Multimedia

§3 Basics of data compression

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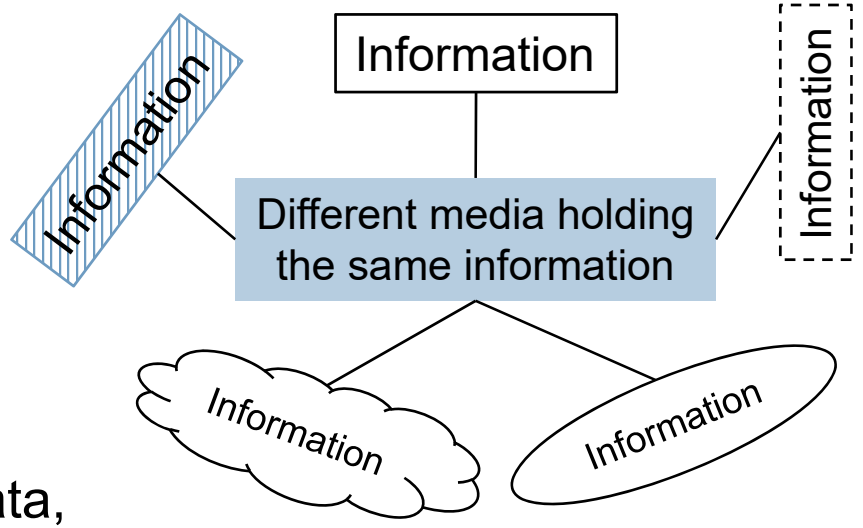
Why data compression?

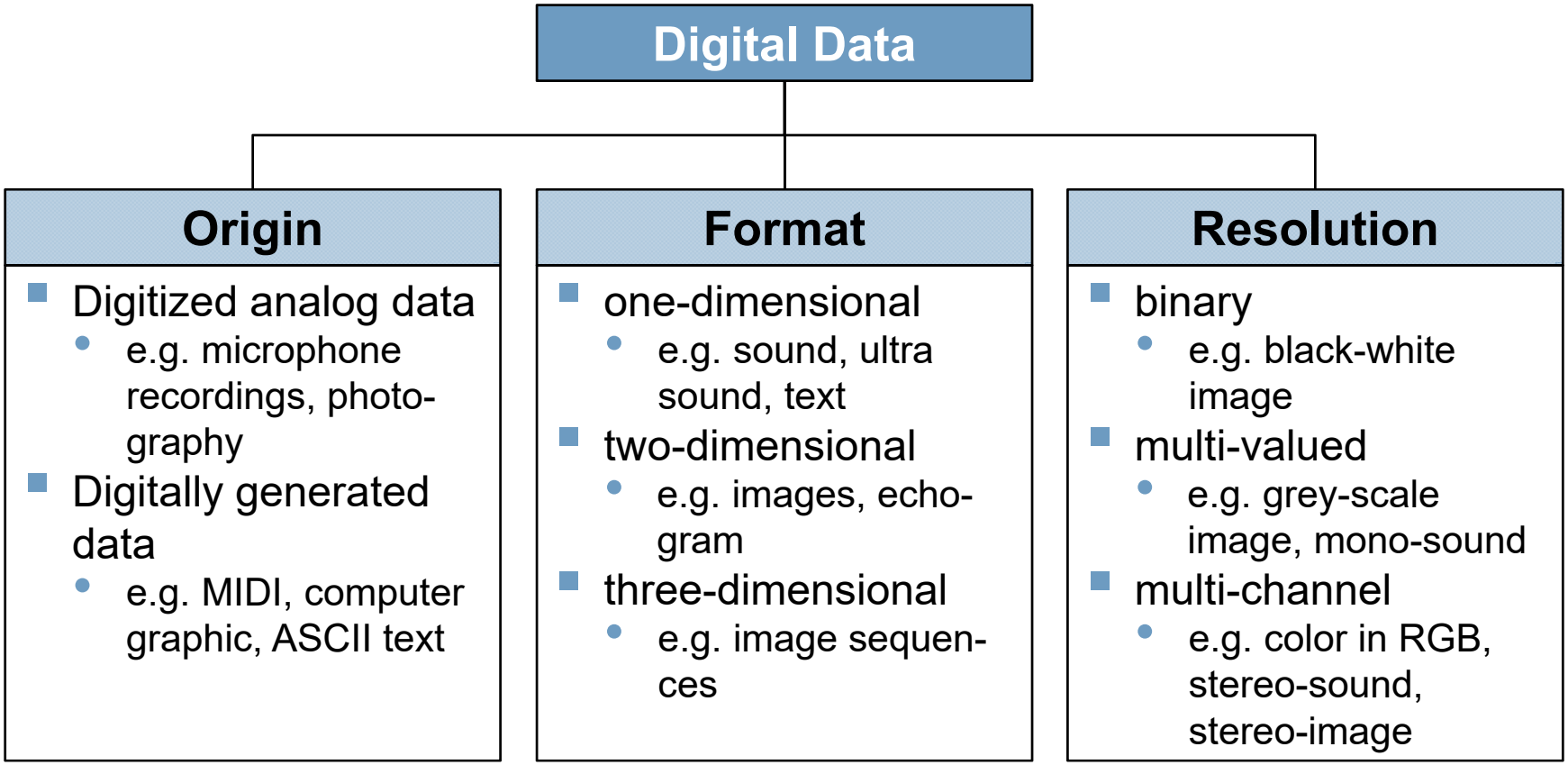
- Limited resources
  - Storage space
  - Transmission rate
- Data becomes increasingly complex
  - complex image-, video- and 3d-data,
  - possible due to powerful hardware.



