Module 6

STILL IMAGE COMPRESSION STANDARDS

Lesson 19

JPEG-2000– Error Resiliency

Instructional Objectives

At the end of this lesson, the students should be able to:

1. Name two different types of lossy channels.
2. Define error correction, error resilience and error concealment.
3. List three major error conditions.
4. State the impact of these conditions in source coding and their remedies.
5. Justify the introduction of resynchronization for error resilience.
6. Define packet resynchronization approach.
7. Define periodic resynchronization approach.
8. Define data partitioning strategy to resynchronization.
9. Explain hierarchical resynchronization and data partitioning in JPEG-2000.
10. List the error detection tools in JPEG-2000.

19.0 Introduction

The JPEG-2000 standard has two major strengths, which were not addressed in the earlier still image compression standard JPEG. These are the capabilities for region of interest (ROI) coding, which were presented in lesson –18 and the error resiliency features, which we are going to discuss in the current lesson.

One of the most significant challenges in still image and video transmission today is to handle errors in lossy channels. In this lesson, we shall first introduce the students to the concepts of error correction, error resilience and error concealment. The major error conditions and their impact on source coding will be discussed. Re-synchronization is an effective means of error resilience and this is incorporated in JPEG-2000 standard also. After reviewing the resynchronization approaches, we shall focus on the error resilience in JPEG-2000 standard and the error resilience tools it support.

19.1 Lossy Channels -

Lossy channels arise in two different forms

a) In *packet networks*, such as internet. Packets can be dropped due to congestion at switches, they may be misrouted or arrive after such delays which make them useless.

b) In *wireless networks*, conditions such as fading interferences, additive white noise etc, can cause bit errors.

In some applications, no data error can be tolerated. In image transmission, some quality degradation is often acceptable, but the effects of error should be minimal.

19.2 Error corrections, error resilience and error concealment

We need to understand the definitions of these three terms very clearly. These are related terms, but their scopes are different.

19.2.1 Error Correction: In error correction schemes, it is possible to correct the errors and recover the original data. Error correction schemes introduce redundant bits to the bit stream. The redundancy usually allows the decoder to detect that a portion of the bit stream is erroneous and it is possible for the decoder to correct the error also. Error correction is incorporated using schemes such as Forward Error Correction (FEC) coding schemes. Image transmission does not attach equal importance to all parts of the bit stream and hence involves unequal error protection (UEP) schemes under FEC.

19.2.2 Error Resilience : In error resilience schemes, errors are not directly corrected, but the damage caused by the errors are restricted. With an error resilient system, an error is confined to just one small chunk of information. This usually involves introduction of resynchronization words, so that the decoder can be back on track after the error condition is over. This will be our main focus of study in the current lesson.

19.2.3 Error Concealment : In error concealment schemes, the decoder, after detecting that some uncorrectable errors have taken place, performs some part processing so as to hide or minimize the glitch from the viewer and present a pleasing rendition of the decoded image. In still images, error concealment often uses spatial domain techniques to interpolate across the missing pixels.

19.3 Error conditions and their impacts on source coding

Error resilience techniques for still image transmission have to deal with different error conditions such as burst errors, random errors and packet losses. Without error resilience, even a small number of bits in error can render the entire bit stream of compressed data useless. For example, let us consider a predictive coding scheme, followed by variable length coding. If a single bit is in error in the final bit stream, the error propagates through the rest of the coded data. One of the solutions may be to re-transmit the data but often, real time applications impose a low delay constraint, making retransmission infeasible.

To overcome these challenges, JPEG-2000 standard has offered error resilient tools, which can be integrated with the core encoding algorithm and does not affect the coding efficiency significantly. The error resilient tools do not replace the standard error correction techniques adopted in the channel coding and can be used together with these techniques.

19.4 Use of resynchronization

Re-synchronization establishes synchronism between the decoder and the bit stream. If the data between two successive synchronizations is in error, that data is discarded and the decoder can again get synchronized to the bit stream. This scheme therefore reduces the impact of the error and small bit errors would keep most parts of the bit-stream unaffected.

