The Audio Technology of

Guy Somberg

GAME DEVELOPERS CONFERENCE
MARCH 16–20, 2020 | #GDC20

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GDC
Short and Snappy Title
Long and Boring Subtitle
GAME DEVELOPERS CONFERENCE
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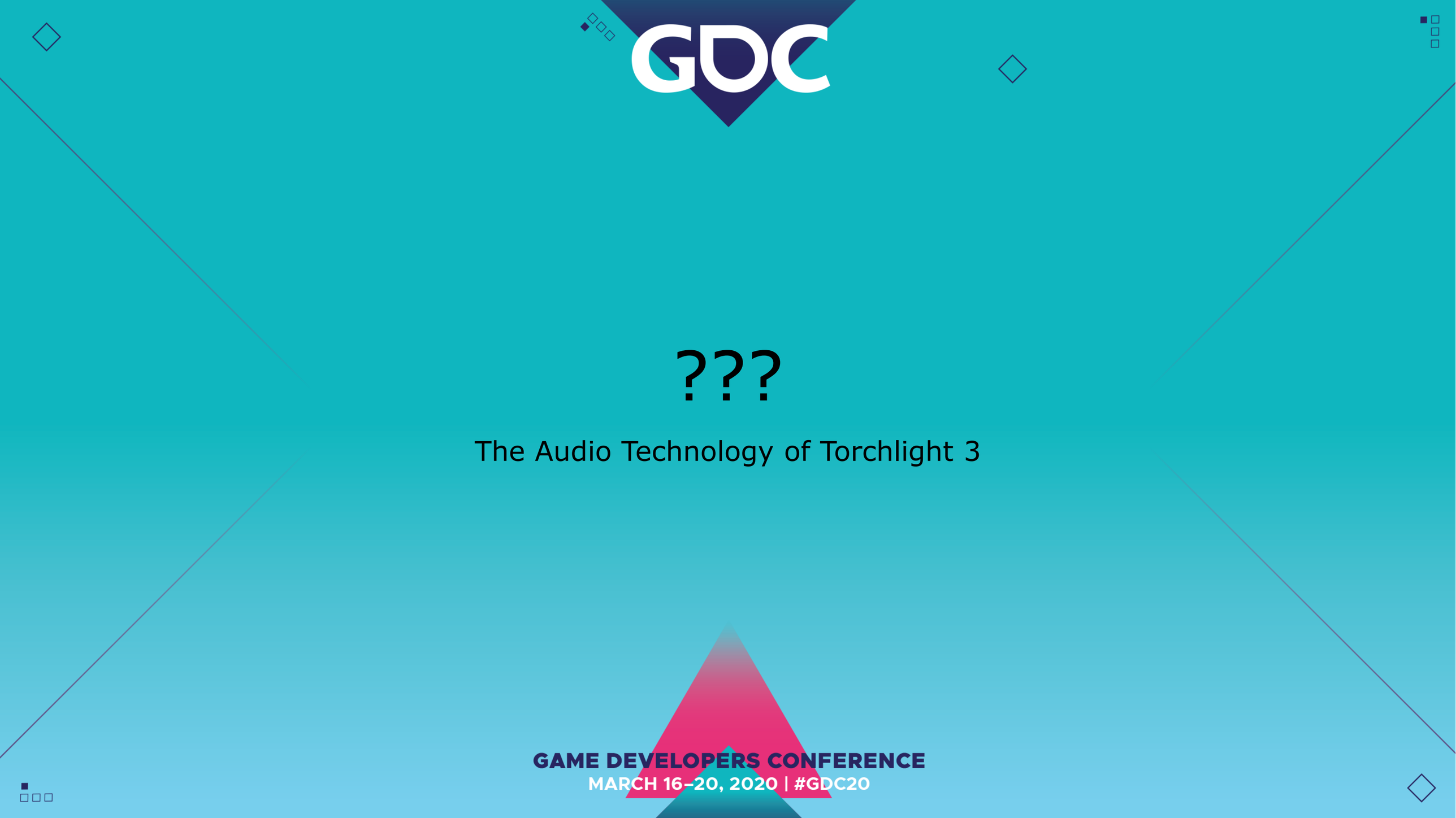

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The Audio Technology of Torchlight 3

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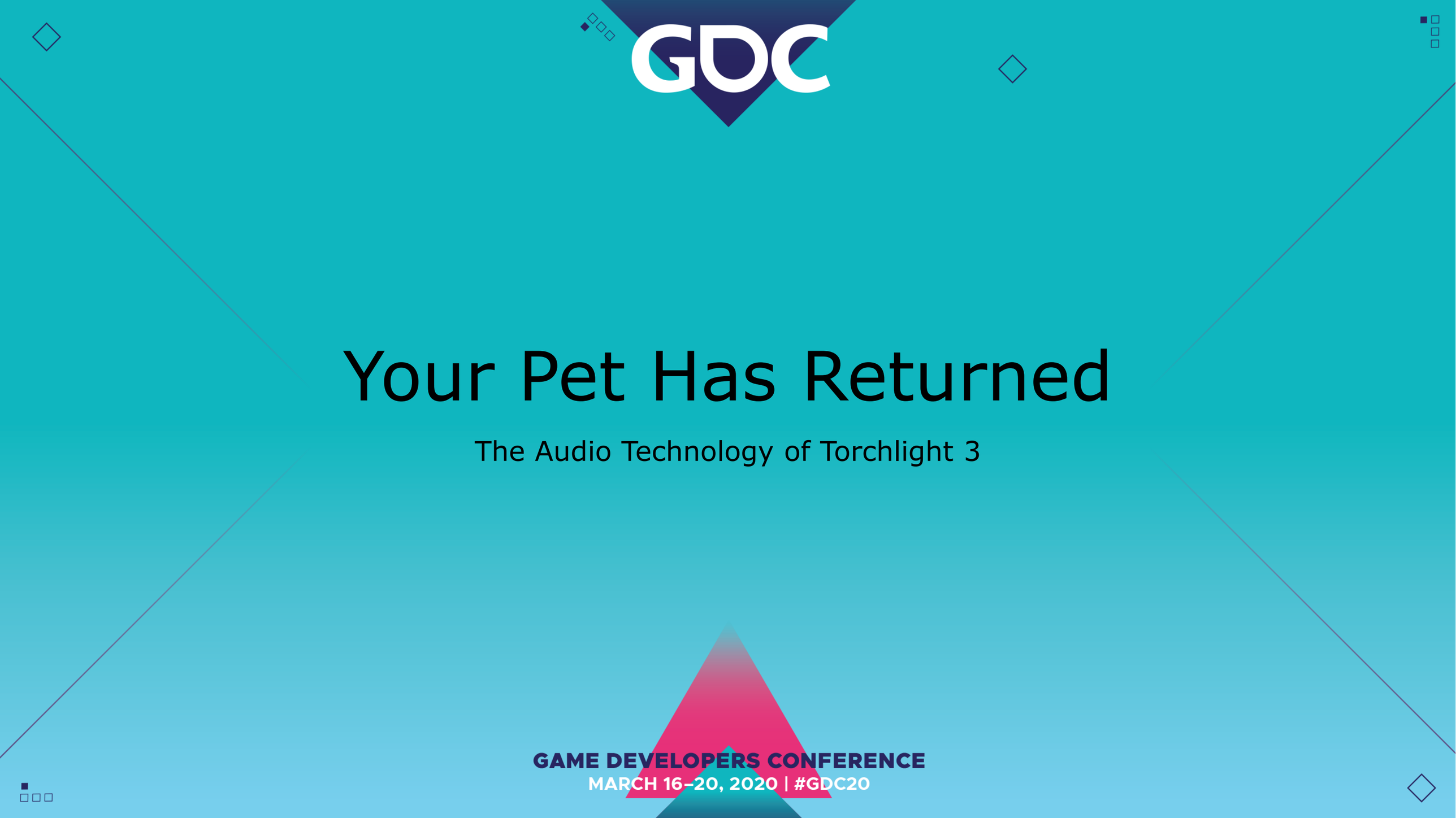

Your Pet Has Returned

The Audio Technology of Torchlight 3

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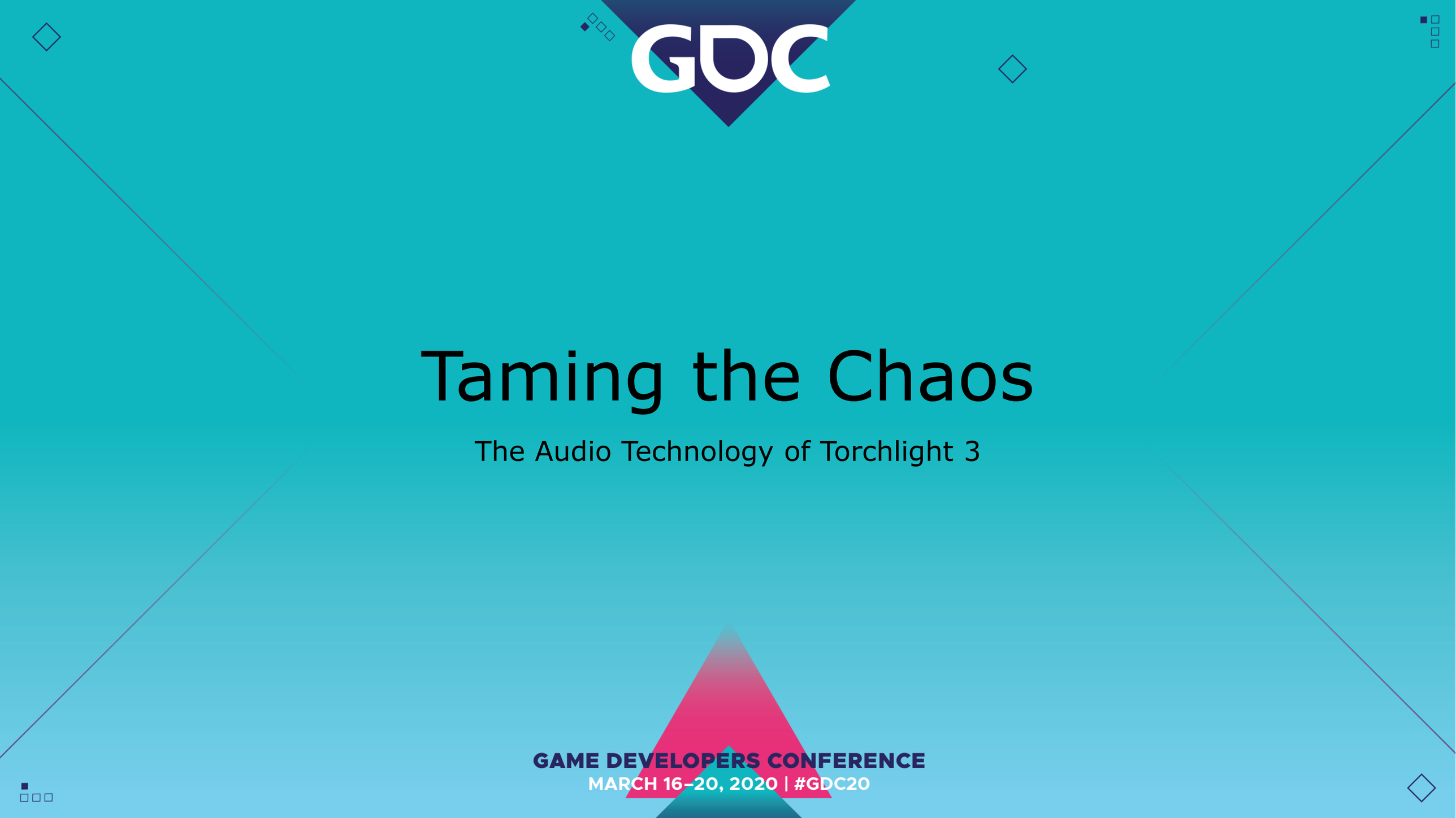

Taming the Chaos

The Audio Technology of Torchlight 3

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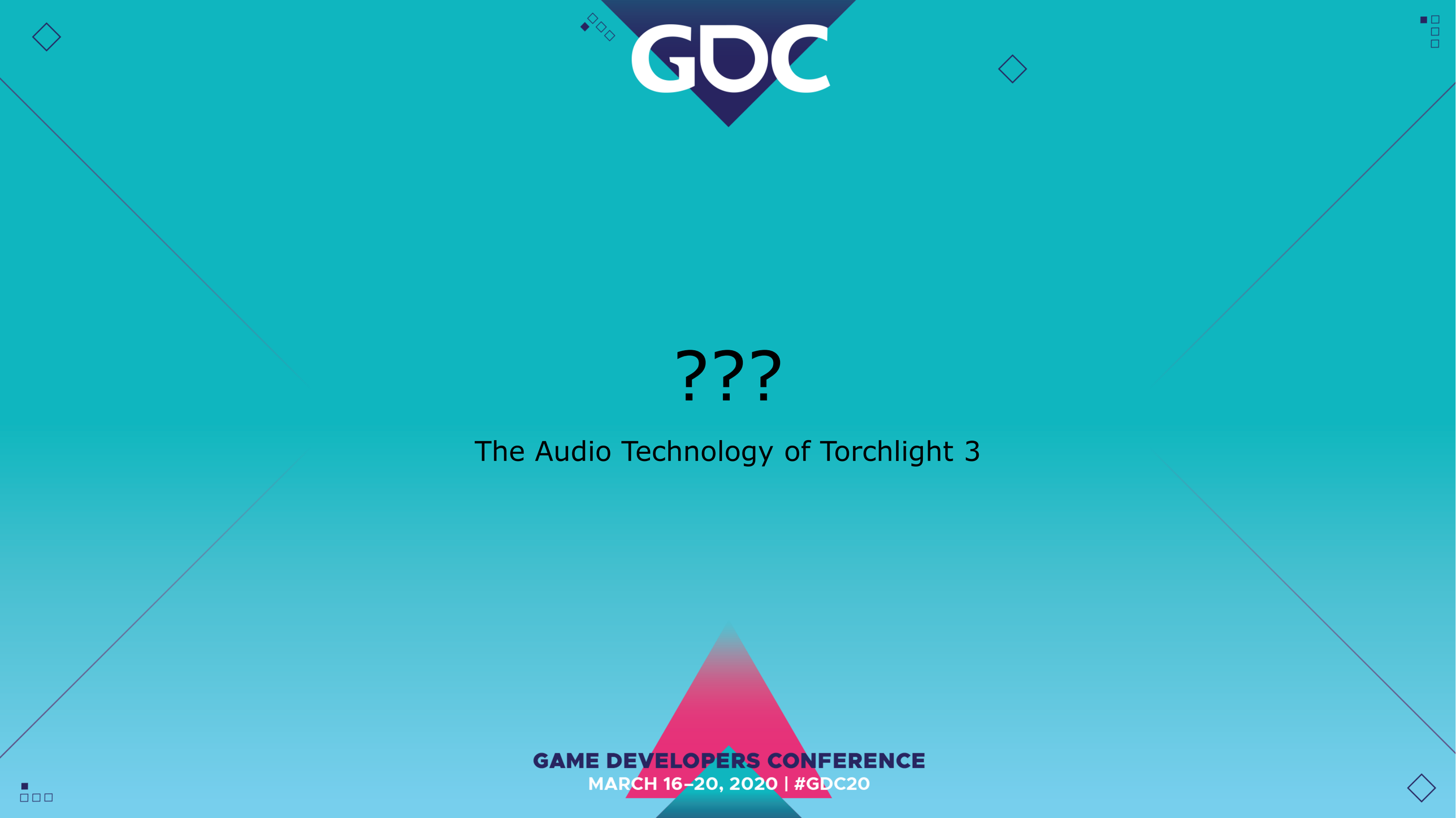

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The Audio Technology of Torchlight 3

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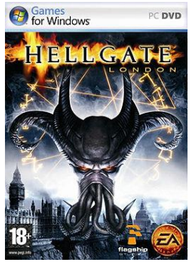
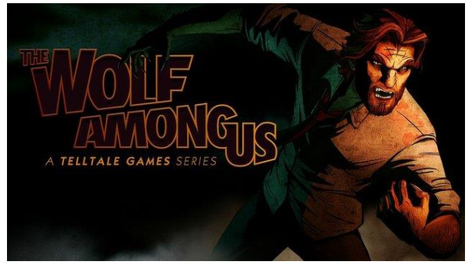
About Guy

