WHOLODANCE

Whole-Body Interaction Learning for Dance Education

Call identifier: H2020-ICT-2015 - **Grant agreement no**: 688865

Topic: ICT-20-2015 - Technologies for better human learning and teaching

Deliverable 2.6

Motion capture sequences and skeleton avatar

Due date of delivery: June 30th, 2017

Actual submission date:

Start of the project: 1st January 2016
Ending Date: 31st December 2018

Partner responsible for this deliverable: Motek Entertainment

Version: 1.0

Dissemination Level: Public

Document Classification

Title	Motion capture sequences and skeleton avatar
Deliverable	2.6
Reporting Period	First
Authors	MOTEK
Work Package	2
Security	Public
Nature	Report
Keyword(s)	Motion capture sequences skeleton avatar

Document History

Name	Remark	Version	Date
Oshri Even Zohar	First draft	1.0	25/5/17

List of Contributors

Name	Affiliation
Oshri Even Zohar	**Motek**
Jasper Brekelmans	**Motek**
Jochem Aarts	**Motek**
Markus Heuklom	**Motek**

List of reviewers

Name	Affiliation
Sarah Whatley	Coventry University

Index

Introduction

The conceptualization development of generic inverse kinematic (1) (IK) avatar skeletons for the WhoLoDance project was derived from the guidelines and requirements that emerged from discussions with the consortium dance partners from the project's start and through several dance partners and technical partners meetings in the last 14 month.

The creation of a unified performer IK Skeleton Fitting (retargeting) and visualization was based on several principles manifested in those guidelines, and pertained to the type of functionality an IK avatar skeleton should have in the project's context.

For the avatar skeletons creation stage to be executed properly, there was first the need to analyse the motion capture sequences from the perspectives of:

- Global scale deviations between performers
- Range of motions rotational scope per performer
- Unified mean deviation across all performers

Once this stage was complete, the data was used to determine the dimensions and internal scale of an empiric unified avatar skeleton that would fit the scaling of all the performers that were captured for the project.

The stages of the skeleton creation pipeline involved 3D modelling of skeletal hierarchies, setting up correct biomechanical human limits rotations constraints for the skeleton and coding of transformation parameters so that motion capture data could be propagated correctly into the avatar skeletons. Furthermore, work was carried out in enabling the use of 3D geometry on top of the avatar skeletons, whether in a form of parent-child relation (2), or as a flexible envelope (3)

This deliverable describes the processes of creation and implementation of inverse kinematic skeletons for the avatars modelled in T2.4, next to the creation of materials, textures, lighting setup and shaders for the models. This deliverable also includes preliminary results of real-time testing of those assets.

In the upcoming WP6, the data will also undergo a stage of 3D modelling optimizations of avatar for volumetric / holographic projection and optimization for alternative projection methods and systems. The last part of this task involves the skeleton fitting (retargeting to fit the anatomy and morphology of the 3D avatars with the human performers that will be captured in the future), optimization of inverse kinematic skeleton, and, finally, optimization of materials, textures, lighting setup and shaders for real-time interactive display.

(1): **Inverse kinematics** is the Mathematical process of recovering the movements of an object in the world from some other data, such as a film of those movements, or a film of the world as seen by a camera which is itself making those movements. This is useful in robotics and in film animation. In robotics, inverse kinematics makes use of the kinematics equations to determine the joint parameters that provide a desired position for each of the robot's end-effectors. Specification of the movement of a robot so that its end-effectors achieve the desired tasks is known as motion planning. Inverse kinematics transforms the motion plan into joint actuator trajectories for the robot. Similar formulae determine the positions of the skeleton of an animated character that is to move in a particular way in a film, or of a vehicle such as a car or boat containing the camera which is shooting a scene of a film. Once a vehicle's motions are known, they can be used to determine the constantly-changing viewpoint for computer-generated imagery of objects in the landscape such as buildings, so that these objects change in perspective while not themselves appearing to move as the vehicle-borne camera goes past them. The movement of a kinematic chain, whether it is a robot or an animated character is modelled by the kinematics equations of the chain. These equations define the configuration of the chain in terms of its joint parameters. Forward kinematics uses the joint parameters to compute the configuration of the chain, and inverse kinematics reverses this calculation to determine the joint parameters that achieves a desired configuration

