SGI-MEI
Sistemas Gráficos Interactivos
Animación de Personajes (1)

Bringing Life to Characters

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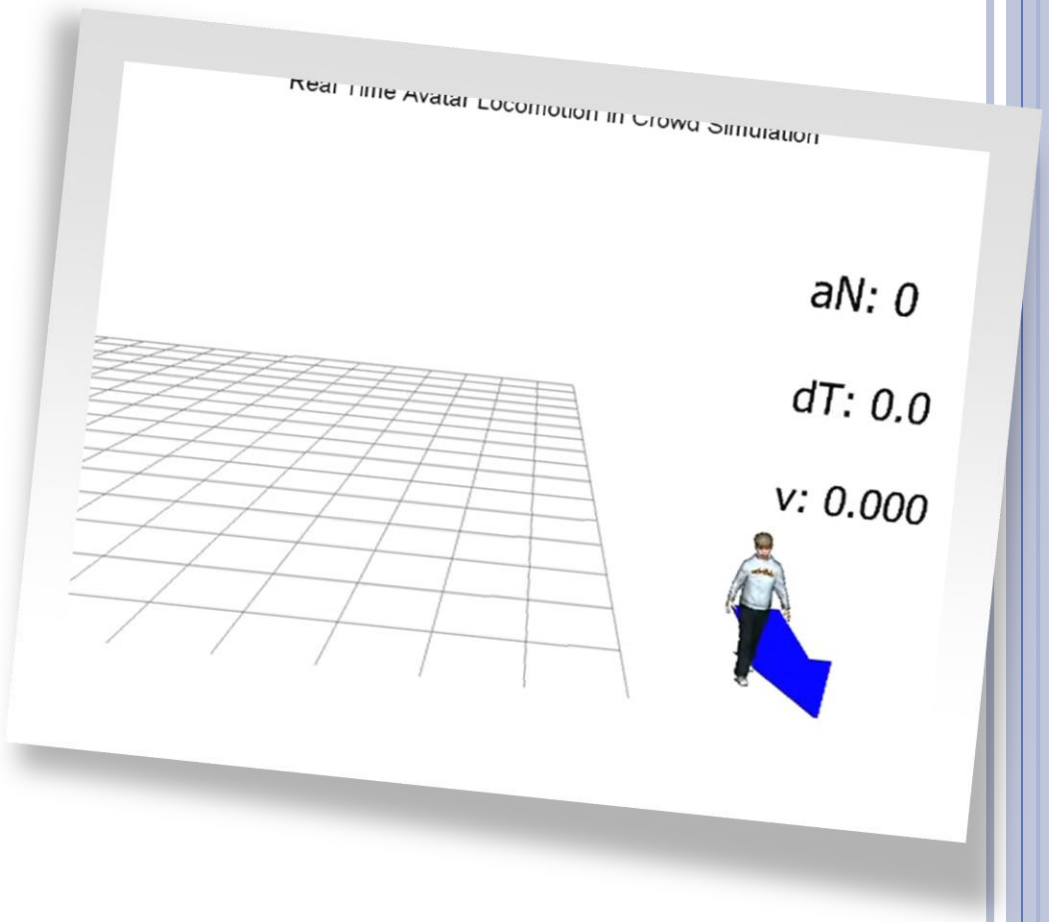
Outline

- 1-Introduction to animation
- 2-Creating animations
- 3-Applying animations
- 4-Software
- 5-Assets

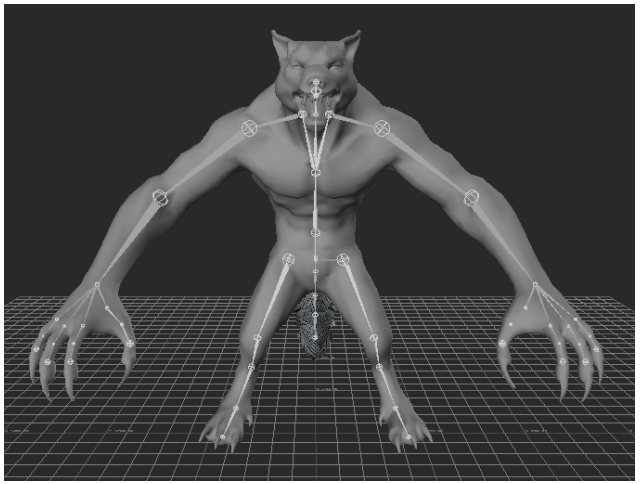


1-Introduction to animation

- 1.1-3D Characters
- 1.2-Traditional animation
- 1.3-Animation for movies
- 1.4-Animation for videogames

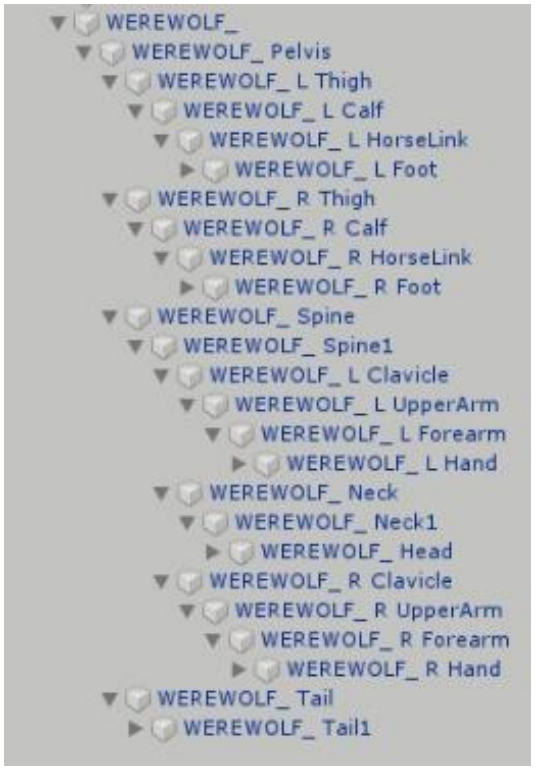
1.1-3D Characters

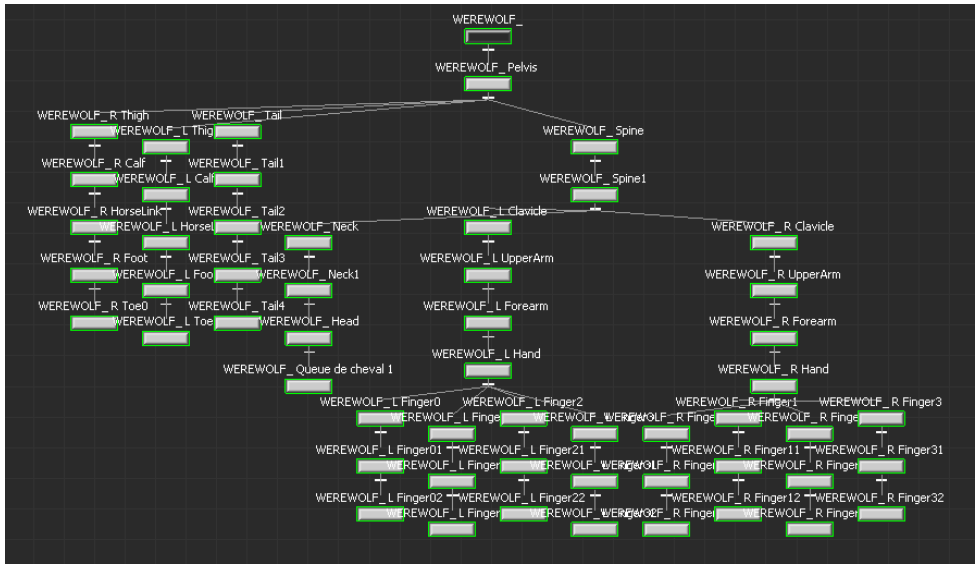
- Avatar
  - Animated 3D representation of a character
  - Has:
    - Skeleton
    - Skinned Mesh

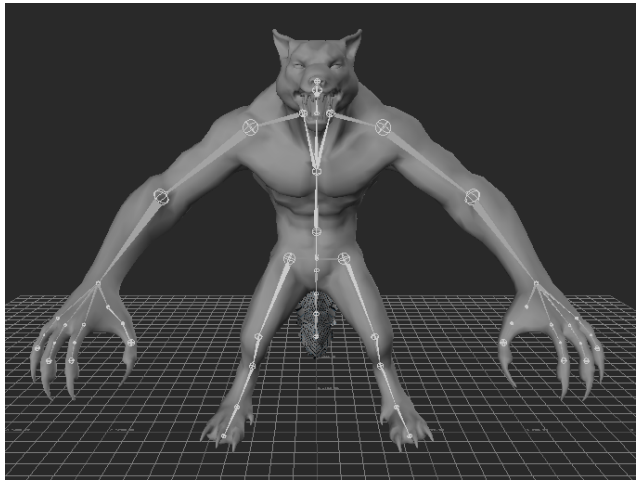


1.1-3D Characters

- Skeleton
  - A hierarchy of joints
  - Joint names usually follow a naming convention

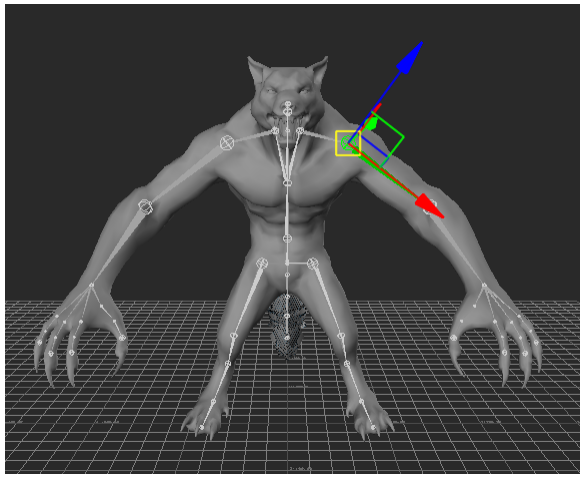


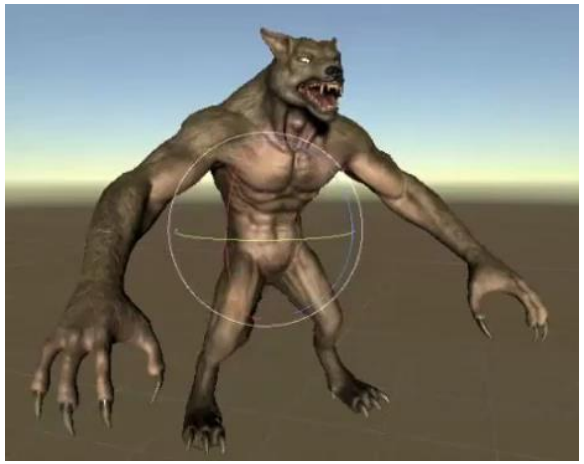




1.1-3D Characters

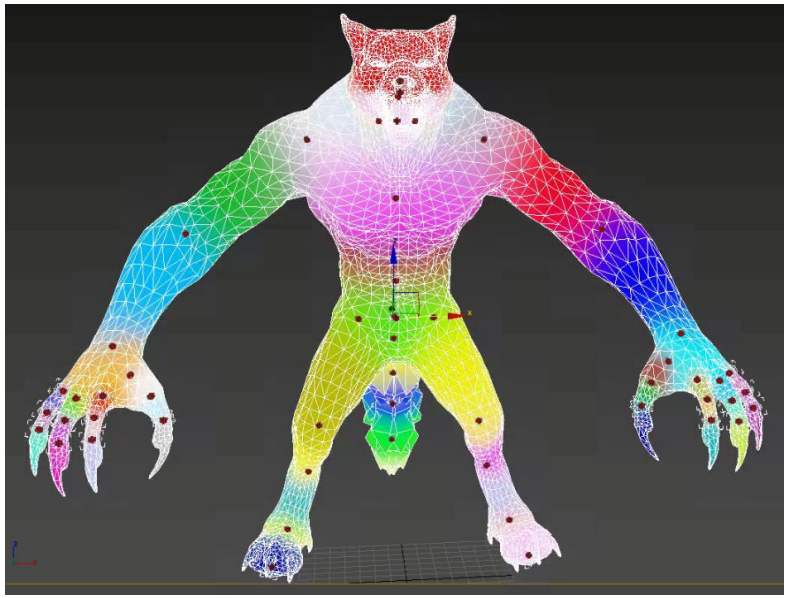
- Joint
  - A node of the skeleton hierarchy
  - Has:
    - Transform matrix:
      - Local position with respect to its parent
      - Local rotation with respect to its parent
      - (Local scale with respect to its parent)
    - Parent
    - Children
  - Root:
    - Special joint with no ancestors
    - World position
    - World rotation
  - Limb:
    - No children