Some of the popular approaches to resynchronization are:

a) packet resynchronization
b) periodic resynchronization
c) data partitioning based resynchronization

19.4.1 Packet resynchronization: In this approach, resynchronization markers are introduced in block based coders at the macro block (group of four spatially adjacent block horizontally and vertically) boundaries. In a variable length coder, the number of bits to be encoded varies from macro block to macro block and hence, the spacing of these markers is even. Thus, the macroblocks containing more number of bits are more susceptible to errors.

19.4.2 Periodic resynchronization: Periodic resynchronization approach introduces the markers at regular and constant bit rate intervals. In this approach, the packet size is not decided by the macro block, but by the number of bits instead.

The difference between packet resynchronization and periodic resynchronization is illustrated in Fig 19.1.

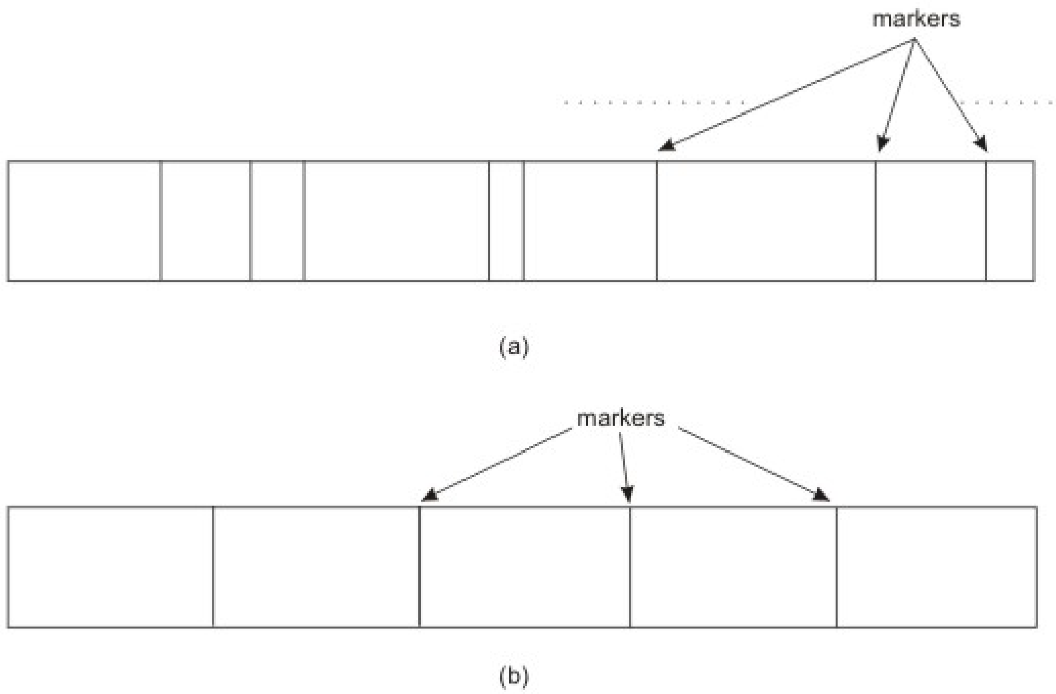

Fig. 19.1 (a) Packet resynchronization
(b) Periodic resynchronization

19.4.3 Data Partitioning based resynchronization: In this approach, the bit stream is partitioned into regions according to their sensitivity of errors and the partitioned bit streams can have different resynchronization intervals and robustness to errors. JPEG-2000 adopts a hierarchical bit stream partitioning with scalable error resilient syntax in which resynchronization markers are introduced at different levels of hierarchy. This will be explained in details in the following section.

19.5 Hierarchical re-synchronization and data partitioning in JPEG-2000

The JPEG-2000 bit stream is arranged in a hierarchical data structure consisting of (i) sub band, (ii) bit planes and (iii) code block, as explained in lesson-17. Packet based resynchronization is adopted. The data partitioning scheme partitions the bit stream into subbands, bit planes and code blocks. Segments from different code blocks are collected into a packet, which is preceded by a resynchronization marker. JPEG-2000 offers a scalability in which the number of code blocks to be included within a packet can be decided by the encoder in accordance with the channel error rate, so as to introduce a trade-off between resynchronization overheads and error robustness.

