Computer Music

An Interactive Approach

Aristotle University of Thessaloniki
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ανοικτάμαθήματα
opencourses

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης

ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ

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ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Introduction to Computer Music

From Sound Waves and the Hearing Mechanism to Musical Instruments

Dionysios Politis

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- **Part C** : Musical Scales, Properties of Music and Musical Instruments

Part A: : Physical Properties of Sound Waves

- **What is sound?** We never mistake the sounds of ocean waves, vehicular traffic or the sound of music!

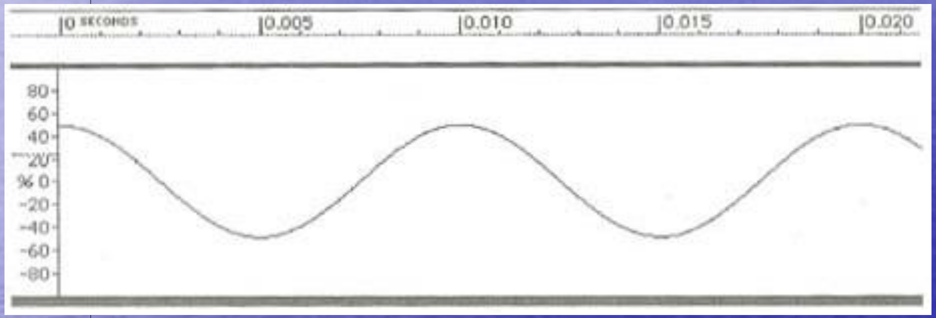
- A simple answer would be this: sound is whatever we hear.

- Sound is produced by any vibrating source and is transferred to our receiver, the ear.

  A carrier is needed to intervene between the transmitter and the receiver, in most cases that being the air; alternatives are the water, the sea, or solid media of any kind, like steel, concrete walls, wood etc.

- Warning: we cannot hear on the moon!

The sinusoidal wave is a periodic signal. It corresponds to one frequency and it expresses more an idealistic situation than an everyday sound. It is called a tone (this one is 100 Hz).



A second characteristic for a wave is the vibration width. The bigger it is, the louder a sound is heard.

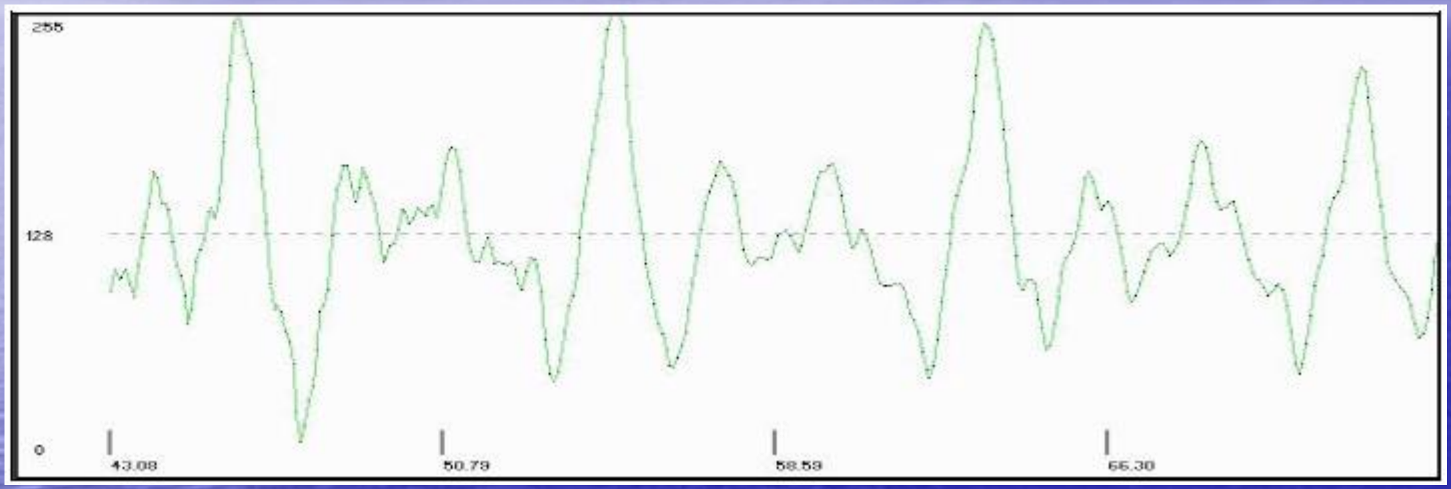
On the other end of the spectrum the sound of sea waves crushing to the shore is considered as noise, and not a tone or a series of tones, since it comprises a bunch of non periodic waves. The same goes for vehicular noise.

