

Lighting and Environment

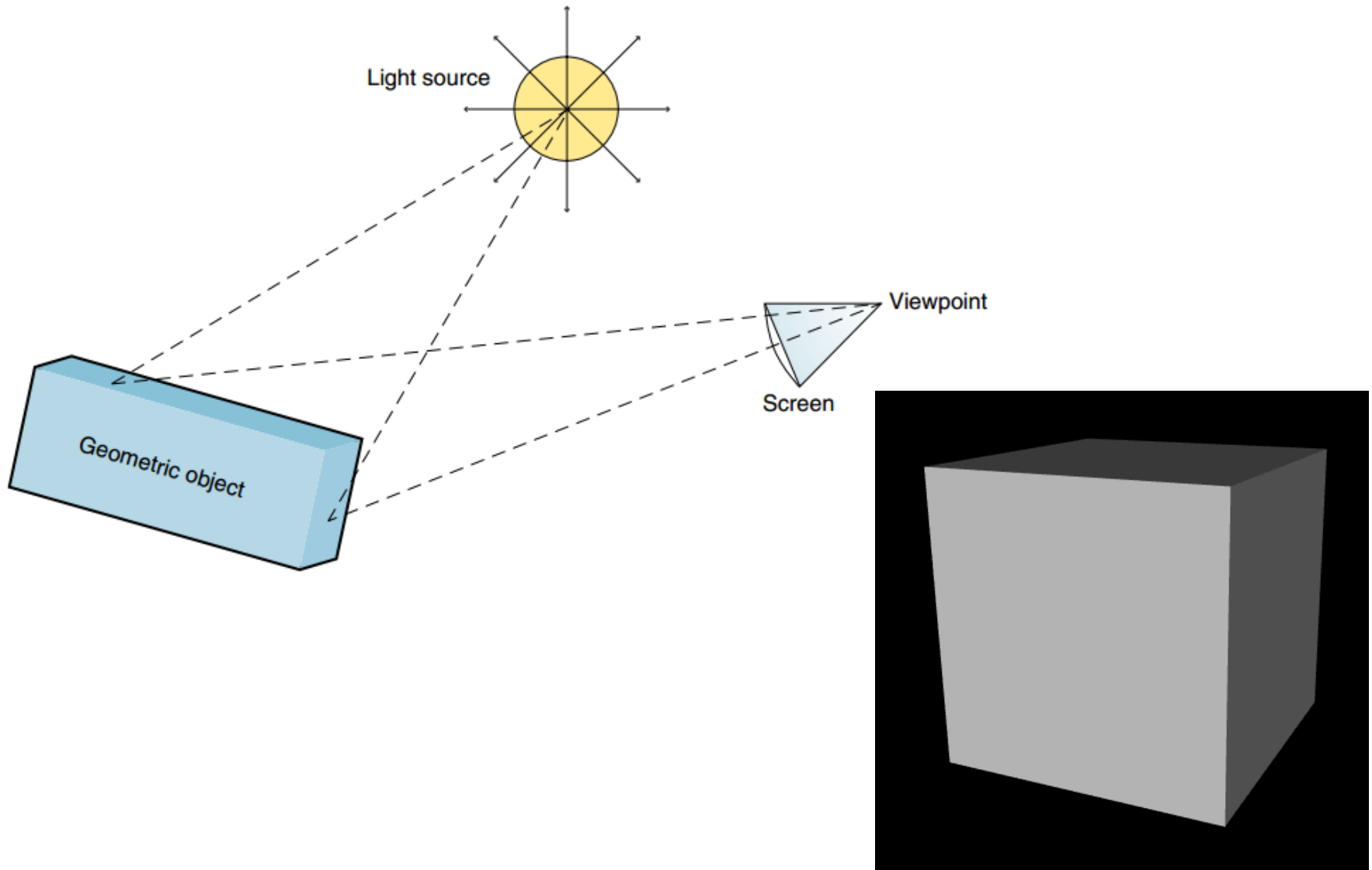
- Abstract node types
 - X3DLightingNode Type
 - X3DBackgroundNode Type
- Nodes
 - DirectionalLight Node
 - PointLight Node
 - SpotLight Node
 - Background Node
 - TextureBackground Node
 - Fog Node

Ray Tracing



Image source: Wikipedia

Lighting Model fundamentals



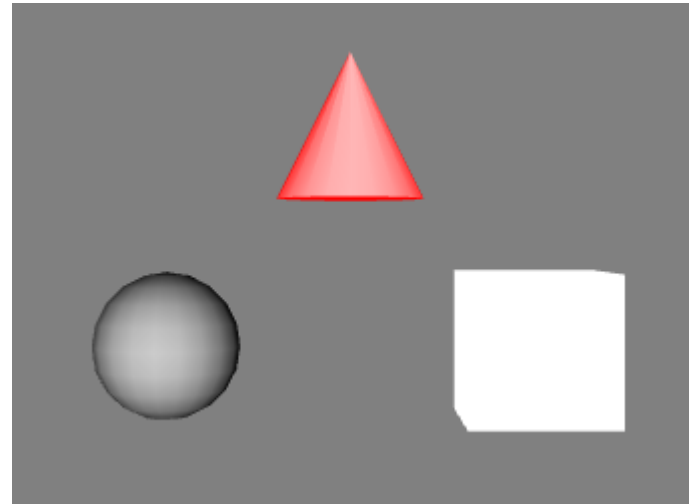
X3D Lighting Model

- Lighting
 - Directional
 - Point
 - Ambient
- X3D specifies a minimum of up to 8 light sources
- No shadows, no direct reflections, no refractions
- A Shape node is unlit if:
 - The shape's *appearance* field is NULL (default)
 - The *material* field in the Appearance node is NULL (default)

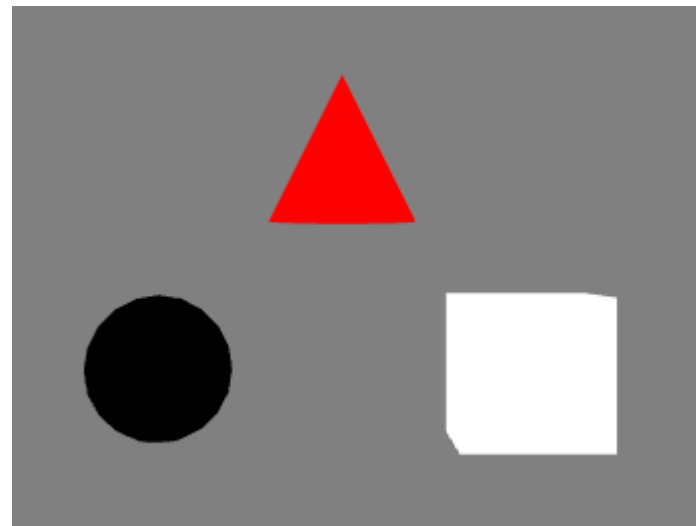
Lit & unlit shapes

```
<Background skyColor="0.50.5 0.5"/>
<Shape>
  <Sphere/>
  <Appearance>
    <Material/>
  </Appearance>
</Shape>
<Transform translation="2.5 3 0">
  <Shape>
    <Cone/>
    <Appearance>
      <Material emissiveColor="1 0 0"/>
    </Appearance>
  </Shape>
</Transform>
<Transform translation="5 0 0">
  <Shape>
    <Box/>
  </Shape>
</Transform>
```

```
<NavigationInfo headlight="true"/>
```



```
<NavigationInfo headlight="false"/>
```



X3DLightNode Type

Type	accessType	Name	Default	Range	Profile
SFFloat	inputOutput	ambientIntensity	0	[0, 1]	Interchange
SFColor	inputOutput	color	1 1 1	[0, 1]	Interchange
SFFloat	inputOutput	intensity	1	[0, 1]	Interchange
SFBool	inputOutput	on	true		Interchange
SFBool	inputOutput	global	false		Interchange
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

X3DBackgroundNode Type

Type	accessType	Name	Default	Range	Profile
MFFloat	inputOutput	groundAngle	[]	$[0, \pi/2]$	Interchange
MFColor	inputOutput	groundColor	[]	$[0, 1]$	Interchange
MFFloat	inputOutput	skyAngle	[]	$[0, \pi]$	Interchange
MFColor	inputOutput	skyColor	0 0 0	$[0, 1]$	Interchange
SFBool	inputOnly	set_bind			Interchange
SFBool	outputOnly	isBound			Interchange
SFTime	outputOnly	bindTime			Interchange
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

