GigaCE

The MPEG-4 standard

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Overview of the MPEG-4 standard, fora and tools.

Colophon

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Synopsis:
This document contains a brief description of the main functional aspects of the MPEG-4 standard, from the perspective of object-based multimedia summarisation and authoring.

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Preface

GigaPort prepares the Dutch industry and knowledge institutes for Next Generation Internet. GigaPort is a joint initiative of industry, higher education, research institutes and the Dutch government. GigaPort aims at giving industry and knowledge institutes a headstart by stimulating Internet innovation. GigaPort-Applications, which is co-ordinated by Telematica Instituut, works on Next Generation Internet applications and supports the execution of pilot projects in industry. The focus is on applications in the areas of computer supported co-operative work, content engineering and e- business. In addition, generic middleware components are developed. In GigaPort-Network, a Next Generation Internet testbed network is being built and operated. This network is about a hundred times faster than the current Internet. In this state-of-the-art environment, organisations can already test new products and services, before broadband Internet capabilities are commercially available. GigaPort-Network, which is co-ordinated by SURFnet, is one of the most advanced research networks in the world.

In the midst of the digital revolution that is taking shape around us, it becomes important to manage content in an effective, efficient and user-friendly manner. The Giga Content Engineering project (GigaCE) positions itself right in the middle of these developments. Content Engineering is the development of information systems that support the entire value chain of multimedia production or parts thereof: creation, digitalisation, storage, search, manipulation, management, distribution and delivery, in an effective, efficient and user-friendly way. Content engineering uses the increase in digital multimedia content to be the partner in supporting and innovating content value chains for core and supportive business by focussing on tailoring and reuse of large volumes of digital multimedia content, through the integration of fundamental knowledge and applied knowledge on content engineering.

In the last years, enormous amounts of digital content have been developed based on modalities such as audio, video and text. In multimedia presentations, these modalities are combined. Several formats have been developed for integrating independent multimedia objects into a single multimedia presentation, such as SMIL from the W3C consortium and VRML from the Web3D consortium. This study shall serve as a basis for assessing the benefits of using MPEG-4 encoded audio and video in advanced multimedia management systems. Particularly, we were interested in evaluating the possible advantages of using structured audio and video for summarisation and authoring. Therefore, we focus here mainly on the functional aspects induced by the object-based structure of MPEG-4, and leave out, or just mention many others.

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1 Introduction

In the last years, enormous amounts of digital content have been developed based on modalities such as audio, video and text. In multimedia presentations, these modalities are combined.

For storage and disclosure of digital content, a variety of formats, database structures, coding techniques, network protocols et cetera is available and used. Standards in this field can improve usability of digital content and make it available to all parties that comply with the standard. The MPEG forum establishes standards in the field of multimedia handling.

1.1 Motivation of this overview

Several formats have been developed for integrating independent multimedia objects into a single multimedia presentation, such as SMIL from the W3C consortium and VRML from the Web3D consortium. SMIL provides techniques for synchronisation, layout, and association of hyperlinks. MPEG-4 was developed to offer more flexibility compared to these formats. E.g. the concept of scalable objects is not encapsulated in SMIL, and VRML does not support streaming over networks. It is this object scaling capability, which gives MPEG-4 so much more potential to be used for scalable applications over various types of networks.

MPEG-1 and MPEG-2 are standards for coding video and the associated audio always by subdividing frames into blocks that are processed with a DCT-based coding transform, in conjunction with motion estimation techniques. MPEG-4 uses a more advanced approach: scenes are decomposed into objects that can be coded separately with the most appropriate compression algorithm. Not only can new compression algorithms based on wavelets and 3D coding techniques be used, but also objects can be scaled and handled on their own. This approach allows for providing MPEG-4 based applications with interactivity, scaling, object manipulation and intellectual property rights management.

This study shall serve as a basis for assessing the benefits of using MPEG-4 encoded audio and video in advanced multimedia management systems. Particularly, we were interested in evaluating the possible advantages of using structured audio and video for summarisation and authoring. Therefore, we focus here mainly on the functional aspects induced by the object-based structure of MPEG-4, and leave out, or just mention many others.

1.2 The MPEG standardisation forum

The Moving Picture Experts Group (MPEG), established in 1988, is a working group of ISO/IEC in charge of the development of international standards for compression, decompression, processing, and coded representation of moving pictures, audio and their combination. So far MPEG has produced:

- MPEG-1, the standard for storage and retrieval of moving pictures and audio on storage media (approved November 1992)
- MPEG-2, the standard for digital television (approved November 1994)
- MPEG-4, the standard for multimedia applications. Version 1 was approved October 1998, version 2 was approved December 1999.

MPEG is now developing:
- MPEG-4 versions 3, 4 and 5
- MPEG-7: the content representation standard for multimedia information search, filtering, management and processing (to be approved July 2001), and has started MPEG-21, the multimedia framework.

MPEG usually holds three meetings a year. These comprise plenary meetings and subgroup meetings on Requirements, Systems, Multimedia Description Schemes, Video, Audio, Synthetic Natural Hybrid Coding, Test, Implementation Studies and Liaison. Over 300 experts from over 20 countries attend MPEG meetings. More information about the MPEG forum and its standards, achievements, current work, working groups, meetings, events, documents and links can be found at the MPEG homepage [CSELTa].

2 Description of the MPEG-4 standard

The MPEG-4 standard, like every other standard developed by the MPEG group, is a collection of requirements and specifications related to the process of *decoding* an MPEG-4 encoded bit stream. It doesn't address, therefore, the methods and techniques required for different stages of processing or analysis involved in encoding. This is actually one of the most important advantages of open standards.

MPEG-4 was originally intended as a standard for compressing audio and video at very low bit rates. However, the specifications for content-based compression opened many other possibilities for object manipulation, interactivity, rights management, inclusion of other types of media, so the final standard evolved in a framework for interactive multimedia content manipulation and management.

This subsection is based on Koenen (1999) and Sikora (2001), two introduction articles to MPEG-4. These give an overview of prominent features of MPEG-4 and the kinds of applications that can be developed around MPEG-4.

2.1 Objects in MPEG-4

The audio, video, graphics and other media components of MPEG-4 are known as *objects*. These can exist independently, or multiple ones can be grouped together. The result of grouping objects is an MPEG-4 *scene* (see

Figure 1). The strength of this object-oriented approach is that any of the components can be easily manipulated, and optimally represented.

Visual objects in a scene are described mathematically and given a position in a two- or three-dimensional space. Similarly, audio objects are placed in a sound space. When placed in 3-D space, the video or audio object need only be defined once; the viewer can change his vantage point, and the calculations to update the screen and sound are done locally, at the user's terminal. This is a critical feature if the response is to be fast and the available bit-rate is limited, or when no return channel is available, as in broadcast situations.

Hence, video and audio in MPEG-4 are not any more collections of uniformly represented pixels or samples, but collection of objects. Of course, one "raster" image from a video, or say 1000 audio samples can also be seen as objects. However, to take full advantage of MPEG-4 functionality, video and audio objects should be defined (by the encoder) in relation with the physical, perceptual, or semantic objects a certain video or audio represents, as described in sections 2.1.2 and 2.1.3.