The frequency of a sound its not its only detector.

We can play the note A_4 with the keyboard of our synthesizer, corresponding to a 440 Hz wave, but the sound we perceive is different when we invoke a guitar, or when we select a flute.

In this case and while both waves have more or less the same frequency and intensity, the *quality* of a tone, or its timbre, makes the difference.

When an acoustic guitar plays note A_4 a signal like this is produced, giving us clues of what its frequency content is about.



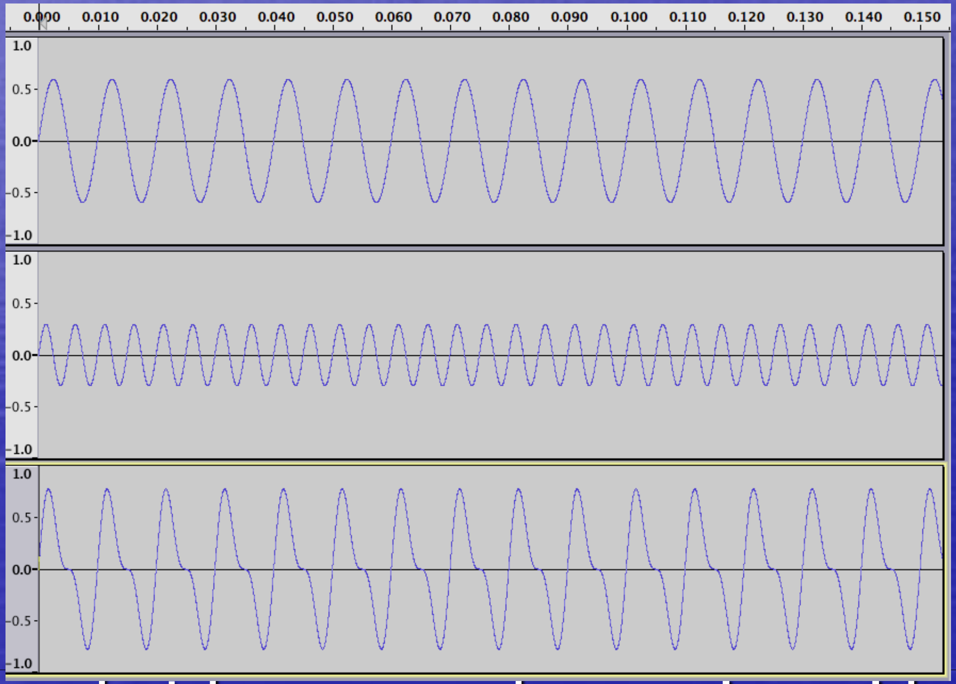
It is evident that every musical sound is made of many harmonically related frequency components, or *partials*. The frequency of the first partial is usually referred to as the fundamental frequency *F0* and is astutely perceived by our brain as a psychoacoustic phenomenon, even when it is not physically present within a sound wave!

In this table we see the range of F0 frequencies for characteristic musical instruments …

Instrument	Frequency range (Hz)
Human voice	70 – 2000
Piano	30 – 3500
Violin	200 – 3000
Flute	260 – 3000
Organ	16 – 4000

Evidently, there is no musical instrument producing a pure tone for each note it plays.

