الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
وزارة التعليم العالي و البحث العلمي
Ministry of Higher Education and Scientific Research

Universityyahiafares of medea
Faculty of Sciences and Technology
Departement of Electronics and Communications

جامعة يحي فارس بالمدية
كليةالعلوموالتكنولوجيا
قسم الإلكترونيك و الاتصالات

**Référence :** ...../BC/2024

**المرجع:**...../مم/2024

# Master's Thesis

**Presented to**

**Departement :** Electrical Engineering
**Domain :** Science and Technology
**Sector :** Electronics
**Speciality :** Electronics of Embedded Systems

**Submitted by:**

**Khaoula GHORFA**

# Thème

## VIDEO COMPRESSION: FROM MPEG-2 TO MPEG-4 AND BEYOND COMPARATIVES STUDIES

Before the examination committee composed of:

| | | | |
|---|---|---|---|
| KROBBA AHMED | Assoc. Prof. Dr. A | USTHB | President |
| AHFIR MAAMAR | Prof. Dr. | Univ. Medea | Examiner |
| SOLTANE MOHAMED | Assoc. Prof. Dr. A | Univ. Medea | Supervisor |

**AcademicYear:: 2023-2024**

# Dedications

First and foremost, I would like to express my gratitude to the Almighty, who grants me the courage and necessary will to face the various challenges of life.

I dedicate this modest work:

To my beloved parents, the source of life, love, and affection—my father Abdelkader and my mother Khaira. I can never fully express my gratitude and appreciation for their love, support throughout my studies, and their prayers. No dedication can compensate for their sacrifices for my well-being and happiness.

To the Ghorfa family, especially my sisters and brothers: Aya, Leila, Nour el Houda, and Mouhamed Amine, sources of joy and happiness.

To my friends and colleagues.

I dedicate this work to my supervisor, Prof. Soltane Mouhamed, for his immeasurable patience, unwavering availability, and valuable guidance that greatly contributed to the completion of this work.

I hope you will find here an expression of my profound gratitude.

To you, dear reader.

And to all those who supported us in successfully completing this project.

# Achnowledgments

First and foremost, I would like to express my gratitude to the Almighty for granting me the strength and courage to bring this work to completion.

I wish to extend my sincere thanks to my supervisor, Prof. Soltane Mouhamed from YAHIA FARES University, for his availability, careful reading, valuable suggestions, and remarks, and above all, for the unlimited trust he placed in me throughout this project. I would like to convey my deep appreciation and utmost respect to him.

I also extend my sincere thanks to the entire teaching staff of the Department of Electrical Engineering at the University of Médéa, an efficient team that has imparted a wealth of knowledge to me during the five years of my education.

Special thanks go to my family for their moral support throughout this work. Thank you for encouraging me.

I also thank my friends and classmates who supported and greatly assisted me throughout this project.

Finally, gratitude to the members of the jury who honored me by agreeing to evaluate this modest work.

# Résumé

Cette mémoire examine l'évolution des techniques de compression vidéo, de MPEG-2 à MPEG-4 et au-delà, en se concentrant sur des études comparatives entre ces normes. Le logiciel MATLAB a été utilisé dans l'aspect pratique pour analyser les performances et l'efficacité de ces normes. Les résultats ont montré des améliorations significatives de la qualité de l'image et de la réduction de la taille des données avec la transition vers des normes plus récentes.



**Mots clés : Compression vidéo, MPEG-2, MPEG-4, MATLAB, Analyse des performances.**



# Abstract

This thesis explores the evolution of video compression techniques from MPEG-2 to MPEG-4 and beyond, focusing on comparative studies between these standards. MATLAB was used in the practical aspect to analyze the performance and efficiency of these standards. The results showed significant improvements in image quality and data size reduction with the transition to newer standards.



**Keywords:Video Compression, MPEG-2, MPEG-4, MATLAB, Performance Analysis.**



# ملخص

تتناول هذه المذكرة تطور تقنيات ضغط الفيديو بدءًا من MPEG-2إلى MPEG-4 ومابعدها، مع التركيزعلى المقارنات بين هذه المعايير. تم استخدام برنامج ماتلاب في الجانب التطبيقي لتحليل الأداء والكفاءة لهذه المعايير. النتائج أظهرت تحسينات ملحوظة في جودة الصورة وتقليل حجم البيانات مع الانتقال إلى المعاييرالأحدث.



**الكلمات المفتاحية : ضغط الفيديو،MPEG-2،MPEG-4،ماتلاب،تحلي لالأداء.**

# Contents

Dedications ..... i
Achnowledgments ..... ii
Abstract ..... iii
Contents ..... iv
List of Figures ..... vi
Lists of Acronyms and Symbol ..... vii

**Chapitre1: 1**

1. Introduction ..... 1
1.1 Amis and Objective ..... 1
1.2 Thesis Organization. ..... 2

**Chapitre2: State Of The Art Video Compressions 5**

2.1 Introduction ..... 5
2.2 Definition of Video ..... 5
2.3 Types of Video. ..... 6
2.3.1 Analog Video. ..... 6
2.3.2 Digital Video. ..... 9
2.3.3 Progressive Video. ..... 9
2.3.4 Interlaced Video. ..... 10
2.4 Video Compression ..... 10
2.5 Fundamental Concepts of Video Compression. ..... 11
2.5.1 Reduction of Spatial Redundancy. ..... 11
2.5.2 Temporal Compression Techniques. ..... 12
2.6 Summary. ..... 13

**Chapitre3: The MPEG Video Standard Comparatives Studies Presentations 15**

3.1. Introduction ..... 15
3.2 Standardization Bodies for Video Compression Norms. ..... 15
3.3 Video Compression Standards ..... 16
3.3.1 MPEG-2 ..... 16
3.3.2 MPEG-4 ..... 19
3.3.3 MPEG-[A.B.C&D] ..... 21
3.3.4 MPEG-G2019. ..... 22

3.4 Summary. ..... 24

**Chapitre4: Implementation &Experimental Results 25**

4.Implementation &Experimental Results ..... 25

4.1 Implementation MPGE-2 Video Codec. ..... 26
4.2 Basic Architecture on Implemented Codec ..... 30
4.3 Transformation. ..... 32

4.4 Quantization. ..... 33
4.5 DCT Approach forthe Video Compression. ..... 34
4.6 Experimental Results. ..... 36
4.7 Summary. ..... 48

**Chapitre5: Conclusions& Future work 50**

5.1Conclusions. ..... 50
5.2 Future work. ..... 51

**References 53**

# List of Figures

Fig. 2.1. Representation of a Video Stream .....6
Fig. 2.2. Scanning Principle Used for Video and Television .....8
Fig. 2.3. The Color Video Signal.....8
Fig. 2.4. (a) Even lines, (b) Odd lines, (c) A full image.....9
Fig. 2.5. Interlaced Video Sequence .....10
Fig. 2.6. Video Compression System Model.....11
Fig. 2.7. Most video codecs break up a video frame into a number of smaller units for codinges.....12
Fig. 2.8. Temporal redundancy occurs when there is a large amount of similarity between video frames.....13

Fig. 3.1. Timeline for various video coding standards and formats.....16

Fig. 4.1. General information about digital images .....27
Fig. 4.2. Digital representation of an image .....27
Fig. 4.3. Spatial and temporal redundancy.....28
Fig. 4.4. Example of temporal redundancy .....28
Fig. 4.5. The block-based hybrid video coding scheme.....29
Fig. 4.6. Video Compression System.....31
Fig. 4.7. Overall diagram of a video encoder .....31
Fig. 4.8. Modules of a video compression system.....32
Fig. 4.9. Transform Coding by Discrete Cosine Transform (DCT).....35
Fig. 4.10.Védéo original and vedeocomprésé .....39
Fig. 4.11.Folders of works .....40
Fig. 4.12.Montion vector for frame 2.....40
Fig. 4.13.Montion vector for frame 3.....40
Fig. 4.14.Montion vector for frame 4.....41
Fig. 4.15.Montion vector for frame 5.....41
Fig. 4.16.Montion vector for frame 6.....41
Fig. 4.17.Montion vector for frame 7.....42
Fig. 4.18.Montion vector for frame 8.....42

# Lists of Acronyms and Symbol

**MPEG** : Moving Picture Experts Group

**DVD** : digital video broadcasting

**PSNR** : peak signal-to-noise radio

**SSIM** : structural similarity index

**VR** : virtual reality

**AR** : augmented reality

**DCT** : discrete cosine transform

**ITU-T** : International Telecommunication Union-Telecommunication

**VCEG** : Video Coding Experts Group

**ISO** : International Organization for Standardization

**CABAC** : context-adaptive binary arithmetic coding

**CAVLC** : context-adaptive variable-length coding

**VVC** : Versatile Video Coding

**CNNs** : convolutional neural networks

**GANs** : generative adversarial networks

**IoT** : Internet of Things

**MVC** : Multi-View Video Coding

**ASICs** : including dedicated encoding/decoding chips

**GPUs** : graphics processing units

**HEVC** : High Efficiency Video Coding

**NTSC** : National Television System Committee

**PAL** : Phase Alternating Line

**SECAM** : Sequential Color with Memory

**HDTV** : High-definition television

**RGB** : red, green, and blue

**ISO** : International Organization for Standardization

**IEC** : International Electrotechnical Commission

**SD** : Standard Definition

**HD** : High Definition

**DVB** : Digital Video Broadcasting

**AVC** : Advanced Video Coding

**AAC** : Advanced Audio Coding

**MAF** : Multimedia Application Format

**BiM** : Binary Format for Metadata

**SVC** : Scalable Video Coding

**SAOC** : Spatial Audio Object Coding

**USAC** : Unified Speech and Audio Coding

**BD** : Bjøntegaard-Delta.

# Chapitre 1

## 1. Introduction

In today's fast-paced digital world, video compression plays a crucial role in achieving efficient data transmission and enhancing the visual experience for users. With the increasing demand for high-quality video content, from movies and television programs to online videos and educational applications, the technology was once considered a "dark art" mastered only by a few experts and academics due to their partial isolation and lack of access to practical literature on the subject [1].

Historically, the MPEG-2 standard was dominant in the field of video compression, widely adopted in digital television broadcasting and DVDs. However, as technology evolved and the need for improved efficiency and reduced data size without compromising quality arose, new standards such as MPEG-4 emerged, bringing significant improvements in compression capability and handling multimedia content.

This thesis aims to explore and provide a comprehensive comparative study of video compression techniques from MPEG-2 to MPEG-4 and beyond. In the following chapters, we will discuss the main differences between these standards, their impact on video quality, data size, and transmission efficiency. Additionally, we will review recent advancements in video compression techniques and how they affect various practical applications .

The structure of this research consists of 5 main chapters as follows:

Chapitre1:Introduction

Chapitre2:State Of The Art Video Compressions

Chapitre3:The MPEG Video Standard Comparatives Studies Presentations

Chapitre4:Implementation & Experimental Results

Chapitre5:Conclusions & Futurework.

## 1.1. Aims And Objectives

The primary aim of this thesis is to explore the progression of video compression technologies from MPEG-2 to MPEG-4 and beyond, providing a thorough comparative analysis of these standards. The research seeks to uncover the technical nuances, performance attributes, and application scenarios of each standard, thereby contributing to a deeper understanding of their role in optimizing data transmission and video quality. Additionally, this study aims to implement these compression techniques using MATLAB, offering practical insights and experimental validation of their effectiveness.

**Objectives:**

1. **Technical Analysis:**

To analyze the technical distinctions between MPEG-2, MPEG-4, and subsequent video compression standards, including MPEG-A, B, C, D, and MPEG-G 2019.

2. **Performance Evaluation:**

To assess the impact of each standard on video quality, data size, and transmission efficiency, utilizing metrics such as PSNR and bitrate reduction.

3. **Application Study:**

To review practical applications of various video compression techniques in digital broadcasting, online streaming, and storage, highlighting specific advantages in different contexts.

4. **Recent Developments:**

To explore the latest advancements in video compression technologies and their implications for the future of visual data transmission.

5. **Experimental Implementation:**

To implement video compression techniques using MATLAB, specifically focusing on MPEG-2 and MPEG-4 codecs, and compare their performance.

6. **Comparative Analysis:**

To perform a comprehensive comparative study of the implemented video codecs, analyzing their efficiency and effectiveness based on experimental results obtained from MATLAB.

By addressing these aims and objectives, this thesis will provide a comprehensive overview of video compression technologies, illustrating their evolution and impact on modern data transmission and video quality standards, supported by practical experimentation and comparative analysis using MATLAB.

## 1.2. Thesis Organization

This thesis is organized into several chapters, each addressing specific aspects of video compression technologies and their comparative analysis. The structure of the thesis is designed to guide the reader through the evolution, technical details, practical implementations, and experimental results of video compression standards from MPEG-2 to MPEG-4 and beyond.

**Chapter 1: Introduction**

This chapter provides an overview of the research topic, including the aims and objectives of the study. It sets the stage for the subsequent chapters by outlining the importance of video compression and the motivation behind the research.

**Chapter 2: Literature Review**

In this chapter, we review the existing literature on video compression technologies. The focus is on understanding the historical context, key developments, and the current state of research in the field. This review forms the basis for the comparative analysis presented later in the thesis.

**Chapter 3: The MPEG Video Standard Comparative Studies Presentations**

This chapter delves into the technical aspects of various MPEG video compression standards. It includes:

**Introduction:** An overview of the chapter's content.

**Standardization Bodies for Video Compression Norms:** Discussion of the organizations responsible for developing and maintaining video compression standards.

**Video Compression Standards:** Detailed exploration of MPEG-2, MPEG-4, and subsequent standards (MPEG-A, B, C, D, and MPEG-G 2019).

**Summary:** A recap of the key points discussed in the chapter.

**Chapter 4: Implementation & Experimental Results**

This chapter focuses on the practical implementation and experimental validation of video compression techniques using MATLAB. It includes:

**Implementation of MPEG-2 Video Codec:** Description of the implemented codec.

**Basic Architecture of the Implemented Codec:** Overview of the codec's architecture.

Transformation, Quantization, and DCT Approach for Video Compression: Detailed explanation of these core techniques.

**Experimental Results:** Presentation and analysis of the results obtained from the experiments.

**Summary:** Summary of the findings and their implications.

**Chapter 5: Discussion and Conclusion**

This chapter provides a discussion of the findings, linking them back to the aims and objectives outlined in Chapter 1. It also offers conclusions drawn from the research and suggests potential areas for future work.

# Chapitre 2

# *2 State Of The Art Video Compressions*

## 2.1. Introduction

Video compression is a fundamental technology that underpins a wide array of modern multimedia applications, from digital television and streaming services to video conferencing and storage solutions. The primary objective of video compression is to reduce the amount of data required to represent a video signal while preserving an acceptable level of visual quality. This reduction in data facilitates more efficient storage, transmission, and processing of video content [2].

High bitrate connections to homes have become ubiquitous, and the storage capacity of hard disks, flash memories, and optical media has never been greater. With the continuous decline in the cost per transmitted or stored bit, the necessity for video compression might not be immediately apparent. However, video compression remains crucial for two main reasons.

