Appraising the Recital of Joints in Human Running Gait through 3D Optical Motion

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Abstract

Recital costing of Joints in human running is biometrics evaluation technology. It has skillful series of realizations in scientific research in the last decade. In this work, we present human running joints (hip, knee and ankle) valuation recital based on the statistical computation techniques. We use the One-way ANOVA, least significant difference (LSD) test and Bartlett's test for equality of variances to determine which joint has more variation with other joints during human running gait style. These three joints rotation angle data were computed from the Biovision Hierarchical data (BVH) motion file, because these joints provide the richest information of the human lower body joints (hip, knee and ankle). The use of BVH file to estimate the participation and performance of the joints during running gait is a novel feature of our study. The experimental results indicated that the knee joint has the decisive influence (variation) as compared to the other two joints, hip and ankle, during running gait.

Keyword: *Joints importance; Running concept; Size up joint*

1. Introduction

Human motion is a very complex field of study. A broad field of applications can be found for human motion synthesis and joint performance measure in human running. The current state of knowledge is presented as it fits in the context of the history of analysis of movement. Using human motion data has been a popular approach for analyzing animation and retarget motion, and synthesizing human joints motion, particularly thanks to recent improvement of motion capture systems. In particular, there has been a lot of interest in the ways of using and re-using motion capture data [1-4].

Gait joints evaluation is a kind of biometrics and clinical science defined by Whittle [5], which uses energy and power to evaluate individual joint performance. Gait analysis methodology and clinical gait evaluation are explained in [6]; more formal definition of human gait, kinesiological recording and measurement techniques is given by [7], and three-dimensional human running is given by [8]. Davis et al. [9] used 3D marker position information to determine joint moments and powers. Diedrich et al. [10] defined methods at running gait joints. Growney et al. [11] proposed a statistical approach for gait evolutions using joints kinematic and kinetic data collected on normal subjects. The range of motion of the human body joints was described by Mackenzie [12]. Dona et.al [13] performed principal component analysis (PCA) to determine the dependence of the knee joint angle in human gait. The PCA has also been used for gait joints analysis in [14]. Steudel-Numbers et.al [15] proposed a relationship between limb length and cost for human running. There are also medical applications, for example, to control active prostheses, or to detect and understand the motion of motor impaired individual. Most researchers in motion gait analysis, synthesis, animation, retarget motion and gait

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recognition consider the whole motion of joints [10,15-17]. There are many choices [1-4,25-27] for representing motion data. In this paper, we apply statistical methods to determine which joint has utmost contribution (variance) with the usage of the human running motion data of the BVH file, inspired by the aforementioned research.

The motion capture data format files are explained by Meredith et al [18]. It typically includes the position of the root and orientation of other joints. We have used a motion data captured from the optical motion capture system. We used BVH file format because it is easy to extract motion data from BVH file. This file format has two parts: the skeleton information shown in Figure 1 and the motion data listed in Table 1.

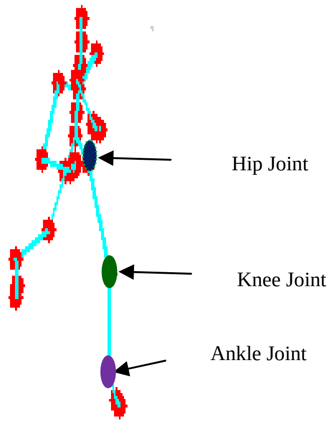

Figure 1. Skeleton joints in running gait

Table 1. Example of 3D motion data of joints extracted from BVH file with 17 frames

