glTF-Tutorials

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Animations

As shown in the Simple Animation example, an `animation` can be used to describe how the `translation`, `rotation`, or `scale` properties of nodes change over time.

The following is another example of an `animation`. This time, the animation contains two channels. One animates the translation, and the other animates the rotation of a node:

```
  "animations": [
    {
      "samplers" : [
        {
          "input" : 2,
          "interpolation" : "LINEAR",
          "output" : 3
        },
        {
          "input" : 2,
          "interpolation" : "LINEAR",
          "output" : 4
        }
      ],
      "channels" : [
        {
          "sampler" : 0,
          "target" : {
            "node" : 0,
            "path" : "rotation"
          }
        },
        {
          "sampler" : 1,
          "target" : {
            "node" : 0,
            "path" : "translation"
          }
        }
      ]
    }
  ],
```

Animation samplers

The `samplers` array contains `animation.sampler` objects that define how the values that are provided by the accessors have to be interpolated between the key frames, as shown in Image 7a.

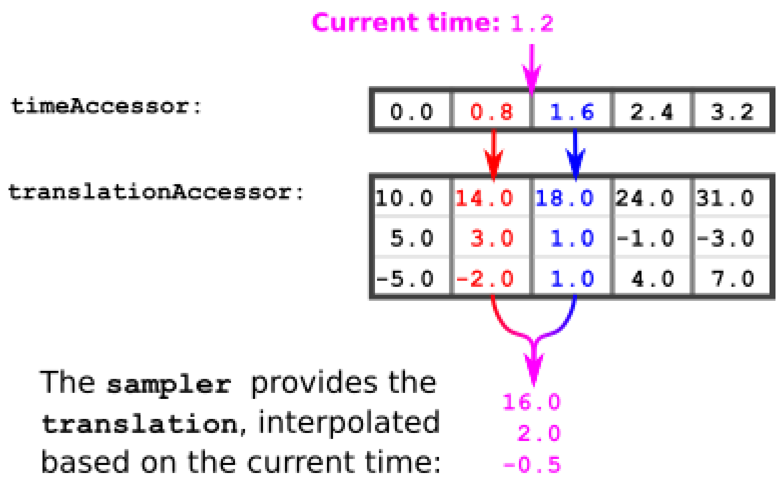


Image 7a: Animation samplers.

In order to compute the value of the translation for the current animation time, the following algorithm can be used:

- Let the current animation time be given as `currentTime`.
- Compute the next smaller and the next larger element of the *times* accessor:

  `previousTime` = The largest element from the *times* accessor that is smaller than the `currentTime`

  `nextTime` = The smallest element from the *times* accessor that is larger than the `currentTime`

- Obtain the elements from the *translations* accessor that correspond to these times:

  `previousTranslation` = The element from the *translations* accessor that corresponds to the `previousTime`

  `nextTranslation` = The element from the *translations* accessor that corresponds to the `nextTime`

- Compute the interpolation value. This is a value between 0.0 and 1.0 that describes the *relative* position of the `currentTime`, between the `previousTime` and the `nextTime`:

  ```
  interpolationValue = (currentTime - previousTime) / (nextTime - previousTime)
  ```

- Use the interpolation value to compute the translation for the current time:

`currentTranslation = previousTranslation + interpolationValue * (nextTranslation - previousTranslation)`

Example:

Imagine the `currentTime` is **1.2**. The next smaller element from the *times* accessor is **0.8**. The next larger element is **1.6**. So

```
previousTime = 0.8
nextTime     = 1.6
```

The corresponding values from the *translations* accessor can be looked up:

```
previousTranslation = (14.0, 3.0, -2.0)
nextTranslation     = (18.0, 1.0,  1.0)
```

The interpolation value can be computed:

```
interpolationValue = (currentTime - previousTime) / (nextTime - previousTime)
                   = (1.2 - 0.8) / (1.6 - 0.8)
                   = 0.4 / 0.8
                   = 0.5
```

From the interpolation value, the current translation can be computed:

