Game Audio Programming

EECS 4462 - Digital Audio

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Most material in this slide set is from
Game Audio Programming 2: Principles and Practices,
by Guy Somberg, CRC Press

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Audio for movies vs games

- Similarities
  - 3 main audio components: Music, Dialogue, Sound effects
  - Need quality audio for all three
    - Music: Appropriate genre, well recorded, different music for different parts of the movie/game
    - Dialogue: Clearly recorded with no background noise
    - Sound FX: Realistic sounds / foley
- https://www.youtube.com/watch?v=U_tqB4IZvMk

Audio Personnel

- Many different roles for audio people (depending on the size of the project)
  - Sound designers will decide create original sounds
  - Composers will write original music and music professionals will play it
  - Recording engineers will record all audio components
  - Audio post production personnel will put everything together in the end to create an immersive experience
  - A game audio programmer is also doing audio post production, but…

Audio for movies vs games

- Differences
  - Audio post production takes place after the visual aspect of a movie has been fixed
  - A movie is a passive experience
  - Games are interactive
  - Sounds must be mixed together on the fly depending on what the player and all the characters in the game are doing
  - Limited resources in terms of memory and CPU time will be available for audio

Game production lifecycle

- Game audio should be a part of game production form the beginning
- The three phases of game production and their milestones:

1. Preproduction ➔ First Playable (Vertical Slice)
2. Production ➔ Alpha (Content Complete)
3. Postproduction ➔ Beta (Content Finalized)

Audio middleware

- Keeps track of all the audio content, as well as the audio infrastructure, e.g.
    - Audio assets contain raw audio as well as information about volume, positioning, pitch etc.
    - Audio events are triggered by the game engine and contain information as to how an audio asset should sound, e.g. how it will attenuate over distance
    - Audio triggers are in-game entities that trigger audio events

Preproduction

- Decide on the audio modules that will be part of the game
  - Player
  - Cast
  - Levels
  - Environment
  - Music
- Brainstorm on ideas for all the above

Audio prototypes

- Small test cases to help us define triggers, events, and their interaction
- Audio assets can be simple but as realistic as possible at this point
- Examples
  - Surface types
  - Reverb areas
  - Equipment / vehicles
  - Environments
  - Other characters

Audio design layers

- Feedback
  - Indicates that something has happened, e.g. a beep in PONG
- Immersion
  - More realistic sounds, e.g. a racket flick, that may change based on speed or direction
- Emotion / Experience
  - The audio changes depending on whether the player is winning or losing, or gets louder as time goes by
- In preproduction, we focus on feedback and try to incorporate as much immersion as possible

Preproduction milestone

- **First Playable**
  - Limited / condensed version of the final product
- Showcases only a few basic options
- Main goal to set up and test the audio infrastructure of events and triggers

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Production

- Fill up every element of the game
- Can use placeholders when audio is not available
  - E.g. say the name of the event, or the state of different characters, or of the sound effect
  - Many audio assets are created in post production where things like character clothes or shoes are finalized
- Debug placeholders, e.g. a beep, can be used when game states or parameters are not specified or missing
- Build towards immersion as much as possible

Production milestone

- **Alpha**
- The game is content complete, i.e. can be played from start to finish without crashes
- There is audio for every event even if it is a placeholder
- All audio assets conform to the EBU R128 Loudness Recommendation Standard
  - Measures loudness in loudness units (LU) across an audio asset, not only at the peak level
  - Much closer to how loudness is perceived
  - https://www.youtube.com/watch?v=iuEtQqC-Sqo

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Postproduction

- Finalize all audio assets
- Test!
  - Typically done in pairs: One tester plays, the other mixes, i.e. adjusts volumes, effects etc.
  - Bug fixing
- Milestone: **Beta**

Dealing with multiple characters

- In many modern games, there is a variety of characters on the screen at at time that could generate audio
- Mixing audio from many sources can make the final mix sound muddy, and uses many resources
- The HW platform may also have a playback limit
- Solution: Virtual Channels
  - Some sources of audio (sometimes also called channels) are declared virtual, i.e. do not contribute audio
  - It is up to the audio programmer to decide how this will be implemented

Choosing virtual channels

- Assign a priority to each sound, and play only those sounds of highest priority
- The listener's distance to the sound must be factored in
  - Further sounds must have lower priority
- In modern HW, the global playback limit is not an issue, but audio programmers often impose local limits to avoid making the mix too muddy
  - For example, limit gunshot sounds to at most 20