Hip Joint			Ankle Joint			Knee Joint		
X	Y	Z	X	Y	Z	X	Y	Z
-4.5460	1.4421	2.3608	-0.0334	-7.8904	-4.7895	4.0793	12.2651	36.6764
-4.3387	1.7707	2.0255	0.1684	-7.0803	-8.2387	4.5927	12.9098	39.0319
-4.0652	1.9428	1.6285	0.3107	-6.9239	-10.3465	4.8878	13.2563	40.3355
-2.9478	2.0493	1.4823	0.4275	-7.3381	-11.9686	5.1050	13.5011	41.2744
-1.2787	2.0037	1.6024	0.5776	-7.1865	-13.6925	5.2359	13.6447	41.8323
0.1048	1.7511	2.0087	0.7287	-6.7494	-15.2555	5.2778	13.6900	42.0096
0.0512	1.6948	2.3671	0.8252	-7.1454	-16.2406	5.2848	13.6975	42.0390
-0.1114	1.8252	2.6543	0.9079	-7.5548	-17.0477	5.2482	13.6580	41.8842
0.0954	1.9387	2.9625	0.9588	-7.7192	-17.5212	5.1059	13.5021	41.2782
0.3216	1.9214	3.1650	0.9509	-7.7340	-17.4514	4.8928	13.2621	40.3575
0.4809	1.9248	3.2901	0.9031	-7.8396	-17.0262	4.5814	12.8963	38.9814
0.7967	2.1492	3.4701	0.8063	-7.7740	-16.1135	4.2816	12.5260	37.6190
1.2139	2.4471	3.6886	0.6547	-7.8097	-14.6076	3.9472	12.0899	36.0506
1.6840	2.7879	3.9556	0.4708	-7.7280	-12.5683	3.6316	11.6534	34.5165
1.9763	3.3398	4.2089	0.2634	-8.2147	-10.0770	3.2982	11.1628	32.8309
2.3675	3.9177	4.4975	0.0522	-8.5184	-6.9434	2.9625	10.6341	31.0555
2.2861	4.2583	4.7371	-0.1108	-8.1714	-3.0537	2.6077	10.0312	29.0777

Regarding 3D motion data, we refer to the part of the BVH file containing the data corresponding to each of the joints during movement of the skeleton. In this work, we will be concerned with three joints hip, knee and ankle. The data corresponding to these three joints in the BVH files will be called *Three Dimension Motion Data* (TDMD).

Both Figure 1 and Table 1 together show an example of three joints TDMD that was computed from the BVH file. This is running gait data of three joints that are participated to generation of the motion. The motion part is generated with the help of movement of the skeleton joints. Gait joints performance measures the participation of joints based on the style of human running gait of a subject. In this paper, an algorithm for human gait (running) joints performance evaluation is introduced. We think that it will be more helpful for motion analysis, physical animation, retarget motion, clinical field and gait recognition research. We determined, by statistical techniques, which joint has more weight during human running gait in natural style. Primarily, means and variances are measured for all the three coordinates of each joint i.e. X, Y and Z .These measures are then used to show how much variation occurs during human running gait. The joint with the highest variance, therefore, has maximum participation and consequently is the one which has the maximum effect [20]. Based on this concept, the highest importance can be given to only one joint during running gait. This will greatly reduce the complexity of the problem of human gait analysis and in retarget motion and physical animation techniques in the future.

We have used it to actually extract motion data and draw conclusions from statistical analysis of the data. This is a novel technique which we think will be of great use in the field of biometrics. Importance of the knee joint in running has been established in various studies [8,10,15]. Gait analysis and observation were also described by Saleh et al. [23]. Roach et al. [24] defined a range of motion of the hip and knee joints. Sajid et al. [29] proposed a method to calculate the participation of the lower body joint in the human walk by using TDMD.

This paper is organized as follows. Section 2 contains an overview of materials and methods**,** describes the construction of the database, and presents our proposed flowchart. Section 3 is reserved for main results and discussion. Section 4 concludes the article along with the future work.

2. Materials and Methods

Our concept is to evaluate the joints during running gait style. We selected three important joints: hip, knee and ankle. We then apply statistical techniques to the selected joints motion data and determine which joint has more variation in generating running gait motion. Figure 1 and Table 1 describe file format which we use in our work .The construction of our database is displayed in Figure 2; the flow chart for our purposed method is shown in Figure 3.

2.1. Database construction

The process for building the proposed motion database is summarized in Figure 2. The user provides motion files of subject running in ASF/AMC format [21] represented as a pair of skeleton and motion information (joints angle). The skeleton part contains human skeleton, and the motion part is related to joints angle movement of the human, typically obtained by a human motion capture system. However, joint angle representation strictly depends on the skeleton model of the human. After that, these pairs of files are converted into a single BVH file format by using BVH Converter script techniques.

