly

Fig. 3. Exercise is performed incorrectly

IV. Testing of the program

The program has been tested by 10 users and each of them tested all 10 exercises represented in the program. The results of the testing are shown in the tables 1 and 2. If the user was able to do a few repetitions of the exercise in the table this exercise was marked with +. If the user wasn't able to do even one repetition of the exercise in the table this exercise was marked with -. If the user was able to do a few repetitions of the exercise with some difficulties in the table this exercise was marked with +-.

Thrusters and hip raises caused the biggest difficulties among users. It means that we need to make these exercises easier (for example, by decreasing the percent of correctness threshold value) or replace them with the other exercises.

It is also worth mentioning that most of the users needed some time to get used to the way the exercises should be performed. Perhaps, decreasing the percent of correctness threshold value of the exercises would be the good idea not

Table I. RESULTS OF THE TESTING, PART 1

	User 1	User 2	User 3	User 4	User 5
Hand raises	+	+	+	+	+
Elbow rotation	+	+	+-	+	+
Military press	+	+	+	+	+
Jumping Jack	+	+-	+-	+	+
Side bend	+	+-	+-	+-	+-
Squats	+	+-	+-	+-	+-
Overhead squats	+	+	+-	+-	+-
Thrusters	+	-	-	-	-
Side lunges	+	+	+	+	+
Hip raises	+	-	-	-	-

Table II. RESULTS OF THE TESTING, PART 2

	User 6	User 7	User 8	User 9	User 10
Hand raises	+	+	+	+	+
Elbow rotation	+	+	+-	+	+
Military press	+-	+	+	+	+
Jumping Jack	+-	+-	+-	+	+-
Side bend	+-	+	+-	+	+-
Squats	+-	+-	+-	+	+-
Overhead squats	+	+-	+-	+	+
Thrusters	-	-	-	+-	-
Side lunges	+	+	+	+	+
Hip raises	-	-	-	-	-

only for those movement that caused some difficulties among users but also for the other exercises.

Summing up the results of the testing we may say that users handled the performance of most of the exercises quite well. Nevertheless, some of the exercises still need corrections or replacing.

V. CONCLUSION

This document contains the description of the program for the control of the correct physical exercises performance implementation using Microsoft Kinect.

The implementation of the program was divided into two main phases: recording phase and comparison phase.

In the first phase we had to record the human-motion and save it into a file for later processing. A few approaches (on how to read and save those data from tracked human skeleton) have been tried here. The successful approach that is used now is a serialization – saving the collection of skeleton frames into a data structure in binary format.

The second phase is a comparison between live motions performed by the user and recorded motions. The main idea is to calculate recorded motion's joint angles and user's joint angles, compare them, considering a little error and then with the use of the production rule system analyze performed exercise to know whether the motion was correct or not.

At the moment there are ten exercises represented in the program, involving different joints and muscle groups. Program gives user the feedback about the performance of the exercises by marking the joints in which user make mistakes with red colour. Also, for more detailed information about the accuracy of the repetition performance user can open the output file that contains the percents of the accuracy for every joint in every exercise in every repetition. The format of the output file is shown in the appendix A.

The further development of the program is planned for the future. The plan is to combine the current method of the comparison with the gesture recognition methods to increase efficiency and accuracy and also to include more exercise to the program.

APPENDIX A
FORMAT OF THE OUTPUT FILE

Designations "L Sh", "R Sh", "L El" etc. are abbreviated names of the joints. L and R mean left and right side respectively. Name of the joints may be written fully (Spine, Hip etc.), or reduced to the first two letters (Sh - Shoulder, El = Elbow etc.).

An example of a fragment of the output file:

Exercise 1: L Sh=90 R Sh=90 R El=78,8888888888889 L El=81,1111111111111 Hip Center R=100 Hip Center L=100 Spine=98,8888888888889 Overall = 91,2698412698413

Exercise 1: L Sh=100 R Sh=98,8888888888889 R El=100 L El=100 Hip Center R=100 Hip Center L=100 Spine=100 Overall = 99,8412698412698

Exercise 2: L Sh=93,3333333333333 R Sh=83,3333333333333 R El=90 L El=93,3333333333333 Hip Center R=100 Hip Center L=100 Spine=100 Overall = 94,2857142857143

REFERENCES

[1] MSDN - Microsoft Developer Network Serialization (C# and Visual Basic) - https://msdn.microsoft.com/ru-ru/library/ms233843.aspx.

[2] Hemed Ali, Motion Comparison using Microsoft Kinect 2012 : FIT3036 - Computer Science Project : 16.11.2012 / Hemed Ali ; Monash University - 27 p.

[3] Orlova Y.A. Automation of the control of the physical exercises performance for rehabilitation using Microsoft Kinect / Y.A. Orlova, V.L. Rozaliev, A.A. Shpirko // Physical education and sports training. - 2013. - N1. - p. 53-58.

ПРОВЕРКА ПРАВИЛЬНОСТИ ВЫПОЛНЕНИЯ ФИЗИЧЕСКИХ УПРАЖНЕНИЙ С ИСПОЛЬЗОВАНИЕМ КАМЕРЫ MICROSOFT KINECT

Выборный А.И., Розалиев В.Л., Орлова Ю.А., Заболеева-Зотова А.В., Петровский А.Б.

В данной работе рассмотрен подход контроля правильности выполнения физических упражнений с использованием технологии Microsoft Kinect, а также метод сравнения заранее записанных движений с движениями, производимыми пользователем. В работе рассматриваются системы для проведения тренировок с использованием различных видеокамер. Описывается продукционная модель для проверки правильности выполнения физических упражнений. Приводятся результаты экспериментов при тестировании разработанной системы. Планируется дальнейшее развитие системы для проверки большего количества упражнений, в том числе и произвольных.