The rule of two and a half

- Used in movie audio post production
- When one actor is walking, it is important that the sound of their footsteps match the visuals
- Similarly, when two actors are walking
- When we pass the threshold of 2.5 actors, it is no longer necessary to synchronize footsteps to actors
    - Audio of multiple people walking is sufficient

Mixing

- The act of bringing all audio assets (music, voice, SFX) together in a way that is enjoyable and supports the gameplay
- Offline mixing: Mixing happens in a separate program (usually a DAW). The result is fixed and is reproduced as is
- Games require **real time mixing**
  - Volumes and frequencies of audio assets are changed as the game is running

Real time mixing (passive)

- The behaviour of audio is authored in a static way, so that the audio signal changes dynamically by being routed to a DSP effect
- Example: **Ducking** music when dialogue is heard
- This can be done programmatically (active mixing) but is often done by side-chaining the dialogue audio bus on to a dynamic range compressor on the music bus
  - More on this on the next module

Realtime mixing (active)

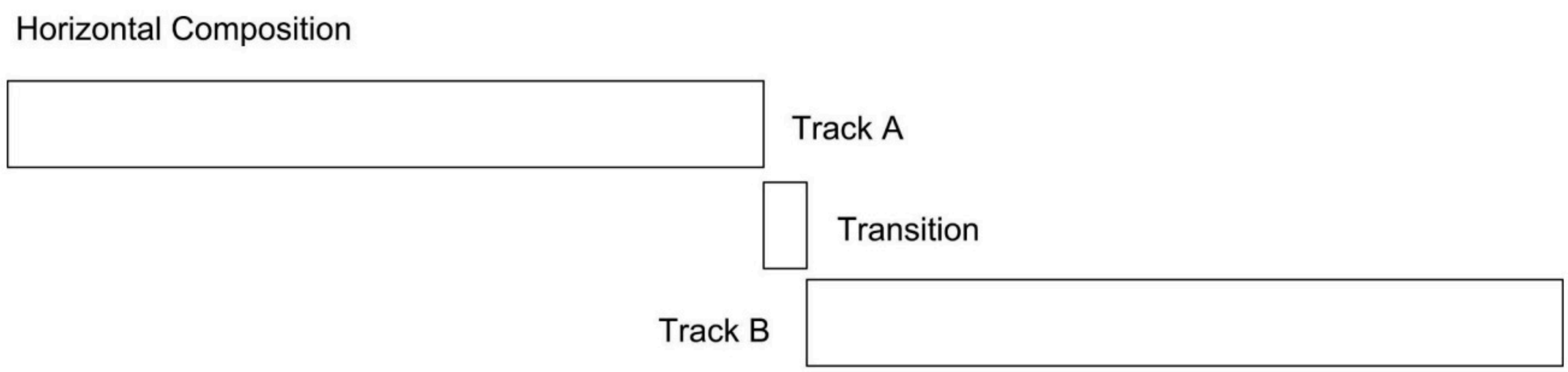
- Events in the gameplay manipulate the mix
- Audio assets are being changed on the fly
- Example: An explosion happens very close to the player. Instead of playing an explosion sound very loud, the game ducks the SFX bus and plays a ringing sound instead

Music transitions

- Music background for games is often pre-composed and recorded
- Looping the same audio file can quickly become boring
- Different levels in a game will typically have different music
- Dramatic events also require music transitions
- Two ways to accomplish this
  - Horizontal Composition
  - Vertical Composition