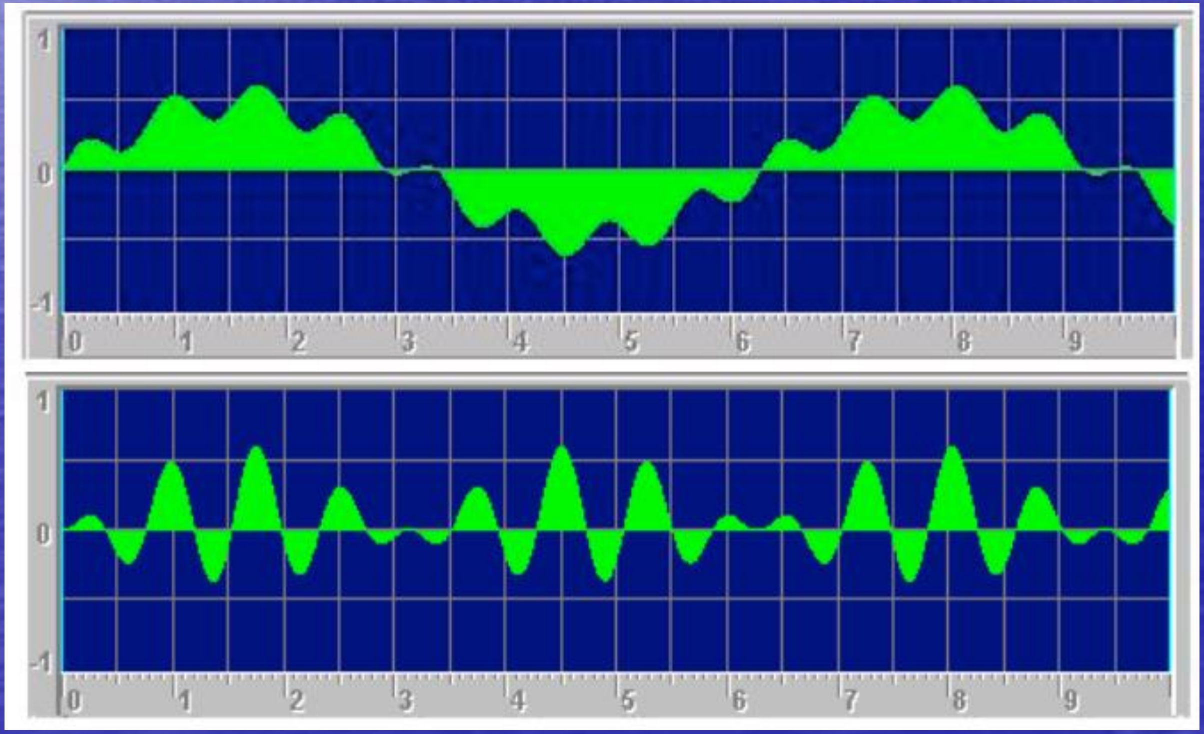
When the note A_4 is played, apart from the fundamental frequency of a tone at 440 Hz, harmonic tones with significantly smaller intensity are produced at 880 Hz, 1320 Hz, 1760 Hz …



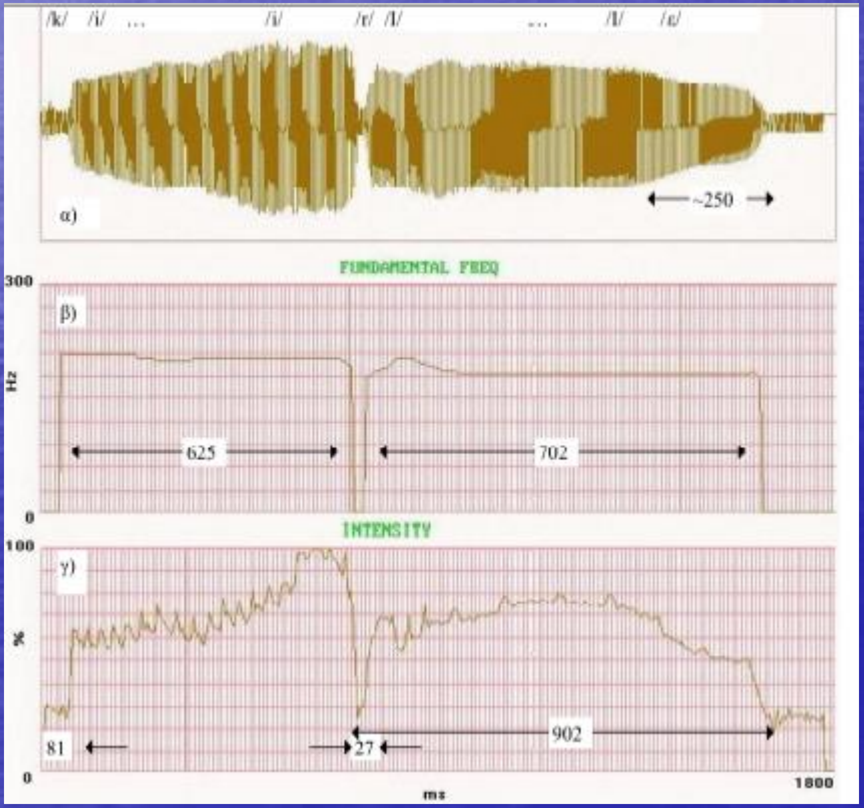
In this figure we see what happens when a sinusoidal tone of 100 Hz is superimposed with another one double that frequency, at 200 Hz, and half its intensity.