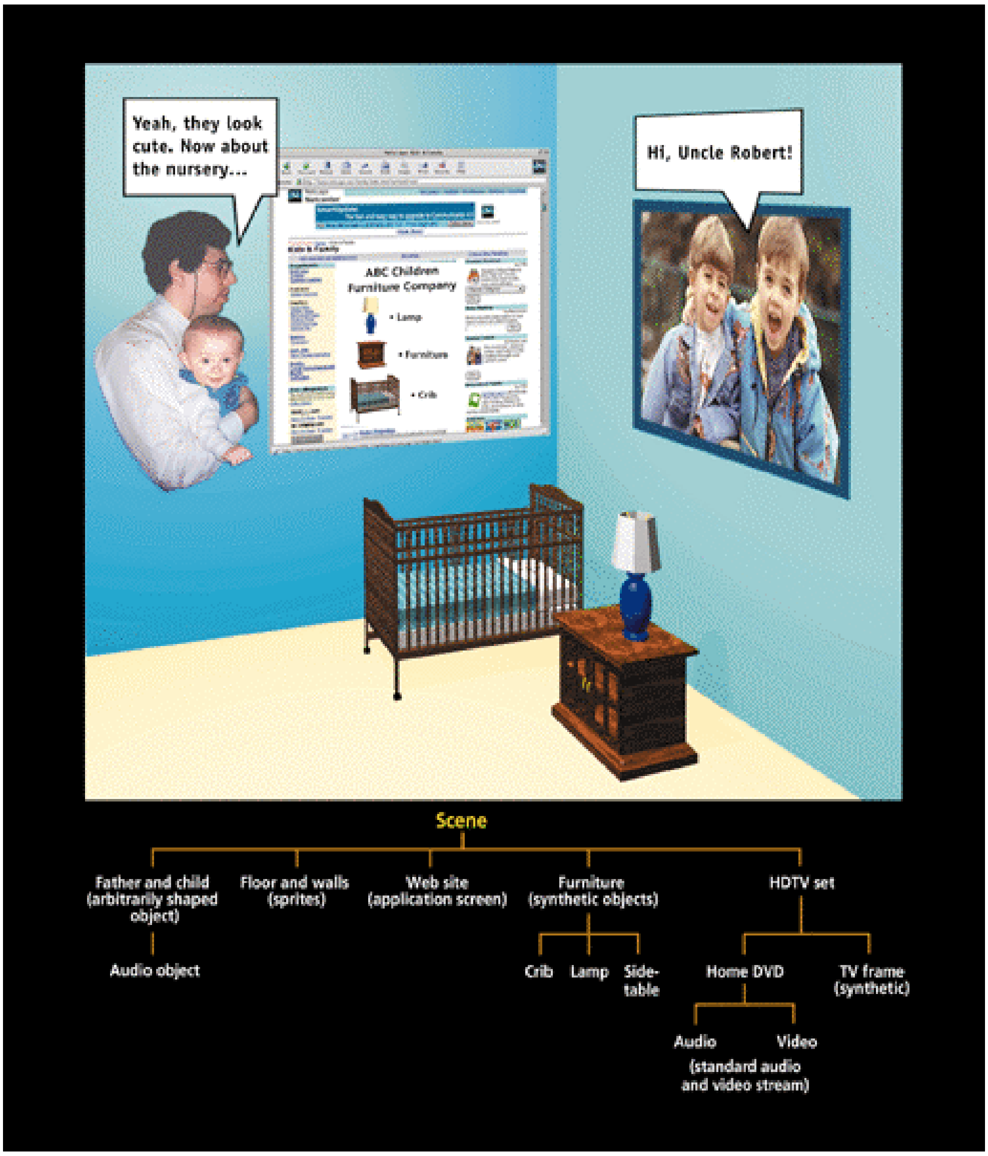

Figure 1. Different types of multimedia that can be transmitted with MPEG-4 appear in the scene above, a man and his infant son on-line with his offstage wife. The tree chart below, called a scene graph, represents the media as independent or compound objects. One compound object comprises the father and child (an arbitrarily shaped video) and the audio track of his voice. Other objects are the floor and walls, which are so-called sprites for easily changing backgrounds, the web site of the furniture store, an application mapped as a screen texture, and the computer-generated (synthetic) furniture the father has chosen from the web site for his wife to look at and interactively move around. Simultaneously playing on a synthetic HDTV set is a movie from the family's home digital versatile disk (DVD).

2.1.1 Describing and decoding objects in MPEG-4

MPEG-4's representation of multimedia content and its scheme for preparing that content for transportation, storage and decoding is versatile (see

Figure 2). Objects are placed in so-called elementary streams (ESs). Some objects, such a sound track or a video, have a single elementary stream, while others objects may have two or more. In particular, scalable objects can have an ES for basic-quality information plus one or more so-called enhancement layers, each of which can have its own ES for improved quality, such as video with finer detail or faster motion.

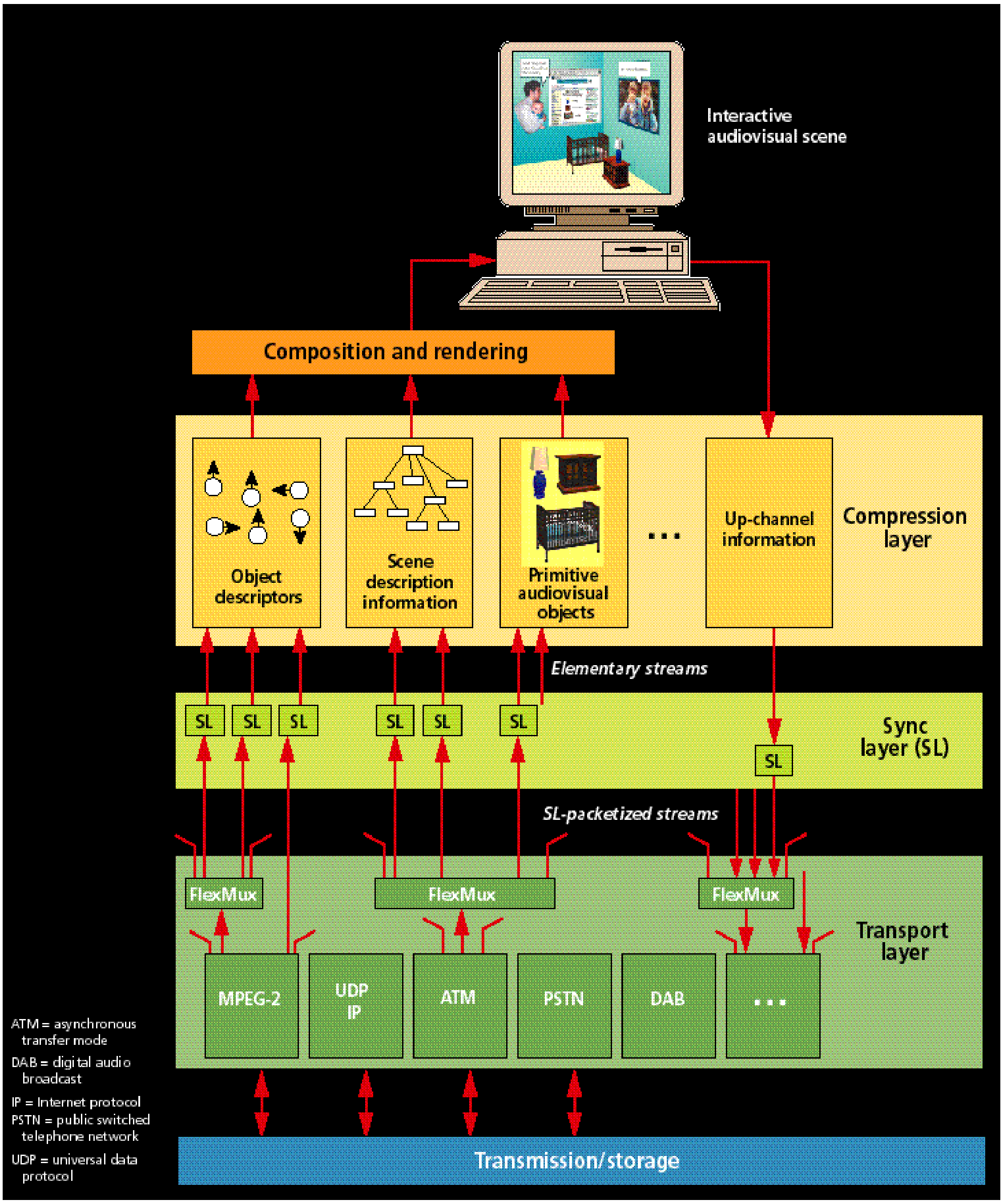

Figure 2. MPEG-4 has a versatile encoding and decoding process. A broad choice of transport protocols can be used with its interface, FlexMux [bottom]. At the sync layer, packetised elementary streams (ESs) are reassembled based on their timing information [middle]. The information in an ES [top] is a primitive audio-visual object, here the object in Fig. 1, how it is to be decoded (the object descriptors), how it is organised in the scene (the scene graph), plus any interactive information from the terminal.