- In games since 2002
- Owned the audio engine at (nearly) every company

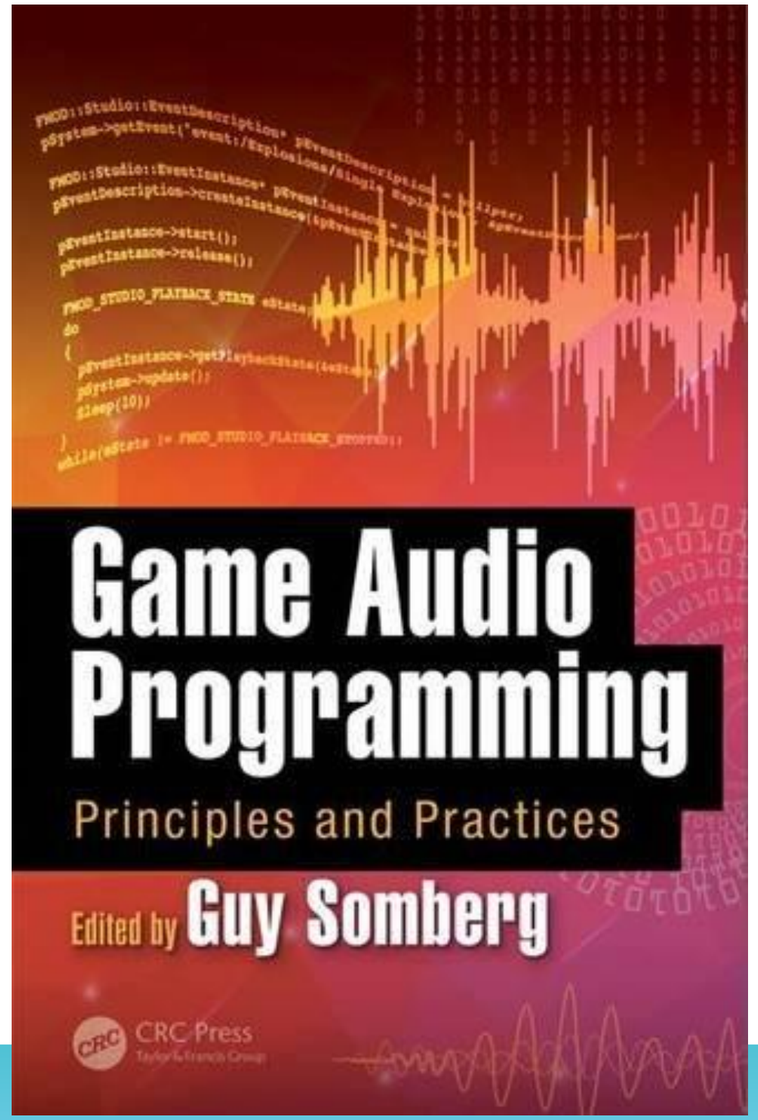
About Guy

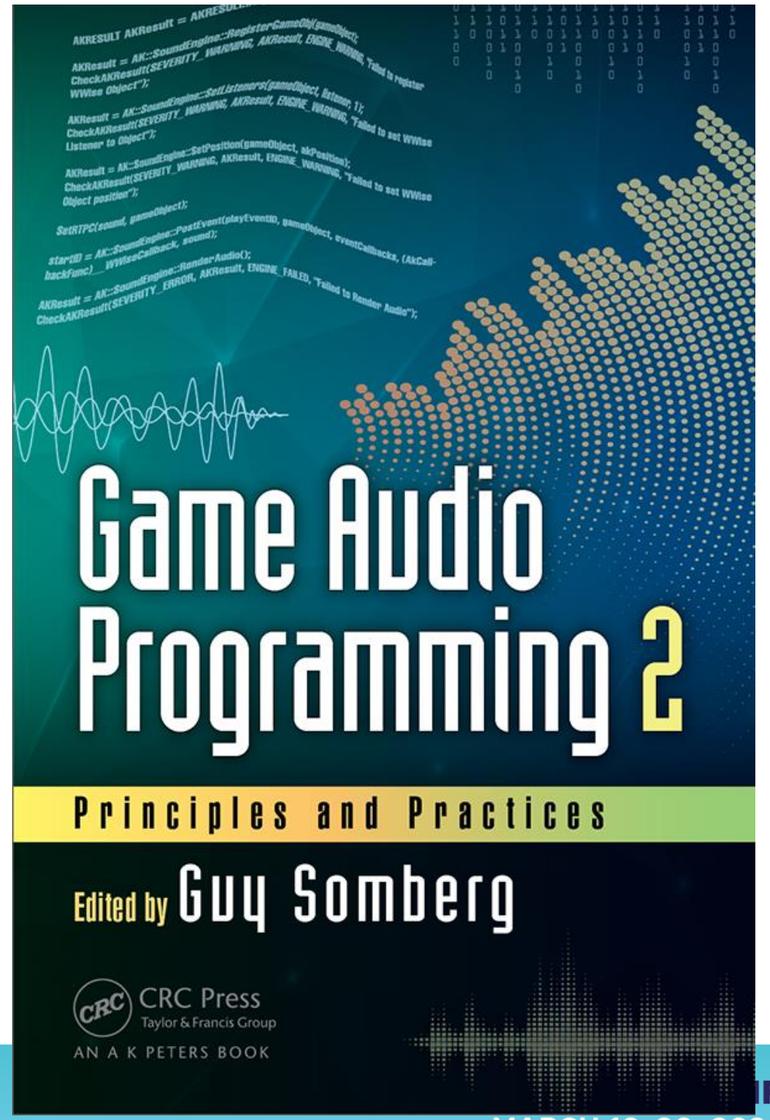
- …and shipped lots of games

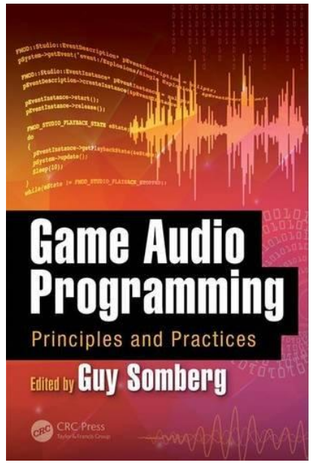



Shameless Plug

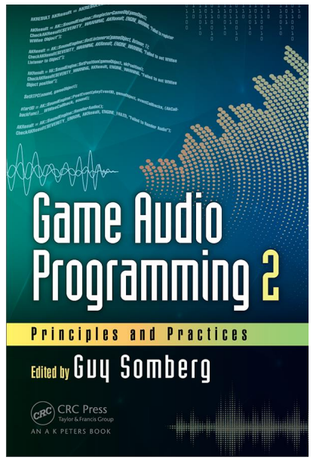




Shameless Plug



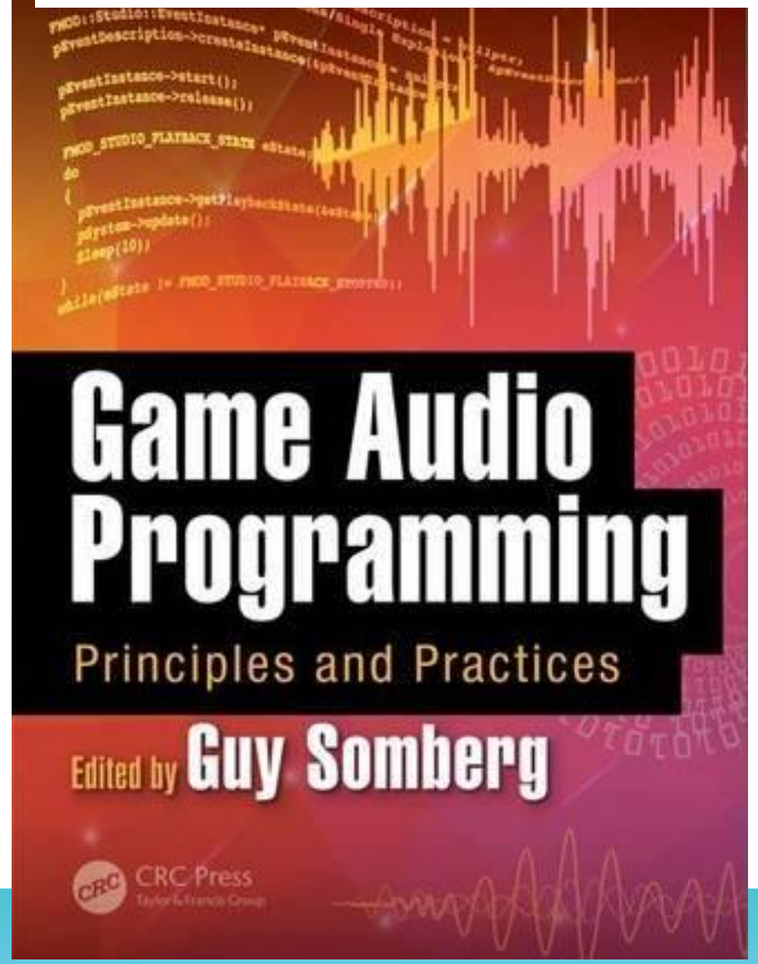
https://www.crcpress.com/Game-Audio-Programming-Principles-and-Practices/Somberg/p/book/9781498746731

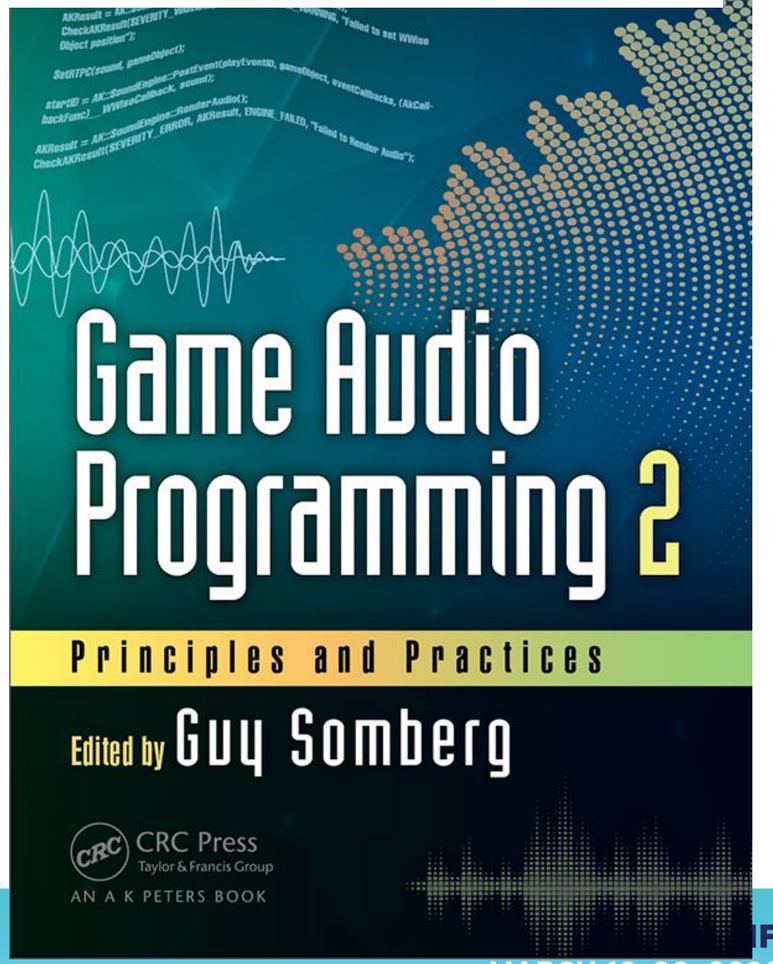


https://www.crcpress.com/Game-Audio-Programming-2-Principles-and-Practices/Somberg/p/book/9781138068919

Shameless Plug

Coming Soon: Volume 3!






TORCHLIGHT
FRONTIERS

ARPGs are Hard

- Everything is happening on the screen in front of you
  - See also: RTS, Adventure Games, etc.
- Chaotic action
  - See also: FPS, MOBA, etc.
- Randomized level layout
  - See also: Roguelikes, Strategy, etc.

Today’s Topics

- Importance-Based Mixing
- Volumetric Sounds
- Screen-Space Distance Attenuation

Not talking about:

- Narrator
- Music
- Modified FMOD Studio Unreal Plugin
- Tool-time Bank Building
    - Other cool stuff that we’ve done

Today’s Topics

- Importance-Based Mixing
- Volumetric Sounds
- Screen-Space Distance Attenuation

Mixing Woes

- Fundamental Problem:
  - Chaotic mix: dozens of events playing all at once
  - Traditional mixing techniques: Snapshots, Prioritization, Culling, HDR
    - All useful, and we use most of them
  - All insufficient when faced with our game

Early Attempts

- Special case: “Nearby monster count”
- Offline: Categorization
- Didn’t really solve the problem


The
Chasm
Level: 5
RedOctober_NOLOGIN0


The
Chasm
Level: 5
RedOctober_NOLOGIN0

Solution: Importance

- In Torchlight 3, Importance is the most important mixing technique that we use
  - Thanks to Tomas Neumann and Paul Lackey from the Overwatch team!

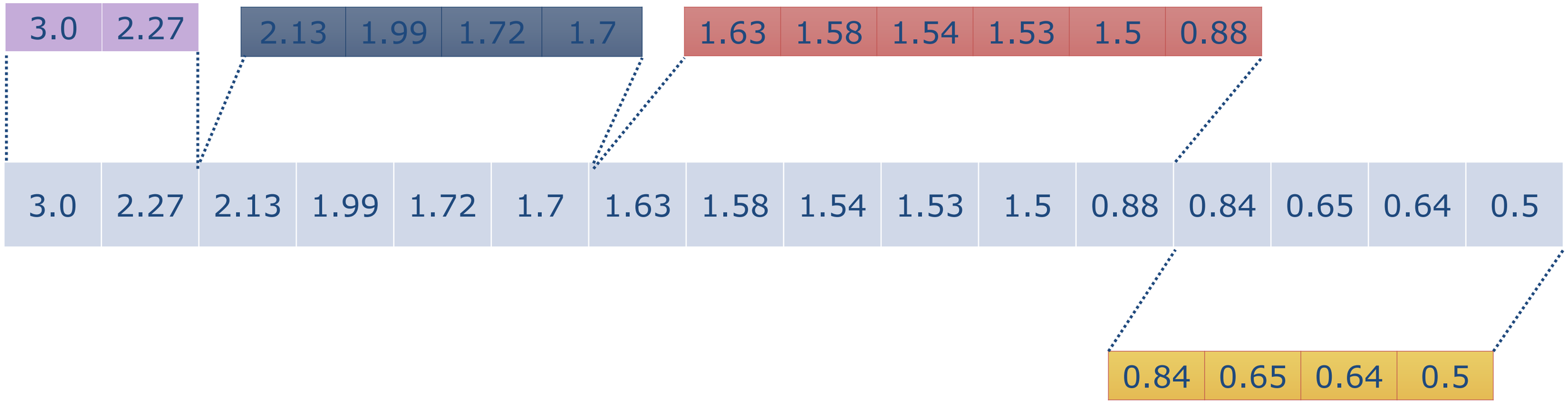
Importance

- Assign each object an importance score
- Sort all objects by score
- Place sorted objects into buckets
- Apply effect to each sound in the bucket

Importance Scores

- Extremely game-specific
- In Torchlight 3:
  - Identity
  - Distance to player
  - Relative “drama” score
  - Skill target
- Total score = weighted sum of individual scores


The Chasm
Level: 5
0.84
0.5
0.65
RedOcto
0.88
OGIN0
2.13
0.64
2.27
1.99
1.5
1.7
3.0
1.53
1.72
1.58
1.63
1.54


3.0
2.27
2.13
1.99
1.72
1.7
1.63
1.58
1.54
1.53
1.5
0.88
3.0
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1.53
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0.88
0.84
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0.5


The Chasm
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1.5
1.7
3.0
1.53
1.72
1.58
1.63
1.54

Importance Bucket Effects

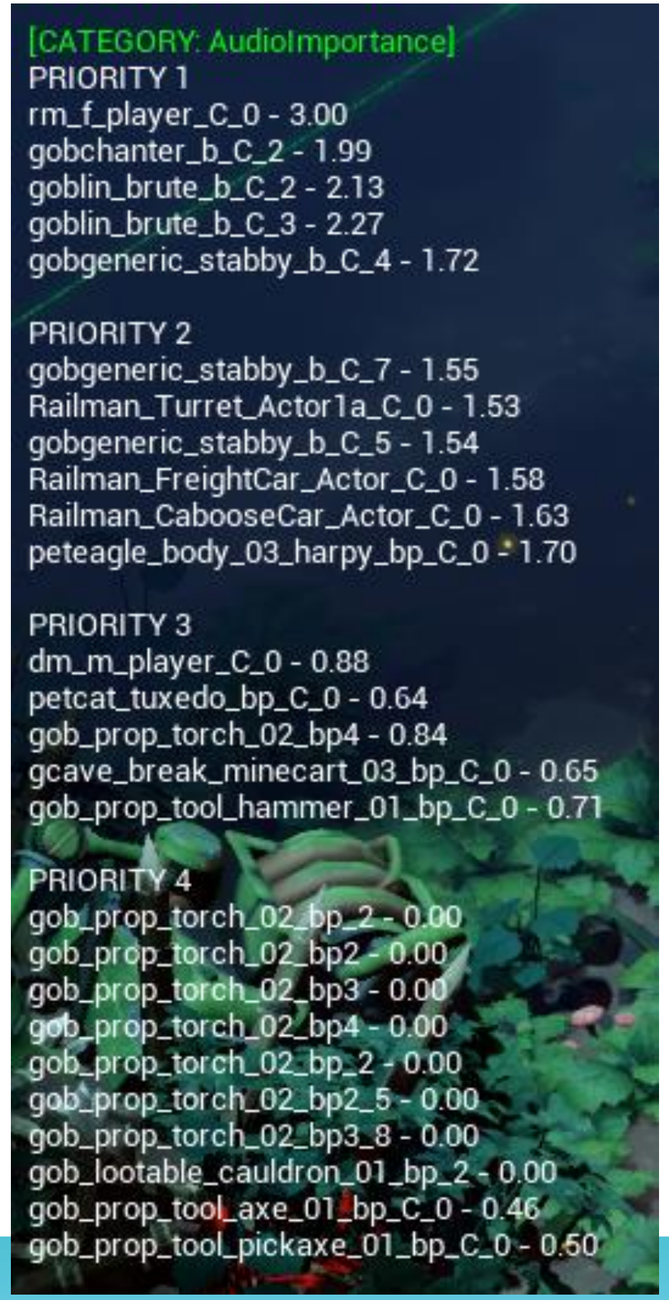
- Volume, Peaking Filter, High Shelf Filter
  - Implementation detail: Peaking and High Shelf Filters implemented using Multiband EQ

Priority	Effect
1	Peaking Filter
2	No change
3	Volume Reduction
4	Volume Reduction, High Shelf
5	Volume Reduction, High Shelf

Importance in Action

- Live Demo

Debug Display



Debug Display

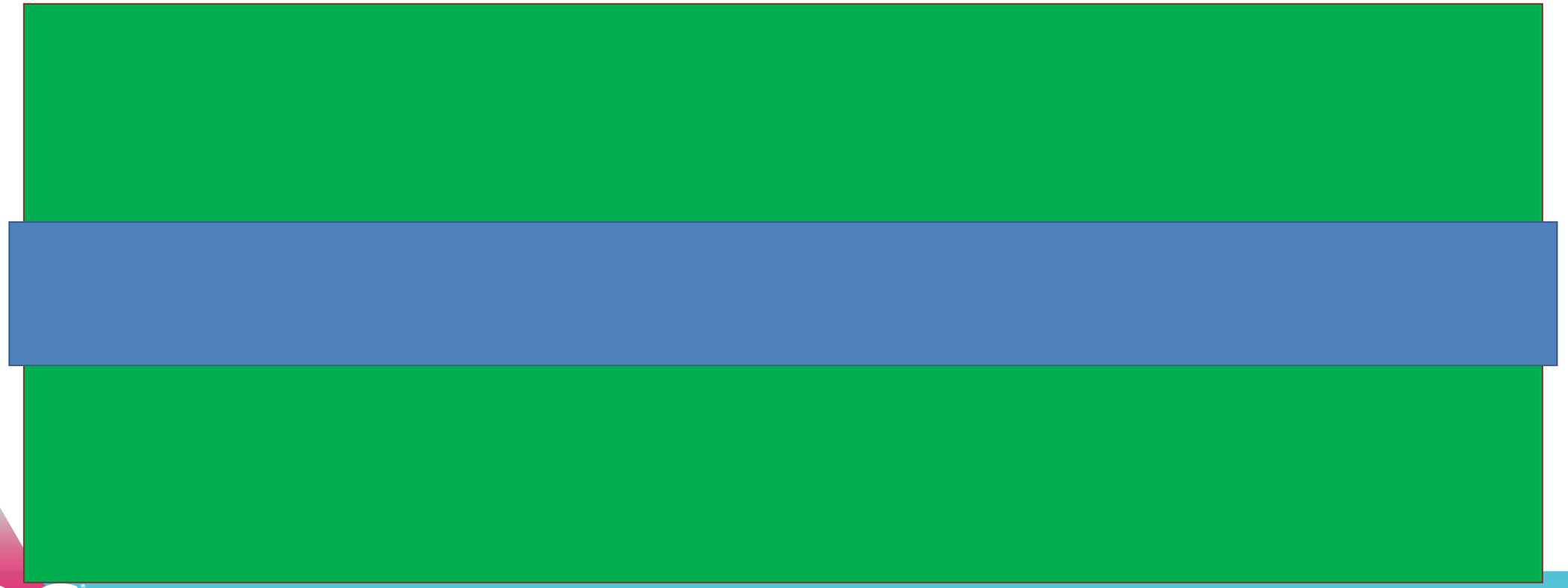
Debug Display

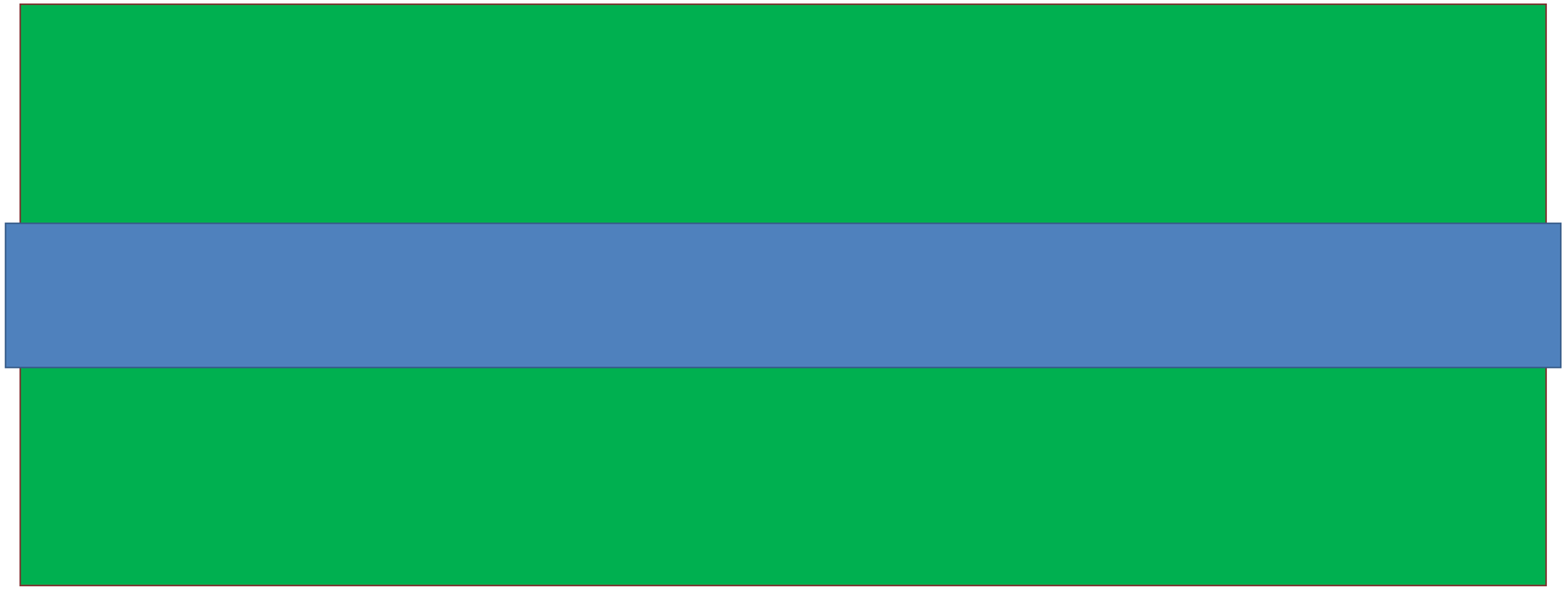
Today’s Topics

- Importance-Based Mixing
- Volumetric Sounds
- Screen-Space Distance Attenuation

