X3D Graphics for Web Authors

Chapter 7

Event Animation

If it ain't moving, it ain't 3D.

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Chapter Overview

Overview: Event Animation

Behaviors, events, ROUTE connections, animation

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Interpolation nodes

- TimeSensor and event timing
- ScalarInterpolator and ColorInterpolator
- OrientationInterpolator, PositionInterpolator, PositionInterpolator2D and NormalInterpolator
- CoordinateInterpolator2D, CoordinateInterpolator

Concepts

review

Behaviors

Behavior defined as changing the value of some field contained by some node in scene graph

Animation nodes, user interaction nodes and network updates can produce updated values

ROUTE statements connect output of one node as an input to field in another node

Event defined as the time-stamped value passed by a ROUTE, from one field to another

Thus the values held by nodes in scene graph can change as time advances

Behavior traversal of scene graph

Double buffer: once frame is swapped to update screen image, repeat and update scene values

Event model consists of

- Examining clock-driven and user-initiated events
- Updating scene-graph values
- Triggering and updating new events as appropriate
- Continue until all events handled, loops not allowed

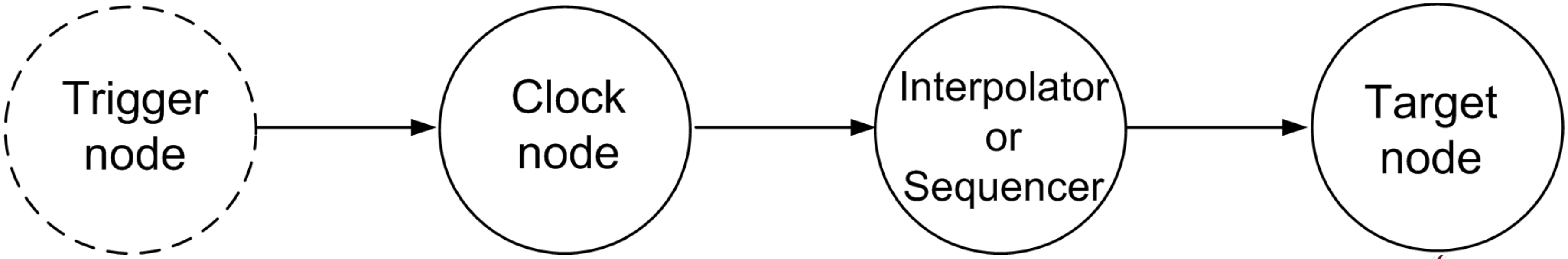
Event updates modify the scene graph

- Changing rendering properties, or
- Generating further event outputs

review

Example behavior event chain

- User clicks button to start a timer clock
- Clock outputs new event at start of each frame,
- ... which stimulates linear-interpolation function which produces another output value
- ... which updates some target value in scene graph
- Repeat event traversal after each frame redraw



ROUTE connections

ROUTE connection enables the output field of one node to pass a value that then stimulates the input field of another node

- The passed value also includes a time stamp

Field data type and accessType must both match between node/field of source and target

- Chapter 1, Technical Introduction lists field types
- Also provided in tooltips and specification
- Authors usually must carefully check these

Animation as scene-graph modification

Behavior = changing a field value in a node, somewhere in the scene graph

Event = time-stamped value going over a ROUTE

Event cascade is a series of events, each one triggering the next, before next frame is drawn

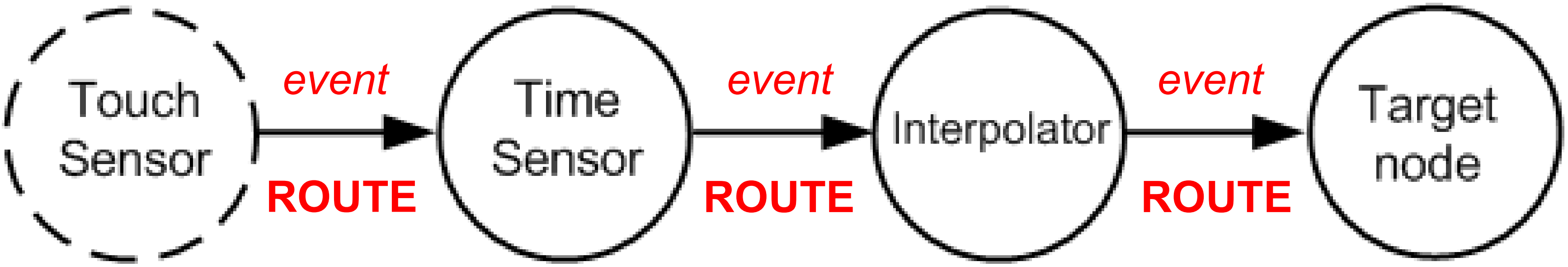
- No event loops allowed, guaranteeing completion

Thus all X3D animation can be considered as modification of the scene graph at run time

Event-animation design pattern

X3D can be imposing, there are many nodes

Nevertheless a simple design pattern is used for nearly every kind of animation



This consistent event ROUTE pattern enables you to expertly animate most X3D scene behaviors

Visualizing scenes on paper

It is good practice to sketch out 3D scene drafts

- Consider what models are needed, and how multiple models might be composed

Consider user experience, from their perspective

- What tasks and goals, what use cases
- What might things look like when first seen

Storyboarding can help build long-form content

- Series of vignettes to tell a larger story
- Each scene defines needed models and behaviors
- Build each piece, put them together

Review

Field data types

X3D is a strongly typed language

- Each field in each node (i.e. each XML attribute) has a strictly defined data type
- Data types for boolean, integer, floating point

Types are either single or multiple-value

- Example: SFFloat, SFVec2f, SFVec3f, SFRotation

Also have arrays for all types

SF = Single Field, MF = Multiple Field (array)

Failure to match data types correctly is an error!

- During schema validation, loading or at run time

X3D has strong data typing

Data typing is very important to prevent errors

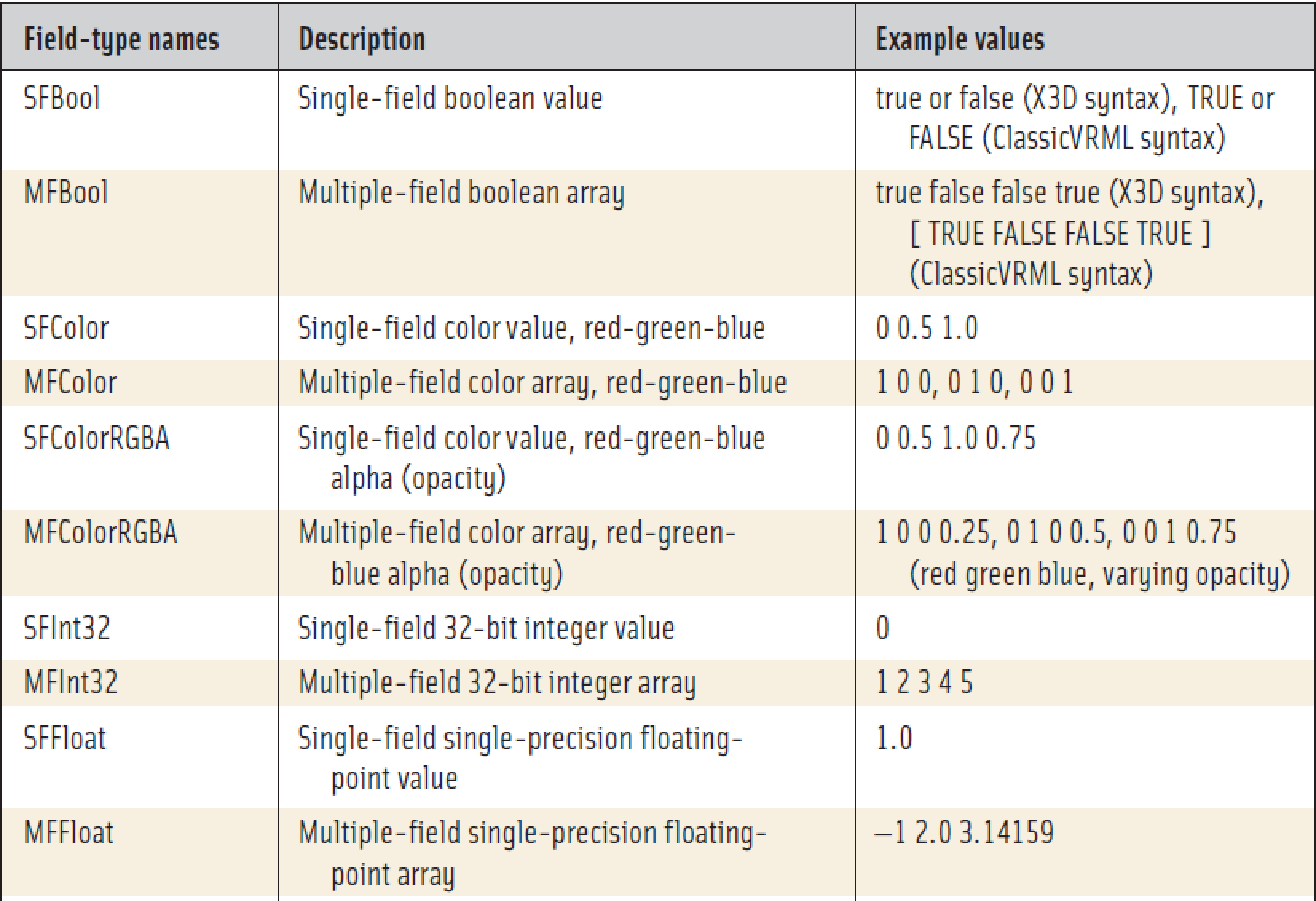
- *Strong data typing* means that all data types must match (or be converted) exactly
- *Weak data typing* means data types may be promoted or changed by the system automatically without author direction (or quality control)

Data type errors lead to erroneous computations and system crashes, in any computer language

X3D has strong data typing

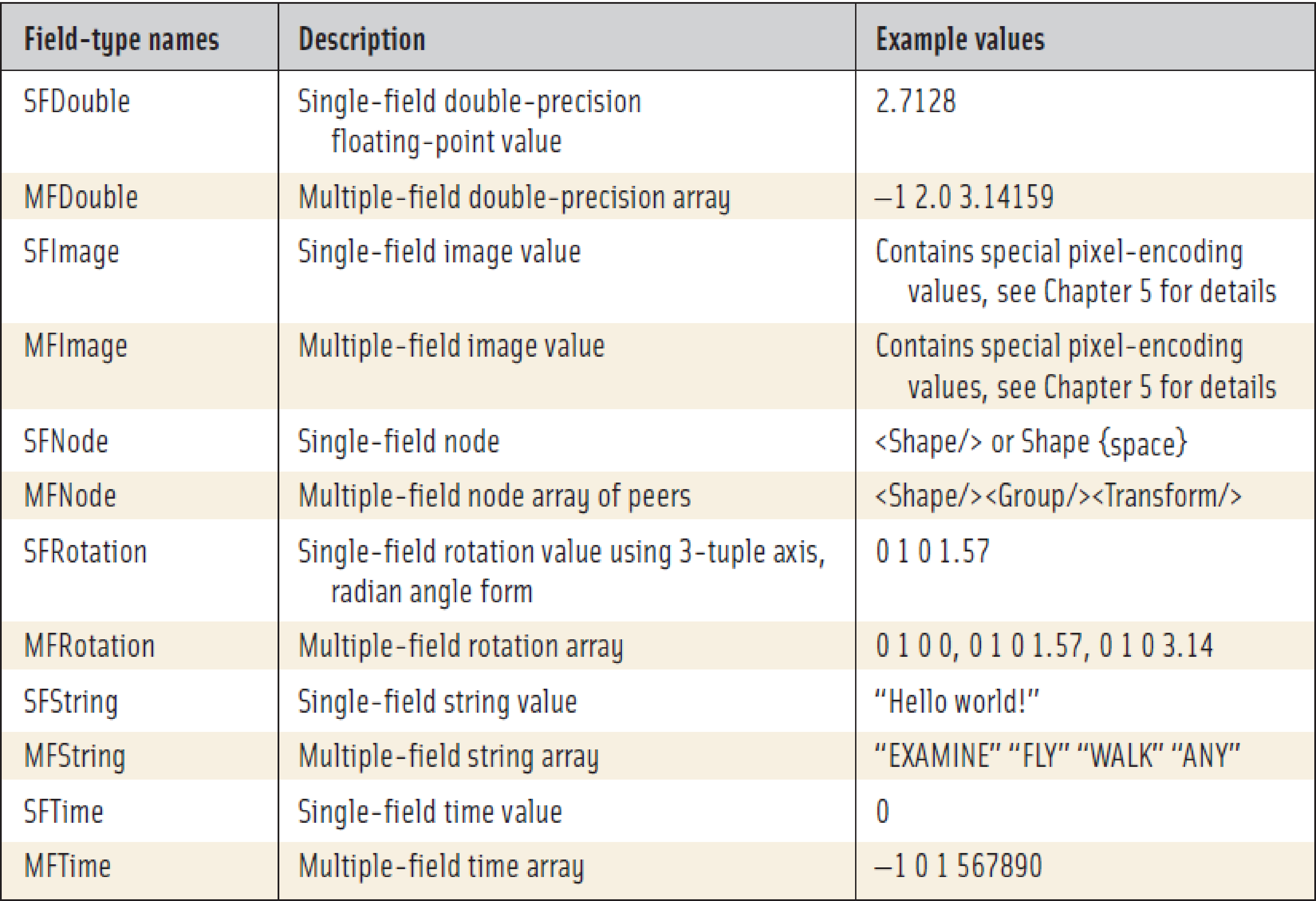
- Cost: authors must ensure their scene is correct
- Benefit: mysterious run-time errors avoided

Field data types 1



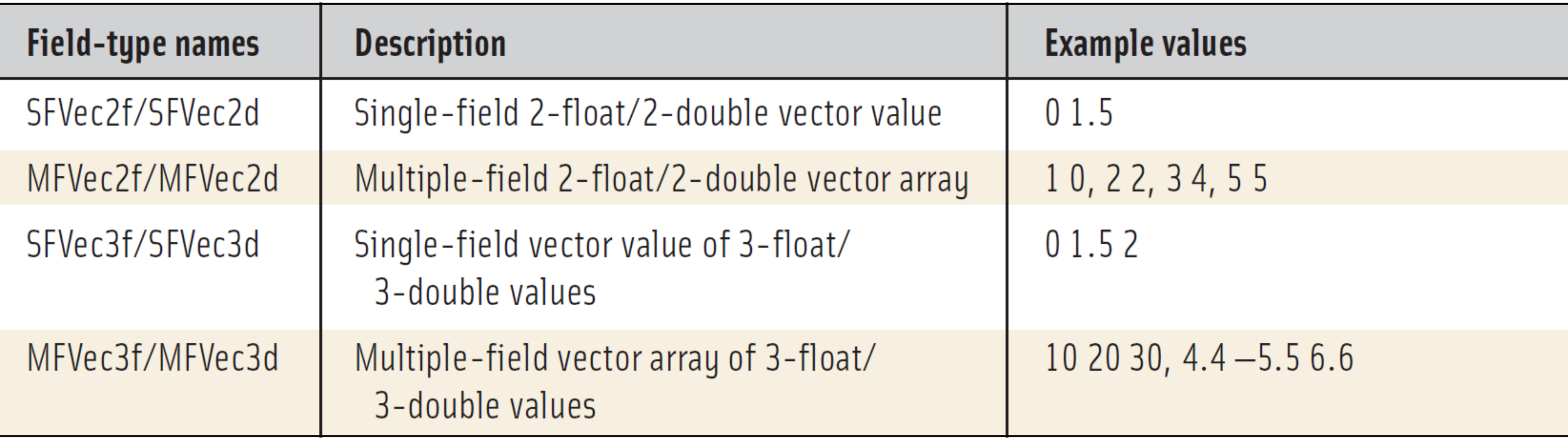
Field-type names	Description	Example values
SFBool	Single-field boolean value	true or false (X3D syntax), TRUE or FALSE (ClassicVRML syntax)
MFBool	Multiple-field boolean array	true false false true (X3D syntax), [TRUE FALSE FALSE TRUE] (ClassicVRML syntax)
SFColor	Single-field color value, red-green-blue	0 0.5 1.0
MFColor	Multiple-field color array, red-green-blue	1 0 0, 0 1 0, 0 0 1
SFColorRGBA	Single-field color value, red-green-blue alpha (opacity)	0 0.5 1.0 0.75
MFColorRGBA	Multiple-field color array, red-green-blue alpha (opacity)	1 0 0 0.25, 0 1 0 0.5, 0 0 1 0.75 (red green blue, varying opacity)
SFInt32	Single-field 32-bit integer value	0
MFInt32	Multiple-field 32-bit integer array	1 2 3 4 5
SFFloat	Single-field single-precision floating-point value	1.0
MFFloat	Multiple-field single-precision floating-point array	−1 2.0 3.14159

Field data types 2



Field-type names	Description	Example values
SFDouble	Single-field double-precision floating-point value	2.7128
MFDouble	Multiple-field double-precision array	–1 2.0 3.14159
SFImage	Single-field image value	Contains special pixel-encoding values, see Chapter 5 for details
MFImage	Multiple-field image value	Contains special pixel-encoding values, see Chapter 5 for details
SFNode	Single-field node	<Shape/> or Shape {space}
MFNode	Multiple-field node array of peers	<Shape/><Group/><Transform/>
SFRotation	Single-field rotation value using 3-tuple axis, radian angle form	0 1 0 1.57
MFRotation	Multiple-field rotation array	0 1 0 0, 0 1 0 1.57, 0 1 0 3.14
SFString	Single-field string value	"Hello world!"
MFString	Multiple-field string array	"EXAMINE" "FLY" "WALK" "ANY"
SFTime	Single-field time value	0
MFTime	Multiple-field time array	–1 0 1 567890

Field data types 3



Field-type names	Description	Example values
SFVec2f/SFVec2d	Single-field 2-float/2-double vector value	0 1.5
MFVec2f/MFVec2d	Multiple-field 2-float/2-double vector array	1 0, 2 2, 3 4, 5 5
SFVec3f/SFVec3d	Single-field vector value of 3-float/ 3-double values	0 1.5 2
MFVec3f/MFVec3d	Multiple-field vector array of 3-float/ 3-double values	10 20 30, 4.4 –5.5 6.6

ClassicVRML syntax notes

- TRUE and FALSE (rather than XML true and false)
- MF multiple-field array values are surrounded by square brackets, e.g. `[ 10 20 30, 4.4 -5.5 6.6 ]`
- No special XML escape characters such as `&amp;`

accessType: input, output, initialize

accessType determines if field is data sender, receiver, or holder

- inputOnly: can only receive events
- outputOnly: can only send events
- initializeOnly: cannot send or receive
- inputOutput: can send, receive and be initialized

Failure to match accessType correctly is an error!

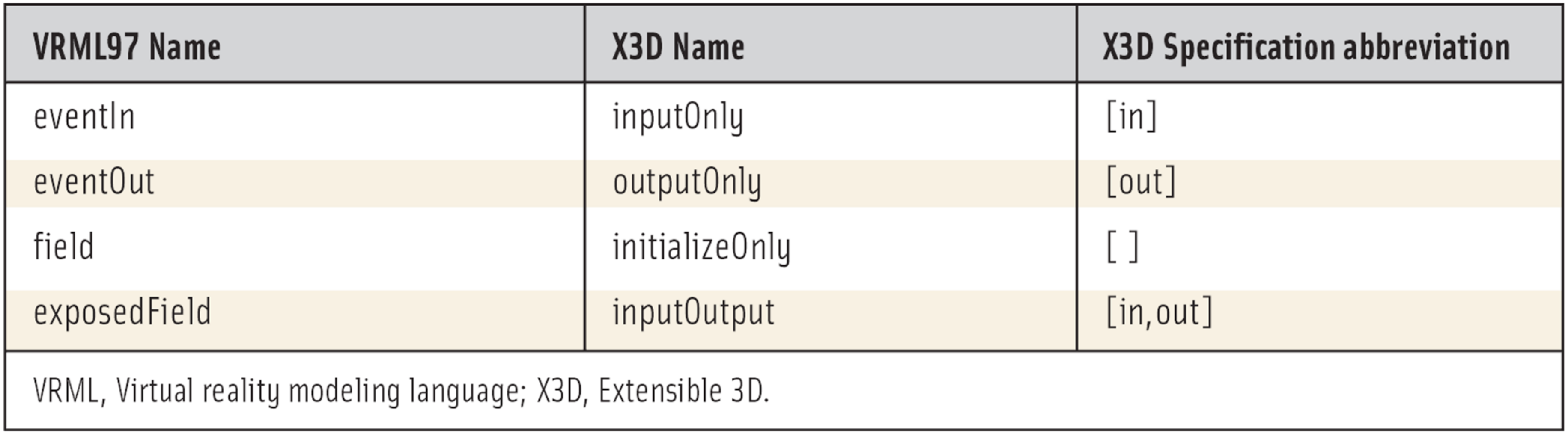
- Detected during authoring-tool checks, or run time
- inputOnly and outputOnly values cannot be listed as attributes in .x3d scene file, since they are transient

accessType naming conventions 1

The accessType names were changed when VRML97 was upgraded to X3D

- Functionality remains essentially unchanged

X3D specification entries for each node use yet another shorthand, as shown here



VRML97 Name	X3D Name	X3D Specification abbreviation
eventIn	inputOnly	[in]
eventOut	outputOnly	[out]
field	initializeOnly	[ ]
exposedField	inputOutput	[in,out]

VRML, Virtual reality modeling language; X3D, Extensible 3D.

accessType naming conventions 2

Field names often reveal special accessType

- Prefix *set_* indicates inputOnly field
- Prefix *_changed* indicates outputOnly field
- Prefix *is* for outputOnly boolean field (e.g. isActive)

inputOnly, outputOnly fields not allowed in files

Understanding naming conventions helps authors understand ROUTE definitions and results

Looking ahead: we will name our own fields when creating Scripts and prototypes, further underscoring importance of naming

Interpolating animation chains: 10-step design process

The following 10-step process can be used for all animation tasks

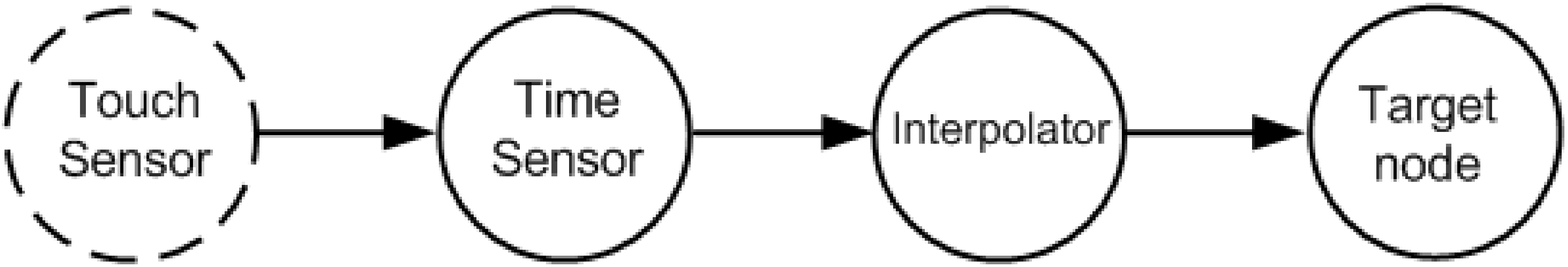
Table is also provided in order to look up how to produce typed-value outputs corresponding to each interpolator or sequencer node

A detailed example follows

This 10-step process is a good check to perform each time you create an animation chain

Interpolating animation chains 1-2

1. ***Pick target***. Pick node and target field to animate (i.e., field that receives changing animation values)



2. ***Name target***. Provide a DEF label for the node of interest, giving it a name

Interpolating animation chains 3-4

3. ***Check accessType and data type*.**
   - Ensure target field has *accessType* of inputOnly or inputOutput, so that it can receive input events
   - Determine if target field has floating-point type: SFFloat, SFVec3f, SFColor, SFRotation, and so on... If so, use an interpolator node as the event source
4. ***Determine if Sequencer or Script*.**
   - If the target type is an SFBool or SFInt32, use a sequencer node as event source
   - If the target type is an SFNode or MFNode, use a Script node as the event source

Interpolating animation chains 5-6

5. ***Determine which Interpolator***. If you are not using a sequencer or Script node, determine corresponding Interpolator which produces the appropriate data type for *value_changed* output using lookup table
   - Example: PositionInterpolator produces SFVec3f *value_changed* events
6. ***Triggering sensor***. If desired, add sensor node at beginning, to provide appropriate SFTime or SFBool trigger to start animation
   - Sometimes the triggering event is an output event from another animation chain

Interpolating animation chains 7-8

7. ***TimeSensor clock***. Add a TimeSensor as the animation clock, then set its *cycleInterval* field to the desired duration interval of animation
   - Set *loop*='false' if an animation only runs once at certain specific times. (Will need triggering event.)
   - Set *loop*='true' if it loops repeatedly
8. ***Connect trigger***. ROUTE sensor or trigger node's output field to the TimeSensor input in order to start the animation chain
   - Each node in animation chain needs a DEF name, so that ROUTE can connect to/from

Interpolating animation chains 9-10

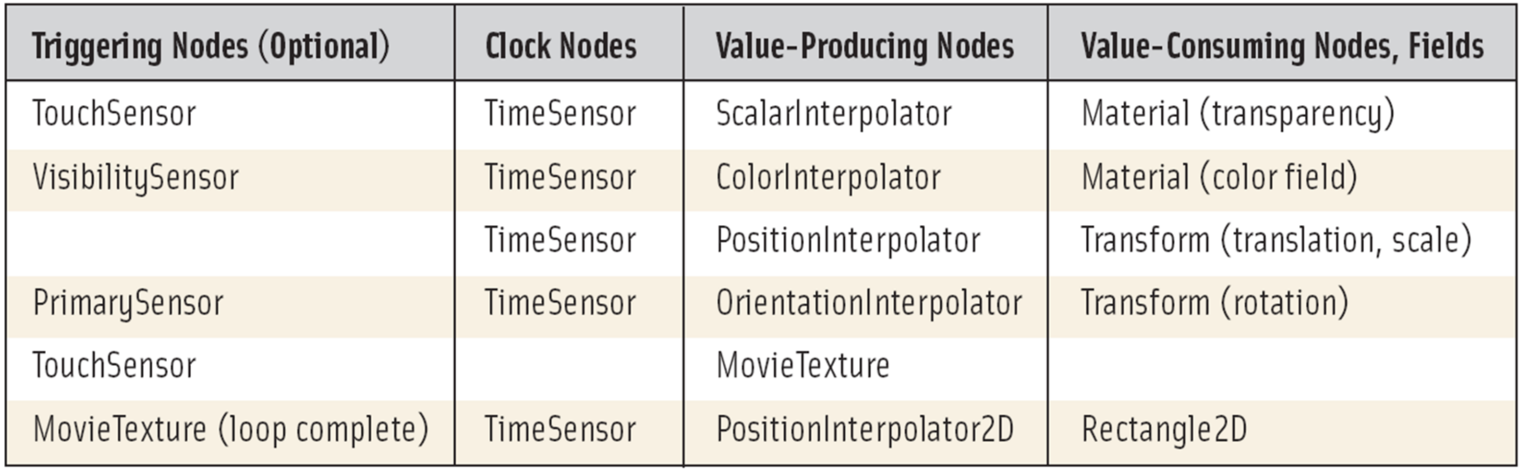
9. ***Connect clock***. ROUTE the TimeSensor *fraction_changed* field to the interpolator (or sequencer or Script) node's *set_fraction* field, in order to drive the animation chain

10. ***Connect animation output***. ROUTE the interpolator, sequencer, or Script node's *value_changed* field to target field of interest in order to complete the animation chain

Construction of animation-chain design pattern is complete, now test whether animation works

Example animation chains

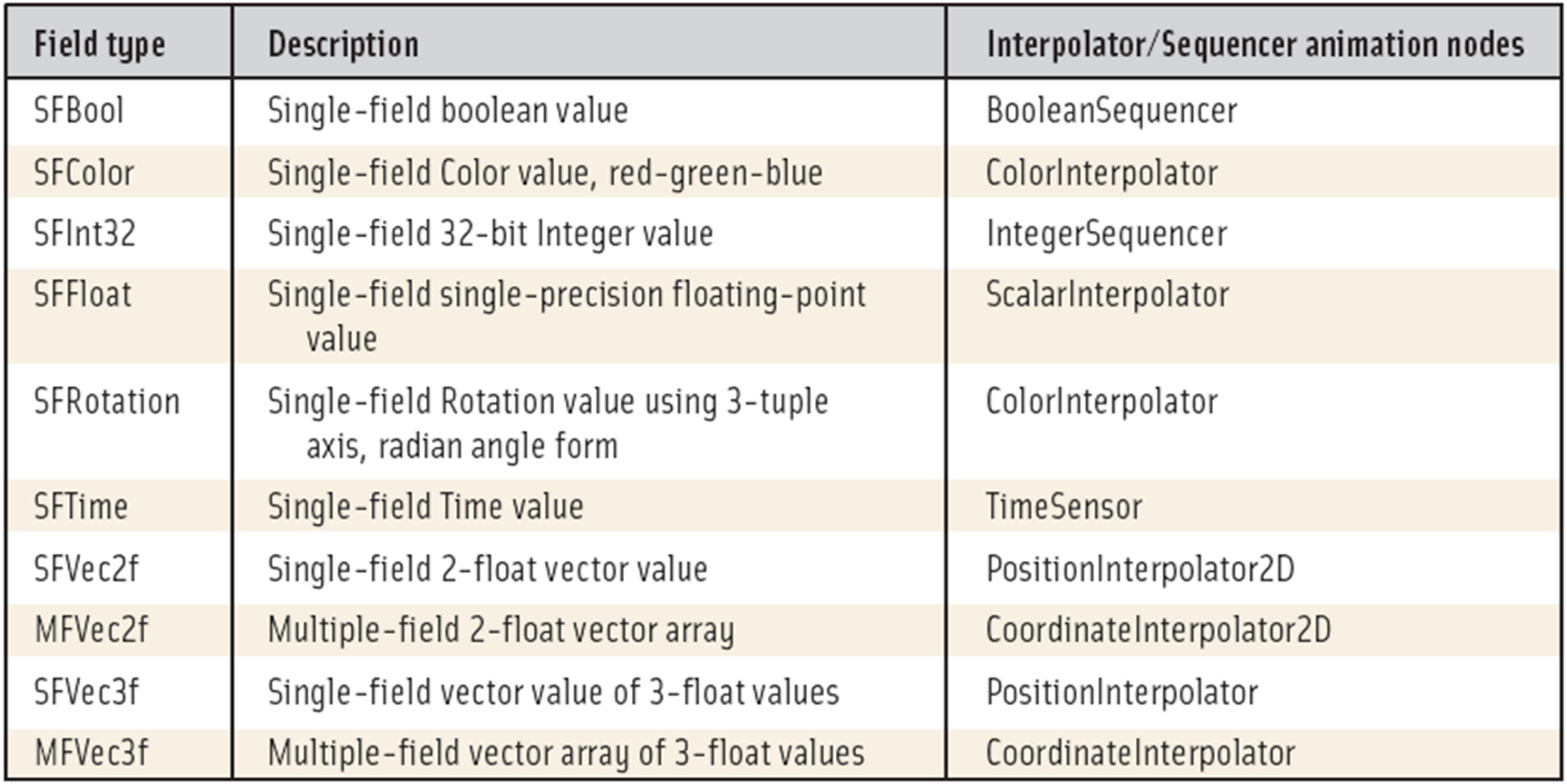
Each row in Table 7.2 shows commonly authored sequences of nodes in animation chains



Triggering Nodes (Optional)	Clock Nodes	Value-Producing Nodes	Value-Consuming Nodes, Fields
TouchSensor	TimeSensor	ScalarInterpolator	Material (transparency)
VisibilitySensor	TimeSensor	ColorInterpolator	Material (color field)
	TimeSensor	PositionInterpolator	Transform (translation, scale)
PrimarySensor	TimeSensor	OrientationInterpolator	Transform (rotation)
TouchSensor		MovieTexture	
MovieTexture (loop complete)	TimeSensor	PositionInterpolator2D	Rectangle2D

Used in Step 5: Determine which Interpolator

X3D field types and corresponding animation nodes



Field type	Description	Interpolator/Sequencer animation nodes
SFBool	Single-field boolean value	BooleanSequencer
SFColor	Single-field Color value, red-green-blue	ColorInterpolator
SFInt32	Single-field 32-bit Integer value	IntegerSequencer
SFFloat	Single-field single-precision floating-point value	ScalarInterpolator
SFRotation	Single-field Rotation value using 3-tuple axis, radian angle form	ColorInterpolator
SFTime	Single-field Time value	TimeSensor
SFVec2f	Single-field 2-float vector value	PositionInterpolator2D
MFVec2f	Multiple-field 2-float vector array	CoordinateInterpolator2D
SFVec3f	Single-field vector value of 3-float values	PositionInterpolator
MFVec3f	Multiple-field vector array of 3-float values	CoordinateInterpolator

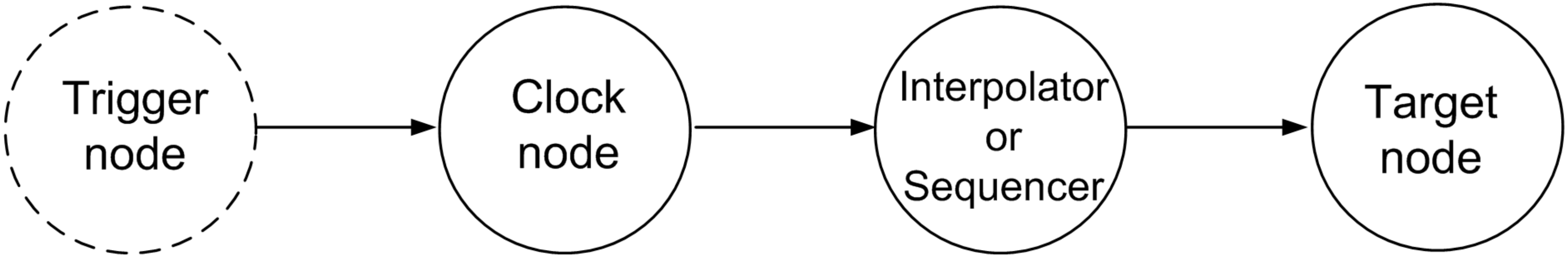
Used in Step 5: Determine which Interpolator

Animation chain for this example

HelloX3dAuthorsAnimationChain.x3d

is our detailed animation-chain example

TouchSensor TimeSensor OrientationInterpolator Transform


Trigger node

Clock node

Interpolator or Sequencer

Target node

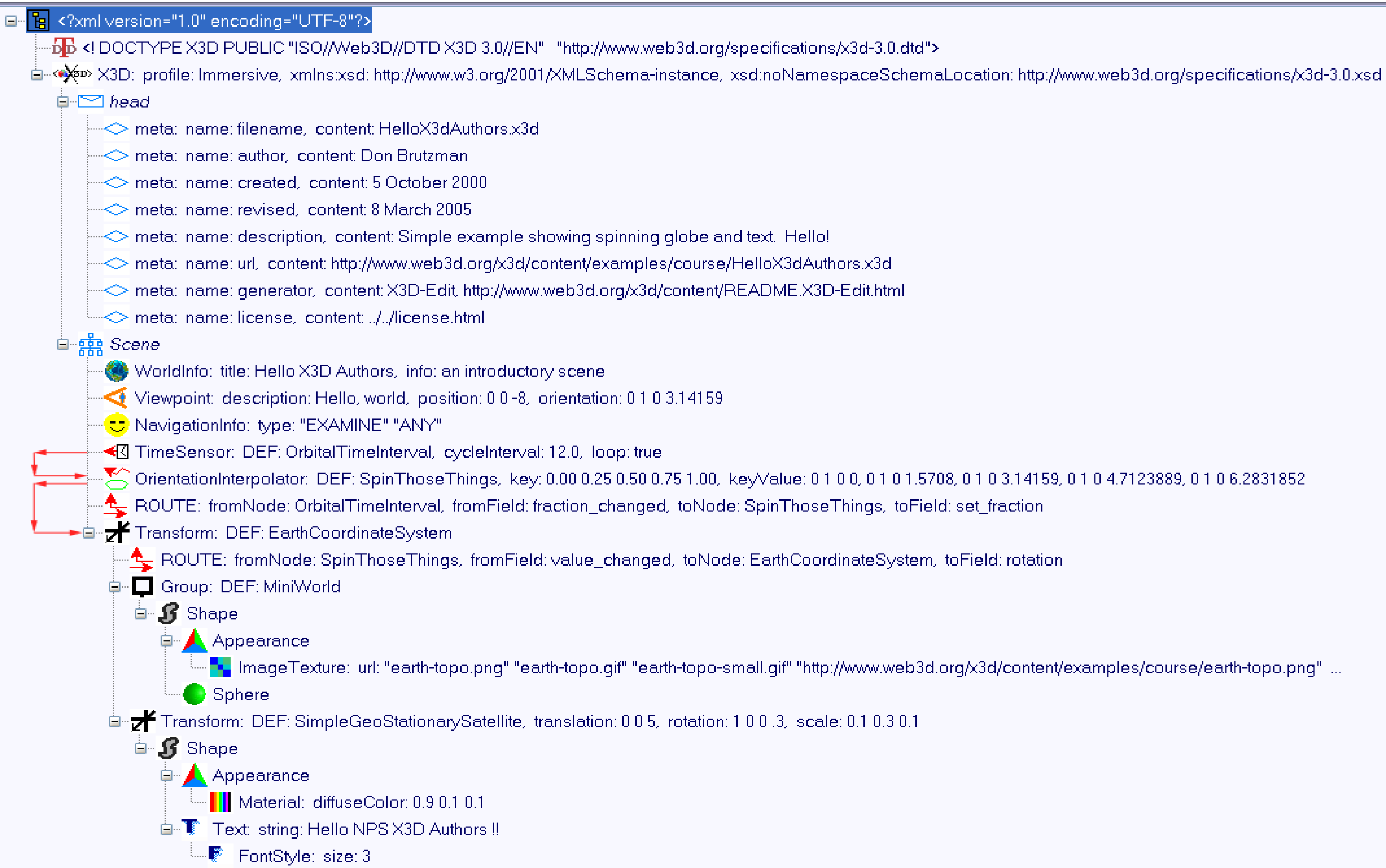
SFTime event **SFFloat event** **SFRotation event**

touchTime => startTime

value_changed => rotation

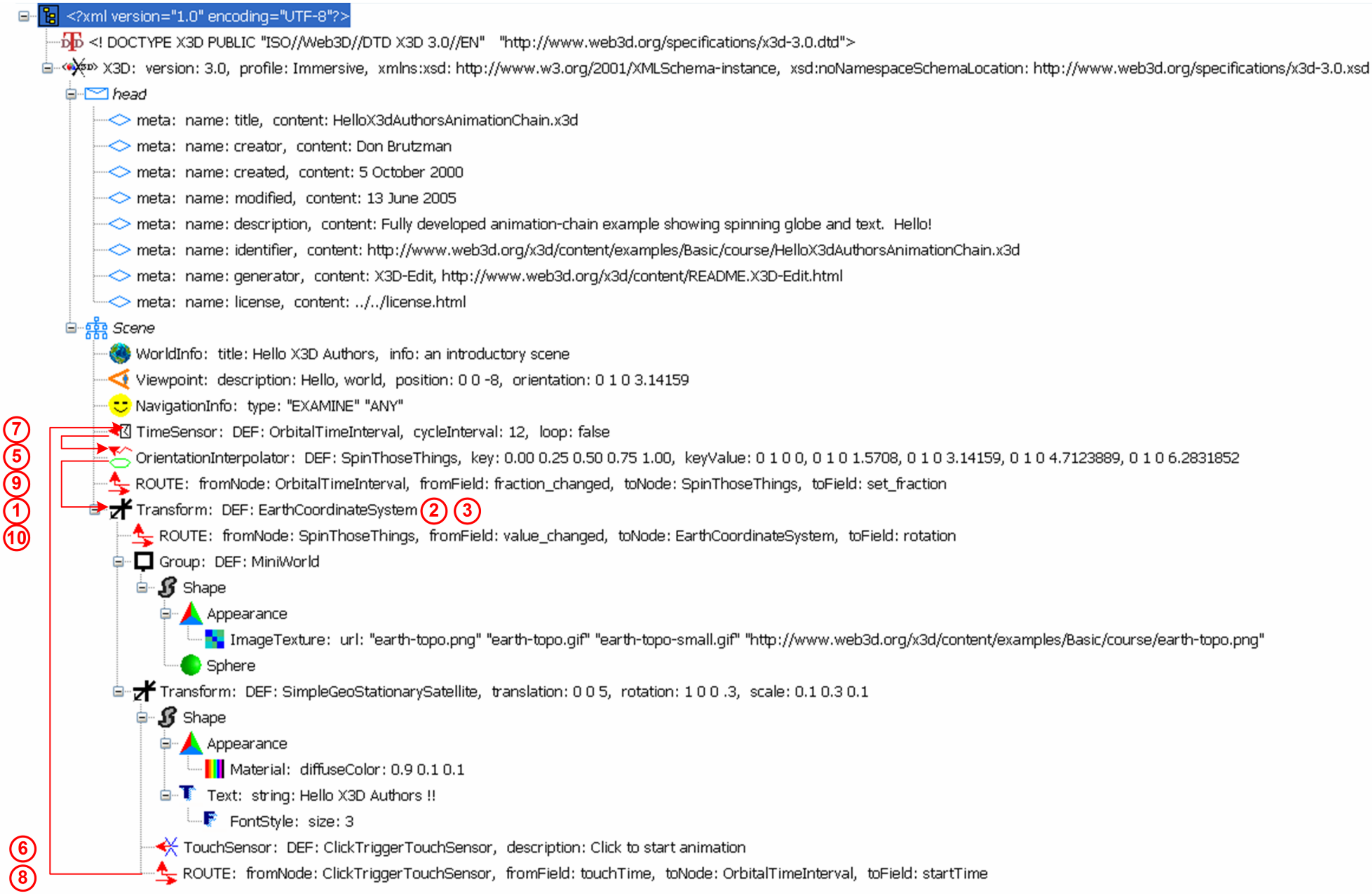
fraction_changed => set_fraction

Hello X3D Authors showing ROUTEs



```
<?xml version="1.0" encoding="UTF-8"?>
  <! DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN"  "http://www.web3d.org/specifications/x3d-3.0.dtd">
  X3D:  profile: Immersive,  xmlns:xsd: http://www.w3.org/2001/XMLSchema-instance,  xsd:noNamespaceSchemaLocation: http://www.web3d.org/specifications/x3d-3.0.xsd
    head
      meta:  name: filename,  content: HelloX3dAuthors.x3d
      meta:  name: author,  content: Don Brutzman
      meta:  name: created,  content: 5 October 2000
      meta:  name: revised,  content: 8 March 2005
      meta:  name: description,  content: Simple example showing spinning globe and text.  Hello!
      meta:  name: url,  content: http://www.web3d.org/x3d/content/examples/course/HelloX3dAuthors.x3d
      meta:  name: generator,  content: X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html
      meta:  name: license,  content: ../../license.html
    Scene
      WorldInfo:  title: Hello X3D Authors,  info: an introductory scene
      Viewpoint:  description: Hello, world,  position: 0 0 -8,  orientation: 0 1 0 3.14159
      NavigationInfo:  type: "EXAMINE" "ANY"
      TimeSensor:  DEF: OrbitalTimeInterval,  cycleInterval: 12.0,  loop: true
      OrientationInterpolator:  DEF: SpinThoseThings,  key: 0.00 0.25 0.50 0.75 1.00,  keyValue: 0 1 0 0, 0 1 0 1.5708, 0 1 0 3.14159, 0 1 0 4.7123889, 0 1 0 6.2831852
      ROUTE:  fromNode: OrbitalTimeInterval,  fromField: fraction_changed,  toNode: SpinThoseThings,  toField: set_fraction
      Transform:  DEF: EarthCoordinateSystem
        ROUTE:  fromNode: SpinThoseThings,  fromField: value_changed,  toNode: EarthCoordinateSystem,  toField: rotation
        Group:  DEF: MiniWorld
          Shape
            Appearance
              ImageTexture:  url: "earth-topo.png" "earth-topo.gif" "earth-topo-small.gif" "http://www.web3d.org/x3d/content/examples/course/earth-topo.png" ...
            Sphere
        Transform:  DEF: SimpleGeoStationarySatellite,  translation: 0 0 5,  rotation: 1 0 0 .3,  scale: 0.1 0.3 0.1
          Shape
            Appearance
              Material:  diffuseColor: 0.9 0.1 0.1
            Text:  string: Hello NPS X3D Authors !!
              FontStyle:  size: 3
```

Hello X3D Authors 10-step process



```
<?xml version="1.0" encoding="UTF-8"?>
  <! DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN"   "http://www.web3d.org/specifications/x3d-3.0.dtd">
  X3D:  version: 3.0,  profile: Immersive,  xmlns:xsd: http://www.w3.org/2001/XMLSchema-instance,  xsd:noNamespaceSchemaLocation: http://www.web3d.org/specifications/x3d-3.0.xsd
    head
      meta:  name: title,  content: HelloX3dAuthorsAnimationChain.x3d
      meta:  name: creator,  content: Don Brutzman
      meta:  name: created,  content: 5 October 2000
      meta:  name: modified,  content: 13 June 2005
      meta:  name: description,  content: Fully developed animation-chain example showing spinning globe and text.  Hello!
      meta:  name: identifier,  content: http://www.web3d.org/x3d/content/examples/Basic/course/HelloX3dAuthorsAnimationChain.x3d
      meta:  name: generator,  content: X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html
      meta:  name: license,  content: ../../license.html
    Scene
      WorldInfo:  title: Hello X3D Authors,  info: an introductory scene
      Viewpoint:  description: Hello, world,  position: 0 0 -8,  orientation: 0 1 0 3.14159
      NavigationInfo:  type: "EXAMINE" "ANY"
      TimeSensor:  DEF: OrbitalTimeInterval,  cycleInterval: 12,  loop: false
      OrientationInterpolator:  DEF: SpinThoseThings,  key: 0.00 0.25 0.50 0.75 1.00,  keyValue: 0 1 0 0, 0 1 0 1.5708, 0 1 0 3.14159, 0 1 0 4.7123889, 0 1 0 6.2831852
      ROUTE:  fromNode: OrbitalTimeInterval,  fromField: fraction_changed,  toNode: SpinThoseThings,  toField: set_fraction
      Transform:  DEF: EarthCoordinateSystem
        ROUTE:  fromNode: SpinThoseThings,  fromField: value_changed,  toNode: EarthCoordinateSystem,  toField: rotation
        Group:  DEF: MiniWorld
          Shape
            Appearance
              ImageTexture:  url: "earth-topo.png" "earth-topo.gif" "earth-topo-small.gif" "http://www.web3d.org/x3d/content/examples/Basic/course/earth-topo.png"
            Sphere
        Transform:  DEF: SimpleGeoStationarySatellite,  translation: 0 0 5,  rotation: 1 0 0 .3,  scale: 0.1 0.3 0.1
          Shape
            Appearance
              Material:  diffuseColor: 0.9 0.1 0.1
            Text:  string: Hello X3D Authors !!
              FontStyle:  size: 3
          TouchSensor:  DEF: ClickTriggerTouchSensor,  description: Click to start animation
          ROUTE:  fromNode: ClickTriggerTouchSensor,  fromField: touchTime,  toNode: OrbitalTimeInterval,  toField: startTime
```

Hello X3D Authors 10-step process

1. Pick target. The target node is a Transform, and the target field is *set_rotation*.

2. Name target. The Transform is named *DEF*='EarthCoordinateSystem'.

3. Check accessType and data type. As shown by the Transform node field-definition table in Chapter 3 and the X3D-Edit tooltip, the *set_rotation* field has type SFRotation.

4. Determine whether Sequencer or Script. These special node types are not applicable to this example, because the data type for *set_rotation* is SFRotation which is a floating-point type.

5. Determine which Interpolator. The animating OrientationInterpolator is named *DEF*="SpinThoseThings" and placed just before the Transform.

6. Triggering sensor. A triggering TouchSensor is added next to the geometry to be clicked, and then named *DEF*='ClickTriggerTouchSensor'.

7. TimeSensor clock. The TimeSensor is added at the beginning of the chain, named *DEF*='OrbitalTimeInterval' and has both the *cycleInterval* and *loop* fields set.

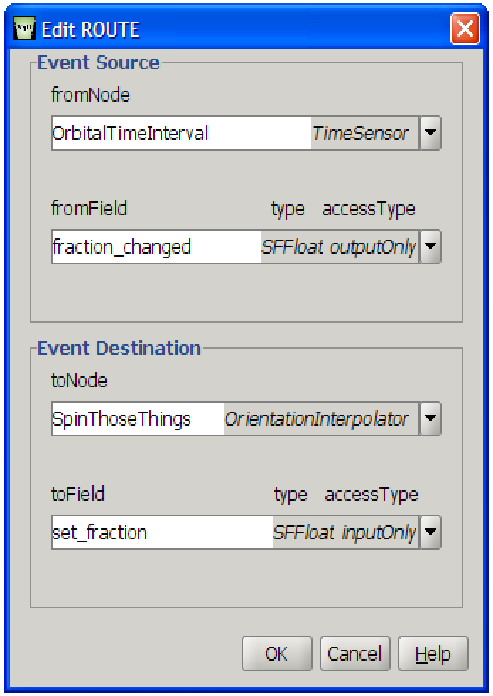
8. Connect trigger. Add ROUTE to connect the triggering TouchSensor node's *touchTime* output field to the clock node's startTime input field.

9. Connect clock. Add ROUTE to connect the clock node's *fraction_changed* output field to the interpolator node's set_fraction input field.

10. Connect animation output. Add ROUTE to connect the interpolator node's *value_changed* output field to the original target input field, *set_rotation*.

ROUTE editor examples

```
<ROUTE
    fromNode='OrbitalTimeInterval'
    fromField='fraction_changed'
    toNode='SpinThoseThings'
    toField='set_fraction' />
```



Edit ROUTE

Event Source

fromNode: OrbitalTimeInterval *TimeSensor*

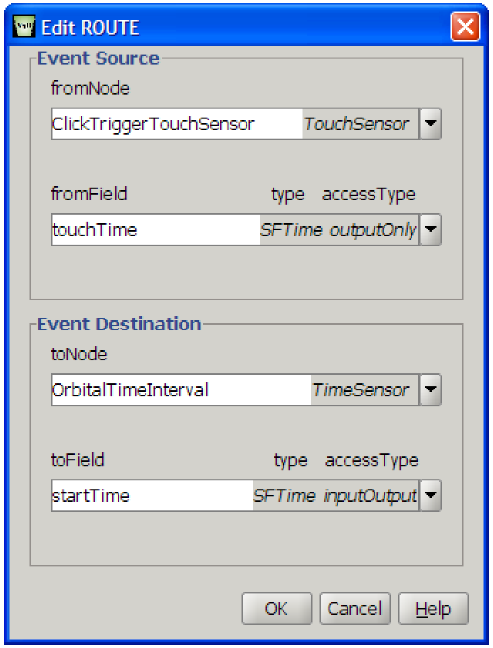
fromField: fraction_changed — type / accessType: *SFFloat outputOnly*

Event Destination

toNode: SpinThoseThings *OrientationInterpolator*

toField: set_fraction — type / accessType: *SFFloat inputOnly*

```
<ROUTE
    fromNode='ClickTriggerTouchSensor'
    fromField='touchTime'
    toNode='OrbitalTimeInterval'
    toField='startTime' />
```



Edit ROUTE

Event Source

fromNode: ClickTriggerTouchSensor *TouchSensor*

fromField: touchTime — type / accessType: *SFTime outputOnly*

Event Destination

toNode: OrbitalTimeInterval *TimeSensor*

toField: startTime — type / accessType: *SFTime inputOutput*

Interpolation

Interpolation is the estimation of intermediate values from other values

Computing averages is computationally efficient and highly optimizable

Linear approximation is thus well suited for high-performance graphics animation

X3D provides interpolation nodes for each of the floating-point data types

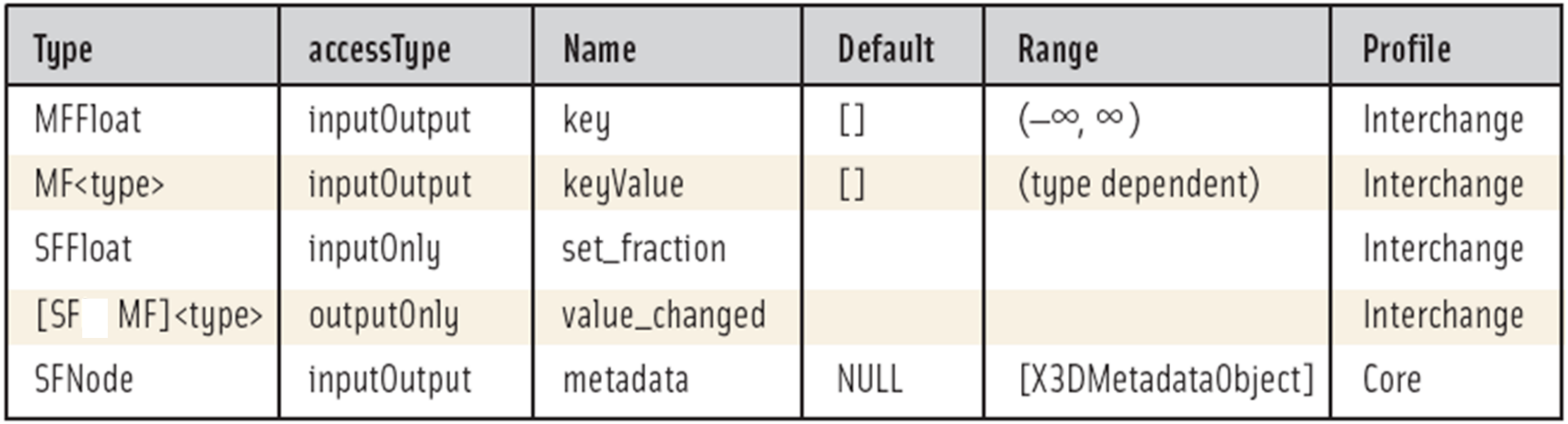
- including multiple-value types: Color, Vec3f, etc.

Interpolation node type

X3DInterpolationNode is the formal name for the interpolation node type

Each interpolation node includes the following common fields and naming conventions

- SF, MF <type> definition must be consistent for node in order to properly define response function



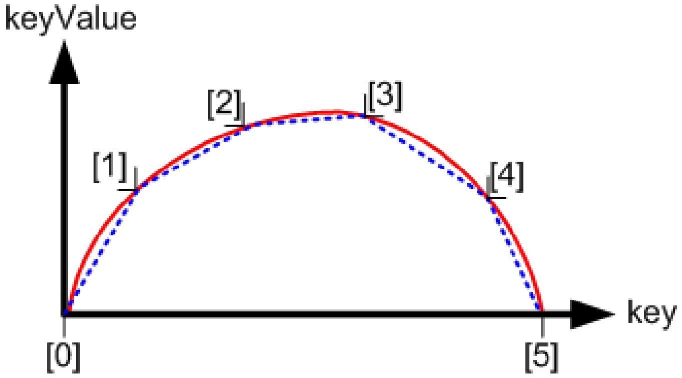
Type	accessType	Name	Default	Range	Profile
MFFloat	inputOutput	key	[]	(–∞, ∞)	Interchange
MF<type>	inputOutput	keyValue	[]	(type dependent)	Interchange
SFFloat	inputOnly	set_fraction			Interchange
[SF MF]<type>	outputOnly	value_changed			Interchange
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

Common interpolator fields

- *key, keyValue* hold the point values defining the characteristic function
- *key* array always has type MFFloat
- *keyValue* array data type matches the named type of the parent Interpolator node
  - final value must equal first value in *keyValue* array if smooth looping is desired
- Lengths of *key, keyValue* arrays must be equal
- Note that *keyValue* array can hold values which are themselves MF (multi-field) array type
- Function output *value_changed* always has same name, but data type matches the Interpolator node

Linear interpolation

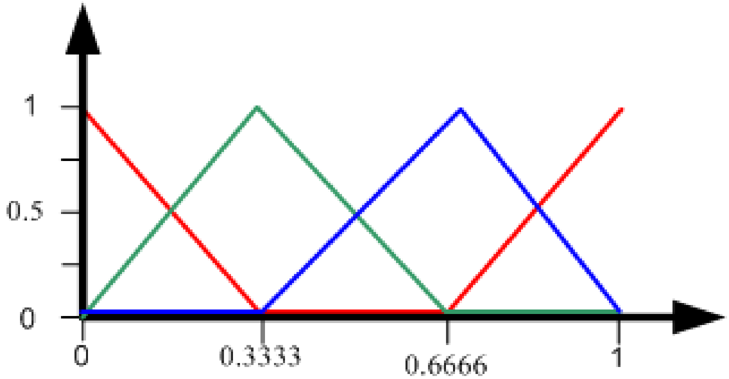
Piecewise-linear curve fitting can approximate any curve with arbitrary accuracy



Multi-field (MF) values are individually interpolated proportionately

key='0 0.3333 0.666 1'

keyValue='1 0 0, 0 1 0,
0 0 1, 1 0 0'



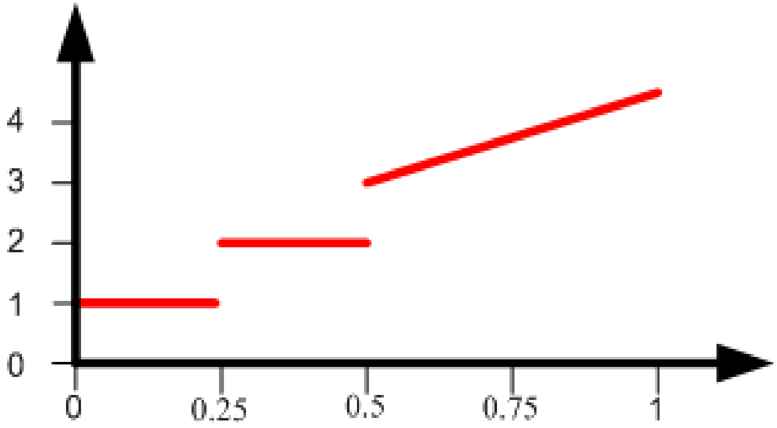
Step-wise linear interpolation

Step functions are created by repeating time values and corresponding output

key='0 0.25 0.25 0.5 0.5 1'

keyValue='1 1 2   2   3 4'

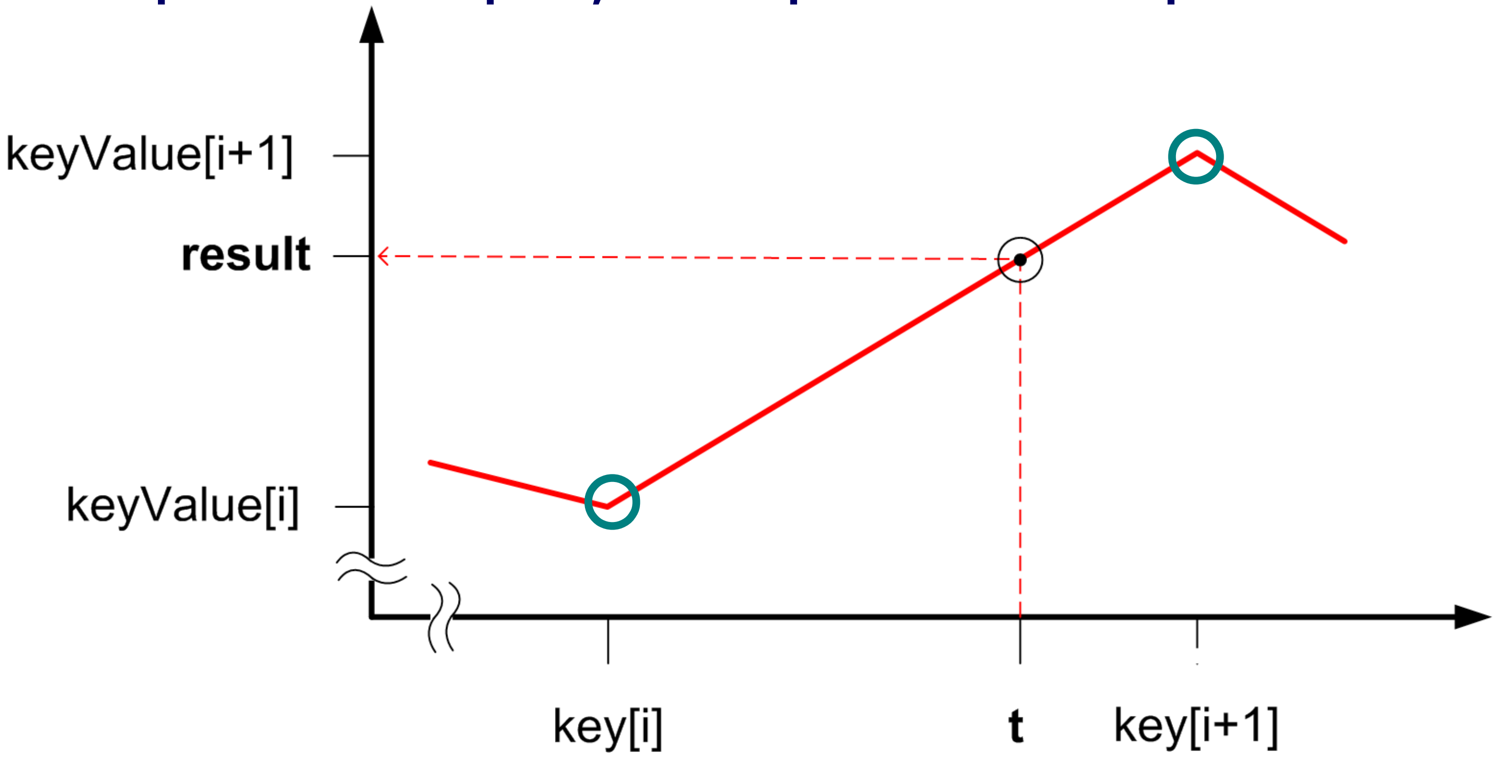
Note that time-fraction key array must always be monotonically (steadily) increasing



Double linear-interpolation averaging

Matched *key, keyValue* arrays define the points for a linear-interpolator approximation function

Two-way weighted averaging is used to compute interpolated-input, interpolated-output results



X3D Nodes and Examples

TimeSensor

TimeSensor is the heartbeat of an animation

- provides pulse that triggers event cascades
- initiates computations for drawing next frame
- Outputs values as fraction_changed, from 0 to 1

TimeSensor samples elapsed time based on the computer clock, rather than screen update rate

- Ensures that animations are smooth and realistic
- Fixed (constant) frame rate is typically not feasible since computation varies for screen-image updates

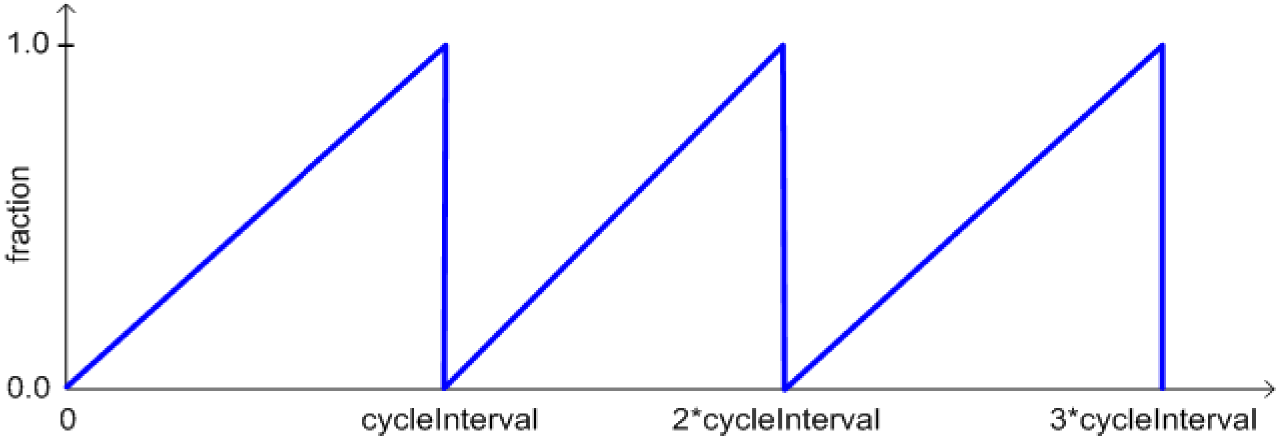
TimeSensor output

Output time is an SFTime ramp function ranging [0,1] that repeats every *cycleInterval* seconds

- Sometimes called a 'sawtooth' function
- SFFloat output field *fraction_changed* used as input to other interpolators, sequencers

```
time = now
temp = (now - startTime) / cycleInterval
f    = fractionalPart (temp)

 if (now ≤ startTime)
       fraction_changed = 0.0
 if ((f == 0.0) && (now > startTime))
       fraction_changed = 1.0
 else fraction_changed = f
```