Higher-level data that describe the scene and the data that define, update and position the media objects is conveyed in its own ES. Thus objects can be reused in the production of new multimedia content. If parts of a scene are to be delivered only under certain conditions, e.g. when enough bandwidth is available, multiple scene description ESs for the different circumstances may be used to describe the same scene.

To inform the system which elementary streams belong to a certain object, an object descriptor (OD) is used. Object descriptors in turn contain elementary stream descriptors (ESDs) to tell the system which decoders are needed to decode a stream. Optionally, textual information about the object can be supplied. Object descriptors are sent in a dedicated elementary stream, which allows them to be added or deleted dynamically as the scene changes.

The play-out of a scene with multiple MPEG-4 objects is co-ordinated at a synchronisation layer. Here, elementary streams are split into packets, and timing information is added to these packets. The packets are then passed on to the transport layer.

Timing information for the decoder consists of time stamps of the incoming streams. There are two time stamps for a piece of information: one says when the information must be decoded, the other says when the information must be ready for presentation. The former time stamp is important as it allows for decoding other pieces of information which are dependent on the decoding of another piece of information. This happens e.g. when video frames are calculated as an interpolation between previous and following frames.

For a single MPEG-4 scene there can be many transport channels, an MPEG-4 tool called FlexMux aligns these different data streams. In addition, another interface defined in MPEG-4 lets the application ask for connections with a certain quality of service, in terms of parameters like bandwidth, error rate, or delay. This interface is the same for broadcast channels, interactive sessions, and local storage media from an application point of view, so that application designers need not worry about the underlying delivery mechanisms. Further, version 2 of MPEG-4 allows differing channels to be used at either end of a transmission/receive network, e.g. an Internet protocol channel on one end and an ATM one on the other.

Another important addition in version 2 is the definition of a file format named mp4, which can be used for exchange of content and conversion. This will enable users to exchange complete files of MPEG-4 content.

2.1.2 Video objects in MPEG-4

An example of video object is shown in

Figure 3. To obtain such an object, some segmentation procedure has to be applied on the original ("raw") video. Another video object, the background, results immediately. An example of an audio object can be the voice of a person, separated from a background including music and other voices, or the sound of an instrument in an orchestra.

Once having separated all video objects that make a visual scene, they can be optimally compressed, and represented. Although there are many aspects involved by object encoding and representation, we will only outline here the main ideas. To specify a video object, several types of information are needed: its shape, its position and size, and the actual visual content of that object. The most challenging of these, remains the extraction of objects' shapes.

MPEG-4 includes two ways of describing arbitrary shapes: *binary* and *grey-scale*. In the first, an encoded pixel is either part of the object, or of the background (or, generally, the rest of the image). This is a very simple technique, useful in low bit-rate environments. For higher-quality content, the grey scale (or alpha) shape description is used. Here, each pixel belonging to a shape is assigned a value for its transparency. This way, objects can be smoothly blended, either into a background or with other visual objects.

Note that MPEG does not specify how shapes are to be extracted. Automatic shape/object extraction from images and video, or generally video segmentation, is still an open research problem. Likewise, the encoding of object's shape, position, and visual content (pixel colours, local texture, local motion, etc.) are not subject to specifications within this standard.

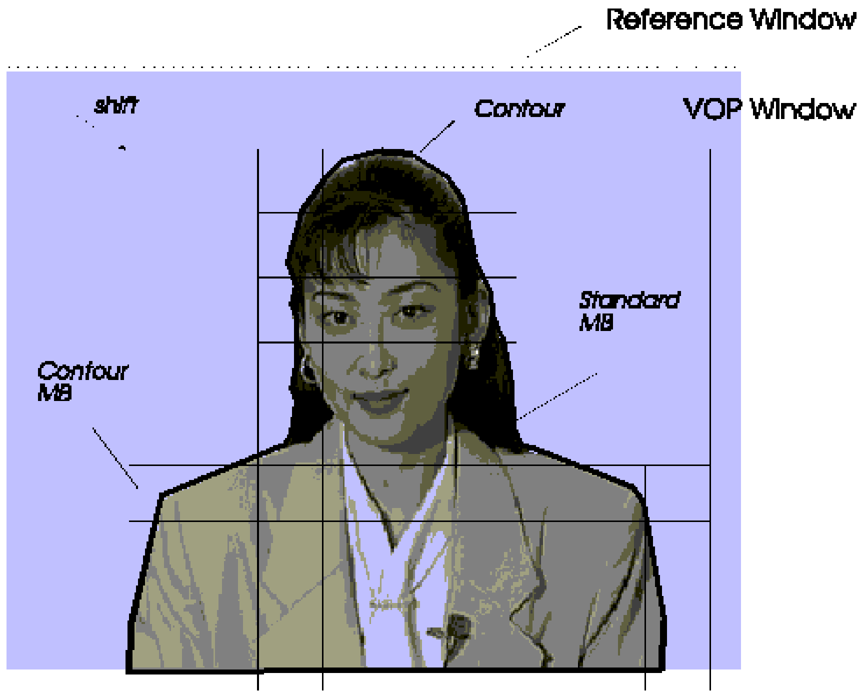

Figure 3. Example of video object [ISO/IEC 2001].

2.1.3 Audio objects in MPEG-4

Like video, audio is also represented in the form of objects. An audio object can be a monaural speech channel or a multi-channel, high-quality sound object. The composition process is in fact far more strictly prescribed for audio than for video. With the audio available as objects in a scene graph, different mixes from input channels (objects) to output channels (speakers) can be defined for different listening situations.

Another advantage of having audio as objects is that they then can have effects selectively applied to them. For example, if a soundtrack includes one object for speech and one for background audio, an artificial reverberation can be applied to the speech as distinct from the background music. If a user moves a video object in the scene, the audio can move along with it, and the user could also change how audio objects are mixed and combined.

Like video objects, audio objects may be given a location in a 3-D sound space, by instructing the terminal to spatially position sounds at certain spots. This is useful in an audio conference with many people, or in interactive applications where images as well as audio are manipulated.

A feature known as environmental spatialisation is included in MPEG-4 version 2. This feature establish how a sound object is heard dependent on the room definition sent to the decoder, while the sound object itself need not be touched. In other words, the spatialisations work locally, at the terminal, so again virtually no bit-transmission overhead is incurred.

As in the case of video objects, MPEG-4 does not specify how to obtain the audio objects. Different techniques for automatic discrimination between voice, noise, and music are already available. Although automatic speaker identification is still a challenging problem, phoneme and word identification and speech to text conversion techniques can be reliably used within a limited context.

2.1.4 Scaling objects in MPEG-4

MPEG-4 supports scaling objects. This is a useful capability in low bit-rate environments because presentation quality can be decreased gracefully if little bandwidth is available. Also MPEG-4 based services can be made adaptive if providers of audio-visual media sense the available bit-rate and adjust the transmitted objects. MPEG-4 makes moving video possible for mobile devices at very low bit-rates. The standard has been found usable for streaming wireless video transmission at 10 kb/s based on GSM.

Unchanging backgrounds are called sprites and cost few bits. A sprite defining the image of the background needs to be sent only once. After that, new views, e.g. from a different angle, are created by simply sending the new positions of four pre-defined points. A typical example is the transmission of a sports event, where all scenes evolve in a very limited environment (see Figure 4). A sprite can be obtained by image registration techniques, applied on a consistent sequence of images from the raw video. At the decoder side, an actual video frame can be composed using the previously stored sprite, by selecting the region to be displayed at that particular moment, and by applied some perspective transformations to match the original camera viewing angle and focal distance. Then, the needed video object are superimposed on the current background image.