Computer music gives emphasis on our ability to combine tones for creating sounds, whether new ones or artificial ones, stimulating existing music sounds. This process is usually called Frequency Modulation Synthesis, a reverse procedure to the one that analyzes music sounds.

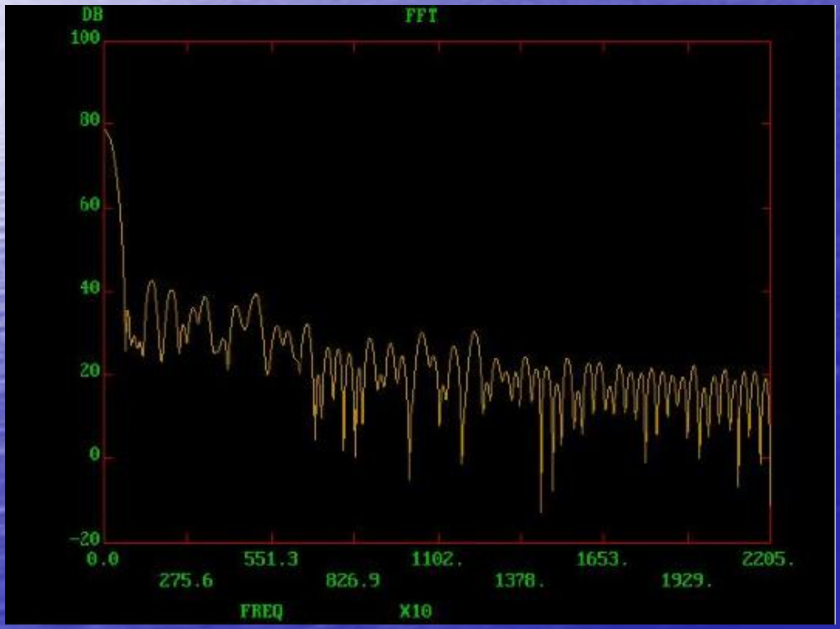
The synthetic waves seen in this figure have (with rough approximation) the same envelope, the same energy, but different crossing rates: 2/π the upper, 8/π the lower.

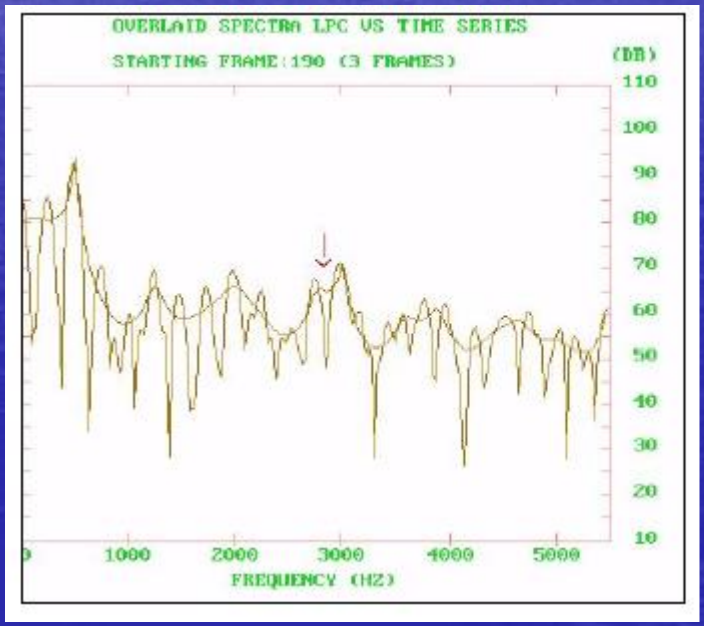


Analyzing music signals is a fascinating process trying to correlate what our brain perceives with what acoumeters and instrumentation decipher…