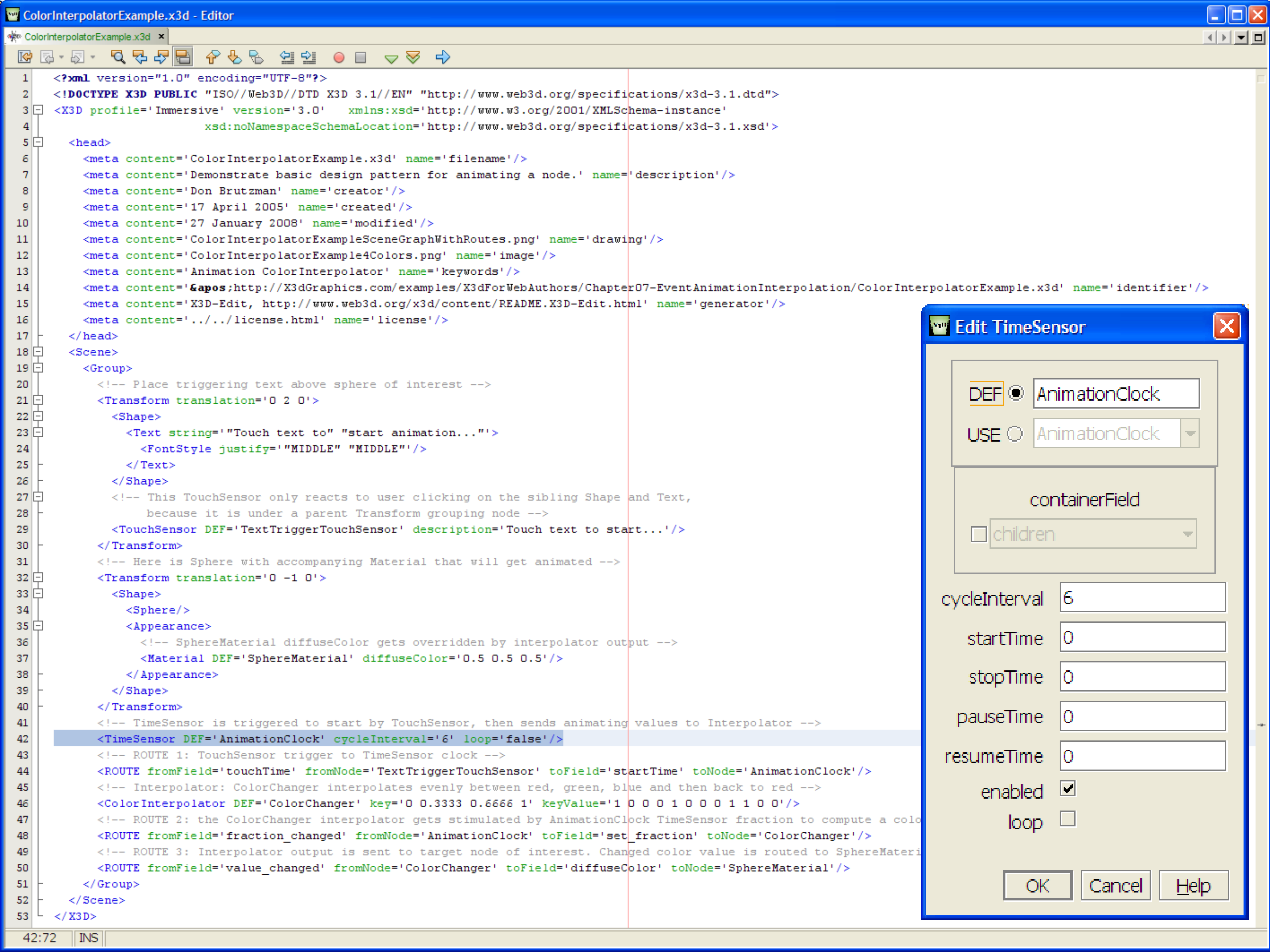


TimeSensor fields 1

- *enabled* controls whether node enabled or disabled
- *loop* is an SFBool indicating whether to continue looping indefinitely after first cycle is complete
- *cycleInterval* defines total loop duration in seconds, either for single-shot animation or looped repetition
- *cycleTime* field is sent an SFTime output value upon completion of each loop

TimeSensor fields 2

- *startTime, stopTime* are provided (or contain) SFTime values for when to start, stop respectively
  - ROUTE an SFTime value to *startTime* or *stopTime*
  - *isActive, isPaused* are output SFBool true/false events sent whenever the TimeSensor is set to run or paused
- *pauseTime, resumeTime a*re SFTime values for current clock time whenever paused or resumed
  - Corresponding boolean *isPaused* event is also sent, with value of true when paused and false when resuming
- *elapsedTime* output provides cumulative number of seconds since TimeSensor was activated and began running, without including paused time



ColorInterpolatorExample.x3d - Editor

ColorInterpolatorExample.x3d

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive' version='3.0'   xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <meta content='ColorInterpolatorExample.x3d' name='filename'/>
    <meta content='Demonstrate basic design pattern for animating a node.' name='description'/>
    <meta content='Don Brutzman' name='creator'/>
    <meta content='17 April 2005' name='created'/>
    <meta content='27 January 2008' name='modified'/>
    <meta content='ColorInterpolatorExampleSceneGraphWithRoutes.png' name='drawing'/>
    <meta content='ColorInterpolatorExample4Colors.png' name='image'/>
    <meta content='Animation ColorInterpolator' name='keywords'/>
    <meta content='&apos;http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d' name='identifier'/>
    <meta content='X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html' name='generator'/>
    <meta content='../../license.html' name='license'/>
  </head>
  <Scene>
    <Group>
      <!-- Place triggering text above sphere of interest -->
      <Transform translation='0 2 0'>
        <Shape>
          <Text string='"Touch text to" "start animation..."'>
            <FontStyle justify='"MIDDLE" "MIDDLE"'/>
          </Text>
        </Shape>
        <!-- This TouchSensor only reacts to user clicking on the sibling Shape and Text,
             because it is under a parent Transform grouping node -->
        <TouchSensor DEF='TextTriggerTouchSensor' description='Touch text to start...'/>
      </Transform>
      <!-- Here is Sphere with accompanying Material that will get animated -->
      <Transform translation='0 -1 0'>
        <Shape>
          <Sphere/>
          <Appearance>
            <!-- SphereMaterial diffuseColor gets overridden by interpolator output -->
            <Material DEF='SphereMaterial' diffuseColor='0.5 0.5 0.5'/>
          </Appearance>
        </Shape>
      </Transform>
      <!-- TimeSensor is triggered to start by TouchSensor, then sends animating values to Interpolator -->
      <TimeSensor DEF='AnimationClock' cycleInterval='6' loop='false'/>
      <!-- ROUTE 1: TouchSensor trigger to TimeSensor clock -->
      <ROUTE fromField='touchTime' fromNode='TextTriggerTouchSensor' toField='startTime' toNode='AnimationClock'/>
      <!-- Interpolator: ColorChanger interpolates evenly between red, green, blue and then back to red -->
      <ColorInterpolator DEF='ColorChanger' key='0 0.3333 0.6666 1' keyValue='1 0 0 0 1 0 0 0 1 1 0 0'/>
      <!-- ROUTE 2: the ColorChanger interpolator gets stimulated by AnimationClock TimeSensor fraction to compute a colo
      <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='ColorChanger'/>
      <!-- ROUTE 3: Interpolator output is sent to target node of interest. Changed color value is routed to SphereMateri
      <ROUTE fromField='value_changed' fromNode='ColorChanger' toField='diffuseColor' toNode='SphereMaterial'/>
    </Group>
  </Scene>
</X3D>
```

42:72 INS

Edit TimeSensor

DEF ● AnimationClock

USE ○ AnimationClock

containerField

☐ children

cycleInterval: 6

startTime: 0

stopTime: 0

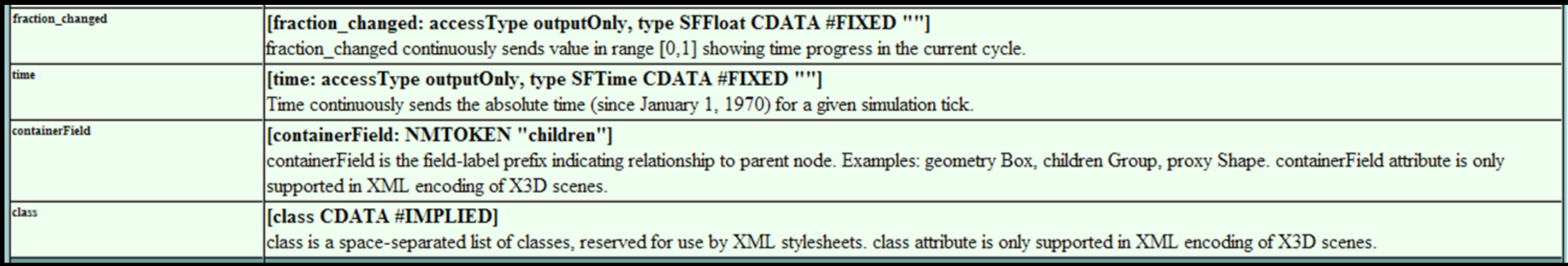
pauseTime: 0

resumeTime: 0

enabled: ☑

loop: ☐

TimeSensor	**TimeSensor continuously generates events as time passes. Typical use: ROUTE thisTimeSensor.fraction_changed TO someInterpolator.set_fraction.** **Interchange profile hint: TimeSensor may be ignored if cycleInterval < 0.01 second.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
enabled	**[enabled: accessType inputOutput, type SFBool (true|false) "true"]** Enables/disables node operation.
cycleInterval	**[cycleInterval: accessType inputOutput, type SFTime CDATA "1.0"]** cycleInterval is loop duration in seconds. Interchange profile hint: TimeSensor may be ignored if cycleInterval < 0.01 second.
loop	**[loop: accessType inputOutput, type SFBool (true|false) "false"]** Repeat indefinitely when loop=true, repeat only once when loop=false.
startTime	**[startTime: accessType inputOutput, type SFTime CDATA "0"]** When time now >= startTime, isActive becomes true and TimeSensor becomes active. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value.
stopTime	**[stopTime: accessType inputOutput, type SFTime CDATA "0"]** When stopTime becomes <= time now, isActive becomes false and TimeSensor becomes inactive. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value.
cycleTime	**[cycleTime: accessType outputOnly, type SFTime CDATA #FIXED ""]** cycleTime sends a time outputOnly at startTime, and also at the beginning of each new cycle (useful for synchronization with other time-based objects).
isActive	**[isActive: accessType outputOnly, type SFBool (true|false) #FIXED ""]** isActive true/false events are sent when TimeSensor starts/stops running.
isPaused	**[isPaused: accessType outputOnly, type SFBool (true|false) #FIXED ""]** isPaused true/false events are sent when TimeSensor is paused/resumed. Warning: not supported in VRML97.
pauseTime	**[pauseTime: accessType inputOutput, type SFTime CDATA "0"]** When time now >= pauseTime, isPaused becomes true and TimeSensor becomes paused. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value. Warning: not supported in VRML97.
resumeTime	**[resumeTime: accessType inputOutput, type SFTime CDATA "0"]** When resumeTime becomes <= time now, isPaused becomes false and TimeSensor becomes inactive. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value. Warning: not supported in VRML97.
elapsedTime	**[elapsedTime: accessType outputOnly, type SFTime CDATA #FIXED ""]** Current elapsed time since TimeSensor activated/running, cumulative in seconds, and not counting any paused time. Warning: not supported in VRML97.



fraction_changed	**[fraction_changed: accessType outputOnly, type SFFloat CDATA #FIXED ""]** fraction_changed continuously sends value in range [0,1] showing time progress in the current cycle.
time	**[time: accessType outputOnly, type SFTime CDATA #FIXED ""]** Time continuously sends the absolute time (since January 1, 1970) for a given simulation tick.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

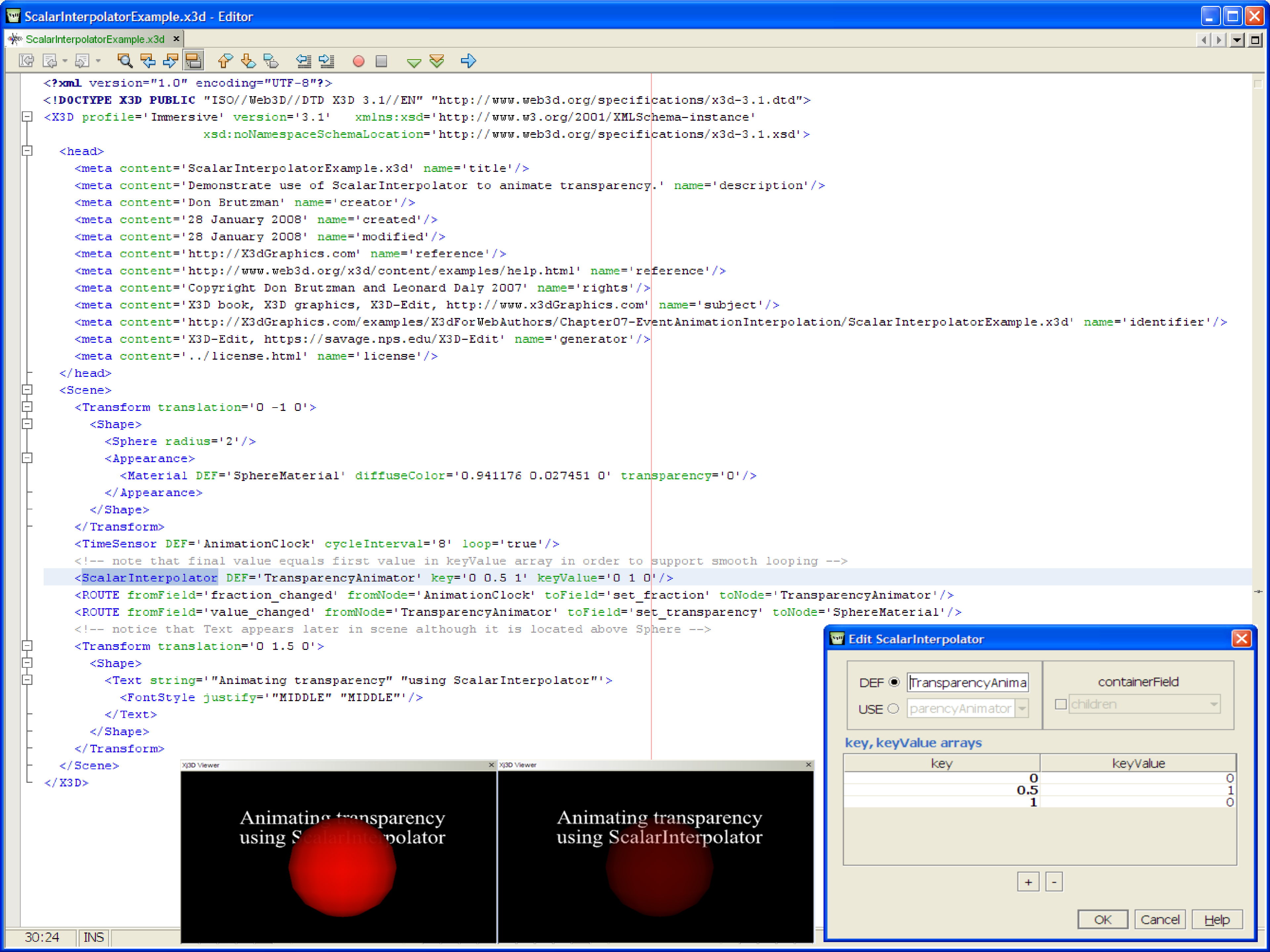
ScalarInterpolator node

Generates a scalar (single-valued) SFFloat for *value_changed* output

key and *keyValue* arrays contain SFFloat values

set_fraction determines input value to piece-wise linear function

- Percentage between bracketing *key*[i], *key*[i+1] values used to compute corresponding output value_changed as weighted average between *keyValue*[i], *keyValue*[i+1]
- Which is same algorithm for all interpolators



```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive' version='3.1'   xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <meta content='ScalarInterpolatorExample.x3d' name='title'/>
    <meta content='Demonstrate use of ScalarInterpolator to animate transparency.' name='description'/>
    <meta content='Don Brutzman' name='creator'/>
    <meta content='28 January 2008' name='created'/>
    <meta content='28 January 2008' name='modified'/>
    <meta content='http://X3dGraphics.com' name='reference'/>
    <meta content='http://www.web3d.org/x3d/content/examples/help.html' name='reference'/>
    <meta content='Copyright Don Brutzman and Leonard Daly 2007' name='rights'/>
    <meta content='X3D book, X3D graphics, X3D-Edit, http://www.x3dGraphics.com' name='subject'/>
    <meta content='http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ScalarInterpolatorExample.x3d' name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='../license.html' name='license'/>
  </head>
  <Scene>
    <Transform translation='0 -1 0'>
      <Shape>
        <Sphere radius='2'/>
        <Appearance>
          <Material DEF='SphereMaterial' diffuseColor='0.941176 0.027451 0' transparency='0'/>
        </Appearance>
      </Shape>
    </Transform>
    <TimeSensor DEF='AnimationClock' cycleInterval='8' loop='true'/>
    <!-- note that final value equals first value in keyValue array in order to support smooth looping -->
    <ScalarInterpolator DEF='TransparencyAnimator' key='0 0.5 1' keyValue='0 1 0'/>
    <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='TransparencyAnimator'/>
    <ROUTE fromField='value_changed' fromNode='TransparencyAnimator' toField='set_transparency' toNode='SphereMaterial'/>
    <!-- notice that Text appears later in scene although it is located above Sphere -->
    <Transform translation='0 1.5 0'>
      <Shape>
        <Text string='"Animating transparency" "using ScalarInterpolator"'>
          <FontStyle justify='"MIDDLE" "MIDDLE"'/>
        </Text>
      </Shape>
    </Transform>
  </Scene>
</X3D>
```

Edit ScalarInterpolator

DEF ● TransparencyAnima

USE ○ parencyAnimator

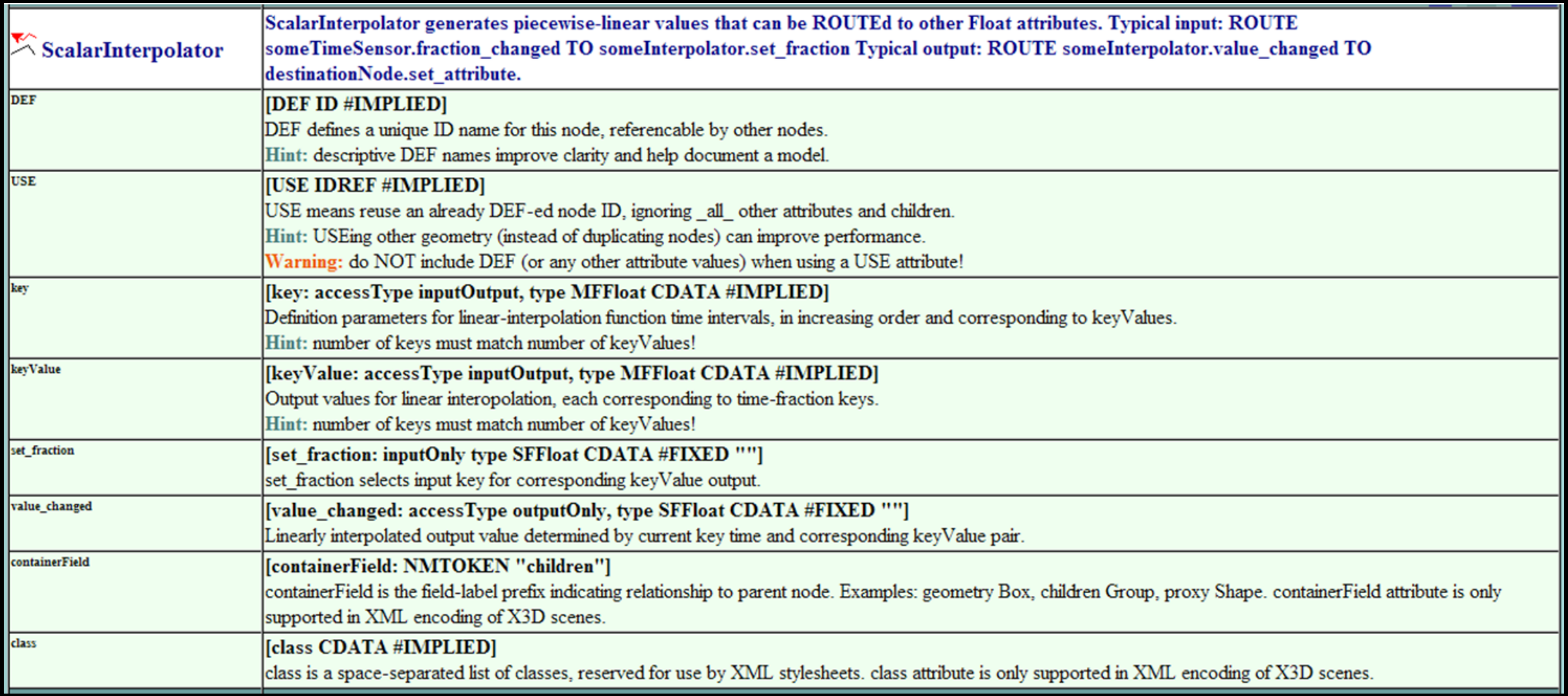
containerField □ children

key, keyValue arrays

key	keyValue
0	0
0.5	1
1	0

+ -

OK Cancel Help



ScalarInterpolator	**ScalarInterpolator generates piecewise-linear values that can be ROUTEd to other Float attributes. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. **Hint:** descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. **Hint:** USEing other geometry (instead of duplicating nodes) can improve performance. **Warning:** do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. **Hint:** number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. **Hint:** number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFFloat CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

ColorInterpolator node

Generates a 3-tuple (triple-valued) SFColor for continuous *value_changed* output

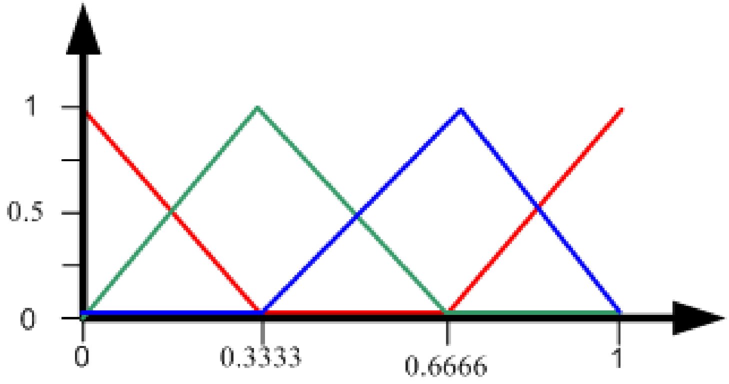
key array contains SFFloat values

keyValue array contains SFColor values

Linear interpolation of red, green, blue (RGB) values is respectively performed for each bracketing *keyValue* pair

key='0 0.3333 0.666 1'

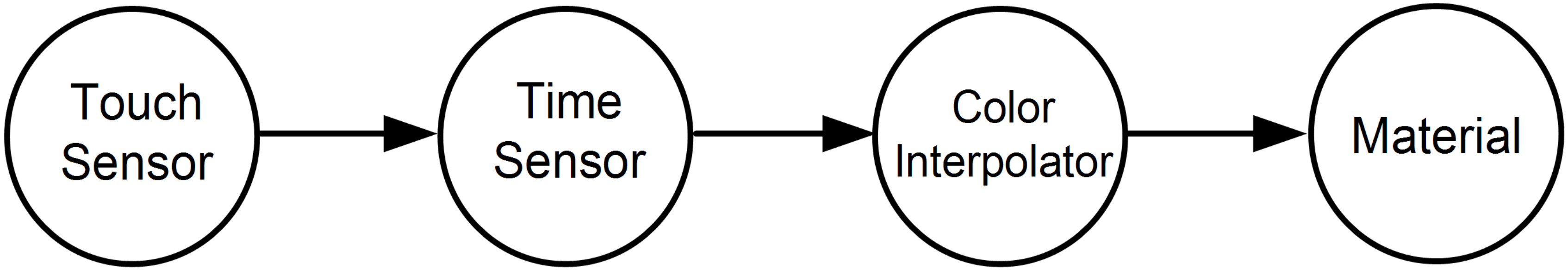
keyValue='1 0 0, 0 1 0,
0 0 1, 1 0 0'



ColorInterpolator animation chain

Each node's output field matches data type of next node's input field

accessType outputOnly to inputOnly, initializeOnly also match



Touch Sensor

Time Sensor

Color Interpolator

Material

TextTriggerTouchSensor
output: touchTime

AnimationClock
input: startTime
output: fraction_changed

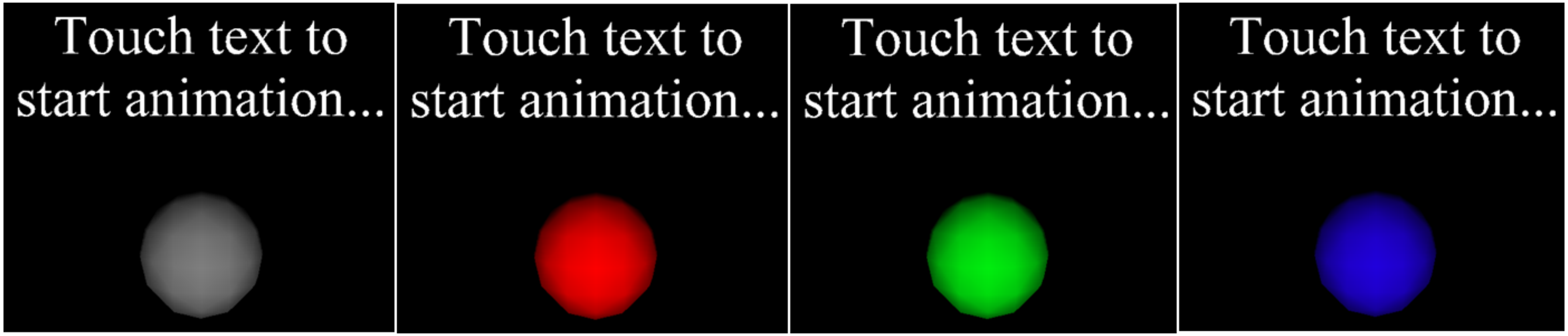
ColorChanger
input: set_fraction
output: value_changed

SphereMaterial
input: diffuseColor

ColorInterpolator example output

Using the pointing device to select the text triggers the ColorInterpolator animation

- Colors vary gradually, by linear interpolation of each of the component red-green-blue RGB values



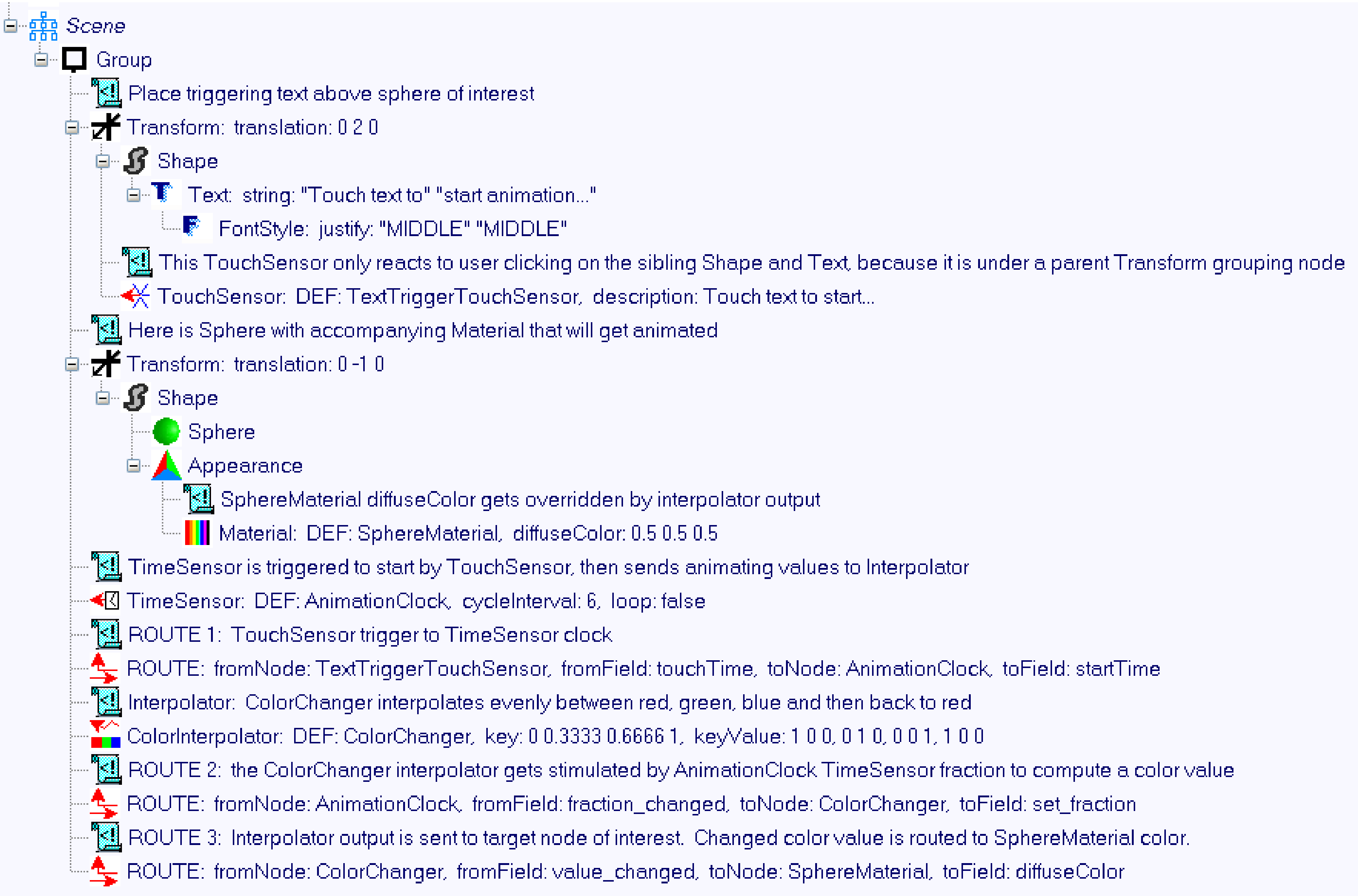
Touch text to start animation...

Touch text to start animation...

Touch text to start animation...

Touch text to start animation...

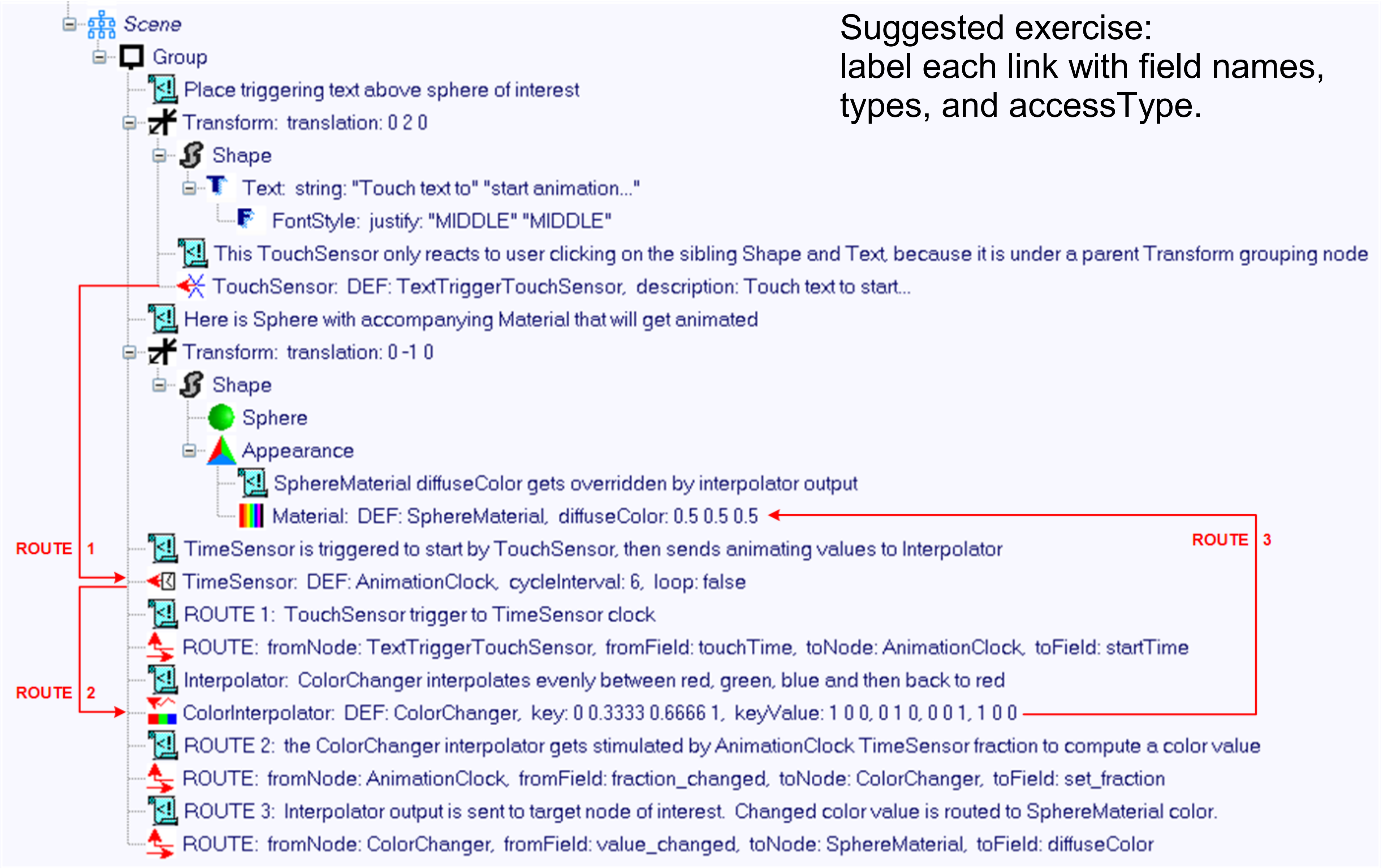
ColorInterpolator scene graph illustration



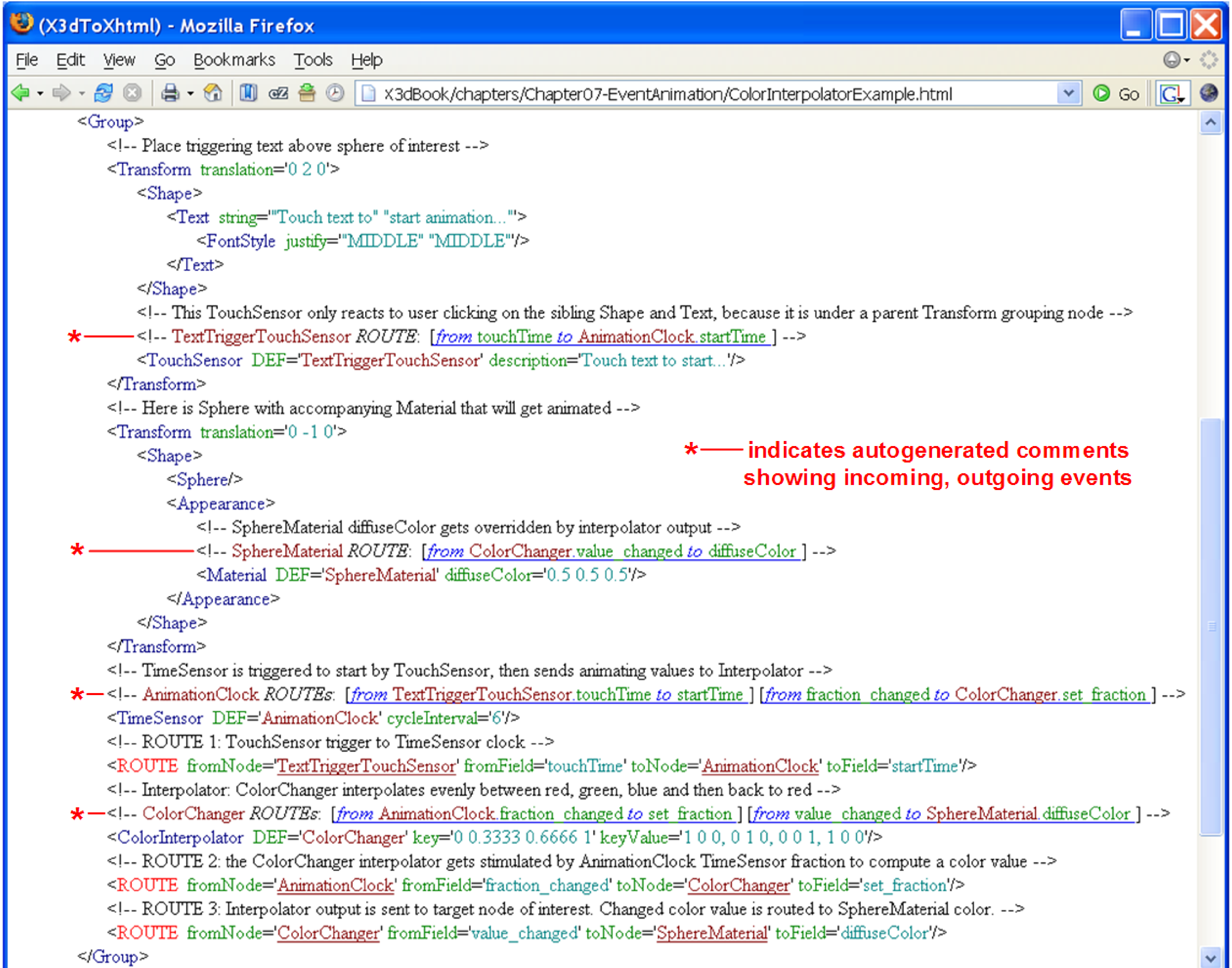
```
Scene
  Group
    Place triggering text above sphere of interest
    Transform:  translation: 0 2 0
      Shape
        Text:  string: "Touch text to" "start animation..."
          FontStyle:  justify: "MIDDLE" "MIDDLE"
      This TouchSensor only reacts to user clicking on the sibling Shape and Text, because it is under a parent Transform grouping node
      TouchSensor:  DEF: TextTriggerTouchSensor,  description: Touch text to start...
    Here is Sphere with accompanying Material that will get animated
    Transform:  translation: 0 -1 0
      Shape
        Sphere
        Appearance
          SphereMaterial diffuseColor gets overridden by interpolator output
          Material:  DEF: SphereMaterial,  diffuseColor: 0.5 0.5 0.5
    TimeSensor is triggered to start by TouchSensor, then sends animating values to Interpolator
    TimeSensor:  DEF: AnimationClock,  cycleInterval: 6,  loop: false
    ROUTE 1:  TouchSensor trigger to TimeSensor clock
    ROUTE:  fromNode: TextTriggerTouchSensor,  fromField: touchTime,  toNode: AnimationClock,  toField: startTime
    Interpolator:  ColorChanger interpolates evenly between red, green, blue and then back to red
    ColorInterpolator:  DEF: ColorChanger,  key: 0 0.3333 0.6666 1,  keyValue: 1 0 0, 0 1 0, 0 0 1, 1 0 0
    ROUTE 2:  the ColorChanger interpolator gets stimulated by AnimationClock TimeSensor fraction to compute a color value
    ROUTE:  fromNode: AnimationClock,  fromField: fraction_changed,  toNode: ColorChanger,  toField: set_fraction
    ROUTE 3:  Interpolator output is sent to target node of interest.  Changed color value is routed to SphereMaterial color.
    ROUTE:  fromNode: ColorChanger,  fromField: value_changed,  toNode: SphereMaterial,  toField: diffuseColor
```

ColorInterpolator scene graph with ROUTEs

Suggested exercise:
label each link with field names, types, and accessType.



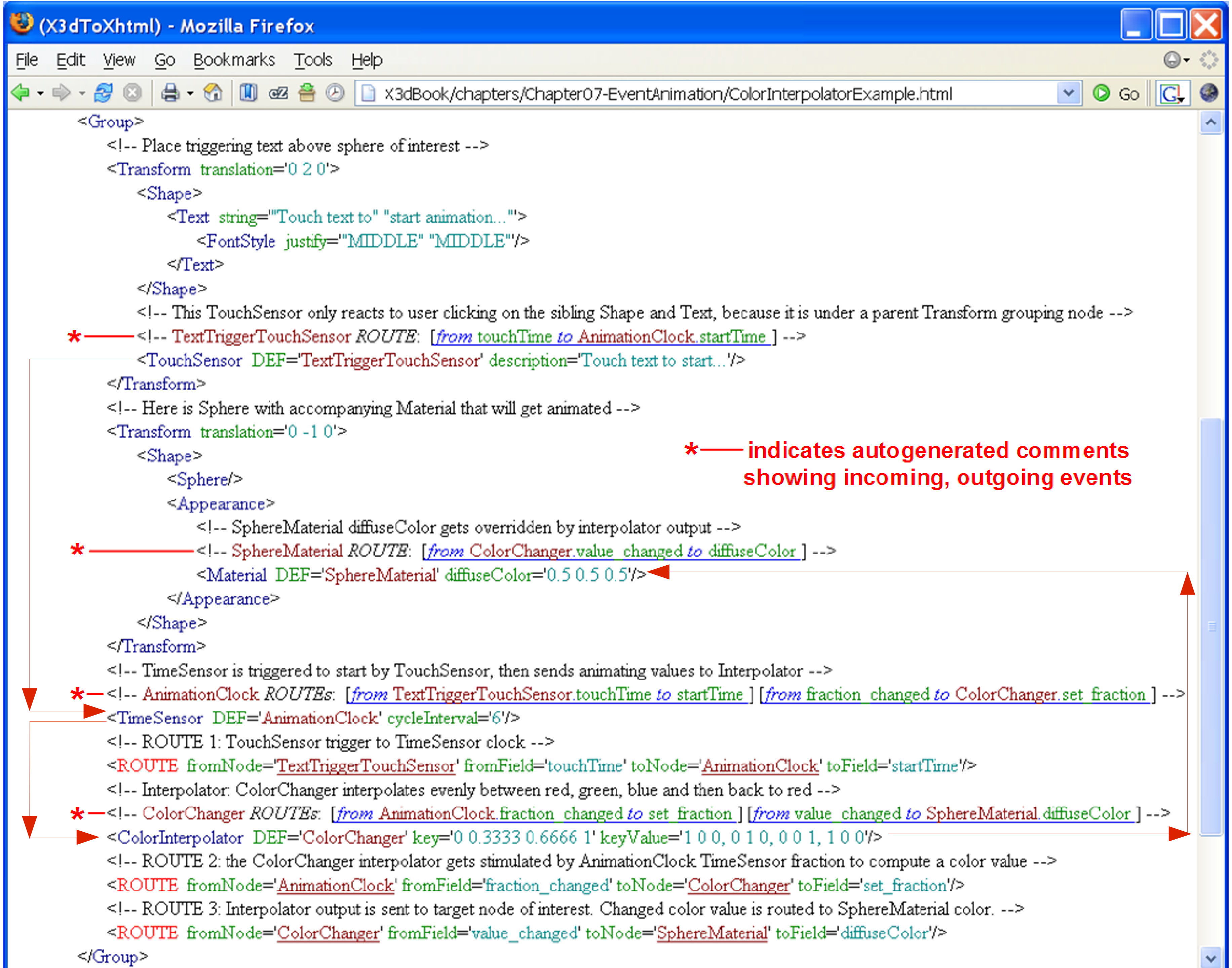
```
Scene
  Group
    Place triggering text above sphere of interest
    Transform:  translation: 0 2 0
      Shape
        Text:  string: "Touch text to" "start animation..."
          FontStyle:  justify: "MIDDLE" "MIDDLE"
      This TouchSensor only reacts to user clicking on the sibling Shape and Text, because it is under a parent Transform grouping node
      TouchSensor:  DEF: TextTriggerTouchSensor,  description: Touch text to start...
    Here is Sphere with accompanying Material that will get animated
    Transform:  translation: 0 -1 0
      Shape
        Sphere
        Appearance
          SphereMaterial diffuseColor gets overridden by interpolator output
          Material:  DEF: SphereMaterial,  diffuseColor: 0.5 0.5 0.5
    TimeSensor is triggered to start by TouchSensor, then sends animating values to Interpolator
    TimeSensor:  DEF: AnimationClock,  cycleInterval: 6,  loop: false
    ROUTE 1:  TouchSensor trigger to TimeSensor clock
    ROUTE:  fromNode: TextTriggerTouchSensor,  fromField: touchTime,  toNode: AnimationClock,  toField: startTime
    Interpolator:  ColorChanger interpolates evenly between red, green, blue and then back to red
    ColorInterpolator:  DEF: ColorChanger,  key: 0 0.3333 0.6666 1,  keyValue: 1 0 0, 0 1 0, 0 0 1, 1 0 0
    ROUTE 2:  the ColorChanger interpolator gets stimulated by AnimationClock TimeSensor fraction to compute a color value
    ROUTE:  fromNode: AnimationClock,  fromField: fraction_changed,  toNode: ColorChanger,  toField: set_fraction
    ROUTE 3:  Interpolator output is sent to target node of interest.  Changed color value is routed to SphereMaterial color.
    ROUTE:  fromNode: ColorChanger,  fromField: value_changed,  toNode: SphereMaterial,  toField: diffuseColor
```



(X3dToXhtml) - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
X3dBook/chapters/Chapter07-EventAnimation/ColorInterpolatorExample.html
Go

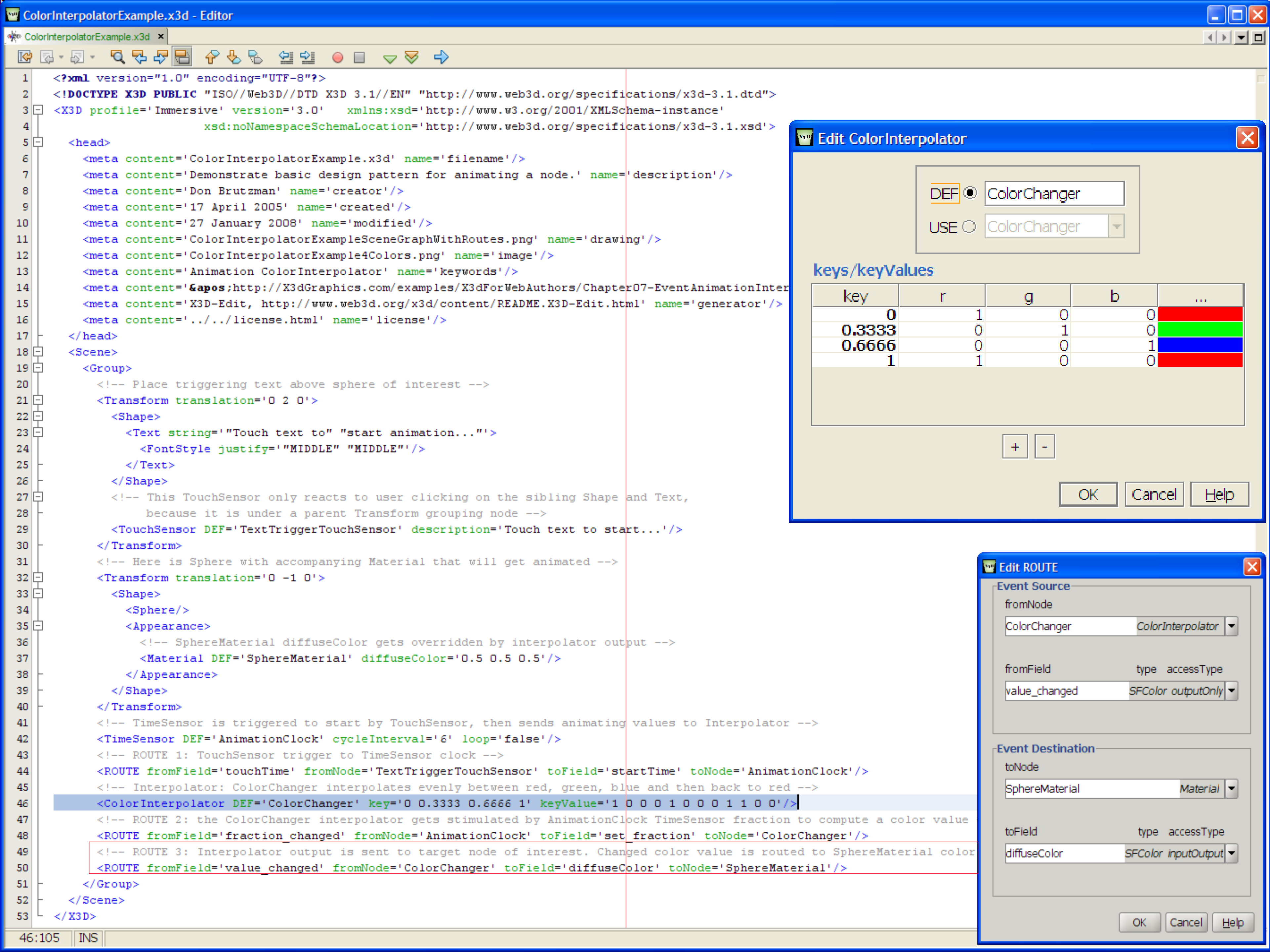
```
<Group>
    <!-- Place triggering text above sphere of interest -->
    <Transform translation='0 2 0'>
        <Shape>
            <Text string='"Touch text to" "start animation..."'>
                <FontStyle justify='"MIDDLE" "MIDDLE"'/>
            </Text>
        </Shape>
        <!-- This TouchSensor only reacts to user clicking on the sibling Shape and Text, because it is under a parent Transform grouping node -->
*———<!-- TextTriggerTouchSensor ROUTE: [from touchTime to AnimationClock.startTime ] -->
        <TouchSensor DEF='TextTriggerTouchSensor' description='Touch text to start...'/>
    </Transform>
    <!-- Here is Sphere with accompanying Material that will get animated -->
    <Transform translation='0 -1 0'>
        <Shape>
            <Sphere/>
            <Appearance>
                <!-- SphereMaterial diffuseColor gets overridden by interpolator output -->
*———————<!-- SphereMaterial ROUTE: [from ColorChanger.value_changed to diffuseColor ] -->
                <Material DEF='SphereMaterial' diffuseColor='0.5 0.5 0.5'/>
            </Appearance>
        </Shape>
    </Transform>
    <!-- TimeSensor is triggered to start by TouchSensor, then sends animating values to Interpolator -->
*—<!-- AnimationClock ROUTEs: [from TextTriggerTouchSensor.touchTime to startTime ] [from fraction_changed to ColorChanger.set_fraction ] -->
    <TimeSensor DEF='AnimationClock' cycleInterval='6'/>
    <!-- ROUTE 1: TouchSensor trigger to TimeSensor clock -->
    <ROUTE fromNode='TextTriggerTouchSensor' fromField='touchTime' toNode='AnimationClock' toField='startTime'/>
    <!-- Interpolator: ColorChanger interpolates evenly between red, green, blue and then back to red -->
*—<!-- ColorChanger ROUTEs: [from AnimationClock.fraction_changed to set_fraction ] [from value_changed to SphereMaterial.diffuseColor ] -->
    <ColorInterpolator DEF='ColorChanger' key='0 0.3333 0.6666 1' keyValue='1 0 0, 0 1 0, 0 0 1, 1 0 0'/>
    <!-- ROUTE 2: the ColorChanger interpolator gets stimulated by AnimationClock TimeSensor fraction to compute a color value -->
    <ROUTE fromNode='AnimationClock' fromField='fraction_changed' toNode='ColorChanger' toField='set_fraction'/>
    <!-- ROUTE 3: Interpolator output is sent to target node of interest. Changed color value is routed to SphereMaterial color. -->
    <ROUTE fromNode='ColorChanger' fromField='value_changed' toNode='SphereMaterial' toField='diffuseColor'/>
</Group>
```

*—— indicates autogenerated comments showing incoming, outgoing events


(X3dToXhtml) - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
X3dBook/chapters/Chapter07-EventAnimation/ColorInterpolatorExample.html
Go

```
<Group>
  <!-- Place triggering text above sphere of interest -->
  <Transform translation='0 2 0'>
    <Shape>
      <Text string='"Touch text to" "start animation..."'>
        <FontStyle justify='"MIDDLE" "MIDDLE"'/>
      </Text>
    </Shape>
    <!-- This TouchSensor only reacts to user clicking on the sibling Shape and Text, because it is under a parent Transform grouping node -->
    <!-- TextTriggerTouchSensor ROUTE: [from touchTime to AnimationClock.startTime ] -->
    <TouchSensor DEF='TextTriggerTouchSensor' description='Touch text to start...'/>
  </Transform>
  <!-- Here is Sphere with accompanying Material that will get animated -->
  <Transform translation='0 -1 0'>
    <Shape>
      <Sphere/>
      <Appearance>
        <!-- SphereMaterial diffuseColor gets overridden by interpolator output -->
        <!-- SphereMaterial ROUTE: [from ColorChanger.value_changed to diffuseColor ] -->
        <Material DEF='SphereMaterial' diffuseColor='0.5 0.5 0.5'/>
      </Appearance>
    </Shape>
  </Transform>
  <!-- TimeSensor is triggered to start by TouchSensor, then sends animating values to Interpolator -->
  <!-- AnimationClock ROUTEs: [from TextTriggerTouchSensor.touchTime to startTime ] [from fraction_changed to ColorChanger.set_fraction ] -->
  <TimeSensor DEF='AnimationClock' cycleInterval='6'/>
  <!-- ROUTE 1: TouchSensor trigger to TimeSensor clock -->
  <ROUTE fromNode='TextTriggerTouchSensor' fromField='touchTime' toNode='AnimationClock' toField='startTime'/>
  <!-- Interpolator: ColorChanger interpolates evenly between red, green, blue and then back to red -->
  <!-- ColorChanger ROUTEs: [from AnimationClock.fraction_changed to set_fraction ] [from value_changed to SphereMaterial.diffuseColor ] -->
  <ColorInterpolator DEF='ColorChanger' key='0 0.3333 0.6666 1' keyValue='1 0 0, 0 1 0, 0 0 1, 1 0 0'/>
  <!-- ROUTE 2: the ColorChanger interpolator gets stimulated by AnimationClock TimeSensor fraction to compute a color value -->
  <ROUTE fromNode='AnimationClock' fromField='fraction_changed' toNode='ColorChanger' toField='set_fraction'/>
  <!-- ROUTE 3: Interpolator output is sent to target node of interest. Changed color value is routed to SphereMaterial color. -->
  <ROUTE fromNode='ColorChanger' fromField='value_changed' toNode='SphereMaterial' toField='diffuseColor'/>
</Group>
```

* indicates autogenerated comments showing incoming, outgoing events



ColorInterpolatorExample.x3d - Editor

ColorInterpolatorExample.x3d

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive' version='3.0'  xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <meta content='ColorInterpolatorExample.x3d' name='filename'/>
    <meta content='Demonstrate basic design pattern for animating a node.' name='description'/>
    <meta content='Don Brutzman' name='creator'/>
    <meta content='17 April 2005' name='created'/>
    <meta content='27 January 2008' name='modified'/>
    <meta content='ColorInterpolatorExampleSceneGraphWithRoutes.png' name='drawing'/>
    <meta content='ColorInterpolatorExample4Colors.png' name='image'/>
    <meta content='Animation ColorInterpolator' name='keywords'/>
    <meta content='&apos;http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInter
    <meta content='X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html' name='generator'/>
    <meta content='../../license.html' name='license'/>
  </head>
  <Scene>
    <Group>
      <!-- Place triggering text above sphere of interest -->
      <Transform translation='0 2 0'>
        <Shape>
          <Text string='"Touch text to" "start animation..."'>
            <FontStyle justify='"MIDDLE" "MIDDLE"'/>
          </Text>
        </Shape>
        <!-- This TouchSensor only reacts to user clicking on the sibling Shape and Text,
             because it is under a parent Transform grouping node -->
        <TouchSensor DEF='TextTriggerTouchSensor' description='Touch text to start...'/>
      </Transform>
      <!-- Here is Sphere with accompanying Material that will get animated -->
      <Transform translation='0 -1 0'>
        <Shape>
          <Sphere/>
          <Appearance>
            <!-- SphereMaterial diffuseColor gets overridden by interpolator output -->
            <Material DEF='SphereMaterial' diffuseColor='0.5 0.5 0.5'/>
          </Appearance>
        </Shape>
      </Transform>
      <!-- TimeSensor is triggered to start by TouchSensor, then sends animating values to Interpolator -->
      <TimeSensor DEF='AnimationClock' cycleInterval='6' loop='false'/>
      <!-- ROUTE 1: TouchSensor trigger to TimeSensor clock -->
      <ROUTE fromField='touchTime' fromNode='TextTriggerTouchSensor' toField='startTime' toNode='AnimationClock'/>
      <!-- Interpolator: ColorChanger interpolates evenly between red, green, blue and then back to red -->
      <ColorInterpolator DEF='ColorChanger' key='0 0.3333 0.6666 1' keyValue='1 0 0 0 1 0 0 0 1 1 0 0'/>
      <!-- ROUTE 2: the ColorChanger interpolator gets stimulated by AnimationClock TimeSensor fraction to compute a color value
      <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='ColorChanger'/>
      <!-- ROUTE 3: Interpolator output is sent to target node of interest. Changed color value is routed to SphereMaterial color
      <ROUTE fromField='value_changed' fromNode='ColorChanger' toField='diffuseColor' toNode='SphereMaterial'/>
    </Group>
  </Scene>
</X3D>
```

46:105 INS

Edit ColorInterpolator

DEF ● ColorChanger

USE ○ ColorChanger

keys/keyValues

key	r	g	b	...
0	1	0	0	🟥
0.3333	0	1	0	🟩
0.6666	0	0	1	🟦
1	1	0	0	🟥

Edit ROUTE

Event Source

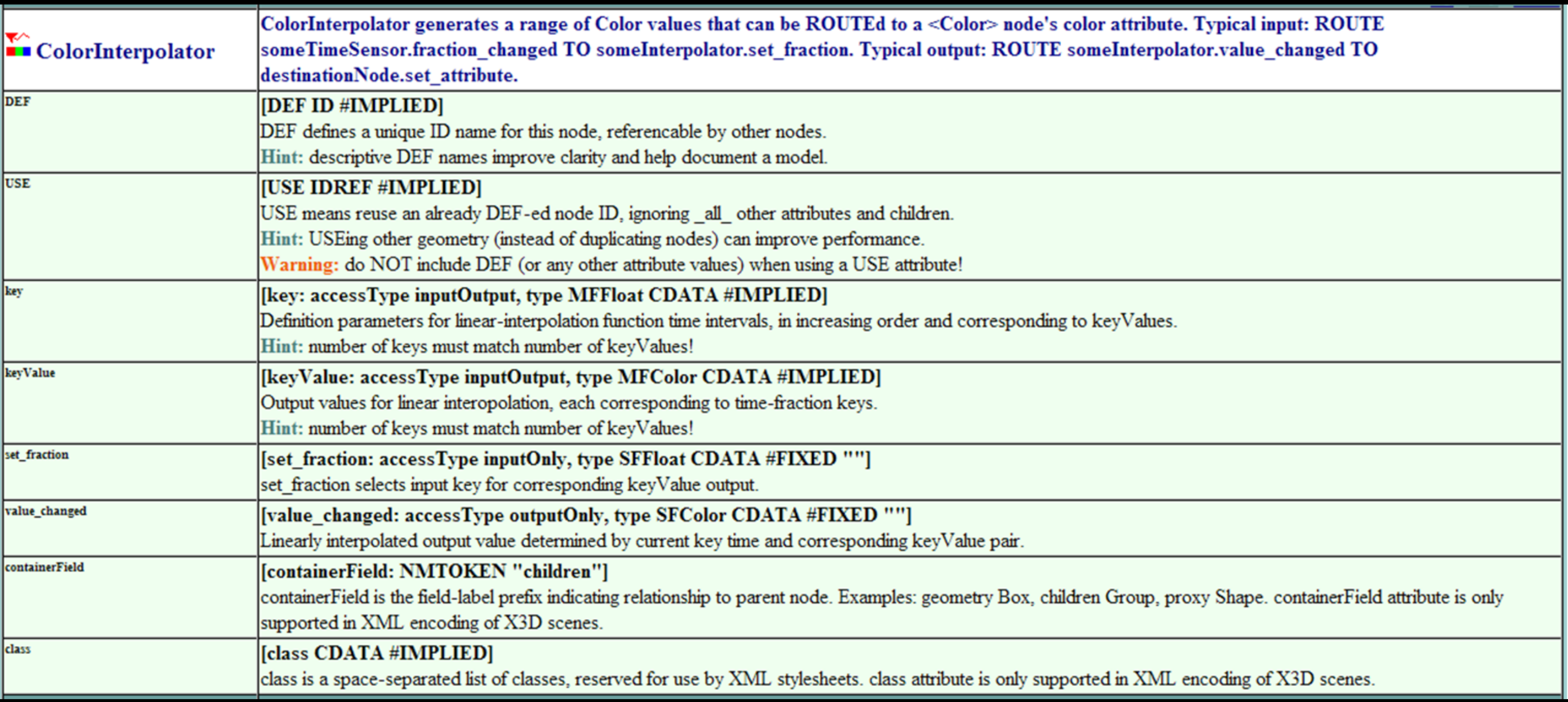
fromNode: ColorChanger ColorInterpolator

fromField: value_changed — type accessType: SFColor outputOnly

Event Destination

toNode: SphereMaterial Material

toField: diffuseColor — type accessType: SFColor inputOutput



ColorInterpolator	**ColorInterpolator generates a range of Color values that can be ROUTEd to a <Color> node's color attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFColor CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: accessType inputOnly, type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFColor CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

OrientationInterpolator node

Generates a 4-tuple (four-valued orientation) SFRotation for *value_changed* output

key array contains SFFloat fraction values

keyValue array contains SFRotation output values

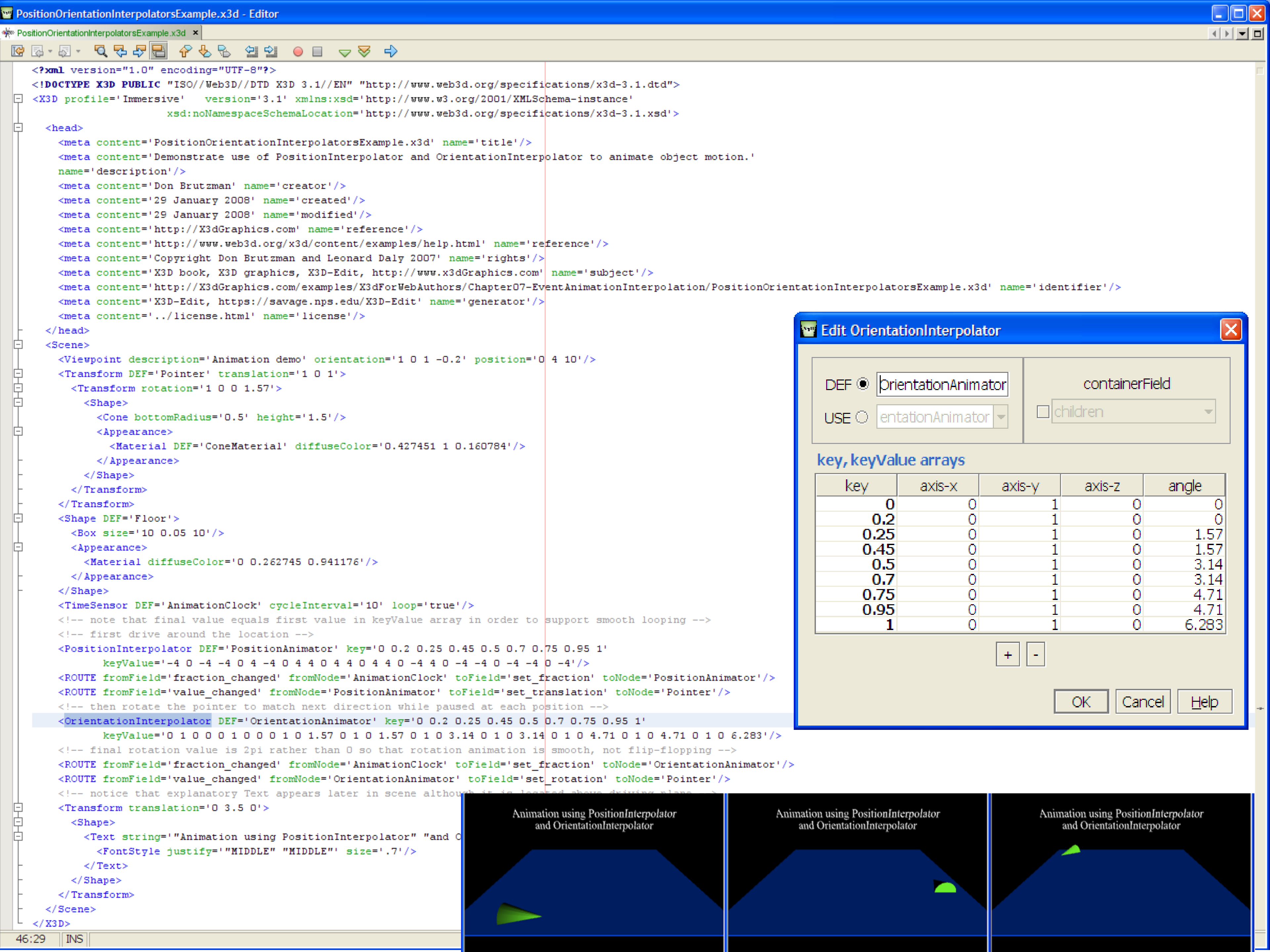
- As always: same number of *key*, *keyValue* entries