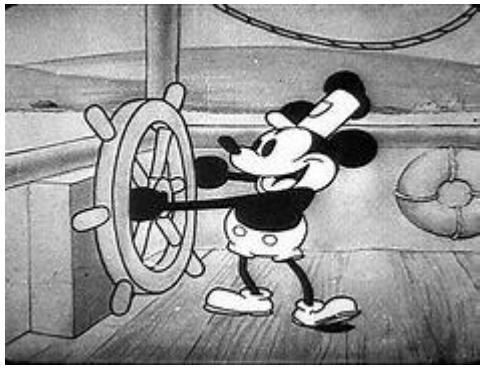
1.1-3D Characters

- Skinned Mesh:
  - Mesh with vertices associated to joints of the skeleton
    - Rigging process
  - Every vertex
    - Up to 4 indexs to joints
    - Up to 4 weights (sum 1)



1.2-Traditional Animation

- Disney first animated movies:
  - Oswald the Lucky Rabbit (1927)
    - http://www.youtube.com/watch?v=c9LmDpMO2k0&list=PLOEymwZx923gVUpi8ig3KQIpr7YqAkE0y
  - Mickey Mouse debuts (1928)
    - https://www.youtube.com/watch?v=BBgghnQF6E4



1.2-Traditional Animation

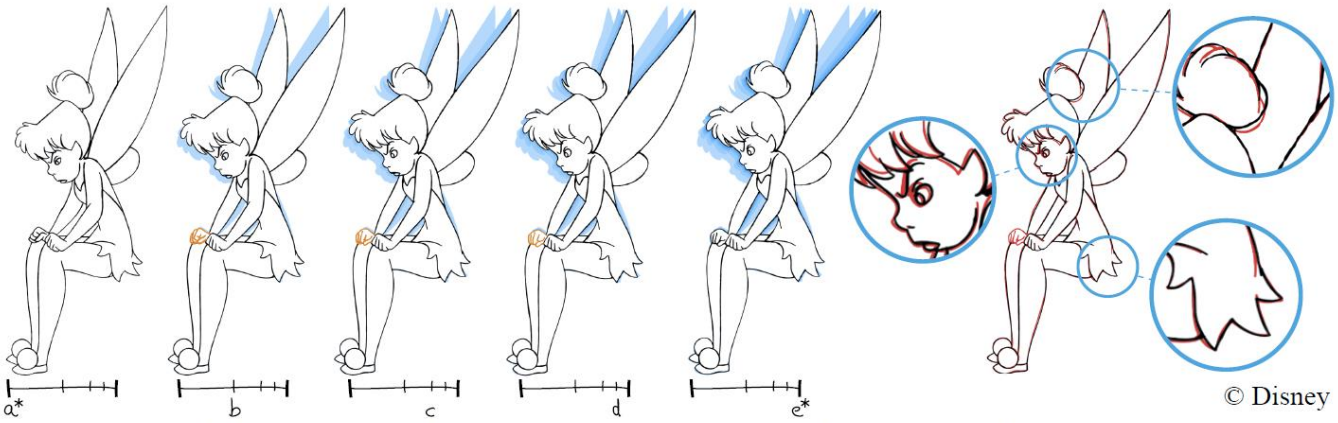
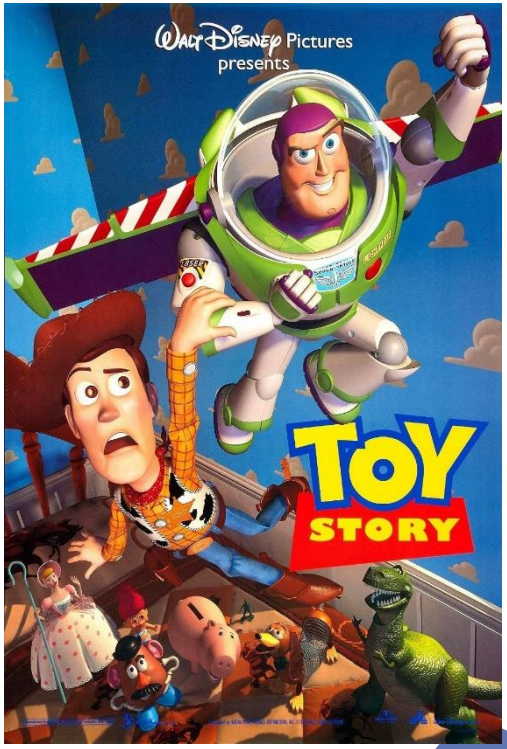


Figure 1: *Tinker Bell: Frames (a) and (e) are the given key frames and (b-d) (except for the right hand) were generated automatically. The "shadows" of previous frames are used to visualize their evolution. The topology of the right hand is not compatible across the two keys and therefore not suitable for automation: the portion indicated in red was hand-drawn. Frame (c) is overlaid on top of the original hand drawn inbetween (red) on the right.*

BetweenIT: An Interactive Tool for Tight Inbetweening. B. Whited, G. Noris, M. Simmons, R.W. Sumner, M. Gross, J. Rossignac. Eurographics 2010

1.3-Animation for Movies

- Lucasfilm short movie (1984):
  - The Adventures of André & Wally B.
    - https://www.youtube.com/watch?v=a_9Tsbduk9E
- First Pixar Movie (1995)
  - Toy Story (first CGI feature film)
    - https://youtu.be/6W_HL3nULMM
- No interaction → scripted / guided animation
- Rendering → no optimization needed



1.3-Animation for Movies

- Technical challenges for specific characters
  - https://www.youtube.com/watch?v=Nn0S2vmSCU0

1.4-Animation for Videogames

- Dragon's Lair (1983) for Laserdisc
  - https://www.youtube.com/watch?v=W1ktj5Squ2c
  - Ex-Disney animator Don Bluth
  - Laserdisc → overcomes hardware limitations (memory, resolution, framerate) of the time
  - Full Motion Video (FMV) → Limited interaction
  - 2D Interactive movie

1.4-Animation for Videogames

- Prince of Persia (1989)
  - https://jordanmechner.com/backstage/journals/
  - long, tedious task

(Now free for Windows!)

1.4-Animation for Videogames

- Tomb Raider (1996)
  - 3D Third person adventure
  - Many actions and animations
  - Button to switch from running to walking

1.4-Animation for Videogames

- Super Mario 64 (1996)
  - Before: fake analogue control by holding button
  - Introduction of analogue joystick (Nintendo 64)
  - Full range of speeds
  - focused on momentum via inertia

1.4-Animation for Videogames

- Real time framerates
- Interactivity → perform many actions
  - Locomotion
  - Parkour
  - Combat
  - Interactions
  - …
- User control → to move in a 3D environment smoothly with different speeds and directions
- Transitions → smooth switching between motions at any time

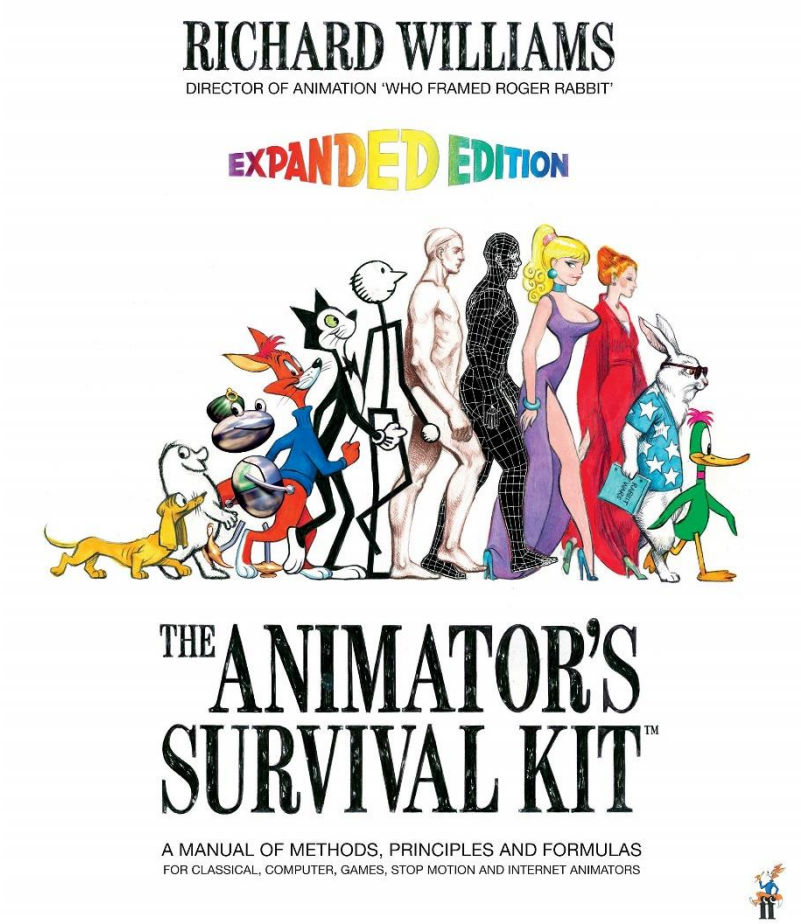
2-Creating animations

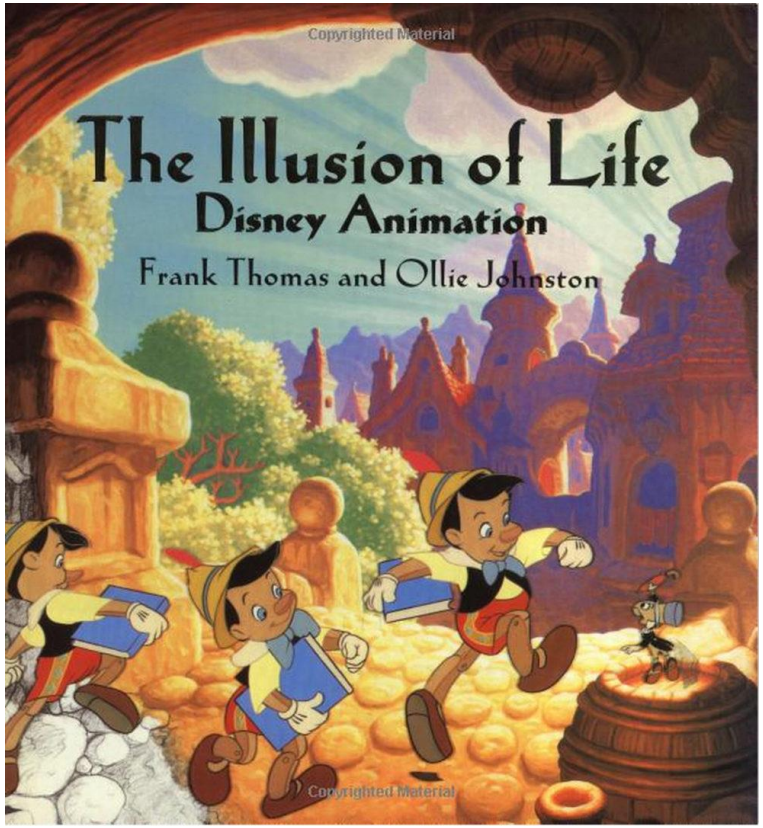
- 2.1-Artist
- 2.2-Mocap
- 2.3-Time warping
- 2.4-Blending animations
- 2.5-Avatar masks and animation layers
- 2.6-Control rigs, FK + IK
- 2.7-Blendshapes

2.1-Artist

- Manual work
- Art
- Inspiration
- Reference model
- Movies: 12 basic principles of animations (Disney) https://en.wikipedia.org/wiki/Twelve_basic_principles_of_animation
- Videogames: 5 fundamentals https://www.gameanim.com/2020/04/04/the-five-fundamentals-of-video-game-animation/

2.1-Artist


RICHARD WILLIAMS
DIRECTOR OF ANIMATION 'WHO FRAMED ROGER RABBIT'
EXPANDED EDITION
THE ANIMATOR'S SURVIVAL KIT™
A MANUAL OF METHODS, PRINCIPLES AND FORMULAS
FOR CLASSICAL, COMPUTER, GAMES, STOP MOTION AND INTERNET ANIMATORS