(2): **Parent-child relational modelling** In the world of 3D, users are able to organize their scenes by creating a hierarchy. The hierarchy is created through the process of parenting objects to one another from inside the program. When an object becomes a Child of another object (Parent), it will follow all transformations applied to the Parent. This is useful in the case where a character or 3D object has multiple parts and needs to move around in the scene. That way you only need to animate the Parent model and the Child objects will follow automatically.

(3): **Flexible envelope** Avatars can be enveloped (skinned) to a skeletal rig. The skeletal rig is then animated with keyframes, or in the case of Wholodance, driven by motion capture data. This animation in turn, deforms the envelope.

Mocap sequences analysis and skeleton guidelines

Mocap sequences analysis

The motion capture repository of the four dance styles that were captured (Classic, Contemporary, Greek and Flamenco) contains data from multiple performers. The performers (8 in total) are from both genders and have very different anthropomorphic parameters. There are differences in height, weight, range of motions and additional parameters relating to motion –types (Attack-Decay length, fluidity, acceleration and velocity etc.)

In order to achieve unified avatar skeletons, the data from all the takes had to be analysed to determine the variances in:

1: Global scale deviations between performers. This pertains to differences in global height, differences in body part segmentation length and variations in width. The performer specific set of parameters were derived from the T-pose motion capture data that every performer executed prior to capture.

2: Range of motions rotational scope per performer was derived from from the ROM sequences every performer had to do during the subject calibration takes prior to every capture session

Once all the motion capture data was processes and analysed, the results were used in setting the segment length dimensions and rotation limits constraints of the avatar skeleton. Having a unified mean deviation (cross performer) skeleton, means that we can have in the future any new performer drive the avatar skeleton and be correctly re-targeted to fit their body dimensions and dynamic behaviour.

The final cleaned and edited sets of loop-able motion capture data individual sequence per genre is residing on the project's Dropbox shared account. The data is divided in a directory structure that is constructed according to: Genre→Motion principle→List of sequences.

Skeleton guidelines

Naming convention, FBX, Unity3D, Hierarchy structure, Real-time,

Animating an articulated figure usually requires expensive hardware in terms of motion capture equipment, processing power and rendering power. In order to be able to drive avatars in virtual environments in real-time, we customised a system to drive an articulated full body avatar in real-time, using position and orientation data for the limbs from the Wholodance motion capture repository. The system had to drive an avatar in a virtual environment on a low-end computer. The use of inverse kinematics to solve for the articulated chains making up the topology of the articulated figure was coded in a way that utilises fast real-time optimizations. Furthermore, we created the avatar skeleton articulated chains to specify various levels of redundancy for use in articulated figures. We then provided the needed constraints to reduce the redundancy of non-defined articulated chains, specifically for chains found in an articulated human upper body. (Clavici bones and neck links for example)

Such methods include ways to solve for the redundancy in the orientation of the neck link, as well as the redundancy of the articulated human arm. The first method involves eliminating a degree of freedom from the chain, thus reducing its redundancy. The second method calculates the elevation angle of the elbow position from the elevation angle of the hand. The third method determines the actual position of the elbow from an average of previous positions of the elbow according to the position and orientation of the hand. This was also needed in order top create unified skeleton to fit all performers.
In combination with a virtual reality system, these processes allow for the real-time animation of an articulated figure to drive avatars in virtual environments or for low quality animation on a low-end computer.

Skeleton avatar specifications.

Skeleton structure

The figures below show the created avatr skeleton structure of the full body and a detail picture showing the skeleton elements of the fingers. This is already with the unified scaling so it can fit any performer. The namespace of the hierarchy is created based on the performer's name.