OrientationInterpolator animates along shortest path between the two normal vectors, also computes linear average between two corresponding angles, in *keyValue* array

OrientationInterpolator example

This animation-chain example can be added to any scene (via cut and paste) to create a look-around Viewpoint. This bound camera view rotates about a fixed position.

```
<Viewpoint DEF='DizzyViewpoint' description='Rotating viewpoint'
   position=”[somewhere you want it]” orientation='0 1 0 0'/>
<OrientationInterpolator DEF='Spinner' key='0 0.25 0.5 0.75 1'
   keyValue='0 1 0 0, 0 1 0 1.57, 0 1 0 3.14, 0 1 0 4.71, 0 1 0 6.28'/>
<TimeSensor DEF='SpinClock' cycleInterval='12' loop='true'/>
<ROUTE fromField='fraction_changed' fromNode='SpinClock'
   toField='set_fraction' toNode='Spinner'/>
<ROUTE fromField='value_changed' fromNode='Spinner'
         toField='orientation' toNode='DizzyViewpoint'/>
```



PositionOrientationInterpolatorsExample.x3d - Editor

PositionOrientationInterpolatorsExample.x3d ×

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive'   version='3.1' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <meta content='PositionOrientationInterpolatorsExample.x3d' name='title'/>
    <meta content='Demonstrate use of PositionInterpolator and OrientationInterpolator to animate object motion.'
    name='description'/>
    <meta content='Don Brutzman' name='creator'/>
    <meta content='29 January 2008' name='created'/>
    <meta content='29 January 2008' name='modified'/>
    <meta content='http://X3dGraphics.com' name='reference'/>
    <meta content='http://www.web3d.org/x3d/content/examples/help.html' name='reference'/>
    <meta content='Copyright Don Brutzman and Leonard Daly 2007' name='rights'/>
    <meta content='X3D book, X3D graphics, X3D-Edit, http://www.x3dGraphics.com' name='subject'/>
    <meta content='http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionOrientationInterpolatorsExample.x3d' name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='../license.html' name='license'/>
  </head>
  <Scene>
    <Viewpoint description='Animation demo' orientation='1 0 1 -0.2' position='0 4 10'/>
    <Transform DEF='Pointer' translation='1 0 1'>
      <Transform rotation='1 0 0 1.57'>
        <Shape>
          <Cone bottomRadius='0.5' height='1.5'/>
          <Appearance>
            <Material DEF='ConeMaterial' diffuseColor='0.427451 1 0.160784'/>
          </Appearance>
        </Shape>
      </Transform>
    </Transform>
    <Shape DEF='Floor'>
      <Box size='10 0.05 10'/>
      <Appearance>
        <Material diffuseColor='0 0.262745 0.941176'/>
      </Appearance>
    </Shape>
    <TimeSensor DEF='AnimationClock' cycleInterval='10' loop='true'/>
    <!-- note that final value equals first value in keyValue array in order to support smooth looping -->
    <!-- first drive around the location -->
    <PositionInterpolator DEF='PositionAnimator' key='0 0.2 0.25 0.45 0.5 0.7 0.75 0.95 1'
           keyValue='-4 0 -4 -4 0 4 -4 0 4 4 0 4 4 0 4 4 0 -4 4 0 -4 -4 0 -4 -4 0 -4'/>
    <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='PositionAnimator'/>
    <ROUTE fromField='value_changed' fromNode='PositionAnimator' toField='set_translation' toNode='Pointer'/>
    <!-- then rotate the pointer to match next direction while paused at each position -->
    <OrientationInterpolator DEF='OrientationAnimator' key='0 0.2 0.25 0.45 0.5 0.7 0.75 0.95 1'
           keyValue='0 1 0 0 0 1 0 0 0 1 0 1.57 0 1 0 1.57 0 1 0 3.14 0 1 0 3.14 0 1 0 4.71 0 1 0 4.71 0 1 0 6.283'/>
    <!-- final rotation value is 2pi rather than 0 so that rotation animation is smooth, not flip-flopping -->
    <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='OrientationAnimator'/>
    <ROUTE fromField='value_changed' fromNode='OrientationAnimator' toField='set_rotation' toNode='Pointer'/>
    <!-- notice that explanatory Text appears later in scene although it is located above driving plane -->
    <Transform translation='0 3.5 0'>
      <Shape>
        <Text string='"Animation using PositionInterpolator" "and O
          <FontStyle justify='"MIDDLE" "MIDDLE"' size='.7'/>
        </Text>
      </Shape>
    </Transform>
  </Scene>
</X3D>
```

46:29 INS

Edit OrientationInterpolator

DEF ● OrientationAnimator

USE ○ entationAnimator

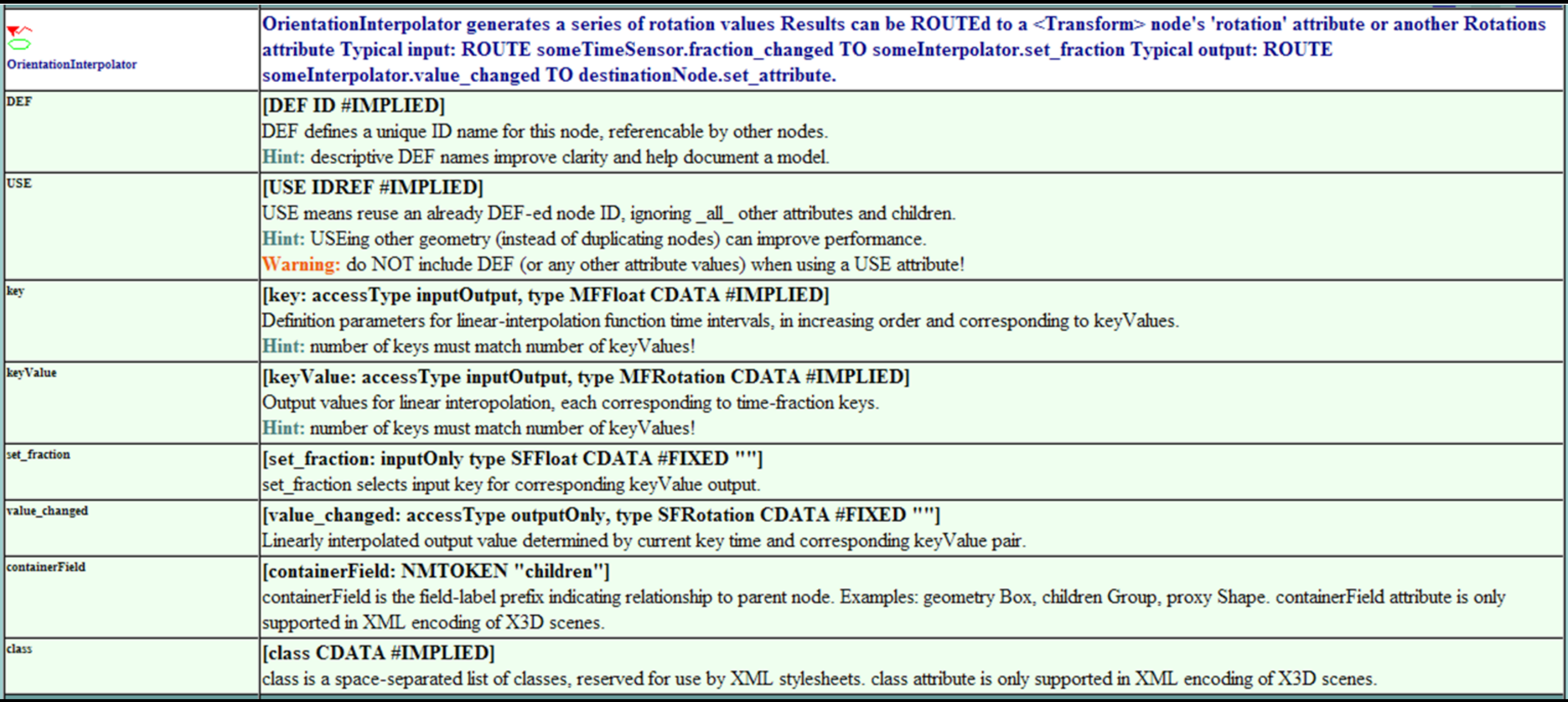
containerField

□ children

key, keyValue arrays

key	axis-x	axis-y	axis-z	angle
0	0	1	0	0
0.2	0	1	0	0
0.25	0	1	0	1.57
0.45	0	1	0	1.57
0.5	0	1	0	3.14
0.7	0	1	0	3.14
0.75	0	1	0	4.71
0.95	0	1	0	4.71
1	0	1	0	6.283

+
-
OK
Cancel
Help
Animation using PositionInterpolator and OrientationInterpolator
Animation using PositionInterpolator and OrientationInterpolator
Animation using PositionInterpolator and OrientationInterpolator



OrientationInterpolator	**OrientationInterpolator generates a series of rotation values Results can be ROUTEd to a <Transform> node's 'rotation' attribute or another Rotations attribute Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFRotation CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFRotation CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

PositionInterpolator node

Generates a 3-tuple (three-valued floating point) SFVec3f for *value_changed* output

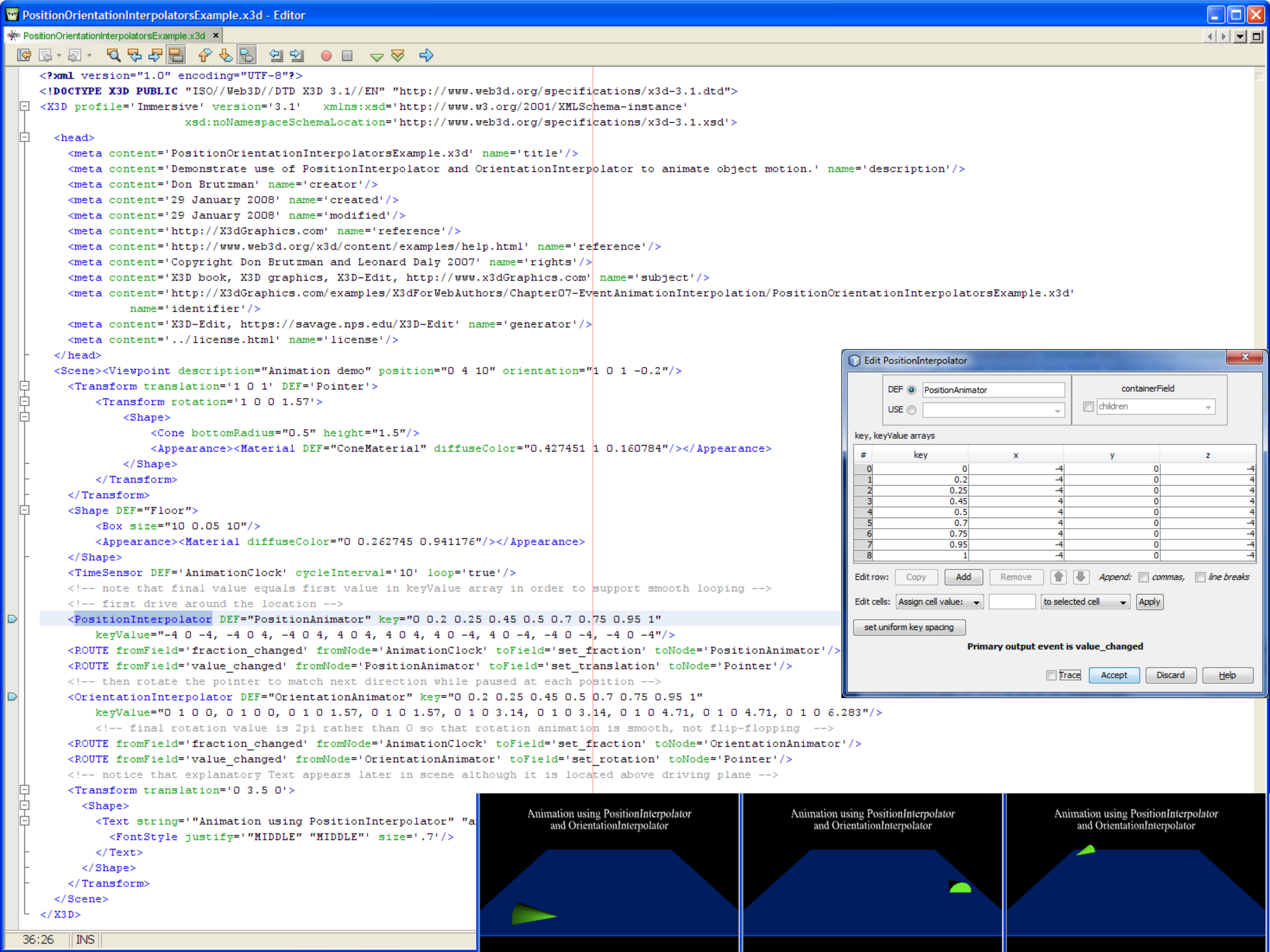
key array contains SFFloat *fraction* values

keyValue array contains SFVec3f output values

- As always: same number of *key, keyValue* entries

PositionInterpolator computes weighted average between corresponding x, y and z pairs in the *keyValue* array

- ROUTE to Transform, either *translation* or *scale*



PositionOrientationInterpolatorsExample.x3d - Editor
PositionOrientationInterpolatorsExample.x3d

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive' version='3.1'  xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <meta content='PositionOrientationInterpolatorsExample.x3d' name='title'/>
    <meta content='Demonstrate use of PositionInterpolator and OrientationInterpolator to animate object motion.' name='description'/>
    <meta content='Don Brutzman' name='creator'/>
    <meta content='29 January 2008' name='created'/>
    <meta content='29 January 2008' name='modified'/>
    <meta content='http://X3dGraphics.com' name='reference'/>
    <meta content='http://www.web3d.org/x3d/content/examples/help.html' name='reference'/>
    <meta content='Copyright Don Brutzman and Leonard Daly 2007' name='rights'/>
    <meta content='X3D book, X3D graphics, X3D-Edit, http://www.x3dGraphics.com' name='subject'/>
    <meta content='http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionOrientationInterpolatorsExample.x3d'
         name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='../license.html' name='license'/>
  </head>
  <Scene><Viewpoint description="Animation demo" position="0 4 10" orientation="1 0 1 -0.2"/>
    <Transform translation='1 0 1' DEF='Pointer'>
        <Transform rotation='1 0 0 1.57'>
            <Shape>
                <Cone bottomRadius="0.5" height="1.5"/>
                <Appearance><Material DEF="ConeMaterial" diffuseColor="0.427451 1 0.160784"/></Appearance>
            </Shape>
        </Transform>
    </Transform>
    <Shape DEF="Floor">
        <Box size="10 0.05 10"/>
        <Appearance><Material diffuseColor="0 0.262745 0.941176"/></Appearance>
    </Shape>
    <TimeSensor DEF='AnimationClock' cycleInterval='10' loop='true'/>
    <!-- note that final value equals first value in keyValue array in order to support smooth looping -->
    <!-- first drive around the location -->
    <PositionInterpolator DEF="PositionAnimator" key="0 0.2 0.25 0.45 0.5 0.7 0.75 0.95 1"
        keyValue="-4 0 -4, -4 0 4, -4 0 4, 4 0 4, 4 0 4, 4 0 -4, 4 0 -4, -4 0 -4, -4 0 -4"/>
    <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='PositionAnimator'/>
    <ROUTE fromField='value_changed' fromNode='PositionAnimator' toField='set_translation' toNode='Pointer'/>
    <!-- then rotate the pointer to match next direction while paused at each position -->
    <OrientationInterpolator DEF="OrientationAnimator" key="0 0.2 0.25 0.45 0.5 0.7 0.75 0.95 1"
        keyValue="0 1 0 0, 0 1 0 0, 0 1 0 1.57, 0 1 0 1.57, 0 1 0 3.14, 0 1 0 3.14, 0 1 0 4.71, 0 1 0 4.71, 0 1 0 6.283"/>
        <!-- final rotation value is 2pi rather than 0 so that rotation animation is smooth, not flip-flopping  -->
    <ROUTE fromField='fraction_changed' fromNode='AnimationClock' toField='set_fraction' toNode='OrientationAnimator'/>
    <ROUTE fromField='value_changed' fromNode='OrientationAnimator' toField='set_rotation' toNode='Pointer'/>
    <!-- notice that explanatory Text appears later in scene although it is located above driving plane -->
    <Transform translation='0 3.5 0'>
      <Shape>
        <Text string='"Animation using PositionInterpolator" "a
          <FontStyle justify='"MIDDLE" "MIDDLE"' size='.7'/>
        </Text>
      </Shape>
    </Transform>
  </Scene>
</X3D>
```

Edit PositionInterpolator

DEF ● PositionAnimator

USE ○

containerField

□ children

key, keyValue arrays

#	key	x	y	z
0	0	-4	0	-4
1	0.2	-4	0	4
2	0.25	-4	0	4
3	0.45	4	0	4
4	0.5	4	0	4
5	0.7	4	0	-4
6	0.75	4	0	-4
7	0.95	-4	0	-4
8	1	-4	0	-4

Edit row: Copy Add Remove
Append: □ commas, □ line breaks
Edit cells: Assign cell value: to selected cell Apply
set uniform key spacing

Primary output event is value_changed

□ Trace
Accept
Discard
Help
Animation using PositionInterpolator and OrientationInterpolator
Animation using PositionInterpolator and OrientationInterpolator
Animation using PositionInterpolator and OrientationInterpolator

Event tracing

X3D-Edit author-assist feature provides support for tracing output events

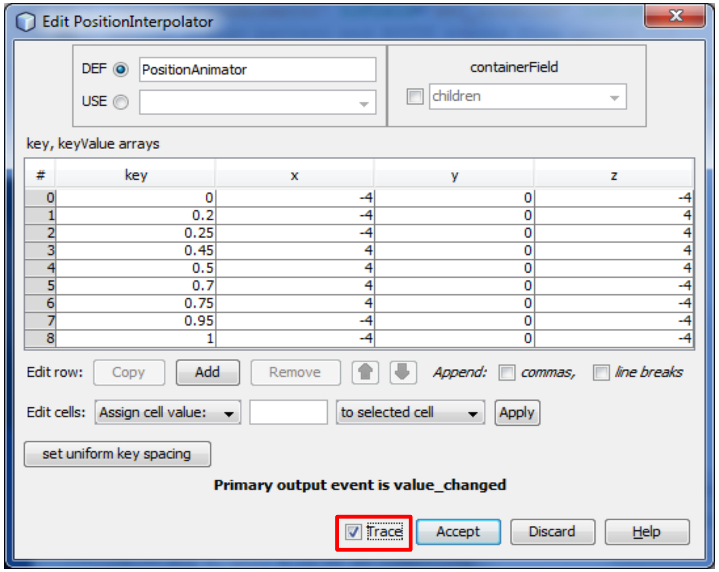
- “Trace” checkbox on editing pane adds some extra X3D source to your scene
- Captures all output events, routes them to a Script
- Script outputs event values to X3D browser console at run time so that you can trace execution logic

Can be helpful for selective debugging when animation chains are not behaving as expected

- Available for ROUTE, most event-producing nodes
- Simply remove when done troubleshooting

Event tracing example

PositionOrientationInterpolatorsExampleTraced.x3d



Edit PositionInterpolator

DEF ● PositionAnimator

USE ○

containerField

□ children

key, keyValue arrays

#	key	x	y	z
0	0	-4	0	-4
1	0.2	-4	0	4
2	0.25	-4	0	4
3	0.45	4	0	4
4	0.5	4	0	4
5	0.7	4	0	-4
6	0.75	4	0	-4
7	0.95	-4	0	-4
8	1	-4	0	-4

Edit row: Copy Add Remove
Append: □ commas, □ line breaks
Edit cells: Assign cell value: to selected cell Apply
set uniform key spacing

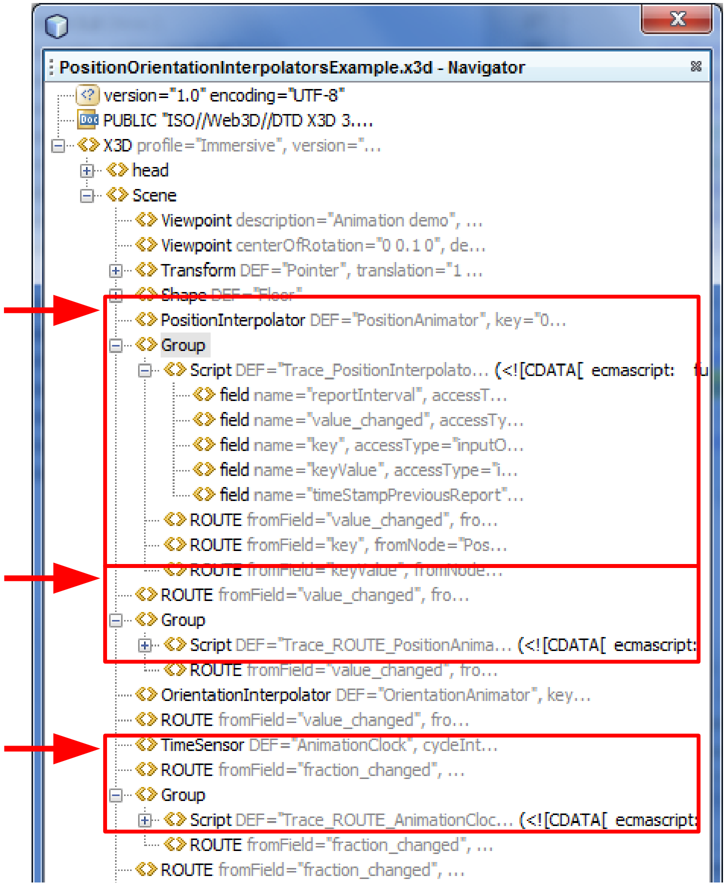
Primary output event is value_changed

☑ Trace

√ Trace

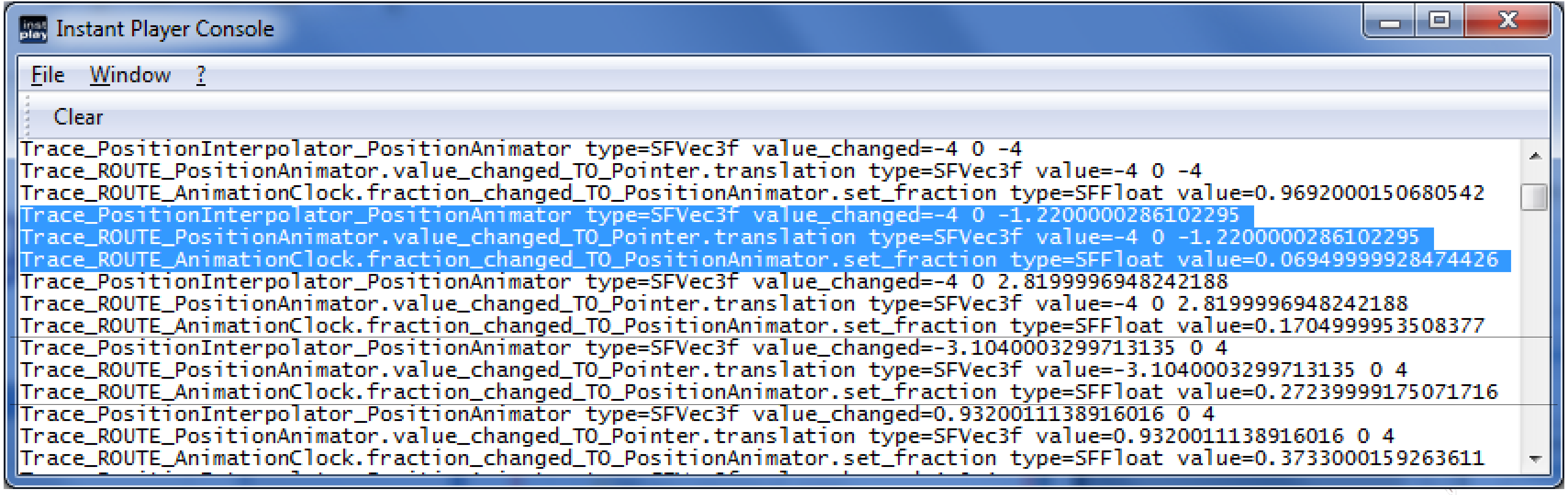
√ Trace

√ Trace



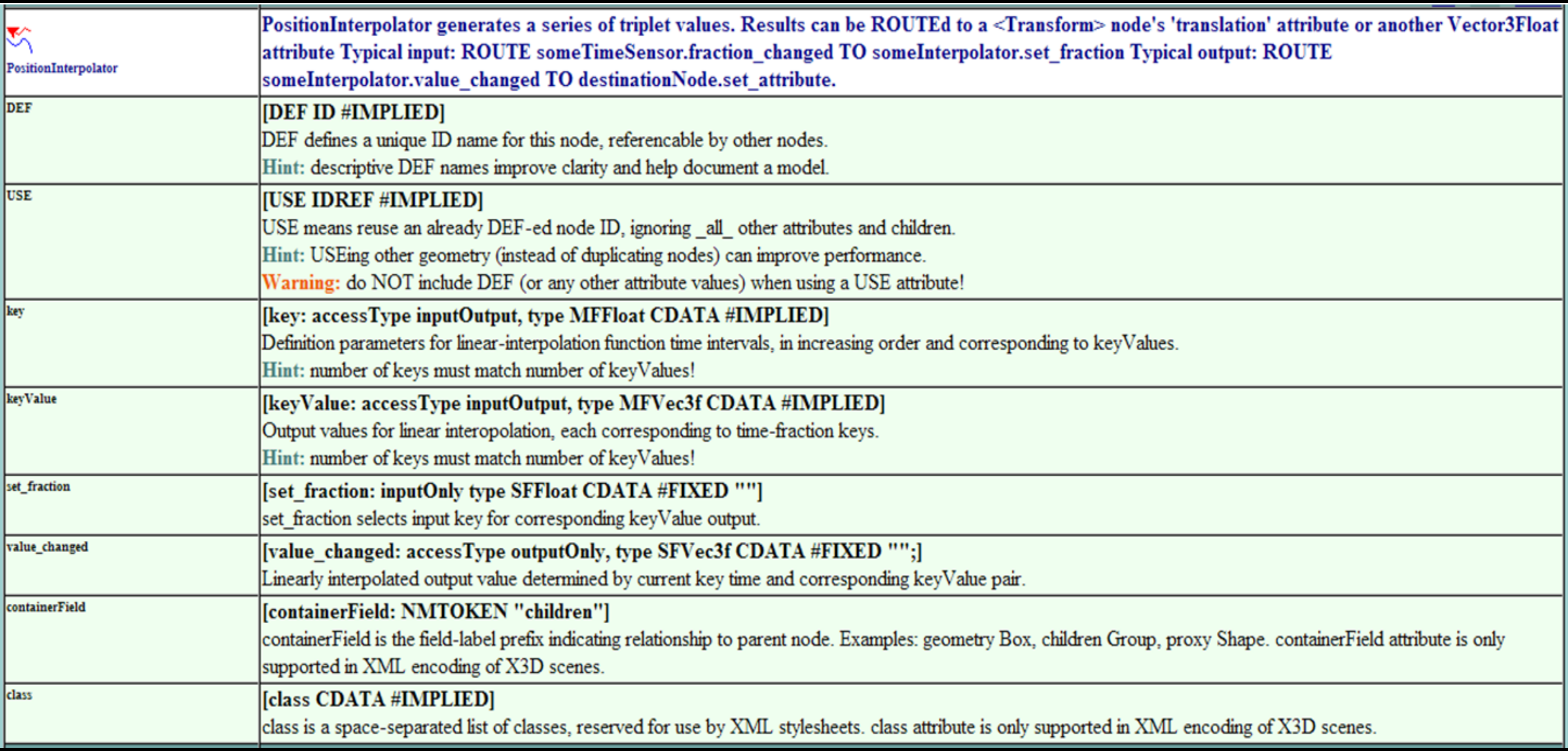
PositionOrientationInterpolatorsExample.x3d - Navigator

```
version="1.0" encoding="UTF-8"
PUBLIC "ISO//Web3D//DTD X3D 3....
X3D profile="Immersive", version="...
  head
  Scene
    Viewpoint description="Animation demo", ...
    Viewpoint centerOfRotation="0 0.1 0", de...
    Transform DEF="Pointer", translation="1 ...
    Shape DEF="Floor"
    PositionInterpolator DEF="PositionAnimator", key="0...
    Group
      Script DEF="Trace_PositionInterpolato... (<![CDATA[ ecmascript:  fu
        field name="reportInterval", accessT...
        field name="value_changed", accessTy...
        field name="key", accessType="inputO...
        field name="keyValue", accessType="i...
        field name="timeStampPreviousReport"...
      ROUTE fromField="value_changed", fro...
      ROUTE fromField="key", fromNode="Pos...
      ROUTE fromField="keyValue", fromNode...
    ROUTE fromField="value_changed", fro...
    Group
      Script DEF="Trace_ROUTE_PositionAnima... (<![CDATA[ ecmascript:
      ROUTE fromField="value_changed", fro...
    OrientationInterpolator DEF="OrientationAnimator", key...
    ROUTE fromField="value_changed", fro...
    TimeSensor DEF="AnimationClock", cycleInt...
    ROUTE fromField="fraction_changed", ...
    Group
      Script DEF="Trace_ROUTE_AnimationCloc... (<![CDATA[ ecmascript:
      ROUTE fromField="fraction_changed", ...
    ROUTE fromField="fraction_changed", ...
```



Instant Player Console

```
Trace_PositionInterpolator_PositionAnimator type=SFVec3f value_changed=-4 0 -4
Trace_ROUTE_PositionAnimator.value_changed_TO_Pointer.translation type=SFVec3f value=-4 0 -4
Trace_ROUTE_AnimationClock.fraction_changed_TO_PositionAnimator.set_fraction type=SFFloat value=0.9692000150680542
Trace_PositionInterpolator_PositionAnimator type=SFVec3f value_changed=-4 0 -1.2200000286102295
Trace_ROUTE_PositionAnimator.value_changed_TO_Pointer.translation type=SFVec3f value=-4 0 -1.2200000286102295
Trace_ROUTE_AnimationClock.fraction_changed_TO_PositionAnimator.set_fraction type=SFFloat value=0.06949999928474426
Trace_PositionInterpolator_PositionAnimator type=SFVec3f value_changed=-4 0 2.8199996948242188
Trace_ROUTE_PositionAnimator.value_changed_TO_Pointer.translation type=SFVec3f value=-4 0 2.8199996948242188
Trace_ROUTE_AnimationClock.fraction_changed_TO_PositionAnimator.set_fraction type=SFFloat value=0.17049999535083770
Trace_PositionInterpolator_PositionAnimator type=SFVec3f value_changed=-3.104003299713135 0 4
Trace_ROUTE_PositionAnimator.value_changed_TO_Pointer.translation type=SFVec3f value=-3.104003299713135 0 4
Trace_ROUTE_AnimationClock.fraction_changed_TO_PositionAnimator.set_fraction type=SFFloat value=0.27239999175071716
Trace_PositionInterpolator_PositionAnimator type=SFVec3f value_changed=0.9320011138916016 0 4
Trace_ROUTE_PositionAnimator.value_changed_TO_Pointer.translation type=SFVec3f value=0.9320011138916016 0 4
Trace_ROUTE_AnimationClock.fraction_changed_TO_PositionAnimator.set_fraction type=SFFloat value=0.3733000159263611
```



PositionInterpolator	**PositionInterpolator generates a series of triplet values. Results can be ROUTEd to a <Transform> node's 'translation' attribute or another Vector3Float attribute Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFVec3f CDATA #FIXED "";]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

PositionInterpolator2D node

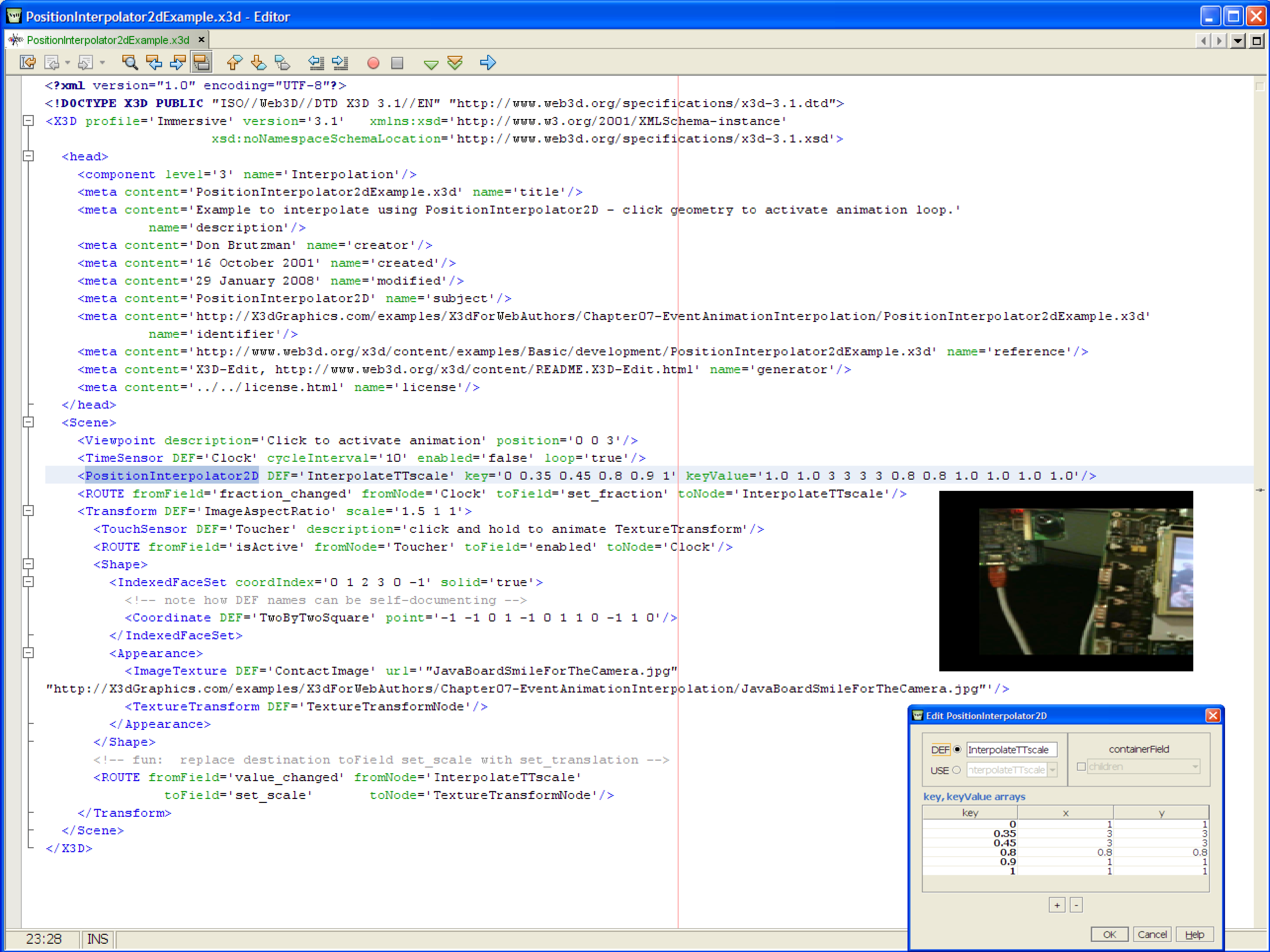
Generates a 2-tuple (two-valued floating point) SFVec2f for *value_changed* output

key array contains SFFloat *fraction* values

keyValue array contains SFVec2f output values

- As always: same number of *key, keyValue* entries

PositionInterpolator2D computes weighted average between corresponding (x, y) pairs in the *keyValue* array



PositionInterpolator2dExample.x3d - Editor

PositionInterpolator2dExample.x3d

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive' version='3.1'   xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <component level='3' name='Interpolation'/>
    <meta content='PositionInterpolator2dExample.x3d' name='title'/>
    <meta content='Example to interpolate using PositionInterpolator2D - click geometry to activate animation loop.'
             name='description'/>
    <meta content='Don Brutzman' name='creator'/>
    <meta content='16 October 2001' name='created'/>
    <meta content='29 January 2008' name='modified'/>
    <meta content='PositionInterpolator2D' name='subject'/>
    <meta content='http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionInterpolator2dExample.x3d'
             name='identifier'/>
    <meta content='http://www.web3d.org/x3d/content/examples/Basic/development/PositionInterpolator2dExample.x3d' name='reference'/>
    <meta content='X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html' name='generator'/>
    <meta content='../../license.html' name='license'/>
  </head>
  <Scene>
    <Viewpoint description='Click to activate animation' position='0 0 3'/>
    <TimeSensor DEF='Clock' cycleInterval='10' enabled='false' loop='true'/>
    <PositionInterpolator2D DEF='InterpolateTTscale' key='0 0.35 0.45 0.8 0.9 1' keyValue='1.0 1.0 3 3 3 3 0.8 0.8 1.0 1.0 1.0 1.0'/>
    <ROUTE fromField='fraction_changed' fromNode='Clock' toField='set_fraction' toNode='InterpolateTTscale'/>
    <Transform DEF='ImageAspectRatio' scale='1.5 1 1'>
      <TouchSensor DEF='Toucher' description='click and hold to animate TextureTransform'/>
      <ROUTE fromField='isActive' fromNode='Toucher' toField='enabled' toNode='Clock'/>
      <Shape>
        <IndexedFaceSet coordIndex='0 1 2 3 0 -1' solid='true'>
          <!-- note how DEF names can be self-documenting -->
          <Coordinate DEF='TwoByTwoSquare' point='-1 -1 0 1 -1 0 1 1 0 -1 1 0'/>
        </IndexedFaceSet>
        <Appearance>
          <ImageTexture DEF='ContactImage' url='"JavaBoardSmileForTheCamera.jpg"
"http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/JavaBoardSmileForTheCamera.jpg"'/>
          <TextureTransform DEF='TextureTransformNode'/>
        </Appearance>
      </Shape>
      <!-- fun:  replace destination toField set_scale with set_translation -->
      <ROUTE fromField='value_changed' fromNode='InterpolateTTscale'
             toField='set_scale'       toNode='TextureTransformNode'/>
    </Transform>
  </Scene>
</X3D>
```

Edit PositionInterpolator2D

DEF ● InterpolateTTscale

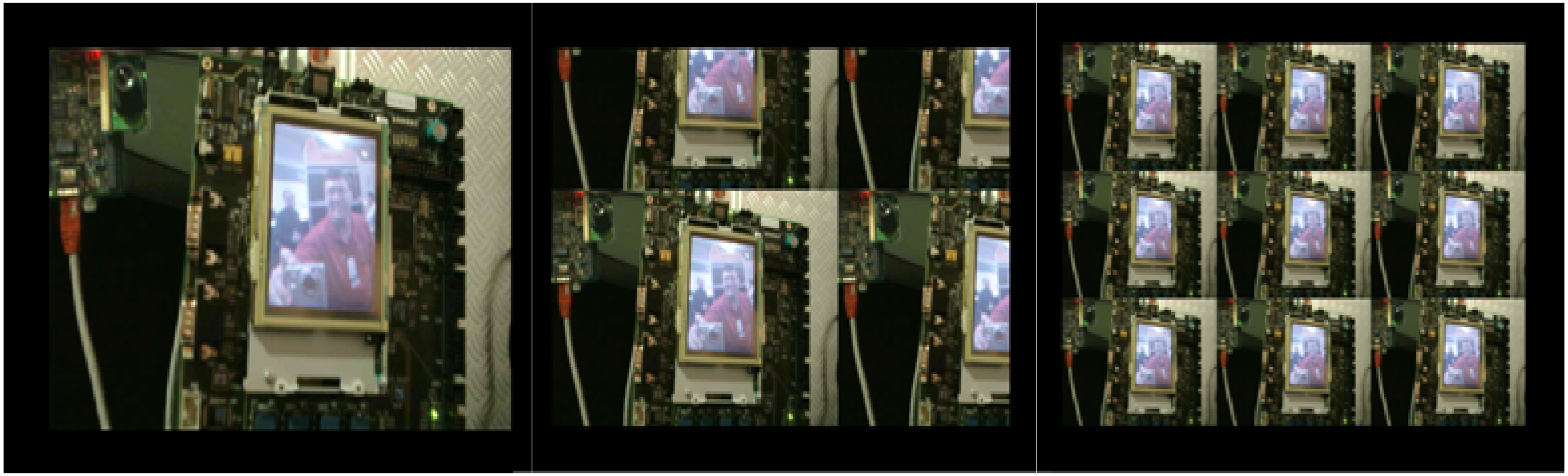
USE ○ nterpolateTTscale

containerField ☐ children

key, keyValue arrays

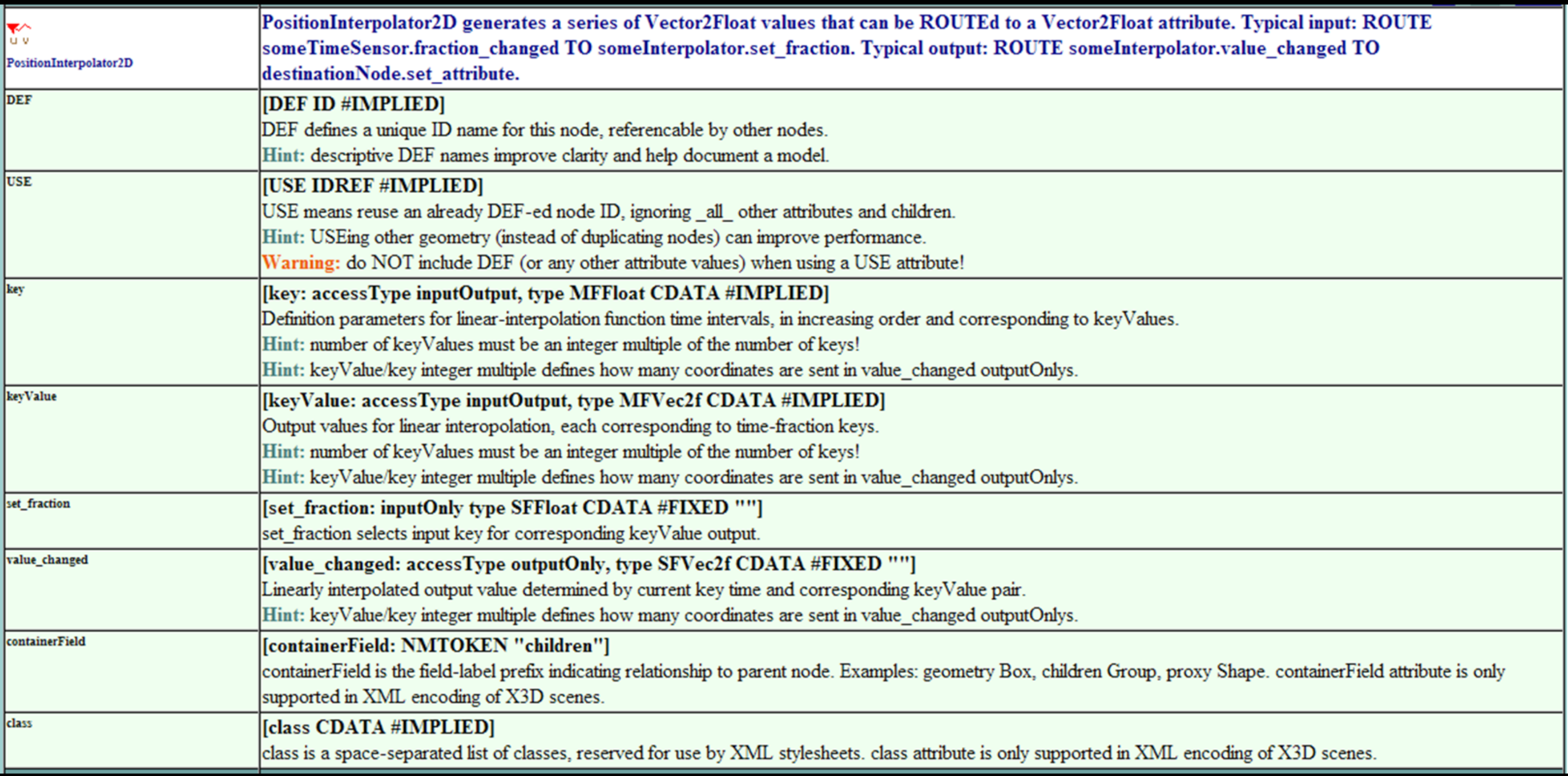
key	x	y
0	1	1
0.35	3	3
0.45	3	3
0.8	0.8	0.8
0.9	1	1
1	1	1

PositionInterpolator2D screen captures



Selecting the texture with the mouse pointer starts the TextureTransform *scale* animation,

deselecting the texture stops the animation



PositionInterpolator2D	**PositionInterpolator2D generates a series of Vector2Float values that can be ROUTEd to a Vector2Float attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
keyValue	**[keyValue: accessType inputOutput, type MFVec2f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFVec2f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair. Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

NormalInterpolator node

Generates a 3-tuple (three-valued floating point) SFVec3f for *value_changed* output

key array contains SFFloat values

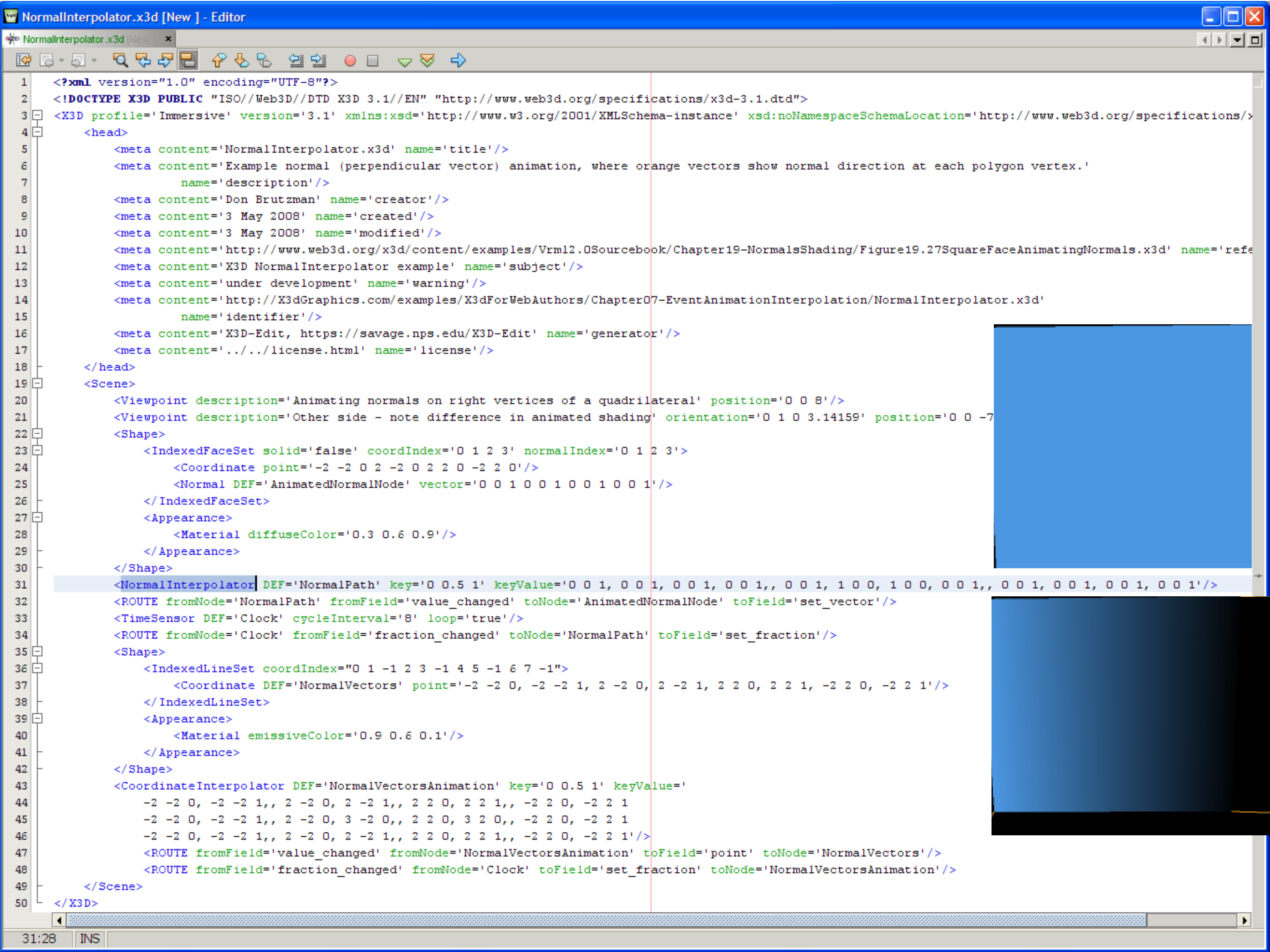
keyValue array contains SFVec3f values

- As always: same number of *key, keyValue* entries
- SFVec3f outputs: unit-normal vectors, magnitude=1

NormalInterpolator animates along shortest path between the pair of normal vectors currently being referenced in *keyValue* array

Normal vectors used for special shading effects

- see Chapter13 - Geometry Triangles Quadrilaterals



NormalInterpolator.x3d [New] - Editor
NormalInterpolator.x3d [New]
31:28
INS

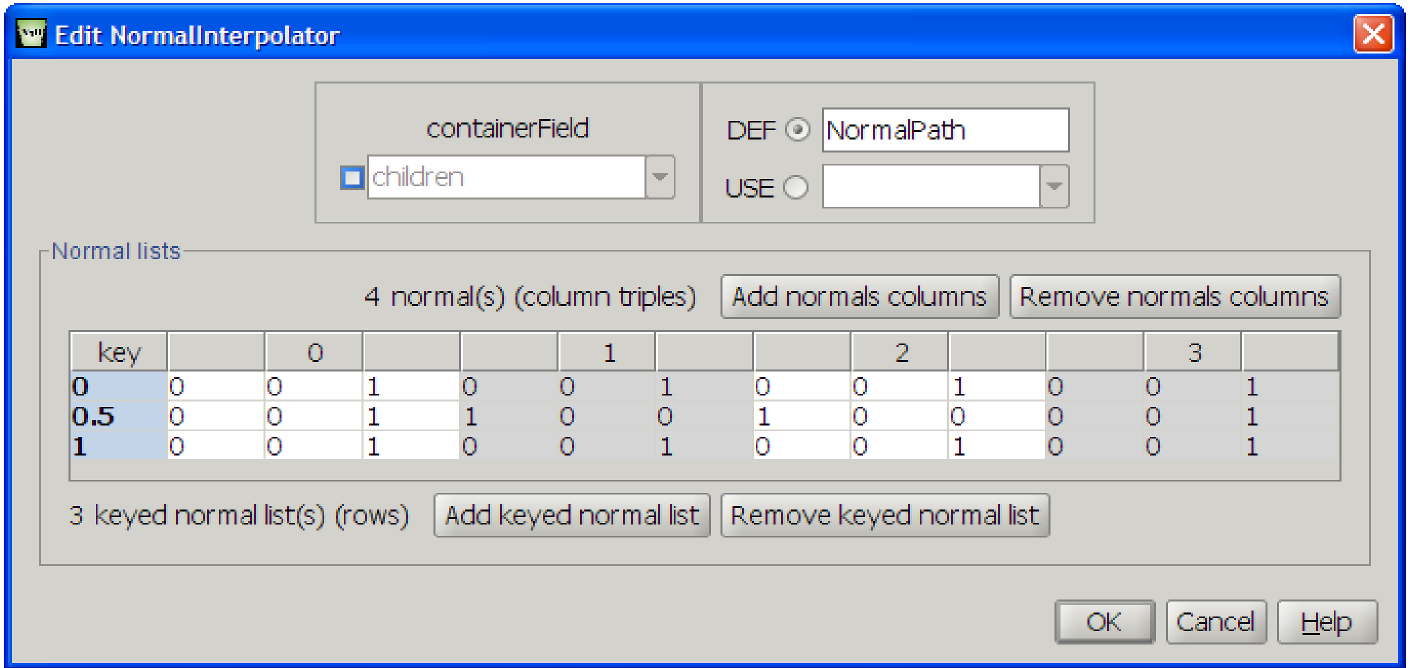
```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive' version='3.1' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x
    <head>
        <meta content='NormalInterpolator.x3d' name='title'/>
        <meta content='Example normal (perpendicular vector) animation, where orange vectors show normal direction at each polygon vertex.'
                  name='description'/>
        <meta content='Don Brutzman' name='creator'/>
        <meta content='3 May 2008' name='created'/>
        <meta content='3 May 2008' name='modified'/>
        <meta content='http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook/Chapter19-NormalsShading/Figure19.27SquareFaceAnimatingNormals.x3d' name='refe
        <meta content='X3D NormalInterpolator example' name='subject'/>
        <meta content='under development' name='warning'/>
        <meta content='http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/NormalInterpolator.x3d'
                  name='identifier'/>
        <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
        <meta content='../../license.html' name='license'/>
    </head>
    <Scene>
        <Viewpoint description='Animating normals on right vertices of a quadrilateral' position='0 0 8'/>
        <Viewpoint description='Other side - note difference in animated shading' orientation='0 1 0 3.14159' position='0 0 -7
        <Shape>
            <IndexedFaceSet solid='false' coordIndex='0 1 2 3' normalIndex='0 1 2 3'>
                <Coordinate point='-2 -2 0 2 -2 0 2 2 0 -2 2 0'/>
                <Normal DEF='AnimatedNormalNode' vector='0 0 1 0 0 1 0 0 1 0 0 1'/>
            </IndexedFaceSet>
            <Appearance>
                <Material diffuseColor='0.3 0.6 0.9'/>
            </Appearance>
        </Shape>
        <NormalInterpolator DEF='NormalPath' key='0 0.5 1' keyValue='0 0 1, 0 0 1, 0 0 1, 0 0 1,, 0 0 1, 1 0 0, 1 0 0, 0 0 1,, 0 0 1, 0 0 1, 0 0 1, 0 0 1'/>
        <ROUTE fromNode='NormalPath' fromField='value_changed' toNode='AnimatedNormalNode' toField='set_vector'/>
        <TimeSensor DEF='Clock' cycleInterval='8' loop='true'/>
        <ROUTE fromNode='Clock' fromField='fraction_changed' toNode='NormalPath' toField='set_fraction'/>
        <Shape>
            <IndexedLineSet coordIndex="0 1 -1 2 3 -1 4 5 -1 6 7 -1">
                <Coordinate DEF='NormalVectors' point='-2 -2 0, -2 -2 1, 2 -2 0, 2 -2 1, 2 2 0, 2 2 1, -2 2 0, -2 2 1'/>
            </IndexedLineSet>
            <Appearance>
                <Material emissiveColor='0.9 0.6 0.1'/>
            </Appearance>
        </Shape>
        <CoordinateInterpolator DEF='NormalVectorsAnimation' key='0 0.5 1' keyValue='
            -2 -2 0, -2 -2 1,, 2 -2 0, 2 -2 1,, 2 2 0, 2 2 1,, -2 2 0, -2 2 1
            -2 -2 0, -2 -2 1,, 2 -2 0, 3 -2 0,, 2 2 0, 3 2 0,, -2 2 0, -2 2 1
            -2 -2 0, -2 -2 1,, 2 -2 0, 2 -2 1,, 2 2 0, 2 2 1,, -2 2 0, -2 2 1'/>
            <ROUTE fromField='value_changed' fromNode='NormalVectorsAnimation' toField='point' toNode='NormalVectors'/>
            <ROUTE fromField='fraction_changed' fromNode='Clock' toField='set_fraction' toNode='NormalVectorsAnimation'/>
    </Scene>
</X3D>
```

NormalInterpolator editor

Rows correspond to each key

Correct results have same number of MFVec3f values in each row

Normal-to-normal interpolation occurs on each column, allowing easier comparison



Edit NormalInterpolator

containerField ☐ children

DEF ● NormalPath

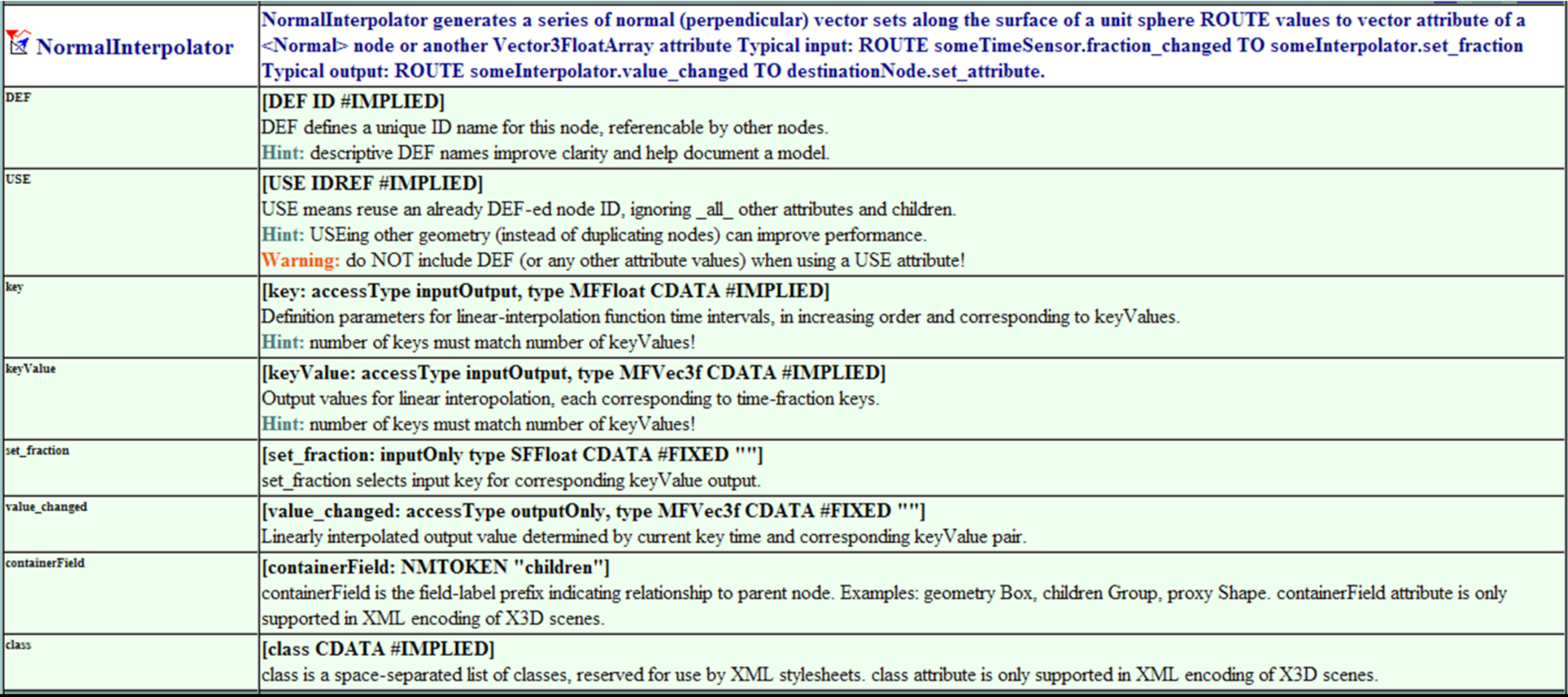
USE ○

Normal lists

4 normal(s) (column triples)

key		0			1			2			3	
0	0	0	1	0	0	1	0	0	1	0	0	1
0.5	0	0	1	1	0	0	1	0	0	0	0	1
1	0	0	1	0	0	1	0	0	1	0	0	1

3 keyed normal list(s) (rows)



NormalInterpolator	NormalInterpolator generates a series of normal (perpendicular) vector sets along the surface of a unit sphere ROUTE values to vector attribute of a <Normal> node or another Vector3FloatArray attribute Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. **Hint:** descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. **Hint:** USEing other geometry (instead of duplicating nodes) can improve performance. **Warning:** do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. **Hint:** number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. **Hint:** number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type MFVec3f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

CoordinateInterpolator2D node

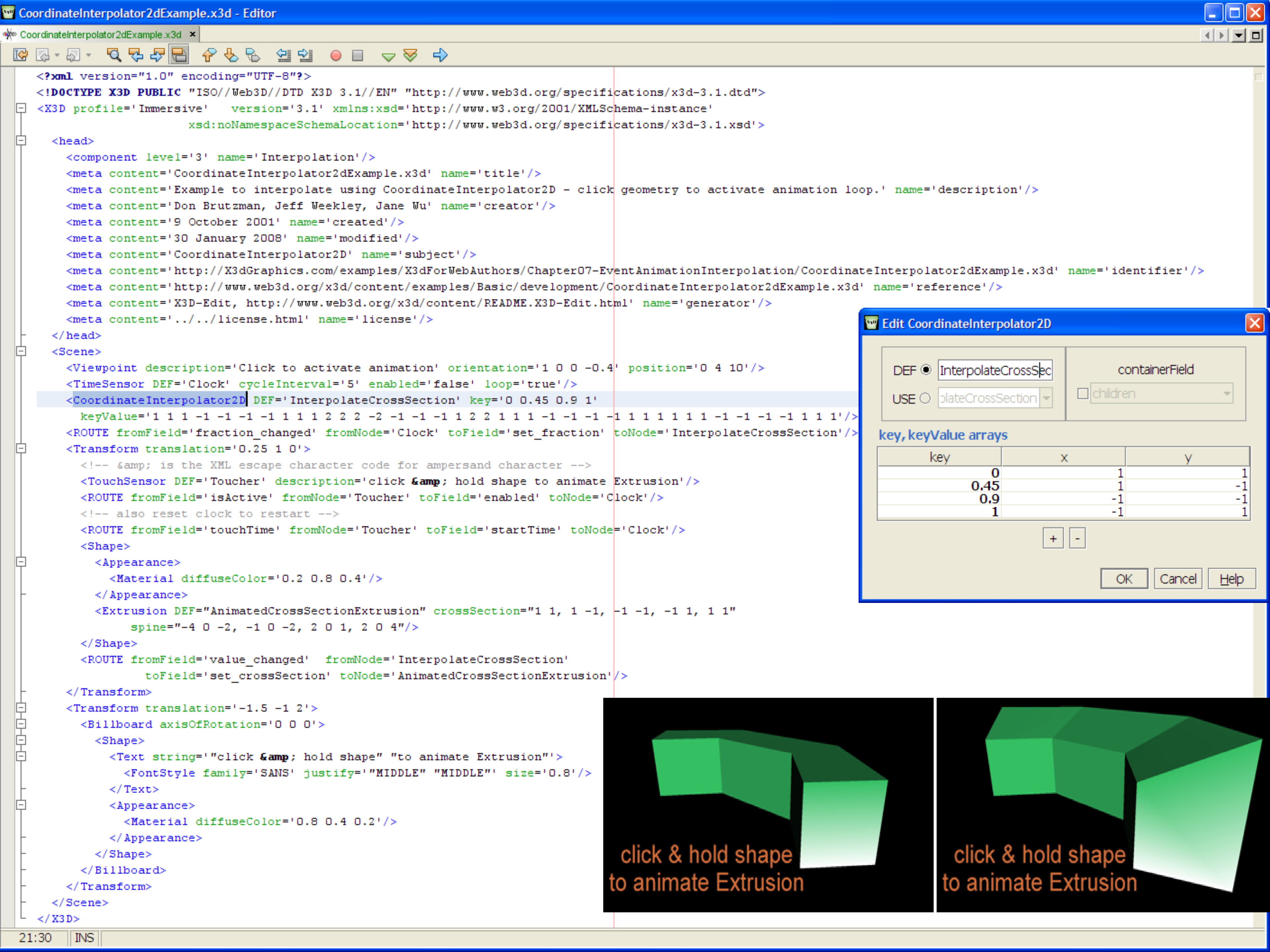
Generates 2-tuple (two-valued floating point) array, MFVec2f for *value_changed* output

key array contains SFFloat values

keyValue array contains MFVec2f values

- As always: same number of *key, keyValue* entries
- Counting is very important for arrays of arrays!

CoordinateInterpolator2D computes weighted average between corresponding x and y pairs for each subarray in the *keyValue* array



CoordinateInterpolator2dExample.x3d - Editor

CoordinateInterpolator2dExample.x3d

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.1//EN" "http://www.web3d.org/specifications/x3d-3.1.dtd">
<X3D profile='Immersive'  version='3.1' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance'
                     xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.1.xsd'>
  <head>
    <component level='3' name='Interpolation'/>
    <meta content='CoordinateInterpolator2dExample.x3d' name='title'/>
    <meta content='Example to interpolate using CoordinateInterpolator2D - click geometry to activate animation loop.' name='description'/>
    <meta content='Don Brutzman, Jeff Weekley, Jane Wu' name='creator'/>
    <meta content='9 October 2001' name='created'/>
    <meta content='30 January 2008' name='modified'/>
    <meta content='CoordinateInterpolator2D' name='subject'/>
    <meta content='http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/CoordinateInterpolator2dExample.x3d' name='identifier'/>
    <meta content='http://www.web3d.org/x3d/content/examples/Basic/development/CoordinateInterpolator2dExample.x3d' name='reference'/>
    <meta content='X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html' name='generator'/>
    <meta content='../../license.html' name='license'/>
  </head>
  <Scene>
    <Viewpoint description='Click to activate animation' orientation='1 0 0 -0.4' position='0 4 10'/>
    <TimeSensor DEF='Clock' cycleInterval='5' enabled='false' loop='true'/>
    <CoordinateInterpolator2D DEF='InterpolateCrossSection' key='0 0.45 0.9 1'
      keyValue='1 1 1 -1 -1 -1 -1 1 1 1 2 2 2 -2 -1 -1 -1 1 2 2 1 1 1 -1 -1 -1 -1 1 1 1 1 1 1 1 -1 -1 -1 -1 1 1 1'/>
    <ROUTE fromField='fraction_changed' fromNode='Clock' toField='set_fraction' toNode='InterpolateCrossSection'/>
    <Transform translation='0.25 1 0'>
      <!-- &amp; is the XML escape character code for ampersand character -->
      <TouchSensor DEF='Toucher' description='click &amp; hold shape to animate Extrusion'/>
      <ROUTE fromField='isActive' fromNode='Toucher' toField='enabled' toNode='Clock'/>
      <!-- also reset clock to restart -->
      <ROUTE fromField='touchTime' fromNode='Toucher' toField='startTime' toNode='Clock'/>
      <Shape>
        <Appearance>
          <Material diffuseColor='0.2 0.8 0.4'/>
        </Appearance>
        <Extrusion DEF="AnimatedCrossSectionExtrusion" crossSection="1 1, 1 -1, -1 -1, -1 1, 1 1"
             spine="-4 0 -2, -1 0 -2, 2 0 1, 2 0 4"/>
      </Shape>
      <ROUTE fromField='value_changed'  fromNode='InterpolateCrossSection'
             toField='set_crossSection' toNode='AnimatedCrossSectionExtrusion'/>
    </Transform>
    <Transform translation='-1.5 -1 2'>
      <Billboard axisOfRotation='0 0 0'>
        <Shape>
          <Text string='"click &amp; hold shape" "to animate Extrusion"'>
            <FontStyle family='SANS' justify='"MIDDLE" "MIDDLE"' size='0.8'/>
          </Text>
          <Appearance>
            <Material diffuseColor='0.8 0.4 0.2'/>
          </Appearance>
        </Shape>
      </Billboard>
    </Transform>
  </Scene>
</X3D>
```

21:30 INS

Edit CoordinateInterpolator2D

DEF ● InterpolateCrossSec

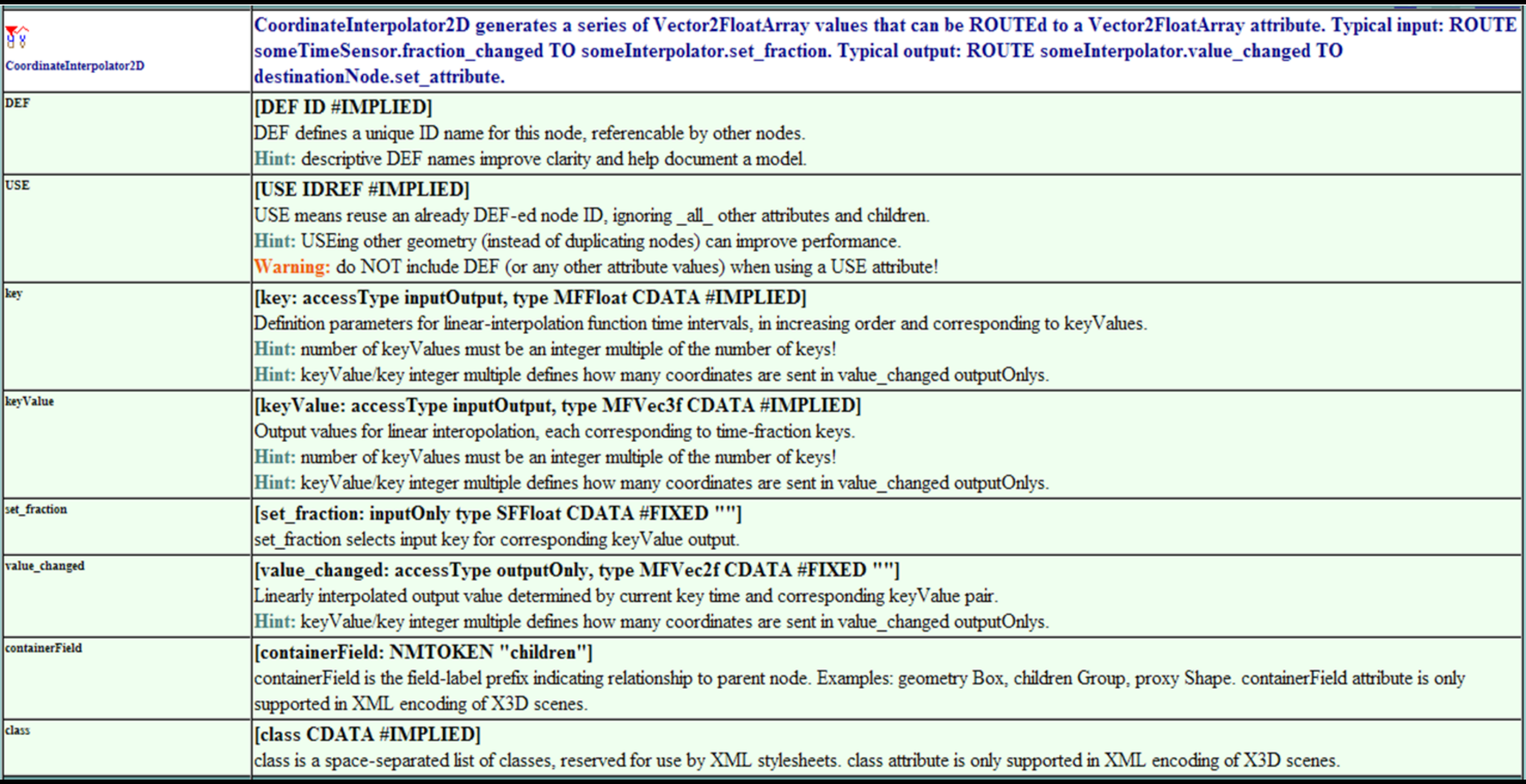
USE ○ olateCrossSection

containerField

□ children

key, keyValue arrays

key	x	y
0	1	1
0.45	1	-1
0.9	-1	-1
1	-1	1



CoordinateInterpolator2D	**CoordinateInterpolator2D generates a series of Vector2FloatArray values that can be ROUTEd to a Vector2FloatArray attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type MFVec2f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair. Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

CoordinateInterpolator node

Generates *n*-tuple (multiple-valued floating point) array, MFFloat for *value_changed* output

key array contains *n* SFFloat values

keyValue array contains *n* MFFloat values

- As always: same number of *key, keyValue* entries
- Counting is very important for arrays of arrays!