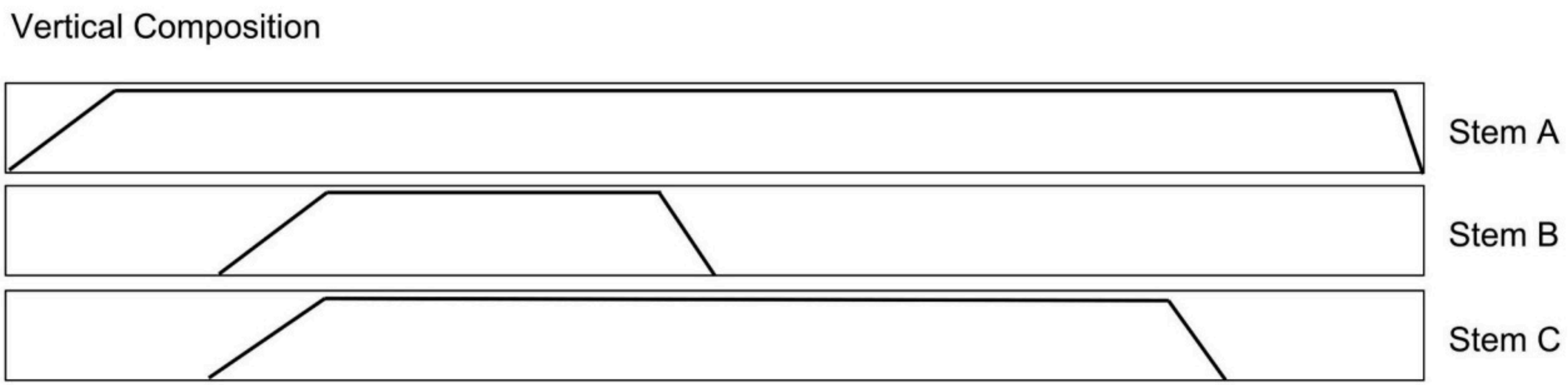
Horizontal Composition

- Music switches from one pre-recorded track to another
- Transition can be done through fade in/out, but more often through a **stinger**, a small piece of audio that corresponds to the event that required the transition, e.g. an explosion



Vertical Composition

- Different sets of instruments are recorded in separate tracks, called **stems**
- Based on game events, different stems are faded in or out, e.g. drums may come in for a fight scene, or piano for a more quiet part, while strings are playing throughout



MIDI in games

- To allow more flexibility in the tempo and texture of game music, modern audio middleware supports MIDI
- This allows for different instruments to be swapped in
- Each musical piece can be played in different keys
- Different scales can be used in different situations, e.g. major for action, minor for more somber parts
- Randomizing some notes in terms of pitch of velocity can allow for many variations
- CPU intensive as samples have to be created on the fly

Low-level issues

- Audio waits for nothing
- Your audio device makes a callback every few milliseconds
- `void callback(float *buffer,`
  `                  int channels, int samples)`
- Your implementation of the callback must finish within these few milliseconds
- Must be done on a separate thread that does not lock!
- https://www.youtube.com/watch?v=boPEO2auJj4&t=15m43s

Audio resampling

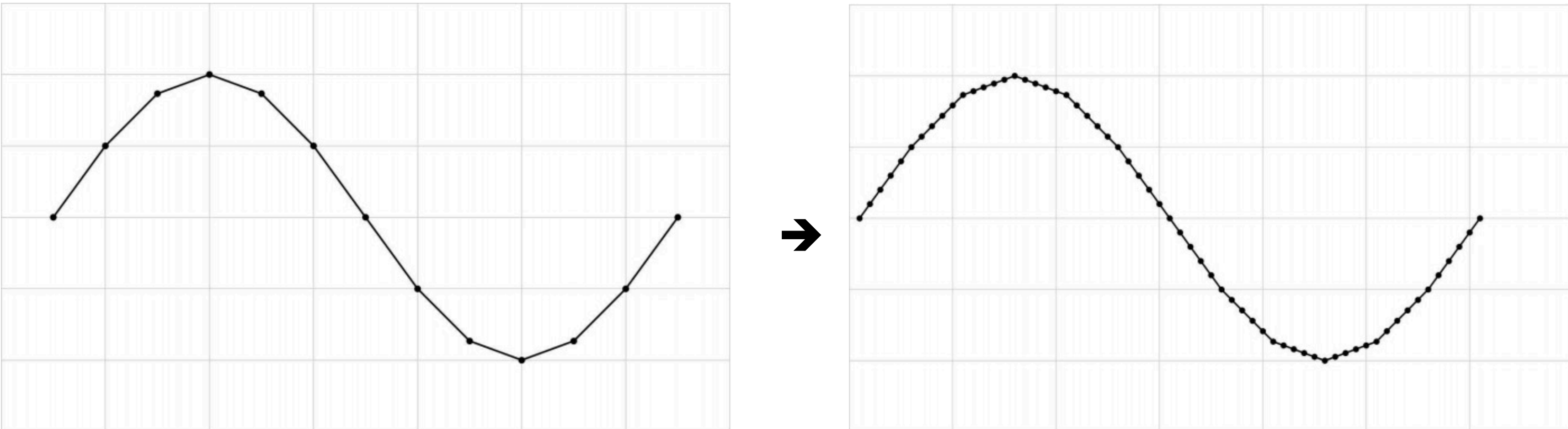
- Sample rate conversion is a fundamental operation for an audio engine
- Used for including audio recorded at different sample rates, or for effects, such as pitch shifting
- Need to write a function like

```
void Resample(int input_frequency, int output_frequency,
  const float* input, size_t input_length,
  float* output, size_t output_length)
{ ... }
```

