Multimedia Data and Its Encoding

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Media Variety and Multimedia

Today's hypermedia systems expand on the idea of allowing access to a number of different media types and formats (text, image, audio or video information). These various media formats are described as multimedia.

All types of media that are to be processed by a computer must first be digitally (binary) encoded.

Media Variety and Multimedia

Text

To encode alpha-numeric information – that is, encoding the displayed information by means of characters and letters of different alphabets - many different procedures exist.

For example, ASCII, the 7 bit standard, which dates back to the days of the telegraph, or the 32-bit Unicode, which can be used to encode nearly all alphabets in the world.

Media Variety and Multimedia

Graphics

Based on the complexity of the displayed visual information, different procedures are used for encoding image information. The range extends from simple procedures for monochromatic images to those for so-called true color display.

- **Monochrome:** *Only one color is used here*. The image to be displayed is created by coloring the individual pixels with this color. The implemented encoding methods are kept quite simple.
- **Limited color palette:** *Information graphics, symbols and pictograms often contain only a few colors.* To enable a space-efficient representation of this information, encoding is carried out with a predetermined color palette, or a predetermined color intensity.
- **True color:** Photographs depicting reality often have millions of color values. At the same time, these color values are usually not random (i.e., randomly arranged) but appear in the form of so-called color gradients. These can also be encoded in a space-efficient way. *A distinction is made between lossy and lossless coding.*

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Audio

In the playback of acoustic information, such as speech or music, the dimension of time plays a critical role.

The encoded data must be reproduced in real time, otherwise the value of the information, such as speech intelligibility, will be lost for the user.

Besides complex, lossless encoding, there exists a number of lossy procedures. These methods are based on so called psychoacoustic models. The frequencies and sound signals that cannot be detected by the human ear are filtered out and not saved.

Media Variety and Multimedia

Video and Animation

Just as in the playback of acoustic information, the suitability for reproduction in real-time is also of importance in encoding video and animation sequences.

To be able to encode an image sequence in a space-efficient way, *often only the differential image sequence is saved*. This means that just the changes in successive images are saved.

It is also possible that only predictions are made about the sequence of images and accordingly just the difference between the predicted image and the actual image is encoded. The better the prediction, the less this difference is and the smaller the memory is needed.

Media Variety and Multimedia

A distinction is made between two variations of multimedia data.

Time-independent media
Text and graphics are members of this media group consisting of a sequence of elements without a relevant time component. This group is often referred to as discrete media. While representation and processing should be done as quickly as possible it is not subject to time restraints.

Time-dependent media
Acoustic information or video images are essentially characterized by their change over a span of time. The information to be displayed is not just a result of the information content alone but first revealed completely in its chronological execution over a span of time. The presentation of such media is time-critical and its correct reproduction dependent on time factors.

Information and Encoding

Basic concepts from information and encoding theory

A **message** can be understood as a series of characters from an alphabet that are transmitted by a sender (source) to a receiver (sink). The message string cannot be finite but needs to be countable so that the individual characters of the message can be numbered with natural numbers based on a mapping function and thus clearly identified.

(Permissible) messages are constructed according to specific, predefined rules (**syntax**). Through their subsequent transfer to processing, messages are given a meaning (**semantics**).

An **alphabet** consists of a countable set of characters. It defines the character set from which a message is constructed. The quantity of all messages that can be formed with the characters of an alphabet is referred to as the **message space**.

An **encoding** is the mapping of character strings from one message space into another. In computer science, the encoding of messages as a series of bits is of particular importance, i.e, message space via the alphabet $\{0, 1\}$ (**binary encoding**).
A **code word** is a sequence of code elements (signs) of the destination message space, which has been assigned to a message from the source message space.

Redundancy denotes that part of a message which conveys no information within the communication process. The redundant portion of the message ensures that the message will still be understood if it has been received incorrectly.

Fig. 4.1 Basic concepts of information and encoding theory.

