5 Methods of Signal Compression

This chapter introduces fundamental concepts of signal coding, as they are commonly applied for various types of multimedia signals (image, video, graphics, audio, speech) and associated components (e.g. depth maps of images/video). A common property is correlation between samples, which can be removed by signal processing, performing a mapping into an equivalent representation which exposes less statistical dependencies between samples and is sparse, i.e. concentrating information in few relevant samples. The main approaches for this are predictive coding, where the original signal is mapped to a prediction error signal, and transform coding, where a mapping into transform coefficients is made. Sparseness is important, as it allows representing many values by zero, which can be encoded quite efficiently. On the other hand, multimedia signals can hardly be classified as stationary random processes, they typically change local statistical properties. Therefore, adaptation of the compression methods is important, both in predictive and in transform coding. Though the methods of adaptation are often specific for a certain type of multimedia signals and are with more detail discussed in upcoming chapters, common principles are introduced here.

5.1 Run-length coding

Most types of multimedia signals and related components require representation by multiple amplitude levels. Examples requiring direct binary representation include two-tone images and any kind of on-off information e.g. for representation of shapes and contours, or for signalling of on/off switching flags. Methods of entropy coding can directly be applied to binary signals, where in simple cases of sequential dependencies, the conditional probabilities can be modeled by discrete Markov chains (see Sec. 2.5.4).

It is also possible to encode a binary signal into a multi-level signal with less samples using run-length coding (RLC), which expresses positions of changes between the two levels in a binary sample sequence. This is a lossless, reversible transformation of a two-level signal into a multi-level signal, the latter typically
having a lower number of samples. If combined with variable-length coding, RLC can also be interpreted as a method of conditional entropy coding for the two-level signal. An advantage of the run-length transformation is the implicit joint encoding of binary samples, where the complexity of the code only grows linearly by the maximum run-length\(^1\). The run length indicates the number of subsequent samples having an equal level in the binary signal. Two different methods are commonly used, which are illustrated in Fig. 5.1; it depends on the properties of the binary signal which of these methods would be the better choice:

- **Method A:** The run-length code signifies the number of subsequent samples of same value, i.e. in principle the positions of transitions ('0'→'1', '1'→'0') are signaled (Fig. 5.1a). It is further necessary to convey the starting level (here: ‘1’) to the decoder. The smallest possible run length is one. This method is preferable if both levels have approximately identical probability, or if the probability to remain in the states is significantly higher than the probability of a state change.

- **Method B:** The run-length code describes the number of subsequent samples only for a default level (level 0 in Fig. 5.1b), where a sample of the non-default level implicitly follows after that. A run-length value of zero is required to express that another sample of the non-default level follows immediately. It is not necessary to convey the starting level: This is assumed to be the default level; otherwise, the first run-length has to be zero, as in the example shown. This method is efficient if the default level has significantly higher probability than the non-default level, and/or if longer runs in the less probable level are not typical.

![Fig. 5.1. Run-length coding a Method A b Method B [with default level zero, \(Pr(0) > Pr(1)\)]](image)

Run-length coding of 1D binary sequences can be modeled by the 2-state Markov chain (Sec. 2.5.4), for which the entropy is determined by (2.182). Accordingly, the entropy of the two-level signal, separate for the two states, is

\[ \text{Entropy} = \sum \text{Pr} \times \log \frac{1}{\text{Pr}} \]

\(^1\) In contrast, if binary samples are combined into vectors for the purpose of entropy coding, the complexity would grow exponentially with the vector length. The design of a run-length code, even in tandem combination with VLC of the run length, could have a much lower complexity than direct VLC encoding of the binary sequence.