Motion Capture as a Tool for Gait Recognition and Creation Realistic Animation of Human-like Figures

Ryszard Klempous
Institute of Computer Engineering, Control and Robotics
Wroclaw University of Technology
11/17 Janiszewskiego Street, 50-372 Wroclaw, Poland
ryszard.klempous@pwr.wroc.pl.

Abstract
Motion capture or Mocap are terms used to describe the process of recording movement and translating that movement on to a digital model. It is used in military, entertainment, sports, and medical applications, and for validation of computer vision and robotics. In filmmaking it refers to recording actions of human actors, and using that information to animate digital character models in 2D or 3D computer animation. In motion capture sessions, movements of one or more actors are sampled many times per second, although with most techniques (recent developments from Weta use images for 2D motion capture and project into 3D), motion capture records only the movements of the actor, not his or her visual appearance. This animation data is mapped to a 3D model so that the model performs the same actions as the actor. This is comparable to the older technique of rotoscope, such as the 1978 The Lord of the Rings animated film where the visual appearance of the motion of an actor was filmed, then the film used as a guide for the frame-by-frame motion of a hand-drawn animated character. Camera movements can also be motion captured so that a virtual camera in the scene will pan, tilt, or dolly around the stage driven by a camera operator while the actor is performing, and the motion capture system can capture the camera and props as well as the actor's performance. This allows the computer-generated characters, images and sets to have the same perspective as the video images from the camera. A computer processes the data and displays the movements of the actor, providing the desired camera positions in terms of objects in the set. Retroactively obtaining camera movement data from the captured footage is known as match moving or camera tracking.
Keywords: motion capture, gait recognition, animation.

1 Introduction

Motion capture, motion tracking, or mocap are terms used to describe the process of recording movement and translating that movement on to a digital model. It is used in military, entertainment, sports, and medical applications, and for validation of computer vision and robotics. In filmmaking, it refers to recording actions of human actors, and then using that information to animate digital character models in 2D or 3D computer animation. The approach is often referred to as *performance capture,* when it involves face and fingers or captures subtle expressions. In motion capture sessions, movements of one or more actors are sampled multiple times per second, however, with most techniques (some recent developments use images for 2D motion capture and project into 3D [i, ii]), motion capture records only the movements of the actor, and not his/her visual appearance. This *animation data* is mapped to a 3D model so that the model performs the same actions as the actor. This is comparable to the older technique of rotoscope, such as the one used in 1978 *The Lord of the Rings* animated film, where the visual appearance of the actor's motion was filmed, then the film used as a guide for the frame-by-frame motion of a hand-drawn animated character.

Camera movements can also be motion captured, so that a virtual camera used in the scene will pan, tilt, or dolly around the stage, driven by a camera operator while the actor is performing. Following this technique, the motion capture system can capture the camera, props and the actor's performance. The approach allows the computer-generated characters, images and sets to have the same perspective as the video images taken by the camera. A computer processes the data and displays the movements of the actor, ensuring the desired camera positions in terms of objects involved in the set. Obtaining camera movement data from the captured footage retroactively is also known as camera tracking or match moving.

2 Motion Capture Technique

The main purposes of this paper are approaches and estimation methods for creating virtual human motion models, with special attention given to methods that construct Gait Differentiating Algorithms from data acquired by Motion Capture (MC) systems as well as Creation Realistic Animation of Human-like Figures (Fig. 1).

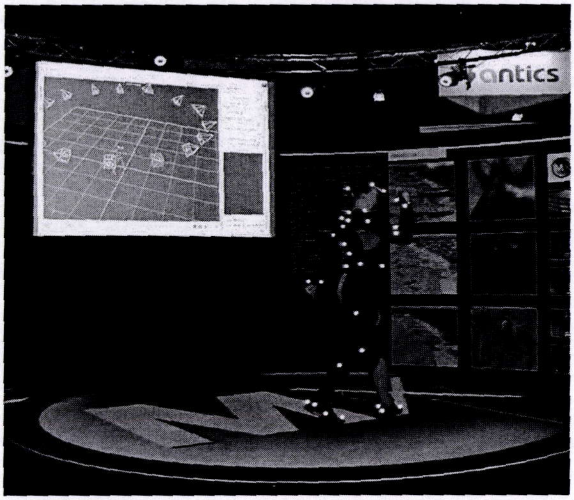

Figure 1: A typical motion capture studio1; optical markers are set on the actor.

[1] http://upload.wikimedia.org/wikipedia/commons/7/73/MotionCapture.jpg

Motion Capture [7, 16, 19, 21] is an important source of data for human recognition task. Actor's motion is captured using different kinds of sensors and recorded in 3D virtual space [8, 16, 17, 20, 23-27]. Data can be saved using suitable representations that take into consideration skeleton hierarchy. Following this technique many subtle details can be recorded, which could prove difficult to simulate using analytical motion models alone. Actor's motion is captured using various kinds of sensors and then recorded in 3D virtual space.