Firstly, video compression enables the use of digital video in transmission and storage environments that cannot support uncompressed ('raw') video. For instance, the current Internet throughput rates are insufficient to handle real-time uncompressed video, even at low frame rates or small frame sizes. Similarly, a Digital Versatile Disk (DVD) can only store a few seconds of raw video at television-quality resolution and frame rate, making DVD-Video storage impractical without compression.

Secondly, video compression allows for more efficient use of transmission and storage resources. Even when high bitrate transmission channels are available, it is preferable to send high-resolution compressed video or multiple compressed video channels rather than a single low-resolution, uncompressed stream. Despite the continuous advances in storage and transmission capacities, compression remains an essential component of multimedia services. [2].

## 2.2. Definitionof Video

We consider a video stream as a sequence of 2D images. The resolution of the video, expressed in the number of pixels, defines the dimensions of these images. The time duration between two images ($\Delta t$) is very short, given that the frame rate of the video typically ranges from 24 to 60 frames per second. This high frame rate ensures smooth motion perception and

is crucial for maintaining visual continuity in both standard and high-definition videos. Additionally, modern video technologies often employ various compression techniques to efficiently handle the vast amount of data involved in high-resolution and high-frame-rate video streams [3].

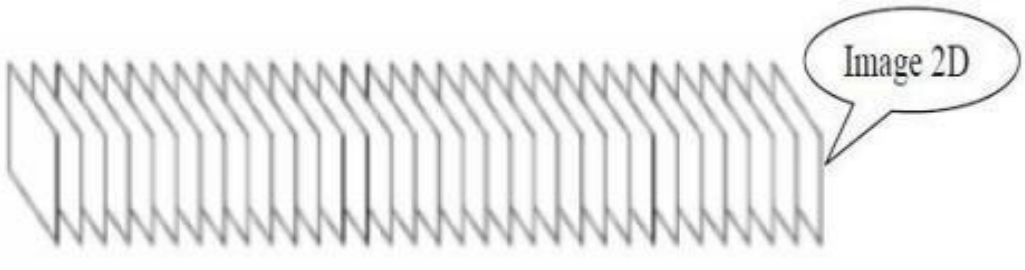



**Fig.2.1.** ***Representation of a Video Stream*** **[4].**

## 2.3 Types of Videos

The video signal is the signal that enables the transmission of a sequence of images from the source to a display device in electrical form. Depending on how the signals are processed, we can distinguish between the following two modes:

### 2.3.1. AnalogVideo:

Analog video represents transmitted information in the form of an analog signal, typically through waves or cables, with television being the most commonly used video display medium. A color analog video image is characterized by being reconstructed through the mixture of the three primary colors: red, green, and blue (RGB) in varying quantities. However, in practice, the video signal does not always present itself as three separate RGB signals; it can take on different forms [4].

There are three basic standards for analog color video encoding [4]:

**NTSC Standard:** The National Television System Committee (NTSC) standard was launched in the United States in 1953. It provides a video format of 525 lines and 30 frames per second in grayscale (29.97 in color). NTSC is also used for DVD-video with a resolution of 720 × 480 lines. The NTSC standard was the first analog color TV system that was

backward compatible with existing black-and-white (B&W) signals. To combine a chroma signal with the existing luma (Y) signal, a quadrature sub-carrier chroma signal is used. On the Cartesian grid, the x and y axes are defined with B−Y and R−Y respectively. When transmitted along with the luma (Y), the G−Y signal can be recovered from the B−Y and R−Y signals. [5].

**PAL Standard:** Phase Alternating Line (PAL) was developed as an alternative to NTSC and SECAM, historically competing with these standards. PAL provides better color stability and is commonly used in Europe and other parts of the world. However, a significant flaw in PAL's design involves adding the frame rate to the chroma frequency to re-arrange the on-screen chroma dots into a non-objectionable pattern. This design creates an unlocked relationship between the horizontal and chroma frequencies, unlike in NTSC, where they are locked. This unlocked condition complicates efficient digital coding. The pattern varies with the number of scan lines and the four-phase states of PAL color. With 625 lines, the two fields within a frame pair lines with the same chroma dot position on-screen. The next pair of lines within a frame shifts 90° to the left or right, resulting in diagonal lines moving in a four-frame step repeat pattern. This pattern is not fast enough to blur the motion, necessitating alteration. By adding the frame rate, the first line in the next field inverts 180° from its original phase. The inverted order on a scan line in a field is two lines away (four lines in a frame). Adjusting by adding or subtracting four frame lines breaks this pattern, making it unnecessary to add the frame rate to the chroma frequency, thus keeping the horizontal and chroma frequencies locked. Conventional PAL-N sets can handle this four-line adjustment, as it represents less than a 1% change in the lines per frame. [2].

**SECAM Standard:** SECAM (Séquentiel couleur à mémoire) was developed in France as an alternative to NTSC and PAL standards, known for its superior color stability under certain conditions. Unlike NTSC and PAL, SECAM transmits color signals sequentially rather than in parallel, which reduces interference from high frequencies. SECAM gained widespread adoption in France, parts of Eastern Europe, and Africa, proving effective in challenging broadcasting environments. [6].

Color television uses the same scanning principle as black-and-white TV but with three beams instead of one, one for each primary color: red, green, and blue (RGB). These RGB signals are then converted into a luminance signal and two chrominance signals.

High-definition television (HDTV) employs the same basic principles but doubles the number of lines to enhance image quality. Additionally, it uses a 16:9 aspect ratio instead of 4:3 to better fit the format of cinema films.

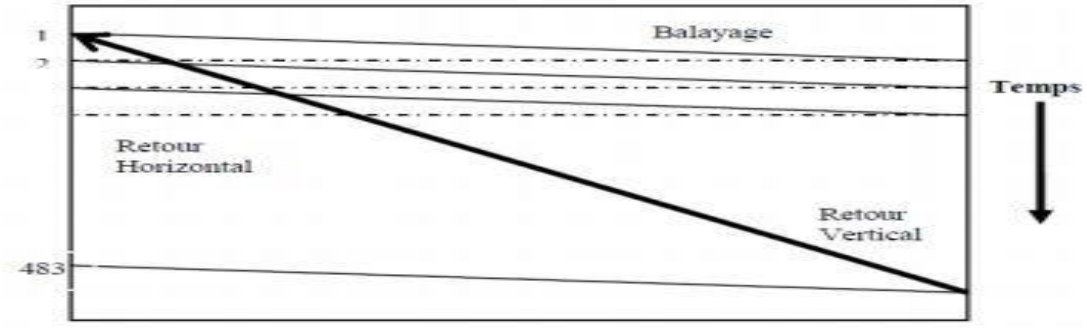



**Fig.2.2.** ***Scanning Principle Used for Video and Television*** **[4].**

Color television uses the same scanning principle but employs three beams instead of one, with each beam corresponding to one of the primary colors: red, green, and blue (RGB). The RGB signals are then converted into a luminance signal and two chrominance signals, allowing for a full-color image to be displayed. High-definition television (HDTV) enhances this principle by doubling the number of lines to achieve superior image quality. Additionally, HDTV adopts a 16:9 aspect ratio instead of the traditional 4:3, better fitting the format of cinematic films and providing a more immersive viewing experience. Advances in digital technology have further improved the precision and efficiency of these processes, ensuring high-quality video output across various devices[12].

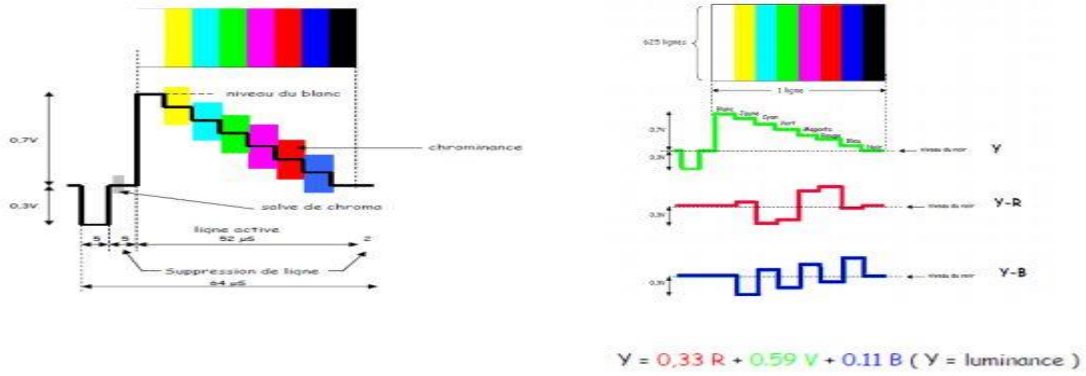



**Fig.2.3.** ***The Color Video Signal*** **[4]**

### 2.3.2. DigitalVideo:

Digital video is a sequence of images composed of a matrix of pixels. To achieve color images, at least 8 bits are used, corresponding to 256 levels of color. For digital color video, 8 bits are used for each of the three primary colors: red, green, and blue, resulting in 24 bits per pixel, which can represent approximately 16.8 million colors. The scanning principle used in digital video is similar to that of analog video [2]. The most common digital signals used are RGB and YCbCr. RGB is simply the digitized version of the analog RGB video signals. YCbCr is basically the digitized version of the analog YPbPr video signals, and is the format used by DVD and digital television [8].

### 2.3.3. ProgressiveVideo:

Progressive video is a display mode used by electronic screens, contrasting with interlaced scanning. This technique is primarily employed by computer monitors and high-definition televisions. The principle of progressive mode is to display the entire image in a single pass, unlike interlaced scanning, where the odd lines of the image are displayed first, followed by the even lines. In progressive scanning, each frame corresponds to a complete image, and the screen refresh rate matches the frame rate. In contrast, with interlaced scanning, the refresh rate is twice the frame rate. This method ensures smoother motion and sharper images, making it ideal for modern high-resolution displays [4].




**Fig.2.4.** ***Even lines, (b) Odd lines, (c) A full image*** **[4].**

### 2.3.4. InterlacedVideo:

When you watch your television, your eye actually sees half-images called fields. For instance, the screen displays 50 fields per second, with one composed of even lines and the next composed of odd lines. When these fields interlace, they create a full image. This system, known as "interlacing," represents half of the information in each complete video

frame (intended to double the perceived frame rate without increasing the bandwidth). For example, the abbreviation 50i refers to interlaced scanning at 50 fields per second (i for interlaced). This method was commonly used in older television systems and is still found in some broadcast formats today [9].

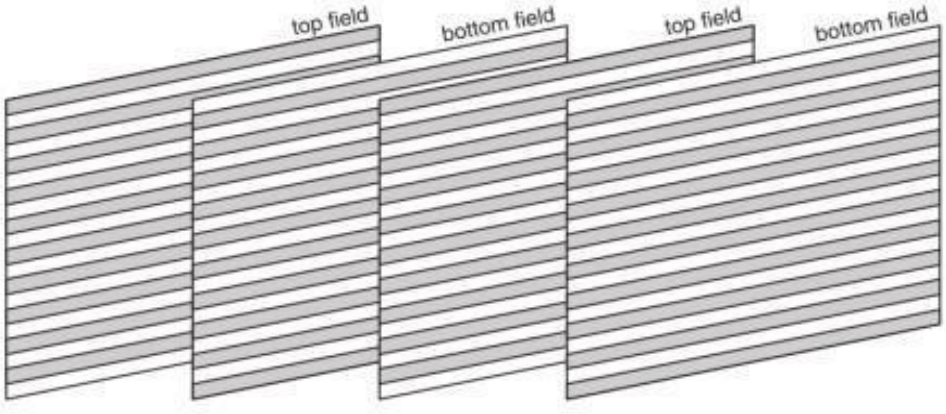



**Fig.2.5.** ***Interlaced Video Sequence*** **[4].**

## 2.4. Video Compression

Video compression is a process aimed at reducing the amount of information representing a video to achieve a bitrate measured in bits per second (bps).

The compression system employs two complementary modules: the encoding compression module, which converts the data source before transmission or storage into a compressed form occupying fewer bits, and a decompressor (decoder) that converts the compressed form into a representation of the original source. The encoder/decoder pair is called a codec.

Video represents a significant amount of data, and despite the increase in processor power and storage device capabilities, there is a need to represent it in a more concise format. The quality of a compressed video varies greatly depending on the input frame rate, input resolution, imposed output bitrate, and required quality.

Compression of digital video data is only possible if the redundancies existing in a video are eliminated, and there are essentially three types [8]:

Spatial redundancy: correlation between neighboring pixels.

Temporal redundancy: correlation between video frames.

Psycho-visual redundancy: properties of human vision.

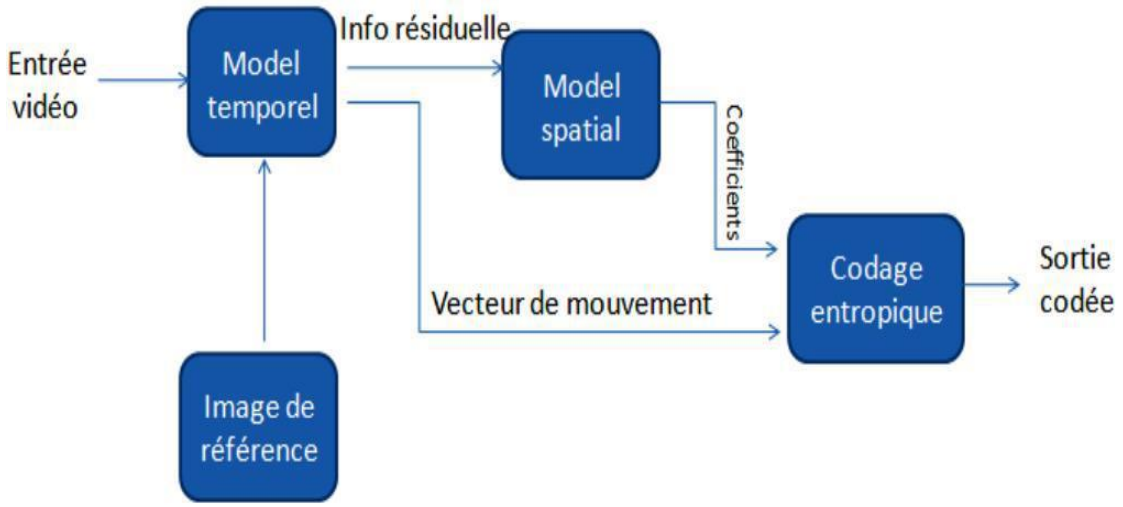



**Fig.2.6.** ***Video Compression System Model*** **[15].**

## 2.5. Fundamental Concepts of Video Compression

Video compression is essential for reducing the size of video files to enable efficient storage, transmission, and playback. The fundamental concepts of video compression involve several key techniques and principles:

### 2.5.1. Reductionof Spatial Redundancy

Spatial compression techniques aim to minimize data redundancy within video frames, thereby reducing the amount of data needed to represent each frame efficiently. These techniques utilize mathematical transformations like the Discrete Cosine Transform (DCT), which converts pixel blocks from the spatial to the frequency domain, separating the image into components of varying importance. Additionally, spatial prediction algorithms exploit correlations between neighboring pixels to predict values and encode only the differences, while quantization reduces data precision to further compress video data, albeit at the cost of potential artifacts and reduced image quality, particularly at lower bitrates. Overall, these methods are crucial for achieving significant compression ratios while maintaining acceptable visual fidelity in video compression [2].

