Muscle Deformation Techniques

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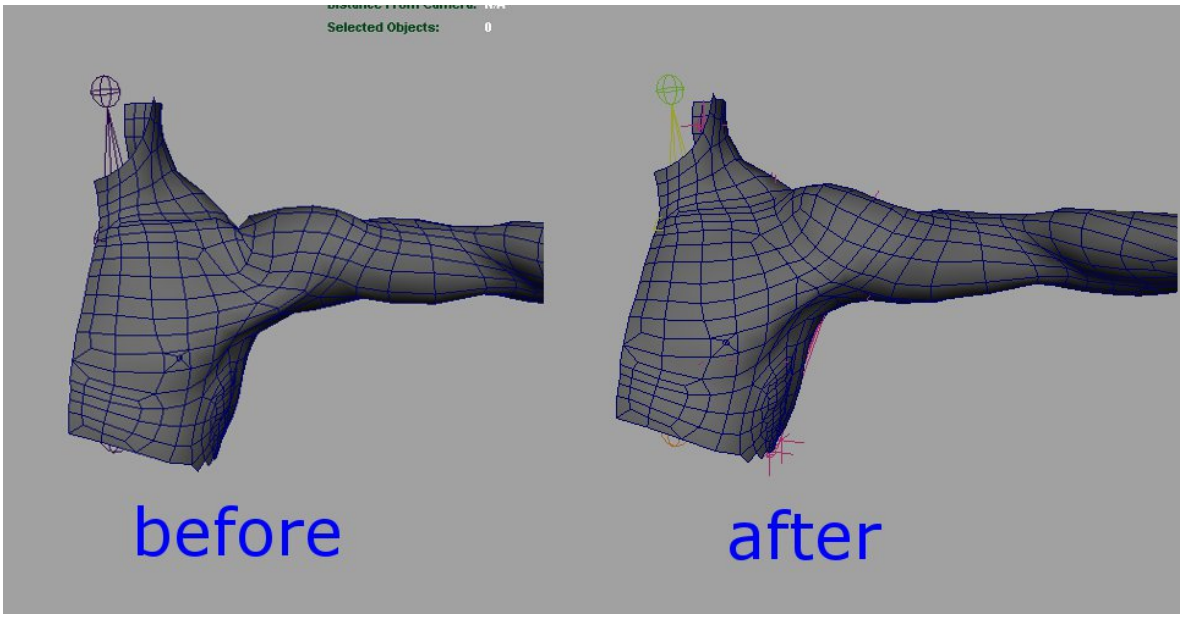
Helper Joints
(Simple Muscles)



Helper joints is a skinning technique to make the character look more realistic using additional joint transforms. Some of them are also called simple muscles, as their setup is similar to how muscles work, but very simplified.

The main benefit of helper joints is how they describe flesh around the joints. They are bridge between simple skeleton skinning and curve-based muscle influence objects. I would also recommend to first learn these before building curve-based muscle setups. The way how helper joints are attached to the main skeleton is focusing on particular muscle area and its relationships to other muscles and body skeleton. Sometimes they just help to interpolate the skinning distribution.
Also, everything that helper joints use is translation, rotation and scale. This is also called *affine transformation*. Same type as basic skeleton skinning.

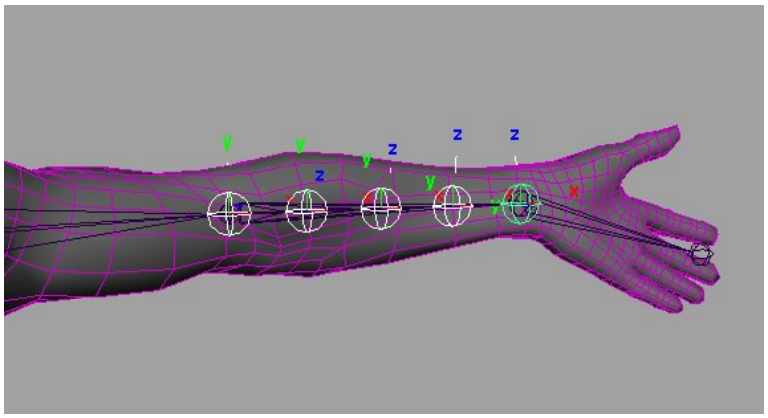
So basically, using helper joints means that you will just use more joints to skin your character.