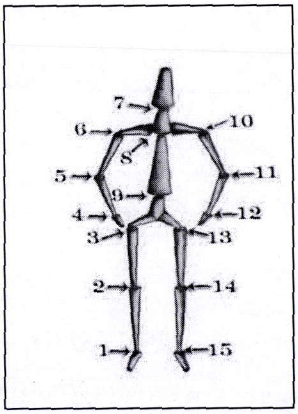

Figure 2: A typical skeleton model, where the natural numbers denote skeleton parts as follows: 1 Left Ankle Joint; 2 Knee Joint; 3 Hips Joint; 4 Wrist Joint; 5 Elbow Joint; 6 Shoulder Joint; 7 Neck-Head; 8 Torso-Neck; 9 Pelvis; 10 Shoulder Joint; 11 Elbow Joint; 12 Wrist Joint; 13 Hips Joint; 14 Knee Joint ; 15 Right Ankle Joint [19].

Data are saved using proper representation taking into consideration skeleton hierarchy. In this technique many subtle details can be recorded, which are difficult to simulate using analytical motion model.

2.1 Skeleton Mode

The skeleton model is organized in an invariable hierarchy and considerations usually consists of fixed number of bones (between15 and 23, see Fig. 2). Each bone can have at most one predecessor and one or more successors. The beginning of the whole hierarchy in the skeleton is virtual *root* bone and bones can move only by rotation around given axes. The data about the rotation of each bone is recorded. There are two most known types of data representations for rotations: Euler's angles and rotational matrices and quaternions [3, 8, 10, 12, 14, 16, 17]. Euler's angles are more popular; however, quaternions determine representation that is invariant to the coordinate system. Both approaches are widely used in animation systems, games and computer graphics software, gait recognition.

2.2 The main ideas of *MC* Systems

The data motion registration process has several intrinsic requisites, as for example: The registration should be held in the studio equipped with an appropriate system of cameras (between eight and sixteen) as well as sufficiently powerful computer system. Special sensors (markers) should be attached to the characteristic points of the actor (or person identified. Actor's motion is captured using different kinds of sensors and recorded in 3D virtual space.

The level of the realism of the animation determines the quantity of attached sensors. It also depends on what we want to reach. In this technique many subtle details can be recorded, which are difficult to simulate using analytical motion model. Data are saved using proper representation taking into consideration skeleton hierarchy. These data are sent to the computer which processes them then one receives the figure three-dimensional model in the result. There are several types of Motion Capture systems. Among the most popular are: Optical Systems, Inertial systems, Electromagnetic Systems.

Due to applying various models of hierarchic skeletons and their dimensionality the development of the Motion Capture interception systems result itself in the more advanced generation of systems of the capturing of the motion.

2.3 Methods of collecting data - Data Standards 3D

Among the most popular data standards of motion captures are: BVA and BVH file formats, MNM file format, ASK/SDL file format, AOA file format, ASF/AMC file formats, BRD file format, HTR and GTR file formats, TRC file format, CSM file format, V/VSK file format, 1.11 C3D file format, GMS file format and HDF file format.

There are however, three formats of particular importance, namely: BVA and BVH file formats, ASF/AMC file formats, and C3D file format.

2.3.1 BVA and BVH file format

The BVH (BioVision Hierarchical Data) replaced former BVA format. Both formats were introduced by BioVision, a defunct motion capture services company. The standards are mostly used as a typical representation of human motion and provide skeleton hierarchy information as well as the motion data. There is a right handed coordinate system defined for the BVH hierarchy.

2.3.2 ASF/AMC file formats

Acclaim Video Game Company [ix] introduced ASF/AMC formats. These formats are composed of one file for skeleton data and another one for motion data. The ASF file contains Acclaim Skeleton File, which can be used for different motions. The ACM file contains Acclaim Motion Capture data.

2.3.3 C3D file format

The National Health Institute in Maryland [x] introduced very helpful the C3D binary (mostly ASCII files) format in the biomechanical applications. The system is mostly used for athletes or physically handicapped person needs. It carries the most complete amount of information useful for the biomechanics research, because of the following features:

- storage of three-dimensional data directly coming from the measure instrument,
- storage of position marker, force captors, sampling rate, date, type of examination as well as name, age, physical parameter(s),
- a facility to enlarge the data by adding new data to the ones already stored.

3 Methods of Motion Data Analysis

The following set important observations can be made based on currently published research results: For the process of recognition, the analysis of motion of legs seems to be the most important. In many papers, for example [4-7, 9], demonstrate that person can be identified using legs motion.

Motion capture data can be obtained both from the commercial system to test proposed methods. In this research, we use *LifeForms* 3D database produced by *Credo Interactive Inc.* [iii] motion library, which contains different action sequences played by real actors and processed using *motion capture* technique (Fig. 2). The method of video analysis can be successful even when parts of the body are covered by clothes – legs are easier to distinguish (for example by using Hough transform: [8]). In the papers [10 - 12, 14] it is proposed to take into consideration rotation along one axis and only 3 coefficients of amplitude spectrum analysis (I, II amplitudes of X rotation of hip, I amplitude of X rotation of an knee). Motion can be considered and analyzed as time-series [1]. Many traditional time-series analysis methods (Fig. 4) have been successfully applied to human motion, including both deterministic and probabilistic approaches, stationary and time-varying statistical models, analysis in time and frequency domains. Among the more popular approaches of time-series modeling applied to human motion are Dynamic Time Warping (DTW), Hidden Markov Models (HMM), Markov Random Fields (MRF), algorithms directed towards time-series comparison such as Longest Common Subsequence (LCSS), spectral analysis methods including Fourier and wavelet transforms, dimensionality reduction methods including Principal Component Analysis (PCA), kernel based methods, and Latent Variable Model (LVM) [13, 19, 21]. Variety of filtering techniques are used for filtering, estimation, prediction and tracking of motion data, including autoregressive models such as AR, ARMA or ARIMA, Kalman filter and Extended Kalman Filter (EKF), kernel based methods, and Monte Carlo based techniques such as a Particle Filter [20], [22] and MCMC. An emerging important and fruitful branch of human motion research is directed towards recovery of skeletal pose from video sequences without the use of special suits and markers, referred to as Markerless Motion Capture [23], [24], [25], [26]. Monte Carlo filtering methods such as Particle Filter (Condensation method) are often used for markerless body tracking. Human body dynamics and inverse dynamics analysis can be used to provide informative constrains [2, 18] for filtering and tracking of pose from markerless video data. One of the most challenging problems in markerless motion capture, but offering a widespread application potential is that of estimation of body pose from single video sequence (Monocular Markerless Tracking) [27].

