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1 Efforts to Improve X3D Audio

1.1 Audio in X3D ISO

Spatial sound has a conceptual role in the Web3D environments, due to highly realism scenes that can provide. Since Web Audio API is the most popular sound engine, we propose to get the necessary steps required to make X3D fully compatible with this library.

Particularly, two types of nodes are included in the X3D, the first is about the sound description and the other one for the sound source. Specifically, the first node is the **X3DSoundNode**, which is an abstract node for all sound nodes. It is minimalist with only one attribute, *metadata*, which expresses important information for the significance, appearance and the proposed role of the model. The second node is the **X3DSoundSourceNode**, which is the abstract node for each node that is used to emit sound and it has a number of common fields with the *TimeSensor*, for example the *loop*, the *startTime*, the *stopTime*, the *pauseTime* and *resumeTime* (see Figure 1).

<pre>X3DSoundNode X3DSoundNode : X3DChildNode { SFNode [in,out] metadata NULL [X3DMetadataObject] }</pre>	<pre>X3DSoundSourceNode X3DSoundSourceNode : X3DTimeDependentNode { SFString [in,out] description "" SFBool [in,out] loop FALSE SFNode [in,out] metadata NULL [X3DMetadataObject] SFTime [in,out] pauseTime 0 (-∞,∞) SFFloat [in,out] pitch 1.0 (0,∞) SFTime [in,out] resumeTime 0 (-∞,∞) SFTime [in,out] startTime 0 (-∞,∞) SFTime [in,out] stopTime 0 (-∞,∞) SFTime [out] duration_changed SFTime [out] elapsedTime SFBool [out] isActive SFBool [out] isPaused }</pre>
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Figure 1: X3DSoundNode - X3DSoundSourceNode in X3D

The third node is the **Sound**, which is derived from the X3DSoundNode. It is designed for the description of the X3D scene sounds. Specifically, it determines both the location and the behaviour of the sound. Additionally, the geometry describes that the sound can be directed and be emitted in an elliptical pattern. Two ellipsoids constitute the pattern, which specifies the borders for level of loudness of the sound. Also, ellipsoids can be reshaped in order to provide more or less directional focus from the location of the sound. Consequently, the sound node is intended to recognize the source and is related to the direction, the location, the priority and general, the spatial features of the sound source (see Figure 2).

<pre>Sound Sound : X3DSoundNode { SFVec3f [in,out] direction 0 0 1 (-∞,∞) SFFloat [in,out] intensity 1 [0,1] SFVec3f [in,out] location 0 0 0 (-∞,∞) SFFloat [in,out] maxBack 10 [0,∞) SFFloat [in,out] maxFront 10 [0,∞) SFNode [in,out] metadata NULL [X3DMetadataObject] SFFloat [in,out] minBack 1 [0,∞) SFFloat [in,out] minFront 1 [0,∞) SFFloat [in,out] priority 0 [0,1] SFNode [in,out] source NULL [X3DSoundSourceNode] SFBool [] spatialize TRUE }</pre>	<pre>AudioClip AudioClip : X3DSoundSourceNode, X3DUrlObject { SFString [in,out] description "" SFBool [in,out] loop FALSE SFNode [in,out] metadata NULL [X3DMetadataObject] SFTime [in,out] pauseTime 0 (-∞,∞) SFFloat [in,out] pitch 1.0 (0,∞) SFTime [in,out] resumeTime 0 (-∞,∞) SFTime [in,out] startTime 0 (-∞,∞) SFTime [in,out] stopTime 0 (-∞,∞) MFString [in,out] url [] [URI] SFTime [out] duration_changed SFTime [out] elapsedTime SFBool [out] isActive SFBool [out] isPaused }</pre>
--	--

Figure 2: Sound-AudioClip in X3D

The fourth node is the **AudioClip**, which is derived from the X3DSoundSourceNode. It specifies audio data that can be referenced by Sound nodes. Basically, it loads an external audio file with a view to handle playing, stopping and starting (see Figure 2). As regard the attributes, AudioClip has a number of fields in common with TimeSensor, because it is an X3DSoundSourceNode and implements the X3DTimeDependentNode abstract type. Basically, the fields of the sound nodes and their interrelation are presented in Figure 3 by an interpretive hierarchic diagram.

