JMR

http://jmr.tums.ac.ir

Research Article

Toward a New Approach for Analysis of Joint Range of Motion in Three-dimensional Digitized Analysis by One Camera

Saeed Talebian*[1], Roya Mehdikhani[2], Mahmood Talebian[3], Maryam Saba[4], Gholam Reza Olyaei[1]

1- Professor, Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran
2- PhD Candidate, Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran
3- Software Engineer, Neurosense Co. and Batab Instituted of Softwares Research, Tehran, Iran
4- PhD Candidate, Department of Physiotherapy, School of Rehabilitation, Ahvaz University of Medical Sciences, Ahvaz, Iran

ARTICLE INFORMATION

Article Chronology:
Received: 23.07.2016
Revised: 19.08.2016
Accepted: 27.09.2016

Corresponding Author:
Saeed Talebian
Emial: talebian@tums.ac.ir
Tel: +98 2144285821
Fax: +98 2144285821

ABSTRACT

Introduction: The use of multiple cameras for motion analysis and single joint motion is very difficult and needs high technology in laboratory conditions. Detection of single joint motion in kinesthesia and analysis of its changes can be done by one camera at one direction. In this study, we present the validity and reliability of a new prototype simulator system used for motion analysis application.

Material and Methods: A moveable lever arm can rotate in three dimensions (3D) and can be controlled by three goniometers separately. A special software was written for the detection of four reflective markers that fixed to moveable liver arm, by one camera in front of it. Two approaches for this study were (a) selective and (b) random 3D simulation. Three repetitions for each variation and each dimension were selected and correlation was computed between simulator and images captured by camera.

Results: There are high correlations between simulator and one camera system for each condition. In addition, a minimum degree error appeared.

Conclusion: Results indicated that this new approach can be useful for all clinical and research approaches in biomechanical or occupational areas.

Keywords: Joint motion; Motion analysis; Three-dimensional software

Citation: Talebian S, Mehdikhani R, Talebian M, Saba M, Olyaei GR. **Toward a New Approach for Analysis of Joint Range of Motion in Three-dimensional Digitized Analysis by One Camera.** J Mod Rehab 2016; 10(3): 134-8.

Introduction

The camera digitizing analysis systems are useful for joint range of motion analysis in ergonomics, medical sciences, sport sciences, and biomechanical researches. These techniques provide exact information about the changes of joint motion and evaluation of some properties of kinesthesia and proprioception of soft tissue around joint. The examination of joint motion by camera digitizing can produce knowledge about the human kinematics. It seems that this kind of system can be more user-friendly, low cost, and low dependency to complex software or apparatuses. In some biomechanical laboratories or clinics, use of very expensive motion analyzers is very difficult. One way to manage these problems is to invent a new system which can be used easily and support the previous aims. The first step is to use a simple and available technique to calculate degrees of one joint in three dimensions at the single frame. The second step is the use of one camera which is calibrated and has high resolution (5 mega pixel) and the last is the use of special software for analysis of marker data. Previous researches in this area [one camera and three-dimensional (3D) analysis] are limited, but the use of mirror systems to obtain stereo images with a single camera is known for many years (1). All these systems need complex technical machines and software. Our aim was to design a low cost and useful system for analysis of joint motion in three dimensions.

Materials and methods

Human for vision by two eyes receive two pictures about the subject and differences between the pictures in the central nervous system compare and results as a

3D image. Most of the 3D systems are designed to use the same theory, two synchronized cameras record the motion, and the computer creates the 3D image. On the other hand, 3D vision can be carried out with one eye. In this case, the central nervous system has to operate using other rules and forms pseudo 3D vision. This means, the rules, 3D image can be created in a computer by only one camera and reduces the costs (only one camera, no synchronizing hardware). In this manner, we built up a primary 3D prototype simulator which moved in three controlled dimensions (Figure 1).