The *LifeForms* 3D database is a very convenient tool to check the performance of the listed above methods. The 3D models are used in investigations in medicine (diagnosis of a variety of balance disorders as Parkinson, Multiple Sclerosis and other degenerative conditions), allow us to recognize easily pathological movements of a patient and would help to choose the way of a treatment, for analysis of athletic performance of sportsmen, ergonomic design, and reconstruction of accidents involving humans. It is also possible analysis of crowd behavior or from detecting and recognizing people movements for security purposes. It can helpful to create and verify similar methods but using 2D database for gait recognition and identification (Fig .4) as well as for security goals.

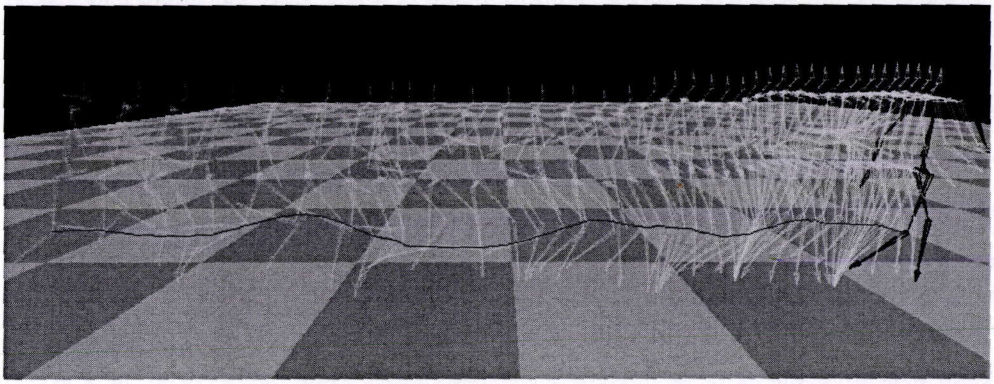

Figure 3: Motion capture technique - examples of motion model of human gait [16].

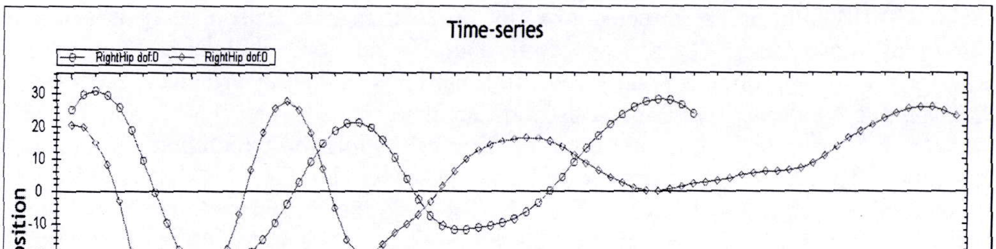

Figure 4: Gait identification example [16].

3.1 Dynamic Time Warping

The *Dynamic Time Warping (DTW)* method [28-30] is considered to compare motion sequences. The method is based on dynamic programming and is widely used for different time-series [1] comparison applications (like voice recognition [12]). The application for motion processing was presented in different papers [11, 13]. The proposal of database structure based on DTW was proposed in [14].

3.2 Spectrum Analysis

Some authors suggest that spectrum analysis of the motion signal can lead to interesting results concerning person identification [5 – 9]. I would like to verify if the method is suitable also for motion capture data which are represented either by Euler's angles or by quaternions. The initial experiment consists of the comparison of the energy accumulated in the most important part of the spectrum of signals. We compared the first few spectrum amplitude coefficients in signals of rotations along 3 axes. The first 30 coefficients were taken into account, because one can notice it is the main band, where the majority of the energy is accumulated.

4 Motion Model of Human Gait and Human Recognition Task

There are typical Data representations: absolute translations, relative translations, Euler's angles (transformation matrices), unit quaternions.

4.1 Methods of Motion Data Analysis

Motion can be considered as specific time-series. Time-series analysis:

Dynamic Time Warping – DTW, Hidden Markov Models – HMM, other algorithms prepared for time-series comparison (e.g. LCSS – Longest Common Subsequence)

Spectrum analysis: legs data: legs angle, legs length, steps frequency, foots positioning techniques, roots movement, hips movement

4.2 Data analysis – Dynamic Time Warping

Dynamic Time Warping method: Initially the method was used for voice recognition. The method is based on dynamic programming. The comparison of time-series of different lengths is possible, different modification taking into consideration specific measures of similarity.

