CHARACTER ANIMATION

Dr. Andreas Aristidou

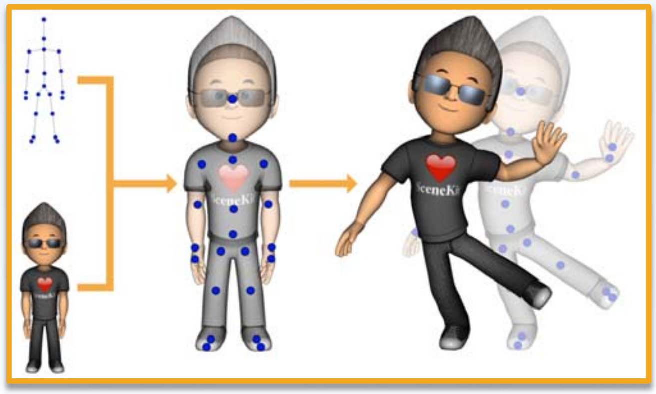

Image taken from https://marionettestudio.com/

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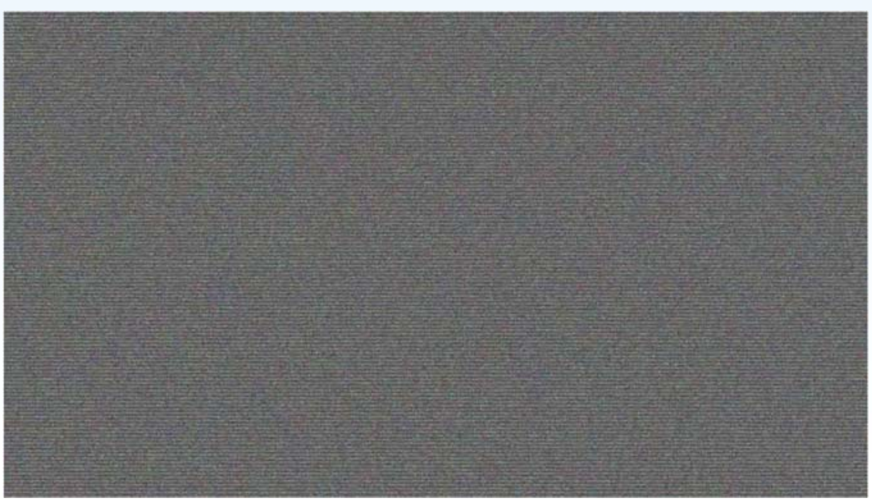
How does the magic happen?



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Dr. Andreas Aristidou, {a.aristidou@ieee.org}

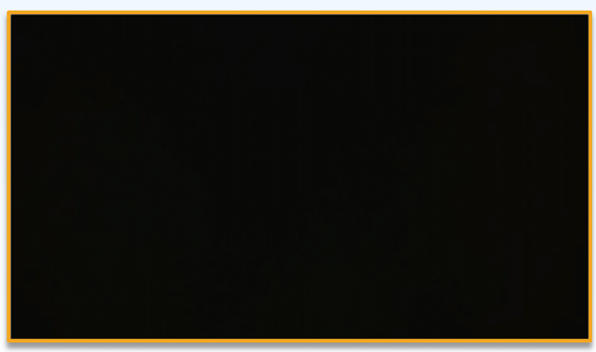
Overview

- Introduction to Character Animation
- Character Rigging
  - Setup the skeletal system ("rig") of the character.
- Character Skinning
  - Attach a mesh ("skin") to the skeletal system of the character.
- Motion Capture
  - Motion Capture Technologies.
  - Limitations
- Motion Retargeting
  - Retarget motion from one character to another.
- Motion Synthesis
  - Motion graphs.
  - Blending
- Style Transfer
  - Transfer style from one character to another or modify current to a different style.

Character Animation

Motivation

- Bring Animated characters to life
  - Animator analogous to film actors
- Many applications use **character** or **object** animation
  - Entertainment technology (e.g., films, games)
  - Virtual, or augmented reality
  - Simulations, Demonstrations, or training systems
- Other forms of animation?
  - Trees, liquids, animals, clouds, etc.



© Pixar Animation

Character Animation

Introduction

- Computer-assisted animation
  - 2D & 2 1/2 D.
  - In-betweening.
  - Inking, virtual camera, managing data, etc.
- Computer generated animation
  - Low level techniques.
    - Precisely specifying motion.
  - High level techniques.
    - Describe general motion behavior.

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Computer-assisted animation
Key-framing: Walk Cycle

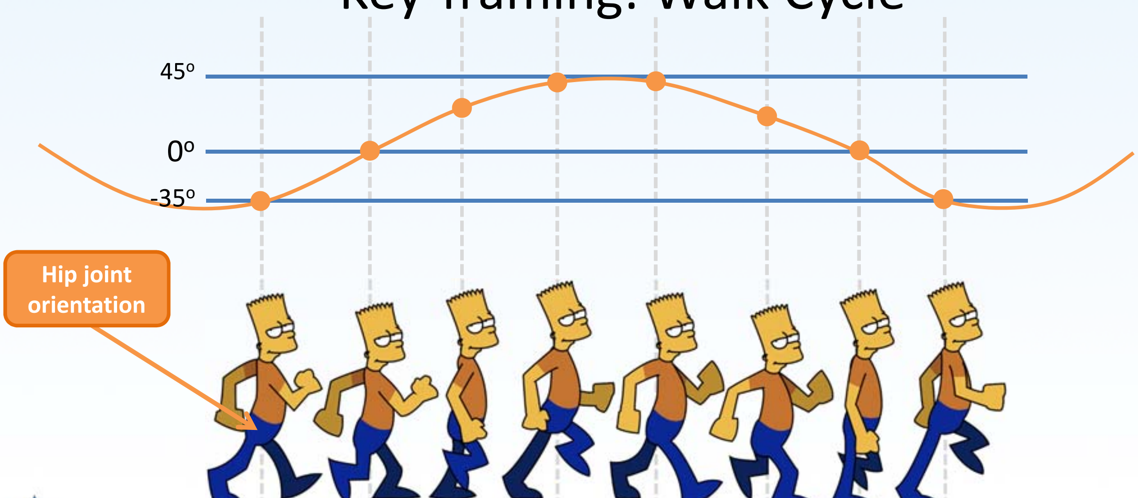

Image taken from: http://krznmedia.wordpress.com

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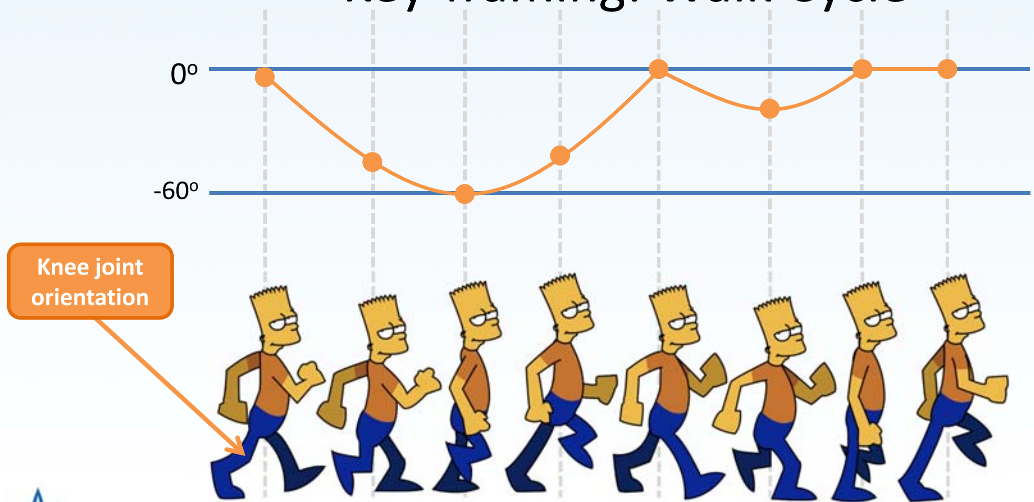
Computer-assisted animation
Key-framing: Walk Cycle



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Character Animation
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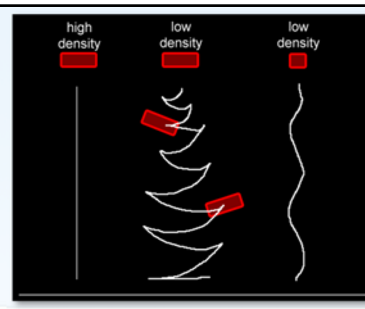
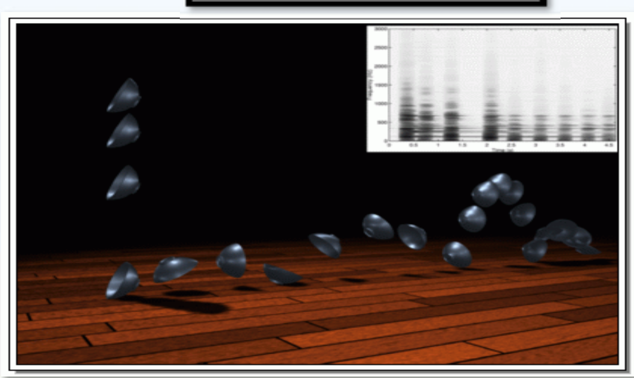
Character Animation
Low level techniques

Character Animation
High level techniques



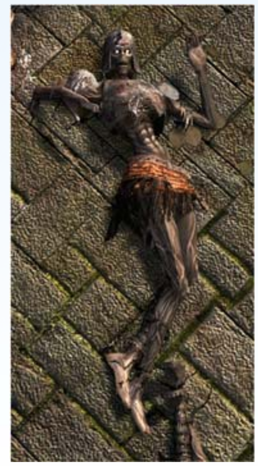
- Generate motion with set of rules or constraints
  - Physics-based motion
    - Take into consideration laws of physics
    - Centers of mass
    - Etc.



Character Animation
Physics-Based Animation

Physics-based techniques generate new motion without using existing clips – in theory.

Common for passive objects such as rag dolls, but still rare for living creatures in commercial games.



Rag doll from *Dark Souls*.

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Character Animation
Challenges and Advantages of Physics-Based Animation

Challenges

All motion must be applied through forces and torques – more difficult than poses.

Must simulate biomechanics of the body.

Hard to control the style of motion.

Advantages

Inherently realistic.

Not limited by database.

Can simulate motion that is impossible in motion capture (dangerous stunts, imaginary animals).

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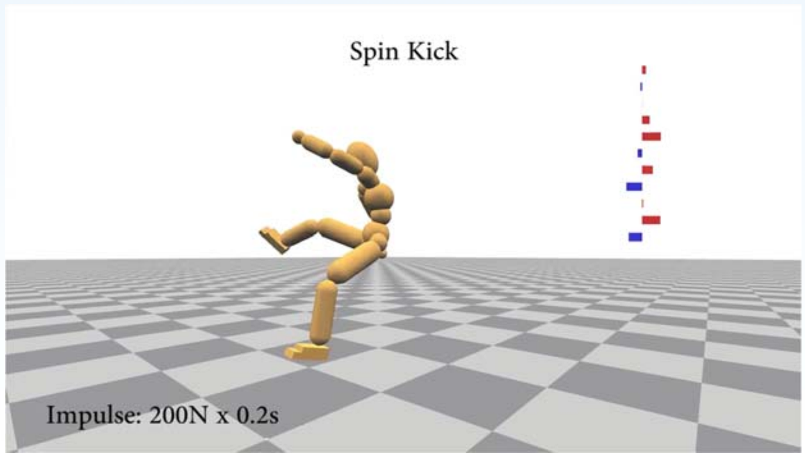
Learning Approaches
to Physics-Based Animation

Recently impressive results have been achieved using machine learning.

