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*To Laura and Phyllis*
*and in memory of Jim Riley*

# Contents

# Introduction 1

## 1.1 DIGITAL VIDEO COMMUNICATIONS

Digital video has emerged in the last few years as a technology that can provide a new "dimension" to electronic communications. *Digital video* is video information represented in digital form. Digital representation has a number of key advantages over "traditional" analog video and television. All information can be represented in digital form, so the same techniques and systems can be used to store, process, and transmit a wide range of different types of data (multiple media or "multimedia"). The rapid growth in digital processing power means that complex processing and coding operations can be carried out on digital video data in real time. Digital video can be integrated into computer applications and systems. This in turn makes it possible to create interactive applications, where the user is no longer a "passive" observer but has the opportunity to interact with the video information.

Advances in computing and processing capabilities have been matched by advances in data networking technology. In a short space of time, the number of computers and systems connected by networks such as the Internet has grown exponentially. As well as becoming more widespread, networks can handle higher volumes of data and higher transmission rates. The current networking structure is loosely defined and "heterogeneous" (consisting of a range of interconnected networks with different technologies and capabilities). Broadband networks based on the asynchronous transfer mode, in which all data is processed and transmitted as small, fixed-length cells, can support efficient transmission of high data rates, and these networks are beginning to replace older, less efficient technologies.

As we shall describe in Chapter 3, digital video has an inherently high bandwidth (i.e., a digitized video signal requires a very high data rate for transmission). In order to store and transmit this information effectively, it has been necessary to develop techniques for compressing the video data (i.e., encoding it into a smaller number of bits). The emergence of international standards for encoding video data has enabled a wide range of applications that make use of digital video transmission and storage. Image coding provides a means of compressing digitized photographic images by around 10 to 20 times. Current video coding techniques enable video data to be compressed by between 20 and 50 times. By using these techniques, it has become practical to store, transmit, and manipulate digital image and video information using currently available storage systems and data networks. The range of applications for digital video continues to grow and includes the following:

- *Video conferencing and videotelephony.* Two way, real-time video and audio communications. Video and audio information is transmitted via data networks such as integrated services digital network (ISDN) and the Internet (IP-based network). Implementations range from one-to-one videotelephony to studio-based group conferencing.
- *Home entertainment digital video.* The video compact disc (based on the CD-ROM format) provides a digital alternative to analog home video. Compact disc digital video brings many of the advantages of audio compact discs (e.g., durability and random access) to video entertainment, together with further features such as user interaction and interactive video games.
- *Broadcast digital television.* Digital television channels are beginning to replace analog transmissions over cable, satellite, and terrestrial broadcast media. This should provide (arguably) greater choice and picture quality to the viewer together with further advantages and features associated with digital transmission.
- *Video databases and video on demand.* These applications involve the storage of digital video information in large databases. The user can access the stored information and play back the video data. Application areas include home selection and viewing of centrally stored films and programs ("video on demand") as well as archival and access of educational learning video material.
- *Medical applications.* Many of the above techniques can be integrated into the healthcare system. Experimental trials to date have made use of videoconferencing between medical practitioners as well as medical image communication and storage using electronic media.

These applications are all in use at the time of writing. The continual improvements in processing power and network capacities should lead to a wider penetration of digital video into the marketplace. Digital video communication has the capability to change dramatically the way we communicate and do business.

Many more potential applications have been identified that make use of digital video techniques. These include high definition digital television (HDTV), which provides higher spatial and temporal resolutions than existing analog (or digital) television, applications that involve much more interaction from the user (for example, where the video information is manipulated as individual components or objects within a scene) and stereoscopic (three-dimensional) or multiple viewpoint video. Advanced encoding techniques may offer very high compression of video information that could enable high-quality video at low bit rates and should lead to further availability of digital video applications.

## 1.2 THE MARKET

The rapidly expanding digital video market has been studied in a number of marketing reports. It is widely predicted that in many of the application areas, growth will be extremely rapid over the next few years.

For example, videoconferencing has been identified as one of the major application areas. This can be divided into systems based in specially equipped rooms (referred to as suites) and desktop conferencing. Desktop videoconferencing is carried out from a user's desktop with a specially equipped personal computer (PC). With regard to suites, it has been stated [1] that

> Research commissioned by GPT (and others) estimates that global sales of small and large group [videoconferencing] systems reached 14,000 units and generated a revenue of [US]$621m in 1994. This year [1995] those figures are expected to rise to 20,000 units and [US]$819m and in 1998 it will be 40,000 units and [US]$1.345 Bn.

The situation for desktop systems is considered [1] to be even more promising:

> This steady growth contrasts with the data provided for PC-based desktop systems where 1994 figures suggest sales of 12,500 units and revenue of [US]$31m and 1995 is expected to generate sales of 86,000 units and [US]$120m in revenue. Then, according to the research, the market will soar with 987,000 units likely to be shipped and revenue leaping to [US]$789m.

According to [1], this explosion in revenue will lead to a 1998 market of 5.225m units and revenue of over (U.S.)$2 billion.