DirectionalLight Node

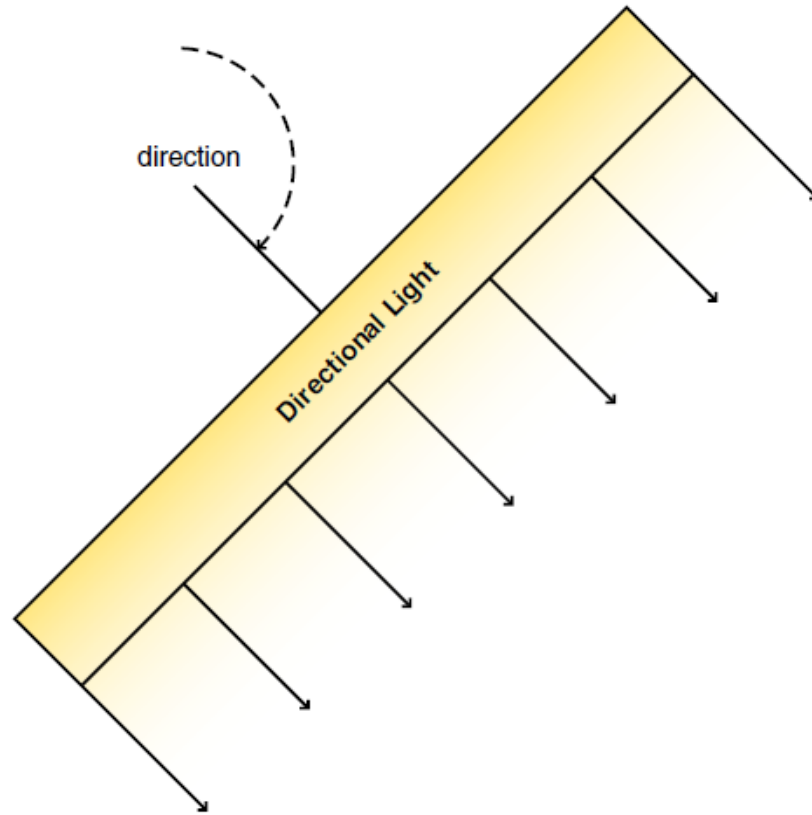
Type	accessType	Name	Default	Range	Profile
SFFloat	inputOutput	ambientIntensity	0	[0, 1]	Interchange
SFColor	inputOutput	color	1 1 1	[0, 1]	Interchange
SFVec3f	inputOutput	direction	0 0 -1	$(-\infty, \infty)$	Interchange
SFFloat	inputOutput	intensity	1	[0, 1]	Interchange
SFBool	inputOutput	on	true		Interchange
SFBool	inputOutput	global	false		Interchange
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

```
<DirectionalLight  
  DEF="MyDirectionalLight"  
  ambientIntensity=".2"  
  color="1 .5 0"  
  direction="-1 0 0"  
  intensity=".7"  
  on="true"  
>
```

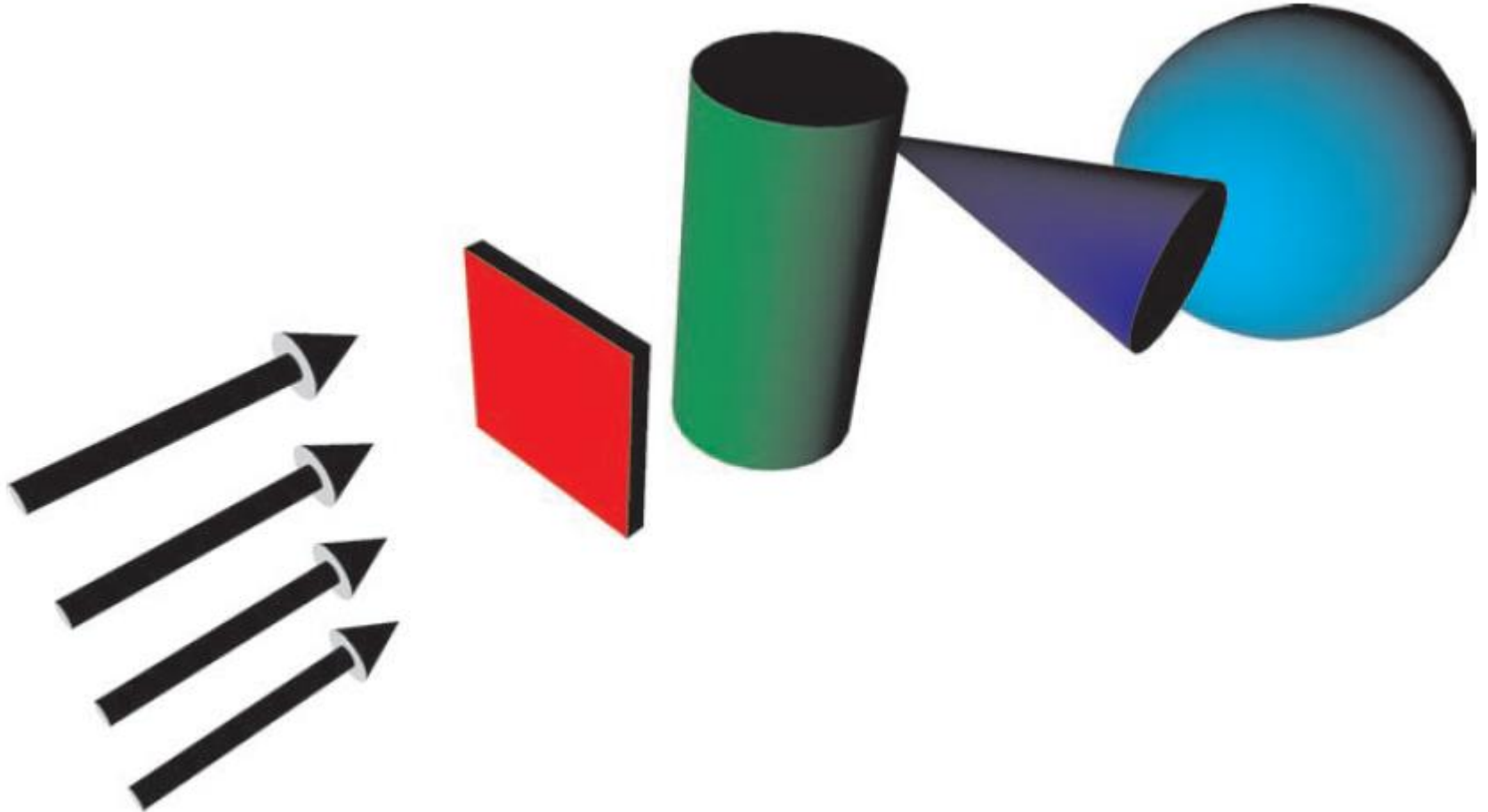
DirectionalLight

- Infinite range
- Infinite area
- No single (x,y,z) source position
- Enclosing in a Transform node only matters in terms of rotation
 - added to the “direction” field

DirectionalLight



DirectionalLight model



headlight field

- A SFBool field in NavigationInfo nodes
- NOT an X3DLightNode type
 - not even a node at all!
- A default DirectionalLight, fixed on the current viewpoint.
- Always
 - intensity="1"
 - color="1 1 1"
 - ambientIntensity="0.0"
 - direction="0 0 -1" (within the local coord. frame)