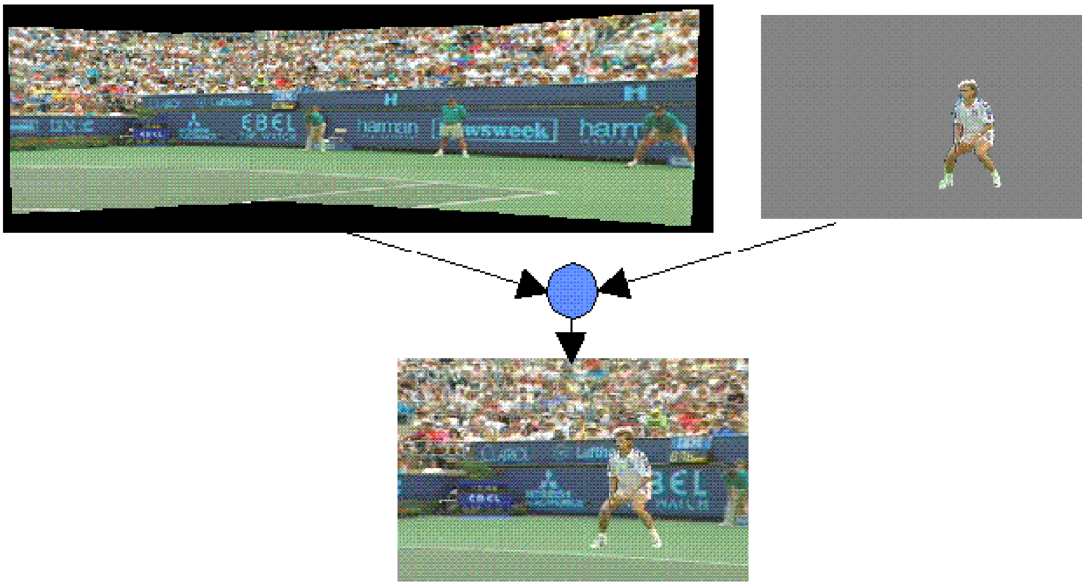

Figure 4. A sprite (upper-left), a video object (upper-right) and an actual image (lower) [ISO/IEC 2001].

In scaling of each object a base layer contains all the information in some basic quality. One or more enhancement layers can be used to get higher-quality presentations if the required bit-rate is available. When a scene is composed of different objects, it is also possible to send only the most important of them. Scalability also allows differentiated error protection, protecting the most important objects best (more bits are needed for better error protection).

2.1.5 Shaping objects in MPEG-4

The object-oriented approach of MPEG-4 allows for mapping images onto computer-generated shapes. A mesh (

Figure 5), which represents a shape, may have any image mapped onto it. A few parameters to deform the mesh can create the impression of moving video from a still picture, e.g. a waving flag. For more advanced effects, moving video images could also be mapped onto the mesh. Thus, rather than sending entirely new images for each deformation, just the directions to do so are sent, and the warping is done locally, saving much bandwidth.

Interesting meshes are pre-defined faces with a repertory of motions and a few common emotional states. This can be combined with MPEG-4's text-to-speech interface for building a digital on-line stand-in for a human or synthesised presence. The appearance of the face may be left to the decoder, or complete custom facial models may be downloaded. Any feature on the model, such as lips and eyes may be animated by special commands that make them move synchronised with speech. Parameters for defining and animating entire bodies are in MPEG-4 version 2. MPEG-4 can utilise written text to generate corresponding motions of synthetic face models. The text may be synchronised with those motions and spoken by a speech generator (not included in the standard) supplied with so-called prosodic parameters (information about stress and changes in speed). Parameters like age, gender, and accent may also be specified.

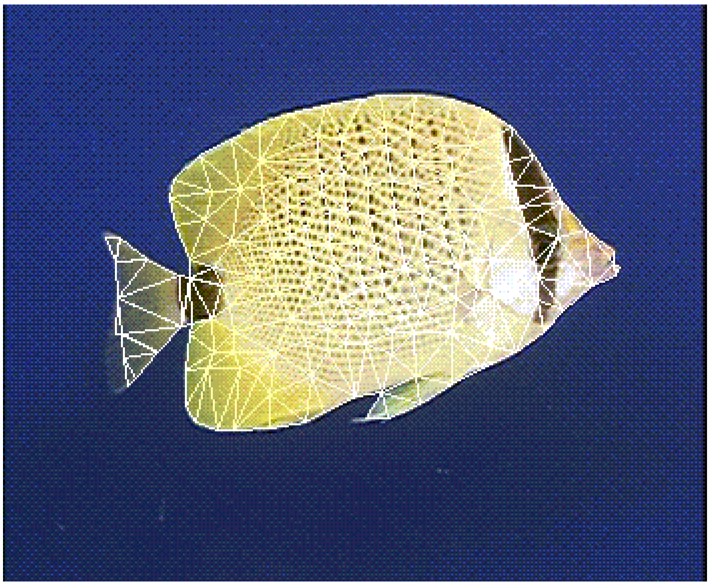

Figure 5. A 2-D mesh that models a certain object. To animate the object, very simple warping techniques can be applied [ISO/IEC 2001].

2.2 Interactivity

MPEG-4 allows the user to interact with objects within a scene derived from so-called real sources such as moving video, or from synthetic sources such as computer-generated graphics. Authors of content can give users the power to modify scenes by deleting, adding, or repositioning objects, or to alter the behaviour of the objects; for example, a click on a box could set an object spinning.

2.3 Encoders and decoders

MPEG-4 supplies tools with which to create uniform and high-quality audio and video encoders and decoders on the Internet, pre-empting what may become a wealth of proprietary formats. Normally users must choose among video formats such as QuickTime, AVI and RealVideo as well as a great number of formats for audio.

Actually MPEG-4 specifies only the decoding process. Encoding processes are left to the marketplace.

2.4 Scalability of content

MPEG-4 has been designed for both high bit-rate and low bit-rate communication, such as wireless telephones. Whether wired or not, devices can have differing access speeds depending on the type of connection and traffic. MPEG-4 supports scalable content, i.e. it allows content to be encoded once and automatically played out at different rates with acceptable quality for the communication environment at hand.

2.5 Integration of content

It is likely that future television sets will accept content from both broadcast and interactive digital sources. MPEG-4 provides tools for seamlessly integrating broadcast content with interactive MPEG-4 objects. The expectation is that content of broadcast-grade quality is displayed within World Wide Web screen layouts with all kinds of variations.

2.6 Protection of intellectual property

Recently, digital copying of audio from the Internet has become a popular practice and an increasingly worrying one to the music industry. For video, the same situation is likely to arise when MPEG-4 encoding and higher bandwidths become widespread and as digital storage prices continue to drop. Accordingly, MPEG-4 includes features for protection of intellectual property and digital content.

2.7 Audio in MPEG-4

2.7.1 Audio coding in MPEG-4

Audio used to be regarded simply as a signal associated with video. Now the audio is of the same importance and quality as the video. MPEG-4 includes several audio tools for achieving a good complexity-performance ratio at bit-rates starting at 6 kb/s and reaching beyond 128 kb/s. The range embraces everything from a mono signal to stereo sound with no audible degradation. The quality is not only better than for a CD, but uses less than a tenth of the latter's encoding rate of 1411 kb/s.

For audio of the highest quality, MPEG-4 includes the advanced audio coding (AAC) algorithm of the MPEG-2 standard. The algorithm gives indistinguishable-quality audio, from mono to multichannel surround sound, at considerably lower bit-rates than the mp3 audio format widely used on the Internet today.

2.7.2 Speech coding

Speech can be coded by two algorithms. One is a parametric coder which operates at 2-4 kb/s, or even lower in variable bit-rate mode. The other, based on the CELP algorithm (code excited linear prediction), operates at 4-24 kb/s. The latter uses sampling at 8 or 16 kHz for narrowband and wideband speech respectively.

2.7.3 Audio synthesis in MPEG-4

Audio can be decomposed in frequencies or collections of frequencies, which forms a format for describing methods of synthesis to define sounds at very low bit-rates. MPEG-4 can accommodate descriptors for many signal-processing elements for sound synthesis, such as oscillators and digital filters, which can be used as parameters for small networks of elements which create the specific sounds. Such a network can produce the sound of e.g. a specific music instrument. So the networks of instruments can be downloaded and then played through commands in the bit-stream.

There are two languages for structuring and generating sounds: the Structured Audio Orchestra Language (SAOL, pronounced "sail") and the Structured Audio Score Language (SASL). Instruments can be defined and downloaded with the first language and controlled with the second. Skilled structured-audio programmers annex composers can create any sound, from real-sounding pianos to rushing water. With this method, the output is guaranteed to sound the same from terminal to terminal.