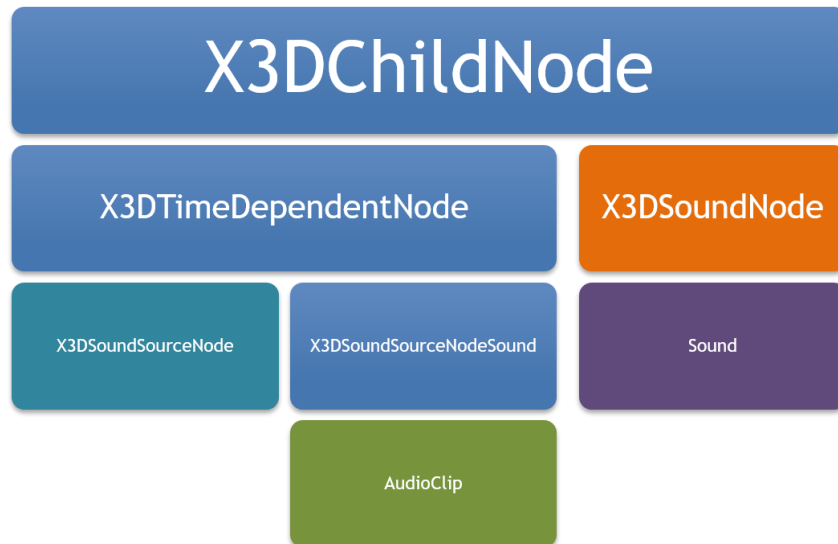


Figure 3: Inheritance diagram of Audio nodes in X3D

1.1 Proposal to Improve X3D Sound Component – Introduction of Web Audio API components

The X3D comprises a fundamental part in the 3D web development. At the same time, the spatial sound should be an integral part of an immersive 3D application, due to the fact that it can improve the sense of realism and the immersion both in complex acoustic environments and dynamic virtual scenes. Based on that, we propose the enrichment of X3D with spatial sound features, using the structure and the functionality of Web Audio API.

Particularly, the Web Audio API involves handling audio operations inside an audio context (AudioContext node) and has been designed to allow modular routing. Particularly, the approach of Web Audio API is based on the concept of audio context, which presents the direction of audio stream flows, between sound nodes (AudioNode).

A simple, typical workflow for web audio API¹ is presented in Figure 4.

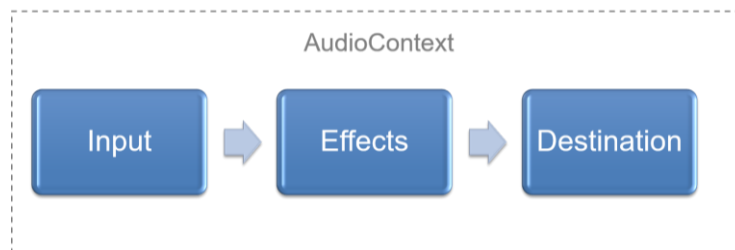


Figure 4: A simple example of modular routing¹

Taking to account all the above together, the proposed method is the registration of a new node, under the X3D Sound node, with the name AudioClip. This node can be used as parent of the AudioNode, which can have all the supported interfaces/nodes of Web Audio API (Figure 5 and Figure 6).

¹ https://developer.mozilla.org/en-US/docs/Web/API/Web_Audio_API

AudioContext: *Sound* {

SFNode [in,out] metadata NULL [X3DMetadataObject]

SFDouble [in, out] latencyHint 0.0 (-∞, ∞) //optional or

SFString [in,out] latencyHint “ ”

SFFloat [in,out] sampleRate 0 (-∞, ∞) //optional

}

The **AudioContext()** constructor creates a new `AudioContext` object which represents an audio processing graph built from audio modules linked together, each represented by an `AudioNode`.

Syntax

```
var audioCtx = new AudioContext();
var audioCtx = new AudioContext(options);
```

Parameters

options | Optional

An object based on the `AudioContextOptions` dictionary that contains zero or more optional properties to configure the new context. Available properties are as follows:

latencyHint | Optional

The type of playback that the context will be used for, as a value from the `AudioContextLatencyCategory` enum or a double-precision floating-point value indicating the preferred maximum latency of the context in seconds. The user agent may or may not choose to meet this request; check the value of `AudioContext.baseLatency` to determine the true latency after creating the context.

sampleRate | Optional

The `sampleRate` to be used by the `AudioContext`, specified in samples per second. The value may be any value supported by `AudioBuffer`. If not specified, the preferred sample rate for the context's output device is used by default.