- We will select some samples from the input signal and fabricate others

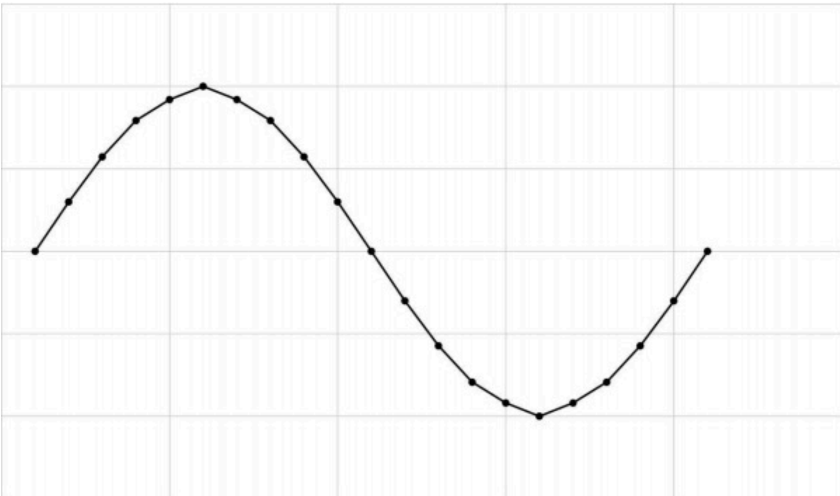
An example: 12Hz → 20Hz

- Take the LCM of the two frequencies and upsample the input by linear interpolation



An example: 12Hz ➔ 20Hz

- Then, downsample to 20Hz
- The result will be different from what would have been obtained by sampling directly at 20 Hz



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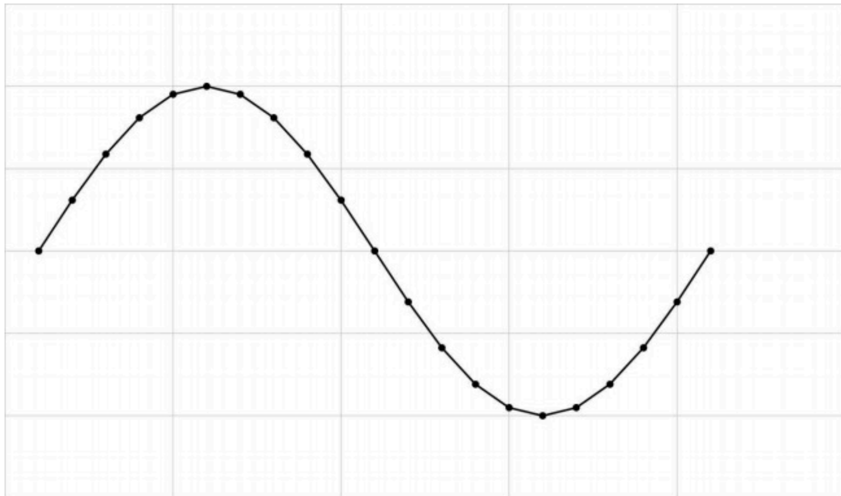

A realistic example

- Going to the LCM does not work well for realistic sample rates
- 192kHz and 44.1kHz have an LCM of 28.2MHz !
- We compute the ratio of the LCM to the two sample rates
  - For 12Hz to 20Hz, we have R_{in} = 60/12 = 5, and R_{out}= 60/20 = 3
  - We have 3 input samples for every 5 output samples
  - For 192kHz to 44.1kHz, we have 640 input samples for every 147 output samples

Let’s look at our example

Output Index
Index number of the output sample

From
Beginning index from the input samples

To
Next sample after From

Offset
The number of LCM samples past the From index

TABLE 5.2 Sampling from 12 to 20 Hz

Output Index	From	To	Offset
0	0	1	0
1	0	1	3
2	1	2	1
3	1	2	4
4	2	3	2
5	3	4	0
6	3	4	3
7	4	5	1
8	4	5	4
9	5	6	2
10	6	7	0
11	6	7	3

Output sample formula

$$From = \left\lfloor \frac{index \cdot R_{out}}{R_{in}} \right\rfloor$$

$$To = From + 1$$

$$Offset = (R_{out} \cdot index) \bmod R_{in}$$

$$Output = Lerp\left(Input_{From}, Input_{To}, \frac{Offset}{R_{in}} \right)$$

Lerp = Linear interpolation

Other resamplers

- Linear interpolation is quite sufficient for games
- Higher order polynomial interpolation is also possible
- Each type of interpolation has different frequency responses