CoordinateInterpolator computes weighted average between corresponding element pairs for each subarray in the *keyValue* array

Morphing images in 2D

Morphing 2D is the smooth transformation of one image into another using digital in-betweening

- Not a feature built into X3D

Typically this is done by identifying control points and gradually changing individual pixel colors from one 2D image into another

- Initial and final 2D images are already defined
- Corresponding control points are carefully chosen
- Special algorithms are applied
- Now a common photographic editing technique

Morphing models in X3D

Morphing 3D is the smooth transformation of one model into another using digital in-betweening

- Supported in X3D by CoordinateInterpolator node

Typically this is done by identifying control points and gradually changing coordinates from one set of values to another

- Linear interpolation value-by-value for each point
- Also usable for colors, normals, texture coordinates

We will use this technique to morph between 3D coordinate sets using CoordinateInterpolator

Creating a morphable model

1. Create baseline model geometry
   - typically an IndexedFaceSet node
2. Create alternate poses in key positions
   - Ensure that same geometric layout is maintained
   - These are referred to as “key frames”
   - Can observe proper sequencing via a Switch node
3. Use each set of point position values as part of a CoordinateInterpolator keyValue array
   - Corresponding key array holds fraction durations, similar to any other interpolator node

CoordinateInterpolator node X3D-Edit

Case-study example: morphing a dolphin model

- Chris Lang, author
- Monterey High School class of 2008
- Models online at

https://savage.nps.edu/Savage/Biologics/Dolphin

Creating a morphable dolphin 1

1. Create baseline model geometry
   - typically an IndexedFaceSet node

Chris Lang first built a dolphin model using Maya

- advanced 3D modeling tool, commercial product
- http://autodesk.com > Products > Maya

Such models tend to be complex, perhaps saved in proprietary or perhaps-confusing formats

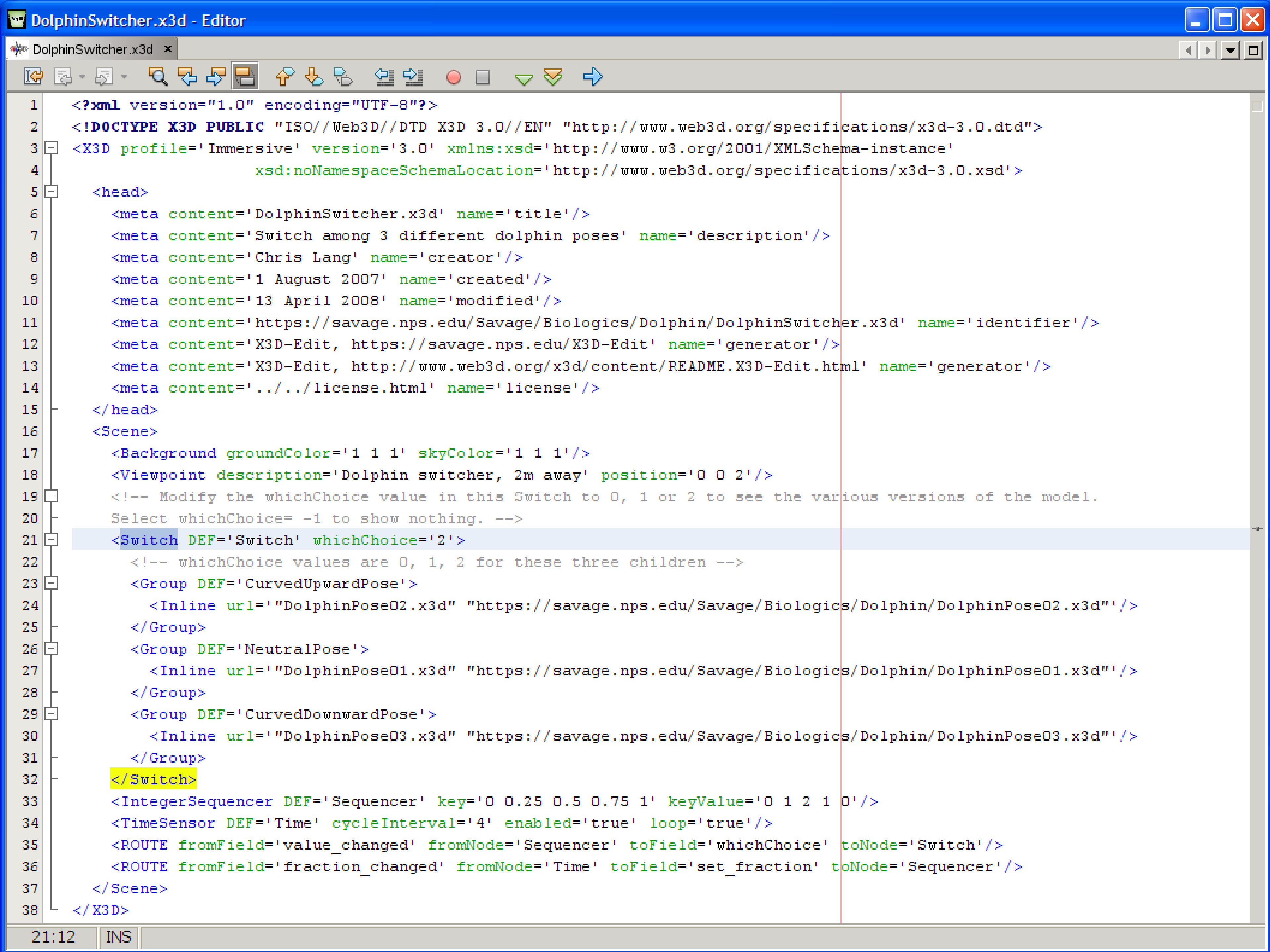
- But can nevertheless be saved as X3D or VRML, making this approach reasonably repeatable
- Can also use Aaron Bergstrom's Rawkee tool

Creating a morphable dolphin 2

2. Create alternate poses in key positions
    - Ensure that same geometric layout is maintained
    - These are referred to as “key frames”
    - Can observe proper sequencing via a Switch node

The original model was then modified to match other poses, making sure each time that no new coordinate points were added or deleted

- Each individually saved as X3D or VRML scenes
- Switch cycler allows direct comparison of each



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                   xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.0.xsd'>
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    <meta content='Switch among 3 different dolphin poses' name='description'/>
    <meta content='Chris Lang' name='creator'/>
    <meta content='1 August 2007' name='created'/>
    <meta content='13 April 2008' name='modified'/>
    <meta content='https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinSwitcher.x3d' name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html' name='generator'/>
    <meta content='../../license.html' name='license'/>
  </head>
  <Scene>
    <Background groundColor='1 1 1' skyColor='1 1 1'/>
    <Viewpoint description='Dolphin switcher, 2m away' position='0 0 2'/>
    <!-- Modify the whichChoice value in this Switch to 0, 1 or 2 to see the various versions of the model.
    Select whichChoice= -1 to show nothing. -->
    <Switch DEF='Switch' whichChoice='2'>
      <!-- whichChoice values are 0, 1, 2 for these three children -->
      <Group DEF='CurvedUpwardPose'>
        <Inline url='"DolphinPose02.x3d" "https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinPose02.x3d"'/>
      </Group>
      <Group DEF='NeutralPose'>
        <Inline url='"DolphinPose01.x3d" "https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinPose01.x3d"'/>
      </Group>
      <Group DEF='CurvedDownwardPose'>
        <Inline url='"DolphinPose03.x3d" "https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinPose03.x3d"'/>
      </Group>
    </Switch>
    <IntegerSequencer DEF='Sequencer' key='0 0.25 0.5 0.75 1' keyValue='0 1 2 1 0'/>
    <TimeSensor DEF='Time' cycleInterval='4' enabled='true' loop='true'/>
    <ROUTE fromField='value_changed' fromNode='Sequencer' toField='whichChoice' toNode='Switch'/>
    <ROUTE fromField='fraction_changed' fromNode='Time' toField='set_fraction' toNode='Sequencer'/>
  </Scene>
</X3D>
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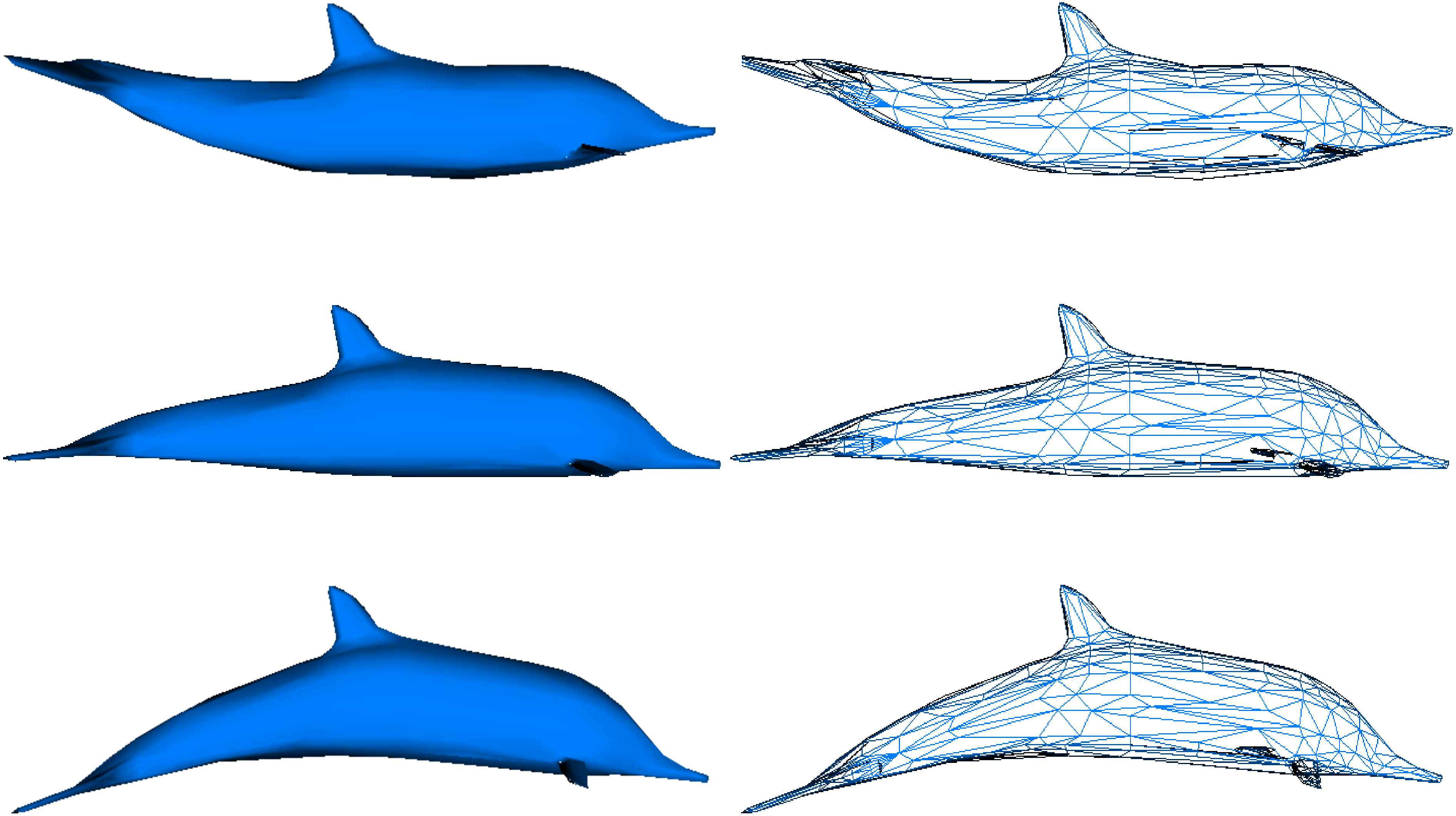
DolphinPose02.x3d DolphinPose01.x3d DolphinPose03.x3d



Creating a morphable dolphin 3

3. Use each set of point position values as part of a CoordinateInterpolator keyValue array

    Corresponding key array holds fraction durations, similar to any other interpolator node

Define pose sequence for CoordinateInterpolator

- 02 CurvedUpwardPose
- 01 NeutralPose
- 03 CurvedDownwardPose
- 01 NeutralPose
- 02 CurvedUpwardPose completes loop, then repeat

Creating a morphable dolphin 4

CoordinateInterpolator *key* array lists all five at equal time-fraction intervals:

- key='0 0.25 0.5 0.75 1'

Now need to build *keyValue* array

- Brute-force approach is then to copy set of array values from each <Coordinate point='...'/> pose

But note that each point sequence is quite long

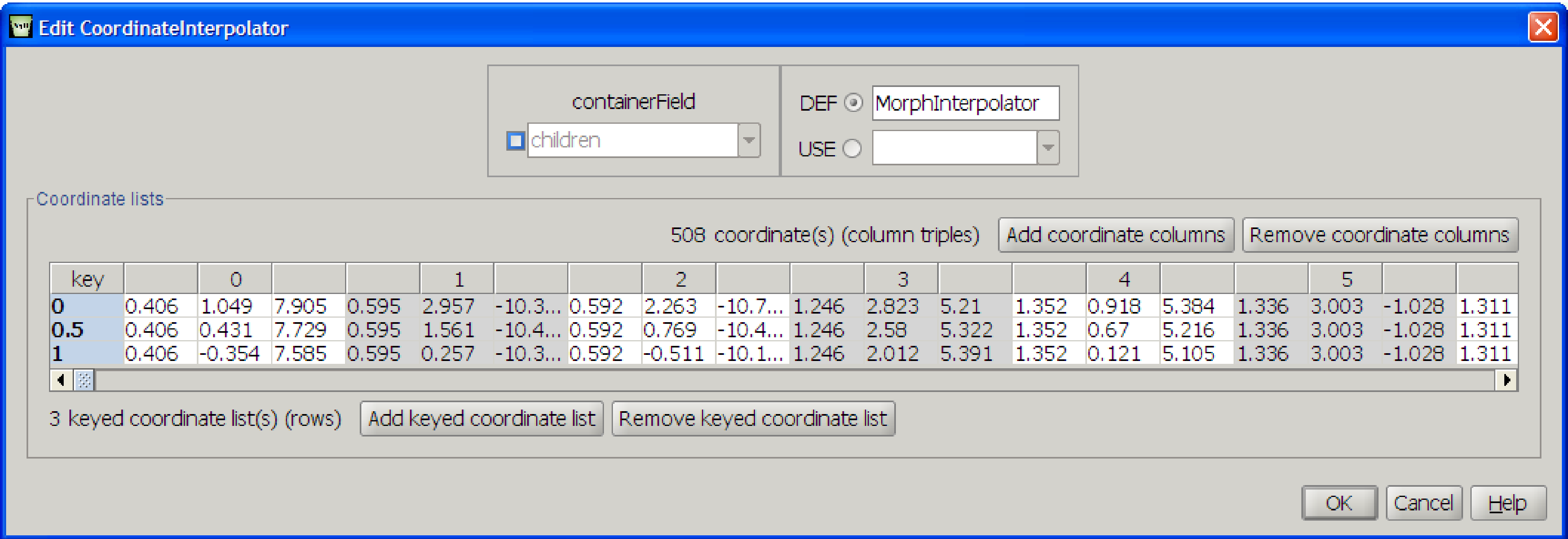
- 508 points, meaning 1524 x-y-z values for each!!
- 5 arrays hold 7620 points total, 40% duplication
- Prefer 3 arrays, 4572 points, no array duplication

CoordinateInterpolator editor

Rows correspond to each key

Correct results have same number of MFVec3f values in each row

Point-by-point interpolation occurs on each column, allowing easier comparison



containerField

□ children

DEF ● MorphInterpolator

USE ○

Coordinate lists

508 coordinate(s) (column triples)

key		0			1			2			3			4			5		
0	0.406	1.049	7.905	0.595	2.957	-10.3...	0.592	2.263	-10.7...	1.246	2.823	5.21	1.352	0.918	5.384	1.336	3.003	-1.028	1.311
0.5	0.406	0.431	7.729	0.595	1.561	-10.4...	0.592	0.769	-10.4...	1.246	2.58	5.322	1.352	0.67	5.216	1.336	3.003	-1.028	1.311
1	0.406	-0.354	7.585	0.595	0.257	-10.3...	0.592	-0.511	-10.1...	1.246	2.012	5.391	1.352	0.121	5.105	1.336	3.003	-1.028	1.311

3 keyed coordinate list(s) (rows)

Modifying TimeSensor outputs 1

Two ways to achieve the same pose sequence

- Five poses: forward 02, 01, 03, 01, 02, repeat
- Three poses: forward 02, 01, 03, backwards, repeat

Build the second approach by modifying the TimeSensor fraction_changed output via a ScalarInterpolator

- TimeSensor output ramps from 0..1 linearly
- Five-pose CoordinateInterpolator uses 0..1 directly
- ScalarInterpolator output ramps 0 to 1 then back to 0
- Three-pose CoordinateInterpolator uses 0..1..0 instead

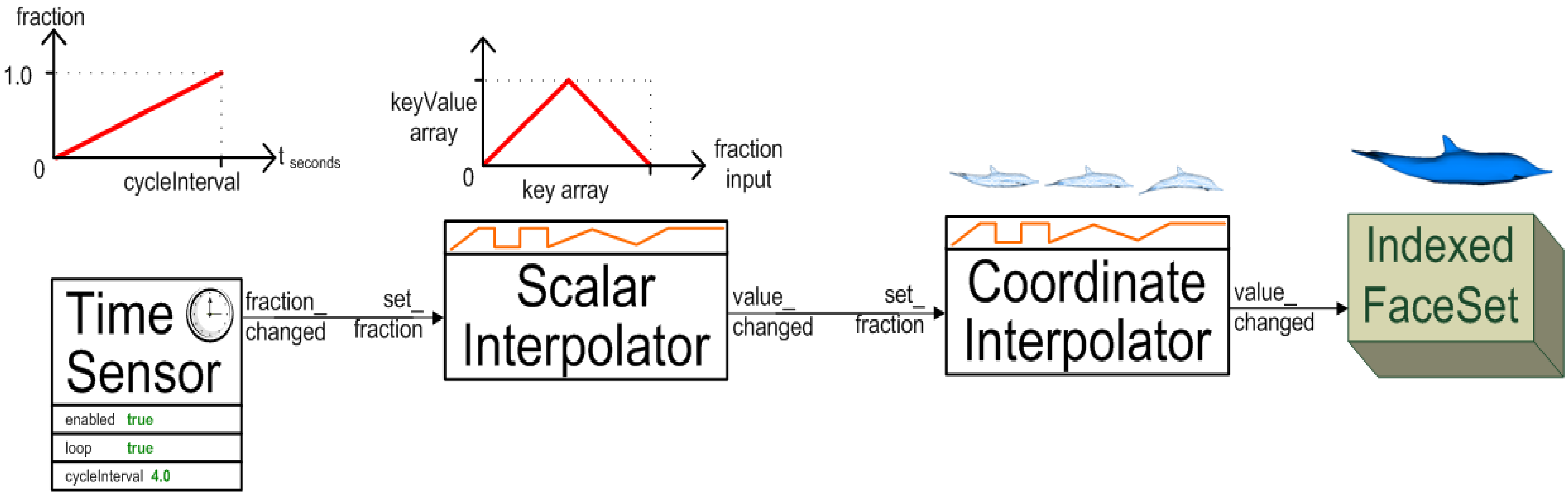
Modifying TimeSensor outputs 2

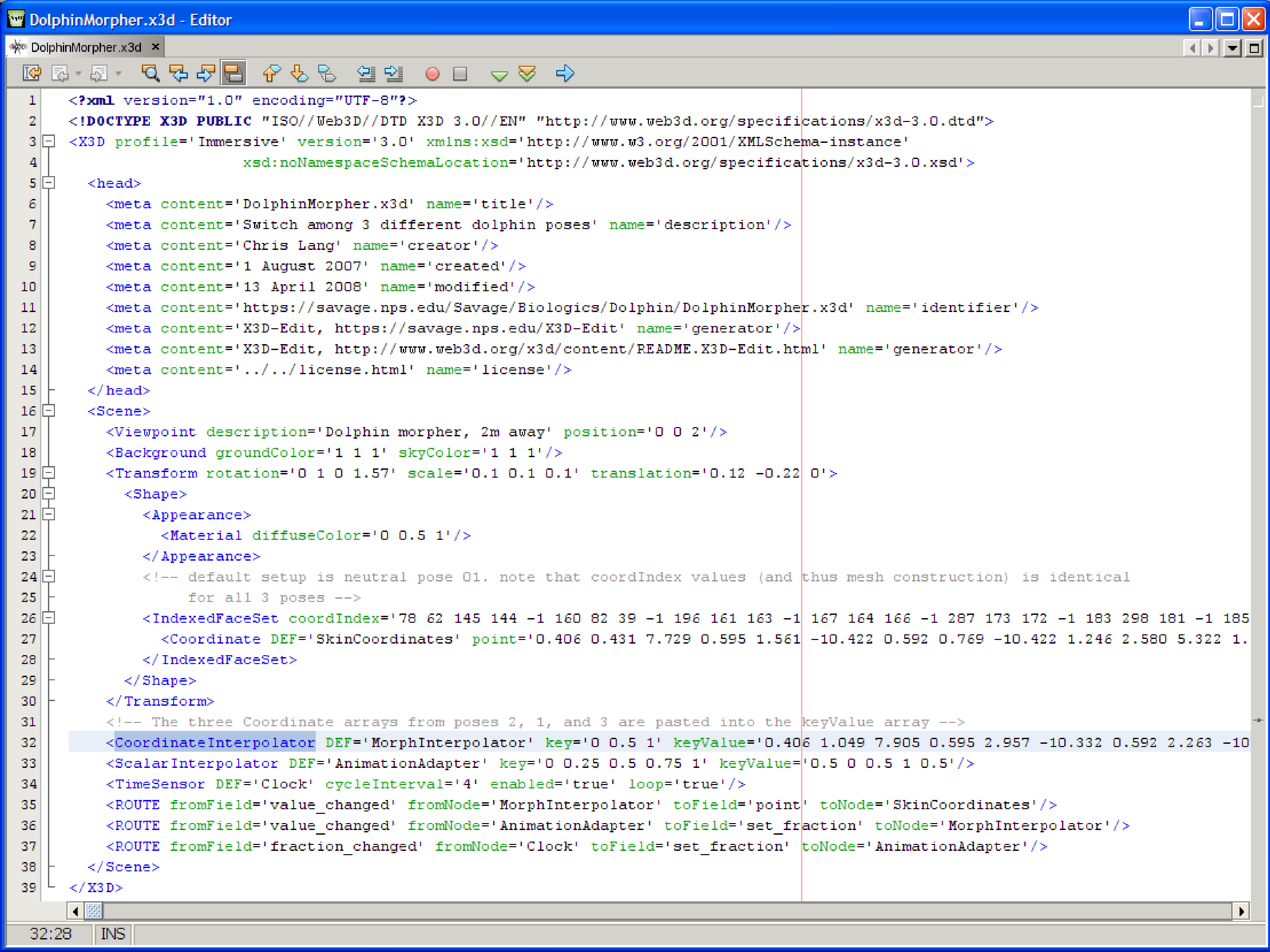
Can modify TimeSensor output by ROUTE connections through a ScalarInterpolator

- Change timing characteristic from 0..1 to 0..1..0

Resulting sequence of five poses:

- forward 02, 01, 03, backwards 03, 01, 02, repeat





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                   xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.0.xsd'>
  <head>
    <meta content='DolphinMorpher.x3d' name='title'/>
    <meta content='Switch among 3 different dolphin poses' name='description'/>
    <meta content='Chris Lang' name='creator'/>
    <meta content='1 August 2007' name='created'/>
    <meta content='13 April 2008' name='modified'/>
    <meta content='https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinMorpher.x3d' name='identifier'/>
    <meta content='X3D-Edit, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='X3D-Edit, http://www.web3d.org/x3d/content/README.X3D-Edit.html' name='generator'/>
    <meta content='../../license.html' name='license'/>
  </head>
  <Scene>
    <Viewpoint description='Dolphin morpher, 2m away' position='0 0 2'/>
    <Background groundColor='1 1 1' skyColor='1 1 1'/>
    <Transform rotation='0 1 0 1.57' scale='0.1 0.1 0.1' translation='0.12 -0.22 0'>
      <Shape>
        <Appearance>
          <Material diffuseColor='0 0.5 1'/>
        </Appearance>
        <!-- default setup is neutral pose 01. note that coordIndex values (and thus mesh construction) is identical
             for all 3 poses -->
        <IndexedFaceSet coordIndex='78 62 145 144 -1 160 82 39 -1 196 161 163 -1 167 164 166 -1 287 173 172 -1 183 298 181 -1 185
          <Coordinate DEF='SkinCoordinates' point='0.406 0.431 7.729 0.595 1.561 -10.422 0.592 0.769 -10.422 1.246 2.580 5.322 1.
        </IndexedFaceSet>
      </Shape>
    </Transform>
    <!-- The three Coordinate arrays from poses 2, 1, and 3 are pasted into the keyValue array -->
    <CoordinateInterpolator DEF='MorphInterpolator' key='0 0.5 1' keyValue='0.406 1.049 7.905 0.595 2.957 -10.332 0.592 2.263 -10
    <ScalarInterpolator DEF='AnimationAdapter' key='0 0.25 0.5 0.75 1' keyValue='0.5 0 0.5 1 0.5'/>
    <TimeSensor DEF='Clock' cycleInterval='4' enabled='true' loop='true'/>
    <ROUTE fromField='value_changed' fromNode='MorphInterpolator' toField='point' toNode='SkinCoordinates'/>
    <ROUTE fromField='value_changed' fromNode='AnimationAdapter' toField='set_fraction' toNode='MorphInterpolator'/>
    <ROUTE fromField='fraction_changed' fromNode='Clock' toField='set_fraction' toNode='AnimationAdapter'/>
  </Scene>
</X3D>
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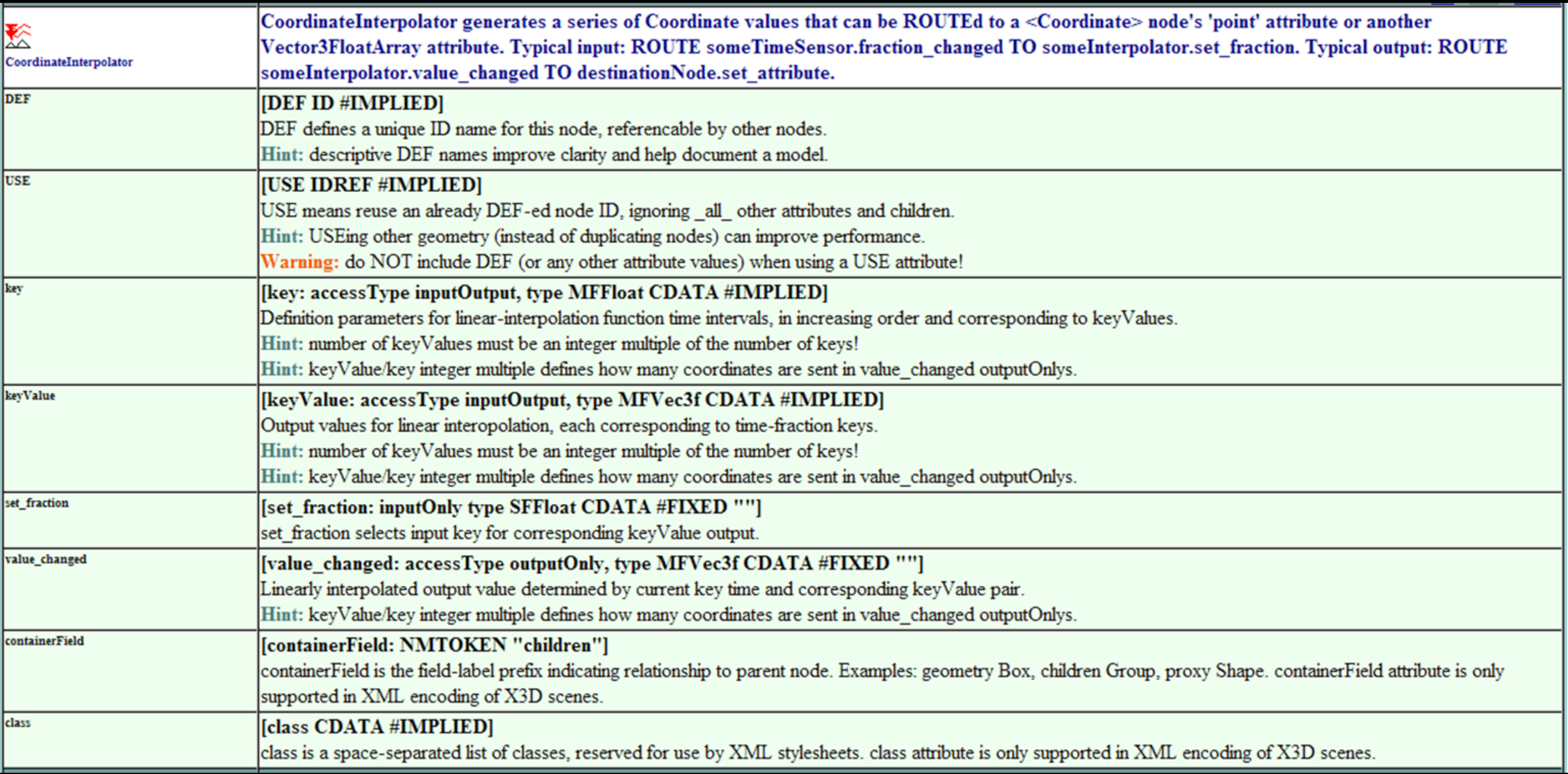


CoordinateInterpolator	**CoordinateInterpolator generates a series of Coordinate values that can be ROUTEd to a <Coordinate> node's 'point' attribute or another Vector3FloatArray attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type MFVec3f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair. Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

Chapter Summary

Chapter Summary: Event Animation

Behaviors, events, ROUTE connections, animation

Animation as scene-graph modification

Event-animation design pattern: 10-step process

Interpolation nodes

- TimeSensor and event timing
- ScalarInterpolator and ColorInterpolator
- OrientationInterpolator, PositionInterpolator, PositionInterpolator2D and NormalInterpolator
- CoordinateInterpolator, CoordinateInterpolator2D

Suggested exercises

Illustrate and annotate ROUTE connections in an animation scene graph (documenting 10 steps)

- Print out one of these scenes in landscape mode, either using the X3dToXhtml.xslt stylesheet version or Netbeans 'Save as HTML' option.
- Then draw all ROUTE connections, label beginning and end of each by name, type and accessType

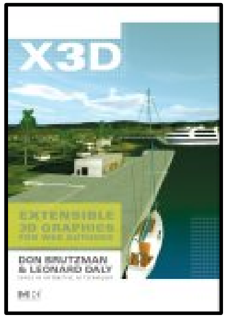
Draw animation chain diagrams to document behaviors in your own example scenes

- Add use-case summaries about user intent

References

References 1

X3D: Extensible 3D Graphics for Web Authors by Don Brutzman and Leonard Daly, Morgan Kaufmann Publishers, April 2007, 468 pages.


X3D
EXTENSIBLE 3D GRAPHICS FOR WEB AUTHORS
DON BRUTZMAN & LEONARD DALY

- Chapter 7, Event Animation and Interpolation
- http://x3dGraphics.com
- http://x3dgraphics.com/examples/X3dForWebAuthors

X3D Resources

- http://www.web3d.org/x3d/content/examples/X3dResources.html

References 2

X3D Scene Authoring Hints

- http://x3dgraphics.com/examples/X3dSceneAuthoringHints.html

X3D Graphics Specification

- http://www.web3d.org/x3d/specifications
- Also available as help pages within X3D-Edit

References 3

VRML 2.0 Sourcebook by Andrea L. Ames, David R. Nadeau, and John L. Moreland, John Wiley & Sons, 1996.

- http://www.wiley.com/legacy/compbooks/vrml2sbk/cover/cover.htm
- http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook
- Chapter 08 – Animating Position Orientation Scale
- Chapter 19 – Normals Shading

Pocock, Lynn and Judson Rosebush, *The Computer Animator's Technical Handbook,* Morgan Kaufmann Publishers, 2001.

References 4

Wikipedia

- Double buffering
  http://en.wikipedia.org/wiki/Double_buffering
- Interlacing
  http://en.wikipedia.org/wiki/Interlace
- Event-based computing
  http://en.wikipedia.org/wiki/Event_(computing)

Contact

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Monterey California 93943-5000 USA
1.831.656.2149 voice

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- as a service to the Computer Graphics community
- freely available, directly prepared for classroom use
- http://cgems.inesc.pt

X3D for Web Authors recognized by CGEMS! ☺

- Book materials: X3D-Edit tool, examples, slidesets
- Received jury award for Best Submission 2008

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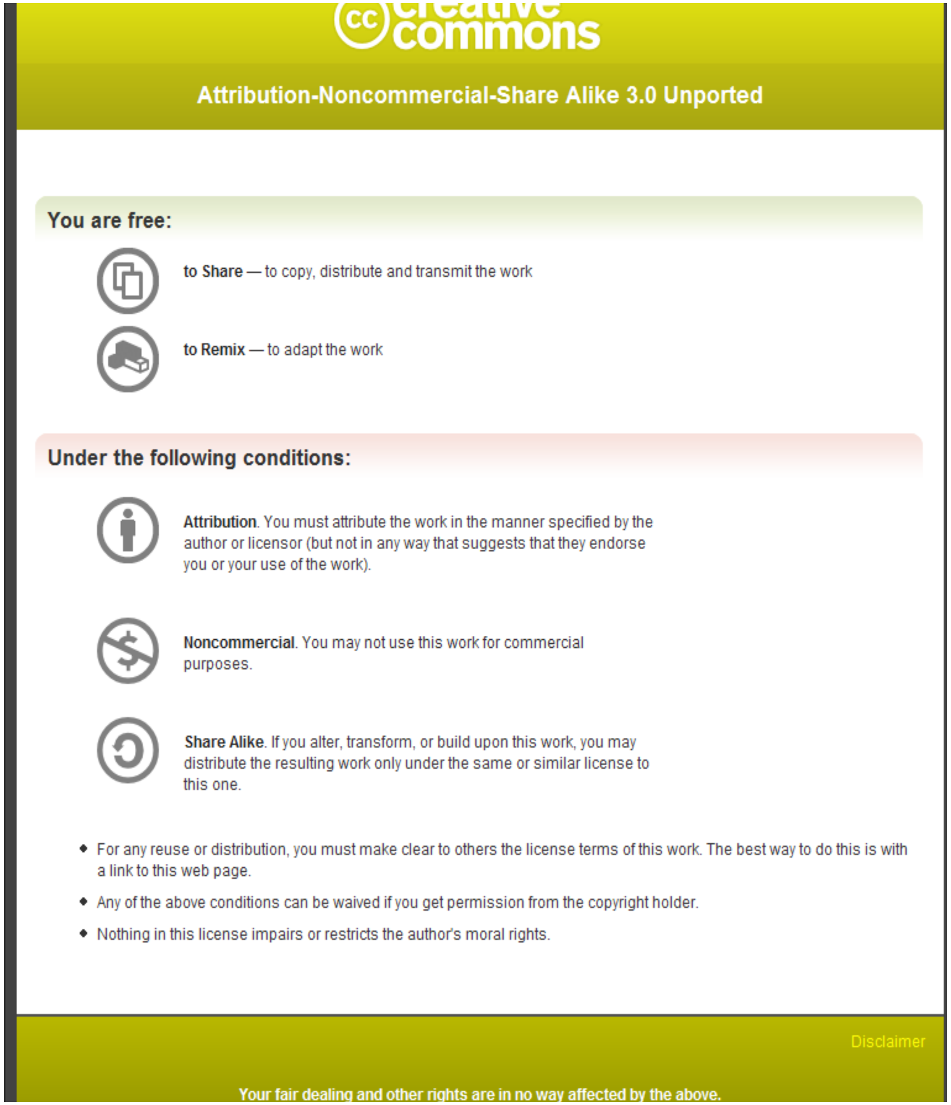

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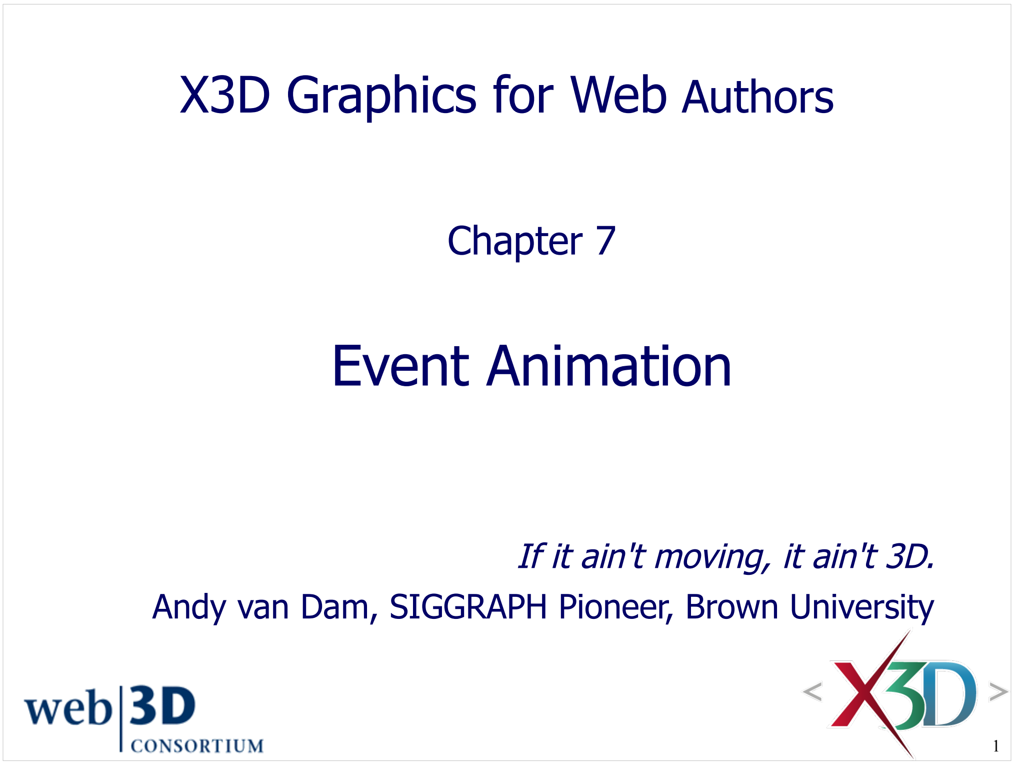


X3D Graphics for Web Authors

Chapter 7

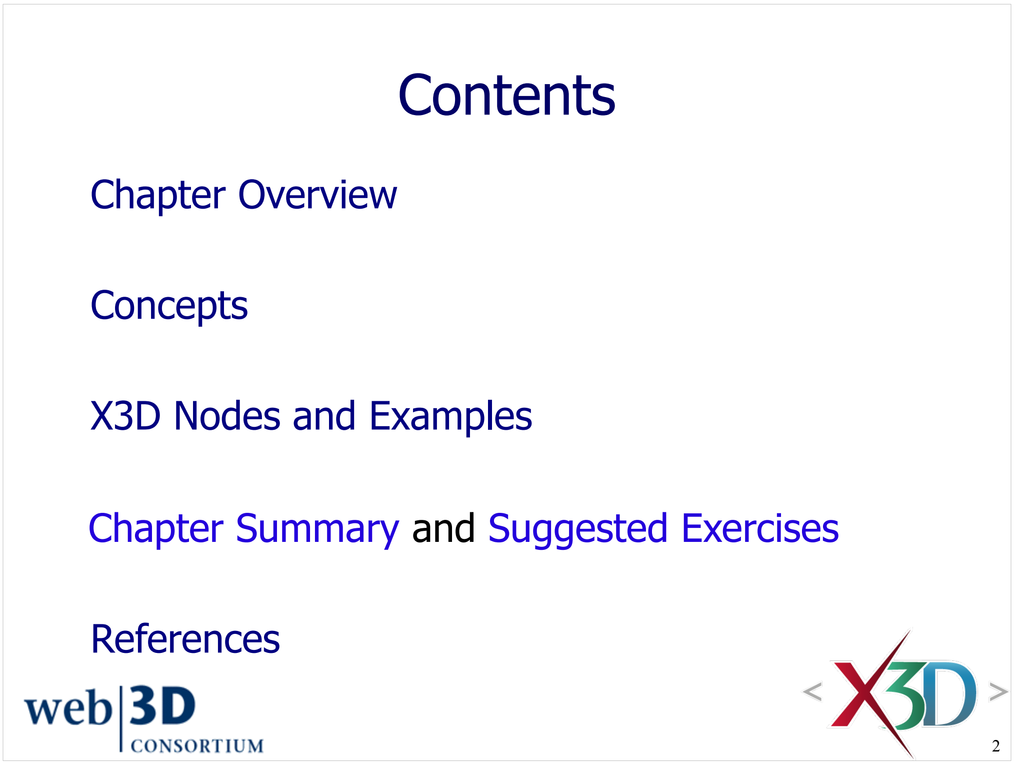
Event Animation

If it ain't moving, it ain't 3D.

Andy van Dam, SIGGRAPH Pioneer, Brown University

Andries van Dam founded SIGGRAPH. He is one of the four authors of the “bible” (or at least “Old Testament”): *Computer Graphics, Principles and Practice*, coauthored with J.D. Foley, S.K. Feiner, and J.F. Hughes, published in 1990 by Addison Wesley.

Dr. van Dam's home page is http://www.cs.brown.edu/~avd



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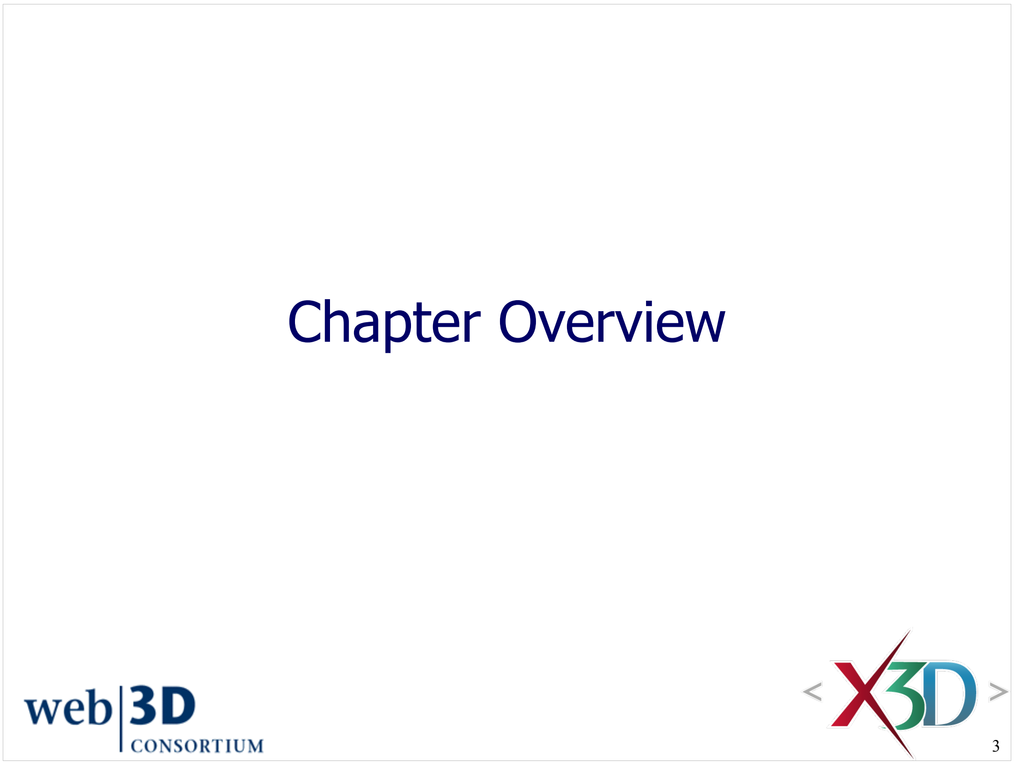
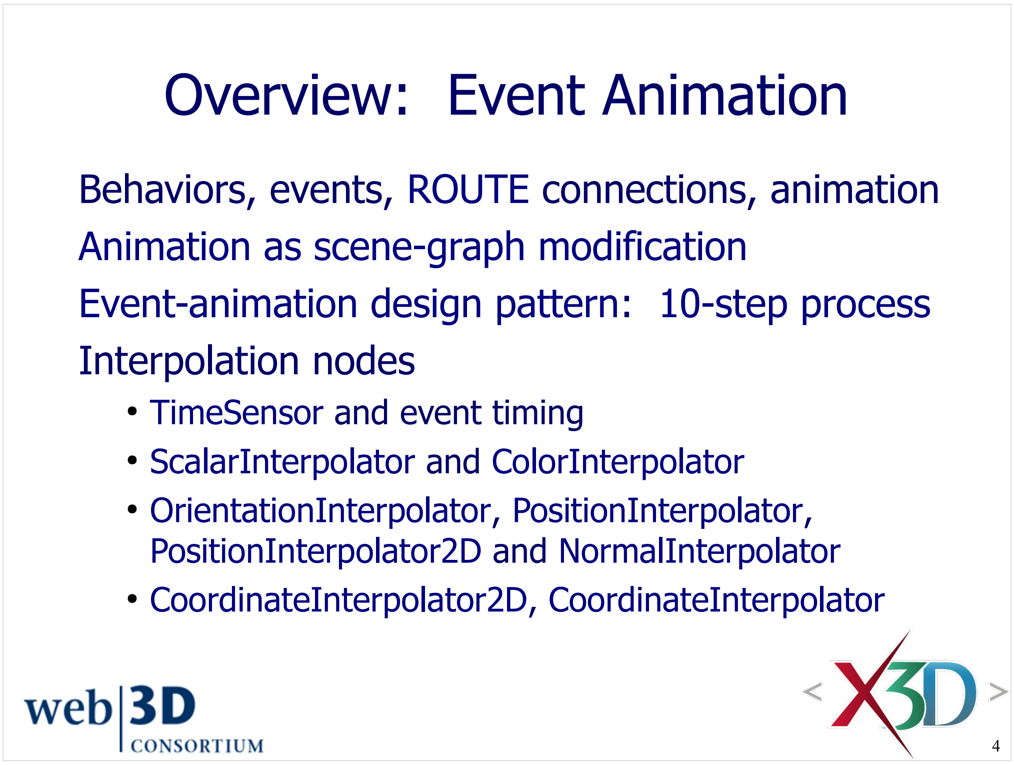
Chapter Summary and Suggested Exercises

References



Chapter Overview



Overview: Event Animation

Behaviors, events, ROUTE connections, animation

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Interpolation nodes

- TimeSensor and event timing
- ScalarInterpolator and ColorInterpolator
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- CoordinateInterpolator2D, CoordinateInterpolator

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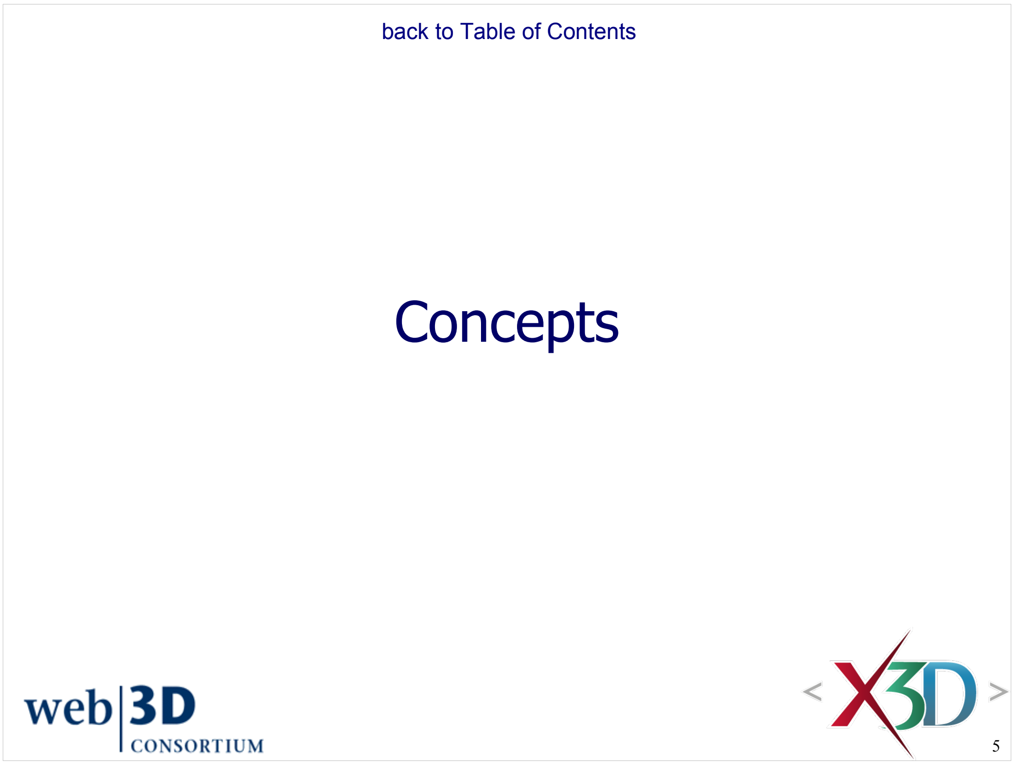
<X3D>

4



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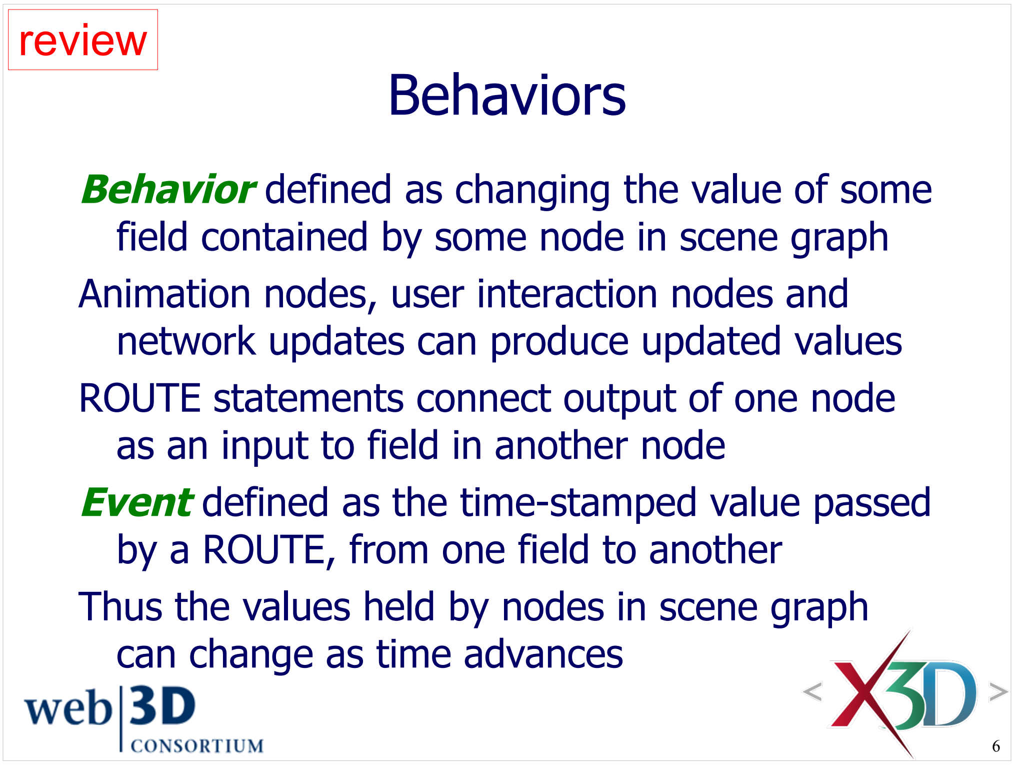
Concepts



review

Behaviors

Behavior defined as changing the value of some field contained by some node in scene graph

Animation nodes, user interaction nodes and network updates can produce updated values

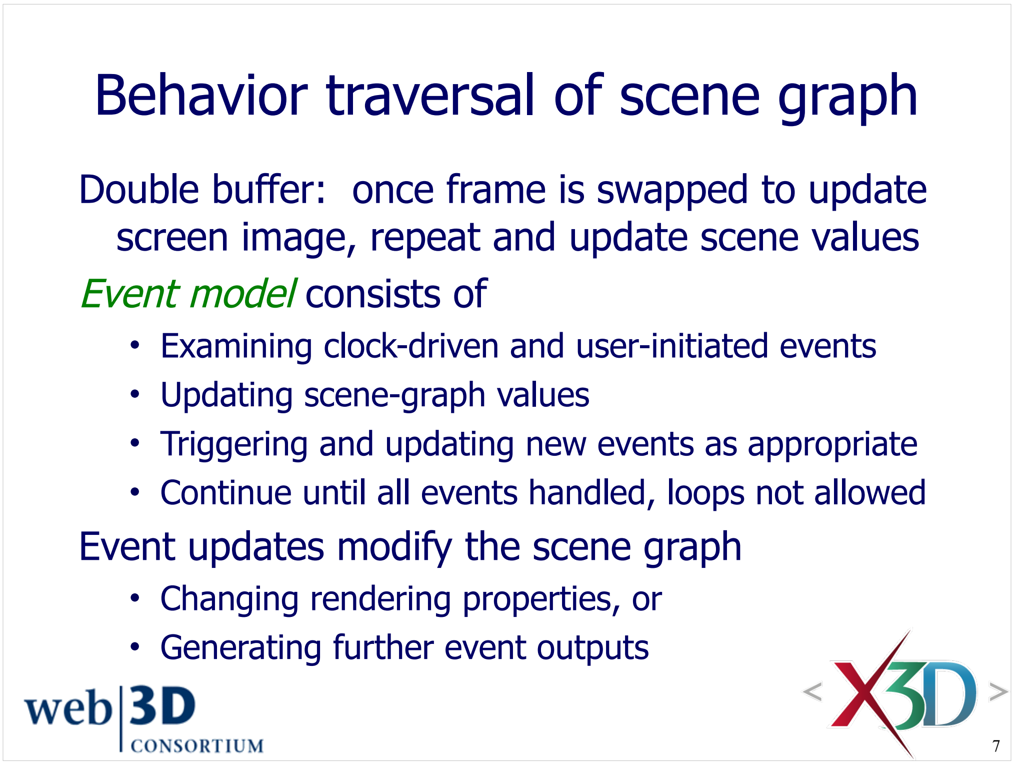
ROUTE statements connect output of one node as an input to field in another node

Event defined as the time-stamped value passed by a ROUTE, from one field to another

Thus the values held by nodes in scene graph can change as time advances

Fun definition of time: “time is what keeps everything from happening at once!”

This is motivation for why events include timestamps. The timestamp values allow ordering of events so that an earlier behavior doesn't mistakenly override a later behavior.



Behavior traversal of scene graph

Double buffer: once frame is swapped to update screen image, repeat and update scene values

Event model consists of

- Examining clock-driven and user-initiated events
- Updating scene-graph values
- Triggering and updating new events as appropriate
- Continue until all events handled, loops not allowed

Event updates modify the scene graph

- Changing rendering properties, or
- Generating further event outputs

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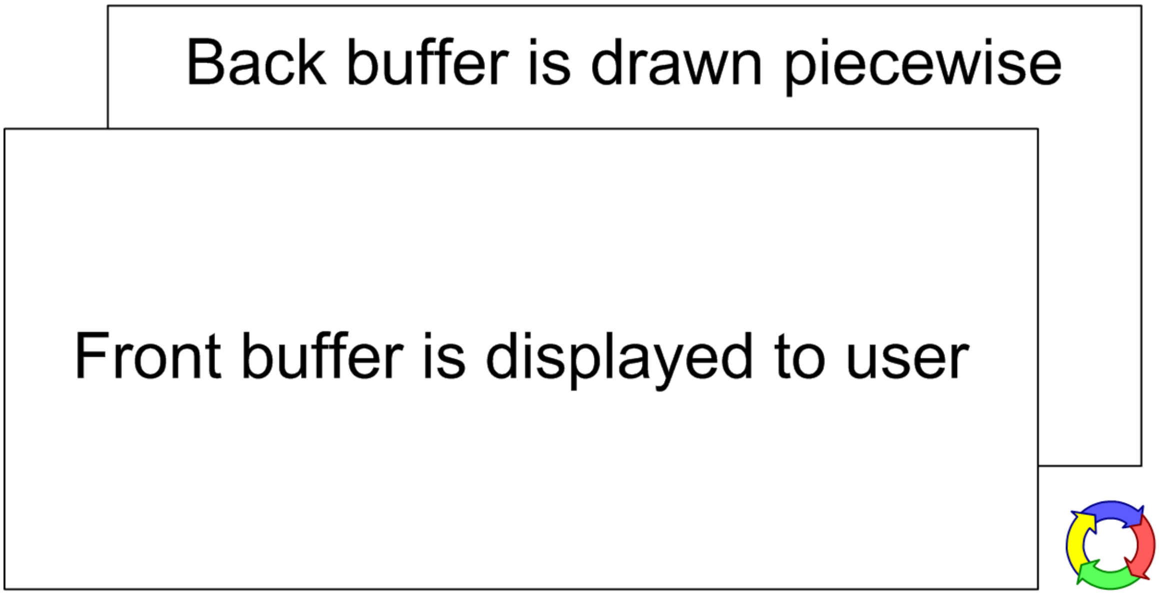
X3D

7

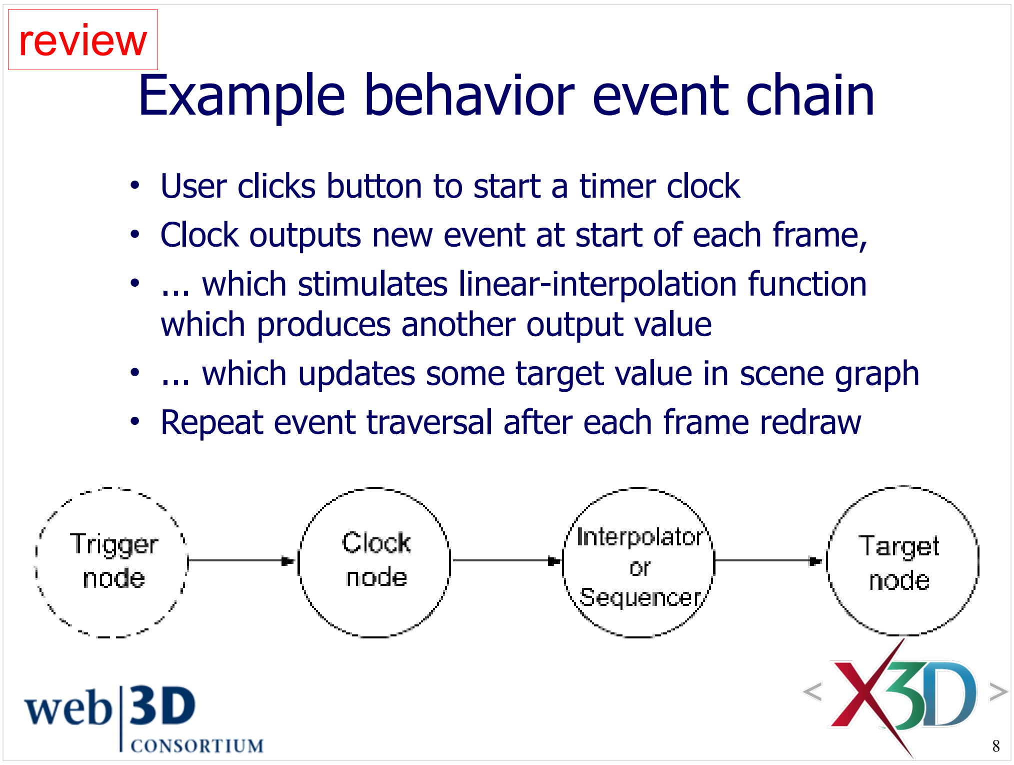
Double buffering is an approach used by most 3D programs to incrementally draw each frame in the background, then swap it with the front buffer when ready. When this repeats at a frame rate of 10 Hz or better, smooth motion is perceived by the user.