Copyrighted Material
The Illusion of Life
Disney Animation
Frank Thomas and Ollie Johnston
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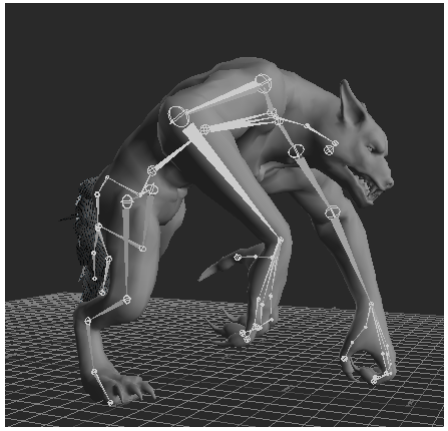
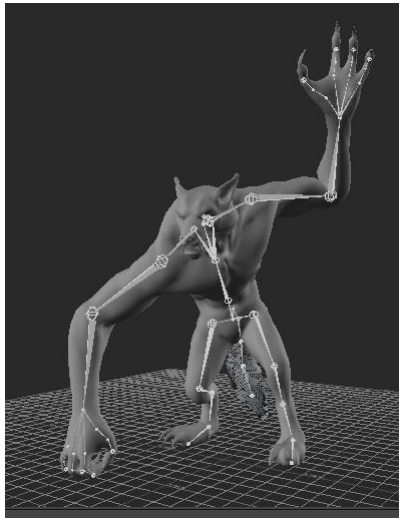
2.1-Artist

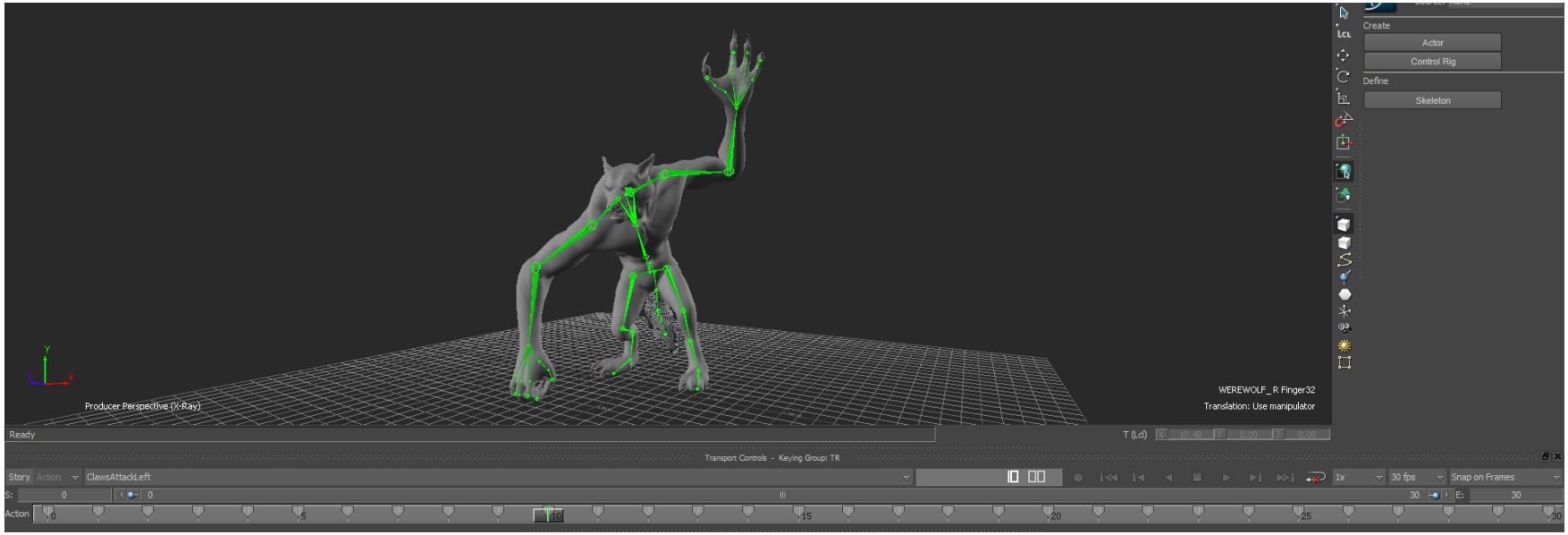
- Pose:
  - A set of transformations for each joint of the skeleton
  - Apply top-down transformations
    - 1 final transformation matrix for each joint





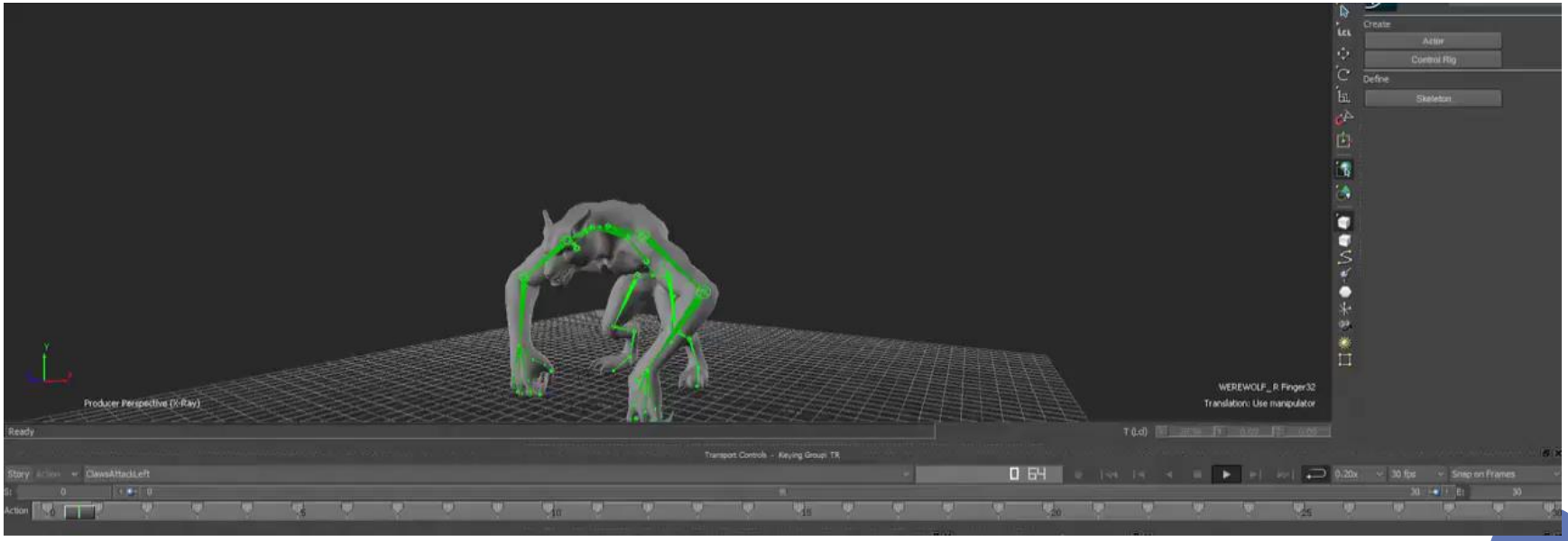
2.1-Artist

- Keyframe:
  - Pose
  - Timestamp



2.1-Artist

- Animation clip:
  - A set of Keyframes
  - Blending / interpolation is achieved between keyframes to obtain middle frames



2.2-MOCAP

- MOtion CAPture
- Tracking, sampling and recording of motion of a person or object as 3D data
- Use to animate an artificial character / object
  - Offline
  - Online
- Body
- Facial
- *Performance capture*

2.2-Mocap

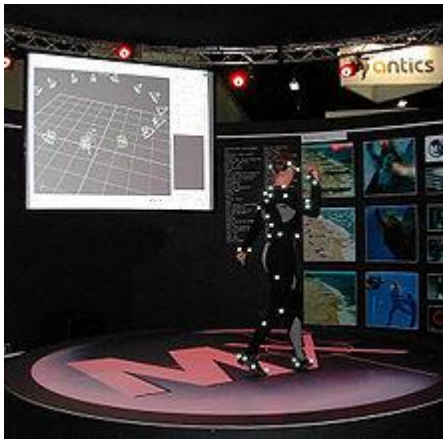
- Animals too!

2.2-MOCAP

- Optical systems
- Non-Optical systems

2.2-MOCAP

- Optical systems
  - Passive markers (retroreflective markers)
  - Active markers (the markers emit light)
  - Markless (Kinect. RGB for color + infrared for depth)



2.2-MOCAP – OPTICAL SYSTEMS

- Developed with CGI applications – Vicon 8 system
- 4-32 cameras
- Markers
  - Active
  - Passive

2.2-MOCAP – OPTICAL SYSTEMS

- Calibrate 3D positions from different cameras
- Rotational information inferred from the relative position of 3 or more markers
- Problems: occlusions!

2.2-MOCAP – MARKLESS

- Computer vision techniques do not require markers
- Computer vision algorithms analyze optical input and identify human forms and track optical flow.

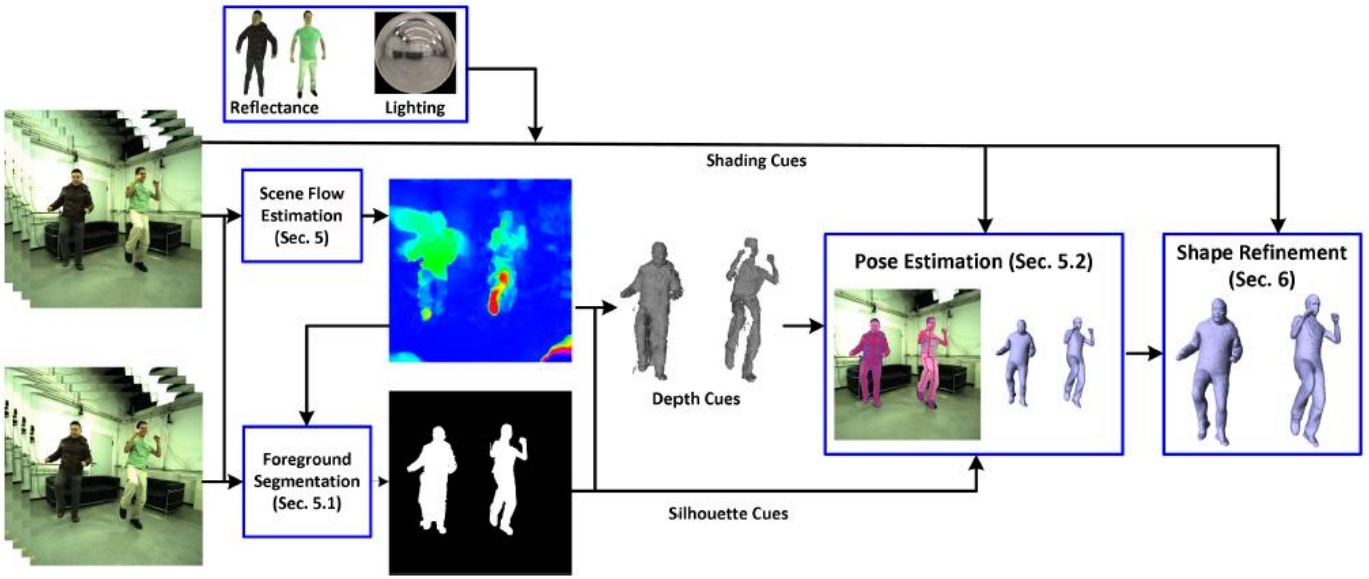
2.2-Mocap – Markless

- Facial mocap in real time (EPFL):
  - Now owned by Apple ☹
  - Learned expressions
  - Expressions recognition → mapping

- Full body:
  - Organic Motion

2.2-MOCAP – MARKLESS

- C. Wu, C. Stoll, L. Valgaerts, C. Theobalt, *On-set Performance Capture of Multiple Actors With A Stereo Camera*. In ACM Transactions on Graphics (SIGGRAPH Asia), 2013
- http://gvv.mpi-inf.mpg.de/projects/BinoCap/



2.2-MOCAP

- Non-Optical Systems
  - Inertial systems
  - Mechanical motion
  - Magnetic systems

2.2-Mocap - Inertial

- Uses miniature inertia sensors, biomechanical models and sensor fusion algorithms
- Motion data transmitted wirelessly to a computer
- Gyroscopes to measure rotational rates
- No external cameras
- Advantages: portability and large captured areas
- Disadvantages: lower positional accuracy

2.2-MOCAP – MECANICAL SYST

- Directly measure joint angles as the capture subject moves
- Device looks like an exo-skeleton
- Real-time
- Free of occlusion
- Free from magnetic of electrical interference and highly portable