This growth is likely to create turmoil in a number of industries since digital video technology involves a combination of telecommunications, television, and computer engineering. Companies are being required to develop expertise in new areas and form strategic partnerships to exploit the rapidly developing market. In this book, we aim to provide an introduction to a range of the relevant technologies and then consider some of the key technical issues.

## 1.3 KEY ISSUES

Many of the applications for digital video that are currently in use have been designed for fixed network topologies and systems. For example, videoconferencing over ISDNs can rely on a fixed transmission bit rate and a well-defined transmission delay and error rate. If these parameters can be accurately predicted, then a video coding system can be designed that provides acceptable performance in this configuration. However, the ever-changing networking infrastructure is made up of an increasingly heterogeneous mix of networks and technologies. The transmission characteristics provided to a particular connection (the *quality of service*) can vary from connection to connection and even during a connection, depending on the path taken through the network and on the other traffic currently in transit through the network.

A communication network offers a particular quality of service (QoS) to traffic transmitted through the network. Important QoS parameters include data rate (mean data rate and rate variation), delay characteristics (transmission delay, delay variation), and error or loss probability (bit error rate, cell or packet loss probability, error patterns).

All of these parameters can affect the quality and reliability of digital video communications. The available data rate has a significant effect on the quality and resolution of coded video information that can be transmitted through the network. Different coding techniques are appropriate for different data rates. Transmission delay and delay variation are very important since real-time video applications are sensitive to changes in transmission delay. Decoded video frames must be presented to the viewer at a constant rate, and if a particular frame is delayed too long then it cannot be displayed and is "lost." Errors and losses have a particularly severe effect on the quality of decoded video. Video coding schemes achieve compression by removing redundant information from the video data, which means that all of the coded data is significant and hence a transmission error is likely to have a significant impact on video quality.

Some of these problems are addressed by the video coding standards themselves. However, many of the implementation details are left to be addressed by the developer of a particular application. The video coding standards have intentionally been kept as broad as is practical. There is therefore considerable scope for optimization of video coding techniques in order to address these problems and provide reliable video communications.

Ideally, a video communication system should provide the user with a service that offers video at an acceptable quality. The networking environment is not likely to "stabilize" in the foreseeable future and so a practical video communication system should be adaptable, reliable, and robust in order to cope with varying QoS from the network. A further useful feature is scalability: a flexible video communication system should be able to scale the quality of the video depending on the capabilities of the network and of the display.

## 1.4 STRUCTURE OF THIS BOOK

This book aims to introduce the concepts and systems required to support digital video communications and to discuss some of the issues that need to be addressed to provide reliable, flexible video communications in the changing networking environment. The intended audience for the book includes:

- Practicing engineers and technical staff who have an involvement in the video, television, computing, and communications industries;
- Academics and researchers in electronic engineering, computer science, and related fields who have a research or teaching interest in digital video communications;
- Final year undergraduate and postgraduate students in electronic engineering, computer science, and related fields who require an introduction to the concepts and issues involved in digital video communications.

In the early chapters, we describe the applications for digital video and introduce some of the key technologies that are required to support digital video communications.

*Chapter 2* describes application areas in which digital video is used, including those areas mentioned in Section 1.1.

*Chapter 3* introduces the techniques for encoding (compressing) and decoding digital video data. In this chapter, we concentrate in particular on the international standards for video encoding.

*Chapters 4* and *5* provide an introduction to key network technologies that are being used for digital video transmission. In Chapter 4 we describe the structure and protocols of the Internet and in Chapter 5 we introduce asynchronous transfer mode (ATM) networks and broadband ISDN.

*Chapter 6* is a pivotal chapter. Here, we discuss the QoS issues related to the transmission of coded digital video through networks. These QoS requirements must be met in order to provide flexible, reliable, and robust video transmission.

The later chapters concentrate on a series of issues related to supporting the QoS required for digital video communications and are based on research work by the authors and others.

*Chapter 7* analyzes the effect of transmission errors on coded video data. Any practical transmission system or network will introduce errors and losses into transmitted data. We discuss the problems that this can cause for video quality and look at ways of improving quality in the presence of errors.

*Chapter 8* deals with forward error correction coding and its application to error control for digital video communications. Forward error correction is particularly suited to real-time information such as digital video and we introduce the fundamental techniques and some of the applications for video communications.

In *Chapter 9* we discuss scalable or layered video coding. We describe some of the main layered coding techniques and how they might be applied to improve the QoS available to coded video data.

*Chapter 10* introduces the topic of rate control for coded video. Practical networks place restrictions on the rate of data that can be transmitted and for this reason rate control is a key part of any video coding system.

Digital video communications offer considerable scope to change the way we communicate. Providing practical and robust digital video communications systems requires an understanding of coding and transmission techniques as well as an appreciation of how video QoS requirements may be supported. We hope that this book goes some way towards meeting these needs.

## Reference

[1] "Bringing Video Conferencing into Line," *Audio-Visual Communications for Business Magazine*, May 1995.