Back buffer is drawn piecewise

Front buffer is displayed to user

Buffers are drawn and swapped rapidly



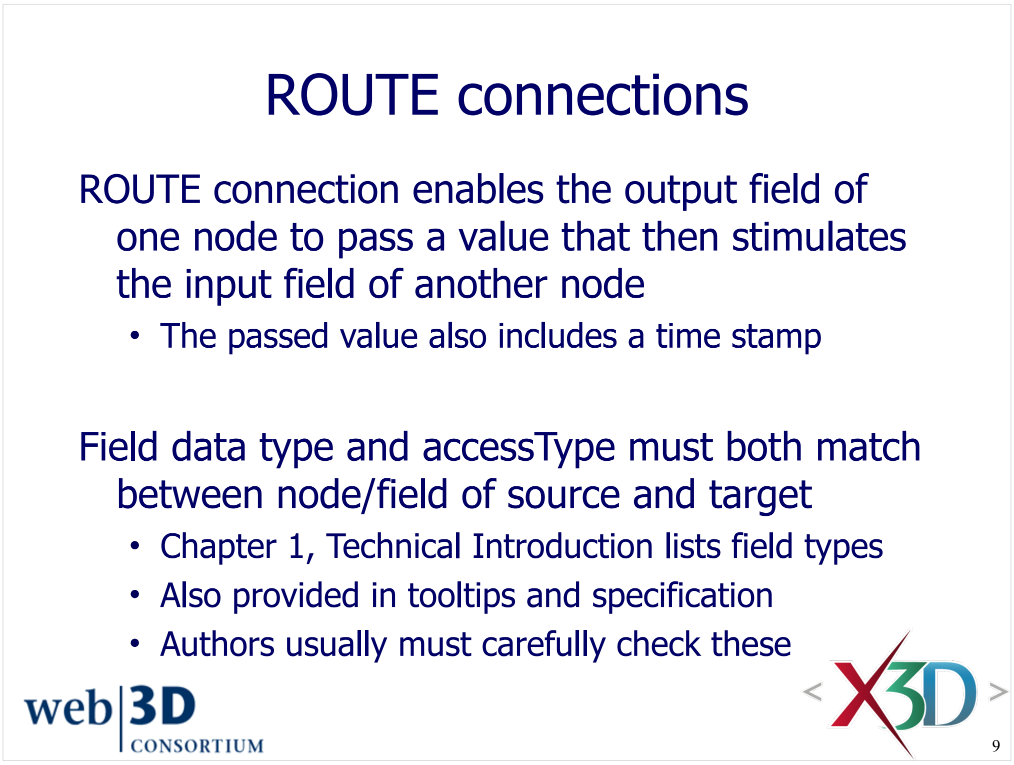
review

Example behavior event chain

- User clicks button to start a timer clock
- Clock outputs new event at start of each frame,
- ... which stimulates linear-interpolation function which produces another output value
- ... which updates some target value in scene graph
- Repeat event traversal after each frame redraw

Trigger node
Clock node
Interpolator or Sequencer
Target node

8



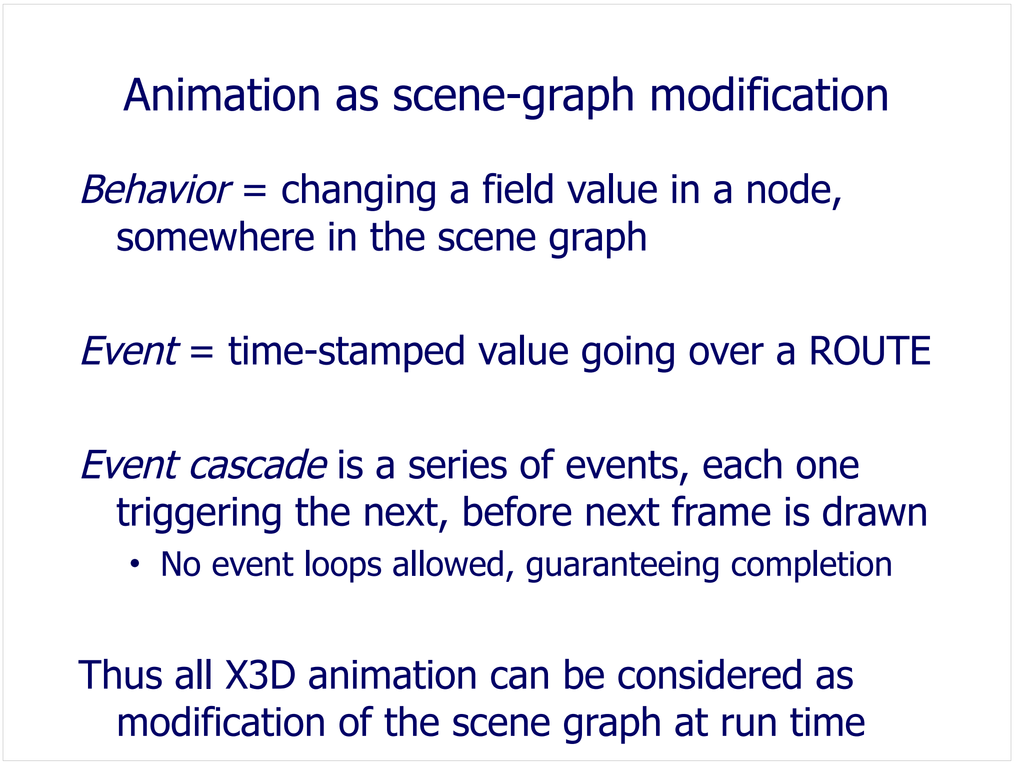
ROUTE connections

ROUTE connection enables the output field of one node to pass a value that then stimulates the input field of another node

- The passed value also includes a time stamp

Field data type and accessType must both match between node/field of source and target

- Chapter 1, Technical Introduction lists field types
- Also provided in tooltips and specification
- Authors usually must carefully check these



Animation as scene-graph modification

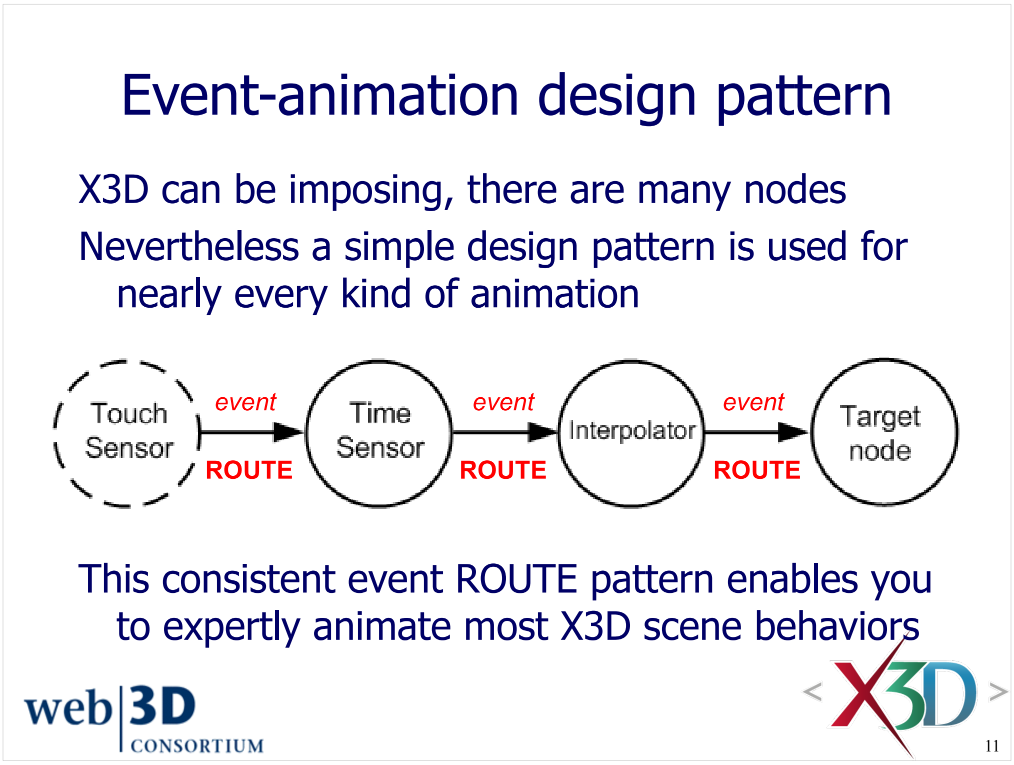
Behavior = changing a field value in a node, somewhere in the scene graph

Event = time-stamped value going over a ROUTE

Event cascade is a series of events, each one triggering the next, before next frame is drawn

- No event loops allowed, guaranteeing completion

Thus all X3D animation can be considered as modification of the scene graph at run time



Event-animation design pattern

X3D can be imposing, there are many nodes

Nevertheless a simple design pattern is used for nearly every kind of animation

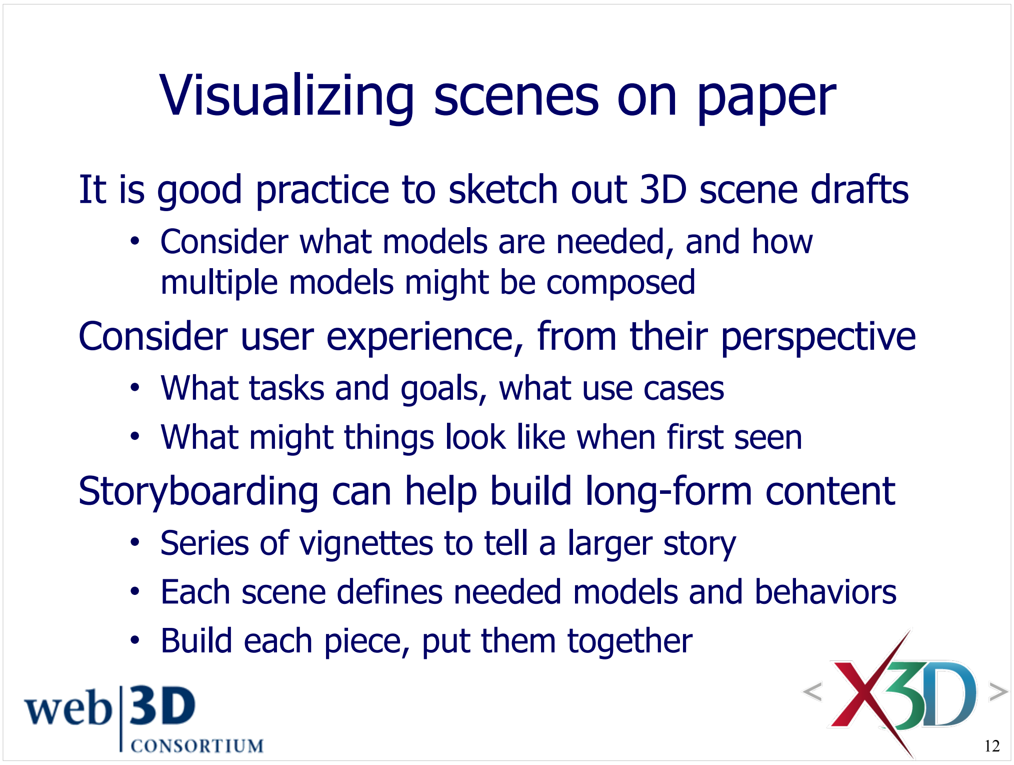
This consistent event ROUTE pattern enables you to expertly animate most X3D scene behaviors

X3D for Web Authors, Figure 7.1, p. 189.

TouchSensor is optional. Some other triggering event may be provided to start the animation chain, or the TimeSensor may be looping indefinitely.

There are many interpolator nodes. The choice of which interpolator to utilize is determined by the data type of the target field in the target node.

A sequencer node is used instead of an interpolator node if the target field is boolean or integer. Sequencer nodes are described in Chapter 9, Event Utilities and Scripting.



Visualizing scenes on paper

It is good practice to sketch out 3D scene drafts

- Consider what models are needed, and how multiple models might be composed

Consider user experience, from their perspective

- What tasks and goals, what use cases
- What might things look like when first seen

Storyboarding can help build long-form content

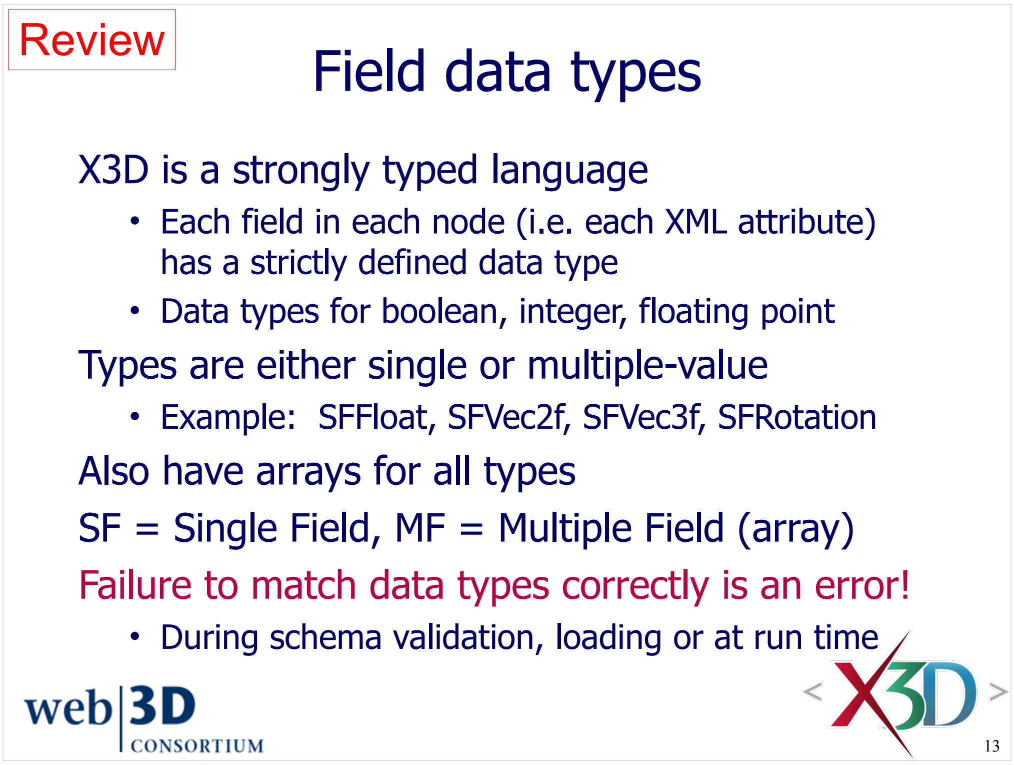
- Series of vignettes to tell a larger story
- Each scene defines needed models and behaviors
- Build each piece, put them together

Storyboarding

- http://en.wikipedia.org/wiki/Story_board
- http://www.mcli.dist.maricopa.edu/authoring/studio/guidebook/storyboard.html
- http://en.wikiversity.org/wiki/Lesson:Thumbnail_Storyboard

Previsualization

- http://en.wikipedia.org/wiki/Previsualization



Review

Field data types

X3D is a strongly typed language

- Each field in each node (i.e. each XML attribute) has a strictly defined data type
- Data types for boolean, integer, floating point

Types are either single or multiple-value

- Example: SFFloat, SFVec2f, SFVec3f, SFRotation

Also have arrays for all types

SF = Single Field, MF = Multiple Field (array)

Failure to match data types correctly is an error!

- During schema validation, loading or at run time

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<X3D>

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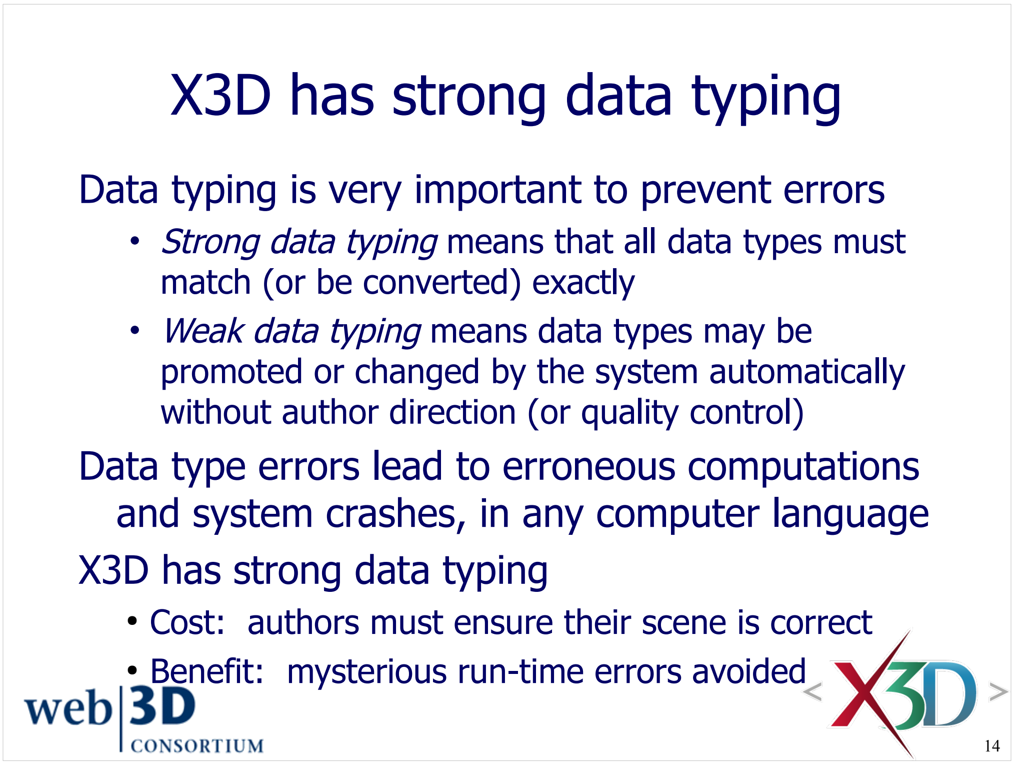
Data type and accessType information is available for each node in the X3D Tooltips and X3D Specification.

When speaking about data types, you can substitute “array of” for the “MF” prefix. Example: “MFColor is an array of Color values.”

For full review see Chapter 1, Technical Overview.



X3D has strong data typing

Data typing is very important to prevent errors

- *Strong data typing* means that all data types must match (or be converted) exactly
- *Weak data typing* means data types may be promoted or changed by the system automatically without author direction (or quality control)

Data type errors lead to erroneous computations and system crashes, in any computer language

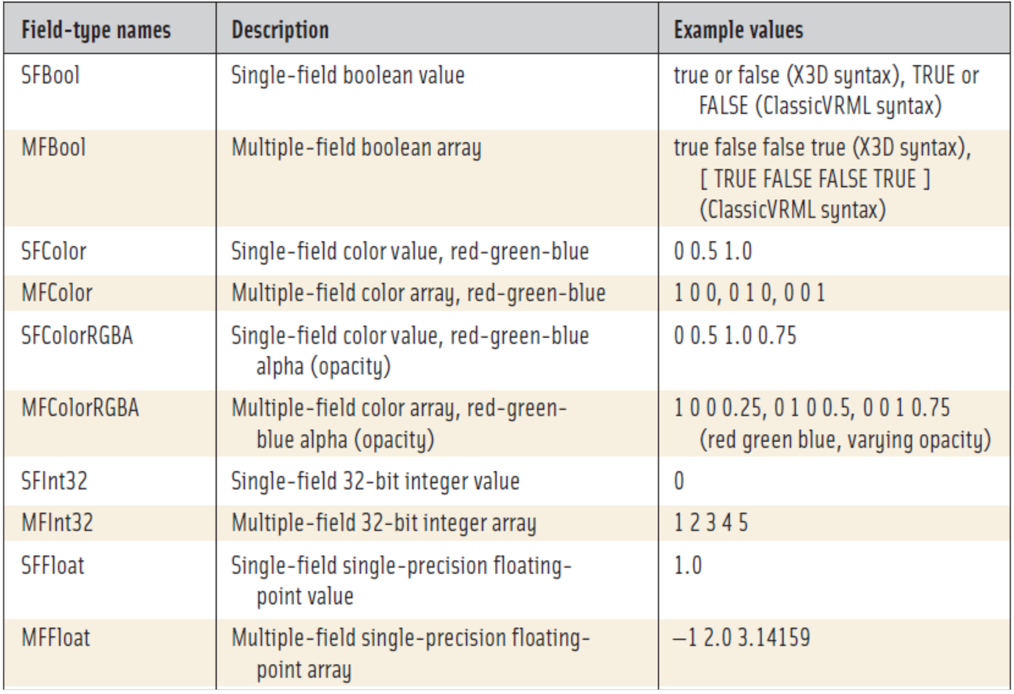
X3D has strong data typing

- Cost: authors must ensure their scene is correct
- Benefit: mysterious run-time errors avoided

Strong data typing, XML validation and a number of other X3D quality-control checks prevent the dreaded errors which arise from Garbage In Garbage Out (GIGO).

GIGO errors can be quite difficult to detect, debug and correct. Thus they are best avoided in the first place. Strong typing, XML validation and tools that report errors are an X3D author's best friend.

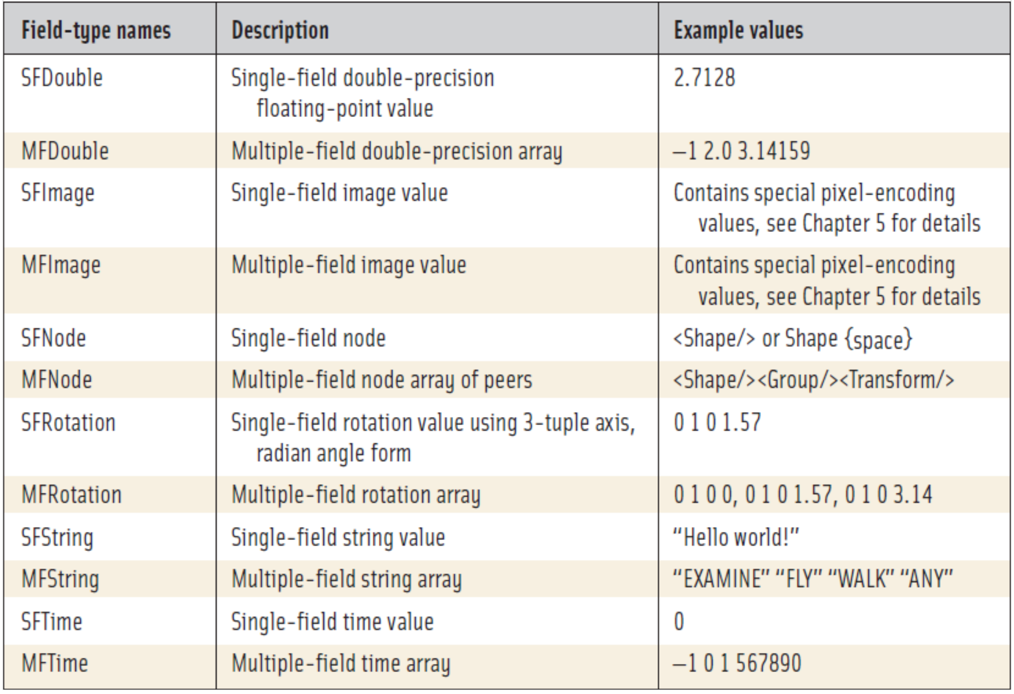
Field data types 1



Field-type names	Description	Example values
SFBool	Single-field boolean value	true or false (X3D syntax), TRUE or FALSE (ClassicVRML syntax)
MFBool	Multiple-field boolean array	true false false true (X3D syntax), [TRUE FALSE FALSE TRUE] (ClassicVRML syntax)
SFColor	Single-field color value, red-green-blue	0 0.5 1.0
MFColor	Multiple-field color array, red-green-blue	1 0 0, 0 1 0, 0 0 1
SFColorRGBA	Single-field color value, red-green-blue alpha (opacity)	0 0.5 1.0 0.75
MFColorRGBA	Multiple-field color array, red-green-blue alpha (opacity)	1 0 0 0.25, 0 1 0 0.5, 0 0 1 0.75 (red green blue, varying opacity)
SFInt32	Single-field 32-bit integer value	0
MFInt32	Multiple-field 32-bit integer array	1 2 3 4 5
SFFloat	Single-field single-precision floating-point value	1.0
MFFloat	Multiple-field single-precision floating-point array	−1 2.0 3.14159

X3D for Web Authors, Table 1.4, pp. 19-20.

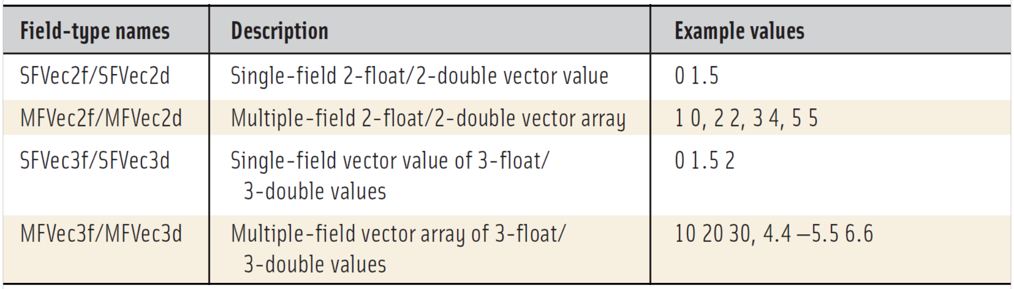
Field data types 2



Field-type names	Description	Example values
SFDouble	Single-field double-precision floating-point value	2.7128
MFDouble	Multiple-field double-precision array	–1 2.0 3.14159
SFImage	Single-field image value	Contains special pixel-encoding values, see Chapter 5 for details
MFImage	Multiple-field image value	Contains special pixel-encoding values, see Chapter 5 for details
SFNode	Single-field node	<Shape/> or Shape {space}
MFNode	Multiple-field node array of peers	<Shape/><Group/><Transform/>
SFRotation	Single-field rotation value using 3-tuple axis, radian angle form	0 1 0 1.57
MFRotation	Multiple-field rotation array	0 1 0 0, 0 1 0 1.57, 0 1 0 3.14
SFString	Single-field string value	"Hello world!"
MFString	Multiple-field string array	"EXAMINE" "FLY" "WALK" "ANY"
SFTime	Single-field time value	0
MFTime	Multiple-field time array	–1 0 1 567890

X3D for Web Authors, Table 1.4, pp. 19-20.

Field data types 3

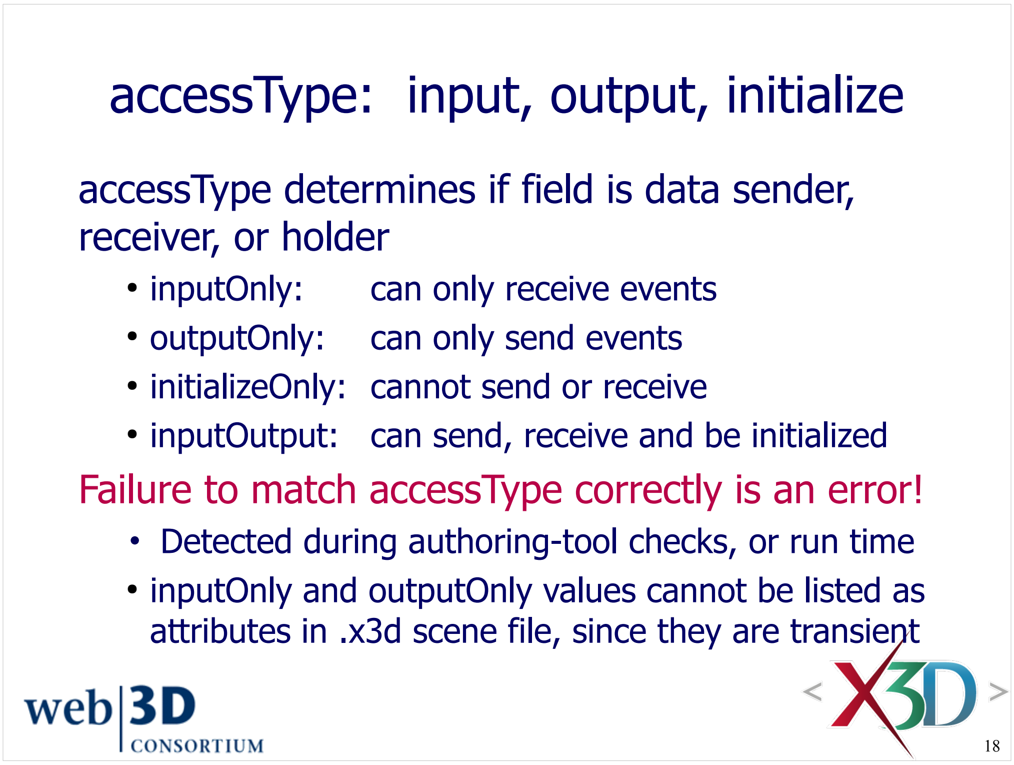


Field-type names	Description	Example values
SFVec2f/SFVec2d	Single-field 2-float/2-double vector value	0 1.5
MFVec2f/MFVec2d	Multiple-field 2-float/2-double vector array	1 0, 2 2, 3 4, 5 5
SFVec3f/SFVec3d	Single-field vector value of 3-float/ 3-double values	0 1.5 2
MFVec3f/MFVec3d	Multiple-field vector array of 3-float/ 3-double values	10 20 30, 4.4 –5.5 6.6

ClassicVRML syntax notes

- TRUE and FALSE (rather than XML true and false)
- MF multiple-field array values are surrounded by square brackets, e.g. `[ 10 20 30, 4.4 -5.5 6.6 ]`
- No special XML escape characters such as **`&amp;`**

X3D for Web Authors, Table 1.4, pp. 19-20.



accessType: input, output, initialize

accessType determines if field is data sender, receiver, or holder

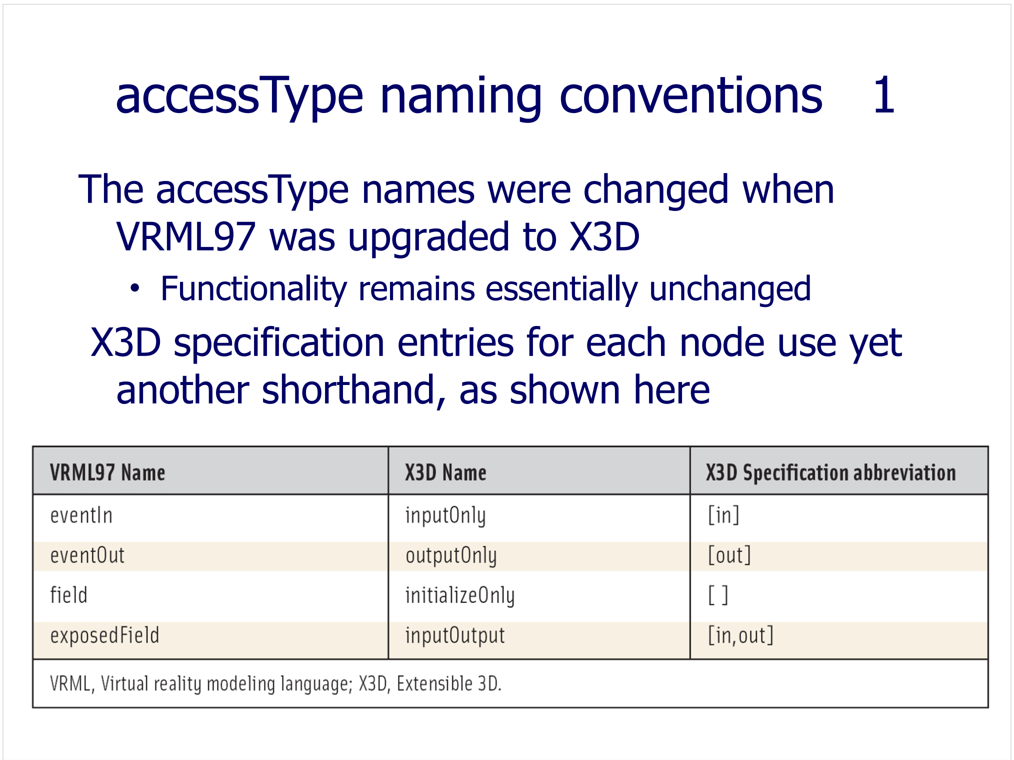
- inputOnly: can only receive events
- outputOnly: can only send events
- initializeOnly: cannot send or receive
- inputOutput: can send, receive and be initialized

Failure to match accessType correctly is an error!

- Detected during authoring-tool checks, or run time
- inputOnly and outputOnly values cannot be listed as attributes in .x3d scene file, since they are transient

Data type and accessType information is available for each node in the X3D Tooltips and X3D Specification.

TODO explain 3D graphics rationale for accessType: performance



accessType naming conventions 1

The accessType names were changed when VRML97 was upgraded to X3D

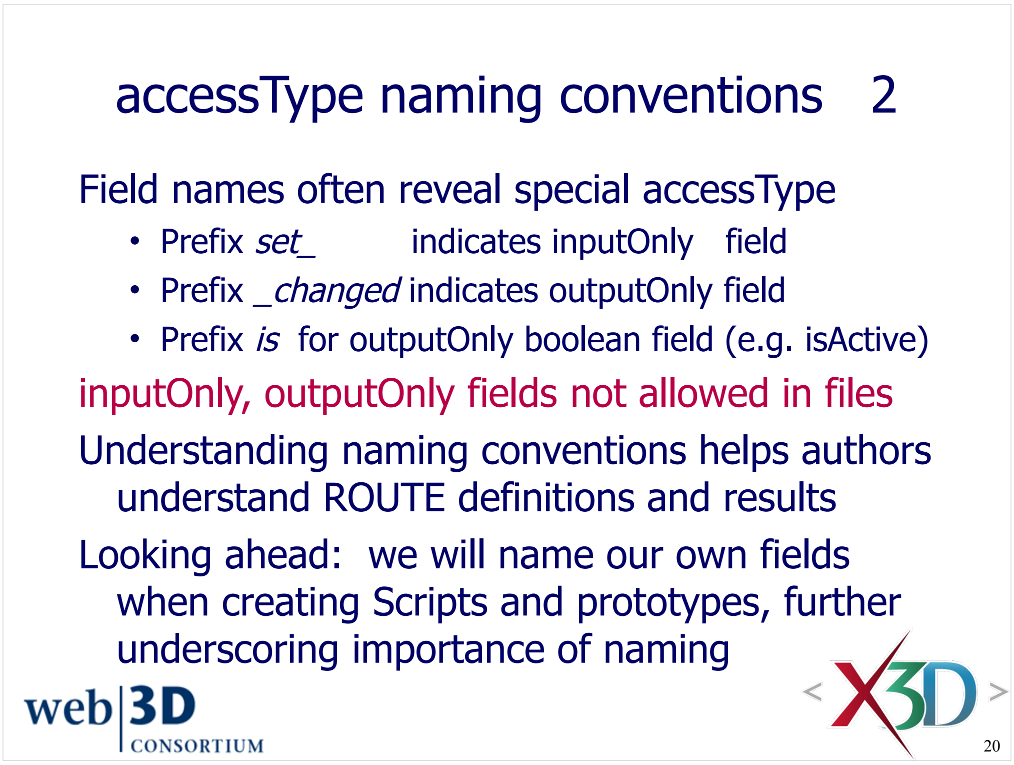
- Functionality remains essentially unchanged

X3D specification entries for each node use yet another shorthand, as shown here

VRML97 Name	X3D Name	X3D Specification abbreviation
eventIn	inputOnly	[in]
eventOut	outputOnly	[out]
field	initializeOnly	[ ]
exposedField	inputOutput	[in,out]

VRML, Virtual reality modeling language; X3D, Extensible 3D.

X3D for Web Authors, Table 1.6, p. 28.



accessType naming conventions 2

Field names often reveal special accessType

- Prefix *set_* indicates inputOnly field
- Prefix *_changed* indicates outputOnly field
- Prefix *is* for outputOnly boolean field (e.g. isActive)

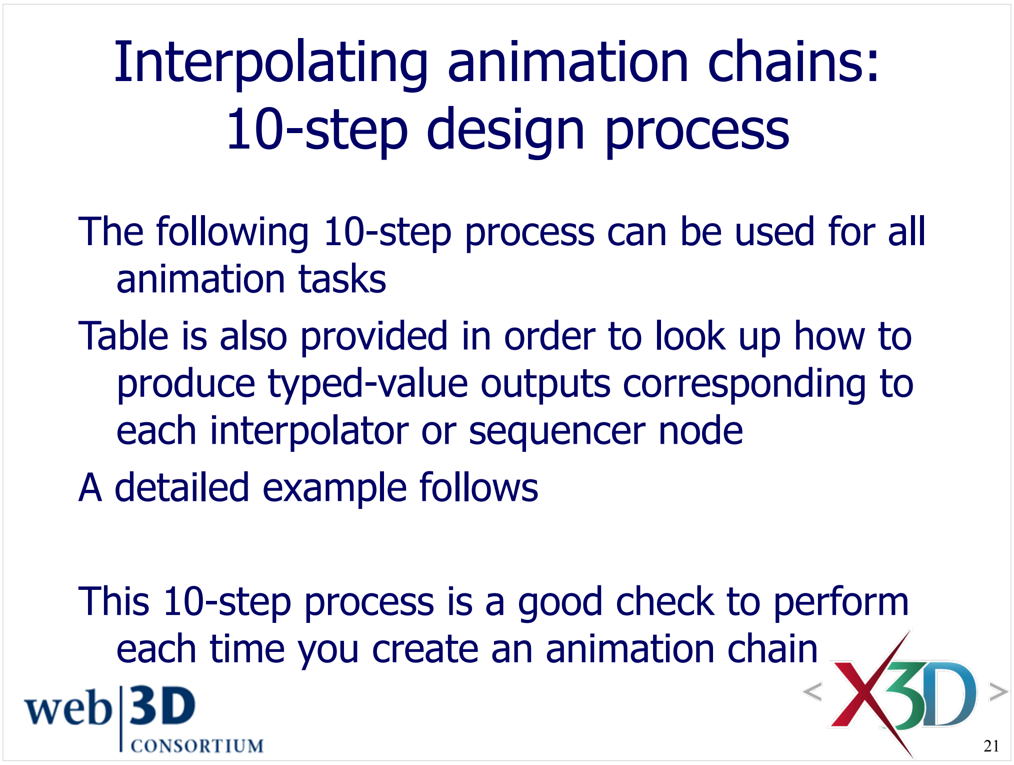
inputOnly, outputOnly fields not allowed in files

Understanding naming conventions helps authors understand ROUTE definitions and results

Looking ahead: we will name our own fields when creating Scripts and prototypes, further underscoring importance of naming

Script nodes allow an author to define the input and output fields of interest. Each Script node can react and respond to input events by performing computations and then sending output events. The contained Script code may be written in Ecmasript (i.e. Javascript) or in Java.

For more on this subject, see Chapter 9, Event Utilities and Scripting.



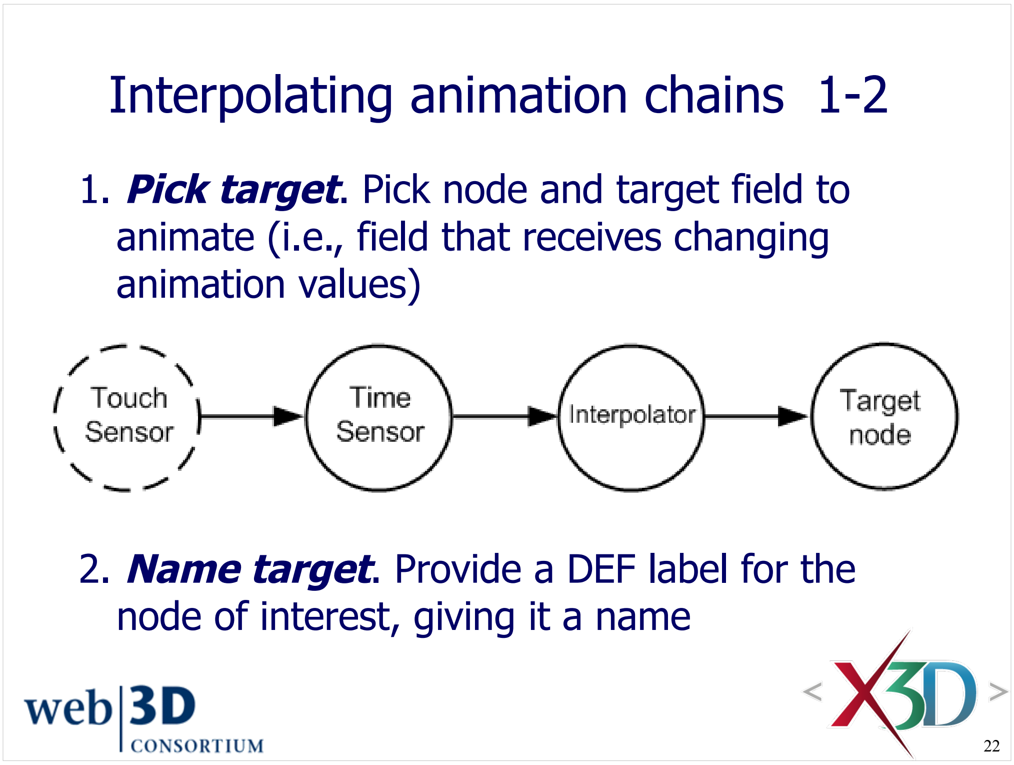
Interpolating animation chains: 10-step design process

The following 10-step process can be used for all animation tasks

Table is also provided in order to look up how to produce typed-value outputs corresponding to each interpolator or sequencer node

A detailed example follows

This 10-step process is a good check to perform each time you create an animation chain



Interpolating animation chains 1-2

1. ***Pick target***. Pick node and target field to animate (i.e., field that receives changing animation values)

Touch Sensor
Time Sensor
Interpolator
Target node

2. ***Name target***. Provide a DEF label for the node of interest, giving it a name

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<X3D>
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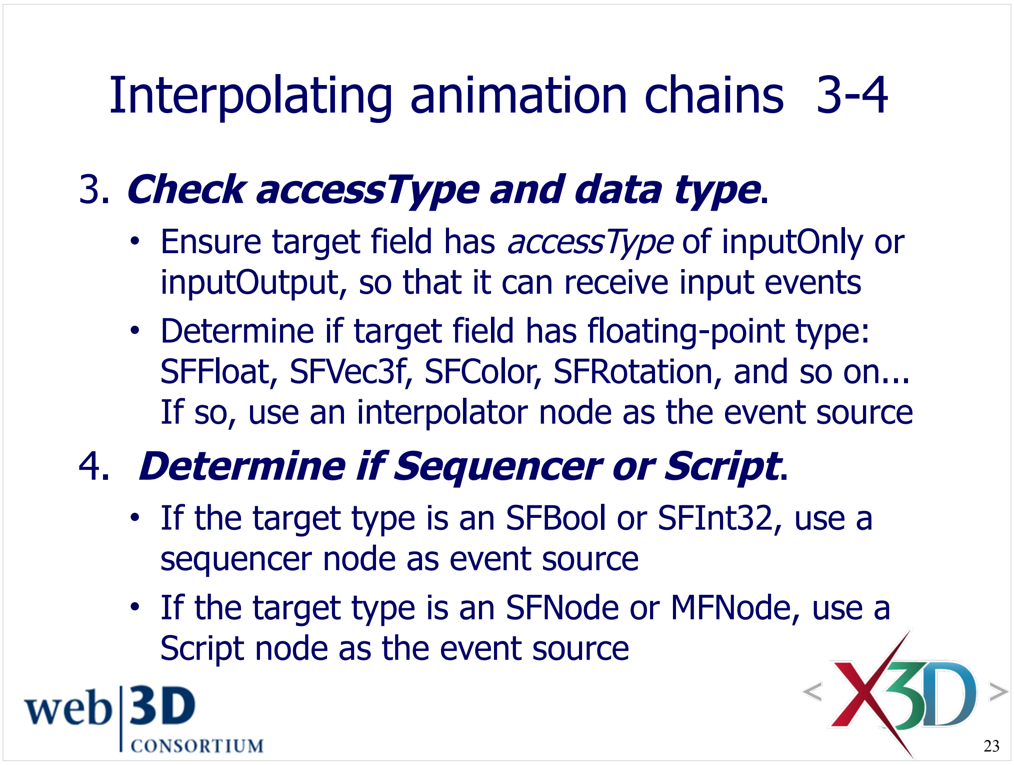
X3D for Web Authors, section 2.5, pp. 192-193



Interpolating animation chains 3-4

3. ***Check accessType and data type*.**
    - Ensure target field has *accessType* of inputOnly or inputOutput, so that it can receive input events
    - Determine if target field has floating-point type: SFFloat, SFVec3f, SFColor, SFRotation, and so on... If so, use an interpolator node as the event source
4. ***Determine if Sequencer or Script*.**
    - If the target type is an SFBool or SFInt32, use a sequencer node as event source
    - If the target type is an SFNode or MFNode, use a Script node as the event source

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<X3D>

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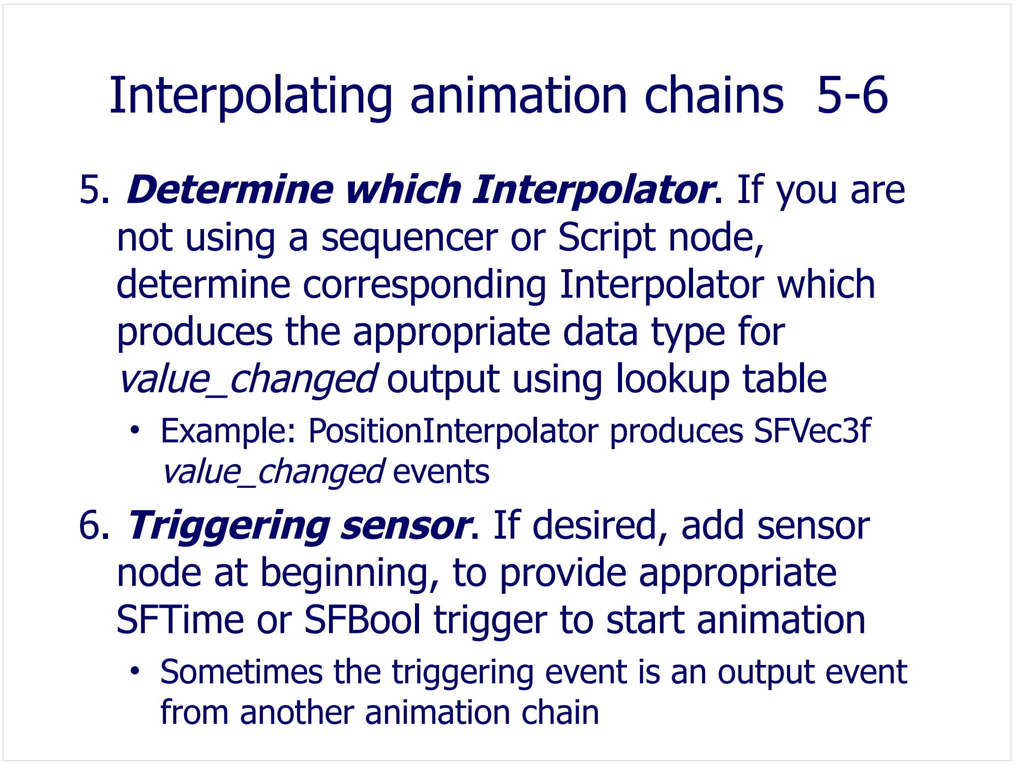
X3D for Web Authors, section 2.5, pp. 192-193

When checking data type:

- The target field can either be singleton SF type or array MF type
- SF means Single Field, MF means Multiple Field (i.e. an array) in the X3D type-naming convention



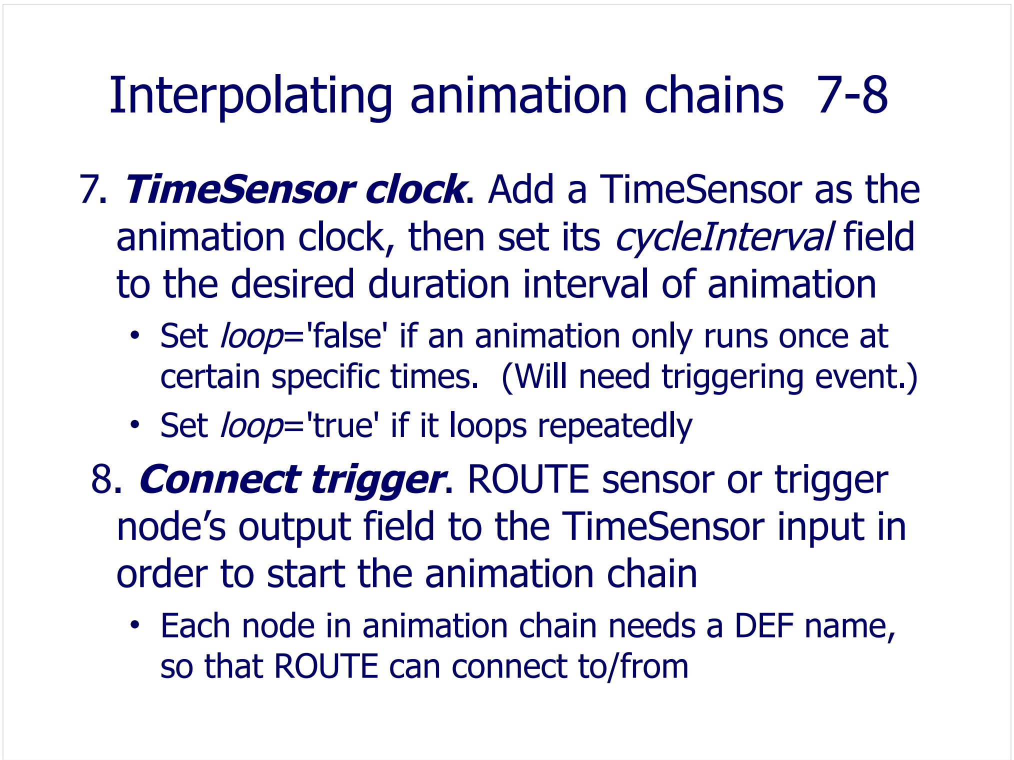
Interpolating animation chains 5-6

5. ***Determine which Interpolator***. If you are not using a sequencer or Script node, determine corresponding Interpolator which produces the appropriate data type for *value_changed* output using lookup table
   - Example: PositionInterpolator produces SFVec3f *value_changed* events
6. ***Triggering sensor***. If desired, add sensor node at beginning, to provide appropriate SFTime or SFBool trigger to start animation
   - Sometimes the triggering event is an output event from another animation chain

X3D for Web Authors, section 2.5, pp. 192-193

for Step 5, Determine which Interpolator:

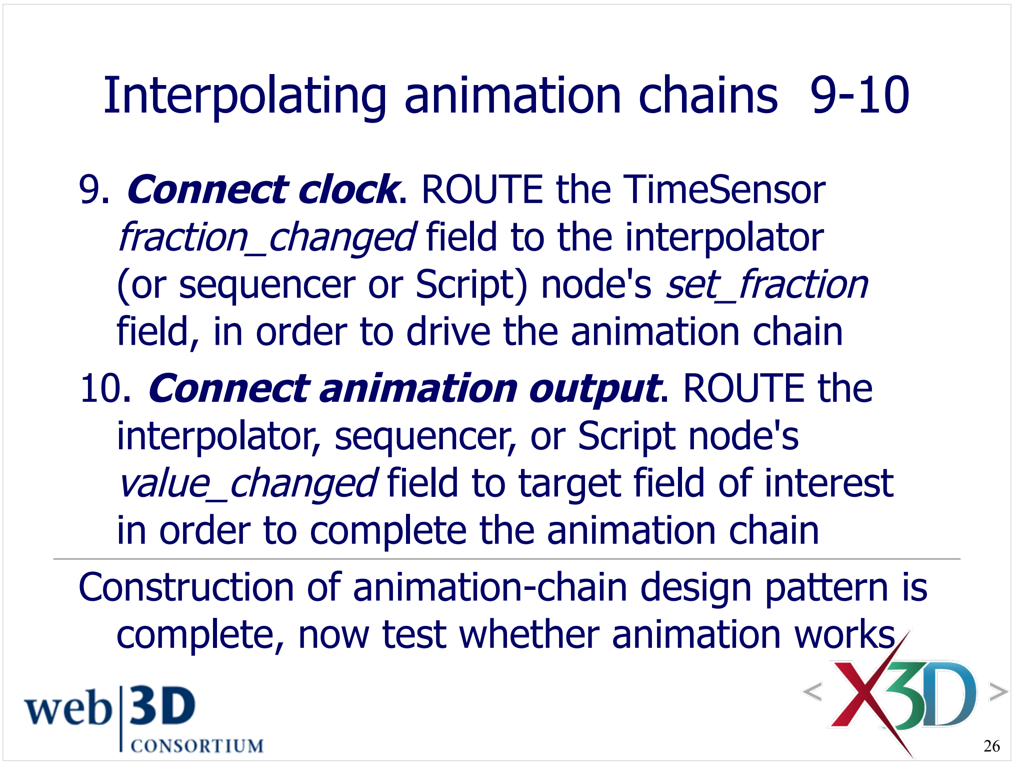
- See Table 7.2 for example interpolator chains
- See Table 7.5 for list of candidate interpolators to use, based on data type



Interpolating animation chains 7-8

7. ***TimeSensor clock***. Add a TimeSensor as the animation clock, then set its *cycleInterval* field to the desired duration interval of animation
   - Set *loop*='false' if an animation only runs once at certain specific times. (Will need triggering event.)
   - Set *loop*='true' if it loops repeatedly
8. ***Connect trigger***. ROUTE sensor or trigger node’s output field to the TimeSensor input in order to start the animation chain
   - Each node in animation chain needs a DEF name, so that ROUTE can connect to/from

X3D for Web Authors, section 2.5, pp. 192-193



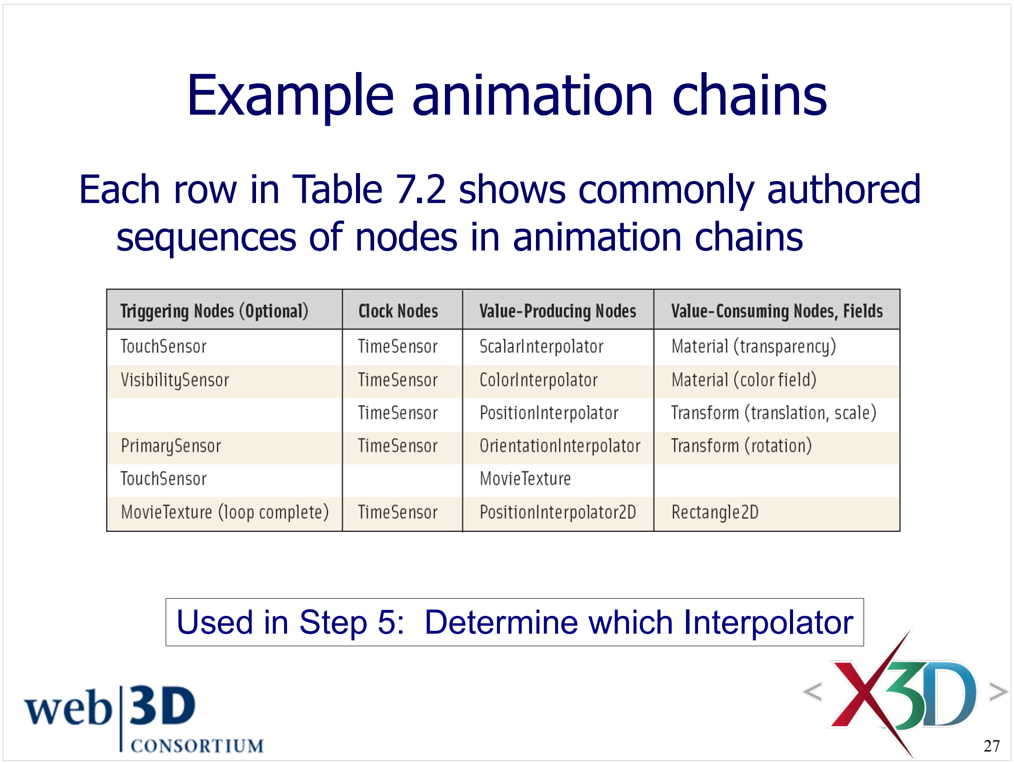
Interpolating animation chains 9-10

9. ***Connect clock***. ROUTE the TimeSensor *fraction_changed* field to the interpolator (or sequencer or Script) node's *set_fraction* field, in order to drive the animation chain
10. ***Connect animation output***. ROUTE the interpolator, sequencer, or Script node's *value_changed* field to target field of interest in order to complete the animation chain

---

Construction of animation-chain design pattern is complete, now test whether animation works

X3D for Web Authors, section 2.5, pp. 192-193



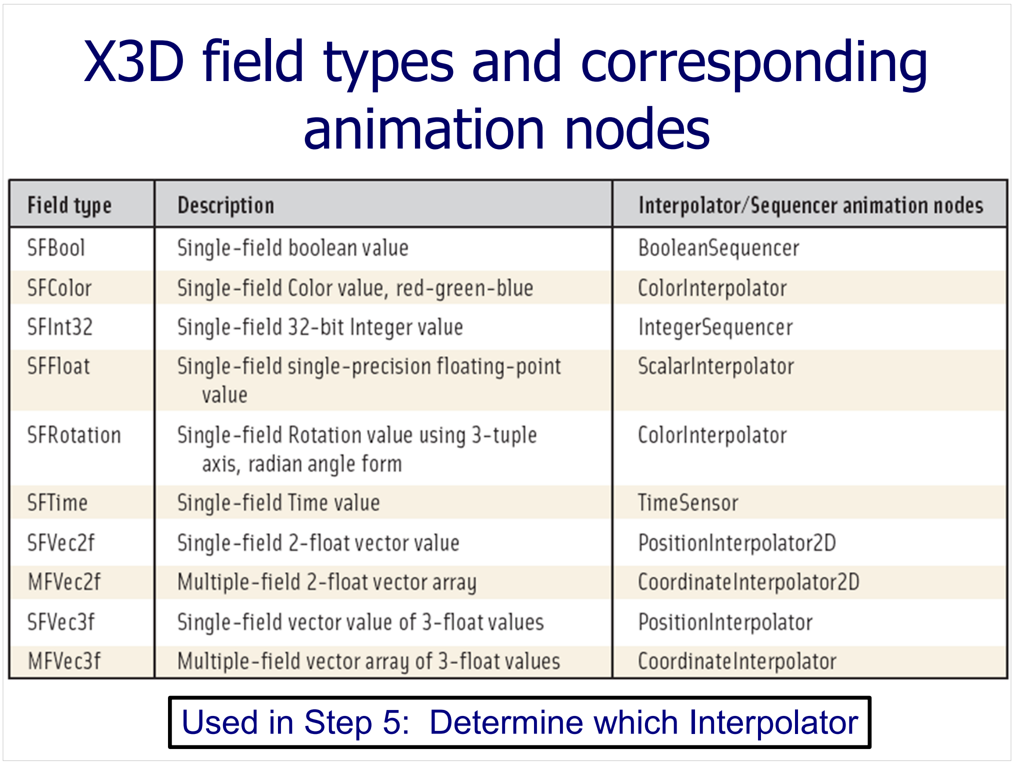
Example animation chains

Each row in Table 7.2 shows commonly authored sequences of nodes in animation chains

Triggering Nodes (Optional)	Clock Nodes	Value-Producing Nodes	Value-Consuming Nodes, Fields
TouchSensor	TimeSensor	ScalarInterpolator	Material (transparency)
VisibilitySensor	TimeSensor	ColorInterpolator	Material (color field)
	TimeSensor	PositionInterpolator	Transform (translation, scale)
PrimarySensor	TimeSensor	OrientationInterpolator	Transform (rotation)
TouchSensor		MovieTexture	
MovieTexture (loop complete)	TimeSensor	PositionInterpolator2D	Rectangle2D

Used in Step 5: Determine which Interpolator

X3D for Web Authors, Table 7.2, p. 196. Example Animation Chains: Each Row Shows a Commonly Authored Sequence of Nodes



X3D field types and corresponding animation nodes

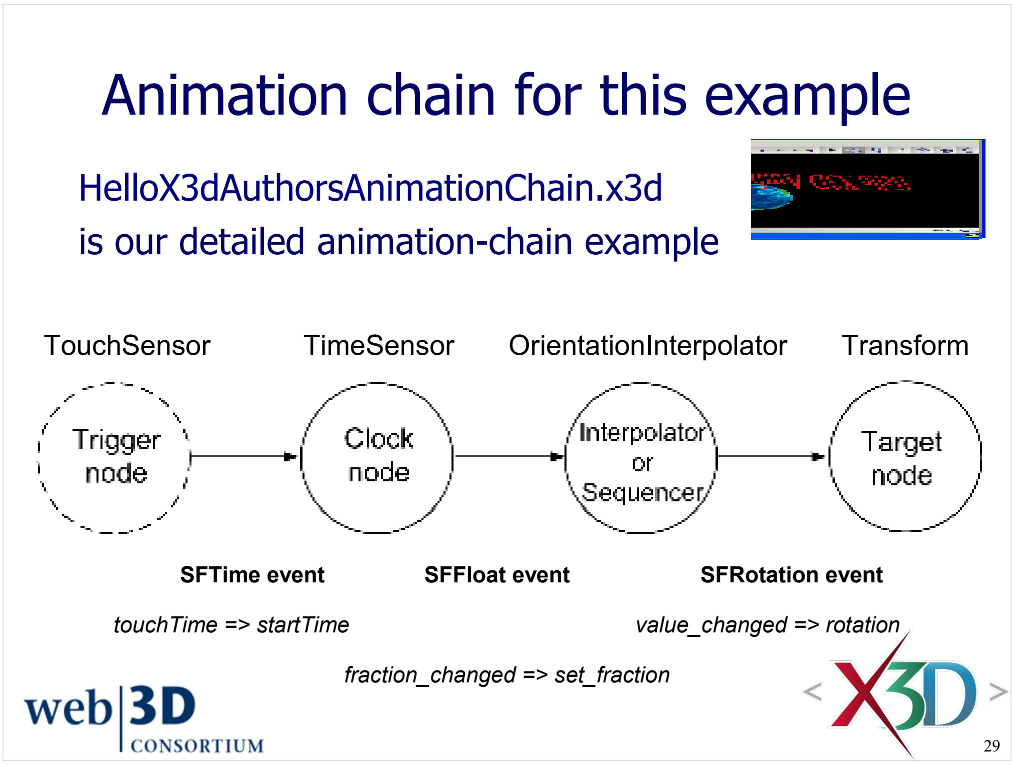
Field type	Description	Interpolator/Sequencer animation nodes
SFBool	Single-field boolean value	BooleanSequencer
SFColor	Single-field Color value, red-green-blue	ColorInterpolator
SFInt32	Single-field 32-bit Integer value	IntegerSequencer
SFFloat	Single-field single-precision floating-point value	ScalarInterpolator
SFRotation	Single-field Rotation value using 3-tuple axis, radian angle form	ColorInterpolator
SFTime	Single-field Time value	TimeSensor
SFVec2f	Single-field 2-float vector value	PositionInterpolator2D
MFVec2f	Multiple-field 2-float vector array	CoordinateInterpolator2D
SFVec3f	Single-field vector value of 3-float values	PositionInterpolator
MFVec3f	Multiple-field vector array of 3-float values	CoordinateInterpolator

Used in Step 5: Determine which Interpolator

X3D for Web Authors, Table 7.5, p. 199.