Usually computations are carried out using FFT algorithm which provides computational complexity of $N*log2(N)$, sampling frequency $f_{sample} >= 2 f_{max}$.

4.3 Modified Motion Model

Instead of taking into consideration selected axis, quaternion based model is proposed along with quaternion measure of similarity between positions of bones.

Similarly four bones are analyzed (a hip and an knee of the left and right leg). Different numbers of spectrum coefficients are taken into account. The quality of the method can be measured by the quality of clustering which can be performed taking into consideration measures introduced by the method.

4.4 Model Based on Computations of the Surface Area under the Motion Curve

The aim of this new method is to compare displacements of selected joints from a given surface level. To simplify the computations required for testing the model, a program was developed to retrieve specific motion data from BVH files.

The program contains a parser for BVH files, an algorithm calculating position of joints using the angle rotations defined in the BVH files, a converter of measurement units (translations are calculated in units nominated by the user (inches or cm) to avoid possible errors related to use of different measuring units) and the module that calculates the surface area under the curve generated by a selected joint of the limb. Users can define the integration range (frames/time) using the Riemann integrals for which a surface area is to be calculated. When executing the program, a user after the selection of a file can define a joint, left or right side and the reference level (here denoted as Level 0) of the surface from which displacements (Y values) are to be calculated. In order for the program to perform various calculation of position of joints recorded in BVH files representing consecutive animation frames, we need to find out the information related to the initial position of joints that is contained in the BVH file, first. The initial position for a concrete joint can be computed by summing up the offset of the given joint together with offsets of its predecessors (parents). This procedure, for example can be represented as follows:

$$[X_{lh}, Y_{lh}, Z_{lh}] = [X_{ro} + X_{lho}, Y_{ro} + Y_{lho}, Z_{ro} + Z_{lho}] \quad (1)$$

$$[X_{lk}, Y_{lk}, Z_{lk}] = [X_{lh} + X_{lko}, Y_{lh} + Y_{lko}, Z_{lh} + Z_{lko}] \quad (2)$$

where, **ro** is a Root Offset, **lho** is LeftHip Offset, **lh** is a calculated pos. LeftHip, **lko** – LeftKnee Offset and **lk** is a calculated pos. LeftHip. After substituting relevant values a result is obtain that is Root translation of the left knew position. In order to mark a given joint position related to a global system off coordinates (a centre position [0,0,0]), the obtained results need to be sum together with the Root translation that is placed in the first frame of the Motion section. This can be expressed by:

$$[X_{lkGlob}, Y_{lkGlob}, Z_{lkGlob}] = [X_{lk} + X_{r1}, Y_{lk} + Y_{r1}, Z_{lk} + Z_{r1}] \quad (3)$$

where **lkGlob** is a position in relation to [0,0,0] and **r1** is the Root translation of the 1st frame.

Calculation of joint positions in all individual frames is a more complicated process. For this task, the following special transformation matrices can be applied:

$$M - \begin{bmatrix} \cos Y \cos Z - \sin X \sin Y \sin Z & -\cos X \sin Z & \sin Y \cos Z + \sin X \cos Y \sin Z & X_{pos} \\ \cos Y \sin Z + \sin X \sin Y \cos Z & \cos X \cos Z & \sin y \sin Z - \sin X \cos Y \cos Z & Y_{pos} \\ -\cos X \sin Z & \sin X & \cos X \cos Y & Z_{pos} \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix} \quad (4)$$

where, ***X, Y, Z*** are rotations of a given joints that are placed in the Motion section of the BHV file.

The rotation angles need to be recalculated these are given in radians as follows:

$$X_{Rad} = \frac{X_{st} \cdot \pi}{180} \qquad (5)$$

where, $\mathbf{X_{Rad}}$ – rotation value calculated in radians and $\mathbf{X_{st}}$ – rotation value as read from Motion section calculated in degrees.

Note that X_{pos}, Y_{pos}, Z_{pos} are the offset values of a given joint in the Hierarchy section and the Root values are transcribed in the Motion section of the BVH file. Hence, in order to calculate positions of a given joint, matrices of all parents of the joint have to be calculated first and then a product of these matrices has to be computed according to:

$$M_{target} = M_{root} M_{child} M_{grandchild} \ldots \qquad (6)$$

For a left knee joint position calculation the following version of (6) can be applied:

$$M_{lkGlob} = M_{Root} M_{lh} M_{lk} \qquad (7)$$

where, M_{lkGlob} is transformation matrix of the local coordinates in relation to the global [0,0,0] coordinates. The next step is multiply the obtained matrix by a unit vector $v =$ [0,0,0,1] resulting in vector value of the given joint position in a relation to the global [0,0,0] system of coordinates.

$$v_{new} = M_{target}{}^{v} \qquad (8)$$

For more detailed analysis of the obtained results, the approach can be further extended by performing additional tasks that use the Amplitude Spectrum Analysis approach based on the rotation along one axis and 3 coefficients of (I, II amplitudes of X rotation of hip, I amplitude of X rotation of an knee), where, for example, a sum of the first 10, 30 and 50 effective values of the harmonic spectrum with a comparison of 3 values for 2 different variants can be studied (Fig 5).