The BVH file format is populated in Biovision with the hierarchical data structure representing the bones of the skeleton. The BVH file consists of two parts: the first section details the hierarchy and initial pose of the skeleton and the second section has channeled data for each frame. These channel data are stored in different orders of *xyz* such as *yzx*, *zxy* and *zyx*. Here we have used the *zyx* order for generating channel data of subject joints and arranged them into *xyz* order. This is to ensure there is no statistical bias towards any particular dataset. We have constructed the database from the BVH files by taking an equal number of frames from each running data and then stored then in the database. This is called *precise database of the human motion.*

2.2. Our proposed flow chart

The flowchart is divided into two units as shown in Figure 3: the preprocessing unit and the calculation unit.

2.2.1 Preprocessing unit

The preprocessing unit has three steps. The first step is to take the ASF/AMC file captured from the motion capture system. The second step converts the ASF/AMC file into a BVH file format. Last step of the preprocessing unit is to store the BVH files, having an equal number of frames and steps on the subject for each time of running gait.

2.2.2 Calculation unit

The calculation unit also has two steps. The first step is to extract the motion data of the concerned joints (hip, knee, ankle) from the precise motion database. The second step is to apply statistical techniques to the selected motion data of the joints so as to obtain the results to measure the participation of the joints during running gait.