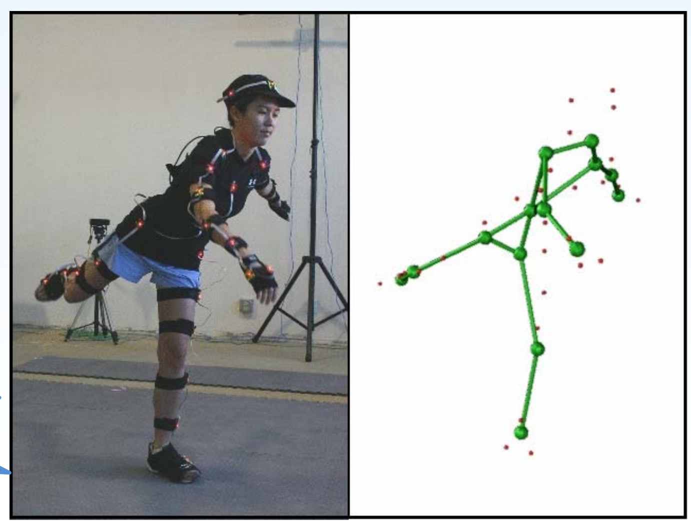
Some approaches use motion capture data to train the animation system.



Character Animation
High level techniques

- Generate motion using a motion capture system
  - Acquire human subjects and re-use motion

We will focus on these methods



What 3D character animation involves?

- Animating characters can be broken down to:
  - **Skeletal animation** – animating their main body parts.

What 3D character animation involves?

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  - **Facial animation** – animating their facial features.

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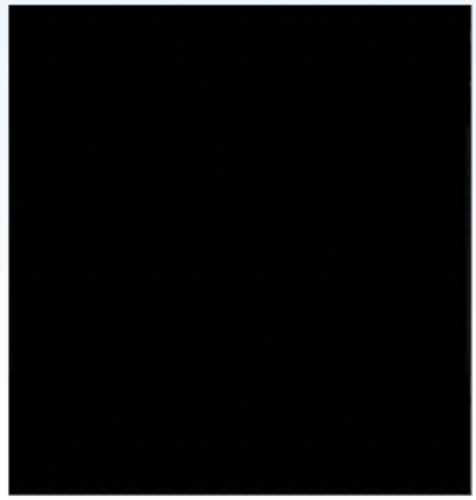
Dr. Andreas Aristidou, {a.aristidou@ieee.org}

What 3D character animation involves?

- Animating characters can be broken down to:
  - **Skeletal animation** – animating their main body parts.
  - **Facial animation** – animating their facial features.
  - **Hair** (and **Fur**) **animation**.



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CHARACTER RIGGING & SKINNING

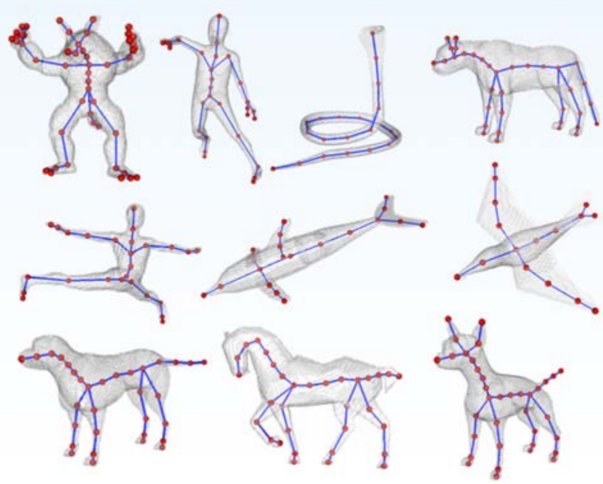
Tel-Aviv, Israel

Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Anatomy of a 3D character

Rigging

- 3D **rigging** is the process of creating a skeleton for a 3D model so it can move.
- A 'rig' has numerous degrees of freedom (DOFs) that can be used to control various properties.
- One character could have several rigs. One rig could control several characters…



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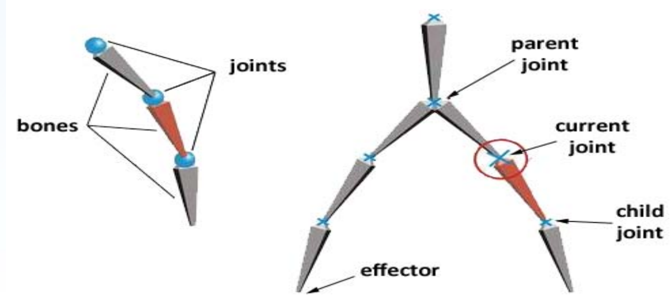
Anatomy of a 3D character
The rig

- A skeletal system (rig) is comprised of kinematic chains:
  - A hierarchical set of interconnected bones.
  - A chain:
    - starts from a *root*,
    - it has multiple *bones*,
    - *connected by joints, and*
    - *ends at the end-effector.*



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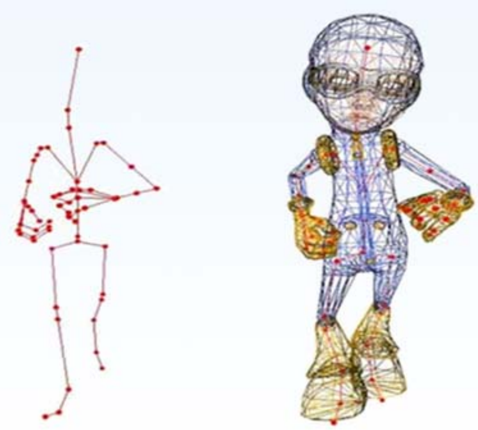
Anatomy of a 3D character
The rig

- A skeleton allows higher-level control of the character's animation.
- The skeleton is only a control mechanism – it is not rendered into the final image.
- Typically there are many constraints.



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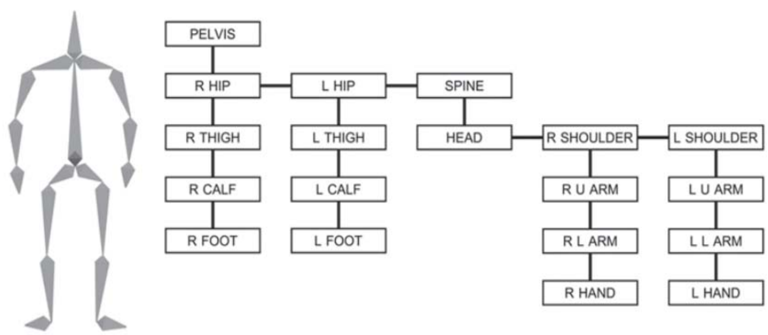
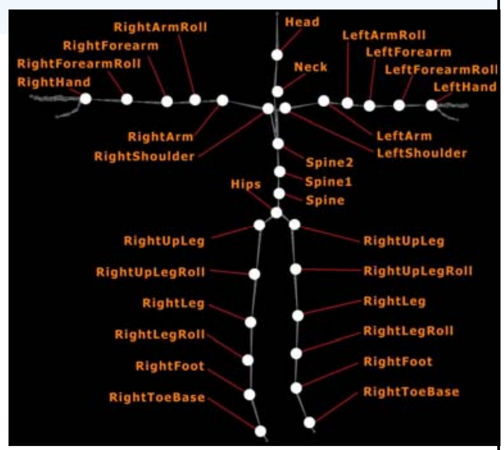
Anatomy of a 3D character

The rig





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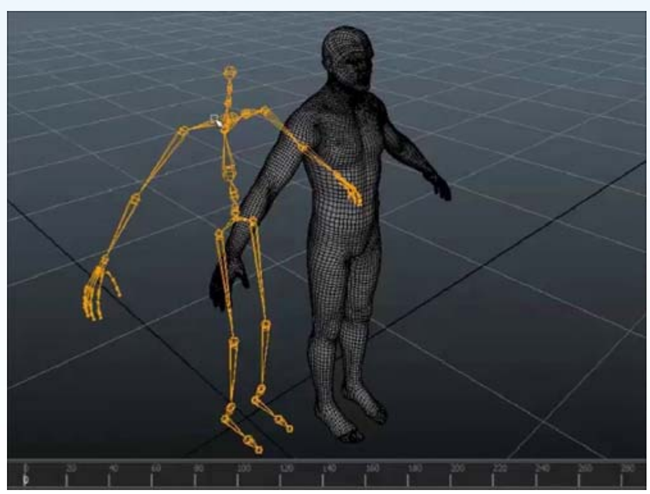
Anatomy of a 3D character

Skinning

- Skinning.
  - Attach a mesh ("skin") to the skeletal system of the character.
- The skin is represented as a polygon mesh, e.g. a set of vertices, or a parametric surface



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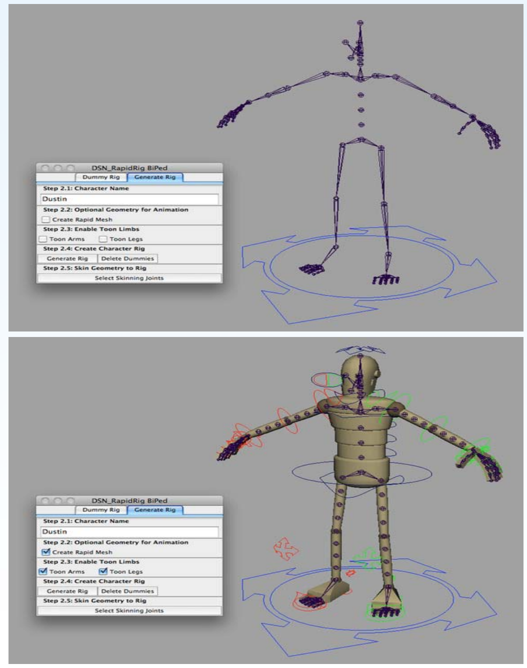
Anatomy of a 3D character

The skin

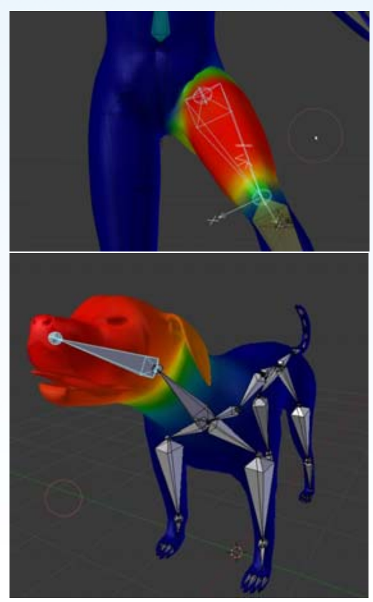
- We bind the skeleton to the mesh when we first associate them.
  - The T-pose (or “bind pose”) refer to the initial transformation matrices of the rig and skin when they are first associated.
  - The T-pose defines a coordinate system used later when animating the skin via the skeleton.
  - The T-pose is a convention used because:
    - modeling the mesh and the skeleton is easier, using symmetry.
    - rigging is much easier when the limbs are spread apart.