➡ Storage and transmission of such data requires efficient and effective reduction of data.

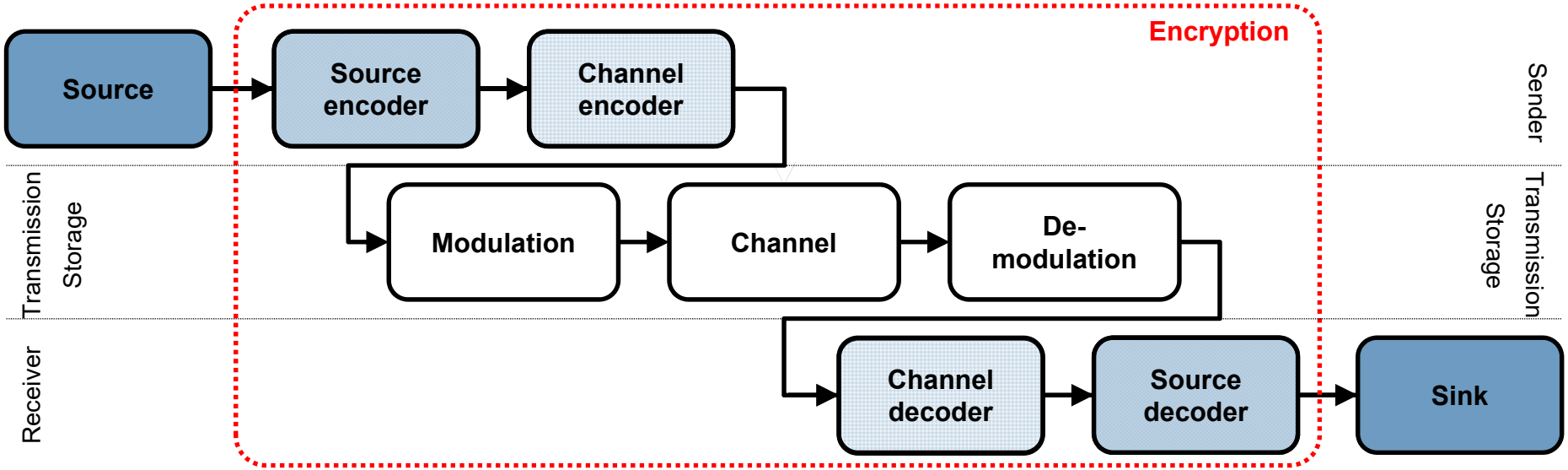
➡ Almost all multimedia data, e.g. audio-, image-, or video-data, is used today in compressed form.

Why data compression?



Encoding

- **Source coding:** Compression of data by sender.
- **Channel coding:** Protection of the data against random errors during transmission or storage.
- **Cryptography:** Protection of the data against interception or modification by unauthorized others.
- **Modulation:** Superimpose data onto the physical medium.



What is data compression?

- Reduce amount of (digital) data, necessary to represent a certain information.

- Compression methods
  - Many different approaches and techniques.
  - Developed for different applications.
  - Perform very different for different applications.

