X3D Geospatial Component and X3D Earth

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Don Brutzman and Byounghyun Yoo

Naval Postgraduate School, MIT Singapore Alliance

brutzman@nps.edu byoo@mit.edu

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Chapter Overview

Overview: Geospatial X3D

Geospatially referenced scenes have special requirements beyond ordinary 3D scenes

- Double-precision accuracy on floating-point displays
- Diverse yet coherent spatial reference systems

X3D Geospatial Component nodes add necessary functionality to X3D in a consistent way

- Goal: easy to integrate Earth with X3D scenes

X3D Earth capabilities enable generation of local regions or full-scale globes using any data

- Without license restrictions, openly scalable

Concepts

History: GeoVRML

Geospatial referencing has always been a goal of X3D in order to make models most useful

The core design efforts for geospatial X3D were performed by GeoVRML working group

This design has been carefully evolved over time to match practical experience gained by producing ever-larger geospatial models

Example: Monterey Bay exploration

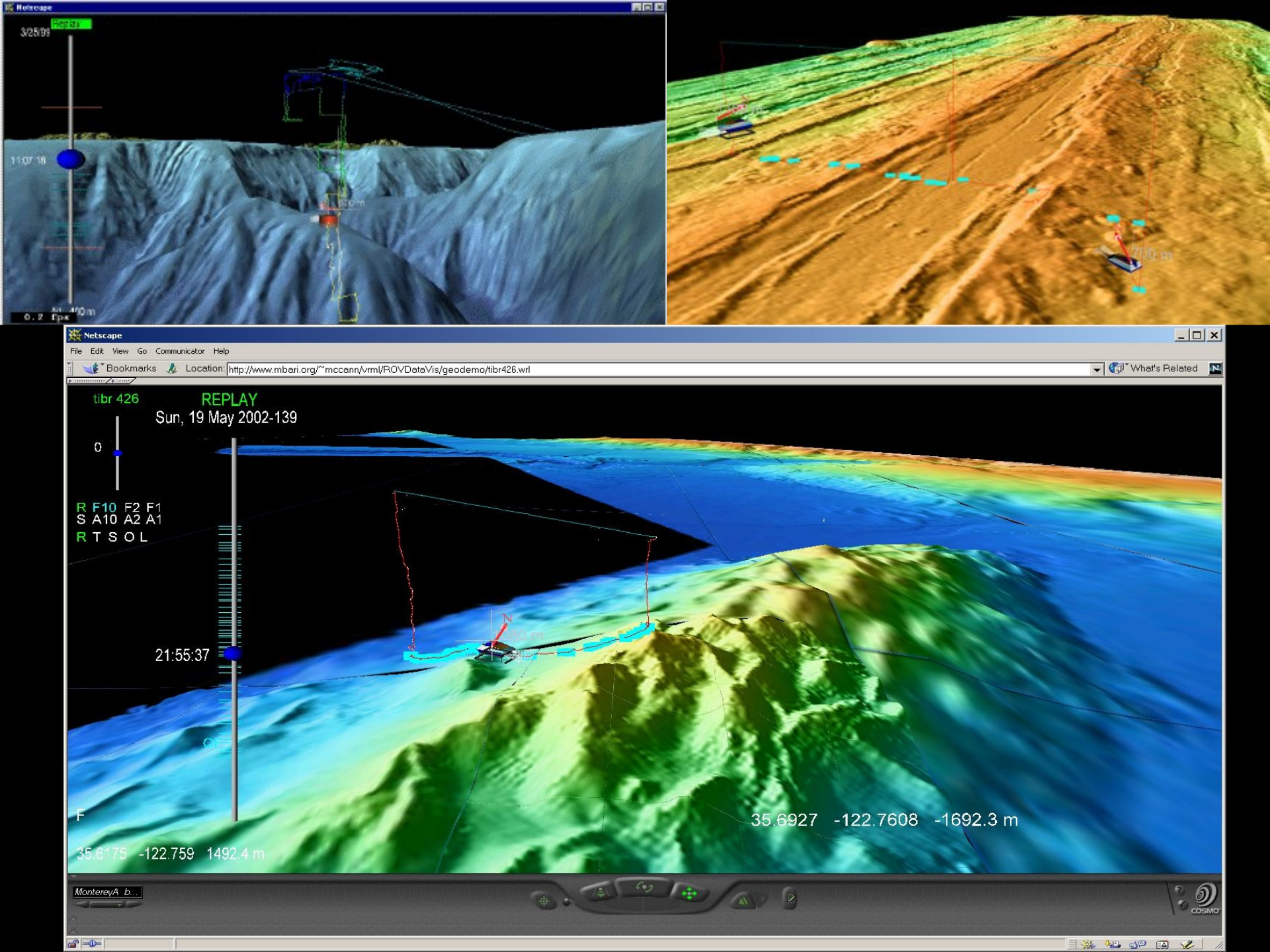
Mike McCann, MBARI

- Monterey Bay Aquarium Research Institute

GeoVRML application for underwater track data from remotely operated vehicles (ROVs)

- Tracks converted to line sets with user interfaces for interpolator-driven playback
- Bathymetry and vessels are geolocated
- Image billboards link photography, videos

Scientists can previsualize, explore missions


Netscape
File Edit View Go Communicator Help
Bookmarks Location: http://www.mbari.org/~mccann/vrml/ROVDataVis/geodemo/tibr426.wrl
What's Related
tibr 426
REPLAY
Sun, 19 May 2002-139
0
R F10 F2 F1
S A10 A2 A1
R T S O L
21:55:37
F
35.6175 -122.759 1492.4 m
35.6927 -122.7608 -1692.3 m
MontereyA b...
COSMO

Double precision requirements

Geospatial position values for latitude, longitude require double precision accuracy

- Otherwise single-precision roundoff jitter equates to 3-10m of positional error

Graphics cards only support single precision

- Single precision 32 bit, double precision 64 bit

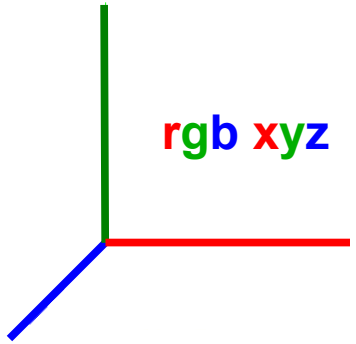
X3D Geospatial component reconciles this mismatch correctly and efficiently

X3D types for double precision

- SFDouble single-field singleton value
- SFVec2d singleton vector of 2 values
- SFVec3d singleton vector of 3 values
- SFVec4d singleton vector of 4 values

- MFDouble multiple-field array of values
- MFVec2d vector array of 2-tuple values
- MFVec3d vector array of 3-tuple values
- MFVec4d vector array of 4-tuple values

Coordinate systems



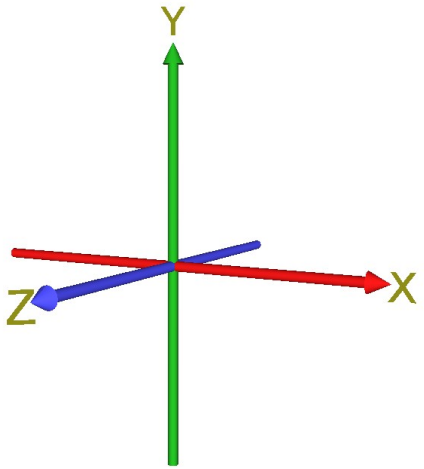
Right hand rule for X Y Z order

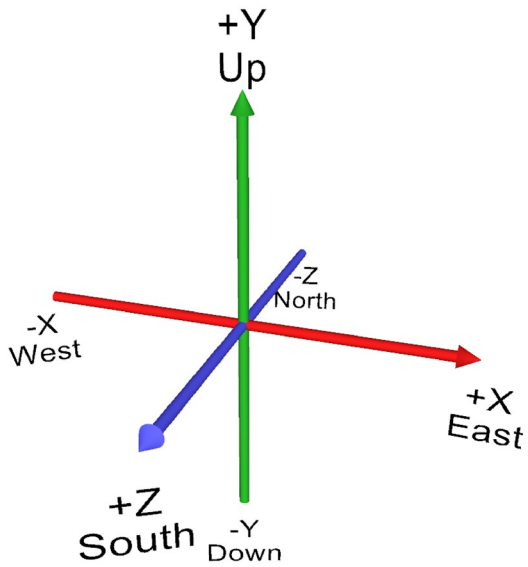
Y axis is up

Correspondence: East, Up, South

Accept no substitutes!

- or at least realign them ☺





Spatial reference frames

X3D is based on a right-handed Cartesion x,y,z coordinate system

- centered at arbitrary (0,0,0)

Geospatial data can be captured in a large variety of earth-oriented coordinate sytems

- It is important to keep these different coordinate systems straight, or else objects do not appear where they are expected
- Related to ellipsoid for actual Earth shape

Spatial reference frames

Primary

- GD Geodetic spatial reference frame
  <latitude> <longitude> <elevation>
- GC Geocentric spatial reference frame
  <x> <y> <z>
- UTM Universal Transverse Mercator
  <northing> <easting> <elevation>

X3D browsers transform geographic coordinates into earth-fixed geocentric coordinates

Supported earth ellipsoids

Code	Ellipsoid Name	Semi-Major Axis (metres)	Inv. Flattening (F-1)
AA	Airy 1830	6377563.4	299.32
AM	Modified Airy	6377340.19	299.32
AN	Australian National	6378160	298.25
BN	Bessel 1841 (Namibia)	6377483.87	299.15
BR	Bessel 1841 (Ethiopia Indonesia...)	6377397.16	299.15
CC	Clarke 1866	6378206.4	294.98
CD	Clarke 1880	6378249.15	293.47
EA	Everest (India 1830)	6377276.35	300.8
EB	Everest (Sabah & Sarawak)	6377298.56	300.8
EC	Everest (India 1956)	6377301.24	300.8
ED	Everest (W. Malaysia 1969)	6377295.66	300.8
EE	Everest (W. Malaysia & Singapore 1948)	6377304.06	300.8
EF	Everest (Pakistan)	6377309.61	300.8
FA	Modified Fischer 1960	6378155	298.3
HE	Helmert 1906	6378200	298.3
HO	Hough 1960	6378270	297
ID	Indonesian 1974	6378160	298.25
IN	International 1924	6378388	297
KA	Krassovsky 1940	6378245	298.3
RF	Geodetic Reference System 1980 (GRS 80)	6378137	298.26
SA	South American 1969	6378160	298.25
WD	WGS 72	6378135	298.26
WE	WGS 84	6378137	298.26

Common field: *geoSystem*

geoSystem field indicates spatial reference frame and corresponding earth ellipsoid

- Used by X3D geospatial nodes containing position data (i.e. most of them)

geoSystem default value is ["GD" "WE"]

- "GD" means geodetic
- "WE" means WGS84 ellipsoid, i.e. the World Geodetic System of 1984 (updated 2004)

Common field: *geoCenter*

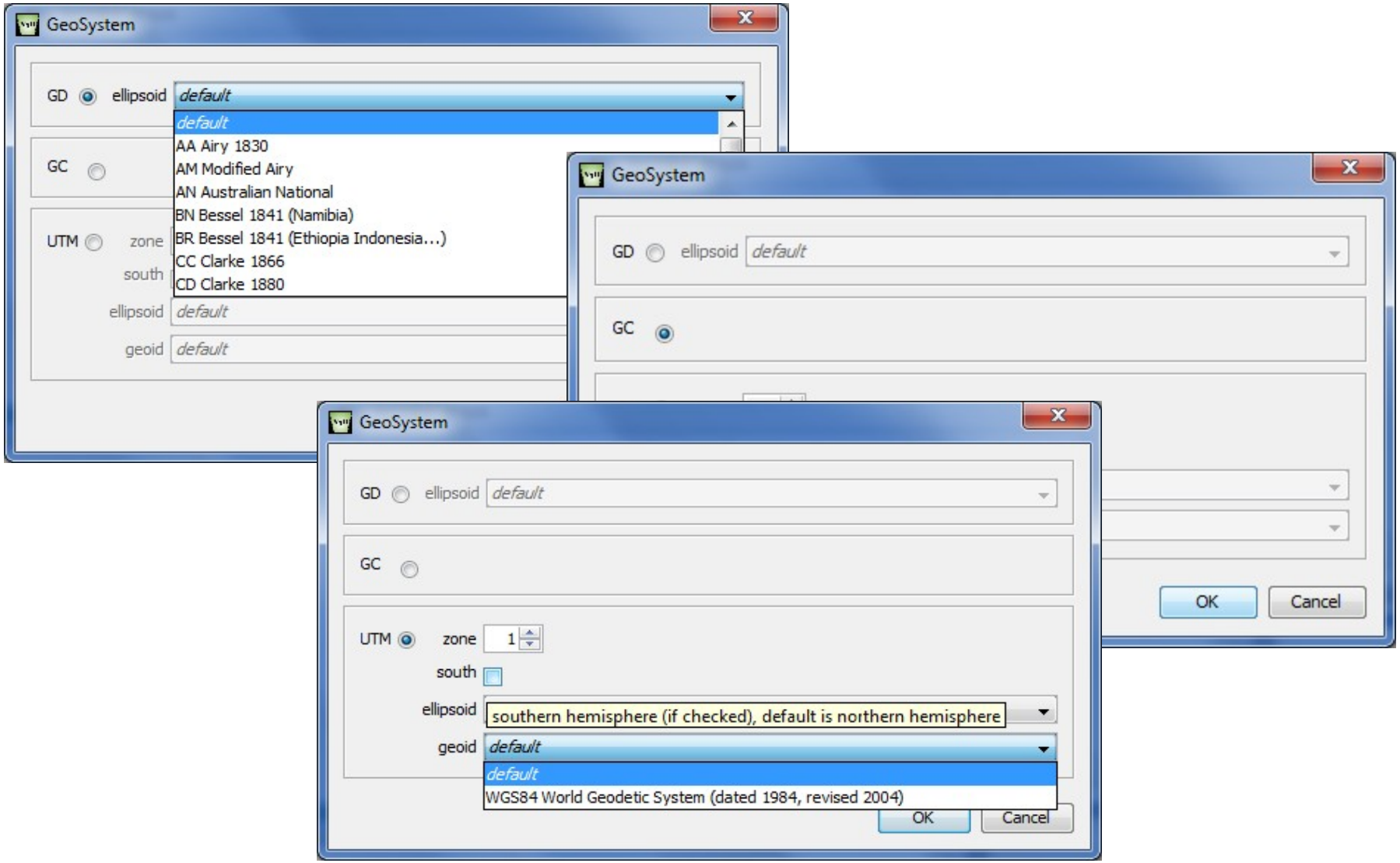
geoCenter field indicates geospatial position of center of the current node's coordinate frame

- Used by several X3D geospatial nodes

Values held by *geoCenter* field are determined by choice of corresponding *geoSystem* field:

- GD <latitude> <longitude> <elevation>
- GC <x> <y> <z>
- UTM <northing> <easting> <elevation>

geoSystem field editor X3D-Edit



Common field: *metadata*

Each node can also contain Metadata nodes

- This is consistent throughout all X3D

Metadata nodes allow authors to add pairs of names and typed values to describe content

- Possible option for annotating, augmenting content in a valid machine-readable way
- MetadataSet, MetadataString, MetadataFloat, MetadataDouble, MetadataInteger

Note that GeoMetadata node also available

X3D Geospatial Implementations

Xj3D: open source Java

- www.xj3D.org

FreeWrl/FreeX3D: open source C++

- http://freewrl.sourceforge.net

BS Contact Geo commercial C++

- http://www.bitmanagement.de

Other players to follow?

Feature comparison:

- Player support for X3D components wiki

Geospatial navigation issues

Regular X3D navigation modes often fail when confronted with geospatial coordinates

- Reason: world coordinate frame is no longer Cartesian x,y,z but rather geospatial surface
- Typical failure that leaves user lost in space: <NavigationInfo type=' "EXAMINE" "ANY" '/>

Special implementation techniques required for X3D players to handle user navigation properly

- Velocity also should be proportional to altitude

X3D Nodes and Examples

Obtaining example scenes

X3D Basic archives, GeoSpatial directory

- http://www.web3d.org/x3d/content/examples/Basic
- Under version control on sourceforge

X3D-Earth globe server

- http://x3d-earth.nps.edu
- A few examples are there, more to follow

Also in NPS Savage archives: specific locations available

Locations

Baltimore Maryland	Bosphorus	Camp Pendleton California
Dardanelles	Fort Lauderdale Florida	Globe Level 0to 4
Hampton Roads Virginia	Hawaii	Malaka
Monterey Bay California	Narragansett Bay Rhode Island Bathymetry	Narragansett Bay Rhode Island Large
Narragansett Bay Rhode Island Small	Panama City Florida	Port Hueneme California
Rio De Janeiro	San Francisco California	Ship Island Mississippi
Singapore	Southern California Border	Straits Of Hormuz
Straits Of Malacca Large	Straits Of Malacca Small	Tunis Airport Tunisia

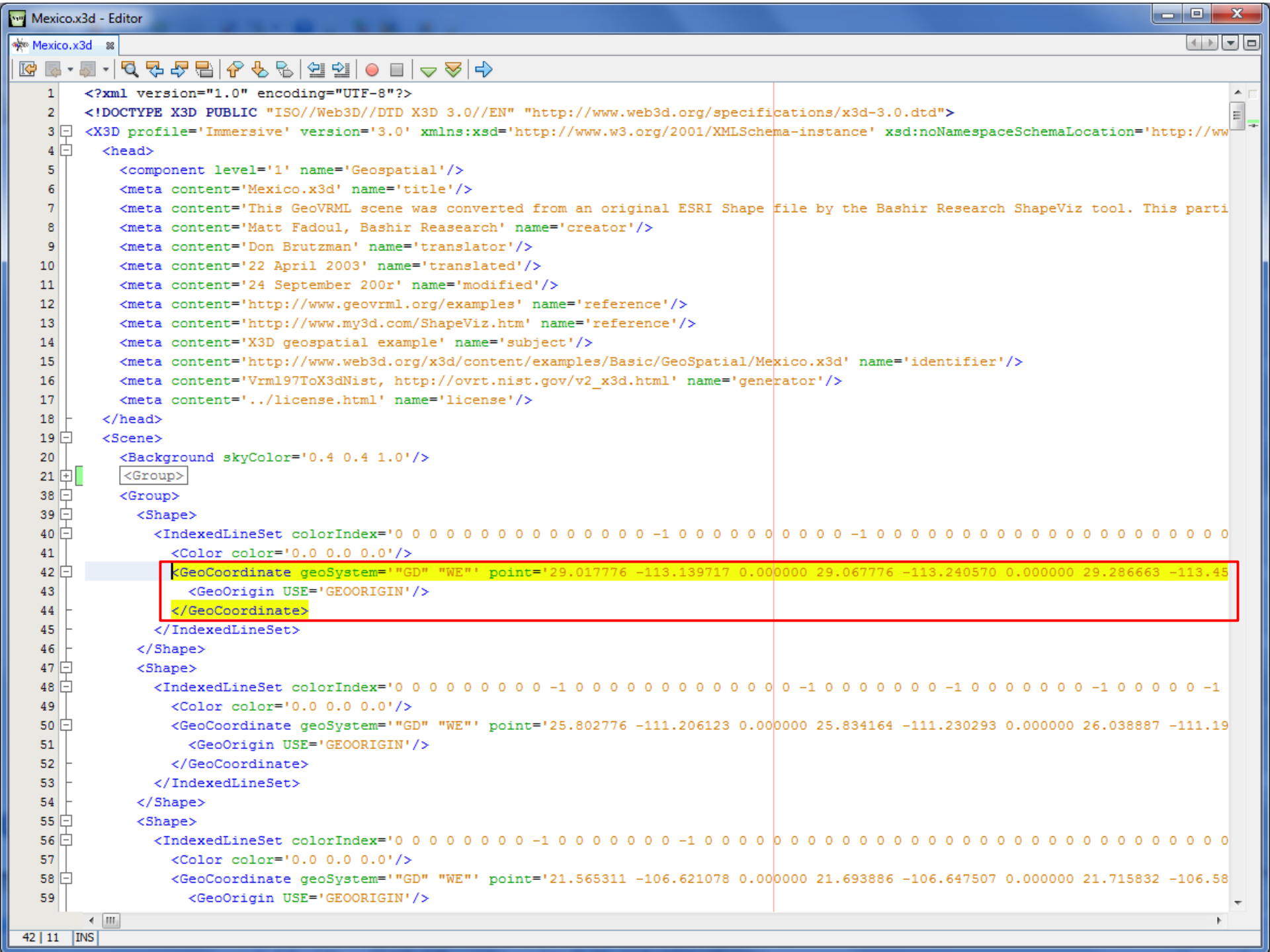
GeoCoordinate node

Defines a list of coordinate values, used as *coord* field of a vertex-based geometry node

- such as IndexedFaceSet, IndexedLineSet, or PointSet node

As described before, each value is defined according to specified coordinate system:

- GD <latitude> <longitude> <elevation>
- GC <x> <y> <z>
- UTM <northing> <easting> <elevation>