2.8 Scenes in MPEG-4

MPEG-4's language for describing and dynamically changing the scene is named the Binary Format for Scenes (BIFS). BIFS commands are available to add objects to or delete them from a scene and to change visual or acoustic properties of an object without changing the object itself; thus the colour alone of a 3-D sphere might be varied. BIFS can be used to animate objects by sending a BIFS command and defining their behaviour in response to user input at the decoder. This allows for building interactive applications. BIFS could also be used to put an application screen (such as a Web browser's) as a "texture" in the scene. Figure 1 shows an example of the structure of a scene according to MPEG-4.

BIFS borrows many concepts from the Virtual Reality Modelling Language (VRML), which is the method used most widely on the Internet to describe 3-D objects and users' interaction with them. BIFS and VRML can be seen as different representations of the same data. In VRML, the objects and their actions are described in text, as in any other high-level language. BIFS code is binary, and thus is shorter for the same content, typically 10 to 15 times. Unlike VRML, MPEG-4 uses BIFS for real-time streaming, that is, a scene does not need to be downloaded in full before it can be played, but can be built up on the fly. BIFS allows defining 2-D objects such as lines and rectangles, something currently not possible in VRML. MPEG and the Web 3-D Consortium are working together on making MPEG-4 and VRML evolve consistently.

2.9 Adaptation with MPEG-J

To further support interactive applications, the second release of the MPEG-4 standard defines MPEG-J. This is an MPEG-4-specific subset of the object-oriented Java language. MPEG-J defines interfaces to elements in the scene (objects or compound objects), network resources (such as available bandwidth and bit-error levels), terminal resources (such as processing power and stack memory), and input devices. The Java interfaces automatically let the content scale down in an intelligent way relative to the player, and thus allow authors to create highly interactive multimedia content and to make optimal use of terminal and network resources. For instance, the background can be decoded only once instead of continuously, or a few less important objects can be omitted altogether.

2.10 Handling transmission errors in MPEG-4

Due to the low redundancy of transmitted data in low bit-rate environments, a bothersome feature of mobile operation is the relatively probability of transmission errors. Various techniques are used in MPEG-4 to overcome the inevitable errors and to enable the decoder to mask the results of errors. One such technique is using *resync markers* in the video bit-stream so that the synchronisation lost after an error can be rapidly regained. A second technique is using MPEG-4's *reversible variable-length code*. This code can be uniquely decoded even when read backwards, which means that the terminal can still use all uncorrupted information from the newly found resync marker back to the place of the error burst.

2.11 The future of MPEG-4

The first systems based on MPEG-4 are likely to be used for Internet delivery of multimedia. One MPEG-4 server and a software decoder was shown by Philips Digital Video Systems at the September 1998 International Broadcasting Convention, in Amsterdam. The video decoder in Microsoft's Windows Media Player now operates according to the text of the final MPEG-4 standard.

Manufacturers of mobile equipment and providers of mobile services will probably be the next adopters. Implementing the entire standard would be overkill for a mobile environment. Instead, a number of profiles, which define subsets of the standard, have been included for their designers to choose from. Profiles are available for simple situations for mobile use or complex ones with advanced 3-D graphics.

2.12 More information about the MPEG-4 standard

This section has given a summarising overview of the MPEG-4 standard. An extensive overview of the MPEG-4 standard can be found in [ISO/IEC 2001] at the MPEG-4 web page.

3 MPEG-4 applications

The MPEG-4 standardisation organisation has listed a number of applications which are enabled by the tools and methods standardised by MPEG-4 [FHG]. With a description of the applications, the application-specific requirements are also given and some prototypical examples. This gives an idea of what is or will be possible using MPEG-4 technology.

An overview of the applications described in the document and functionality for these applications offered by MPEG-4 is given below.

- Broadcast: synchronisation and spatial alignment of audio-visual objects, flexibility in quality and scaling, copy protection, user interaction and user control, downloading of information data about audio-visual objects, virtual studio techniques, integrated service digital broadcast.
- Collaborative scene visualisation and collaborative interior design with stereoscopic views and personalised object scaling.
- Content based storage and retrieval by means of object based storage and retrieval
- Digital AM broadcasting: graceful degradation of sound, omitting singers in songs to allow for karaoke.
- Digital television set-top box: home shopping, conditional access, interactive game show, adaptive content application, program guide application, multimedia services
- DVD: interactive and personalised films, self-learning, games.
- Infotainment: virtual city guide with buildings as objects, request of additional information, changing of content of existing scene nodes.
- Mobile multimedia: graceful degradation by proper object scaling based on available bandwidth, graceful trade-off between quality, performance and cost, face animation for low-bandwidth mobile conferencing.
- Real time communications: low-bandwidth face warping and lip synchronisation, reducing delay by graceful downscaling of data stream.
- Streaming video on the Internet/Intranet: adaptation to available bandwidth by graceful object scaling.
- Studio and television post-production: television object modelling, combining objects from multiple programs, addition of virtual reality techniques, object based mixing, object grabbing, adaptation to language.
- Surveillance: access control to information systems or secured buildings
- Virtual meeting: objects based virtual meeting rooms, participants and their geometry as objects.

4 MPEG-4 tools

A number of parties have developed MPEG-4 compliant tools or intends to promote them. This section explains the parties and the functionality of the tools, which we have discovered in more detail. Some general information about some other products which implement some type of MPEG-4 functionality can be found in the product menu of the MPEG-4 Industry Forum [MPEGInd].

4.1 Flavor Player

Flavor software [Flavor] has developed Flavor Player, a free tool that generates MPEG-4 files, which can accommodate audio, video and hyperlinks from several sources in it. Although the tool can generate and play compact MPEG-4 files, it has no functionality for object handling.

4.2 DivX

DivX [DivX] is the brand name of a video compression technology developed by DivXNetworks, Inc.. DivX is a software technology that compresses digital video with no reduced visual quality. It allows for downloading full-screen, full-motion videos from the Internet that have the same quality as what can be seen on television or a DVD player. The DivX codec is based on the MPEG-4 compression standard and it can reduce an MPEG-2 video to ten percent of its original size. Video on regular VHS tapes can be reduced to about one hundredth of their original size. In essence, DivX makes it possible to download and playback high quality digital movies on PCs and other devices.

DivX 4.0 and later is a joint development effort of DivXNetworks with the assistance of the open source community. The open source version of DivX ("OpenDivX") is headquartered at Project Mayo (http://www.projectmayo.com). DivX aims at achieving an efficient codec for high quality video-on-demand and at protecting the copyrights and interests of content owners and producers.

DivX does not provide any facilities for manipulation of objects, just for compression of video signals.

4.3 3ivx

3ivx [3ivx] is a commercial efficient video compression codec compatible with the MPEG-4v3 specifications. Like DivX, it does not provide any facilities for manipulation of objects, just for compression of video signals.

4.4 Packetvideo

PacketVideo [PacketVideo], who claim to be the global leader in wireless multimedia, develops MPEG-4 compliant software that enables the delivery, management and viewing of video and audio over current wireless networks to mobile information devices such as cellular telephones and personal digital assistants. The company markets its software to wireless operators to ultimately enable mobile consumers to access a variety of applications, such as news, music videos, weather and traffic reports, and home or work security cameras, from any location.

4.5 MPEG-4 reference software

The MPEG homepage [CSELTa] mentions the existence of MPEG-4 reference software, which can be used for implementing MPEG-4 compliant technology. The software can be downloaded from the ISO site by ISO members.

5 MPEG-4 fora

There are several fora which intend to unite people who are interested in the MPEG-4 standard and its deployment. This section describes these fora. More information can be found on [CSELTb].

5.1 The Video Development initiative (ViDe)

The Video Development Initiative (ViDe)[1] [ViDE] is an international multi-institutional effort founded in 1998 to promote the deployment of digital video in higher education. ViDe has gained recognition within the Internet2 and the higher educational IT community for its success in advancing the deployment of emerging digital video technologies, both video-on-demand and video conferencing technologies.

