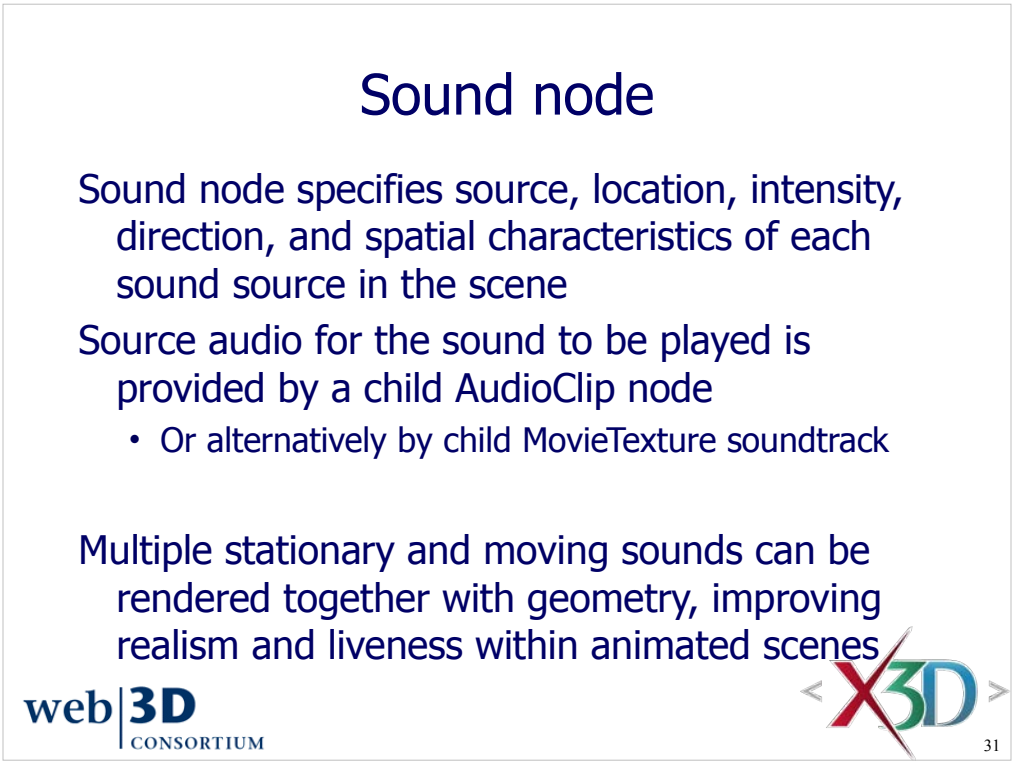

The Sound and AudioClip nodes make an integral pair and work closely together.

AudioClip is a separate node in order to decouple file and stream loading from the spatial characteristics of sound in the scene.

Sound fields: *location, direction, intensity, priority*

location is center position of sound origin

- Relative to local coordinate system

direction is unit-vector direction of sound axis

- Three-tuple vector, not a four-tuple SFRotation
- Relative to local coordinate system

intensity is factor [0..1] adjusts loudness of emitted sound

- Multiplied against original volume level of source

priority [0..1] is a browser hint, if ever needed, to choose which of several sounds to play

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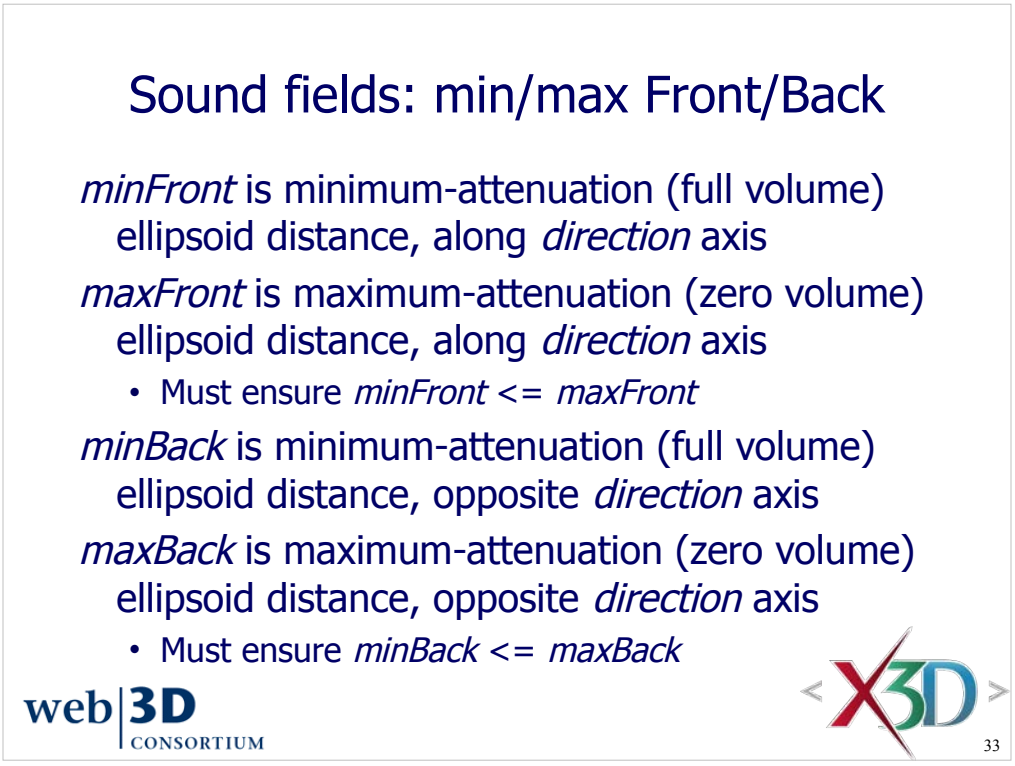
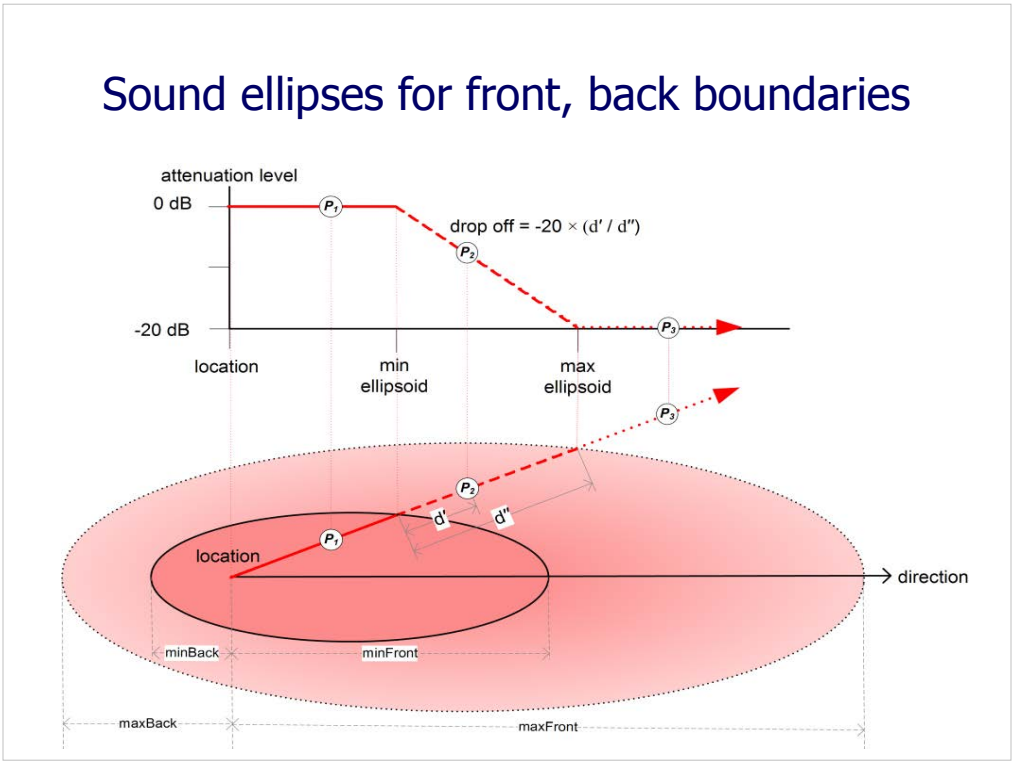