Notice that some types are not on the list! That is because there is no direct way to animate them. Usually a Script node is needed to do this.

- BackgroundColorArrayAnimation.x3d example in Script chapter 9
- TODO: also consider ColorArrayInterpolator node in Prototypes chapter 14



Animation chain for this example

HelloX3dAuthorsAnimationChain.x3d
is our detailed animation-chain example

TouchSensor — Trigger node → TimeSensor — Clock node → OrientationInterpolator — Interpolator or Sequencer → Transform — Target node

SFTime event **SFFloat event** **SFRotation event**

touchTime => startTime

value_changed => rotation

fraction_changed => set_fraction

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http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/HelloX3dAuthorsAnimationChain.x3d

Interestingly our example scene includes the TouchSensor trigger node, but as a default ignores that trigger by setting <TimeSensor *loop*=”true”/> which starts the rotation automatically.

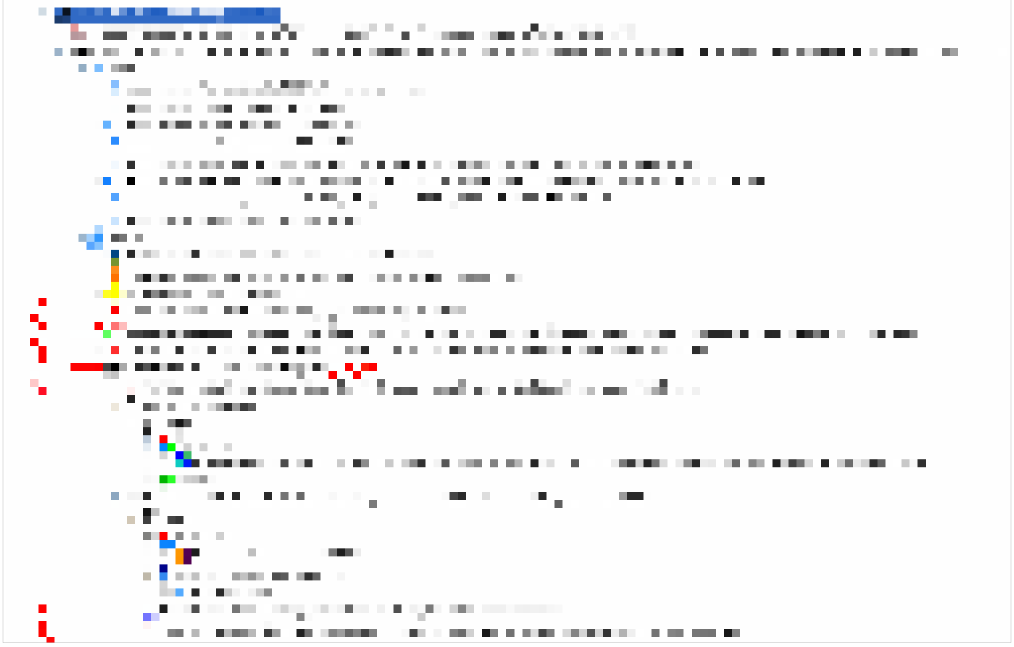
Hello X3D Authors showing ROUTEs

X3D for Web Authors, Figure 7.5, pp. 193-195.

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/HelloX3dAuthorsAnimationChain.x3d

10-step process for constructing animation chains, applied to animated HelloWorld example

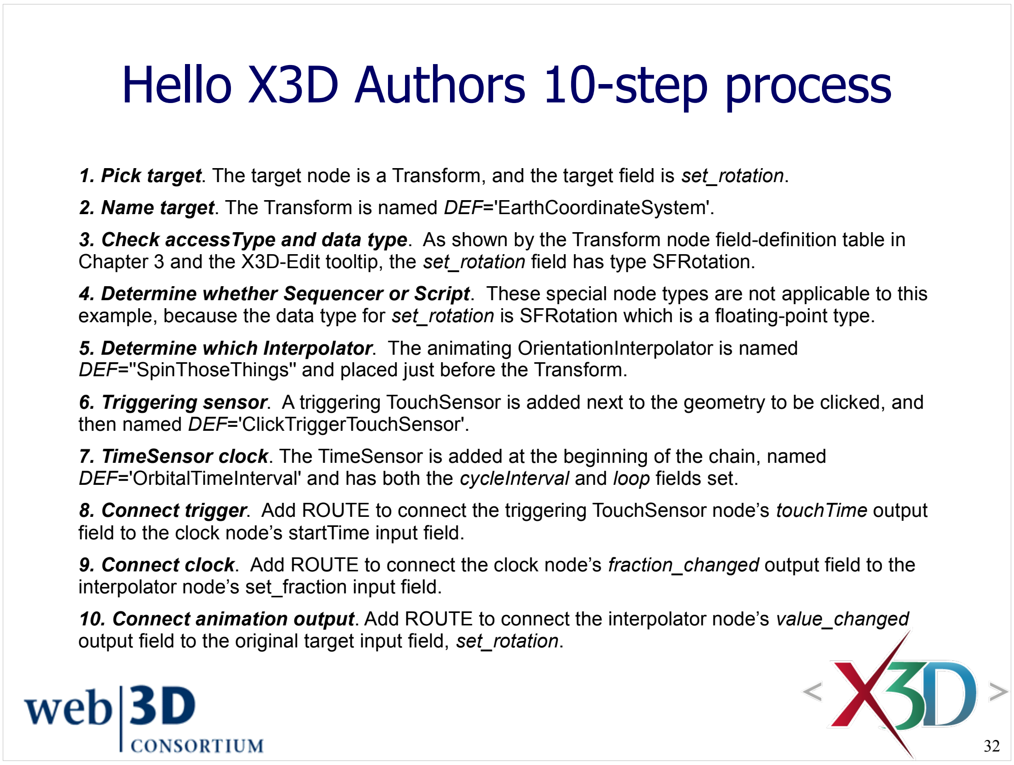
Hello X3D Authors 10-step process



X3D for Web Authors, Figure 7.5, pp. 193-195.

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/HelloX3dAuthorsAnimationChain.x3d

10-step process for constructing animation chains, applied to animated HelloWorld example



Hello X3D Authors 10-step process

1. Pick target. The target node is a Transform, and the target field is *set_rotation*.

2. Name target. The Transform is named *DEF*='EarthCoordinateSystem'.

3. Check accessType and data type. As shown by the Transform node field-definition table in Chapter 3 and the X3D-Edit tooltip, the *set_rotation* field has type SFRotation.

4. Determine whether Sequencer or Script. These special node types are not applicable to this example, because the data type for *set_rotation* is SFRotation which is a floating-point type.

5. Determine which Interpolator. The animating OrientationInterpolator is named *DEF*="SpinThoseThings" and placed just before the Transform.

6. Triggering sensor. A triggering TouchSensor is added next to the geometry to be clicked, and then named *DEF*='ClickTriggerTouchSensor'.

7. TimeSensor clock. The TimeSensor is added at the beginning of the chain, named *DEF*='OrbitalTimeInterval' and has both the *cycleInterval* and *loop* fields set.

8. Connect trigger. Add ROUTE to connect the triggering TouchSensor node's *touchTime* output field to the clock node's startTime input field.

9. Connect clock. Add ROUTE to connect the clock node's *fraction_changed* output field to the interpolator node's set_fraction input field.

10. Connect animation output. Add ROUTE to connect the interpolator node's *value_changed* output field to the original target input field, *set_rotation*.

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X3D for Web Authors, Figure 7.5, pp. 193-195.

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/HelloX3dAuthorsAnimationChain.x3d

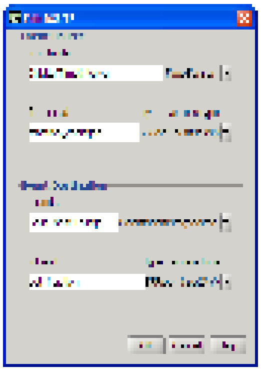
10-step process for constructing animation chains, applied to animated HelloWorld example

I strongly recommend you print this out (or keep it handy) and check off each step as you proceed. After a few times you will find that you are doing this without needing the checklist. Keeping a consistent pattern let's you avoid thinking that the various animation nodes are "really different" when they are not. It also helps you avoid skipping steps and making mistakes that are hard to debug afterwards.

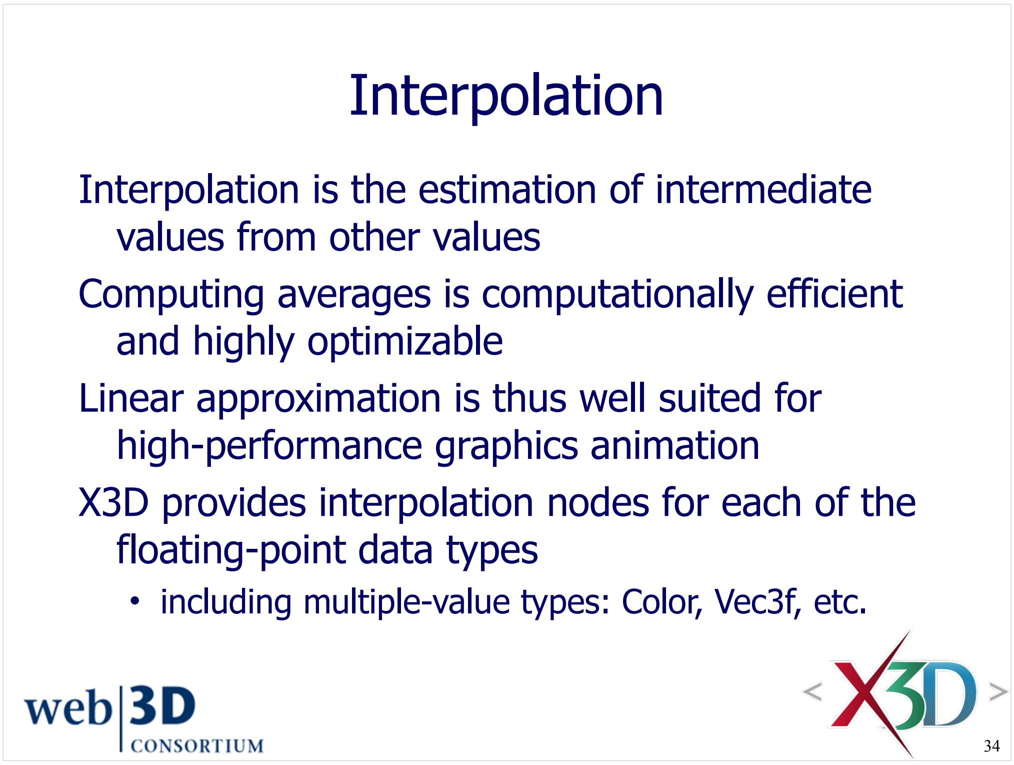
ROUTE editor examples

```
<ROUTE
    fromNode='OrbitalTimeInterval'
    fromField='fraction_changed'
    toNode='SpinThoseThings'
    toField='set_fraction' />

<ROUTE
    fromNode='ClickTriggerTouchSensor'
    fromField='touchTime'
    toNode='OrbitalTimeInterval'
    toField='startTime' />
```



http://www.web3d.org/x3d/content/examples/Basic/course/HelloX3dAuthorsAnimationChain.x3d



Interpolation

Interpolation is the estimation of intermediate values from other values

Computing averages is computationally efficient and highly optimizable

Linear approximation is thus well suited for high-performance graphics animation

X3D provides interpolation nodes for each of the floating-point data types

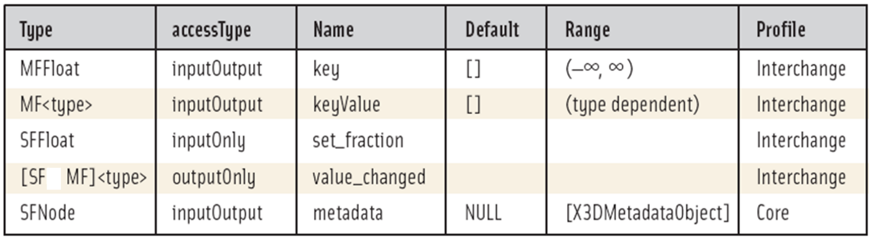
- including multiple-value types: Color, Vec3f, etc.

Interpolation node type

X3DInterpolationNode is the formal name for the interpolation node type

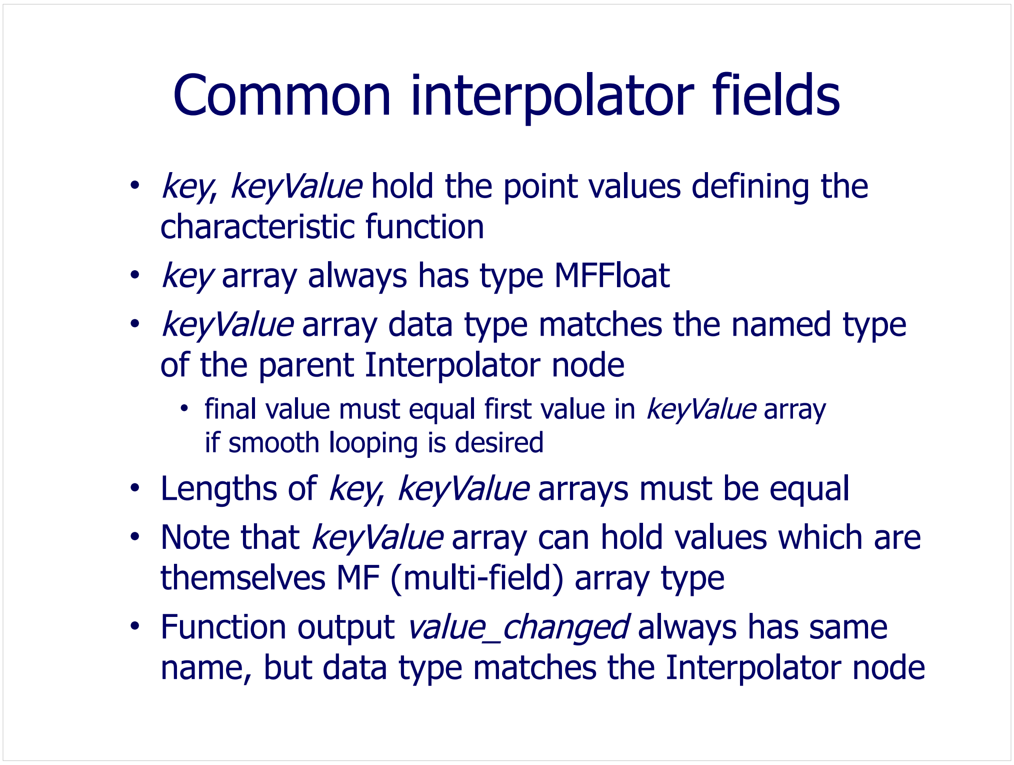
Each interpolation node includes the following common fields and naming conventions

- SF, MF <type> definition must be consistent for node in order to properly define response function



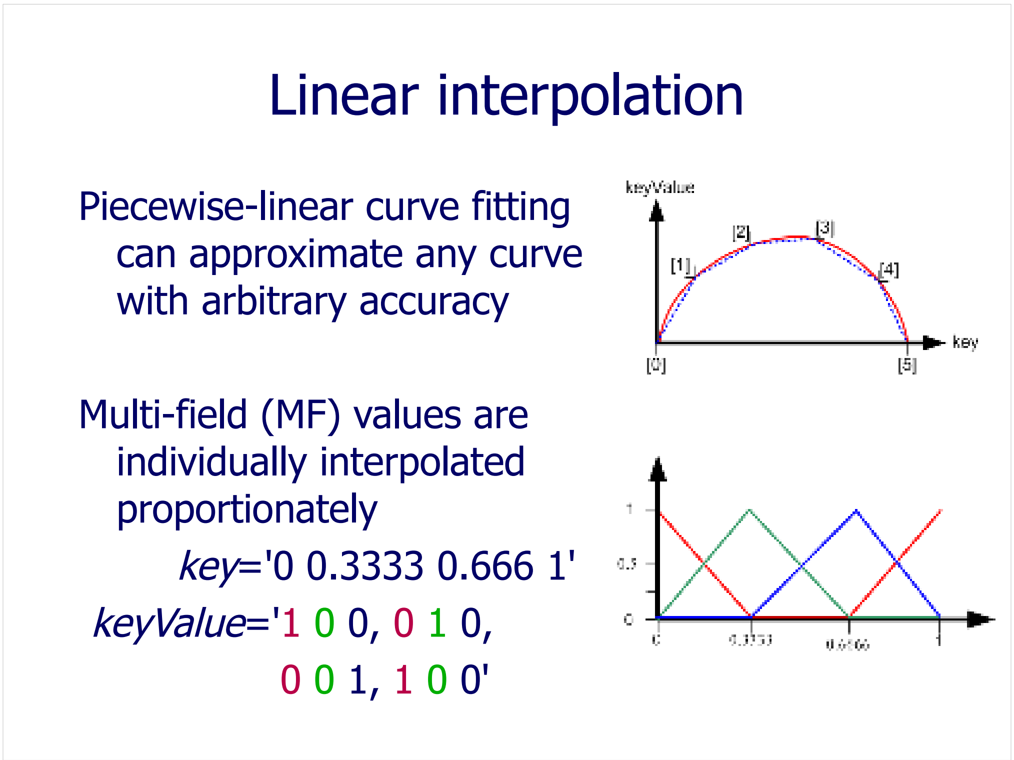
Type	accessType	Name	Default	Range	Profile
MFFloat	inputOutput	key	[]	(–∞, ∞)	Interchange
MF<type>	inputOutput	keyValue	[]	(type dependent)	Interchange
SFFloat	inputOnly	set_fraction			Interchange
[SF MF]<type>	outputOnly	value_changed			Interchange
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

X3D for Web Authors, Table 7.4, p. 197.



Common interpolator fields

- *key, keyValue* hold the point values defining the characteristic function
- *key* array always has type MFFloat
- *keyValue* array data type matches the named type of the parent Interpolator node
  - final value must equal first value in *keyValue* array if smooth looping is desired
- Lengths of *key, keyValue* arrays must be equal
- Note that *keyValue* array can hold values which are themselves MF (multi-field) array type
- Function output *value_changed* always has same name, but data type matches the Interpolator node



Linear interpolation

Piecewise-linear curve fitting can approximate any curve with arbitrary accuracy

Multi-field (MF) values are individually interpolated proportionately

key='0 0.3333 0.666 1'

keyValue='1 0 0, 0 1 0,
0 0 1, 1 0 0'

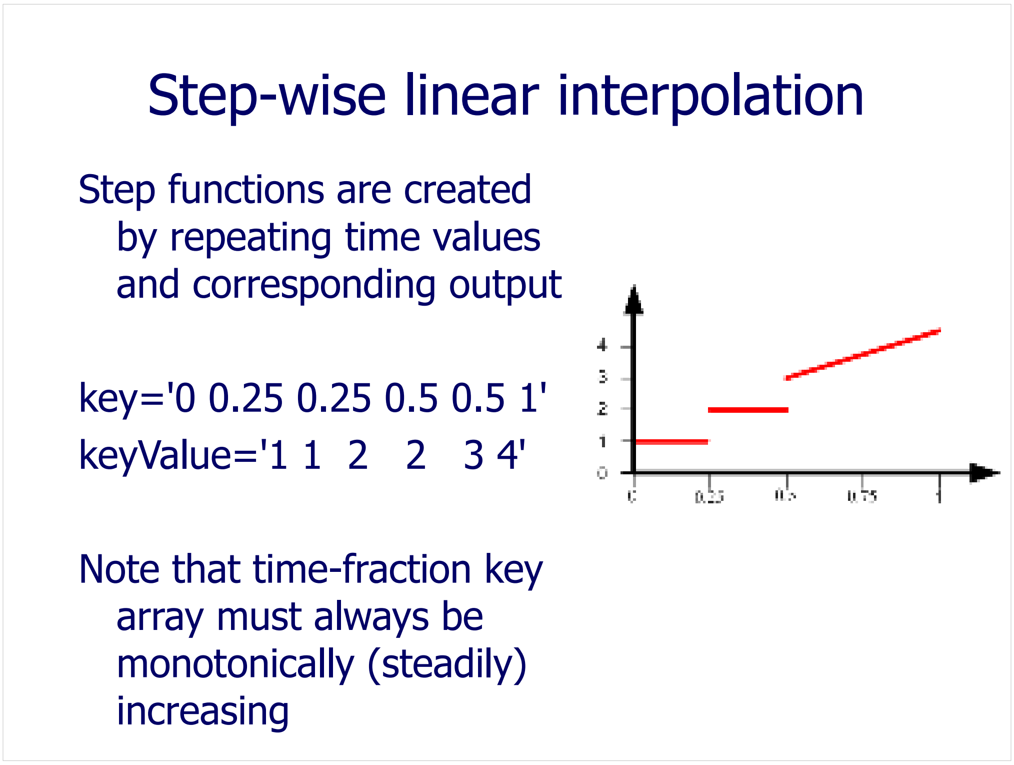
First figure: *X3D for Web Authors*, Figure 7.2, p. 191.

<ScalarInterpolator *key*="0 0.2 0.4 0.6 0.8 1" *keyValue*="0 5 8 9 4 0"/>

Second figure: *X3D for Web Authors*, Figure 7.4, p. 192.

<ColorInterpolator *key*="0, 0.3333, 0.6666, 1" *keyValue*="1 0 0, 0 1 0, 0 0 1, 1 0 0"/>

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d



Step-wise linear interpolation

Step functions are created by repeating time values and corresponding output

key='0 0.25 0.25 0.5 0.5 1'

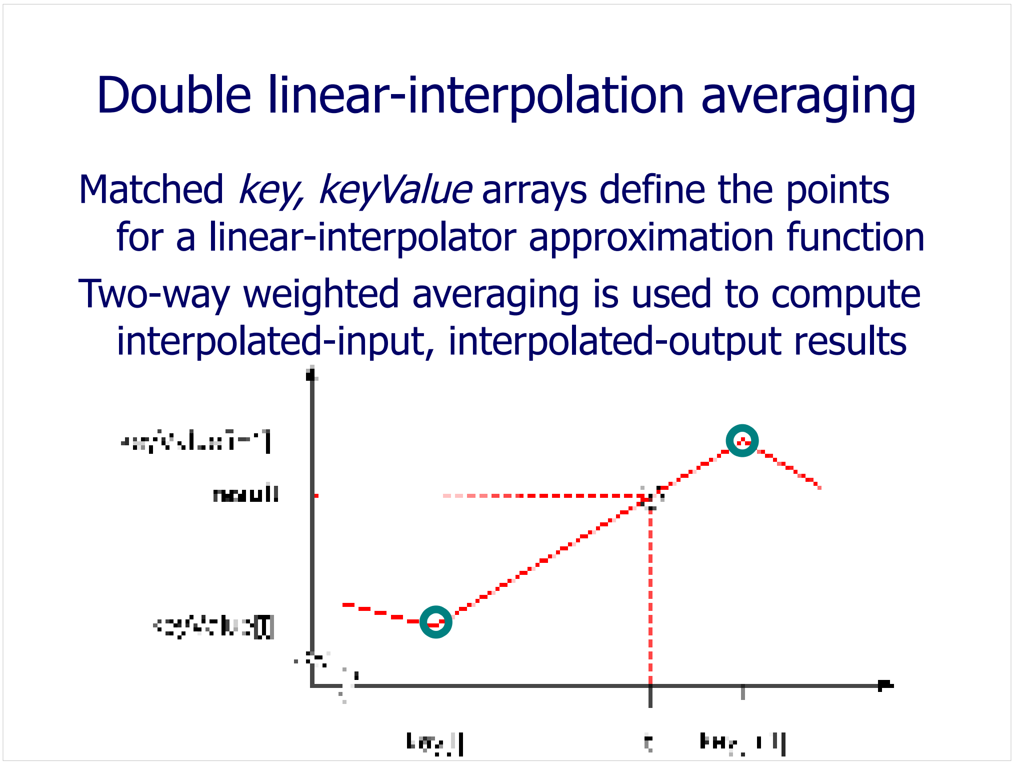
keyValue='1 1 2   2   3 4'

Note that time-fraction key array must always be monotonically (steadily) increasing

4
3
2
1
0
0
0.25
0.5
0.75
1

X3D for Web Authors, Figure 7.3, p. 191.

<ScalarInterpolator *key*="0 0.25, 0.25 0.5, 0.5 1" *keyValue*="1 1, 2 2, 3 4"/>



Double linear-interpolation averaging

Matched *key, keyValue* arrays define the points for a linear-interpolator approximation function

Two-way weighted averaging is used to compute interpolated-input, interpolated-output results

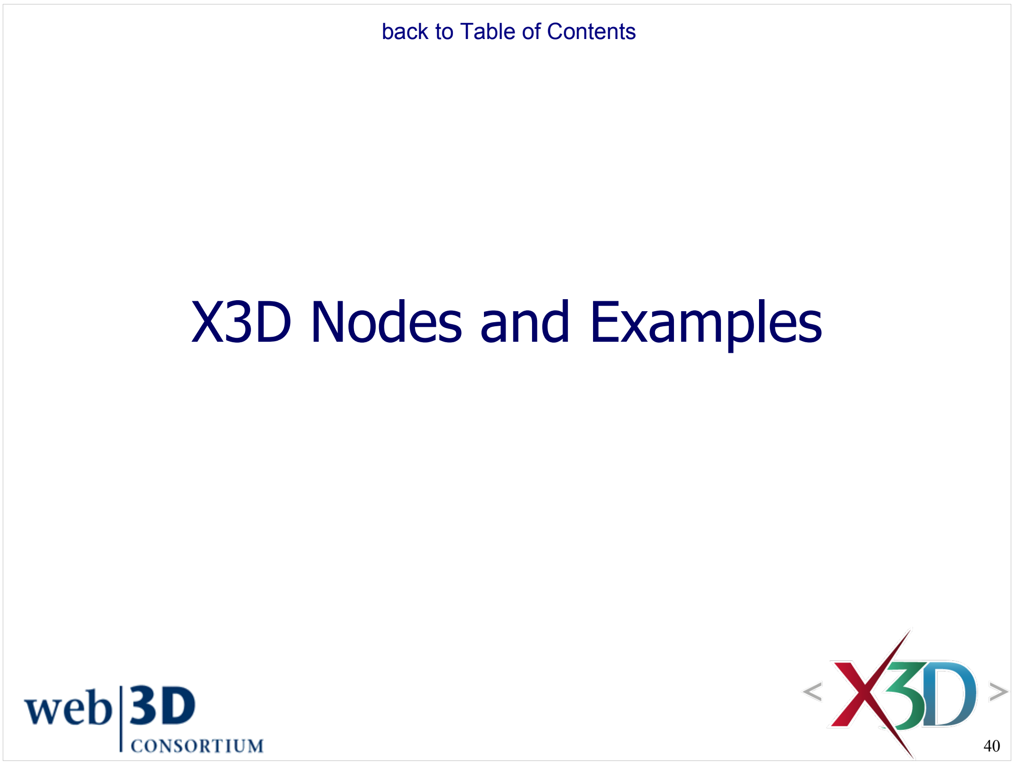
X3D for Web Authors, Figure 7.8, p. 198.

First the entry-value *t* is compared to the *key* array until the prior and following values of *key* are found that are less-than and greater-than *t*.

Then a percentage is computed that accounts for the proportion of t between the bracketing values of *key*[i] and *key*[i+1].

Then this same percentage is applied to compute a new *result* value which equals the same percentage between corresponding output-array values of *keyValue*[i] and *keyValue*[i+1].

Interpolation equations are found on the TimeSensor Output slide and notes.



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X3D Nodes and Examples

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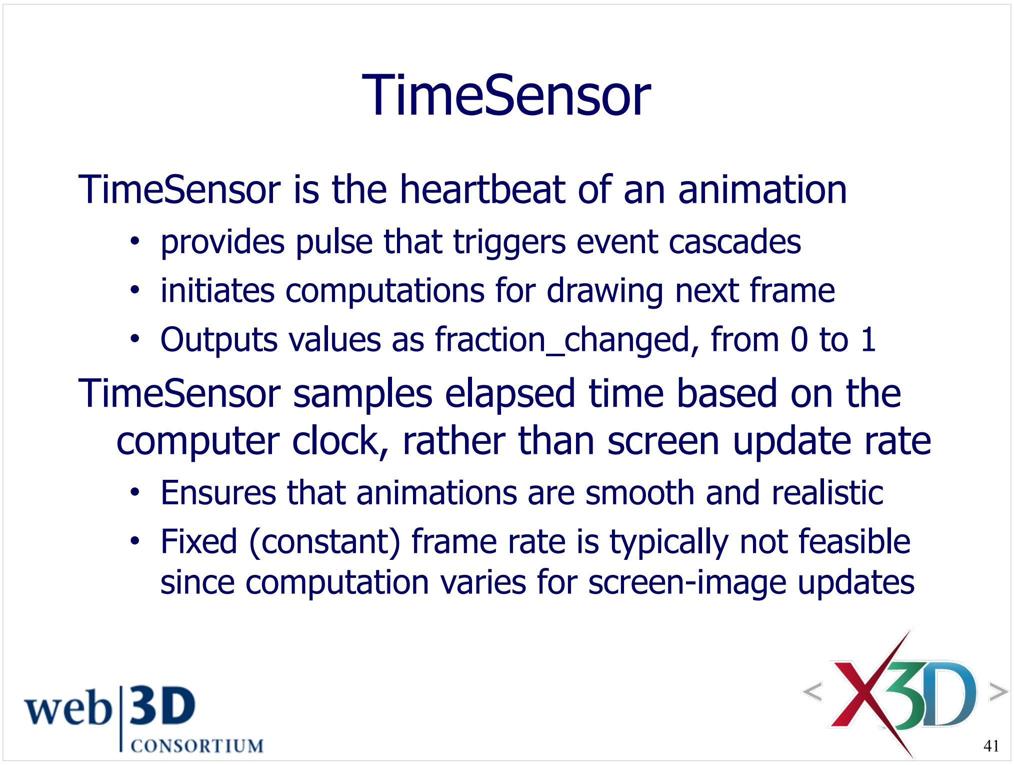


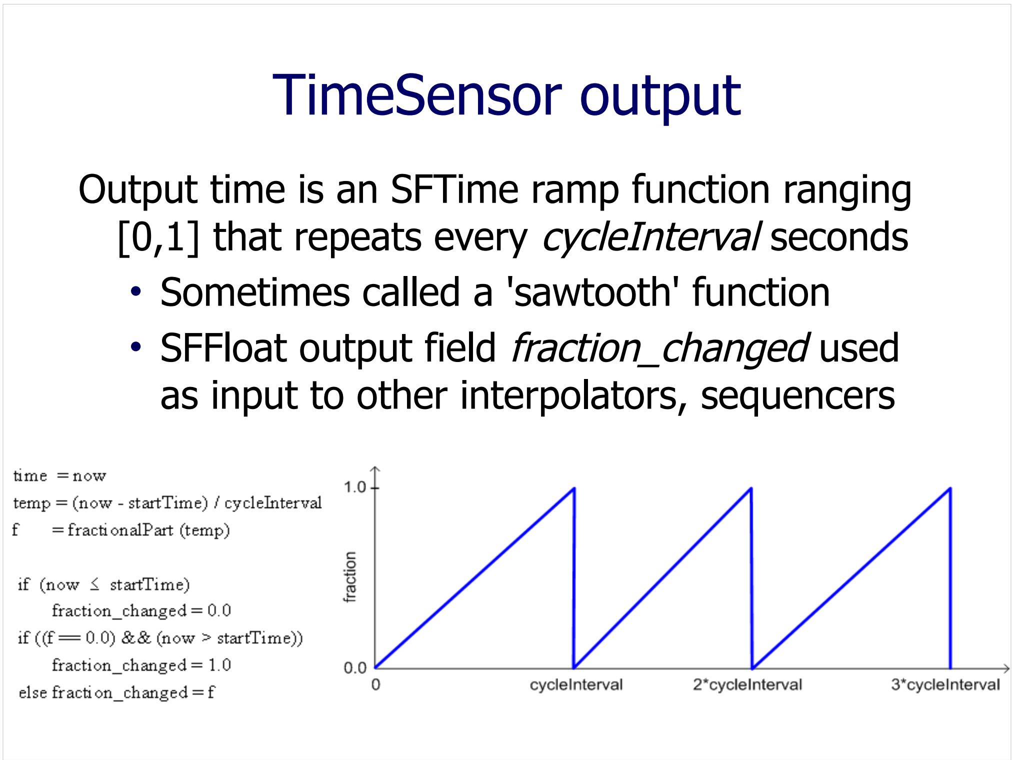
TimeSensor

TimeSensor is the heartbeat of an animation

- provides pulse that triggers event cascades
- initiates computations for drawing next frame
- Outputs values as fraction_changed, from 0 to 1

TimeSensor samples elapsed time based on the computer clock, rather than screen update rate

- Ensures that animations are smooth and realistic
- Fixed (constant) frame rate is typically not feasible since computation varies for screen-image updates



TimeSensor output

Output time is an SFTime ramp function ranging [0,1] that repeats every *cycleInterval* seconds

- Sometimes called a 'sawtooth' function
- SFFloat output field *fraction_changed* used as input to other interpolators, sequencers

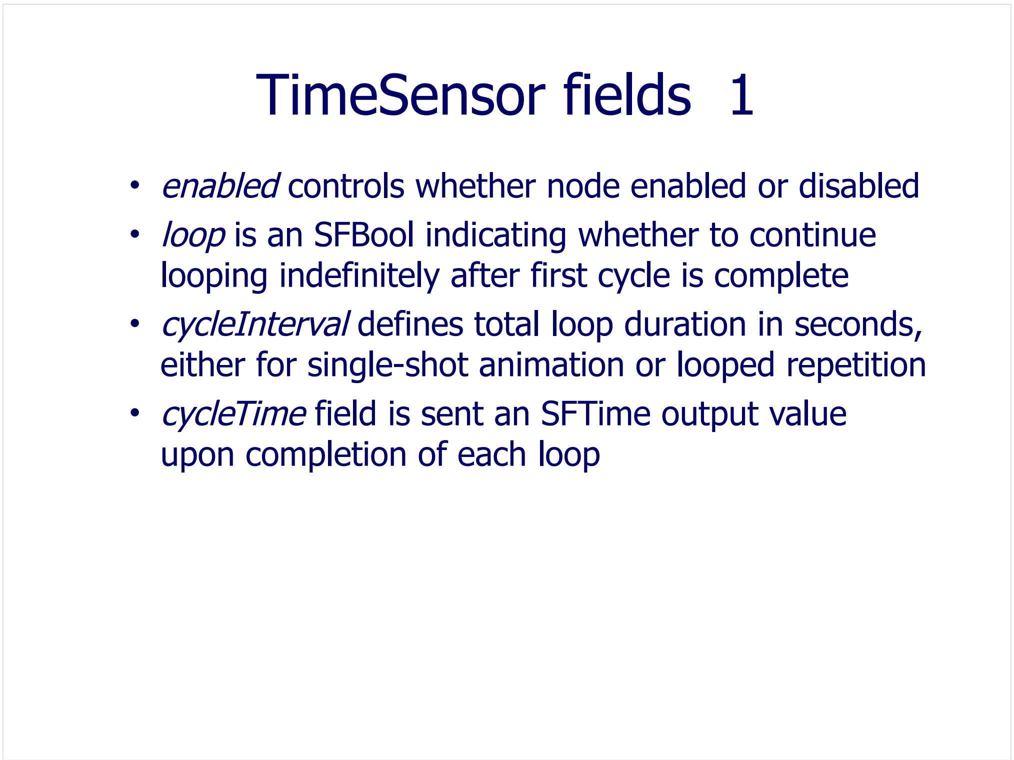
```
time  = now
temp = (now - startTime) / cycleInterval
f     = fractionalPart (temp)

 if (now ≤ startTime)
       fraction_changed = 0.0
 if ((f == 0.0) && (now > startTime))
       fraction_changed = 1.0
 else fraction_changed = f
```

Sawtooth function

X3D for Web Authors, Figure 7.9, p. 201. TimeSensor *fraction_changed* varies over the range [0,1] for each *cycleInterval* repetition.

X3D for Web Authors, Figure 7.10, p. 202. TimeSensor fraction_changed output algorithm, expressed in pseudocode.

```
time=now; // output field value
numberOfLoops=(now-startTime) / cycleInterval; // floating-point calculation
f = fractionalPart (numberOfLoops);
if (now == startTime)
   fraction_changed = 0.0; // output field value
else if ((loop==''false'') && (now == (startTime + cycleInterval)))
   fraction_changed = 1.0; // output field value
else fraction_changed = f; // output field value
```



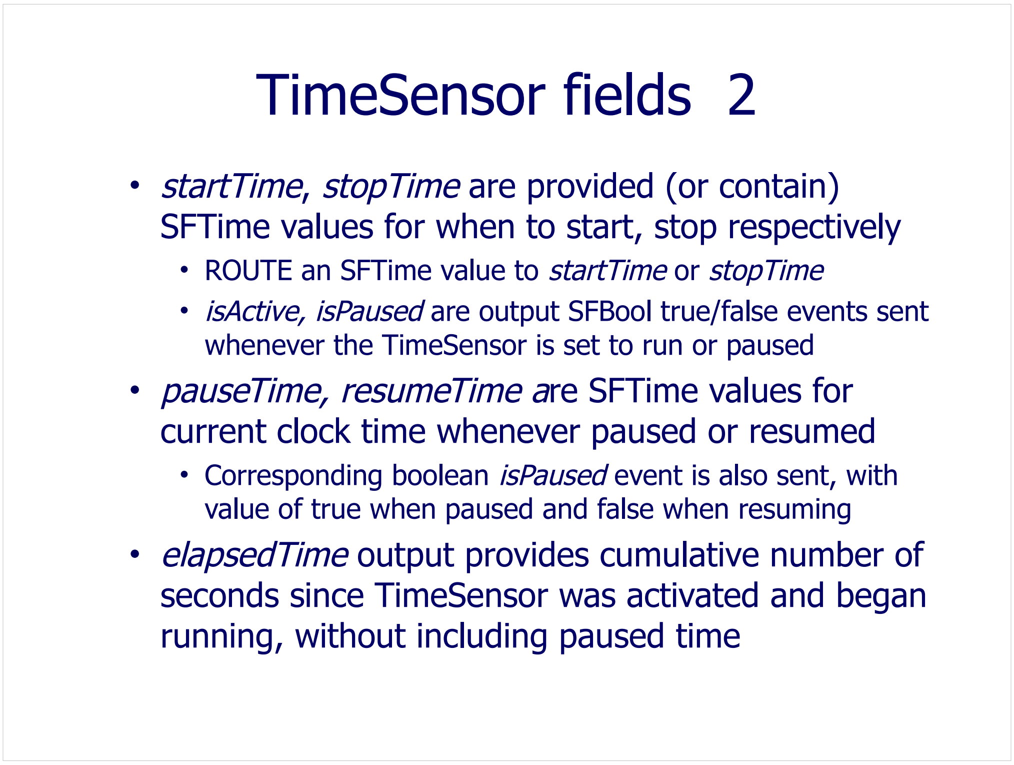
TimeSensor fields 1

- *enabled* controls whether node enabled or disabled
- *loop* is an SFBool indicating whether to continue looping indefinitely after first cycle is complete
- *cycleInterval* defines total loop duration in seconds, either for single-shot animation or looped repetition
- *cycleTime* field is sent an SFTime output value upon completion of each loop

Two ways to stop an animation: set *enabled*='false' or send an SFTime event to *stopTime*

Similarly, must reset enabled or send an SFTime event to *startTime* to begin again.

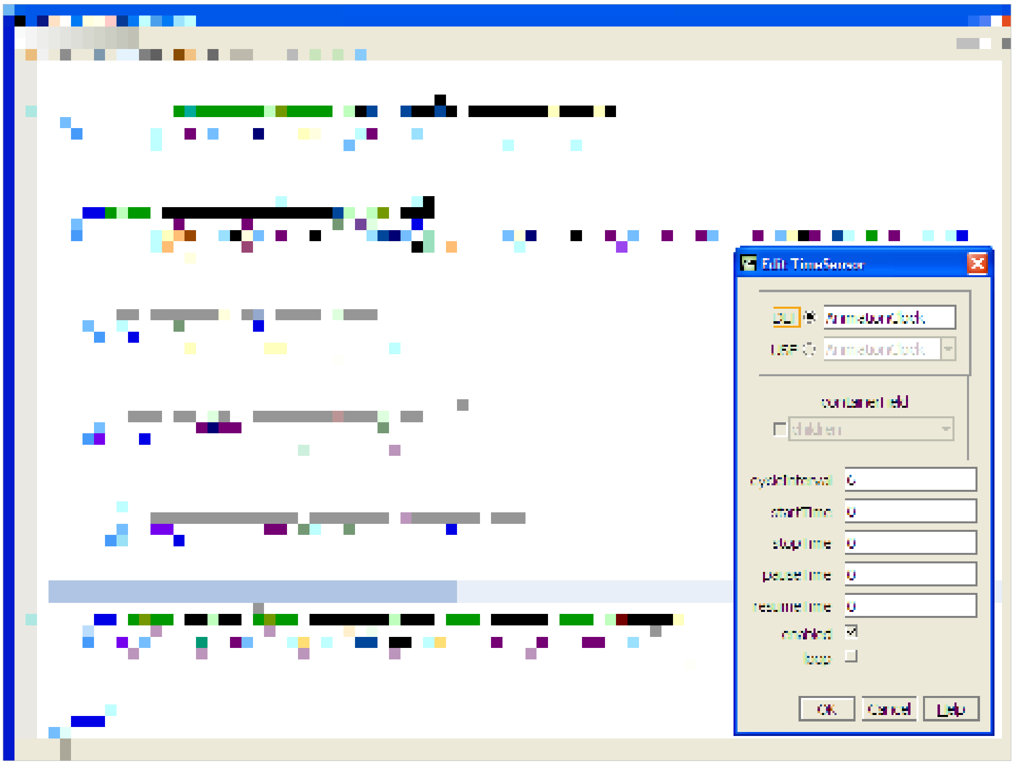
Can alternatively send SFTime values to *set_stopTime, set_startTime*



TimeSensor fields 2

- *startTime*, *stopTime* are provided (or contain) SFTime values for when to start, stop respectively
  - ROUTE an SFTime value to *startTime* or *stopTime*
  - *isActive, isPaused* are output SFBool true/false events sent whenever the TimeSensor is set to run or paused
- *pauseTime, resumeTime a*re SFTime values for current clock time whenever paused or resumed
  - Corresponding boolean *isPaused* event is also sent, with value of true when paused and false when resuming
- *elapsedTime* output provides cumulative number of seconds since TimeSensor was activated and began running, without including paused time

Can alternatively send SFTime values to *set_pauseTime, set_resumeTime*

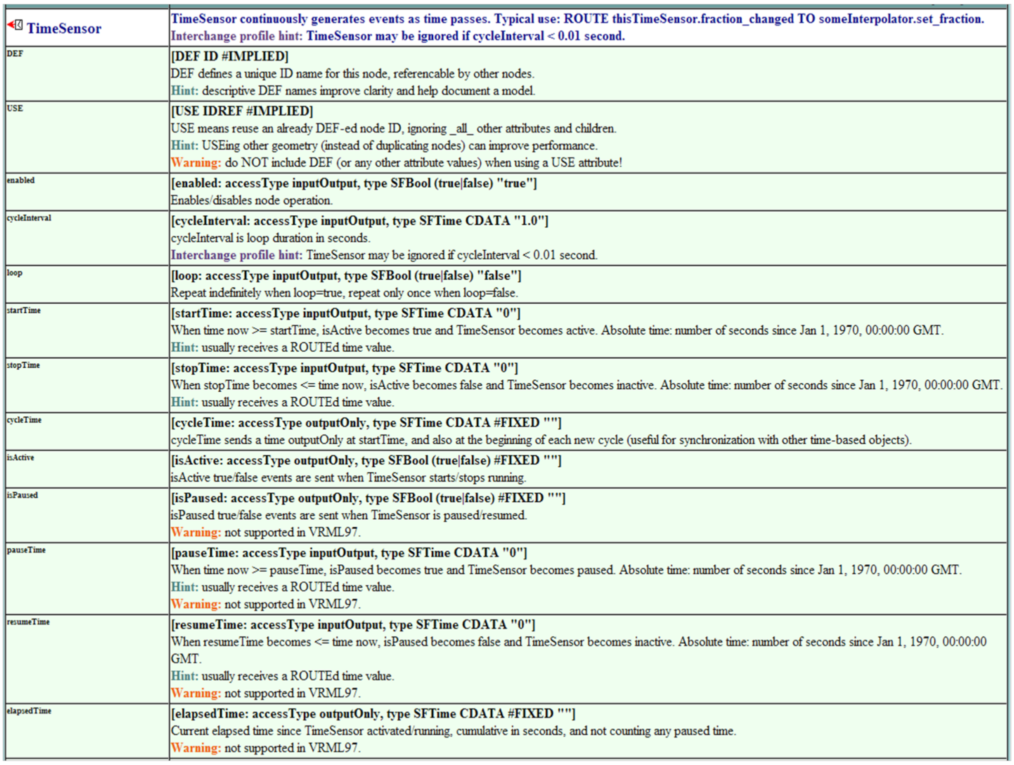


DEF ● AnimationClock
USE ○ AnimationClock

containerField
□ children

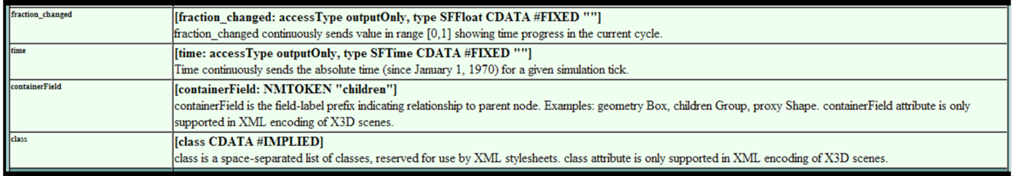
cycleInterval 6
startTime 0
stopTime 0
pauseTime 0
resumeTime 0
enabled ☑
loop □

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d



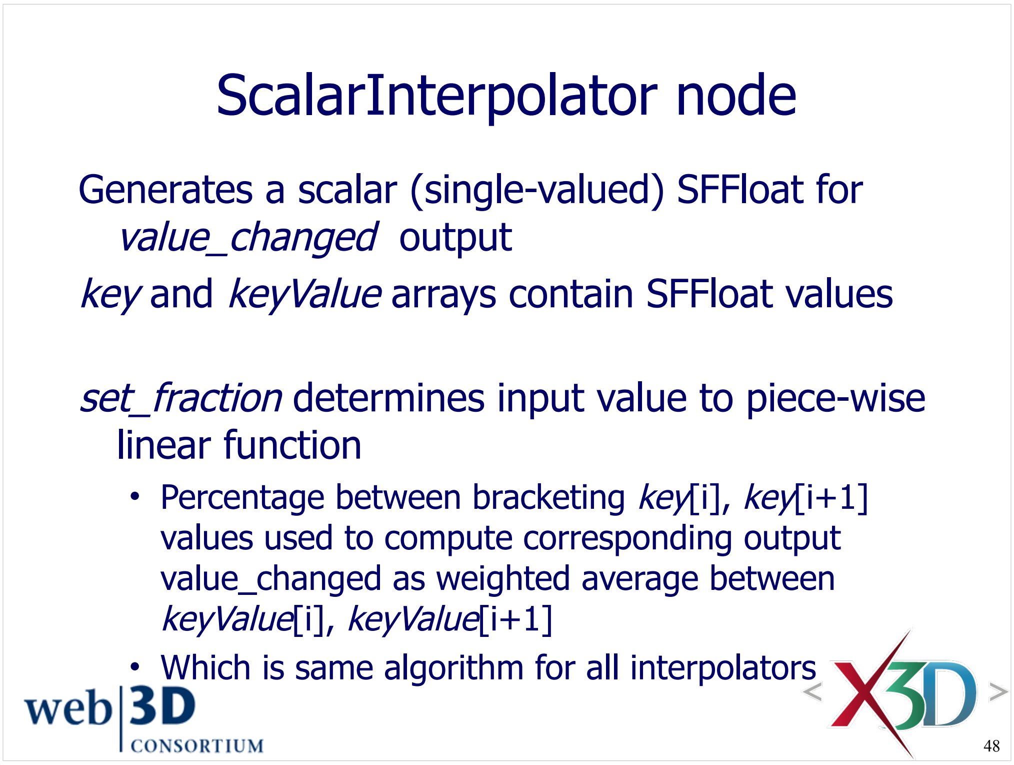
TimeSensor	**TimeSensor continuously generates events as time passes. Typical use: ROUTE thisTimeSensor.fraction_changed TO someInterpolator.set_fraction.** **Interchange profile hint: TimeSensor may be ignored if cycleInterval < 0.01 second.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. **Hint:** descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. **Hint:** USEing other geometry (instead of duplicating nodes) can improve performance. **Warning:** do NOT include DEF (or any other attribute values) when using a USE attribute!
enabled	**[enabled: accessType inputOutput, type SFBool (true|false) "true"]** Enables/disables node operation.
cycleInterval	**[cycleInterval: accessType inputOutput, type SFTime CDATA "1.0"]** cycleInterval is loop duration in seconds. **Interchange profile hint:** TimeSensor may be ignored if cycleInterval < 0.01 second.
loop	**[loop: accessType inputOutput, type SFBool (true|false) "false"]** Repeat indefinitely when loop=true, repeat only once when loop=false.
startTime	**[startTime: accessType inputOutput, type SFTime CDATA "0"]** When time now >= startTime, isActive becomes true and TimeSensor becomes active. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. **Hint:** usually receives a ROUTEd time value.
stopTime	**[stopTime: accessType inputOutput, type SFTime CDATA "0"]** When stopTime becomes <= time now, isActive becomes false and TimeSensor becomes inactive. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. **Hint:** usually receives a ROUTEd time value.
cycleTime	**[cycleTime: accessType outputOnly, type SFTime CDATA #FIXED ""]** cycleTime sends a time outputOnly at startTime, and also at the beginning of each new cycle (useful for synchronization with other time-based objects).
isActive	**[isActive: accessType outputOnly, type SFBool (true|false) #FIXED ""]** isActive true/false events are sent when TimeSensor starts/stops running.
isPaused	**[isPaused: accessType outputOnly, type SFBool (true|false) #FIXED ""]** isPaused true/false events are sent when TimeSensor is paused/resumed. **Warning:** not supported in VRML97.
pauseTime	**[pauseTime: accessType inputOutput, type SFTime CDATA "0"]** When time now >= pauseTime, isPaused becomes true and TimeSensor becomes paused. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. **Hint:** usually receives a ROUTEd time value. **Warning:** not supported in VRML97.
resumeTime	**[resumeTime: accessType inputOutput, type SFTime CDATA "0"]** When resumeTime becomes <= time now, isPaused becomes false and TimeSensor becomes inactive. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. **Hint:** usually receives a ROUTEd time value. **Warning:** not supported in VRML97.
elapsedTime	**[elapsedTime: accessType outputOnly, type SFTime CDATA #FIXED ""]** Current elapsed time since TimeSensor activated/running, cumulative in seconds, and not counting any paused time. **Warning:** not supported in VRML97.

http://www.web3d.org/x3d/content/X3dTooltips.html#TimeSensor



fraction_changed	**[fraction_changed: accessType outputOnly, type SFFloat CDATA #FIXED ""]** fraction_changed continuously sends value in range [0,1] showing time progress in the current cycle.
time	**[time: accessType outputOnly, type SFTime CDATA #FIXED ""]** Time continuously sends the absolute time (since January 1, 1970) for a given simulation tick.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#TimeSensor



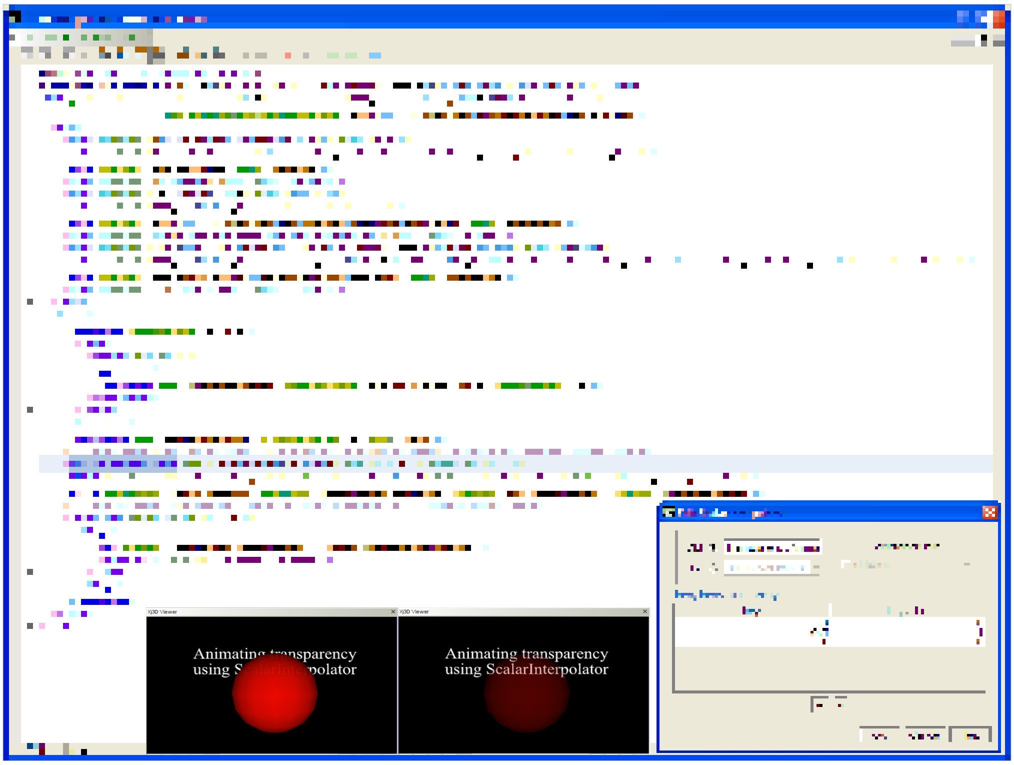
ScalarInterpolator node

Generates a scalar (single-valued) SFFloat for *value_changed* output

key and *keyValue* arrays contain SFFloat values

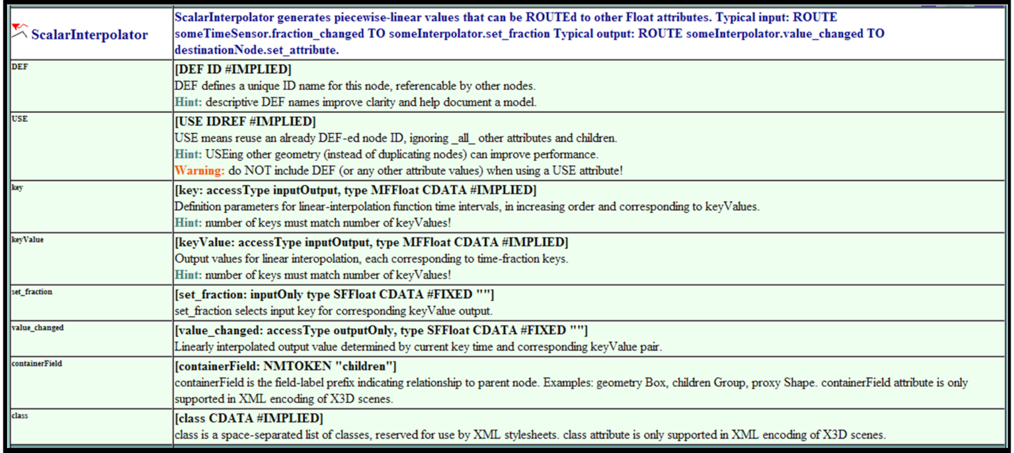
set_fraction determines input value to piece-wise linear function

- Percentage between bracketing *key*[i], *key*[i+1] values used to compute corresponding output value_changed as weighted average between *keyValue*[i], *keyValue*[i+1]
- Which is same algorithm for all interpolators



http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ScalarInterpolator.x3d

The ScalarInterpolator output values are used to modify the Material *transparency* value of the Sphere.



ScalarInterpolator	**ScalarInterpolator generates piecewise-linear values that can be ROUTEd to other Float attributes. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFFloat CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#ScalarInterpolator

ColorInterpolator node

Generates a 3-tuple (triple-valued) SFColor for continuous *value_changed* output

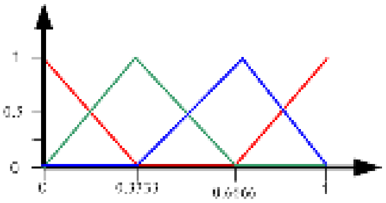
key array contains SFFloat values

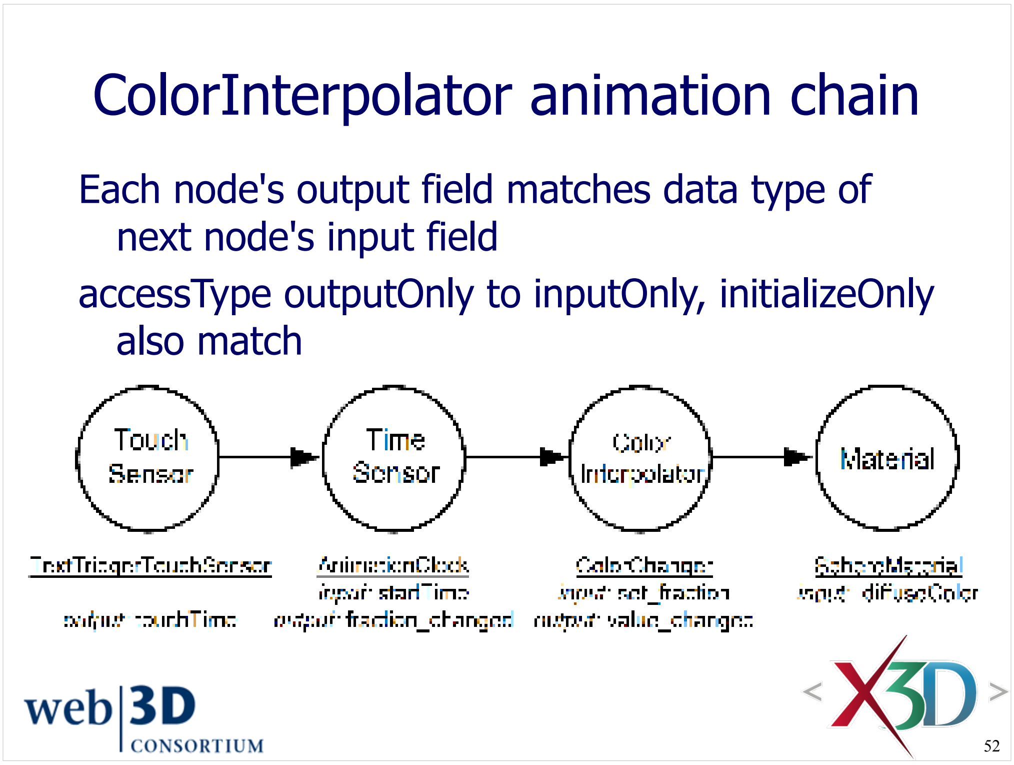
keyValue array contains SFColor values

Linear interpolation of red, green, blue (RGB) values is respectively performed for each bracketing *keyValue* pair

key='0 0.3333 0.666 1'

keyValue='1 0 0, 0 1 0,
0 0 1, 1 0 0'





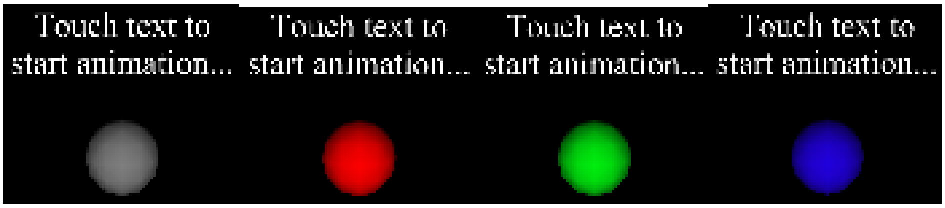
ColorInterpolator animation chain

- Each node's output field matches data type of next node's input field
- accessType outputOnly to inputOnly, initializeOnly also match

ColorInterpolator example output

Using the pointing device to select the text triggers the ColorInterpolator animation

- Colors vary gradually, by linear interpolation of each of the component red-green-blue RGB values

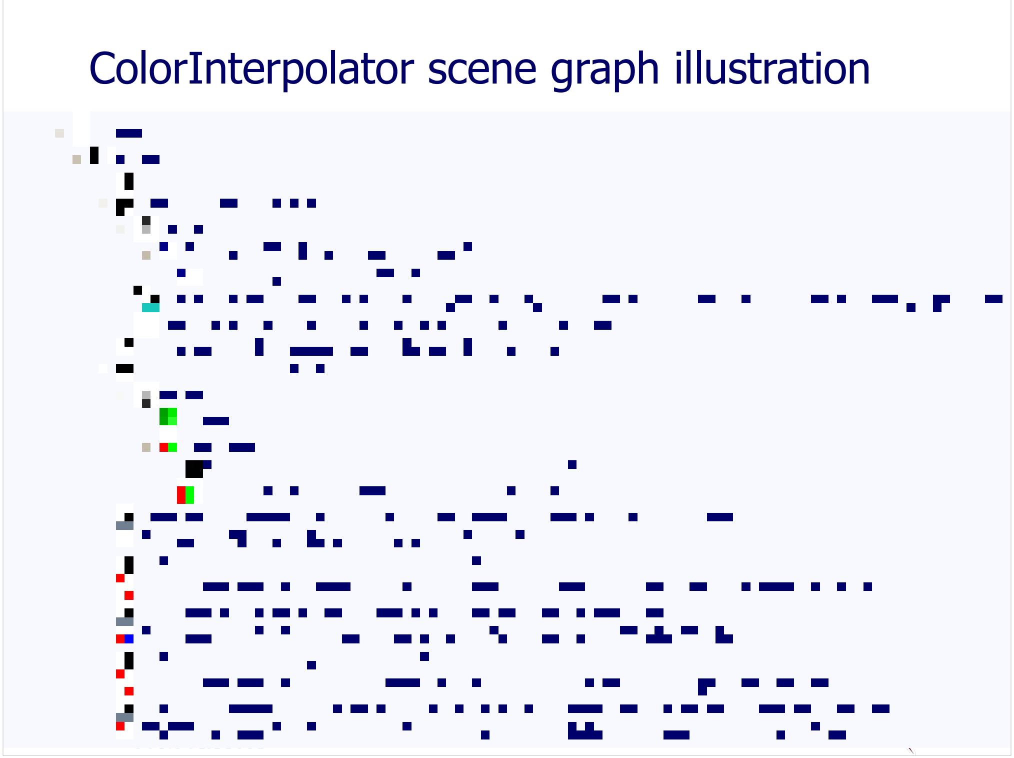


Touch text to start animation...

Touch text to start animation...

Touch text to start animation...

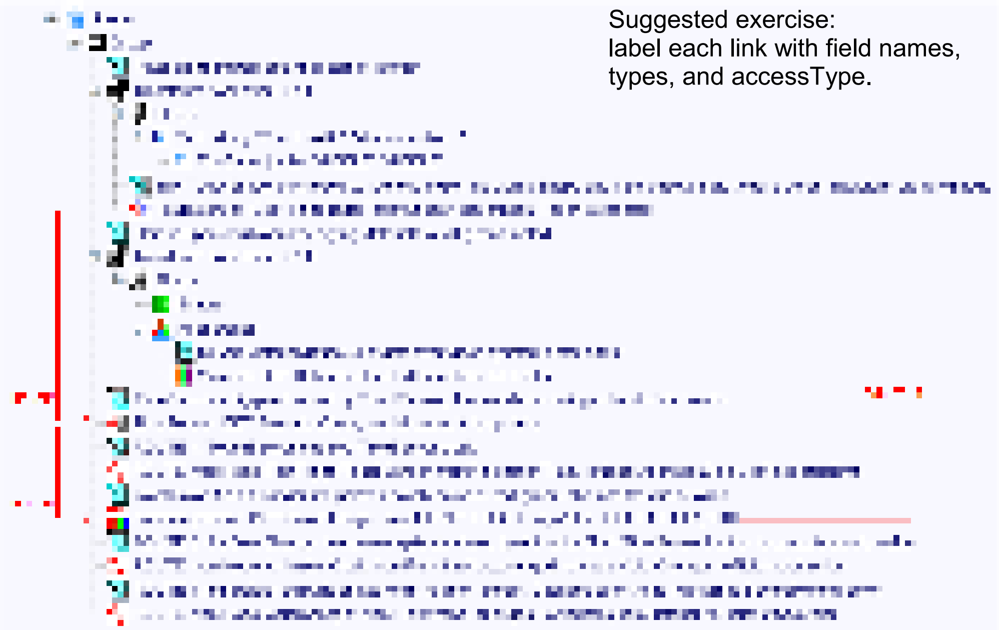
Touch text to start animation...