Anatomy of a 3D character

The skin

- Each vertex is associated with a bone in the skeleton, and moves relative to that bone.
- Each vertex is multiplied by several “weighted” transformation matrices that provide the influence factor each bone has to the vertex, and the results are added together.
  - The skin’s vertices can then be assigned weights.
    - Rigid skinning: 1 bone per vertex (weight = 1.0)
    - Smooth skinning: Multiple bones per vertex (weights != 1.0)



Anatomy of a 3D character
Texture


Skeletal Animation

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Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Introduction

Skeletal Animation

- Having setup and bound together the rig and skin, the character can be animated.
  - The most common ways to do this:
    - Forward or Inverse Kinematics (e.g., keyframing)
    - Motion Files (e.g., motion capture systems)

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Motion Files

Motion Capture Data

- Depending on the sensors used
- Popular file formats:
  - ASF/AMC (Acclaim's skeleton and motion capture files)
  - BVH (BioVision Hierarchy)
  - C3D (Coordinate 3D – biomechanics – C3D.org)

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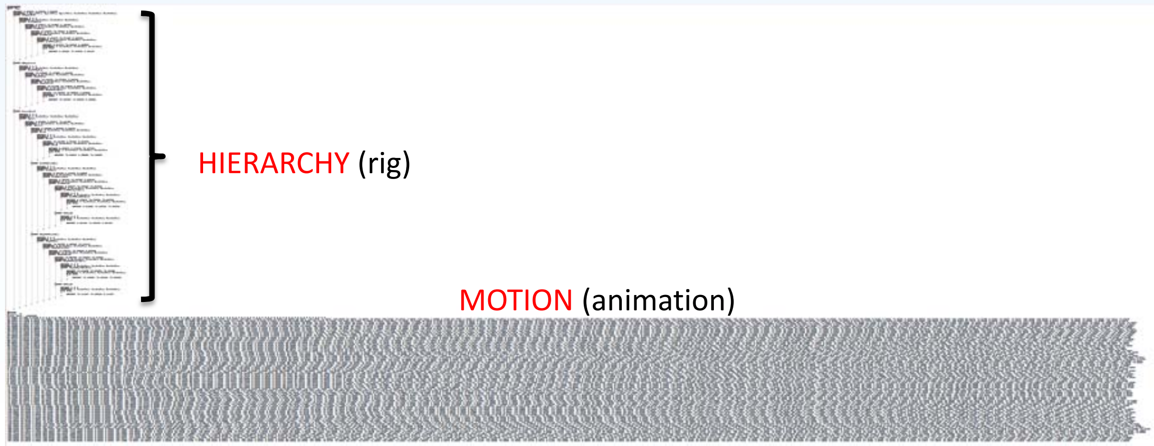
Motion Files

BioVision Hierarchy (BVH)



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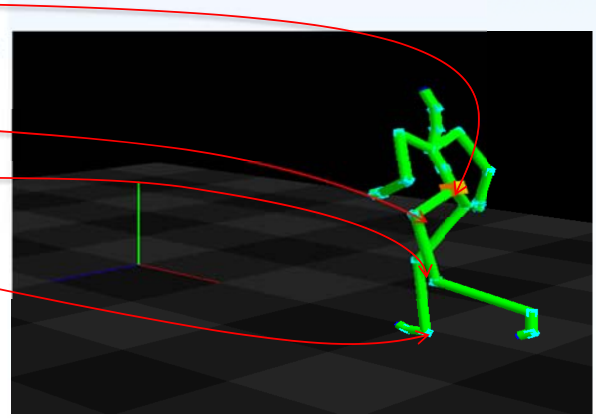
Motion Files

BioVision Hierarchy (BVH)

```
HIERARCHY
ROOT Hips
{
    OFFSET 0.00000 0.00000 0.00000
    CHANNELS 6 Xposition Yposition Zposition Zrotation Yrotation Xrotation
    JOINT LHipJoint
    {
        OFFSET 0 0 0
        CHANNELS 3 Zrotation Yrotation Xrotation
        JOINT LeftUpLeg
        {
            OFFSET 3.13874 -1.57224 1.49786
            CHANNELS 3 Zrotation Yrotation Xrotation
            JOINT LeftLeg
            {
                OFFSET 2.10955 -5.79594 0.00000
                CHANNELS 3 Zrotation Yrotation Xrotation
                JOINT LeftFoot
                {
                    OFFSET 2.41843 -6.64458 0.00000
                    CHANNELS 3 Zrotation Yrotation Xrotation
                    JOINT LeftToeBase
                    {
                        OFFSET 0.04713 -0.12948 1.66229
                        CHANNELS 3 Zrotation Yrotation Xrotation
                        End Site
                        {
                            OFFSET 0.00000 -0.00000 0.85167
                        }
                    }
                }
            }
        }
    }
    JOINT RHipJoint
    {
        OFFSET 0 0 0
```



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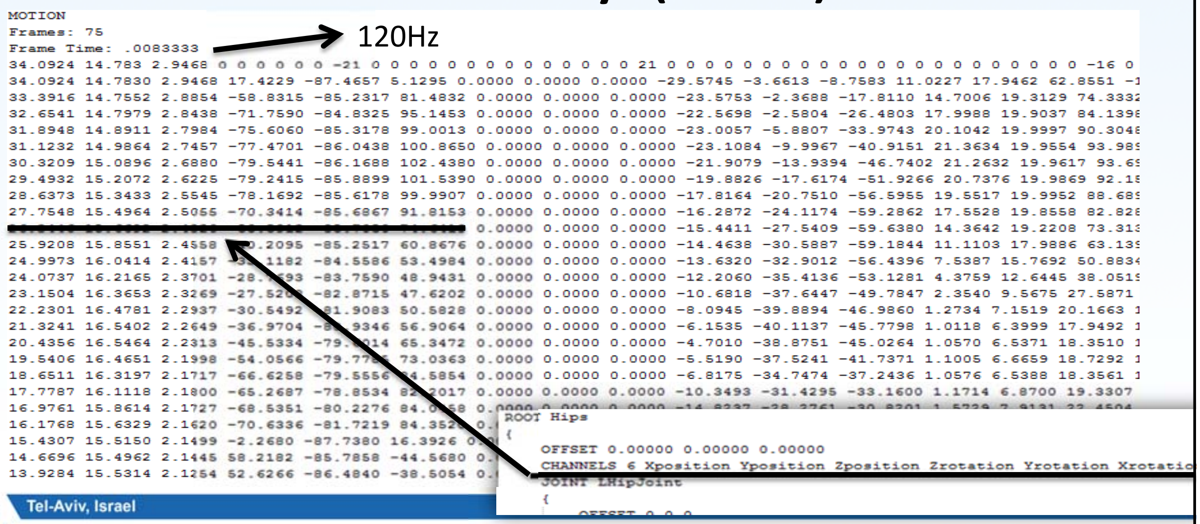
Motion Files

BioVision Hierarchy (BVH)



```
MOTION
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Frame Time: .0083333
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34.0924 14.7830 2.9468 17.4229 -87.4657 5.1295 0.0000 0.0000 0.0000 -29.5745 -3.6613 -8.7583 11.0227 17.9462 62.8551 -1
33.3916 14.7552 2.8854 -58.8315 -85.2317 81.4832 0.0000 0.0000 0.0000 -23.5753 -2.3688 -17.8110 14.7006 19.3129 74.3332
32.6541 14.7979 2.8438 -71.7590 -84.8325 95.1453 0.0000 0.0000 0.0000 -22.5698 -2.5804 -26.4803 17.9988 19.9037 84.1398
31.8948 14.8911 2.7984 -75.6060 -85.3178 99.0013 0.0000 0.0000 0.0000 -23.0057 -5.8807 -33.9743 20.1042 19.9997 90.3048
31.1232 14.9864 2.7457 -77.4701 -86.0438 100.8650 0.0000 0.0000 0.0000 -23.1084 -9.9967 -40.9151 21.3634 19.9554 93.989
30.3209 15.0896 2.6880 -79.5441 -86.1688 102.4380 0.0000 0.0000 0.0000 -21.9079 -13.9394 -46.7402 21.2632 19.9617 93.69
29.4932 15.2072 2.6225 -79.2415 -85.8899 101.5390 0.0000 0.0000 0.0000 -19.8826 -17.6174 -51.9266 20.7376 19.9869 92.15
28.6373 15.3433 2.5545 -78.1692 -85.6178 99.9907 0.0000 0.0000 0.0000 -17.8164 -20.7510 -56.5955 19.5517 19.9952 88.689
27.7548 15.4964 2.5055 -70.3414 -85.6867 91.8153 0.0000 0.0000 0.0000 -16.2872 -24.1174 -59.2862 17.5528 19.8558 82.828
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25.9208 15.8551 2.4558 [illegible].2095 -85.2517 60.8676 0.0000 0.0000 0.0000 -14.4638 -30.5887 -59.1844 11.1103 17.9886 63.139
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20.4356 16.5464 2.2313 -45.5334 -79.[illegible]014 65.3472 0.0000 0.0000 0.0000 -4.7010 -38.8751 -45.0264 1.0570 6.5371 18.3510 1
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17.7787 16.1118 2.1800 -65.2687 -78.8534 82[illegible]2017 0.0000 0.0000 0.0000 -10.3493 -31.4295 -33.1600 1.1714 6.8700 19.3307
16.9761 15.8614 2.1727 -68.5351 -80.2276 84.0[illegible]58 0.[illegible]
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15.4307 15.5150 2.1499 -2.2680 -87.7380 16.3926 0.[illegible]
14.6696 15.4962 2.1445 58.2182 -85.7858 -44.5680 0.[illegible]
13.9284 15.5314 2.1254 52.6266 -86.4840 -38.5054 0.[illegible]
```
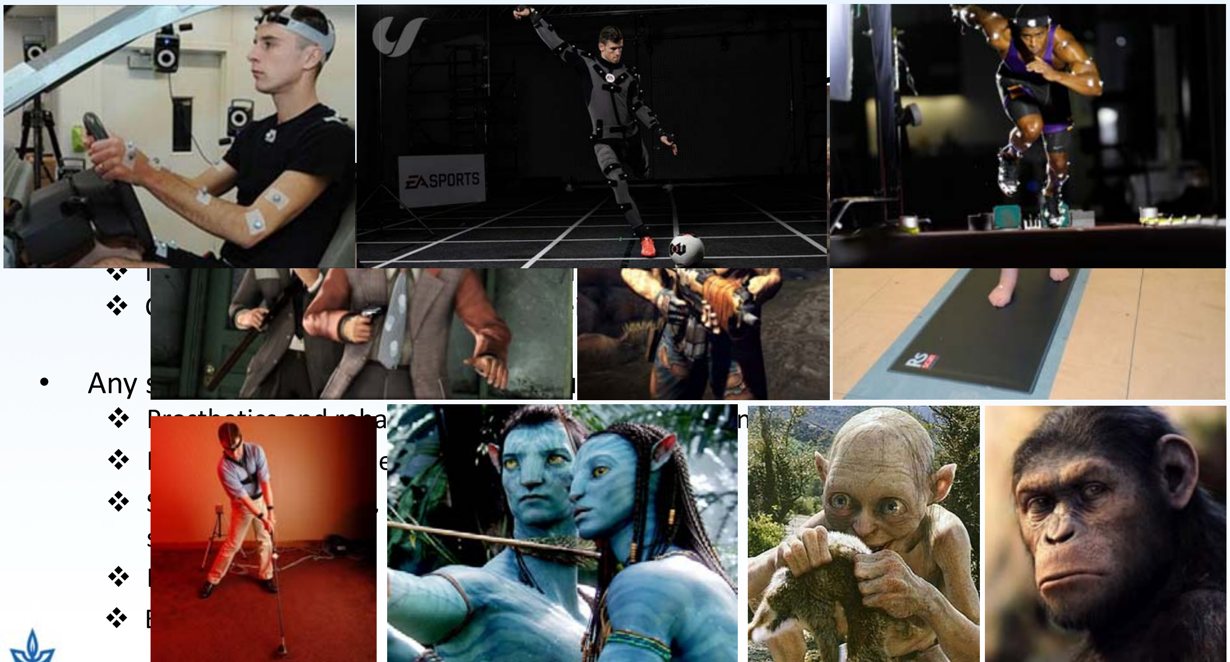



```
ROOT Hips
{
    OFFSET 0.00000 0.00000 0.00000
    CHANNELS 6 Xposition Yposition Zposition Zrotation Yrotation Xrotatio
    JOINT LHipJoint
    {
```