These field names can be confusing.

Hints:

- Minimum refers to inner ellipsoid (full audio volume)
- Maximum refers to outer ellipsoid (zero audio volume)
- Front means along the direction vector
- Back means opposite to the direction vector



p. 343, Figure 12.4. Sound ellipsoids correspond to linear spatialization boundaries for attenuation of Sound node intensity.

Sound field: *spatialize*

spatialize is a boolean determining whether to spatialize sound playback relative to viewer

- Only acts between minimum, maximum ellipsoids
- Stereo effect

Pan-factor computations determine spatialization effect on each channel

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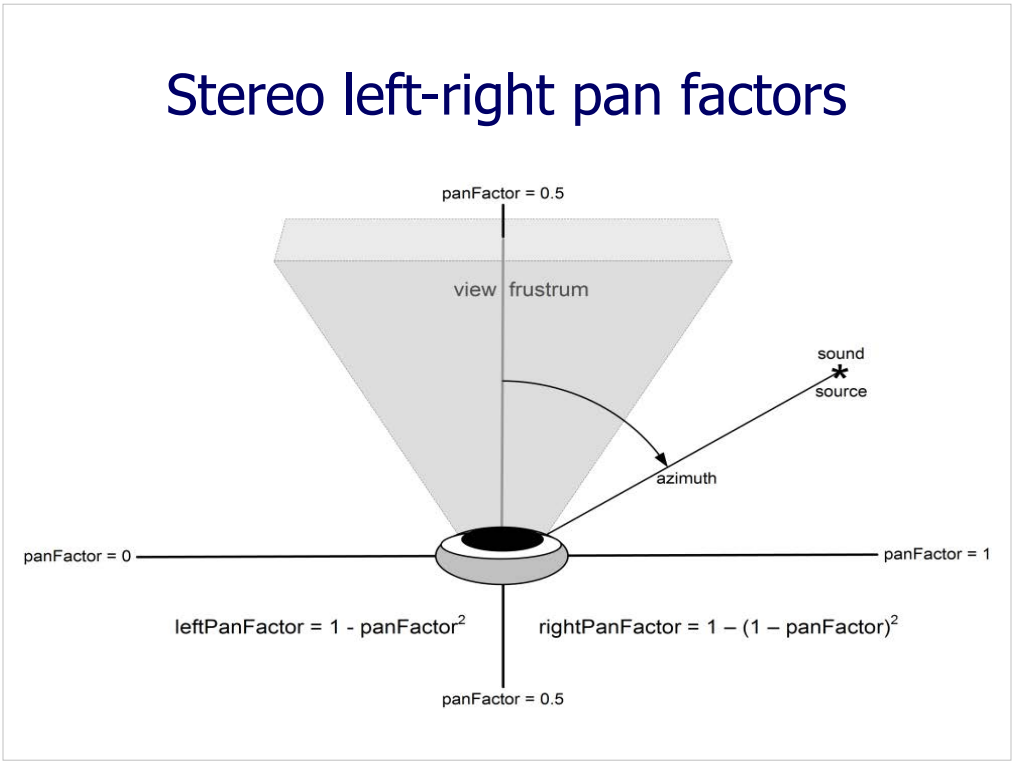

p. 342, Figure 12.3. Stereo-panning algorithm for attenuation of sound intensity is based on the azimuth angle relative to the user's current view direction.

Computing ellipsoid dimensions

location is focus point of the sound ellipsoid

maxFront, *maxBack* define dimensions of outer ellipsoid along and opposite the *direction* axis

Note however that ellipsoid width is not defined by these parameters, because that value is dependent on the other definitions

- The next diagram, equations show how to calculate

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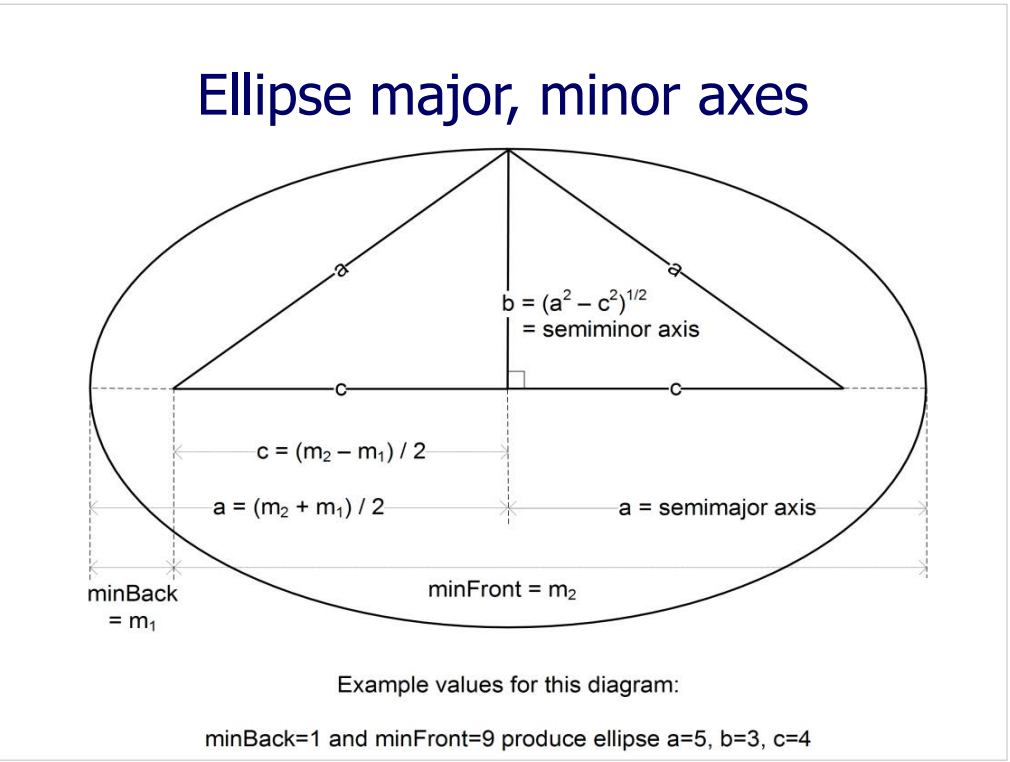