Figure 5: Registration of AudioContext node (Web Audio API) to X3D ([link](#))

AudioNode: *AudioContext* {

SFNode [in,out] metadata NULL [X3DMetadataObject]

SFInt32 [in,out] numberOfInputs 0

SFInt32 [in,out] numberOfOutputs 0

SFString [in,out] channelCount 0

SFString [in,out] channelCountMode max

SFString [in,out] channelInterpretation speakers

}

The **AudioNode** interface is a generic interface for representing an audio processing module.

Properties

AudioNode.context | [Read only](#)

Returns the associated `BaseAudioContext`, that is the object representing the processing graph the node is participating in.

AudioNode.numberOfInputs | [Read only](#)

Returns the number of inputs feeding the node. Source nodes are defined as nodes having a `numberOfInputs` property with a value of 0.

AudioNode.numberOfOutputs | [Read only](#)

Returns the number of outputs coming out of the node. Destination nodes — like `AudioDestinationNode` — have a value of 0 for this attribute.

AudioNode.channelCount | [Read only](#)

Represents an integer used to determine how many channels are used when up-mixing and down-mixing connections to any inputs to the node. Its usage and precise definition depend on the value of `AudioNode.channelCountMode`.

AudioNode.channelCountMode | [Read only](#)

Represents an enumerated value describing the way channels must be matched between the node's inputs and outputs.

AudioNode.channelInterpretation | [Read only](#)

Represents an enumerated value describing the meaning of the channels. This interpretation will define how audio up-mixing and down-mixing will happen. The possible values are "speakers" or "discrete".

Figure 6: Registration of AudioNode node (Web Audio API) to X3D ([link](#))

All the other interfaces of the Web Audio API ([link](#)) could be derived from the AudioNode (Figure 7).

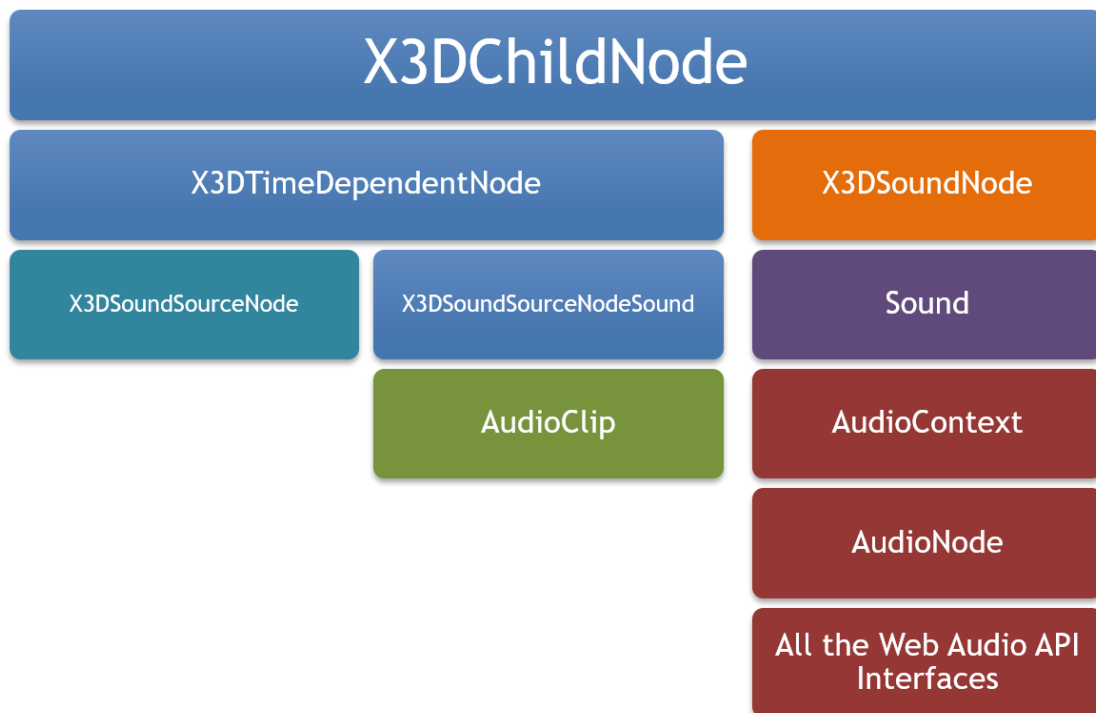


Figure 7: Proposal: Inheritance diagram of enhanced Audio nodes in X3D

2 Extended Efforts in X3D Audio

Many acoustic effects including surface reflection, physical phenomena such as interference and diffraction, the absorption, coefficient of materials should be taken into account, in order to increase the realism of the sound in a web 3D environment. For that reason, the next step, to enrich the X3D sound nodes, is to introduce new acoustical material descriptors. This approach is one of the first to provide sound material characteristics in the web 3D scene.