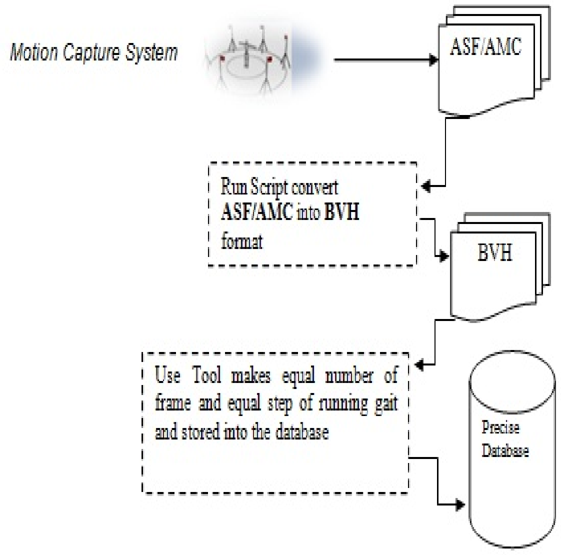

Figure 2. Architecture of the precise database

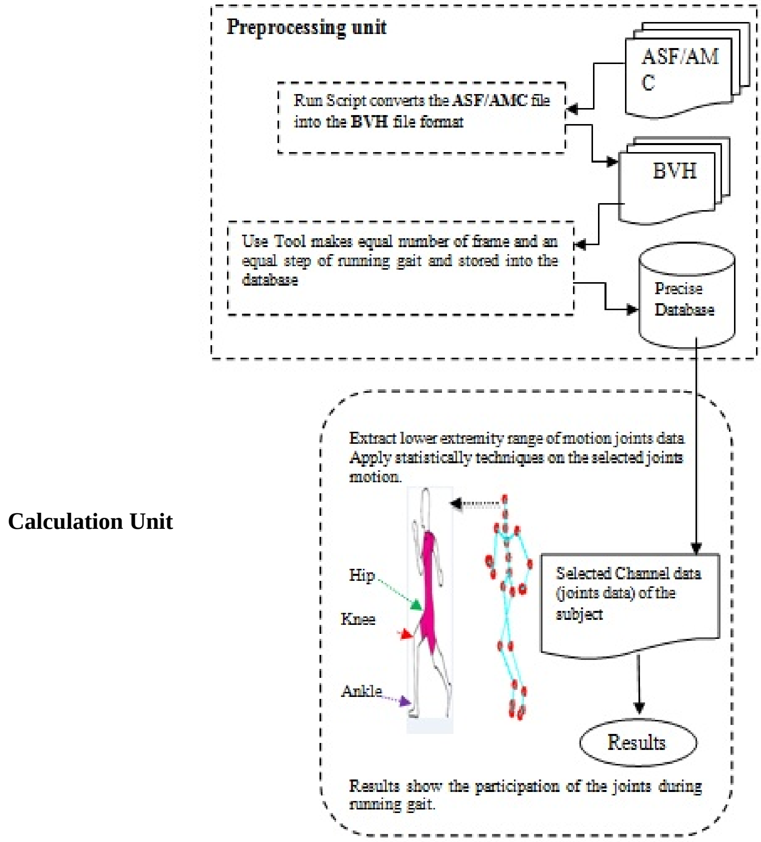

Figure 3. Architecture of flow chat

3. Statistical Methods for Joints Calculation

As mentioned above, we are interested in determining the performance of the three joints during the human running gait. We use static moments and testing techniques to estimate joint variation during running gait. The important quantities are used to measure the participation of the joints movement during running gait under 3D motion. The calculation was carried out as described below.

3.1 Means of the X-Y-Z- coordinates of the joints

First we computed the means of the X-Y-Z- coordinates for hip, knee and ankle joints as follows (for more details about the mean value we refer readers to [19]).

$$\overline{X}_{hip} = \frac{1}{n}\sum_{i=1}^{n} X_{hip_i} \qquad (1)$$

$$\overline{Y}_{hip} = \frac{1}{n}\sum_{i=1}^{n} y_{hip_i} \qquad (2)$$

$$\overline{Z}_{hip} = \frac{1}{n}\sum_{i=1}^{n} z_{hip_i} \qquad (3)$$

i= 1, 2, 3 ………………..*n*

Here *n* is the number of frames during running. Following (1), (2) and (3) the means for the other two joints, i.e. knee and ankle, are computed. The calculated values of these equations can be seen in the experiment section under Table 2.

3.1.1 Compare joints means by one-way ANOVA

Typically, when we think about one-way ANOVA, we think about the feature as dividing the subjects into groups. The goal of our computing is then to evaluate the means of the subject in each joint. Here considering 7 repetitions and one-way ANOVA, the means of coordinates for three joints (hip, knee, ankle) are compared. We compared the means of X-coordinate for hip, knee and ankle joints and a similar comparison is made for Y- and Z-coordinates. We found that the joints have different participations during running gait.

All calculated results of one-way ANOVA can be seen in Table 3 in experiment section. Table 3 shows that there is a significant difference between the means of X-coordinate of hip, knee and ankle joint. A similar conclusion can be drawn for the other two coordinates i.e. Y and Z. The one-way ANOVA gives the results of comparing the means of considered joints but does not give the result of how much difference among the coordinates for each joint. The least significance difference method can give the required result.

3.1 .2 Least significance difference (LSD)

The least significance difference (LSD) method is used for testing the equality of two means when one-way ANOVA rejects the hypothesis of equality of several means. We reject the equality of two means if;

$$\left|\overline{X}_I - \overline{X}_J\right| \geq LSD\,, \qquad (4)$$

where $LSD = t_{\alpha/2}(dfw)\sqrt{MSW\left(\frac{1}{n_I}+\frac{1}{n_J}\right)}$ with

dwf = d.f (within), MSW= Mean Squares Within, n_I and n_J are the respective sample sizes for what $\overline{X}_I$ and $\overline{X}_J$ have been computed. See Montgomery [22] for more details. The calculated values can be seen in Table 4 in the experiment section.

3.2 Variances of the X-Y-Z- coordinates of the joints and Bartlett's statistic

We computed the variances of the means of all the coordinates of the hip joint, given in Table 2 (more detail in [19]) as follows:

$$s^2_{X_{hip}} = \frac{1}{(r-1)}\sum_{j=1}^{r}(\overline{x}_{hip_j} - \overline{\overline{x}}_{hip})^2 \quad (5)$$

$$s^2_{Y_{hip}} = \frac{1}{(r-1)}\sum_{j=1}^{r}(\overline{y}_{hip_j} - \overline{\overline{y}}_{hip})^2 \quad (6)$$

$$s^2_{Z_{hip}} = \frac{1}{(r-1)}\sum_{j=1}^{r}(\overline{z}_{hip_j} - \overline{\overline{z}}_{hip})^2 \quad (7)$$