Mexico.x3d - Editor
Mexico.x3d
<?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' version='3.0' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' xsd:noNamespaceSchemaLocation='http://ww
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<component level='1' name='Geospatial'/>
<meta content='Mexico.x3d' name='title'/>
<meta content='This GeoVRML scene was converted from an original ESRI Shape file by the Bashir Research ShapeViz tool. This parti
<meta content='Matt Fadoul, Bashir Reasearch' name='creator'/>
<meta content='Don Brutzman' name='translator'/>
<meta content='22 April 2003' name='translated'/>
<meta content='24 September 200r' name='modified'/>
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<meta content='Vrml97ToX3dNist, http://ovrt.nist.gov/v2_x3d.html' name='generator'/>
<meta content='../license.html' name='license'/>
</head>
<Scene>
<Background skyColor='0.4 0.4 1.0'/>
<Group>
<Group>
<Shape>
<IndexedLineSet colorIndex='0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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</GeoCoordinate>
</IndexedLineSet>
</Shape>
<Shape>
<IndexedLineSet colorIndex='0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 -1 0 0 0 0 0 -1
<Color color='0.0 0.0 0.0'/>
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</IndexedLineSet>
</Shape>
<Shape>
<IndexedLineSet colorIndex='0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
<Color color='0.0 0.0 0.0'/>
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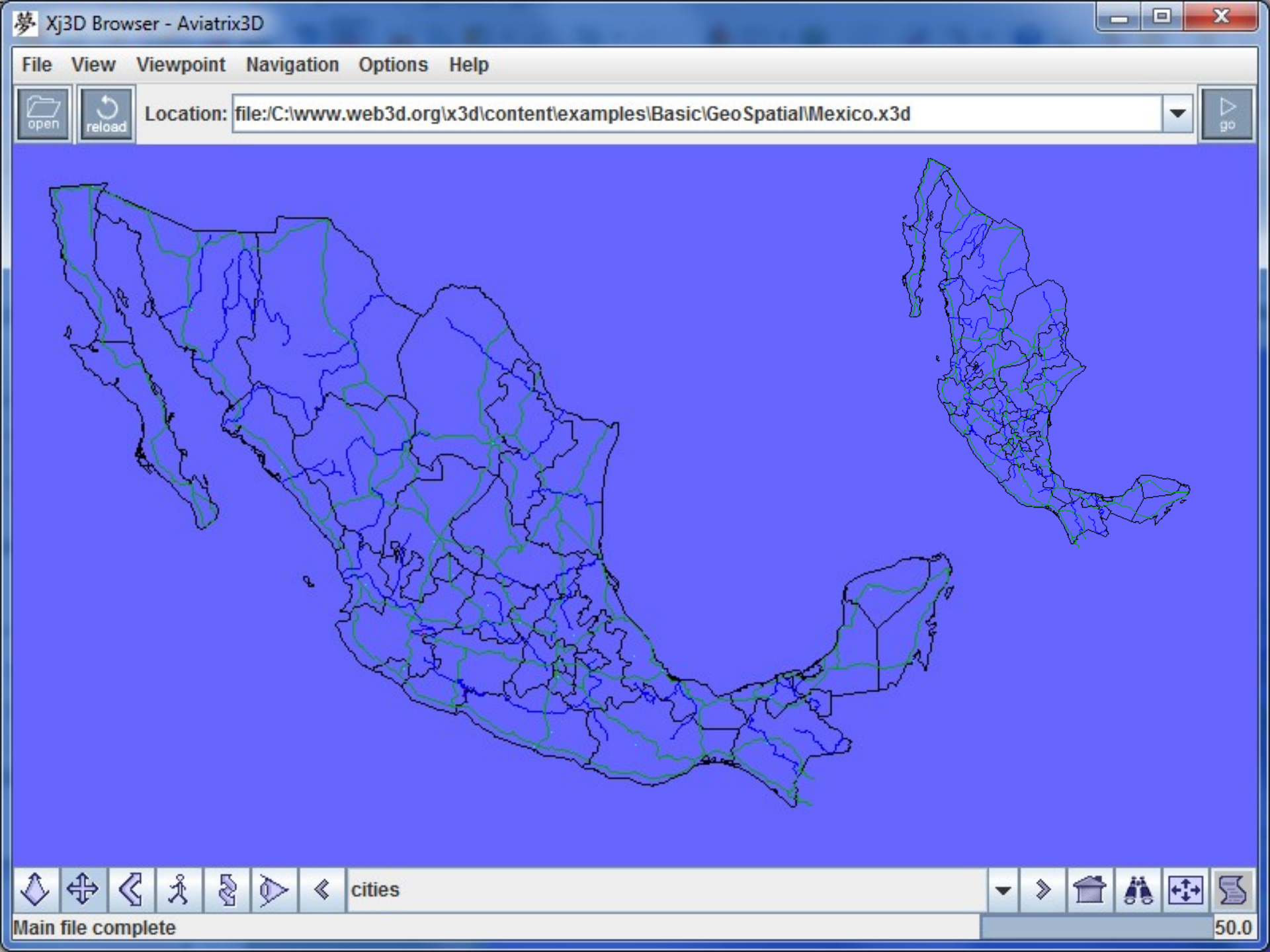
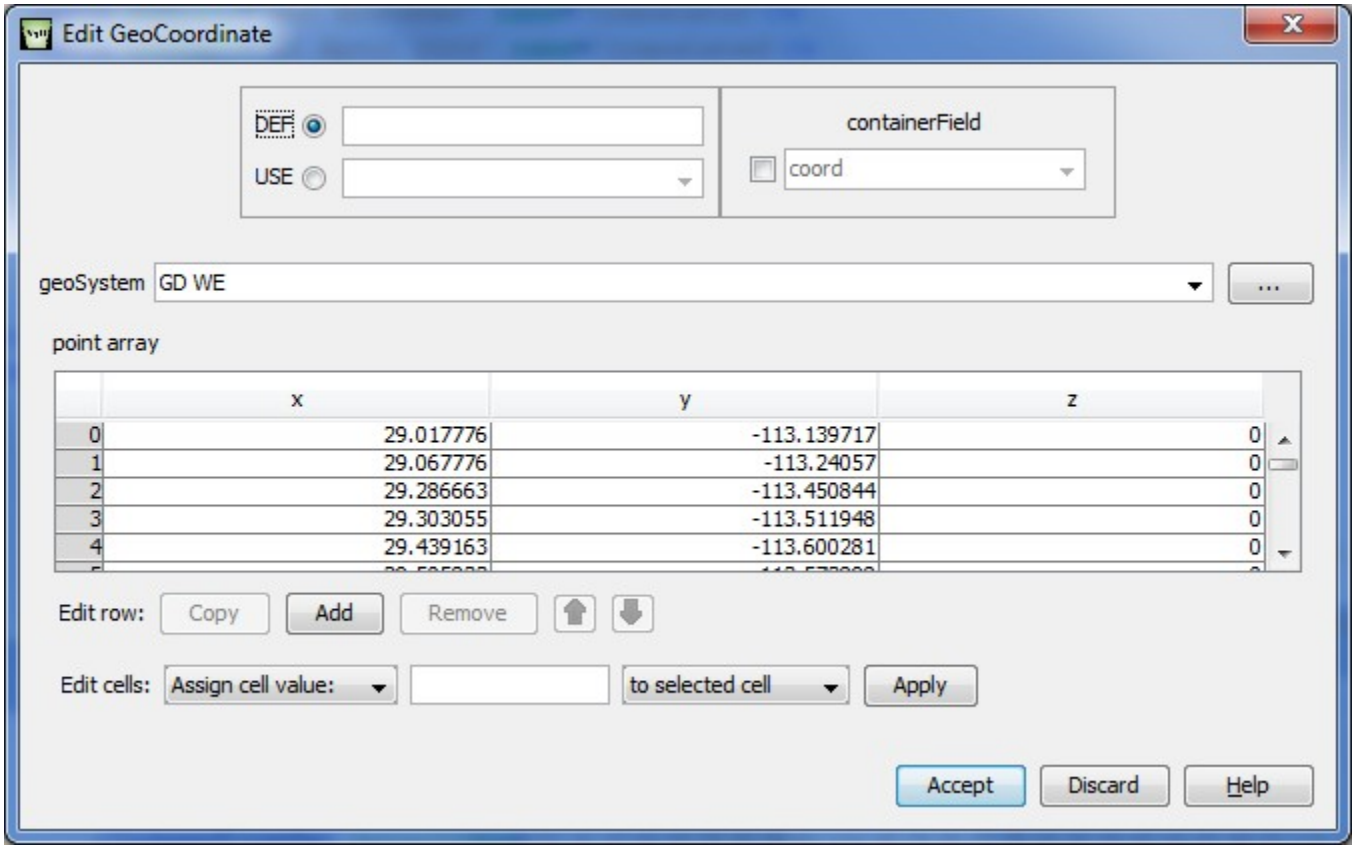
42 | 11
INS


Xj3D Browser - Aviatrix3D
File View Viewpoint Navigation Options Help
open
reload
Location: file:/C:\www.web3d.org\x3d\content\examples\Basic\GeoSpatial\Mexico.x3d
go
cities
Main file complete
50.0

GeoCoordinate node X3D-Edit



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X3D

GeoElevationGrid node 1

Similar to regular ElevationGrid node

- Adds *geoGridOrigin*, *geoSystem* fields
- *height* field is now a double array (not float) representing height above geoid surface
- Also includes *set_height* (inputOnly) field

*Geometry of Ge*oElevationGrid *height* field itself is curved to match geospatial ellipsoid

- Curvature typically not visible for small areas
- Nevertheless holds accurate for large areas, including definition of a full globe!

GeoElevationGrid node 2

geoSystem defines geospatial coordinate system

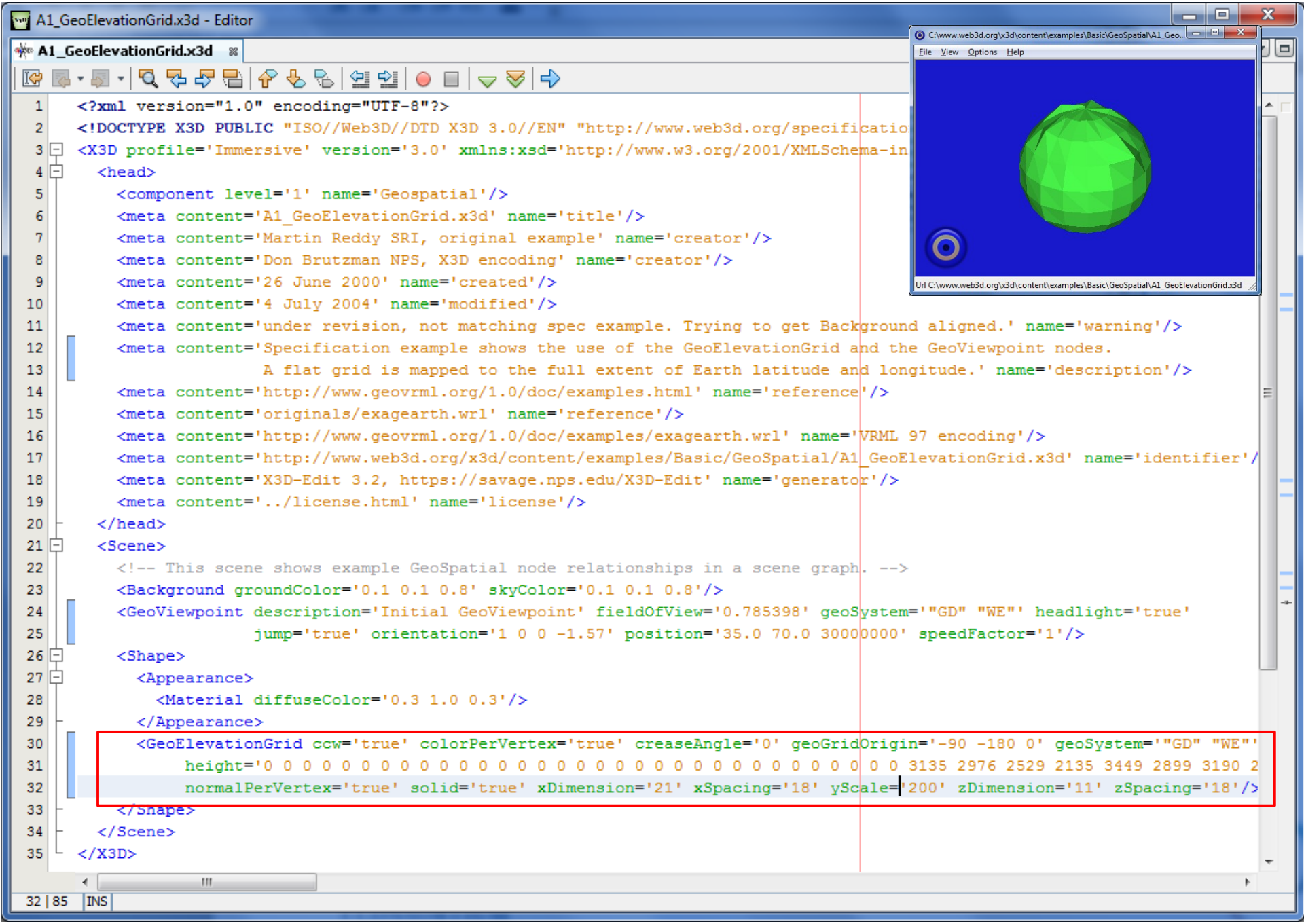
- also affects units of other values

geoSystem "GD"

- *xSpacing* refers to the number of degrees of longitude between adjacent height values
- *zSpacing* refers to the number of degrees of latitude between vertical height values.

geoSystem "UTM"

- *xSpacing* refers to the number of eastings (metres) between adjacent height values
- *zSpacing* refers to the number of northings (metres) between vertical height values.


A1_GeoElevationGrid.x3d - Editor
A1_GeoElevationGrid.x3d
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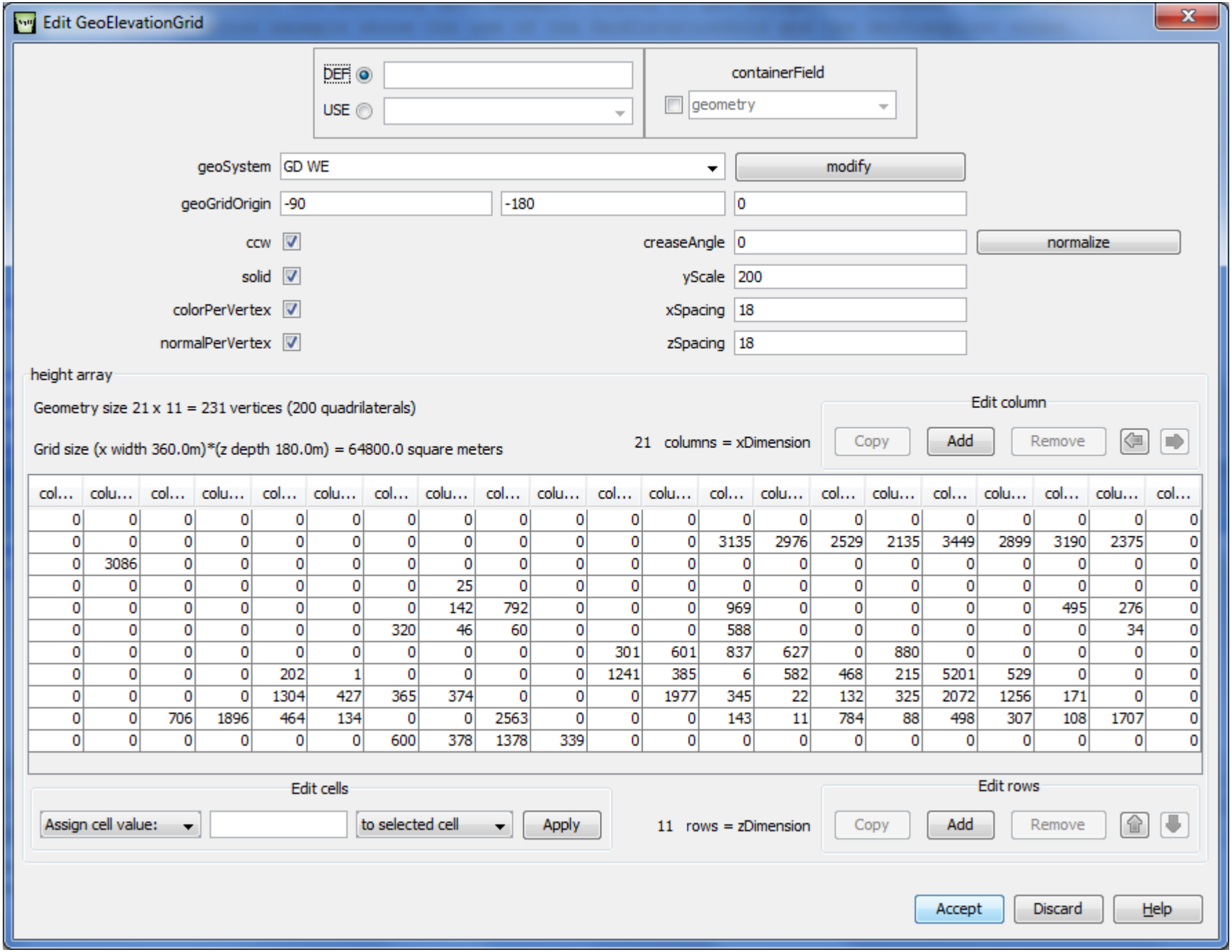
File View Options Help
Url C:\www.web3d.org\x3d\content\examples\Basic\GeoSpatial\A1_GeoElevationGrid.x3d
1 <?xml version="1.0" encoding="UTF-8"?>
2 <!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN" "http://www.web3d.org/specificatio
3 <X3D profile='Immersive' version='3.0' xmlns:xsd='http://www.w3.org/2001/XMLSchema-in
4 <head>
5 <component level='1' name='Geospatial'/>
6 <meta content='A1_GeoElevationGrid.x3d' name='title'/>
7 <meta content='Martin Reddy SRI, original example' name='creator'/>
8 <meta content='Don Brutzman NPS, X3D encoding' name='creator'/>
9 <meta content='26 June 2000' name='created'/>
10 <meta content='4 July 2004' name='modified'/>
11 <meta content='under revision, not matching spec example. Trying to get Background aligned.' name='warning'/>
12 <meta content='Specification example shows the use of the GeoElevationGrid and the GeoViewpoint nodes.
13 A flat grid is mapped to the full extent of Earth latitude and longitude.' name='description'/>
14 <meta content='http://www.geovrml.org/1.0/doc/examples.html' name='reference'/>
15 <meta content='originals/exagearth.wrl' name='reference'/>
16 <meta content='http://www.geovrml.org/1.0/doc/examples/exagearth.wrl' name='VRML 97 encoding'/>
17 <meta content='http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A1_GeoElevationGrid.x3d' name='identifier'/
18 <meta content='X3D-Edit 3.2, https://savage.nps.edu/X3D-Edit' name='generator'/>
19 <meta content='../license.html' name='license'/>
20 </head>
21 <Scene>
22 <!-- This scene shows example GeoSpatial node relationships in a scene graph. -->
23 <Background groundColor='0.1 0.1 0.8' skyColor='0.1 0.1 0.8'/>
24 <GeoViewpoint description='Initial GeoViewpoint' fieldOfView='0.785398' geoSystem='"GD" "WE"' headlight='true'
25 jump='true' orientation='1 0 0 -1.57' position='35.0 70.0 30000000' speedFactor='1'/>
26 <Shape>
27 <Appearance>
28 <Material diffuseColor='0.3 1.0 0.3'/>
29 </Appearance>
30 <GeoElevationGrid ccw='true' colorPerVertex='true' creaseAngle='0' geoGridOrigin='-90 -180 0' geoSystem='"GD" "WE"'
31 height='0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3135 2976 2529 2135 3449 2899 3190 2
32 normalPerVertex='true' solid='true' xDimension='21' xSpacing='18' yScale='200' zDimension='11' zSpacing='18'/>
33 </Shape>
34 </Scene>
35 </X3D>
32 | 85 INS


Edit GeoElevationGrid
DEF
USE
containerField
geometry
geoSystem
GD WE
modify
geoGridOrigin
-90
-180
0
ccw
solid
colorPerVertex
normalPerVertex
creaseAngle
0
normalize
yScale
200
xSpacing
18
zSpacing
18
height array
Geometry size 21 x 11 = 231 vertices (200 quadrilaterals)
Grid size (x width 360.0m)*(z depth 180.0m) = 64800.0 square meters
21 columns = xDimension
Edit column
Copy
Add
Remove
col… colu… col… colu… col… colu… col… colu… col… colu… col… colu… col… colu… col… colu… col… colu… col… colu… col…
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 3135 2976 2529 2135 3449 2899 3190 2375 0
0 3086 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 25 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 142 792 0 0 0 969 0 0 0 0 0 495 276 0
0 0 0 0 0 0 320 46 60 0 0 0 588 0 0 0 0 0 0 34 0
0 0 0 0 0 0 0 0 0 0 301 601 837 627 0 880 0 0 0 0 0
0 0 0 0 202 1 0 0 0 0 1241 385 6 582 468 215 5201 529 0 0 0
0 0 0 0 1304 427 365 374 0 0 0 1977 345 22 132 325 2072 1256 171 0 0
0 0 706 1896 464 134 0 0 2563 0 0 0 143 11 784 88 498 307 108 1707 0
0 0 0 0 0 0 600 378 1378 339 0 0 0 0 0 0 0 0 0 0 0
Edit cells
Assign cell value:
to selected cell
Apply
11 rows = zDimension
Edit rows
Copy
Add
Remove
Accept
Discard
Help

GeoLocation node

GeoLocation node provides ability to georeference any standard X3D model

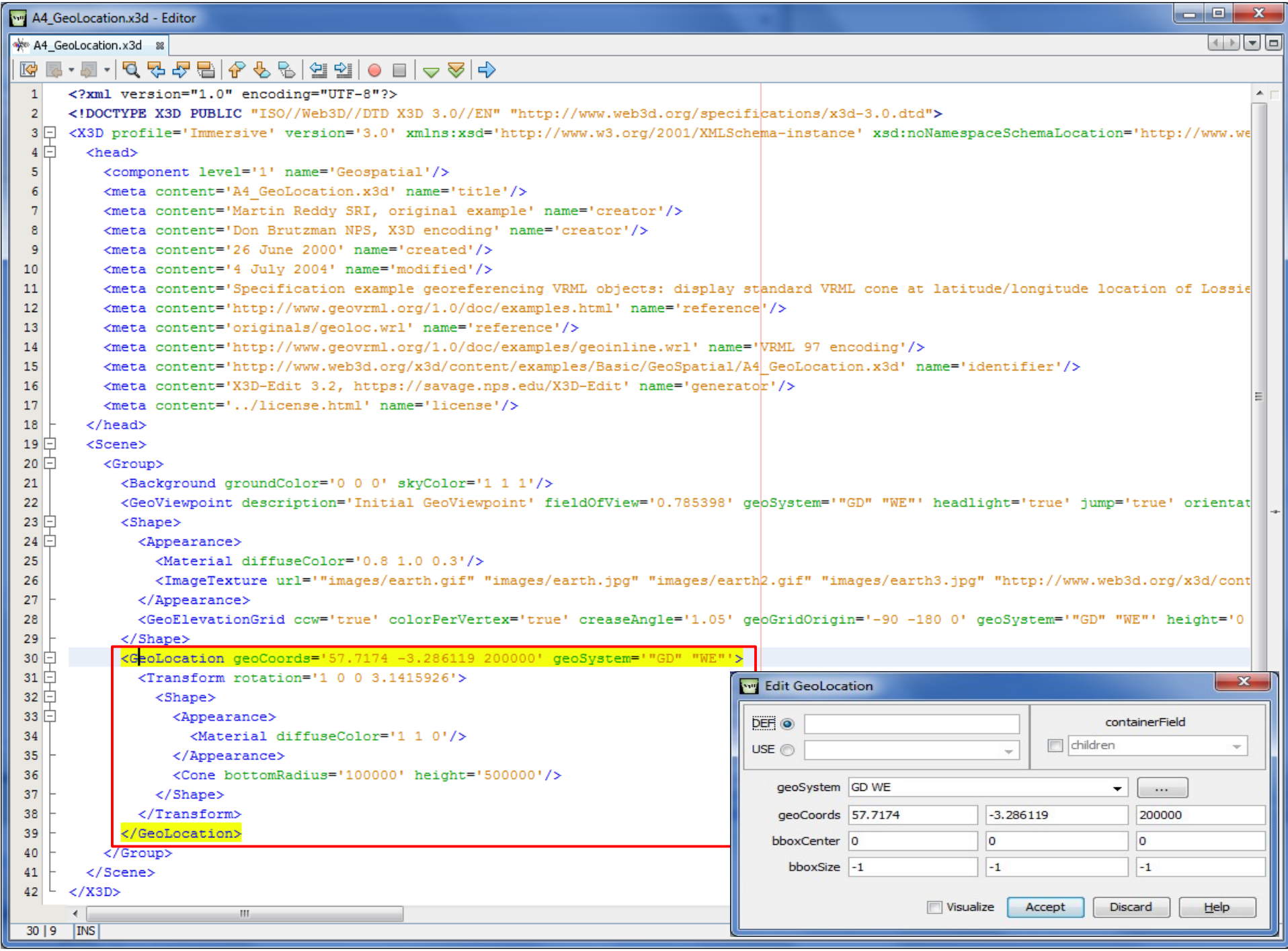
- X3D model is contained as child
- Thus GeoLocation is a grouping node
- Local vertical aligned with +Y axis up

geoSystem gives geospatial coordinate system

geoCoords field indicates location

- can dynamically update this geospatial location using GeoPositionInterpolator

Warning: do not nest GeoLocation nodes within each other, either directly or via Inline