2.2-MOCAP – MAGNETIC SYSTEMS

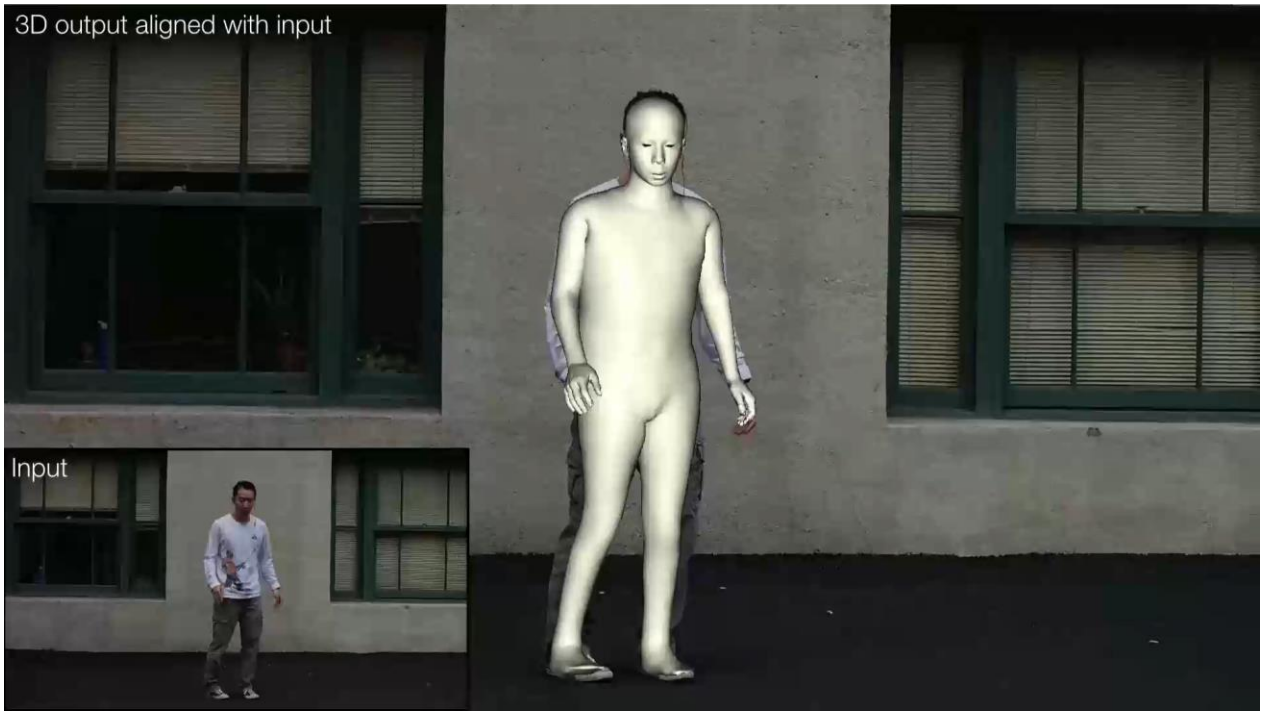
- Calculate position and orientation by the relavive magnetic flux of 3 orthogonal coils on both the transmitter and each receiver
- No occlusions, but can be affected by magnetic and electrical interference → Drift!!

2.2-Mocap – VR trackers

- HTC Vive
- 6 trackers (FK) + IK

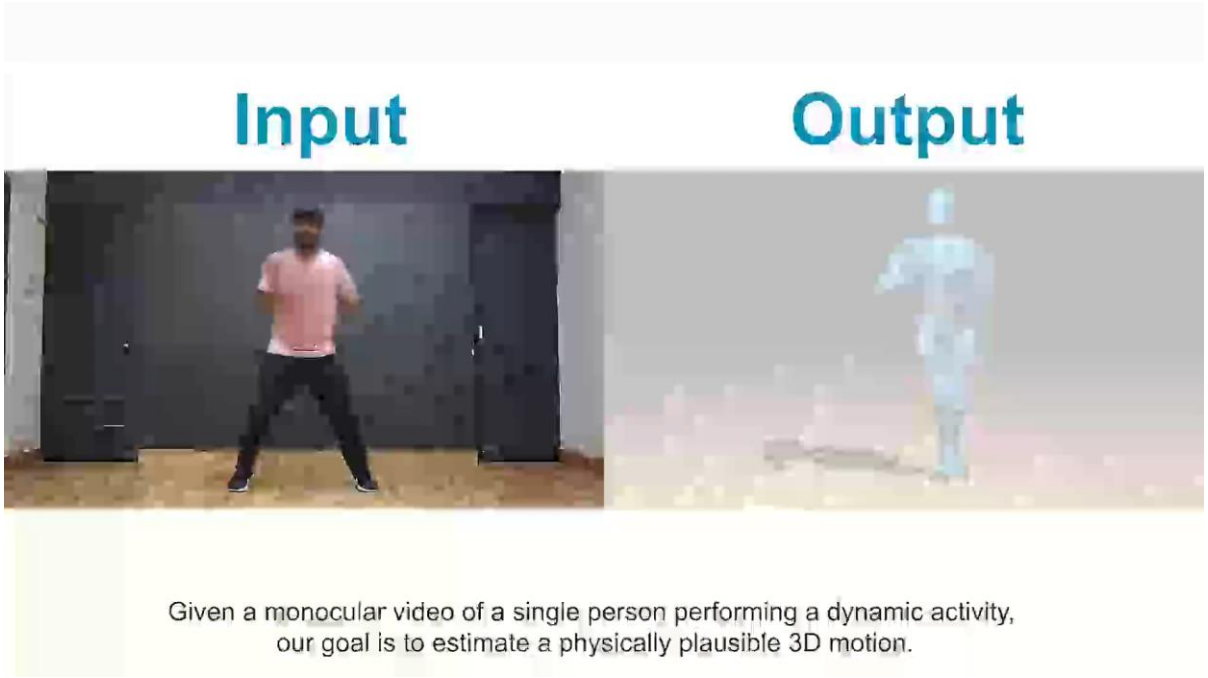
2.2-MOCAP

- Video to motion
  - Computer vision + deep learning
    - Xiang *et al.* Monocular Total Capture, IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2019



2.2-MOCAP

- Video to motion
  - Rempe *et al.* **Contact and Human Dynamics from Monocular Video** *European Conference on Computer Vision (ECCV) 2020*

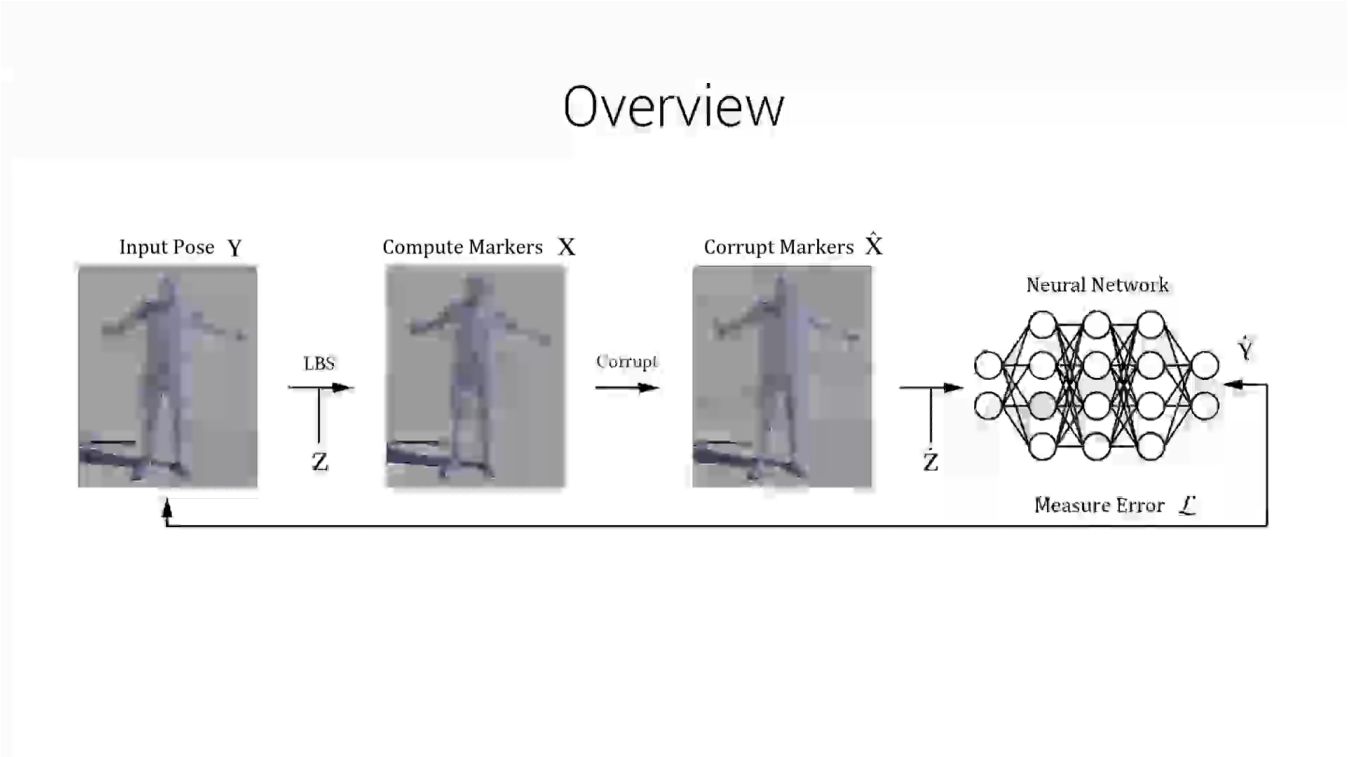


2.2-MOCAP

- Advantages
  - Faster, even real time
  - Reduced cost compare to frame by frame animations
  - Amount of work does not vary with complexity or length of the performance
- Disadvantages
  - Cost of SW and HW
  - Capture system may have specific requirements for the space
  - Artifacts can occur if the animated model differs in proportions from the captured model
  - Lot of post-process and cleaning work

2.2-MOCAP

- Daniel Holden. **Robust solving of optical motion capture data by denoising**. ACM Transactions on Graphics 2018



2.2-MOCAP - LIMITATIONS

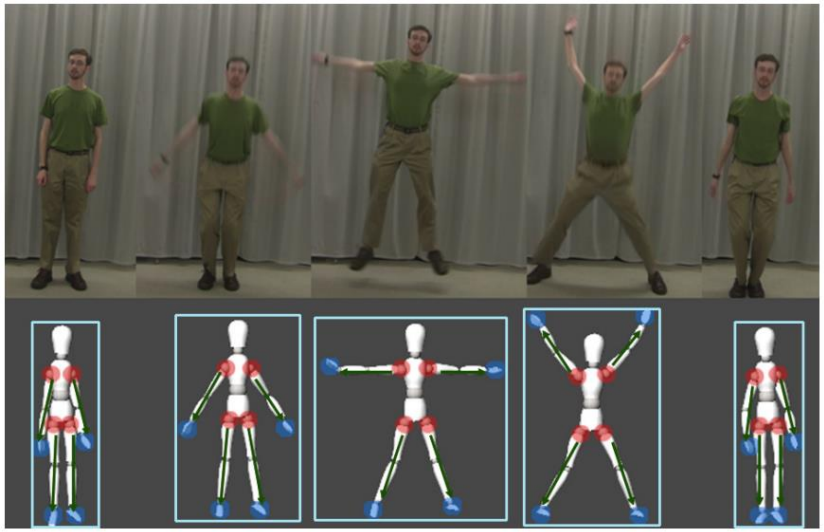
- Capture data can be voluminous
- Processing motion data is computationally intensive
- Capturing all possible motion is impossible
- Solutions:
  - Organize and represent data
  - Combine data intelligently to synthesize new motion
  - Simulate physics to dynamically generate new motion

2.2-MOCAP - DATABASES

- CMU Graphics Lab Motion Capture Database
  - http://mocap.cs.cmu.edu/
- Motion Capture Database HDM05 (max planck institut informatik)
  - http://www.mpi-inf.mpg.de/resources/HDM05/

2.2-MOCAP - DATABASES

- Find motions in databases
- Mubbasir Kapadia, I-kao Chiang, Tiju Thomas, Norman I Badler, Joseph T Kider Jr. Efficient motion retrieval in large motion databases, Proceedings of the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games. 2013
- https://www.youtube.com/watch?v=lZFWEMEdKhE