The decoder decodes the bit stream in the same hierarchical way, that is on a code block by code block basis. With block synchronization, bit errors in one block will not propagates to the other blocks. Re-establishment of the synchronization between the decoder and the bit stream is achieved through unique markers.

19.5.1 Error resilient packet architecture

The architecture of a JPEG-2000 packet is shown in Fig 19.2. Each packet is composed of

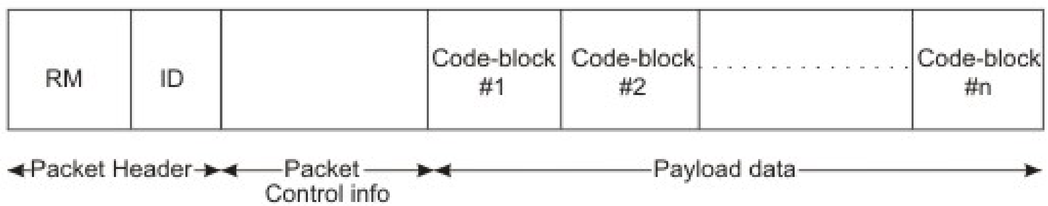

Fig. 19.2 Architecture of JPEG-2000 bitstream

(a) *Packet header*, which includes

- **Re synchronization Marker (RM) –** This should be uniquely decodable from the bit stream and such word cannot be emulated in the bit stream generation process.

- **Identification number (ID) -** This identifies the subbands, SNR layers and the spatial location that the bit stream in the packet corresponds to.

(b) *Packet control information*, which includes

- **Length in bytes** of all the bit stream segments included in the packet. Information pertaining to the code blocks identification and the bit planes which compose the packet.

(c) *Payload data* , which consists of bit stream segments from individual code blocks.

Each code block is encoded independently and hence, if a code block has a bit error, it will not propagate to the next code block if the segment length is extracted correctly from the packet control information

19.6 Error-detection tools in JPEG-2000

The error resilience approach discussed above can only limit the extent of damage bit errors can cause. Still, bit errors will occurs and parts of the image may get corrupted. Under these situations, the decoder should be able to detect the errors and conceal to the extent possible, so that visually observed degradation are kept at a minimum.

The JPEG-200 standard supports the following tools.

a) ***Segmentation markers:*** This encoded at the end of each coding pass. If the decoder is unable to detect this at the end of each decoding pass or is in error, an error flag is set.

b) ***End of bit-stream information:*** From the packet header, the decoder bit stream obtains the length information and if it matches exactly with the number of bytes it actually receives till the last symbol in the block, there is no error. Otherwise, an error flag is set.

c) ***Unequal error protection using QoS channels*:** The JPEG-2000 syntax supports Quality of Service (QoS), which may be provided either through separate channels or through FEC and ARQ schemes. For example, in JPEG-2000 bit stream, the packet header contains the most sensitive information for decoding and this should be sent through lossless or low error channel. The JPEG-2000 bit stream is arranged in order of importance.

Also, the packets from different resolutions and bit planes may be transmitted through different QoS services.

19.7 Summary

The support for error –resilience has made JPEG-2000 a more effective and useful coding standard as compared to its predecessor, JPEG. The error resilience tools of JPEG-2000 deal with channel errors using the following approaches: data partitioning and resynchronization, error detection and concealment and QoS transmission based on priority. Entropy coding of the quantized coefficients is performed within code block. Since encoding and decoding of code block are independent processes, bit errors in a bit stream are restricted within a code block.

At the packet level, a packet with a resynchronization marker allows spatial partitioning and resynchronization.

REFERENCES

1. I. Moccagalta, s. Soudagar, J. Liang and H. Chen " Error resilient coding in JPEG-2000 and MPEG-4", IEEE Journal on Selected Areas in Communications, Vol.18, No.6, June 2000, pp. 899-914.