ColorInterpolator scene graph illustration

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d

ColorInterpolator scene graph with ROUTEs



Suggested exercise:
label each link with field names, types, and accessType.

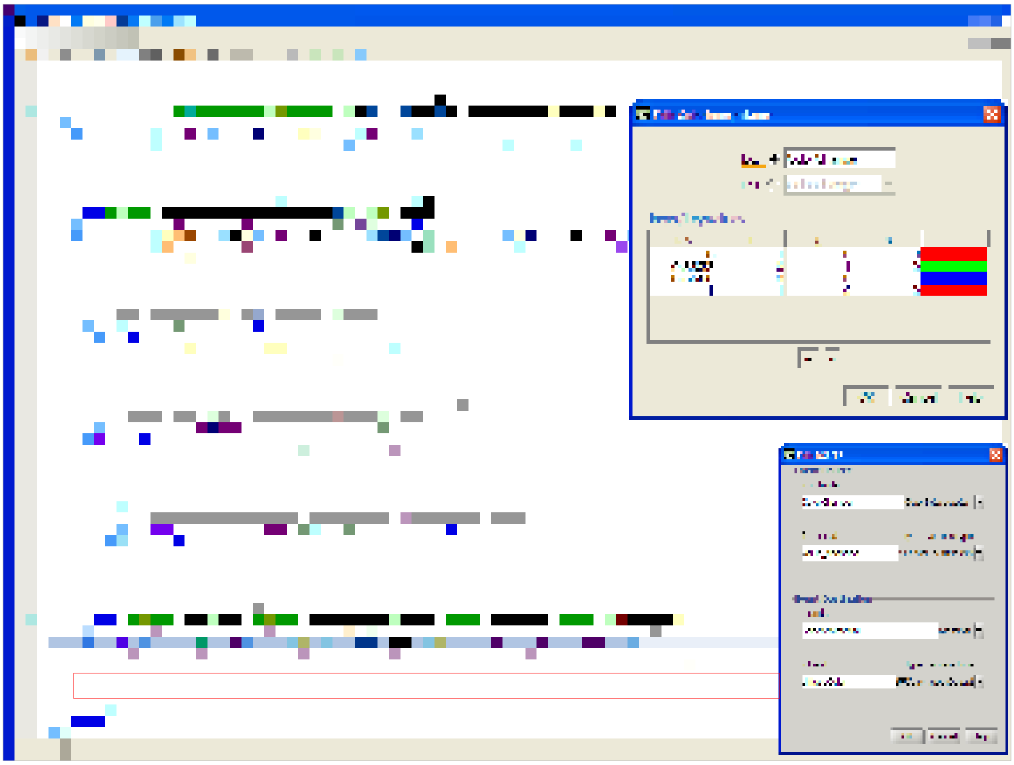
http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d

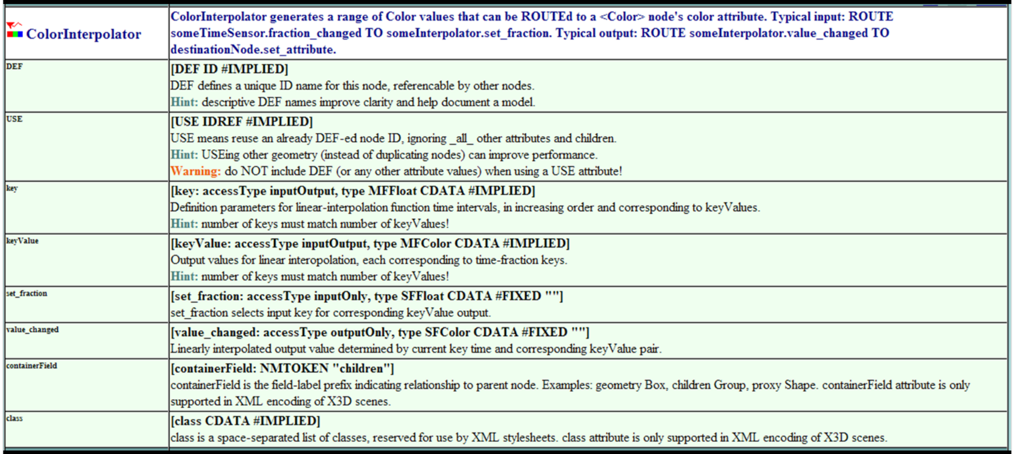
Pretty-printing a scene in HTML, printing it in landscape mode and then annotating it with ROUTE arrows is an excellent way to debug animation chains in a large scene.

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d

Pretty-printing a scene in HTML, printing it in landscape mode and then annotating it with ROUTE arrows is an excellent way to debug animation chains in a large scene.

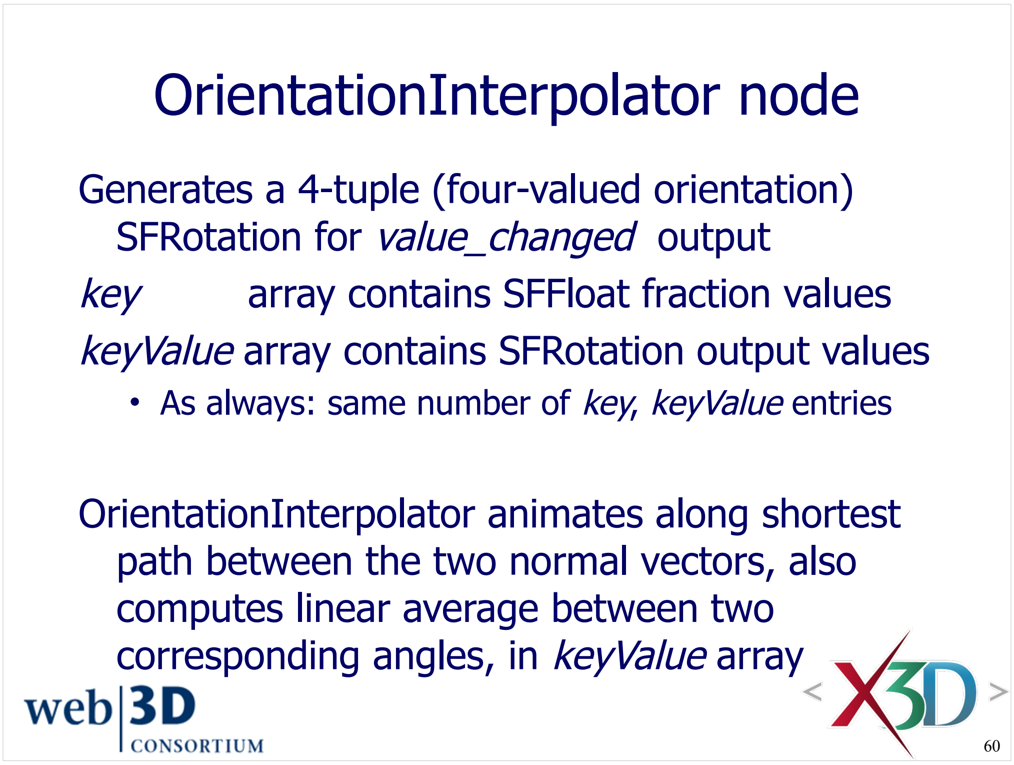


http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/ColorInterpolatorExample.x3d



ColorInterpolator	**ColorInterpolator generates a range of Color values that can be ROUTEd to a <Color> node's color attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. **Hint:** descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. **Hint:** USEing other geometry (instead of duplicating nodes) can improve performance. **Warning:** do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. **Hint:** number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFColor CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. **Hint:** number of keys must match number of keyValues!
set_fraction	**[set_fraction: accessType inputOnly, type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFColor CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#ColorInterpolator



OrientationInterpolator node

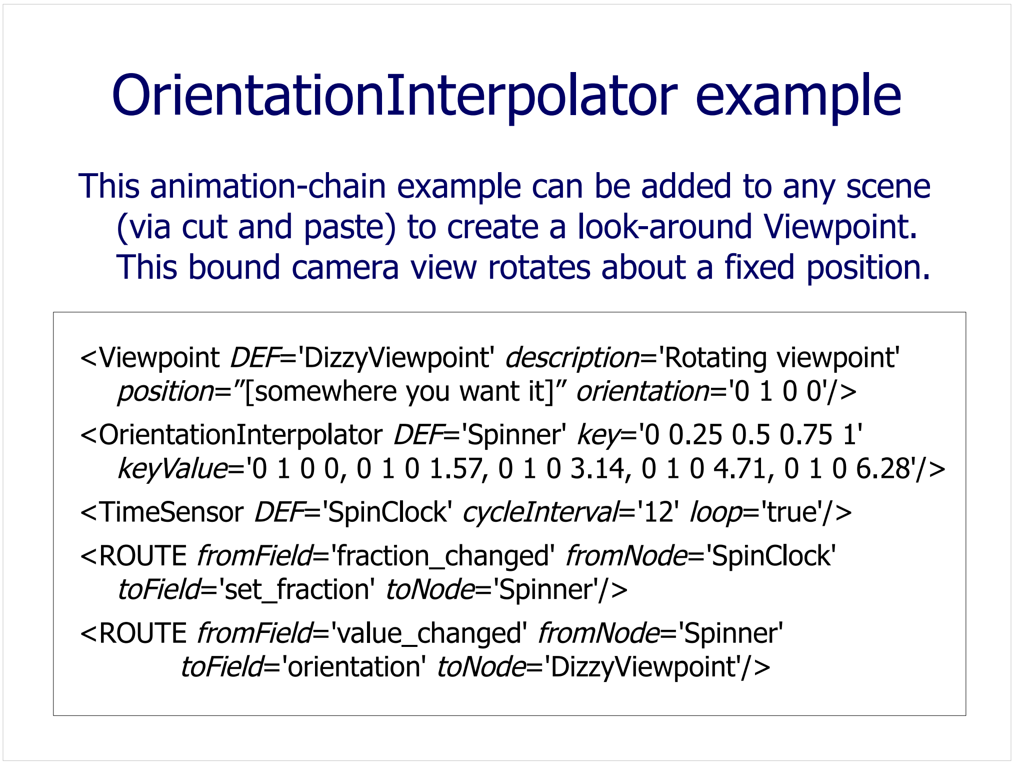
Generates a 4-tuple (four-valued orientation) SFRotation for *value_changed* output

key array contains SFFloat fraction values

keyValue array contains SFRotation output values

- As always: same number of *key*, *keyValue* entries

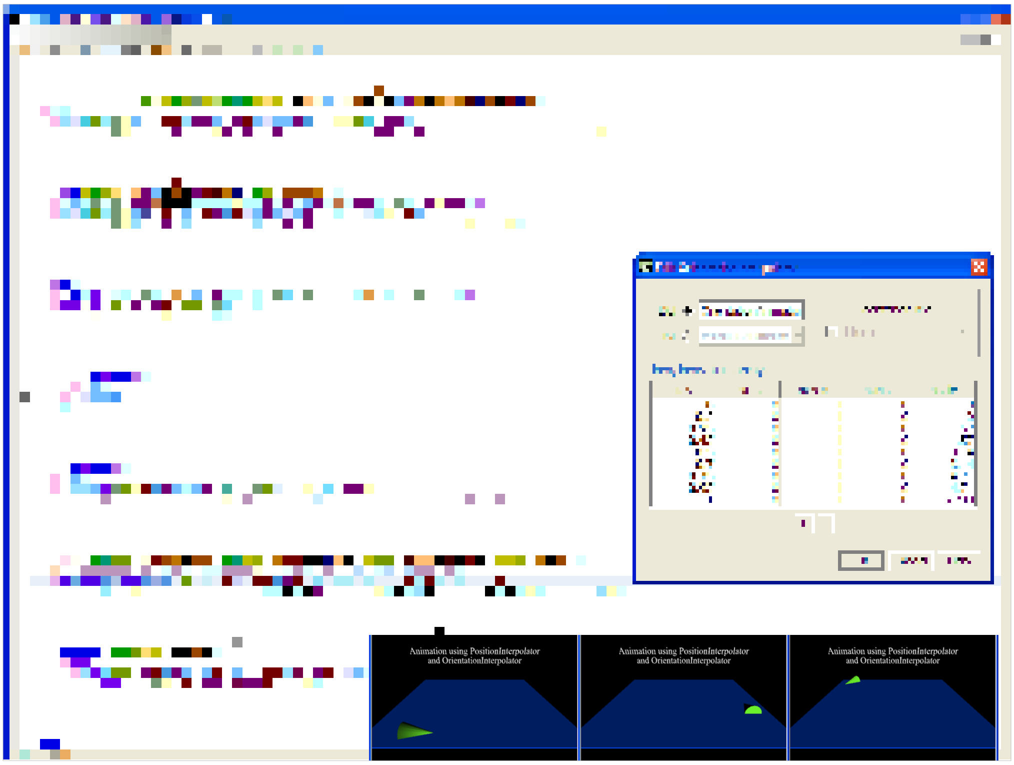
OrientationInterpolator animates along shortest path between the two normal vectors, also computes linear average between two corresponding angles, in *keyValue* array



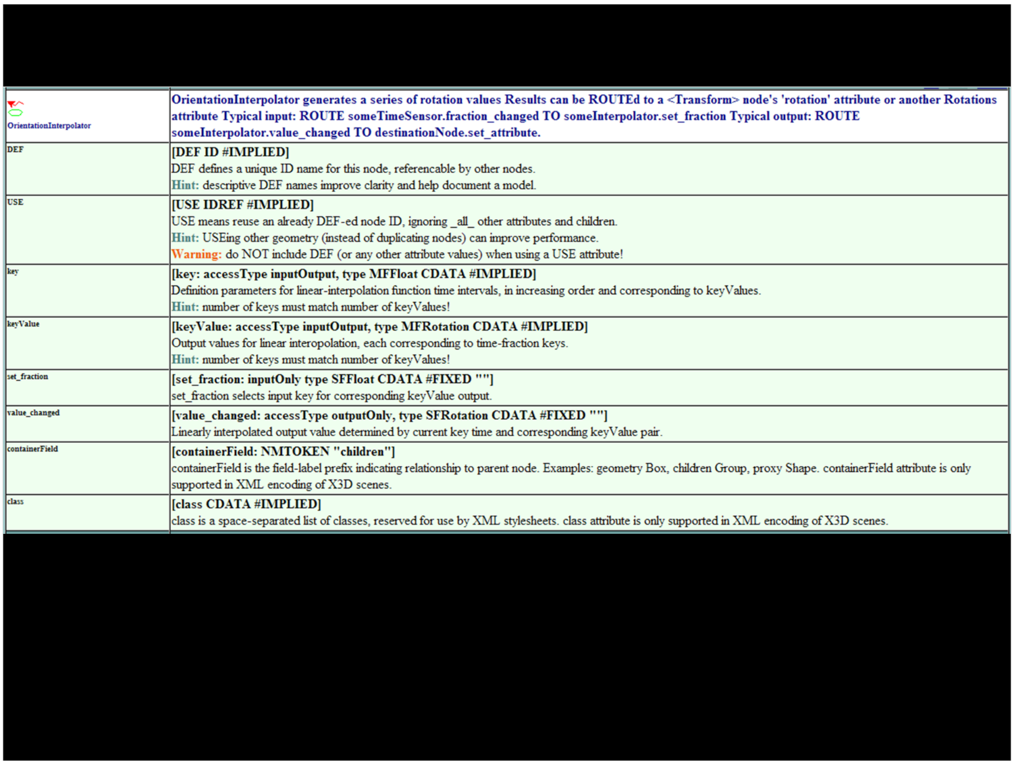
OrientationInterpolator example

This animation-chain example can be added to any scene (via cut and paste) to create a look-around Viewpoint. This bound camera view rotates about a fixed position.

```
<Viewpoint DEF='DizzyViewpoint' description='Rotating viewpoint'
   position="[somewhere you want it]" orientation='0 1 0 0'/>
<OrientationInterpolator DEF='Spinner' key='0 0.25 0.5 0.75 1'
   keyValue='0 1 0 0, 0 1 0 1.57, 0 1 0 3.14, 0 1 0 4.71, 0 1 0 6.28'/>
<TimeSensor DEF='SpinClock' cycleInterval='12' loop='true'/>
<ROUTE fromField='fraction_changed' fromNode='SpinClock'
   toField='set_fraction' toNode='Spinner'/>
<ROUTE fromField='value_changed' fromNode='Spinner'
         toField='orientation' toNode='DizzyViewpoint'/>
```

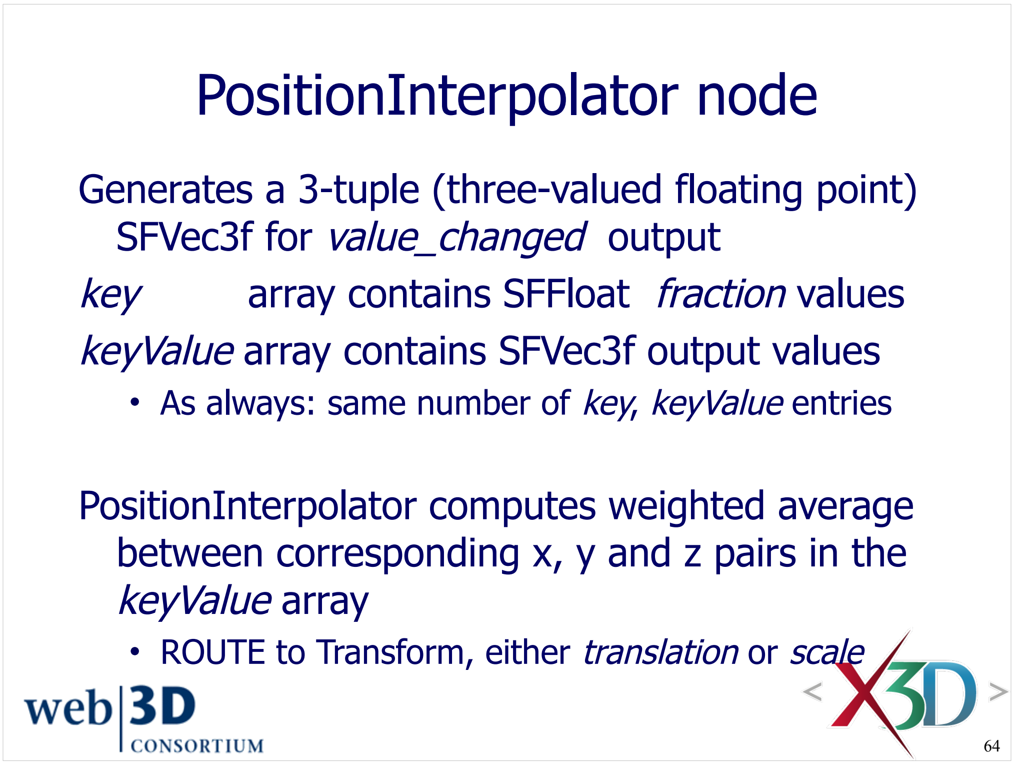

Animation using PositionInterpolator and OrientationInterpolator
Animation using PositionInterpolator and OrientationInterpolator
Animation using PositionInterpolator and OrientationInterpolator

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionOrientationInterpolatorsExample.x3d



OrientationInterpolator	**OrientationInterpolator generates a series of rotation values Results can be ROUTEd to a <Transform> node's 'rotation' attribute or another Rotations attribute Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFRotation CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFRotation CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#OrientationInterpolator



PositionInterpolator node

Generates a 3-tuple (three-valued floating point) SFVec3f for *value_changed* output

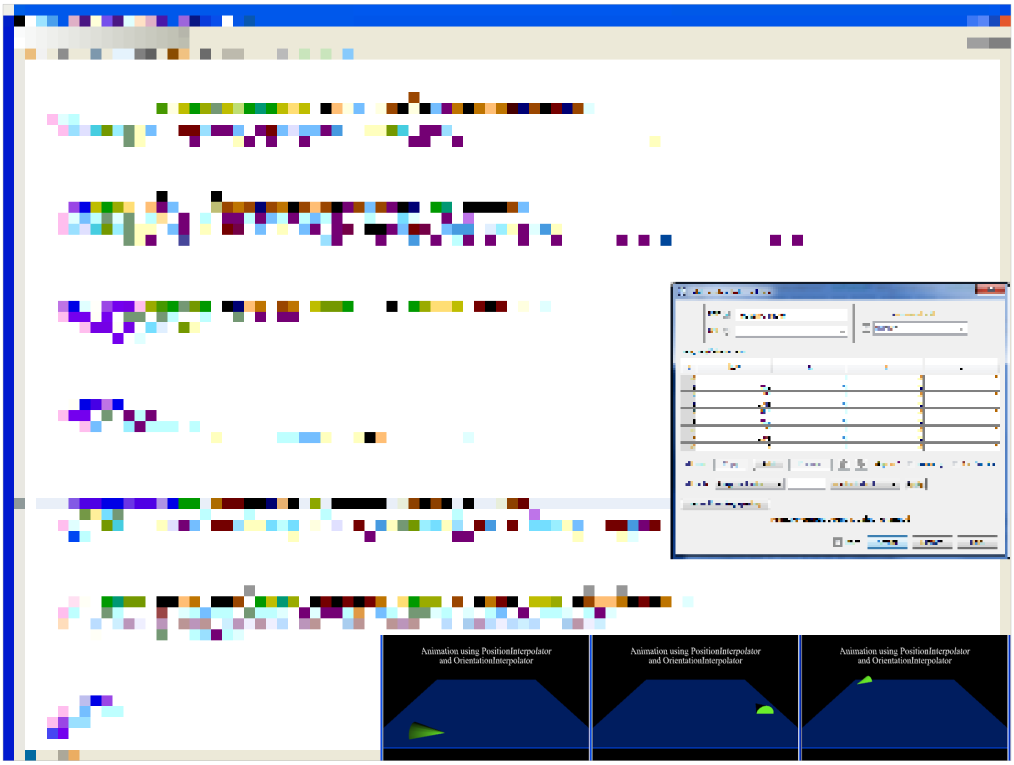
key array contains SFFloat *fraction* values

keyValue array contains SFVec3f output values

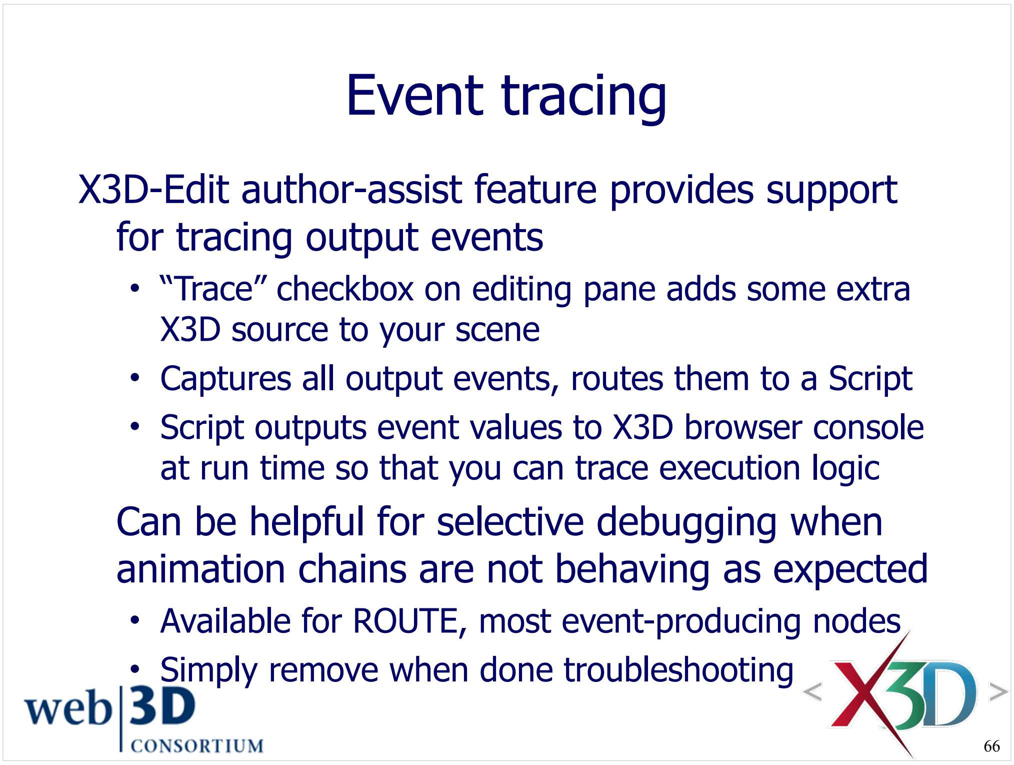
- As always: same number of *key*, *keyValue* entries

PositionInterpolator computes weighted average between corresponding x, y and z pairs in the *keyValue* array

- ROUTE to Transform, either *translation* or *scale*


Animation using PositionInterpolator
and OrientationInterpolator
Animation using PositionInterpolator
and OrientationInterpolator
Animation using PositionInterpolator
and OrientationInterpolator

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionOrientationInterpolatorsExample.x3d



Event tracing

X3D-Edit author-assist feature provides support for tracing output events

- "Trace" checkbox on editing pane adds some extra X3D source to your scene
- Captures all output events, routes them to a Script
- Script outputs event values to X3D browser console at run time so that you can trace execution logic

Can be helpful for selective debugging when animation chains are not behaving as expected

- Available for ROUTE, most event-producing nodes
- Simply remove when done troubleshooting

A long-standing challenge for many X3D authors is debugging event chains. It is sometimes hard to detect when an event is not being passed as expected. Problems can include missing or incorrect ROUTE connections, mismatched types or accessTypes, or other problems.

Sometimes (but only just sometimes) a browser might also be at fault.

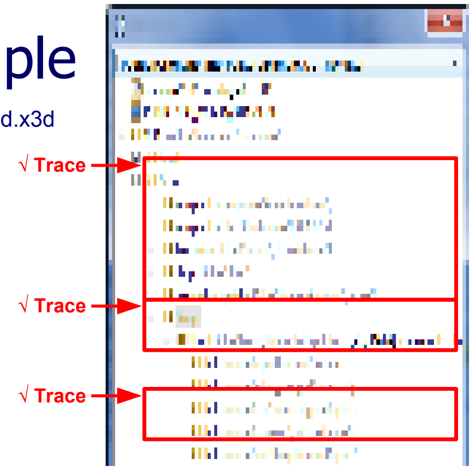
X3D-Edit now includes a new capability when editing ROUTE connections or event-producing nodes. If you select the "Trace" checkbox, then a block of X3D code is inserted that connects all of the output events to a Script which reports whenever an event is passed.

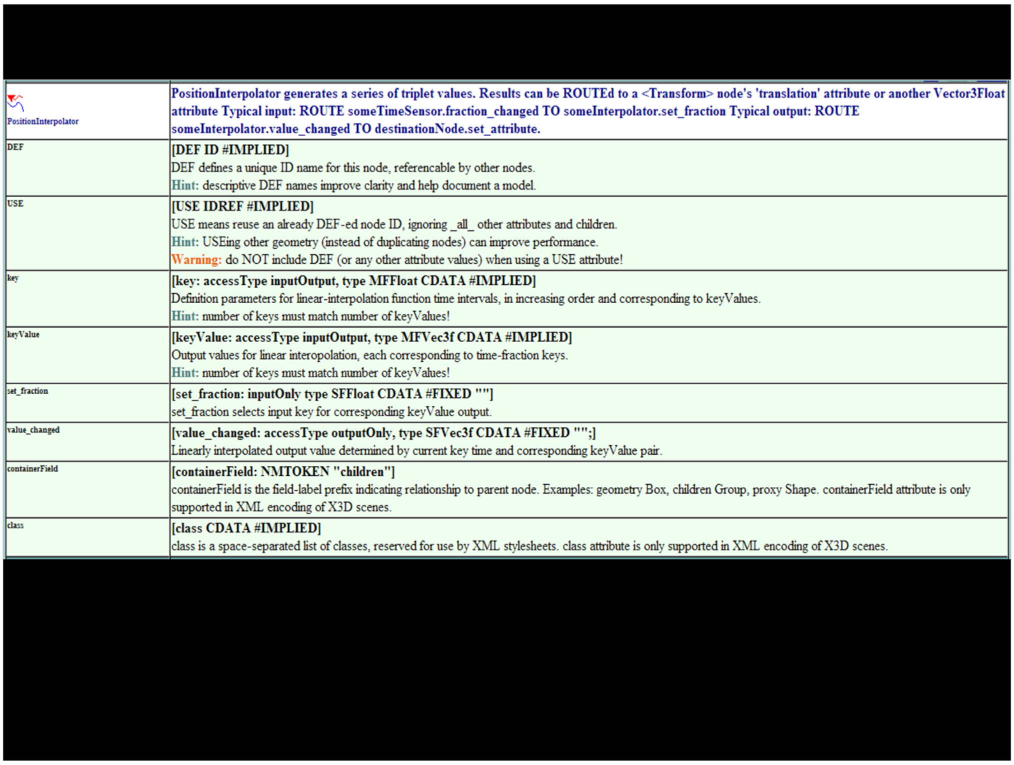
Although a bit verbose, it is a cool capability and can be very helpful whenever you are troubleshooting or tracking progress.

Script nodes and Javascript are covered in Chapter 9, Event Utilities and Scripting.

Event tracing example

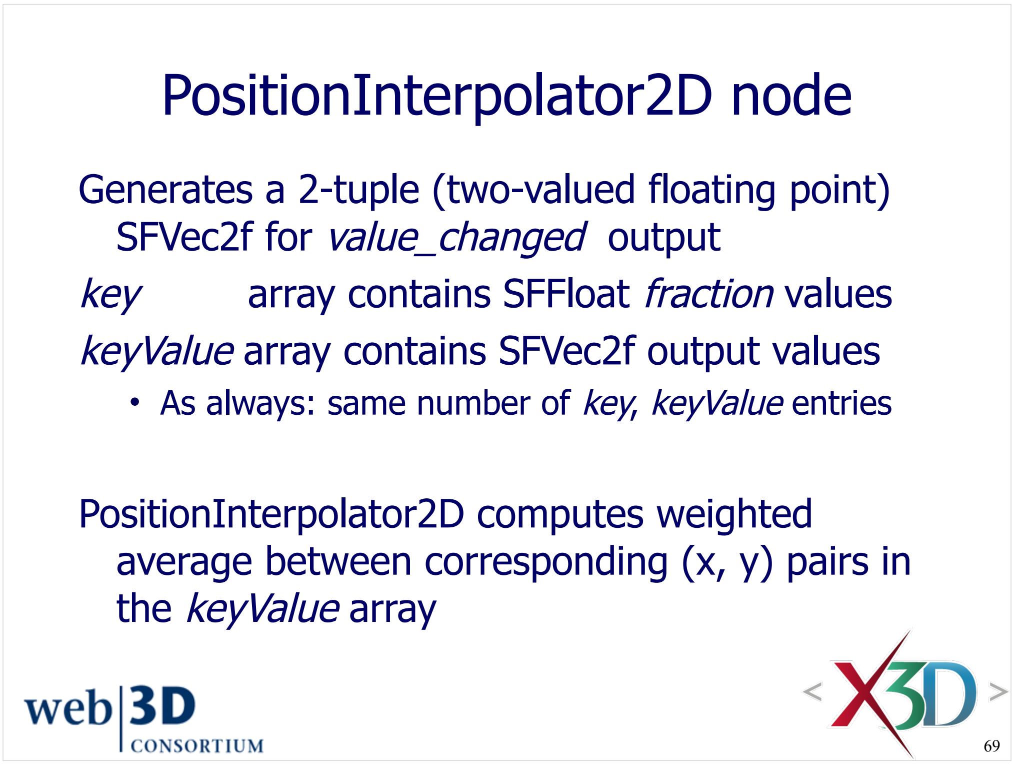
PositionOrientationInterpolatorsExampleTraced.x3d





PositionInterpolator	**PositionInterpolator generates a series of triplet values. Results can be ROUTEd to a <Transform> node's 'translation' attribute or another Vector3Float attribute Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFVec3f CDATA #FIXED "";]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#PositionInterpolator



PositionInterpolator2D node

Generates a 2-tuple (two-valued floating point) SFVec2f for *value_changed* output

key array contains SFFloat *fraction* values

keyValue array contains SFVec2f output values

- As always: same number of *key, keyValue* entries

PositionInterpolator2D computes weighted average between corresponding (x, y) pairs in the *keyValue* array

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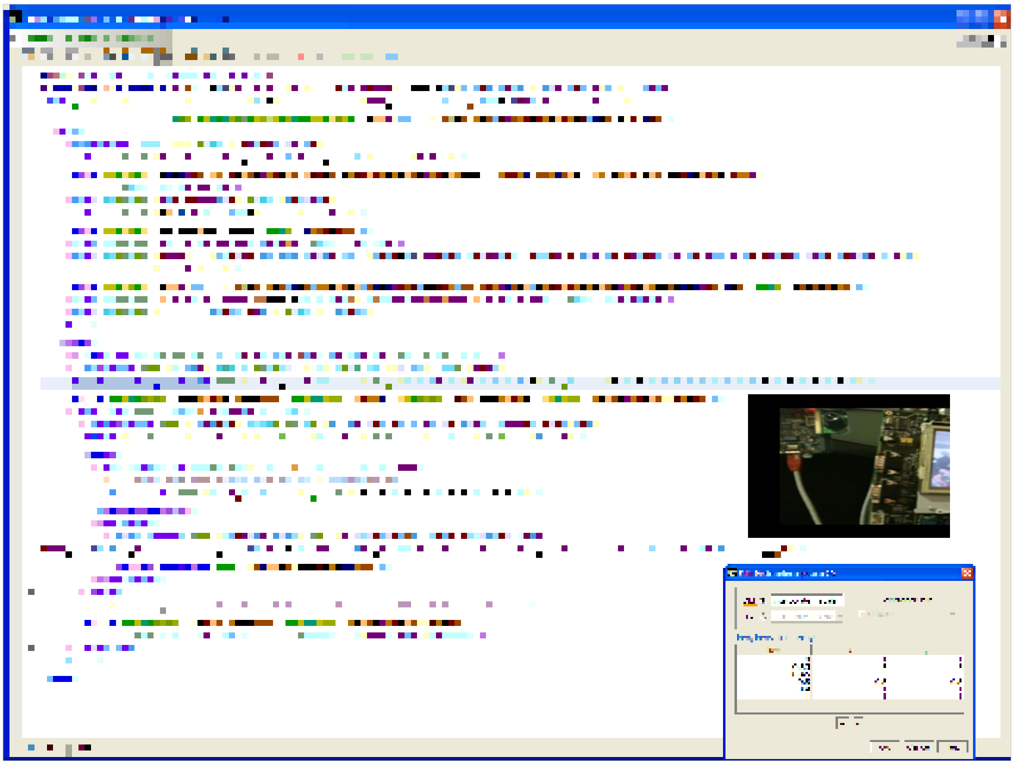
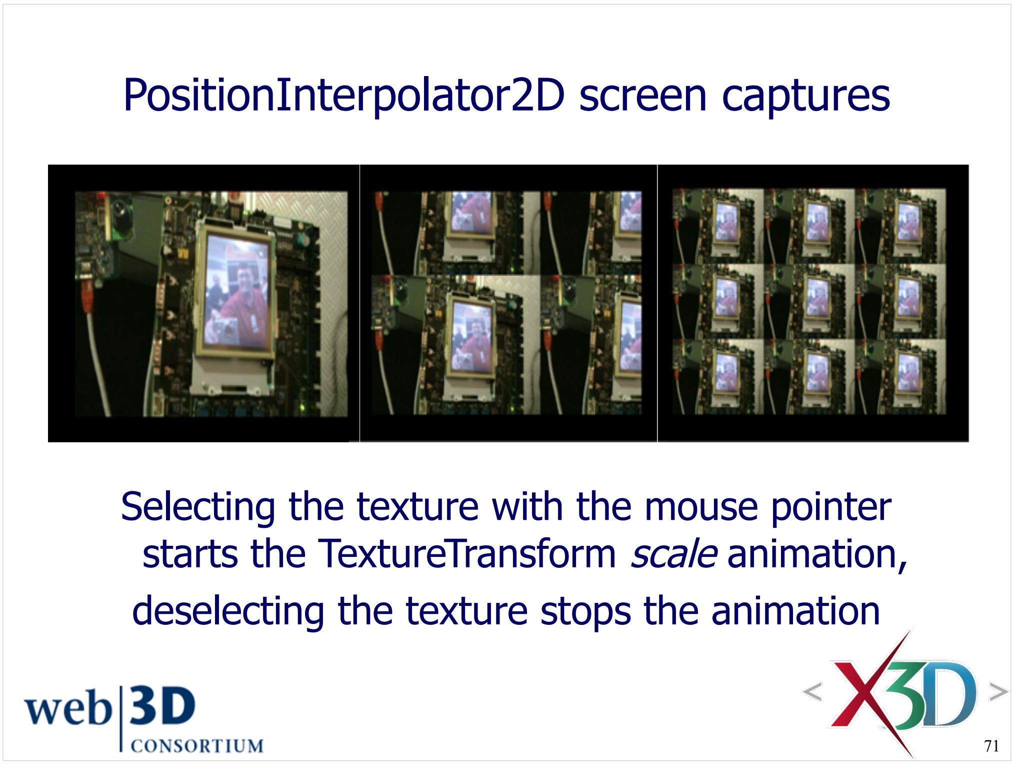
Note that PositionInterpolator2D provides single 2D values, while CoordinateInterpolator2D node produces arrays of 2D vectors.



http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionInterpolator2dExample.x3d

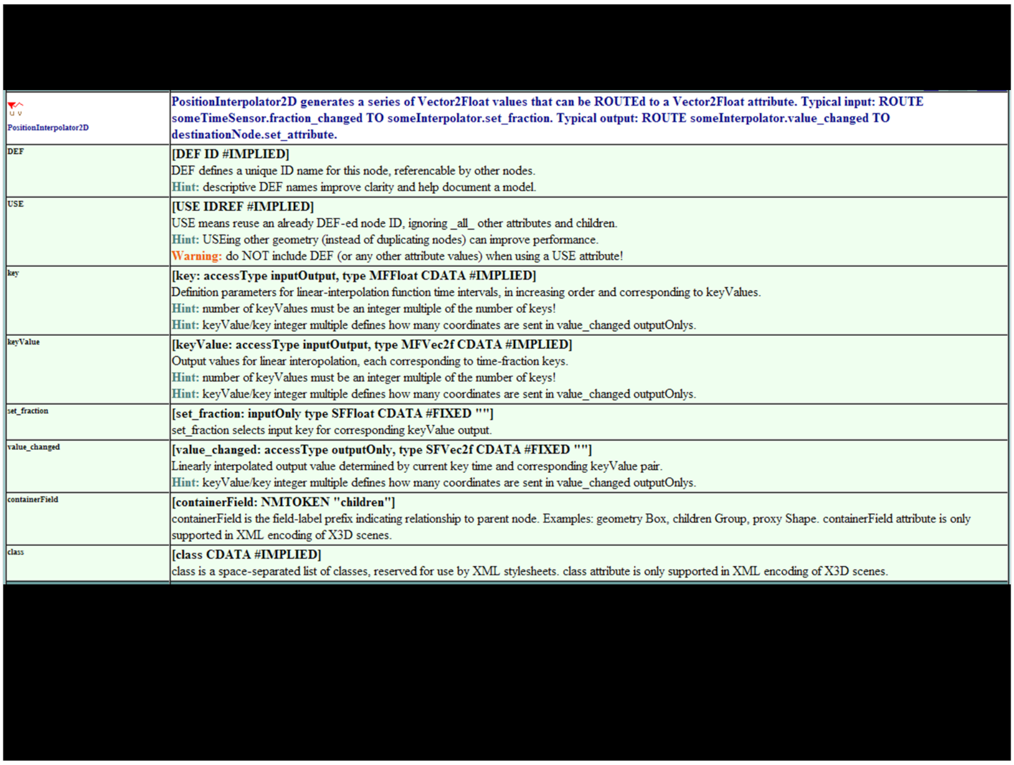


PositionInterpolator2D screen captures

Selecting the texture with the mouse pointer starts the TextureTransform *scale* animation, deselecting the texture stops the animation

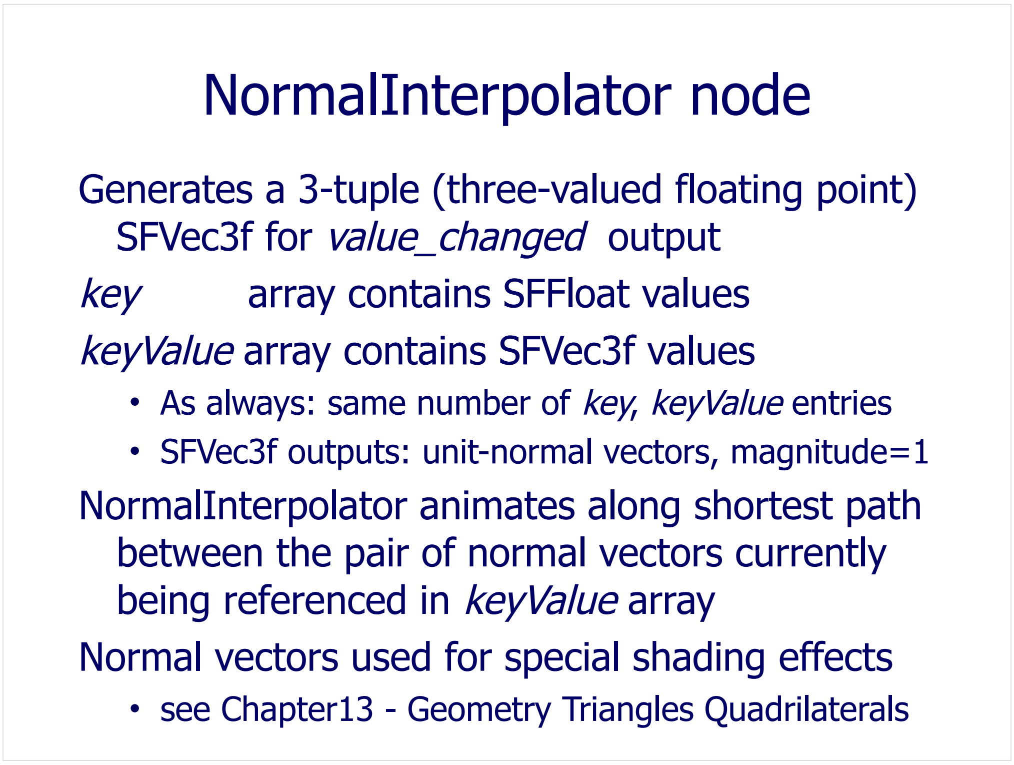
http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/PositionInterpolator2dExample.x3

fun: replace destination toField *set_scale* with *set_translation* in the ROUTE



PositionInterpolator2D	PositionInterpolator2D generates a series of Vector2Float values that can be ROUTEd to a Vector2Float attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
keyValue	**[keyValue: accessType inputOutput, type MFVec2f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keyValues must be an integer multiple of the number of keys! Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type SFVec2f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair. Hint: keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#PositionInterpolator2D



NormalInterpolator node

Generates a 3-tuple (three-valued floating point) SFVec3f for *value_changed* output

key array contains SFFloat values

keyValue array contains SFVec3f values

- As always: same number of *key, keyValue* entries
- SFVec3f outputs: unit-normal vectors, magnitude=1

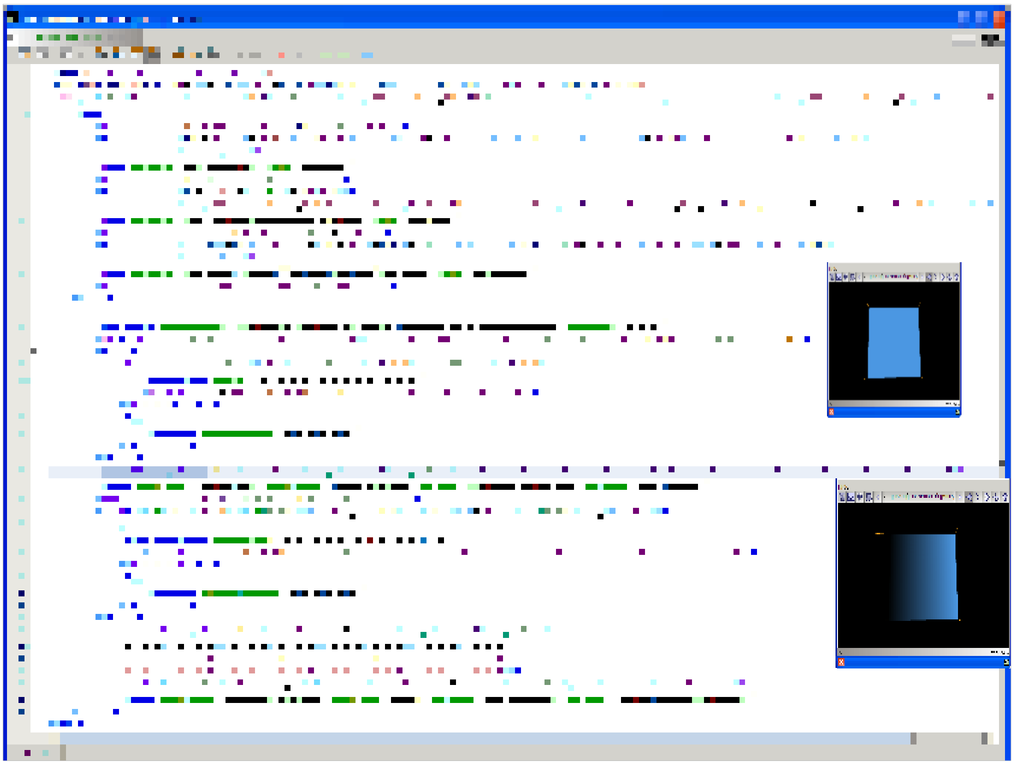
NormalInterpolator animates along shortest path between the pair of normal vectors currently being referenced in *keyValue* array

Normal vectors used for special shading effects

- see Chapter13 - Geometry Triangles Quadrilaterals

Why is NormalInterpolator different than PositionInterpolator?

- Normal vectors are 3-tuple values that begin at the local origin
- Normal vectors have unit length (or can be normalized to unit length)
- Interpolation between normals thus travels along surface of unit sphere
- Position values are points in space
- Position values may also be used as 3D dimensions, e.g. Transform scale
- PositionInterpolator performs linear averaging between position values



http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/NormalInterpolator.x3d

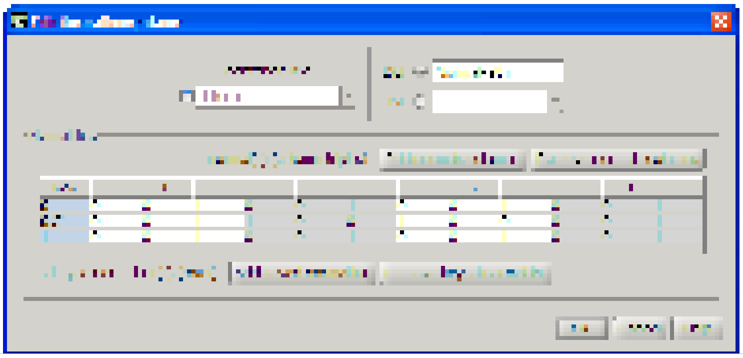
For alternate examples, see

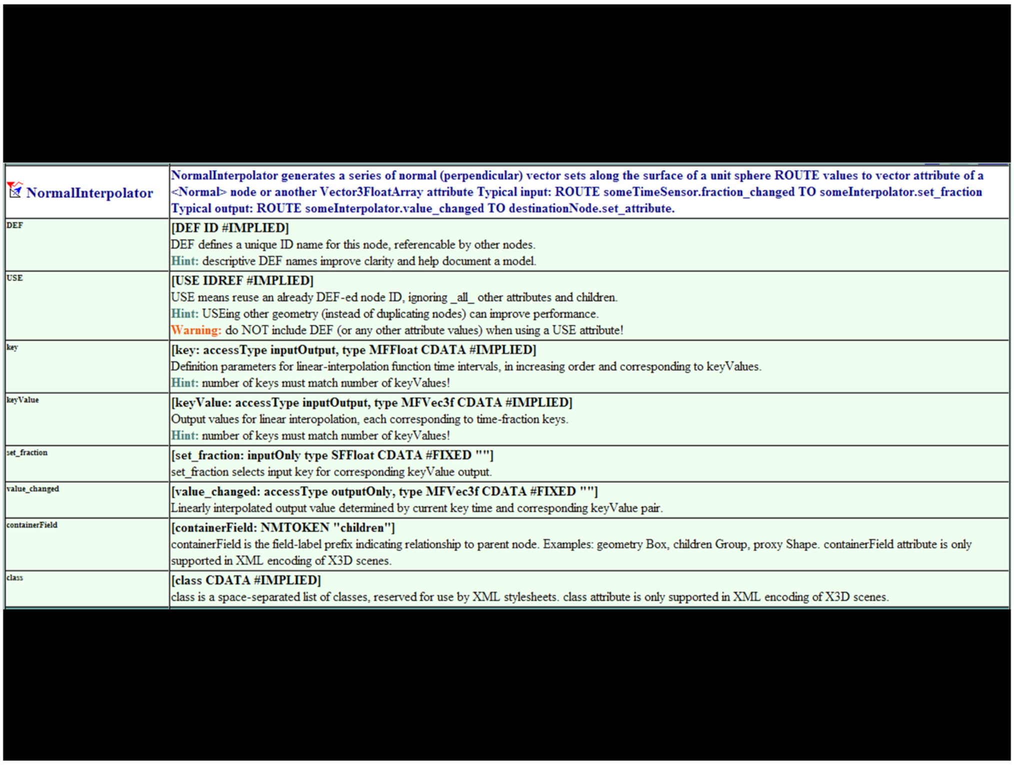
VRML 2.0 Sourcebook, Chapter 19 - Normals Shading

http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook/Chapter19-NormalsShading

NormalInterpolator editor

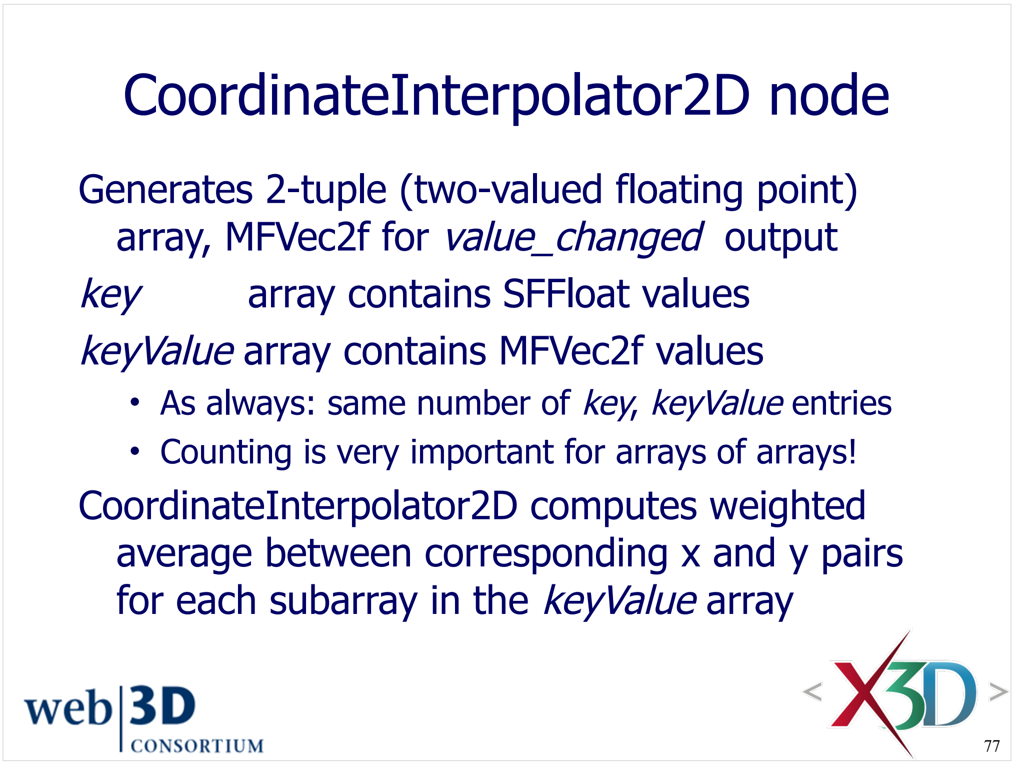
- Rows correspond to each key
- Correct results have same number of MFVec3f values in each row
- Normal-to-normal interpolation occurs on each column, allowing easier comparison





NormalInterpolator	NormalInterpolator generates a series of normal (perpendicular) vector sets along the surface of a unit sphere ROUTE values to vector attribute of a <Normal> node or another Vector3FloatArray attribute Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. Hint: descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. Hint: USEing other geometry (instead of duplicating nodes) can improve performance. Warning: do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. Hint: number of keys must match number of keyValues!
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. Hint: number of keys must match number of keyValues!
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type MFVec3f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#NormalInterpolator



CoordinateInterpolator2D node

Generates 2-tuple (two-valued floating point) array, MFVec2f for *value_changed* output

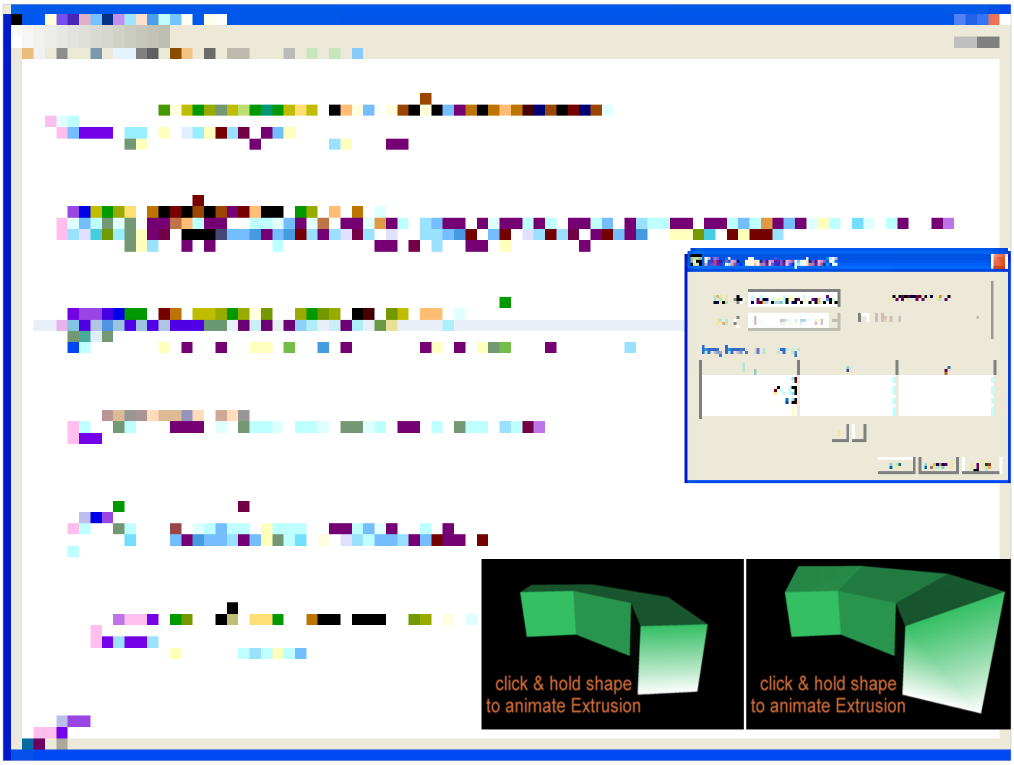
key array contains SFFloat values

keyValue array contains MFVec2f values

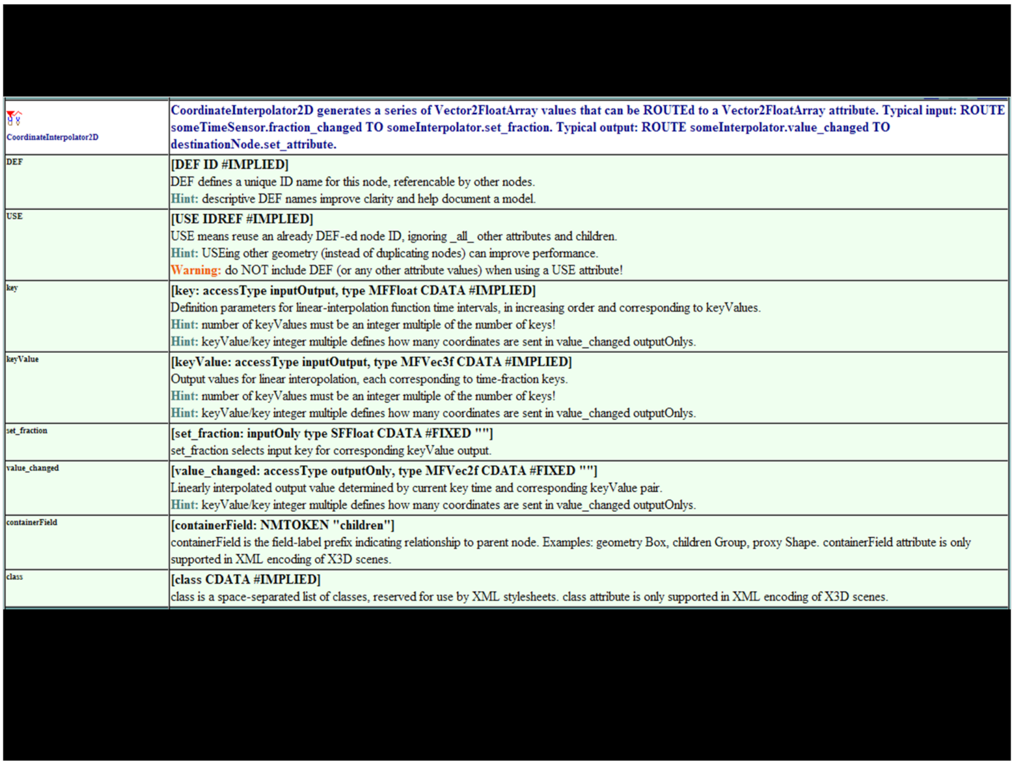
- As always: same number of *key, keyValue* entries
- Counting is very important for arrays of arrays!

CoordinateInterpolator2D computes weighted average between corresponding x and y pairs for each subarray in the *keyValue* array

Note that CoordinateInterpolator2D node produces arrays of 2D vectors, while PositionInterpolator2D provides single 2D values.

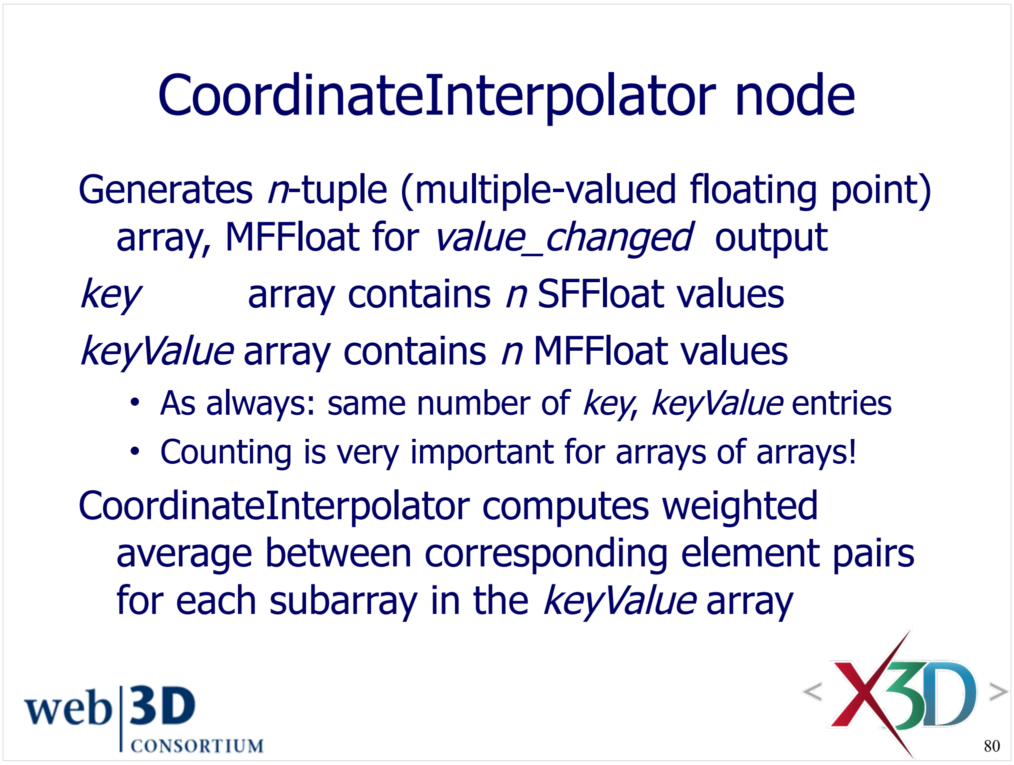


http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter07-EventAnimationInterpolation/CoordinateInterpolator2dExample.x3d



CoordinateInterpolator2D	**CoordinateInterpolator2D generates a series of Vector2FloatArray values that can be ROUTEd to a Vector2FloatArray attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. **Hint:** descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. **Hint:** USEing other geometry (instead of duplicating nodes) can improve performance. **Warning:** do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. **Hint:** number of keyValues must be an integer multiple of the number of keys! **Hint:** keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. **Hint:** number of keyValues must be an integer multiple of the number of keys! **Hint:** keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type MFVec2f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair. **Hint:** keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#CoordinateInterpolator2D



CoordinateInterpolator node

Generates *n*-tuple (multiple-valued floating point) array, MFFloat for *value_changed* output

key array contains *n* SFFloat values

keyValue array contains *n* MFFloat values

- As always: same number of *key*, *keyValue* entries
- Counting is very important for arrays of arrays!