The following figure demonstrates the most important sound propagation phenomena, in order that the overview of acoustical material descriptors will be understandable.

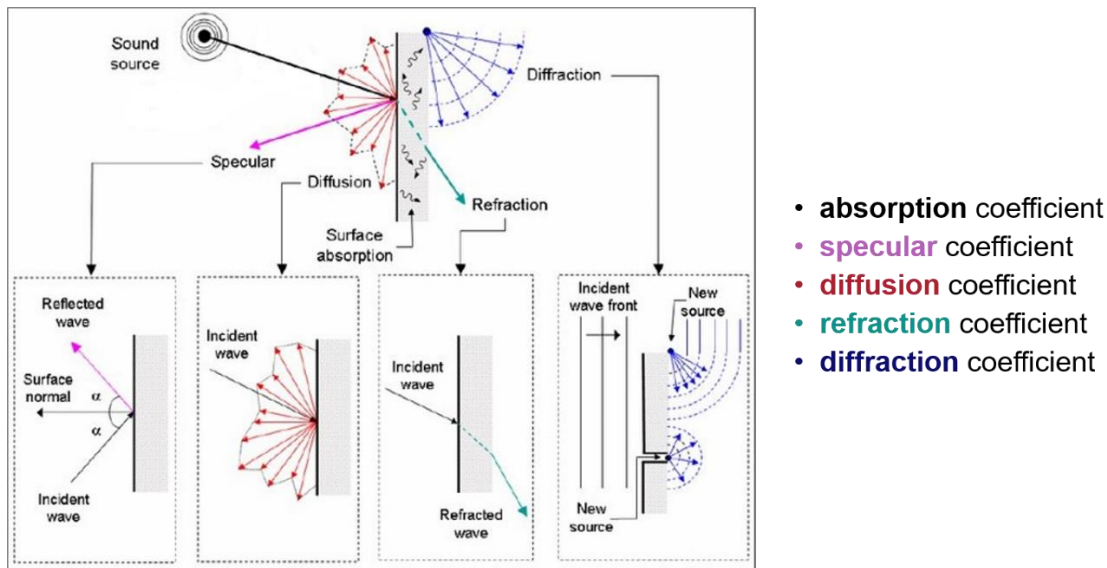


Figure 8: Sound Propagation Phenomena²

2.1 Absorption coefficient

The sound **Absorption Coefficient (a)** of a surface is the ratio of the sound intensity absorbed or otherwise not reflected by a specific surface that of the initial sound intensity. This characteristic depends on nature and thickness of material. Particularly, the sound is absorbed when it encounters fibrous or porous materials, panels that have some flexibility, volumes of air which resonate, openings in the room boundaries (e.g. doorway). Moreover, absorption of sound by a particular material/panel depends on the frequency and angle of incidence of the sound wave.

Some of the typical sound absorbers could be the acoustic panels, membranes, drapes, foams, carpets and can be represent by a variable taking values between zero (zero absorption - total reflection) and one (perfect absorption - no reflection). Absorption coefficients are usually measured in reverberation chambers according to DIN EN ISO standard 354.

2.2 Specular coefficient

The sound **Specular Coefficient (s)** describes specular reflection, one of the physical phenomenon of sound, which occurs when a sound wave strikes a plane surface and a part of the sound energy is reflected back into the space but the angle of reflection is equal to the angle of incidence.

² B. Kapralos, M. Jenkin, and E. Milios, "Sonel Mapping: A Probabilistic Acoustical Modeling Method," Build. Acoust., vol. 15, no. 4, pp. 289–313, Dec. 2008

2.3 Diffuse coefficient

The sound **Diffusion Coefficient (d)** aims to measure the degree of scattering produced on reflection. Specifically, it is produced in the same way as the specular reflection, but in this case, the sound wavelength is comparable with the corrugation dimensions of an irregular reflection surface and the incident sound wave will be scattered in all directions. In other words, it is a measure of the surface's ability to uniformly scatter in all direction. The diffusion coefficient is measured in an anechoic chamber according to the ISO standard 17497-2.