p. 344, Figure 12.5. Derivation and example values for an ellipse semi-minor axis, given focus location and front/back distances. The upper plot shows intensity values corresponding to boundaries in the lower diagram.

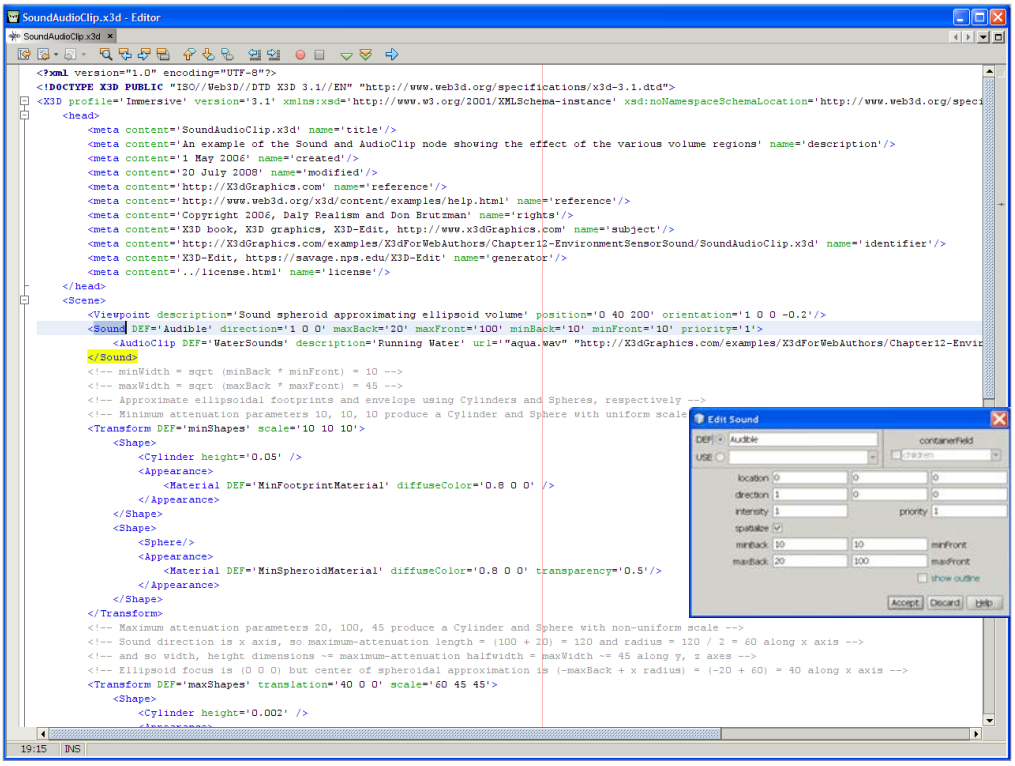
Calculating the width of sound ellipsoid

$$
\begin{aligned}
minHalfWidth = b_{\min} &= \sqrt{a^2 - c^2} \\
&= \sqrt{\left[\frac{m_1 + m_2}{2}\right]^2 - \left[\frac{m_1 - m_2}{2}\right]^2} \\
&= \frac{1}{2}\sqrt{m_1^2 + 2m_1m_2 + m_2^2 - \left(m_1^2 - 2m_1m_2 + m_2^2\right)} \\
&= \frac{1}{2}\sqrt{2m_1m_2 + 2m_1m_2} \\
&= \frac{1}{2}(2)\sqrt{m_1m_2} = \sqrt{m_1m_2} \\
minHalfWidth &= \sqrt{minBack \cdot minFront}
\end{aligned}
$$

similarly

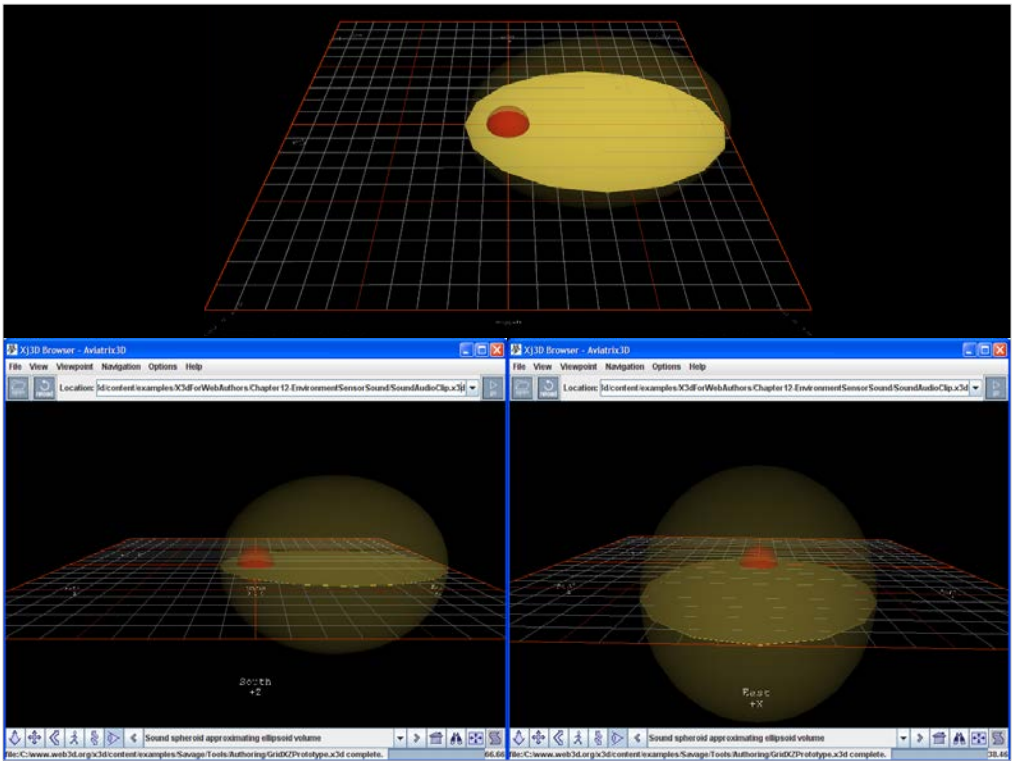
$$maxHalfWidth = \sqrt{maxBack \cdot maxFront}$$

p. 345, Figure 12.6. Derivation of ellipsoid minHalfWidth and maxHalfWidth.



http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/SoundAudioClip.x3d

This is an improved example for Figure 12.7 (shown below).