Figure 1: Full body skeleton structure

Figure 2: Hands & fingers skeleton structure

The figues below show the optical marker hierarchy and a detail schematic example of a skeletal element (Neck+head) and the gemometry attached to it.

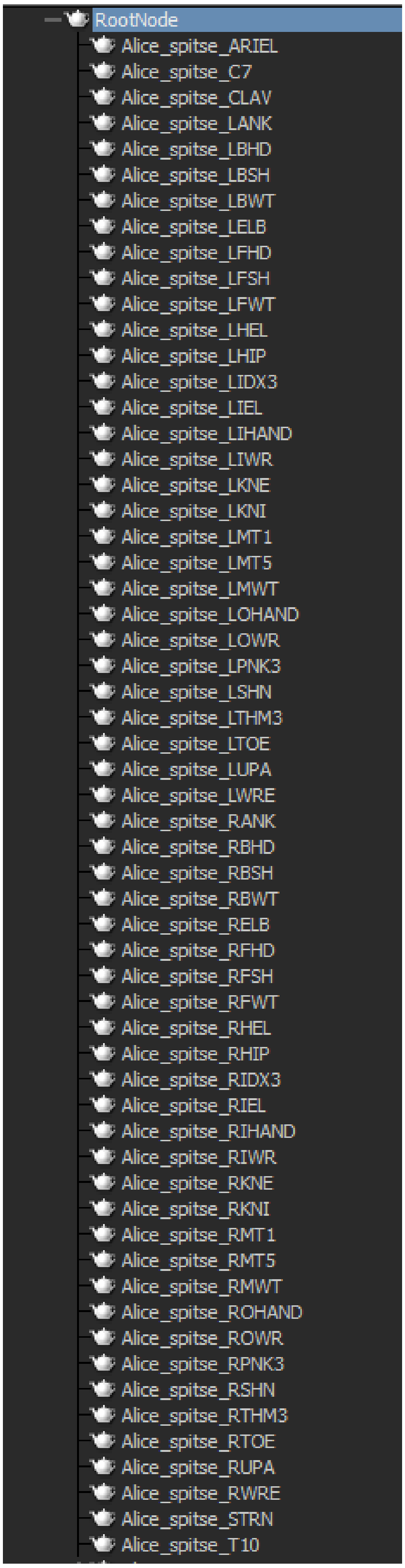


Figure 3: Optical markers structure

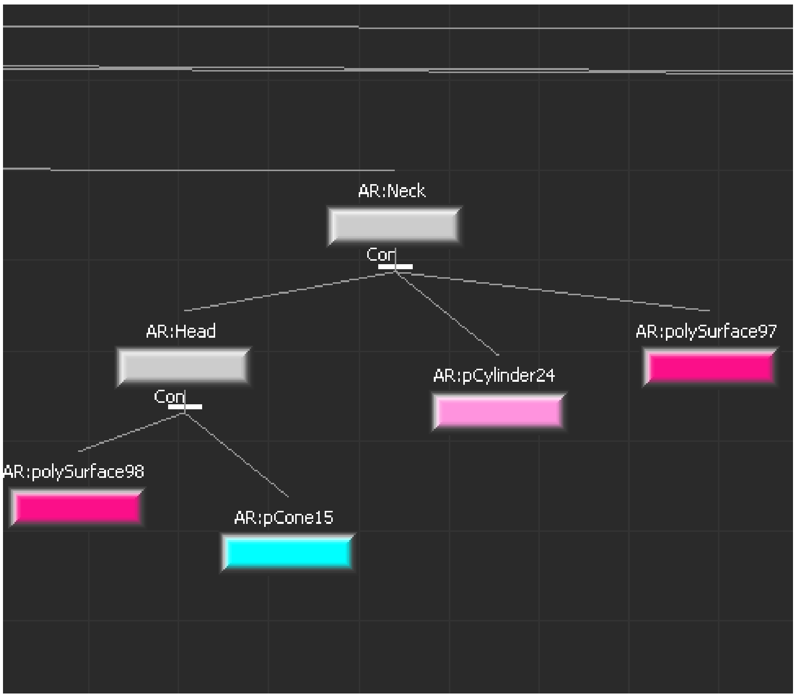


Figure 4: Detail skeletal & geometry hierarchy (Neck-Head structure)

Naming convention

The avatar skeleton naming convention is chosen in order to be compatible with most 3D packages existing in the market today. More specifically to fit inside the skeletal structure of both Motionbuilder (Autodesk) and Unity3D.