The Problem

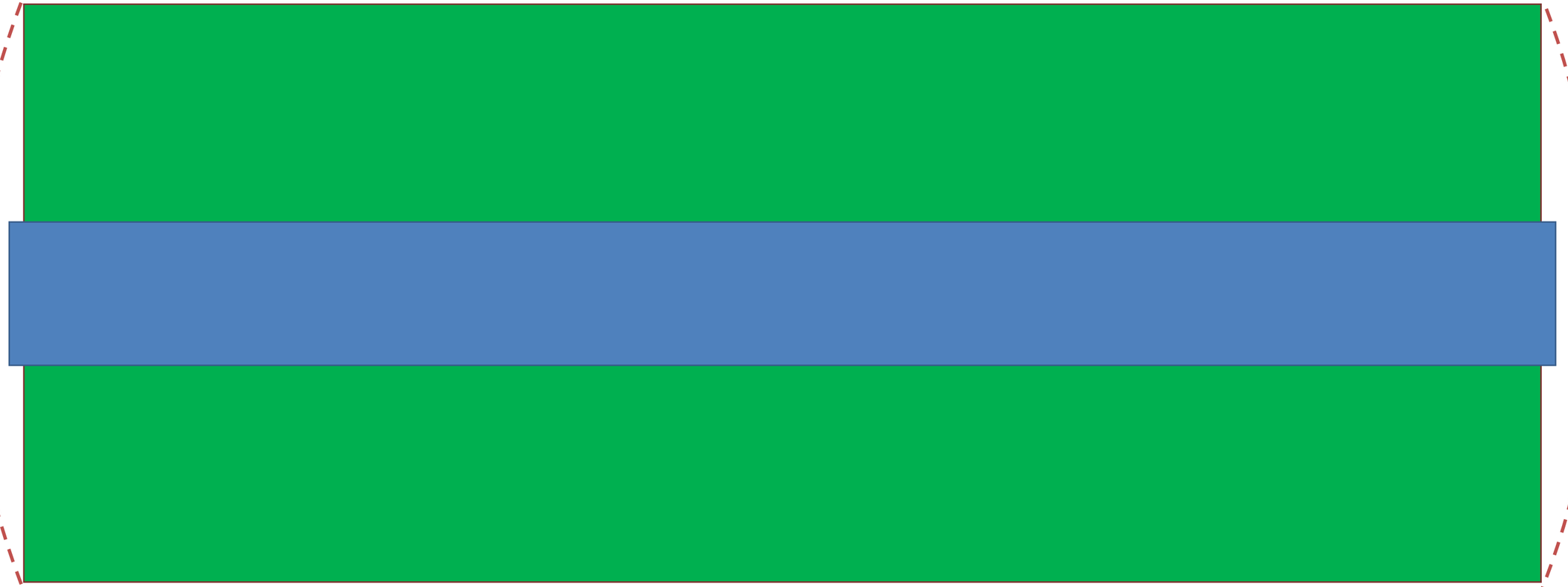
- In one word: rivers





Failed Idea #1

- Single sound source at the river center

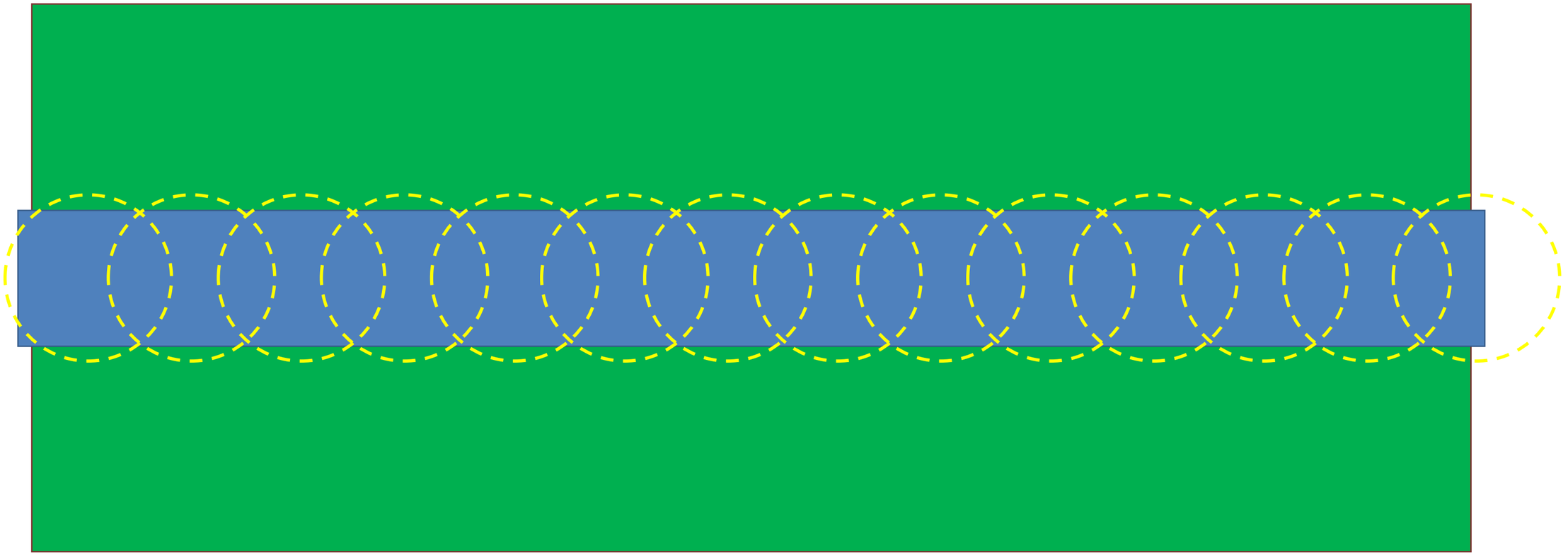


Nope!

- No control over attenuation
- No control over shape
- Doesn’t account for randomized levels

Failed Idea #2

- Many smaller sound sources



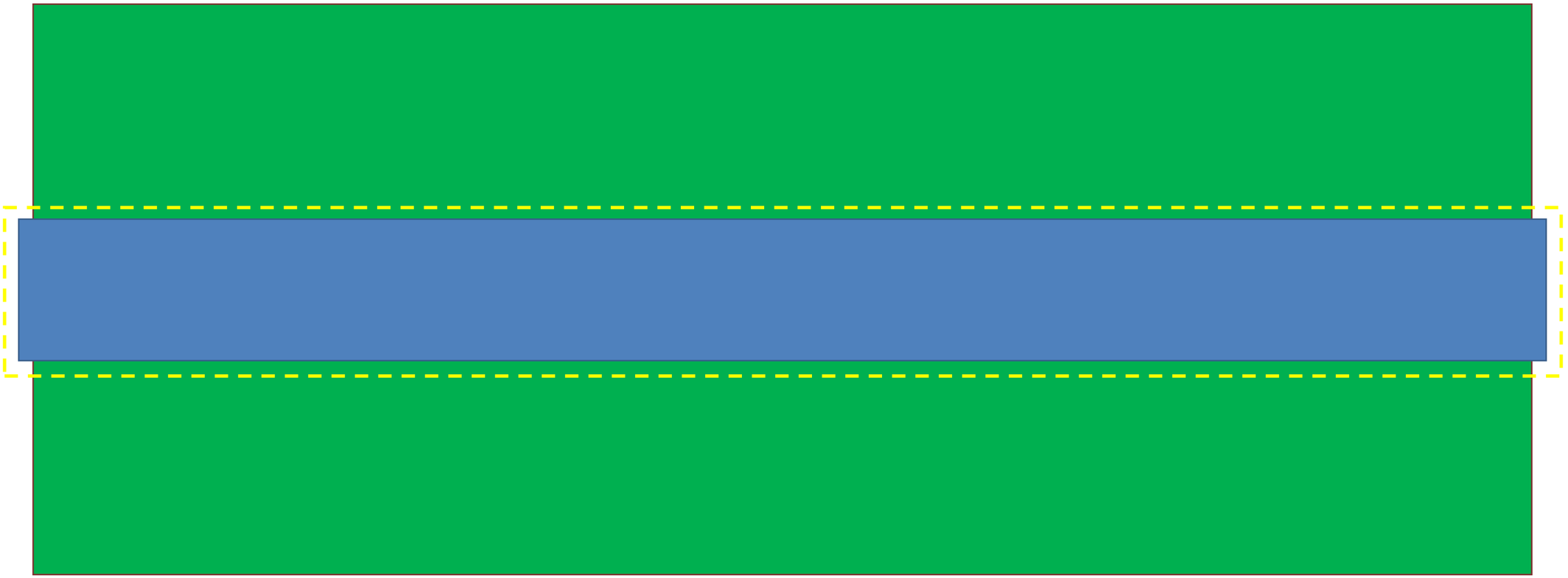
Nope!

- Control over attenuation
- Control over shape
- Deals with random levels

- But:
  - Too many sound sources
  - Phasing
    - Mind-numbing setup

Failed Idea #3

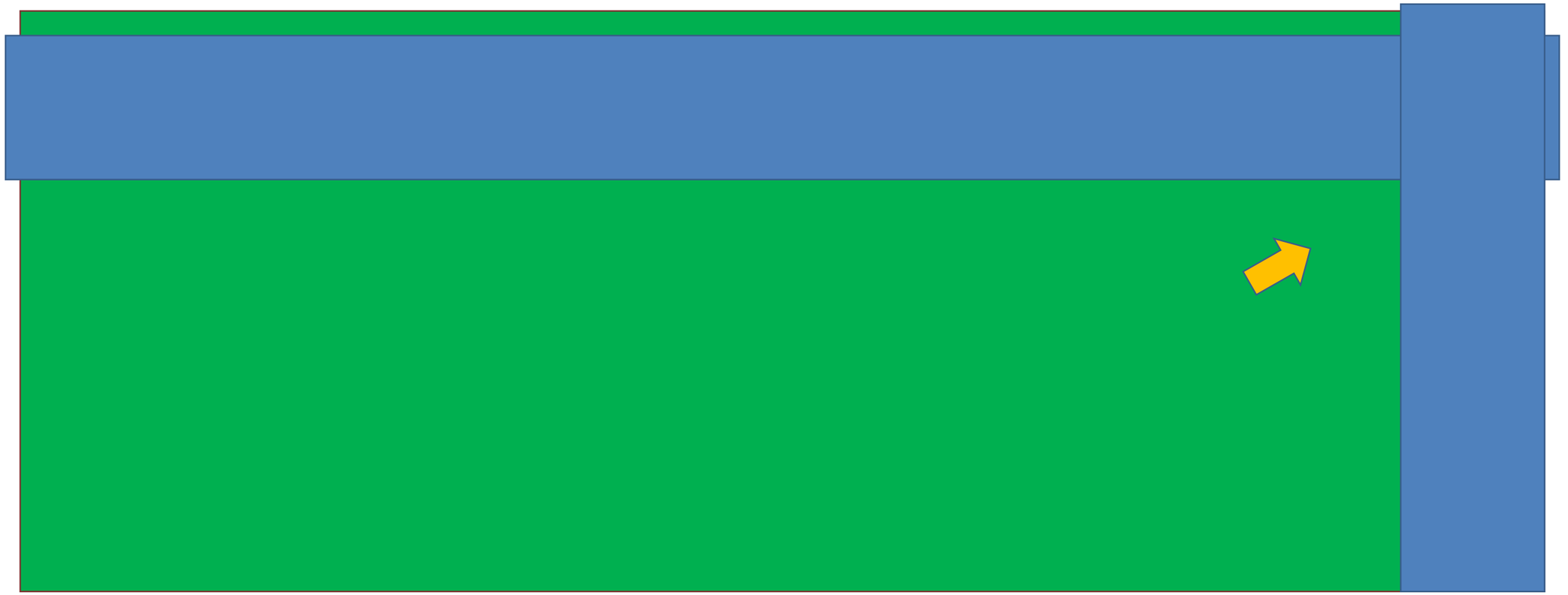
- Nearest point on box

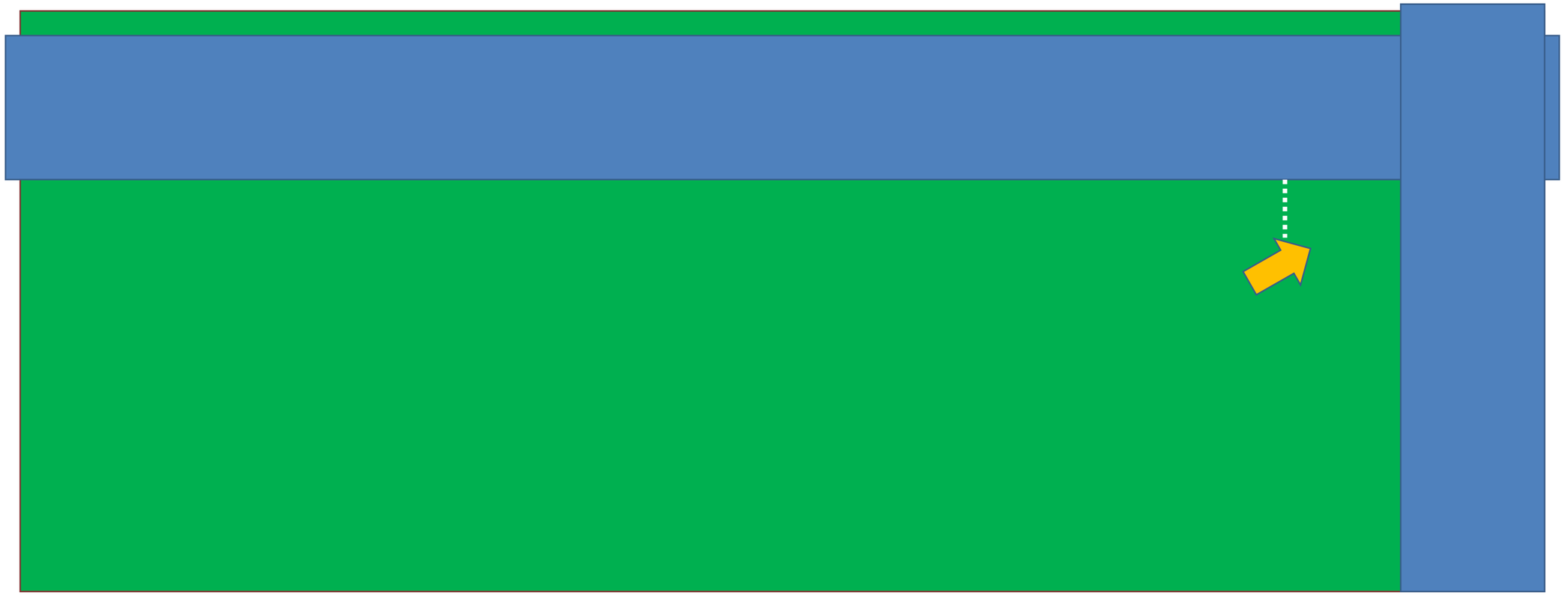


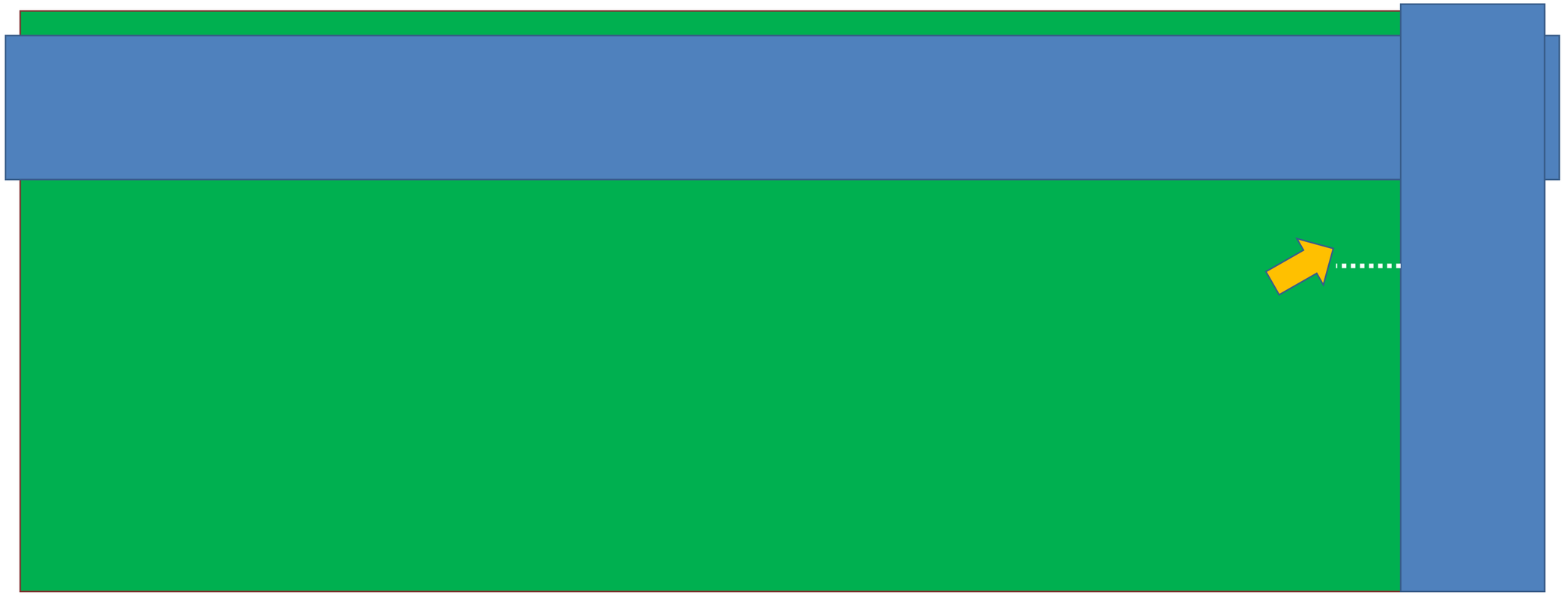
Promising!

- Control over attenuation
- Control over shape
- Deals with random levels
- Only one sound source
- Easy setup

- But…







Darn :(

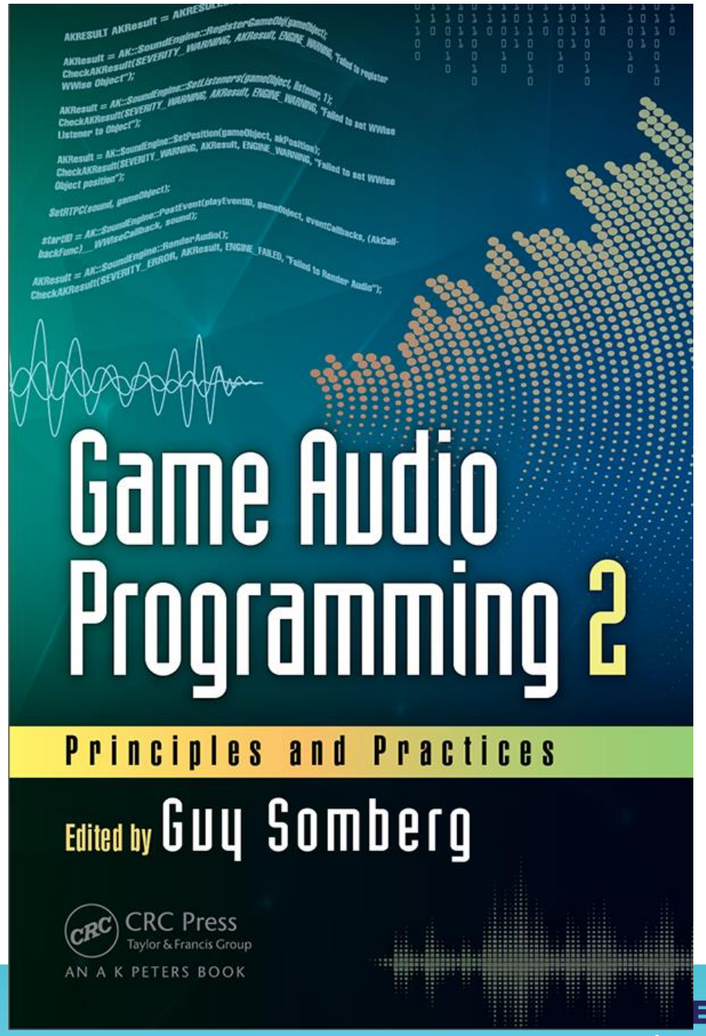
- So close!

Take a Step Back

- We want one single sound source
- Position + Direction is insufficient to describe our sound source
- So what do we actually want to describe?

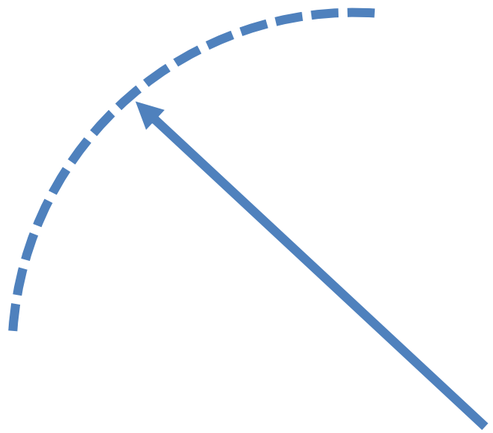
Working Solution

- Game Audio Programming Principles and Practices Volume 2
- Chapter 12: “Approximate Position of Ambient Sounds of Multiple Sources” by Nic Taylor
- Thanks, Nic!