MOTION CAPTURE



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  - Prosthetics and reha

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What

- Human wh
- Portions o
- Facial anir
- Animals

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Advantages of mocap animation

- Low latency; results can be obtained in real-time.
- Secondary motions and all the subtle motions are captured.
  - more realism!
- Physical interactions between performers and props can be captured.
  - more realism!

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Disadvantages of mocap animation

- The cost of the software, equipment and personnel required can be prohibitive for small productions.
  – It is getting cheaper year by year
- Manipulating mocap data is often difficult.
  – Re-capturing or key framing a shot with bad data is often easier.
- Mapping mocap data of a performer to a 3D character with a different proportion may cause issues.

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Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Popular Motion Capture Systems

- **Magnetic** – active sensors sense their position and orientation in magnetic field.
- **Electro-Mechanical** – attach of a skeletal-like structure.
- **Optical** – uses video capture.
  - passive – markers just reflect light.
  - active – markers emit light.
- **Inertial sensors (IMUs)** – Motion is capture using accelerometers, gyroscopes etc.
- **RGB-Depth** cameras and computer vision.

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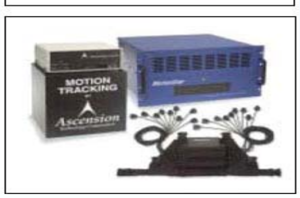
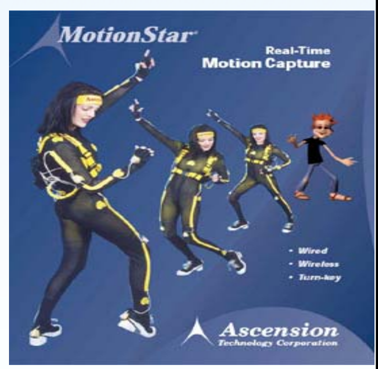
Popular Motion Capture Systems
Magnetic

- Calculate position and orientation by the relative magnetic flux of three orthogonal coils.
- External transmitters establish magnetic fields in space.
- Sensors can then measure the position and orientation of the object.



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Popular Motion Capture Systems
Magnetic

Advantages
- free-of occlusion.

Disadvantages
- the acqu ing motion as les egrees of freedom the
- Noisy.
- capture
- interference objects

Old technology, not used anymore

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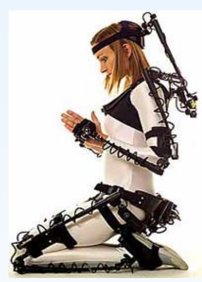
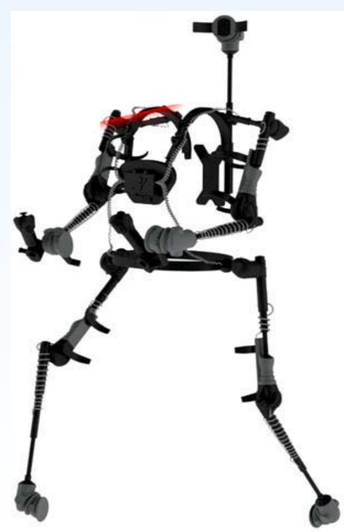
Popular Motion Capture Systems
Electro-Mechanical

- Known as exoskeleton motion capture systems (e.g. Gypsy),
- Performers attach the skeletal-like structure to their bodies,
- The articulated mechanical parts measure the performer’s relative motion by converting analog voltage changes to digital values.
  - Direct track of body joint angles





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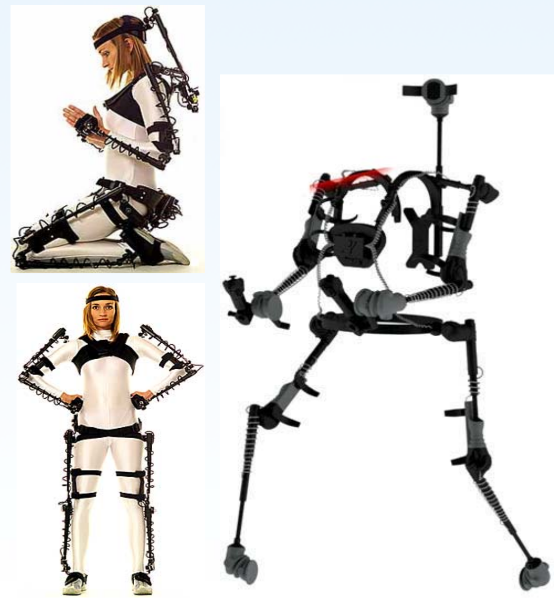
Popular Motion Capture Systems

Electro-Mechanical

Advantages

- computes rotations directly.
- self-contained with unlimited capture volume.
- inexpensive.
- can capture multiple performances simultaneously.
- free-of occlusion.



Popular Motion Capture Systems

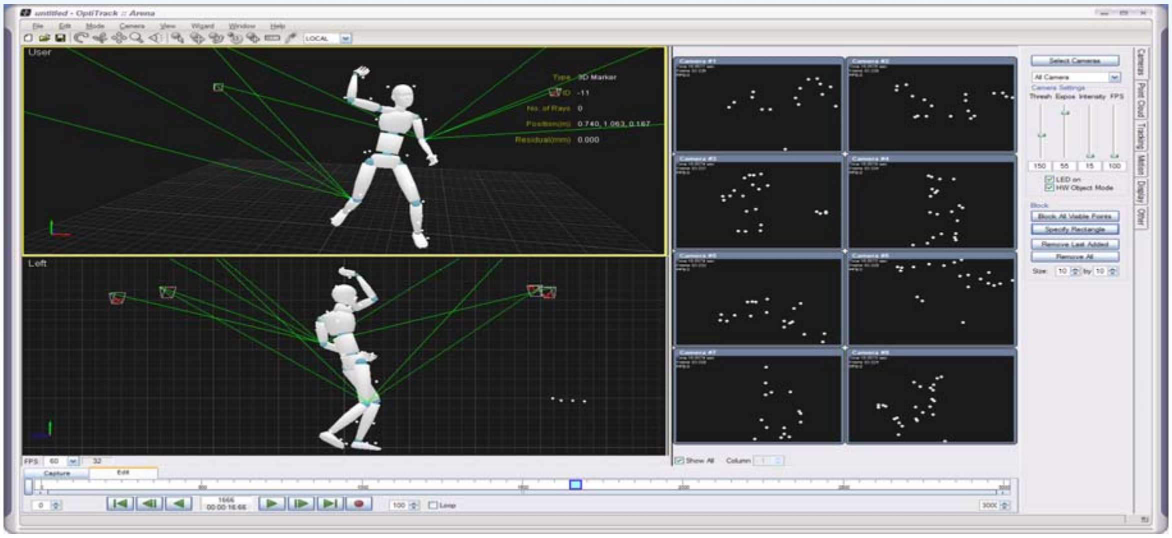
Electro-Mechanical

Disadvantages

- they are restrictive.
- they need to match body proportions.
- configuration of sensors is f[illegible]ed.
- only retu[illegible] local m[illegible]ions

Too restrictive, has never been popular

Popular Motion Capture Systems
Optical Systems



Popular Motion Capture Systems
Optical Systems

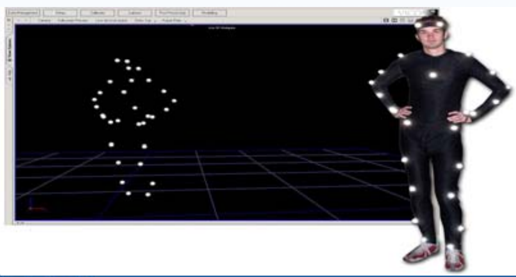
This is currently the state-of-the-art motion capture technology

- The system combines the information of the tra
  the 3D position of the object
  - Repeat this operation several times per second
    volumetric trajectory of the marker according to tim
    from
    30Hz to 960Hz)
- Minimum number of cameras – 2
- Visible and occluded markers
  - Solution: use of multiple cameras
- **Capture volume** is the physical space where the cameras can combine their fields of view

Popular Motion Capture Systems

Optical Systems - Passive

- Each person wears a mocap suit with markers attached.
- Each marker coated with a retroreflective material to reflect.
- The cameras are equipped with infrared LED's and filters.
- The cameras see reflector markers.
- e.g. Vicon, Motion Analysis, Optitrack.



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Tel-Aviv, Israel

Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Popular Motion Capture Systems

Optical Systems - Passive

Advantages

- freedom of movement.
- high quality capture.
- high throughput.
  - fast sampling (200 fps at a high resolution).
  - can capture fast motions.
  - can have a large capture space.
  - can capture many markers.

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Popular Motion Capture Systems

Optical Systems - Passive

Disadvantages

- Occlusion, markers are can be hidden from the camera.
  - additional performers will increase occlusion,
  - may be able to add redundant cameras.
- Sensitive to environmental lights.
- Marker crossove; which marker are you looking at?
- High cost.
- Extensive post processing (the marker’s have to be located and identified).
- Provide only positional data.
  - joint angles need to be computed.

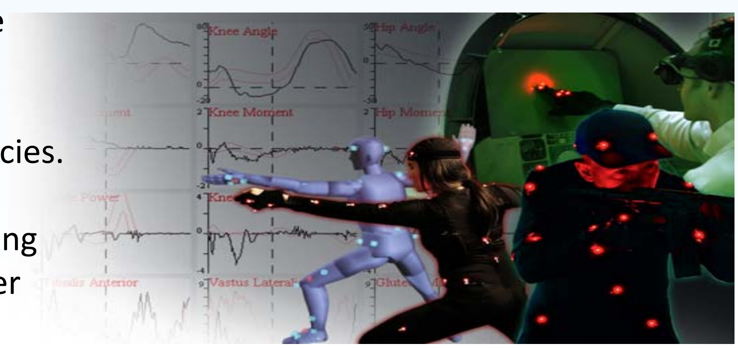
Popular Motion Capture Systems

Optical Systems - Active

- Use of active markers
  (infra technology – LEDs).

