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Analog signal (audio, video) representation

Analog signal - continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity, i.e., analogous to another time varying signal.
ex.: in sound recording, fluctuations in air pressure representing the actual sound "is analogus" to the variations induced by a vibrating diaphragm in the electrical current/voltage produced by the coil/condensor in an electromagnetic microphone; in radio modulation of a sinusoidal carrier wave (e.g. amplitude modulation – AM, frequency modulation – FM)
advantages:

- ✓ has the potential of infinite resolution of the signal (high density)
- ✓ processing is simple

disadvantages:

- ✓ noise – as the signal is copied and re-copied or transmitted over long distances random variations occur
- ✓ impossible to recover from noise/distortion

Digital signal (audio, video) representation

Digital signal = a signal which is represented as a sequence of numbers (usually in binary numbers)
ex.: digital image – matrix of pixels, digital sound – vector of sound amplitudes
advantages:

- ✓ as opposed to analog signals, degradation of the signal (i.e. noise) can not only be detected but corrected as well
- ✓ scales well with the increased complexity of the system

disadvantages:

- ✓ it is error prone (due to quantization and sampling)
- ✓ it has lower resolution than analog signals

Analog-to-digital signal conversion

converting a continuous analog signal into a discrete digital signal has 2 subprocesses:

1. sampling - conversion of a continuous-space/time (audio, video) signal into a discrete-space/time (audio, video) signal
2. quantization - converting a continuous-valued (audio, video) signal that has a continuous range (set of values that it can take) of intensities and/or colors into a discrete-valued (audio, video) signal that has a discrete range of intensities and/or colors; this is usually done by rounding, truncation or other irreversible non-linear process of information destruction

Sound basics

Audio (sound) wave

- ✓ one-dimensional acoustic pressure wave
- ✓ causes vibration in the eardrum or in a microphone
- ✓ Frequency range of human ear
- ✓ 20 – 20.000 Hz (20 KHz)

perception nearly logarithmic, relation of amplitudes A and B is expressed as dB = 20 $\log_{10}$ (A/B)

very low pressure (20 µPascal) …………….	0 dB
conversation ……………………………………….	50-60 dB
heavy traffic ……………………………………….	80 dB
rock band ………………………………………….	120 dB
pain threshold …………………………………..	130 dB

Analog-to-digital conversion of sound

Sampling of the audio wave in every T secs

- ✓ If the sound wave is a linear superposition of noiseless sine waves, with a maximum frequency f :
- ✓ Sampling rate = 2f, more is useless: Nyquist theorem
- ✓ E.g. CDs are sampled with 44.1 KHz ≈ 2 * 20 KHz
- ✓ Channels with noise (Shannon thereom)
- ✓ Sampling rate = Bandwidth * log2 (1+Signal/Noise)
- ✓ Quantization
- ✓ Precision of the digital sample depends on the number of bits
- ✓ Quantization noise - Error due to finite number of bits/sample

Compression

Data compression is a reduction in the number of bits needed to represent data. Compressing data can save storage capacity, speed up file transfer, and decrease costs for storage hardware and network bandwidth.

How compression works

Compression is performed by a program that uses a formula or algorithm to determine how to shrink the size of the data. For instance, an algorithm may represent a string of bits -- or 0s and 1s -- with a smaller string of 0s and 1s by using a dictionary for the conversion between them, or the formula may insert a reference or pointer to a string of 0s and 1s that the program has already seen.

Text compression can be as simple as removing all unneeded characters, inserting a single repeat character to indicate a string of repeated characters and substituting a smaller bit string for a frequently occurring bit string. Data compression can reduce a text file to 50% or a significantly higher percentage of its original size.

For data transmission, compression can be performed on the data content or on the entire transmission unit, including header data. When information is sent or received via the internet, larger files, either singly or with others as part of an archive file, may be transmitted in a ZIP, GZIP or other compressed format.

Why is data compression important?

Data compression can dramatically decrease the amount of storage a file takes up. For example, in a 2:1 compression ratio, a 20 megabyte (MB) file takes up 10 MB of space. As a result of compression, administrators spend less money and less time on storage.

Compression optimizes backup storage performance and has recently shown up in primary storage data reduction. Compression will be an important method of data reduction as data continues to grow exponentially.

Data compression methods: lossless and lossy compression

Compressing data can be a lossless or lossy process. Lossless compression enables the restoration of a file to its original state, without the loss of a single bit of data, when the file is uncompressed. Lossless compression is the typical approach with executables, as well as text and spreadsheet files, where the loss of words or numbers would change the information.

Lossy compression permanently eliminates bits of data that are redundant, unimportant or imperceptible. Lossy compression is useful with graphics, audio, video and images, where the removal of some data bits has little or no discernible effect on the representation of the content.

Graphics image compression can be lossy or lossless. Graphic image file formats are typically designed to compress information since the files tend to be large. JPEG is an image file format that supports lossy image compression. Formats such as GIF and PNG use lossless compression.

Standards for multimedia communications

- ✓ Standards are necessary because it is essential that the two or more items of equipment that are used for the application interpret the integrated information stream in the same way.
- ✓ It is necessary also to ensure that both communicating parties utilize the same standards for detecting the presence of bit errors in the received information stream.

Standards: The need for standard cannot be overemphasized standard guarantee the interoperability. These include both hardware and software standards like buses, cables, connectors, signals, file formats, data transmission protocols, compression and de-compression techniques.

Bandwidth: A powerful processing machine and large files sizes also means that a large amount of data need to transferred at high speed between devices or components. This requires high bandwidth and data rates between internal and external components of a system. For example, in 1 second 44100 elementary samples of digital audio are to be playback from an audio CD for a faithful representation of the original sound.