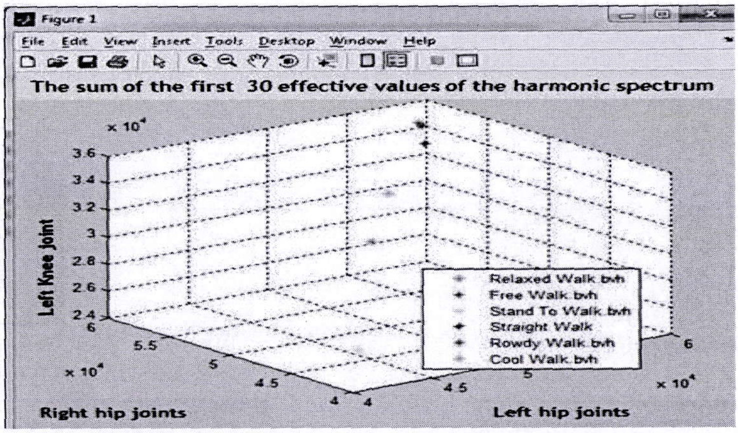

Figure 5: Analysis of Amplitude Spectrum.

5 Experimental Results

The main aim of the presented investigation and conducted experiments was to compare recorded human motions from the perspective of their belonging to the same person or different actors. The analysis of the human gait was registered in 2D. Various tests were performed to validate the claims that human motion is a unique phenomenon that is characteristic for each and every individual human. The first set of experiments concentrated on analysis of a displacement (from a given surface level) values of the selected joints of a person. The tests involved a hip, an knee and an ankle joints of both left and right limbs. The choice of limbs for the study allows for a simpler process of analysis than it would be the case for other parts/joints of a human body.

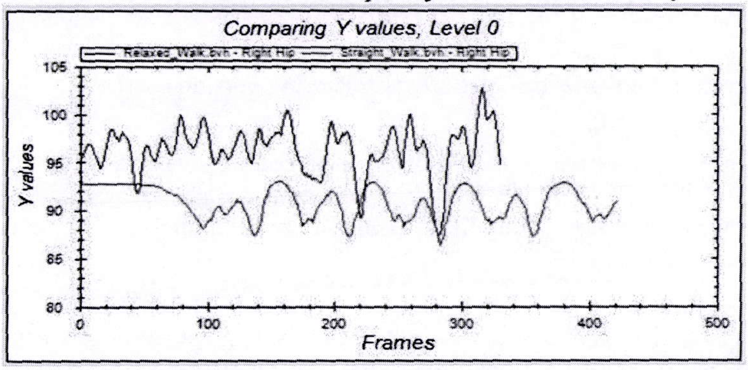

Figure 5: Shifts of the right hip from the surface for Free_Walk and Rowdy_Walk

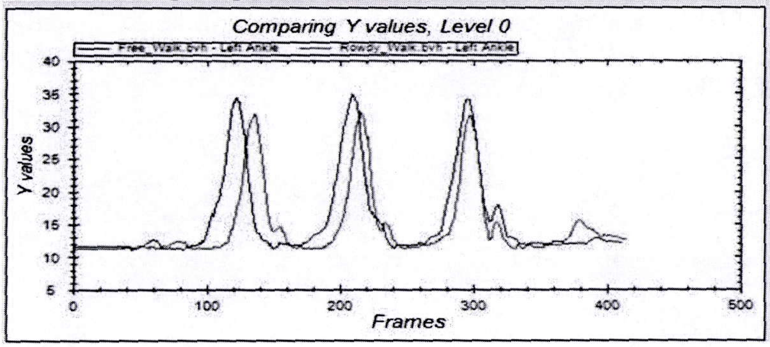

Figure 6: Shifts of the right hip from the surface for Free_Walk and Rowdy_Walk movements.

On a typical diagram (Fig. 5) that depict displacements, the Y axis represents values of the hight(s) at which the joint is placed while the X axis represents consecutive animation frames of a given motion. On Fig 6, the recorded hip motions for the same person for Free_Walk and Rowdy_Walk movement types are phase shifted; However, the size of the surface areas under curves that are drawn as a result of these motions are very similar.

The Table 1 shows a typical calculation of the surface area under curve (Fig. 6) for a selected joint.

Table 1: Computing the surface areas of the presented diagrams.

PARAMETERS:	**COMPUTED RESULTS:**
Beginning of the integration range : **80** End of the integration range : **280** Number of frames analysed: **200**	Surface Area for Free-Walk.bvh: **3387.61** Surface Area: Rowdy-Walk.bvh: **3111.21** An absolute size difference of 2 areas: **276.40**

The capability to compute the surface area(s) for curves depicting motion of joints allows for applications of various combinations of computing methods. The following combination of computing methods were tested in our experiments:

- calculations based on the absolute value of the difference of surface areas for corresponding limb joints motions (Table 2),
- calculations based on a ratio of the absolute value of the difference of surface areas for limb joints motions to number of frames within the tested/calculated range (Table 2),
- calculations based on a ratio of surface areas for limb joints motions of one set to analogous areas of another set of motions (Table 3, Table 5),
- calculations based on a ratio [surface/frame] of all areas in one set of motions to analogous areas of another set (Table 4) .

Table 2: Computing the absolute value of the difference of surface for left and right hips; a ratio of the absolute value to the number of frames.