Advantage

- Easier to be identified from the background.
- Labelling is achieved by using markers with different frequencies.
  - reduce the turnaround by eliminating marker swapping and providing much cleaner data.



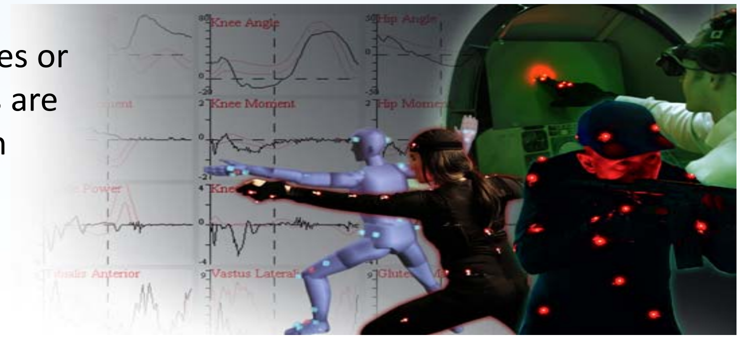
Popular Motion Capture Systems

Optical Systems - Active

- Use of active markers (infra technology – LEDs).

Disadvantage

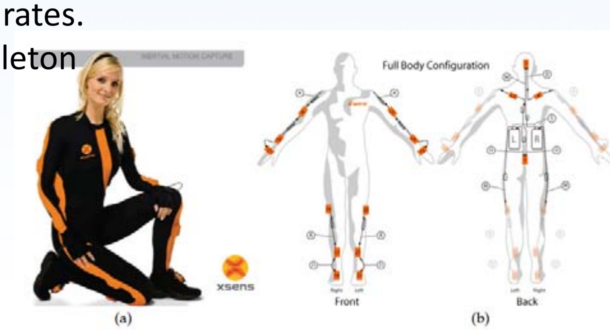
- Less portable.
- Users are required to wear wires or electronic equipment (markers are connected to a synchronization unit).
- Markers may still be occluded.



Popular Motion Capture Systems

Inertial Systems

- Micro-inertial sensors, biomechanical models and sensor fusion algorithms.
- Use a number of gyroscopes and accelerometers to measure rotational rates.
- These rotations are translated to a skeleton model.



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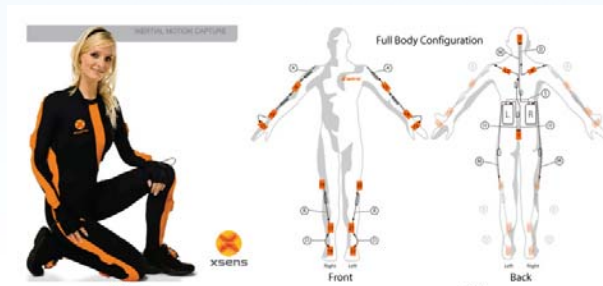
Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Popular Motion Capture Systems
Inertial Systems

Advantages
- Inexpensive.
- No external cameras are required.
- No occlusions .
- Self-contained.
- Portable and functional outdoors.



(a) (b)

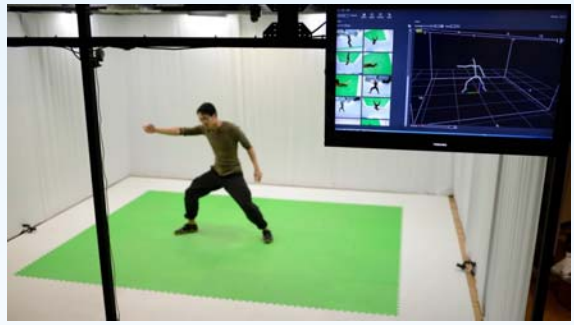
Popular Motion Capture Systems
Inertial Systems

Disadvantages
- High complexity.
- Inability to measure orientation of body segments.
- Incapacity to acquire the actual motion resulting in lower positional accuracy.

(a) (b)

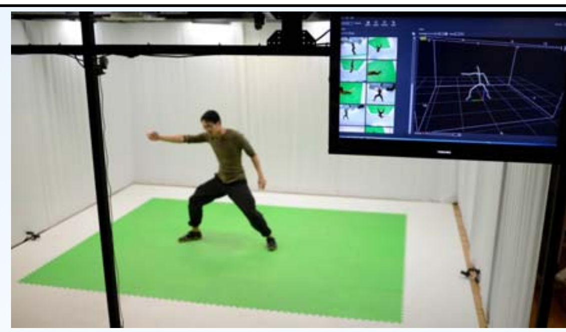
Popular Motion Capture Systems
RGB & RGB-Depth

- Use a combination of color cameras and depth sensors.
  - the subject's silhouette is captured from multiple angles.
- Reconstruct the object's volume (mesh) from the point clouds.
- Fit a skeleton into the 3D model to estimate motion.



Popular Motion Capture Systems
RGB & RGB-Depth

- **Generative methods**
  - reconstruct human pose by fitting a template model to the observed data
- **Discriminative methods**
  - infer mode-to-depth correspondences, cluster pixels to hypothesize body joint positions, fit a model and then track the skeleton
- **Hybrid methods**
  - Combine the two methods



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Popular Motion Capture Systems

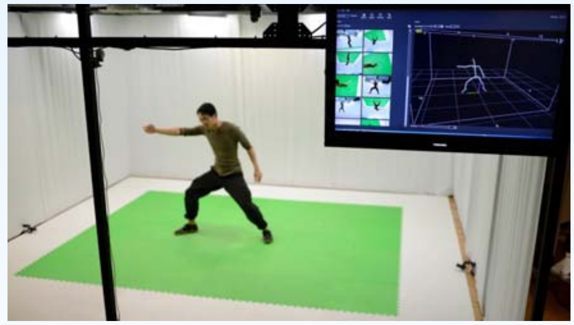
RGB & RGB-Depth

Advantages

- No need to wear a suit or attach markers.

Disadvantages

- Not reached yet the same fidelity and versatility.
- Controlled lighting and background environments.
- Problems with subjects' occlusion by other elements in the scene.



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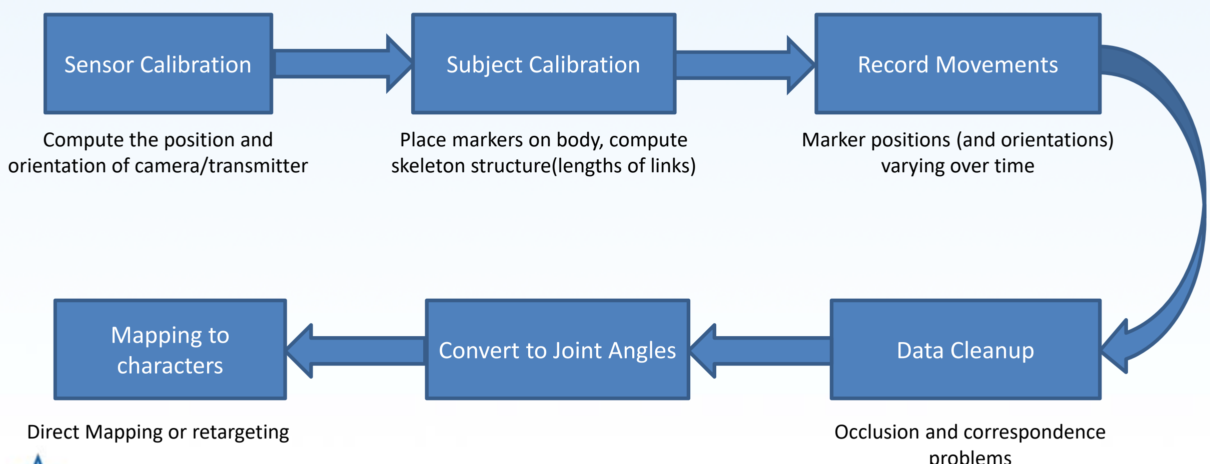
Motion Capture Pipeline



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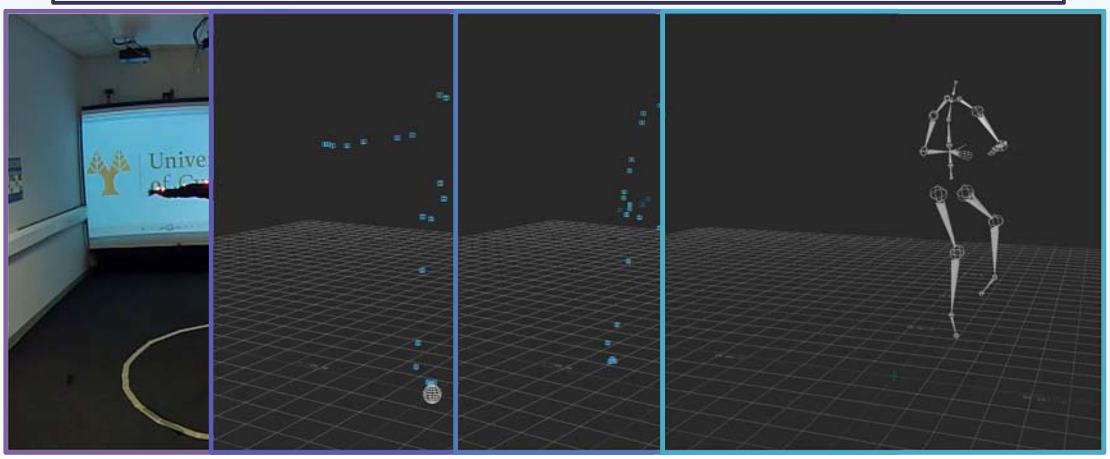
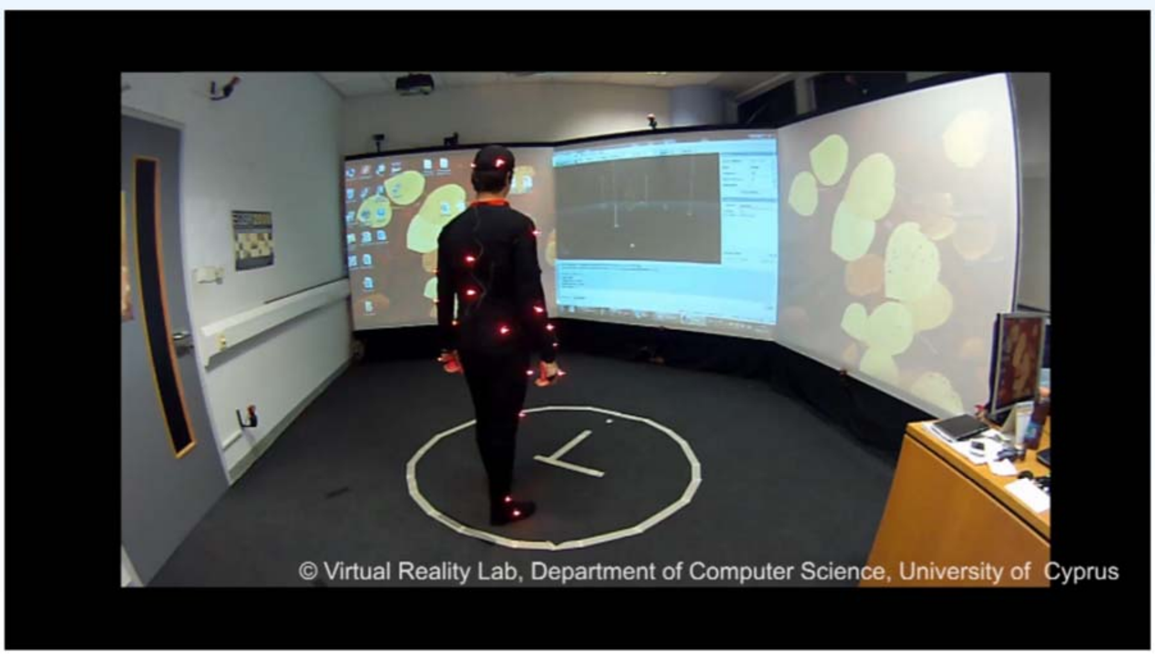
Common Motion Capture Pipeline