A4_GeoLocation.x3d - Editor
A4_GeoLocation.x3d
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<meta content='4 July 2004' name='modified'/>
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<Appearance>
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</Appearance>
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</Shape>
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<Appearance>
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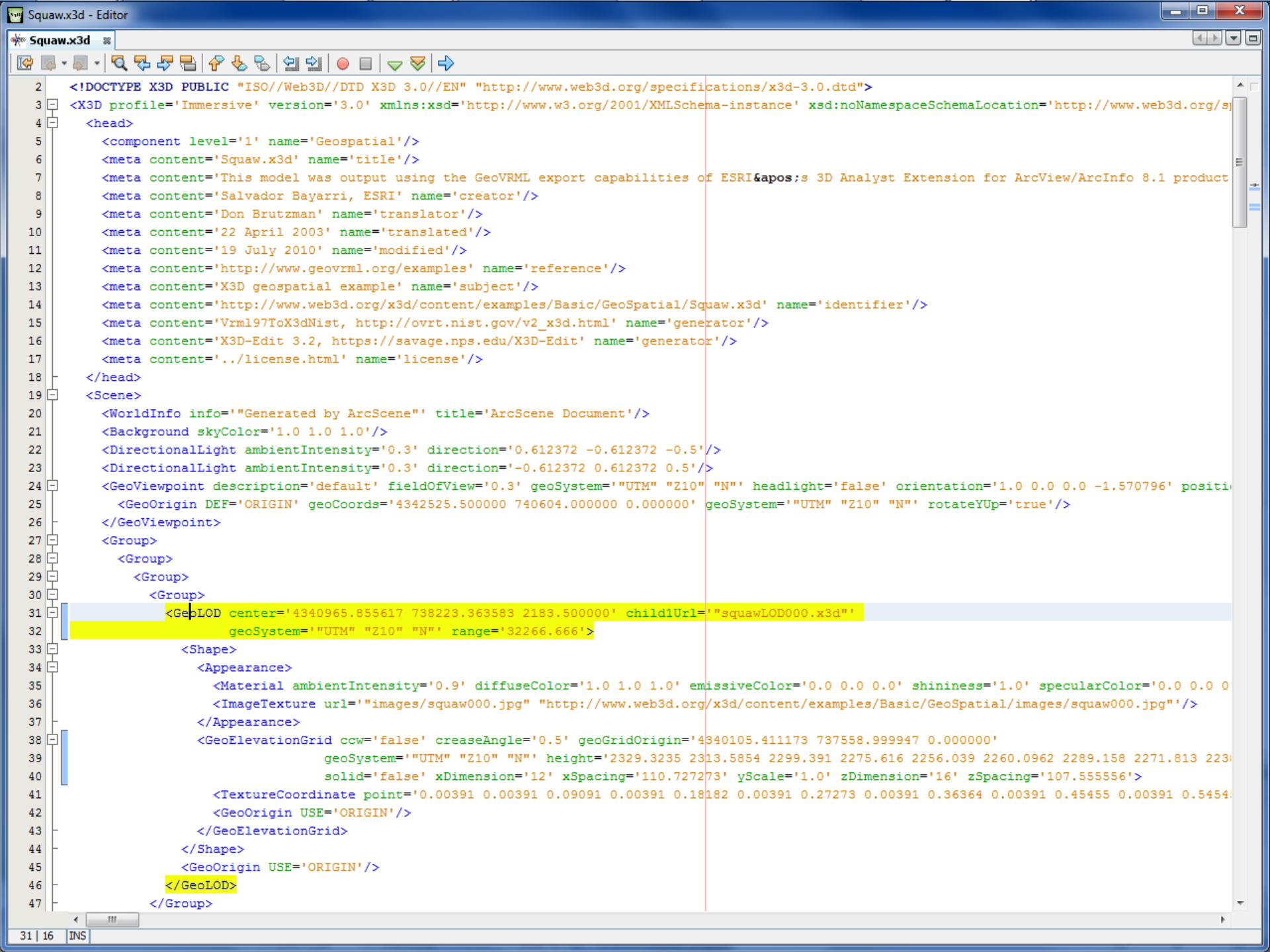
</Appearance>
<Cone bottomRadius='100000' height='500000'/>
</Shape>
</Transform>
</GeoLocation>
</Group>
</Scene>
</X3D>
30 | 9
INS
Edit GeoLocation
DEF
USE
containerField
children
geoSystem
GD WE
...
geoCoords
57.7174
-3.286119
200000
bboxCenter
0
0
0
bboxSize
-1
-1
-1
Visualize
Accept
Discard
Help

GeoLOD node

GeoLOD node provides a terrain-specialized form of the regular LOD node

- *rootUrl* or *rootNode* are used to define geometry shown at default level
- *Child1Url* ... *child4Url* fields define quadtree links to children subscenes
- *geoSystem* defines geospatial coordinate system
- Also includes output event for *level_changed*

Wish list: children within node, vice urls


Squaw.x3d - Editor
Squaw.x3d
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<meta content='Don Brutzman' name='translator'/>
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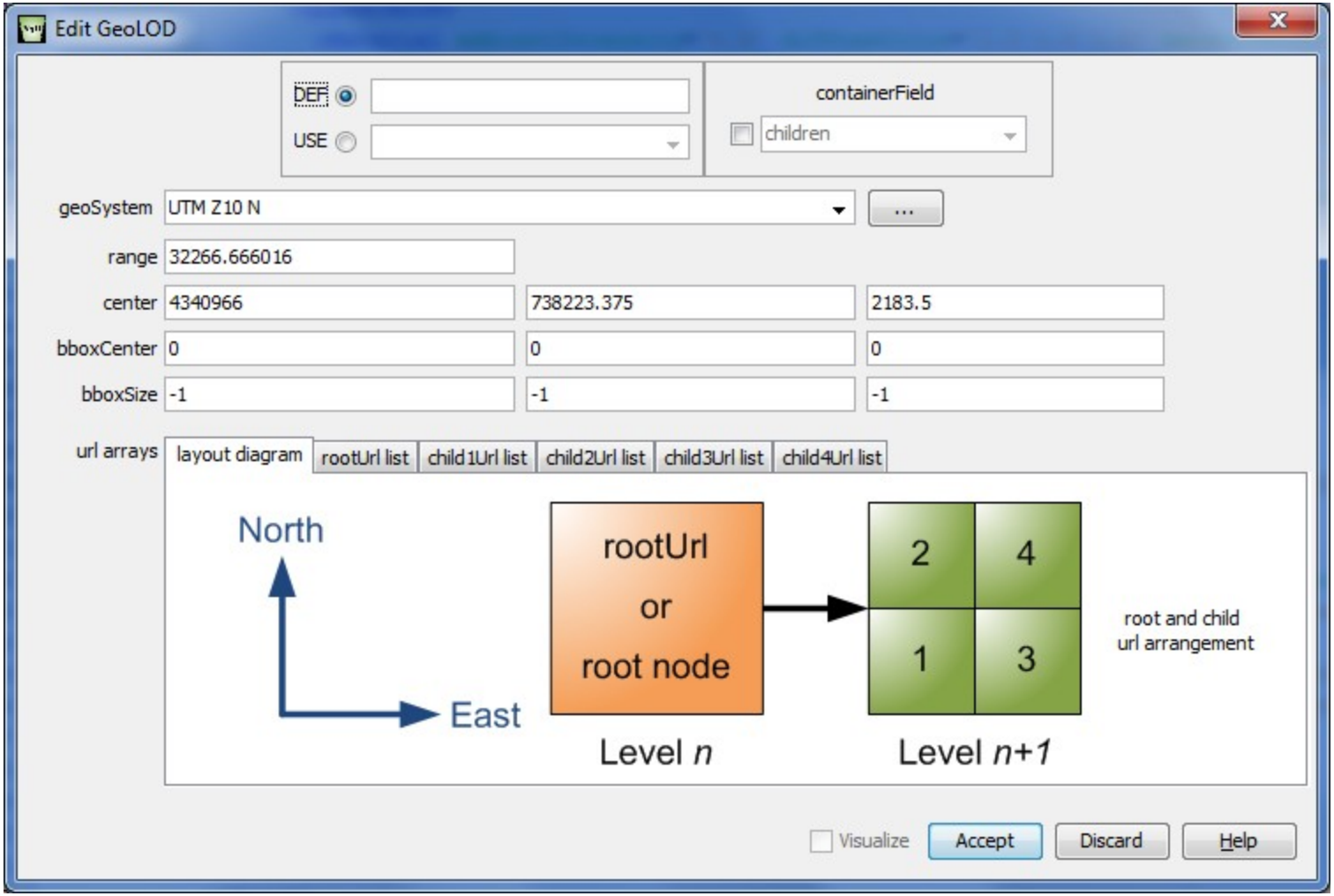
<meta content='http://www.geovrml.org/examples' name='reference'/>
<meta content='X3D geospatial example' name='subject'/>
<meta content='http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/Squaw.x3d' name='identifier'/>
<meta content='Vrml97ToX3dNist, http://ovrt.nist.gov/v2_x3d.html' name='generator'/>
<meta content='X3D-Edit 3.2, https://savage.nps.edu/X3D-Edit' name='generator'/>
<meta content='../license.html' name='license'/>
</head>
<Scene>
<WorldInfo info='"Generated by ArcScene"' title='ArcScene Document'/>
<Background skyColor='1.0 1.0 1.0'/>
<DirectionalLight ambientIntensity='0.3' direction='0.612372 -0.612372 -0.5'/>
<DirectionalLight ambientIntensity='0.3' direction='-0.612372 0.612372 0.5'/>
<GeoViewpoint description='default' fieldOfView='0.3' geoSystem='"UTM" "Z10" "N"' headlight='false' orientation='1.0 0.0 0.0 -1.570796' positi
<GeoOrigin DEF='ORIGIN' geoCoords='4342525.500000 740604.000000 0.000000' geoSystem='"UTM" "Z10" "N"' rotateYUp='true'/>
</GeoViewpoint>
<Group>
<Group>
<Group>
<Group>
<Group>
<GeoLOD center='4340965.855617 738223.363583 2183.500000' child1Url='"squawLOD000.x3d"'
geoSystem='"UTM" "Z10" "N"' range='32266.666'>
<Shape>
<Appearance>
<Material ambientIntensity='0.9' diffuseColor='1.0 1.0 1.0' emissiveColor='0.0 0.0 0.0' shininess='1.0' specularColor='0.0 0.0 0
<ImageTexture url='"images/squaw000.jpg" "http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/images/squaw000.jpg"'/>
</Appearance>
<GeoElevationGrid ccw='false' creaseAngle='0.5' geoGridOrigin='4340105.411173 737558.999947 0.000000'
geoSystem='"UTM" "Z10" "N"' height='2329.3235 2313.5854 2299.391 2275.616 2256.039 2260.0962 2289.158 2271.813 223
solid='false' xDimension='12' xSpacing='110.727273' yScale='1.0' zDimension='16' zSpacing='107.555556'>
<TextureCoordinate point='0.00391 0.00391 0.09091 0.00391 0.18182 0.00391 0.27273 0.00391 0.36364 0.00391 0.45455 0.00391 0.5454
<GeoOrigin USE='ORIGIN'/>
</GeoElevationGrid>
</Shape>
<GeoOrigin USE='ORIGIN'/>
</GeoLOD>
</Group>
31 | 16
INS

GeoLOD node X3D-Edit



GeoMetadata node

Describes geospatial information of interest

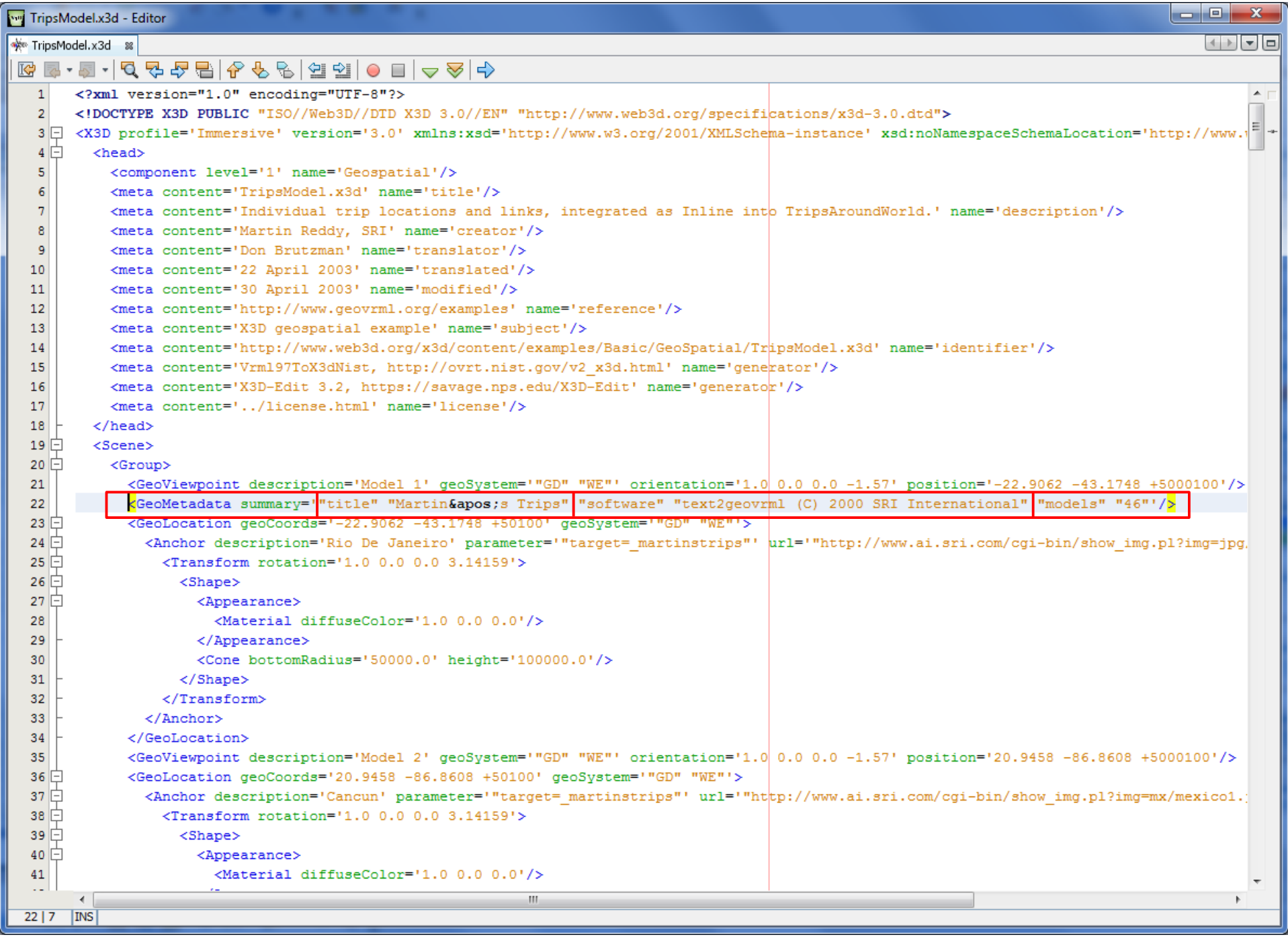
- Design is similar to WorldInfo node
- Developed and approved prior to other Metadata* nodes from X3D Core Component

Note unusual syntax: writing, parsing is difficult

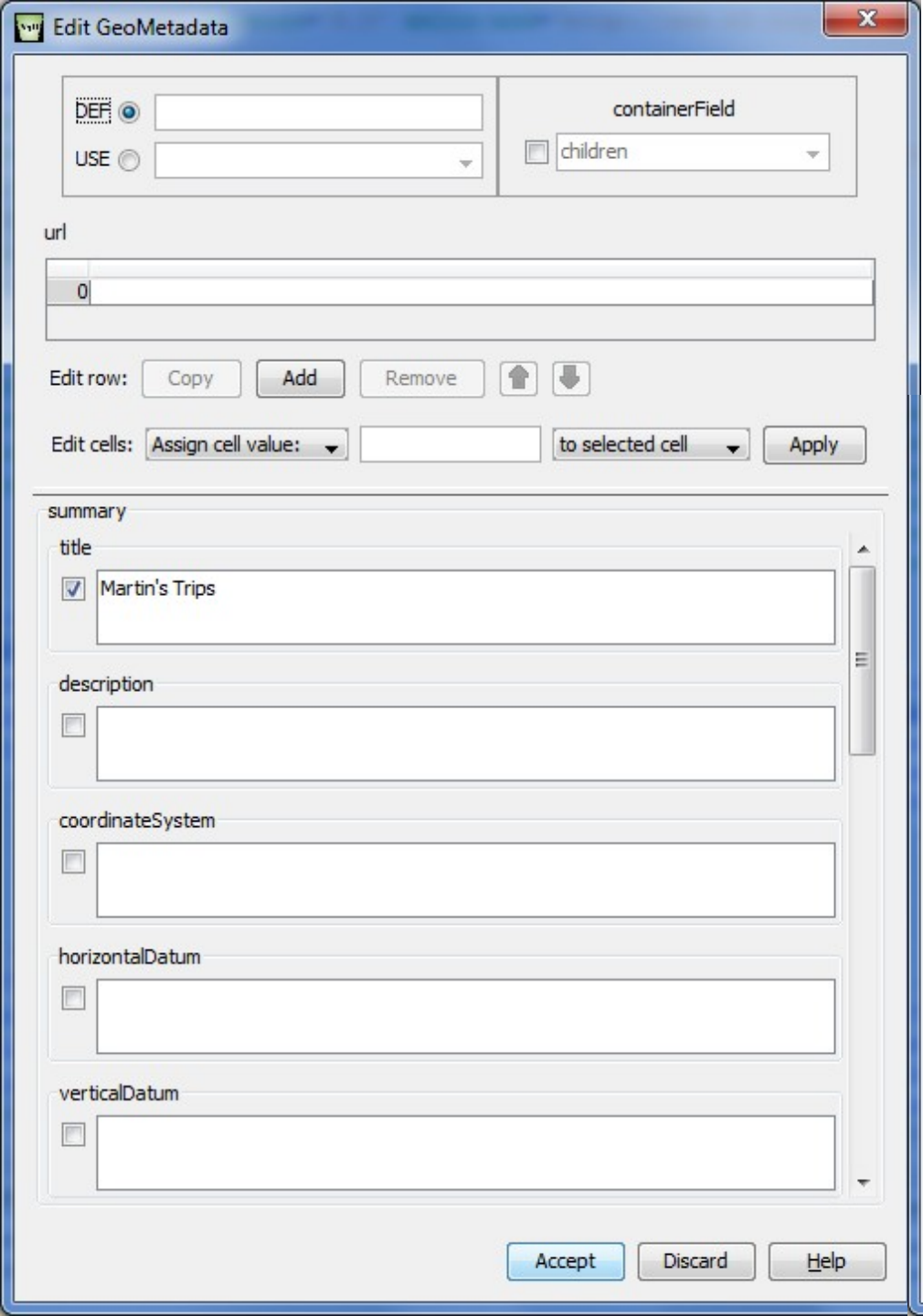
- "`title`" "name-value pairs for GeoMetadata"
- "`description`" "are defined as MFString string arrays"

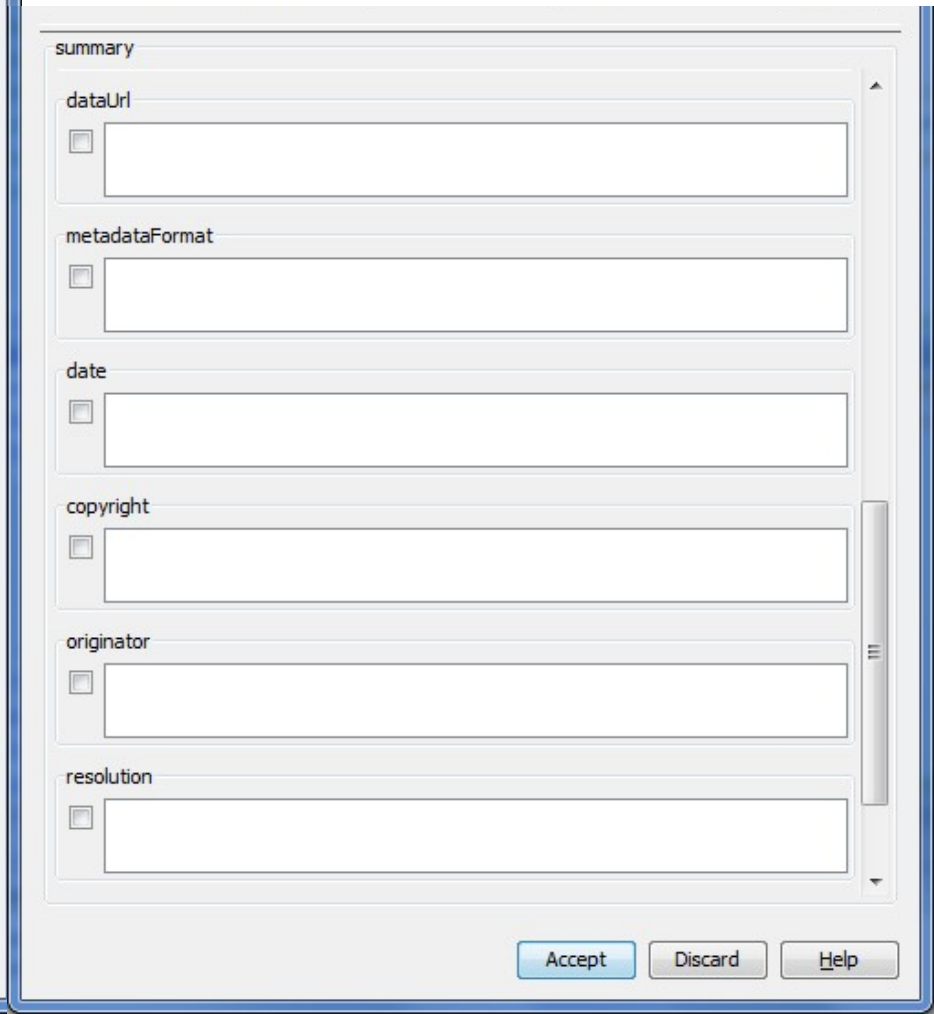
Typically defined names of interest include:

- **`title, description, coordinateSystem, horizontalDatum, verticalDatum, ellipsoid, extent, resolution, originator, copyright, date, metadataFormat, dataUrl, dataFormat`**


TripsModel.x3d - Editor
TripsModel.x3d
<?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' version='3.0' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' xsd:noNamespaceSchemaLocation='http://www.
<head>
<component level='1' name='Geospatial'/>
<meta content='TripsModel.x3d' name='title'/>
<meta content='Individual trip locations and links, integrated as Inline into TripsAroundWorld.' name='description'/>
<meta content='Martin Reddy, SRI' name='creator'/>
<meta content='Don Brutzman' name='translator'/>
<meta content='22 April 2003' name='translated'/>
<meta content='30 April 2003' name='modified'/>
<meta content='http://www.geovrml.org/examples' name='reference'/>
<meta content='X3D geospatial example' name='subject'/>
<meta content='http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/TripsModel.x3d' name='identifier'/>
<meta content='Vrml97ToX3dNist, http://ovrt.nist.gov/v2_x3d.html' name='generator'/>
<meta content='X3D-Edit 3.2, https://savage.nps.edu/X3D-Edit' name='generator'/>
<meta content='../license.html' name='license'/>
</head>
<Scene>
<Group>
<GeoViewpoint description='Model 1' geoSystem='"GD" "WE"' orientation='1.0 0.0 0.0 -1.57' position='-22.9062 -43.1748 +5000100'/>
<GeoMetadata summary='"title" "Martin's Trips" "software" "text2geovrml (C) 2000 SRI International" "models" "46"'/>
<GeoLocation geoCoords='-22.9062 -43.1748 +50100' geoSystem='"GD" "WE"'>
<Anchor description='Rio De Janeiro' parameter='"target=_martinstrips"' url='"http://www.ai.sri.com/cgi-bin/show_img.pl?img=jpg.
<Transform rotation='1.0 0.0 0.0 3.14159'>
<Shape>
<Appearance>
<Material diffuseColor='1.0 0.0 0.0'/>
</Appearance>
<Cone bottomRadius='50000.0' height='100000.0'/>
</Shape>
</Transform>
</Anchor>
</GeoLocation>
<GeoViewpoint description='Model 2' geoSystem='"GD" "WE"' orientation='1.0 0.0 0.0 -1.57' position='20.9458 -86.8608 +5000100'/>
<GeoLocation geoCoords='20.9458 -86.8608 +50100' geoSystem='"GD" "WE"'>
<Anchor description='Cancun' parameter='"target=_martinstrips"' url='"http://www.ai.sri.com/cgi-bin/show_img.pl?img=mx/mexico1.
<Transform rotation='1.0 0.0 0.0 3.14159'>
<Shape>
<Appearance>
<Material diffuseColor='1.0 0.0 0.0'/>
22 | 7
INS