Motion Type	Tested joints	Start of integration range	Start of integration range	Number of analysed frames [k]	Area of the tested range	An absolute diff of areas [n]	Value [n/k]
Free_Walk.bvh	Left Hip	80	280	201	18 599,29	**100,43**	**0,50**
Rowdy_Walk.bvh					18 498,86		
Free_Walk.bvh	Right Hip	80	280	201	18 572,34	**121,28**	**0,60**
Rowdy_Walk.bvh					18 693,62		

In order to facilitate more detailed analysis, tables that depict matrices of various motions can be prepared. These tables contain such values as:

- a ratio of the absolute difference of the surface areas for a hip and an knee joints as well as an knee and an ankle joints of one motion to analogous values of another motion,
- a ratio of the absolute difference between the surface areas a hip and an knee joints to a value of a hip surface area.
- a ratio of the absolute difference between the surface areas an knee and an ankle joints to a value of an knee surface area.

Table 3: Computing ratios of the surface areas of the left hip motions

			Relaxed_Walk.bvh	Free_Walk.bvh	Stand_To_Walk.bvh	Straight_Walk.bvh	Rowdy_Walk.bvh	Cool_Walk.bvh
			LH	LH	LH	LH	LH	LH
			19 306,69	18 599,29	20 276,10	18 119,22	18 498,86	19 830,08
Relaxed_Walk.bvh	LH	19 306,69	1,00	0,96	1,05	0,94	0,96	1,03
Free_Walk.bvh	LH	18 599,29	1,04	1,00	1,09	0,97	0,99	1,07
Stand_To_Walk.bvh	LH	20 276,10	0,95	0,92	1,00	0,89	0,91	0,98
Straight_Walk.bvh	LH	18 119,22	1,07	1,03	1,12	1,00	1,02	1,09
Rowdy_Walk.bvh	LH	18 498,86	1,04	1,01	1,10	0,98	1,00	1,07
Cool_Walk.bvh	LH	19 830,08	0,97	0,94	1,02	0,91	0,93	1,00

Table 4: Computing the absolute difference between the surface areas of a hip and an knee joints to a value of the surface for an knee and an ankle as well as ratio of this value to number of tested frames for *Free_Walk* types.

Motion Type	Tested joints	Start of integration range	Start of integration range	Number of analysed frames [k]	Area of the tested range	An absolute diff of areas [n]	Value [n/k]
Free_Walk.bvh	Left Hip	80	280	201	18 599,29	7 421,42	36,92
	Left Knee	80	280	201	11 177,87		
	Left Knee	80	280	201	11 177,87	7 790,26	38,76
	Left Ankle	80	280	201	3 387,61		
	Right Hip	80	280	201	18 572,34	7 441,84	37,02
	Right Knee	80	280	201	11 130,50		
	Right Knee	80	280	201	11 130,50	7 694,07	38,28
	Right Ankle	80	280	201	3 436,43		

Table 5: Computing ratios of an absolute difference between surface areas of the right knee and ankle in one motion set to anther analogues difference of another motion set.

			Relaxed_Walk.bvh	Free_Walk.bvh	Stand_To_Walk.bvh	Straight_Walk.bvh	Rowdy_Walk.bvh	Cool_Walk.bvh
			RK-RA	RK-RA	RK-RA	RK-RA	RK-RA	RK-RA
			7 773,18	7 694,07	8 265,16	7 291,71	7 900,88	8 128,22
Relaxed_Walk.bvh	RK-RA	7 773,18	1,00	0,99	1,06	0,94	1,02	1,05
Free_Walk.bvh	RK-RA	7 694,07	1,01	1,00	1,07	0,94	1,03	1,06
Stand_To_Walk.bvh	RK-RA	8 265,16	0,94	0,93	1,00	0,88	0,96	0,98
Straight_Walk.bvh	RK-RA	7 291,71	1,07	1,06	1,13	1,00	1,08	1,11
Rowdy_Walk.bvh	RK-RA	7 900,88	0,98	0,97	1,05	0,92	1,00	1,03
Cool_Walk.bvh	RK-RA	8 128,22	0,96	0,95	1,02	0,90	0,97	1,00

It is worth to note that for the most of the tested motions (Free_Walk.bvh, Rowdy_Walk.bvh, Stand_To_Walk.bvh, Straight_Walk.bvh), at the beginning of the animation, the actor is stationary. Hence, a decision was made to calculate the surface area in the integration range declared by the user. This is due to the fact that for each tested file an actor usually performs an actual move around 80^{th} frame. This is the reason why 80-280 range of frames was selected for most of the tests.

6 TRAF System

In this chapter an approach to produce realistic animations based on a motion capture library is considered. Preparing a flexible tool for animators is connected with complex preprocessing of motion clips. Flexibility is created by hierarchical motion models, a database of motion clips and smart methods for motion synthesis based on a constraint structure. Motion capture data are used as a basis for an enhancement of a final animation. The aim is to solve the problem related to a partition of the set of primitive motions according to similarity between motions. The motion models are constructed to easier extract features of given motions. Using these models the measure of discrepancy between motions is proposed. Moreover, it normalizes length of motions and decreases high dimension of considered motion data, so clustering may take place in reduced space [3. 14]. The TRAF system was designed as a tool to create animations of realistic human-like figures [14, 32]. This system is connected with animation systems, based on *motion capture* technology. A distinguishing novelty in this project is a reuse of existing and properly converted motion sequences. In case of repeatedly using this system, TRAF was equipped in multimedia database gathering converted animations.