Marker-based motion acquisition → Label Markers → Marker Data Clean-up → Convert to Joint Angles





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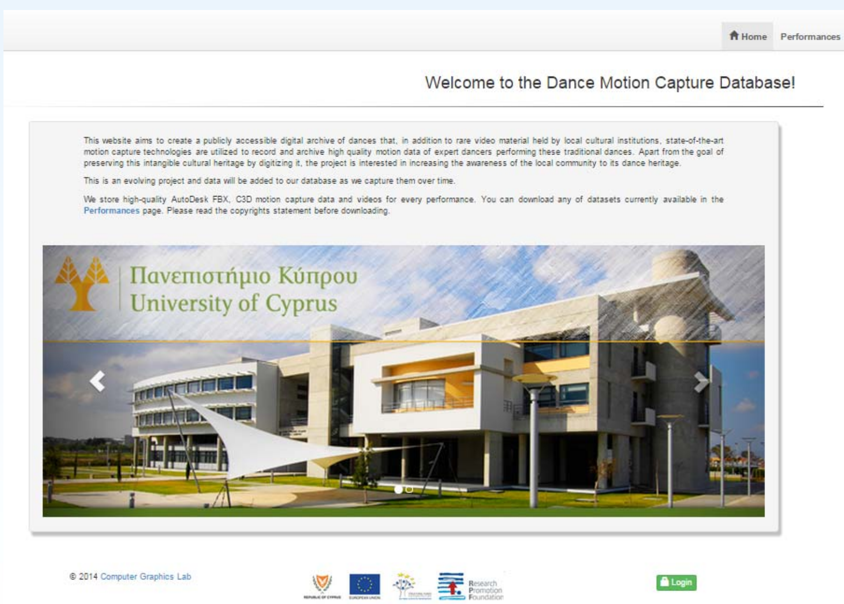

http://dancedb.cs.ucy.ac.cy

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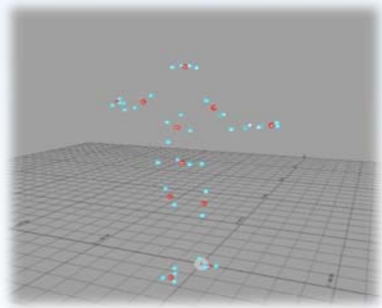
Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Dance Motion Capture Database

Motion formats

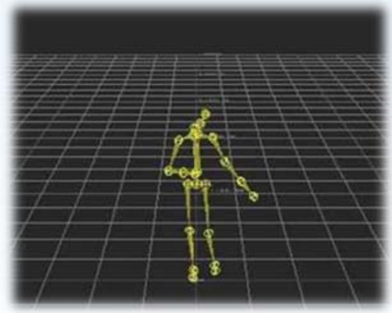
Video

Dance recording using an HD camera. Data saved in MP4 (MPEG-4 part 10 H.264) or FLV (flash) format



Mocap data

C3D - stored 3D coordinate information, analog data and associated information as it is recorded from the motion capture system.



Mocap data

BVH - The Biovision Hierarchy character animation file format that provides the skeleton hierarchy information as well as the motion data.

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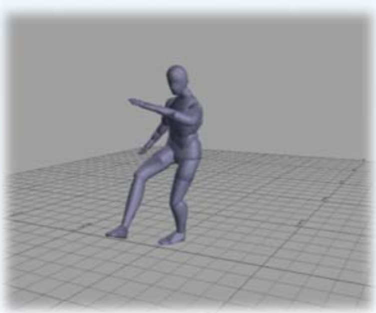
Dance Motion Capture Database

Motion formats



Actor data

FBX – the motion of the performer is saved as an actor. Any virtual character (avatar) can be incorporated to perform the dance

Character data

FBX – A virtual character has been incorporated to the actor. The character cannot be removed

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Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Popular Motion Capture Systems

Limitations

- Only realistic motion captured (movement that does not follow the laws of physics cannot be captured).
  - Cartoony or superhero animations are not possible to be captured.
- WYSIWYG (what you see is what you get).
  - Can't add more expression.
  - Continually need to recapture motion.
- What about muscles?

Animators could use more than 750 controls to create Shrek's performance. Some controlled one joint or muscle, others controlled groups of several.

Data cleaning

Self-similarity Analysis for Motion Capture Cleaning

By Andreas Aristidou, Daniel Cohen-Or, Jessica Hodgins, Ariel Shamir

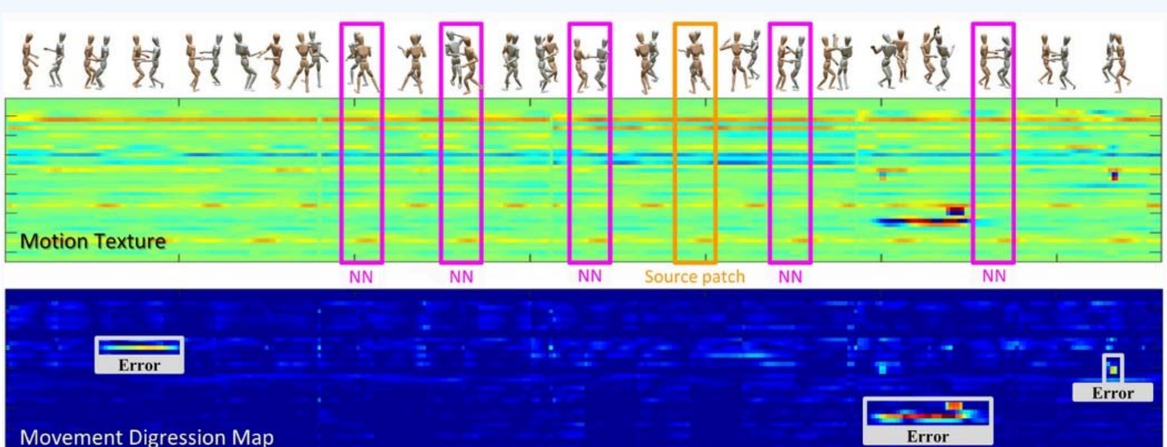

Photo taken from: Bharaj et al., Automatically Rigging Multi-component Characters, *Comput. Graph. Forum* 31(2), 2012.

Motion Retargeting

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Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Motion Retargeting

- What is motion retargeting?
  - A method to retarget animations onto models with different morphologies.
  - A way to remap animations onto characters with very different animation-specific structures.

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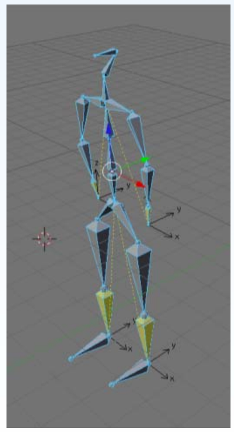
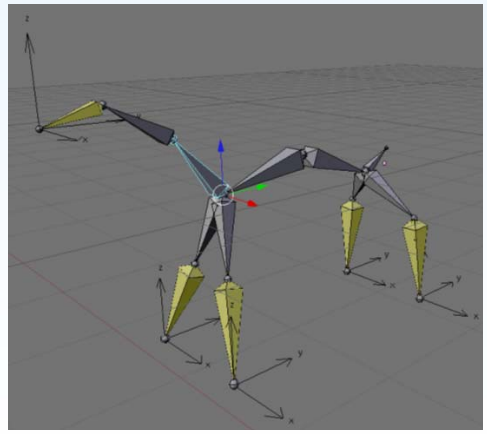
Why Motion Retargeting?

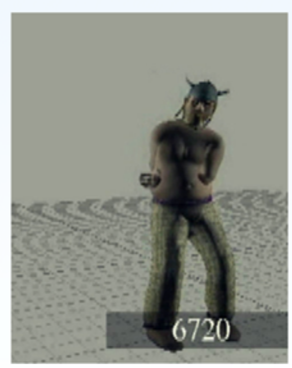
- Improves content reuse.
- Allows for a more dynamic game experience.
- Easy integration of procedurally generated animations.
- Sometimes is not possible to motion capture the subject (e.g. animal with human behavior, character does not exist – fiction movies).





Challenges in
Motion Retargeting

- Solving locally for each frame generates unwanted artifacts.
  - Preserve angles or end-effector positions (flying).
  - foot-skating.
- Characters with different proportions may have body penetration.



Challenges in
Motion Retargeting

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Principles of
Motion Retargeting

- Identify constraints in original motion.
  - joint limits, interaction with environment, collisions, physical laws.
  - parameter in range, point in location, point in region, same place at two different times.
  - time range of a constraint.
- Adapt the motion to target character.
- Re-establish violated constraints (by optimization).

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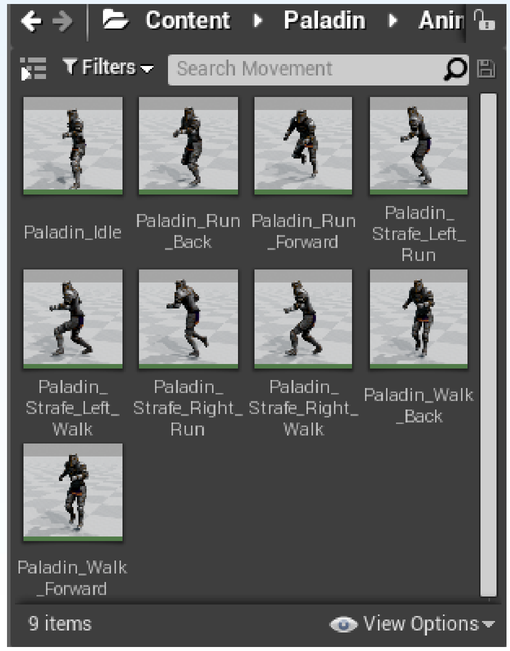
Animation for
Game Characters

Special requirements:
- Respond to player input.
- Respond to unexpected events.
- Realtime performance.

Traditional approach:
Store a library of animation sequences, play them in response to player input and other game events.