Information content and Entropy

The establishment of a message's information content is attributed to *Ralph Hartley* (1888 – 1970). It was expanded by Claude E. Shannon who consistently applied this method in the information theory founded by him. Information – according to Shannon – is nothing more than uncertainty eliminated. If one succeeds in determining the measure of this uncertainty as an equivalent expression of the information contents, an approach to the quantitative definition of information can be achieved. Let us consider a set $X = \{x_1, x_2, \ldots, x_n\}$ of events, whereby the event x_i with the probability $0 \leq p(x_i) \leq 1$ für i=1, 2. . .,n occurs. This event can, for example, be the selection of a certain character from a previous alphabet, therefore, e.g, the selection of a letter from the Latin alphabet. The reciprocal $1/p(x_i)$ then represents a measure for the uncertainty of the occurrence of the event x_i. The greater the probability of the occurrence of a character, the larger $p(x_i)$, the smaller the uncertainty of its occurrence. If the event x_i occurs with certainty, i.e. $p(x_i)=1$, there is then no longer uncertainty as to whether the event has taken place or not, i.e., the uncertainty of an event or its information content is zero. In order to make this condition possible, it is necessary to construct the logarithm (base 2) via the reciprocal $1/p(x_i)$. The information content H_i of the event x_i, occurring with a probability of $0 \leq p(x_i) \leq 1$, is therefore

$$H_i = \log_2 \frac{1}{p(x_i)} = -\log_2 p(x_i).$$

Information content and Entropy

The term H_i is both a measure of uncertainty that existed prior to the occurrence of x_i, as well as a measurement for the information that was also achieved after the occurrence of x_i. The information content of a message results from the information content of each character in the message multiplied by its frequency. If N is a message that consists of a message string of a given alphabet $X = \{x_1, x_2, \ldots, x_n\}$ and its relative frequency within the message N is $0 \leq p(x_i) \leq 1$. If $|N|$ denotes the length of message N, then the information content of message N is

$$H(N) = |N| \cdot \sum_{i=1}^{n} p_i \cdot (-\log_2(p_i)).$$

The unit of measure for the information contents of a message is a **bit**, which denotes a *binary digit*, in Shannon's sense as a *Basic Indissoluble Information Unit* – the smallest unit of information. The average information content of a message is also referred to as **entropy**

Redundancy – Necessary or Superfluous?

Based on the information content of a message, as defined by Shannon, it is possible to derive a lower bound for the length of every encoding of this message.

- Encodings whose message lengths exceed the theoretical lower bound described by Shannon therefore include parts which themselves do not contribute to the information content of the encoded message. These parts of the message are called *redundancy*.

- Redundant message portions are distinguishable in that they can be removed from the message without altering the information content. The removal of redundant portions of a message is known as *message compression*.

Redundancy – Necessary or Superfluous?

We can look at the English language, for example, and immediately identify there a considerable amount of redundancy.

Har_y Pot_er

Redundancy – Necessary or Superfluous?

The word *Harry Potter* can nevertheless still be easily recognized by an English native speaker.

Har_y Pot_er

Redundancy – Necessary or Superfluous?

But if more letters are removed (without violating the uniqueness of the word or the Shannon limit) the readability of the word clearly suffers.

Ha__y Po__er

Redundancy – Necessary or Superfluous?

Redundancy clearly has a purpose in language or in information.

- It is also use in case of *incomplete message delivery* or *transmission error*, so that in spite of a faulty transfer the original message can still be reconstructed and understood.
- Transmission errors can be detected using redundancy together with error detection codes. These type of errors can then be remedied using error-correcting codes.

Redundancy – Necessary or Superfluous?

Redundant messages are (for us human) easier (=more efficient) to read and understand.

- In addition to error tolerance, message processing is also simplified.
- However, these advantage are paid for by the much larger amount of data that must be transmitted or stored for a message with redundant parts.

Redundancy – Necessary or Superfluous?

According to Shannon's definition of the information contents of a message, there is also a lower limit to determine to what extent a message can be compressed without the loss of information (for lossless compression).

- A further compression is then only possible when information bearing parts of a message are deliberately omitted.
- *Lossy compression* is used e.g., in the compression of audio, image or video data.
  - In such cases, weaknesses in the human system of perception can be exploited.