PointLight Node

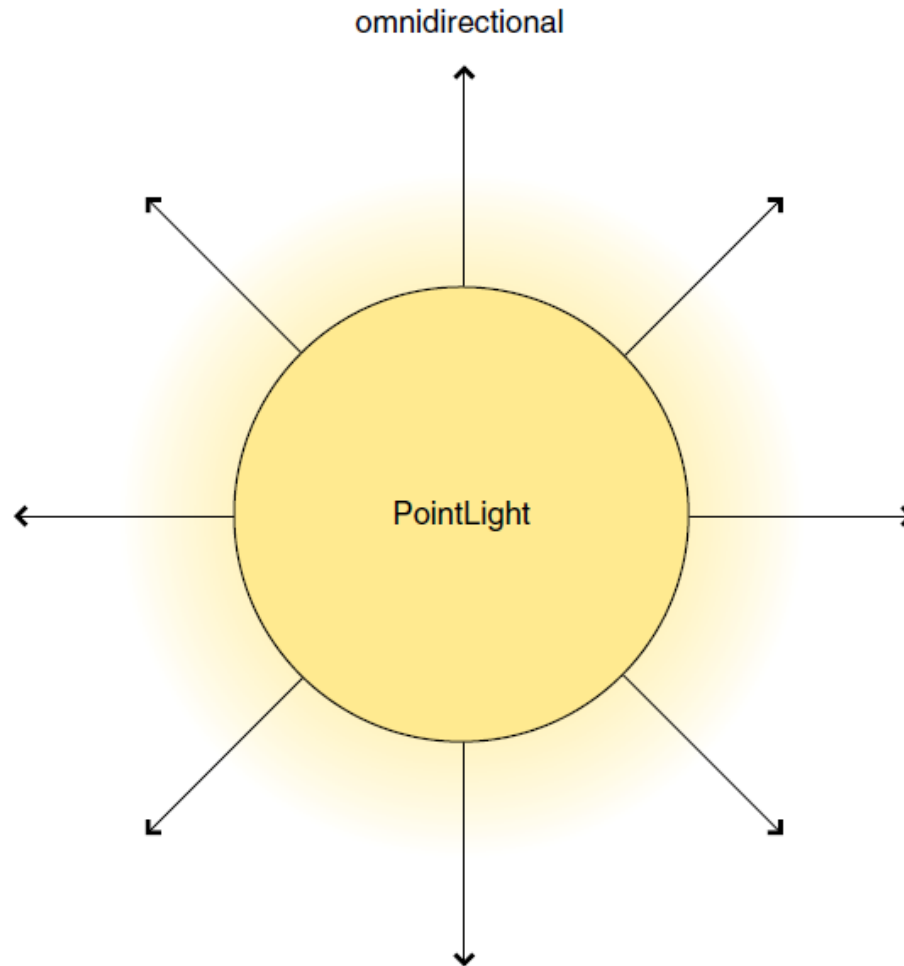
Type	accessType	Name	Default	Range	Profile
SFFloat	inputOutput	ambientIntensity	0	[0, 1]	Interactive
SFVec3f	inputOutput	attenuation	1 0 0	[0, ∞)	Interactive
SFColor	inputOutput	color	1 1 1	[0, 1]	Interactive
SFBool	inputOutput	global	false		Interactive
SFFloat	inputOutput	intensity	1	[0, 1]	Interactive
SFVec3f	inputOutput	location	0 0 0	(-∞, ∞)	Interactive
SFBool	inputOutput	on	true		Interactive
SFBool	inputOutput	radius	100	[0, ∞)	Interactive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

<DirectionalLight

```
  DEF="MyPointLight"  
  ambientIntensity=".3"  
  color="0.5 1 0"  
  direction="-1 0 0"  
  intensity=".7"  
  on="true"
```

/>

PointLight



PointLight attenuation field

*factor=1/max(attenuation[0]+
attenuation[1]×r+
attenuation[2] ×r², 1)*

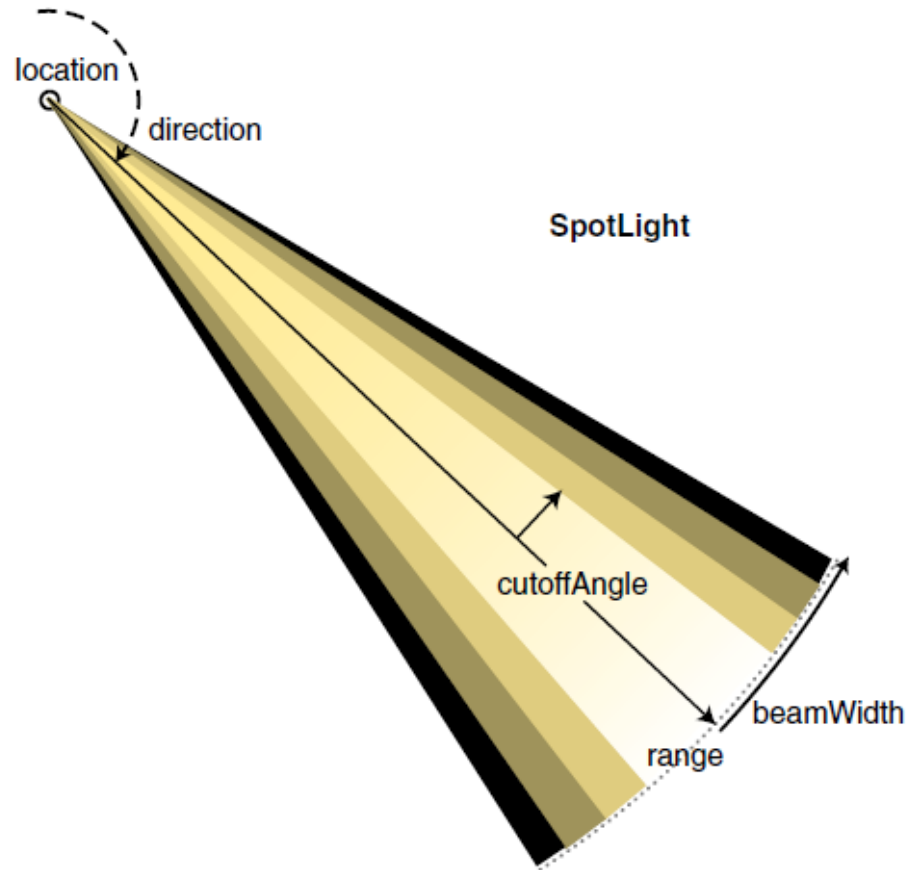
SpotLight Node

Type	accessType	Name	Default	Range	Profile
SFFloat	inputOutput	ambientIntensity	0	[0, 1]	Interactive
SFVec3f	inputOutput	attenuation	1 0 0	[0, ∞)	Interactive
SFFloat	inputOutput	beamWidth	$\pi/2$	[0, $\pi/2$]	Interactive (optional) / Immersive
SFColor	inputOutput	color	1 1 1	[0, 1]	Interactive
SFFloat	inputOutput	cutOffAngle	$\pi/4$	[0, $\pi/2$]	Interactive
SFVec3f	inputOutput	direction	0 0 -1	$[-\infty, \infty]$	Interactive
SFBool	inputOutput	global	false		Interactive
SFFloat	inputOutput	intensity	1	[0, 1]	Interactive
SFVec3f	inputOutput	location	0 0 -1	$(-\infty, \infty)$	Interactive
SFBool	inputOutput	on	true		Interactive
SFBool	inputOutput	radius	100	[0, ∞)	Interactive (optional) / Immersive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

SpotLight Node

```
<SpotLight  
  DEF="MySpotLightNode"  
  ambientIntensity="0"  
  attenuation="1 0 0"  
  beamWidth="1.57"  
  color= "1 1 1"  
  cutOffAngle="0.78"  
  direction="0 0 -1"  
  global="true"  
  intensity="1"  
  on="true"  
  radius="100"  
>
```