Working Solution

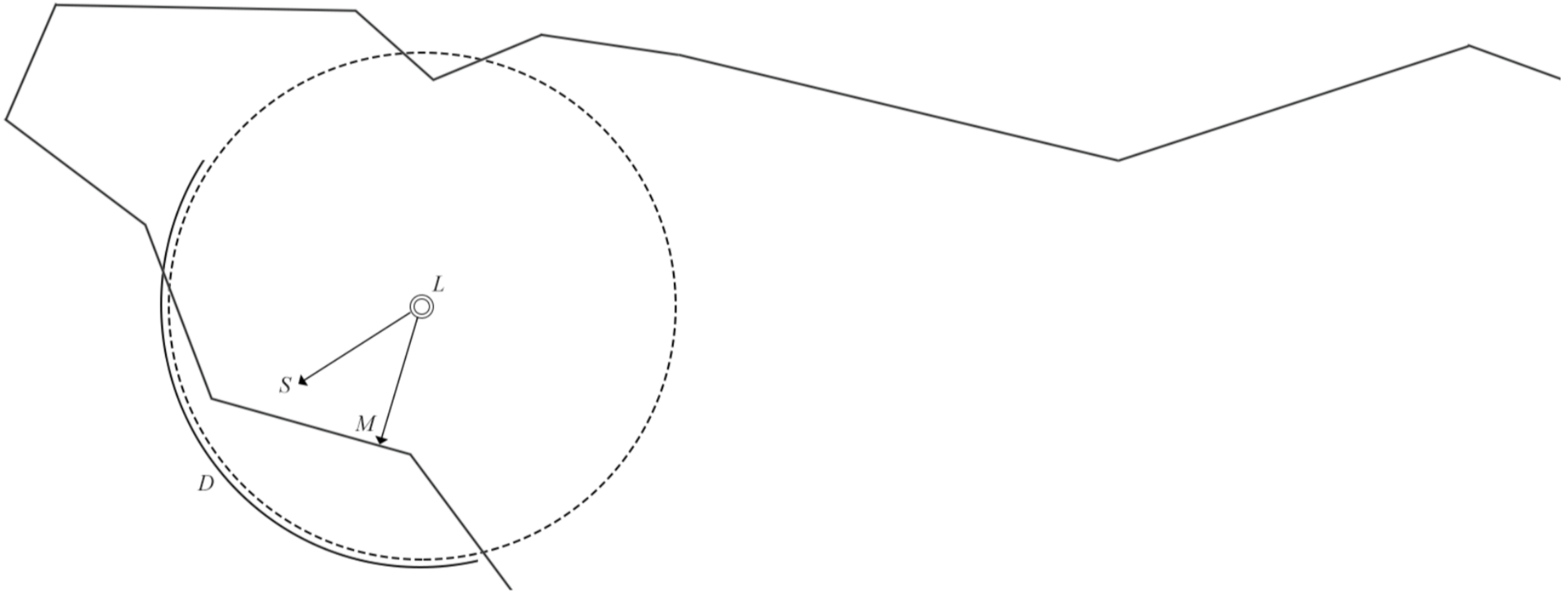
- Direction
- Magnitude
- Spread



Analytical Solution

- Direction and Spread should be impacted less the farther a point is from the listener
- Spread of two parallel lines with listener equidistant should be 1 (full spread)
- Spread of a line segment that passes through the listener should be 0
- Small changes in listener position should result in small changes to Direction, Magnitude, and Spread
  - Subdividing a line segment should not alter Magnitude, Direction, or Spread

Image Credit: Nic Taylor



Math!

$$\hat{\sigma} = \lim_{\Delta s_{i \to 0}} \sum_{i=1}^{n} \frac{\hat{v}}{\|\hat{v}\|} W(\hat{v}) \Delta s_i = \int_C \frac{\hat{v}}{\|\hat{v}\|} W(\hat{v}) \Delta s$$

But…

- All of that is just for line segments
- Upgrading to two dimensions gets us both more features and more flexibility

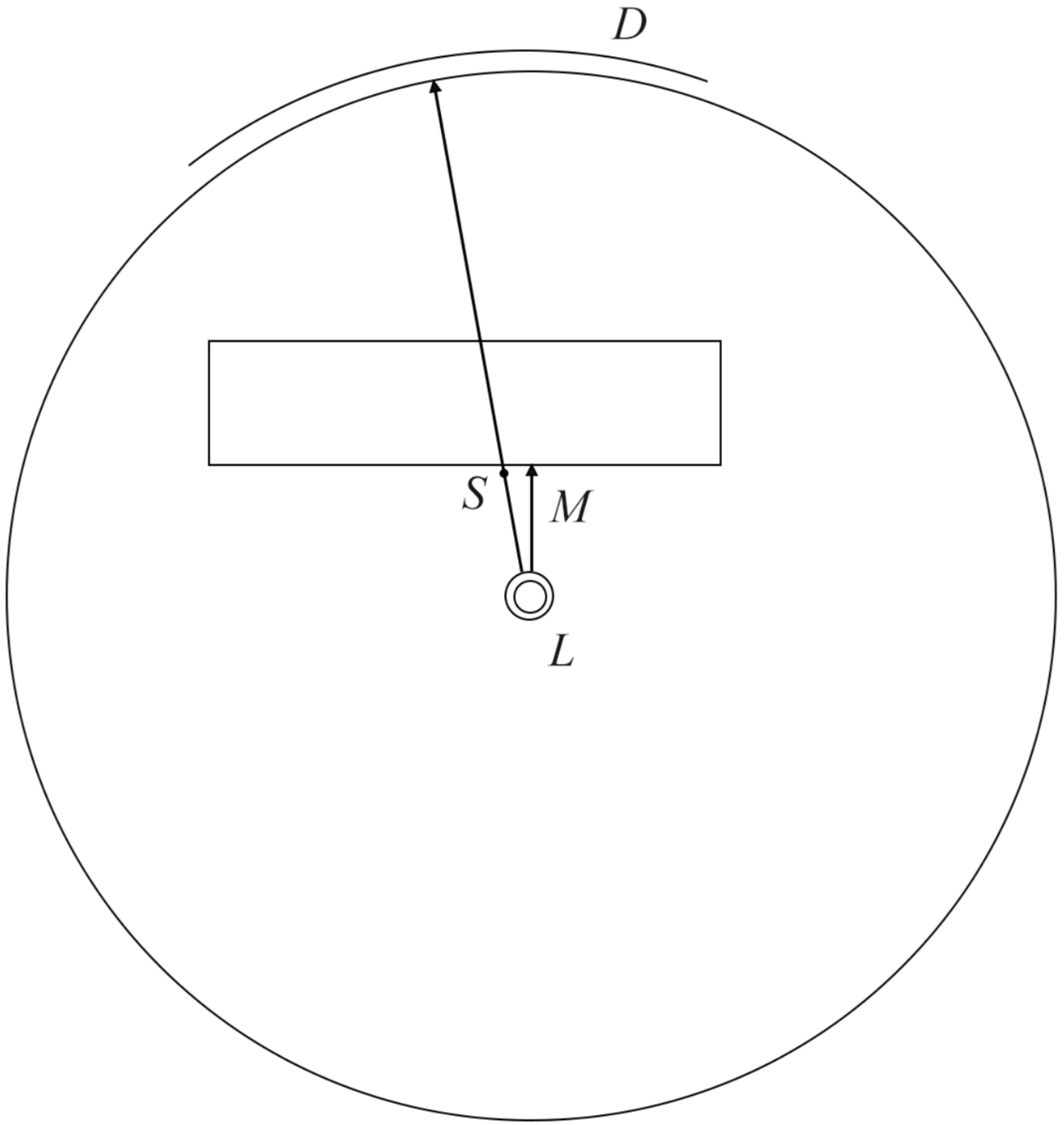
More Math!

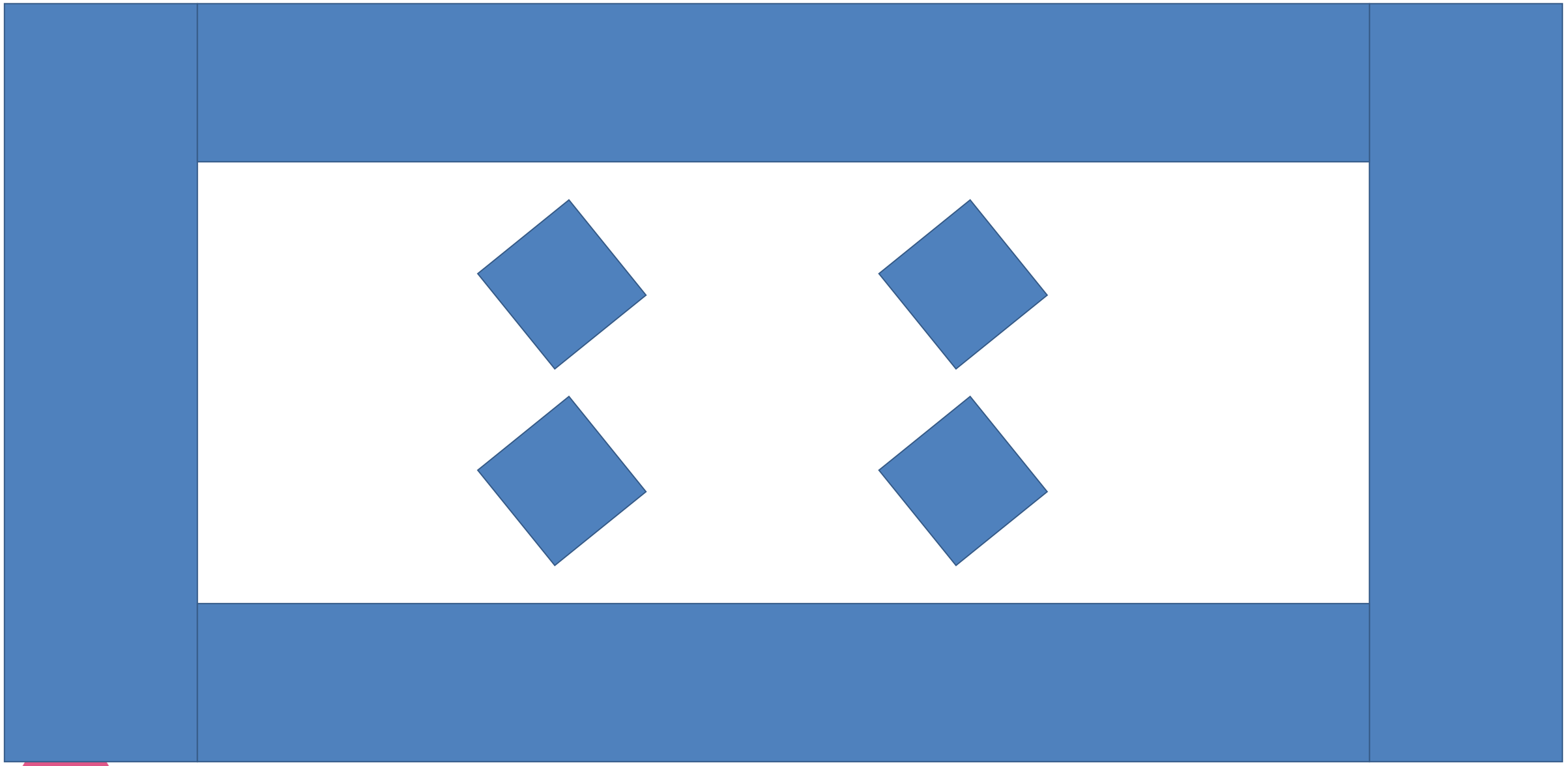
$$\hat{\sigma} = \lim_{\Delta s_{i \to 0}} \sum_{i=1}^{n} \frac{\hat{v}}{\|\hat{v}\|} W(\hat{v}) \Delta s_i = \int_C \frac{\hat{v}}{\|\hat{v}\|} W(\hat{v}) \Delta s$$

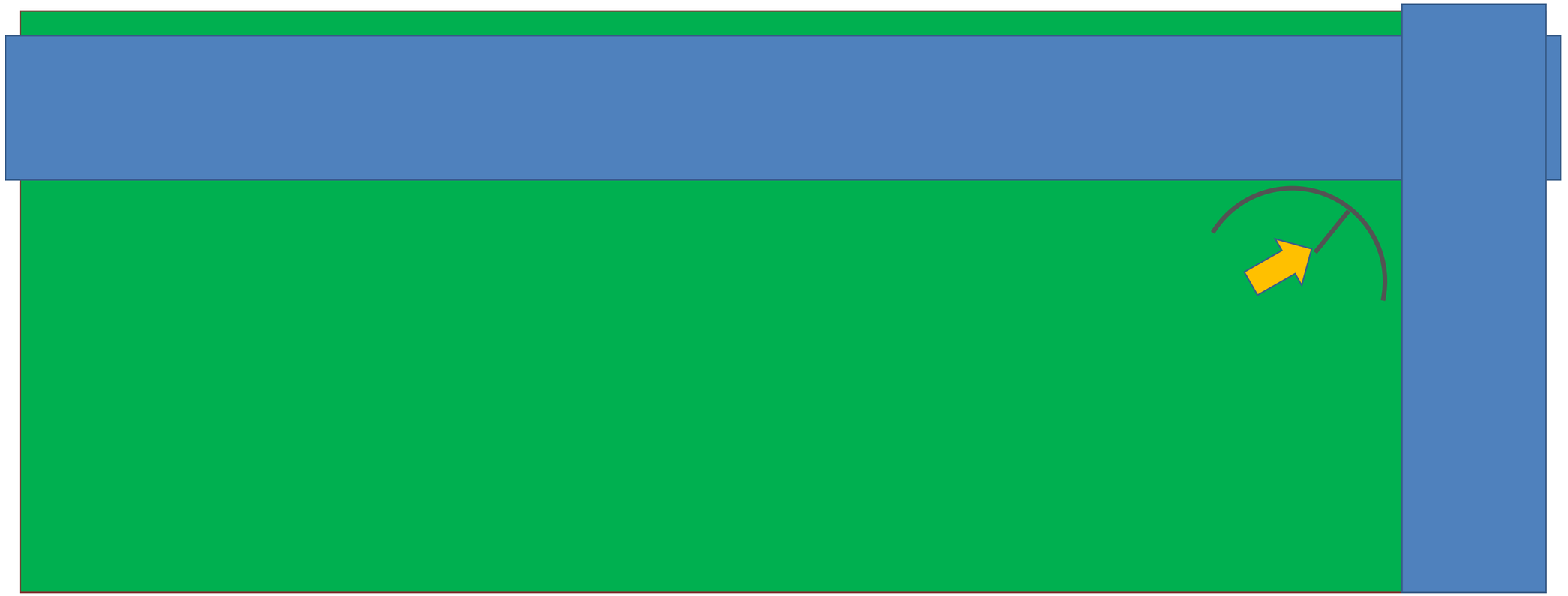
Becomes:

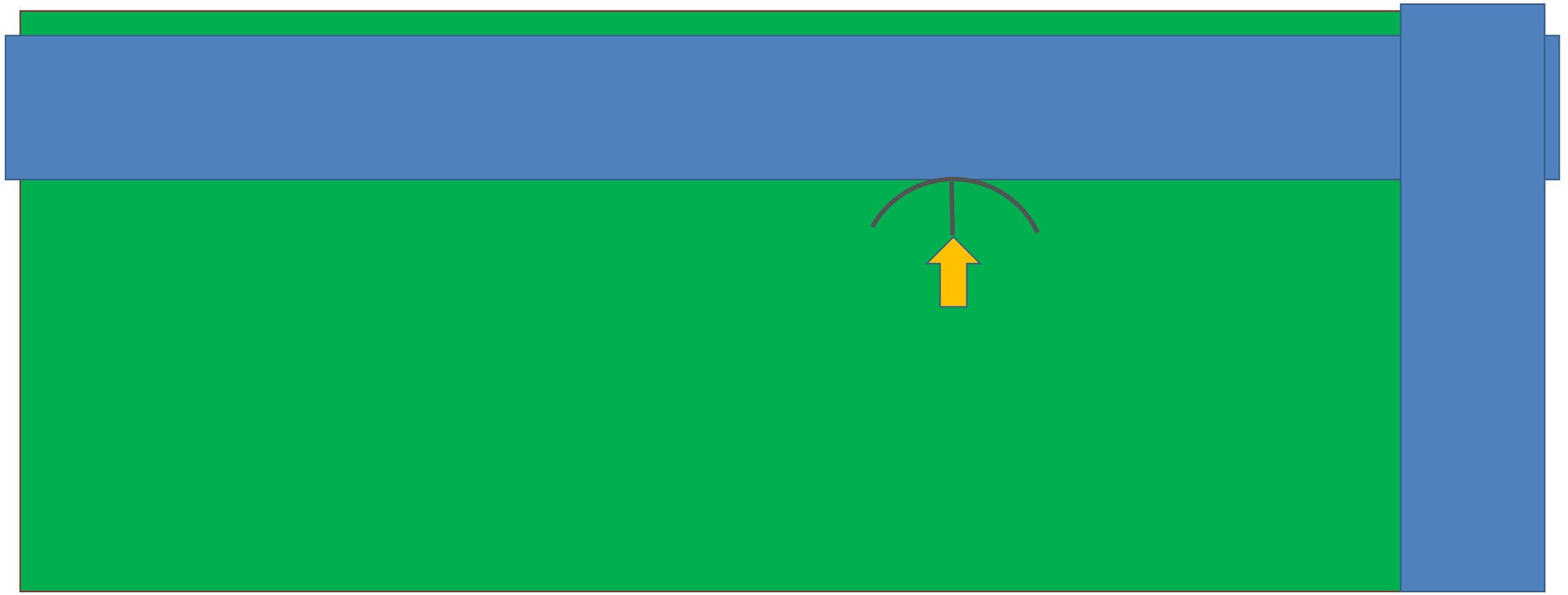
$$\hat{\sigma} = \iint_R \frac{\langle x, y \rangle}{\sqrt{x^2 + y^2}} \left(1 - \sqrt{x^2 + y^2}\right) \Delta x \Delta y$$

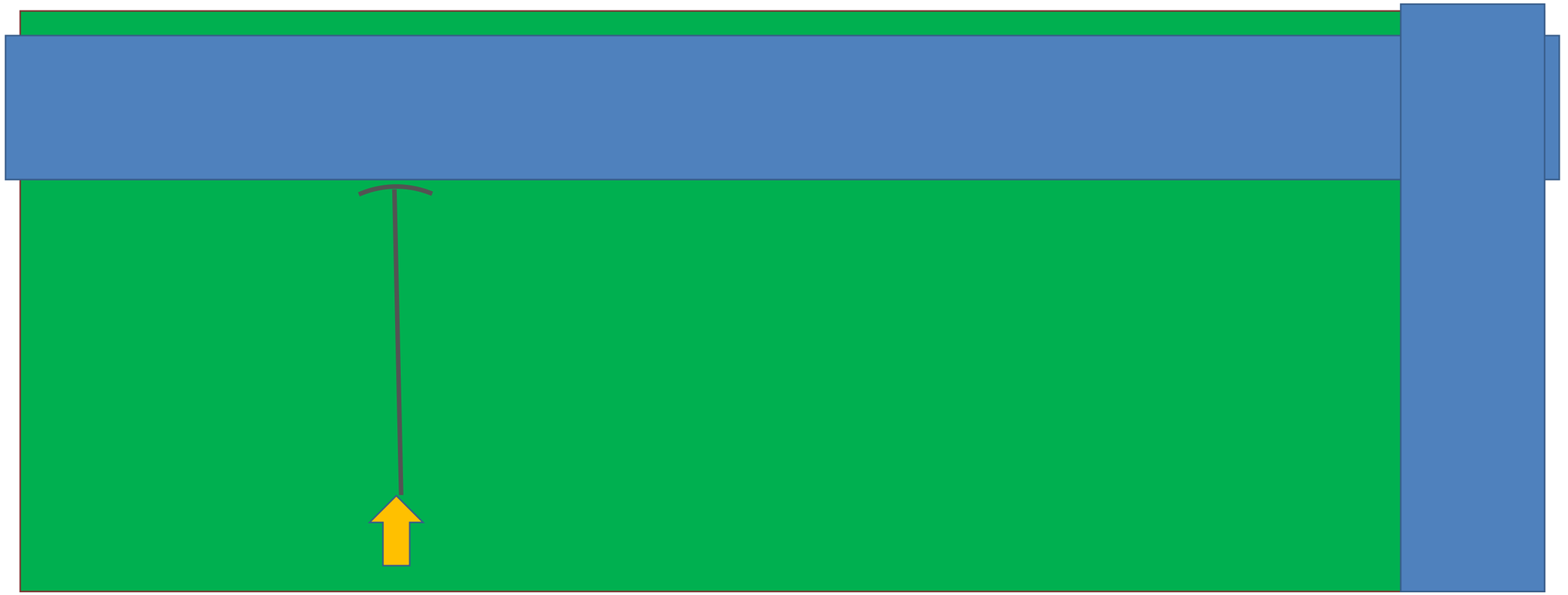
Image Credit: Nic Taylor





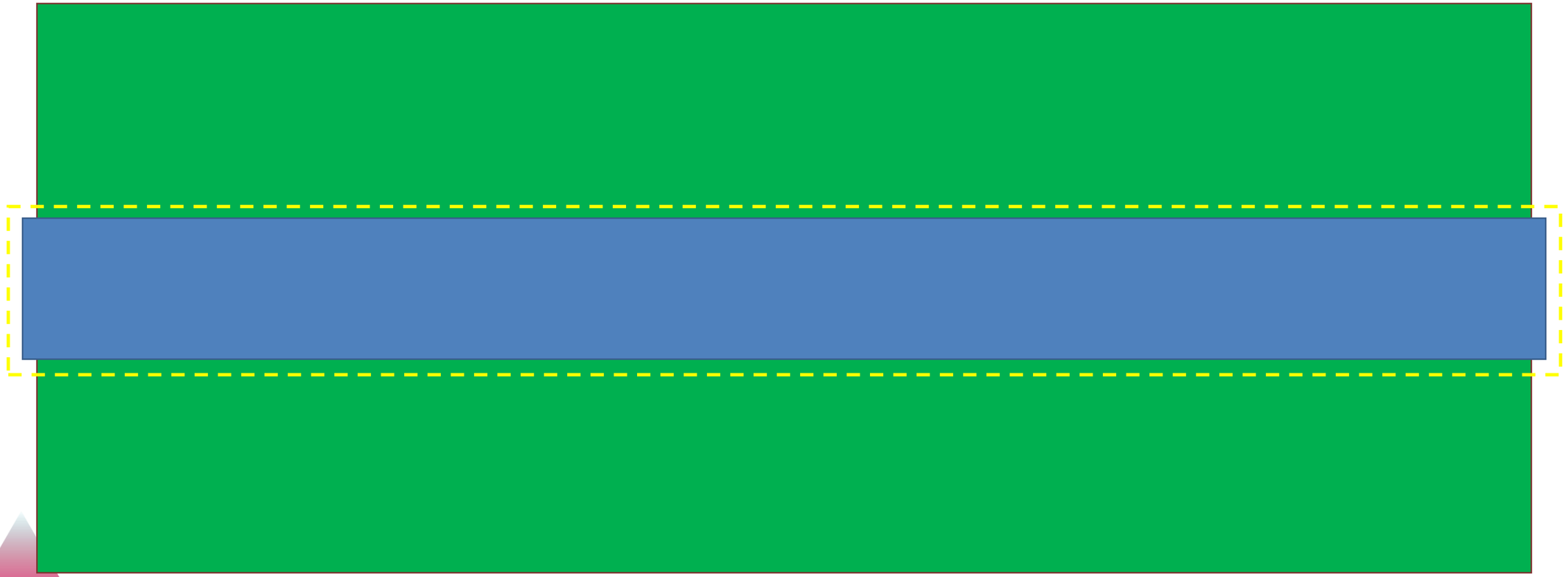






Details: Setup

- Setup is easy:



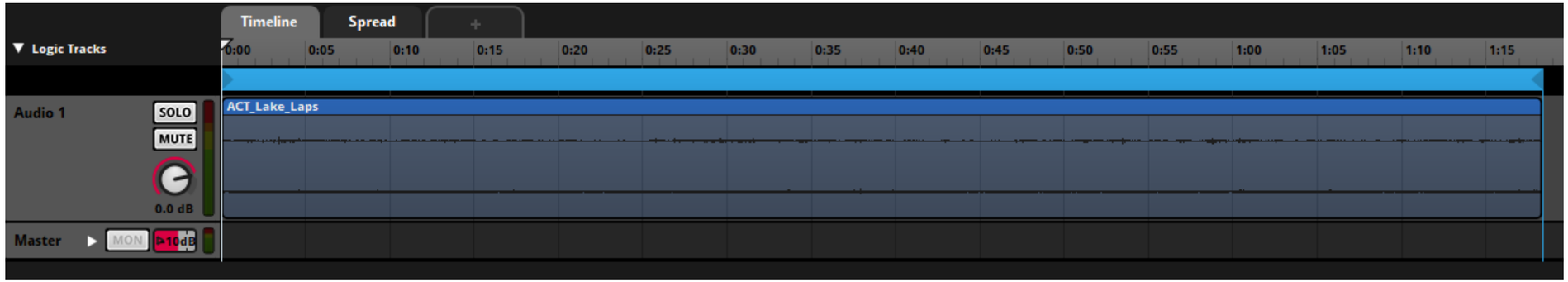
Details: Box Subdivision

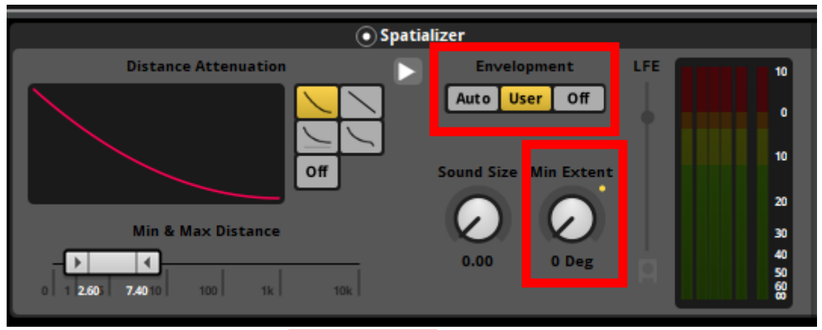
- Two solutions:
  - Subdivide boxes down
  - Build up the shape using voxels
- Both are covered in Game Audio Programming 2
- TL3 subdivides
  - (Minimum axis length – 0.5 meters)

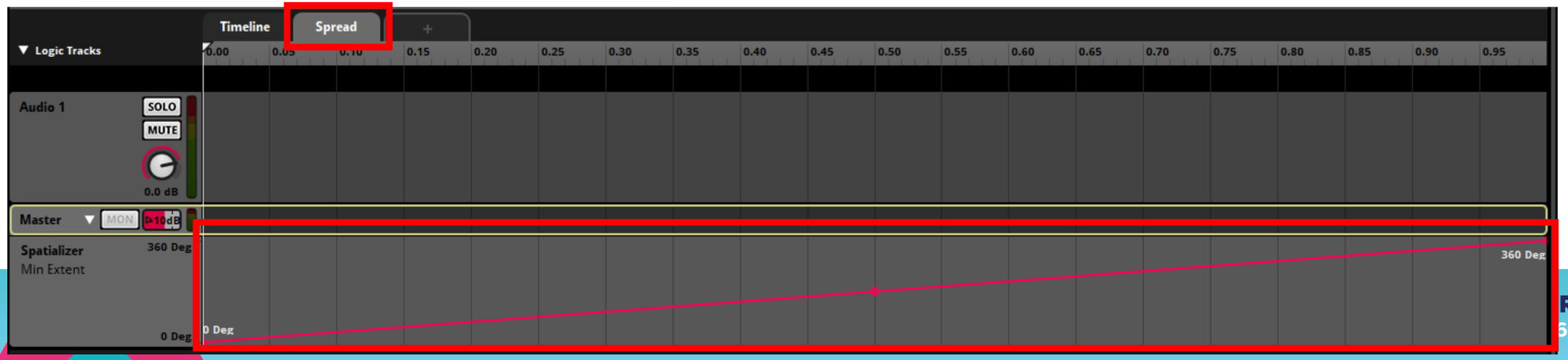
Details: Edge Cases

- Near field
  - As you get near to the volume, the sound needs to transition to full spread
- Popping
  - Add a seek speed to the direction and spread so that sudden changes don’t pop
- Close to zero
  - Certain edge cases are close to zero, and can cause strange values to pop up.
    - TL3 still has a few of these unsolved

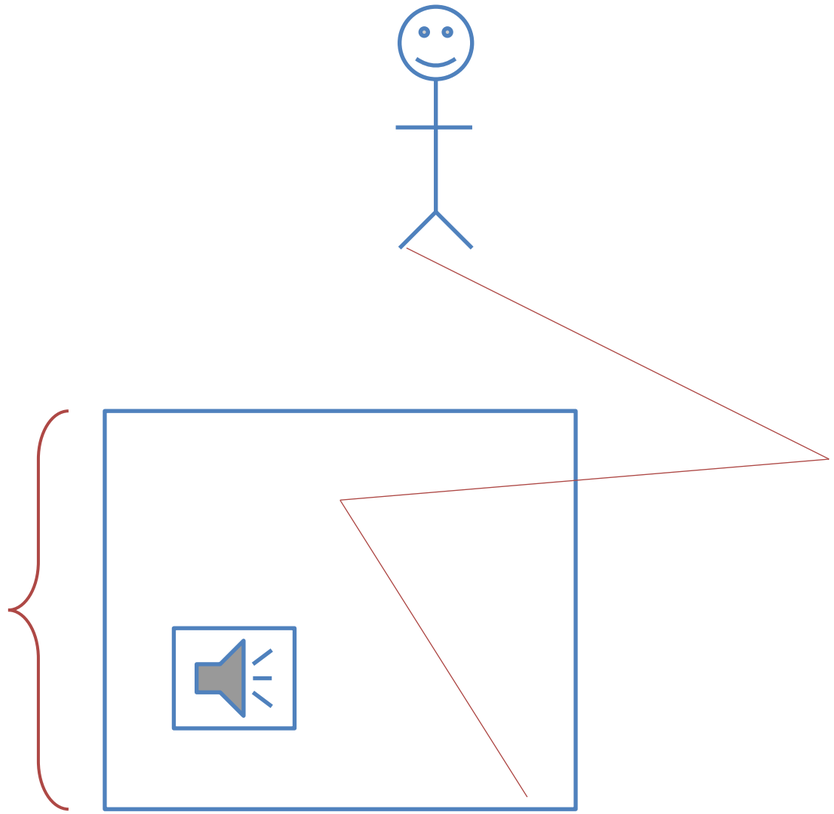
Details: FMOD Studio Setup







Details: Elevation



Details: Debug Display

- Show as much detail as possible:
  - Subdivided Boxes
  - Direction
  - Spread arc

Volumetric Sounds in Action

- Live Demo

Today’s Topics

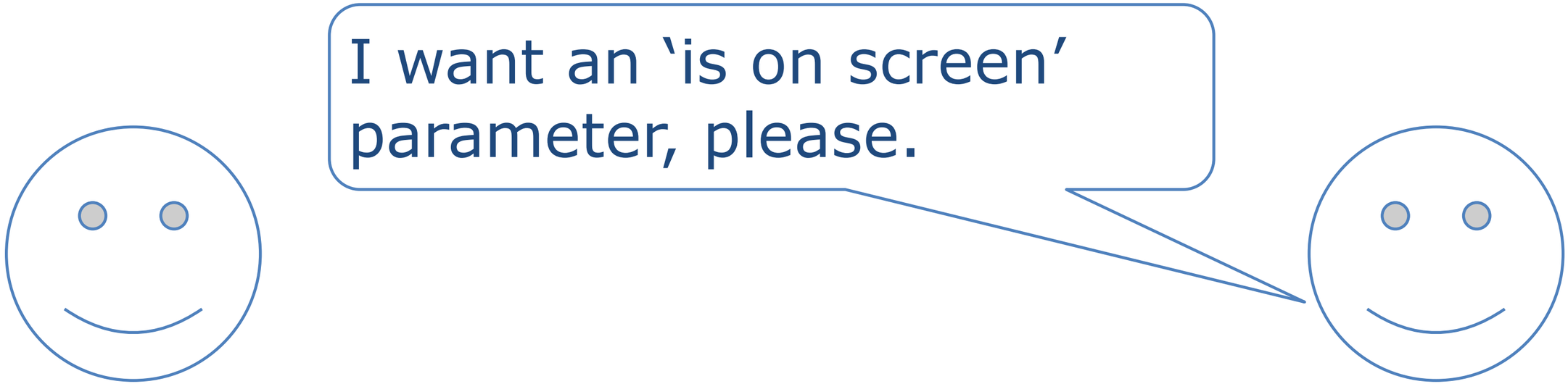
- Importance-Based Mixing
- Volumetric Sounds
- Screen-Space Distance Attenuation

A True Story

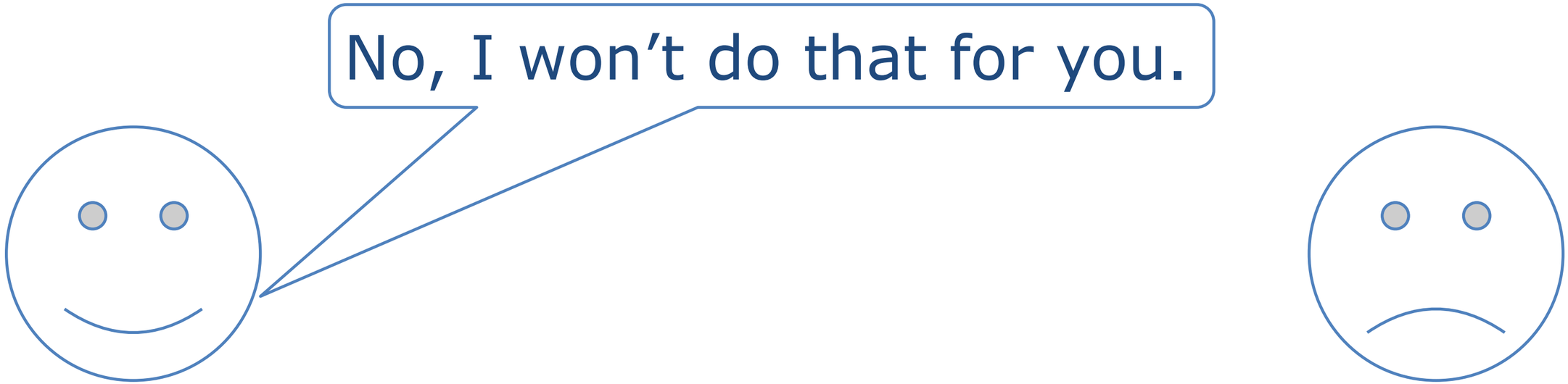
Me

Sound Designer

A True Story



A True Story



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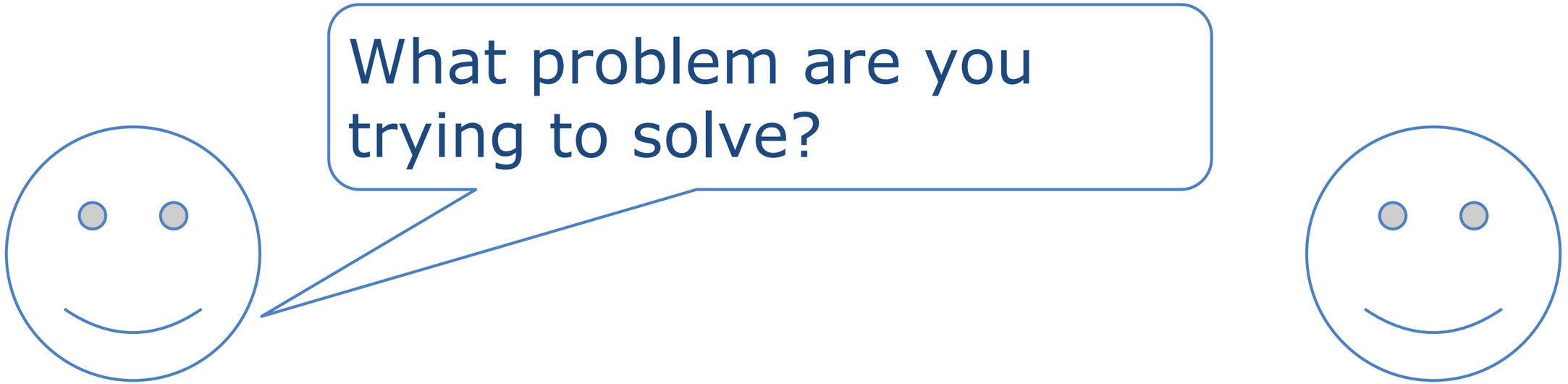
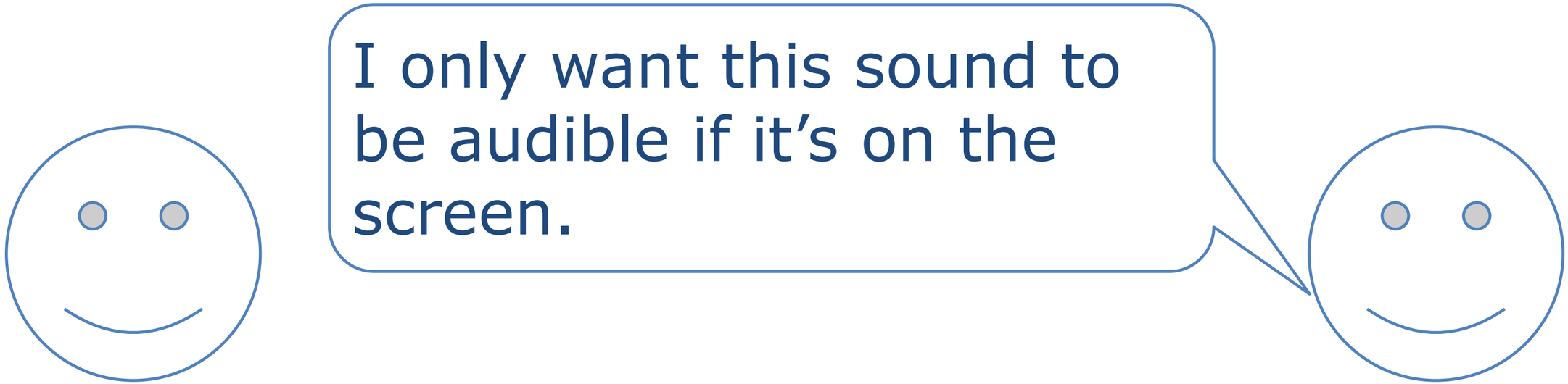
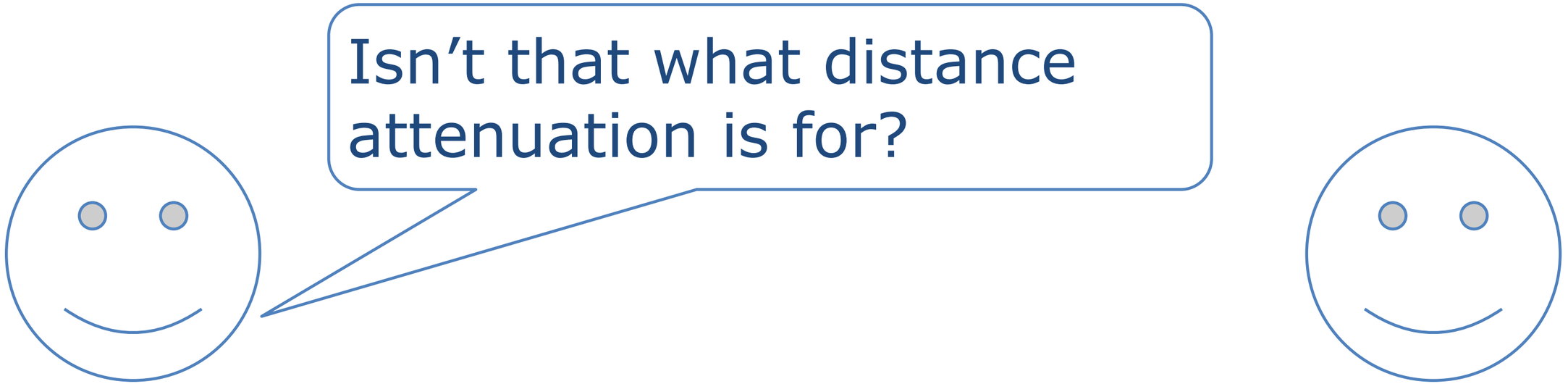