ViDe leverages collective resources and expertise towards addressing challenges to deployment: poor interoperability, volatile standards and high cost. ViDe was founded by four educational institutions: The Georgia Institute of Technology, North Carolina State University, The University of North Carolina at Chapel Hill, and The University of Tennessee, Knoxville. NYSERNet (New York State, Educational and Research Network) became a working partner with ViDe in its efforts shortly thereafter. In May 1999, ViDe expanded its membership to include nine additional institutions: University of Alabama at Birmingham, CANARIE, George Washington University, NYSERNet (New York State, Educational, and Research Network), Ohio State University, The University of Hawaii, Indiana University, The University of South Carolina, Vanderbilt University, The College of William and Mary, and Yale University. The Australian National University joined ViDe in December 2000.

Since June 2000, ViDe has established the MPEG4 Working Group as one of its subcommittees: to focus on testing, standards development and industry partnerships in the video-on-demand arena, and to accelerate the adoption of metadata for digital video assets. The ViDe MPEG-4 Working Group believes MPEG-4 has the potential to greatly enhance many areas such as online learning, collaboration and resource sharing. While MPEG-4 technology and application development is in its infancy, ViDe is seeking opportunities to engage industry in partnerships that will result in the creation of model MPEG-4 applications. Early MPEG-4 deployments in the higher educational domain, especially when realised through private sector participation, will facilitate technology transfer and replication beyond that domain, and thus will accelerate the widespread adoption of the standard.

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MPEG-4 applications in the e-learning, e-medicine and telemedicine, and virtual reality domains are of particular, but not exclusive, interest to the MPEG-4 working group. The group's specific interest is in the potential of MPEG-4 to enhance data mining and content management, rights and access management, annotation, metadata, audio-visual object interaction and manipulation, audio-visual objects in 3-D virtual reality environments, and scalable multimedia delivery, both real-time and on-demand. The group is also interested in exploiting the capabilities of MPEG-4 to improve accessibility for end-users with disabilities.

The ViDe MPEG-4 WG will develop:
- A directory of MPEG-4 players, technologies and developments;
- An overview of the state-of-the-art of MPEG-4 development.

Both the directory and overview will be published online in May '01, and will be publicised in the Internet2 and international advanced research networking communities, and in the U.S. and Australian higher educational communities, and beyond. In addition to the online publications, the MPEG-4 Working Group will establish an MPEG-4 discussion list to disseminate information on MPEG-4 and promote the adoption of the standard within the higher educational community.

MPEG-4 has the capability to transform online content delivery. Not just video and audio, but text, still images, and metadata. In addition to multiple information streams, MPEG-4's object-oriented encoding, with synchronisation and interactivity features across two and three dimensions, will greatly enhance information sharing in diverse fields and enable equitable access for disabled users.

Particular Research interests of the MPEG-4 Working Group, to be explored in joint funding opportunities with the most appropriate vendor(s) are (not in hierarchical order):
- Testing of MPEG-4 encoders, decoders, and editing tools:
- Standards-based annotations and bookmarking:
- Robust use of MPEG-4 text tracks:
- Rights and access management:
- Interoperability with videoconferencing technologies:
- Collaborative data management:

The MPEG-4 Working Group intends to collaborate with vendors to develop robust, standards-based MPEG-4 implementations for education, medicine and other research areas. The intention is to stimulate a dialogue between the MPEG-4 Working Group and interested parties on the development of mutually beneficial collaborative activities, while MPEG-4 is in its earliest development stages. Vendors are encouraged to share their MPEG-4 development interests in any of the six activities proposed above.

5.2 MPEG-4 Systems

MPEG-4 Systems is a subgroup of MPEG in charge of the development of tools to support the coded representation of the combination of streamed elementary audio-visual information in the form of natural or synthetic, audio or visual, 2D and 3D objects within the context of content-based access for digital storage media, digital audio-visual communication and other applications. More precise information on MPEG-4 Systems and in MPEG Systems in general can be found in the MPEG Systems Frequently Asked Questions [MPEGSys].

The MPEG-4 Systems Sub-group has delivered in Tokyo (November 1998) the Systems Final Committee Draft for ISO/IEC 14496-1 (MPEG-4 Systems Version 1). This document specifies a first set of tools and profiles that are made available to the industry. Ongoing activities in the Systems sub-group are developing MPEG-4 Systems Version 2 specification. This specification has become Final Committee Draft in October 1998.

The Systems Implementation AHG (Im1) is in charge of developing the MPEG-4 Systems software and of providing the framework to integrate other MPEG-4 elements (such as audio and visual tools) in the MPEG-4 Browser. The Systems Implementation Web Site is at [MPEGImp], for which a password is needed.

More information about the MPEG-4 Systems subgroup and its meetings, documents, activities, groups, tutorials and MPEG-4 players can be found at their webpage [MPEGSys].

5.3 The MPEG Video Group

Within MPEG the MPEG Video Group is the largest working group and has the mandate to develop and standardise video coding tools and algorithms. The MPEG video group meetings are usually attended by approximately 100-150 video experts from approximately 20 countries. The MPEG video group has successfully completed and released the MPEG-1 video coding standard in 1992 and MPEG-2 video coding standard in 1994.

The web page of the MPEG-4 video group is at [MPEGVid]. It contains no information about their activities from October 1997.

5.4 Synthetic Natural Hybrid Coding subgroup

Since 1995, Synthetic Natural Hybrid Coding (SNHC) Subgroup has been working on developing standard technologies for the coded representation of synthetic elements of audio-visual information.

SNHC is a part of the MPEG-4 standardisation effort in multimedia representation, coding and communications.

SNHC deals with the representation and coding of synthetically and naturally generated audio-visual information. This represents an aspect of MPEG-4 for combining mixed media types including both natural and synthetic, streaming and downloaded A/V objects in useful ways. This enables interoperability of media streams and downloads for hardware- and software-based decoders, and encourages the interchange and wide usage of a variety of media types and their composition into engaging experiences.

The broad objectives addressed by MPEG-4 are high compression, support for service profiles designed for classes of applications, a wide range of channel bandwidths from a few Kbits/sec to many Mbits/sec, content-based access and manipulation, and scalability of A/V objects for different channels and terminal resources. Within this context, SNHC is concerned with the compression of specific media streams (such as geometry, text, animation parameters, or text-to-speech) beyond traditional audio and video, the representation and coding of synthetic objects as well as their natural audio-video counterparts (as in MPEG-2), and the spatial-temporal composition of these natural and synthetic objects.

MPEG-4 seeks to standardise audio and visual objects that correspond with both signal- and model-based coding, and to standardise the framework for spatial-temporal composition of these objects into semantically meaningful scenes. A goal of MPEG-4 and specifically of SNHC is to achieve interoperability and scalability of mixed media types suitable for different storage media, communication bandwidths, and "rendering" power of terminals with varied animation systems, graphics display, and audio synthesis.

The coding of specific A/V objects (e.g. elementary streams of text, video, musical scoring, or facial animation parameters), which are not generally divisible into more elementary parts for composing audio-visual scenes, are treated in the Audio and Visual Sections of the MPEG-4 specifications. Remaining aspects of scene composition, including the instantiation of A/V objects in space and time with respect to each other, the time-critical synchronisation of these objects, and the multiplexing of simultaneous logical channels operating within a physical channel of a transport connection, are handled in the Systems part of MPEG-4. The activities in the SNHC group contribute strongly in all of these areas, and SNHC is jointly responsible for the specification parts into which SNHC functionalities are integrated.

More information about the specific activities of the SNHC subgroup can be found on their web page [SNHC].

5.5 The MPEG audio subgroup

MPEG Audio is a subgroup of MPEG working on all audio aspects of the MPEG standards. More information about their activities and FAQs can be found on their webpage [MPEGAud].

5.6 The MPEG-4 Industry Forum

The MPEG-4 Industry Forum is a not-for-profit organisation with the following goal: to further the adoption of the MPEG-4 standard, by establishing MPEG-4 as an accepted and widely used standard among application developers, service providers, content creators and end users.

The following is a non-exhaustive excerpt from M4IF's Statutes about the way of operation: the purpose of M4IF shall be pursued by promoting MPEG-4, making available information on MPEG-4, making available MPEG-4 tools or giving information on where to obtain these, creating a single point for information about MPEG-4, creating industrial focus around the usage of MPEG-4. The goals are realised through the open international collaboration of all interested parties, on reasonable terms applied uniformly and openly. M4IF will contribute the results of its activities to appropriate formal standards bodies if applicable.