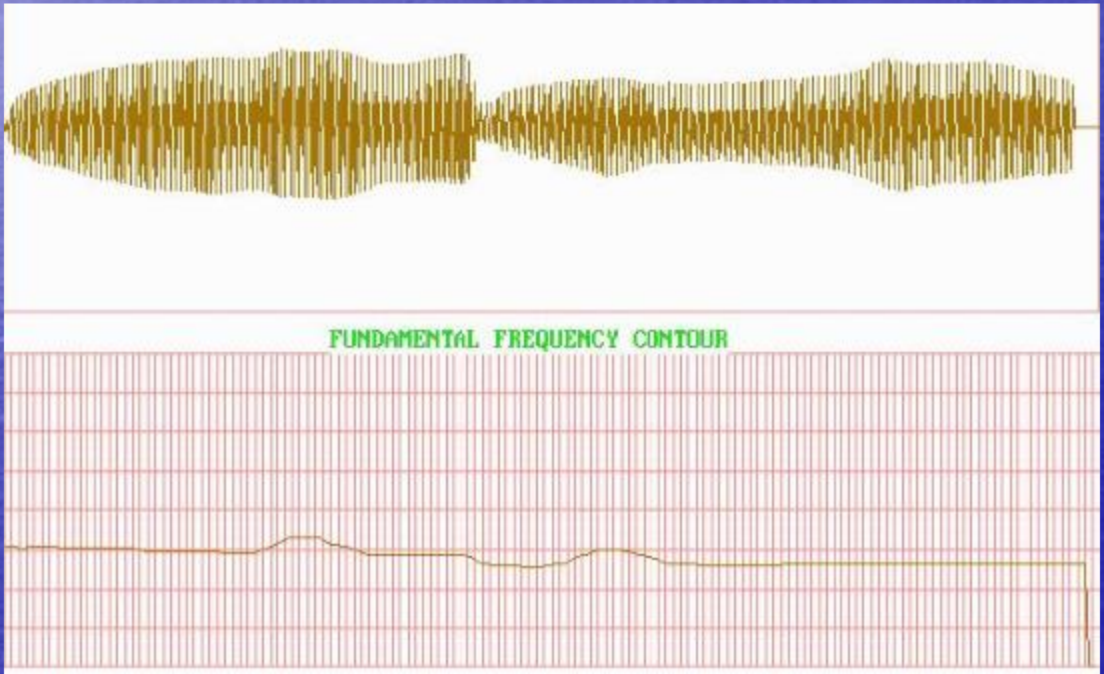


In order to do so, Computer Music employs mathematics and DSP smoothing techniques to decipher the frequency content of a musical signal, in search for F0 and the upper harmonics, the formants F1, F2, F3,…, that reveal the resonators within the spectrum range of a FFT.