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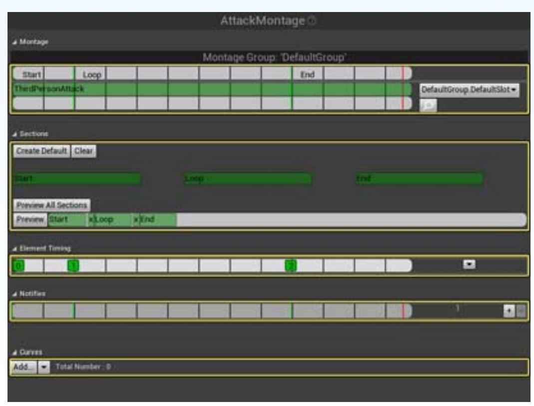
AnimationMontage
Motion Graphs in Unreal Engine 4

Graph is hand authored.

Provide explicit code to choose between multiple possible next clips when a transition point is reached.

Designer manually chooses good transitions and avoids bad transitions.

Plan out required transitions before recording motion capture data.



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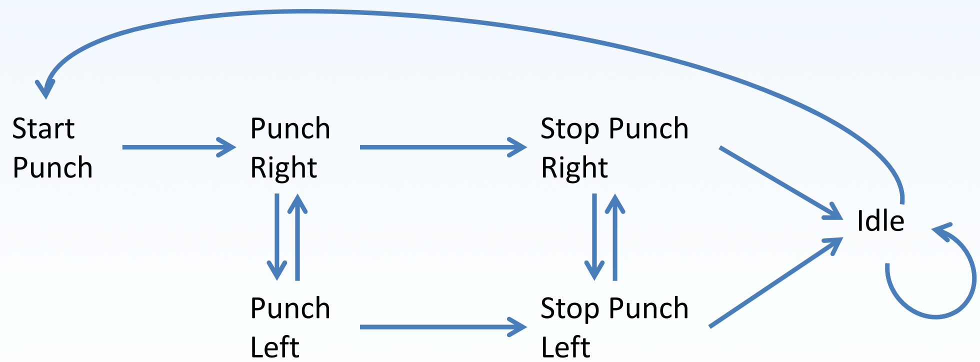
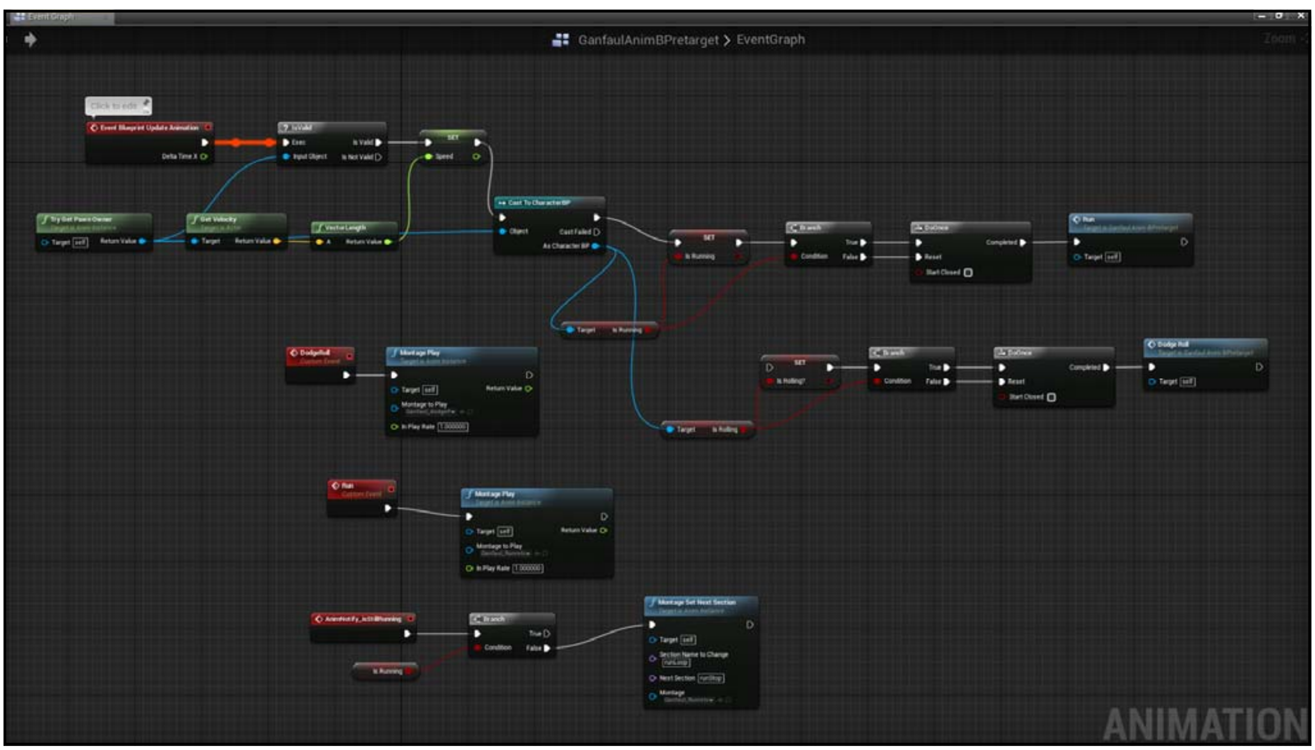
Example
of an AnimationMontage

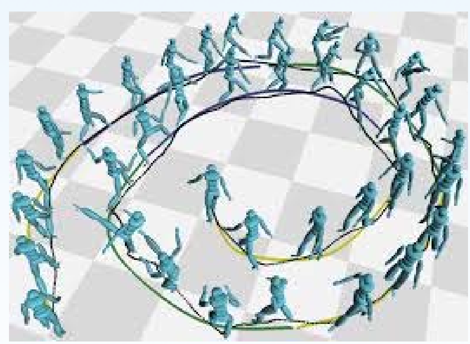


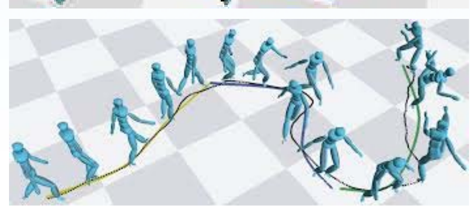


Motion Graphs

Overview
of Motion Graphs

- Automatically add transitions within a motion database so as to allow synthesis of different actions.
  - Allow re-use of motion capture data.
- Motion graphs (Kovar et al.)
  - Multiple timesteps are grouped into a clip.
  - The clips are connected to one another in a graph.





Reference: Lucas Kovar, Michael Gleicher, and Frédéric Pighin. 2002. Motion graphs. *ACM Trans. Graph.* 21, 3 (July 2002), 473-482.

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Motion Synthesis

Example

Reference: Daniel Holden, Jun Saito, Taku Komura, A Deep Learning Framework for Character Motion Synthesis and Editing. *ACM Trans. Graph.* 35, 4 (July 2016).

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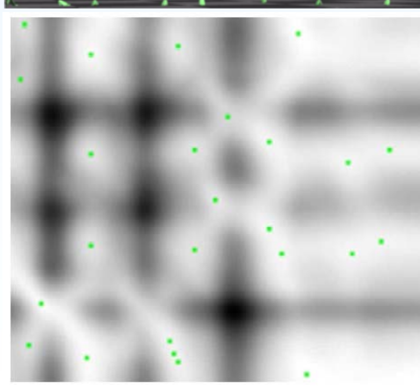
Automatic Generation

of Motion Graphs



Approach:

- Record a long clip of actor doing various motions.
- Compare all frames to find difference between every possible pair of poses – O(N2), but offline.
- Add transitions at local minima that meet some minimum criteria for similarity.
  - White values correspond to lower errors and black values to higher errors. The colored dots represent local minima.
- Avoid bad transitions.

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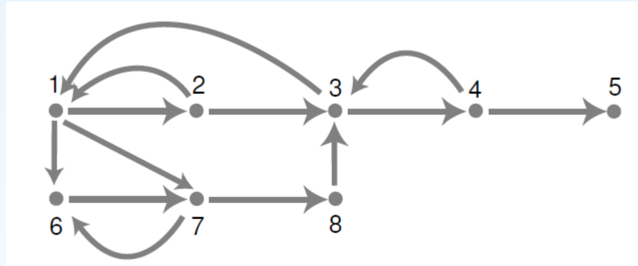
Navigation
on a Generated Motion Graph



- No hand-written rules.
- Choose a desired end state, search the graph for a series of animation clips that will get you there.
- Sometimes results in strange animations.
- Can be improved by annotating animations with information about when they should be used.
    - Automatic classification of motion is a research area.

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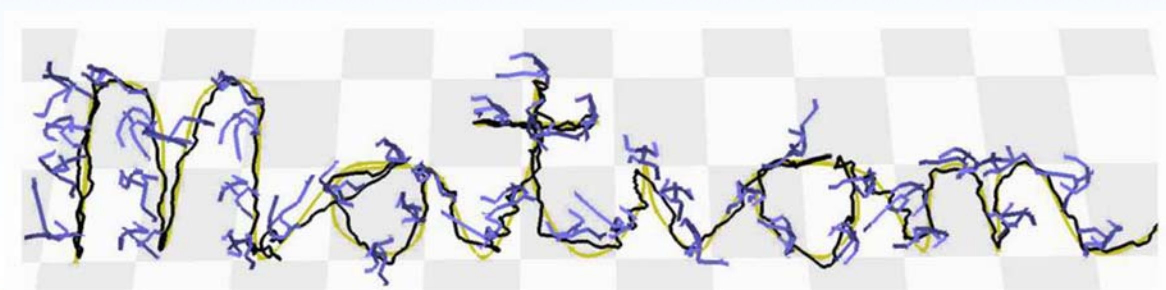
Navigation
on a Generated Motion Graph

Another approach is to select motions that minimize the distance from a desired path. The path can be input by the user or generated by a pathfinding algorithm.



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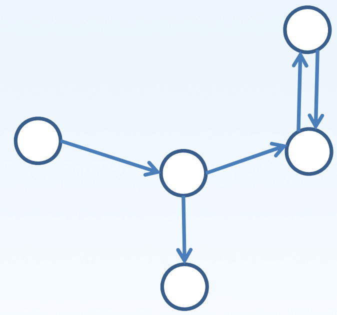
Issues
with Automatic Generation of Motion Graphs



Graph may be poorly connected:

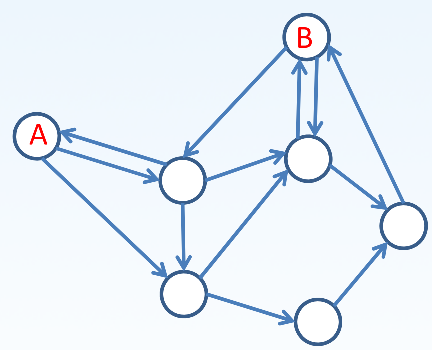
- Loops
- Dead ends (need to find strongly connected components).
- Unreachable motions
  - Search for paths that produce desired motion (branch and bound search)
- Poor blending between, resulting in unnatural and not smooth motion.
  - Transitioning from one clip to another is not as easy as cross-fade or morph from image domain

Still need to produce and store every required transition.