M4IF has its homepage at [MPEGInd].

The Forum has some 400 people subscribed to its mail list, with a very broad, worldwide representation from the following industries: Consumer Electronics, Computer, Telecommunications, Research Institutions. Also, some of the prospective members are 'business users' of MPEG-4. Among the list of current participants, there are many small companies that develop or deploy MPEG-4 technology. Membership goes beyond the MPEG constituency because some companies just don't need to be involved in the development phase.

The activities of M4IF generally start where MPEG stops. This includes issues that MPEG cannot deal with, e.g. because of ISO rules, such as clearance of patents. This following is a list of M4IF's current activities:

- Promoting the standard, and serving as a single point of information on MPEG-4 technology, products and services.
- Initiating discussions leading to the potential establishment of patent pools outside of M4IF, that should grant a license to an unlimited number of applicants throughout the world under reasonable terms and conditions that are demonstrably free of any unfair competition; this work includes studying licensing models for downloadable software decoders, such as internet players.
- Organisation of MPEG-4 exhibitions and tutorials. The first event was a successful exhibition in Geneva from May 28 - May 30 2000. The exhibition space show MPEG-4 products from established companies as well as start-ups, including audio and video players, authoring tools, facial animation, and more.
- Creating industrial focus around the standard - which MPEG-4 profiles to use in which market?

M4IF anticipates holding some 3 to 4 physical meetings per year. These meetings are generally attended by about a hundred people from all over the world. The focus is now on initiating the patent pools. See the home page for meeting details.

6 MPEG-4 functional architectures

This section describes functional system architectures for two kinds of systems with MPEG-4 object handling functionality, namely systems for authoring and for summarisation of multimedia presentations.

6.1 MPEG-4 based authoring

Figure 6 shows a functional architecture for MPEG-4 based authoring of multimedia documents. The functional item “Multimedia document” retrieves and saves documents from or to a repository and buffers a document under construction. The functional items “Objects” allow for adding or deleting objects such as video, graphics and audio, which are retrieved from an object repository. The functional items “features” include shapes, colours, textures, meshes and motion, and possibly original pose parameters. Scenes can be composed by the functional item “scenes”. This comprises the events in time and space in a multimedia document, the relations between objects, and the spatial and temporal evolution of atomic objects within a particular multimedia document.

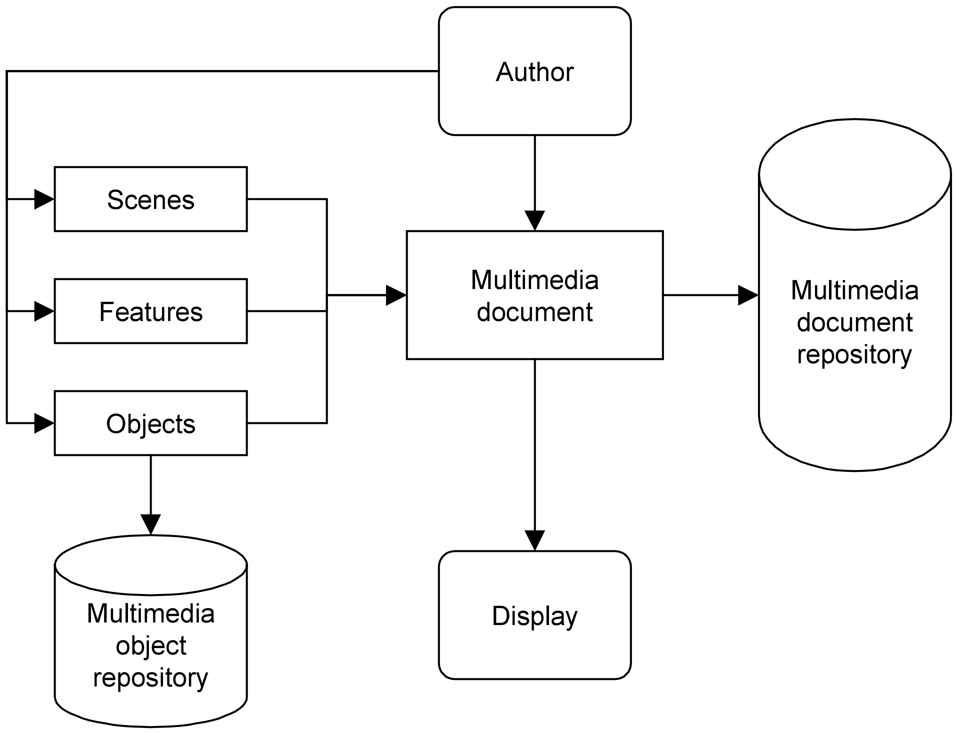

Figure 6. Functional architecture for MPEG-4 based multimedia authoring.

6.2 MPEG-4 based summarisation

To some extent, summarisation of an MPEG-4 encoded multimedia document can be seen as the reverse of authoring. Figure 7 shows the functional reference architecture of MPEG-4 based summarisation of multimedia. A document is decoded and summarisation is performed by selection of objects to be included in the summarisation. The summarisation can then be encoded for (further) transmission or be displayed directly, depending on the particular application.

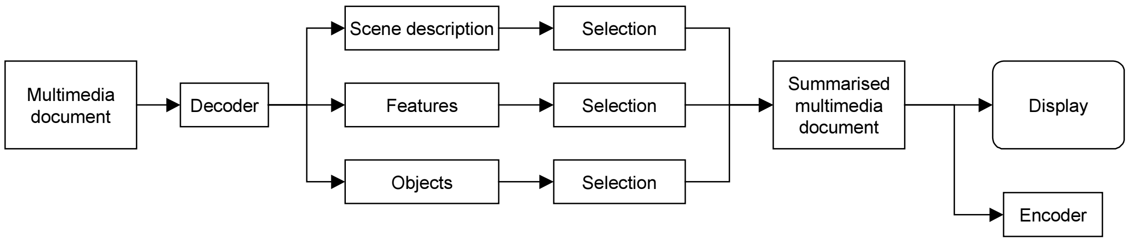

Figure 7. Functional architecture for MPEG-4 based multimedia summarisation.

The main advantage of MPEG-4 encoded multimedia in this case is that scenes, objects, and their features and parameters are already put in a very concise representation during the encoding process. Therefore, the summarisation does not require supplementary analysis or processing for detecting relevant objects, segments, or events. On the contrary, an MPEG-4 based summary can be seen as a partial decoding of the original document. Moreover, multiple summaries can be created just by changing the parameters sent to the selection blocks in the above diagram.

7 Conclusions

Obviously, MPEG-4 is for now the best possible choice for any multimedia application or service that needs to provide either of bandwidth efficiency, interactivity, adaptability, content-based access, summarisation, authoring and content re-purposing, and possibly many other elements of functionality. However, the technical and computational complexity of the encoder led to a substantial delay in developing the tools needed for a fully functional implementation of MPEG-4. As shown in section 4, the currently available tools only implement the basic specifications and aim for achieving better compression ratios, or adaptive bit rate or quality. Therefore, the advanced functionality of object manipulation is still not achievable. However, there is an intense research activity going on in the fields of video segmentation, object detection, modelling and recognition, and scene understanding, so many advanced techniques are likely to become available within a few years.