Three views of this example. Navigate within the scene to hear variations from minimum attenuation (full volume) within the red sphere, then reducing down to maximum attenuation (zero volume) once at our outside the yellow spheroid.

Note that the non-uniformly scaled sphere is an approximation for the sound ellipse. Also note that Sound nodes do not have a visible manifestation for their geometry.

This visualization example was constructed manually. The following visualization example was constructed automatically using the author-assist feature for Sound that is provided by X3D-Edit.

Sound node hints

Since ellipses shrink quickly, raise up the Sound node's location to match Viewpoint eye level

- When navigating in WALK mode, a typical *avatarSize* height is 1.6m
- Example: `<Sound location='0 1.6 0'/>`

Large volumes are good if you want to ensure the user hears what is intended

X3D-Edit includes a visualization author assist to transparently renders minimum (full volume) and maximum (zero audio volume) ellipsoids

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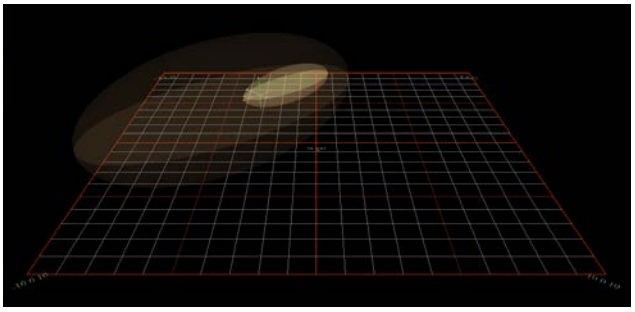
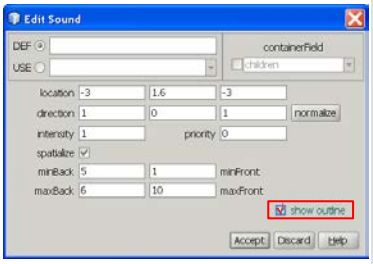
Sound node visualization






```
<Sound location='-3 1.6 -3' direction='1 0 1' minBack='5' maxBack='6' minFront='1' maxFront='10'/>
```

X3D-Edit author-assist feature for Sound node automatically adds ellipsoid visualization to a scene

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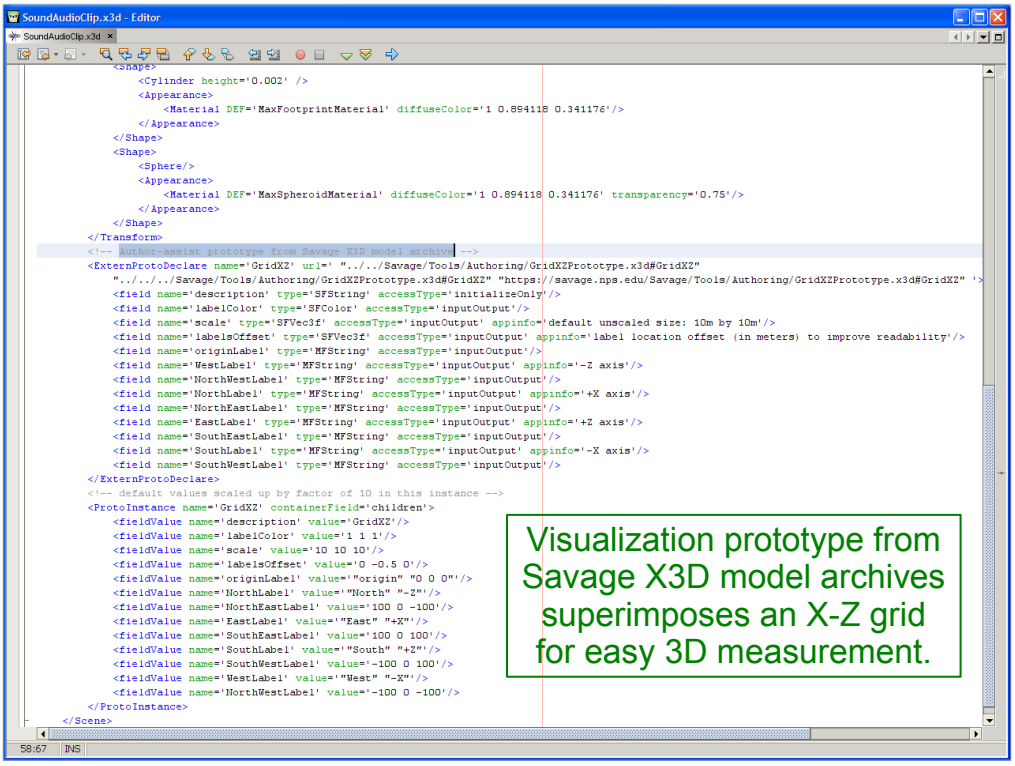
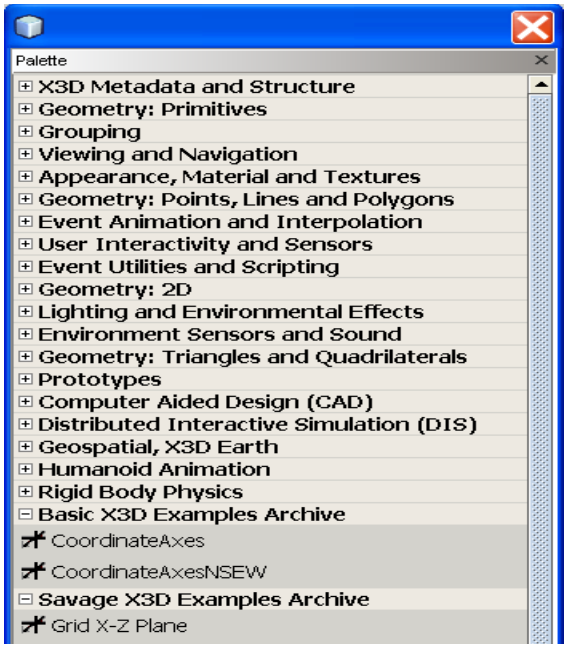
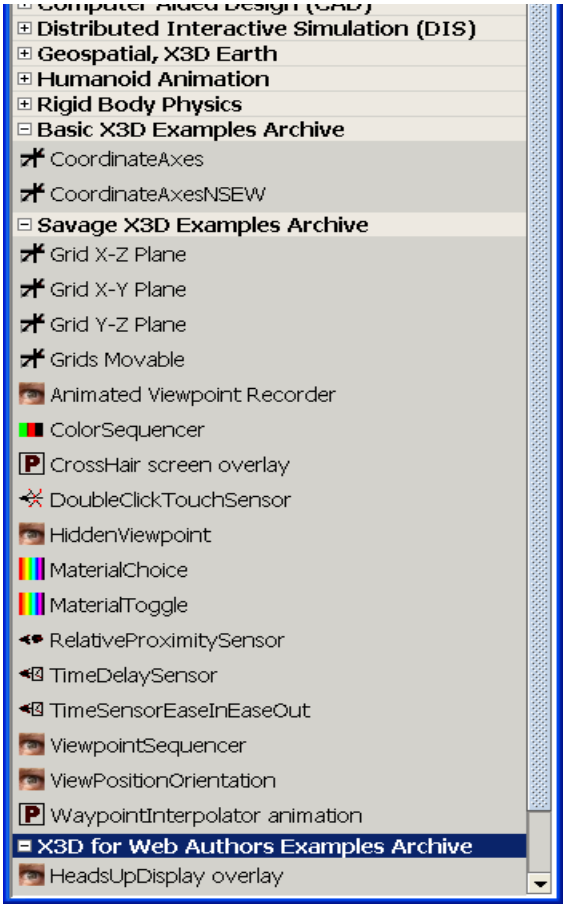
Notice the following visualization properties for the Sound ellipsoid:

