NORWEGIAN CONTRIBUTIONS AND RECENT DEVELOPMENTS IN STILL IMAGE STANDARDIZATION

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ABSTRACT

Error resilience and robust image coding are important topics within still image compression. Considering image transmission e.g. in mobile communications, also the compression standard JPEG2000 currently being developed addresses this area. This paper informs in general about the standardization organization and procedure. Also, it gives an overview of the current state of the art and summerizes error resilience techniques in JPEG2000. Various contributions with regard to an error-robust code stream and results are discussed. The article concludes with an outlook concerning future standardization developments.

Keywords — *Image processing, data compression, robust communications, JPEG2000 standardization, error resilience.*

1. INTRODUCTION TO JPEG2000

Large efforts have been made in recent years to standardize image compression algorithms. The probably most popular still image standard is JPEG, also known as JPG[1]. The standards are meant to facilitate the exchange of images across application boundaries, as well as to significantly reduce the cost of specialized hardware required in many real time image compression systems.

A new standard is currently being developed by the JPEG community, the project name being JPEG-2000. This standard is to complement the existing still image compression standards and should be superior in many ways as this paper will specify later. One aspect concerns image transmission in noisy or error-prone environment. Here, the aim is to make the code stream to transmit as robust as possible to channel or storage errors, such that there is only a minimum quality degradation of the reconstructed image. This is addressed by error resilience. Error resilience is hereby meant to aid subsequent error correction systems, which use e.g. forward error correction (FEC) codes, in alleviating catastrophic decoding failures [**9**].

[1]These abbreviations are explained in Section 2.

In 1998, JPEG2000 was introduced to the NOBIM community [**5**]. The goal of this article is to summerize the efforts which have been done since then and to name the current state of the art. The article shall give insight into the standardization hierarchy and its procedures. Concerning error resilience, both recent work is resumed as well as an outlook is given concerning prospective future developments. Hereby, emphasis is put on the work NTNU and SINTEF contributed.

2. JPEG2000 STANDARDIZATION

The International Standards Organization (ISO) and the International Electrotechnical Commission (IEC) form the Joint Technical Committee JTC1 which in turn has the Sub-Committee SC29 titled Coding of Audio, Picture, Multimedia and Hypermedia Information. SC29 consists of three working groups: WG1 (Coding of Still Pictures), WG11 (Coding of Moving Pictures and Audio), and WG12 (Coding of Multimedia and Hypermedia Information).

WG1 nowadays has more than 100 active members from 18 countries (including Norway) and conducts three main and some interim meetings per year. WG1 consists of two committees: JPEG (Joint Photographic Experts Group) and JBIG (Joint Bi-level Image Experts Group). These committees currently work on three main projects: (1) JBIG2 (project number JTC 1.29.10 or IS 14492), coding of bi-level (black and white) images, mostly for fax applications, compressing images on the average one magnitude better than JBIG1 being used today; (2) JPEG-LS (JTC

1.29.12, IS 14495), lossless and near lossless coding of continuous-tone images; and (3) JPEG2000 (JTC 1.29.14, IS 15444), compression of continuous-tone images using wavelets (instead of discrete cosine transform (DCT) as in the old baseline JPEG standard).

The best known standard from JPEG is the International Standard IS 10918-1 (ITU-T T.81), which is the first of a multi-part set of standards for still image compression as used today on the Web. This baseline JPEG standard typically compresses images up to 32:1 without significant loss of image quality. One disadvantage is that the block-based DCT (e.g. 8×8 pixel blocks) gives perceptible blocking effects for a high compression rate.

The new wavelet-based JPEG2000 standard is capable of compression rates up to 200:1 in special circumstances. Typically, compared to the JPEG standard, it yields on the average 30% more compression or, at the same compression rate, 30% better image quality. However, in addition to these benefits, JPEG-2000 will have a very rich feature set:

- Enabling lossless and lossy compression in a single code stream,
- extension of the maximum image size from (in JPEG) 64K×64K to 4G×4G pixels,
- random access into the bitstream, enabling e.g. arbitrary panning and zooming in large images without decoding the total image,
- high efficiency for continuous-tone, computer-generated, bi-level imagery and compound documents,
- meta data to support native inclusion of image content descriptors,
- progressive transmission by both pixel accuracy and resolution,
- arbitrary-shaped region-of-interest (ROI) coding and image tiling, and
- error-robust transmission in noisy environments.

Applications/markets considered are Internet, mobile communication, printing, scanning, digital photography, remote sensing, facsimile, medical imagery, digital libraries and e-commerce.

2.1. Error Resilience

In mobile and wireless communications, a code stream being robust to channel errors is of major importance since already very small bit error rates may substantially affect the quality of the reconstructed image. Due to information and coding theory, mostly variable-length codes are used for signal coding nowadays. In the presence of channel errors, this mostly leads to loss of synchronization during decoding and hereby to total loss of the transmitted image. Channels being considered are the binary symmetric channel, exposing the code stream to single random bit errors, Raleigh fading channel with burst errors, packet channels like e.g. UDP where packet losses may be encountered, and, of course, the error-free case (EFC).