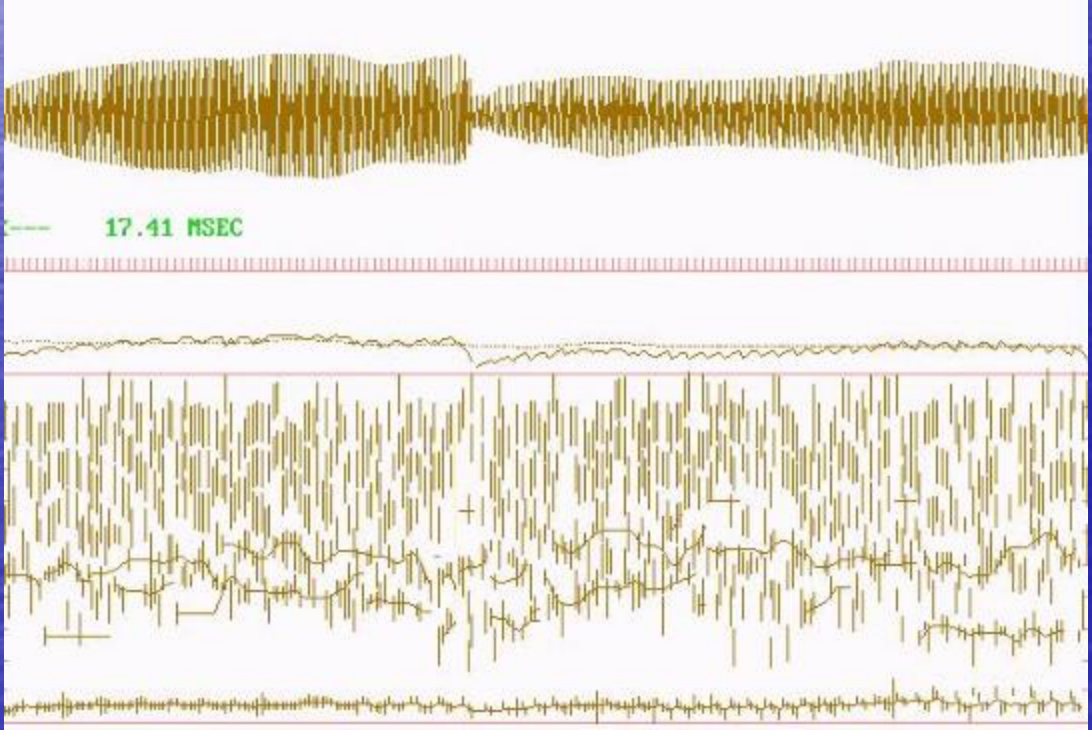




So, we are able to render the fundamental frequency contour of a music phrase that objectively denotes the melodic line that our brain subjectively interprets as a musical motive.

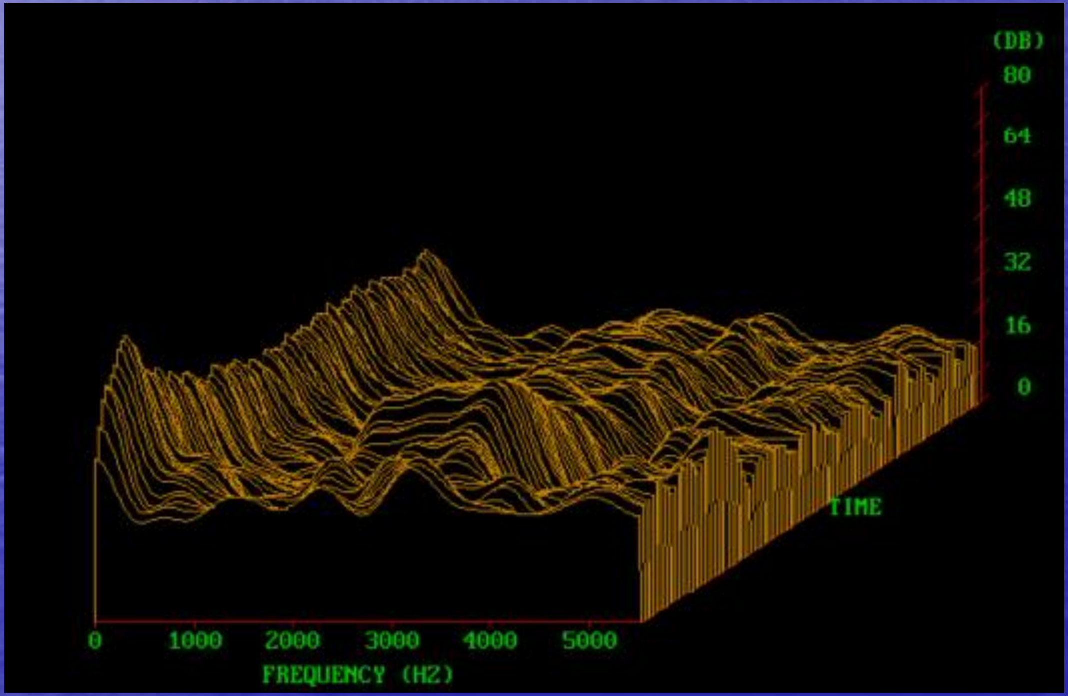


Even further, we can devise tools that clearly denote the formants of a music piece, along with the intensity of the utterance in 2 dimensions …