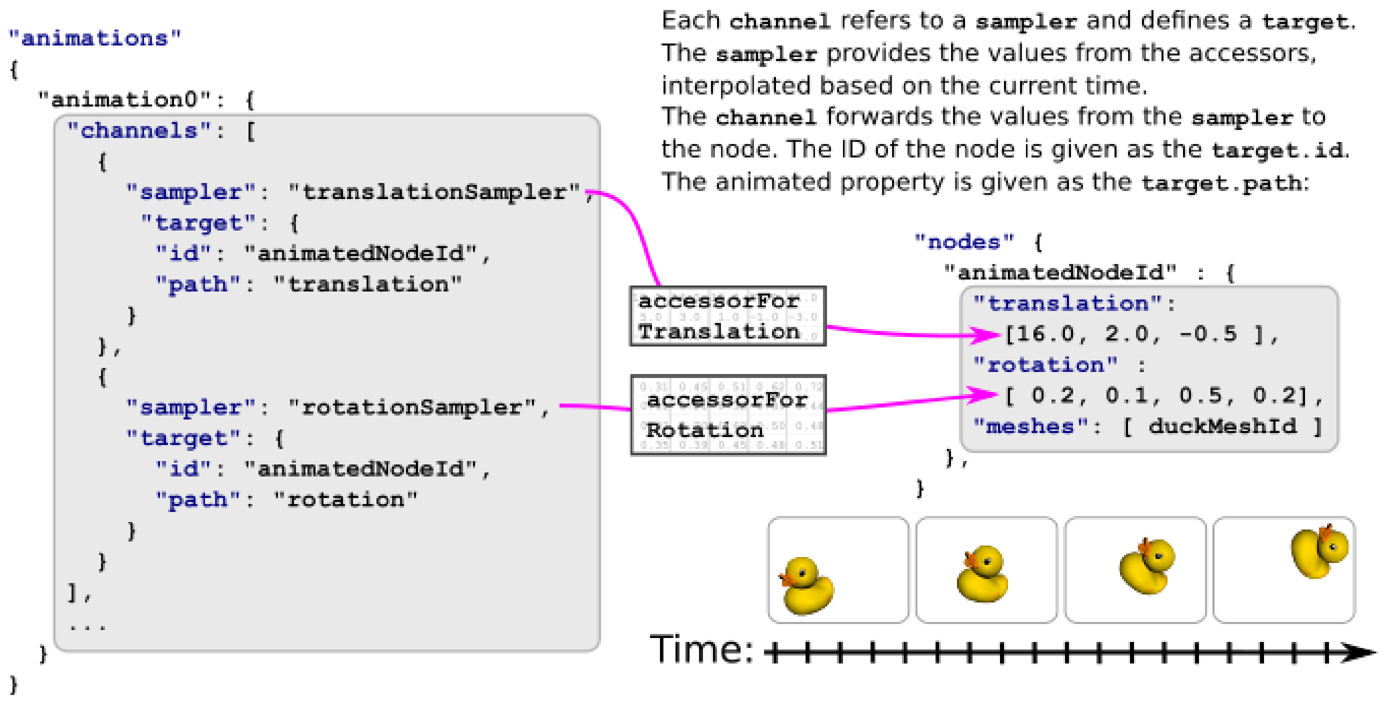
```
currentTranslation = previousTranslation + interpolationValue * (nextTranslation - previou
                   = (14.0, 3.0, -2.0) + 0.5 * ( (18.0, 1.0,  1.0) - (14.0, 3.0, -2.0) )
                   = (14.0, 3.0, -2.0) + 0.5 * (4.0, -2.0, 3.0)
                   = (16.0, 2.0, -0.5)
```

So when the current time is **1.2**, then the `translation` of the node is **(16.0, 2.0, -0.5)**.

Animation channels

The animations contain an array of `animation.channel` objects. The channels establish the connection between the input, which is the value that is computed from the sampler, and the output, which is the animated node property. Therefore, each channel refers to one sampler, using the index of the sampler, and contains an `animation.channel.target`. The `target` refers to a node, using the index of the node, and contains a `path` that defines the property of the node that should be animated. The value from the sampler will be written into this property.

