Chapter 1

Introduction

Multimedia means, from the user's perspective, that computer information can be represented through audio and/or video, in addition to text, image, graphics and animation. For example, using audio and video, a variety of dynamic situations in different areas, such as sport or ornithology lexicon, can often be presented better than just using text and image alone.

The integration of these media into the computer provides additional possibilities for the use of computational power currently available (e.g., for interactive presentation of huge amounts of information). Furthermore, these data can be transmitted through computer and telecommunication networks, which implies applications in the areas of information distribution and cooperative work. Multimedia provides the possibility for a spectrum of new applications, many of which are in place today. On the other hand, one also has to keep in mind the problems of global communication, with its social and legal implications. However, these issues will not be discussed in this book.

One of the first and best-known institutes working on different aspects of multimedia is the MIT Media Lab in Boston [HS93]. Research is going on there on a variety of future applications, such as personal newspaper and holography [Bra87]. In the meantime, many research institutes, universities and computer and telecommunication companies work in the multimedia area.

1.1 Branch-overlapping Aspects of Multimedia

In addition to the strong interest in multimedia systems from the applications and technology viewpoints, one should not underestimate the ongoing migration process, and the evolution of the different industrial branches, as follows:

- *Telecommunication* began primarily with the telephone. Telephone networks changed gradually into digital networks, which are similar to computer networks. In the early days, intermediate switching systems had mechanical switching dials. Today, computers do the job. Now the telephone is becoming more and more of a computer, or is part of a computer (e.g., using an ISDN card).

- *Consumer electronics* contributed massively to the reduction of the price of video support in computers. Similarly, optical disc technology in computing is dependent on the success of the CD player. Consequently, the same companies very often produce CD drives for computer and stereo-systems, or both television and computer monitors.

- *Recording studios* and *TV producers* are pioneers in dealing with professional audio and video equipment. Today, professional systems are available for the digital cutting of TV movies. Some of these systems are standard computers extended through additional special cards. These information providers convey data through cable, satellite and plain old antennas, which will further allow them to serve as information providers via computer networks in the future.

- Many of the large *publishing houses* already offer their publications in electronic form. Further, there are many close relations between publishing houses and movie companies. These branches offer gradually more and more multimedia information.

This short overview shows that the different branches grow together because of coming multimedia technology and applications. However, to allow multimedia applications, many software and hardware components have to be adapted, extended or replaced.

From the technical perspective, besides handling the huge amount of data, the *timing requirements* among all components of the data computation is the major challenge. Traditional data computation tries to finish its task as soon as possible. Real-time systems must work internally within given time bounds, mostly as error-tolerant systems. The fault tolerance in multimedia is generally not the most important aspect.

Another challenge is the *integration requirement* of different types of media in a multimedia application. In such applications, the traditional media (e.g., text, image) as well as the continuous media (e.g., video, audio), must be processed. Moreover, if a timing requirement is set by a multimedia application, it should hold for both classes (traditional and continuous media) to achieve the timing specification of the application. These media are not independent of each other and therefore the integration requires concepts, which are more complex than just the integration of current concepts. In an integrated system, different components have to process both kinds of data, and moreover, different relations can occur in the form of *synchronization* among the media.

The notion of *multimedia* is often defined very differently in the literature in comparison to our (above) description. There is some need for clarification. The technology connections and binding different components, were considered only partially and in isolation from each other. Based on [Ste93b], we wrote this book to provide an integrated, consistent and total view.

1.2 Content

This book has the character of a *reference book*, covering numerous areas and allowing the reader to learn about a topic of interest without having previously studied extensively or having read areas previously covered in this book. Strong connections are provided among the different areas of this book through its *global structure*, which is shown in Figure 1.1. The results presented in this book serve as basis for the development of individual components of a multimedia system and suggest some general parameters one must keep in mind.

1.3 Global Structure

This book aims to achieve a complete and balanced view. Figure 1.1 shows the global view of this book with the main topics covered in it. Figure 1.1 was developed after many iterations of topic structuring. It shows schematically the main fields of multimedia systems. The basic idea of the figure is to express the interactions among the components through spatial proximity.