Here $s^2_{X_{hip}}$, $s^2_{Y_{hip}}$ and $s^2_{Z_{hip}}$ are the variances of the hip joint coordinates and

$\overline{\overline{x}}_{hip} = \frac{1}{r}\sum_{j=1}^{r}\overline{x}_{hip_j}$ $\overline{\overline{y}}_{hip} = \frac{1}{r}\sum_{j=1}^{r}\overline{y}_{hip_j}$ $\overline{\overline{z}}_{hip} = \frac{1}{r}\sum_{j=1}^{r}\overline{z}_{hip_j}$
are the mean of means of the hip joint coordinates and ***r*** is the number of repetitions (i.e. 7 in our case). Following similar approach, we calculated all the variances of the other two joints. In order to compare the variances of different coordinates of the joints, we used Bartlett's test [28] for equality of variances among the three joints.

First of all, we compared the variances of the X-coordinate of the hip, knee and ankle joint by using Eq (8). Here $s_i^2 \in \left\{s^2_{X_{hip}}, s^2_{X_{knee}}, s^2_{X_{ankle}}\right\}$ and these variances are denoted the X-coordinate of the hip, knee and ankle joints.

$$T = \frac{(N-k)\ln s_p^2 - \sum_{i=1}^{k}(N_i-1)\ln s_i^2}{1+\left(1/\left(3(k-1)\right)\right)\left(\left(\sum_{i=1}^{k}1/(N_i-1)\right)-1/(N-k)\right)} \quad (8)$$

In the above, T denoted the critical region values and is the evaluator for the variances values; s_i^2 is the variance of the *i*th group; ***N*** is the total sample size; N_i is the sample size of the *i*th group; ***k*** is the number of groups; s_p^2 is the pooled variance. The pooled variance is a weighted average of the group variance and is defined as:

$$s_p^2 = \sum_{i=1}^{k}(N_i-1)s_i^2/(N-k) \quad (9)$$

Similarly, following the procedure of section 3.2, we compared variances of the other two Y, Z coordinates of joints (knee, ankle) and found which joint has more variation during running gait. The results of T can be seen in Table 5.

4. Results and Discussion

As mentioned above, we are interested in determining the performance of the three joints during the human running gait. To calculate this, we used motion data of one subject that was run a couple of times within 130 frames and each time run several steps [30]. Table 2 shows the simple mean of each coordinate for each joint in every time subject ran. Table 3 shows results of the one-way ANOVA analysis, which indicates that join movements are not same during subject running. Table 4 shows the difference between means of each joint of the coordinate-wise using Eq (4). Table 5 shows the joint variance among the three joints in the same coordinate using Eq (8).

Table 2. Means of X-, Y- and Z- coordinates for hip, knee and ankle joints

Repetition	Hip Joint			Knee Joint			Ankle Joint		
	X	Y	Z	X	Y	Z	X	Y	Z
1	-0.2655	-0.7740	3.8266	7.7897	11.9008	45.3789	1.3002	0.0103	12.8014
2	-2.0831	-2.0334	4.9725	8.2035	12.5768	47.5329	1.1039	1.9458	9.4558
3	-0.2820	-2.4342	3.7750	8.8860	11.9749	48.1651	1.5821	4.4217	16.3857
4	0.0460	-1.1708	4.3509	7.3427	12.1615	44.5491	0.5989	-1.9582	5.5401
5	-0.2522	-1.3485	4.7345	12.2890	13.4182	60.4401	0.6384	-0.1766	10.3119
6	-1.3712	-2.0227	4.5449	11.8483	12.7250	58.3214	1.3669	3.2688	15.8283
7	-1.0797	0.6972	4.7361	7.6337	11.5997	44.4397	0.9297	0.4799	8.6608

Table 3. Comparison of means of X-, Y- and Z- coordinates for hip, knee and ankle joints

	Joints	Sum of Squares	df	Mean Square	F	p-value
X	Between Groups	388.239	2	194.119	116.650	0.000
	Within Groups	29.954	18	1.664		
	Total	418.193	20			
Y	Between Groups	740.104	2	370.052	175.756	0.000
	Within Groups	37.899	18	2.105		