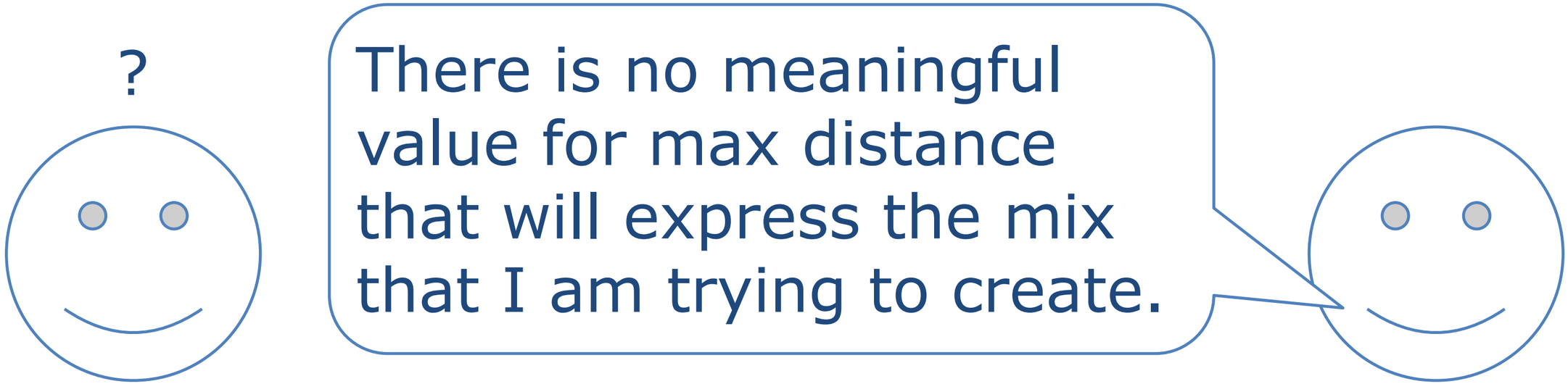
A True Story


I only want this sound to be audible if it’s on the screen.
Me
Sound Designer

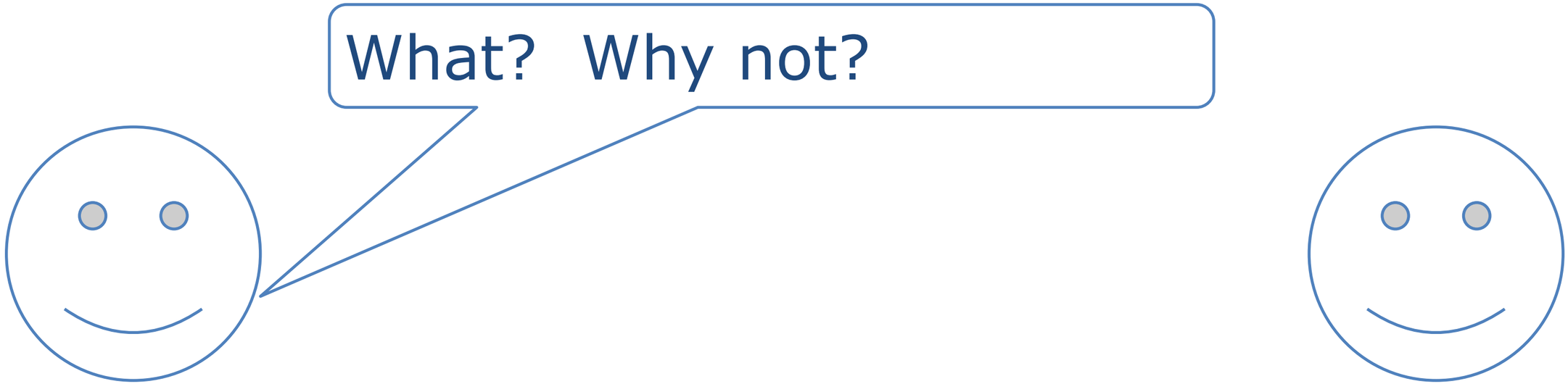
A True Story


Isn’t that what distance attenuation is for?
Me
Sound Designer

A True Story

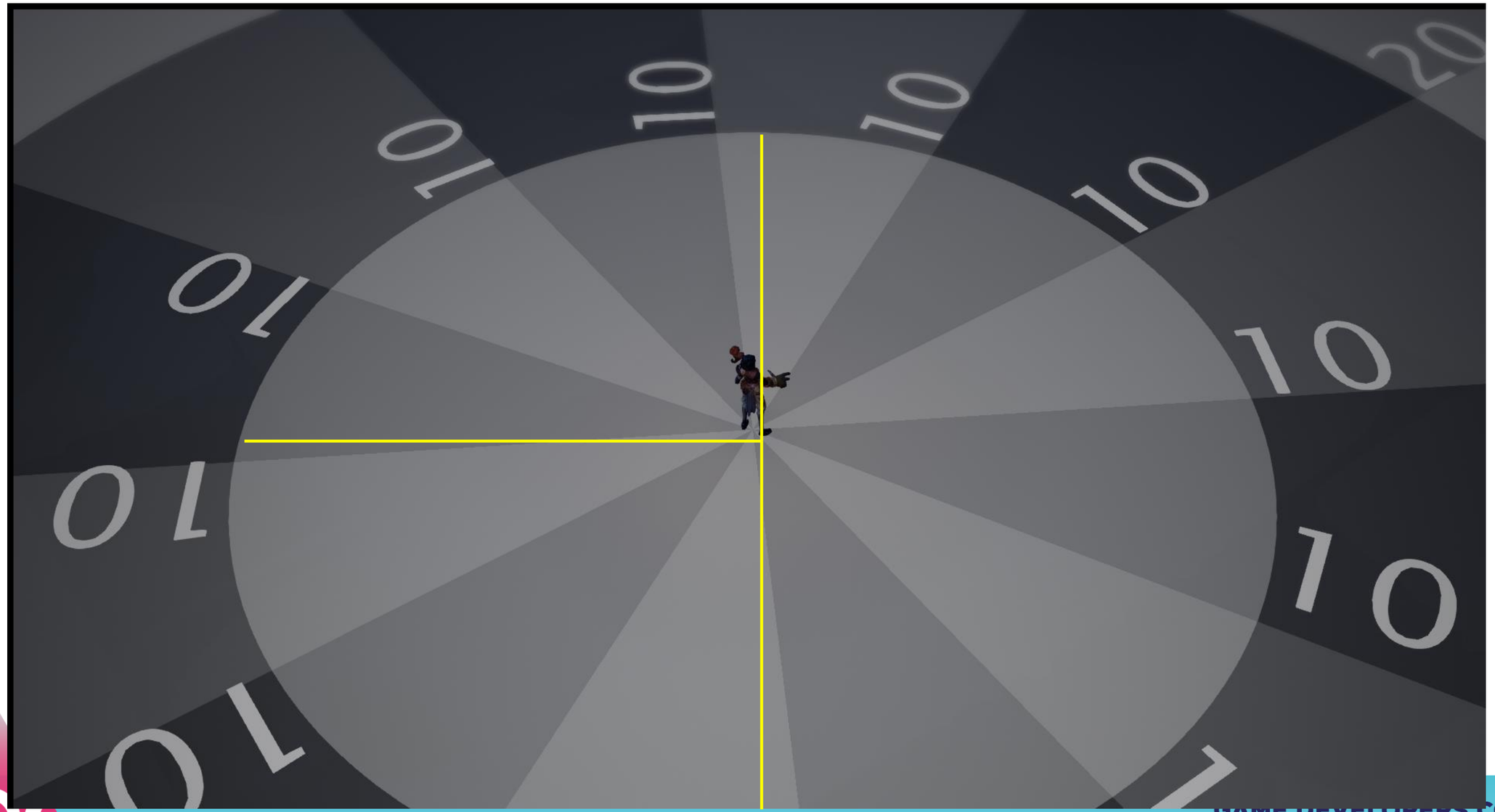

?
There is no meaningful value for max distance that will express the mix that I am trying to create.
Me
Sound Designer

A True Story

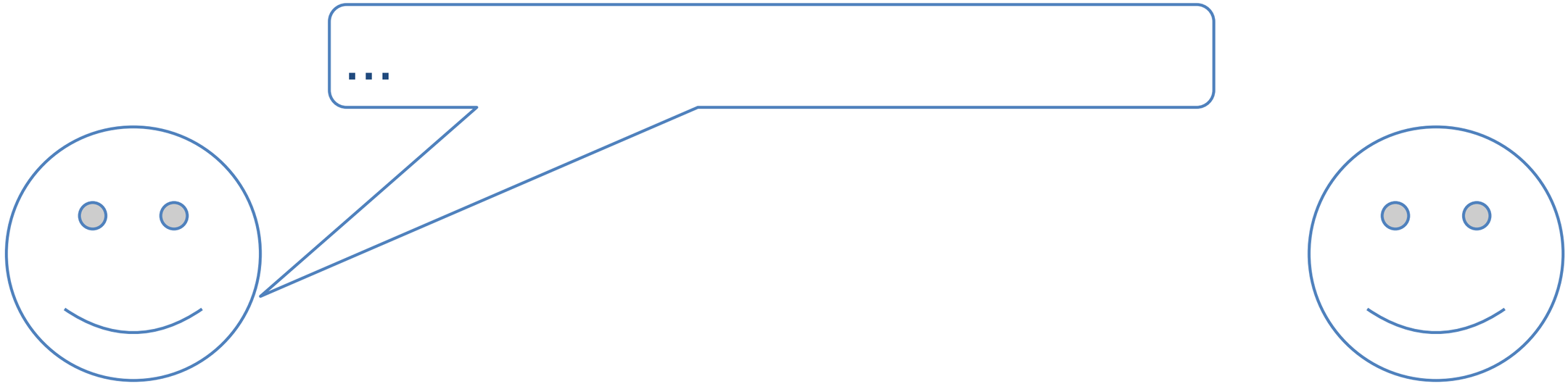


The Problem

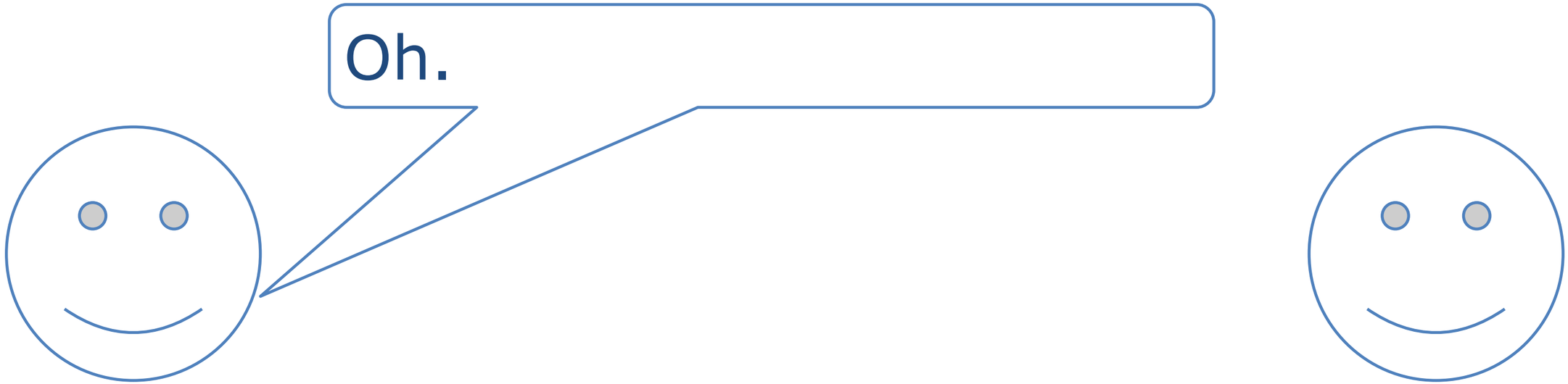
The Problem



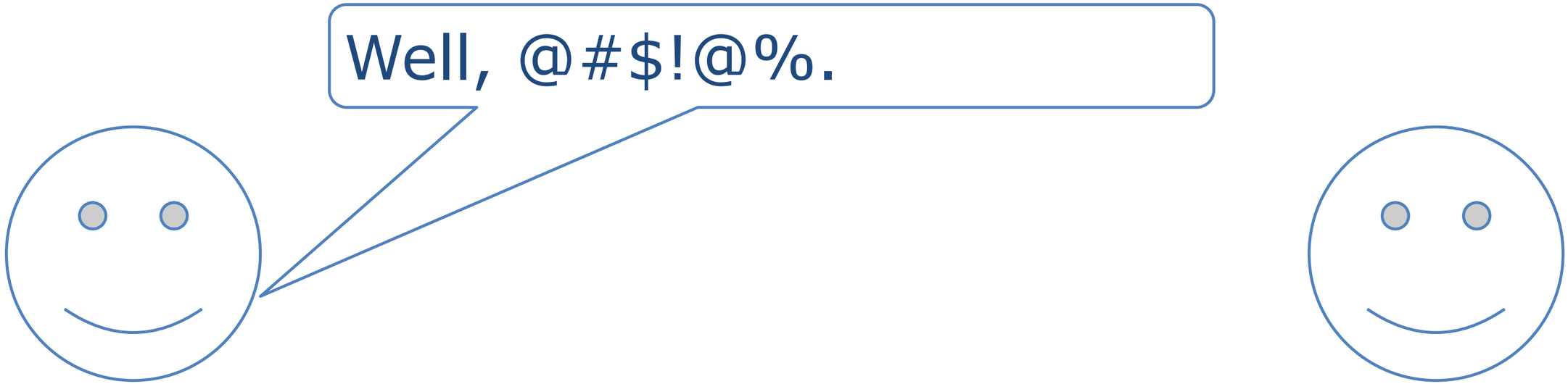
A True Story



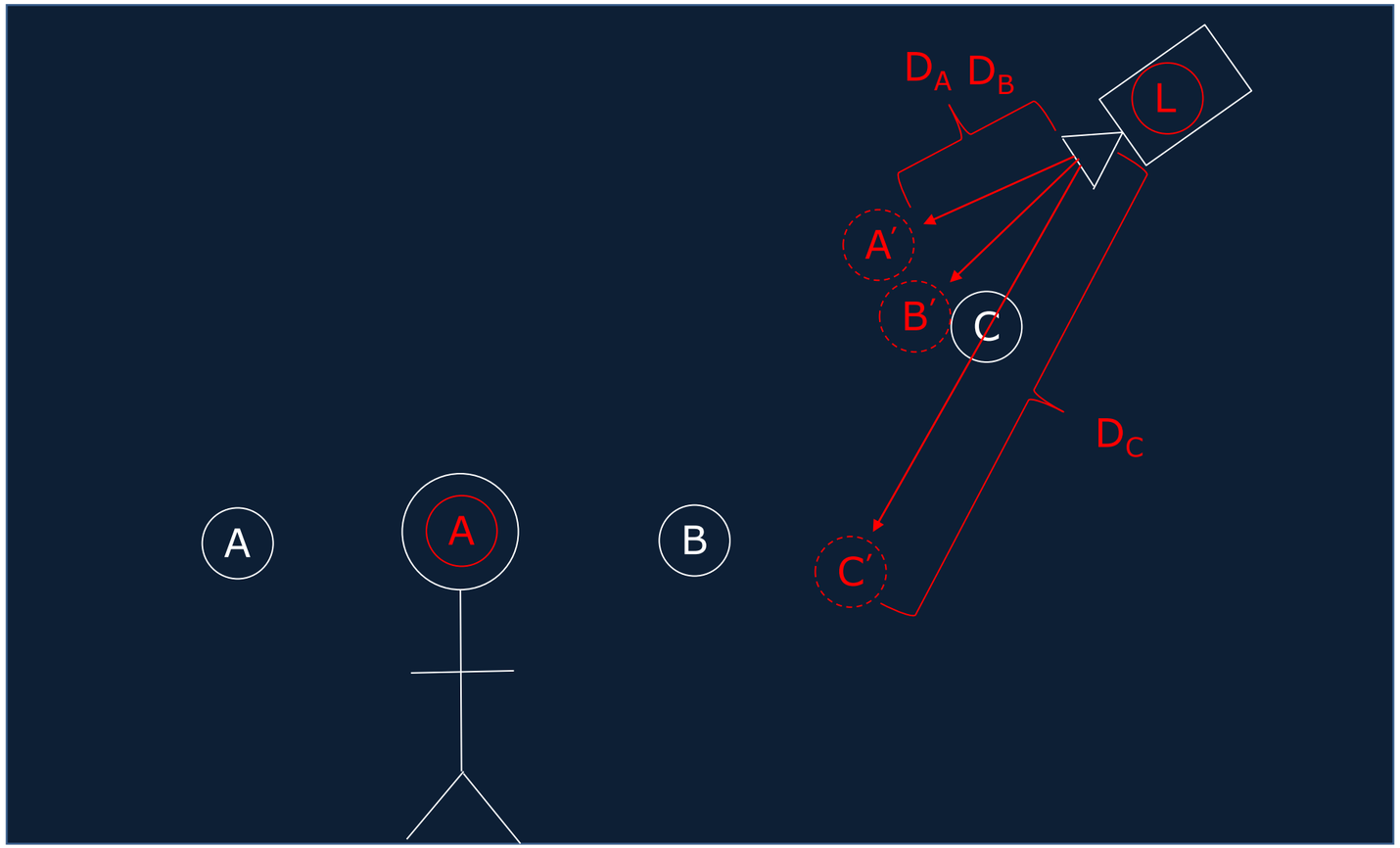
A True Story



A True Story



This is a given:



Original Listener Algorithm

- For each Channel
  - Calculate distance (d) from Channel Position to Attenuation Position
  - Find normalized vector ($\vec{N}$) from Listener Position (L) to Channel position
  - Place actual playing Channel at $L + d\vec{N}$

Screen-Space Distance Attenuation

- Project points onto unclipped screen space.
- Make distance equal to the screen-space distance to attenuation position

Adjusted Listener Algorithm

- For each Channel
  - Project Channel Position and Attenuation Position to screen space, and calculate 2D distance (d)
  - Find normalized vector ($\vec{N}$) from Listener Position (L) to Channel position
  - Place actual playing Channel at $L + d\vec{N}$

Implementation Details

- Scale is challenging
- Zooming in shouldn’t affect attenuation
- Debug Display
- Every sound’s distance attenuation must be re-authored

Scale Issues

- By default, screen-space projections give you either 0..1 or -1..+1
- Sound designer tools don’t like to work in such small scales
  - Also: Sound designers don’t like to work in such small scales

- Multiply all positions/distances by an agreed-upon factor
  - Torchlight 3 uses a scale of 20

Camera Zoom

- We can’t just call `ProjectWorldToScreen()`

Camera Zoom

- We can’t just call `ProjectWorldToScreen()`

Camera Zoom

- Project to where the camera would be if it were fully zoomed-out
- Need a function that will do the projection at a different location than the camera
  - (This is particularly useful for debug info)

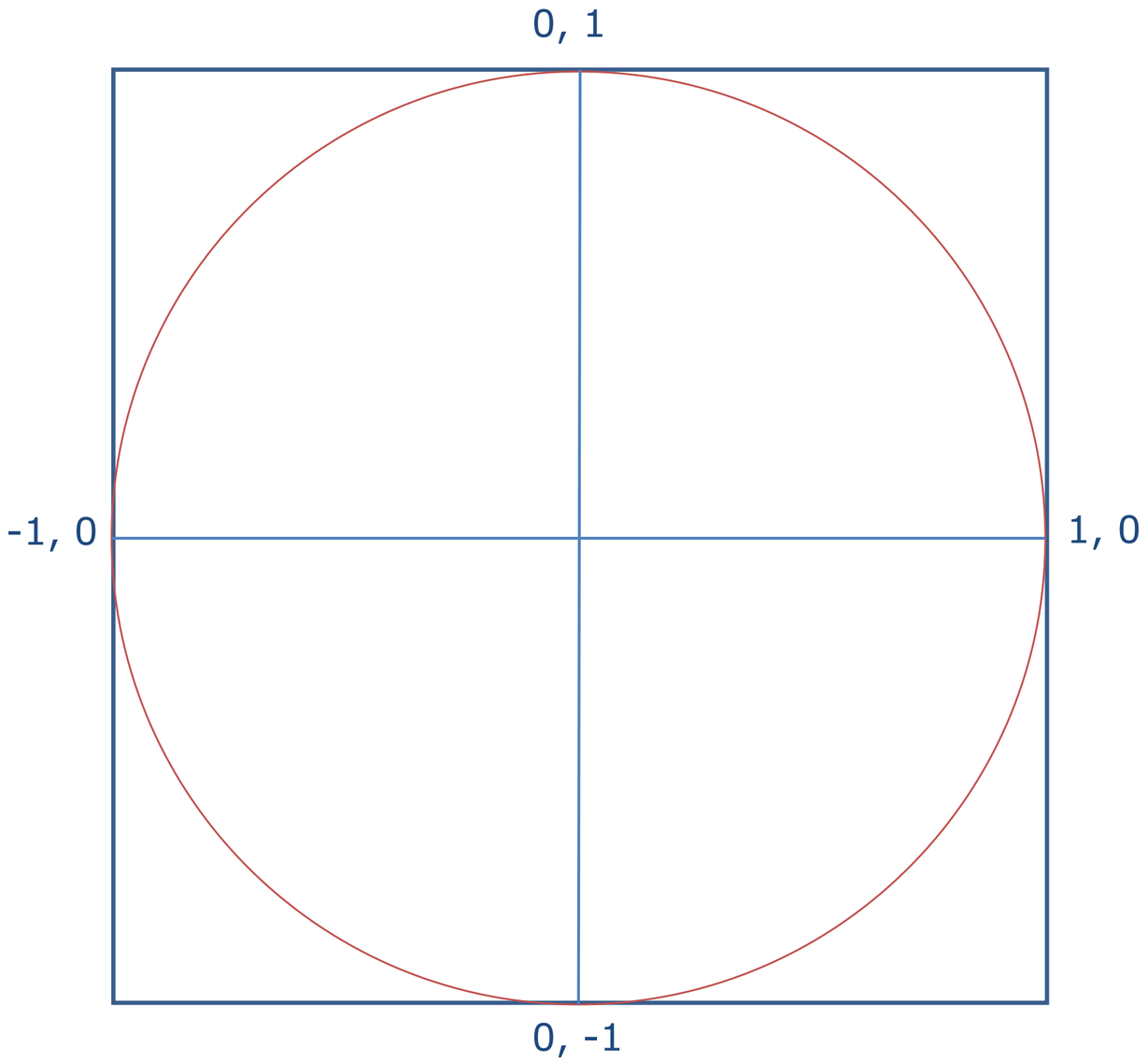
Debug Display

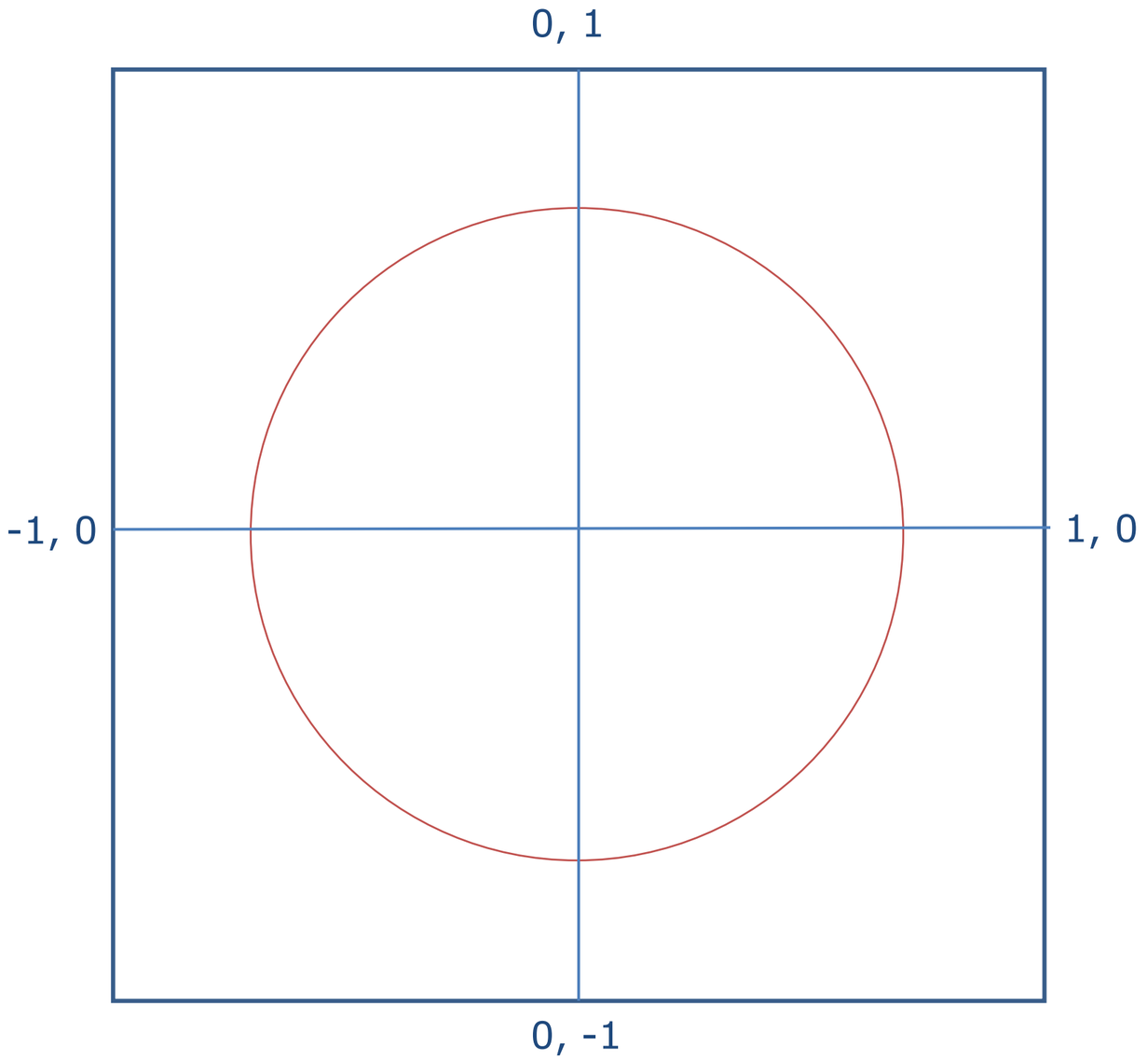
- Traditionally, we display a sphere of the appropriate radius.
- Not anymore: distance attenuation isn’t shaped like a sphere (or a circle) anymore
- How do we help the sound designers understand where in world space the sound will be audible?