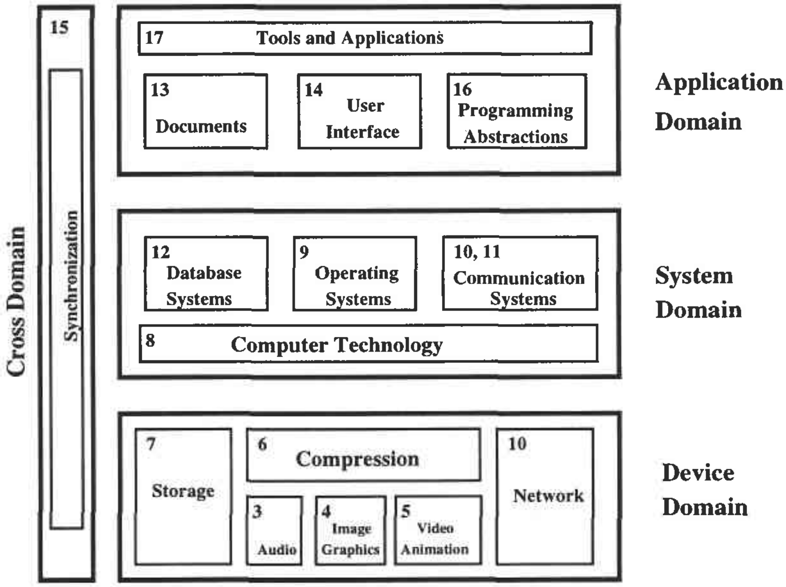

Figure 1.1: *The main topics covered in this book with chapter number information.*

The following areas can be distinguished:

- **Device Domain**

  Basic concepts for the processing of *digital audio* and *video* data are based on digital signal processing. Hence, these concepts are described and some possible practical implementations are presented. Different methods for the processing of *image*, *graphics* and *animation* are described. The audio techniques section includes music (MIDI) and speech processing. The understanding of video techniques is built mainly on TV development, including digital representation and HDTV. The originated data rates of these media demand, because of the current quality requirements and available technology, corresponding *compression* methods. The corresponding hardware and some software are briefly described.

The diminishing cost of *optical storage* space has contributed significantly to the current development of computer technology. Almost all developments are based on CD-DA (Compact Disc-Digital Audio), known from home electronics.

On the other hand, networks, with their higher bandwidth and their capacity for transmitting all media types, have led to *networked multimedia systems.* Not such a long time ago, local and distributed multimedia systems consisted of a set of external analog devices controlled by a computer. Today, development tends toward full digital working systems.

- **System Domain**

  The interface between the device domain and the system domain is specified by the *computer technology.* To utilize the device domain, several system services are needed. Basically, three services exist. These services are mostly implemented in software:

  - The *operating system* serves as an interface between computer hardware/system software and all other software components. It provides the user with a programming and computational environment, which should be easy to operate. In its function as an interface, the operating system provides different services that relate to the computer resources, such as: processor, main memory, secondary storage, input and output devices and network.
  - The *database system* allows a structured access to data and a management of large databases.
  - The *communication system* is responsible for data transmission according to the timing and reliability requirements of the networked multimedia application.

- **Application Domain**

  The services of the system domain are offered to the application domain through proper *programming abstractions.* Moreover, such abstractions can be, for example, part of a multimedia operating system, programming language or object-oriented class hierarchy.

Another topic embedded in the application domain is *document handling.* A document consists of a set of structured information, represented in different media, and generated or recorded at the time of presentation.

Many functions of *document handling* and other *applications* are accessible and presented to the user through a *user interface.*

- **Cross Domain**

  It turns out that some aspects, such as synchronization aspects, are difficult to locate in one or two components or domains. The reason is that *synchronization*, being the temporal relationship among various media, relates to many components across all domains.

1.4 Multimedia Literature

All individual topics mentioned in this work have been considered to some extent, and often in more detail, though in isolation, in the literature. Likewise, the groundwork for signal processing, audio, video, graphics, image and animation techniques and various networks have been published in relevant works. In this book, all the parts of an integrated multimedia system will be considered.

Some publications, such as [BD92, EH92, Gia92, Koe94], are composed of individual articles or chapters originated by different authors, with the goal of presenting the topics of user interfaces or applications from different points of view. In contrast to the present work, there was no attempt to provide a coherent integral presentation of the multimedia area.

Other publications serve as individual product descriptions, e.g., [BS92]. They present mostly the properties of individual products without giving a global view. In [Bur93] and [Ste92], besides the application and product descriptions, there is also some groundwork for audio techniques, video techniques, compression and optical storage media. But, in contrast to the present study, all scientific aspects, as well as an overall, integrated view, are neglected. This is the case also in [PF92, V. 93, Wod92].