GeoMetadata node X3D-Edit





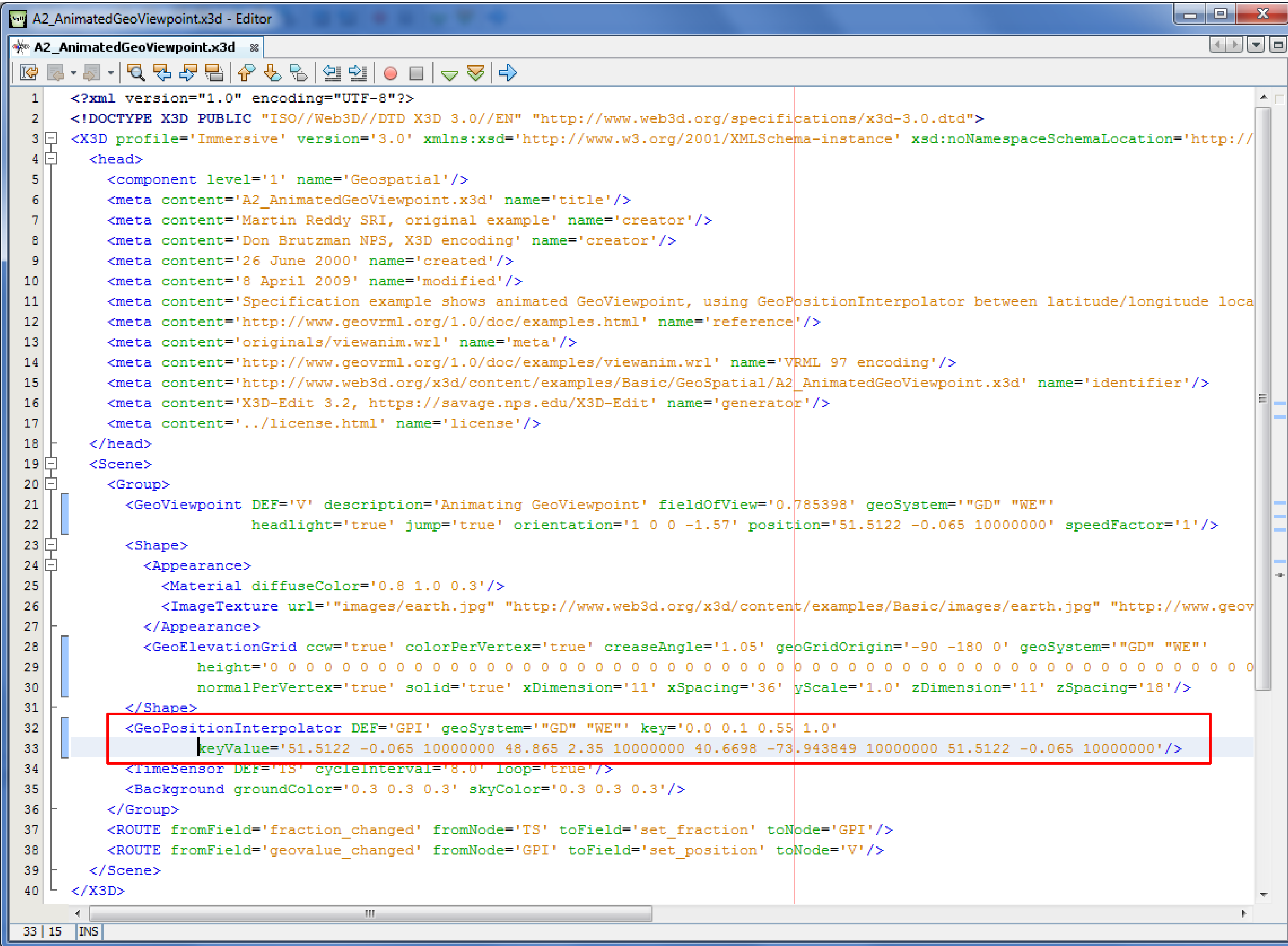
GeoPositionInterpolator node

Similar to regular PositionInterpolator node

- Adds *geovalue_changed*, *geoSystem* fields

Consistent behavior throughout

- *geovalue_changed* value corresponds to the world position returned by *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*



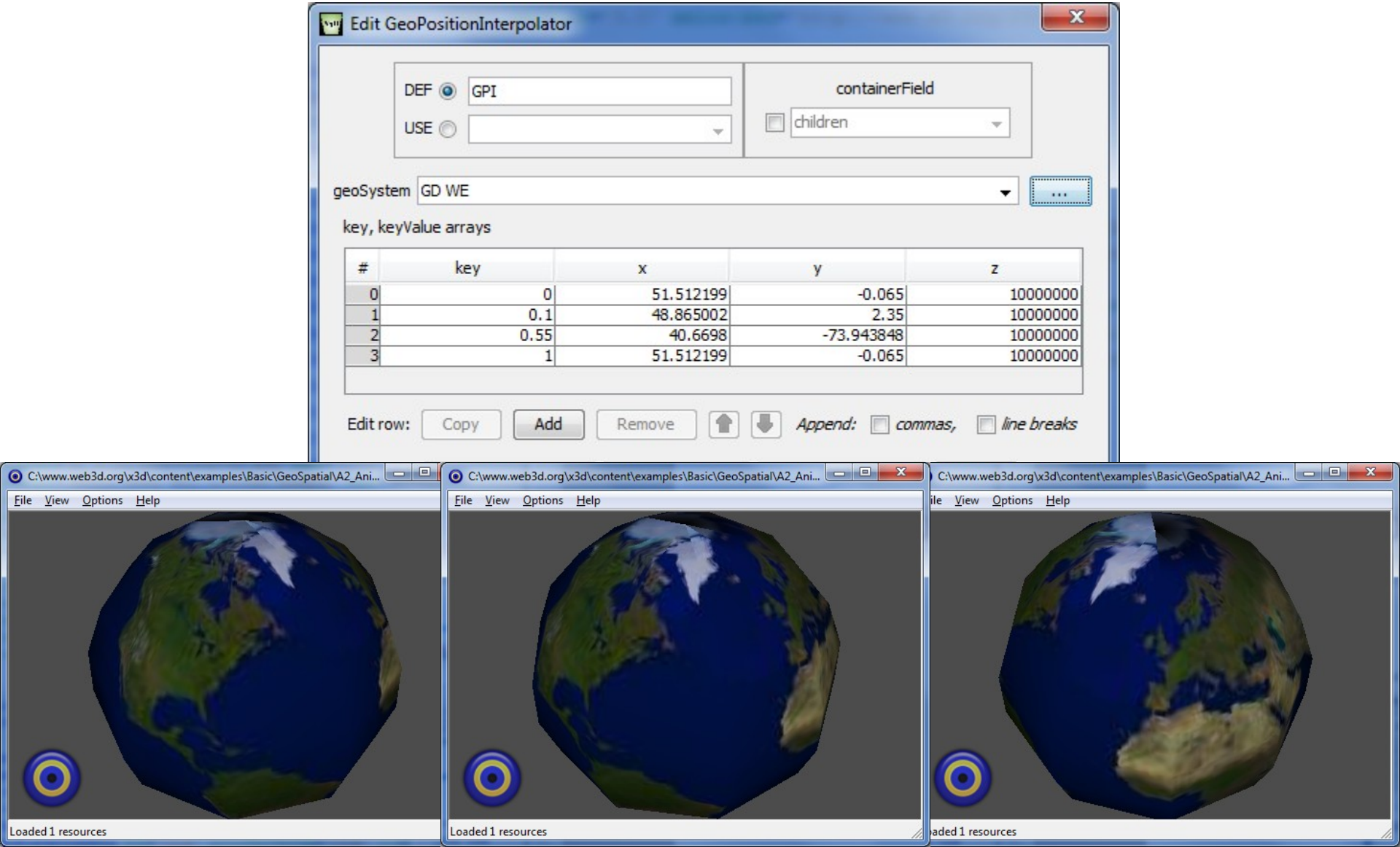
A2_AnimatedGeoViewpoint.x3d - Editor

A2_AnimatedGeoViewpoint.x3d

```xml
<?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' version='3.0' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' xsd:noNamespaceSchemaLocation='http://
  <head>
    <component level='1' name='Geospatial'/>
    <meta content='A2_AnimatedGeoViewpoint.x3d' name='title'/>
    <meta content='Martin Reddy SRI, original example' name='creator'/>
    <meta content='Don Brutzman NPS, X3D encoding' name='creator'/>
    <meta content='26 June 2000' name='created'/>
    <meta content='8 April 2009' name='modified'/>
    <meta content='Specification example shows animated GeoViewpoint, using GeoPositionInterpolator between latitude/longitude loca
    <meta content='http://www.geovrml.org/1.0/doc/examples.html' name='reference'/>
    <meta content='originals/viewanim.wrl' name='meta'/>
    <meta content='http://www.geovrml.org/1.0/doc/examples/viewanim.wrl' name='VRML 97 encoding'/>
    <meta content='http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A2_AnimatedGeoViewpoint.x3d' name='identifier'/>
    <meta content='X3D-Edit 3.2, https://savage.nps.edu/X3D-Edit' name='generator'/>
    <meta content='../license.html' name='license'/>
  </head>
  <Scene>
    <Group>
      <GeoViewpoint DEF='V' description='Animating GeoViewpoint' fieldOfView='0.785398' geoSystem='"GD" "WE"'
              headlight='true' jump='true' orientation='1 0 0 -1.57' position='51.5122 -0.065 10000000' speedFactor='1'/>
      <Shape>
        <Appearance>
          <Material diffuseColor='0.8 1.0 0.3'/>
          <ImageTexture url='"images/earth.jpg" "http://www.web3d.org/x3d/content/examples/Basic/images/earth.jpg" "http://www.geov
        </Appearance>
        <GeoElevationGrid ccw='true' colorPerVertex='true' creaseAngle='1.05' geoGridOrigin='-90 -180 0' geoSystem='"GD" "WE"'
            height='0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
            normalPerVertex='true' solid='true' xDimension='11' xSpacing='36' yScale='1.0' zDimension='11' zSpacing='18'/>
      </Shape>
      <GeoPositionInterpolator DEF='GPI' geoSystem='"GD" "WE"' key='0.0 0.1 0.55 1.0'
            keyValue='51.5122 -0.065 10000000 48.865 2.35 10000000 40.6698 -73.943849 10000000 51.5122 -0.065 10000000'/>
      <TimeSensor DEF='TS' cycleInterval='8.0' loop='true'/>
      <Background groundColor='0.3 0.3 0.3' skyColor='0.3 0.3 0.3'/>
    </Group>
    <ROUTE fromField='fraction_changed' fromNode='TS' toField='set_fraction' toNode='GPI'/>
    <ROUTE fromField='geovalue_changed' fromNode='GPI' toField='set_position' toNode='V'/>
  </Scene>
</X3D>
```

33 | 15 INS

GeoPositionInterpolator node X3D-Edit



GeoProximitySensor node

Generates events when the viewer enters, exits, and moves within a box region of space

- Vertically aligned with local +Y axis up

Similar to regular ProximitySensor node

- Adds *geoCenter*, *geoCoord_changed*, *geoSystem* fields

Consistent behavior throughout

- *geoCoord_changed* value corresponds to the world position returned by *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*

GeoProximitySensor example

- TODO: example needed!

GeoProximitySensor node X3D-Edit

- TODO: implementation needed!

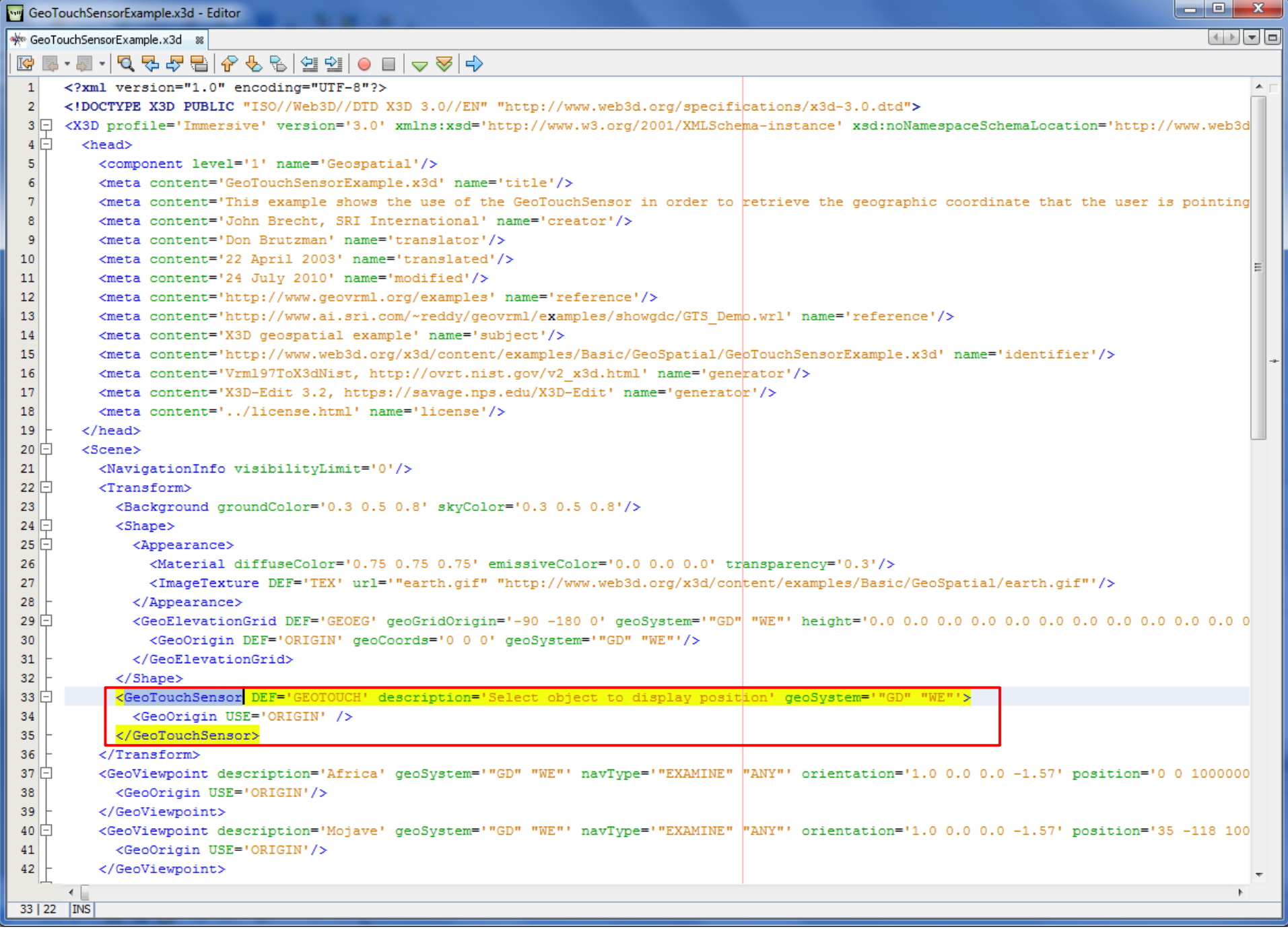
GeoTouchSensor node

Similar to regular TouchSensor node

- Adds *hitGeoCoord_changed*, *geoSystem* fields

Consistent behavior throughout

- *hitGeoCoord_changed* value replaces TouchSensor *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*



GeoTouchSensorExample.x3d part 1

GeoTouchSensorExample.x3d part 2

GeoTouchSensorExample.x3d - Editor

GeoTouchSensorExample.x3d

```
39      </GeoViewpoint>
40      <GeoViewpoint description='Mojave' geoSystem='"GD" "WE"' navType='"EXAMINE" "ANY"' orientation='1.0 0.0 0.0 -1.57' position='35 -118 100
41        <GeoOrigin USE='ORIGIN'/>
42      </GeoViewpoint>
43      <GeoLocation DEF='GEOLOC'>
44        <Shape>
45          <Appearance>
46            <Material diffuseColor='1.0 0.0 0.0'/>
47          </Appearance>
48          <Sphere radius='100000.0'/>
49        </Shape>
50        <Billboard axisOfRotation='0.0 0.0 0.0'>
51          <Transform translation='0.0 0.0 0.0'>
52            <Shape>
53              <Appearance>
54                <Material diffuseColor='1.0 1.0 1.0'/>
55              </Appearance>
56              <Text DEF='TXT' string='"GeoTouchSensor"'>
57                <FontStyle size='300000.0'/>
58              </Text>
59            </Shape>
60          </Transform>
61        </Billboard>
62        <GeoOrigin USE='ORIGIN'/>
63      </GeoLocation>
64      <Script DEF='SFTOMF'>
65        <field accessType='outputOnly' name='value_changed' type='MFString'/>
66        <field accessType='inputOnly' name='set_value' type='SFString'/>
67        <![CDATA[ecmascript: function set_value( value ) {
68             var s = value.split(' ',3);
69             var s2 = s[2]/1000;
70             value_changed = new MFString( 'Lat: ' + s[0] + ' ',
71                                           'Lon: ' + s[1] + ' ',
72                                           'Elev: ' + s2 + ' km' );
73          }
74        ]]>
75      </Script>
76      <ROUTE fromField='hitGeoCoord_changed' fromNode='GEOTOUCH' toField='set_geoCoords' toNode='GEOLOC'/>
77      <ROUTE fromField='geoCoords_changed' fromNode='GEOLOC' toField='set_value' toNode='SFTOMF'/>
78      <ROUTE fromField='value_changed' fromNode='SFTOMF' toField='string' toNode='TXT'/>
79    </Scene>
80  </X3D>
```

Edit GeoTouchSensor

DEF GEOTOUCH

USE

containerField

containerField is field-label prefix indicating relati

geoSystem GD WE ...

enabled

description Select object to display position

Accept Discard Help

Conversion script to edit position value for display in Text node

9 | 53 INS

GeoTransform node

Similar to regular Transform node

- Adds *geoCenter*, *geoSystem* fields
- Vertically aligned with local +Y axis up

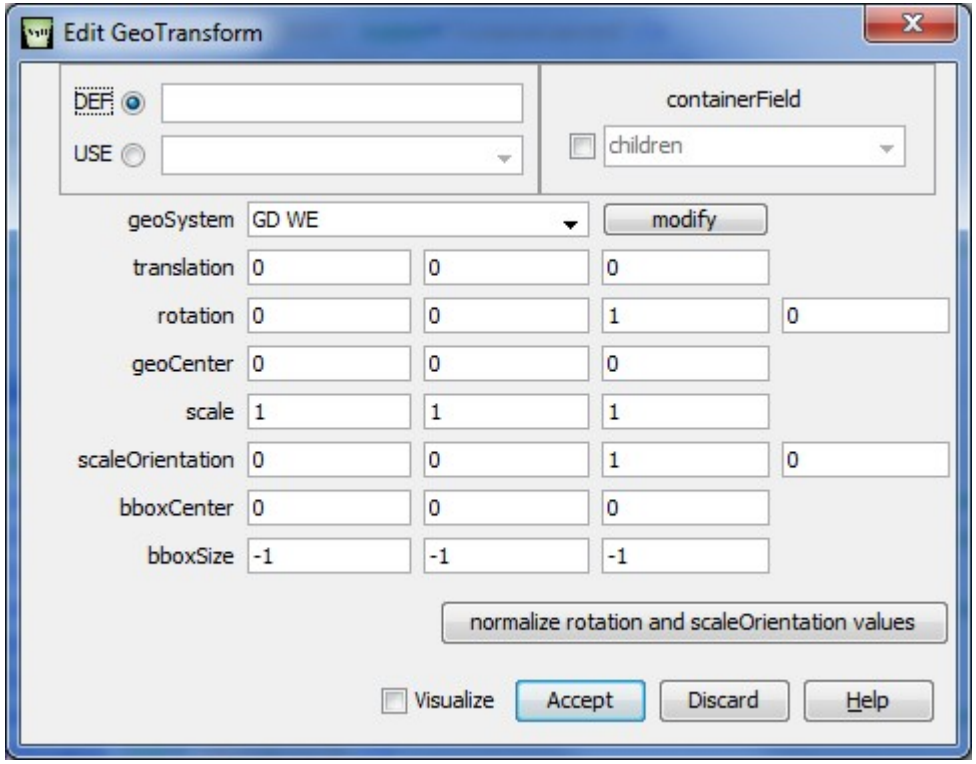
Consistent behavior throughout

- Allows regular animation of *translation*, *rotation*, other fields in a geospatial context

GeoTransform example

- TODO: example needed!

GeoTransform node X3D-Edit



GeoViewpoint node

Similar to regular Viewpoint node, but also integrates some fields from NavigationInfo

- Adds *hitGeoCoord_changed*, *geoSystem* fields

Consistent behavior throughout

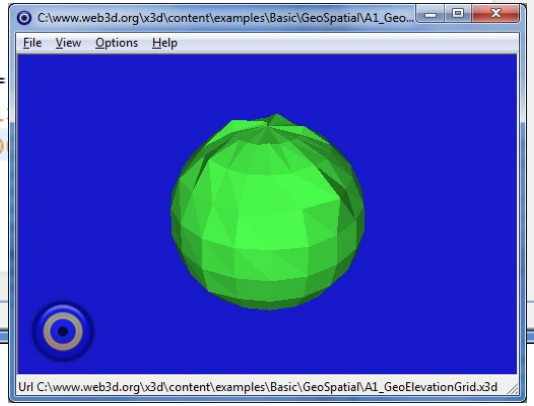
- *hitGeoCoord_changed* value replaces TouchSensor *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*

