LOW-COST SOLUTION FOR MEASUREMENT OF COGNITIVE ABILITIES AND MOBILITY

Daria Varga[1], Bojan Banjac[2], Lidija Krstanović[3]

[1] Computer Graphics Chair, Faculty of Technical Sciences, University of Novi Sad (SERBIA), dariavarga@uns.ac.rs

[2] Computer Graphics Chair, Faculty of Technical Sciences, University of Novi Sad; Intens doo, Bulevar Evrope 28, Novi Sad (SERBIA), bojan.banjac@uns.ac.rs

[3] Computer Graphics Chair, Faculty of Technical Sciences, University of Novi Sad; lidijakrstanovic@uns.ac.rs

Abstract

The topic of this paper is related to the problems of computer vision, extracting data from images for the purpose of analyzing the movement of a human subject.

Due to the classical methods of computer vision proving to be inefficient, here we tackle making a more efficient, low-budget system for estimating the current physical and cognitive abilities of the subject using machine learning. Using Google's MediaPipe we implemented tests that can assess certain aspects of the subject's physical and cognitive abilities. A system with such tests is lightweight and easy to use for quick assessments, along with enabling self-assessment, while eliminating the need for costly equipment.

Keywords: machine learning, computer vision, computer graphics, subject's physical abilities, subject's cognitive abilities.

1 INTRODUCTION

Currently, most commonly used methods for estimating the physical abilities of the subject involve a certain amount of costly equipment, rendering them inaccessible for routine checkups of aspects such as high jump performance and general mobility, along with certain cognitive abilities, such as alertness. The most reliable method for measuring high jump performance entails the usage of systems for motion detection in combination with pressure plates. Another solution consists of making use of mobile phone applications, which are all unfortunately proprietary software [1]. This paper aims to create an open source system that is capable of estimating both the physical and cognitive abilities of the subject while keeping the required resources at a minimum and enabling quick and easy access to the results. This is made possible by expanding upon existing work in movement detection in fitness [2][3] and incorporating estimation of cognitive abilities, along with subjective assessment of the subject's current physical state, thereby creating a tool for comprehensive assessment of the subject's current mental and physical state that can then be tracked over time.

After taking into account other systems with various sensors for acquiring the necessary data, we reached the conclusion that the simplest and most accessible one, a webcam, is the best choice for this paper. By using one webcam and artificial intelligence support for pose estimation we tried to estimate the physical and cognitive abilities of the subject.

2 METHODOLOGY

Considering the task at hand, it was important to assess the necessary tools, making the lowering of the cost the top priority. This involved having to research all contemporary motion capture systems.

2.1 Motion Capture Systems

Most motion capture systems can be sorted into mechanical, acoustic, magnetic and optical [4]. Each sort of system has specific advantages, but the choice came down to cost, resulting in a markerless optical system based on machine learning being the top contender. These systems don't require any equipment other than a simple camera. Amongst different systems in this category, several are available for use at no cost, some of which are MediaPipe and OpenPose.

In this case, MediaPipe proved to be the best-suited system for this paper. This system is based on a convolutional neural network and optimized for real-time usages, using visual data as input for completing a wide variety of computer vision tasks [5]. The OpenPose system accomplishes similar tasks, but requires the presence of an NVIDIA graphical processing unit to operate at top speed and was ruled out for the purpose of keeping the cost of the system down. This eliminates the need for the user of the algorithm to have a powerful graphical processing unit, along with the fact that, when using MediaPipe, one is only required for the purpose of training the neural network, which can then be used without a graphical processing unit being present. The lack of this requirement ensures that a larger number of users will be able to access and use this algorithm.

2.2 Estimation of Physical and Cognitive Abilities

The estimation of the subject's abilities is here split into one subjective survey and three objective tests. The survey aims to collect important data about the subject, such as their name, age and whether they have problems with their vision, along with their own subjective assessment of certain aspects of their lives, such as how much sleep they got the previous night, how tired they feel, how healthy their eating habits have been lately and how stressed they feel. All of these aspects are factors that may have an influence on the cognitive and physical abilities of the subject and are to be taken into account when analyzing the results of the objective tests, which consist of a test of alertness, a test of mobility and a test measuring high jump performance. More specifically, the test of alertness measures the subject's reaction time to prompts shown on screen, which consist of 10 consecutive yellow circles shown on screen that the subject is supposed to place their hands over, not unlike one of the tests used in paper [6], the test of mobility prompts the subject to copy poses consecutively shown on screen, which can be seen in fig. 1, the success of which is expressed by keeping track of a gamified score, and the final test prompts the subject to perform three high jumps, measuring the height of each jump, whose average is then calculated, along with a percentage showing how the average jump height relates to the subject's height. These three tests can be seen in fig. 2.