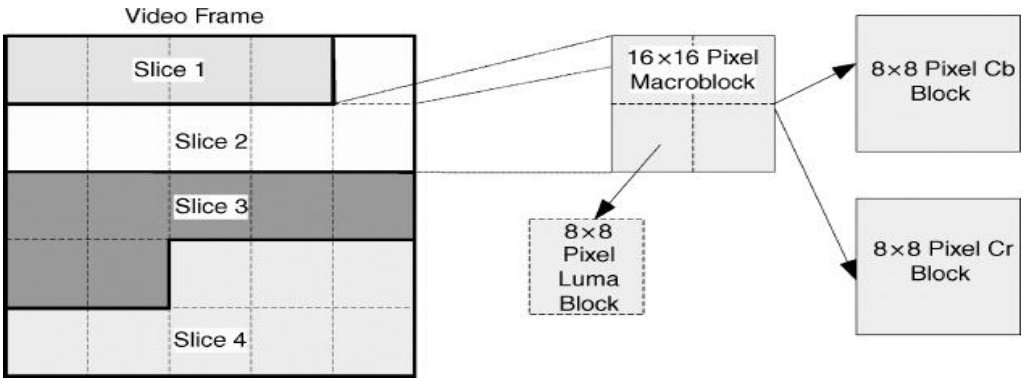



**Fig.2.7.** ***Most video codecs break up a video frame into a number of smaller units for codinges*** **[4].**

### 2.5.2. Temporal Compression Techniques

Temporal compression techniques are essential for reducing temporal redundancy between consecutive frames in a video, thereby minimizing the amount of data required to represent the video sequence. These techniques leverage predictive coding, motion estimation, and quantization to achieve compression while maintaining visual quality. One of the primary temporal compression techniques is motion estimation, which involves analyzing the motion between frames to identify areas of similarity. By determining the motion vectors that describe the movement of objects between frames, motion estimation enables the encoding of only the differences or residuals between frames, significantly reducing the amount of data needed to represent the video sequence [10].

Predictive coding plays a crucial role in temporal compression as well. Predictive coding algorithms utilize information from previous frames to predict the content of the current frame. By encoding only the prediction error, which represents the difference between the predicted frame and the actual frame, predictive coding further reduces redundancy in the video data. Quantization is another important aspect of temporal compression. It involves mapping a large set of input values to a smaller set of output values, reducing the precision of the data. In the context of video compression, quantization simplifies the representation of the video signal, particularly after spatial compression techniques like DCT. This further compresses the video data while maintaining acceptable visual quality. Overall, temporal compression techniques, including motion estimation, predictive coding, and quantization, are integral to video compression. By exploiting temporal redundancies between frames and leveraging these techniques, video compression algorithms achieve significant compression ratios while maintaining high-quality video playback [10].

Statistical structure is being used to provide compression in these examples, but that is not the only kind of structure that exists in the data. There are many other kinds of structures existing in data of different types that can be exploited for compression. Consider speech. When we speak, the physical construction of our voice box dictates the kinds of sounds that we can produce. That is, the mechanics of speech production impose a structure on speech. Therefore, instead of transmitting the speech itself, we could send information about the conformation of the voice box, which could be used by the receiver to synthesize the speech. An adequate amount of information about the conformation of the voice box can be represented much more compactly than the numbers that are the sampled values of speech. Therefore, we get compression. This compression approach is being used currently in a number of applications, including transmission of speech over mobile radios and the synthetic voice in toys that speak. An early version of this compression approach, called the vocoder (voice coder), was developed by Homer Dudley at Bell Laboratories in 1936. The vocoder was demonstrated at the New York World's Fair in 1939, where it was a major attraction [11].



(a) Frame 1 (b) Frame 2

**Fig.2.8.** ***Temporal redundancy occurs when there is a large amount of similarity between video frames*** **[4].**

## 2.6. Summary

Unit 2 has provided a comprehensive overview of various aspects of video technology, ranging from its fundamental definitions to the latest advancements in video compression techniques.

We began by delving into the definition of video, which encompasses the representation of moving images through a series of frames. This understanding laid the groundwork for our exploration into the different types of videos, including analog, digital, progressive, and interlaced video formats.

Our examination of video compression was particularly enlightening, as we explored the fundamental concepts underlying this process. We learned how video compression aims to reduce data volume while preserving perceptual quality, utilizing techniques such as spatial and temporal redundancies elimination.

Furthermore, we delved into the advancements in video compression, witnessing the evolution from traditional standards like HEVC to cutting-edge technologies driven by artificial intelligence. These advancements have revolutionized the field, enabling higher compression ratios, improved visual fidelity, and enhanced efficiency in video streaming and storage.

In conclusion, the study of video technology is dynamic and ever-evolving, with constant innovation driving progress. By understanding the foundational concepts and staying abreast of the latest advancements, we can continue to harness the power of video technology to enrich communication, entertainment, and various other domains of human endeavor.

# Chapter 3

# *3 The MPEG Video Standard Comparatives Studies Presentations*

## 3.1. Introduction

Unit 3 delves into a critical exploration of the MPEG video standard through comparative studies and presentations. Building upon the foundational knowledge established in the previous units, this section offers a deeper understanding of the various MPEG standards and their applications in the realm of video encoding and compression.

The MPEG (Moving Picture Experts Group) video standard has become synonymous with digital video encoding, playing a pivotal role in numerous multimedia applications. Understanding its intricacies and comparing different iterations is essential for professionals and enthusiasts alike in the field of multimedia technology.

In this unit, we embark on a journey to dissect and compare key MPEG standards, including MPEG-2, MPEG-4, MPEG-[A, B, C & D], and the latest developments such as MPEG-G 2019. Each standard serves distinct purposes and presents unique features, ranging from encoding efficiency to support for emerging technologies.

Through comparative analyses, we aim to unravel the strengths, weaknesses, and practical applications of each MPEG standard. By examining factors like compression efficiency, quality, complexity, and suitability for diverse applications, we gain valuable insights into the evolving landscape of video compression technology [12].

## 3.2. Standardization Bodies For Video Compression Norms

Two prominent standards dominate the landscape of video coding: the H26x standard and the MPEGx standard, developed respectively by ITU-T and ISO/IEC. These standards, such as MPEG-1, MPEG-2, MPEG-4, H.261, H.262, H.263, and H.263+, have significantly influenced the media industry. The coding objectives determine the structure and principles of the encoder, tailoring standards like H26x for video conferencing, characterized by slow movements and static backgrounds, while MPEGx targets digital video, computing

applications, and digital television. A video coding standard outlines a bitstream structure and decoding method, shaping the compression toolkit. Although not every tool in the toolkit needs implementation for compliance, decoders must implement a subset. Additionally, over the years, other formats like Theora, VC-1, VPx, and Daala have emerged, reflecting the continuous evolution of video coding standards. This historical timeline, spanning the last 25 years, showcases the ongoing advancements in the field [13].

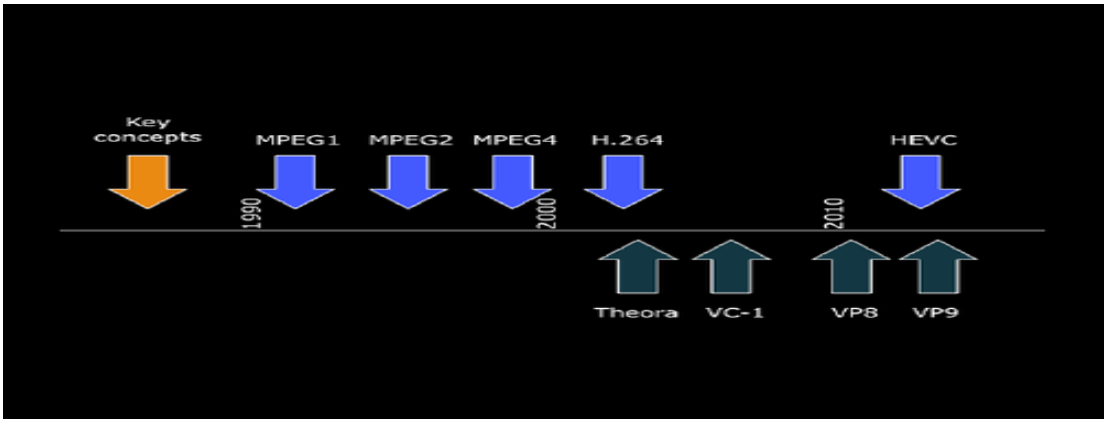



**Fig.3.1.** ***Timeline for various video coding standards and formats*** **[14].**

## 3.3. Video Compression Standards

Video compression standard is the key to compress a raw video, the encoding process mainly goes through four steps: prediction, transformation, quantization, and entropy coding, while decoding is a just reverted encoding process. With different codecs manufactured on different devices (e.g., DVD player with MPEG-2 , BluRay player with H.264 , 4K TV with HEVC ), an encoded video may have to be converted to the supported codec on that device. Changing codec is the most compute-intensive type of transcoding since it has to decode the bitstream with the old codec first and then encode it again with the new codec [14].

### 3.3.1.MPEG-2

MPEG-2, a standard for "the generic coding of moving pictures and associated audio information," is a cornerstone of digital video and audio compression. Developed by the Moving Picture Experts Group (MPEG), it has played a significant role in the evolution of digital media, enabling a variety of applications from broadcasting to physical media. This article delves into the history, functionality, applications, and characteristics of MPEG-2, highlighting its impact on the digital media landscape [16].

- **History of MPEG-2**

The development of MPEG-2 began in the early 1990s, with the need for a standard that could efficiently compress video and audio for broadcasting and storage. The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) were involved in this effort, with MPEG-2 officially introduced in 1995.

MPEG-2 was designed to address the limitations of its predecessor, MPEG-1, which was suitable for low-bitrate applications such as Video CDs but inadequate for higher-quality broadcasting and storage needs. The MPEG-2 standard provided a framework that could support a wide range of bitrates and resolutions, making it versatile enough for various applications [16].

- **How MPEG-2 works**

MPEG-2 compresses video and audio data by exploiting both spatial and temporal redundancy. The standard uses several key techniques:

**1. Intra-frame compression:** similar to JPEG compression, intra-frame compression reduces spatial redundancy within individual frames using techniques such as discrete cosine transform (DCT).

**2. Inter-frame compression:** It reduces temporal redundancy by comparing consecutive frames and encoding only the differences (motion vectors) between them. This method is called predictive coding and includes techniques such as P-frames (predictive frames) and B-frames (bidirectional predictive frames).

**3. Quantization:** After transformation, the coefficients are quantized to reduce accuracy, which leads to further compression. This is a lossy process, i.e. some original data is discarded.

**4. Entropy coding:** Techniques such as Huffman coding or arithmetic coding are used to further compress the data by reducing the redundancy in the quantized coefficients.

**5. Audio compression:** MPEG-2 also includes an audio compression standard that supports multi-channel audio, which is often used for surround sound systems [17].

- **Applications of MPEG-2**

MPEG-2 has a wide range of applications due to its flexibility and efficiency:

**1. Digital television broadcasting:** MPEG-2 is the standard for digital television broadcasting, including satellite, cable and terrestrial broadcasts. It supports standard definition (SD) and high definition (HD) video.

**2. DVDs:** MPEG-2 is the video compression standard for DVDs, enabling high-quality video and audio data on a widely accessible medium.

**3. Digital Video Broadcasting (DVB):** MPEG-2 is used in DVB systems, which are used worldwide for digital television services.

**4. Video streaming:** Although newer standards such as H.264 have become more prevalent, MPEG-2 is still used in some streaming applications, particularly where backward compatibility is required.

**5. Video production and editing:** MPEG-2 is used in professional video production and editing environments where its quality and versatility make it a reliable choice [17].

- **Characteristics of MPEG-2**

MPEG-2 is characterized by several important features:

**1. Scalability:** MPEG-2 supports a range of bit rates and resolutions, making it suitable for both low-quality streaming and high-resolution broadcasting.

**2. Compatibility:** MPEG-2 is widely supported by hardware and software, ensuring broad compatibility with different devices and platforms.

**3. Quality:** While MPEG-2 is a lossy compression standard, it achieves a good balance between compression ratio and video quality, making it suitable for broadcast and physical media applications.

**4. Multi-channel audio:** MPEG-2 supports advanced audio features, including multi-channel audio for surround sound systems.

**5. Error resilience:** MPEG-2 includes features to maintain video quality even in the presence of transmission errors, which is critical for broadcasting applications [17].

- **Evolution and Legacy**

MPEG-2 has been superseded by more advanced standards such as MPEG-4 and H.264, which offer higher compression efficiency and better quality at lower bit rates. Nevertheless, MPEG-2 continues to be used due to its established infrastructure and compatibility with existing systems. It laid the foundation for the development of subsequent video compression technologies and is still important for certain applications.

MPEG-2 has had a major impact on the digital media industry as it is a versatile and efficient standard for video and audio compression. Its use in broadcasting, DVDs and various other applications has made it a ubiquitous technology. Although MPEG-2 has been superseded by more advanced standards, the legacy of MPEG-2 endures and reflects its importance in the history of digital media [17].

### 3.3.2.MPEG-4

MPEG-4, a standard developed for the encoding of audiovisual objects, represents a significant development in the compression and transmission of digital media. MPEG-4 was developed by the Moving Picture Experts Group (MPEG) and offers advanced features for interactive multimedia applications, higher compression efficiency and support for different types of media. This article looks at the history, functions, applications and features of MPEG-4 and highlights its importance to modern digital media [18].

- **History of MPEG-4**

MPEG-4 was developed in the late 1990s and officially released in 1998. It was designed to build on the capabilities of earlier standards, particularly MPEG-2, to provide improved compression efficiency, support for a wider range of applications and improved interactivity. The development was driven by the need for a versatile standard that could accommodate the growing diversity of digital media formats and delivery methods, including streaming, interactive content and mobile applications.

MPEG-4 is maintained and developed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Over the years, it has undergone several updates and improvements, cementing its role in the digital media ecosystem [19].

**How MPEG-4 Works**

MPEG-4 uses a number of techniques to achieve efficient compression and versatile media presentation:

**1. Object-based compression:** unlike previous standards that treat video as a sequence of frames, MPEG-4 can process individual objects within a scene. This allows for more efficient compression and flexible editing of media elements.

**2. Advanced Video Coding (AVC):** Also known as H.264, this is one of MPEG-4's most notable profiles. AVC provides high compression efficiency by utilising advanced techniques such as intra- and inter-frame prediction, variable block sizes, and sophisticated entropy coding.

**3. Audio compression:** MPEG-4 includes several audio coding standards, such as Advanced Audio Coding (AAC), which offers high audio quality at lower bit rates.

**4. 3D graphics and animation:** MPEG-4 supports 3D mesh coding, animation and other advanced graphics features, making it suitable for interactive multimedia applications.

**5. Scalability:** MPEG-4 enables scalable encoding, allowing the transmission and storage of media at different quality levels, from low to high resolution.

**6. Fault tolerance:** Techniques such as data partitioning and error correction codes are integrated to maintain quality in lossy transmission environments [18].