CoordinateInterpolator computes weighted average between corresponding element pairs for each subarray in the *keyValue* array

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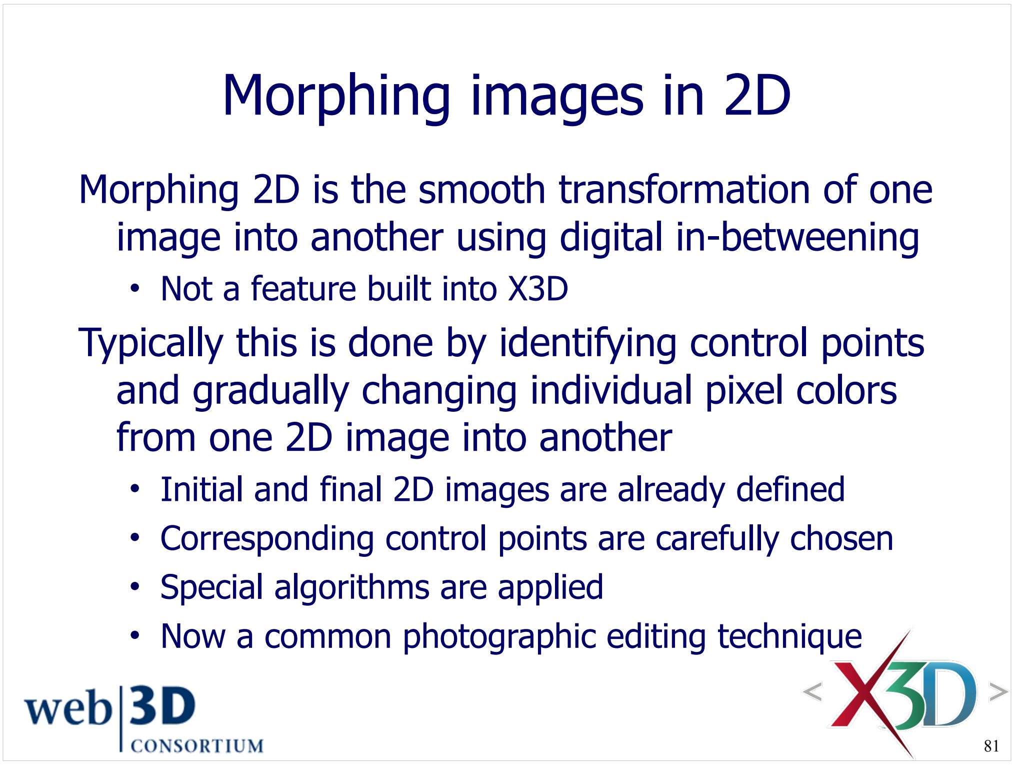


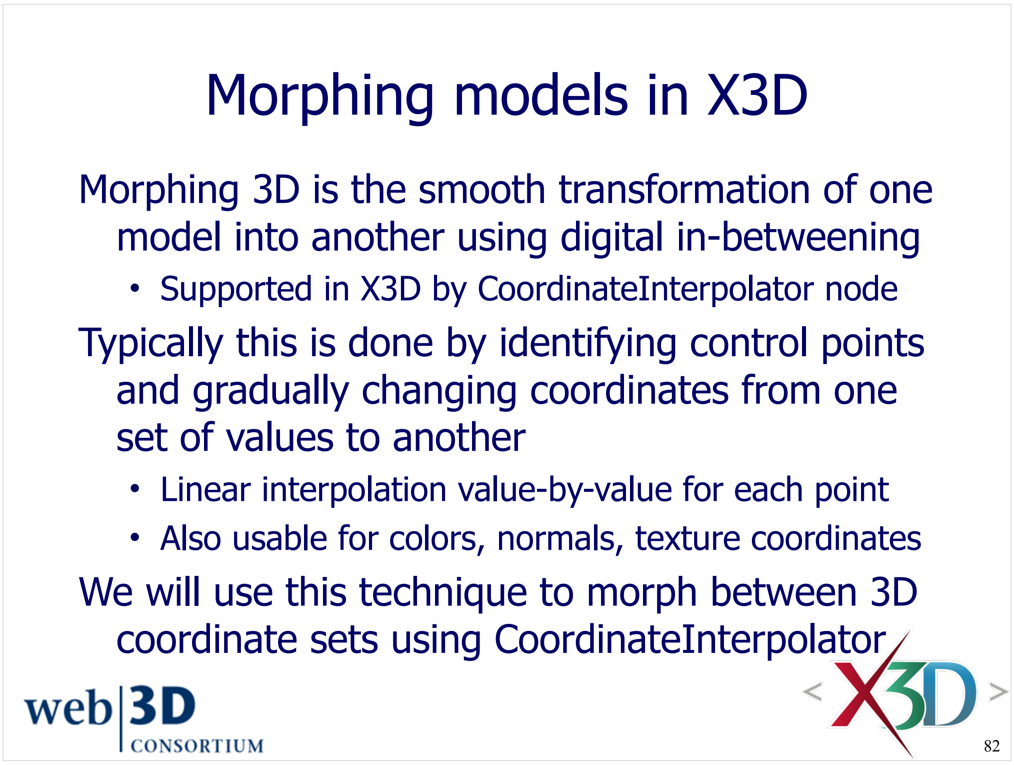
Morphing images in 2D

Morphing 2D is the smooth transformation of one image into another using digital in-betweening

- Not a feature built into X3D

Typically this is done by identifying control points and gradually changing individual pixel colors from one 2D image into another

- Initial and final 2D images are already defined
- Corresponding control points are carefully chosen
- Special algorithms are applied
- Now a common photographic editing technique



Morphing models in X3D

- Morphing 3D is the smooth transformation of one model into another using digital in-betweening
  - Supported in X3D by CoordinateInterpolator node
- Typically this is done by identifying control points and gradually changing coordinates from one set of values to another
  - Linear interpolation value-by-value for each point
  - Also usable for colors, normals, texture coordinates
- We will use this technique to morph between 3D coordinate sets using CoordinateInterpolator

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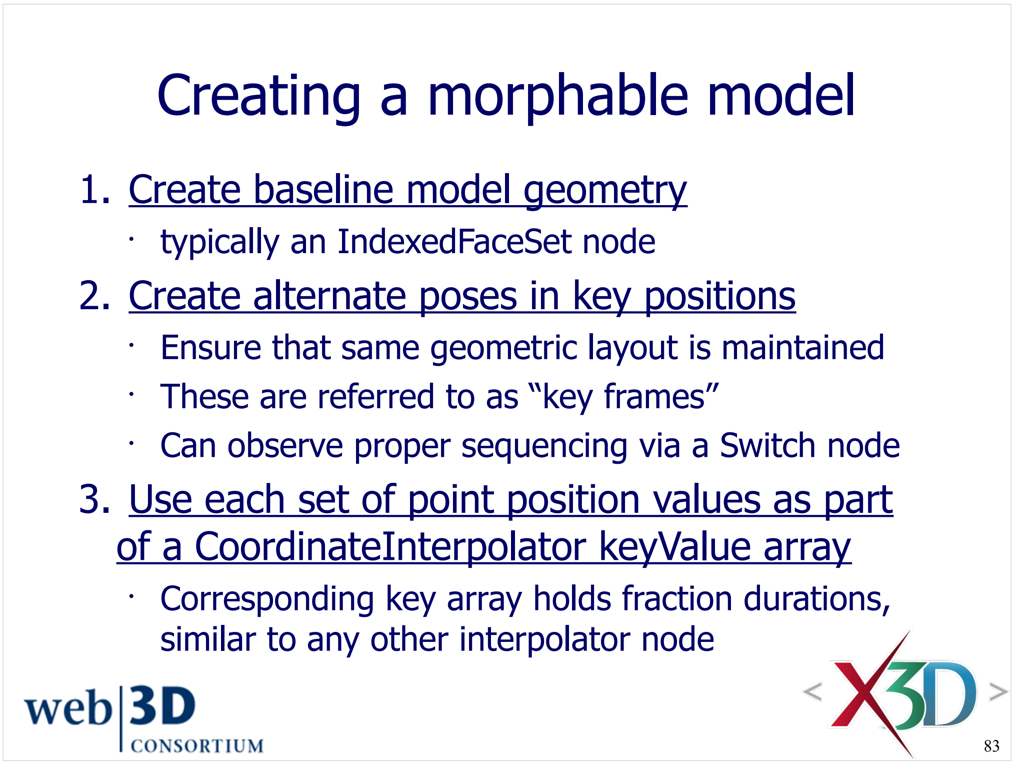
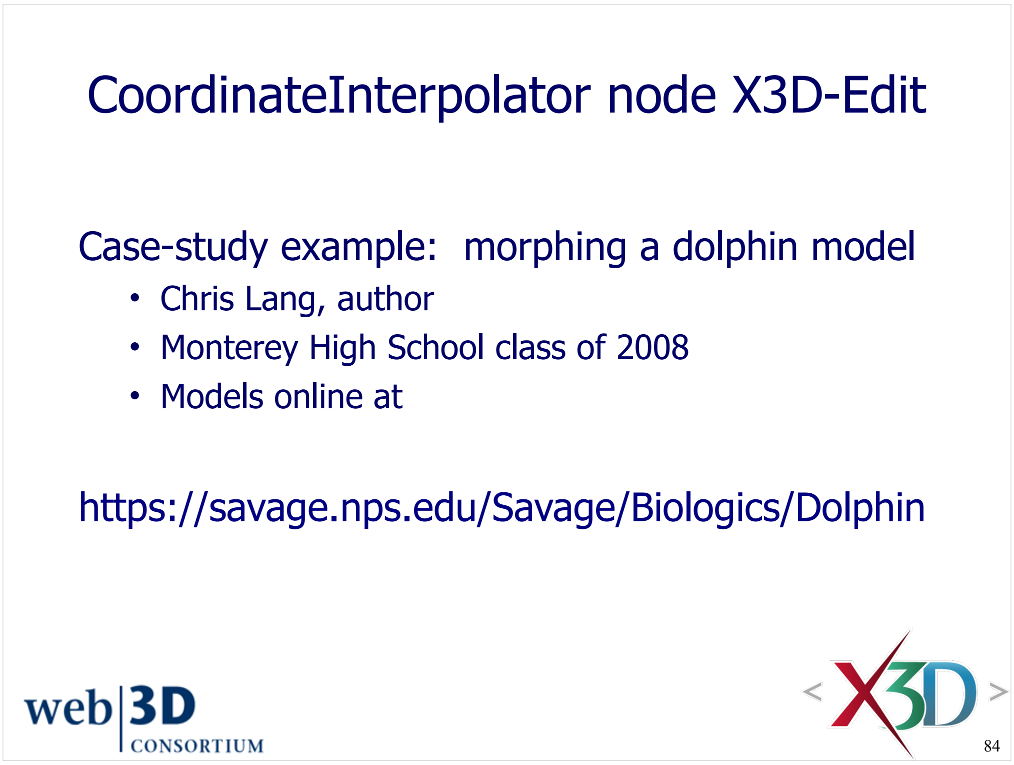
SIGGRAPH 1992. Image Morphing History. Morphing is the process of turning one image into another through a seamless transition. The following slideset by Thaddeus Beier and Shawn Neeley includes case study examination of Michael Jackson's “Black or White” which first applied this technique to music video,

http://www.cs.unc.edu/~lazebnik/research/fall08/qi_mo.ppt



Creating a morphable model

1. Create baseline model geometry
   - typically an IndexedFaceSet node
2. Create alternate poses in key positions
   - Ensure that same geometric layout is maintained
   - These are referred to as “key frames”
   - Can observe proper sequencing via a Switch node
3. Use each set of point position values as part of a CoordinateInterpolator keyValue array
   - Corresponding key array holds fraction durations, similar to any other interpolator node

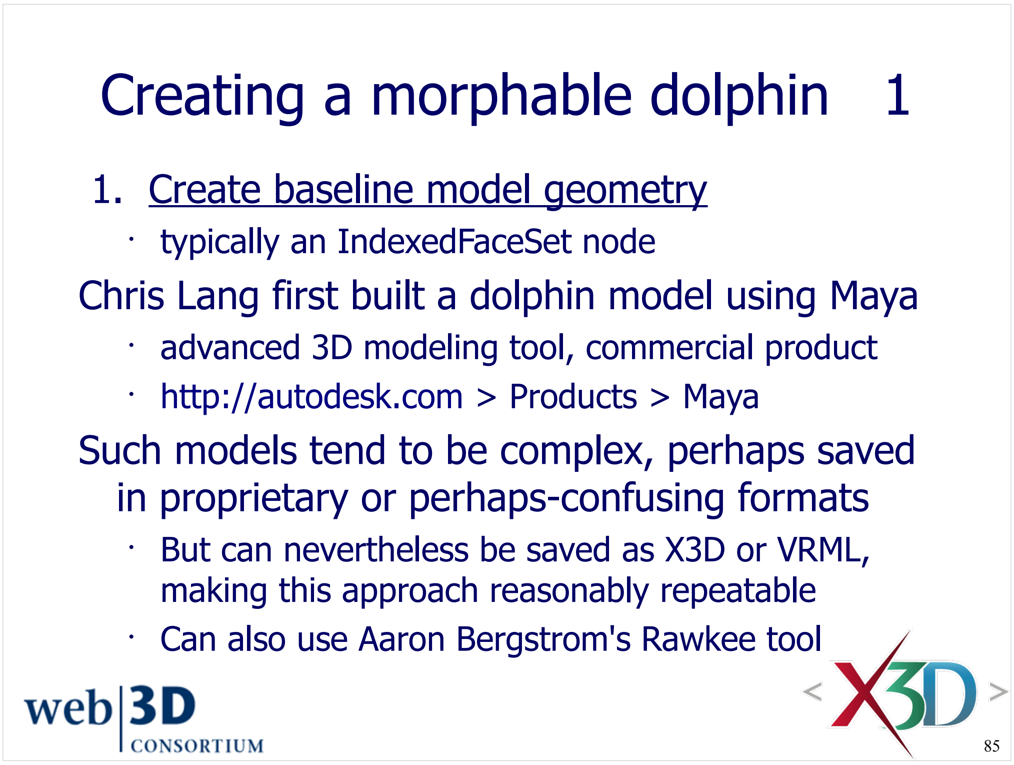


CoordinateInterpolator node X3D-Edit

Case-study example: morphing a dolphin model

- Chris Lang, author
- Monterey High School class of 2008
- Models online at

https://savage.nps.edu/Savage/Biologics/Dolphin



Creating a morphable dolphin 1

1. Create baseline model geometry
   - typically an IndexedFaceSet node

Chris Lang first built a dolphin model using Maya

- advanced 3D modeling tool, commercial product
- http://autodesk.com > Products > Maya

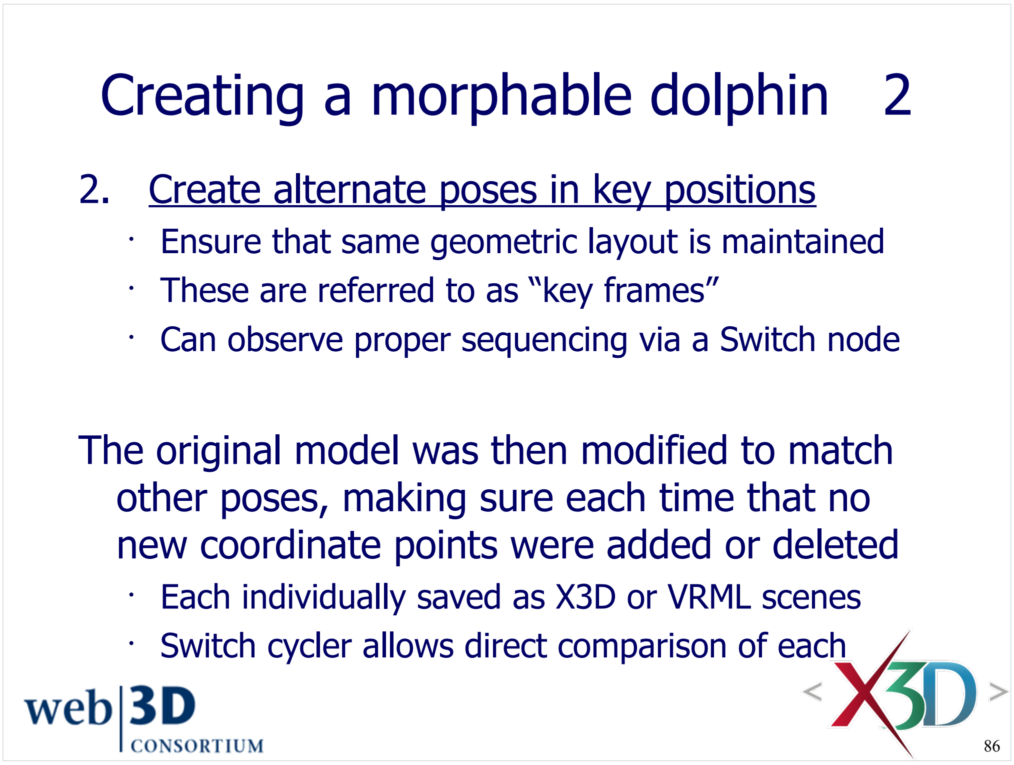
Such models tend to be complex, perhaps saved in proprietary or perhaps-confusing formats

- But can nevertheless be saved as X3D or VRML, making this approach reasonably repeatable
- Can also use Aaron Bergstrom's Rawkee tool

Rawkee is for Maya version 7.

- Maya is a commercial authoring tool by Autodesk
- http://autodesk.com   http://en.wikipedia.org/wiki/Maya_software
- Project Rawkee: Open-Source X3D Plugin for Maya by the Archaeology Technologies Laboratory (ATL) of North Dakota State University (NDSU).
- http://rawkee.sourceforge.net

Currently we simply save Maya models as VRML or X3D.

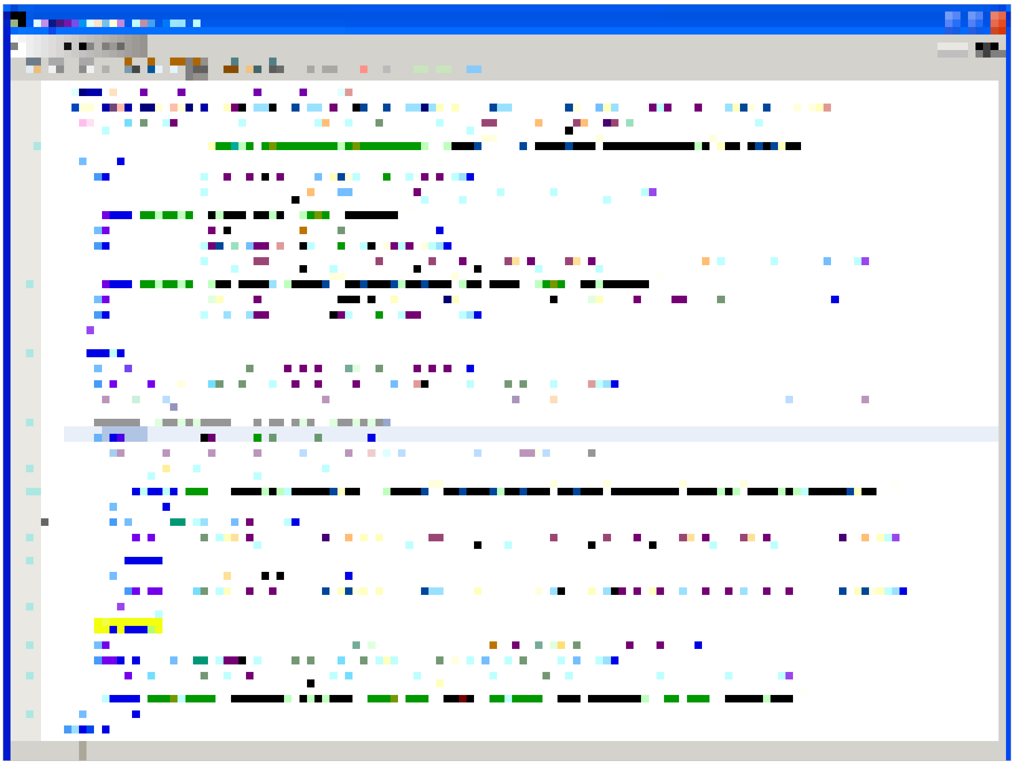


Creating a morphable dolphin 2

2. Create alternate poses in key positions
   - Ensure that same geometric layout is maintained
   - These are referred to as “key frames”
   - Can observe proper sequencing via a Switch node

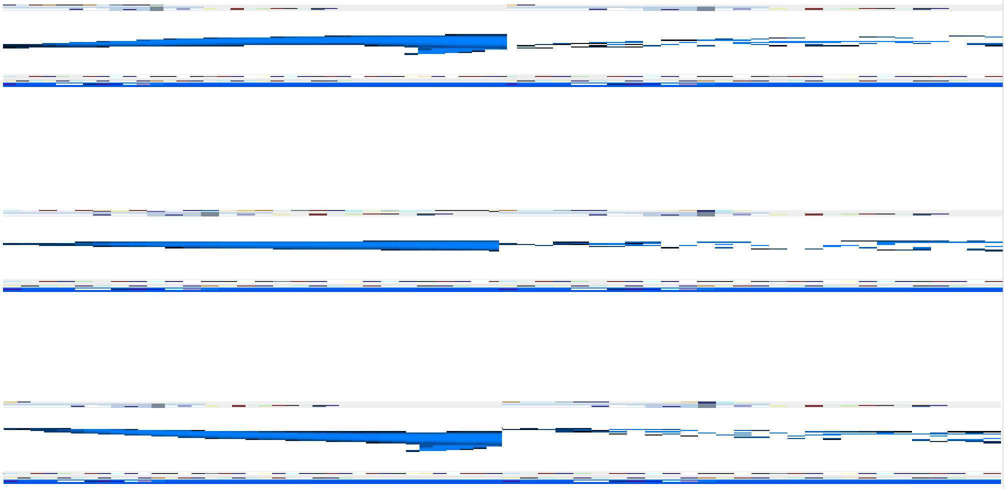
The original model was then modified to match other poses, making sure each time that no new coordinate points were added or deleted

- Each individually saved as X3D or VRML scenes
- Switch cycler allows direct comparison of each



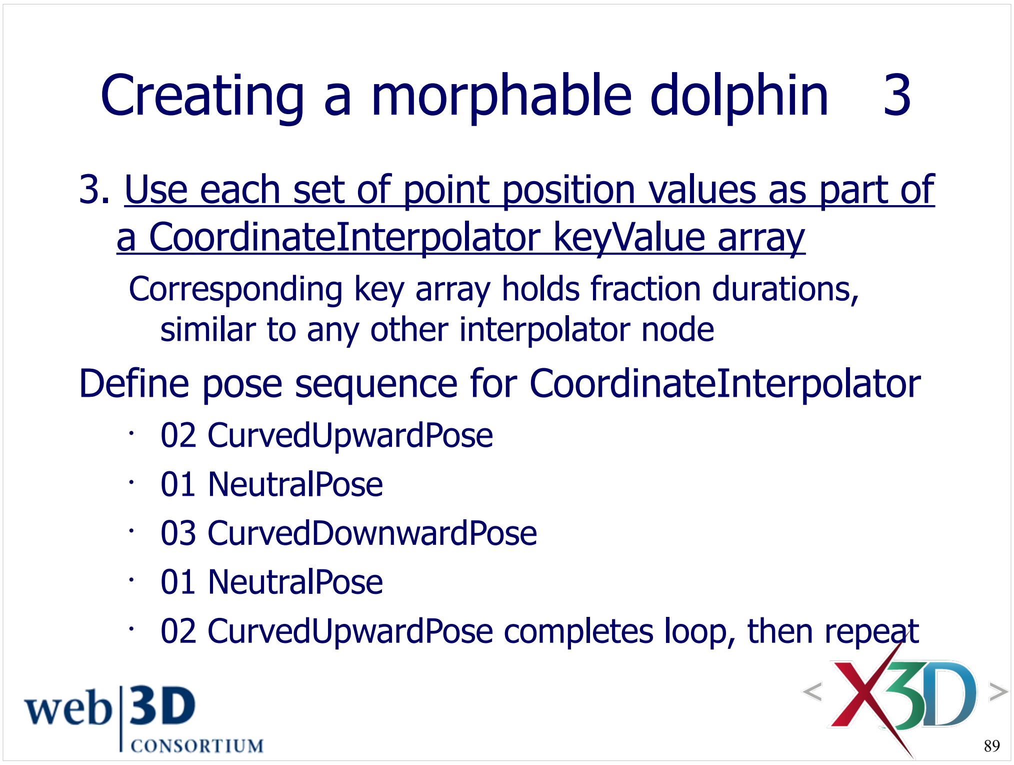
https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinSwitcher.x3d

DolphinPose02.x3d DolphinPose01.x3d DolphinPose03.x3d



https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinPose02.x3d
https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinPose01.x3d
https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinPose03.x3d

X3jD viewer wireframe mode is toggled with key Alt-w



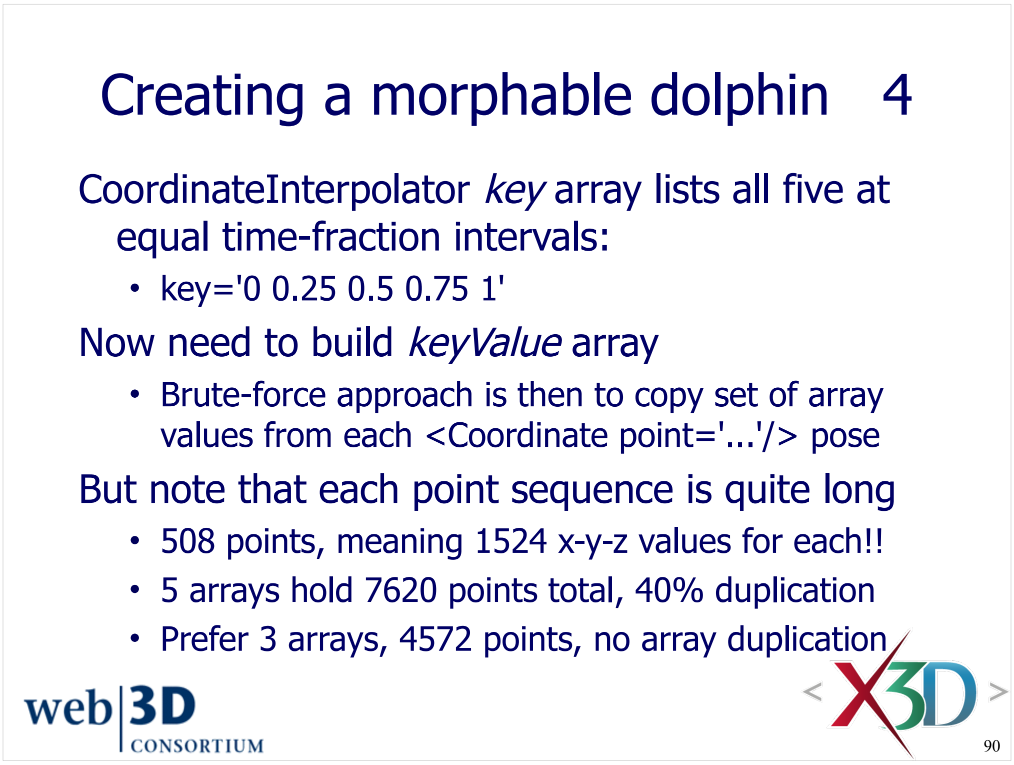
Creating a morphable dolphin 3

3. Use each set of point position values as part of a CoordinateInterpolator keyValue array

Corresponding key array holds fraction durations, similar to any other interpolator node

Define pose sequence for CoordinateInterpolator

- 02 CurvedUpwardPose
- 01 NeutralPose
- 03 CurvedDownwardPose
- 01 NeutralPose
- 02 CurvedUpwardPose completes loop, then repeat



Creating a morphable dolphin 4

CoordinateInterpolator *key* array lists all five at equal time-fraction intervals:

- key='0 0.25 0.5 0.75 1'

Now need to build *keyValue* array

- Brute-force approach is then to copy set of array values from each <Coordinate point='...'/> pose

But note that each point sequence is quite long

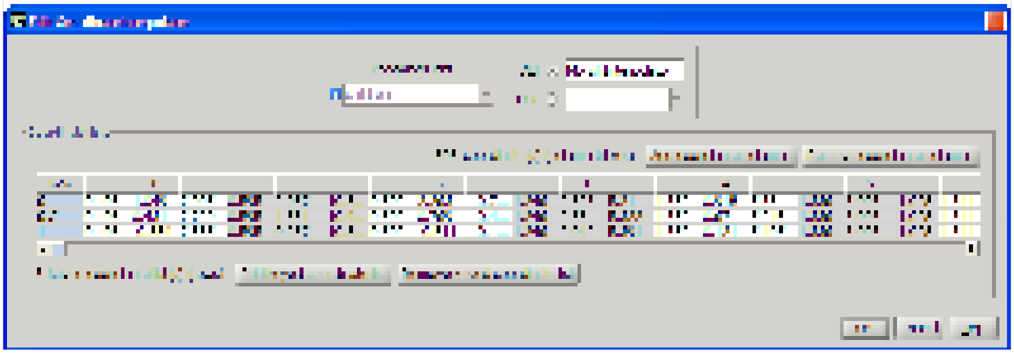
- 508 points, meaning 1524 x-y-z values for each!!
- 5 arrays hold 7620 points total, 40% duplication
- Prefer 3 arrays, 4572 points, no array duplication

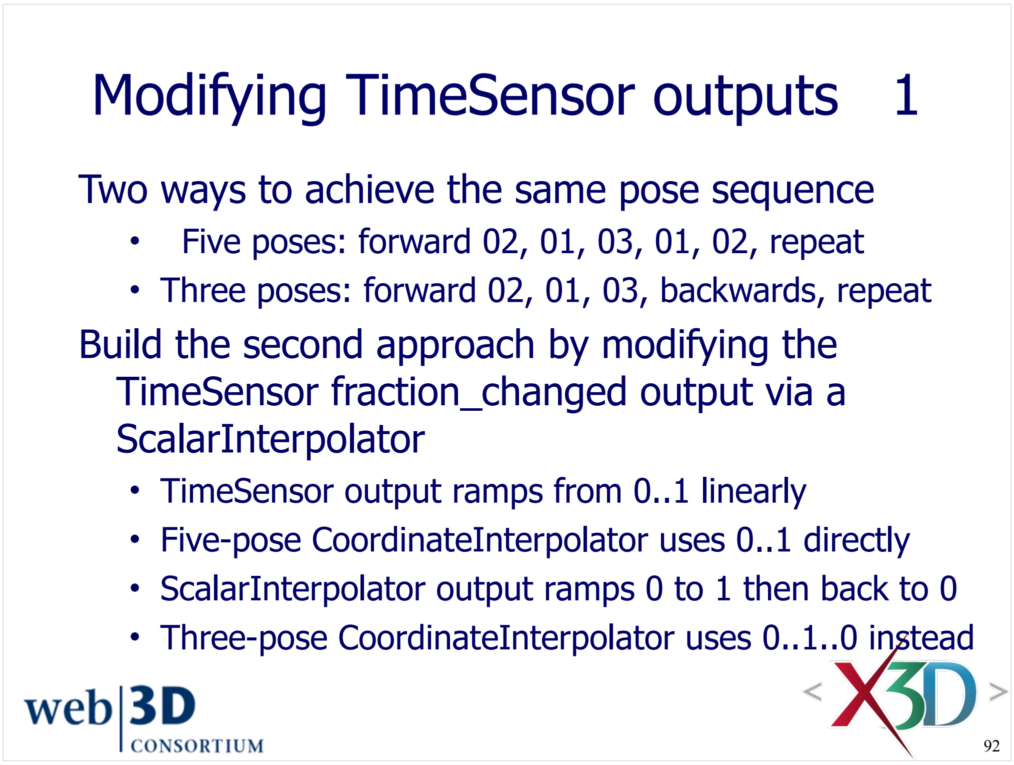
CoordinateInterpolator editor

Rows correspond to each key

Correct results have same number of MFVec3f values in each row

Point-by-point interpolation occurs on each column, allowing easier comparison





Modifying TimeSensor outputs 1

Two ways to achieve the same pose sequence

- Five poses: forward 02, 01, 03, 01, 02, repeat
- Three poses: forward 02, 01, 03, backwards, repeat

Build the second approach by modifying the TimeSensor fraction_changed output via a ScalarInterpolator

- TimeSensor output ramps from 0..1 linearly
- Five-pose CoordinateInterpolator uses 0..1 directly
- ScalarInterpolator output ramps 0 to 1 then back to 0
- Three-pose CoordinateInterpolator uses 0..1..0 instead

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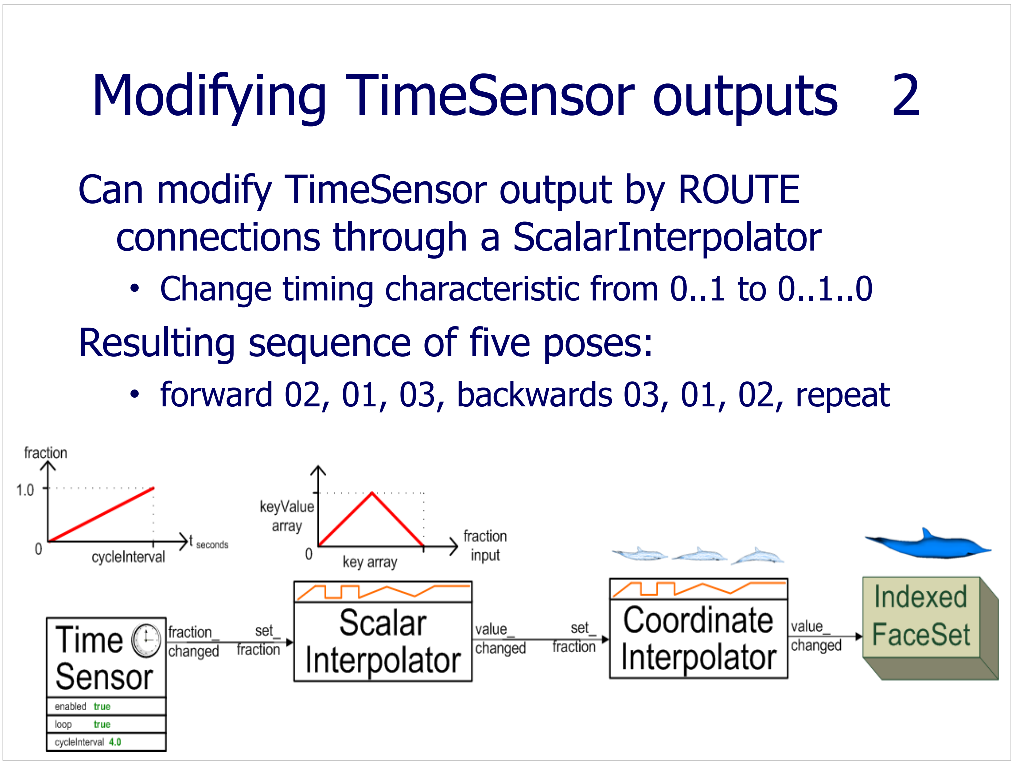


Modifying TimeSensor outputs 2

Can modify TimeSensor output by ROUTE connections through a ScalarInterpolator

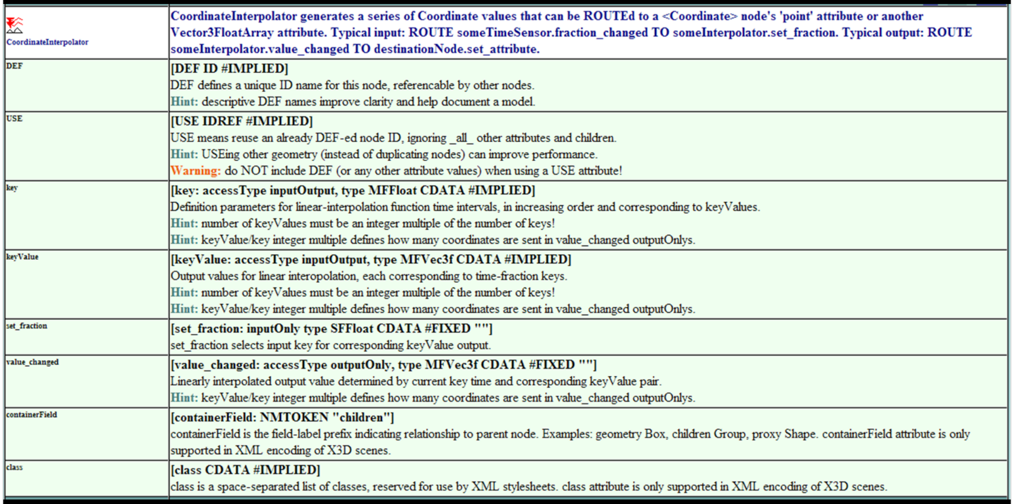
- Change timing characteristic from 0..1 to 0..1..0

Resulting sequence of five poses:

- forward 02, 01, 03, backwards 03, 01, 02, repeat

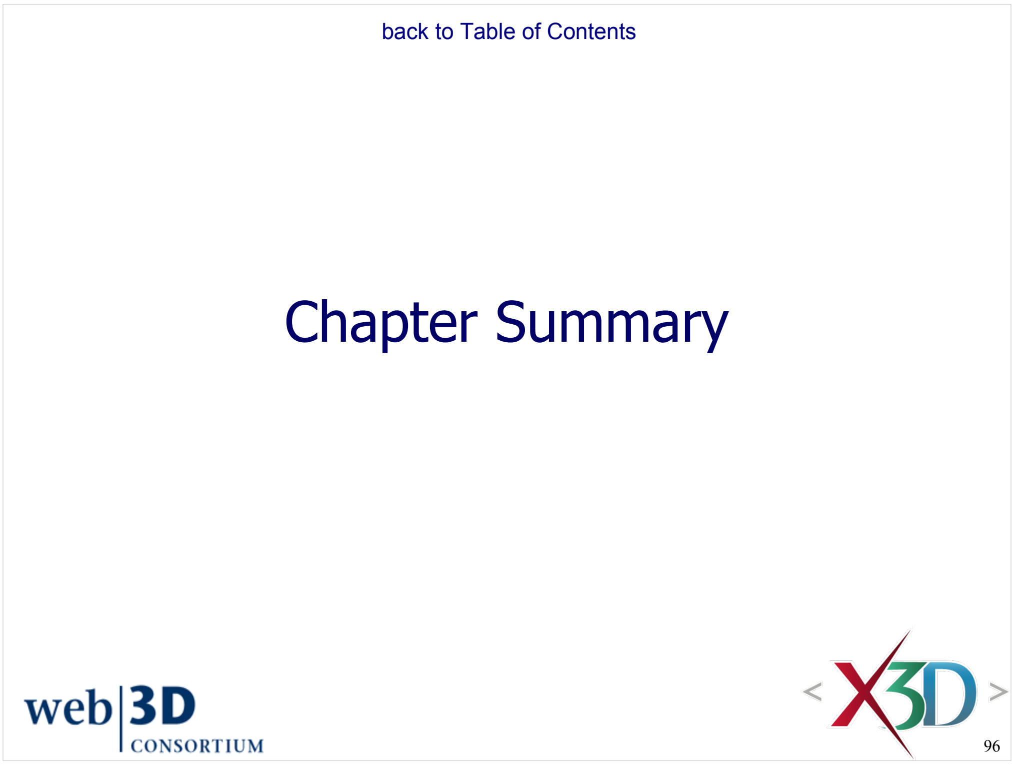
Try it yourself: you might even reduce the CoordinateInterpolator further by removing the middle neutral pose. Is the resulting animation still satisfactory, or is it too jerky? You decide. (Thanks to Terence Tan for this suggestion.)

https://savage.nps.edu/Savage/Biologics/Dolphin/DolphinMorpher.x3d



CoordinateInterpolator	**CoordinateInterpolator generates a series of Coordinate values that can be ROUTEd to a <Coordinate> node's 'point' attribute or another Vector3FloatArray attribute. Typical input: ROUTE someTimeSensor.fraction_changed TO someInterpolator.set_fraction. Typical output: ROUTE someInterpolator.value_changed TO destinationNode.set_attribute.**
DEF	**[DEF ID #IMPLIED]** DEF defines a unique ID name for this node, referencable by other nodes. **Hint:** descriptive DEF names improve clarity and help document a model.
USE	**[USE IDREF #IMPLIED]** USE means reuse an already DEF-ed node ID, ignoring _all_ other attributes and children. **Hint:** USEing other geometry (instead of duplicating nodes) can improve performance. **Warning:** do NOT include DEF (or any other attribute values) when using a USE attribute!
key	**[key: accessType inputOutput, type MFFloat CDATA #IMPLIED]** Definition parameters for linear-interpolation function time intervals, in increasing order and corresponding to keyValues. **Hint:** number of keyValues must be an integer multiple of the number of keys! **Hint:** keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
keyValue	**[keyValue: accessType inputOutput, type MFVec3f CDATA #IMPLIED]** Output values for linear interopolation, each corresponding to time-fraction keys. **Hint:** number of keyValues must be an integer multiple of the number of keys! **Hint:** keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
set_fraction	**[set_fraction: inputOnly type SFFloat CDATA #FIXED ""]** set_fraction selects input key for corresponding keyValue output.
value_changed	**[value_changed: accessType outputOnly, type MFVec3f CDATA #FIXED ""]** Linearly interpolated output value determined by current key time and corresponding keyValue pair. **Hint:** keyValue/key integer multiple defines how many coordinates are sent in value_changed outputOnlys.
containerField	**[containerField: NMTOKEN "children"]** containerField is the field-label prefix indicating relationship to parent node. Examples: geometry Box, children Group, proxy Shape. containerField attribute is only supported in XML encoding of X3D scenes.
class	**[class CDATA #IMPLIED]** class is a space-separated list of classes, reserved for use by XML stylesheets. class attribute is only supported in XML encoding of X3D scenes.

http://www.web3d.org/x3d/content/X3dTooltips.html#CoordinateInterpolator



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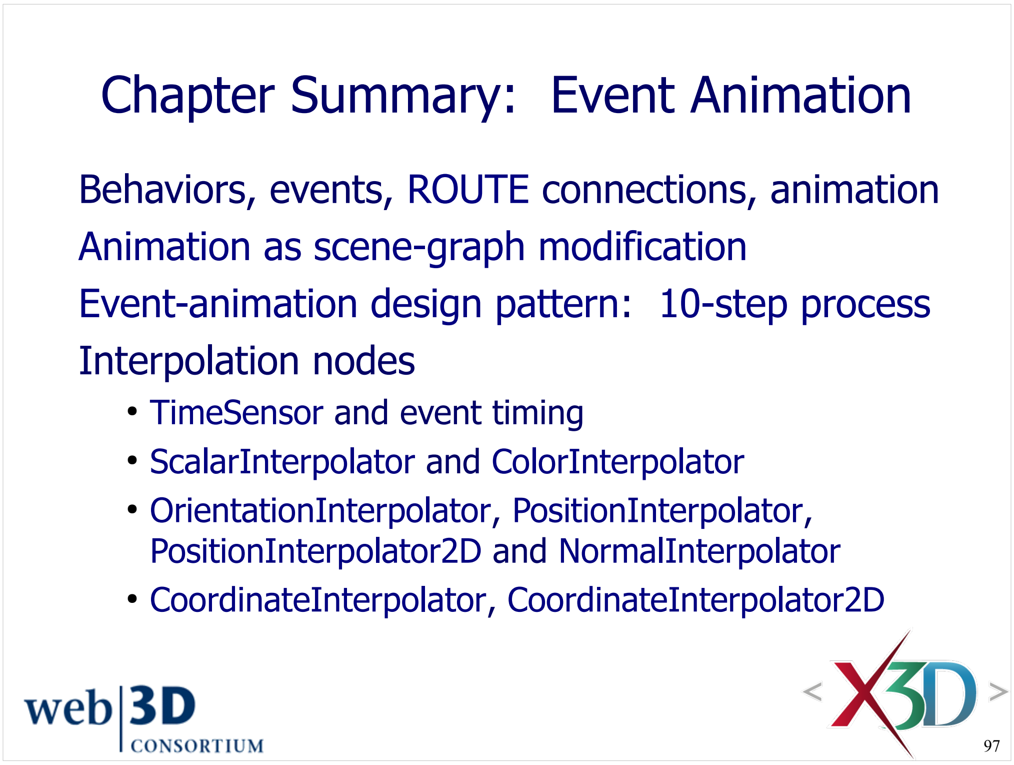
Chapter Summary



Chapter Summary: Event Animation

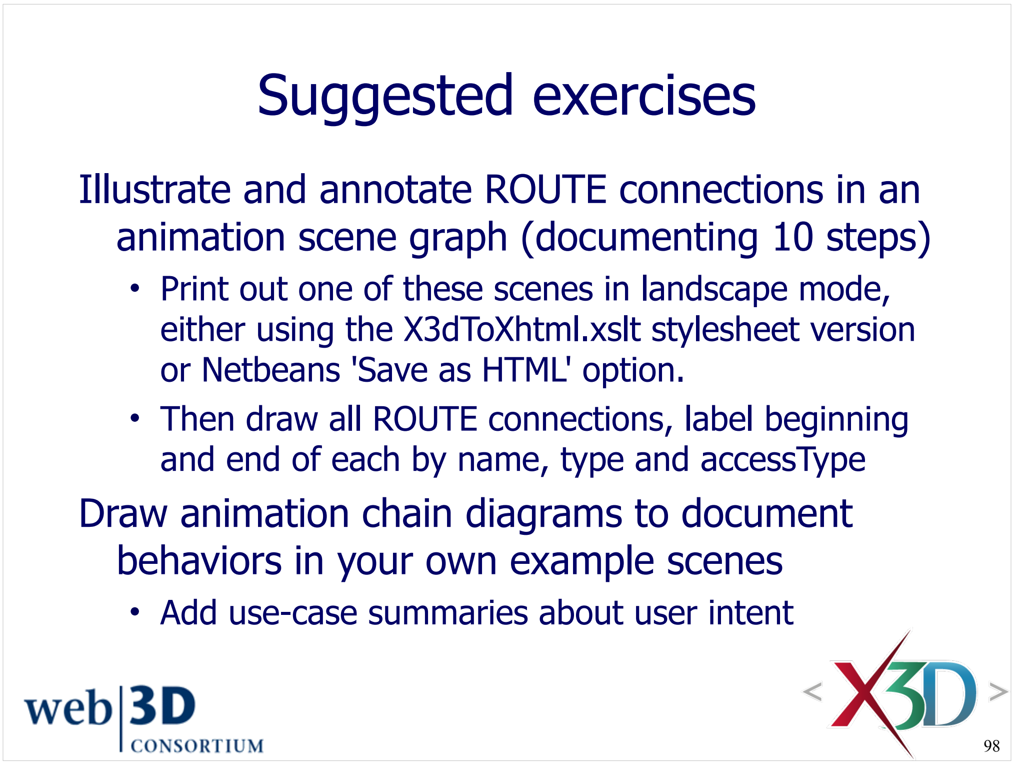
Behaviors, events, ROUTE connections, animation

Animation as scene-graph modification

Event-animation design pattern: 10-step process

Interpolation nodes

- TimeSensor and event timing
- ScalarInterpolator and ColorInterpolator
- OrientationInterpolator, PositionInterpolator, PositionInterpolator2D and NormalInterpolator
- CoordinateInterpolator, CoordinateInterpolator2D



Suggested exercises

Illustrate and annotate ROUTE connections in an animation scene graph (documenting 10 steps)

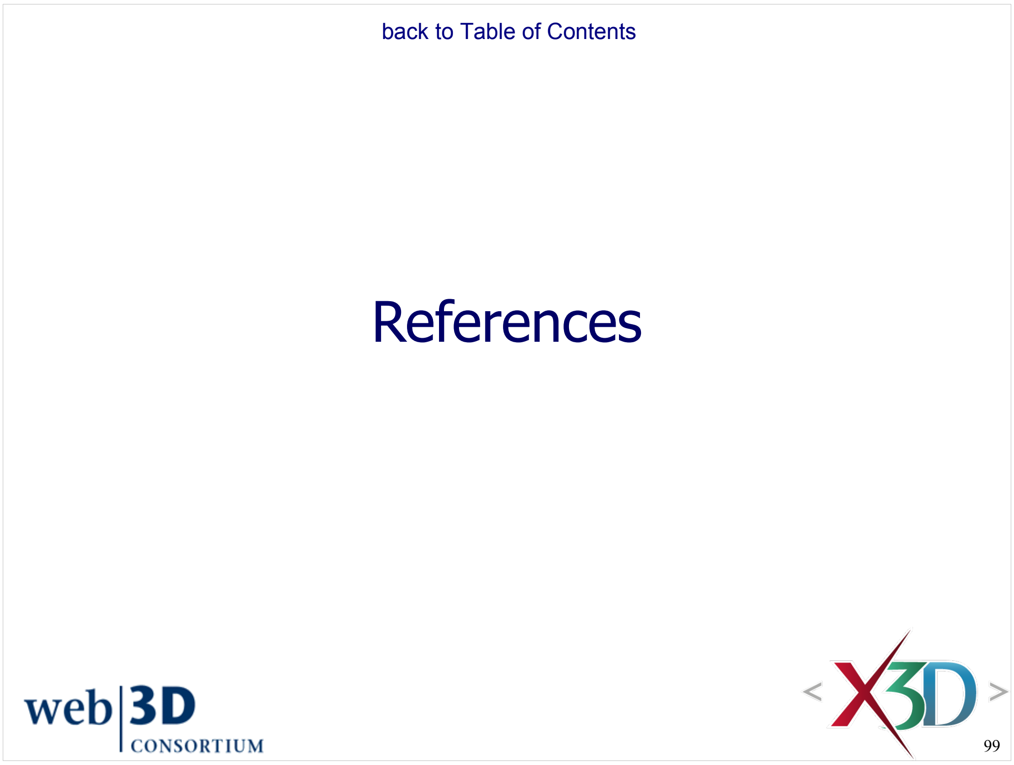
- Print out one of these scenes in landscape mode, either using the X3dToXhtml.xslt stylesheet version or Netbeans 'Save as HTML' option.
- Then draw all ROUTE connections, label beginning and end of each by name, type and accessType

Draw animation chain diagrams to document behaviors in your own example scenes

- Add use-case summaries about user intent

Someday we hope to automate the production of such diagrams.

X3dToXhtml.xslt is available via X3D-Edit menu *File, Export from X3D, Export as Annotated XHTML...*



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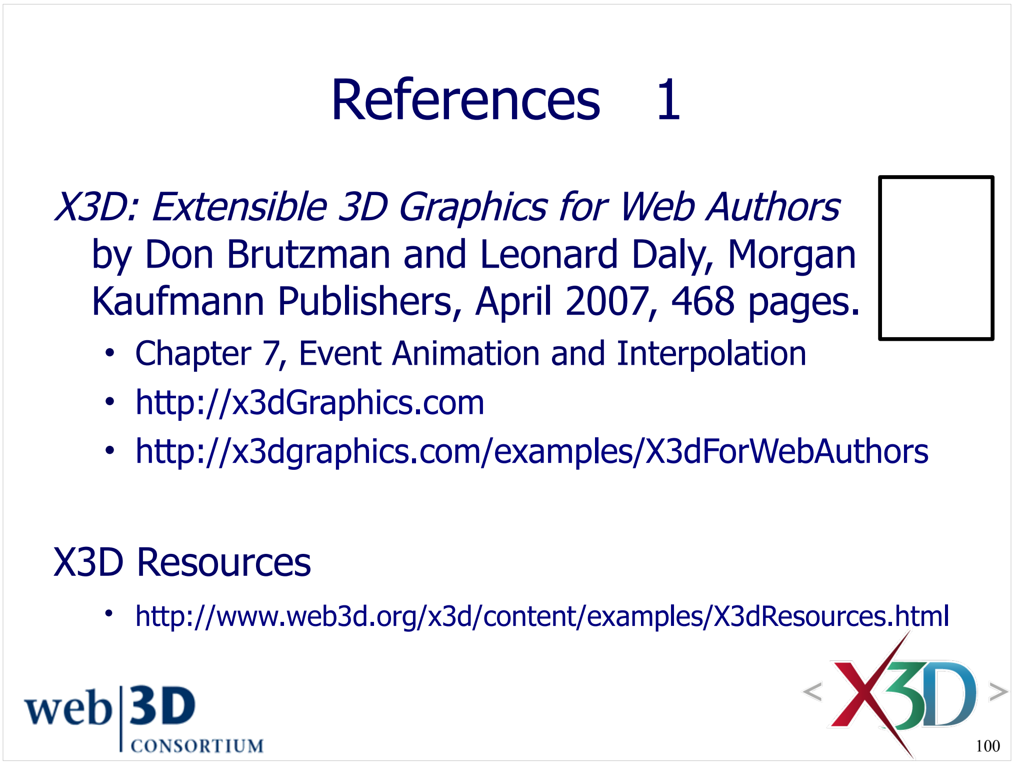


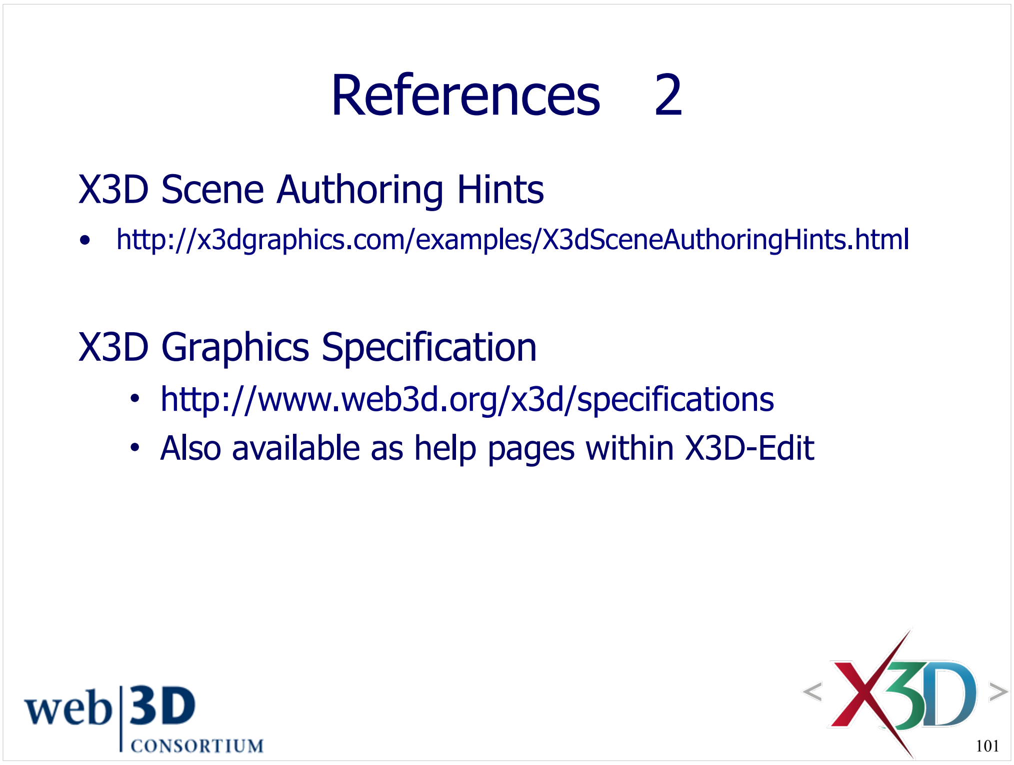
References 1

X3D: Extensible 3D Graphics for Web Authors by Don Brutzman and Leonard Daly, Morgan Kaufmann Publishers, April 2007, 468 pages.

- Chapter 7, Event Animation and Interpolation
- http://x3dGraphics.com
- http://x3dgraphics.com/examples/X3dForWebAuthors

X3D Resources

- http://www.web3d.org/x3d/content/examples/X3dResources.html



References 2

X3D Scene Authoring Hints

- http://x3dgraphics.com/examples/X3dSceneAuthoringHints.html

X3D Graphics Specification

- http://www.web3d.org/x3d/specifications
- Also available as help pages within X3D-Edit

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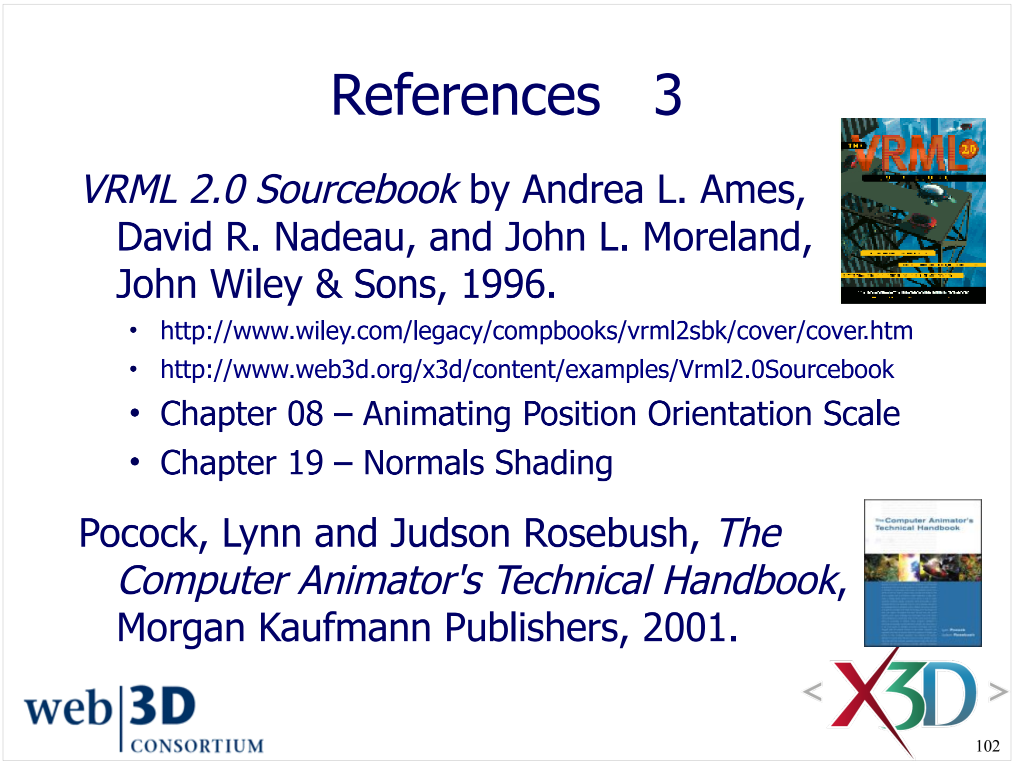

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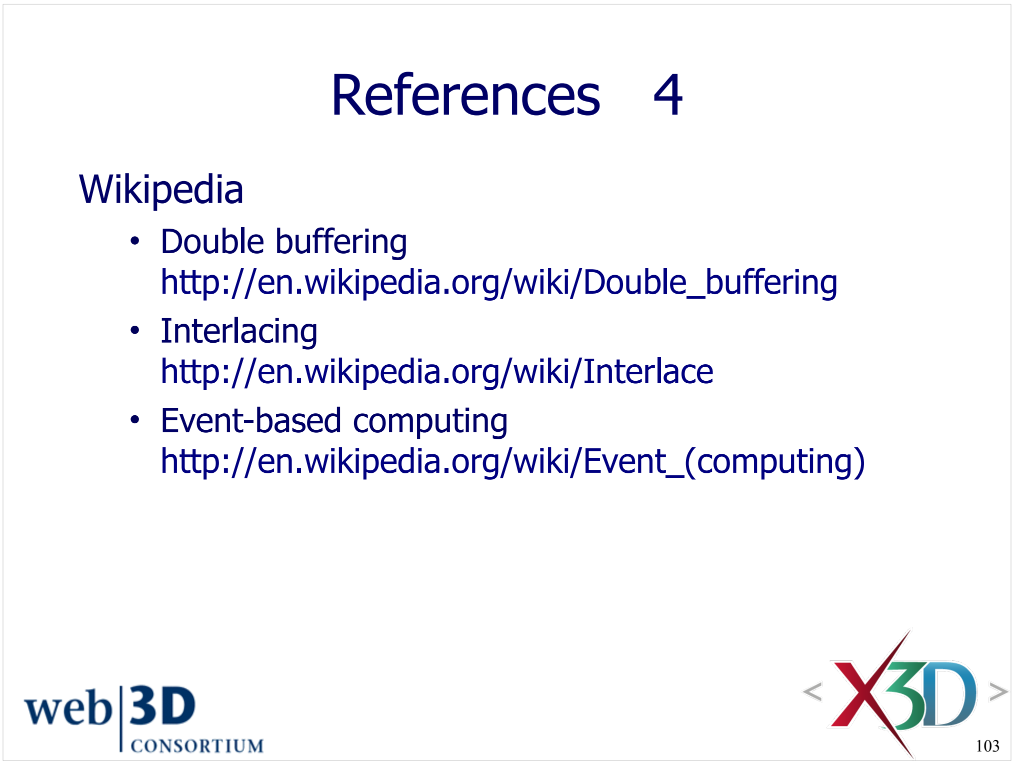
VRML 2.0 Sourcebook by Andrea L. Ames, David R. Nadeau, and John L. Moreland, John Wiley & Sons, 1996.

- http://www.wiley.com/legacy/compbooks/vrml2sbk/cover/cover.htm
- http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook
- Chapter 08 – Animating Position Orientation Scale
- Chapter 19 – Normals Shading

Pocock, Lynn and Judson Rosebush, *The Computer Animator's Technical Handbook*, Morgan Kaufmann Publishers, 2001.



References 4

Wikipedia

- Double buffering
  http://en.wikipedia.org/wiki/Double_buffering
- Interlacing
  http://en.wikipedia.org/wiki/Interlace
- Event-based computing
  http://en.wikipedia.org/wiki/Event_(computing)

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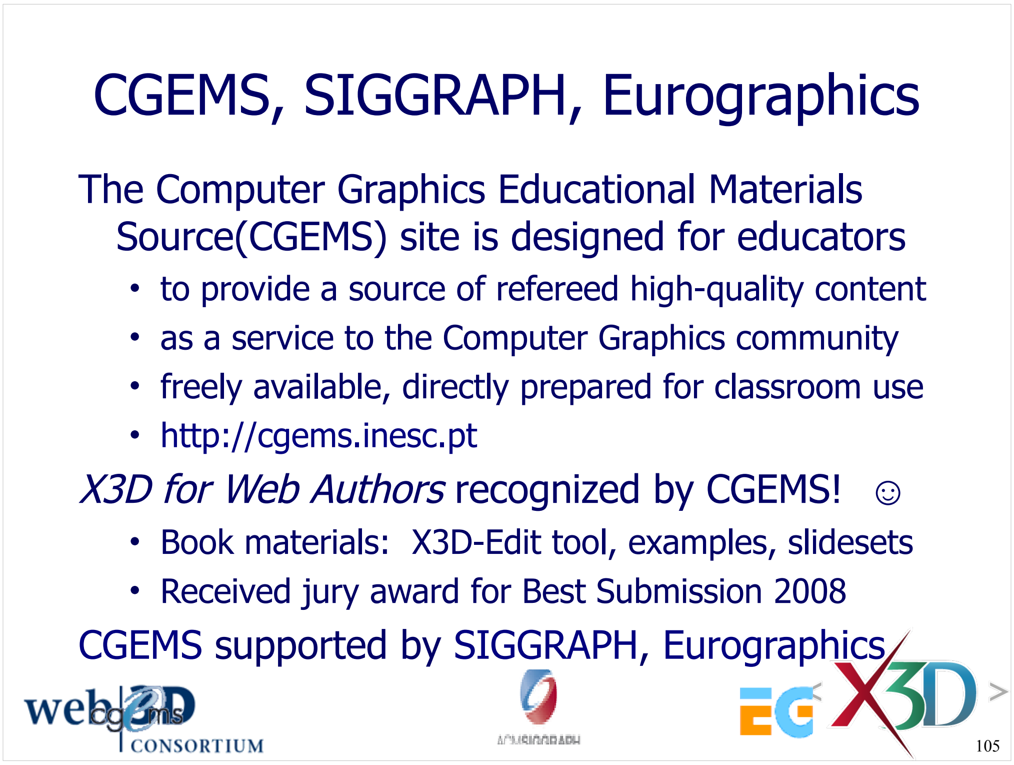

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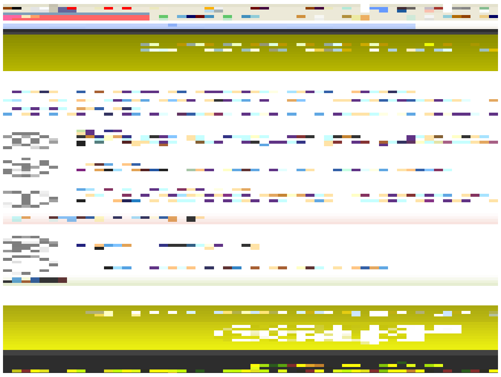

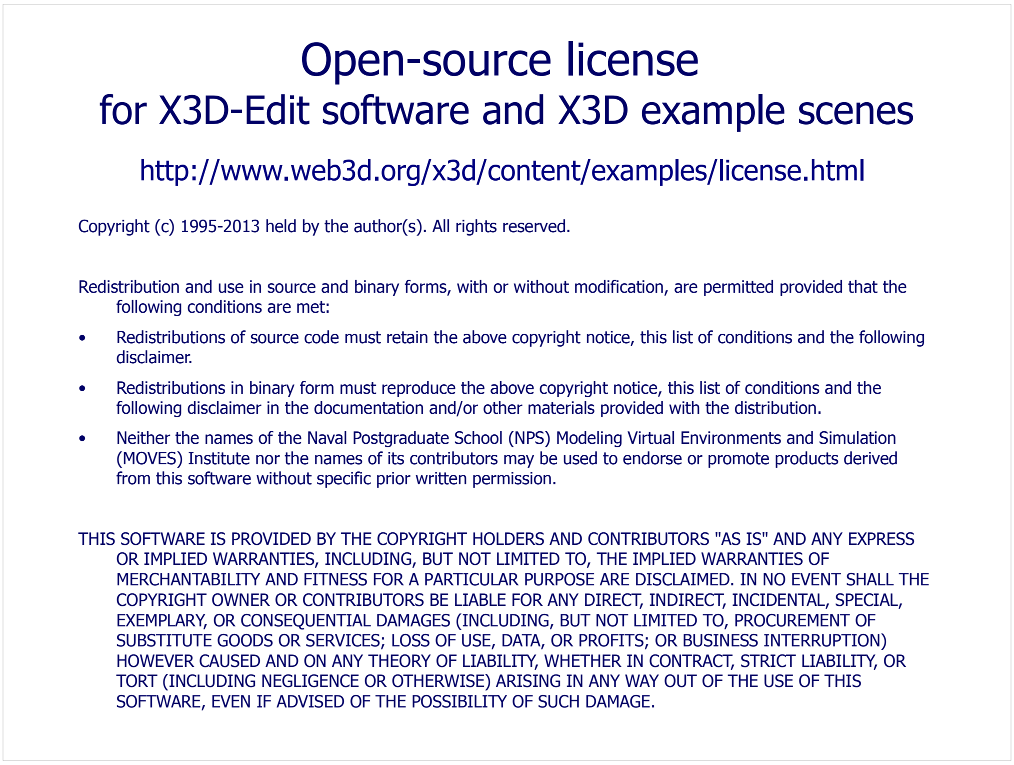

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GUIDE TO NAVIGATING LICENSING ISSUES IN EXISTING & NEW SOFTWARE
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ANDREW ST. LAURENT

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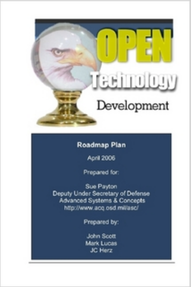

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