Hypertext and hypermedia are documented in a large number of publications, most of which offer hypermedia document descriptions. A very good presentation is given in [Nie90a]. We consider hypermedia a part of multimedia.

Besides a number of national and international workshops in the multimedia area, new conferences such as ACM Multimedia Conference (first in August 1993, Anaheim, CA) and IEEE Multimedia Conference (first in May 1994, Boston, MA) evolved. Also, in addition to many product and commercial only oriented magazines, dedicated publications, such as the ACM Springer journal *"Multimedia Systems"* (end of 1993), *"Multimedia Tools and Applications"* (beginning of 1995) and the *"IEEE Multimedia Magazine"* (beginning of 1994) are being published.

Chapter 2

Multimedia: Media and Data Streams

The following chapter introduces terminology and gives a sense of the commonality of the elements of multimedia. The introduction of terminology begins with a clarification of the notion *multimedia*, followed by a description of media and the important properties of multimedia systems. Subsequently, characteristics of *data streams* in such systems and the introduction of the notion *Logical Data Unit* (LDU) follow.

One way of defining multimedia can be found in the meaning of the composed word.

- *Multi-* [lat.: much] many; much; multiple.
- *Medium* [lat.: middle] An intervening substance through which something is transmitted or carried on; A means of mass communication such as newspaper, magazine, or television (from American Heritage Electronic Dictionary, 1991).

This description is derived from the common forms of human interaction. It is not very exact and has to be adapted to computer processing. Therefore, we discuss in the next section the notion *medium* in more detail with respect to computer processing.

2.1 Medium

In general, one describes medium as a means for distribution and presentation of information. Examples of a medium are text, graphics, speech and music. In the same way, one can also add water and atmosphere to it (according to the above medium description from the American Heritage Dictionary).

Media can be classified with respect to different criteria [ISO93a]. We classify media according to perception, representation, presentation, storage, transmission, and information exchange.

2.1.1 The Perception Medium

Perception media help humans to sense their environment. The central question is: *How do humans perceive information in a computer environment?* The answer is that the perception of information occurs mostly through *seeing* or *hearing* the information, although tactile perception increases its presence in a computer environment.

There is a primary difference between *seeing* and *hearing* information when using a computer. For the perception of information through seeing, the visual media such as *text, image* and *video* are used. For the perception of information through hearing, auditory media such as *music*, *noise* and *speech* are relevant.

The difference among media can be further refined. For example, video can be further decomposed into different video scenes, which again are composed of individual images.

2.1.2 The Representation Medium

Representation media are characterized by internal computer representations of information. The central question is: *How is the computer information coded?* The answer is that various formats are used to represent media information in a computer. For example:

- A text character is coded in ASCII or EBCDIC code.
- Graphics are coded according to CEPT or CAPTAIN videotext standard. The graphics standard GKS can also serve as a basis for coding,
- An audio stream can be represented using a simple PCM (Pulse Coding Method) with a linear quantization of 16 bits per sample.
- An image can be coded as a facsimile (the group 3 according to the ISO Standard Specification) or in JPEG format.
- A combined audio/video sequence can be coded in different TV standard formats (e.g., PAL, SECAM, NTSC), and stored in the computer using an MPEG format.

2.1.3 The Presentation Medium

Presentation media refer to the tools and devices for the input and output of information. The central question is: *Through which medium is information delivered by the computer, or introduced into the computer?* The media, e.g., paper, screen and speaker are used to deliver the information by the computer (output media); keyboard, mouse, camera and microphone are the input media.

2.1.4 The Storage Medium

Storage media refer to a data carrier which enables storage of information. However, the storage of data is not limited only to the available components of a computer. Therefore, paper is also a storage medium. The central question is: *Where will the information be stored?* Microfilm, floppy disk, hard disk, and CD-ROM are examples of storage media.

2.1.5 The Transmission Medium

The transmission medium characterizes different information carriers, that enable continuous data transmission. Therefore, storage media are excluded from this kind of medium. The central question is: *Over what will the information be transmitted?* The answer is that information is transmitted over networks, which use wire and cable transmission, such as coaxial cable and fiber optics, as well as free air space transmission, which is used for for wireless traffic.

2.1.6 The Information Exchange Medium

The information exchange medium includes all information carriers for transmission, i.e., all storage and transmission media. The central question is: *Which information carrier will be used for information exchange between different places?* The answer is that information can flow through *intermediate* storage media, where the storage medium is transported outside of computer networks to the destination, through *direct* transmission using computer networks, or through *combined* usage of storage and transmission media (e.g., electronic mailing system).