Player Input
with Motion Graphs

Natural conflict between smooth transitions and quick response to player input.

- Might miss required transitions if graph is not planned before motion capture session.



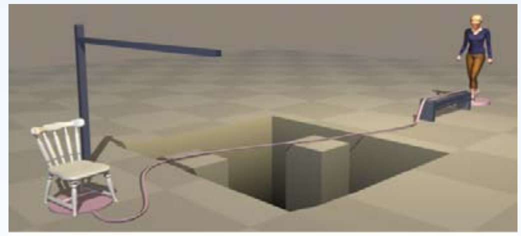
No good transition from A to B.

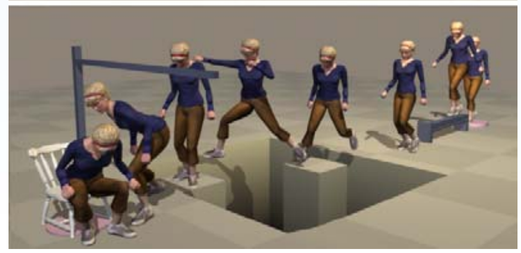
Commercial games prefer to use a poor transition rather than imposing a delay on the player.

Return as often as possible to standard "idle" pose.

Extending
Motion Graphs

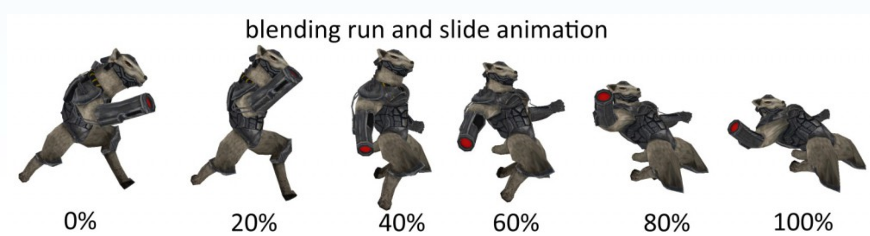
- Motion Graphs have been extended to generate motions that meet certain goals or constraints.
  - e.g. Alla Safonova and Jessica K. Hodgins. Construction and optimal search of interpolated motion graphs. *ACM Trans. Graph.* 26, 3, 2007.
- Stylistic coherence.
  - e.g. Andreas Aristidou, Efstathios Stavrakis, Margarita Papaefthimiou, George Papagiannakis, and Yiorgos Chrysanthou, “Style-based Motion Analysis for Dance Composition”, *The Visual Computer*, 2017.

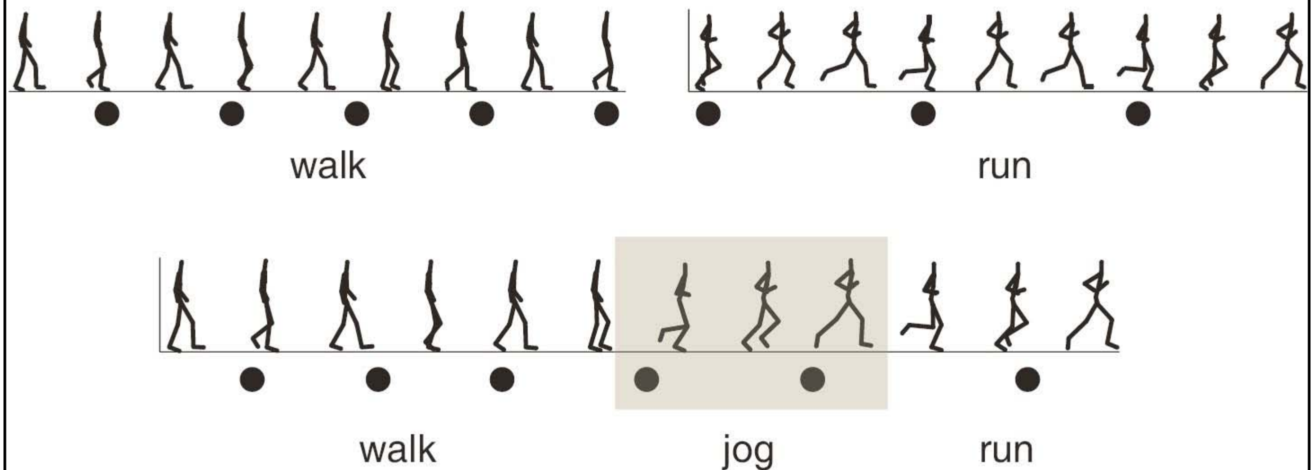




Overview
of Animation Blending

- Using a library of existing clips limits the range of actions a character can perform.
- Mix together two (or more) animation clips to create a new animation.
- Make animation library more versatile without requiring additional motion capture.

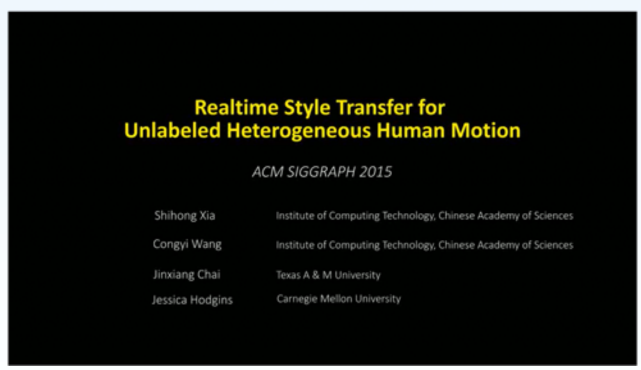




Allow some time to blend from one motion to another

Style Transfer

- Human movements are characterized by style.
  - Personal style.
  - Male/Female.
  - Age.
  - Emotions.
  - Intentions.
  - Etc.
- One of the mocap limitations is that you cannot add more expression in captured data.
  - Usually need to recapture the session -> Expensive



Reference: Shihong Xia, Congyi Wang, Jinxiang Chai, and Jessica Hodgins. Realtime style transfer for unlabeled heterogeneous human motion. *ACM Trans. Graph.* 34, 4, (July 2015)

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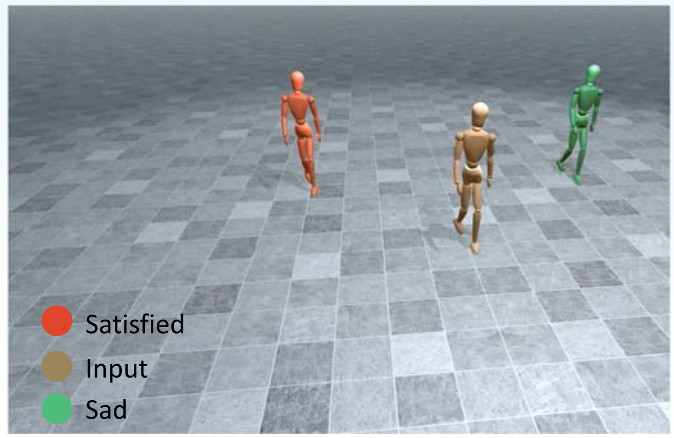
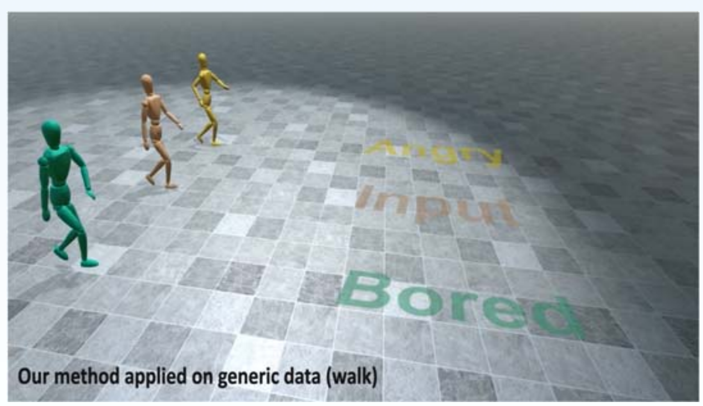
Style Transfer

- Altering the style expressed is of high-importance for control over the animation.
- How to modify motion style?



Style Transfer

- Style Transfer
  - Interpolate and extrapolate stylistic variations learned from unsupervised training data.
- Style modification
  - Learning motion parameters from stylized motion examples.
  - Synthesize motion to satisfy constraints.



Andreas Aristidou, Qiong Zeng, Efstathios Stavrakis, Kangkang Yin, Daniel Cohen-or, Yiorgos Chrysanthou, and Baoquan Chen, "Emotion Control of Unstructured Dance Movements", *Proceedings of the ACM SIGGRAPH/ Eurographics Symposium on Computer Animation, SCA'17. Eurographics Association, Aire-la-Ville, Switzerland,* 2017.

Morphing

Morphing

- Morphing is a deformation applied to a set of vertices.
- Morphing is used for character facial animation.
  - Morph targets are keyframes of facial vertex positions.
  - Morph targets allow finer control of vertex animation compared to skeletal animation.

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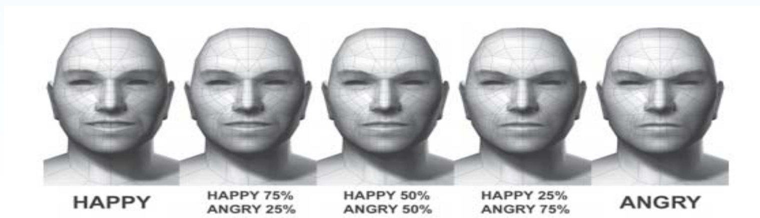
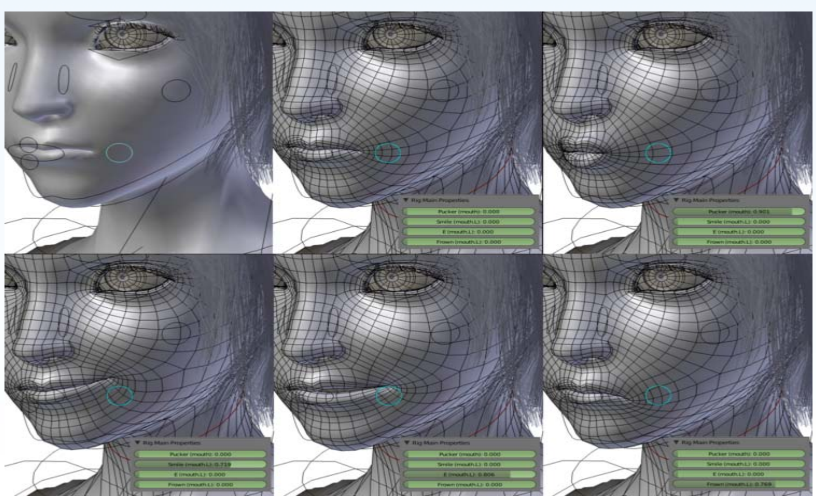
  - Morph targets are keyframes of facial vertex positions.
  - Morph targets allow finer control of vertex animation compared to skeletal animation.



Morphing



TEL AVIV UNIVERSITY
Tel-Aviv, Israel
Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Thank you - תודה

Dr. Andreas Aristidou, {a.aristidou@ieee.org}

Thank you - תודה

- Questions?

Dr. Andreas Aristidou, {a.aristidou@ieee.org}