Spotlight parameters



SpotLight fall-off



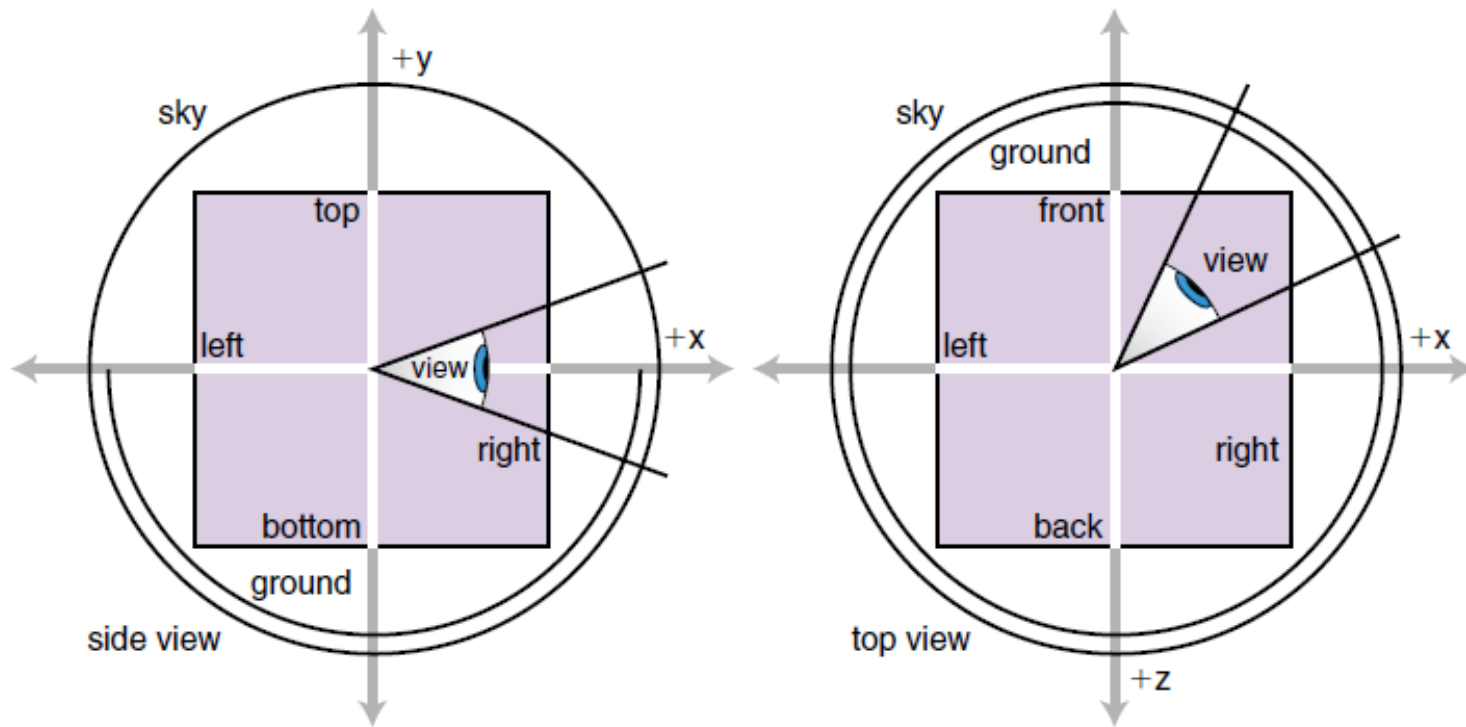
Background Node

Type	accessType	Name	Default	Range	Profile
MFFloat	inputOutput	groundAngle	[]	$[0, \pi/2]$	Interactive (optional)
MFColor	inputOutput	groundColor	[]	$[0, 1]$	»
MFFloat	inputOutput	skyAngle	[]	$[0, \pi]$	Interactive
MFColor	inputOutput	skyColor	0 0 0	$[0, 1]$	Interactive
MFString	inputOutput	leftUrl		[urn]	Interactive (optional)
MFString	inputOutput	rightUrl		[urn]	»
MFString	inputOutput	frontUrl		[urn]	»
MFString	inputOutput	backUrl		[urn]	»
MFString	inputOutput	topUrl		[urn]	»
MFString	inputOutput	bottomUrl		[urn]	»
SFFloat	inputOutput	transparency	0	$[0, 1]$	»
SFBool	inputOnly	set_bind			Interactive
SFBool	outputOnly	isBound			Interactive
SFTime	outputOnly	bindTime			Interactive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

Background Node

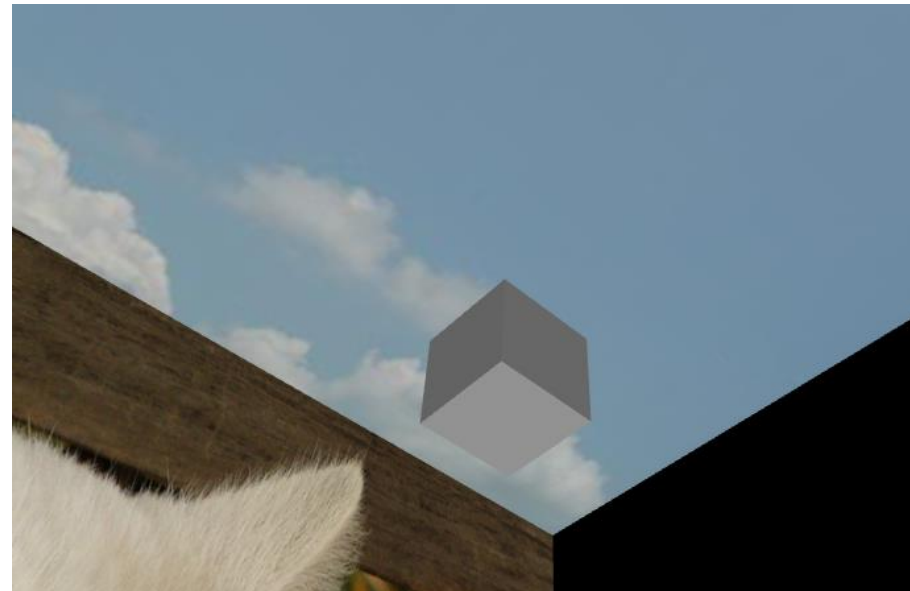
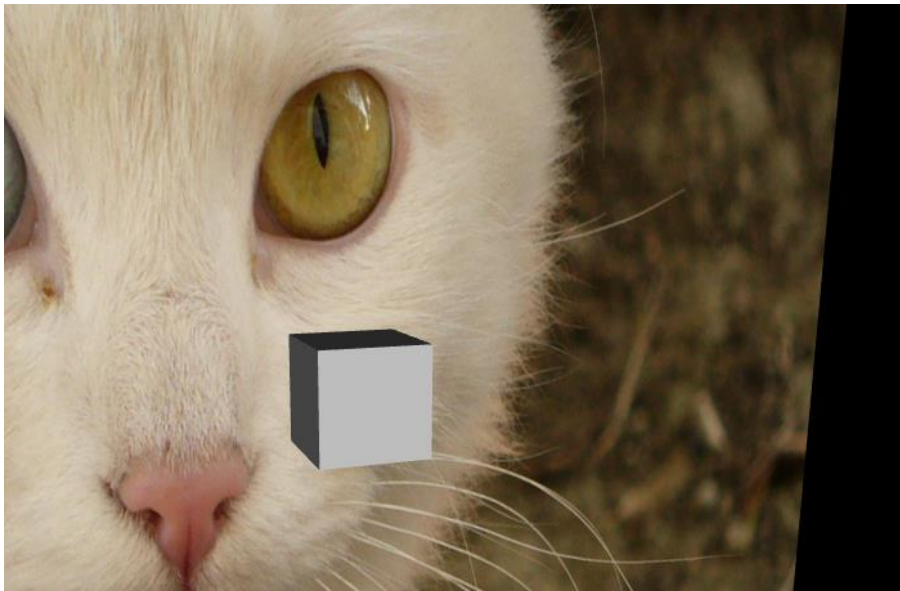
```
<Background  
  DEF="MyBackgroundNode"  
  groundAngle="1.55"  
  groundColor="0 1 0, 0.1 1 0.3"  
  skyAngle"1.45"  
  skyColor="0.7 1 0.7, 0.9 1 0.9"  
  leftUrl="leftImage.png"  
  rightUrl="rightImage.png"  
  frontUrl="frontImage.png"  
  backUrl="backImage.png"  
  topUrl="topImage.png"  
  bottomUrl="bottomImage.png"  
>
```