A1_GeoElevationGrid.x3d - Editor

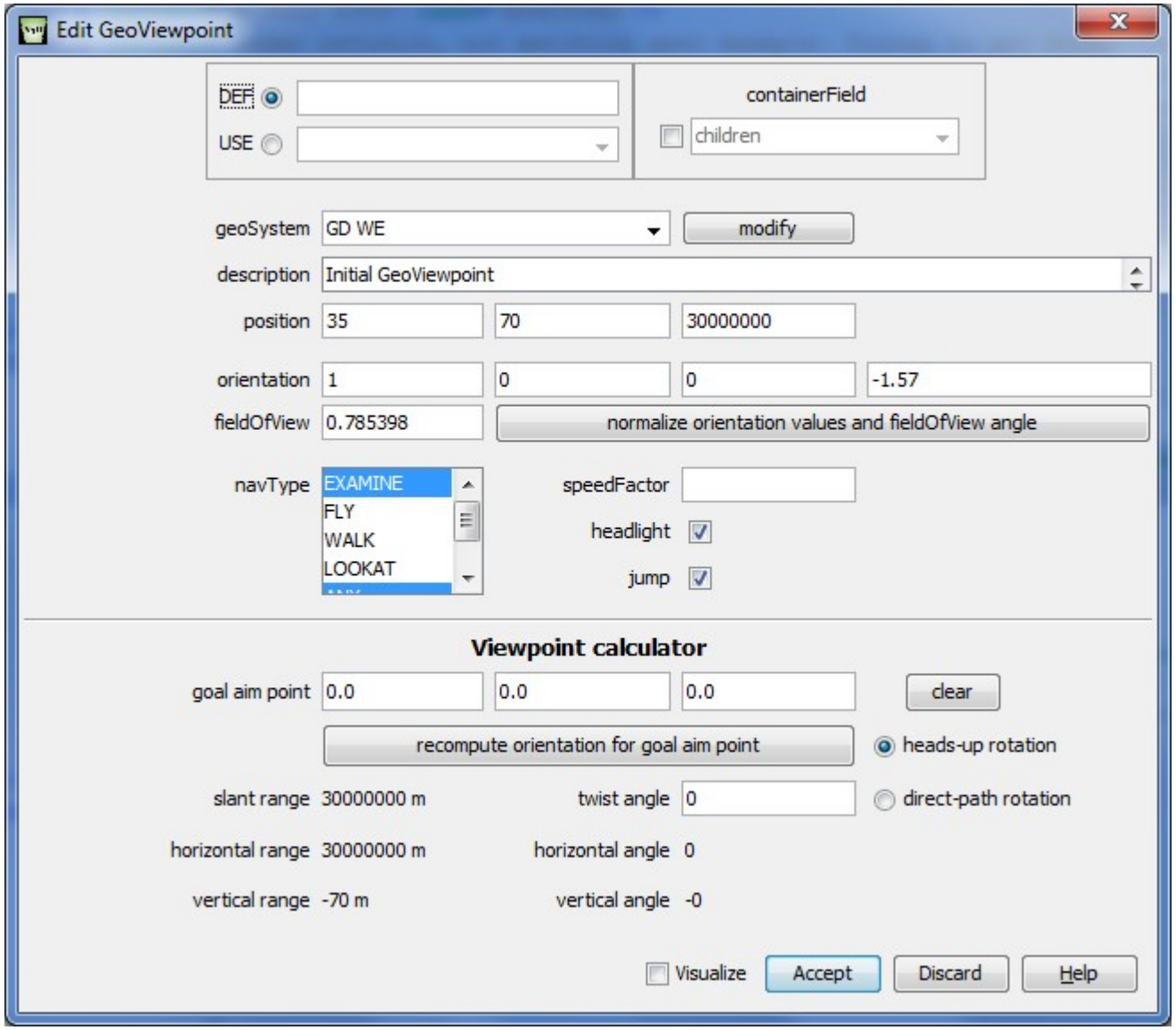
A1_GeoElevationGrid.x3d

```
1  <?xml version="1.0" encoding="UTF-8"?>
2  <!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN" "http://www.web3d.org/specifications/x3d-3.0.dtd">
3  <X3D profile='Immersive' version='3.0' xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' xsd:noNamespaceSchemaLocatic
4    <head>
5      <component level='1' name='Geospatial'/>
6      <meta content='A1_GeoElevationGrid.x3d' name='title'/>
7      <meta content='Martin Reddy SRI, original example' name='creator'/>
8      <meta content='Don Brutzman NPS, X3D encoding' name='creator'/>
9      <meta content='26 June 2000' name='created'/>
10     <meta content='4 July 2004' name='modified'/>
11     <meta content='under revision, not matching spec example. Trying to get Background aligned.' name='warning'/>
12     <meta content='Specification example shows the use of the GeoElevationGrid and the GeoViewpoint nodes.
13                    A flat grid is mapped to the full extent of Earth latitude and longitude.' name='description'/>
14     <meta content='http://www.geovrml.org/1.0/doc/examples.html' name='reference'/>
15     <meta content='originals/exageath.wrl' name='reference'/>
16     <meta content='http://www.geovrml.org/1.0/doc/examples/exageath.wrl' name='VRML 97 encoding'/>
17     <meta content='http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A1_GeoElevationGrid.x3d' name='identifier'/
18     <meta content='X3D-Edit 3.2, https://savage.nps.edu/X3D-Edit' name='generator'/>
19     <meta content='../license.html' name='license'/>
20   </head>
21   <Scene>
22     <!-- This scene shows example GeoSpatial node relationships in a scene graph. -->
23     <Background groundColor='0.1 0.1 0.8' skyColor='0.1 0.1 0.8'/>
24     <GeoViewpoint description='Initial GeoViewpoint' fieldOfView='0.785398' geoSystem='"GD" "WE"' headlight='true'
25                   jump='true' orientation='1 0 0 -1.57' position='35.0 70.0 30000000' speedFactor='1'/>
26     <Shape>
27       <Appearance>
28         <Material diffuseColor='0.3 1.0 0.3'/>
29       </Appearance>
30       <GeoElevationGrid ccw='true' colorPerVertex='true' creaseAngle='0' geoGridOrigin=
31           height='0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 31
32           normalPerVertex='true' solid='true' xDimension='21' xSpacing='18' yScale='20
33     </Shape>
34   </Scene>
35 </X3D>
```

32 | 85 | INS



GeoViewpoint node X3D-Edit



deprecated: GeoOrigin node

Originally included in GeoVRML, X3D scenes to provide shared-reference origin point

- Intended to reduce spatial roundoff errors
- Adds to scene complexity

However this scene information is duplicative

- Since latitude/longitude or UTM coordinates also provide precise location information

Thanks to research by Chris Thorne, proper player workarounds have been figured out

- Deprecated = allowed but unnecessary

X3D Earth

Example X3D Earth globes

Multiple globes are available online, although resolution is still fairly low

- HelloEarthOpenStreetMap.x3d using OpenStreetMap
- http://x3d-earth.nps.edu/7_levels_plus/tiles/0/globe.x3d
- http://x3d-earth.nps.edu/globe/MBARI1MinuteBathy/world.x3d
- http://x3d-earth.nps.edu/globe/SRTM30Plus/world.x3d

Globe production process

Dr. Byounghyun Yoo, MIT Singapore Alliance

- Tutorial for terrain Tile Production Chain
- Terrain Tile Production Course Slideset
- Rez tiling tool
- Example X3D-Earth Globes

X3D Earth vision, mission

X3D Earth Working Group

- http://www.web3d.org/x3d-earth

Vision

- Make it easier to create, use 3D spatial data

Mission

- Promote spatial data use within X3D via open architectures

X3D Earth design workshop

X3D Earth Technical Requirements Workshop

- Naval Postgraduate School, Monterey California USA, 14-15 November 2006
- Summary report available

Twenty presentations provide motivating requirements that continue to guide us today

web|3D CONSORTIUM

< X3D >

Motivating goals: X3D Earth

Use the Web architecture, XML languages and open protocols

Build a standards-based X3D Earth of geospatial models

Results usable by governments, industry, scientists, academia and the general public

web|3D CONSORTIUM

X3D Earth: what is it

Build a backdrop X3D model of planet Earth

- Use publicly available terrain datasets
- Use publicly available imagery
- Use X3D Geospatial Component throughout
- Provide linkable locations for any place
- Provide hooks for physical models
- Use open standards, extensions and process

Why X3D Earth is needed 1

Proprietary commercial approaches are viable, but not necessarily over long term

- Many past commercial failures, shutdowns
- Even very large companies sometimes subject to economic pressures beyond their control

Government, science, research and academic needs are different than commercial needs

Why X3D Earth is needed 2

Public and government assets need to be openly available over long term, indefinitely.

- Huge investment in data preparation
- Future rework/rewrite may not be possible
- Archiving, availability is essential prerequisite for many agencies
- New spatial applications become possible
  - including Semantic Web and search applications

What we are not proposing

Commercial competitor to other schemes

- They already have technologies of choice, economic imperatives and business models

Vive la difference

- Some commercial approaches may actually benefit by having an open approach widely available, providing new services & products

The key challenge is scalability

Because the only information systems capable of scalably growing to match global scope are the Internet and the World Wide Web, X3D Earth will deliberately follow the architectural principles of World Wide Web.

- *Architecture of the World Wide Web, Volume One*
  http://www.w3.org/TR/webarch

Data

3D, GIS communities have a wealth of data and imagery

- Both freely available and sustainably funded
- Significant metadata usually included
- Many different formats, not always searchable

Let's get consistent and professional about how to

- Represent, compose and harmonize such data in X3D
- Create "path of least resistance" to success
- Some converters already available (e.g. KML2X3D)
- [Insert 1 million metric tons of data resources here]

Science

Researchers model the world in detail already

- but rarely interconnect one to another

Most interesting part of “virtual reality” ?

- Reality – which means physics

Need hooks to connect physics engines, virtual sensors, propagation algorithms, live sources

Stepping up is inevitable

Long-running experience in 3D graphics has shown that each accomplishment leads to new (and sometimes unforeseen) challenges

- "Graphics Internetworking: Bottlenecks and Breakthroughs," chapter 4, *Digital Illusion*, Clark Dodsworth editor, ACM Press, Addison-Wesley, Reading Massachusetts, August 1997

X3D past, present are prelude to our next steps

Big trump cards

The hardest parts of the technical infrastructure are already proven possible

- Web3D X3D specifications
- W3C Recommendations
- OpenGIS Consortium (OGC) specifications
- Synthetic Environmental Data Representation and Interchange System (SEDRIS) specifications

Server-side 3D graphics

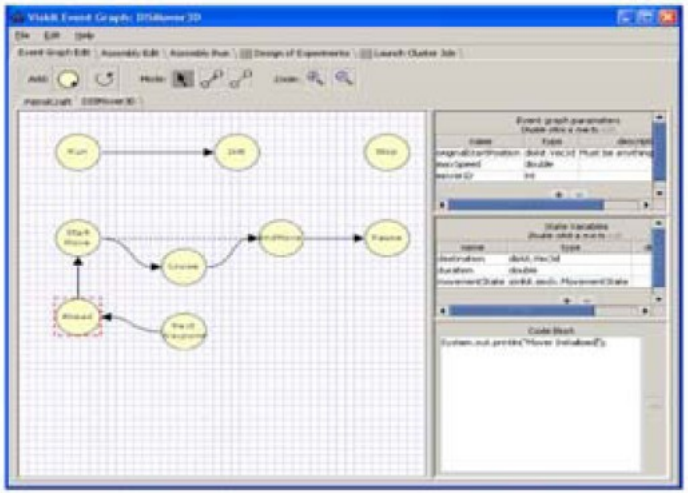
- Our classical bias in the SIGGRAPH community is to think in terms of client-side 3D graphics
- With terrain databases, imagery, cartography and worlds of related objects, the subject of attention becomes server-side 3D graphics
- New issues of interest include preprocessing, prerendering, decimation and compression, digital signature, encryption, streaming etc.
- Important work to mainstream X3D continues

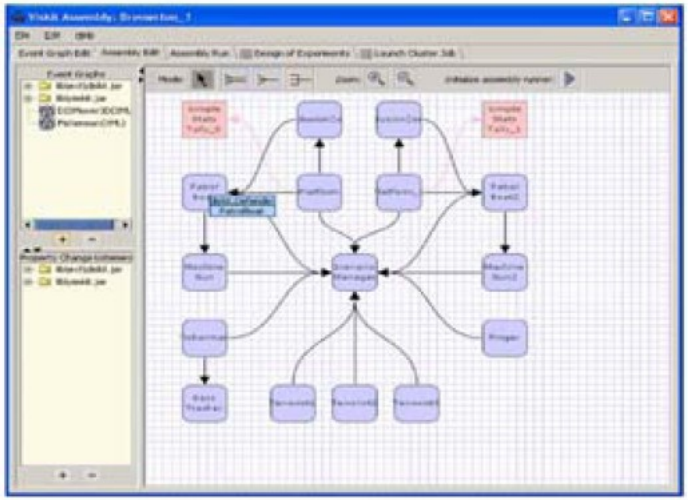
Proven success story

Web3D Consortium members have the capabilities, resources and staying power to undertake this major new Web initiative.

Proof point: NPS already proposing and executing multiple ambitious projects with many Web3D members

All this work is unencumbered, repeatable





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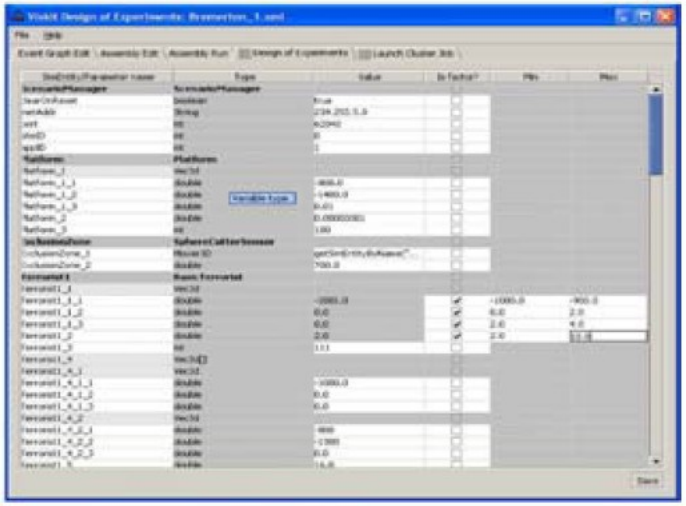
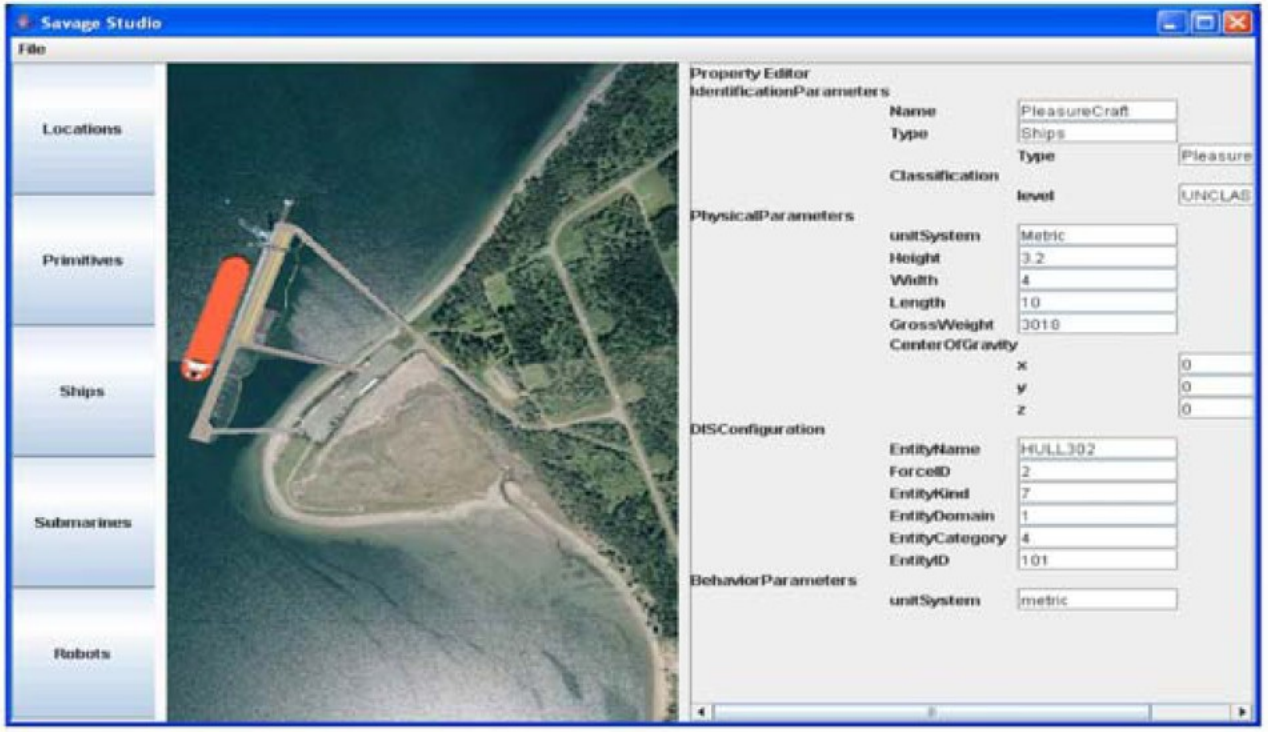
X3D



X3D-Earth


Savage Studio
File
Locations
Primitives
Ships
Submarines
Robots
Property Editor
IdentificationParameters
Name
PleasureCraft
Type
Ships
Type
Pleasure
Classification
level
UNCLAS
PhysicalParameters
unitSystem
Metric
Height
3.2
Width
4
Length
10
GrossWeight
3010
CenterOfGravity
x
0
y
0
z
0
DISConfiguration
EntityName
HULL302
ForceID
2
EntityKind
7
EntityDomain
1
EntityCategory
4
EntityID
101
BehaviorParameters
unitSystem
metric

Globe generation by supercomputer

Obtain (usually LARGE) datasets

- Image files
- Terrain files

Generate scripts

- process data into quad-tree pyramids

Dispatch scripts to supercomputer

- Tasks scheduled via Sun Grid Engine (SGE)
- Link top-level globe together with pyramids
- Publish to appropriate data server for access

Assets: Rez by Chris Thorne

"Open source framework and tools for translating gridded data, mainly geospatial, to different formats including images and multiresolution models for X3D or VRML web browsing"

Java program with multiple input/output plugins

Can be executed using a GUI or command line

Rez formats

Inputs

- DTED
- ASCII Grid
- XYZ
- DEM
- GeoVRML ElevationGrid

Outputs

- X3D
- VRML
- Contoured Jpeg
- Grey Scale Jpeg

Continuing work

Proposed work: X3D v3.3 draft

- Maintained on member-only wiki
- Errata: fix GeoViewpoint field accessType to match Viewpoint
- Add full geospatial support to X3D nodes for Distributed Interactive Simulation (DIS) network protocol
- Need metadata linking scheme to allow rapid transition to high-resolution data, rather than forced loading of all intermediate quadtrees

Proposed: GeoTerrainLOD node

Reported in Web3D 2009 Symposium

Harmonization of techniques

- backwards compatibility kept strictly separate

Is more refactoring needed?

- Overlapping functionality remains for GeoLOD, GeoTerrainLOD

Proposed: NavigationInfo *accuracy* field

User navigation might be more forgiving or natural if accuracy constraints are sometimes relaxed

- Are there consistent lessons learned regarding such improvements for X3D?

Proposed: GpsSensor node?

Many mobile devices include GPS capabilities

X3D sensor types are designed to be generally extendable

Should we provide native support in X3D so that authors can easily write GPS-aware scenes and applications?

Proposed: additional image formats?

Some formats commonplace for Earth imagery

- JPEG 2000
- GeoTIFF
- NITF
- TGA?

Some formats also embed information

- Such as geospatial metadata

Should X3D players support them natively, rather than requiring conversion to disseminate?

Proposed: Projective Texture Mapping

PTM algorithm

- Project an image texture at some geometry
- Texture is then wrapped over that geometry

Obvious geospatial application to apply aerial imagery (or video) to terrain geometry

Requires multi-pass rendering

- Please see Korea Chapter proposal

Proposed: KML Interoperability

Multiple ways to improve interoperability between X3D and KML

- X3D embedded in KML files (allowed)
- KML embedded in X3D scenes as XML
- KML to X3D conversions (some available)
- Custom X3D nodes to represent KML data (some prototypes available)

This is an active area of current work

Testing

Need common baseline for consistent testing

- Dataset distribution of heavyweight archives? Local copies needed for consistent comparison of results
- OpenAerialMap restart a potential candidate, once ready
- Creating additional content for fly-throughs etc. using KML and conversion stylesheets

Performance measurement

Performance testing needed across X3D-Earth server, intervening network, and client display

- Collaborative partnership needed among builders of X3D-Earth software and globes
- Agreed-upon test suite
- Common reporting of results
- Hudson server-side build tests might automate the conduct of testing

Implementing experimental features

- Browser supported needed to test new fields before we can agree on new X3D capabilities or new “best practices”
- Use X3D Earth wiki to propose, record and analyze both progress and problems

Getting more people involved

- Making "wish lists" of needed activity, along with benefits to contributors and community
- Better documentation: website, wiki, code
- Video showcase?
- Reporting enterprise-wide approval, usage
  - Example: Navy Marine Corps Internet (NMCI)

Siggraph 2010 Carto BOF

- Introductory Remarks (5 minutes) - Theresa-Marie Rhyne, Carto BOF Director
- X3D Update and Demonstrations - Don Brutzman & Team
- Visitcity Project using X3D & OGC technology) Peter Schickel. BitManagement
- RayGun, an iPhone and Android based Geographic Platform - David Colleen, Planet9

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Additional Resources

KmlToX3dViewpointTour Prototype

Input

- KML file containing placemarks

Conversion

- XSLT stylesheet

Output

- X3D scene with corresponding set of viewpoints
- plus a ViewpointTour prototype to sequence through them

Chapter Summary

Chapter Summary

X3D geospatial component allows positioning objects at correct geospatial locations

X3D Earth project is building globes of interest using a variety of terrain, imagery datasets

Ongoing work to build repeatable, royalty-free results available for broad use

Suggested exercises

Map a building or object to geospatial location

- Then add Inline for an X3D-Earth globe

Create a terrain tile

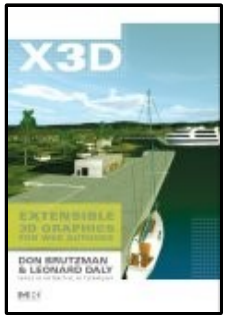
- Pick a location of interest
- Use GlobalMapper (or some other tool for assisted downloads) to retrieve terrain geometry and corresponding imagery
- Follow details in tutorial to accomplish this

Convert GPS tracks or other data into X3D

References

References 1

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



- Chapter 3, Grouping Nodes
- http://x3dGraphics.com
- http://x3dgraphics.com/examples/X3dForWebAuthors

X3D Resources

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

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< X3D >

References 2

X3D-Edit Authoring Tool

- https://savage.nps.edu/X3D-Edit

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

TODO

- Martin Reddy book
- Chris Thorne disseration
- Mike McCann papers, site, GeoVRML
- Craig Anslow thesis

References 4

TODO

- GeoVRML, X3D geospatial papers
- NPS thesis list

Contact

Don Brutzman

brutzman@nps.edu

http://web.nps.navy.mil/~brutzman

Code USW/Br, Naval Postgraduate School
Monterey California 93943-5000 USA
1.831.656.2149 voice
1.831.656.7599 fax

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CGEMS, SIGGRAPH, Eurographics

The Computer Graphics Educational Materials Source(CGEMS) site is designed for educators

- to provide a source of refereed high-quality content
- 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

CGEMS supported by SIGGRAPH, Eurographics

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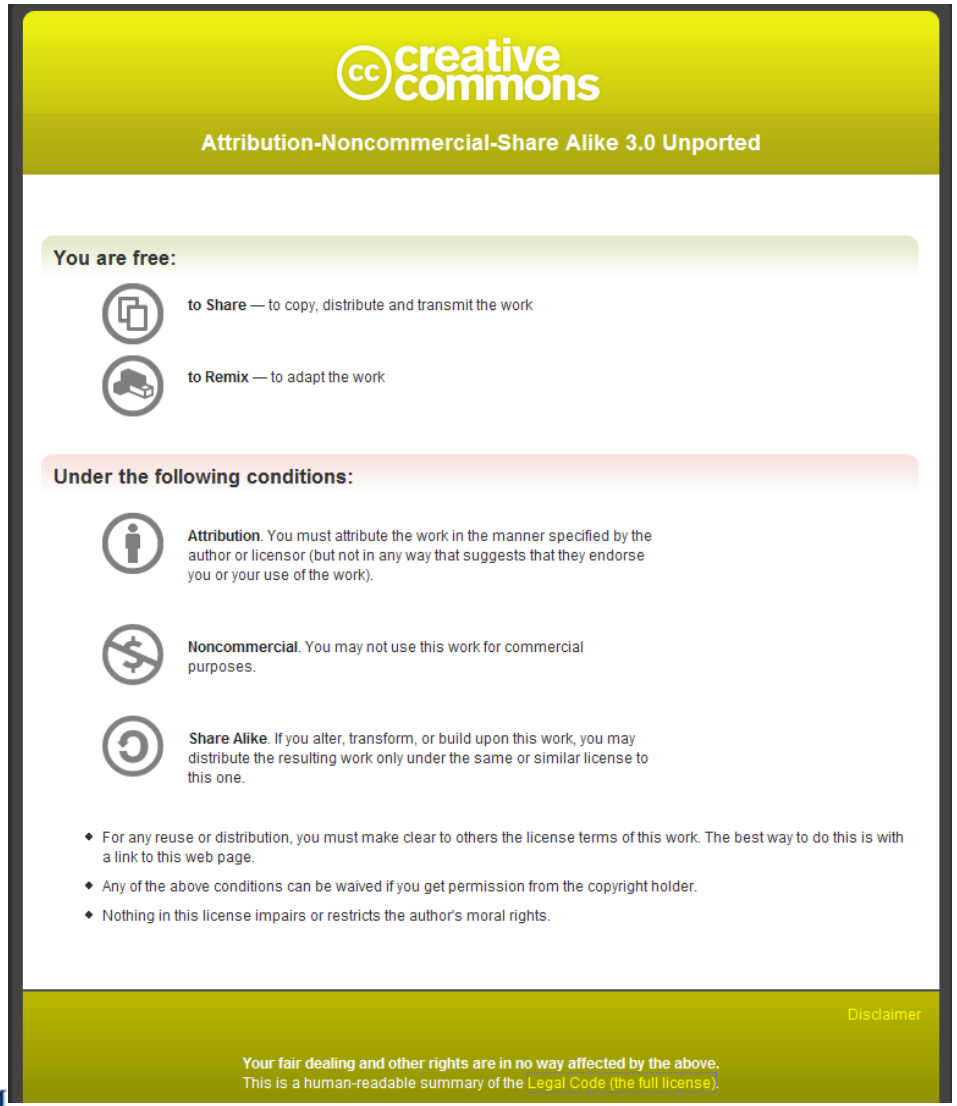
http://creativecommons.org/licenses/by-nc-sa/3.0