**Applications of MPEG-4**

The versatility of MPEG-4 has led to it being used in a wide range of applications:

**1. Streaming Media:** MPEG-4 is commonly used in Internet video streaming services because it provides efficient compression that maintains high quality while minimizing bandwidth usage. Platforms such as YouTube, Netflix and Vimeo use MPEG-4 for video delivery.

**2. Digital television:** MPEG-4 is used in the transmission of digital television, including terrestrial, satellite and cable television. It supports both standard and high-definition transmissions and offers better compression than MPEG-2.

**3. Mobile video:** With its efficient compression and scalability, MPEG-4 is ideal for mobile video applications and ensures good quality even with limited bandwidth.

Interactive multimedia: Support for object-based compression and 3D graphics makes MPEG-4 suitable for interactive applications, including video games and virtual reality.

**4. Digital Rights Management (DRM):** MPEG-4 includes features to support DRM, allowing content providers to protect their intellectual property while delivering digital media [18].

**Characteristics of MPEG-4**

MPEG-4 is characterized by several important features:

**1. High compression efficiency:** MPEG-4, particularly the AVC profile, offers significantly better compression than previous standards such as MPEG-2, reducing file sizes while maintaining high quality.

**2. Flexibility and versatility:** MPEG-4 supports a wide range of media types, including video, audio, graphics and text, making it suitable for a variety of applications.

**3. Interactivity:** The ability to edit individual objects within a scene enables interactive features and advanced media manipulation.

**4. Scalability:** MPEG-4 can deliver media at different quality levels, from low to high resolution, adapting to different bandwidth and storage constraints.

**5. Error resilience:** Built-in error correction mechanisms ensure robust performance under varying transmission conditions [19].

**Evolution and Legacy**

MPEG-4 is constantly evolving, with ongoing improvements and the introduction of new profiles such as High Efficiency Video Coding (HEVC or H.265), which further

improves compression efficiency. The influence of MPEG-4 extends to various modern codecs and standards, reflecting its fundamental role in the development of digital media technology.

MPEG-4 has significantly shaped the digital media landscape with its advanced compression techniques and versatile application support. Its development marked a shift towards more interactive and efficient media handling, influencing everything from streaming services to mobile video and digital television. Understanding MPEG-4 is critical to understanding the advances in digital media compression and the technologies that continue to build on its foundations [18].

### 3.3.3.MPEG-[A, B, C & D]

The MPEG (Moving Picture Experts Group) standards comprise a large number of specifications for audio and video compression and transmission, each with its own focus and applications. MPEG-A, known as the Multimedia Application Format (MAF), provides a framework for integrating various multimedia components such as video, audio and metadata into a single, interoperable package. This enables seamless multimedia experiences across different platforms and devices. MPEG-B, or MPEG Systems, defines the system level that manages the synchronization and multiplexing of multimedia data. It includes specifications for the transport stream used in broadcasting and the program stream for storage applications. MPEG-C, also referred to as MPEG Video, encompasses the standards related to video coding, such as MPEG-1, MPEG-2, MPEG-4, and the more recent HEVC (High Efficiency Video Coding). These standards have been pivotal in advancing video compression techniques, enabling efficient storage and transmission of high-quality video content. Lastly, MPEG-D, known as MPEG Audio, focuses on audio coding standards, including well-known formats like MP3 and AAC (Advanced Audio Coding). These standards have revolutionized audio compression, making it possible to store and stream high-quality audio with minimal bandwidth. Together, MPEG-A, B, C, and D form a comprehensive suite of standards that have significantly shaped modern multimedia technology, ensuring interoperability, efficiency, and high-quality media experiences [20].

### 3.3.4.MPEG-G 2019

MPEG-G, introduced in 2019, is a revolutionary standard within the MPEG family, designed specifically for the complexity of genomic information. With the rapid advancement in genomic sequencing technologies, a critical need for efficient compression, storage and transmission of genomic data has emerged. MPEG-G (Genomic Information Representation) addresses this need by providing a standardized framework for processing genomic data. This article looks at the history, functions, applications and unique features of MPEG-G 2019 [21].

- **Origins and Development:**

MPEG-G was developed in response to the explosion in the generation of genomic data. Conventional methods of storing and transmitting genomic information were becoming increasingly inadequate due to the sheer volume of data. The Moving Picture Experts Group (MPEG), in collaboration with the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), developed MPEG-G to meet these challenges.

- **Objective:**

The main goal of MPEG-G is to create a comprehensive standard for the efficient compression, transport and processing of genomic data. It aims to reduce storage requirements and improve the accessibility of genomic information to enable advances in personalized medicine, research and various other applications.

- **Core Components:**

MPEG-G encompasses several key components designed to optimize the handling of genomic data:

1. **Compression:** MPEG-G employs advanced compression algorithms to significantly reduce the size of genomic data files without compromising the integrity of the information.
2. **Transport:** It provides mechanisms for the efficient transmission of genomic data across different platforms and networks.
3. **Metadata:** The standard includes robust support for metadata, ensuring that essential contextual information is preserved and easily accessible.
4. **Security:** MPEG-G incorporates security features to protect sensitive genomic data during storage and transmission.

- **Technological Innovations:**

1. **Segmented Data Storage:** MPEG-G divides genomic data into smaller, more manageable segments, enhancing compression efficiency and facilitating faster data retrieval.
2. **Adaptive Coding:** The standard uses adaptive coding techniques to optimize compression based on the specific characteristics of the genomic data being processed.
3. **Interoperability:** MPEG-G ensures that genomic data can be seamlessly exchanged and used across different systems and platforms.

- **Applications**

1. **PersonalizedMedicine:**

MPEG-G plays a crucial role in personalized medicine by enabling the efficient storage and analysis of large-scale genomic data. This facilitates the development of targeted therapies and personalized treatment plans based on an individual's genetic profile.

2. **GenomicResearch:**

Researchers benefit from MPEG-G's ability to compress and manage vast amounts of genomic data, making it easier to share and analyze datasets. This accelerates the pace of discovery and enhances collaborative efforts across the scientific community.

3. **Clinical Diagnostics:**

In clinical settings, MPEG-G supports the rapid and secure transmission of genomic data between laboratories and healthcare providers. This improves the accuracy and speed of diagnostic processes, leading to better patient outcomes.

**4 Data Archiving:**

MPEG-G provides an efficient solution for the long-term archiving of genomic data. Its compression capabilities significantly reduce storage costs while ensuring data integrity and accessibility over time.

- **Characteristics**

1. **Efficiency:**MPEG-G's advanced compression algorithms drastically reduce the size of genomic data files, leading to significant savings in storage and transmission costs. This efficiency is particularly important given the exponential growth of genomic data.
2. **Scalability:**The standard is designed to handle the varying scales of genomic data, from small datasets used in specific studies to massive databases encompassing

entire populations. This scalability ensures that MPEG-G remains relevant as genomic technologies continue to evolve.

3. **Security:**Given the sensitive nature of genomic information, MPEG-G incorporates robust security measures to protect data from unauthorized access and breaches. This includesencryption and secure data transmission protocols.
4. **Interoperability:**MPEG-G ensures that genomic data can be easily exchanged and integrated across different systems, platforms, and institutions. This interoperability is crucial for collaborative research and the broader application of genomic information in healthcare.

MPEG-G 2019 represents a significant advance in the field of genomic data management. By providing a standardized framework for the efficient compression, transport and manipulation of genomic information, MPEG-G addresses the challenges posed by the rapid growth of genomic data. Its applications in personalized medicine, genomic research, clinical diagnostics and data archiving underscore its transformative potential. As genomic technologies continue to advance, MPEG-G will play an increasingly important role in ensuring that genomic data is accessible, manageable and secure, paving the way for new discoveries and innovations in the field of genomics [21].

## 3.4. Summary

MPEG-2 was developed in the early 1990s and is a standard for encoding audio and video data that is widely used in digital television broadcasts, DVDs and some streaming media due to its efficient compression. MPEG-4, which was introduced in the late 1990s, offers advanced compression techniques and supports various multimedia applications such as streaming, web distribution and broadcast television, offering 3D rendering and object-oriented composite files. MPEG-A, B, C and D cover different aspects of multimedia content processing: MPEG-A focuses on application formats, MPEG-B on middleware, MPEG-C on content distribution standards and MPEG-D on audio standards. MPEG-G, which will be introduced in 2019, is tailored to genomic data and provides efficient compression, storage and transmission, which is crucial for personalized medicine, genomic research, clinical diagnostics and long-term data archiving. Together, these MPEG standards improve the handling of multimedia and genomic data through innovative and efficient technologies.

# Chapitre 4

# *4 Implementation&ExperimentalResults*

## 4. Implementation&ExperimentalResults

The "Implementation & Experimental Results" section focuses on the practical aspect of the study, providing a comprehensive overview of the implementation process and presenting the results obtained from the conducted experiments In this section, the video compression techniques discussed in the previous sections are put into practice. The chosen algorithms, such as those based on MPEG-2 and MPEG-4, are implemented using appropriate software tools and frameworks. The implementation involves translating the theoretical concepts into executable code, ensuring accuracy and efficiency in the compression process.

To conduct meaningful experiments, a well-designed experimental setup is established. This includes selecting a diverse range of video samples with varying content, resolutions, and complexities. These video samples are then subjected to the implemented compression algorithms, producing compressed video streams.

The performance of the compression algorithms is evaluated using various metrics and indicators. Objective measures such as compression ratio, bit rate, and computational complexity are considered. Additionally, subjective assessments of visual quality may be conducted, involving human observers who evaluate the compressed videos based on perceived artifacts, clarity, and overall viewing experience.

The experimental results are carefully analyzed, comparing the performance of different compression techniques. Statistical analysis techniques may be applied to draw meaningful conclusions from the data. The results highlight the strengths and limitations of each algorithm, providing insights into their efficiency, effectiveness, and suitability for different video applications

In summary, the "Implementation & Experimental Results" section presents the practical implementation of video compression algorithms, the experimental methodology employed, and the results obtained.

## 4.1. Implemented MPEG-2 Video Codec

Developing an MPEG-2 video codec within MATLAB presents a multifaceted challenge, necessitating a deep understanding of video compression principles and the MPEG-2 standard. Below is a broad outline of the steps involved in such an implementation:

Study the MPEG-2 Standard: Begin by acquainting yourself with the MPEG-2 video coding standard. This entails grasping the intricacies of I, P, and B frames, motion compensation, DCT (Discrete Cosine Transform), quantization, and entropy coding.

Frame Processing: Implement algorithms to process frames. This involves converting frames to the YCbCr color space, executing chroma subsampling, and employing block-based coding techniques.

Motion Estimation: For P and B frames develop motion estimation algorithms to ascertain the motion vectors describing macroblock movement across frames.

DCT and Quantization: Apply the DCT to macroblocks and subsequently quantize the coefficients to achieve compression.

Entropy Coding: Utilize entropy coding methods such as Huffman coding or arithmetic coding to further compress the DCT coefficients.

Bitstream Packaging: Package the encoded data into a suitable bitstream format adhering to MPEG-2 specifications.

Decoding Process: Implement the decoding process, essentially the reverse of the encoding process, to reconstruct the video from the compressed bitstream.

Testing and Optimization: Thoroughly test the codec using various video inputs and optimize the code for both performance and quality.

For a hands-on implementation.

For standarscompresions :

.Standardized functions include defining the structure of the data stream and how the decoder understands it.

.Non-standardized functions encompass pre-processing tasks like filtering and scaling, as well as encoding strategies such as mode, quantizer, and block pattern selection, along with motion estimation.

.Post-filtering actions like scaling, block filtering, and error concealment are also part of the non-standardized functions.

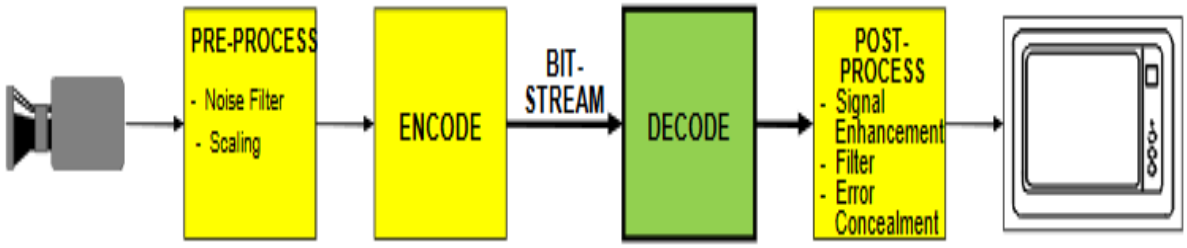



**Fig.4.1.** ***General information about digital images*** **[22].**

A digital image is defined by a matrix of points called pixels (Figure 1.2). Introducing the representation of a digital image here is to ensure a clear understanding of video processing techniques.




**Fig.4.2.** ***Digital representation of an image*** **[23]**

An uncompressed digital video is characterized by its pixel representation system, size, and refresh rate

Video compression, also known as encoding, seeks to lower the bitrate of a video sequence, thereby decreasing storage expenses or enabling its distribution without burdening the network. This process involves eliminating two types of redundancies to achieve effective compression (refer to Figure 4.3).

Spatial redundancy: This encoding method utilizes the spatial relationship between data points within a single image, disregarding other images in the sequence. Typically, adjacent pixels in an image exhibit minimal differences in color and brightness. Hence, instead of

storing the precise value of each pixel, it's more effective to encode only the variances in value between consecutive pixels.

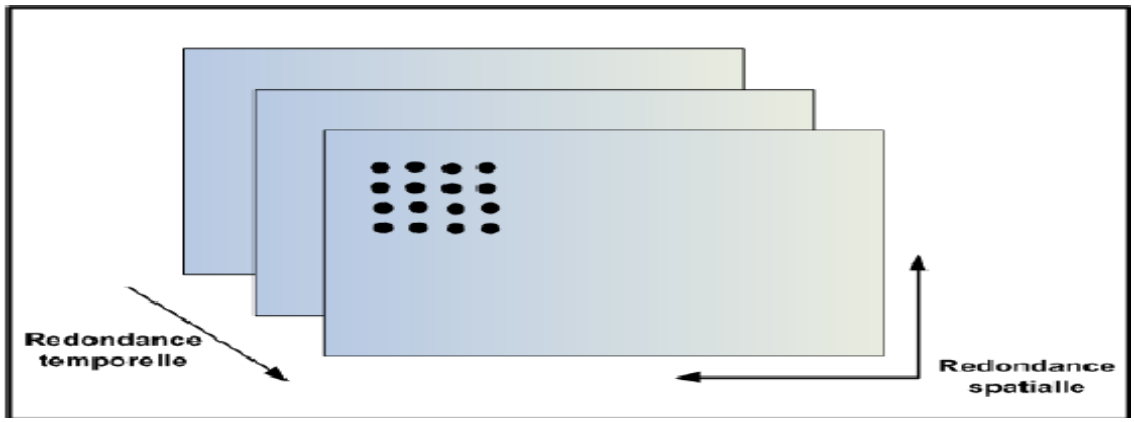



**Fig.4.3.** ***Spatial and temporal redundancy*** **[23].**

Temporal redundancy: This coding technique capitalizes on the temporal relationship between consecutive frames in a video sequence. It comes into play when there is little variation between two adjacent frames In such cases, the goal is to reduce the storage requirements for transmitting the subsequent frame by detecting the pixel shifts between these two successive frames. Consequently, the data (pixel values) of the second frame are encoded with reference to the preceding frame. Only the disparities between these two frames are subsequently transmitted. This methodisknown as inter-frame coding.