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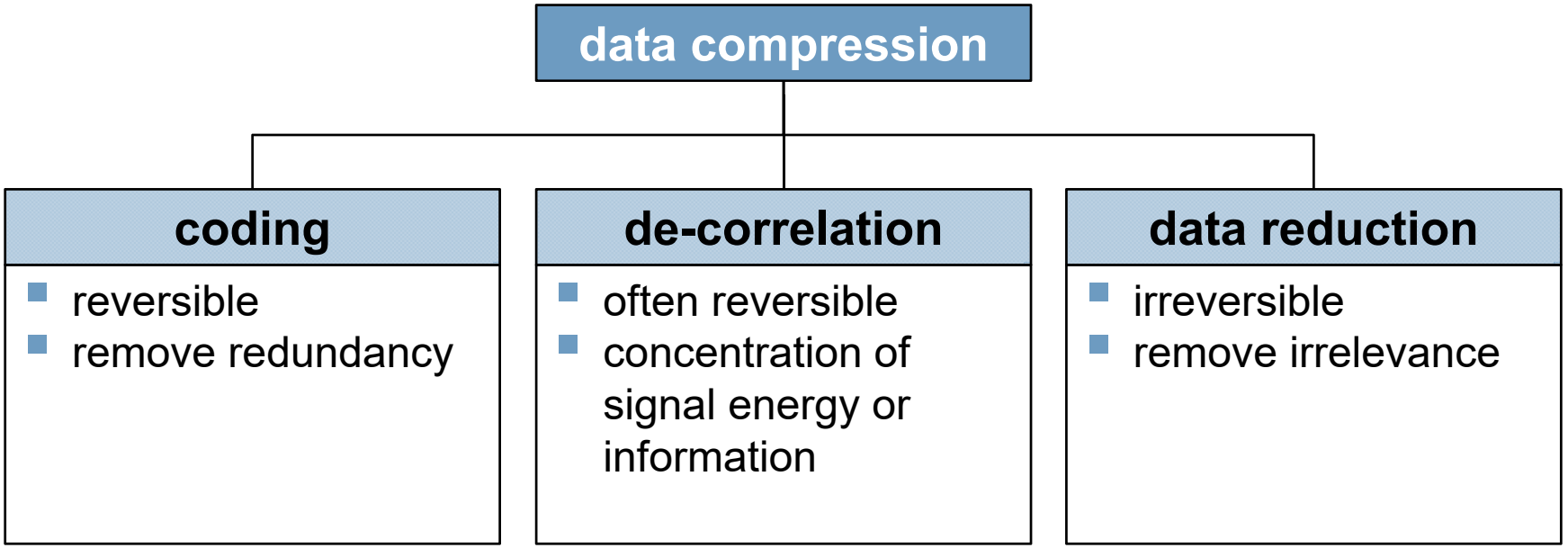
§3.2 Data compression

What is data compression based on?

- Content of files can be
  - redundant (repetitions, patterns, etc.) and/or
  - partially unimportant (too much detail, etc.).
- ➡ Use redundancy, regularity, repetitions, correlation, similarity
  - ➡ **Coding**
- ➡ Unimportant Information can be ignored.
  - ➡ **Data Reduction**
  - ➡ Depended on the perception of humans.

- ➡ Both aspects can be used to shorten the representation of the information, i.e. compress the representation of the information.

What is data compression based on?



Lossless compression

- Text-, program-, and data files must be compressed without loss of information.
- Only redundancy can be remove.
- ➡ Original can (in principle) be reconstructed perfectly without errors.
- E.g.: Huffman-Coding, run-length-coding, arithmetic Coding, LZW coding.

Lossy compression

- For image-, video-, and audio-files the compressed file can differ slightly, as long as the difference is unrecognizable (invisible or inaudible).
  - Used physiological properties of human eyes and ears.
  - ➡ Compress file to target size.
  - ➡ Compress data to target transfer rate.
- ➡ There is a difference between the original and the decoded object.
  - ➡ Data cannot be reconstructed perfectly without errors.
- Allows for larger compression rates.
- E.g.: JPEG, MPEG

Application: text files

- Order of characters in a file is usually not arbitrary.
- Letters of an alphabet occur with different frequencies.
- Encode frequent letters using „short“ symbols and infrequent letters using „long“ symbols.
  - ➡ Reduce the average length of symbol for the letters.
  - ➡ Encode analogously frequent and infrequent letter sequences.

Application: audio files

- A single tone (sinus) can be represented more compactly than a complex sound.

Application: image files

- Not all areas in an image have the same degree of complexity:
  - Large, homogenous areas (e.g. single-colored or regular patterns) can be represented more compactly.
  - Highly detailed areas need a more expensive representation.

Application: video files

- Similar to images:
  - Use coherence between succeeding frames.
  - Image areas that do not change, do not need to be encoded again.

Aspects of data compression (1)

- Compression and de-compression is realized in so-called **Codecs**.
- Complexity and run-time
  - Dependent on application, data volume and the data itself.
- Compression performance, compression rate
  - Increases usually with increasing recourses (computing power, storage space).
  - $\text{Compression rate} = \frac{\text{Un-compressed size of the data}}{\text{Compressed size of the data}}$ [in percent].
  - $\text{Saving} = 1 - \frac{1}{\text{Compression rate}}$ [in percent].

Aspects of data compression (2)

- Pre- or Post-Processing
  - (de)-coding of the data „online“ during the generation/transmission?
  - (de)-coding of the data „offline“ in a pre-/post-process?
- Robustness
  - What is the effect of an error in a compressed file?
- Usability
  - Is the compressed file self-extracting or does the receiver need a de-coder?
- Edit ability
  - Can individual blocks of the compressed file be modified without changing the rest of the file?