2.2-Mocap – Real-Time Performance Capture

2.3-Time Warping

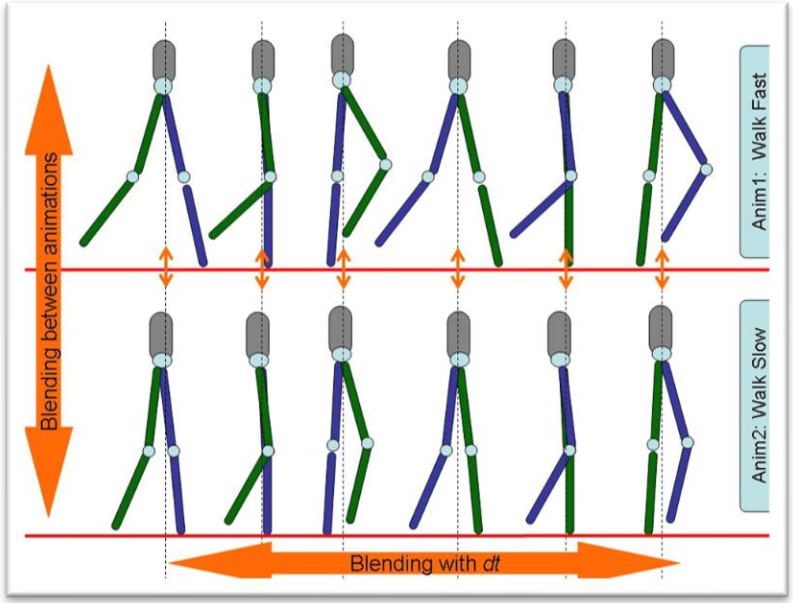
- Play animation the whole at different speed
  - Naïve approach
  - Only natural with time factors very close to 1
  - Otherwise unnatural:
    - Slow motion
    - "Benny hill" effect
- Can be done in real-time by the game engine
  - Sample animation keyframes at different speed
- In motion editing software:
  - Change different parts (joints) of the animation with different speed factors

2.3-Time Warping

Guided Time Warping for Motion Editing
Eugene Hsu, Marco da Silva, Jovan Popovic / SCA 2007

2.4-Blending Animations

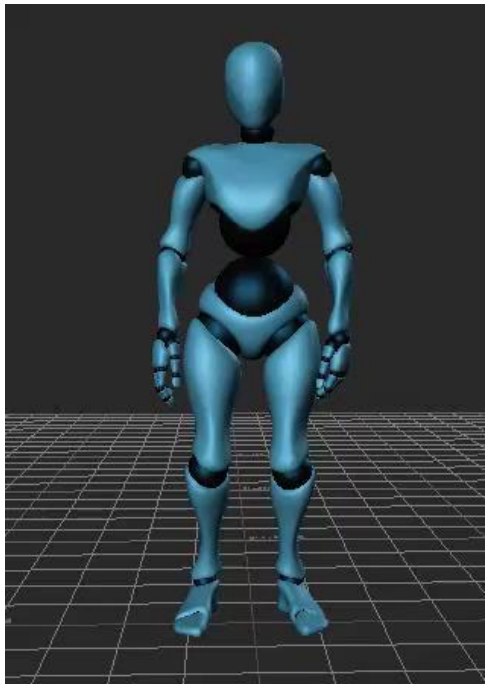
- Blend within animation → between two poses of consecutive frames (time warping)
- Blend between two animations
  - Similar motions
  - Aligned events
  - Cycles of equal length
  - Interpolation of the joint rotations and of the root translation.
  - Blending weights
  - Timing (fadeIn/fadeOut)

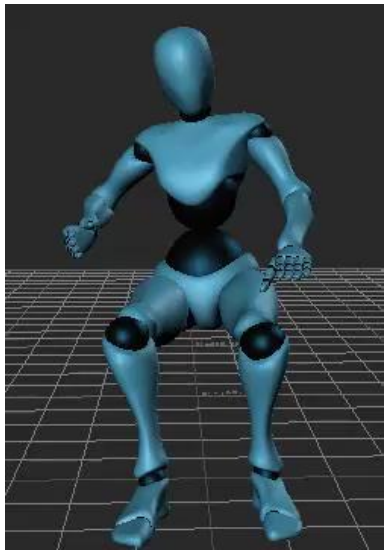


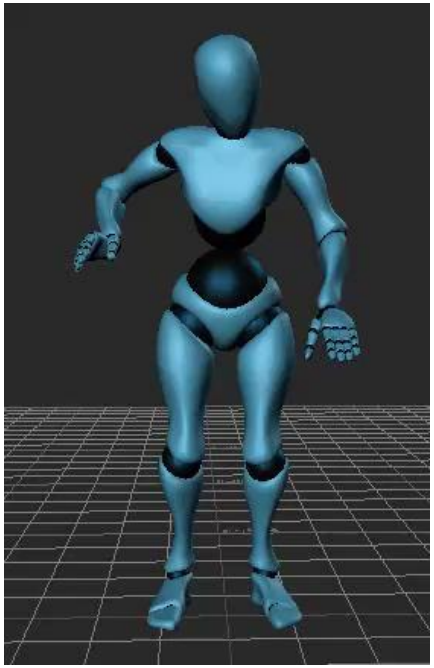
2.5-Avatar Masks and Animation Layers

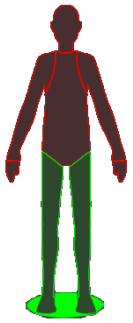
- Avatar Mask
  - Joints mask to decide whether to apply animation or not
  - Usual masks: upper body, lower body, arms, legs, …
- Animation Layer
  - Outputs a pose for each frame
  - Uses Avatar mask to decide what joints use that output
  - Weight (can fade in/out)
  - Blend modes:
    - Override → overrides completely lower layers rotations
    - Additive → adds current layer output to lower layers rotations
- Layered animation
  - Blends poses between different layers
  - Needs a BASE layer!

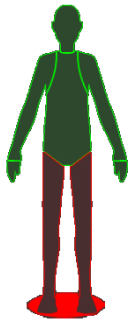
2.5-Avatar Masks and Animation Layers

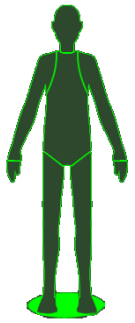




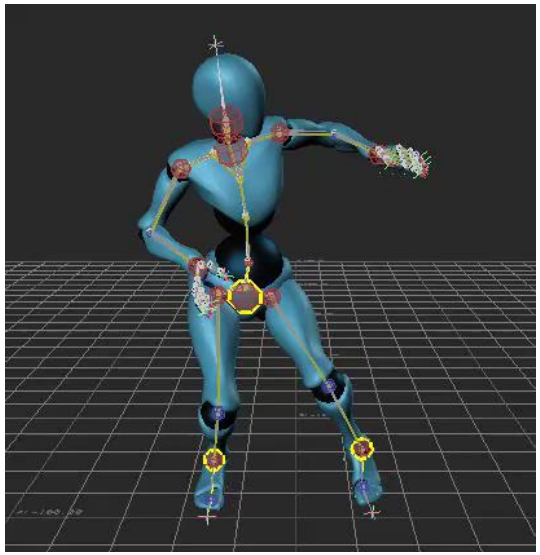


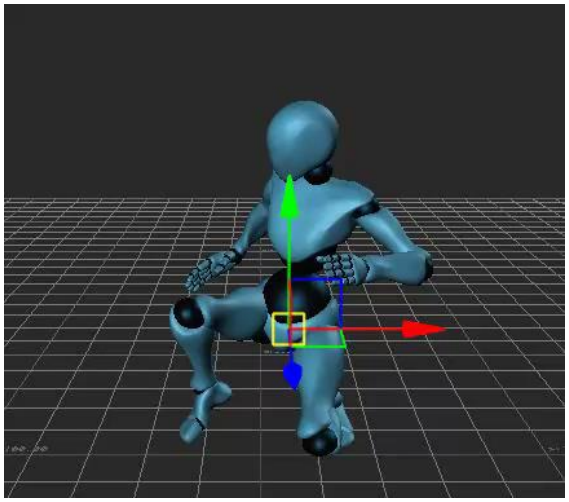






2.6-Control Rigs, FK + IK



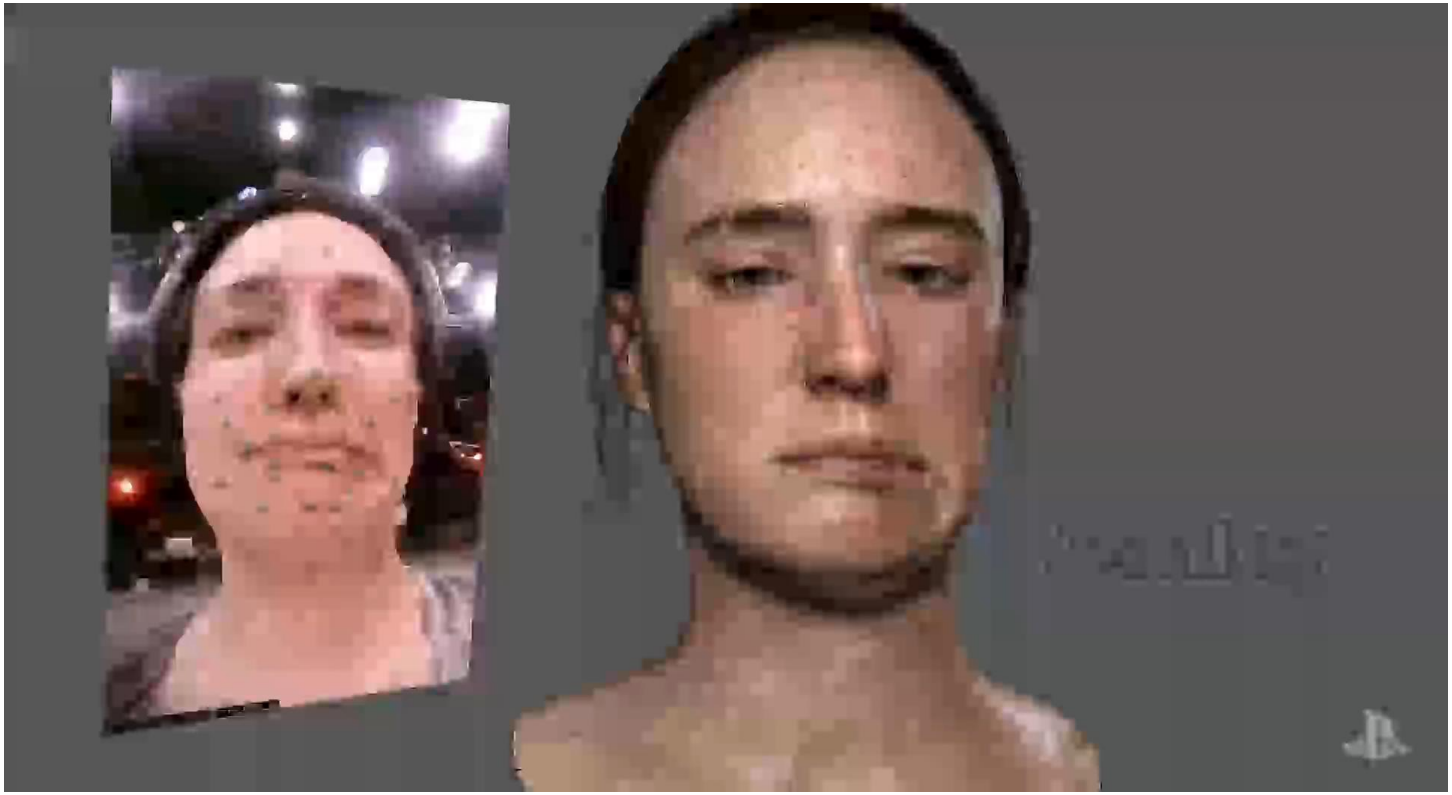


2.7-BLENDSHAPES

- Blendshapes: different shapes with the same topology → same number of vertices, same faces pointing to the same indices of vertices, but different vertex positions
- Different vertex positions → OFFSETS
- Also known as *Morph targets*
- More control over the mesh tan skeletal animation