In the example above, there are two channels for the animation. Both refer to the same node. The path of the first channel refers to the `translation` of the node, and the path of the second channel refers to the `rotation` of the node. So all objects (meshes) that are attached to the node will be translated and rotated by the animation, as shown in Image 7b.



```
"animations"
{
  "animation0": {
    "channels": [
      {
        "sampler": "translationSampler",
         "target": {
          "id": "animatedNodeId",
          "path": "translation"
        }
      },
      {
        "sampler": "rotationSampler",
        "target": {
          "id": "animatedNodeId",
          "path": "rotation"
        }
      }
    ],
    ...
  }
}
```

Each `channel` refers to a `sampler` and defines a `target`. The `sampler` provides the values from the accessors, interpolated based on the current time. The `channel` forwards the values from the `sampler` to the node. The ID of the node is given as the `target.id`. The animated property is given as the `target.path`:

```
"nodes" {
  "animatedNodeId" : {
    "translation":
     [16.0, 2.0, -0.5 ],
    "rotation" :
     [ 0.2, 0.1, 0.5, 0.2],
    "meshes": [ duckMeshId ]
  },
}
```

Image 7b: Animation channels.

Interpolation

The above example only covers `LINEAR` interpolation. Animations in a glTF asset can use three interpolation modes :

- `STEP`
- `LINEAR`
- `CUBICSPLINE`

Step

The `STEP` interpolation is not really an interpolation mode, it makes objects jump from keyframe to keyframe *without any sort of interpolation*. When a sampler defines a step interpolation, just apply the transformation from the keyframe corresponding to `previousTime`.

Linear

Linear interpolation exactly corresponds to the above example. The general case is :

Calculate the `interpolationValue` :

```
interpolationValue = (currentTime - previousTime) / (nextTime - previousTime)
```

For scalar and vector types, use a linear interpolation (generally called `lerp` in mathematics libraries). Here's a "pseudo code" implementation for reference

```
Point lerp(previousPoint, nextPoint, interpolationValue)
    return previousPoint + interpolationValue * (nextPoint - previousPoint)
```

In the case of rotations expressed as quaternions, you need to perform a spherical linear interpolation (`slerp`) between the previous and next values:

```
Quat slerp(previousQuat, nextQuat, interpolationValue)
    var dotProduct = dot(previousQuat, nextQuat)

    //make sure we take the shortest path in case dot Product is negative
    if(dotProduct < 0.0)
        nextQuat = -nextQuat
        dotProduct = -dotProduct

    //if the two quaternions are too close to each other, just linear interpolate betw
    if(dotProduct > 0.9995)
        return normalize(previousQuat + interpolationValue(nextQuat - previousQuat))

    //perform the spherical linear interpolation
    var theta_0 = acos(dotProduct)
    var theta = interpolationValue * theta_0
    var sin_theta = sin(theta)
    var sin_theta_0 = sin(theta_0)

    var scalePreviousQuat = cos(theta) - dotproduct * sin_theta / sin_theta_0
    var scaleNextQuat = sin_theta / sin_theta_0
    return scalePreviousQuat * previousQuat + scaleNextQuat * nextQuat
```

This example implementation is inspired from this Wikipedia article

Cubic Spline interpolation

Cubic spline interpolation needs more data than just the previous and next keyframe time and values, it also need for each keyframe a couple of tangent vectors that act to smooth out the curve around the keyframe points.

These tangent are stored in the animation channel. For each keyframe described by the animation sampler, the animation channel contains 3 elements :

- The input tangent of the keyframe

- The keyframe value
- The output tangent

The input and output tangents are normalized vectors that will need to be scaled by the duration of the keyframe, we call that the deltaTime

```
    deltaTime = nextTime - previousTime
```

To calculate the value for `currentTime`, you will need to fetch from the animation channel :

- The output tangent direction of `previousTime` keyframe
- The value of `previousTime` keyframe
- The value of `nextTime` keyframe
- The input tangent direction of `nextTime` keyframe

note: the input tangent of the first keyframe and the output tangent of the last keyframe are totally ignored

To calculate the actual tangents of the keyframe, you need to multiply the direction vectors you got from the channel by `deltaTime`

```
   previousTangent = deltaTime * previousOutputTangent
   nextTangent = deltaTime * nextInputTangent
```

The mathematical function is described in the Appendix C of the glTF 2.0 specification.

Here's a corresponding pseudocode snippet :

```
   Point cubicSpline(previousPoint, previousTangent, nextPoint, nextTangent, interpolatio
       t = interpolationValue
       t2 = t * t
       t3 = t2 * t

       return (2 * t3 - 3 * t2 + 1) * previousPoint + (t3 - 2 * t2 + t) * previousTangent
```

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