Background colors and images placement



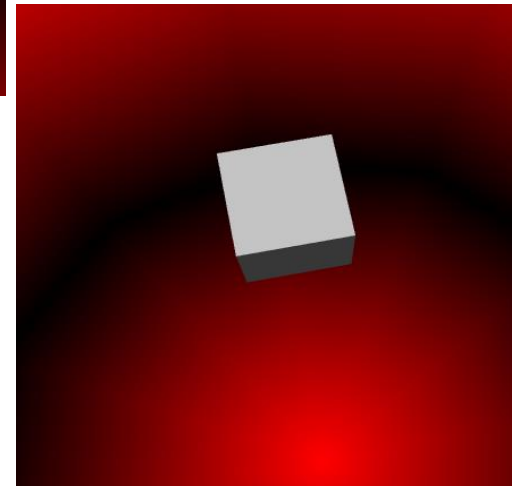
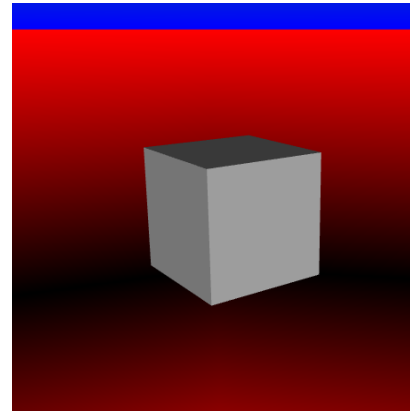
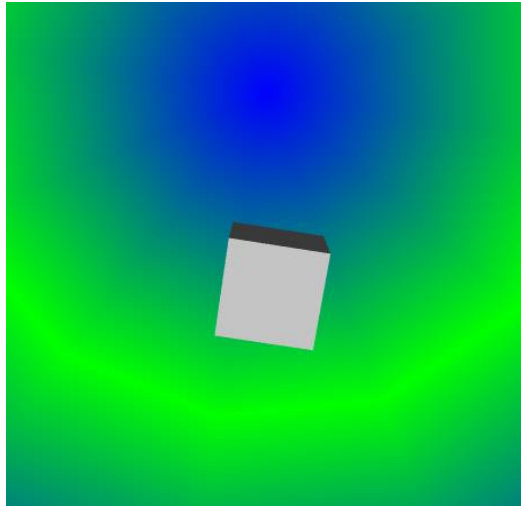
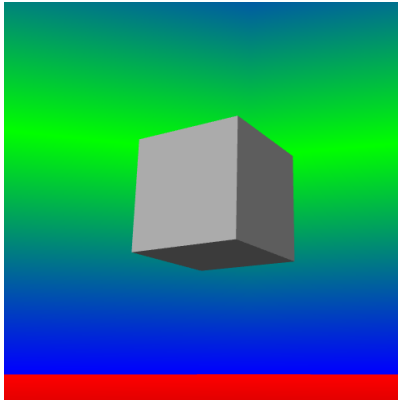
Background colors and images placement

```
<Scene>  
<Background frontUrl='cat.jpg' topUrl='sky.jpg' bottomUrl='dog.jpg'/>  
<Shape>  
  <Box/>  
  <Appearance> <Material/> </Appearance>  
</Shape>  
</Scene>
```



Background colors and images placement

```
<Background skyAngle="0.4 0.8 1.2 1.57"  
skyColor="0 0 1, 0 1 0, 0 0 1, 0 1 0, 0 0 1"  
groundAngle="0.4 0.8 1.2 1.57"  
groundColor="1 0 0, 0 0 0, 1 0 0, 0 0 0, 1 0 0" />  
<Shape> <Box/> <Appearance> <Material/> </Appearance> </Shape>
```



TextureBackground Node

Type	accessType	Name	Default	Range	Profile
SFFloat	inputOutput	transparency	0	[0, 1]	Full
MFFloat	inputOutput	groundAngle	[]	[0, $\pi/2$]	Full
MFColor	inputOutput	groundColor	[]	[0, 1]	Full
MFFloat	inputOutput	skyAngle	[]	[0, π]	Full
MFColor	inputOutput	skyColor	0 0 0	[0, 1]	Full
MFString	inputOutput	leftTexture	NULL	[X3DTextureNode]	Full
MFString	inputOutput	rightTexture	NULL	[X3DTextureNode]	Full
MFString	inputOutput	frontTexture	NULL	[X3DTextureNode]	Full
MFString	inputOutput	backTexture	NULL	[X3DTextureNode]	Full
MFString	inputOutput	topTexture	NULL	[X3DTextureNode]	Full
MFString	inputOutput	bottomTexture	NULL	[X3DTextureNode]	Full
SFBool	inputOnly	set_bind			Full
SFBool	outputOnly	isBound			Full
SFTime	outputOnly	bindTime			Full
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

TextureBackground Node

```
<TextureBackground
  DEF="MyTextureBackgroundNode"
  transparency="0"
  groundAngle="1.55"
  groundColor="0 1 0, 0.1 1 0.3"
  skyAngle"1.45"
  skyColor="0.7 1 0.7, 0.9 1 0.9">
  <ImageTexture containerField="leftTexture" url=' "leftImage.png" '/>
  <ImageTexture containerField="rightTexture" url=' "rightImage.png" '/>
  <ImageTexture containerField="frontTexture" url=' "frontImage.png" '/>
  <ImageTexture containerField="backTexture" url=' "backImage.png" '/>
  <ImageTexture containerField="topTexture" url=' "topImage.png" '/>
  <ImageTexture containerField="bottomTexture" url=' "bottomImage.png" '/>
/TextureBackground>
```

Fog Node

Type	accessType	Name	Default	Range	Profile
SFColor	inputOutput	color	1 1 1		Full
SFString	inputOutput	fogType	"LINEAR"	["LINEAR" "EXPONENTIAL"]	Full
SFFloat	inputOutput	visibilityRange	0	[0, ∞)	Full
SFBool	inputOnly	set_bind			Full
SFBool	outputOnly	isBound			Full
SFTime	outputOnly	bindTime			Full
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

<Fog

DEF="MyFogNode"

color="1 1 1"

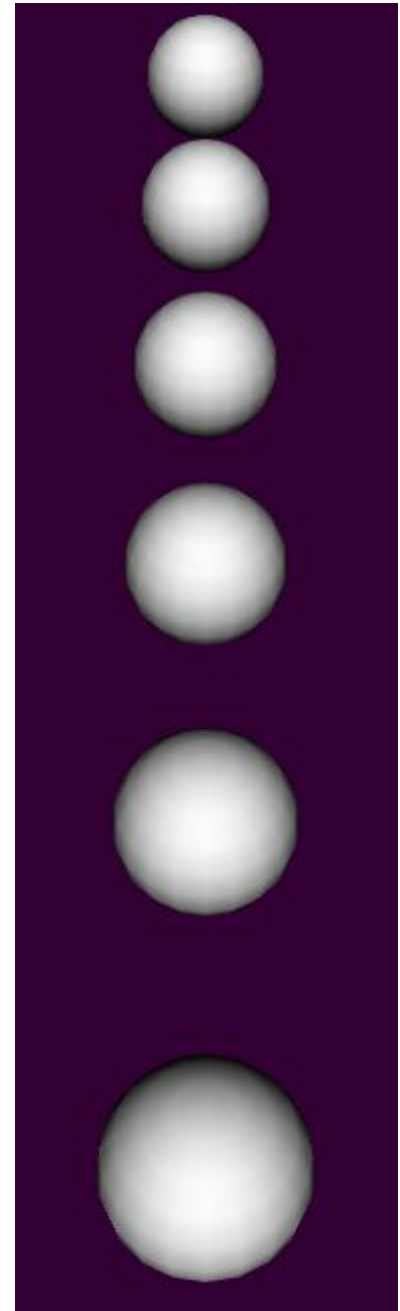
fogType="LINEAR"

visibilityRange="0"

/>

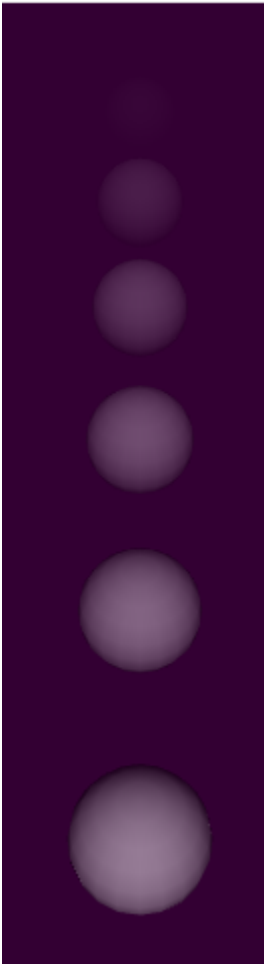
Fog

```
<Scene>  
<Viewpoint position="0 15 0"  
    orientation="1 0 0 -0.8"/>  
<Background skyColor="0.2 0 0.2"/>  
<Shape DEF="SampleShape">  
    <Sphere/><Appearance>  
    <Material diffuseColor="1 1 1"/>  
    </Appearance>  
</Shape>  
<Transform translation="0 0 -4">  
<Shape USE="SampleShape"/>  
<Transform translation="0 0 -4">  
<Shape USE="SampleShape"/>  
[...]  
</Transform>  
</Transform>  
[...]  
</Transform>  
</Scene>
```

