Fundamentals of Video Compression

- Introduction to Digital Video
- Basic Compression Techniques
- Still Image Compression Techniques - JPEG
- Video Compression

Introduction to Digital Video

- Video is a stream of data composed of discrete frames, containing both audio and pictures
- Continuous motion produced at a frame rate of 15 fps or higher
- Traditional movies run at 24 fps
- TV standard in USA (NTSC) uses ≈ 30 fps

Motivation for Video Compression

Main reasons for compression of digital video:

a) large storage requirement (a 30 minute video may require 50 GB of storage!!!)

b) limited network bandwidth for real time video transmission

Compression Constraints

- Quality
- Compression Rate
- Complexity
- Delay

Multimedia Compression Basics

- Compression is a process where a collection of algorithms, and techniques replace the original pixel-related information with more compact mathematical description
- Two basic types of compression are *lossless* and *lossy*

Lossless vs. Lossy Compression

- In lossless compression, data is not altered or lost in the process of compression or decompression
- Some examples of lossless standards are:
  - Run-Length Encoding
  - Dynamic Pattern Substitution - Lampel-Ziv Encoding
  - Huffman Encoding
- Lossy compression is used for compressing audio, pictures, video
- Some examples are:
  - JPEG
  - MPEG
  - H.261 (Px64) Video Coding Algorithm

Run-length Encoding

- Simplest and earliest data compression scheme developed
- Sampled images and audio and video data streams often contain sequences of identical bytes
- by replacing these sequences with the byte pattern to be repeated and providing the number of its occurrence,data can be reduced substantially

Dynamic Pattern Substitution

- When we have no prior knowledge of the sequences of symbols occurring frequently
- While encoding the stream, a code table must be constructed

Lempel-Ziv Encoding

- The basic idea is never to copy a sequence of bytes to the output stream that the encoder has seen before
- This encoding is used in the UNIX compress utility

Algorithm :

1. Initialize the code table with the elements of the alphabet,one entry for each character.
2. Initialize the scan window as empty : [ ].
3. Accept the next chracter K from the input stream and concatenate it with the scan window : [w]k.
4. Do we have an entry for [w]k in the code table ?.
   - -If yes, integrate K into the scan window : w1 := [wK] and goto 3.
   - -If no, add [w]K as a new entry to the code table ,write the index of [w] to the output stream,set [w] :=[K] and goto 3.
5. When the end of the input stream is reached process [w] from left to right,choosing the longest possible substrings from the code.

Huffman Encoding

- David Huffman proposed an algorithm for constructing a variable-length code, an Optimal algorithm
- Winzip the most popular compression utility uses Huffman Algorithm

