Sound Occlusion and Diffraction Effects

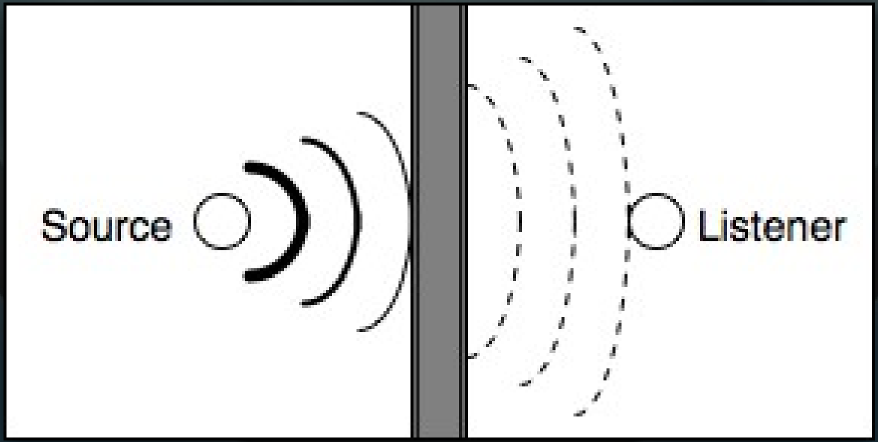
David Thall
Insomniac Games

Overview

- Overview of Sound Occlusion
- Overview of Sound Diffraction
- Fresnel Acoustic Diffraction
- Runtime System
- Future Directions

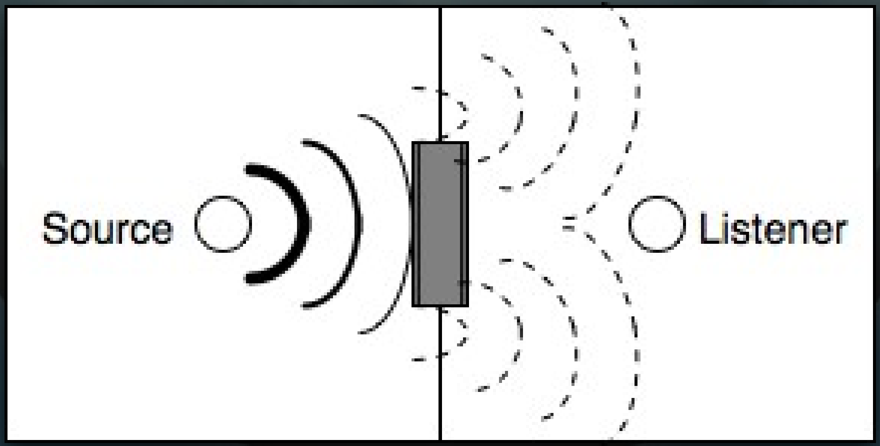
Overview of Sound Occlusion

- Physical
  - The partial absorption of propagating sound waves moving through a transmitting surface.
    - e.g., a window
- Perceptual
  - Attenuation (distance-dependent, surface-dependent)
  - High-Frequency Roll-off (surface-dependent)
  - Phase decorrelation (blurred imaging at high frequencies)



Overview of Sound Diffraction

- Physical
  - The partial absorption of propagating sound waves bending around the edges of an obstructing (or transmitting) surface.
    - e.g., a boulder
- Perceptual
  - Attenuation (distance-dependent, direction-dependent)
  - High-Frequency Roll-off (direction-dependent)
  - Enhanced direct path ITD (Inter-aural Time Difference)



Fresnel Acoustic Diffraction Principle

- Every point on a source's primary wavefront can be thought of as a continuous, direction-dependent emitter of secondary sources that combine to produce a new wavefront in the direction of propagation.

d = distance in units to zone z1

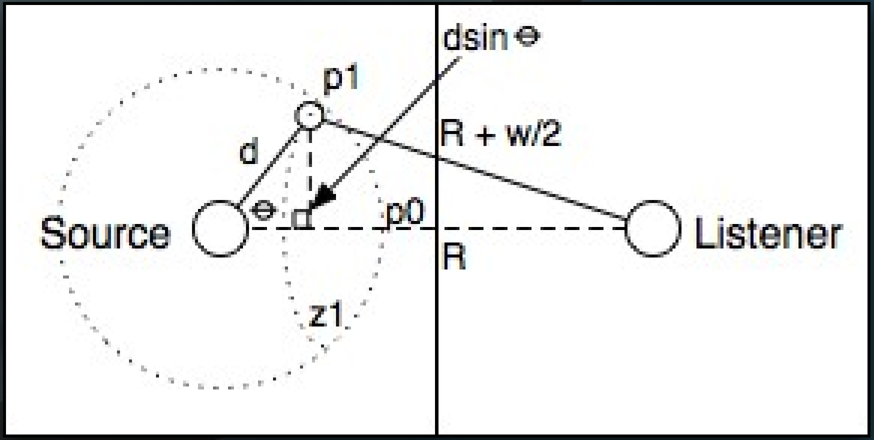
R = source to listener distance

w/2 = half wave length (π rads)