2.1.7 Representation Values and Representation Spaces

The above classification of media can be used as a basis for characterizing the notion *medium* in the context of information processing. Here, the description of perception medium comes closest to our notion of a medium: the media appeal to the human senses. Each medium defines *representation values* and *representation spaces* [HD90, HS91], which involve the five senses.

Examples of visual representation spaces are paper or screen. During a computer-controlled slide show with simultaneous projection of the computer screen content, the whole movie screen counts as a representation space. Stereo and quadraphony determine the acoustic representation spaces. Representation spaces can also be considered part of the above described presentation media for information output.

Representation values determine the information representation of different media: while the *text* medium visually represents a sentence through a sequence of characters, this sentence will be represented by the *speech* medium in the form of a pressure wave. Some representation values are self-contained by their media. In other words, they can be properly interpreted by the recipient. Examples here are temperature, taste, and smell. Other media require a predefined symbol set, which the users must agree upon. Text, speech and gestures are examples of such media.

Representation values can be considered either as a continuum or a sequence of discrete values. Pressure wave fluctuations do not appear as discrete values; instead they determine the acoustic signals. Electromagnetic waves for human eye perception are not discrete values either; rather they are a continuum. Characters of a text and audio sample values in electronic form are sequences of discrete values.

2.1.8 Representation Dimensions

Each representation space consists of one or more *representation dimensions.* A computer screen has two spatial dimensions; holography and stereophony require an additional spatial dimension. Time can occur inside each representation space as an additional dimension, as it has central meaning to multimedia systems. Media are divided into two types with respect to time in their representation space:

1. Some media, such as text and graphics, are time-independent. Information in these media consist exclusively of a sequence of individual elements or of a continuum without a time component. Such media are known as *time-independent* (or *discrete*). Note, the notion 'discrete' is sometimes confusing, because a medium can also be discrete in value but continuous in time.). The text of a book is, for example, a discrete medium. Processing of discrete media should happen as fast as possible, but this processing is not time critical because the validity (and therefore correctness) of the data does not depend on any time condition.

2. The values of other media, such as sound and full-motion video, change over time. Information is expressed not only in its individual value, but also by the time of its occurrence. The semantics depend on the level of the relative change of the discrete values or of the continuum. Such media are *time-dependent.* Also, representation values caused by tactile or temperature sensors with threshold detectors are time-dependent, and therefore also belong to the time-dependent media.

Processing of these media is time-critical because the validity (and therefore correctness) of the data depends on a time condition. For example, a transmitted audio sample delivered too late is invalid if the following samples to the sample in question have already been played back.

Individual representation values occur in audio and video as a continuous sequence. We understand *video* as a sequence of plain images occurring periodically, as well as audio being a sequence of samples with periodic behavior. We call these media *continuous media.* Using this division, time-dependent representation values, which occur aperiodically, are not considered continuous media. Control commands for real-time systems are an example. In multimedia systems, we must also consider non-continuous sequences of representation values. Such sequences occur, for example, by transmission of information (e.g., mouse pointer position) in a cooperative application within a shared window.

Examples of continuous media are: *video* coming from natural source (e.g., video taken by a camera during a live video transmission) or from an artificial source (e.g., video disc); *audio*, which is mostly stored as a sequence of digitalized sound-wave samples; and *signals of different sensors*, such as those that sense air pressure, temperature, humidity, pressure or radioactivity.

These notions of time-dependent, discrete and continuous media do not have any connection to internal representation. They relate to the impression of the viewer or listener. For example, a movie as a representative of continuous media often consists of a sequence of discrete values, which change in representation space according to a time function. The inertia of the human eye only leads to the impression of continuity if a sequence of at least 16 individual images per second is provided.

2.2 Main Properties of a Multimedia System

2.2.1 Multimedia System Definition

If we derive a multimedia system from the meaning of the words in the American Heritage Dictionary, then a multimedia system is any system which supports more than a single kind of media. This characterization is insufficient because it only deals with a *quantitative* evaluation of the system. For example, each system processing text and graphics would be classified as a multimedia system according to this narrow definition. Such systems already existed before the multimedia notion was used in a computer environment. Hence, the notion *multimedia* implies a new quality in a computer environment.

We understand multimedia more in a *qualitative* rather than a quantitative way. Therefore, the kind rather than the number of supported media should determine if a system is a multimedia system. It should be pointed out that this definition is controversial. Even in the standardization bodies, e.g., ISO, a weaker interpretation is often used.