	Total	778.003	20			
Z	Between Groups	8389.309	2	4194.654	207.476	0.000
	Within Groups	363.916	18	20.218		
	Total	8753.225	20			

Table 4. Multiple means comparisons using LSD

Dependent Variable	(I) Joint	(J) Joint	Mean Difference (I-J)	p-value
X	Hip	Knee	-9.90	0.000
		Ankle	-1.83	0.016
	Knee	Hip	9.90	0.000
		Ankle	8.07	0.000
	Ankle	Hip	1.83	0.016
		Knee	-8.07	0.000
Y	Hip	Knee	-13.63	0.000
		Ankle	-2.44	0.006
	Knee	Hip	13.63	0.000
		Ankle	11.20	0.000
	Ankle	Hip	2.44	0.006
		Knee	-11.20	0.000
Z	Hip	Knee	-45.41	0.000
		Ankle	-6.86	0.011
	Knee	Hip	45.41	0.000
		Ankle	38.55	0.000
	Ankle	Hip	6.86	0.011
		Knee	-38.55	0.000

From Table 4, we see that both the means of hip and knee are significantly different and knee had more contribution to running than hip did in X-coordinate. Similarly we can interpret the other results from the Y, Z coordinates. It can be concluded that for all the three coordinates (X, Y and Z), knee has the largest mean compared to the other two joints (hip, ankle).

Table 5. Bartlett's test for equality of variance

Coordinates	Joints	Variances	Bartlett's Statistic	p-value
X	Hip	0.60		
	Knee	4.25	14.33	0.0008
	Ankle	0.14		
Y	Hip	1.11		
	Knee	0.38	8.54	0.0140
	Ankle	4.83		
Z	Hip	0.22	22.39	0.0000

Knee	44.91
Ankle	15.52

Table 5 presents the variances, Bartlett's statistic and p-values. It is clear that the variances for all the joints are significantly different. Moreover, knee has largest variances for X- and Z-coordinates. For Y-coordinate, ankle has the largest variance over the other tow. These statistical results are presented graphically in Figures 4-6.

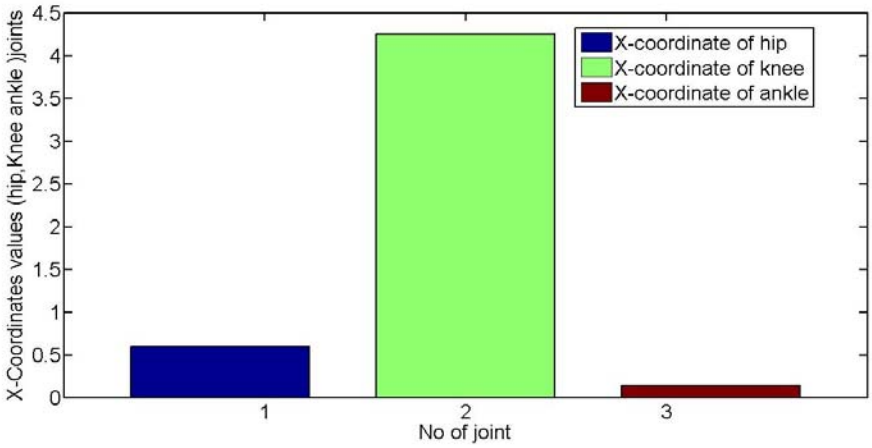

Figure 4. X-coordinate variation of the three joints (hip, knee, and ankle)

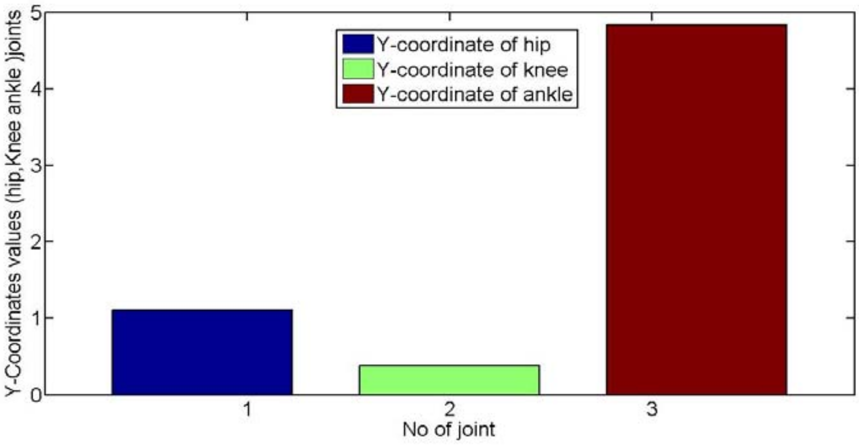

Figure 5. Y-coordinate variation of the three joints (hip, knee, and ankle)