Still Image Compression - JPEG

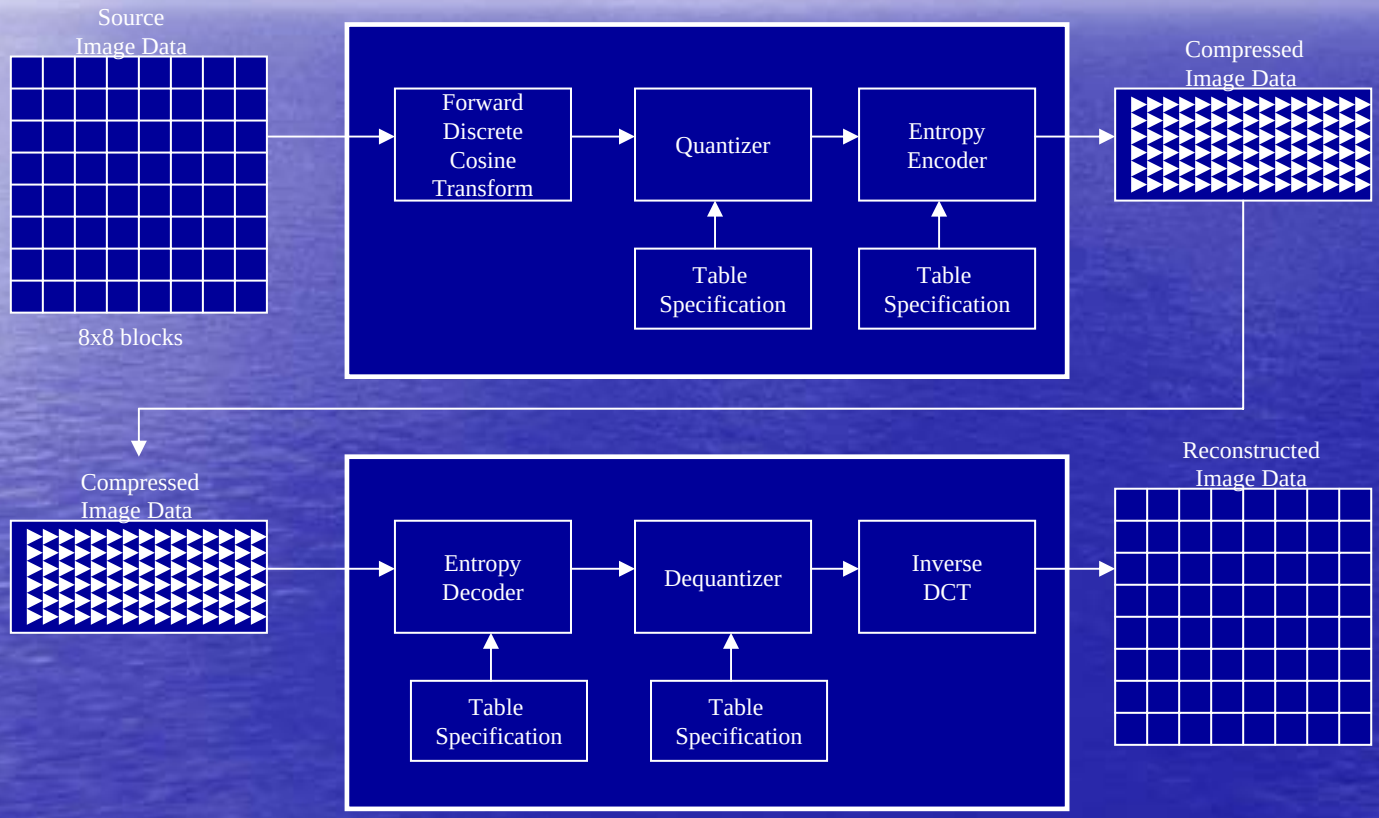
- Defined by *Joint Photographic Experts Group*
- Released as an ISO standard for still color and gray-scale images
- Provides four modes of operation:
  - Sequential (each pixel is traversed only once)
  - progressive (image gets progressively sharper)
  - Hierarchical (image compressed to multiple resolutions)
  - lossless (full detail at selected resolution)

Definitions in the JPEG Standard

Three levels of definition:

- Baseline system (every codec must implement it)
- Extended system (methods to extend the baseline system)
- Special lossless function (ensures lossless compression/ decompression)

Sequential JPEG Encoder and Decoder



Benefits Provided by DCT

- DCT is proven to be optimal transform for large classes of images
- DCT is an orthogonal transform: it allows conversion of the spatial representation an 8x8image to the frequency domain therefore reducing the number of data points
- DCT coefficients are easily quantized to achieve good compression
- DCT algorithm is efficient and easy to implement
- DCT algorithm is symmetrical

Quantization

- Quantization is a process that attempts to determine what information can be safely discarded without a significant loss in visual fidelity (“lossy” stage)
- Based on a set of quantization tables derived from empirical experimentation

Video Compression

Utilizes two basic compression techniques:

- **Interframe** compression
  - compression between frames
  - designed to minimize data redundancy in successive pictures(Temporal redundancy)
- **Intraframe** compression
  - occurs within individual frames
  - designed to minimize the duplication of data in each picture(Spatial Redundancy)

Classification of Scalable Video Compression Techniques

- DCT-based schemes
  - — MPEG1
  - — MPEG2
  - — H.261
  - — H.263
- Wavelet/sub-band
- Fractal-based
- Image segmentation/region based
  - — MPEG4