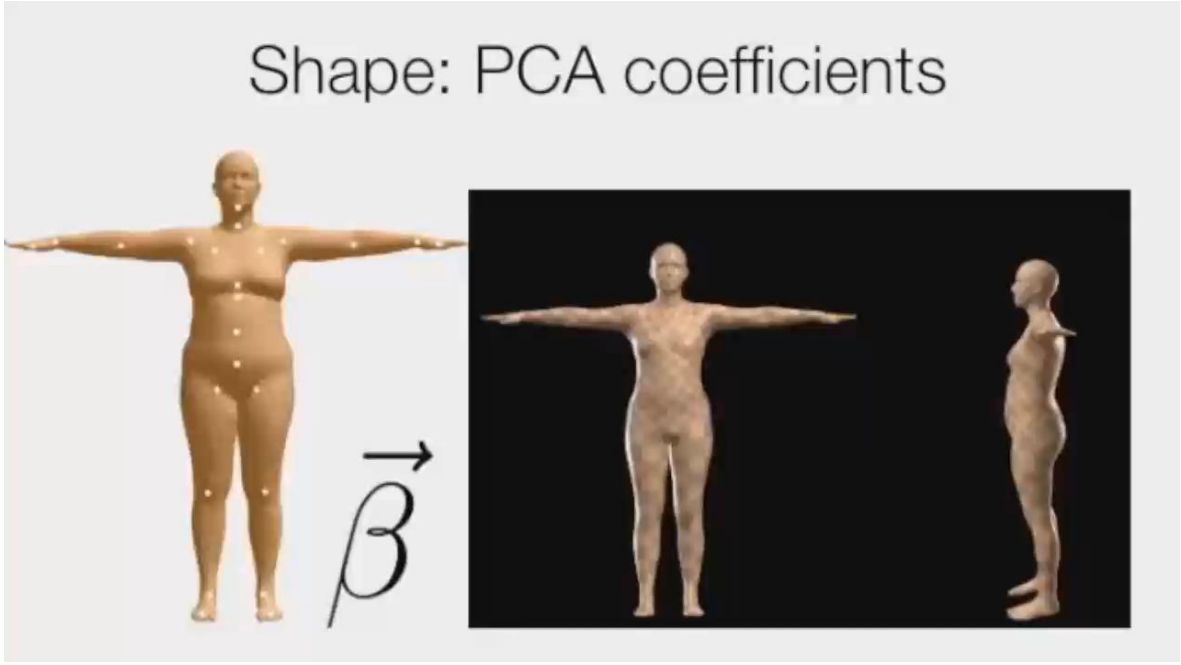
2.7-Blendshapes

- Often used for facial animation



2.7-BLENDSHAPES

- But also for body deformations
- Loper *et al.* SMPL: A Skinned Multi-Person Linear Model. 2015



3-Applying animations

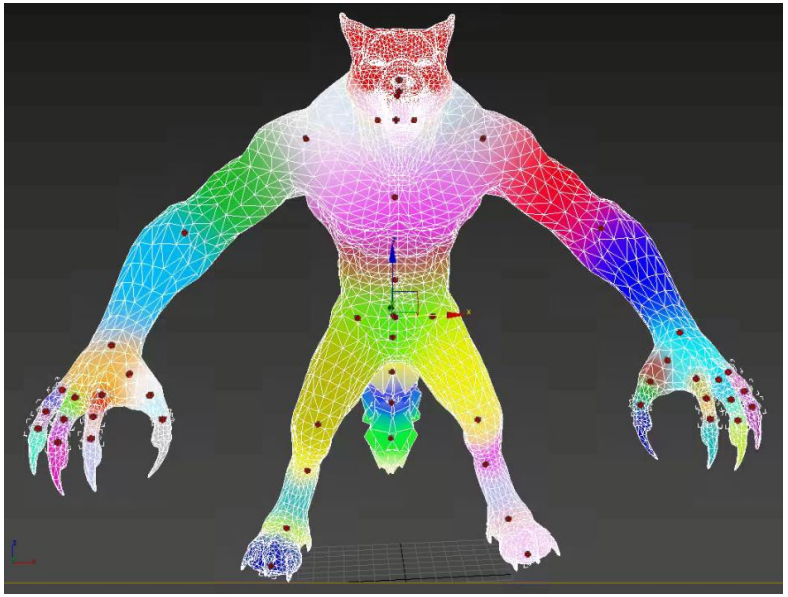
- 3.1-Avatar (mesh, skeleton, skinning)
- 3.2-Enhancing skin realism
- 3.2-Applying blendshapes
- 3.3-Animation retargeting

3.1-Avatar (mesh, skeleton, skinning)

- Rigging
- Binding pose
- Skin deformations
- Auto rigging
- Transfer skin
- Wrap

3.1-Avatar (mesh, skeleton, skinning)

- Rigging:
  - Associate mesh vertices to joints of the skeleton
  - Every vertex
    - Up to 4 indexs to joints
    - Up to 4 weights (sum 1)
- Difficult / Painfull
  - http://www.youtube.com/watch?v=MrutbhglsMw
  - http://www.youtube.com/watch?v=fpU1yqsT8_A



3.1-Avatar (mesh, skeleton, skinning)

- Binding pose:
  - Pose of the skeleton when rigging was done
    - The state of the mesh when no transformation is applied
  - Animation poses are basically rotations from the original skeleton definition pose
  - The bind pose must be reverted before applying animation to vertices

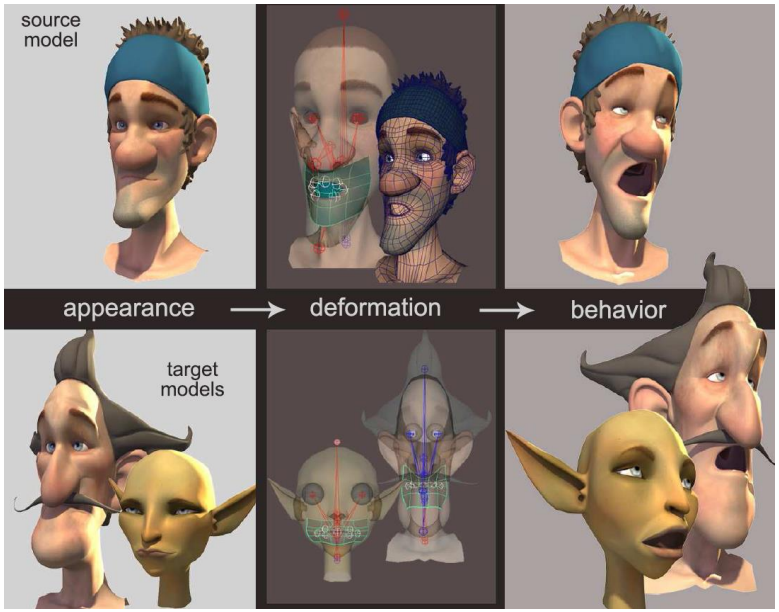
3.1-Avatar (mesh, skeleton, skinning)

- Skin deformations (CPU / GPU)
  - *Linear blend skinning*
  - The full transform of a bone is the product of all the transformations from him to the root (FK)
  - Vertices change position with the movement of the underlying skeleton
  - M = M1*W1 + M2*W2 + M3*W3 + M4*W4
  - CPU
    - Final vertices are computed in the CPU prior to be sent to the GPU
  - GPU
    - Bone matrices and vertex skinning data (weights and bone indexs) are sent to the GPU
    - Final matrix computation is performed in the shader for every vertex

3.1-Avatar (mesh, skeleton, skinning)

- Auto rigging
  - Online tool: http://www.mixamo.com/c/auto-rigger
  - Reallusion actorcore accuRIG: https://actorcore.reallusion.com/auto-rig

Fast and Reusable Facial Rigging and Animation.
V. Costa Orvalho, A. Susin.
Siggraph sketches 2007

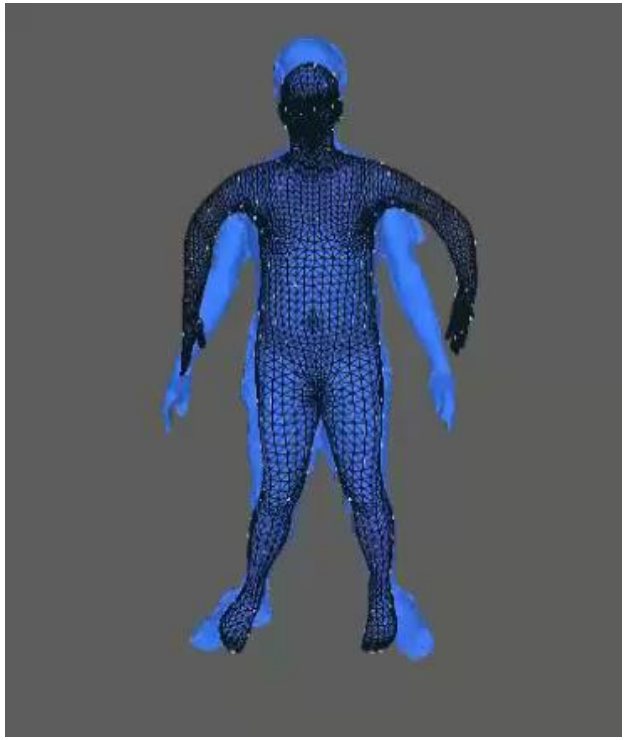


3.1-Avatar (mesh, skeleton, skinning)

- Transfer skin
  - 3D Max, Maya, …
  - Align a skinned mesh with one that is not skinned
  - Transfer skin weights from one mesh to the others
    - By distance
    - By projection
    - …
  - Useful for adding clothes for example

3.1-Avatar (mesh, skeleton, skinning)

- Wrap
  - Change mesh topology (retopologize)
  - Base/template skinned mesh
  - Align mesh to template
  - Transform template to the shape of the new mesh
  - Transfer color, texture, etc…
  - Same technology than for scanning meshes
  - https://www.russian3dscanner.com/

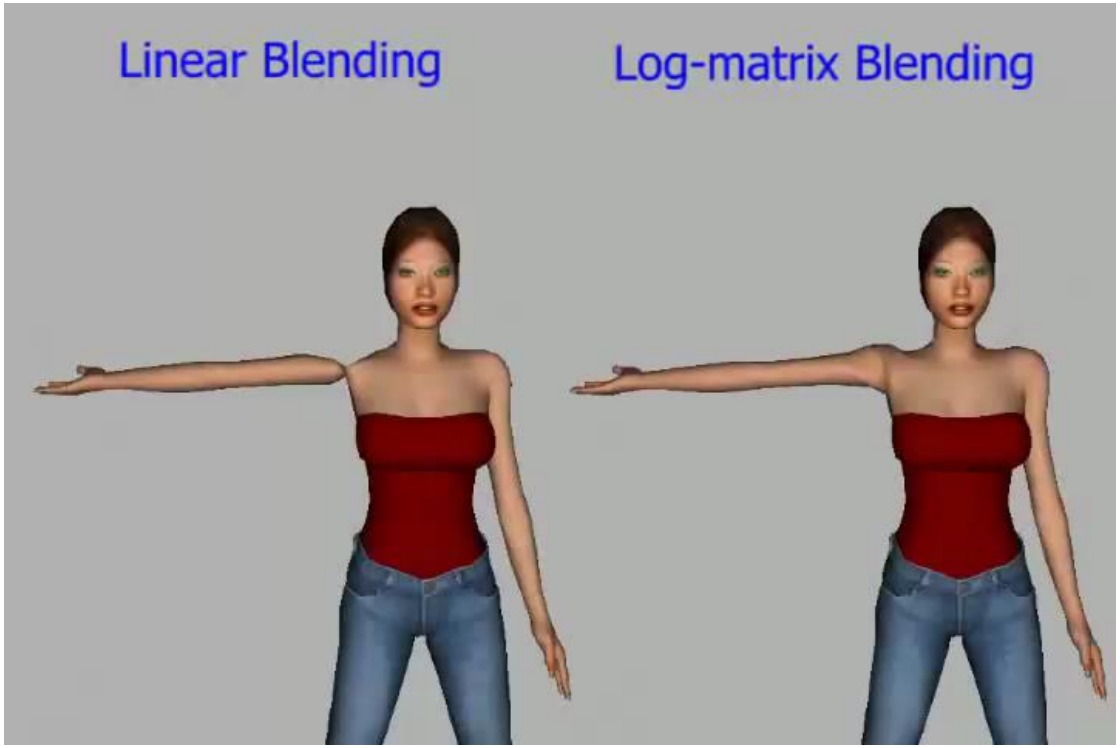


3.2-Enhancing skin realism

- Rigging strengths:
  - A bone represents a set of vertices (ex. arm)
  - Animator controls fewer characteristics of the model (moves many vertices simultaneously)
  - Bones are independently movable
- Weaknesses:
  - No muscle deformation
  - No skin motion (wrinkles, tendons, etc)

3.2-Enhancing skin realism

- Linear blend skinning
  - Candy wrapper effect
- Dual Quaternions
  - Kavan *et al.* "Skinning with Dual Quaternions", I3D 2007