Let`s look at 3 most used types of helper joint setups: **Twist Joints**, **Interpolate Joints and Simple Muscles**.

Have a look at file below to see simple skeleton skinning before extra joints were added:

Maya file: 02_helperJoints/helpJnt_simple_skeleton_skin.ma

Twist Joints

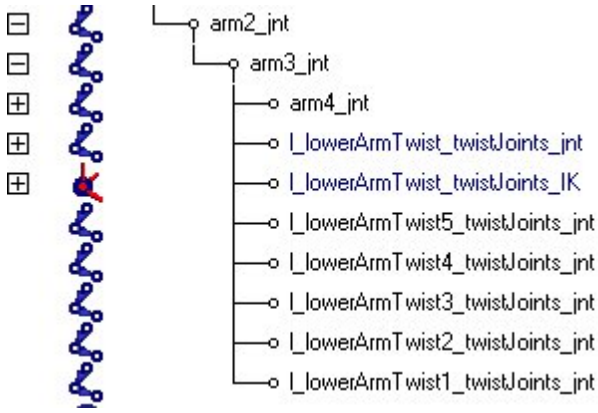


This technique is used very often on arms, legs and neck. Twist joints are interpolating twist rotation and help loosing volume as well. Usually you use about 3 to 6 of them if applied to linear skinning deformer. Maya 2011 introduced dual quaternion mode for skinCluster where you only need to skin one twist joint, so you can use the Twist joint for getting twist value and skinning in the same time. Read more about Twist joint below.

Maya file: 02_helperJoints/helpJnt_twist_setup.ma

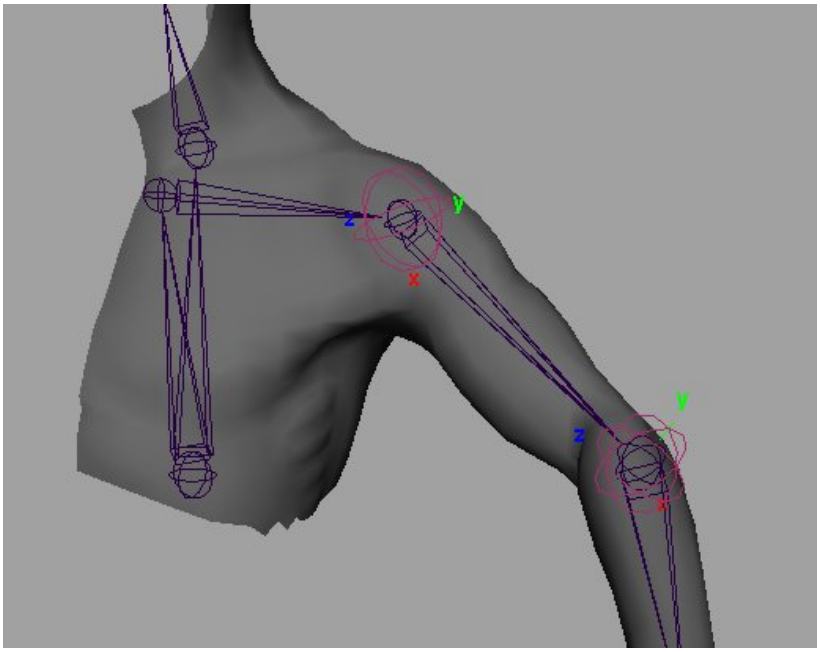
It`s quite simple to understand how you need to deform your skin, as you just paint weights for each twist joint with some falloff. Also make sure that each joint has full weight at some point to properly use its rotation.

The setup consists of **twist joint** with **IK handle** which is parented under the arm joint which we will build the twist joints around. In this case, arm joint would be called the **base joint**. The joint we compare the twist rotation to is **reference joint**.
First we make the Twist joint with the same orientation as the base joint, but aiming towards our reference joint, in case of wrist setup it wil aim the same direction. In case of shoulder setup, it will aim towards shoulder, opposite to arm joint. We can just parent it under our base joint.
Then we make IK handle (Single Chain) and parent it under the base joint as well. Then orientConstraint this IK with offset to the reference joint. And we are done with the most important part.
Notice that for more stable rotations, it`s better to setup twist joint for upper arm with arms raised as T pose. Just to minimize the difference to reference joint, when arm will rotate forward, as we could also get flipping. Twist setup has its limits.