Skeletal Degrees of freedom (Dof's) and constraints

The avatar skeleton is comprised out of the following degrees of freedom per bodypart:

Hips / Pelvis - 6 Dofs (XYZ global translation and XYZ Global rotations)
Chest/Trunk - 3 Dofs (XYZ Local rotations)
Shoulders - 5 Dofs (YZ Local translations and XYZ Local rotations)
Elbows – 1 Dof (Local X rotation)
Palms – 3 Dofs (XYZ Local rotations)
Fingers - 1 Dof (Local X rotation per finger per joint)
Knees - 1 Dof (Local X rotation)
Feet - 3 Dofs (XYZ Local rotations)
Toes - 1 Dof (Local X rotation)

The following constraints are applied:

1:Rotation limits on all joints to stay coherennt within human biomechanics limits to avoid intersections between limbs.
2: Rotation limits on elbows and knees to avoid rotating beyond what is physically possible.

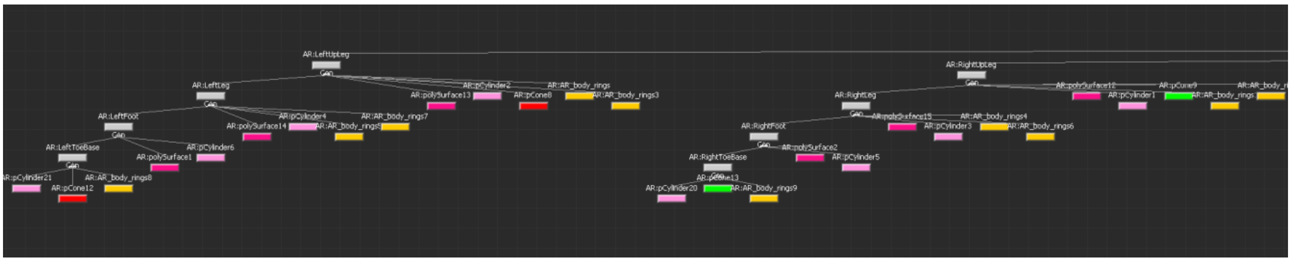


Figure 5: Detail example (Legs) naming convention of skelatal hirarchy

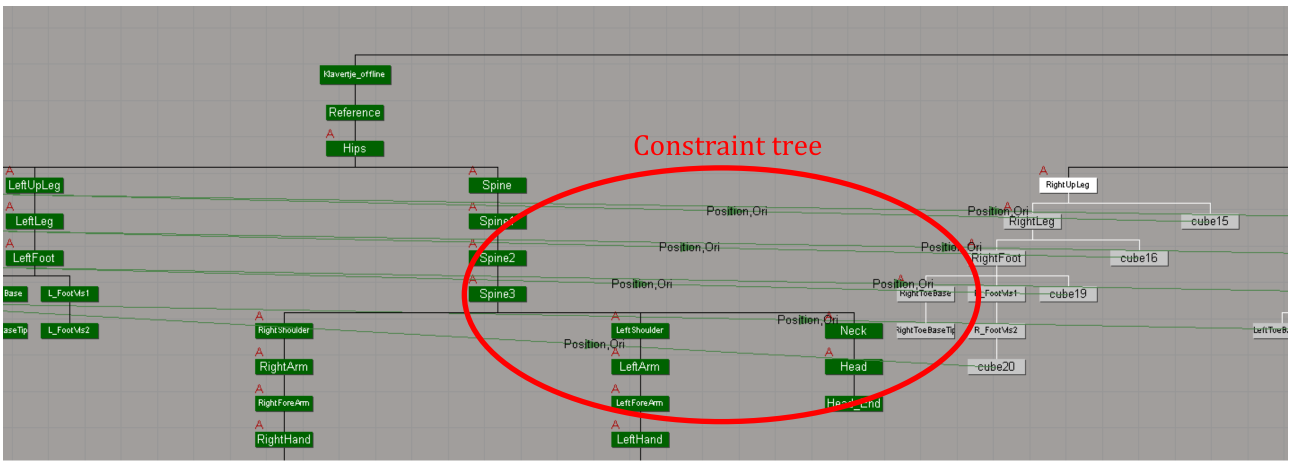