**Fig.4.4.** ***Example of temporal redundancy*** **[24].**

**Assessing Image Quality :**

The compression of video often diminishes the quality of compressed frames to different extents. Evaluating their quality is quite intricate. There are objective metrics for

quality assessment that rely on distortion calculations, with the Peak Signal to Noise Ratio (PSNR) being a commonly utilized metric in signal processing overall.

$$PSNR = 10 * log10 \left( \frac{(Amplitude\ Max)^2}{\frac{1}{N} * \sum_0^{N-1} (Original - Reconstruite)^2} \right)$$

The PSNR calculates the average squared error across the whole image without weighting. An alternative, SSIM (Structural SIMilarity) , adjusts defects' importance based on their local context. It's true that the human eye is less sensitive to defects in textured regions compared to uniform areas. However, in general, these metrics have significant limitations in gauging how humans perceive defects in images and how the brain processes them.

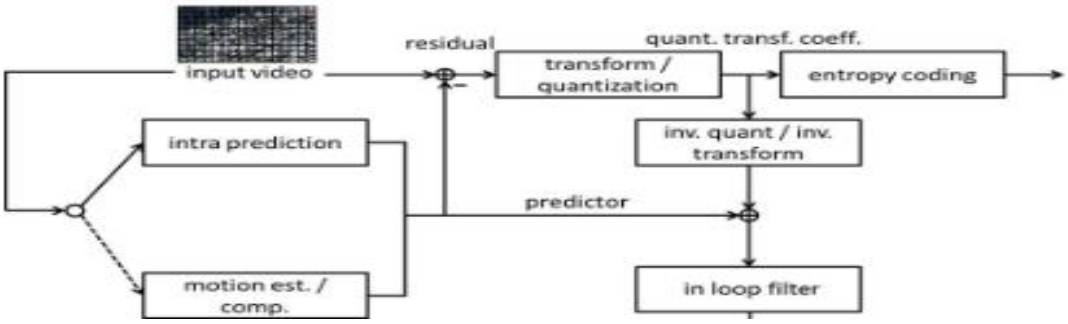



**Fig.4.5.** ***The block-based hybrid video coding scheme*** **[23].**

**Implementation of the standard :**

When crafting a standard, the aim is to grant encoder and decoder developers the utmost freedom to tailor their implementations. However, this freedom's constraint lies in maintaining interoperability, ensuring that all products can be decoded by any decoder regardless of their origin. This is achieved by stipulating the data format or approximation results produced by a decoder, while leaving the encoder's internal processing steps unspecified.

Consequently, there can be numerous implementations of a standard, each yielding varied outcomes such as PSNR-Bitrate curves or encoded fps-bitrate curves. In this particular project, x265 and HEVC HM 8.0 are utilized. Although x265 offers fewer HEVC options, resulting in inferior PSNR-bitrate results in comparison tests, it prioritizes complexity optimization over HM 8.0, hence its faster performance.

## 4.2. Basic Architecture on ImplementedCodec

The basic structure of an MPEG codec includes several essential components that work together to compress and decompress video and audio data. Here is a high level overview:

**Input:** raw video and audio data serve as the original input.

Pre-processing: This stage can include activities such as noise reduction, scaling and color space conversion to prepare the data for encoding.

**Compression:**

**Video:** Video compression typically uses motion compensation, discrete cosine transform (DCT) and quantization. Different MPEG standards such as MPEG-1, MPEG-2, MPEG-4 and MPEG-7 use their own methods and standards for video compression.

**Audio:** Audio data is compressed using techniques such as MP3 or AAC, depending on the MPEG standard.

**Encoding:** The compressed data is encoded into a format suitable for transmission or storage, often using bitstream encoding methods such as Context-Adaptive Binary Arithmetic Coding (CABAC).

**Output:** The encoded data is packaged into a container format such as MP4 or MPEG-2 Systems for distribution or storage.

When decoding, the process is carried out in reverse order. The encoded data is unpacked, decoded and post-processed to reconstruct the original audio and video content.

Each MPEG standard has its own architecture and functions. MPEG-1, for example, was developed for encoding moving images and associated audio for digital storage media at up to approx. 1.5 Mbps. MPEG-2 introduced support for interlaced video and high-definition television (HDTV), while MPEG-4 introduced video coding for video objects.

For a deeper insight, we recommend that you explore resources that provide systematic overviews of the algorithms and architecture of hardwired MPEG-like coders, focusing on H.264/AVC as the target of analysis. These resources address recent advances in the hardware architectures of popular H.264/AVC encoders.

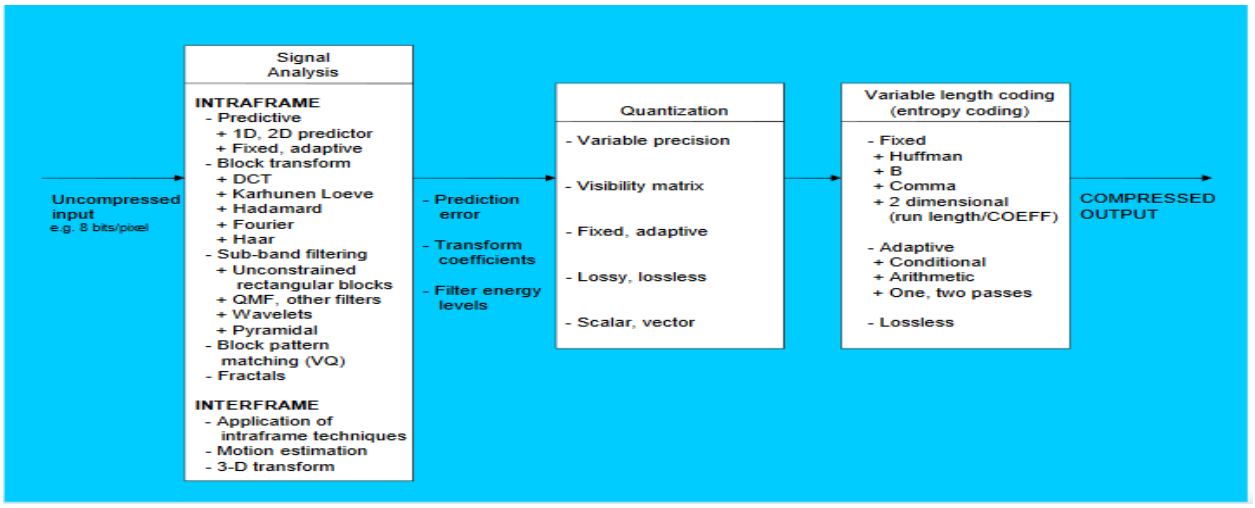



**Fig.4.6.** ***Video Compression System*** **[22]**

### Video Compression System :

All contemporary video compression systems function based on a shared principle and follow similar fundamental steps. The essence of video compression lies in minimizing file sizes by eliminating redundant data and non-critical information that is imperceptible to human vision. This process capitalizes on both temporal and spatial redundancies to extract the essential data needed for accurately reproducing the original images. A typical video compression setup consists of an encoder and a decoder, as depicted in Figure 4.7

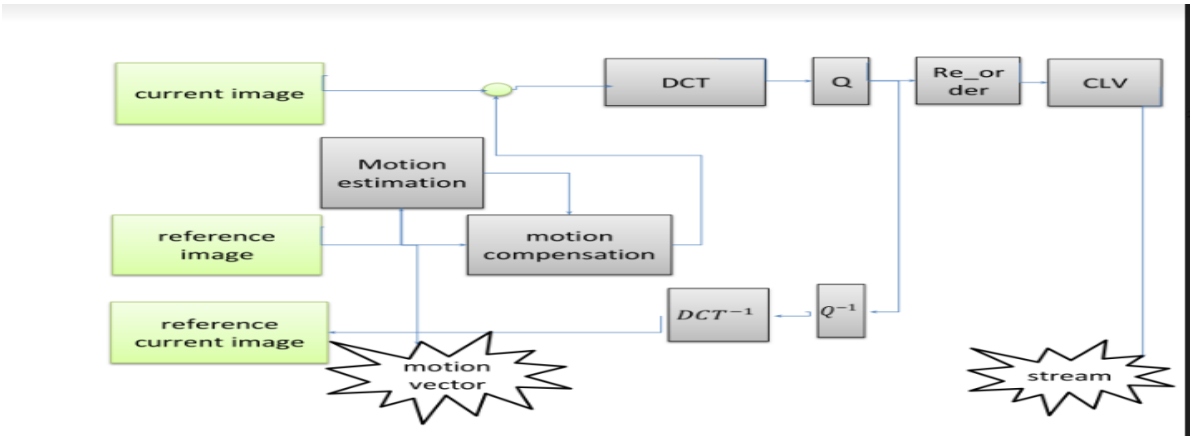



**Fig.4.7.** ***Overall diagram of a video encoder*** **[23]**

The encoder comprises three main modules: spatial compression, temporal compression (or prediction), and entropy coding. Initially, a parameterized video sequence is fed into the encoder.

Spatial compression works by removing redundancy between pixels within the same frame, exploiting the correlation among neighboring pixels. Through transformation, a frame is converted into coefficients, which are then quantized to yield a set of significant coefficients representing the frame more efficiently.

Temporal compression (or prediction), on the other hand, takes advantage of redundancy between adjacent frames to forecast subsequent frames using reference frames.

These compression processes transform a frame into coefficients, which are then subjected to additional statistical compression through entropy coding.

Conversely, the decoder reconstructs the video using the output sequence from the encoder. An entropy decoder decodes the coefficients and motion vectors, after which the decoder reconstructs a version of the residual frame. Following this, by utilizing a previously reconstructed frame, motion vectors, and the residual frame, the decoder retrieves the original frame.

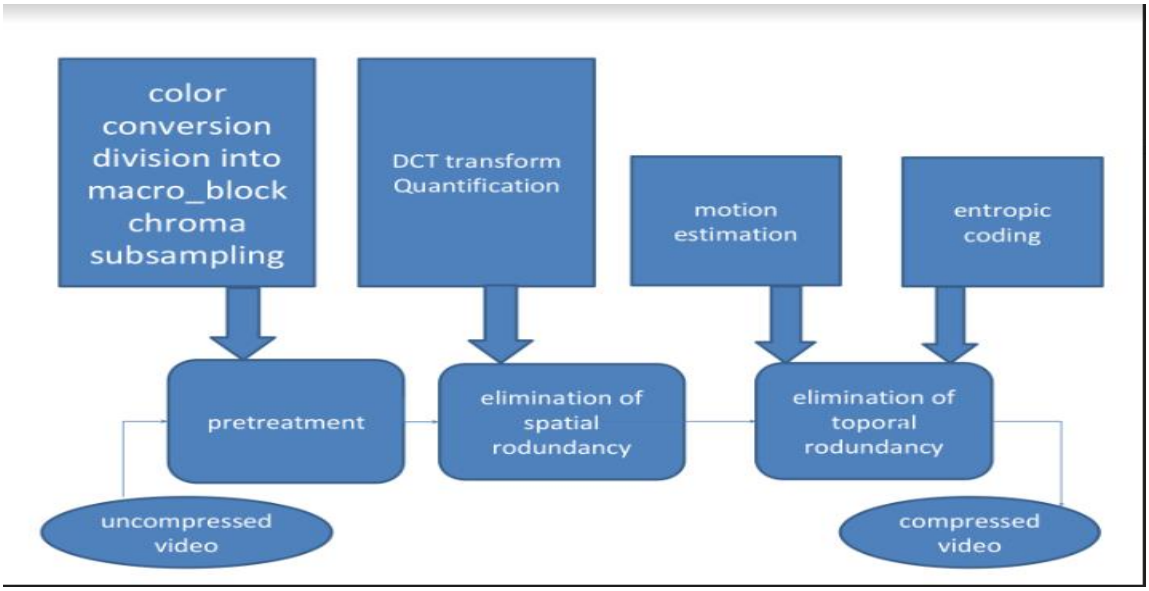



**Fig.4.8.** ***Modules of a video compression system*** **[23].**

## 4.3. Transformation

The concept of "transformation of MPEG" encompasses multiple facets related to MPEG (Moving Picture Experts Group) standards. Here are several key aspects:

MPEG Standards: MPEG functions as a consortium of working groups tasked with establishing standards for media coding. These standards cover the compression of audio, video, graphics, and genomic data, as well as defining transmission protocols and file formats for various applications.

Transform Coding: Within the realm of MPEG, transform coding represents a technique for encoding images. This process involves dividing an image into sub-pictures, applying a linear transformation to each sub-picture, and subsequently quantizing and coding the resulting coefficients.

MPEG Compression: MPEG utilizes algorithms for video and audio compression aimed at achieving higher compression ratios while retaining satisfactory quality. This entails employing methods such as spatial compression and motion compensation.

File Conversion: Additionally, "transformation" can signify the conversion of MPEG files into other formats. For example, this might involve converting MPEG video files into MP3 audio files, facilitating compatibility across different media platforms.

In summary, the term "transformation of MPEG" encompasses various dimensions, including standard setting, encoding techniques, compression strategies, and file format conversions.

## 4.4. Quantization

Quantization, as employed within MPEG (Moving Picture Experts Group), denotes a lossy compression method utilized in image and video processing. It entails condensing a range of values into a single quantum value, enhancing the compressibility of the data stream. This proves crucial for the efficient storage and transmission of digital media.

In MPEG video codecs, the image is segmented into discrete blocks, typically measuring 8x8 pixels. Each block undergoes a Discrete Cosine Transform (DCT) to compute its frequency components. Subsequently, the quantization process simplifies these frequency components by reducing the number of bits necessary for their representation. This is achieved by mapping a range of coefficient values to a single value, resulting in some loss of detail but significantly reducing the data volume.

For instance, higher frequency coefficients, which are generally less perceptible to the human eye, are typically more coarsely quantized than lower frequency coefficients. As a consequence, regions of the video with less intricate detail or movement can be depicted with fewer bits, whereas areas with greater detail receive more bits to maintain quality.

MPEG standards, such as MPEG-1 and MPEG-2, leverage this quantization process alongside other techniques like motion compensation and psycho-visual models to attain high compression rates without substantial deterioration in visual quality. This enables digital videos to be stored on media like CDs and DVDs and transmitted over bandwidth-constrained channels while upholding a quality comparable to or superior to VHS tapes.

## 4.5. DCT Approach For The Video Compression

The Discrete Cosine Transform (DCT) method stands as a widely employed technique in video compression, functioning by segmenting the video into pixel blocks and converting these blocks into the frequency domain through DCT. This transformation aids in segregating the image into segments of varying significance concerning visual quality.

Within the frequency domain, the majority of crucial visual information tends to reside in the lower frequencies. The DCT facilitates condensing this information, permitting the higher frequencies, which often contain less crucial visual data, to be coarsely quantized or discarded entirely. This process, termed lossy compression, entails some data loss but substantially reduces the data volume required to represent the video while preserving visual quality.