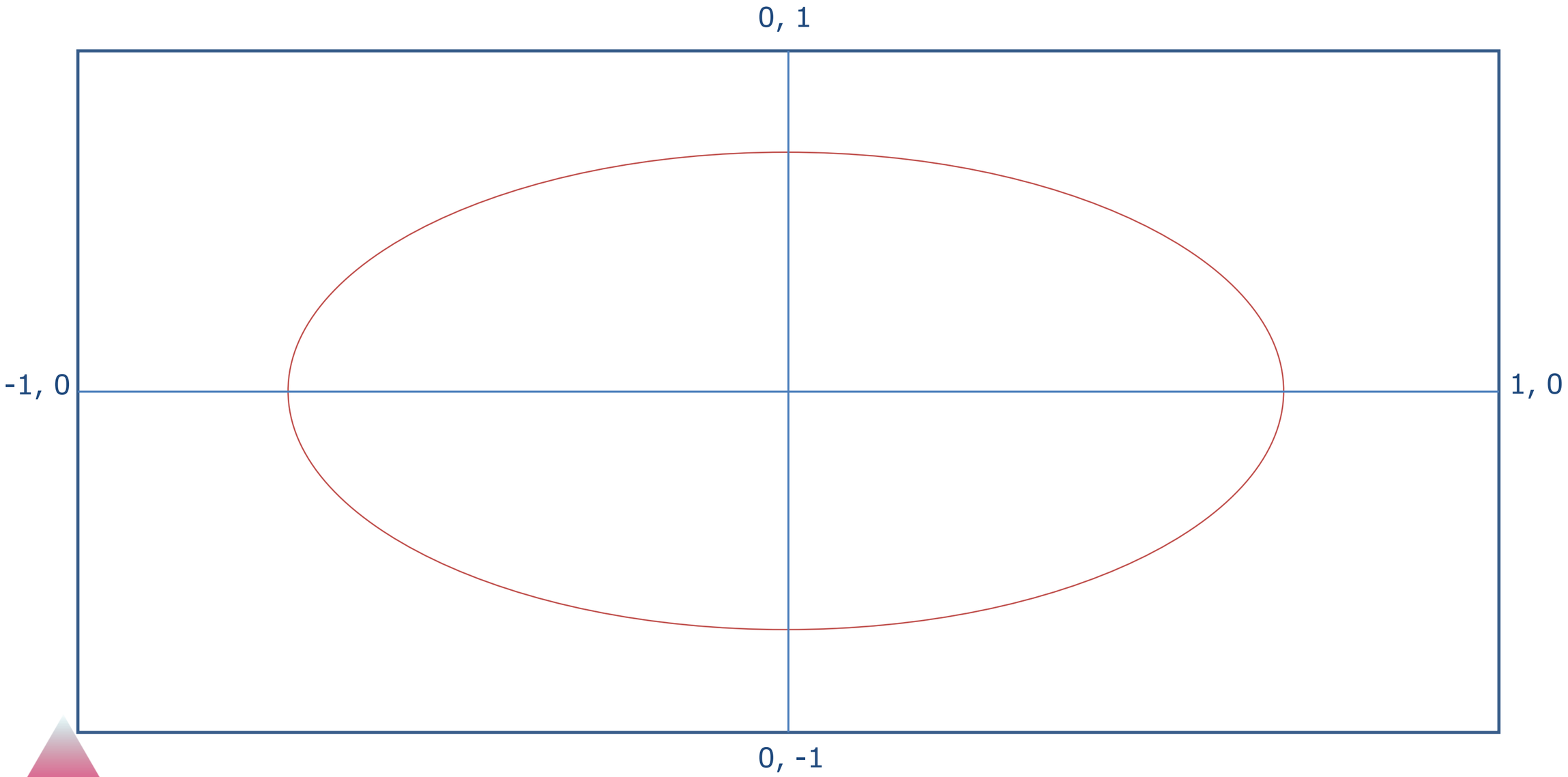
  - We need to invert the process of projection

Algorithm:

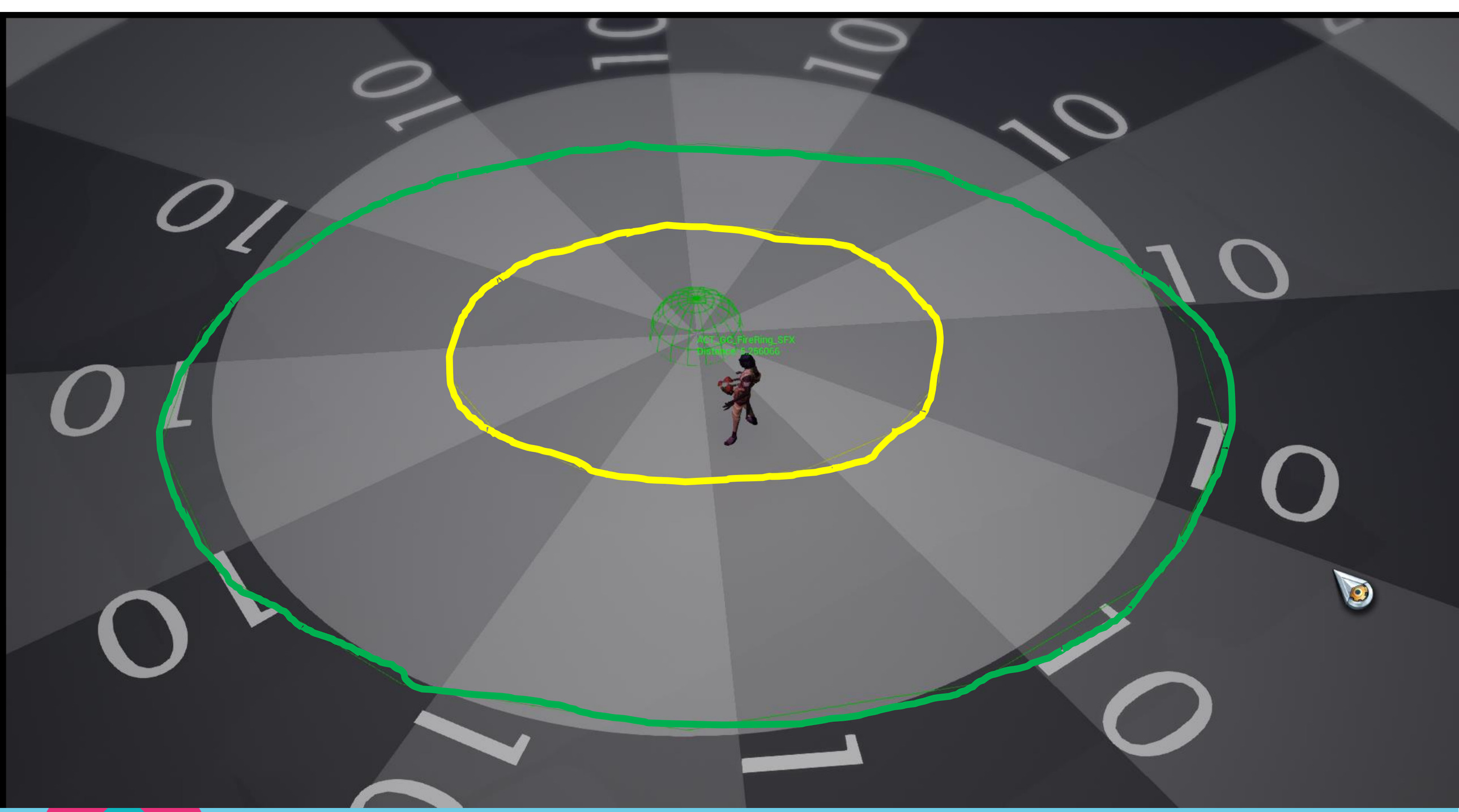
- Take the vector (S_x, S_y, A_z) and project onto screen space
- Make a circle in screen-space at a radius of Distance/20 (or whatever your screen-space scale is), centered on the projected point
  - Convert to pixel coordinates if necessary
    - In Torchlight 3, we must first convert from -1..+1 to 0..1, then convert to pixel coordinates
  - Deproject screen to world position + ray
  - Intersect ray with the attenuation position's plane
    - Flip intersected X and Y around original sound location