Examples for compressed file formats

- Text: ZIP, RAR
- Images: GIF, JPEG, PNG, TIFF
- Video: AVI, MPEG
- Audio: WAV, MP3, MPEG
- Hybrid: PDF
- Others: ZIP, GZIP, RAR

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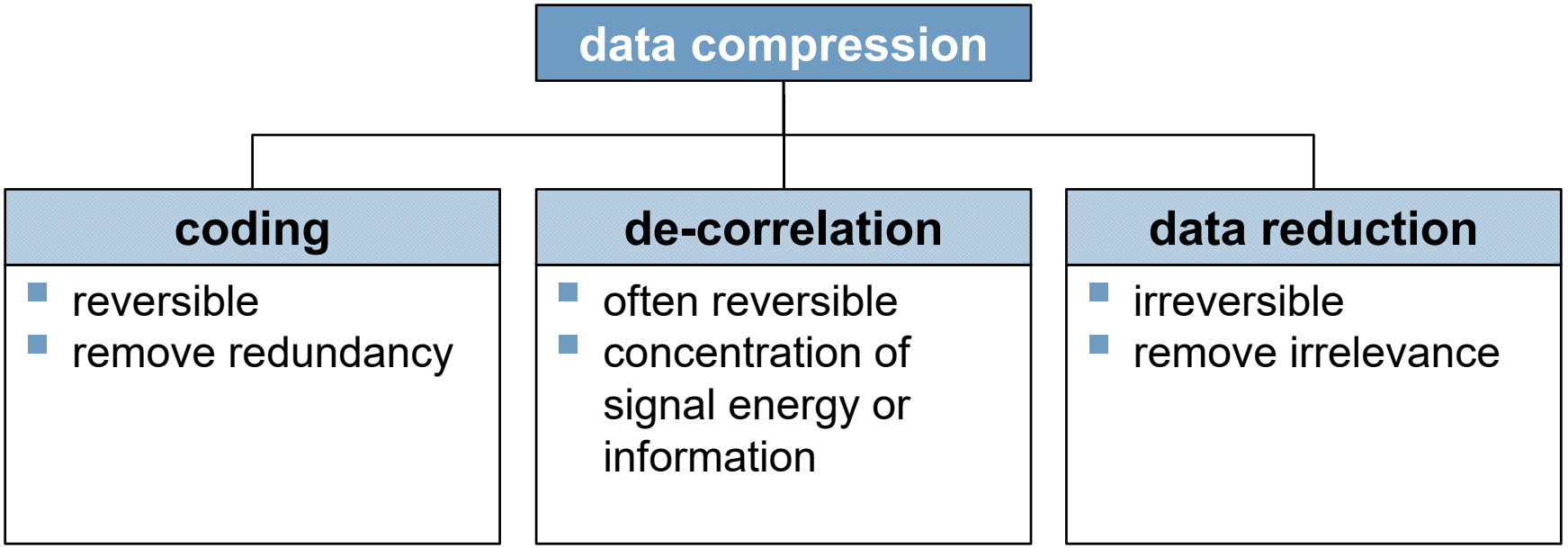
§3.3 Classification of compression methods