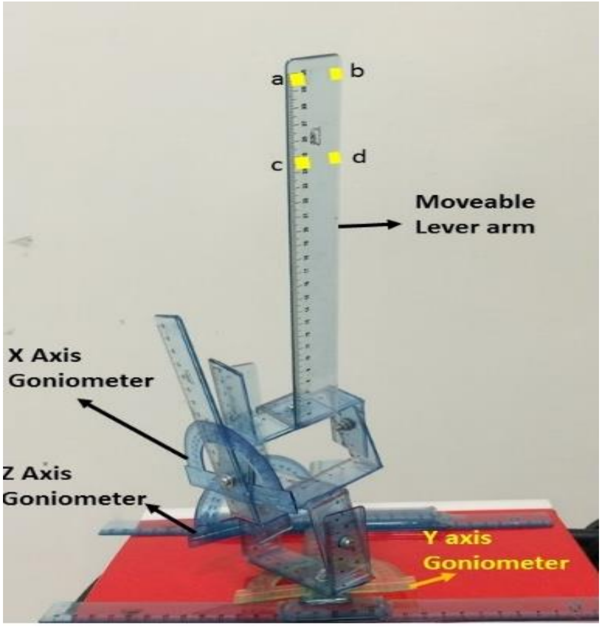

Figure 1. Primary three-dimensional (3D) prototype simulator which moves in three controlled dimensions by three goniometers adjusted to Z, Y, and X axes. Four reflective markers (yellow square), namely, a, b, c, and d for calculating the value of degree changes in 3D motion by one camera system and Batab 67 software

This system is mobile in 3D and can rotate in X, Y, and Z axes. The rotation of these three axis can be controlled by goniometers which are fixed to stable lever arms. This system has a moveable lever arm which can be fixed at different degrees in three dimensions (Figure 1). Four reflective markers (a, b, c, d) were attached to four corners of moveable lever arm in a square shape (Figure 2). The change of this square shape to other forms in space, after the changes of three dimensions of moveable lever arm, was captured by camera and estimated as the change of 3D degrees, by offline analysis of special computerized software namely 3D Batab 67 (Batab research company, Mexico) (Figure 3). This software was designed by C# language for Windows and Linux, as base of position vector to body markers (2-4). The software analyzed the changes of markers as the base of coordinate system.

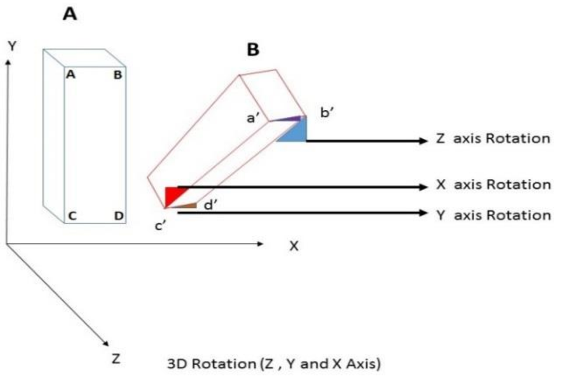

Figure 2. Fixed coordinator and object at position A as primary condition, after motion of object, it may be received to position B with different rotations at each axis. Three rectangular angles can be detected. Matrix between their angles can estimate degree of rotation at each direction by Batab 67 software

Rotation about the three axes was calculated by the change of "b" and "d" markers for Z axis, "a" and "b" markers for Y axis (in comparison to a' and b'), and "a", "c" markers for X axis (in comparison to a' and c') (Figure 2).

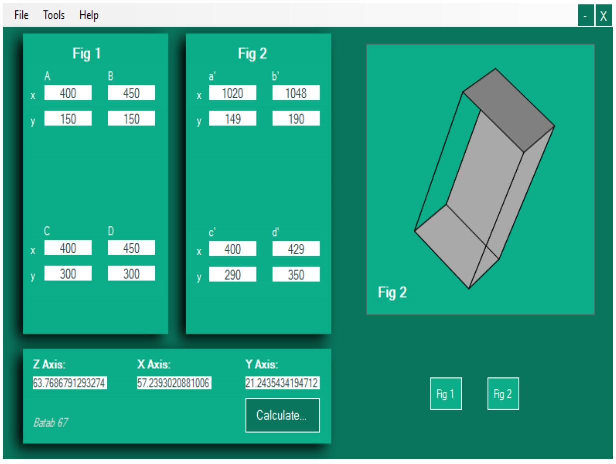

Figure 3. Menu file of Batab 67 software. By inserting X and Y coordinate parameters, from primary (Figure 1) position of moveable vector and secondary (Figure 2), software computes three-dimensional motion