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X3D

Open-source license
for X3D-Edit software and X3D example scenes

http://www.web3d.org/x3d/content/examples/license.html

X3D Geospatial Component and X3D Earth

Web3D 2010 Conference
Los Angeles California, 24-25 July 2010

Don Brutzman and Byounghyun Yoo
Naval Postgraduate School, MIT Singapore Alliance
brutzman@nps.edu byoo@mit.edu

Contents

Chapter Overview

Overview: Geospatial X3D

Geospatially referenced scenes have special requirements beyond ordinary 3D scenes

- Double-precision accuracy on floating-point displays
- Diverse yet coherent spatial reference systems

X3D Geospatial Component nodes add necessary functionality to X3D in a consistent way

- Goal: easy to integrate Earth with X3D scenes

X3D Earth capabilities enable generation of local regions or full-scale globes using any data

- Without license restrictions, openly scalable

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Concepts

History: GeoVRML

Geospatial referencing has always been a goal of X3D in order to make models most useful

The core design efforts for geospatial X3D were performed by GeoVRML working group

This design has been carefully evolved over time to match practical experience gained by producing ever-larger geospatial models

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Example: Monterey Bay exploration

Mike McCann, MBARI

- Monterey Bay Aquarium Research Institute

GeoVRML application for underwater track data from remotely operated vehicles (ROVs)

- Tracks converted to line sets with user interfaces for interpolator-driven playback
- Bathymetry and vessels are geolocated
- Image billboards link photography, videos

Scientists can previsualize, explore missions

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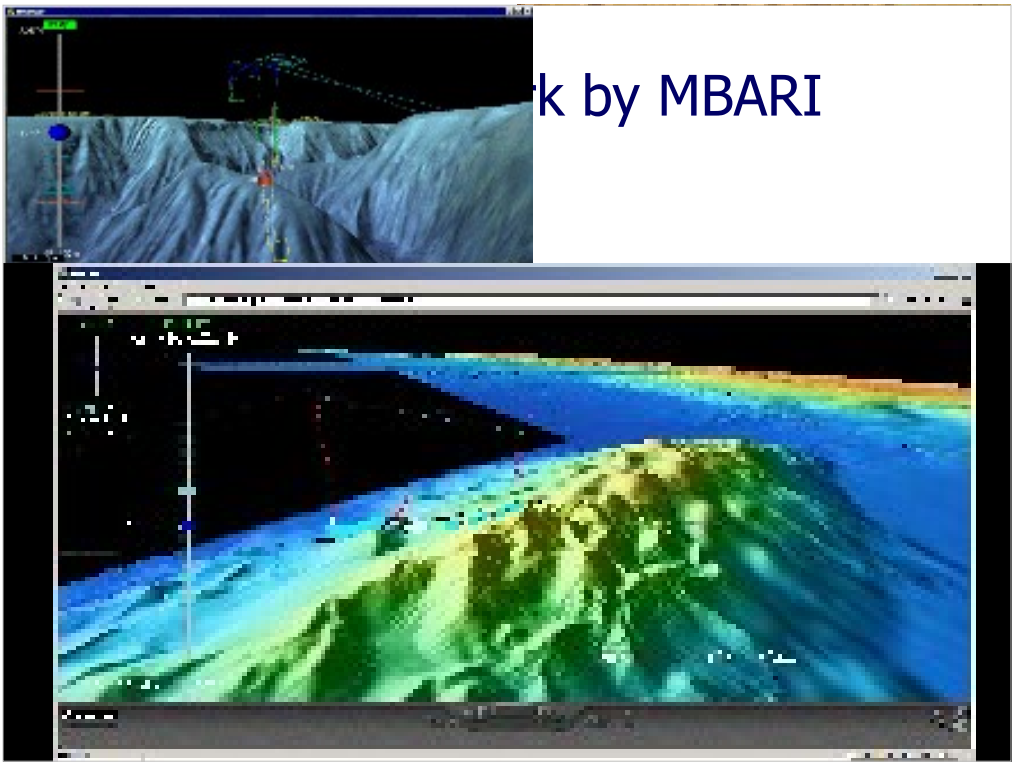

MBARI Web3D Applications

- http://www.mbari.org/staff/mccann/vrml/ROVDataVis

MBARI Web3D Applications: 3D Replay requirements and FAQ

- http://www.mbari.org/staff/mccann/vrml/ROVDataVis/geodemo/geoVRMLreqts.html

Michael P. McCann, “Creating 3D Oceanographic Data Visualizations for the Web,” Web3D 2002 Sympsium. ACM SIGGRAPH.

- http://www.mbari.org/staff/mccann/vrml/ROVDataVis/papers/w3ds2002Paper.pdf

Double precision requirements

Geospatial position values for latitude, longitude require double precision accuracy

- Otherwise single-precision roundoff jitter equates to 3-10m of positional error

Graphics cards only support single precision

- Single precision 32 bit, double precision 64 bit

X3D Geospatial component reconciles this mismatch correctly and efficiently

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X3D types for double precision

- SFDouble single-field singleton value
- SFVec2d singleton vector of 2 values
- SFVec3d singleton vector of 3 values
- SFVec4d singleton vector of 4 values

- MFDouble multiple-field array of values
- MFVec2d vector array of 2-tuple values
- MFVec3d vector array of 3-tuple values
- MFVec4d vector array of 4-tuple values

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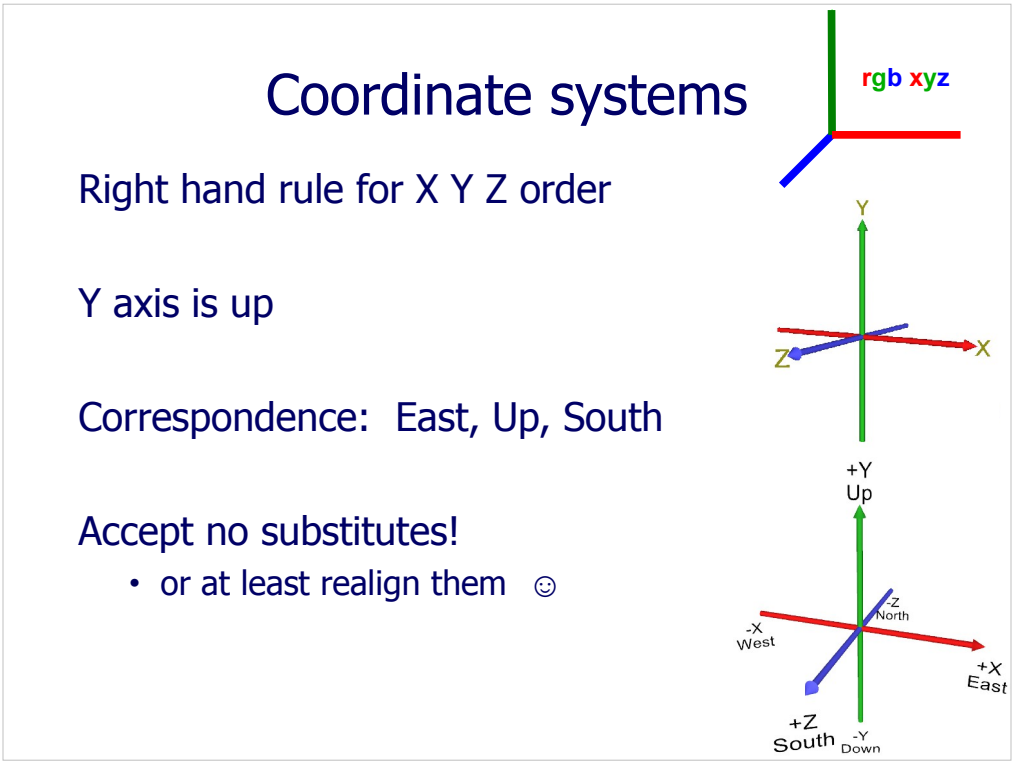
X3D Specification: field types reference

• http://www.web3d.org/x3d/specifications/ISO-IEC-19775-1.2-X3D-AbstractSpecification/Part01/fieldsDef.html



See Figures 3.1 and 3.1, page 68, *X3D for Web Authors*

There are a total of eight different Euler angle systems, each with different relative orientations for the X, Y and Z axes.

Half of these follow a left-hand rule, rather than a right-hand rule. Occasionally a graphics book comes out that presents mathematical equations using a left-hand rule. Immediately throw such books in the fire so that further pain and suffering is prevented!

The second and third displayed examples are

http://www.x3dbook.com/examples/X3dForWebAuthors/Chapter03-Grouping/CoordinateAxesNSEW.x3d

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter03-Grouping/CoordinateAxes.x3d

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter03-Grouping/CoordinateAxesInlineExample.x3d

Ordinarily we ignore correspondences with geographic North, South, East and West, since regular X3D coordinates are single-precision floating point, while the Geospatial nodes use double-precision floating-point values in order to capture latitude and longitude coordinates with sufficient accuracy.

Spatial reference frames

X3D is based on a right-handed Cartesion x,y,z coordinate system

- centered at arbitrary (0,0,0)

Geospatial data can be captured in a large variety of earth-oriented coordinate sytems

- It is important to keep these different coordinate systems straight, or else objects do not appear where they are expected
- Related to ellipsoid for actual Earth shape

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Spatial reference frames

Primary

- GD Geodetic spatial reference frame
  <latitude> <longitude> <elevation>
- GC Geocentric spatial reference frame
  <x> <y> <z>
- UTM Universal Transverse Mercator
  <northing> <easting> <elevation>

X3D browsers transform geographic coordinates into earth-fixed geocentric coordinates

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Supported earth ellipsoids

Code	Ellipsoid Name	Semi-Major Axis (metres)	Inv. Flattening (F-1)
AA	Airy 1830	6377563.4	299.32
AM	Modified Airy	6377340.19	299.32
AN	Australian National	6378160	298.25
BN	Bessel 1841 (Namibia)	6377483.87	299.15
BR	Bessel 1841 (Ethiopia Indonesia...)	6377397.16	299.15
CC	Clarke 1866	6378206.4	294.98
CD	Clarke 1880	6378249.15	293.47
EA	Everest (India 1830)	6377276.35	300.8
EB	Everest (Sabah & Sarawak)	6377298.56	300.8
EC	Everest (India 1956)	6377301.24	300.8
ED	Everest (W. Malaysia 1969)	6377295.66	300.8
EE	Everest (W. Malaysia & Singapore 1948)	6377304.06	300.8
EF	Everest (Pakistan)	6377309.61	300.8
FA	Modified Fischer 1960	6378155	298.3
HE	Helmert 1906	6378200	298.3
HO	Hough 1960	6378270	297
ID	Indonesian 1974	6378160	298.25
IN	International 1924	6378388	297
KA	Krassovsky 1940	6378245	298.3
RF	Geodetic Reference System 1980 (GRS 80)	6378137	298.26
SA	South American 1969	6378160	298.25
WD	WGS 72	6378135	298.26
WE	WGS 84	6378137	298.26

Common field: *geoSystem*

geoSystem field indicates spatial reference frame and corresponding earth ellipsoid

- Used by X3D geospatial nodes containing position data (i.e. most of them)

geoSystem default value is ["GD" "WE"]

- "GD" means geodetic
- "WE" means WGS84 ellipsoid, i.e. the World Geodetic System of 1984 (updated 2004)

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World Geodetic System, http://en.wikipedia.org/wiki/WGS84

From Wikipedia, the free encyclopedia (Redirected from WGS84)

The World Geodetic System is a standard for use in cartography, geodesy, and navigation. It comprises a standard coordinate frame for the Earth, a standard spheroidal reference surface (the datum or reference ellipsoid) for raw altitude data, and a gravitational equipotential surface (the geoid) that defines the nominal sea level.

The latest revision is WGS 84 (dating from 1984 and last revised in 2004), which will be valid up to about 2010. Earlier schemes included WGS 72, WGS 66, and WGS 60. WGS 84 is the reference coordinate system used by the Global Positioning System.

Common field: *geoCenter*

geoCenter field indicates geospatial position of center of the current node's coordinate frame

- Used by several X3D geospatial nodes

Values held by *geoCenter* field are determined by choice of corresponding *geoSystem* field:

- GD <latitude> <longitude> <elevation>
- GC <x> <y> <z>
- UTM <northing> <easting> <elevation>

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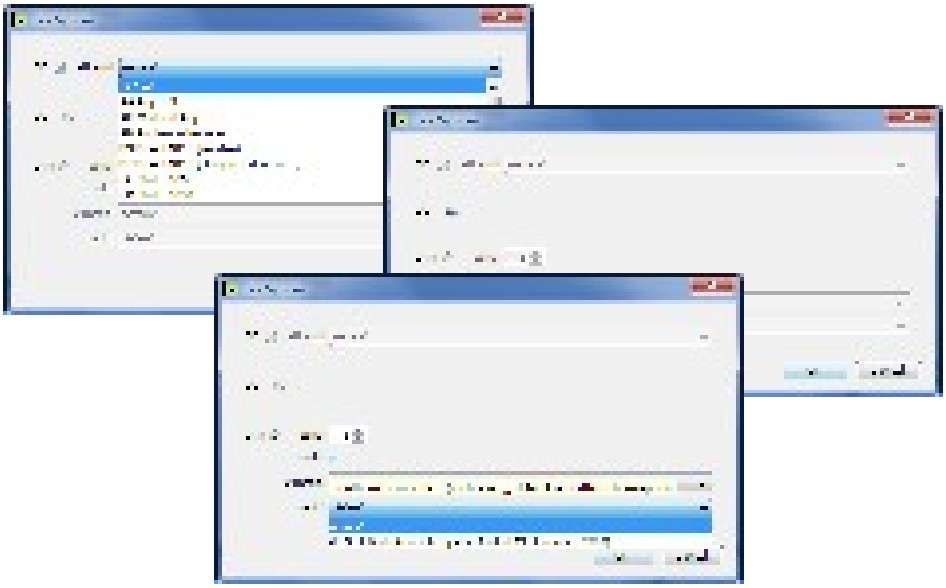
geoSystem field editor X3D-Edit



TODO: GC tooltip

Common field: *metadata*

Each node can also contain Metadata nodes

- This is consistent throughout all X3D

Metadata nodes allow authors to add pairs of names and typed values to describe content

- Possible option for annotating, augmenting content in a valid machine-readable way
- MetadataSet, MetadataString, MetadataFloat, MetadataDouble, MetadataInteger

Note that GeoMetadata node also available

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See X3D Abstract Specification Core Componentfor Metadata node definitions

X3D for Web Authors textbook includes a free online Metadata chapter

X3D Geospatial Implementations

Xj3D: open source Java

- www.xj3D.org

FreeWrl/FreeX3D: open source C++

- http://freewrl.sourceforge.net

BS Contact Geo commercial C++

- http://www.bitmanagement.de

Other players to follow?

Feature comparison:

- Player support for X3D components wiki

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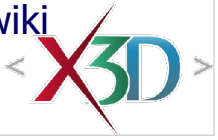

Geospatial navigation issues

Regular X3D navigation modes often fail when confronted with geospatial coordinates

- Reason: world coordinate frame is no longer Cartesian x,y,z but rather geospatial surface
- Typical failure that leaves user lost in space: <NavigationInfo type=' "EXAMINE" "ANY" '/>

Special implementation techniques required for X3D players to handle user navigation properly

- Velocity also should be proportional to altitude

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X3D Nodes and Examples

Obtaining example scenes

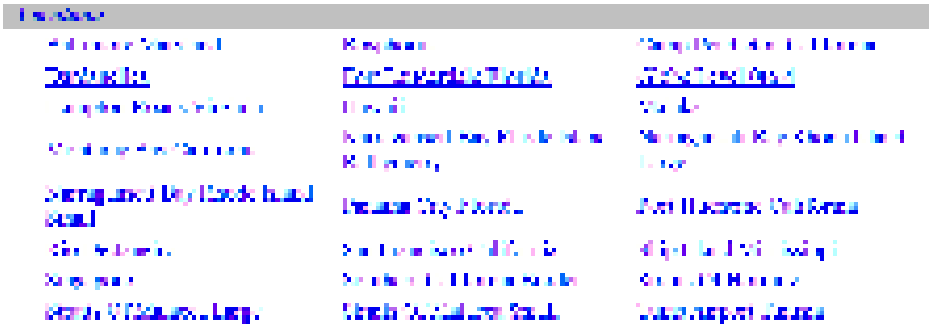
X3D Basic archives, GeoSpatial directory

- http://www.web3d.org/x3d/content/examples/Basic
- Under version control on sourceforge

X3D-Earth globe server

- http://x3d-earth.nps.edu
- A few examples are there, more to follow

Also in NPS Savage archives: specific locations available



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GeoCoordinate node

Defines a list of coordinate values, used as *coord* field of a vertex-based geometry node

- such as IndexedFaceSet, IndexedLineSet, or PointSet node

As described before, each value is defined according to specified coordinate system:

- GD <latitude> <longitude> <elevation>
- GC <x> <y> <z>
- UTM <northing> <easting> <elevation>

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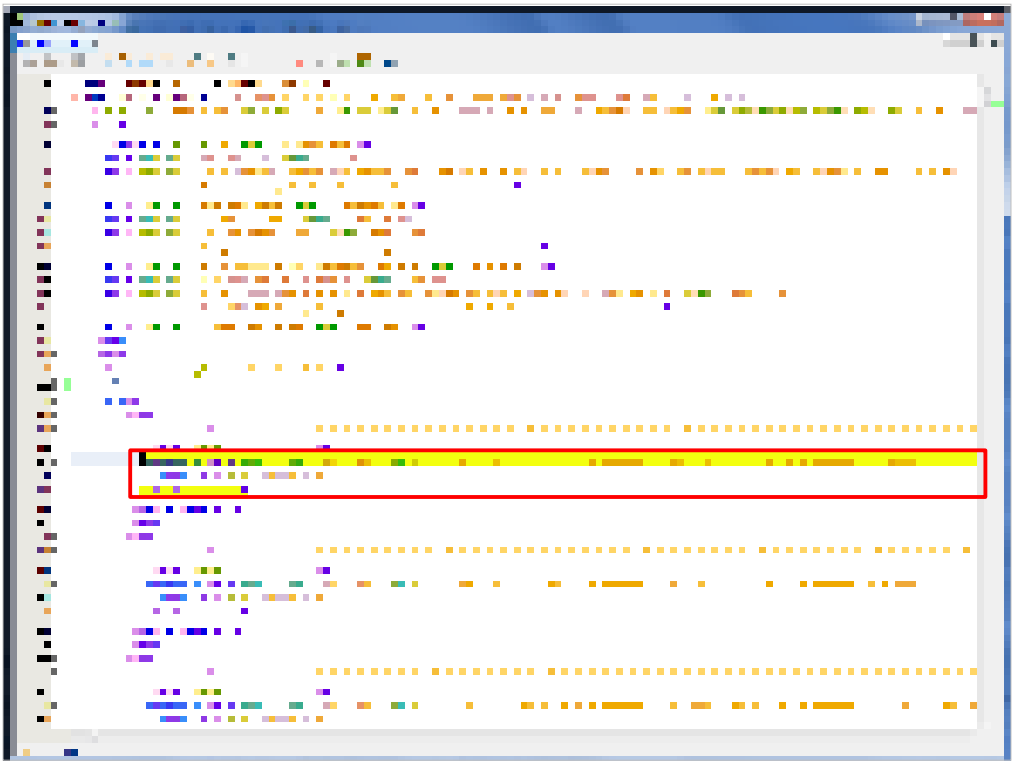
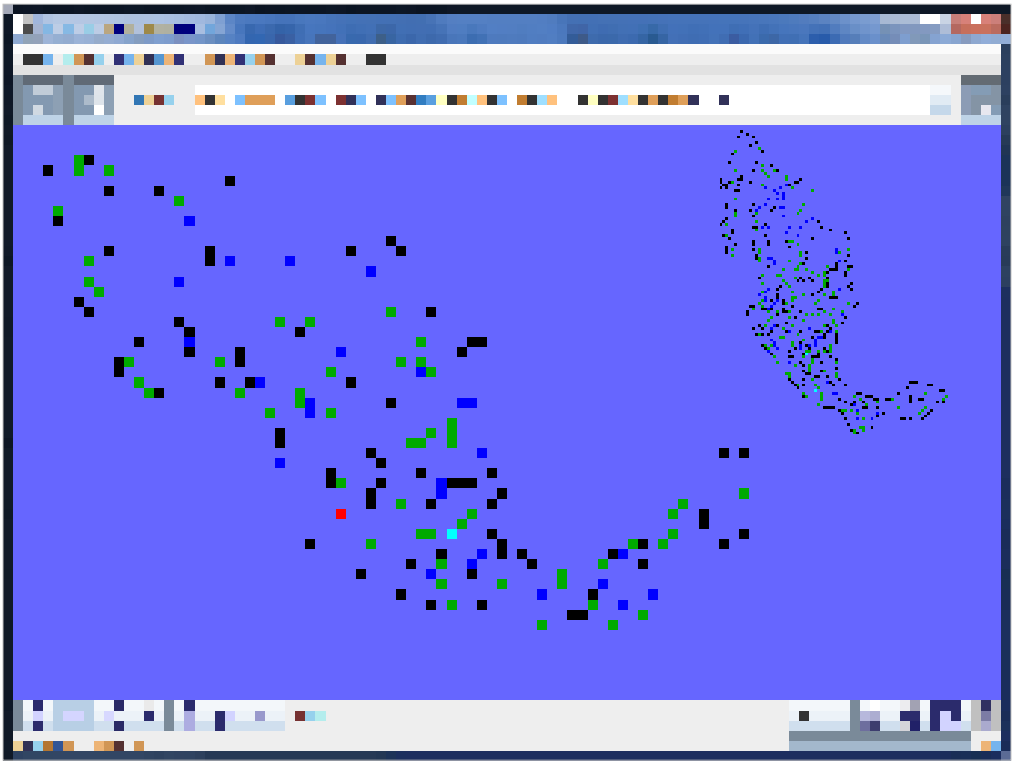


http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/Mexico.x3d

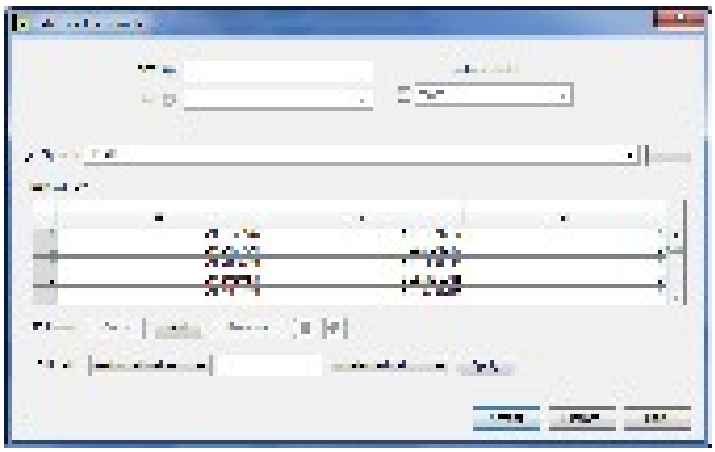


http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/Mexico.x3d

This is an interesting model of Mexico's major roads and rivers. Upon initial viewing, it simply looks like any other map of Mexico. Upon rotating the scene, however, it immediately becomes evident that the curvature of the Earth's surface is quite significant even at this scale.

One might conclude that we are so used to flat projections of curved Earth surfaces that we really do not have a good intuitive feel of their actual shape.