Overview



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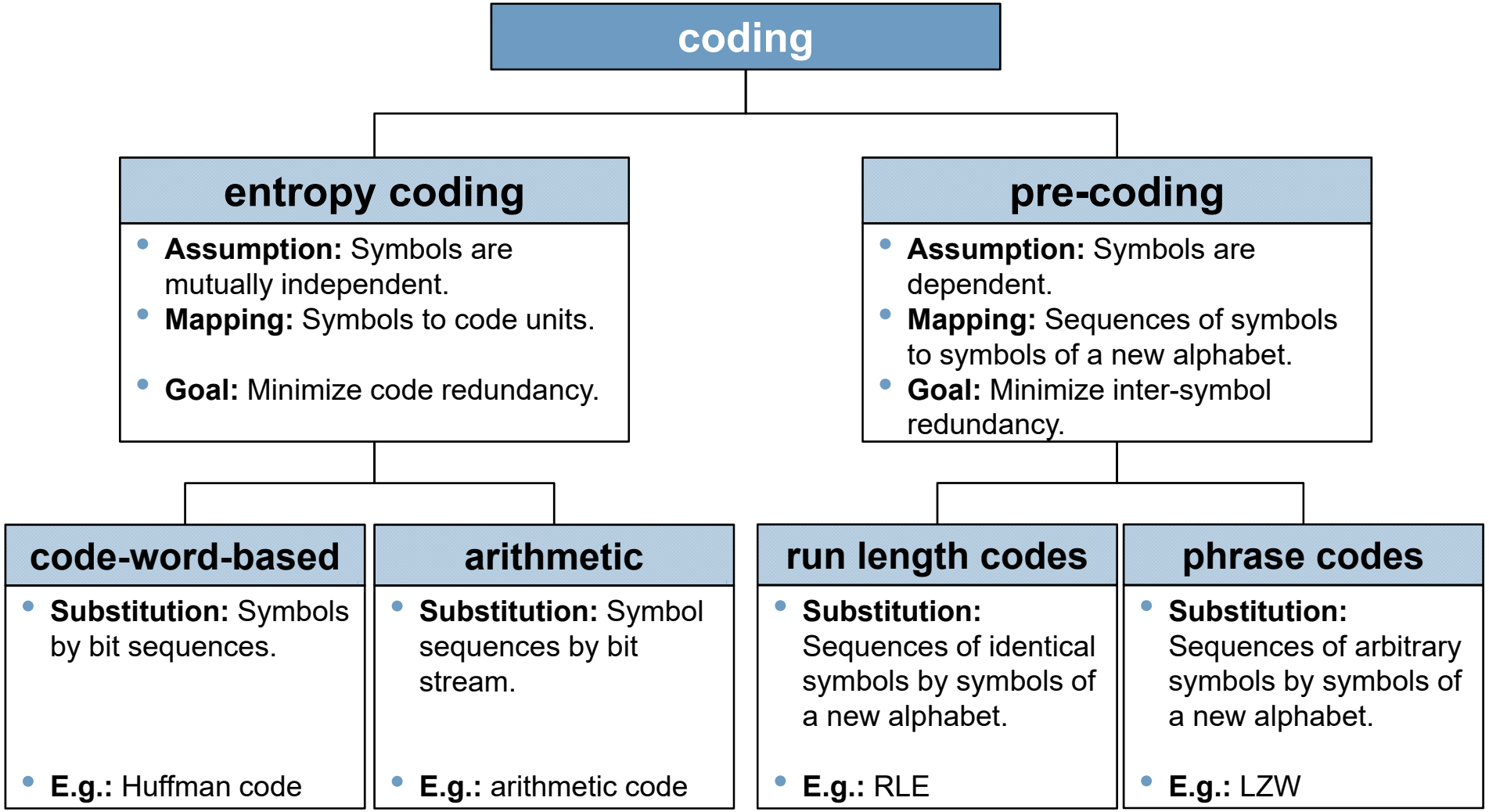

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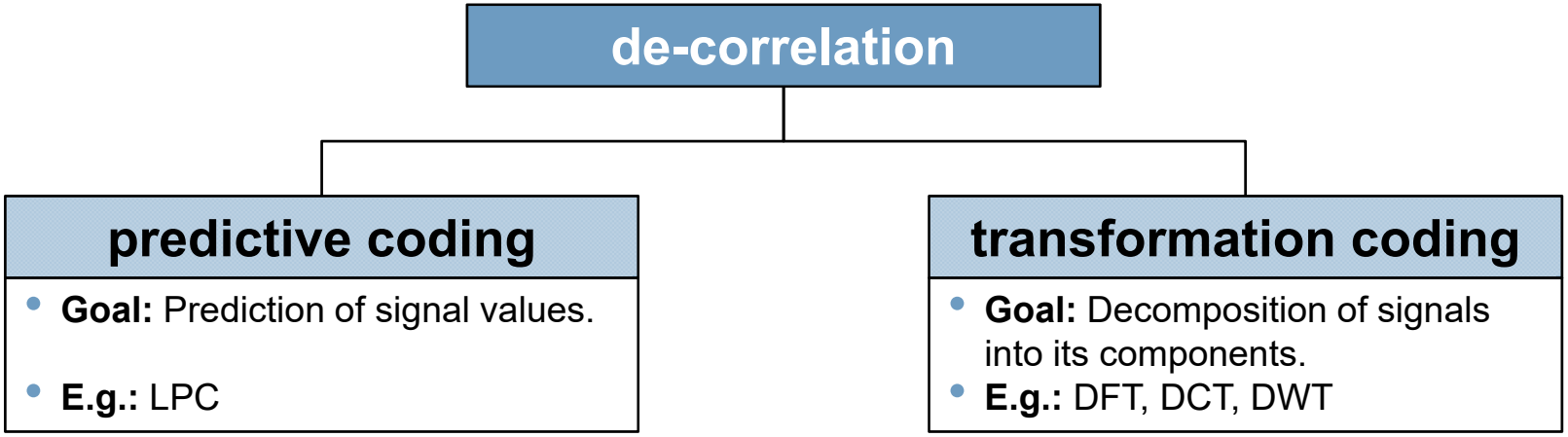