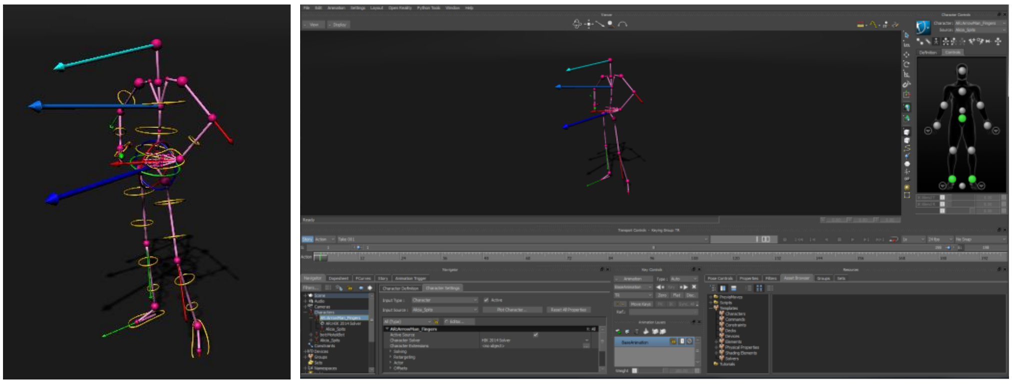
Figure 6: Detail example of internal rotational constraints inside the skelatal hirarchy

Textured and shaded 3D scene templates.

The scene templates are residing in the project's Dropbox repository. The scenes are mastered in FBX format (for running in MotionBuilder and UNITY3D and for import in most other 3D packages. The internal 3D scene shaders, materials and textures were applied to insure robust real-time performance. There is optimizations in texture sizes (power of 2), optimizations in the chosen lighting models (Phong shading, Blinn shading and fast anti-aliasing shaders) and optimizations in model shadowing (hard-semi tyransparant real-time shadow models).

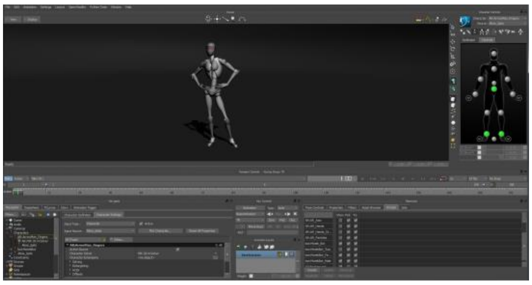
The scene templates are:

"Arrowman" avatar scene

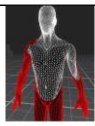


"Humanoid Blob" avatar scene

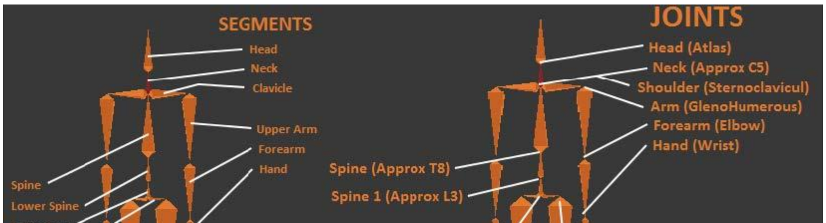
"Robot" avatar scene.