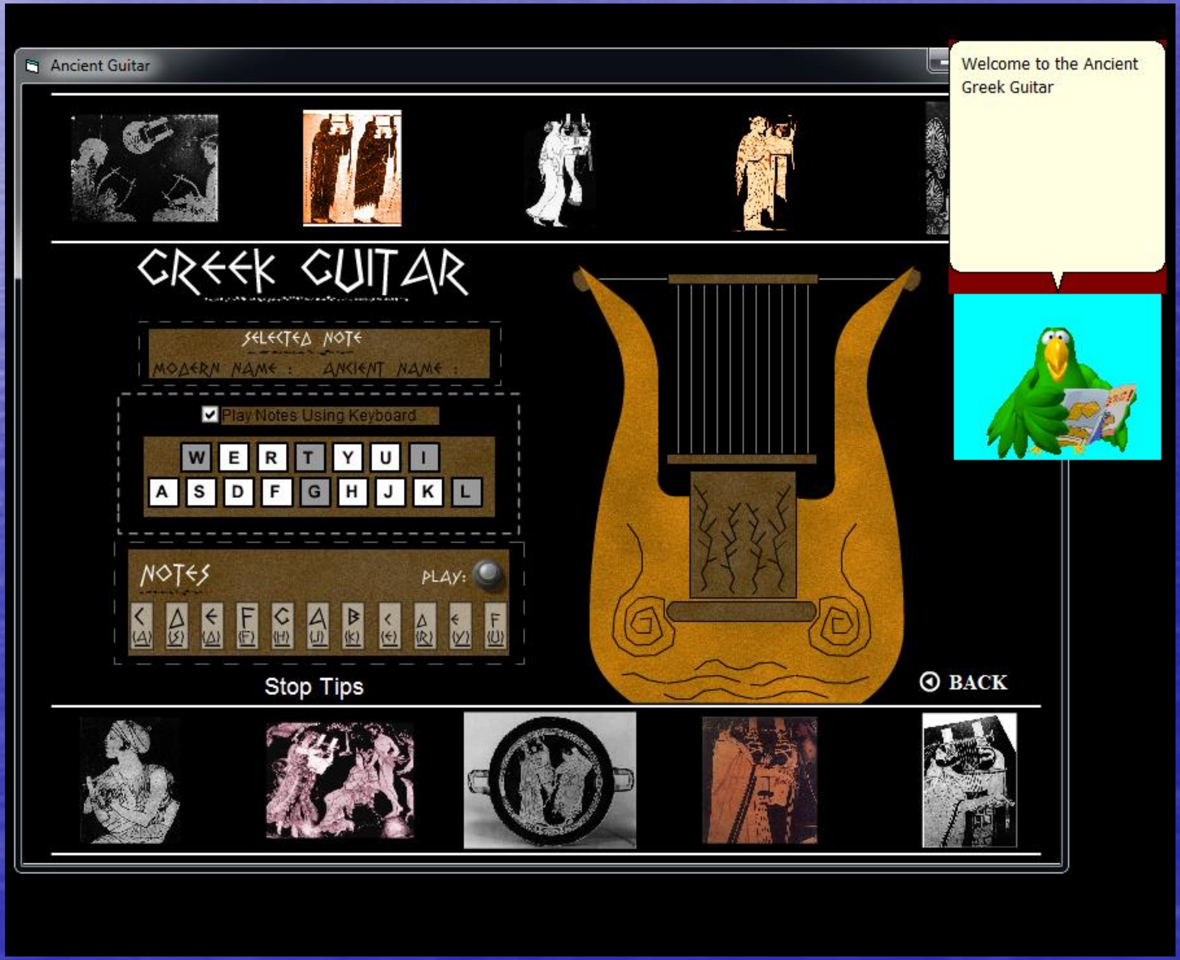
… or in 3 dimensions, when cepstrally smoothed logarithmic spectra are deployed. This in depth analysis is vital for the reverse process of synthesizing electronically music.

It is also vital for depicting what our brain conceives as melody, and how singing for instance recreates musicality!