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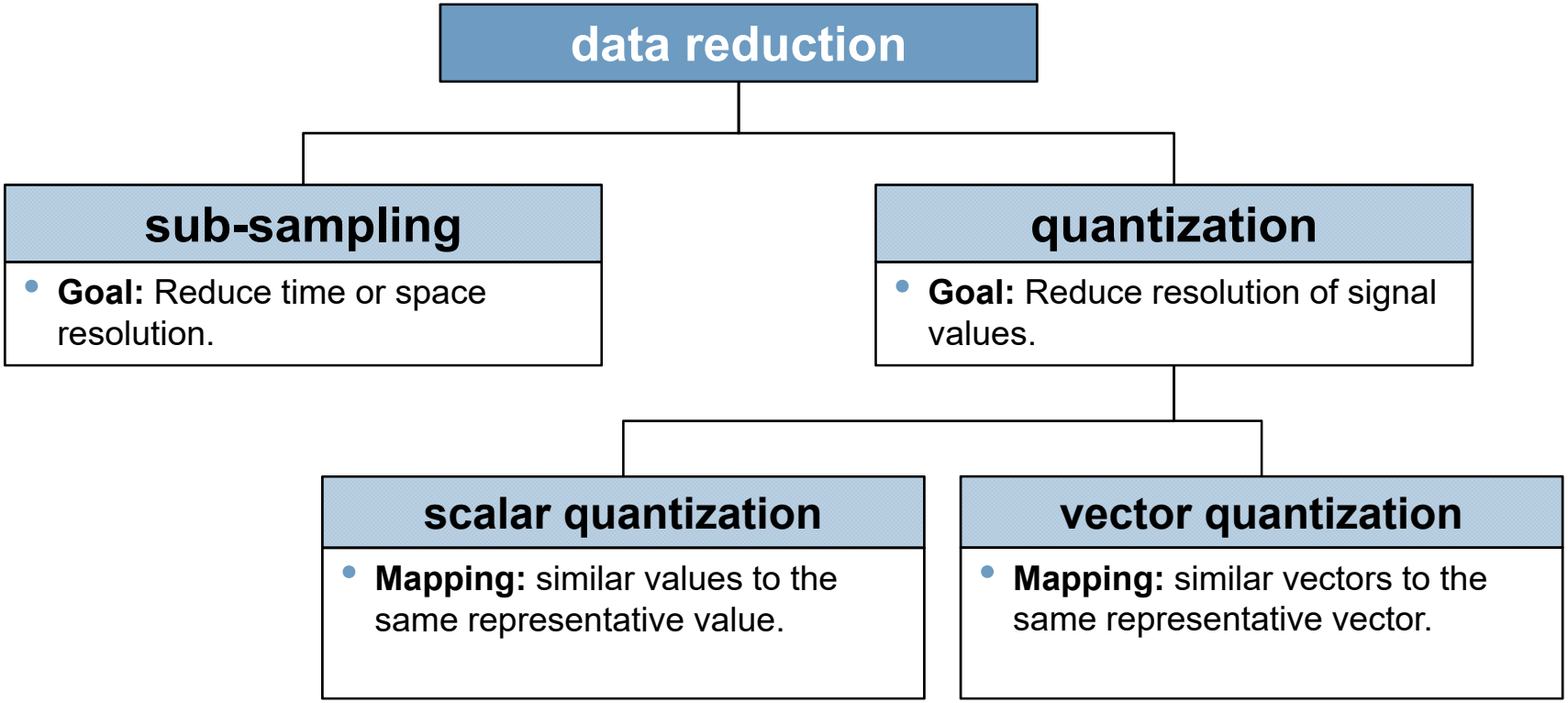