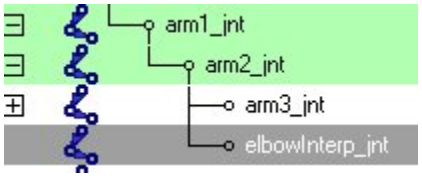
Now just make couple of twist joints and connect twist rotation from the Twist joint to them using some multiply node to set how much they rotate (basically percentage of full twist: 1.0, 0.75, 0.5, 0.25).
You can again parent them all under the base joint. This will give you option to change amount of rotation per each joint without influencing others.

Interpolate Joints



This is probably the most simple helper joint. A single joint that interpolates rotation. It can be used directly for skinning on fingers, elbows, knees or even shoulders. Or it doesn`t need to be skinned but actually be a target for some muscle constraint.

There are several ways to set this up. The most simple is using local rotation value of a child joint and divide it by 2 (using multiplyDivide or multDoubleLinear multiplication by 0.5) and connect it to the interpolation joint which has the same parent. So it will move the same, only have this rotation offset. This works fine for setups where you have just one axis of freedom - fingers, elbows etc.

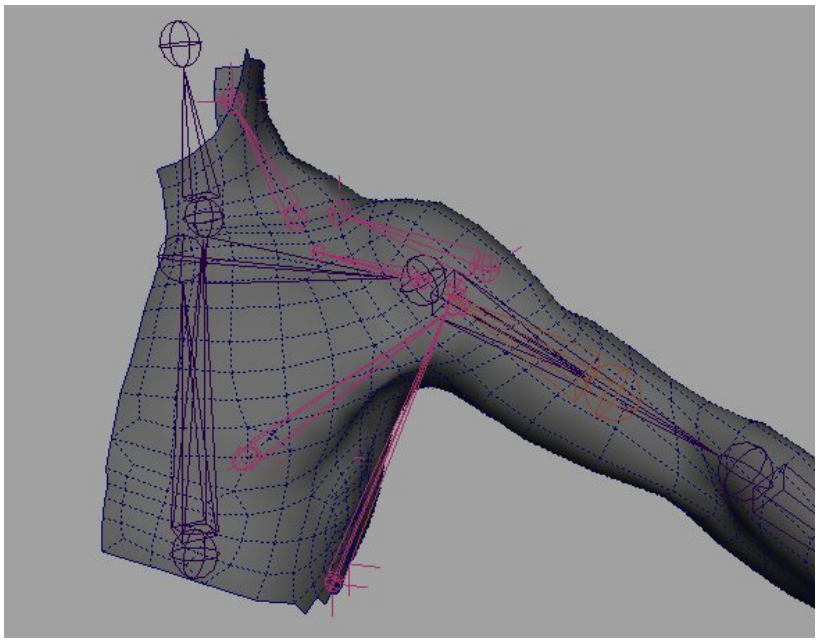


In case you want to interpolate more then one axis, blending matrices comes to work. You can use Maya Muscle node called **cMuscleSmartConstraint**. This takes 2 world matrices and outputs world space rotation and translation.

Maya 2011 file: 02_helperJoints/helpJnt_interp_setup.ma

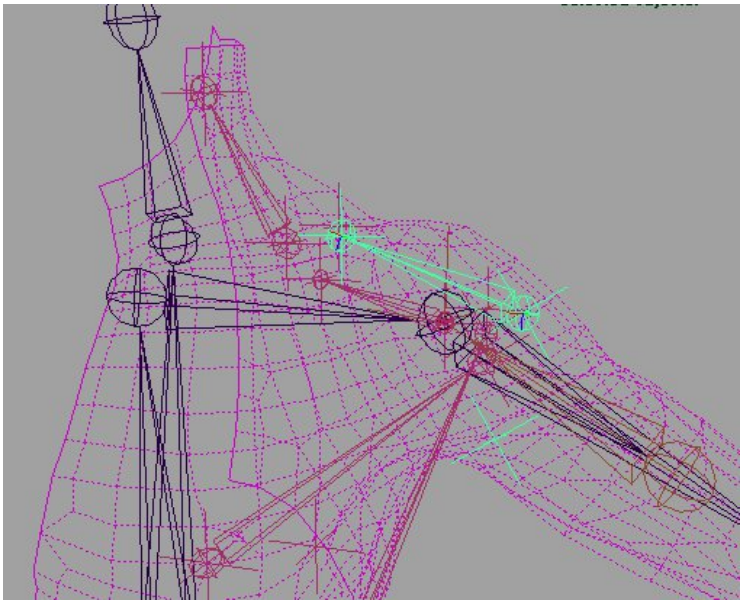
The image below shows the matrix blending connections and output to interpolation joint. cMuscleSmartConstraint takes both world matrices as matrixA and matrixB connections and outputs world rotation and translation values which you can connect to your interpolation joint. The best is making the default joint in the origin and then connecting it, to get correct values.