In addition, we used a custom camera (Nikon D7100 with 24 MP APS-C Sensor) at horizontal distance of 80 cm from 3D simulator (distance between the center of camera lens and moveable lever arm of simulator). The distance between the center of camera lens and floor was arranged and adjusted to the level of moveable lever arm of simulator at about 80 cm. The next step was to test validity and reliability of this system by five selective and then random degrees of simulator lever arm for three times and receive them with digitized image by three different testers. These sequences are explained as follows:

Table 1. Comparison of the three time tests for selective simulator degrees (Z axis)

Selective degree A			Test 1			Test 2			Test 3		
Z	Y	X	Z	Y	X	Z	Y	X	Z	Y	X
10	0	0	11.56	1.6	0.6	10.23	0	3	9.92	0	2
20	0	0	20.31	0	−0.3	19.31	1.2	0	21.9	0	1
30	0	0	28.3	−1.2	0	29.6	0.4	0	30.3	−0.3	1
40	0	0	39.95	1	2	40.7	0.98	0.32	38.2	−0.1	0
50	0	0	53.12	0.86	−1.4	50.01	0	−0.41	51.9	0	0

At the first step, three axes were moved (five selected degrees) at the following directions:

A. 1-Z: 10, 20, 30, 40, 50l 2-X: 0, 0, 0, 0, 0. 3-Y: 0, 0, 0, 0, 0

B. 1-Z: 0, 0, 0, 0, 0; 2-X: 0, 0, 0, 0, 0; 3-Y: 10, 20, 30, 40, 50

C. 1-Z: 0, 0, 0, 0, 0; 2-X: 10, 20, 30, 40, 50; 3-Y: 0, 0, 0, 0, 0

D. 1-Z: 10, 20, 30, 40, 50; 2-X: 10, 20, 30, 40, 50; 3-Y: 10, 20, 30, 40, 50.

The second step was five random degrees in three axes at the following directions:

E. 1-Z: 50, 40, 30, 20, 10; 2-X: 10, 30, 40, 50, 20; 3-Y: 30, 20, 10, 40, 50.

After analyzing all images by Batab 67 software, data were entered into Excel software and the mean, mean difference, and error of degree estimations and also R^2 regression for each test were computed compared to selective and random primary simulator (A to E conditions of above steps) degrees.

Results

Validity of system and Batab 67 software by 3 times recording in five different degrees at selective and random changes of moveable lever arm of simulator was above 99% (Tables 1-6).

Table 1 shows that primary axis Z with different angles (10-50) and zero of other axis (Y and X) of simulator system were estimated by Batab 67 software and indicated that all degrees were similar to simulator system.

Axis of Y at different selective degrees was estimated by one camera system (OCS) for all the three tests.

Selective degrees at X axis were estimated by this new system for all the three tests.

3D selective degrees at Z, Y, and X axes were estimated by OCS for all the three tests.

Average of the three repetition tests at 3D selective simulator degrees indicated a high correlation between OCS and selective primary axis (Table 5 and Figures 4-6).

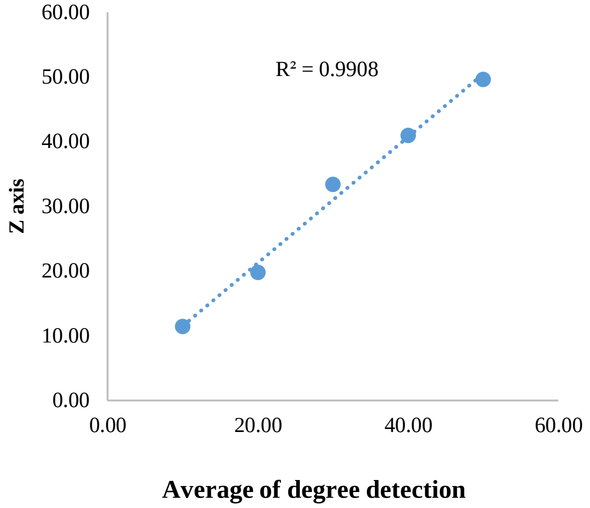

Figure 4. Correlation between Z axis and one camera system measurement

Table 5 indicates that there is minimum absolute error in 3D assessment by OCS for each axis below 2 degrees, where Z axis = 1.28, Y axis = 1.66, and X axis = 1.56°.