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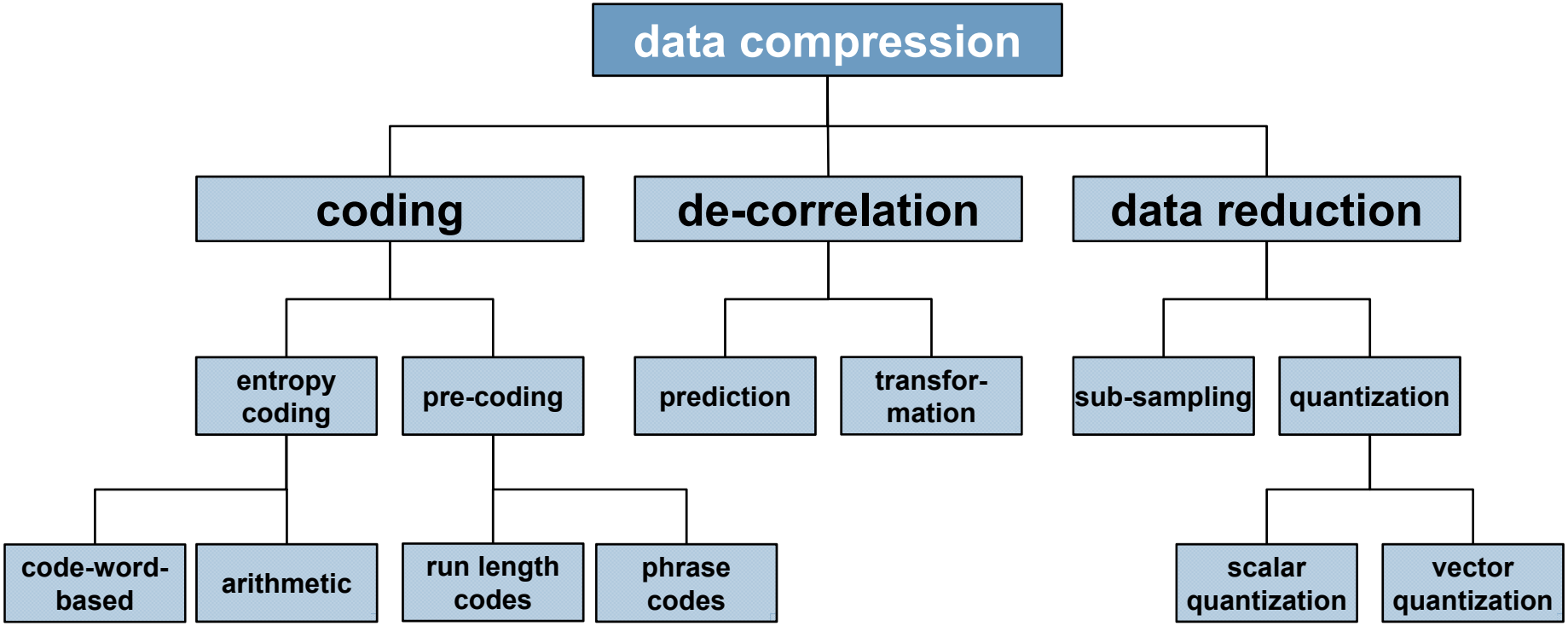

§3.3 Classification of compression methods

Overview of compression methods

Type	Form	Method	Chapter
Lossless compression		• RLE (run-length coding)	§4.1
	Statistical coding	• LZW-coding • Huffman-coding • arithmetic coding	§4.4 §4.2 §4.3
Lossy compression	Layered coding	• Bit-position • Sub-sampling • Sub-band-coding	§5.1 §7.3.2
	Quantization	• Vector quantization	§5.2
	Transformation	• DFT/FFT (Fourier-Transformation) • DCT (Cosines-Transformation) • DWT (Wavelet-Transformation)	§6.1 §6.2 §6.3
	Prediction	• LPC (linear predictive coding)	§7.3.3
Hybrid compression		• JPEG • MPEG • H.264, H.265	§8.4.6 §9.2 §9.2

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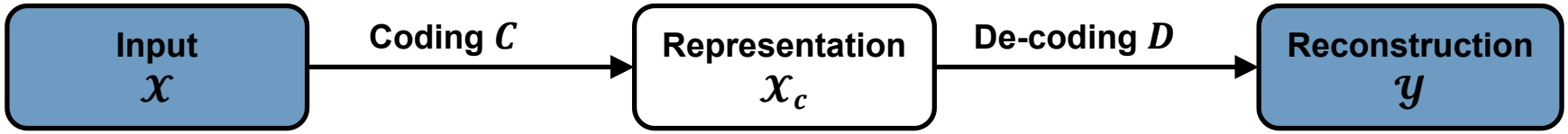
§3.4 Measures for compression methods

How to evaluate the performance of a compression method?

1. Compare data size before and after the compression.
   - ➡ Compare x and x_c, e.g. compression rate.
2. Compare data quality before and after the compression.
   - ➡ Compare x and y, e.g. distortion measures.



- Lossless compression, if $x = y$.
- Lossy compression, if $x \neq y$.

Measures for the quality of a compression method

- Compression performance, compression rate
  - Compression rate $= \frac{\text{Un-compressed size of the data}}{\text{Compressed size of the data}}$ [in percent].
  - Saving $= 1 - \frac{1}{\text{Compression rate}}$ [in percent].
  - Compression factor: Ratio of compressed size of a file to the un-compressed size of the file.
    - Example: Compression factor 1:100 means, the compressed file size is a hundredth of the original file size.
- Speed for the compression.
- Speed for the de-compression.