GeoCoordinate node X3D-Edit



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GeoElevationGrid node 1

Similar to regular ElevationGrid node

- Adds *geoGridOrigin*, *geoSystem* fields
- *height* field is now a double array (not float) representing height above geoid surface
- Also includes *set_height* (inputOnly) field

*Geometry of Ge*oElevationGrid *height* field itself is curved to match geospatial ellipsoid

- Curvature typically not visible for small areas
- Nevertheless holds accurate for large areas, including definition of a full globe!

GeoElevationGrid node 2

geoSystem defines geospatial coordinate system

- also affects units of other values

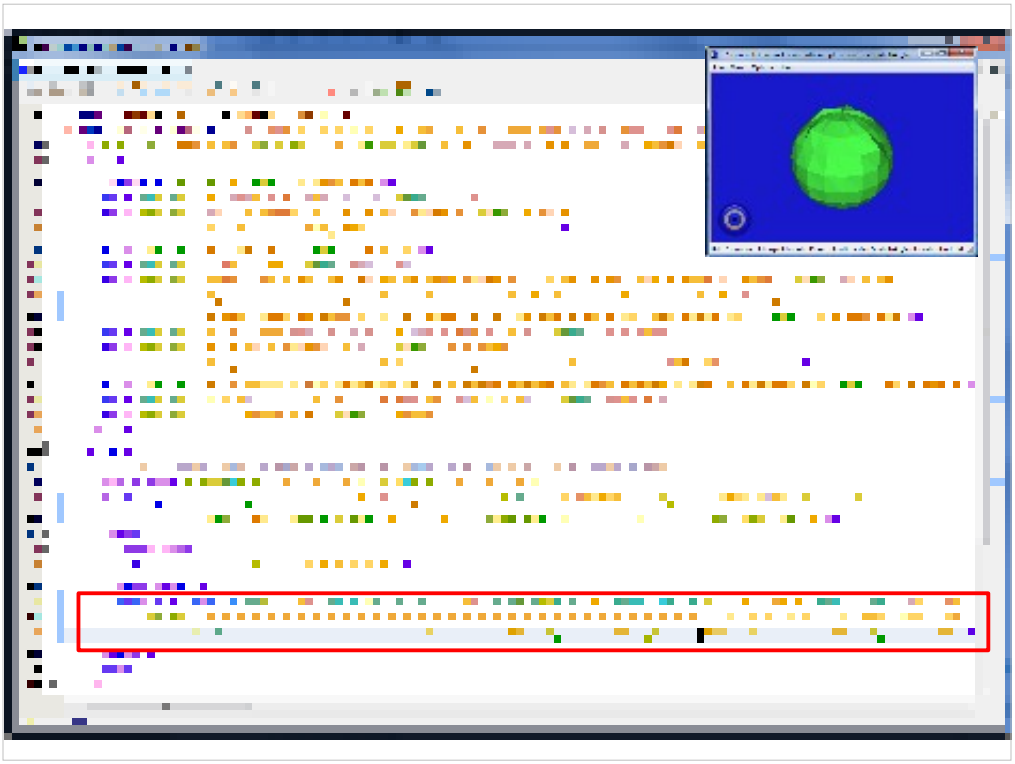
geoSystem "GD"

- *xSpacing* refers to the number of degrees of longitude between adjacent height values
- *zSpacing* refers to the number of degrees of latitude between vertical height values.

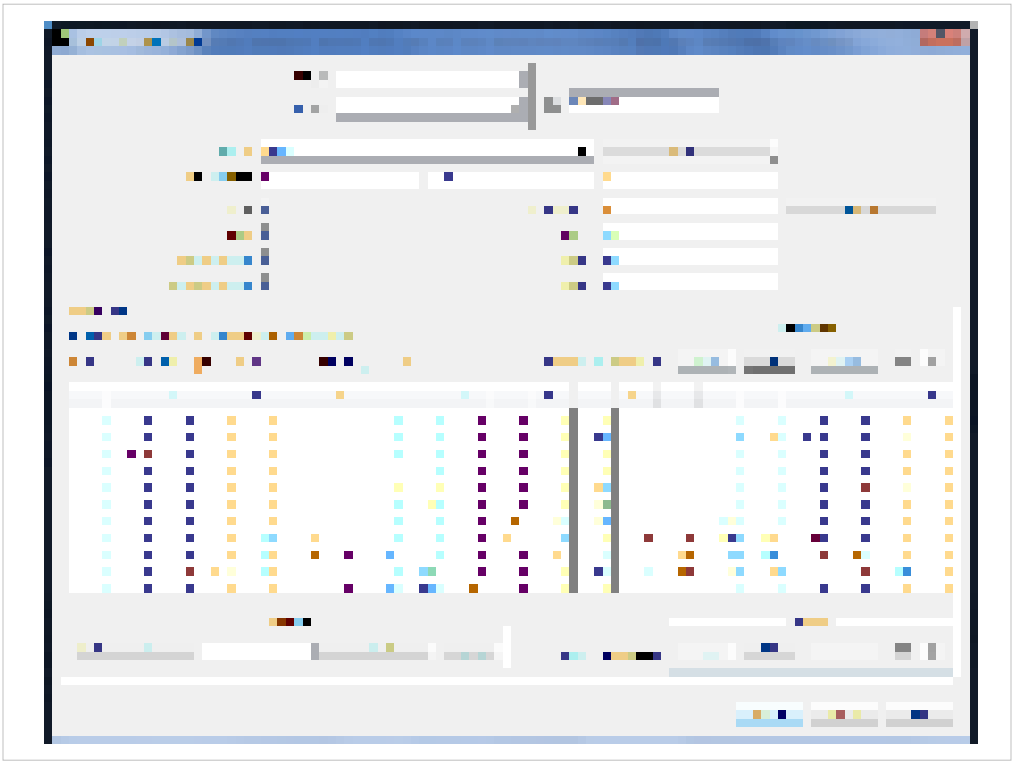
geoSystem "UTM"

- *xSpacing* refers to the number of eastings (metres) between adjacent height values
- *zSpacing* refers to the number of northings (metres) between vertical height values.

geoSystem "GC" is geocentric and so *xSpacing*, *zSpacing* units remain in meters.



http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A1_GeoElevationGrid.x3d



GeoLocation node

GeoLocation node provides ability to georeference any standard X3D model

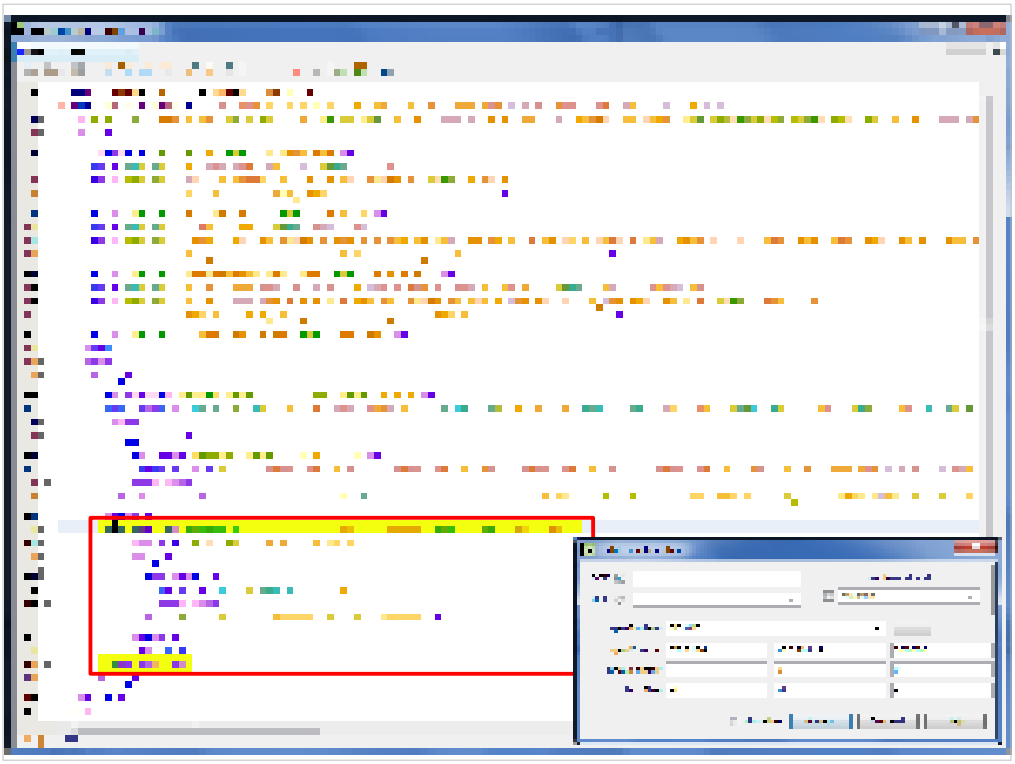
- X3D model is contained as child
- Thus GeoLocation is a grouping node
- Local vertical aligned with +Y axis up

geoSystem gives geospatial coordinate system

geoCoords field indicates location

- can dynamically update this geospatial location using GeoPositionInterpolator

Warning: do not nest GeoLocation nodes within each other, either directly or via Inline



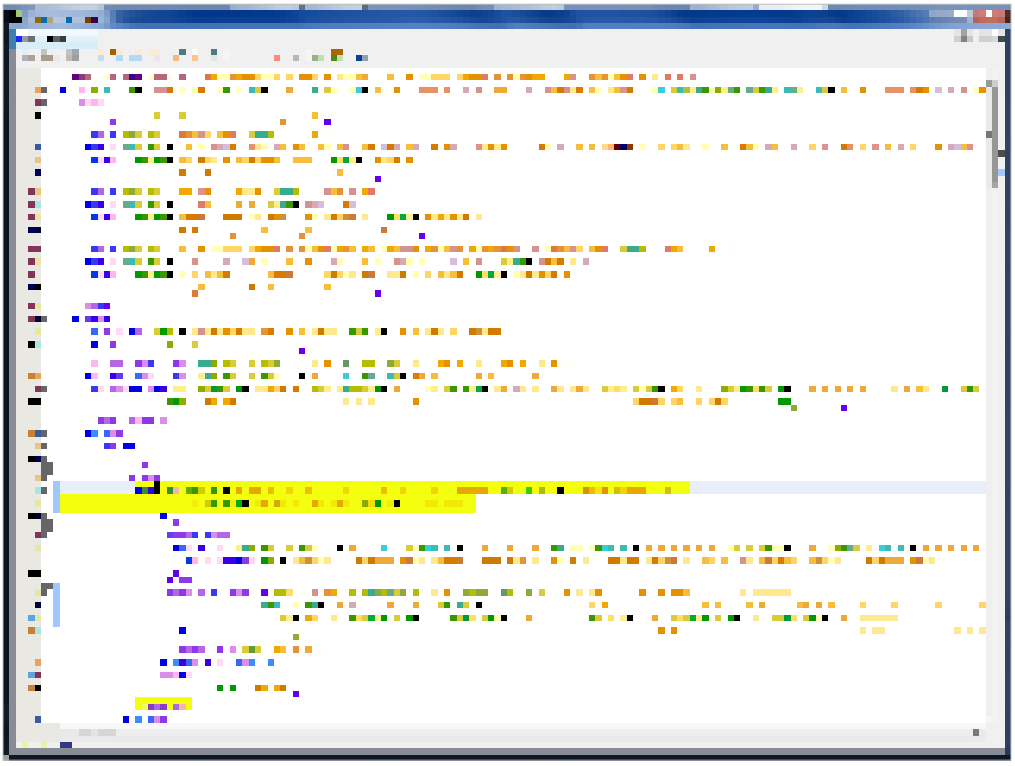
http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A4_GeoLocation.x3d

GeoLOD node

GeoLOD node provides a terrain-specialized form of the regular LOD node

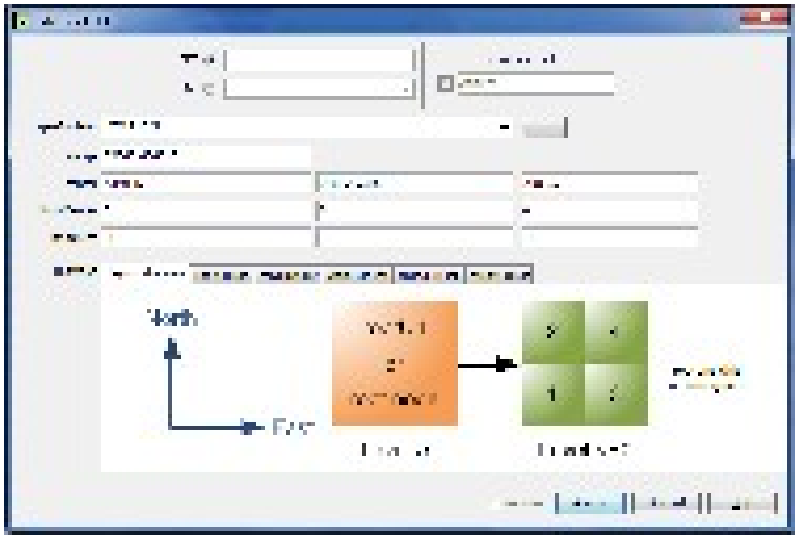
- *rootUrl* or *rootNode* are used to define geometry shown at default level
- *Child1Url* ... *child4Url* fields define quadtree links to children subscenes
- *geoSystem* defines geospatial coordinate system
- Also includes output event for *level_changed*

Wish list: children within node, vice urls



http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/Squaw.x3d

GeoLOD node X3D-Edit



GeoMetadata node

Describes geospatial information of interest

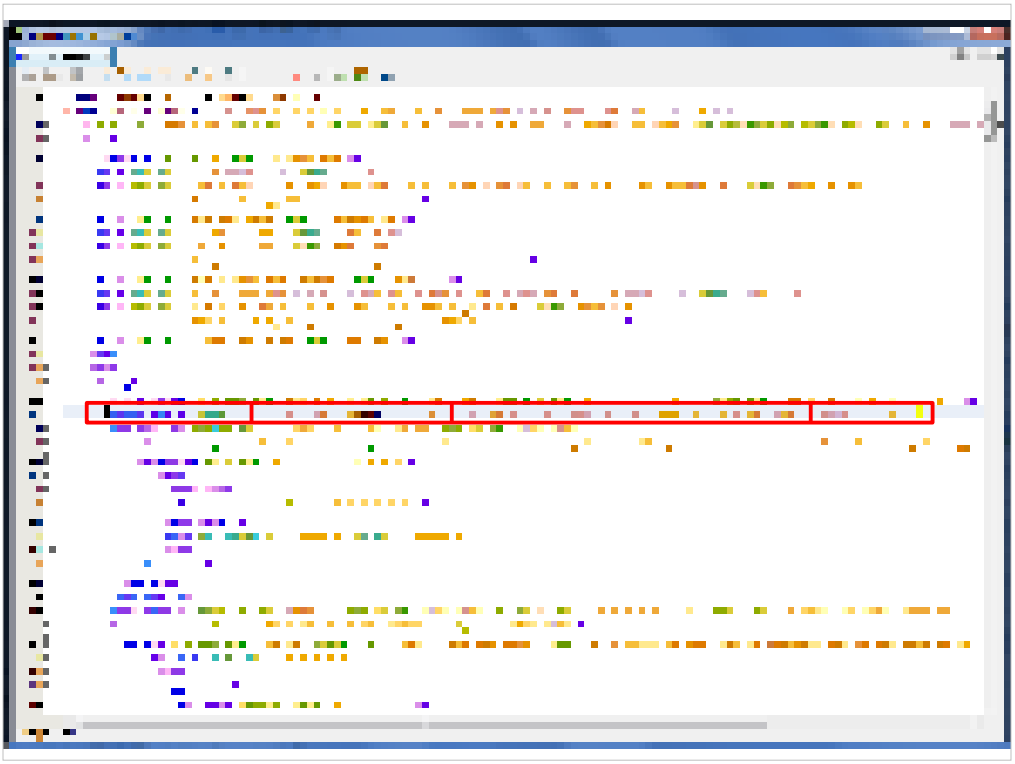
- Design is similar to WorldInfo node
- Developed and approved prior to other Metadata* nodes from X3D Core Component

Note unusual syntax: writing, parsing is difficult

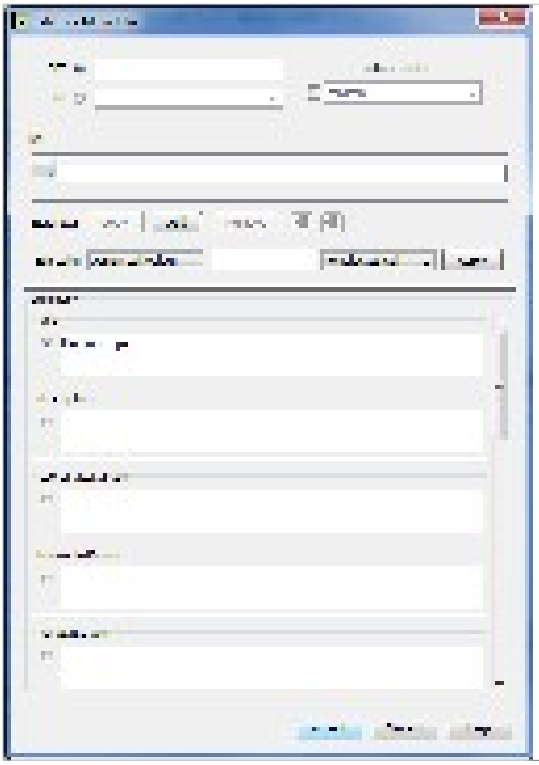
- "`title`" "name-value pairs for GeoMetadata"
- "`description`" "are defined as MFString string arrays"

Typically defined names of interest include:

- **`title, description, coordinateSystem, horizontalDatum, verticalDatum, ellipsoid, extent, resolution, originator, copyright, date, metadataFormat, dataUrl, dataFormat`**



http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/TripsModel.x3d



GeoMetadata node X3D-Edit

GeoPositionInterpolator node

Similar to regular PositionInterpolator node

- Adds *geovalue_changed*, *geoSystem* fields

Consistent behavior throughout

- *geovalue_changed* value corresponds to the world position returned by *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*

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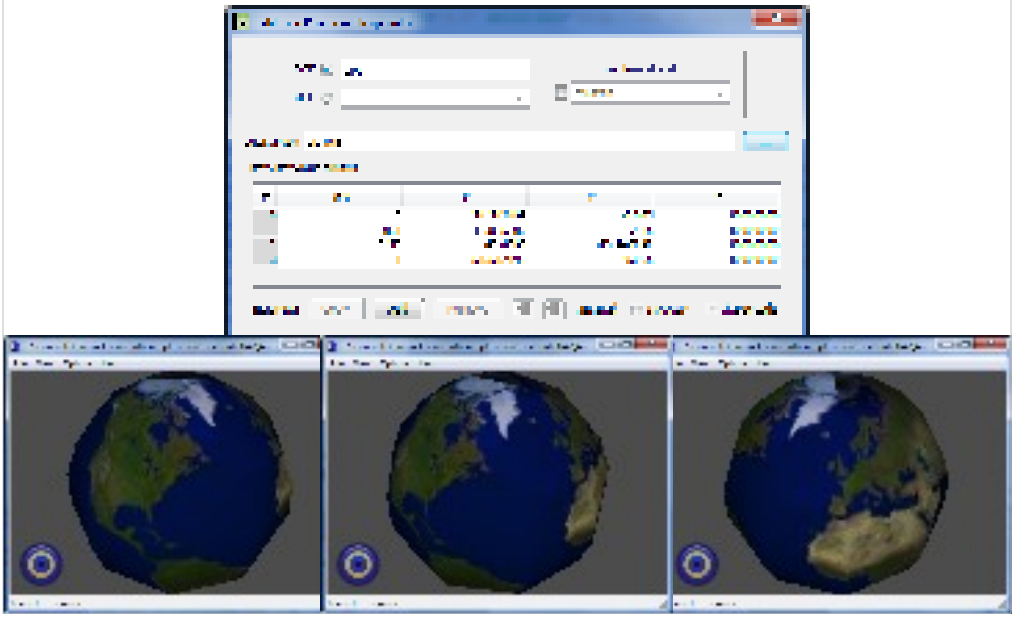
http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A2_AnimatedGeoViewpoint.x3d

GeoPositionInterpolator node X3D-Edit



GeoProximitySensor node

Generates events when the viewer enters, exits, and moves within a box region of space

- Vertically aligned with local +Y axis up

Similar to regular ProximitySensor node

- Adds *geoCenter*, *geoCoord_changed*, *geoSystem* fields

Consistent behavior throughout

- *geoCoord_changed* value corresponds to the world position returned by *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*

GeoProximitySensor example

- TODO: example needed!

GeoProximitySensor node X3D-Edit

- TODO: implementation needed!

GeoTouchSensor node

Similar to regular TouchSensor node

- Adds *hitGeoCoord_changed*, *geoSystem* fields

Consistent behavior throughout

- *hitGeoCoord_changed* value replaces TouchSensor *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*

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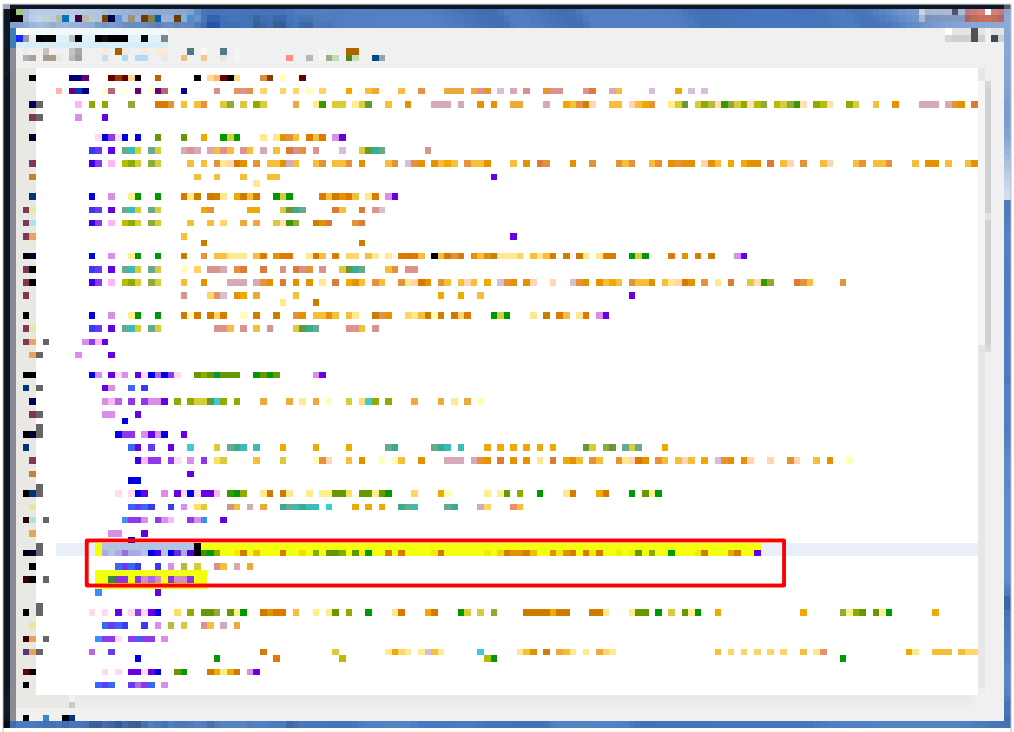
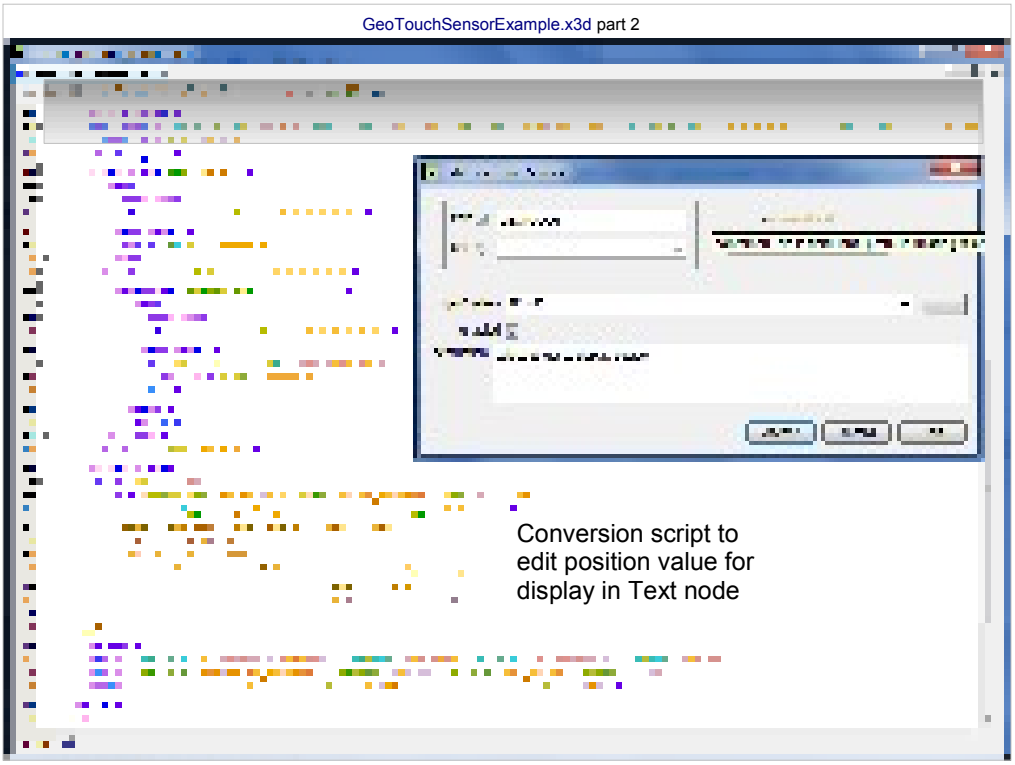


GeoTouchSensorExample.x3d part 1

http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/GeoTouchSensorExample.x3d

GeoTouchSensorExample.x3d part 2



http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/GeoTouchSensorExample.x3d

GeoTransform node

Similar to regular Transform node

- Adds *geoCenter*, *geoSystem* fields
- Vertically aligned with local +Y axis up

Consistent behavior throughout

- Allows regular animation of *translation*, *rotation*, other fields in a geospatial context

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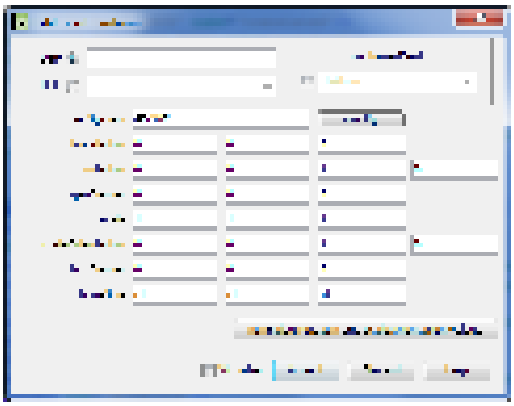
GeoTransform example

- TODO: example needed!