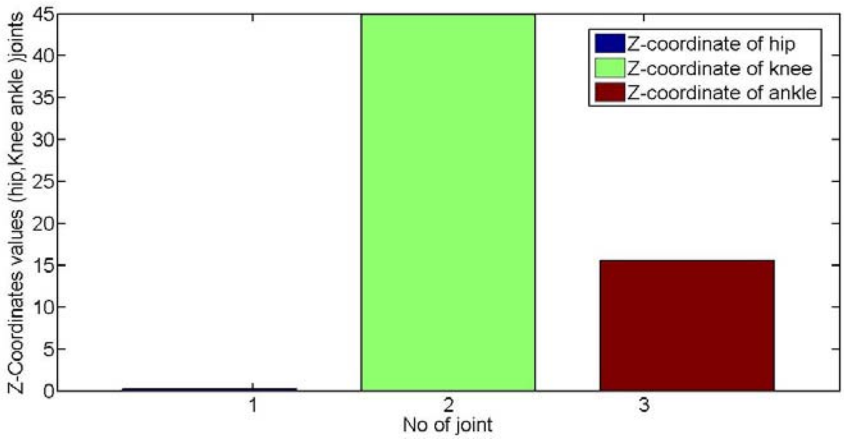

Figure 6. Z-coordinate variation of the three joints (hip, knee, and ankle)

5. Conclusion and Future work

In this paper we proposed a statistical method to estimate joint performance (contribution) through human running under 3D motion data that can identify which joint has the decisive influence among the joints in human running gait. Novelty of our work is that we are the first to use the BVH file to estimate the performance of human joints during running gait. Previously, it has been used for animation, retarget motion [3,4] but not for evaluating the performance of joints. The experimental results indicate that knee has the decisive influence (variation) among the three joints (hip, knee and ankle) and has the largest contribution during human running gait. The research approach and results may be useful for sports, gait recognition technology, robotic, retarget motion, clinical studies and physical animator. In future, we would like to further our study by applying it to a larger database for gait recognition and physical animation.

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References

[1] Xiaohui Xu; Chang Leng; Zhongke Wu; ,"Rapid 3D Human Modeling and Animation Based on Sketch and Motion Database," Digital Media and Digital Content Management (DMDCM), 2011 Workshop on , vol., no., pp.121-124, 15-16 May 2011.
[2] Z. Popovi´c and A. Witkin. Physically based motion transformation. Proceedings of SIGGRAPH 99, pages 11–20, August 1999.
[3] Zordan, V. B., and Horst, N. C. V. D. Mapping optical motion capture data to skeletal motion using a physical model. In ACM SIGGRAPH / Eurographics Symposium on Computer Animation, pages 245-250, 2003.
[4] Ming-Kai Hsieh; Bing-Yu Chen; Ming Ouhyoung.”Motion retargeting and transition in different articulated figures," Computer Aided Design and Computer Graphics, Ninth International Conference on, vol., no., pp. 6 pp., 7-10 Dec. 2005.