- Proper location and direction
- The inner minimum (full volume) ellipsoid tends to the left of the local origin along the back direction, while
- The outer maximum (zero audio volume) ellipsoid tends to the right of the local origin along the front direction



Various coordinate axes grids are easily available via the X3D-Edit palettes for the Basic and Savage X3D Archive models.





Sound	Sound contains an AudioClip or MovieTexture for sound playback. You can also substitute a type-matched ProtoInstance for content.
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!
location	**[location: accessType inputOutput, type SFVec3f CDATA "0 0 0"]** Position of sound center, relative to local coordinate system.
direction	**[direction: accessType inputOutput, type SFVec3f CDATA "0 0 1"]** direction of sound axis, relative to local coordinate system.
intensity	**[intensity: accessType inputOutput, type SFFloat CDATA "1"]** Factor [0..1] adjusting loudness (decibels) of emitted sound.
minFront	**[minFront: accessType inputOutput, type SFFloat CDATA "1"]** Minimum-attenuation (full volume) ellipsoid distance, along direction ensure minFront <= maxFront.
minBack	**[minBack: accessType inputOutput, type SFFloat CDATA "1"]** Minimum-attenuation (full volume) ellipsoid distance, opposite direction ensure minBack <= maxBack.
maxFront	**[maxFront: accessType inputOutput, type SFFloat CDATA "10"]** Maximum-attenuation (zero volume) ellipsoid distance, along direction ensure minFront <= maxFront.
maxBack	**[maxBack: accessType inputOutput, type SFFloat CDATA "10"]** Maximum-attenuation (zero volume) ellipsoid distance, opposite direction ensure minBack <= maxBack.
priority	**[priority: accessType inputOutput, type SFFloat CDATA "0"]** Browser hint [0..1] to choose which sounds to play.
spatialize	**[spatialize: accessType initializeOnly, type SFBool (true|false) "true"]** Whether to spatialize sound playback relative to viewer. Hint: only effective between minimum and maximum ellipsoids.
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.

AudioClip node

AudioClip retrieves to an audio file for playing by the parent Sound node

- Sound can also use MovieTexture soundtrack as alternate to AudioClip

AudioClip also provides controls for playback

- *startTime* or *stopTime*, *pauseTime* or *resumeTime*, *isActive*, *isPaused, elapsedTime*, *loop*, *duration*

AudioClip fields 1

description is short text summary of sound clip

loop is boolean whether to play once or repeat

pitch is multiplication factor for playback speed

- Default *pitch*='1', slowdown pitch is smaller than 1, speedup greater than 1, must be greater than zero

url holds one or more equivalent addresses for audio file (or stream) to be retrieved

duration_changed event is sent whenever file is loaded, reporting time needed for full play

- Not affected by *pitch* speedup/slowdown factor

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duration_changed='-1' means that audio data is not yet loaded or not available

AudioClip fields 2

startTime
stopTime
pauseTime
resumeTime
elapsedTime
isActive
isPaused

These fields are defined the same (and operate the same) as the corresponding fields defined for TimeSensor node in Chapter 7.

Computing current sound time within a source clip:

$$t_{sound} = (now - startTime)\ modulo\ (duration \div pitch)$$

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AudioClip fields 3: *url*

Sound source for retrieval defined by *url* field

Ordered list: one or more addresses

- May be local file, remote file, or streaming source
- Browser can cache, check timestamps via http/https

Can be monitored by LoadSensor node, e.g.

- <LoadSensor> <AudioClip *containerField*='watchlist *USE*='OtherAudioClip'/> </LoadSensor>
- See following example SoundLoadSensorTest.x3d

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X3D Specification reference:

- X3D Abstract Specification, Sound component, section 16.4.1 AudioClip

http://www.web3d.org/x3d/specifications/ISO-IEC-FDIS-19775-1.2-X3D-AbstractSpecification/Part01/components/sound.html#AudioClip

WAV format reference:

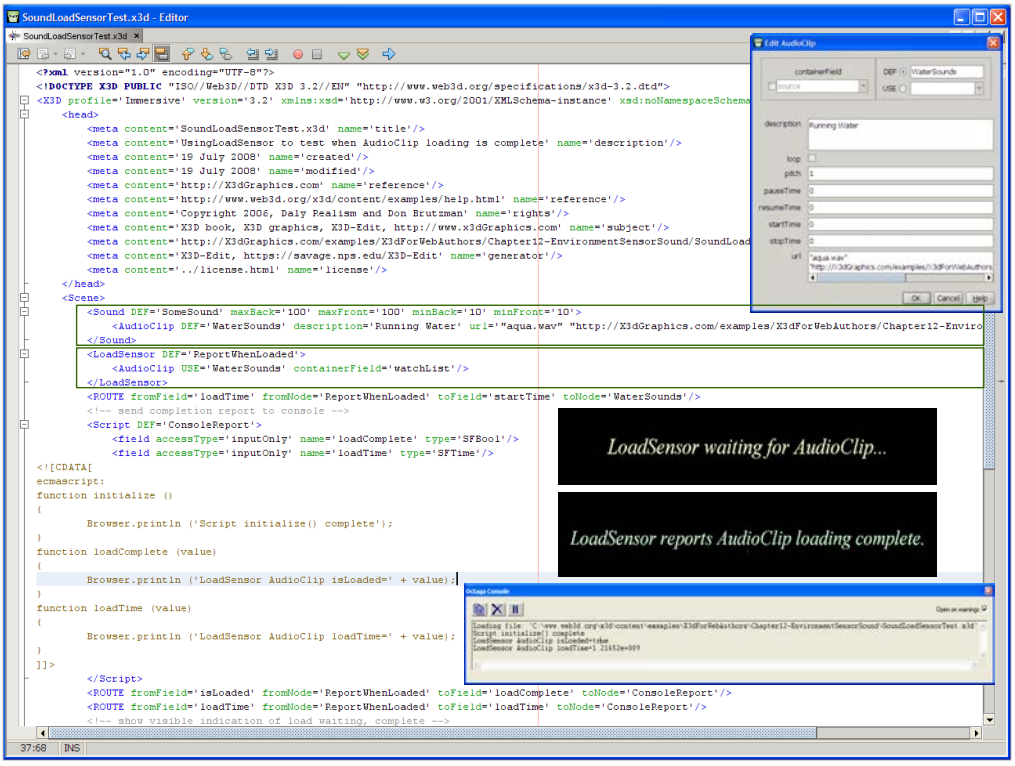
- Waveform Audio File Format, Multimedia Programming Interface and Data Specification v1.0, Issued by IBM & Microsoft, 1991. ftp://ftp.cwi.nl/pub/audio/RIFF-format
- https://en.wikipedia.org/wiki/WAV