GeoTransform node X3D-Edit



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GeoViewpoint node

Similar to regular Viewpoint node, but also integrates some fields from NavigationInfo

- Adds *hitGeoCoord_changed*, *geoSystem* fields

Consistent behavior throughout

- *hitGeoCoord_changed* value replaces TouchSensor *position_changed*
- Output values are referenced to geospatial coordinate system defined by *geoSystem*

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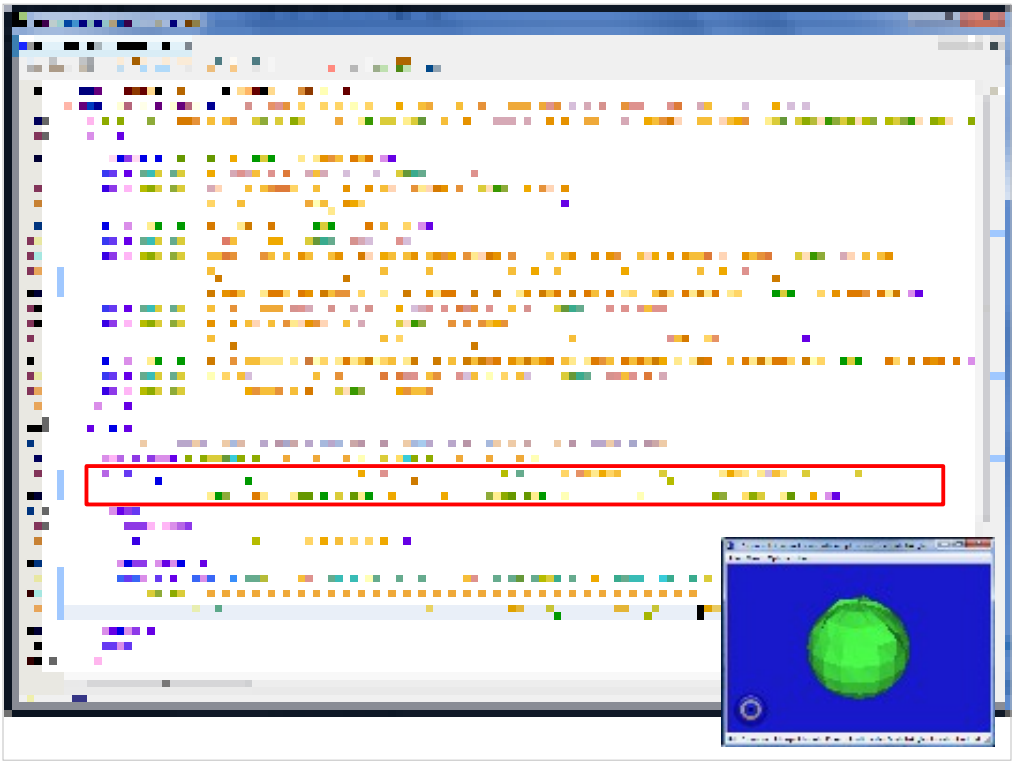
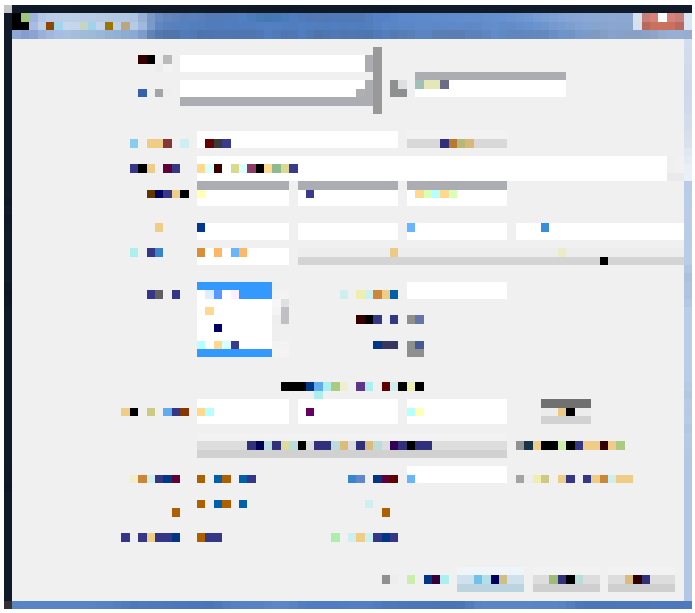


http://www.web3d.org/x3d/content/examples/Basic/GeoSpatial/A1_GeoElevationGrid.x3d

GeoViewpoint node X3D-Edit



deprecated: GeoOrigin node

Originally included in GeoVRML, X3D scenes to provide shared-reference origin point

- Intended to reduce spatial roundoff errors
- Adds to scene complexity

However this scene information is duplicative

- Since latitude/longitude or UTM coordinates also provide precise location information

Thanks to research by Chris Thorne, proper player workarounds have been figured out

- Deprecated = allowed but unnecessary

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Deprecated means

> Obsolescent; said of a construct in a computing language considered obsolete but still available for use, though planned to be phased out.

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X3D Earth

Example X3D Earth globes

Multiple globes are available online, although resolution is still fairly low

- HelloEarthOpenStreetMap.x3d using OpenStreetMap
- http://x3d-earth.nps.edu/7_levels_plus/tiles/0/globe.x3d
- http://x3d-earth.nps.edu/globe/MBARI1MinuteBathy/world.x3d
- http://x3d-earth.nps.edu/globe/SRTM30Plus/world.x3d

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TODO linked images

Globe production process

Dr. Byounghyun Yoo, MIT Singapore Alliance

- Tutorial for terrain Tile Production Chain
- Terrain Tile Production Course Slideset
- Rez tiling tool
- Example X3D-Earth Globes

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X3D Earth vision, mission

X3D Earth Working Group

- http://www.web3d.org/x3d-earth

Vision

- Make it easier to create, use 3D spatial data

Mission

- Promote spatial data use within X3D via open architectures

X3D Earth design workshop

X3D Earth Technical Requirements Workshop

- Naval Postgraduate School, Monterey California USA, 14-15 November 2006
- Summary report available

Twenty presentations provide motivating requirements that continue to guide us today

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Motivating goals: X3D Earth

Use the Web architecture, XML languages and open protocols

Build a standards-based X3D Earth of geospatial models

Results usable by governments, industry, scientists, academia and the general public

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X3D Earth: what is it

Build a backdrop X3D model of planet Earth

- Use publicly available terrain datasets
- Use publicly available imagery
- Use X3D Geospatial Component throughout
- Provide linkable locations for any place
- Provide hooks for physical models
- Use open standards, extensions and process

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Why X3D Earth is needed 1

Proprietary commercial approaches are viable, but not necessarily over long term

- Many past commercial failures, shutdowns
- Even very large companies sometimes subject to economic pressures beyond their control

Government, science, research and academic needs are different than commercial needs

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Why X3D Earth is needed 2

Public and government assets need to be openly available over long term, indefinitely.

- Huge investment in data preparation
- Future rework/rewrite may not be possible
- Archiving, availability is essential prerequisite for many agencies
- New spatial applications become possible
  - including Semantic Web and search applications

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What we are not proposing

Commercial competitor to other schemes

- They already have technologies of choice, economic imperatives and business models

Vive la difference

- Some commercial approaches may actually benefit by having an open approach widely available, providing new services & products

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The key challenge is scalability

Because the only information systems capable of scalably growing to match global scope are the Internet and the World Wide Web, X3D Earth will deliberately follow the architectural principles of World Wide Web.

- *Architecture of the World Wide Web, Volume One*
  http://www.w3.org/TR/webarch

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Data

3D, GIS communities have a wealth of data and imagery

- Both freely available and sustainably funded
- Significant metadata usually included
- Many different formats, not always searchable

Let's get consistent and professional about how to

- Represent, compose and harmonize such data in X3D
- Create "path of least resistance" to success
- Some converters already available (e.g. KML2X3D)
- [Insert 1 million metric tons of data resources here]

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Science

Researchers model the world in detail already

- but rarely interconnect one to another

Most interesting part of "virtual reality" ?

- Reality – which means physics

Need hooks to connect physics engines, virtual sensors, propagation algorithms, live sources

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Stepping up is inevitable

Long-running experience in 3D graphics has shown that each accomplishment leads to new (and sometimes unforeseen) challenges

- "Graphics Internetworking: Bottlenecks and Breakthroughs," chapter 4, *Digital Illusion*, Clark Dodsworth editor, ACM Press, Addison-Wesley, Reading Massachusetts, August 1997

X3D past, present are prelude to our next steps

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Big trump cards

The hardest parts of the technical infrastructure are already proven possible

- Web3D X3D specifications
- W3C Recommendations
- OpenGIS Consortium (OGC) specifications
- Synthetic Environmental Data Representation and Interchange System (SEDRIS) specifications

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Server-side 3D graphics

- Our classical bias in the SIGGRAPH community is to think in terms of client-side 3D graphics
- With terrain databases, imagery, cartography and worlds of related objects, the subject of attention becomes server-side 3D graphics
- New issues of interest include preprocessing, prerendering, decimation and compression, digital signature, encryption, streaming etc.
- Important work to mainstream X3D continues

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Proven success story

Web3D Consortium members have the capabilities, resources and staying power to undertake this major new Web initiative.

Proof point: NPS already proposing and executing multiple ambitious projects with many Web3D members

All this work is unencumbered, repeatable

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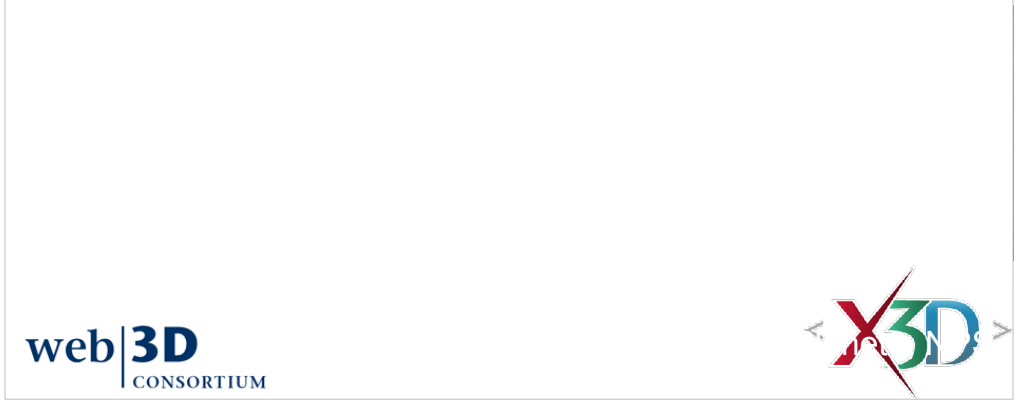
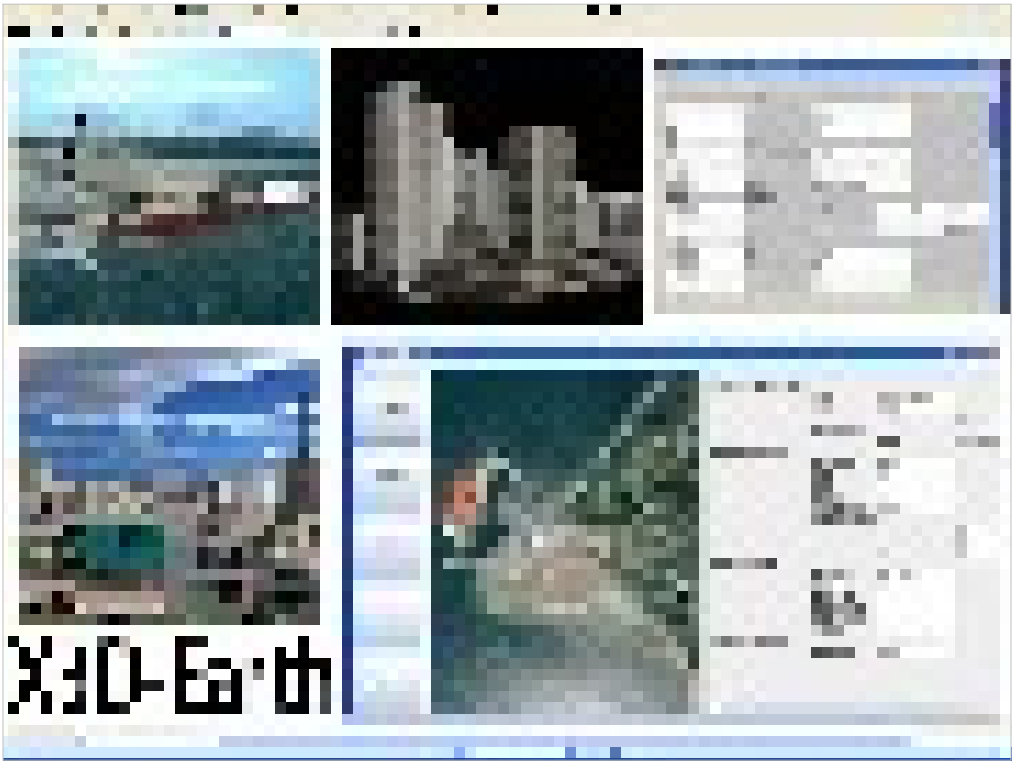
X3D Earth proposal image montage 1





Globe generation by supercomputer

Obtain (usually LARGE) datasets

- Image files
- Terrain files

Generate scripts

- process data into quad-tree pyramids

Dispatch scripts to supercomputer

- Tasks scheduled via Sun Grid Engine (SGE)
- Link top-level globe together with pyramids
- Publish to appropriate data server for access

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Assets: Rez by Chris Thorne

"Open source framework and tools for translating gridded data, mainly geospatial, to different formats including images and multiresolution models for X3D or VRML web browsing"

Java program with multiple input/output plugins

Can be executed using a GUI or command line

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Rez formats

Inputs

- DTED
- ASCII Grid
- XYZ
- DEM
- GeoVRML ElevationGrid

Outputs

- X3D
- VRML
- Contoured Jpeg
- Grey Scale Jpeg

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Continuing work

Proposed work: X3D v3.3 draft

- Maintained on member-only wiki
- Errata: fix GeoViewpoint field accessType to match Viewpoint
- Add full geospatial support to X3D nodes for Distributed Interactive Simulation (DIS) network protocol
- Need metadata linking scheme to allow rapid transition to high-resolution data, rather than forced loading of all intermediate quadtrees

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Proposed: GeoTerrainLOD node

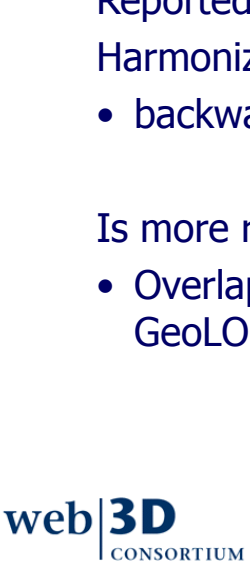
Reported in Web3D 2009 Symposium

Harmonization of techniques

- backwards compatibility kept strictly separate

Is more refactoring needed?

- Overlapping functionality remains for GeoLOD, GeoTerrainLOD



Proposed: NavigationInfo *accuracy* field

User navigation might be more forgiving or natural if accuracy constraints are sometimes relaxed

- Are there consistent lessons learned regarding such improvements for X3D?

Proposed: GpsSensor node?

Many mobile devices include GPS capabilities

X3D sensor types are designed to be generally extendable

Should we provide native support in X3D so that authors can easily write GPS-aware scenes and applications?

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Proposed: additional image formats?

Some formats commonplace for Earth imagery

- JPEG 2000
- GeoTIFF
- NITF
- TGA?

Some formats also embed information

- Such as geospatial metadata

Should X3D players support them natively, rather than requiring conversion to disseminate?

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Proposed: Projective Texture Mapping

PTM algorithm

- Project an image texture at some geometry
- Texture is then wrapped over that geometry

Obvious geospatial application to apply aerial imagery (or video) to terrain geometry

Requires multi-pass rendering

- Please see Korea Chapter proposal

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Proposed: KML Interoperability

Multiple ways to improve interoperability between X3D and KML

- X3D embedded in KML files (allowed)
- KML embedded in X3D scenes as XML
- KML to X3D conversions (some available)
- Custom X3D nodes to represent KML data (some prototypes available)

This is an active area of current work

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Testing

Need common baseline for consistent testing

- Dataset distribution of heavyweight archives? Local copies needed for consistent comparison of results
- OpenAerialMap restart a potential candidate, once ready
- Creating additional content for fly-throughs etc. using KML and conversion stylesheets

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Performance measurement

Performance testing needed across X3D-Earth server, intervening network, and client display

- Collaborative partnership needed among builders of X3D-Earth software and globes
- Agreed-upon test suite
- Common reporting of results
- Hudson server-side build tests might automate the conduct of testing

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Implementing experimental features

- Browser supported needed to test new fields before we can agree on new X3D capabilities or new "best practices"
- Use X3D Earth wiki to propose, record and analyze both progress and problems

Getting more people involved

- Making "wish lists" of needed activity, along with benefits to contributors and community
- Better documentation: website, wiki, code
- Video showcase?
- Reporting enterprise-wide approval, usage
  - Example: Navy Marine Corps Internet (NMCI)

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Siggraph 2010 Carto BOF

- Introductory Remarks (5 minutes) - Theresa-Marie Rhyne, Carto BOF Director
- X3D Update and Demonstrations - Don Brutzman & Team
- Visitcity Project using X3D & OGC technology) Peter Schickel. BitManagement
- RayGun, an iPhone and Android based Geographic Platform - David Colleen, Planet9

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Additional Resources

KmlToX3dViewpointTour Prototype

Input

- KML file containing placemarks

Conversion

- XSLT stylesheet

Output

- X3D scene with corresponding set of viewpoints
- plus a ViewpointTour prototype to sequence through them

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Chapter Summary

Chapter Summary

X3D geospatial component allows positioning objects at correct geospatial locations

X3D Earth project is building globes of interest using a variety of terrain, imagery datasets

Ongoing work to build repeatable, royalty-free results available for broad use

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Suggested exercises

Map a building or object to geospatial location

- Then add Inline for an X3D-Earth globe

Create a terrain tile

- Pick a location of interest
- Use GlobalMapper (or some other tool for assisted downloads) to retrieve terrain geometry and corresponding imagery
- Follow details in tutorial to accomplish this

Convert GPS tracks or other data into X3D

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References

References 1

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

- Chapter 3, Grouping Nodes
- http://x3dGraphics.com
- http://x3dgraphics.com/examples/X3dForWebAuthors

X3D Resources

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

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References 2

X3D-Edit Authoring Tool

- https://savage.nps.edu/X3D-Edit

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

TODO

- Martin Reddy book
- Chris Thorne disseration
- Mike McCann papers, site, GeoVRML
- Craig Anslow thesis

References 4

TODO

- GeoVRML, X3D geospatial papers
- NPS thesis list

Contact

Don Brutzman

brutzman@nps.edu

http://web.nps.navy.mil/~brutzman

Code USW/Br, Naval Postgraduate School
Monterey California 93943-5000 USA
1.831.656.2149 voice
1.831.656.7599 fax

CGEMS, SIGGRAPH, Eurographics

The Computer Graphics Educational Materials Source(CGEMS) site is designed for educators

- to provide a source of refereed high-quality content
- 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

CGEMS supported by SIGGRAPH, Eurographics

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- http://cgems.inesc.pt

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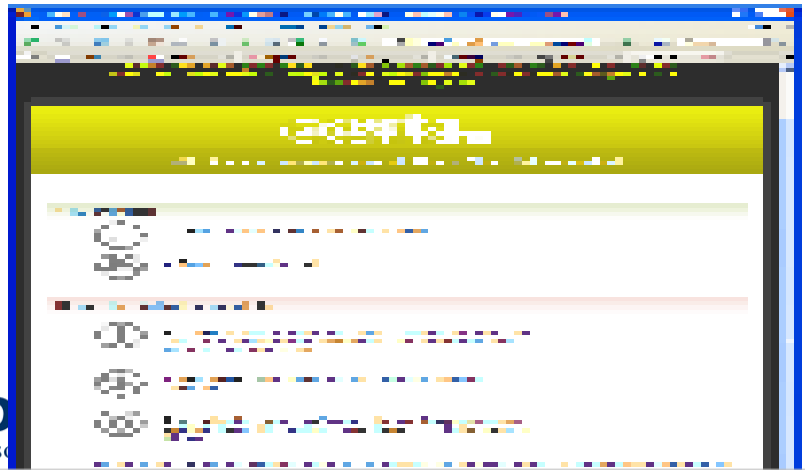

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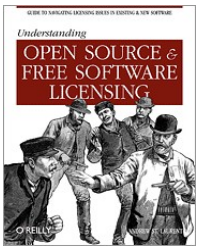
License available at

http://www.web3d.org/x3d/content/examples/license.txt

http://www.web3d.org/x3d/content/examples/license.html

Good references on open source:



Andrew M. St. Laurent, *Understanding Open Source and Free Software Licensing*, O'Reilly Publishing, Sebastopol California, August 2004. http://oreilly.com/catalog/9780596005818/index.html

Herz, J. C., Mark Lucas, John Scott, *Open Technology Development: Roadmap Plan*, Deputy Under Secretary of Defense for Advanced Systems and Concepts, Washington DC, April 2006. http://handle.dtic.mil/100.2/ADA450769