A multimedia system distinguishes itself from other systems through several properties. We elaborate on the most important properties such as combination of the media, media-independence, computer control and integration.

2.2.2 Combination of Media

Not every arbitrary combination of media justifies the usage of the term *multimedia*. A simple text processing program with incorporated images is often called a multimedia application because two media are processed through one program. But one should talk about multimedia only when both continuous and discrete media are utilized. A text processing program with incorporated images is therefore not a multimedia application.

2.2.3 Independence

An important aspect of different media is their level of *independence* from each other. In general, there is a request for independence of different media, but multimedia may require several levels of independence. On the one hand, a computer-controlled video recorder stores audio and video information, but there is an inherently tight connection between the two types of media. Both media are coupled together through the common storage medium of the tape. On the other hand, for the purpose of presentations, the combination of DAT recorder (Digital Audio Tape) signals and computer-available text satisfies the request for media-independence.

2.2.4 Computer-supported Integration

The media-independence prerequisite provides the possibility of combining media in arbitrary forms. Computers are the ideal tool for this purpose. The system should be capable of computer-controlled media processing. Moreover, the system should be programmable by a system programmer or even a user. Simple input or output of different media through one system (e.g., a video recorder) does not satisfy the requirement for a computer-controlled solution. Computer-controlled data of independent media can be integrated to accomplish certain functions. For such a purpose, timing, spatial and semantic synchronization relations will be included. A text processing program that supports text, table calculations and video clips does not satisfy the demand for integration if program supporting the connection between the data cannot be established. A high integration level is accomplished if changing the content of a table row causes corresponding video scene and text changes.

Such flexible processing of media is not obvious – even in many of the best available multimedia products. Therefore, this aspect must be emphasized in terms of an *integrated multimedia system.* Simply put, in such systems, everything can be presented with video and sound that is presented with text and graphics today [AGH90]. For example, in conventional systems, a text message can be sent to other users; but, a multimedia system with a high level of integration allows this function also for audio messages or even for a combination of audio and text.

2.2.5 Communication Systems

Communication-capable multimedia systems must be approached. A reason for this is that most of today's computers are interconnected; considering multimedia functions from only the local processing viewpoint would be a restriction, if not a step back. Another reason is that distributed environments enable particularly interesting multimedia applications. Here multimedia information cannot only be created, processed, presented and stored, but also distributed above the single computer's boundary.

2.3 Multimedia

Considering the first explanation of multimedia at the beginning of this chapter, it is apparent that the notion is insufficient. We derive the following definition for multimedia from the American Heritage Dictionary definitions and the above considerations with respect to the medium (Section 2.1) and to the main properties of a multimedia system (Section 2.2):

A multimedia system is characterized by computer-controlled, integrated production, manipulation, presentation, storage and communication of independent information, which is encoded at least through a continuous (time-dependent) and a discrete (time-independent) medium.

Multimedia is very often used as an attribute of many systems, components, products, ideas, etc., without satisfying the above presented characteristics. From this viewpoint our definition is deliberately restrictive.

Thus, two notions of multimedia can be distinguished:

- **"Multimedia", strictly speaking:**

  This notion was explained in Section 2.2 and will be used further. In this context, continuous media will always be included in a multimedia system. At the same time important timely marginal conditions (through the continuous media) for the processing of discrete media will be introduced. They have barely been considered in computer use until now.

- **"Multimedia", in the broader sense:**

  Often the notion *multimedia* is used to describe the processing of individual images and text, although no continuous medium is present. Many of the processing tasks in this environment will also be necessary in the multimedia system according to the restrictive definition. In any case, if more media are processed together, one can talk about multimedia according to this second notion.

2.4 Traditional Data Streams Characteristics

In Sections 2.1, 2.2, and 2.3 we clarified the multimedia notion from the local computer-based point of view. But the presented work also includes the consideration of multimedia communication systems. Therefore, we need to specify the multimedia notion from the communication point of view.

In distributed multimedia communication systems, data of discrete and continuous media are transmitted and information exchange takes place. Moreover, in each digital system, transmitted information is divided into *individual units* (in general, these are packets) and subsequently sent away from one system component (the source) to another (the destination). The source and destination can be located either on the same computer or on different machines. A sequence of individual packets transmitted in a time-dependent fashion is called a *data stream* (The term "data stream" will be used here as a synonym for "data flow".). Packets can carry information of either continuous or discrete media. An example of a continuous media data stream is the transmission of speech in a telephone system. The retrieval of a document from a database can be seen as setting up a discrete media data stream.