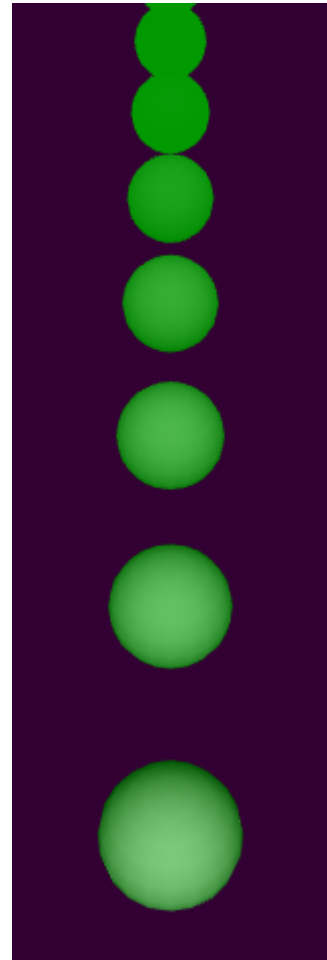


Fog

```
<Fog color="0.2 0 0.2"  
visibilityRange="30"/>
```



```
<Fog color="0 0.6 0"  
visibilityRange="30"/>
```



Lecture 5 Addendum: Moving objects through arrow keys (I)

```
<NavigationInfo type="NONE"/> <KeySensor DEF="MyKeySensor"/>
<Transform DEF="MyTransf" rotation="0.8 -1 0 0.7" >
  <Shape> <Box/> <Appearance> <Material/> </Appearance> </Shape> </Transform>
<Script DEF='KeyToBoolMappingScript' directOutput='true'>
  <field accessType='inputOnly' name='keyPressedCode' type='SFInt32'/>
  <field accessType='outputOnly' name='CurrentPosition' type='SFVec3f'/>
  <![CDATA[ecmascript:
function keyPressedCode (value) { switch (value) {
case 17: CurrentPosition[1]=CurrentPosition[1]+0.2; break;
case 18: CurrentPosition[1]=CurrentPosition[1]-0.2; break;
case 19: CurrentPosition[0]=CurrentPosition[0]-0.2; break;
case 20: CurrentPosition[0]=CurrentPosition[0]+0.2; break; } } ]]> </Script>
<ROUTE fromNode="MyKeySensor" fromField="actionKeyPress"
  toNode="KeyToBoolMappingScript" toField="keyPressedCode"/>
<ROUTE fromNode="KeyToBoolMappingScript" fromField="CurrentPosition"
  toNode="MyTransf" toField="translation"/>
```

Lecture 5 Addendum: Moving objects through arrow keys (II)

```
<NavigationInfo type="NONE"/> <KeySensor DEF="MyKeySensor"/>
<Transform DEF="MyTransf" rotation="0.8 -1 0 0.7" >
  <Shape> <Box/> <Appearance> <Material/> </Appearance> </Shape> </Transform>
<Script DEF='KeyToBoolMappingScript' directOutput='true'>
  <field accessType='inputOnly' name='keyPressedCode' type='SFInt32'/>
  <field accessType='initializeOnly' name='ObjectMove' type='SFNode'>
    <Transform USE="MyTransf"/> </field>
  <![CDATA[ecmascript:
function keyPressedCode (value) { switch (value) {
case 17: ObjectMove.translation[1]=ObjectMove.translation[1]+0.2; break;
case 18: ObjectMove.translation[1]=ObjectMove.translation[1]-0.2; break;
case 19: ObjectMove.translation[0]=ObjectMove.translation[0]-0.2; break;
case 20: ObjectMove.translation[0]=ObjectMove.translation[0]+0.2; break; } } ]]>
</Script>
<ROUTE fromNode="MyKeySensor" fromField="actionKeyPress"
toNode="KeyToBoolMappingScript" toField="keyPressedCode"/>
```

Environment Sensor and Sound

- Abstract node types
 - X3DEnvironmentSensorNode Type
 - X3DNetworkSensor Type
 - X3DSoundNode Type
 - X3DSoundSourceNode Type
- Nodes
 - LoadSensor Node
 - ProximitySensor Node
 - VisibilitySensor Node
 - Sound Node
 - AudioClip Node

X3DEnvironmentSensorNode type

Type	accessType	Name	Default	Range	Profile
SFVec3f	inputOutput	center	0 0 0	$(-\infty, \infty)$	Interactive
SFVec3f	inputOutput	size	0 0 0	$[0, \infty)$	Interactive
SFBool	inputOutput	enabled	true		Interactive
SFBool	outputOnly	isActive			Interactive
SFTime	outputOnly	enterTime			Interactive
SFTime	outputOnly	exitTime			Interactive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

X3DNetworkSensorNode type

Type	accessType	Name	Default	Range	Profile
SFBool	inputOutput	enabled	true		Interactive
SFBool	outputOnly	isActive			Interactive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

X3DSoundNode type

Type	accessType	Name	Default	Range	Profile
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

X3DSoundSourceNode type

Type	accessType	Name	Default	Range	Profile
SFString	inputOutput	description	""	$(-\infty, \infty)$	Immersive
SFBool	inputOutput	loop	false	$[0, \infty)$	Immersive
SFTime	inputOutput	pitch	1.0		Immersive
SFTime	inputOutput	pauseTime	0		Immersive
SFTime	inputOutput	resumeTime	0		Immersive
SFTime	inputOutput	startTime	0		Immersive
SFTime	inputOutput	stopTime	0	[X3DMetadataObject]	Immersive
MFString	inputOutput	url	""		Immersive
SFTime	outputOnly	duration_changed			Immersive
SFTime	outputOnly	elapsedTime			Immersive
SFBool	outputOnly	isActive			Immersive
SFBool	outputOnly	isPaused			Immersive
SFNode	inputOutput	metadata	NULL		Core

LoadSensor Node

Type	accessType	Name	Default	Range	Profile
SFBool	inputOutput	enabled	true		Immersive
SFTime	inputOutput	timeOut	0	[0, ∞)	Immersive
MFNode	inputOutput	watchList	[]	[X3DUrlObject]	Immersive
SFBool	outputOnly	isActive			Immersive
SFBool	outputOnly	isLoaded			Immersive
SFTime	outputOnly	loadTime			Immersive
SFFloat	outputOnly	progress		[0,1]	Immersive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

```

<LoadSensor DEF="MyLoadSensor"
  enabled="true"
  timeOut="100">
  <ImageTexture USE="TextureNode1"
    containerField="watchList"/>
  <AudioClip USE="AudioNode2"
    containerField="watchList"/>
  <Inline USE="InlineScene3"
    containerField="watchList"/>
</LoadSensor>

```

ProximitySensor

Type	accessType	Name	Default	Range	Profile
SFVec3f	inputOutput	center	0 0 0	$(-\infty, \infty)$	Interactive
SFVec3f	inputOutput	size	0 0 0	$[0, \infty)$	Interactive
SFBool	inputOutput	enabled	true		Interactive
SFBool	outputOnly	isActive			Interactive
SFTime	outputOnly	enterTime			Interactive
SFTime	outputOnly	exitTime			Interactive
SFVec3f	outputOnly	centerOfRotation_changed			Interactive
SFRotation	outputOnly	orientation_changed			Interactive
SFVec3f	outputOnly	position_changed			Interactive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