List of abbreviations

AAC Advanced Audio Coding

AVI Audio Video Interleave

BIFS Binary Format for Scenes

CELP Code Excited Linear Prediction

ES Elementary Stream

ESD Elementary Stream Descriptor

FAQ Frequently Asked Questions

GSM Global System for Mobile communications

HDTV High Definition Television

IEC International Engineering Consortium

ISO International Standardisation Organisation

MPEG Motion Picture Expert Group

OD Object Descriptor

VRML Virtual Reality Modelling Language

Definitions

Concept	Definition
Bandwidth	In the case of digital data transmission, the bandwidth is the number of bits per second, which is transmitted across a communication medium. Bandwidth is used as a measure of the transmission capacity of digital communication channels. For instance, a communication channel, which has a bandwidth of 1 Mbit/s, can be used for transmitting one million bits of data per second.
Bitstream	A bitstream is a sequence of bits of data transmitted across a digital communication channel. A bitstream occurs when a certain amount of data is transmitted bit after bit. For instance, data coded in digital form can be transmitted as a bitstream across a digital communication channel.
Broadband	A wired or wireless communication link that is considered high capacity. Often used in the sense that the link can carry a streaming video stream of moderate quality.
Codec	A communication device used for (en)coding and decoding data. Such a device is usually needed to meet some application or service specific requirements. See also encoding.
Compression	An invertible transformation by which the size, in number of bits, of a given data set is reduced. Data compression is possible only if either data representation or data values are redundant. If the first is excluded as trivial, one may observe that a sequence of random symbols is non compressible, and the average number of bits required for representing these symbols equals the source's entropy. "Lossy" compression is a special case where the transformation is not required to be invertible. The effect is that original data can never be completely recovered by decompression. This is usually the case for audio, video, and image compression.
Content	Content is a media object and its metadata.
Content Engineering	Content engineering is the development of information systems that support the value network of multimedia production: creation, digitalisation, storage, search, manipulation, management, distribution and delivery, in an effective, efficient and user-friendly way.
Content Management System	A content management system (CMS) is an information system used to manage the content in a content collection. Typically, a CMS consists of two elements: the content management application (CMA) and the content delivery (deployment) application (CDA). The CMA element allows the content manager or author, to manage the creation, modification, and removal of content from a content collection. The CDA element uses and compiles that information to update the content collection. The features of a CMS system vary, but most include (Web-based) publishing, format management, revision control, indexing, search, and retrieval. Example for a website: A content management system (CMS) is a system used to manage the content of a Web site. The CMA element allows the content manager or author, who may not know Hypertext Mark-up Language (HTML), to manage the

Concept	Definition
	creation, modification, and removal of content from a Web site without needing the expertise of a Webmaster. The CDA element uses and compiles that information to update the Web site. The features of a CMS system vary, but most include Web-based publishing, format management, revision control, indexing, search, and retrieval.
Conversion	Conversion is the translating of one media type to another media type, for instance text to speech. There are many different kinds of conversion: analog to digital, text to speech, NTSC to PAL, RGB to YUV, MPEG to AVI, etcetera.
Data	Data is a collection of raw material, which can be used to create information. For instance the letters of the alphabet or zeros and ones.
Decoding	Decoding is the reverse of encoding. See also: encoding, codec.
Digital item	A Digital Item is a structured digital object with a standard representation, identification and description within the MPEG-21 framework. This entity is also the fundamental unit of distribution and transaction within the MPEG-21 framework.
Document	Any writing conveying information. Traditionally, a document is a text written on paper. In the context of computers, a document can be any file stored on a computer system, typically containing some kind of human-readable data. Documents are used to store information, for later use and/or for dissemination. Examples of documents are books, reports, meeting minutes, and personal notes.
Encoding	A linear mapping of a finite set of discrete values onto another finite set of discrete "code words". The purpose of such a mapping is to induce some new properties on the original data set. Examples of codes are: the date, the ISBN, the Morse "alphabet", the natural binary code 1001 for number 9, or 50022-350-0227676-054423 for the identifier of a copy of Microsoft Windows.
Information	(1) A collection of data that is relevant to one or more recipients at a point in time. It must be meaningful and useful to the recipient at a specific time for a specific purpose. Information is data in context, data that have meaning, relevance, and purpose. (2) Data that has been processed in such a way that it can increase the knowledge of the person who receives it. Information is the output, or "finished goods," of information systems. Information is also what individuals start with before it is fed into a Data Capture transaction processing system.
Internet	Internet is the global network through which millions of computer users exchange data. The Internet comprises thousands of smaller networks, each associated with an organisation such as a firm, a university, a government agency, or an ISP. Communication is possible because of voluntary agreements to use certain communication standards such as TCP/IP. The World Wide Web and e-mail are the best known uses of the Internet.
Media	Abstract datatype. A description of the structure of a dataobject together with the set of operations defined on that object.
Media asset	A media asset is content and its permissions.
Media object	'Raw data' like a piece of music, image or video (also called *essence*).

Concept	Definition
Metadata	Metadata is data about content. Metadata is information about (digital) objects, such as the title, genre and summary of a television program. In a broader definition, metadata also includes for instance consumer profile and history data.
Multicast	Multicast in the context of Internet is a procedure for minimising the Internet backbone capacity requirements of broadcasting identical simultaneous bitstreams to multiple recipients. When multicasting, a server sends a single stream of data, which can be received by any client that has registered with the multicast group. Multicasting is often used to reduce he bandwidth requirements of video conferencing and Near Video on Demand.
Multimedia	The integration of different media (i.e. text, video, audio, and pictures) via spatial, temporal and/or logical composition.
Narrowband	A low-capacity communications link, such as a telephone cable.
Segmentation	The process of partitioning a given set of data values according to some intrinsic or induced properties, such that the resulting subsets are uniform with respect to those properties. Example: the image of a tree on a blue sky background may be segmented into three distinct sub-images: the background, the trunk, and the foliage. The intrinsic properties are the colors, and an induced property is the boundary of the foliage.
Streaming	A real-time bitstream conveying audio or video information, which makes it possible to view the information before the transmission has been completed. Streaming can be contrasted with simple downloading which requires that the entire file be transferred before it can be used.
Transcoding	The conversion from one encoding format to another. Examples are transcoding from MPEG4 to MPEG2, from PAL to SECAM, and from binary to hexadecimal.

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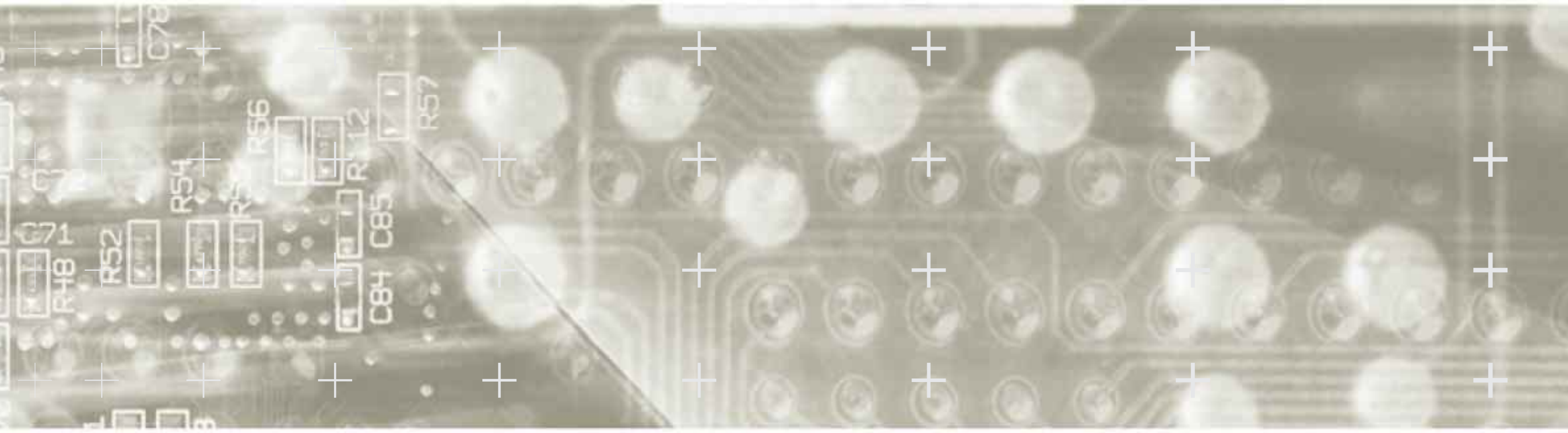

GigaCE

The GigaPort research project GigaCE (Giga Content Engineering) focusses on the technology that supports the entire value chain of multimedia production: storage, search, manipulation, distribution and delivery of multimedia for large groups of end users. The approach that GigaCE takes is: evaluate, build and validate CE demonstrators. The actual products are: state of the art studies, courses, seminars, book(lets), papers and a large amount of hands-on experience, which results in operational platforms and demonstrators. The project is part of the research programme of the Telematica Instituut within the GigaPort project.

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