Transmission of information carrying different media leads to data streams with very different features. The attributes of *asynchronous*, *synchronous*, and *isochronous* data transmission come from the fields of computer communication and switching. They are also used, for example, in FDDI (Fiber Distributed Data Interface) networks for the description of different data transmission modes with respect to end-to-end delay of individual packets (see Figures 10.5 and 10.6).

2.4.1 Asynchronous Transmission Mode

The *asynchronous transmission mode* provides for communication with no timely restrictions. Packets reach the receiver as fast as possible.

Protocols of the worldwide Internet for electronic mail transmission are an example. In local area networks, Ethernet is a further example. All information of discrete media can be transmitted as an asynchronous data stream. Data of discrete media can also include time restrictions through the timely connection to continuous media synchronization. In this case an asynchronous transmission might not be appropriate. If an asynchronous mode is chosen for transmission of continuous media, additional techniques must be applied to provide the time restrictions.

2.4.2 Synchronous Transmission Mode

The *synchronous transmission mode* defines a maximum end-to-end delay for each packet of a data stream. This upper bound will never be violated. Moreover, a packet can reach the receiver at any arbitrary earlier time. Thus, an important claim of multimedia applications is satisfied: a maximal end-to-end delay can be guaranteed.

Additionally, an audio connection can be established over a local area network which supports synchronous transmission mode. The uncompressed transfer of video data in a retrieval mode is characterized by a high data rate and relatively high maximal end-to-end delay. Here the typical data rate is 140 Mbit/s and a maximal delay can be 1 second. In extreme cases packets arrive at the receiver 1 second too early and have to be stored intermediately. In our example, a receiver would need a temporary storage of about 17.5 Mbytes.

2.4.3 Isochronous Transmission Mode

The *isochronous transmission mode* defines, besides a maximum end-to-end delay for each packet of a data stream, a minimum end-to-end delay. This means that the delay jitter (in short, "jitter") of individual packets is bounded.

In this case, the necessary storage of video data at the receiver, mentioned in the above example, would be strongly reduced. These demands on intermediate storage must be considered in all components along the data route between source(s) and sink(s).

2.5 Data Stream Characteristics for Continuous Media

The following section describes data stream characteristics that relate to any audio and video data transfer in a multimedia systems (*multimedia data streams*). Moreover, we consider the effects of compression on data stream characteristics during data transfer. These data stream characteristics apply to distributed as well as local environments.

2.5.1 The Time Interval Between a Complete Transmission of Consecutive Packets

This first property relates to the time interval between a complete transmission of consecutive packets. Based on the availability of packets, we distinguish among the following possibilities:

- If the time interval between two consecutive packets is constant, a data stream is called *strongly periodic*. Therefore, in an ideal case, jitter has the value zero. Figure 2.1 shows such a data stream. An example is PCM-coded speech in

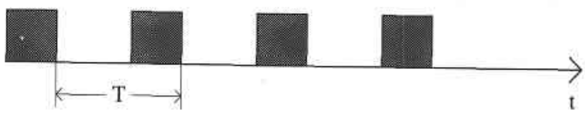

Figure 2.1: *Strongly periodic stream, (T-time limit between two consecutive packets), i.e., time intervals are of the same length between two consecutive packets.*

traditional telephone switching systems.

- The duration of the time interval between two consecutive packets can be described through a periodical function with finite period, but the time interval between consecutive packets is not constant (otherwise it would be a strongly periodic data stream). The data stream is called *weakly periodic*. This case is shown in Figure 2.2.

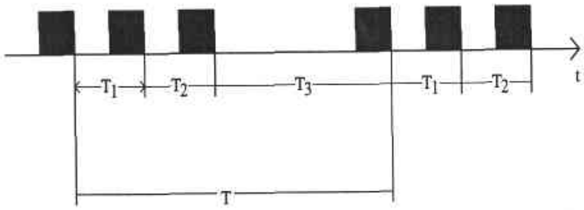

Figure 2.2: *Weakly periodic stream, i.e., time intervals between consecutive packets are of periodic nature.*

- All other possibilities of transmission with respect to time interval are known as *aperiodic data streams.* Figure 2.3 shows such a data stream.