The fundamental steps involved in DCT-based video compression include:

**Block Splitting:** The video frame undergoes division into small blocks, typically measuring 8x8 pixels.

DCT Transformation: Each block experiences transformation from the spatial domain to the frequency domain using the DCT.

**Quantization:** The frequency coefficients undergo quantization, diminishing the precision of less visually significant high-frequency components.

**Entropy Coding:** The quantized coefficients subsequently undergo entropy coding using techniques like Huffman coding or arithmetic coding to further compress the data.

A recent study has integrated DCT with the Discrete Wavelet Transform (DWT) to achieve enhanced-scale video compression, demonstrating notable enhancements in performance metrics such as maximum difference, mean square error, and peak signal-to-noise ratio. This hybrid approach harnesses the strengths of both DCT and DWT to optimize video compression.

For more in-depth and technical insights, reference research articles exploring the specifics of these techniques. If interested in the mathematical representation of the DCT, it is typically defined as:

$$DCT(u,v) = 12C(u)C(v)\sum x = 07\sum y$$
$$= 07f(x,y)cos[(2x+1)u\pi 16]cos[(2y+1)v\pi 16]\,DCT(u,v)$$
$$= 21C(u)C(v)\sum x = 07\sum y$$
$$= 07f(x,y)cos[16(2x+1)u\pi]cos[16(2y+1)v\pi]$$

**Where:**

$(x)f(x,y)$Represents the intensity of the pixel in the $xx$-th row and $yy$-th column of the block.

$(u)C(u)$ and $(v)C(v)$ are coefficients dependent on the frequency variables $uu$ and $vv$, equal to 1221 for $u,v=0u,v=0$, and 1 otherwise.

This transformation proves pivotal in the compression process as it concentrates most of the signal within a few low-frequency components of the DCT.

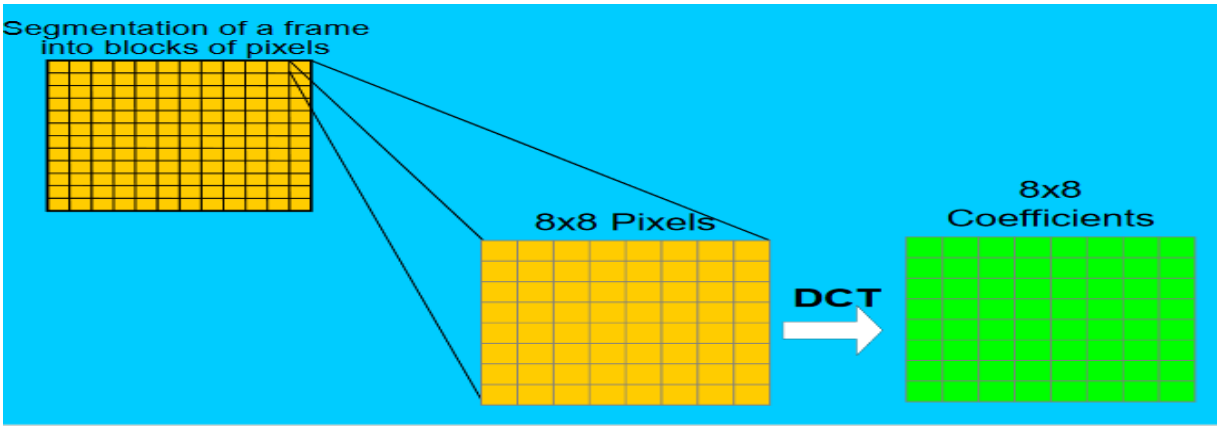



**Fig.4.9.** ***Transform Coding by Discrete Cosine Transform (DCT)*** **[22]**

The Discrete Cosine Transform (DCT) is a fundamental technique used in video compression, particularly within MPEG standards such as MPEG-1, MPEG-2, MPEG-4, and H.264/AVC. Here's how the DCT approach works for video compression within MPEG:

**1. *Spatial Domain to Frequency Domain Conversion:*** In video compression, each frame is divided into blocks of pixels, typically 8x8 or 16x16 pixels. The DCT is applied to each block independently, converting spatial domain pixel values into frequency domain coefficients.

**2. *Energy Concentration:*** The DCT process tends to concentrate the signal energy in a small number of low-frequency coefficients, while higher-frequency coefficients represent finer details or noise. This property makes the DCT well-suited for signal compression, as it allows for efficient quantization and coding of the transform coefficients.

**3. *Quantization:*** After the DCT, quantization is applied to the frequency coefficients to reduce the precision of the values. This step introduces lossy compression by discarding fine details and adjusting the amplitude of coefficients based on perceptual criteria or bitrate constraints.

**4. *Entropy Coding:***The quantized DCT coefficients are then encoded using entropy coding techniques such as Huffman coding or arithmetic coding. These coding schemes exploit statistical redundancies in the coefficient values to achieve further compression.

**5. *Motion Compensation:*** In addition to intra-frame compression using DCT, MPEG standards also employ inter-frame compression techniques such as motion compensation. Motion compensation exploits temporal redundancies between consecutive frames by estimating motion vectors and encoding the difference between predicted and actual pixel values.

**6. *Variable Bitrate Encoding:*** MPEG standards support variable bitrate encoding, allowing the allocation of more bits to complex or high-motion video sequences and fewer bits to less demanding sequences. This adaptive bitrate allocation improves coding efficiency and maintains consistent video quality across different scenes.

**7. *Hierarchical Structure:*** MPEG video compression typically employs a hierarchical structure, where video sequences are organized into Group of Pictures (GOP) consisting of I-frames (Intra-coded), P-frames (Predictive-coded), and B-frames (Bidirectional-coded). This structure enables efficient compression by exploiting both spatial and temporal redundancies within video sequences.

Overall, the DCT approach within MPEG video compression plays a central role in transforming spatial pixel data into frequency coefficients, enabling efficient compression through quantization, entropy coding, and motion compensation techniques.

## 4.6. Experimental Results

The experimental findings regarding MPEG (Moving Picture Experts Group) standards are extensive, covering various aspects of video and audio compression. Here are some notable insights gleaned from recent research:

.An analysis featured in the APSIPA Transactions on Signal and Information Processing offers a comprehensive examination of the rate-distortion performance within MPEG point cloud compression. This study is a component of the collaborative endeavors between the JPEG and MPEG standardization committees aimed at establishing an emerging standard for point cloud compression.

.Another investigation delves into the comparison between MPEG-2 and H.264 video coding, focusing on transform video coding and motion-compensated video coding. This study presents experimental results evaluating each feature in H.264, accompanied by a detailed discourse on the digital video quality.

Research presented in the IEEE Transactions on Broadcasting addresses the coding efficiency of diverse MPEG tools for 3D point clouds. Experimental outcomes reveal that TMC2 exhibits the highest coding efficiency on average for dense point clouds, whereas TMC13 achieves optimal performance for sparse and noisy point clouds.

These studies play a crucial role in advancing and refining MPEG standards, ensuring the efficient and high-quality compression of digital media.

## Evaluation :

**1/** [mov,imgRgb]=loadFileY4m('bus_cif.y4m',352,288,150);

This line loads a Y4M format video file named 'bus_cif.y4m' with a resolution of 352x288 and a duration of 150 frames. It stores the movie data in mov and the RGB image in imgRgb.

**2 /** s = loadFileYuv('BUS_352x288_15_orig_01.yuv',352,288,150);

Loads a YUV format video file named 'BUS_352x288_15_orig_01.yuv' with a resolution of 352x288 and a duration of 150 frames. The data is stored in s.

**3/** save bus movimgRgb

Saves the mov and imgRgb data into a MATLAB file named 'bus.mat'.

**4/**sec2timestr(1), sec2timestr(11), sec2timestr(111), etc.

These lines call the sec2timestr function with different arguments (time in seconds) to convert the time into a string representing the number of hours, minutes, and seconds.

**5/**mpegprojThis line seems to call a function named mpegproj, probably for MPEG video processing or projection.

**6/**progressbar, progressbar(0), progressbar(0,4), etc.

These lines seem to call the progressbar function with different arguments to display or initialize a progress bar.

**7/** n = 1000;, for i = 1:n, progressbar(i/n), etc.

These lines seem to define a for loop from 1 to 1000, and at each iteration, they update the progress bar with the loop's progress.

**8/**quiverplotThis line seems to call a function quiverplot to display a vector plot, often used in physics or image processing to represent vector fields.

This code appears to be a series of MATLAB commands and function calls. Let'sevaluateeach part:

1. **LoadingVideo Files:**

[mov,imgRgb]=loadFileY4m('bus_cif.y4m',352,288,150);

s = loadFileYuv('BUS_352x288_15_orig_01.yuv',352,288,150);

save bus movimgRgb

.This section loads two video files ('bus_cif.y4m' and 'BUS_352x288_15_orig_01.yuv') and saves the movie data and RGB image data into a MATLAB file named 'bus.mat'. Without knowledge of the loadFileY4m and loadFileYuv functions, it's difficult to assess the correctness or effectiveness of this section.

2. **Converting Seconds to Time String:**

sec2timestr(1) % => '1 sec'

sec2timestr(11) % => '11 sec'

sec2timestr(111) % => '1 min, 51 sec'

sec2timestr(1111) % => '18 min'

sec2timestr(11111) % => '3 hr, 5 min'

sec2timestr(111111) % => '1 day, 6 hr'

sec2timestr(1111111)% => '12 day 3 hr'

.These lines seem to test a function sec2timestr which converts time in seconds to a human-readable format. The expected output isprovided as comments.

3. **MPEG Projection**

This line presumably calls a function named mpegproj related to MPEG video processing. Without knowing its implementation, it's hard to evaluate its purpose or correctness.

4. **Progress Bar Initialization and Update:**

progressbar % Initialize/reset

progressbar(0) % Initialize/reset

progressbar(0,4)  % Initialize/reset and specify position

progressbar(0,[0.2 0.7])  % Initialize/reset and specify position

progressbar(0.5)  % Update

progressbar(1)

These lines seem to deal with initializing and updating a progress bar. The function progressbar is likely used for this purpose, with different arguments for initialization and update.

**5. Progress Bar Loop:**

n = 1000;

progressbar(0.5) % Create figure and set starting time

fori = 1:n

pause(0.01) % Do something important

progressbar(i/n) % Update figure

end

.This section initializes a loop with 1000 iterations and updates the progress bar inside the loop. It pauses for a small amount of time in each iteration (0.01 seconds) to simulate some important computation.

**6. Quiver Plot:**

This line appears to call a function quiverplot, possibly to generate a vector plot. Its purpose and correctness depend on the implementation of the quiverplot function, which is not provided here.