3.2-Enhancing skin realism

- *Musculotendon Simulation for Hand Animation*. S. Sueda, A. Kaufman, D.K. Pai. Siggraph 2008

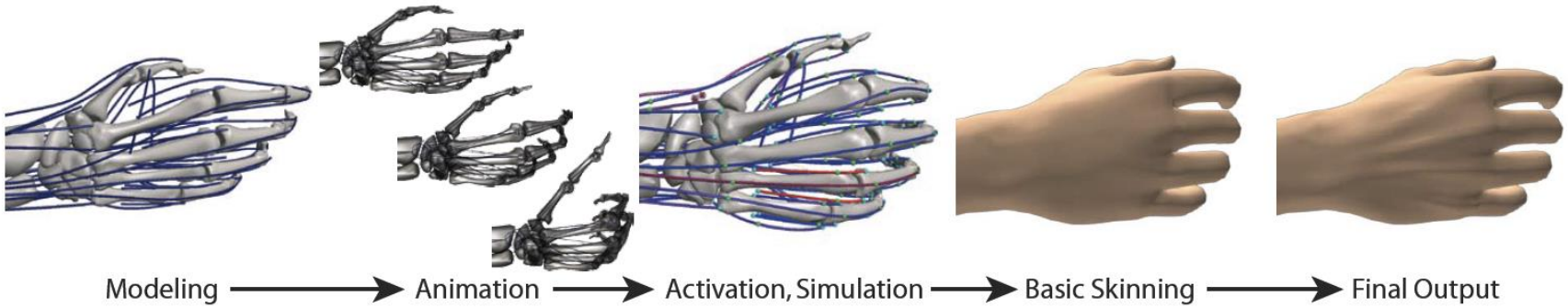


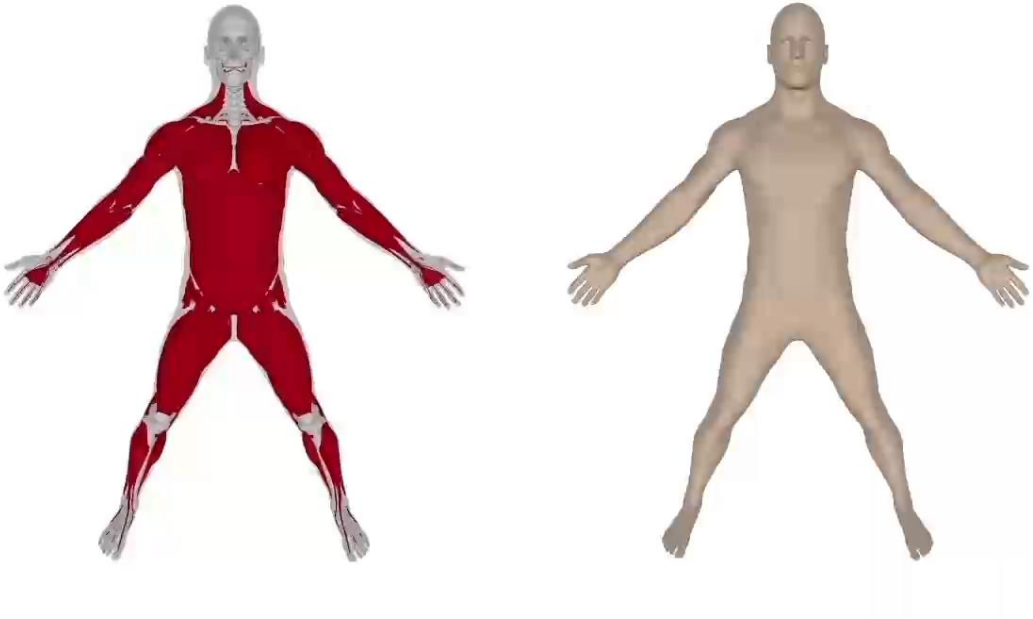
Figure 1: *Pipeline: The user specifies the model and its corresponding animation. Our system computes the required activations, and simulates the muscles, tendons, and bones. The skin is then attached to the skeleton, and the subcutaneous deformation from tendon motion is added as a post-process.*

3.2-Enhancing skin realism

- *Practical and Realistic Facial Wrinkles Animation*. J. Jimenez, J. I. Echevarria, C. Oat, D. Gutierrez. GPU Pro 2. 2011
- The animator can independently blend multiple wrinkle maps across regions of a character's face. This combined with real-time skin rendering can produce stunning results that bring out the personality and emotional state of a character.

3.2-Enhancing skin realism

- *Computational Bodybuilding: Anatomically-based Modeling of Human Bodies*. S. Saito, Z. Zhou, L. Kavan. ACM Transaction on Graphics 34(4) [Proceedings of SIGGRAPH], 2015.
  - Model: https://www.zygotebody.com/
  - 111 mucles and 204 bones.



3.2-Enhancing skin realism

- Modeling skin + muscle + fat
  - Physics-based simulation of soft tissues (muscle, fat, internal organs or blood vessels)
  - Muscle and fat can grow. Others are non-growing elastic tissues.
  - Bones rigid, only grow during editing

3.3.-Applying blendshapes

- Blendshapes can also be blended in and out
- Using weight with lerp function
- Can also be interpolated and/or mixed
- Be careful! Sum of weights of every blendshape must be <= 1.

3.4-Animation retargeting

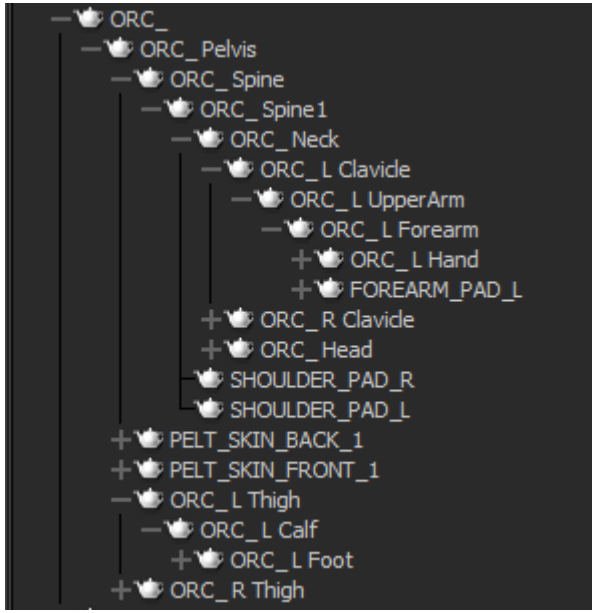
- Apply/transfer an animation designed for one character (skeleton) to another character with a different skeleton definition (different joints).

3.4-Animation retargeting

- Avatar/skeleton definition
- Intermediate skeleton
- Mapping
- Retargeting
- Blendshapes retargeting (Wrap)

3.4-Animation retargeting

- Avatar/skeleton definition
  - A hierarchy of joints
  - Joint names usually follow a naming convention
  - Every joint has its own local space defined

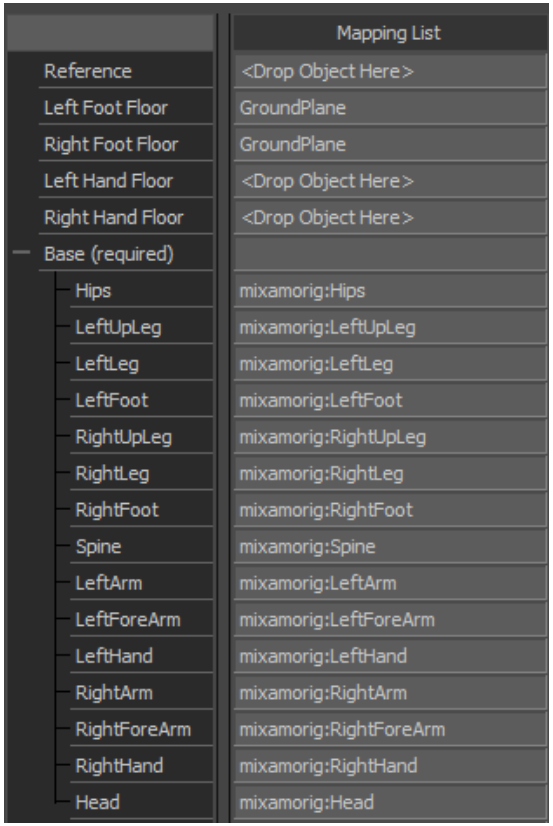


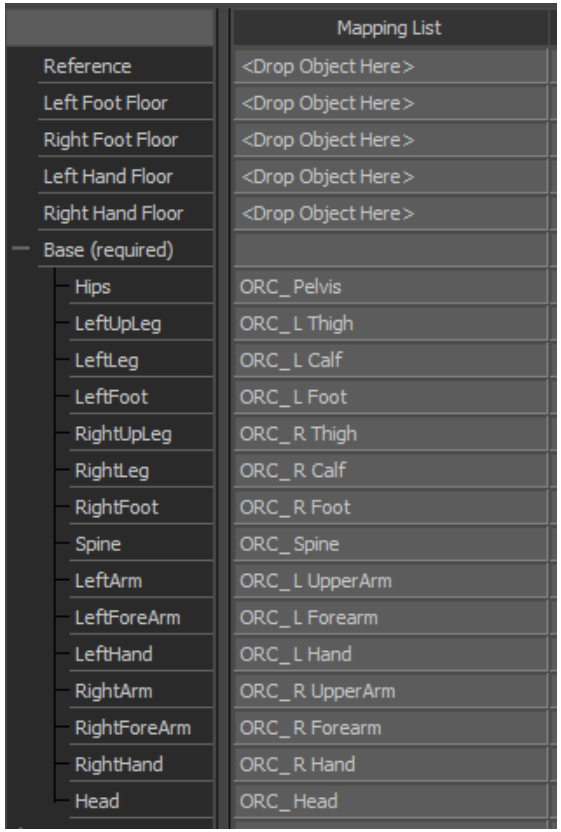
3.4-Animation retargeting

- Intermediate skeleton
  - The default skeleton your system will be working with
  - A new space of transformations
  - All animations will be translated into this new space
  - Can have limits / constraints
  - In Unity (Mecanim) it's a muscle space

3.4-Animation retargeting

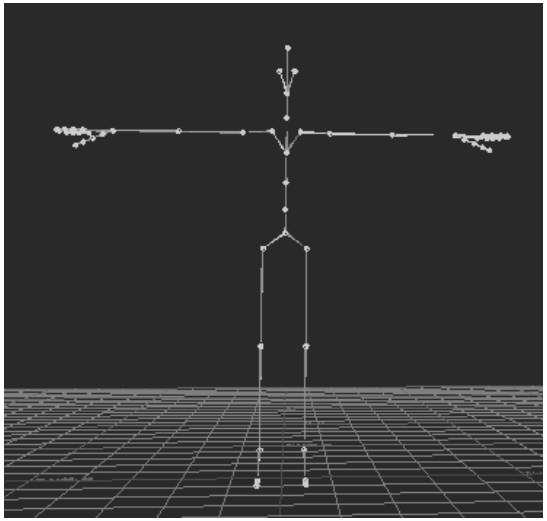
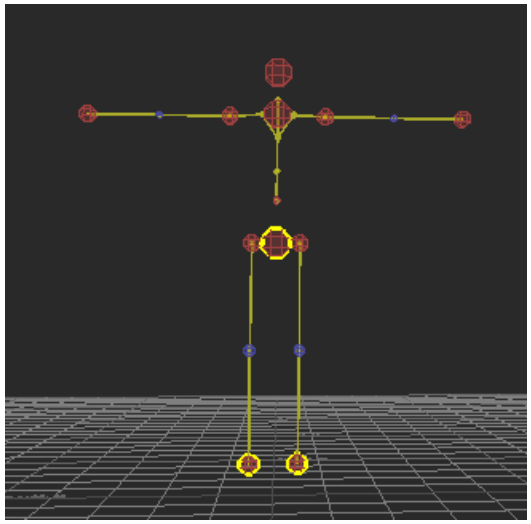
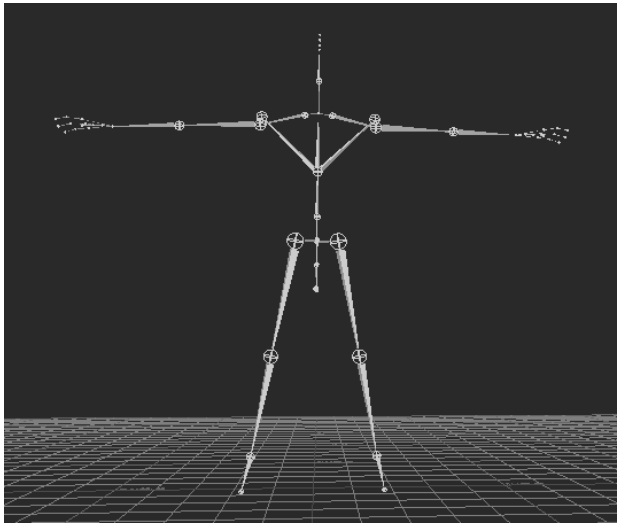
- Mapping
  - Both source and target skeletons must be mapped to the intermediate skeleton
  - Can be automatized by naming conventions
    - Finding keywords (Left, Right, Leg, Foot, etc…)
  - Compute mathematic transformations to go from one skeleton joint to its mapped one





