Informatica per le Digital Humanities
Lecture 5
March 17 2025
Texts

Slides 2-6
In the previous lecture we saw that an ‘e’ can look in very different ways, but all kinds of ‘e’ stimulate in your brain the memory of a specific sound. In this lecture we will focus on how digital technology can deal with sounds. If we had a young girl counting on her fingers to introduce numbers and figures, for sounds we have an even younger child.

Slides 7-14
From a simplistic and physical perspective, sounds can be defined as vibrations that move like waves through a medium. Usually, we have sounds travelling in air, but they can travel even faster if there is more matter around, like in water or though the ground. In space, where there is no air, sound cannot travel, hence the tagline for the horror sci-fi movie Alien.

Slides 15-21
The ear plays a very important role in all this, because it is our organ which catches those vibrations in the medium and transmits them to the eardrum, and then to some tiny bones, and eventually converts them to some stimuli running through nerves to the brain, where (by a phenomenon that is still not fully known, not even to the most knowledgeable neuroscientists) these stimuli give us the sensation of hearing sounds. In that sense, if there were no functioning ear to catch the vibrations, there would be no sound heard by anyone. Hence, a more precise definition of sound would be vibrations hitting a functioning ear. No ear, no sound; so, a tree that falls on a deserted island would produce no sound. Vibrations in the air yes, but no sound because nobody is there to catch those vibrations with their ears.

Slides 22-24
One way to analyze (and then digitize) sounds is to study the waves that travel in the medium. All sounds (from a piano to a crying baby) can be described as a specific type of a soundwave hitting your ear. A soundwave can be fully described with 3 characteristics: frequency, amplitude, and waveform, which determine the characteristics of the sound when the wave hits your ears: pitch, volume, and timbre, respectively.

Slides 25-27
The frequency of a soundwave is how many times it goes up and down during an interval of time. The higher the frequency, the more often the wave does it. Waves with a high frequency determine sounds with a high pitch in our brain. (E.g.: the more to the right we play a piano, the higher the pitch of the sound we hear)

Slides 28-30
The amplitude of a soundwave is how wide is the range between its highest point and its lowest. The amplitude of a wave determines the volume of the sound it produces. The bigger the amplitude, the louder the sound.

Slides 31-33
The waveform of a sound wave refers to its shape: the profile of its curve when plotted on a graph over time. Such shape determines the quality of the sound, that ineffable character that

is difficult to describe with words but it makes you distinguish immediately the sound of a piano from that of a violin, or the voice of your mother from the sound of the doorbell.

Slides 34-38
It is not at all easy to recognize a sound by just looking at its waveform. Indeed, what I have shown you as the waveform of a crying baby is actually the waveform of a violin. A crying baby creates much denser waveforms.

Slides 39-40
It has become clear that when we talk about sounds, we cannot help involving the ear of the hearer as well and, given the very subjective character of perception (the “dress” meme -is it black and blue or white and gold?- is an example of how our visual perception can differ from each other), we must not forget the mysterious gap between an objective description of a soundwave and the subjective effects that it can have on different ears and brains.

Slides 41-44
There are no doubts that sounds can be dealt with by digital artefacts: you’ve been listening to sounds with computers and earphones for years. Digital sounds exist. We just need to find out how they are created and elaborated by computers, in a similar fashion as what is done for digital images (with LEDs and pixels described in terms of position and color components).

Slides 45-49
The digitization of sounds starts with the insertion of the soundwave in a Cartesian plane, which establishes xy coordinates for each point in the soundwave. In this way, we associate a pair of numbers (e.g. (15,10)) to a point in a soundwave and we can use that pair as a numerical way to describe and place it.

Slides 50-58
However, the theory of geometry tells us that there are infinite points in a line (since a point does not have dimensions, so it does not occupy even the tiniest amount of space). Does this mean that we have to compute the coordinates for an infinite amount of points? This is impossible because we don’t have an infinite amount of time to do so, not an infinite amount of space where to store those numbers. We have to rely on sampling: we pick a finite number of points of the soundwave onto which we map xy coordinates, os that we have a finite amount of numerical data that describe the soundwave. Of course, the more samples we have, the more accurate the description and viceversa.

Slides 59-60
This is the fundamental basis of digital sounds: each soundwave can be (more or less roughly) described in terms of a finite sequence of pairs of numbers.

Slides 61-66
However, we do not have any sounds if we just stick to pairs of numbers. We need soundwaves hitting our ears. We need something like monitors for digital images, that is, a device that turns those numbers describing a physical phenomenon into the phenomenon itself (a decoding of sorts). For sounds, we have loudspeakers. A loudspeaker, whether big or small like an earphone, is always comprised of a spiral-shaped electric cable (dotted line in slide 65) inserted in a magnet (dark gray area in slide 65). The computing machine creates an electrical signal that is shaped after the profile of the soundwave thanks to the numerical description given by the numerical pairs, and such signal is sent through the spiral-shaped

cable. From the laws of electromagnetism, we know that whenever there is a change in an electrical field, such change produces a magnetic field. The spiral-shaped cable is shaped in a way that, when electricity runs through it, it produces a magnetic field that varies in accordance with the waves in electricity. Since such magnetic field is produced in the space of another magnetic field (the one provided by the magnet in the loudspeaker) the two fields interact, sometimes reinforcing each other, sometimes opposing each other (depending on the dynamics of the wave). This interaction makes the spiral move and hit the membrane of the loudspeaker, creating vibrations that, when they hit a listening ear, produce the original sound, or a rather faithful copy of it.

Slides 67-71

Strictly speaking, loudspeaker are not digital technology. Indeed, they existed way before computers and digital technology were invented. The physical principles are the same, the difference is how the electrical wave is produced. In digital technology, it is a sequence of coordinates that give the position of the samples. In analog technology, like in vinyl record, the groove in the record is a miniature description of the soundwave. This technology is analog because it is based on an analogy, the analogy in shape between the original soundwave and the profile of the groove on the record onto which soundwave it was recorded (in italian the verb “incidere”, to engrave, points at the very action of creating the groove).

Slides 72-74

Compact discs appear to be very similar to vinyls, but they are digital, in that on their surface there is no groove that resembles the original soundwave, but some laser incisions that stand for 0s and 1s, which describe in binary terms the coordinates of the samples of the original soundwave. You may think that short lines stand for 0 and long lines stand for 1, but the standard is a bit more complex than that: if there is a change in height on the surface (because a groove starts or it finishes) we have a 0, and if there is no change (because the groove keeps going on, or the intact surface doesn’t show a groove) we have a 1. The reading of 0s and 1s in such a system must be carefully coordinated with a motor that makes the disc rotate at the correct speed.

Slide 75

Despite the different ways in which soundwaves are recorded, vinyls and CDs show us that analog and digital technology, especially in the field of sounds and music, have a lot in common.