**Notes**

**Topic: Audio Signal Processing**

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Xavier Serra

* Universitat Pompeu Fabra, Barcelona
* Stanford University

Audio signal processing:

* The intentional alteration of sound.

Applications

* Storage
* Data compression

. WAV --> perceptual audio coder (data compression) --> MP3

* Effects and transformations

. Compressor, echo, equalizer, flanger, phaser, chorus, pitch shifter, time stretching, voice effects, 3D audio effects, morphing, reverb, etc.

* Synthesis

. Subtractive synthesis: filter out component to create another sound.

. FM synthesis: modulating a frequency to create another sound.

. Additive synthesis: add sounds together to create another sound.

. Others: granular synthesis, physical modeling, wave-shaping, sampling, spectral synthesis.

* Description

. Model meaningful characteristics of the sound.

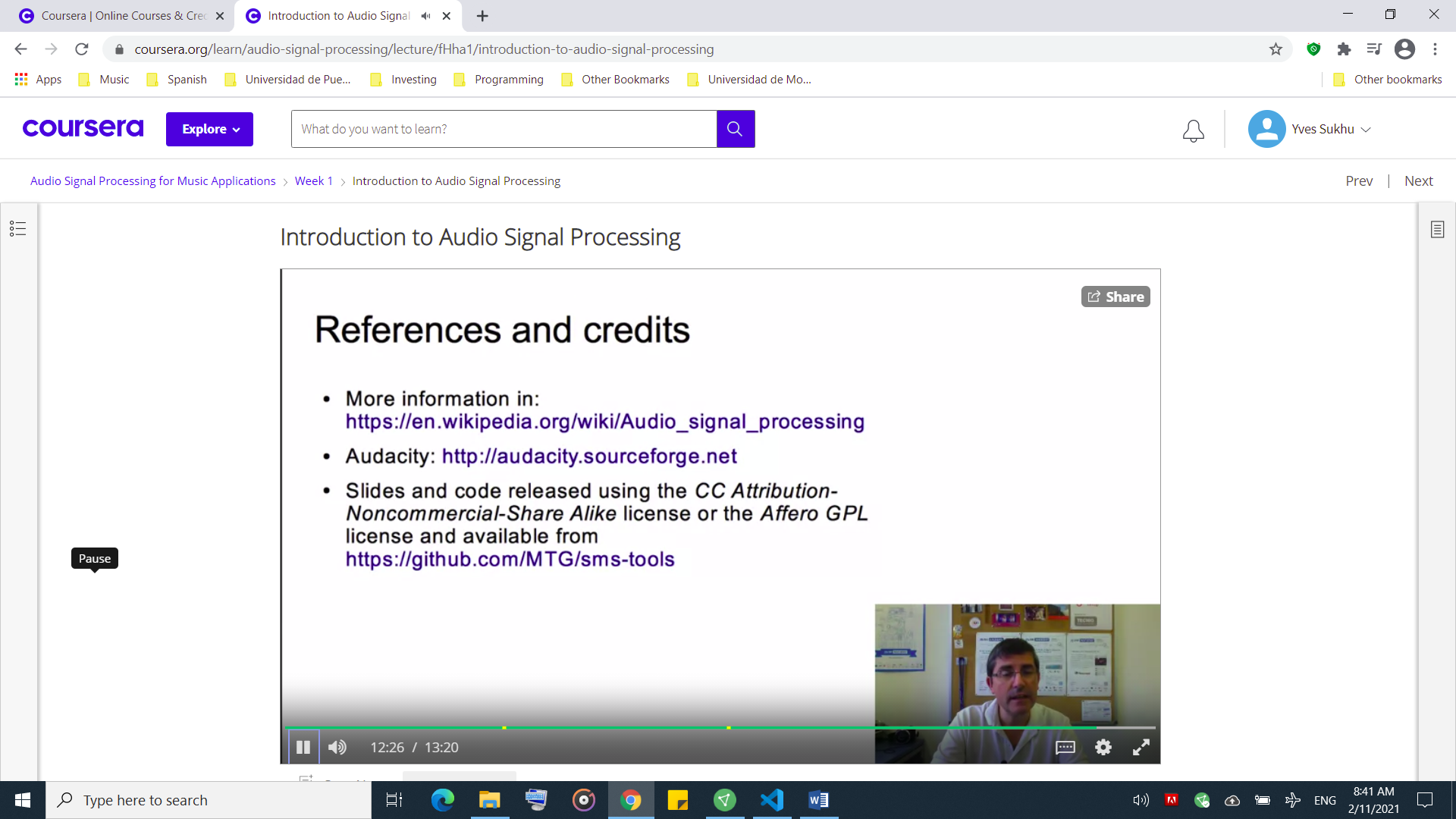
. Useful for music information retrieval.

. Low-level: loudness, timbre, pitch.

. Mid-level: rhythm, harmony, melody.

. High-level: genre, emotions, similarity.

Techniques for digital signal processing are much more powerful than analog signal processing.



Course Outline

* 1. Introduction

. Basic mathematics

* 2. Discrete Fourier Transform

. DFT equation

. Complex exponentials

. Scalar product in the DFT

. DFT of complex sinusoids

. DFT of real sinusoids

. Inverse-DFT

* 3. Fourier Transform Properties

. Linearity, shift, symmetry, convolution

. Energy, conservation, and decibels

. Phase unwrapping, zero padding

. Fast Fourier Transform (FFT)

. FFT and zero-phase windowing

. Analysis/synthesis

* 4. Short-time Fourier transform

. STFT equation

. Analysis window

. FFT size and hop size

. Time-frequency compromise

. Inverse STFT

* 5. Sinusoidal model

. Sinusoidal model equation

. Sinewaves in a spectrum

. Sinewaves as spectral peaks

. Time-varying sinewaves in spectogram

. Sinusoidal synthesis

* 6. Harmonic model

. Harmonic model equation

. Sinusoids-partials-harmonics

. Monophonic/polyphonic signals

. Harmonic detection

. Fundamental frequency detection

* 7. Sinusoidal plus residual modeling

. Stochastic model

. Stochastic approximation of sounds

. Sinusoidal/harmonic plus residual model

. Residual subtraction

. Sinusoidal/harmonic plus stochastic model

. Stochastic model of residual

* 8. Sound transformations

. Short-time Fourier transform: filtering, morphing.

. Sinusoidal model: time and frequency scaling.

. Harmonic plus residual model: pitch transposition.

. Harmonic plus stochastic model: Time stretching; morping.

* 9. Sound/music description.

. Spectral-based audio features.

. Description of sound/music events and collections.

* 10. Concluding topics

. Review of class

. Beyond audio signal processing for music applications

Mathematics

* Sinusoidal function: describes smooth, repetitive oscillation.
* x[n] = Acos(wnT + phi) = Acos(2pifnT + phi)

A: amplitude

w (omega): angular frequency (radians/second)

f = w/2pi: frequency in Hertz (cycles/second)

phi: initial phase in radians

n: time index

T = 1/f: sampling period in seconds (t = nT = n/f)

* Complex numbers: describes numbers in the complex plane.

. Rectangular form: (a + ib)

. Polar form: (A, phi) where A = sqrt(a^2 + b^2) and phi = atan2(b/a)

* Euler’s formula: establishes relation between rectangular and polar coordinates of a complex number.
* e^iphi = cosphi + isinphi
* Richard Feynman called this equation the most remarkable equation in mathematics.