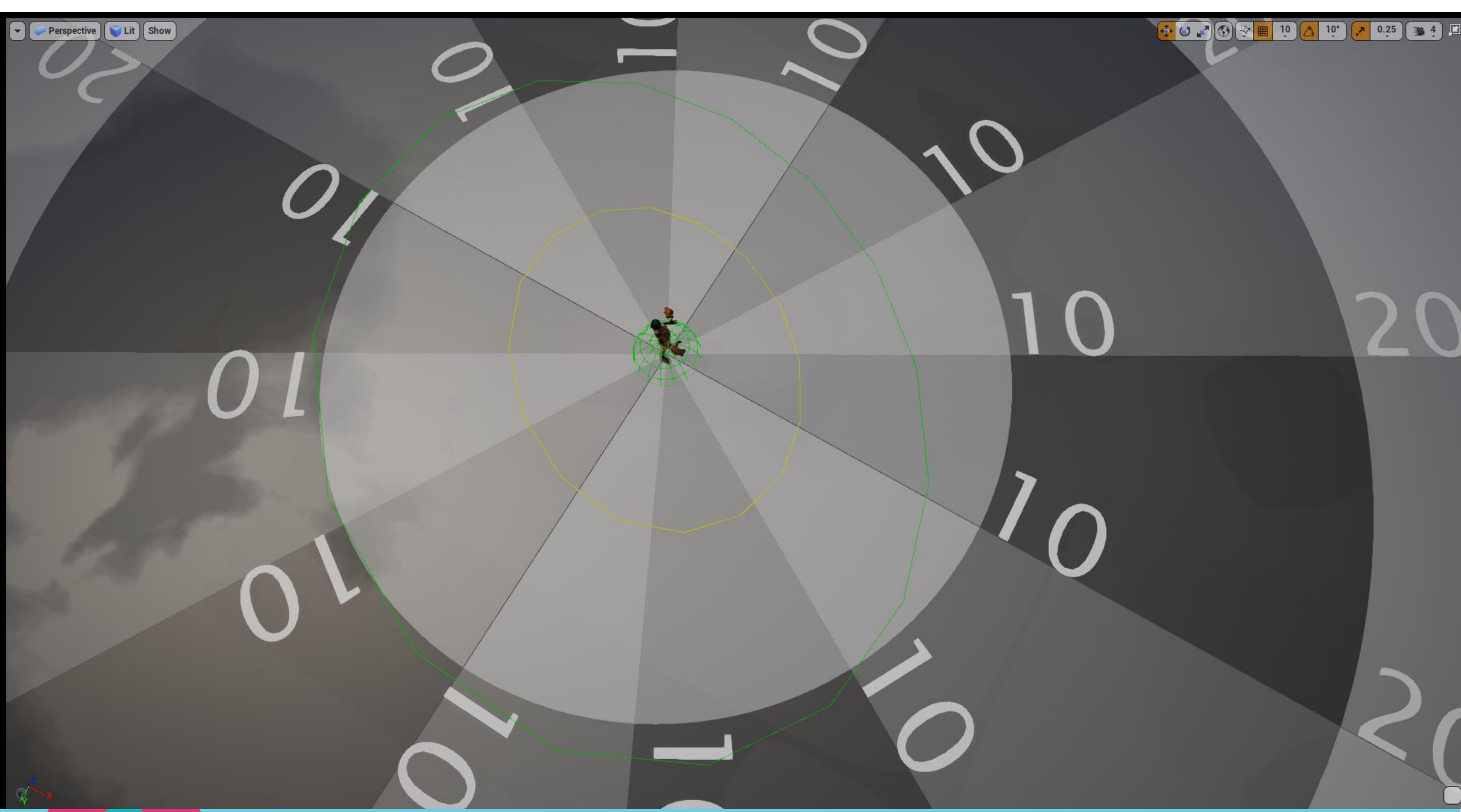

0, 1
-1, 0
1, 0
0, -1

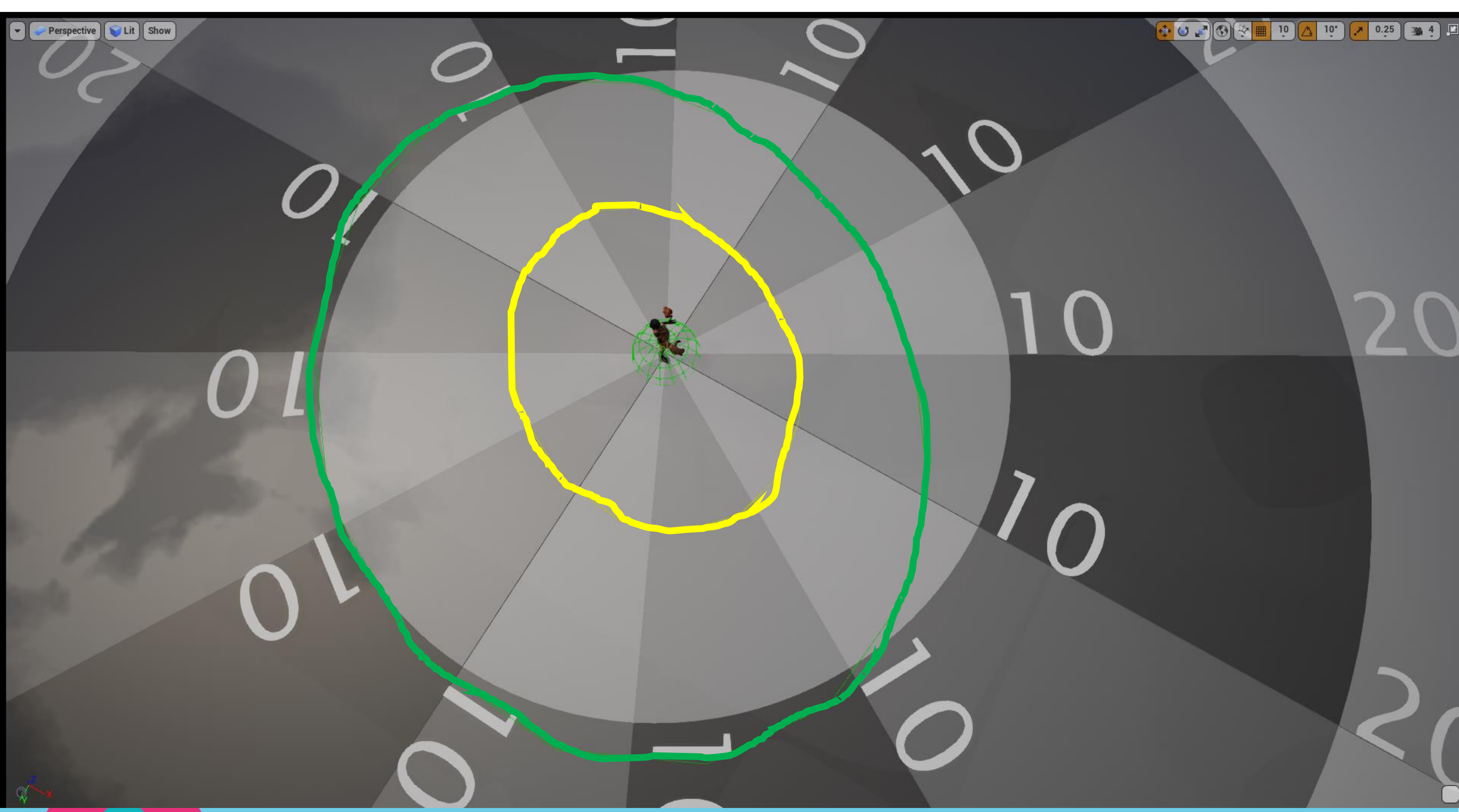

0, 1
-1, 0
1, 0
0, -1


0, 1
-1, 0
1, 0
0, -1


ACT_GC_FireRing_SFX
Distance: 5.256066

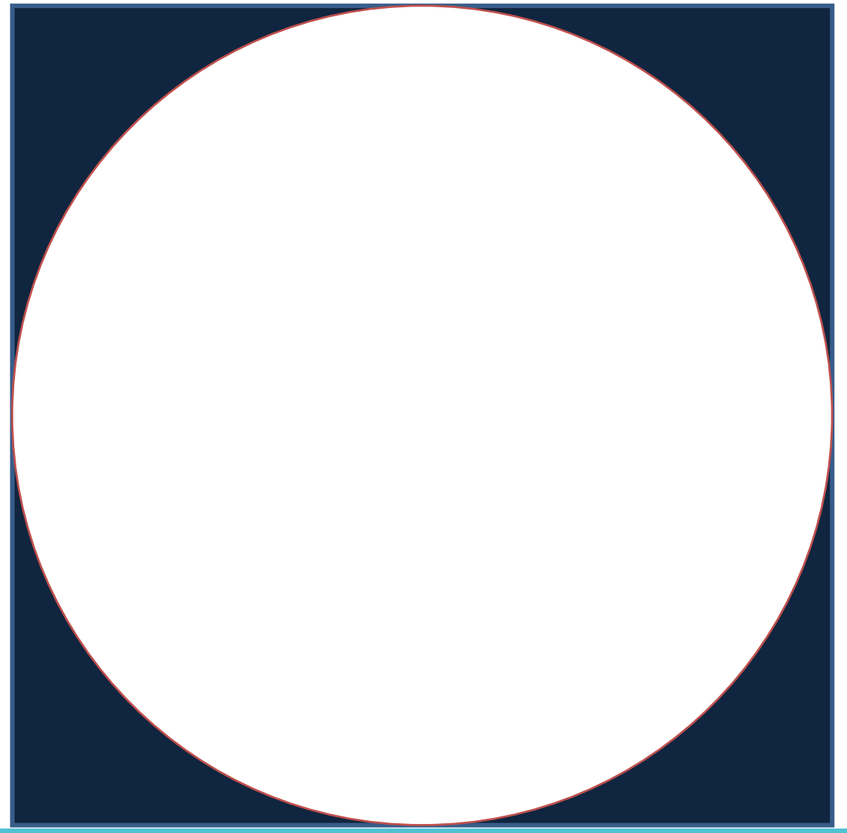

ACT_GC_FireRing_SFX

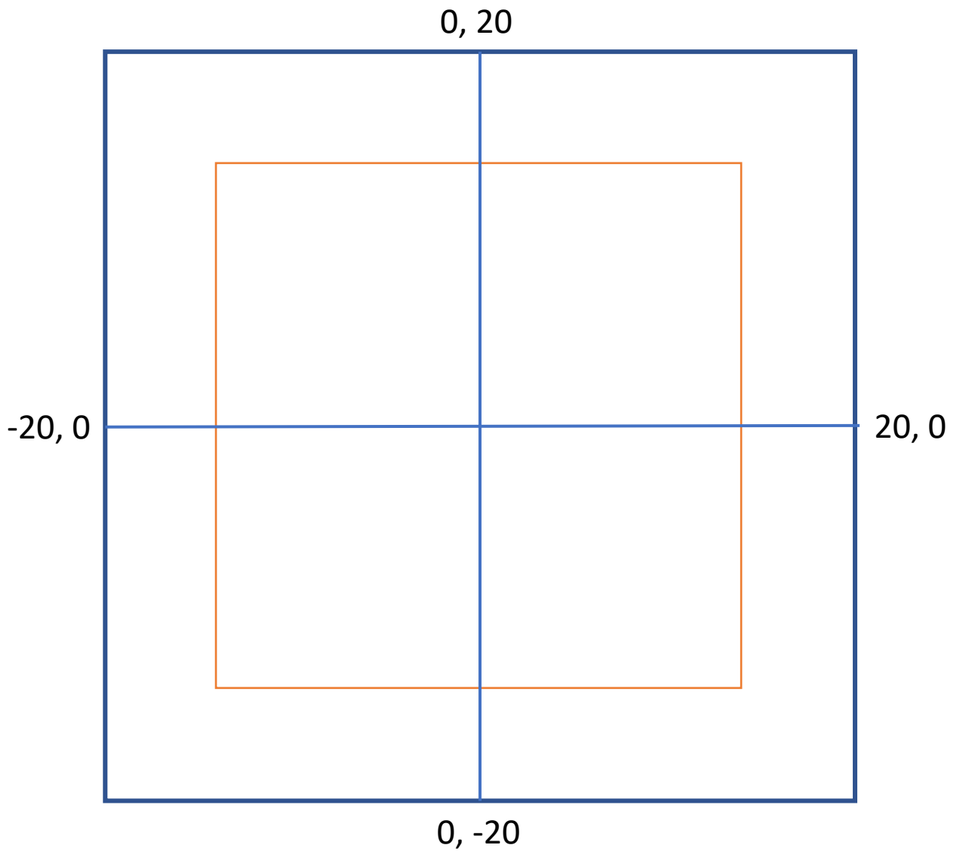

Perspective
Lit
Show
10
10°
0.25
4
10
20

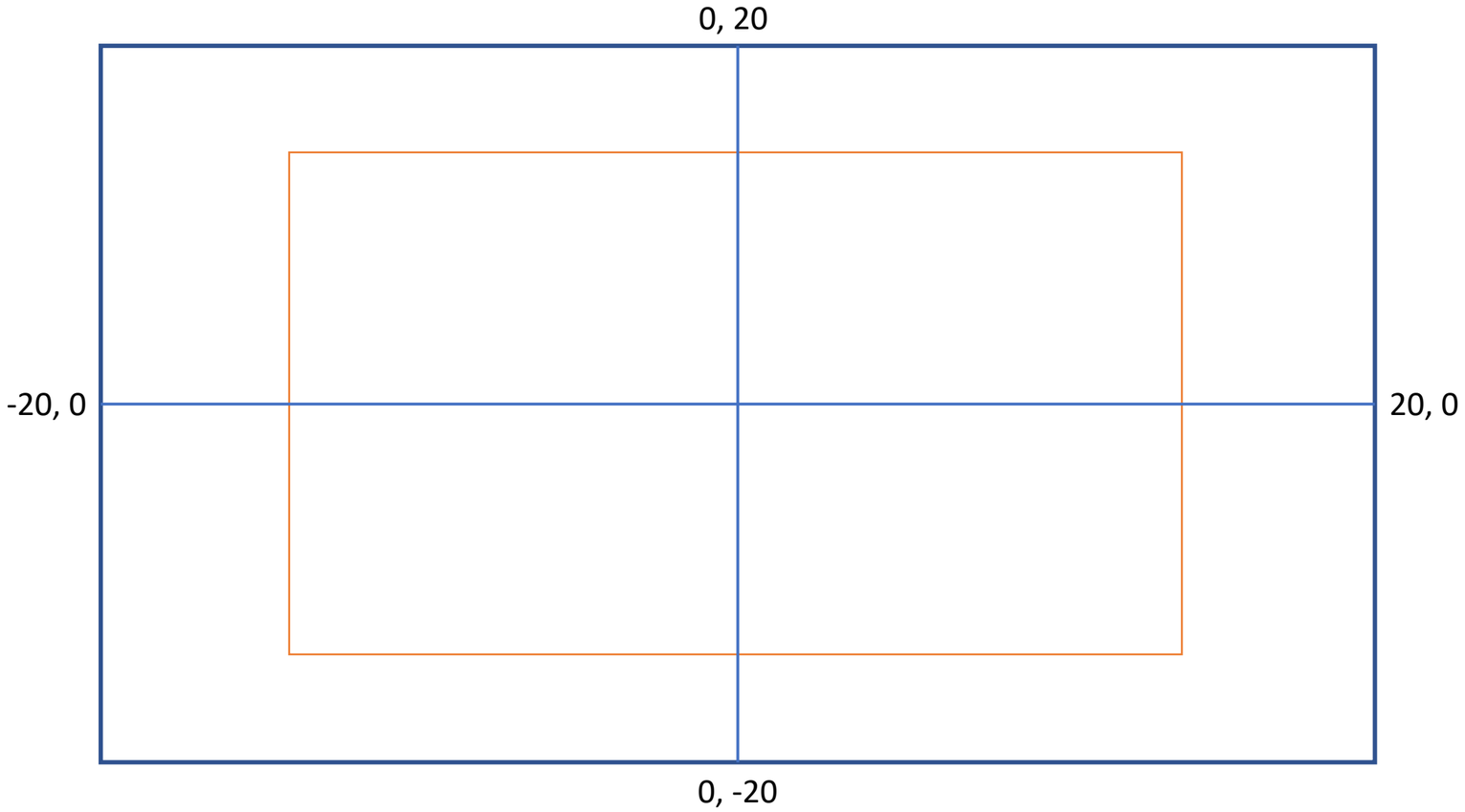

Perspective
Lit
Show
10
10°
0.25
4
10
20

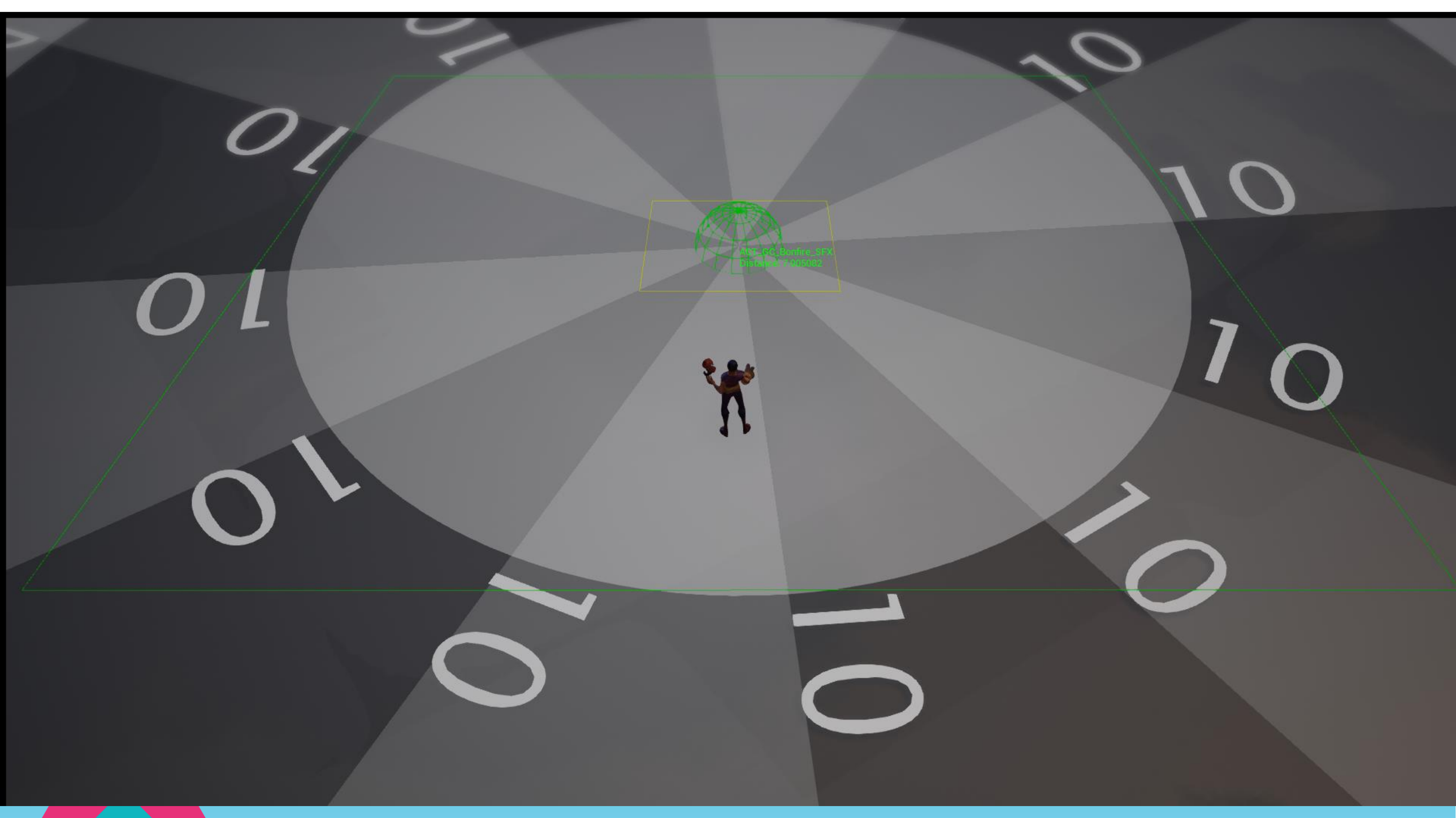
But wait…

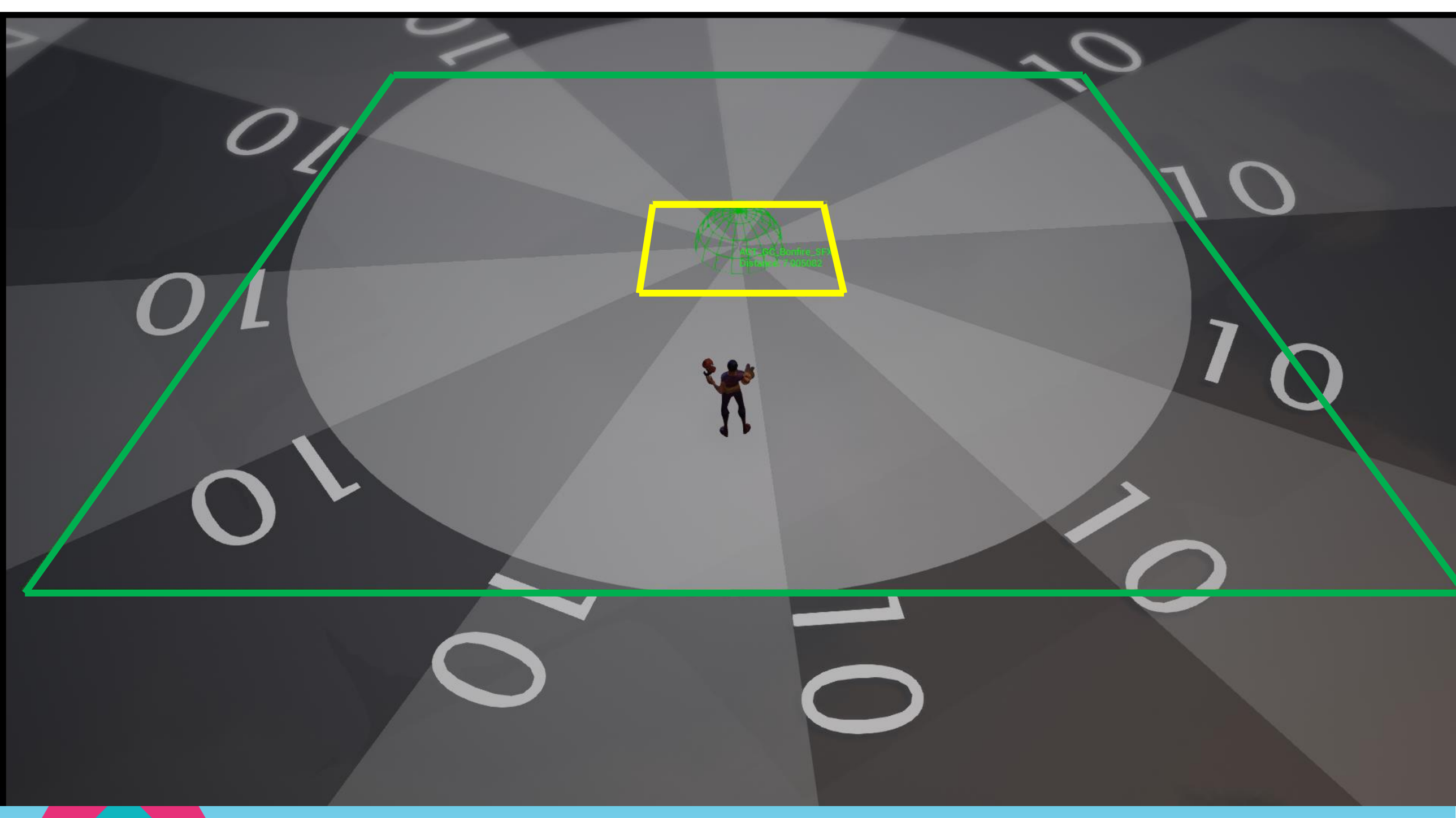
- We’ve been doing all of this work in screen-space
- What about the corners?

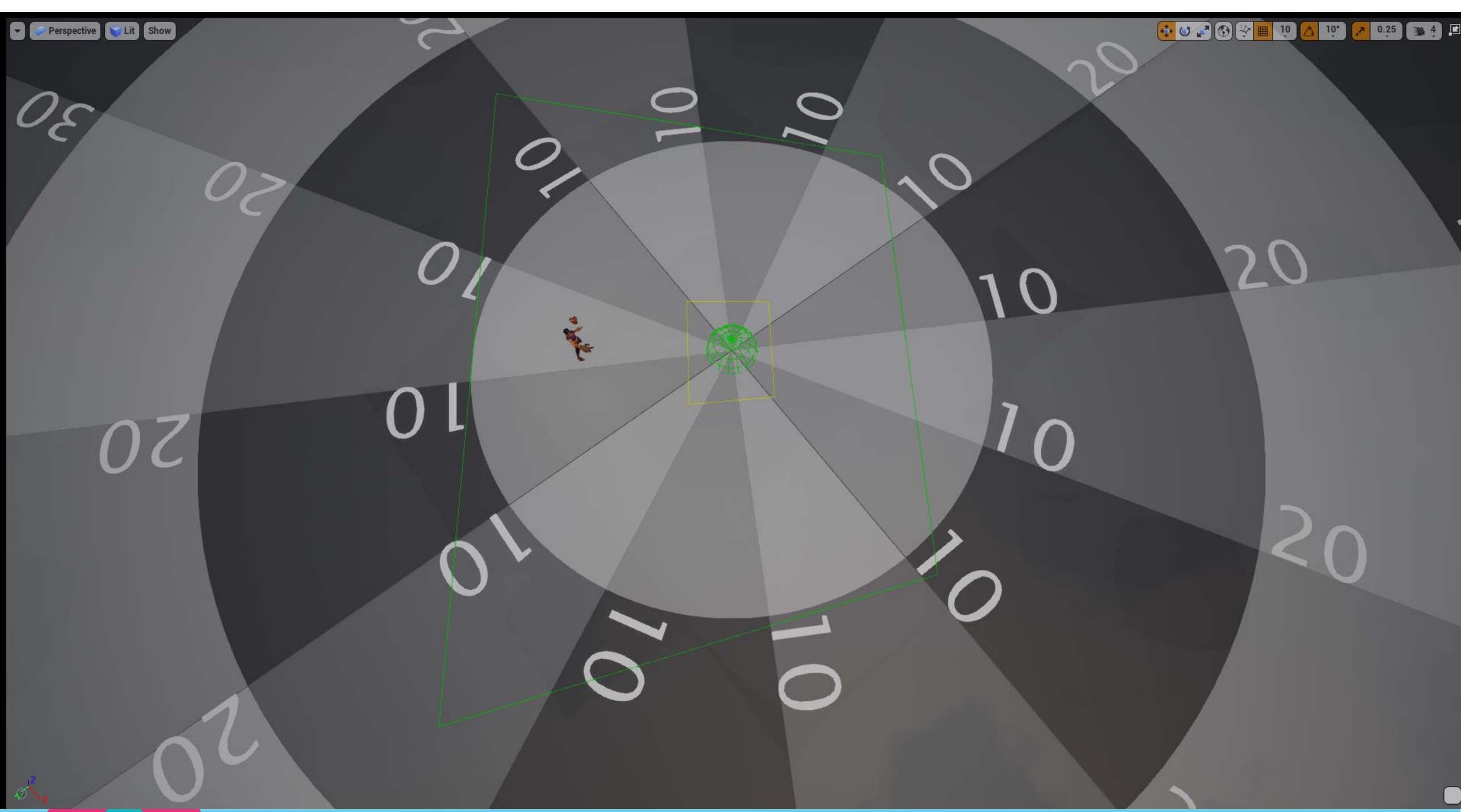


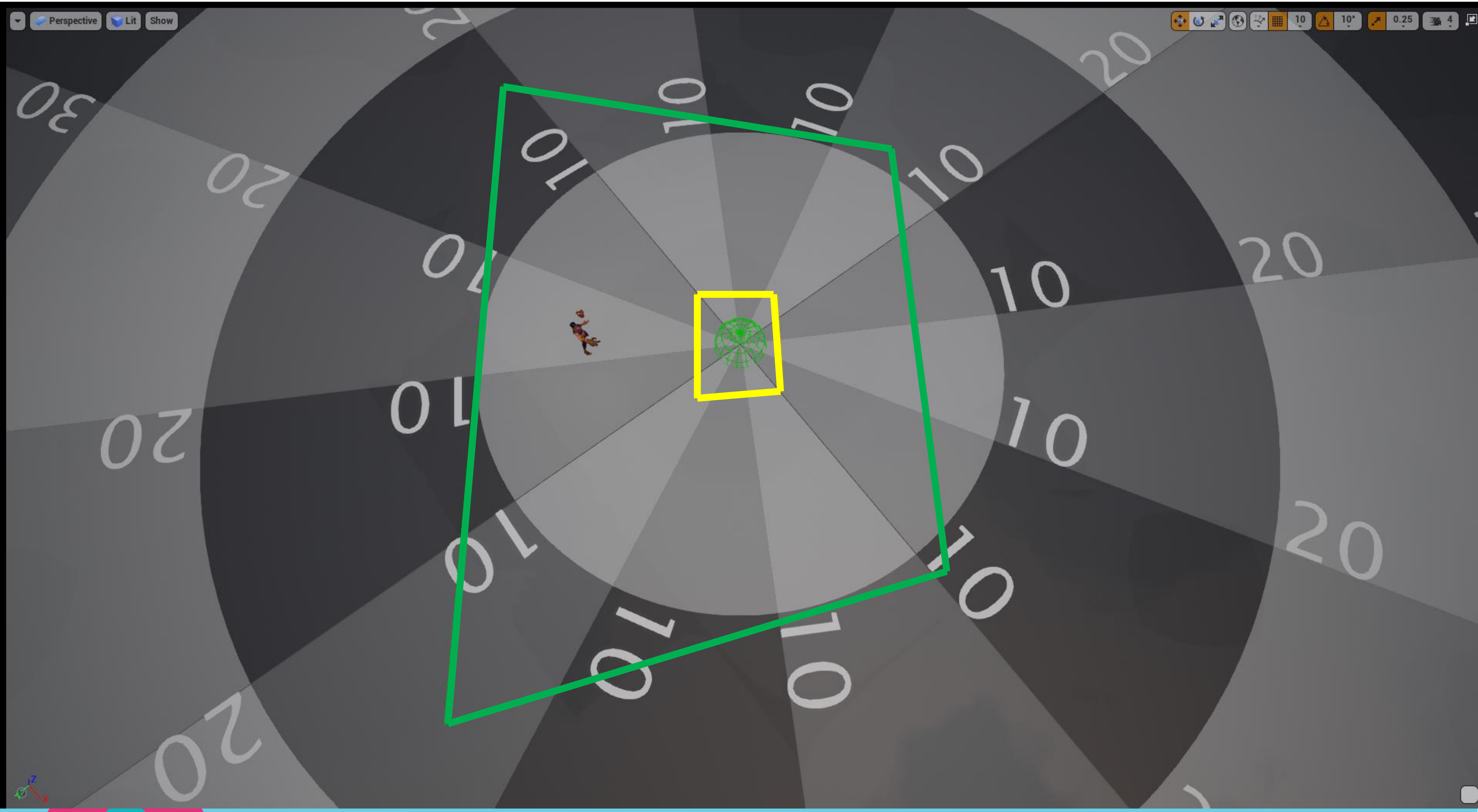

0, 20
-20, 0
20, 0
0, -20


0, 20
-20, 0
20, 0
0, -20


AGT_GC_Bonfire_SFX
Distance: 7.005082


AGT_GC_Bonfire_SFX
Distance: 7.005082


Perspective
Lit
Show
10
10°
0.25
4
10
20
30


Perspective
Lit
Show
10
10°
0.25
4

Content Tendrils

- We have replaced a 3D world-space value with a 2D screen-space value
- Distance no longer means the same thing that it used to

- Every 3D sound event must be reauthored to account for this new idea of distance
  - Every distance calculation must make a decision whether to use 3D or 2D distance

Screen-Space Distance Attenuation in Action

- Live Demo

Conclusion

- ARPGs have distinctive (but not unique) challenges

- Importance-Based Mixing is a fundamental feature
  - Part of every audio engine from day 1
- Volumetric Sounds solve the river problem elegantly
  - You don’t necessarily have to understand the math
- Screen-space distance attenuation is also a fundamental feature
    - (If you have a fixed-camera game like an ARPG or RTS)

Conclusion

- Complex features are complex
- Debugging and visualization routines are *critical*
- Good visualization can be hard, but it’s always worthwhile

Questions

- Comments
- Compliments
- Complaints
- Queries
- Inquiries
- Inquests
- Observations
- Opinions

- Remarks
- Commendations
- Objections
- Impressions
- Thoughts
- Commentary
- Assertions
  - (Just kidding! Everybody knows that game devs ignore asserts.)