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Synthesis of Audio Signals
Semester Work Report

1. Introduction

Depeche Mode, a pioneering band in electronic and alternative music, has profoundly influenced the music industry with their innovative soundscapes and iconic tracks like *Enjoy the Silence*. For this project, I explored the principles of audio signal synthesis by modifying a MIDI version of *Enjoy the Silence* using MATLAB. By leveraging the flexibility of MIDI files, which encode musical notes and instrument data, I applied various audio effects to individual instruments, transforming their timbre and dynamics. This approach allowed for creative manipulation of the track while maintaining its core musical structure.

2. MIDI and audio signal processing

MIDI (Musical Instrument Digital Interface) encodes musical information like notes, duration, and instruments, allowing precise control over each track of a composition. Unlike audio files, MIDI focuses on structure, making it ideal for manipulation.

Audio signal processing modifies sounds using techniques like reverb, equalization, and distortion. In this project, MIDI files were used to isolate instruments and apply effects in MATLAB, showcasing how digital signal processing transforms musical compositions.

3. Tools and methodology

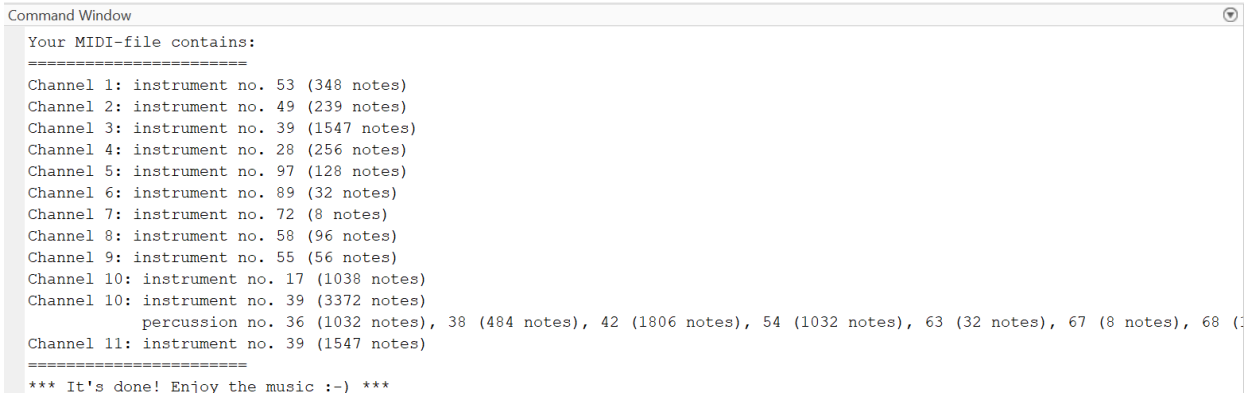
MATLAB was chosen for its robust capabilities in audio signal processing. The project began by importing MIDI files and separating individual instrument tracks. Various effects, such as reverb, equalization or Karplus Strong effect can be applied to these tracks to modify their sound properties.

Each effect was designed to enhance or alter the tonal and spatial characteristics of the music, demonstrating the flexibility and precision of MATLAB in processing MIDI-based compositions.

4. Implementation and results

Each instrument track from the MIDI file was processed individually in MATLAB. Effects like reverb, distortion, and equalization were applied to transform their tonal and spatial qualities. The modified version of *Enjoy the Silence* was compared to the original, highlighting the impact of these changes.

Here are the different instruments that are found by the program on the MIDI file “enjoy.mid”.



According to the table “MIDI_instrument_table.pdf”, are present on this track, the instrument “Choir Aah” (no. 53), “String Ensemble 1” (no. 49), “Electric Clean Guitar” (no. 28), etc. ; as well as the percussion “Bass Drum 1” (no. 36), “Closed Hi-hat” (no. 42), etc.

Here’s an example of MATLAB code used to modify the no. 49 instrument track (String Ensemble 1), where a Karplus Strong effect is applied to enhance the spatial characteristics of the sound by processing the extracted MIDI track as an audio signal.

The Karplus-Strong effect synthesizes plucked string sounds by using a feedback loop with a delay line and low-pass filtering, mimicking string vibrations efficiently.

Editor - C:\Users\arthu\Documents\PRAGUE CTU\SIGNAL AUDIO\Semester_Project\synth.m

main.m | synthchallenge.m | synth.m

```
%% Synthèse en fonction du canal et de l'instrument
if channel ~= 10
    if synthtype == 49
        % MIDI Instrument 49 : String Ensemble 1

        % Generate excitation (white noise) to simulate an attack
        D = floor(Fs / freq);       % Delay line length
        x = zeros(1, N);            % Initialize excitation signal to zero
        x(1:D) = 2 * rand(1, D) - 1; % Excitation: white noise

        % Karplus-Strong filter coefficients
        k = 0.994;                  % Feedback factor controlling decay
        g = k * 0.5;                % Additional decay factor
        b = [1];                    % Filter numerator
        a = [1, zeros(1, D - 1), -g, -g]; % Stabilized denominator

        % Normal acoustic guitar signal
        y_normal = filter(b, a, x);             % Karplus-Strong filtering
        y_normal = amp * y_normal / max(abs(y_normal)); % Normalization

        % Apply distortion
        zz = amp * y_normal / max(abs(y_normal));   % Normalize before distortion
        index = 0.999;                                % Distortion parameter (0 to 1)
        kk = 20 * index / (1 - index);             % Non-linearity factor
        y_distorted = (1 + kk) * zz ./ (1 + kk * abs(zz)); % Non-linear distortion

        % Final signal normalization
        y = amp * y_distorted / max(abs(y_distorted));

%%
```

Here is a short table summarizing the effects applied to each instrument in the track.

Some of them do not have effect because it would be too much, the song would be too different from the original and we could not hear it properly.

Instrument number	Instrument	Effect applied	Objective
49	String Ensemble 1	Karplus Strong, Phaser	Karplus-Strong effect synthesizes realistic plucked string sounds by using a feedback loop with delay and filtering to simulate string vibrations.
39	Synth Bass 1	Phaser	The phaser effect creates a sweeping, spacey sound by splitting an audio signal, phase-shifting one part, and then recombining them to produce dynamic peaks.
28	Electric Clean Guitar	Karplus Strong, Phaser	
97	Rain Effect	Phaser	
89	New Age Pad	Phaser	
72	Clarinet	Phaser	
58	Trombone	Phaser	
36 (percussion)	Bass Drum 1	Dynamic Kick Synth	This effect synthesizes a bass drum sound by combining a decaying tonal component with noise to create a realistic percussive timbre.
38 (percussion)	Snare Drum	Snare Drum Synth	This effect synthesizes a snare drum sound by combining a decaying tonal component with modulated white noise, resulting in a percussive, snare-like texture with a controlled envelope.
54 (percussion)	Tambourine	None	
63 (percussion)	Open High Conga	None	

The final result is found as “enjoy.m4a” file.

5. Conclusion

This project demonstrated the creative potential of MIDI manipulation and audio signal processing using MATLAB. The applied effects transformed the original track, showcasing how digital tools can enhance musical compositions. The experience provided valuable insights into DSP techniques and their applications, with possibilities for further exploration in sound design and music production.

The final result is quite good; the Depeche Mode song is recognizable, although I had to remove some effects to make it clearer.