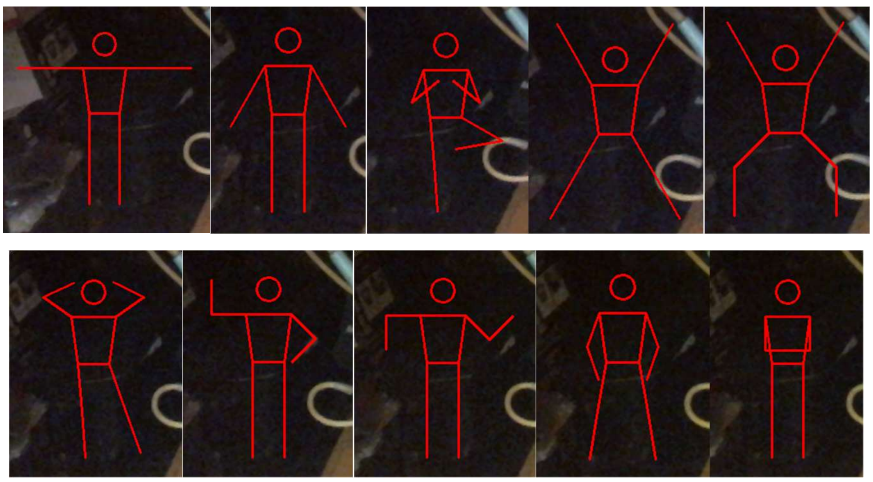

Fig.1. The set of poses the subject is prompted to copy in the test of mobility

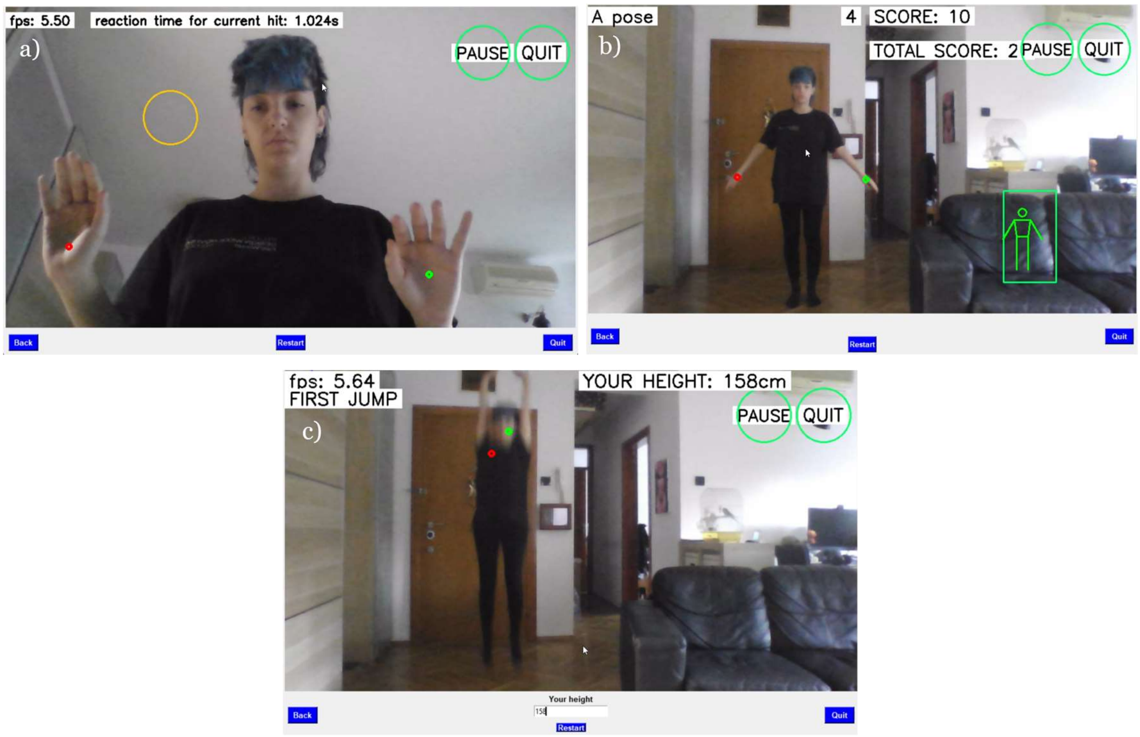

Fig.2. The display of the three objective tests: a) test of alertness, b) test of mobility and c) high jump performance, where the yellow circle represents the prompt the subject is asked to react to and the red and green dots represent the estimate of the current position of the center of the subject's palms

3 RESULTS

The results we acquired by testing three subjects over three days show that a system powered by machine learning can successfully estimate the cognitive and physical abilities of the subject. These results are displayed in tables 1-4. Due to the aim of these measurements being to test the functionality of the algorithm, the number of subjects was limited, but further research is planned to incorporate more subjects, with privacy protection measures in place.