2.4 Refraction coefficient

The sound **Refraction Coefficient (r)** of a medium determines the propagation speed of the wave. This, for a wave travelling from medium one into medium two, then the ratio of the refractive indices is equal to the inverse of the velocity ratios. Furthermore, the sound waves are refracted when parts of a wave front travel at different speeds. This happens in uneven winds or temperatures. Sound waves tend to bend away from warm ground, since it travels faster in warmer air.

2.5 Proposal to Improve X3D Sound Component – Introduction of Acoustical Material Descriptors

Our proposal is not just to customize an environment but instead to fully integrate Web Audio API into X3D language, by introducing new sound nodes and incorporate them in X3D. Specifically, the first approach to improve X3D sound components provides the introduction of the new acoustical material descriptors to **Material** node of X3D. Figure 9 presents the current X3D node of **Material** and the first proposed approach:

```
Material : X3DMaterialNode {  
  SFFloat [in,out] ambientIntensity 0.2 [0,1]  
  SFColor [in,out] diffuseColor 0.8 0.8 0.8 [0,1]  
  SFColor [in,out] emissiveColor 0 0 0 [0,1]  
  SFNode [in,out] metadata NULL [X3DMetadataObject]  
  SFFloat [in,out] shininess 0.2 [0,1]  
  SFColor [in,out] specularColor 0 0 0 [0,1]  
  SFFloat [in,out] transparency 0 [0,1]  
}
```



```
Material : X3DMaterialNode {  
  SFFloat [in,out] ambientIntensity 0.2 [0,1]  
  SFColor [in,out] diffuseColor 0.8 0.8 0.8 [0,1]  
  SFColor [in,out] emissiveColor 0 0 0 [0,1]  
  SFNode [in,out] metadata NULL [X3DMetadataObject]  
  SFFloat [in,out] shininess 0.2 [0,1]  
  SFColor [in,out] specularColor 0 0 0 [0,1]  
  SFFloat [in,out] transparency 0 [0,1]  
  SFFloat [in,out] absorption 0 [0,1]  
  SFFloat [in,out] specular 0 [0,1]  
  SFFloat [in,out] diffuse 0 [0,1]  
  SFFloat [in,out] refraction 0 [0,1]  
}
```

Figure 9: Strategies to Improve X3D Sound Component – 1st Structure

Finally, Figure 10 illustrates the second proposed approach, in which the new acoustical material descriptors is introduced to new **AcousticMaterial** node within **Shape** node of X3D.

```

Shape : X3DShapeNode {
  SFNode [in,out] appearance NULL [X3DAppearanceNode]
  SFNode [in,out] geometry NULL [X3DGeometryNode]
  SFNode [in,out] metadata NULL [X3DMetadataObject]
  SFVec3f [] bboxCenter 0 0 0 (-∞,∞)
  SFVec3f [] bboxSize -1 -1 -1 [0,∞) or -1 -1 -1
}

```



```

Shape : X3DShapeNode {
  SFNode [in,out] appearance NULL [X3DAppearanceNode]
  SFNode [in,out] geometry NULL [X3DGeometryNode]
  SFNode [in,out] metadata NULL [X3DMetadataObject]
  SFVec3f [] bboxCenter 0 0 0 (-∞,∞)
  SFVec3f [] bboxSize -1 -1 -1 [0,∞) or -1 -1 -1
  SFNode [in, out] AcousticMaterial NULL [X3DAcousticMaterial]
}

```

```

AcousticMaterial : X3DAcousticMaterial {
  SFNode [in,out] metadata NULL [X3DMetadataObject]
  SFFloat [in,out] absorption 0 [0,1]
  SFFloat [in,out] specular 0 [0,1]
  SFFloat [in,out] diffuse 0 [0,1]
  SFFloat [in,out] refraction 0 [0,1]
  SFString [in,out] name //Name (and only the name) of the material
  SFString [in,out] description //Detailed description of the material
}

```

Figure 10: Strategies to Improve X3D Sound Component – 2nd Structure