One of the project's partners has investigated also using additional "off the shelf" 3rd party avatars in the project. (Coming from the Mixamo library of the web) We have investigated those scenes and they are compatible with the chosen skeletal structure. Further integration work for those avatar skeletons will be carried out as part of WP6 3D display tuning. Below is a table describing the 3rd party avatars on evaluation.

Avatar	3D Model	Unity Shader	File Format	Naming Convention	Skeletal Structure	Image
Wireframe Man/Woman	Sculpted Mesh	Wireframe	FBX	"mixamorig:" prefix (i.e.: mixamorig:Hips == Pelvis)	Standard Biped with Pelvis as root. Rigging made in Mixamo. BVH Skeleton Structure.	
Hulk	Brute	VertexLit	FBX	"B_" prefix for single bones and "B_L" or "B_R" for Left and Right respectively (i.e.:B_Pelvis==Pelvis and B_L_Thigh==Left Hip)	Standard Biped with Pelvis as root. BVH Skeleton Structure.	
Robot	Kyle Robot	Bumped Diffuse	FBX	Every child bone except for Neck and Head has a "_Joint_01" suffix (i.e.:Left_Shoulder_Joint_01==Left Shoulder)	Standard Biped with Pelvis as root. BVH Skeleton Structure.	
Sorceress	Sorceress	Standard	FBX	Same as Hulk Avatar	Same as Hulk Avatar	

The following image is the Kinematic Structure of the project's partner MoCap System. The Avatars might have one or more extra joints (i.e. an third spine).



For information on the selection of the 'final' avatars and the final scene templates as developed, the reader is referred to deliverable D2.5**: "3D avatar scenes"**

Related research

The links below is based on specific searches in online publications, next to some previous projects where Motek has been contributing to.

Style-based inverse kinematics - K Grochow, SL Martin, A Hertzmann… - ACM transactions 2004
dl.acm.org https://pdfs.semanticscholar.org/69ab/9e293ae3b54f7b004ac89d789716e0ea5aa4.pdf

Real-time human pose recognition in parts from single depth images. Jamie Shotton Toby Sharp Alex Kipman Andrew Fitzgibbon Mark Finocchio Andrew Blake Mat Cook Richard Moore
http://dl.acm.org/citation.cfm?id=2398381

3D Modeling and Animation: Synthesis and Analysis Techniques for the Human Body.
Nikos Sarris, Michael G. Strintzis
https://books.google.co.il/books?id=GUaFGxQI8gwC&lpg=PP2&dq=3d%20character%20modeling%20related%20research&lr&pg=PP1#v=onepage&q=3d%20character%20modeling%20related%20research&f=false

Automatic rigging and animation of 3D characters. Ilya Baran Jovan Popović
http://dl.acm.org/citation.cfm?id=1276467

Mapping optical motion capture data to skeletal motion using a physical model. Victor Brian Zordan Nicholas C. Van Der Horst. http://dl.acm.org/citation.cfm?id=846311

Augmented Reality: A Balance Act between High Quality and Real-Time Constraints Gudrun Klinker (1), Didier Stricker (2), Dirk Reiners (2) Technical University of Munich, Germany Fraunhofer Project Group for Augmented Reality at ZGDV, Germany http://far.in.tum.de/pub/klinker1999ismr/klinker1999ismr.pdf

Dynamic 3D models with local and global deformations: deformable superquadrics. D. Terzopoulos ; D. Metaxas
http://ieeexplore.ieee.org/abstract/document/139605/?reload=true

Application of a new Iterative pseudo-inverse Jacobian Neural Network Matrix technique for controlling geckodrive DC motors of manipulators - A Olaru, S Olaru, N Mihai - Robotics and Mechatronics (ICROM), 2015 - ieeexplore.ieee.org
http://ieeexplore.ieee.org/abstract/document/7367770/

Interactive control of avatars animated with human motion data - J Lee, J Chai, PSA Reitsma, JK Hodgins - ACM Transactions - dl.acm.org http://dl.acm.org/citation.cfm?id=566607