**Fig.4.10.** ***Védéo original and vedeocomprésé***

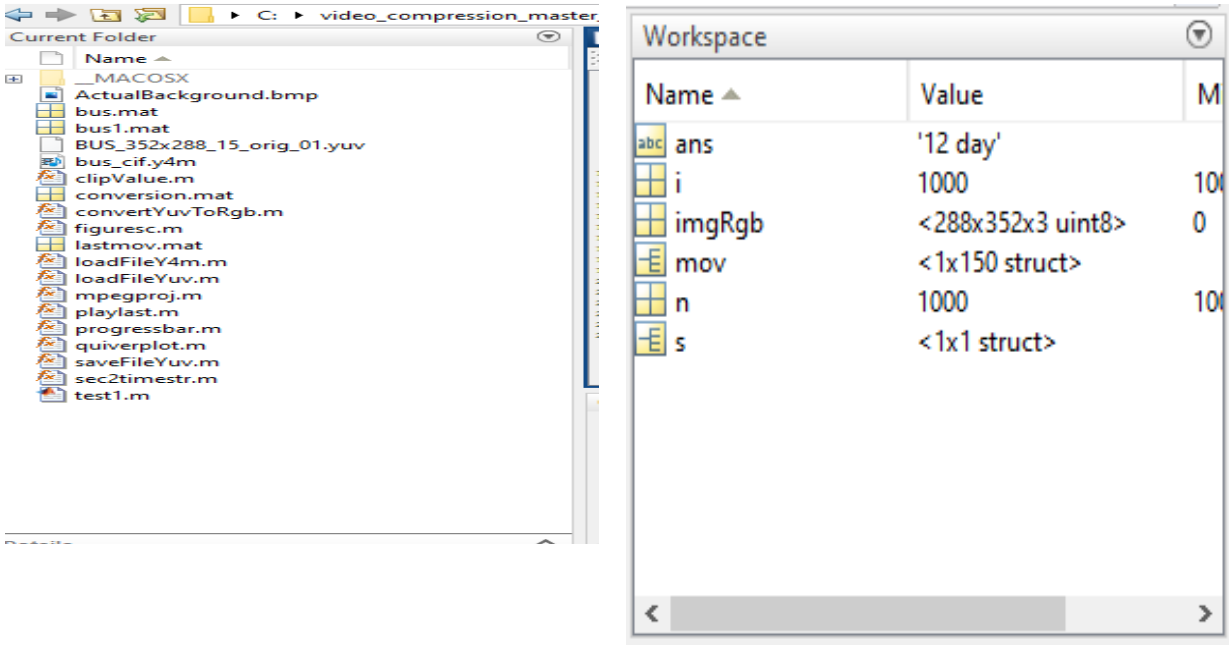



**Fig.4.11.** ***:folders of works***

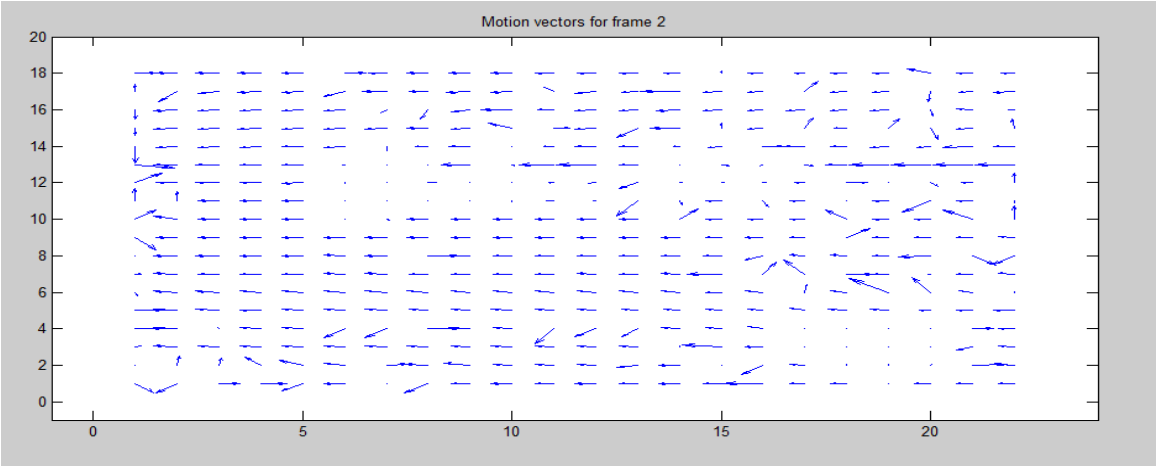



**Fig.4.12.** ***:Montionvector for frame 2***

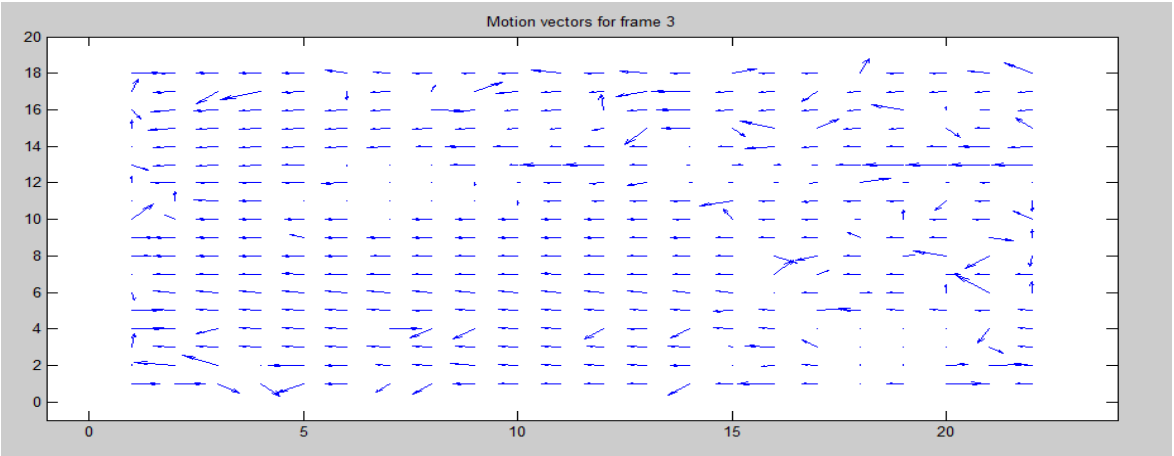



**Fig.4.13.** ***:Montionvector for frame 3***

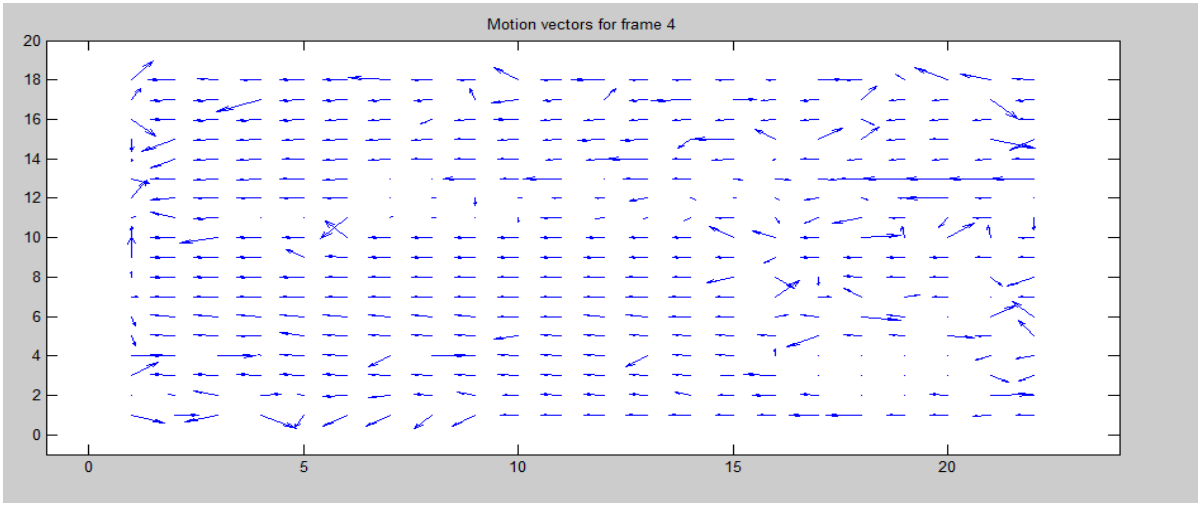



**Fig.4.14.** ***:Montionvector for frame 4***

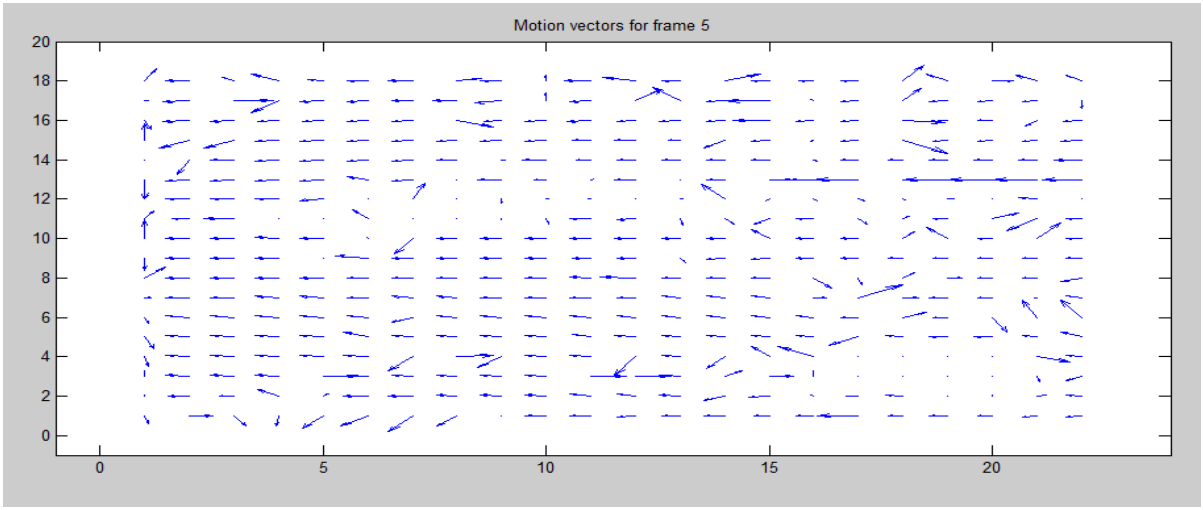



**Fig.4.15.** ***:Montionvector for frame 5***

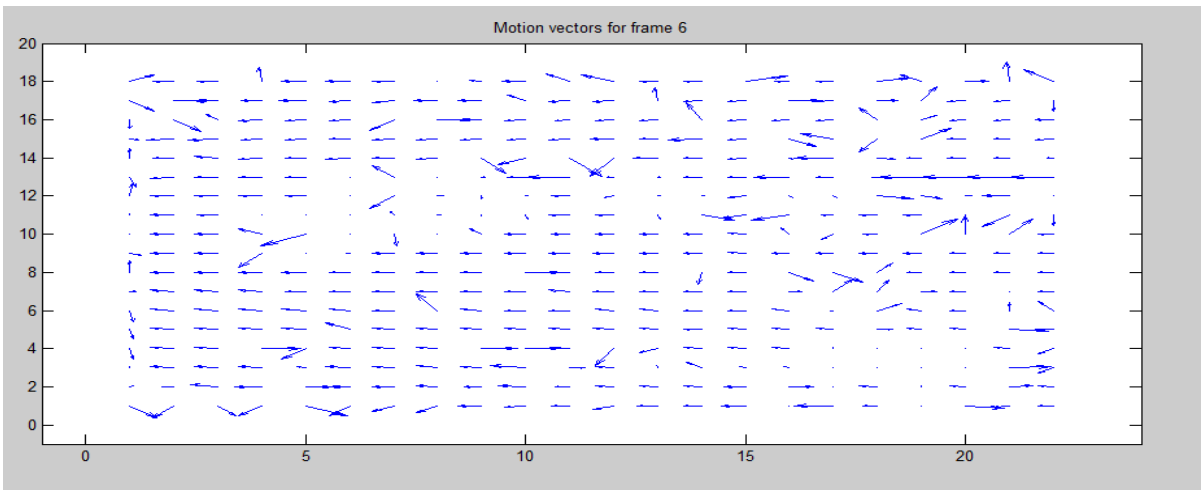



**Fig.4.16.** ***:Montionvector for frame 6***

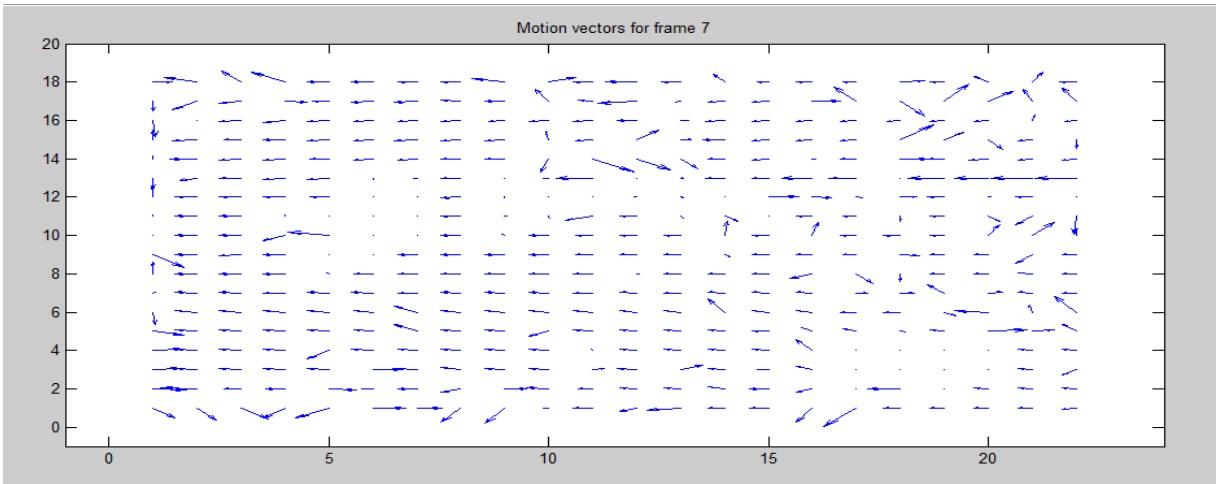



**Fig.4.17.** ***:Montionvector for frame 7***

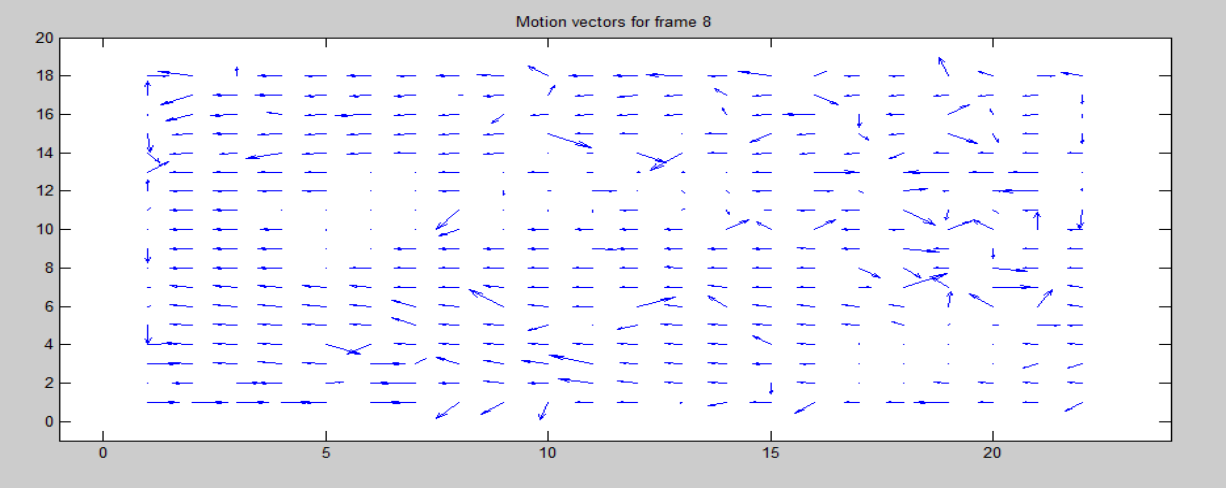



**Fig.4.18.** ***:Montionvector for frame 8***

In summary, the evaluation of this code depends heavily on the implementation of the custom functions (loadFileY4m, loadFileYuv, sec2timestr, mpegproj, progressbar, and quiverplot) and their correctness and effectiveness cannot be determined without further context or examining their definitions. Additionally, the code seems to involve video processing, time conversion, progress tracking, and vector plotting.

And The combination of motion-compensated prediction techniques and the Discrete Cosine Transform (DCT) can be defined as the key elements of MPEG-type video compression. A third characteristic element is that these techniques are used for small image blocks (often 16x16 pixels for motion compensation and 8x8 pixels for DCT coding). For these reasons, MPEG coding is part of the DPCM/DCT hybrid algorithms.

**Summary of MPEG Implementation and Experimental Results for MPEG-2, MPEG-4, and MPEG-G :**

**MPEG-2 Implementation and Experimental Results**

**Implementation:**

- **Purpose:** Designed for digital television broadcasting and DVDs, supporting both standard definition (SD) and high definition (HD) video.

- **Components:**

- ***Video Encoding*:** Utilizes techniques such as Discrete Cosine Transform (DCT), motion compensation, and variable-length coding. It supports interlaced video.

- ***Audio Encoding*:** Includes support for multiple audio channels and various sampling rates.

- ***Multiplexing*:** Combines multiple streams (audio, video, and data) into a single stream.

**Experimental Results:**

- ***Compression Efficiency*:** Improved over MPEG-1, providing higher quality video at similar bitrates.

- ***Quality*:** Maintains good quality for broadcast and DVD standards, handling both interlaced and progressive video efficiently.

- ***Adoption*:** Widely adopted for broadcasting and DVDs due to its robustness and compatibility across various devices.

**MPEG-4 Implementation and Experimental Results**

**Implementation:**

- ***Purpose*:** Advanced multimedia standard supporting various content types, including video, audio, 3D graphics, and interactive applications.

- **Components:**

- ***Video Encoding*:** Incorporates advanced techniques such as object-based coding, shape coding, texture coding, and improved motion estimation. It supports both simple and complex profiles for different applications.

- ***Audio Encoding*:** Includes advanced audio codecs like AAC (Advanced Audio Coding).

- ***Interactivity*:** Supports rich interactive content and 3D graphics.

**Experimental Results:**

- ***Compression Efficiency*:** Higher than MPEG-2, especially at lower bitrates, making it suitable for streaming and mobile applications.

- ***Quality*:** Provides better quality at lower bitrates due to advanced coding techniques.

- ***Flexibility*:** Highly flexible and scalable, supporting various multimedia applications from simple video streaming to interactive and 3D content.

- ***Adoption*:** Widely used in online streaming, mobile video, and video conferencing.

**MPEG-G Implementation and Experimental Results (2019)**

**Implementation:**

- ***Purpose*:** Designed specifically for genomic information representation, addressing the needs of genomics data compression and efficient processing.

- **Components:**

  - ***Compression*:** Efficiently compresses large genomic datasets.

  - ***Data Access*:** Allows for fast access and querying of compressed genomic data.

- ***Interoperability*:** Ensures compatibility across different genomic data processing systems.

**Experimental Results:**

- ***Compression Efficiency*:** Demonstrates significant reduction in storage requirements for genomic data.

- ***Processing Speed*:** Enables faster processing and querying of genomic data compared to traditional formats.