Various MPEG Standards

- MPEG-1
  - 320x240 full-motion video
  - 1.5 Mb/s
- MPEG-2
  - higher resolution and transmission rate 3-15Mb/s
  - defines different levels (profiles) for scalability
- MPEG-4
  - full-motion video at low bitrate (9-40 Kbps)
  - intended for interactive multimedia, video telephony

MPEG Compression Standards

Implements both **intraframe** and **interframe** coding

•**Intraframe(Spatial Redundancy)** is DCT-based and very similar to JPEG

• **Interframe(Temporal Redundancy)** uses block-based motion compensation

— utilized for reducing temporal redundancy

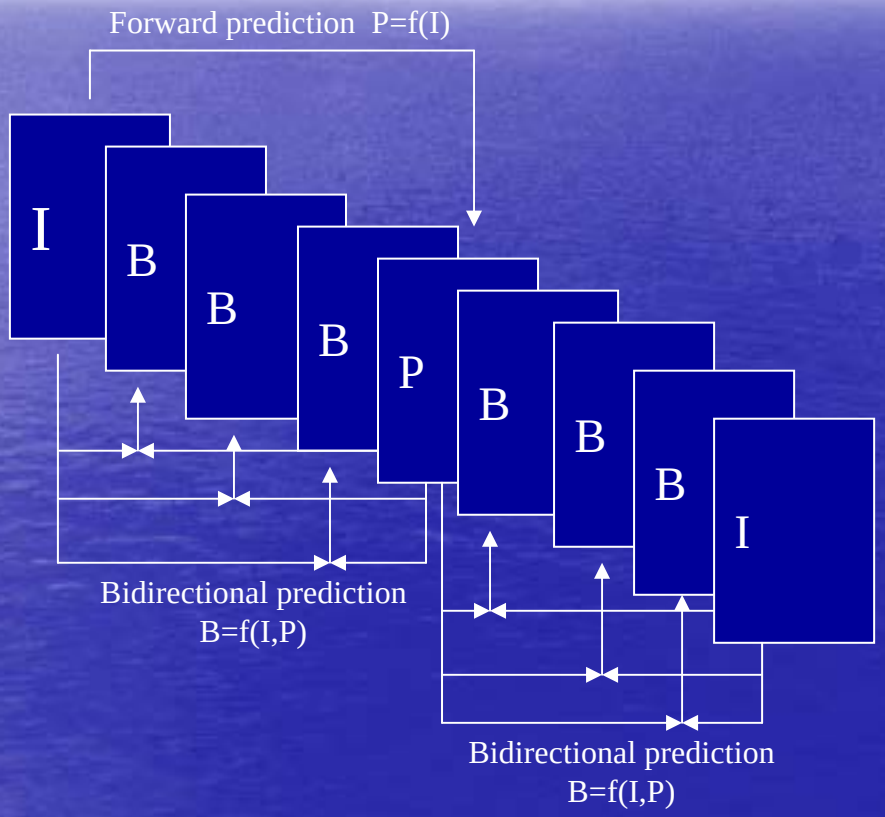
MPEG Picture Types

Three types of pictures:

- **Intrapictures** (I)
- **Unidirectional predicted pictures** (P)
- **Bidirectional predicted pictures** (B)

Grouped together (typically 12 pictures) in GOPs

Motion Compression for Coding MPEG



H.261 (Px64)

- H.261 was designed for datarates which are multiples of 64Kbit/s, and is sometimes called p x 64Kbit/s (p is in the range 1-30).
- These datarates suit ISDN lines, for which this video codec was designed for
- Intended for videophone and video conferencing systems

H.263 Standard

- The development of modems allowing transmission in the range of 28-33 kbps paved the way for the development of an improved version of H.261
- It was designed for low bitrate communication , however this limitationhas now been removed
- It is expected that H.263 will replace H.261

Non-DCT Based Compression Techniques

- Image Compression by Fractals
- Image compression by Wavelets