Figure 2.3: *Aperiodic stream, i.e., the sequence of time intervals is neither strongly nor weakly periodic.*

An example of an aperiodic data stream can be found in a cooperative application with shared windows. Very often, the status and actual coordinates of the user's mouse must be distributed among all participants of the multimedia conference. If this information is transmitted periodically, extremely high redundancy is present. Thus, given that an optimal system should transmit information only when necessary, after an initialization phase, data are exchanged only when a change in position or status occurs.

2.5.2 Variation of Consecutive Packet Amount

A second characteristic of data streams is the variation of the amount of consecutive packets.

- If the amount of data stays constant during the lifetime of a data stream, one calls the data stream *strongly regular.* Such a data stream is shown in Figure 2.4. This feature is typical for uncompressed digital data transmission.

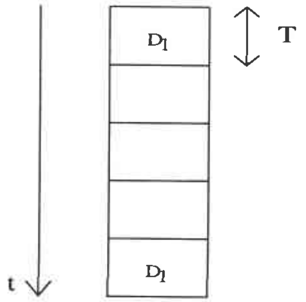

Figure 2.4: *Strongly regular stream, i.e., constant data size of all packets.*

Examples are the video stream taken from a camera in uncompressed form and the audio stream from an audio CD.

- If the amount of data varies periodically (with time), this is a *weakly regular* data stream. An example of a weakly regular data stream is a compressed video stream which uses a compression method as follows: individual images are coded and compressed as an individual, whole unit, which represents a relatively large packet inside the data stream (bounded packet length of network transmission is left out in this consideration.). Packets will be periodically transmitted, e.g., every two seconds. Inbetween the two second periods, additional packets will be sent which include the information about the difference of the two consecutive compressed images.

  An example of a compression method which works similarly to the above description is the MPEG compression method (see Section 6.7). MPEG differentiates among I, P and B images in a compressed video stream. I-images represent compressed individual images, while P- and B-images take into account image differences. With this approach the data rate is reduced essentially. There is no constant bit rate for individual I, P, B compressed packets, but the I:B:P relation of the created data amount for every image is known (often used value of the I:B:P relation is 10:1:2 for individual images.). Such a data stream can be characterized on average over a long time period as *weakly regular* (Figure 2.5).

- Data streams are *irregular* if the amount of data is neither constant nor changes according to a periodic function (see Figure 2.6). Transmission and processing

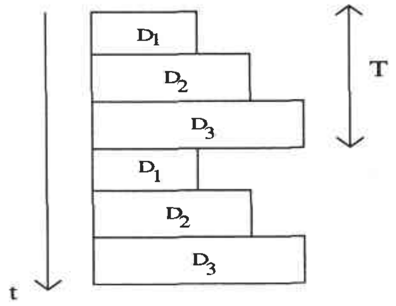

Figure 2.5: *Weakly regular stream, i.e., data size of the packets changes periodically.*

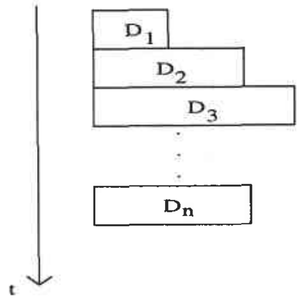

Figure 2.6: *Irregular data stream, i.e., data size of the packets is neither constant nor changing periodically.*

is more complicated in this case. In the case when a compression method is applied to the data stream, the data stream has a variable bit rate, and the size of an individual packet (derived from an individual image) is determined from the content of the previous changed image. The size of the created information unit is therefore dependent on the video sequence and the data stream is *irregular.*

2.5.3 Contiguous Packets

A third property characterizes *continuity*, or the connection between consecutive packets. Are consecutive packets transmitted directly one after another, or is there a gap between the packets? This can be seen as utilization of a certain system resource, such as a network.

- Figure 2.7 shows a *connected* information transfer. All packets are trans-

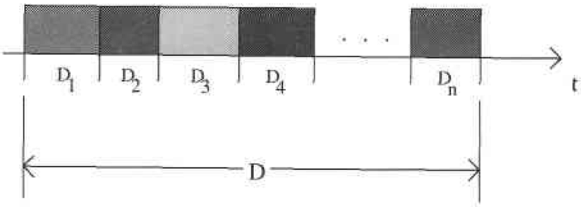

Figure 2.7: *Continuous stream, i.e., the packets are transmitted without intermediate gaps.*

mitted successively without a gap. Necessary additional information (e.g., error control codes) of the data is considered. In this case, the considered system resource is 100% utilized. A connected data stream allows maximal data throughput and reaches optimal utilization of the system resource. A B-channel of ISDN with transmission of 64 kbit/s audio data is an example.