- ***Adoption*:** Gaining traction in the field of genomics for efficient data handling and storage.

**MPEG [A, B, C, D] Implementation and Experimental Results**

These designations typically refer to specific parts or profiles within the MPEG standards. Here's a generalized summary:

**Implementation:**

- ***MPEG-A*:** Multimedia Application Formats, designed to ensure interoperability across different multimedia applications.

- ***MPEG-B*:** Provides support technologies, such as binary MPEG format for XML (BiM).

- ***MPEG-C*:** Covers MPEG tools and frameworks, including Reconfigurable Media Coding (RMC).

- ***MPEG-D*:** Relates to audio standards, including audio coding and processing frameworks.

**Experimental Results:**

- ***Interoperability*:** Ensures smooth integration across various multimedia applications and devices.

- ***Efficiency*:** Each part (A, B, C, D) addresses specific needs, improving efficiency in multimedia processing and delivery.

- ***Adoption*:** Widely adopted in respective domains, such as multimedia application formats, XML data handling, reconfigurable coding, and audio processing.

**MPEG2 vs MPEG4:**

When it comes to the MPEG2 vs MPEG4 debate, several crucial distinctions define their respective strengths and applications.

MPEG2 gives better video quality but at the cost of larger file size compared to MPEG4.

MPEG4 shows higher compression ratio, which is better when it comes to conserve storage space and data transmission.

MPEG2 requires much more bandwidth for online streaming while MPEG2 faciliates smoother streaming experience.

MPEG-4 is a far more versatile encoding format overall compared to MPEG-2.

MPEG2 is the encoding method for DVDs, while MPEG4 is tailored for portable devices and online use.

For its higher compression, smaller size and extensive applications, so ripping DVD to MPEG4 would be a good choice.

MPEG2 and MPEG4 are popular formats used in different domains. Which one is more suitable for you is depend on your specific demands. For example, it is good to convert DVD to MPEG4 in order to play discs on various devices Differences between MPEG2 and MPEG4 MPEG2 vs MPEG4 – Filename Extensions

MPEG2: .mpg, .mpeg, .m2v, .mp2, mp3 are some of a number of filename extensions used

MPEG-2 audio and video file formats.

MPEG4: .mp4, .m4a, .m4b, .m4r, .m4v are some file extensions of MPEG4 video/audio.

MPEG2 vs MPEG4 – Compression :

Video and audio compression aim to maintain audio or video quality while reducing the number of bits required. In this regard, MPEG4 outperforms MPEG2 due to its more advanced compression algorithm. MPEG2 employs lossy video compression and lossy audio data compression methods, whereas MPEG4 files can be lossless, though commonly, they are lossy to achieve smaller file sizes.

MPEG2 vs MPEG4 - File Size :

MPEG4 encodes video files in significantly smaller sizes, enabling full-length movies to occupy less than 1 GB of space, while MPEG2 results in files approximately five times larger.

MPEG2 is suitable for DVD storage, given its compatibility with capacities greater than GB, but is less practical for portable devices. In contrast, the smaller size of MPEG4 Facilitates online video purchasing and downloading. This difference also signifies a higher compression ratio for MPEG4, albeit at the expense of file size, while MPEG2 offers superior video quality at the cost of larger files.

MPEG2 vs MPEG4 – Quality :

MPEG2 produces flawless quality compared to MPEG4 but it is not made for multimedia

applications or online streaming. As mentioned above, MPEG2 can deliver better video audio quality but larger fize size is a payoff. The large size of MPEG2 makes the format impractical for network streaming. While MPEG4 provides better performance when being streamed online.

MPEG2 vs MPEG4 – Application:

MPEG2 is the encoding method used for television broadcast and DVDs. MPEG-2 is also a video coding formats supported by Blu-ray Disc. But new Blu-ray discs prefer H.264

instead of MPEG2. Blu-ray only supports MPEG-2 video (MPEG-2 part 2), MPEG-2 audio (parts 3 and 7) is not compatible. While MPEG4 coding standard is primarily applied to portable devices, Internet streaming, CD distribution, and broadcast television applications because of its smaller file size compared to MPEG2.

The Future of Video Compression:

Looking ahead, the future of video compression is likely to be shaped by the ongoing quest for higher quality video, more efficient compression algorithms, and new features that enhance the viewing experience. New video compression standards, such as H.265 (also known as HEVC) and AV1, are already pushing the boundaries of what's possible with video compression. These standards offer even greater compression efficiency than MPEG-4, Enabling higher quality video at even lower bit rates. They also introduce new features, such as support for 4K and 8K video, high dynamic range (HDR), and 360-degree video. As these new standards are adopted by the industry, it's likely that we'll see a shift away from MPEG-2 and MPEG-4 towards these more advanced standards. However, MPEG-2 and MPEG-4 will likely continue to play a role in the industry for many years to come, thanks to their widespread adoption and robustness in handling a wide range of video formats and resolutions. In conclusion, the evolution of video compression technology is a testament to the ingenuity and innovation of the engineers, researchers, and industry professionals who have worked tirelessly to push the boundaries of what's possible with digital video. As we look to the future, it's clear that the journey is far from over, and we can expect to see even more exciting advancements in the years to come.

As we delve into the future of video compression, it's impossible to ignore the rapid advancements in technology that are shaping this landscape. The world of video compression is a dynamic one, with new standards and technologies emerging at a rapid pace. These developments are driven by the ever-increasing demand for high-quality video content, coupled with the need for efficient data transmission and storage. The evolution from MPEG-2 to MPEG-4 has already marked a significant leap in video compression technology, but what does the future hold? Let's embark on a journey of speculation, exploring the potential developments in this fascinating field.

**Conclusion**

MPEG-2 and MPEG-4 have significantly contributed to digital video and audio compression, enabling advancements in broadcasting, DVD technology, and online streaming. MPEG-G, focusing on genomic data, has introduced efficient data compression and processing methods for genomics. The various parts of MPEG [A, B, C, D] ensure

comprehensive support and interoperability across different multimedia applications and technologies. Each standard and component has been experimentally validated to ensure robustness, efficiency, and high-quality multimedia experiences.

## 4.7. Summary

In this section, the focus was on the implementation and experimental results of various video compression techniques, particularly those related to the MPEG-2 video codec. The study aimed to provide a comprehensive understanding of how these techniques are applied in practical scenarios, their underlying architecture, and their effectiveness through experimental evaluation. The MPEG-2 video codec was implemented to understand its practical applications and performance, involving the development of a functional codec capable of encoding and decoding video streams according to MPEG-2 standards. The basic architecture of the implemented codec was dissected to reveal its core components, including input video preprocessing, transformation stages, quantization, and entropy coding, with each component's role in the overall compression process highlighted.

The transformation stage focused on converting spatial domain video data into the frequency domain using techniques like the Discrete Cosine Transform (DCT), crucial for reducing spatial redundancy and preparing data for subsequent quantization. Quantization was explored as the process of reducing the precision of transformed coefficients, essential for achieving high compression ratios by discarding less significant data, though it introduces some level of lossy compression. The impact of various quantization strategies on video quality and compression efficiency was analyzed. The study delved deeper into the DCT approach for video compression, central to the MPEG-2 codec, discussing its effectiveness in transforming video data, reducing redundancy, and facilitating efficient compression. Various experiments were conducted to evaluate the performance of DCT-based compression.

The experimental results presented a comprehensive evaluation of the implemented MPEG-2 video codec, using metrics such as compression ratio, video quality (measured using PSNR and SSIM), and computational efficiency to assess performance. The results demonstrated the codec's capability to balance compression efficiency with video quality effectively. The evaluation highlighted the strengths and weaknesses of the implemented MPEG-2 video codec, noting that while MPEG-2 offers robust compression and maintains reasonable video quality, there are trade-offs in terms of computational complexity and the extent of lossy compression. The findings provided insights into potential areas for improvement and future research directions in video compression technologies. Overall, this

section illustrated the practical aspects of implementing a video codec, the critical processes involved, and the evaluation of its performance through experimental analysis.

# Chapter 5

# *5 Conclusions& Future work*

## 5.1. Conclusions

The Moving Picture Experts Group (MPEG) has significantly transformed the digital media landscape through its pioneering standards for audio and video compression, transmission, and storage. By developing universally accepted standards such as MPEG-1, MPEG-2, MPEG-4, and HEVC, MPEG has enabled efficient compression techniques that reduce bandwidth and storage requirements while maintaining high-quality media content. This has facilitated the proliferation of digital media across a wide range of platforms and devices.

MPEG's commitment to interoperability has ensured seamless integration and compatibility across diverse media ecosystems, fostering a cohesive and connected digital environment. The group's adaptability in incorporating emerging technologies has allowed it to support advancements in high-definition video, immersive experiences like VR and AR, and new content formats including 3D graphics and genomic data.

The broad adoption of MPEG standards across industries, including broadcasting, streaming, digital cinema, and mobile communications, highlights their critical role in modern multimedia experiences. MPEG has driven innovation in multimedia applications, enhancing user experiences through improved video quality, interactive features, and efficient content delivery mechanisms.

In conclusion, MPEG has been a cornerstone in the evolution of digital media, providing essential technologies that underpin efficient, high-quality, and interoperable audio and video experiences globally. Its ongoing evolution and responsiveness to technological advancements ensure that MPEG standards will continue to play a pivotal role in the future of digital media.

## 5.2. Future Work

The future work of the Moving Picture Experts Group (MPEG) will likely focus on several key areas to continue advancing multimedia technology and addressing emerging needs. Here are some general directions for MPEG's future work:

**1. *Enhanced Compression Efficiency:***

- Developing new video and audio codecs that offer higher compression efficiency, such as VVC (Versatile Video Coding) and beyond, to support even higher resolution content like 8K and beyond.

- Focusing on reducing latency and improving real-time processing capabilities for live streaming and interactive applications.

**2. *Support for Emerging Technologies:***

- Expanding standards to support immersive media experiences, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), ensuring high-quality and low-latency performance.

- Developing standards for new types of content, such as volumetric video and light field displays, which can capture and render complex 3D scenes.

**3. *Integration of AI and Machine Learning:***

- Leveraging artificial intelligence (AI) and machine learning (ML) techniques to optimize compression algorithms and improve content delivery networks.

- Enhancing content personalization and recommendation systems through AI-driven analytics and user behavior insights.

**4. *Improving Interoperability and Compatibility:***

- Ensuring backward compatibility with existing standards while introducing new features and capabilities.

- Promoting interoperability across different platforms and devices, including IoT (Internet of Things) and smart home ecosystems.

**5. *Advancing Audio Standards:***

- Continuing to improve audio compression standards to support high-resolution audio, spatial audio, and immersive sound experiences.

- Developing standards for emerging audio applications, such as binaural audio for VR and AR.

**6. *Security and Privacy:***

- Enhancing security features within MPEG standards to protect against piracy, unauthorized access, and cyber threats.

- Implementing robust privacy controls to ensure compliance with evolving data protection regulations and safeguard user information.

**7. *Sustainability and Efficiency:***

- Focusing on energy-efficient encoding and decoding processes to reduce the environmental impact of large-scale media processing and distribution.

- Encouraging sustainable practices in content creation, delivery, and consumption.

**8. *Genomic Data and Bioinformatics:***

- Expanding the application of MPEG standards to fields like bioinformatics and genomic data compression, facilitating efficient storage and analysis of large-scale biological datasets.

**9. *Standardization and Collaboration:***

- Continuing to work with international standardization bodies, industry stakeholders, and academic institutions to develop and refine standards.

- Facilitating collaboration and knowledge sharing to ensure that MPEG standards remain at the forefront of multimedia technology advancements.

By focusing on these areas, MPEG will continue to drive innovation and set the benchmarks for multimedia technology, ensuring high-quality, efficient, and secure media experiences for the future

# *References*


**[1] Richardson, I. E. G. (2010). Codec Design: Developing Image and Video Compression Systems. John Wiley & Sons.**

**[2] Iain E Richardson. Video codec design: developing image and video compression systems, John Wiley & Sons, 2002.**

**[3] M. Brogui& N. Boumaraf, (2015), "Detection and Tracking of a Suspicious Object in the Context of Video Surveillance", KasdiMerbah University-Ouargla.**

**[4] A. Neggara (2021), " Compression of Video Sequences Using Wavelet Transform and Their Application to Communication Systems", SaadDahlab University- BLIDA 1.**

**[5] National Television System Committee (NTSC) Modulation Standard. (n.d.). The Impressionistic Era of TV.**

**[6] Jakobs, K. New applications in IT standards development and progress. Aachen University, Germany**

**[7] Gulati, R.R. Monochrome and colour television: Revised second edition. New Delhi, India: New Age International (P) Limited.**

**[8] Jack.K (2005).Video Demystified: A Handbook for the Digital Engineer (5th ed).Newnes .**

**[9] Quora. (n.d.). How does interlaced video use less bandwidth? Retrieved June 6, 2024, from https://www.quora.com/How-does-interlaced-video-use-less-bandwidth**

**[10] Zalameda, J. N., Howell, P. A., & Winfree, W. P.Compression techniques for improved algorithm computational performance. U. S. Army Research Laboratory, Vehicle Technology Directorate, Nondestructive Evaluation Sciences Branch MS 231, NASA Langley Research Center 23681.**

**[11] Sayood, K. (2012). Introduction to Data Compression (4th ed.). Morgan Kaufmann.**

**[12] Watkinson, J. (Year of Publication). The art of digital video (4th ed.).**

**[13] Vcodex. (s.d.)."Historical Timeline of Video Coding Standards and Formats." Retrieved from https://www.vcodex.com/historical-timeline-of-video-coding-standards-and-formats**

**[14] VCODEX. (n.d.). Historical timeline of video coding standards and formats. Retrieved June 12, 2024, from https://www.vcodex.com/historical-timeline-of-video-coding-standards-and-formats**

**[15] Science Direct. (s.d.).Video Compression Standard. Retrieved from https://www.sciencedirect.com/topics/computer-science/video-compression-standard**

**[16] Wikipedia. (s.d.).MPEG-2. Retrieved from https://en.wikipedia.org/wiki/MPEG-2**

**[17] M.P. Polytechnic College.(s.d.)."CS88MPEG2new.pdf." Retrieved from https://mppolytechnic.ac.in/mp-staff/notes_upload_photo/CS88MPEG2new.pdf**

**[18] I. E. G. Richardson, H.264 and MPEG-4 Video Compression, Wiley, Hoboken, NJ, 2003.**

**[19] MPEG. (s.d.).White Paper on MPEG AAC Family of Codecs. Retrieved fromhttps://mpeg.chiariglione.org/standards/mpeg-4/white-paper-mpeg-aac-family-codecs**

**[20] Angelides, M. C., &Agius, H. (2013). The Handbook of MPEG Applications: Standards in Practice.**

**[21] MPEG-G." Standards – MPEG, www.mpeg.org/standards/MPEG-G/.**

**[22] Delta Digital Video. (n.d.). An introduction to video compression.**

**[23] Bouzenad, A. (2013). Étude des différentes normes de compression vidéo. École Nationale Polytechnique, juin 2013.**

**[24] Journal of Visual Communication and Image Representation. (2011). Volume 22, Issue 7, Pages 615-626.**