p0 = first ray/sphere intersect

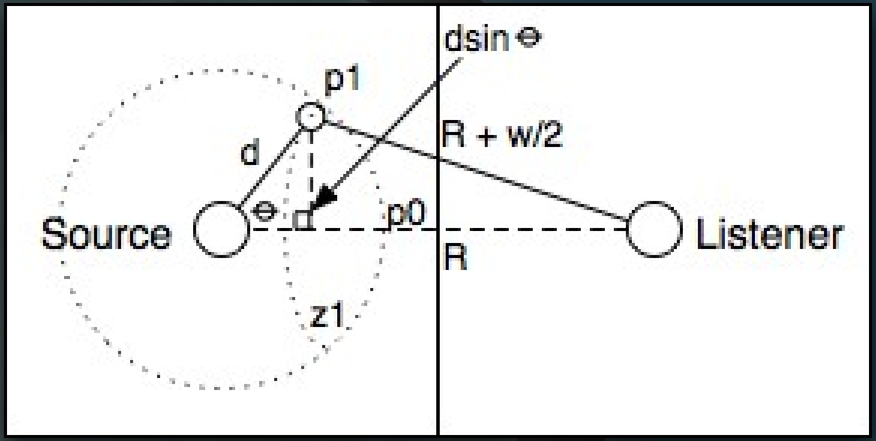
p1 = a single, projected emitter

theta = angle to p1



Fresnel Acoustic Diffraction Zones and Emitters

- For a given primary sound source, we can project N secondary emitters Pn across the surface of a sphere of radius d.
- Each of the N secondary emitters has the following attributes:
  - equidistant from the primary sound source
  - scaled by a common inclination factor
  - phase-locked with respect others in the same zone.



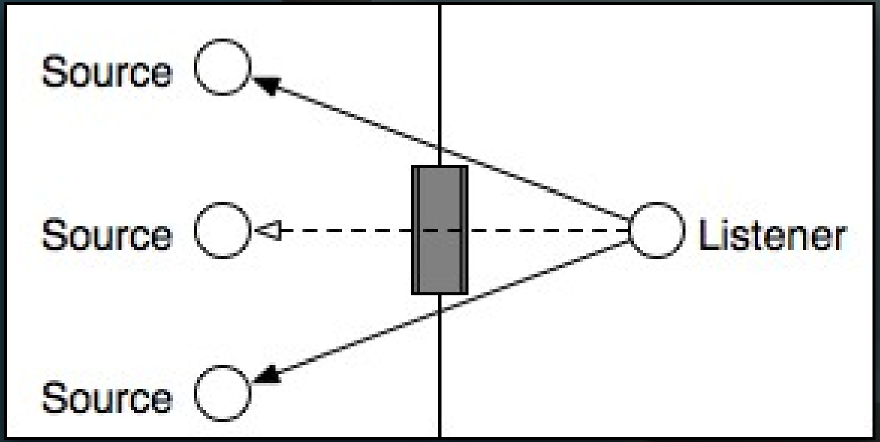
$$Z_n = \lfloor ((d - R)/w) + ٠.٥ \rfloor$$

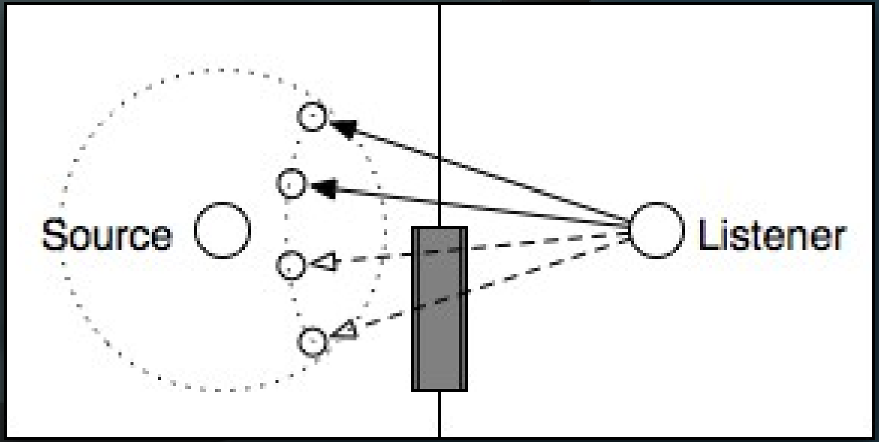
$$f(\theta) = (١ + \cos(\theta)) * ٠.٥$$

$$P_n = d\sin(\theta)$$

Fresnel Acoustic Diffraction Sampling

- Emit rays from the listener to N uniformly sampled positions P within a zone Z.
  - Special Case: N == 1 (only process occlusion)
- Determine visibility ratio V ($N_{visible}/N_{total}$)





Runtime System Rendering

- Occlusion and Diffraction Filters
  - Must support wet and dry path filtering.
  - Coefficient-resultant magnitudes and slopes must scale smoothly, both in high frequency and low frequency visibility tests.
    - Will need to write an adaptive moving-average filter.
      - low-pass notch frequency response
      - variable length averaging
      - modulation in series (multiple poles)

Runtime System Optimizations

- Variable Sample Size (LOD)
  - Each source has a maximum sample count. We roll off this count toward 0 as the relative gain-based distance increases relative to the listener's position.
- Staggered Collision Tests
  - As the collision test count increases, staggering the tests may result in lower overall computational averages.
- Cone-based Collision Test
  - Perform a single broad phase test. Then perform multiple narrow phase tests in the sampling region. This would require an addition to the Collision Sys.

Runtime System Benefits

- Extends occlusion to include diffraction
- Size-dependent filtering effects
- Avoids self-occlusion issues with sources
- Scalable algorithm and filter processing

Future Directions

- Integrate over multiple Fresnel Zones
  - Averages sample lines at increased distance
- Add spatial filtering (phase delays) based on listener orientation with respect to collision distance from sample zone.

Questions?