Also, there is a high correlation between selective degrees in 3D with average of detected degrees by OCS (Figures 4-6).

Furthermore, three repetitive random degrees for 3D simulator indicated minimum error with high correlation between simulator and OCS (Table 6).

Table 6 indicates that there is minimum absolute error in 3D assessment by OCS for each axis below 2 degrees, where Z axis = 1.50, Y axis = 1.00, and X axis = 1.10°.

A high correlation appeared between random degrees in 3D with average of detected degrees by OCS (Z = 0.98, Y = 0.99, X = 0.99). In addition, t-test indicated no difference between the three trials in each condition.

Table 2. Comparison of the three time tests for selective simulator degrees (Y axis)

Selective degree B			Test 1			Test 2			Test 3		
Z	Y	X	Z	Y	X	Z	Y	X	Z	Y	X
0	10	0	0	10.81	0.9	0	10.1	1	0.09	10.05	0.2
0	20	0	−0.1	23.8	0	0	20.9	1	1	22.8	0.11
0	30	0	0	29.03	0.9	0	33.8	0	0	29.04	−0.6
0	40	0	0	43.8	0	0	40.09	0.09	0	40.2	0.02
0	50	0	0.2	49.86	0	0.6	50.9	0.3	0.1	52.5	0

Table 3. Comparison of the three time tests for selective simulator degrees (X axis)

Selective degree C			Test 1			Test 2			Test 3		
Z	Y	X	Z	Y	X	Z	Y	X	Z	Y	X
0	0	10	0.2	0.06	11	0	−2.8	12.9	2.09	0	9.4
0	0	20	0	0.09	21.09	0.65	0.9	20	0	0.8	20.8
0	0	30	0.09	2.8	32.8	0.01	3.1	32.07	1.1	0	32.9
0	0	40	0	0	41.12	0	0	35.9	0	0.1	39.98
0	0	50	0.8	0	48.1	−0.9	0.9	53.11	0.8	−0.6	49.31