MIDI Specification reference:

- Complete MIDI 1.0 Detailed Specification v96.1 (second edition), MIDI Manufacturers Association, P.O. Box 3173, La Habra, CA 90632-3173 USA, 2001. http://www.midi.org

MP3 Specification reference:

- ISO/IEC 11172-1:1993, Information technology - Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/seconds - Part 1: Systems. MPEG-1 or MPEG-2 Audio Layer III (not to be confused with MPEG-3).
- https://en.wikipedia.org/wiki/Mp3



http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/SoundLoadSensorTest.x3d

AudioClip file formats

Browser support for .wav format is required

- MIDI and MP3 support are recommended
- See SoundFileFormats.x3d to test browser support

Other audio formats are optionally supported

- Can check documentation for browsers of interest
- So far, no streaming protocol required in X3D

Video soundtracks of various types also playable

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X3D Specification reference:

- X3D Abstract Specification, Sound component, section 16.4.1 AudioClip

http://www.web3d.org/x3d/specifications/ISO-IEC-FDIS-19775-1.2-X3D-AbstractSpecification/Part01/components/sound.html#AudioClip

WAV format reference:

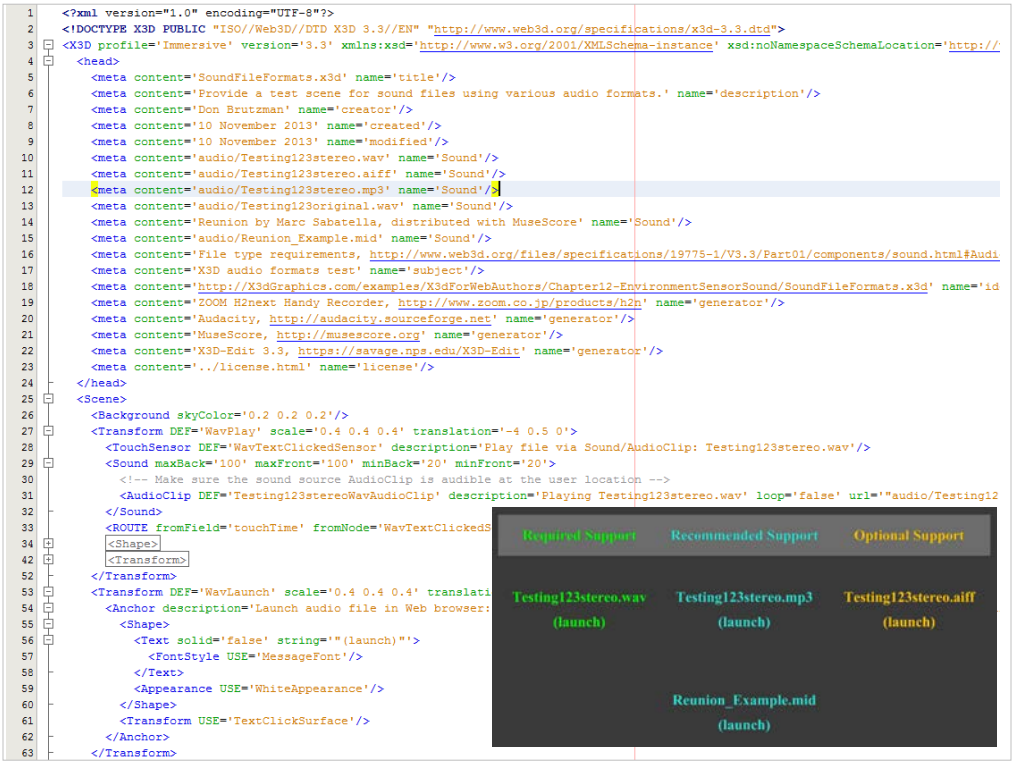
- Waveform Audio File Format, Multimedia Programming Interface and Data Specification v1.0, Issued by IBM & Microsoft, 1991. ftp://ftp.cwi.nl/pub/audio/RIFF-format
- https://en.wikipedia.org/wiki/WAV

MIDI Specification reference:

- Complete MIDI 1.0 Detailed Specification v96.1 (second edition), MIDI Manufacturers Association, P.O. Box 3173, La Habra, CA 90632-3173 USA, 2001. http://www.midi.org

MP3 Specification reference:

- ISO/IEC 11172-1:1993, Information technology - Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/seconds - Part 1: Systems. MPEG-1 or MPEG-2 Audio Layer III (not to be confused with MPEG-3).
- https://en.wikipedia.org/wiki/Mp3



http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/SoundFileFormats.x3d

File type requirements, .wav and .midi support is required for X3D:
http://www.web3d.org/files/specifications/19775-1/V3.3/Part01/components/sound.html#AudioClip

Audio test files:

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/audio/Testing123stereo.wav

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/audio/Testing123stereo.aiff

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/audio/Testing123stereo.mp3

http://X3dGraphics.com/examples/X3dForWebAuthors/Chapter12-EnvironmentSensorSound/audio/Reunion_Example.mid