<ProximitySensor

DEF="MyProximitySensor"

center="10 20 30"

size="40 40 40"/>

VisibilitySensor node

Type	accessType	Name	Default	Range	Profile
SFVec3f	inputOutput	center	0 0 0	$(-\infty, \infty)$	Interactive
SFVec3f	inputOutput	size	0 0 0	$[0, \infty)$	Interactive
SFBool	inputOutput	enabled	true		Interactive
SFBool	outputOnly	isActive			Interactive
SFTime	outputOnly	enterTime			Interactive
SFTime	outputOnly	exitTime			Interactive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

<VisibilitySensor

DEF="MyVisibilitySensor"

center="10 20 30"

size="10 8 4" />

Collision Node

Type	accessType	Name	Default	Range	Profile
SFBool	inputOutput	enabled		true	Immersive
SFTime	inputOutput	collideTime			Immersive
SFBool	outputOnly	isActive			Immersive
SFNode	initializeOnly	proxy	NULL	Shape or X3DChildNode	Immersive
MFNode	inputOutput	children	[]	[X3DChildNode]	Immersive
MFNode	inputOnly	addChildren	[]	[X3DChildNode]	Immersive
MFNode	inputOnly	removeChildren	[]	[X3DChildNode]	Immersive
SFVec3f	initializeOnly	bboxCenter	0 0 0	$(-\infty, \infty)$	Immersive
SFVec3f	initializeOnly	bboxSize	-1 -1 -1	$[0, \infty)$ or -1 -1 -1	Immersive
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

Collision Node

```
<Collision DEF="MyCollisionNode"  
  enabled="true"  
  bboxCenter="0 0 0"  
  bboxSize="-1 -1 -1">  
  <Group DEF="MyCollidableGroup"  
    containerField="children"/>  
  <Shape DEF="MyHiddenProxy"  
    containerField="proxy"/>  
</Collision>
```

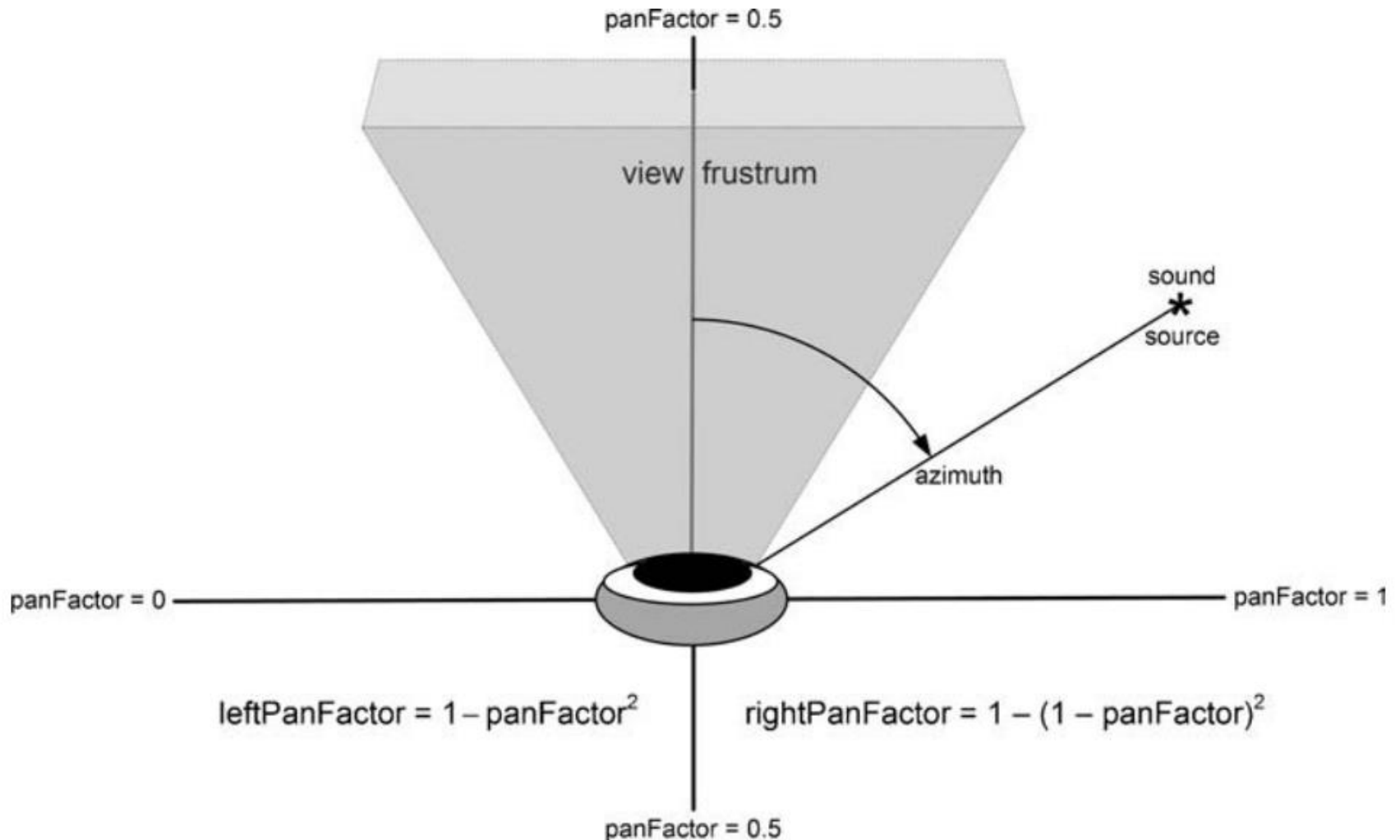
Sound node

Type	accessType	Name	Default	Range	Profile
SFVec3f	inputOutput	location	0 0 0	$(-\infty, \infty)$	Immersive
SFVec3f	inputOutput	direction	0 0 1	$(-\infty, \infty)$	Immersive
SFFloat	inputOutput	intensity	1	[0, 1]	Immersive
SFFloat	inputOutput	priority	0	[0, 1]	Immersive
SFBool	inputOutput	spatialize	true		Immersive
SFFloat	inputOutput	minFront	1	[0, ∞)	Immersive
SFFloat	inputOutput	minBack	1	[0, ∞)	Immersive
SFFloat	inputOutput	maxFront	10	[0, ∞)	Immersive
SFFloat	inputOutput	maxBack	10	[0, ∞)	Immersive
SFNode	inputOutput	source	NULL	[X3DSoundSourceNode]	
SFNode	inputOutput	metadata	NULL	[X3DMetadataObject]	Core