6.1 The Structure of the TRAF System

The first functional group consists of two independent parts: Analysis Unit and Database Unit. Motion sequences get from outside in a form of motion capture data into Analysis Module. It is based on a proper division of *motion capture* sequences into smaller parts: *primitive motions*. This process consists of normalization of skeleton shape and motion data. Approximated models and simple motions are data that Analysis Unit transmits into Database Unit. On the grounds of intercepted questions DBU realizes passable database searching operations and gives back results of these operations to other modules. The fundamental task of the system is to produce an animation with a special emphasis on motion's reality. After a suitable ordering these fragments in a system database can be useful to create quite a new motion.

To create such a motion it is necessary to deliver adequate methods and tools and to assure a proper user communication. This short introduction let us to distinguish four blocks in the system, as shown in Figure. 7. TRAF modules consist of two groups, because of functionality: Motion Analysis and Motion Synthesis. There is a special method of database organization; therefore DBU takes over a part of a complex problem creating of an automatic animation. Elementary motions delivered to the database from Analysis Unit, are in DBU divided in groups in accordance of specially defined similarity measure of motion characters. There are assigned motion character standards for individual groups of movements that are represented as models of parametric group (so-called general motion models). Between general models and primitive motions there are established adequate relations, which enable later reconstruction of an obtained division. A new elementary motion loaded into a database is classified into equivalent groups and "bounded" in relation with passable general models [33].

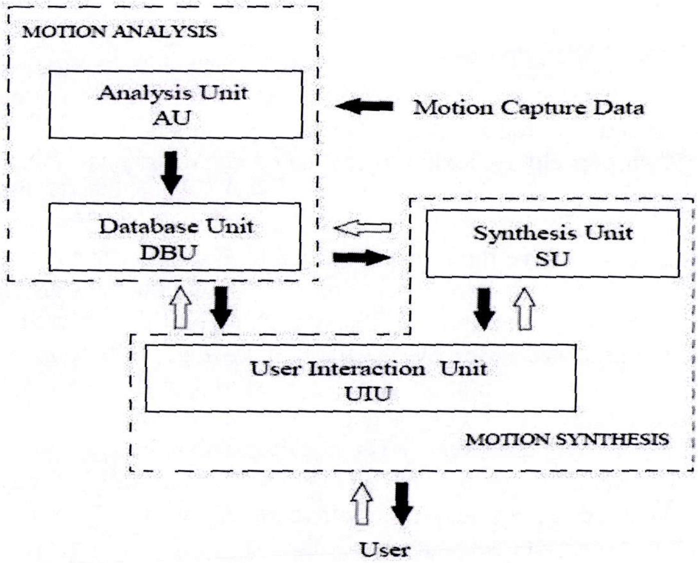

Figure 7: TRAF Modules.

7 Conclusion

Human motion can be an interesting source of information for biometric posture recognition. For the process of recognition, the analysis of motion of limbs (legs) seems to be the most significant. Both frequency based analysis (FFT) as well as time-series analysis (DTW) can be powerful tools for biometric identification. Application of quaternion based model leads to taking into consideration important motion features. As shown, a newly proposed method for gait recognition that uses various techniques of comparing the surface areas under the motion curves offers very accurate results.. Fundamental methods presented in this paper are only a part of methods for creation realistic animations of human like figures. Against a background of existing methods for motion creating it makes sense to present a full solution as proposed in the TRAF project, preliminary described in the previous sections. A solution given by the TRAF system is a specific solution among those proposed at the present time.

References

[1] Batyrshin Ildar Z., Sheremetov Leonid (2007) Perception Based Time Series Data Mining for Decision Making, IFSA (2), pp. 209-219.

[2] Chaczko Z., Klempous R. (2009) Anticipatory Biomimetic Middleware, 9th International Conference CASYS 2009 on Computing Anticipatory Systems, August 3-8, Liège, Belgium.

[3] Kulbacki M., Jablonski B.R., Klempous, R. Segen, J. (2004) Learning from Examples and Comparing Models of Human Motion, Journal of Advanced