Table 1. *Results of the test of alertness*

	Subject 1			Subject 2			Subject 3		
Test of alertness	Day1	Day 2	Day 3	Day1	Day 2	Day 3	Day1	Day 2	Day 3
Minimum (s)	0.744	1.005	0.991	1.001	1.025	0.867	0.127	0.154	0.823
Maximum (s)	1.647	2.28	2.02	2.142	2.046	2.227	1.636	2.215	2.269
Average (s)	0.995	1.34	1.359	1.306	1.419	1.546	0.908	1.389	1.481
Median (s)	0.901	1.164	1.252	1.2515	1.4635	1.5895	0.95	1.3475	1.2755

Table 2. *Results of the test of mobility*

	Subject 1			Subject 2			Subject 3		
Test of mobility	Day1	Day 2	Day 3	Day1	Day 2	Day 3	Day1	Day 2	Day 3
Pose 1	30	30	30	15	15	15	0	20	5
Pose 2	35	21	30	7	15	15	15	15	20
Pose 3	0	20	0	0	0	0	0	0	0
Pose 4	20	30	25	10	20	20	20	15	25
Pose 5	30	30	20	10	20	15	15	26	15
Pose 6	30	15	15	5	10	16	5	5	10
Pose 7	0	0	0	0	0	0	5	0	5
Pose 8	5	0	20	0	10	0	0	0	0
Pose 9	30	25	40	21	15	15	11	20	15
Pose 10	30	30	30	20	10	20	22	20	15
Pose 11	0	0	0	0	0	0	0	0	0

Table 3. *Results of the performed high jumps*

	Subject 1			Subject 2			Subject 3		
High jump performance	Day1	Day 2	Day 3	Day1	Day 2	Day 3	Day1	Day 2	Day 3
Average (cm)	24.863	24.687	24.083	22.24	21.04	19.437	35.16	34.33	38.203
Average percentage of height	16%	16%	15%	14%	13%	12%	20%	20%	22%
Median (cm)	24.57	24.08	24.58	23.29	20.65	20.02	34.15	32.51	38.8
Median percentage of height	16%	15%	16%	15%	13%	13%	19%	18%	22%

Table 4. *Results of the subjective test*

	Subject 1			Subject 2			Subject 3		
Subjective test	Day1	Day 2	Day 3	Day1	Day 2	Day 3	Day1	Day 2	Day 3
Q1	24	24	24	24	24	24	24	24	24
Q2	0	0	0	1	1	1	1	1	1
Q3	2	4	4	2	2	4	5	3	5
Q4	4	2	3	3	3	3	2	2	1
Q5	3	3	3	3	3	3	3	3	3
Q6	3	3	3	3	3	3	3	2	3

The questions asked in the subjective test are as follows:
Q1. *Age?*
Q2. *Vision problems? (includes all diagnosed issues a subject might have with their vision, such as prescription glasses)*
Q3. *How much sleep did you get? (five possible answers on a scale 1-5, where 1 corresponds to very little or no sleep and 5 to a lot of sleep)*
Q4. *How tired do you feel? (five possible answers on a scale 1-5, where 1 corresponds to not tired and 5 to exhausted)*
Q5. *How healthy do you consider your eating habits? (five possible answers on a scale 1-5, where 1 corresponds to not very healthy and 5 to very healthy)*
Q6. *How stressed do you feel? (five possible answers on a scale 1-5, where 1 corresponds to not stressed and 5 to very stressed)*

As can be seen from table 1, the reaction times that the test of alertness resulted in an average time of around 1.3 seconds. Defying expectations, the results of this test didn’t show much of a correlation with the answers the subjects gave in regard to the amount of sleep they got the night before or how tired they felt.

Considering the second test, we can observe that the performance for certain poses was particularly low, which can be ascribed to the likes of a poor choice in those certain poses, the lack of practice and physical activity on the side of the subjects. There was also a negative correlation between performance and the presence of problems with the subject’s vision due to the test being performed from a laptop with an integrated webcam, resulting in the subject being far away from the screen when performing the test and therefore having trouble seeing the prompts shown on screen.

The high jump performance showed the highest correlation in line with our assumptions, showing that the performance drops as subject’s reported tiredness level rises. It should be noted that all of the examinees were of similar age and some future research will observe level of correlation with the additional factor of age variation.

4 CONCLUSIONS

The creation of a low-budget, easy-to-use system for estimating the subject’s physical and cognitive abilities is made easy with tools powered by machine learning, enabling the elimination of costly equipment. However, in order for such a system to be accurate, collaboration with an expert within the field of medicine and work safety is of vital importance. Specifically, in this case, refinement of the poses selected for the test of mobility is necessary, along with an expansion of the questions included in the subjective test. Another needed addition for the test of mobility is output information regarding how the subject performed per joint. Along with that, longer testing periods including more subjects is necessary, which will also help determine how regular physical activity or engagement with sports may affect the results. These improvements are included in the further steps for this project, along with a bigger dataset of test performances.

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