Simple Muscles



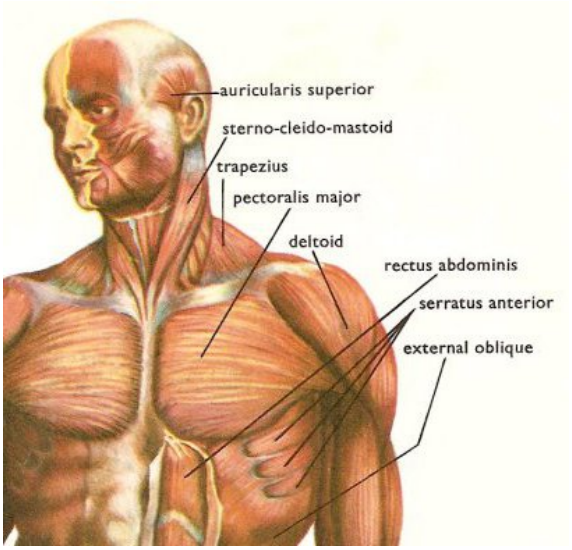
Maya file: 02_helperJoints/helpJnt_simpleMus_setup.ma

This type of helper joints is supposed to be simulating real muscles in the most simple way. Its structure is made basically of one joint with **aimConstraint** and **primary** (length) **axis scale** connection. This joint is positioned roughly around the muscle origin or insertion point and aim to its opposite end. If the distance to its end gets shorter, the scale on the joint gets smaller (and bigger for longer distance). This prevents skinned points of mesh to penetrate into the surface or tear off (as scale stretches them out). The scale is changing distribution of the affected points dynamically. If you compare this to non-scaled influence, as it would get closer to insertion point, you would get intersection at some point even with nice falloff.



The aim setup can be seen in the picture above. It consists of the main group, joint and 3 locators: Aim, Base and Up locator. Usually the main group is parentConstrained to some base joint that will set your twist rotation and then the Aim locator (end of joint) gets constrained as well. The constraining can be more complicated, but this should be enough for most cases. I haven`t used the up locators here.

In the example (seen in the picture) I have created joints for neck trapezoid, lower part of pectoral, middle deltoid (on shoulder), upper part of latissimus dorsi (back) and also scapula. For scapula I have fixed the scale to 1, as it`s a bone as I wanted some of this effect on my skin.



The anatomical relationships in simple muscle setup add extra complexity, as you need to know

a bit more how muscles are attached in real body compared to blendShape correctives, where you just sculpt your desired shape. Simple muscles are not so straightforward and you might find yourself having to move the origin or insertion point, or changing the constraints to get the effect you want (having to rebind the joints).
Also, as this is not the real muscles, you will place the simple muscle joints a bit differently then the real ones to get the right effect.
I would recommend to paint weights for these rather subtly in the desired pose and having in mind that this will have additive effect only. Full weights and too big areas of influence usually don`t work that well with a single simple muscle joint.
And at last, unless you know this technique well, better start with just one or two simple muscle joints only, paint the weights and try to get the most of it before adding more.

Conclusion

Helper joints are fairly simple deformation solution which is being used for many years in 3d character animation in both film visual effects and cartoons. Even with the latest deformation tools, having the knowledge of these old-school solutions is very useful, because they are pretty fast and simple. And they can be very good base for more advanced setups.
For full deformation they are very often used as medium level deformation for mid-ground or background characters. They can also be useful in animation rigs as full muscle setups are often too slow for animators.