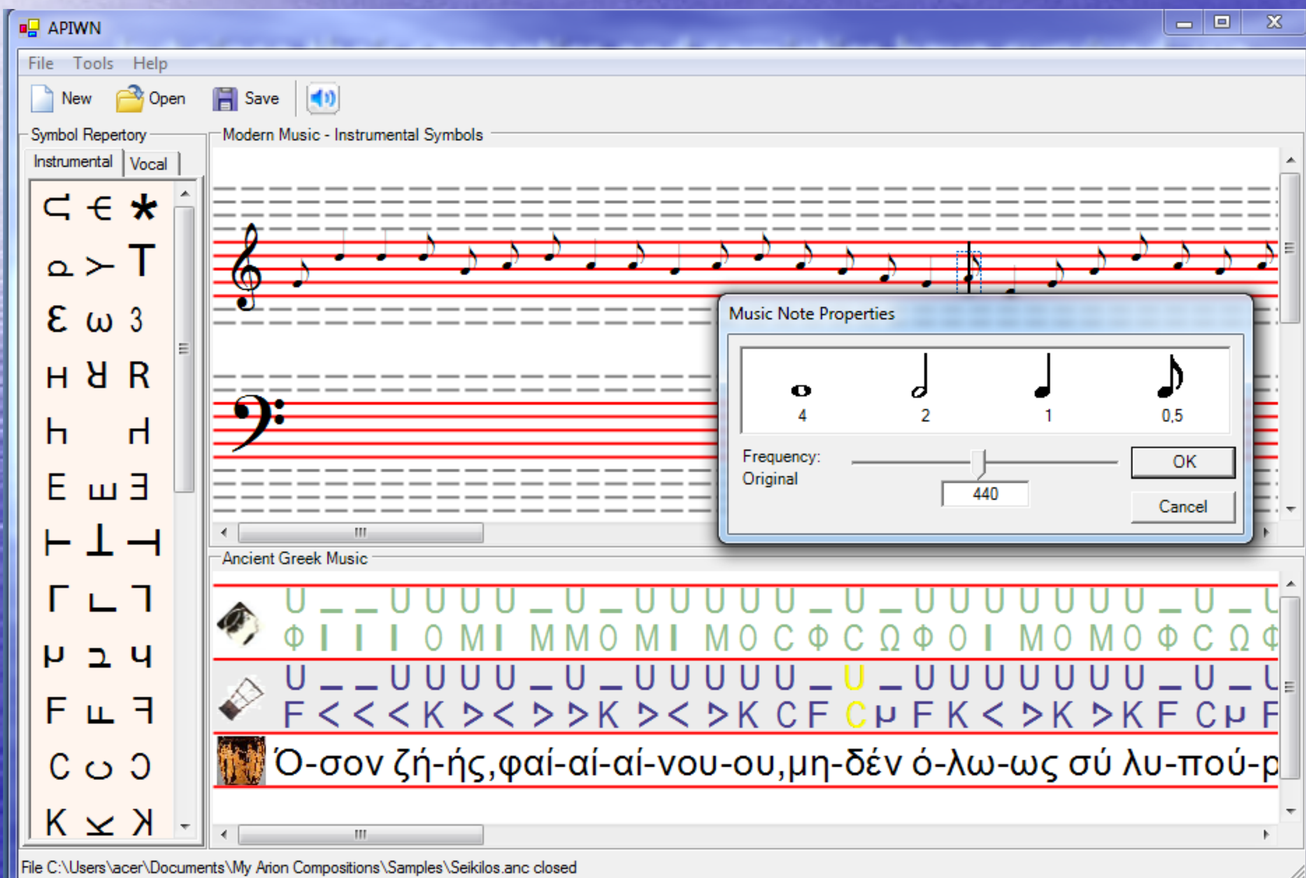


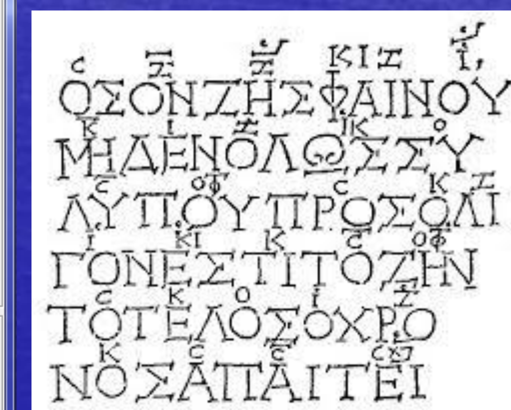
Computer induced composition and synthesis excel by simulating physical instruments with computer generated sounds. The degree of control is amazing, since it is possible from contemporary computers to render a multi instrument symphonic performance from the semantics of the melody!

The prowess of Computer Music does not end here! By devising music programming languages and interfaces we provide the ever growing community with tools that let us recreate synthetic singers and performing devices from worlds that have long ceased to exist …



However, since their semantics and semiotics have survived, we can not only recreate and synthesize the instruments and the vocal articulation, but even further, compose melodies that can be renditioned in nearly real time!





By deploying mathematical methodologies we can deduce the indices and the characteristics for the physical properties of sound waves.

But, as doctors say, we hear with the brain, not the ear!

So, when the hearing apparatus conceives musical vectors with different attributes than those that mathematical analysis designates, we have psychoacoustic effects that prevail.

In any case, computer music is an applied science and its scientific findings have to comply with the music perception that the artistic community has rendered in its Diachrony and Synchrony.

Reference Note

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