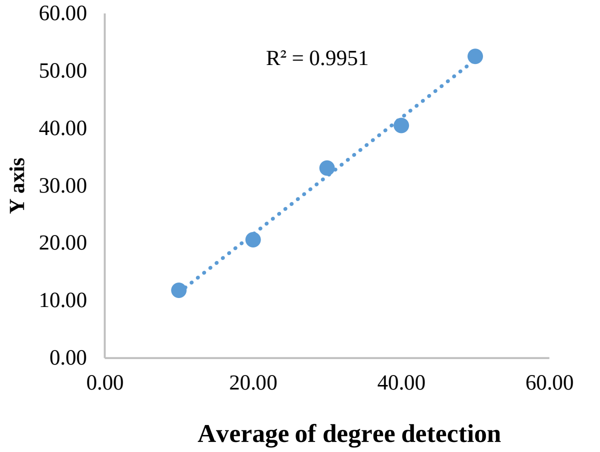

Figure 5. Correlation between Y axis and one camera system measurement

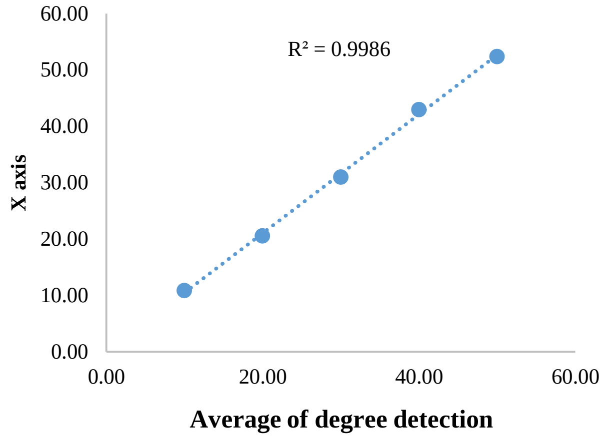

Figure 6. Correlation between X axis and one camera system measurement

Conclusion

In this article, we discussed the application of OCSs to analyze joint range of motion 3D processes. Such measurement systems are a suitable solution for problems caused by the use of multi-camera systems. This setup depends on special software for the detection of motion of joint. The usage of this system for clinical assessment in research centers is easy and it is of very low cost. The next step will be to test this system in clinical treatment in patients with joint difficulty and also to improve it into new versions.

Conflict of Interests

This 3D one camera software (Batab 67 software) is easy to use for all researchers and also it is of low cost in comparison to other 3D motion analysis systems. The limitation of the above software is it is dynamic and has very fast movement so it must be used for one joint and for simple tasks such as joint kinesthesia or other joint analysis before and after interventions.

Acknowledgement

This study was supported by Biomechanics Laboratory

Table 4. Comparison of the three time tests for 3D selective simulator degrees (Z, Y, X axes)

Selective degree D			Test 1			Test 2			Test 3		
Z	Y	X	Z	Y	X	Z	Y	X	Z	Y	X
10	10	10	10.32	12.9	10.67	10.97	10.98	11.9	12.98	11.43	10.09
20	20	20	19.8	22.2	20.65	20.98	19.45	19.86	18.45	20.09	21.13
30	30	30	35	29.8	32.9	30.12	31.9	29.92	34.98	37.43	30.23
40	40	40	37.3	38.31	40.98	40.39	42.05	45.97	45.1	40.98	41.98
50	50	50	48.11	56.11	50.43	50.49	48.91	56.38	50.09	52.41	50.32

3D: Three-dimensional

Table 5. Average of the three time tests for 3D selective simulator degrees (Z, Y, X axes) and absolute errors of each axis

Selective degree D			Average			Absolute error		
Z	Y	X	Z	Y	X	Z	Y	X
10	10	10	11.42	11.77	10.89	1.42	1.77	0.89
20	20	20	19.74	20.58	20.55	0.26	0.58	0.55
30	30	30	33.37	33.04	31.02	3.37	3.04	1.02
40	40	40	40.93	40.45	42.98	0.93	0.45	2.98
50	50	50	49.56	52.48	52.38	0.44	2.48	2.38

Table 6. Average of the three time tests for 3D random simulator degrees (Z, Y, X axes) and absolute errors of each axis

Selective degree E			Average			Absolute error		
Z	**Y**	**X**	**Z**	**Y**	**X**	**Z**	**Y**	**X**
50	30	10	49.82	30.68	11.01	0.18	0.68	1.01
40	20	30	44.54	20.13	30.40	4.54	0.13	0.4
30	10	40	30.48	9.85	41.50	0.48	0.15	1.50
20	40	50	20.61	41.24	50.60	0.61	1.24	0.60
10	50	20	11.68	52.79	22.00	1.68	2.79	2.00

of Rehabilitation Faculty, Tehran University of Medical Sciences.

REFERENCES

1. Schöler H. Production of photogrammetric stereo pairs by beam division in single-lens cameras. In: Szangolies K, editor. Kompendium Photogrammetrie XV. Leipzig, Germany: Akademische Verlagsgesellschaft Geest and Portig; 1981. p. 77-86.
2. Soutas-Little RW. Motion analysis and biomechanics. In: Delisa JA, editor. Gait analysis in the science of rehabilitation. Washington DC: Veterans Administration, Rehabilitation Research and Development Service; 1998. p. 49-55.
3. Chun-sen Z. Motion stereo double matching restriction in 3D movement analysis. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 2008; XXXVII(Part B3b): 675-80.
4. Wipf D, Palmer J, Rao B. Perspectives on sparse bayesian learning. Advances in Neural Information Processing Systems 2003; 16: 1-8. Available from: URL: http://papers.nips.cc/paper/2393-perspectives-on-sparse-bayesian-learning