AudioClip	AudioClip provides audio data used by <Sound> nodes. Hint: add a Sound node first.
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!
description	[description: accessType inputOutput, type SFString CDATA #IMPLIED] text description to be displayed for action of this node. Hint: many XML tools substitute XML character references automatically if needed (like & for & or " for ").
url	[url: accessType inputOutput, type MFString CDATA #IMPLIED] address, name of sound file. Support for .wav format is required, .midi format is recommended, others are optional. Hint: Strings can have multiple values, so separate each string by quote marks. ["http://www.url1.org" "http://www.url2.org" "etc."]. Hint: XML encoding for " is " (a character entity). Warning: strictly match directory and filename capitalization for http links! Hint: can replace embedded blank(s) in url queries with %20 for each blank character.
loop	[loop: accessType inputOutput, type SFBool (true|false) "false"] repeat indefinitely when loop=true, repeat only once when loop=false.
pitch	[pitch: accessType inputOutput, type SFFloat CDATA "1.0"] Multiplier for the rate at which sampled sound is played. changing pitch also changes playback speed.

startTime	**[startTime: accessType inputOutput, type SFTime CDATA "0"]** 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"]** Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value.
duration_changed	**[duration_changed: accessType outputOnly, type SFTime CDATA #FIXED ""]** duration_changed is length of time in seconds for one cycle of audio.
isActive	**[isActive: accessType outputOnly, type SFBool (true|false) #FIXED ""]** isActive true/false events are sent when playback starts/stops.
isPaused	**[isPaused: accessType outputOnly, type SFBool (true|false) #FIXED ""]** isPaused true/false events are sent when AudioClip is paused/resumed.
pauseTime	**[pauseTime: accessType inputOutput, type SFTime CDATA "0"]** When time now >= pauseTime, isPaused becomes true and AudioClip becomes paused. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value.
resumeTime	**[resumeTime: accessType inputOutput, type SFTime CDATA "0"]** When resumeTime becomes <= time now, isPaused becomes false and AudioClip becomes active. Absolute time: number of seconds since Jan 1, 1970, 00:00:00 GMT. Hint: usually receives a ROUTEd time value.
elapsedTime	**[elapsedTime: accessType outputOnly, type SFTime CDATA #FIXED ""]** Current elapsed time since AudioClip activated/running, cumulative in seconds, and not counting any paused time.
containerField	**[containerField: NMTOKEN "source"]** 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.

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Chapter Summary

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Chapter Summary

Environment Sensors

- LoadSensor detects availability of other content
- ProximitySensor detects user location, orientation
- VisibilitySensor detects visibility of region to user
- Provide improved animation timeliness, relevance

Sound Nodes

- Sound controls spatialization of audio outputs
- AudioClip controls retrieval and playback of audio files and streams
- Sound can improve user-perceived realism of scenes and spatial awareness

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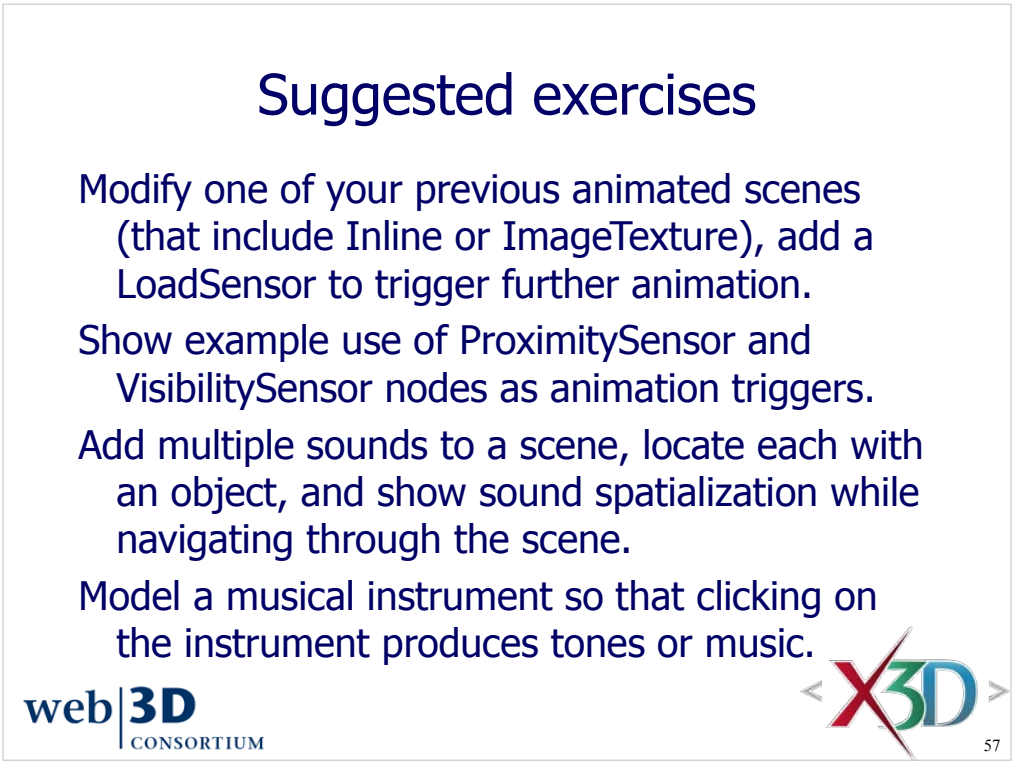

Example ProximitySensor and Visibility scenes can be found in the *VRML 2.0 Sourcebook:*
http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook/Chapter27-SensingVisibilityProximityCollision

Figure 27.1 Visibility Sensor Dungeon Sliding Doors

Figure 27.2 Proximity Sensor Dungeon Sliding Doors

Further example Sound and AudioClip scenes are also found in the *VRML 2.0 Sourcebook:*
http://www.web3d.org/x3d/content/examples/Vrml2.0Sourcebook/Chapter24-Sound

Figure 24.2 Ambient Sound Emitter Markers

Figure 24.3 Touch Sensor Triggered Sound

Figure 24.4 Four Key Keyboard

Figure 24.5 Two Ambient Circling Sounds

Figure 24.6 Directed Ambient Sound

Figure 24.7 Virtual TV

Here is an interesting student example:
http://www.web3d.org/x3d/content/examples/Basic/StudentProjects/KeyboardEightyEightKeys.x3d

Eight-eight key keyboard, extrapolated from VRML Sourcebook Figure 24-4, including animation of key movements coordinated with sounding of key when touched.