3.4-Animation retargeting

- Retargeting
  - Source animation → Intermediate skeleton → target skeleton

3.4-Animation retargeting

- Blendshapes retargeting (Wrap)
  - Source model
    - Blendshapes (morph targets)
  - Target model → different topology
  - Wrap target model to source model → same topology
  - Same topology → can apply same offsets
  - Can apply source blendshapes to new mesh

4-Software

- MOTIONBUILDER
  - Professional animation authoring software
  - IK + FK Control Rigs
  - Layered animation
  - Character definitions and retargetting
  - Clean-up tools
  - Animation filters
  - Python scripting
  - Many other possibilities

4-Software

- MAYA
  - Modeling and animation software
  - Probably the more extended one in movies and videogames industries
  - You can do almost everything just in Maya
  - Scripting in MEL

- 3DS MAX
  - Modeling and animation software

4-Software

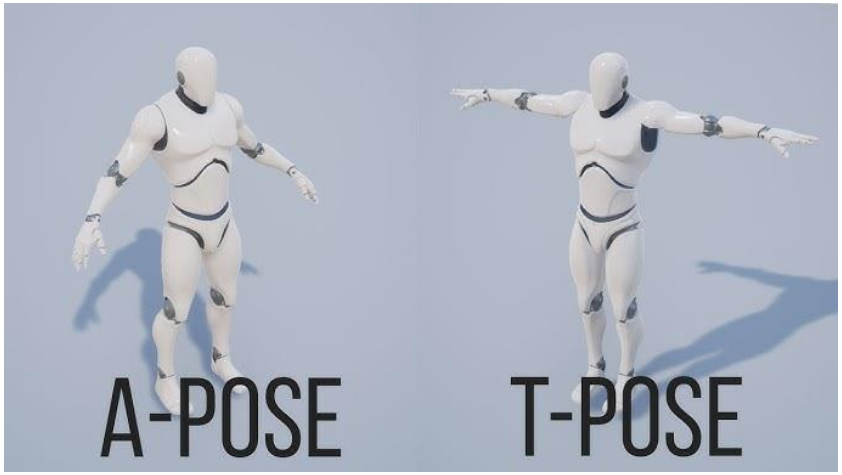
- 
  - Modeling and animations software
  - Open source!
  - Very lightweight
  - Python scripting
  - Check new versions: interface has changed a lot and seems more pleasant now

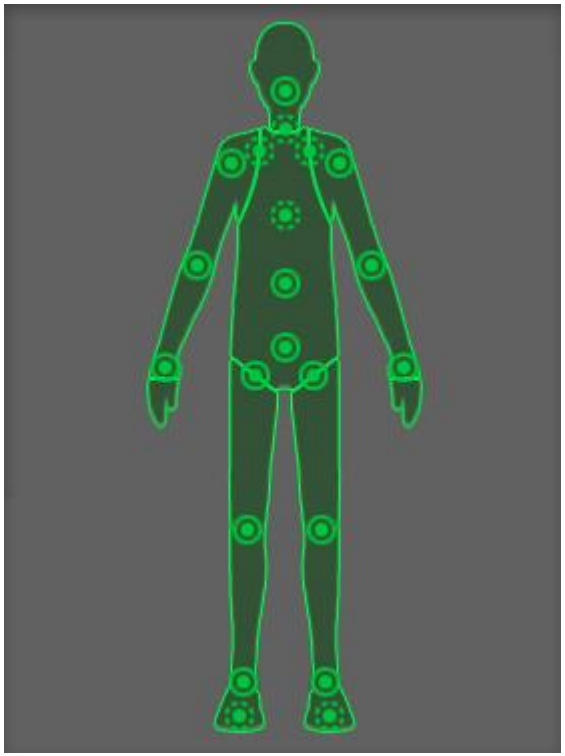
5-Assets

- 5.1-Type of Assets
- 5.2-Resources
- 5.3-AI Tools

5.1-Type of Assets

- Character / Avatar models
  - Rigged model: mesh, skeleton and skin
  - Humanoid (for retargetting)
  - In A-Pose or T-Pose



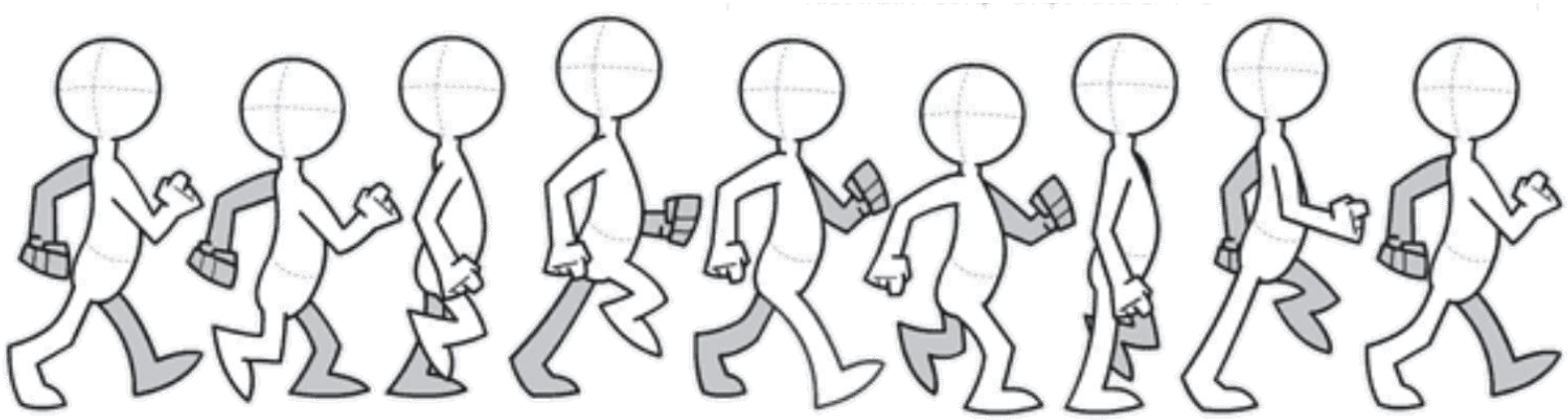


5.1-Type of Assets

- Animation files
  - Can include one or multiple animation tracks (clips)
  - Can include the character too
  - Should include the original skeleton in T-Pose or A-Pose
    - Or you need to have access to the original character for which the animation was created
      - More on this next week! (import options in Unity)

5.1-Type of Assets

- Animation files
  - Loop cycles
    - Equal first and last frames

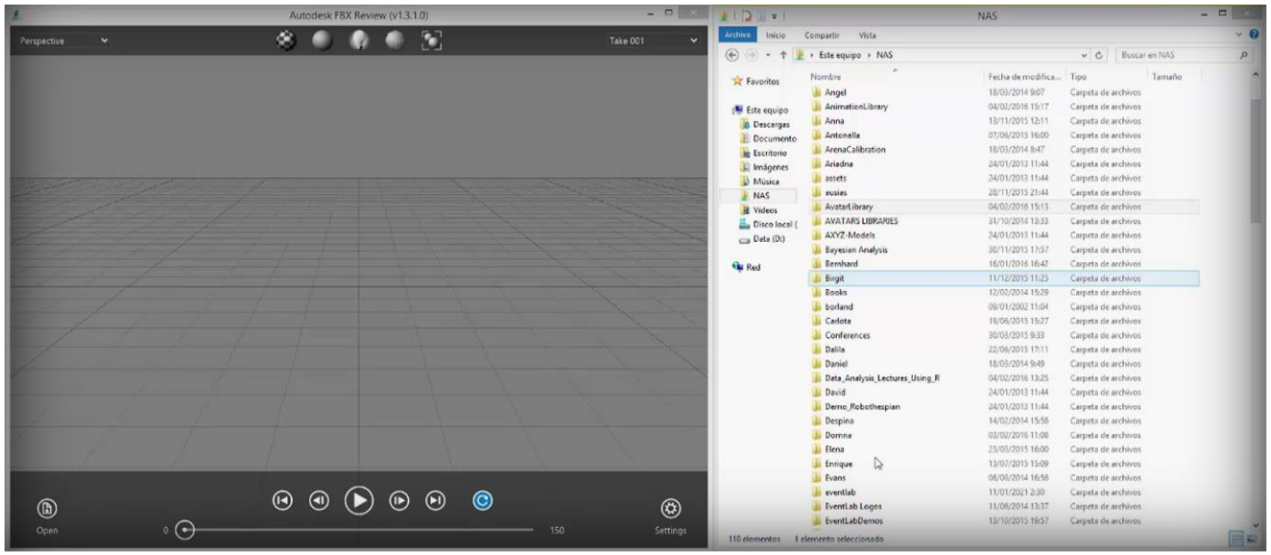


5.1-Type of Assets

- File formats (for both characters and animations):
  - Recommended: FBX format (.fbx, .FBX)
    - Can include materials and textures embeded
  - Other third party file extensions:
    - .max (3D Studio Max)
    - .maya (Maya)
    - .blend (Blender)
    - …
    - Need the correspondent program installed for proper import into Unity

5.1-Type of Assets

- **FBX** Review
  - Simple program to preview 3D models and animations
  - Very useful to quickly previsualize your assets



5.2-Resources

- Gonzalez-Franco *et. al.* ***"The Rocketbox library and the utility of freely available rigged avatars."*** *Frontiers in Virtual Reality. 2020. DOI: 10.3389/frvir.2020.561558 https://github.com/microsoft/Microsoft-Rocketbox*
  - Free characters for research and education
- Mixamo: https://www.mixamo.com
  - Free characters and animations
  - Free autorig
- Autodesk character generator: https://charactergenerator.autodesk.com/
  - Free character editor with student account
- Unity asset store: https://assetstore.unity.com/
  - Free characters and animations
- Render People: https://renderpeople.com/free-3d-people/
  - Some free characters
- Axyz Design: https://secure.axyz-design.com/en/shop/category/free-3d-people
  - Some free characters
- CMU: http://mocap.cs.cmu.edu/
  - Mocap animations
  - Version for Unity: https://drive.google.com/file/d/1TmVkHuyEdIBWB9McM_xZfK42fJoh-LtO/view?usp=sharing
- Reallusion actorcore accuRIG: https://actorcore.reallusion.com/auto-rig
  - Free autorig

5.3- AI Tools

- Text-to-image
  - https://app.leonardo.ai/
  - https://www.canva.com/ai-image-generator/
  - https://dezgo.com/text2image/sdxl
  - https://pixlr.com/es/image-generator/
  - https://monica.im/en/image-tools/ai-image-generator-from-text
  - And many other…

5.3- AI Tools

- Image-to-3D mesh or Text-to-3D mesh
  - https://hyperhuman.deemos.com/rodin
  - https://build.nvidia.com/shutterstock/edify-3d
  - Or any other you can find…

3- AI Tools

- Animation
  - https://saymotion.deepmotion.com/
  - https://www.motorica.ai/
  - https://meshcapade.com/
  - Or any other you can find…

5.3- AI Tools

- Example Pipeline
  - https://app.leonardo.ai/
  - Text prompt:
  - "A **cartoonish**, anthropomorphic male dog, mixture of pekingese, chihuahua and Andalusian wine-cellar rat-hunting dog, with a slender yet athletic build, donning a miniature warrior suit, **standing in a T-Pose on two legs**, with his legs closer together and feet facing front, his weight evenly distributed on both legs, his arms straight out to the sides and his hands open with palms facing downwards, his confident posture still evident despite the stylized pose, his fur a warm dark brown color with a subtle beige marks, **set against a soft, gradient blue background** that evokes a sense of clear skies and open landscapes."

5.3- AI Tools

- Example Pipeline
  - Image to 3D mesh
  - https://hyperhuman.deemos.com/rodin

5.3- AI Tools

- Example Pipeline
  - Automatic Rig
  - https://actorcore.reallusion.com/auto-rig