Computational Intelligence and Intelligent Informatics, 8(5), pp. 477-481.
[4] Murray M. P. (1967) Gait as a Total Pattern of Movement, American Journal Phys. Med. 46(1).
[5] Murray M. P., Drought A.B., Kory R.C. (1996) Walking Patterns of Normal Men, Journal of Bone Joint Surg., 46A (2), pp. 335-360.
[6] Yam C. Y., Nixon M.S., Carter J.N. (2001) Extended Model-Based Automatic Gait Recognition of Walking and Running, Proc. of 3rd Int. Conf. on Audio-and Video- Based Biometric Person Authentication, pp. 278-283.
[7] Yam C. Y. (2003) Automated Person Recognition by Walking and Running via Model-based Approaches, Pattern Recognition 37(5).
[8] Cunado D., Nixon M.S., Carter J.N. (2003) Automatic Extraction and Description of human gait models for recognition purposes, Computer Vision and Image Understanding, 90(1), pp. 1-41.
[9] Mowbray S.D., Nixon M.S. (2003) Automatic Gait Recognition via Fourier Descriptors of Deformable Objects, Proc. of Audio Visual Biometric Person Authentication.
[10] Cunado D., Nixon M.S., Carter J.N. (2003) Using Gait as a Biometric, via Phase-Weighted Magnitude Spectra, Proc. of 1st Int. Conf. on Audio-and Video-Based Biometric Person Authentication, 95-102.
[11] Kuan E.L. (1995) Investigating gait as a biometric, Technical report, Departament of Electronics and Computer Science, University of Southampton.
[12] Rabiner L.R., Juang B. (1993) Fundamentals of speech recognition, Englewood Cliffs, NJ: Prentice-Hall.
[13] Itakura F. (1975) Minimum Prediction Residual Principle Applied to Speech Recognition, IEEE Trans. on Acoustics Speech and Signal Processing, AS23.1, 1975, pp. 67-72.
[12] Bruderlin, A., Williams L. (1995) Motion Signal Processing, Computer Graphics, 29, 97-104.
[14] Kulbacki M., Jablonski B.R., Klempous, R. Segen, J. (2003) Multimodel Approach to Human Motion Designing, Proc. IEEE International Conference on Computational Cybernetics, Siofok, Hungary.
[15] Kratky O., Porod G. (1949) "Röntgenuntersuchung gelöster Fadenmoleküle." "Rec. Trav. Chim. Pays-Bas." **68**: 1106-1123.
[16] Klempous R. (2009) Biometric Motion Identification Based on Motion Capture, *Towards intelligent engineering and information technology / Imre J. Rudas, János Fodor, and Janusz Kacprzyk (eds).* Berlin/Heidelberg, Springer, cop. 2009. pp. 335-348.
[17] Klempous R. (2007) Movement identification analysis based on Motion Capture, *Lecture Notes in Computer Science* 2007, vol. 4739, pp. 629-637.
[18] Moulton, B., Pradhan, G., Chaczko, Z. (2009) Voice Operated Guidance Systems for Vision Impaired People: Investigating a User-centered Open Source Model. International Journal of Digital Content Technology and its Applications, in press, accepted 12 Sep 2009.
[19] Kucharski T. (2005) Animated Human Shape and Movement Modeling (in Polish),

Master's Thesis, Wroclaw University of Technology, 2005,
[20] Cheng Changn I., Shih-Yao Lin, (2010) 3D Human Motion Tracking Based on a Progressive Particle Filter, Pattern Recognition, 43, pp. 3621–3635.
[21] Lawrence N. D. (2003) Gaussian Process Latent Variable Models for Visualisation of High Dimensional Data, Advances in Neural Information Processing Systems, vol. 16, pp. 329–336.
[22] Saboune J., Rose C., Charpillet F. (2007) Factored interval particle filtering for gait analysis, in: International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 3232–3235.
[23] Corazza S., Muendermann L., Chaudhari A., Demattio T., Cobelli C., Andriacchi T. (2006) A Markerless Motion Capture System to Study Musculoskeletal Biomechanics: Visual Hull and Simulated Annealing Approach Annals of Biomedical Engineering, 34(6), pp. 1019-29.
[24] Muendermann L., Corazza S., Andriacchi T. (2006) The Evolution of Methods for the Capture of Human Movement Leading to Markerless Motion Capture for Biomechanical Applications, Journal of NeuroEngineering and Rehabilitation, 3(1).
[25] Corazza S., Mündermann L., Andriacchi T. (2007) A Framework For The Functional Identification Of Joint Centers Using Markerless Motion Capture, Validation For The Hip Joint, Journal of Biomechanics, .
[26] Mündermann L., Corazza S., Andriacchi T., (2007) Accurately measuring human movement using articulated ICP with soft-joint constraints and a repository of articulated models, Proceedings of CVPR 2007.
[27] Shahrokni A., Lepetit V., Fua Pa., (2003) Bundle Adjustment for Markerless Body Tracking in Monocular Video Sequences, ISPRS Workshop on Visualization and Animation of Reality-based 3D Models, Vulpera, Switzerland.
[28] Keogh E. J., and M.J. Pazzani, {2001) "Derivative Dynamic Time Warping," First SIAM International Conference on Data Mining, Chicago, USA.
[29] Jablonski B., Klempous R., Majchrzak D., (2006) Feasibility Analysis of Human Motion Identification Using Motion Capture, Proc. of the Int. Conference on Modelling, Identifcation and Control, Acta Press.
[30] Witkin A., Popovi_ Z., (1995) *Motion Warping*, Proc. of SIGGRAPH 1995, USA.
[31] Myers C.S., Rabiner L.R., (1981) A comparative Study of Several Dynamic Time-warping Algorithms for Connected Word Recognition, The Bell System Technical Journal, 60(7), pp. 1389-1409
[32] Kulbacki M., Rawicki J., Klempous R., Segen J. (2003) Clustering methods for motion Capture, Proceedings of IEEE International Conference on Computational Cybernetics, ICCC 2003, August 29-31, Siofok, Hungary
[33] Jabłoński B., Kulbacki M., Klempous R., Segen J. (2003) Methods for Comparison of Animated Motion Generators, Proceedings of IEEE International Conference on Computational Cybernetics, ICCC 2003, August 29-31, Siofok, Hungary.
[i] http://en.wikipedia.org/wiki/Motion_capture.
[ii] http://thefoundry.s3.amazonaws.com/downloads/CaseStudy_Mari_Avatar.pdf
[iii] http:// www.credo-interactive.com/