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Resources and References

Resources 1

Audacity

- Free, open source software for recording and editing sounds. Mac OS X, Windows, GNU/Linux.
- http://audacity.sourceforge.net

MidiEditor

- http://midieditor.sourceforge.net

Midi editor for Netbeans

- http://blogs.oracle.com/geertjan/entry/midi_editor_for_netbeans_ide

Midi Manufacturers Association

- http://www.midi.org (includes a midi tutorial)

Resources 2

Wikipedia

- http://en.wikipedia.org/wiki/Musical_Instrument_Digital_Interface
- http://en.wikipedia.org/wiki/List_of_MIDI_editors_and_sequencers

Freebyte midi file links

- http://www.freebyte.com/music/#midifiles

Midipedia

- http://en.midipedia.net

MuseScore for music scoring and midi support

- http://musescore.org

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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 12, Environment and Sound 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>

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References 2

X3D-Edit Authoring Tool

- https://savage.nps.edu/X3D-Edit
- Includes launch support for audio editors

X3D Scene Authoring Hints

- http://x3dgraphics.com/examples/X3dSceneAuthoringHints.html
- See section on Audio and Sound tools

X3D Graphics Specification

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

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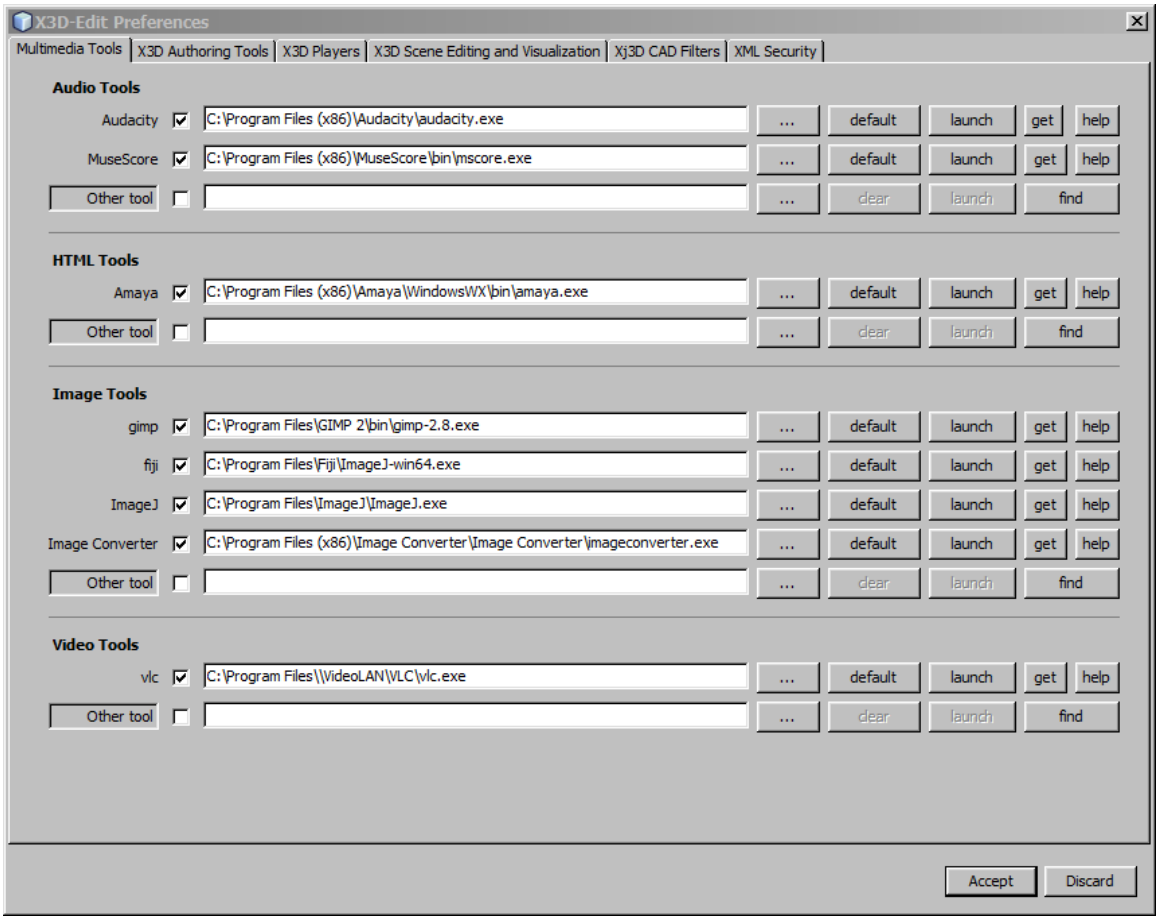

References 3

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 24 – Sound
- Chapter 27 - Sensing Visibility Proximity Collision

Durand Begault, *3D sound for virtual reality and multimedia*, Academic Press, 1994

- http://portal.acm.org/citation.cfm?id=184407

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References 4

Wikipedia: audio

- **Audio codec (coder/decoder)** and **list of codecs**
  http://en.wikipedia.org/wiki/Audio_codec
  http://en.wikipedia.org/wiki/List_of_codecs#Audio_codecs
- **Comparison of audio formats**
  http://en.wikipedia.org/wiki/Comparison_of_audio_formats
- **3D audio effect**
  http://en.wikipedia.org/wiki/3D_audio_effect
- **Digital audio**
  http://en.wikipedia.org/wiki/Digital_audio
- **Surround sound** and **Virtual surround**
  http://en.wikipedia.org/wiki/3D_sound
  http://en.wikipedia.org/wiki/Virtual_surround

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Additional references: digital sound

Begault, Durand R., *3D Sound for Virtual Reality and Multimedia*, Morgan Kaufmann Publishers, September 1994.

Collins, Karen, *Game Sound: An Introduction to the History, Theory, and Practice of Video Game Music and Sound Design*, MIT Press, Cambridge Massachusetts, October 2008. http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=11652

Computer Music Journal, MIT Press, Cambridge Massachusetts. http://www.mitpressjournals.org/cmj

Dobrian, Christopher, *Digital Audio*, from MSP: The Documentation, Cycling '74 and IRCAM, December 1997. Available at http://music.arts.uci.edu/dobrian/digitalaudio.htm

International Community for Auditory Display (ICAD). http://icad.org

Storms, Russell, *Auditory-Visual Cross-Modal Perception Phenomena*, Ph.D. Dissertation, Naval Postgraduate School, Monterey California, September 1998. http://bosun.nps.edu/uhtbin/hyperion-image.exe/98Sep_Storms.pdf

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- 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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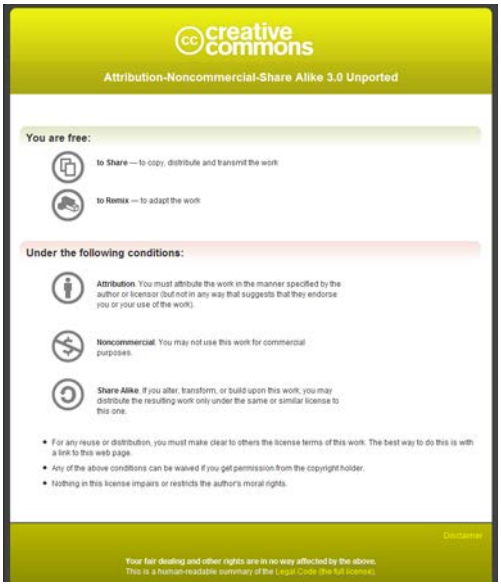

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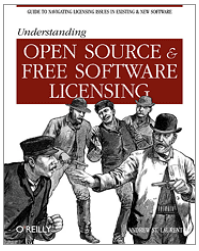

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