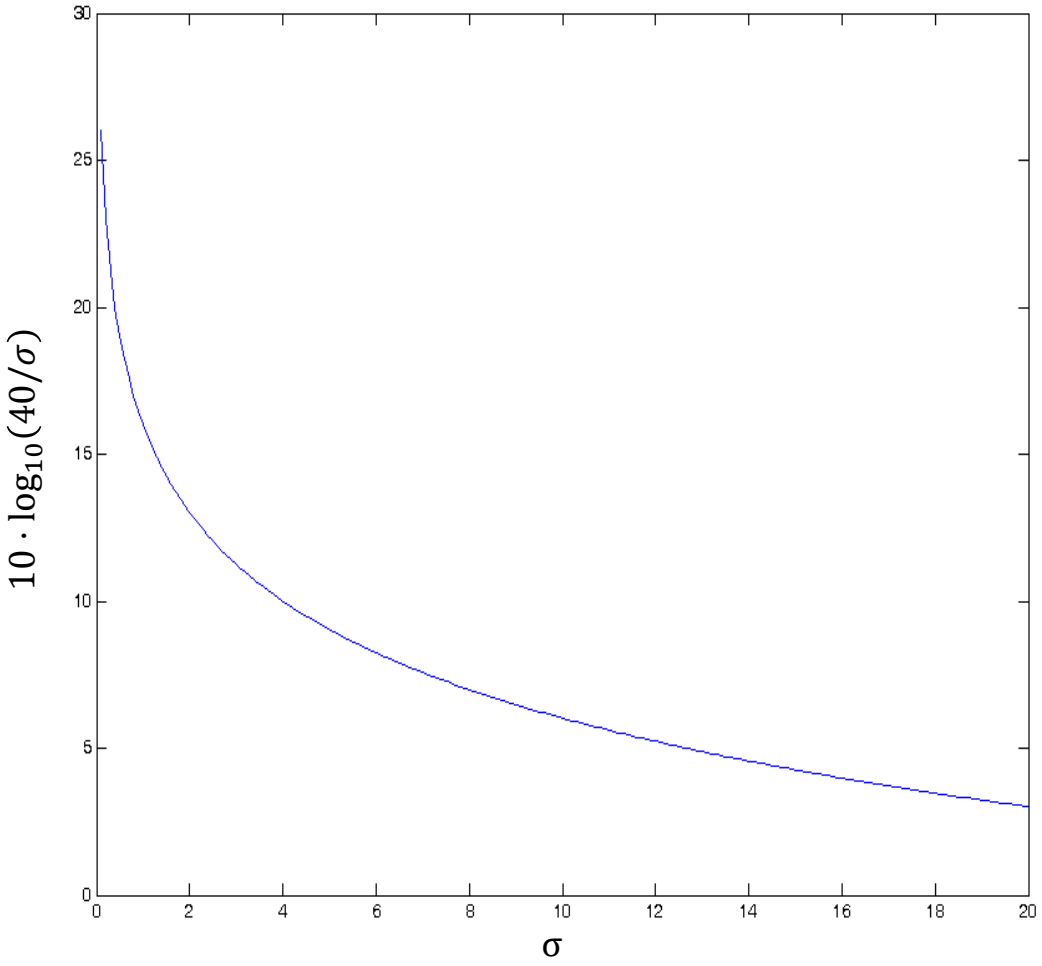
§3.4 Measures for compression methods

Distortion measures for $\mathcal{X} = (x_1, \ldots, x_n), \mathcal{Y} = (y_1, \ldots, y_n)$

- Distortion: $\mathcal{Y} - \mathcal{X}$.
- Absolute error: $|x_i - y_i|, \quad i = 1, \ldots, n.$
- Squared error: $(x_i - y_i)^2, i = 1, \ldots, n.$
- Average distance (AD): $d_1 := \frac{1}{n} \sum_{i=1}^{n} |x_i - y_i|$
- Mean squared error (MSE): $\sigma^2 := \frac{1}{n} \sum_{i=1}^{n} (x_i - y_i)^2$
- Signal-Noise-Ratio (SNR): $SNR = \sigma_{\mathcal{X}}^2 / \sigma^2$ with $\sigma_{\mathcal{X}}^2 := \frac{1}{n} \sum_{i=1}^{n} x_i^2$.
- Logarithmic SNR: $SNR(dB) = 10 \log_{10} \sigma_{\mathcal{X}}^2 / \sigma^2$.
- Peak-SNR (PSNR): $PSNR = \max_i x_i^2 / \sigma^2$.
- Logarithmic PSNR: $PSNR(dB) = 10 \log_{10} (\max_i x_i^2 / \sigma^2)$.

Trend of the PSNR

- A larger PSNR corresponds usually to a better reconstruction quality.



§3.4 Measures for compression methods

Example:

Uncompressed original

PSNR=45.53dB

PSNR=36.81dB

PSNR=31.45dB

Source: Wikipedia

§3.4 Measures for compression methods

- **Problem:** How do these measures correlate with the perceived distortion?

Original image Lena

Compressed image to 25% (jpg)

Goal

- What is source coding?
- What is the difference between lossless and lossy compression?
- When is lossless or lossy compression used?
- What is PSNR?