- The transmission of a connected data stream through a channel with a higher capacity leads to gaps between individual packets. A data stream with gaps between information units is called an *unconnected data stream.* An example is shown in Figure 2.8. However, it is not important if gaps exist among all

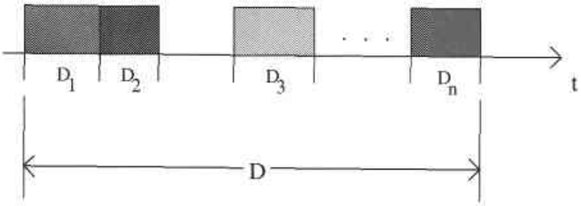

Figure 2.8: *Discrete stream, i.e., gaps exist among the packets.*

packets or if the duration of the gaps varies. For example, the transmission of a data stream, coded with the JPEG method, with 1.2 Mbit/s throughput on average, will lead to gaps among individual packets on an FDDI network.

In the following example, the properties described above should be made clear: an NTSC video signal is captured from a video camera and digitized in a computer, yet no compression is done. The created data stream is strongly periodic, strongly regular and connected, as shown in Figure 2.4. There are no gaps among the packets. During the digitizing process, the DVI_RTV method for compression, using the ActionMedia II^{TM}card, is performed. The resulting data stream (considered over a longer period of time) is now weakly periodic, weakly regular, and, through transmission over a 16 Mbit/second Token Ring, unconnected.

2.6 Information Units

Continuous media consist of a time-dependent sequence of individual information units. Such an information unit is called a *Logical Data Unit* (LDU), which is close to a *Protocol Data Unit* (PDU). The meaning of the information and data amount of an LDU can be different:

1. Consider for example the symphony "*The bear*" by Joseph Haydn. It consists of four sentences: *vivace assai, allegretto, minuet* and *finale vivace.* Each sentence is an independent, self-contained part of this composition, consisting of a sequence of notes for different instruments. The notes are represented in a digital system as a sequence of samples (no compression is considered in our example.). With CD-DA quality, there are 44,100 samples per second, which are coded with 16 bits per sample. On a CD the samples are grouped into units of 1/75 second duration. One could take as the LDU the whole symphony, individual sentences, individual notes, grouped samples of 1/75 second duration or just individual samples. The particular application determines what is considered to be the LDU. For example, applications using output functions of the whole symphony will take the whole symphony as the LDU. Other applications use functions which consider the smallest meaningful units (in our case, notes). A digital system considers samples as the LDUs.

2. An example of an uncompressed video sequence consisting of individual video clips, which present a specific scene, is shown in Figure 2.9. Such a scene is comprised of a sequence of images. An image can be divided, for example, into 16x16 groups of pixels. Each pixel consists again of luminance and chrominance values. The image is therefore not the only possible LDU of a video sequence. A scene or a pixel can also be an LDU. In a video sequence, coded

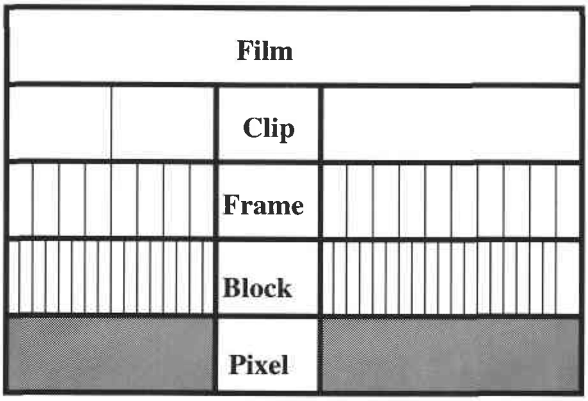

Figure 2.9: *Granularity of a motion picture sequence.*

with MPEG or DVI, existent redundancies can be used through applying an interframe compression method. The smallest self-contained meaningful units here are image sequences.

The notion of *granularity* characterizes the hierarchical division of audio or video data streams into their components. In our examples, the most general names and best-known information units are the symphony and the movie. Yet there exists also another classification of LDU with respect to duration. *Closed LDUs* have a pre-defined duration. An example of such an LDU stream is a data stream of audio samples in the computer. If the duration is not known in advance, we encounter an *open LDU*. An example of such an LDU stream is a data stream sent from a camera or microphone to the computer.