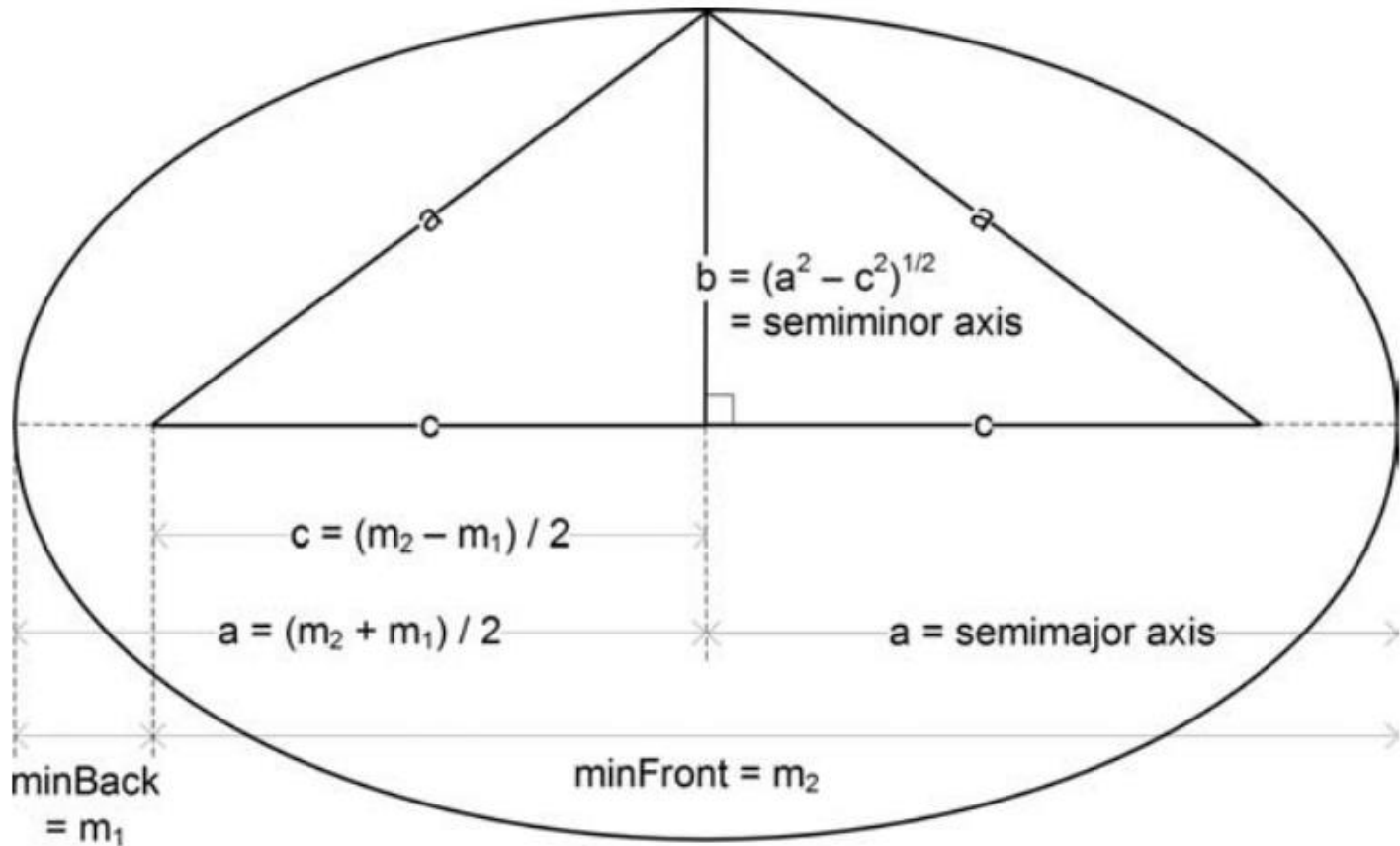
Sound node

```
<Sound DEF="MySoundNode"  
  location="0 0 0"  
  direction="0 0 1"  
  intensity="1"  
  priority="0"  
  spatialize="true"  
  minFront="1"  
  minBack="1"  
  maxFront="10"  
  maxBack="10">  
    <AudioClip containerField="source"/>  
</Sound>
```

Stereo panning – 3D directional attenuation



Ellipse semiminor axis



Example values for this diagram:

$\text{minBack}=1$ and $\text{minFront}=9$ produce ellipse $a=5$, $b=3$, $c=4$

minHalfWidth and maxHalfWidth

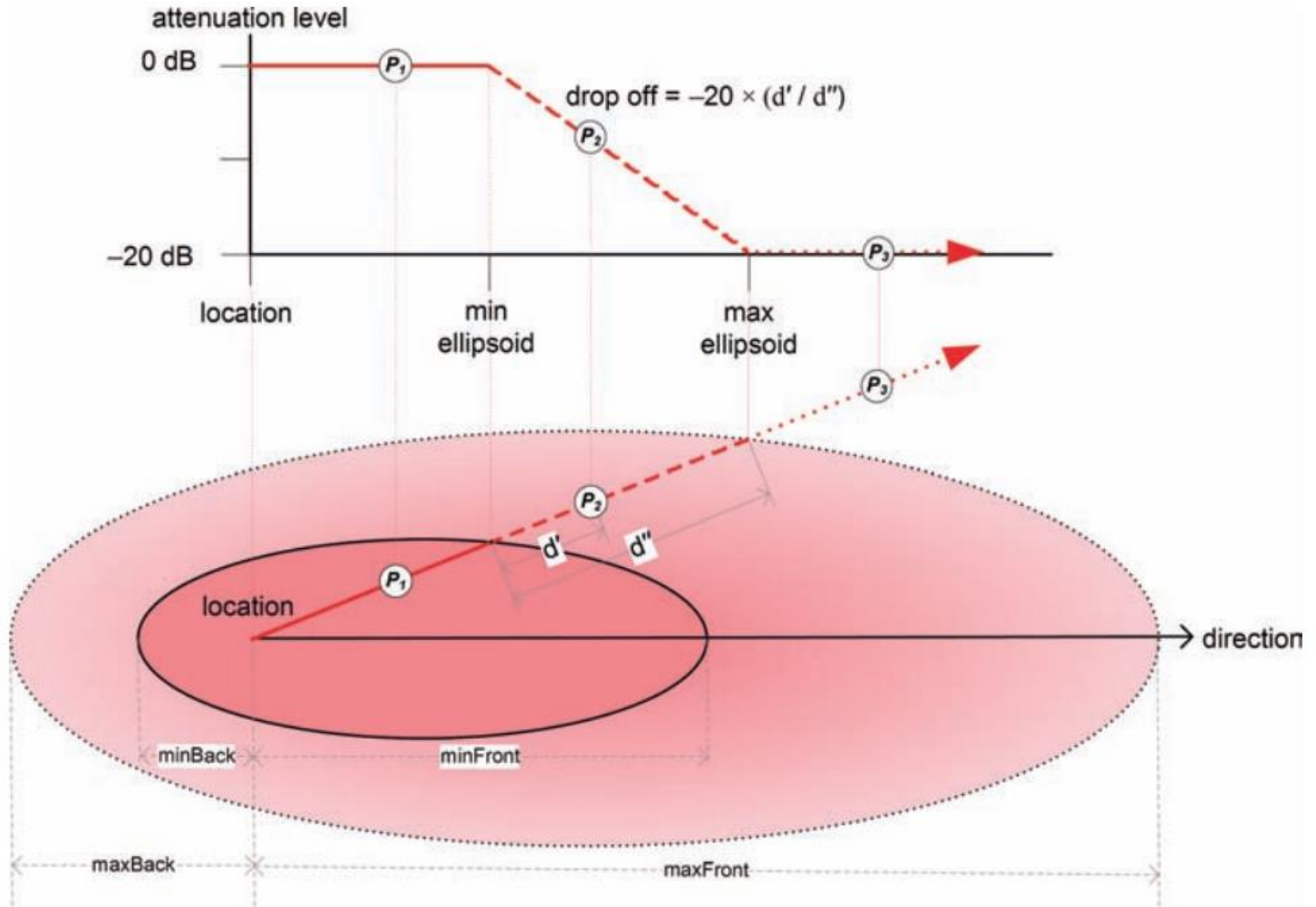
$$\begin{aligned} \text{minHalfWidth} &= b_{\min} = \sqrt{a^2 - c^2} \\ &= \sqrt{\left[\frac{m_1 + m_2}{2}\right]^2 - \left[\frac{m_1 - m_2}{2}\right]^2} \\ &= \frac{1}{2} \sqrt{m_1^2 + 2m_1m_2 + m_2^2 - (m_1^2 - 2m_1m_2 + m_2^2)} \\ &= \frac{1}{2} \sqrt{2m_1m_2 + 2m_1m_2} \\ &= \frac{1}{2} (2) \sqrt{m_1m_2}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

$$\text{minHalfWidth} = \sqrt{\text{minBack} \cdot \text{minFront}}$$

similarly

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

Attenuation ellipsoids



AudioClip node

Type	accessType	Name	Default	Range	Profile
SFString	inputOutput	description	""	$(-\infty, \infty)$	Immersive
SFBool	inputOutput	loop	false	$[0, \infty)$	Immersive
SFTime	inputOutput	pitch	1.0		Immersive
SFTime	inputOutput	pauseTime	0		Immersive
SFTime	inputOutput	resumeTime	0		Immersive
SFTime	inputOutput	startTime	0		Immersive
SFTime	inputOutput	stopTime	0	[X3DMetadataObject]	Immersive
MFString	inputOutput	url	""		Immersive
SFTime	outputOnly	duration_changed			Immersive
SFTime	outputOnly	elapsedTime			Immersive
SFBool	outputOnly	isActive			Immersive
SFBool	outputOnly	isPaused			Immersive
SFNode	inputOutput	metadata	NULL		Core

```
<AudioClip DEF="MyAudioClipNode"
  description="a sound file"
  url=' "Hello.wav" "http://x3dGraphics.com/audio/Hello.wav"'
  loop="true"
```

```
/>
```