[5] Michael W. Whittle. Clinical gait analysis: A review Human Movement Science vol.15, pp 369-387, 1996.
[6] Cappozzo, A.Gait analysis methodology. Human Movement Science vol.3, 27–54, 1984.
[7] Carlsöö, S. How man moves kinesiological studies and methods. Heinemann, London, 1972.
[8] J. K. Hodgins, "Three-Dimensional Human Running," IEEE Int. Conf. on Robotics and Automation, pp. 3271-3276, 1996.
[9] Davis, R.B., III, S. Ounpuu, D. Tyburski and J.R. Gage 1991.A gait analysis data collection and reduction technique. Human Movement Science vol.10, pp .575–87, 1991.
[10] Diedrich, F.J., Warren, W.H. Why change gaits? Dynamics of the walk-run transition. J. Exp. Psychol.: Hum. Percep. Perf. 21,183–202, 1995.
[11] Growney E, Meglan D, Johnson M, Cahalan T, An K. Repeated measures of adult normal walking using a video tracking system. Gait Posture vol.6, pp.147–62, 1997.
[12] Mackenzie, *B.*Range of Movement (ROM). http://www.brianmac.co.uk/musrom.htm, 2004.
[13] Dona, G., Preatoni, Rodano, R. And Cobelli, C. Principal Component analysis of knee angle waveforms during race walking. In Proceedings of the 25th International Symposium on Biomechanics in Sports (ISBS) Ouro Preto (Brazil), August, pp. 63-66, 2007.
[14] Kerrigan DC, Lee LW, Collins JL, Riley PO, Lipsitz LA. Reduced hip extension during walking: healthy elderly and fallers versus young adults. Arch Phys Med Rehabil vol.82, pp. 26-30, 2001.
[15] Steudel-Numbers, K., Weaver, T.D., Wall-Scheffler, C.M.The evolution of human running: effects of changes in lower limb length on locomotor economy.J. Hum. Evol. 53, 191–196. 2007.
[16] Barbic J., Safonova A., Pan J.-Y., Faloutsos C., Hodgins J. K., Pollard N. S.Segmenting motion capture data into distinct behaviors. In Proc.Graphics Interface vol.4, pp. 185–194, 2004.
[17] Yanmei C., Jinchang R., Rongchun Z., and Jingping J. Automatic Gait Recognition using Dynamic Variance Features. In Proceedings of the 7th International Conference on Automatic Face and Gesture Recognition, Northwestern Polytech. Univ., Xi'an April, FGR, 475-480, 2006.
[18] M. Meredith and S.Maddock. Motion capture file formats explained, Technical Report., Department of Computer Science, University of Sheffielf, Sheffield, UK, 2001.
[19] Anthony, D. Statistics for health, life and social sciences. BookBoon, pp. 43-52, 2011.
[20] Lavcanska, V., Taylor, N.F. and Schache, A.G. Familiarization to treadmill running in young unimpaired adults. Human Movement Science 24, 544-557, 2005
[21] Hyun-Sook Chung and Yilbyung Lee. MCML: motion capture markup language for integration of heterogeneous motion capture data, Computer Standards & Interfaces 26, pp, 113– 130, 2004.
[22] Douglas C. Montgomery. Design and Analysis of Experiments. Wiley, New York, 2004.
[23] M. Saleh and G. Murdoch. In defense of gait analysis observation and measurement in gait assessment. Bone Joint Surg.—Br vol.67, pp. 237–241, 1985.
[24] Roach KE, Miles TP. Normal hip and knee active range of motion: the relationship to age. Physical Therapy vol. 71, pp .656-65, 1991.
[25] G. Guerra-Filhoxd and A. Biswas. A human motion database: The cognitive and parametric sampling of human motion. Image and Vision Computing vol.30, pp.261-261, 2012
[26] J. Aggarwal, Q. Cai, Human motion analysis: A review, Computer Vision and Image Understanding 73 (3) (1999) page 428–440.
[27] Lu, W., Liu, Y., Sun, J., Sun, L.A Motion Retargeting Method for Topologically Different Characters. In: Sixth International Conference on Computer Graphics, Imaging and Visualization, pp. 105–108, 2009.
[28] Bartlett, M. S. Properties of sufficiency and statistical tests. Proceedings of the Royal Society of London Series A 160, pp.268–282, 1937
[29] Sajid Ali, Zhongke Wu, Mingquan Zhou, Abdul Razzaq, Muhammad Tariq Pervez. Weigh up Performance of Joints in Human Gait Walk with Motion Block. Advance in Information Sciences and Service Sciences (Accepted).2012
[30] The CMU Graphics Lab Motion Capture Database http://mocap.cs.cmu.edu/