During the standardization process, several techniques have been proposed to enhance the robustness of the code stream. In the following, a wavelet transform combined with a subband decomposition procedure as described in Section 3 is considered.

Apart from the use of FEC codes, error resilience is introduced to prevent catastrophic error propagation and to suppress the effects of noncorrectable channel errors.

ARQ schemes, which are frequently used in mobile communications, reduce the need for error resilience. If at least one bit error is detected in a received packet, the whole packet is requested for repeated transmission. However, in that case, the transmission delay rises exponentially as the retransmission rate increases. This is shown in [4]. Hence, techniques that offer minimum transmission time in exchange for image quality deterioration have to be employed at least as an option.

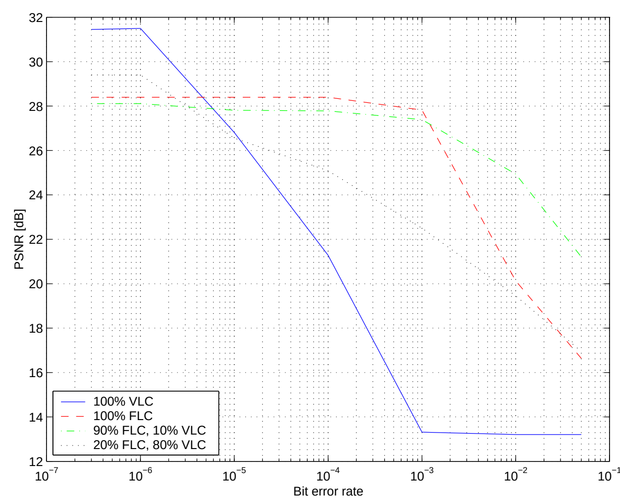

Figure 1: Comparison FLC — VLC for random bit errors

A couple of approaches replaced variable- by fixed-length code words. This was done for (1) the lowest-frequency subband, (2) a certain number of low-frequency subbands, and (3) the complete subband information. In all cases, significant objective and subjective improvements in the presence of errors are achieved. In the EFC, however, image quality degradations with regard to variable-length code word techniques have to be accepted. The first approach yields PSNR improvements up to 6 dB under typical error conditions and maximum 0.1 dB deterioration in the EFC. The last approach reports approxemately 6 dB gain on the average under error conditions and 3.5 dB average PSNR degradation in the EFC. The results of the second approach lie between the results of the two aforementioned experiments for channel errors and the EFC, respectively. The second approach is realized in a flexible implementation with an arbitrary ratio between fixed- and variable-length encoded subbands in [**7**]. The results are shown in Fig. 1.

Smart source-channel symbol mapping aims at assigning neighbouring[2] source to neighbouring channel symbols. A similar approach called multi-level signaling is employed in [**8**]. The output of the quantizer are 3^n-level symbols which are then, combined as symbols of different quantizer classes, mapped to 81-PAM channel symbols. This codec is outperformed by the comparison codec using variable-length codes for the channel SNR both codecs were designed for. For small CSNRs, however, the performance curve of the comparison codec suddenly drops away. In contrast to that, the PSNR of the new codec degrades gracefully. An increasing CSNR leads to substantial PSNR increases of the multi-level approach, whereas the comparison system performances stays constant.

When dealing with variable-lenght codes and data blocks, the so far only used error concealment method is that, when a certain data block is affected by channel errors, all its coefficient are set to zero. Other techniques exist in the literature but are not used in the current state of the art in JPEG2000 due to computational afford and algorithm complexity.

Another approach, adopted from the standardization of MPEG4, is the insertion of resynchronization markers into the code stream, automatically dividing the stream into data partitions or packets. In JPEG-2000, data partitioning consequently follows the concept of already existing logical data blocks like subbands or bit planes. A resynchronization marker typically consists of three bytes put at the beginning of the respective logical block. The first two bytes form the marker itself and represent a code word that cannot be emulated by the encoder. The last byte contains information about the block localization. Partitioning and resynchronization for subbands and bit planes lead to practically no PSNR deterioration in the EFC and yield, in the presence of typical physical channel conditions, appr. 4.2 and 3.5 dB, respectively [**1, 3**]. A further partitioning into code stream segments improves the PSNR up to 1.94 dB with insignificant enlarging of overhead information.

Also, the use of more robust entropy codes has also been investigated [**6**]. Reversible variable-length codes are employed that can be decoded from both code stream beginning and end. Especially, the use of reversible Huffman and Golomb codes was considered. If an error is encountered, the code words that have been decoded so far are kept, and the decoder begins to decode the code stream starting at the end, again, until the next error is detected. So, parts of the coefficients are recovered instead of setting all of them to zero. In the presence of errors, typically 2 dB gain are achieved, while in the EFC, the PSNR is approximately 3 dB lower than without reversible codes.

[2] Neighbouring symbols differ in one bit.

3. JPEG2000 CODEC

The JPEG2000 standard is very extensive, and a detailed specification of all its features is beyond the scope of this article. For further information, the reader is therefore referred to [**2**].

A discrete wavelet transform with a dyadic decomposition process is the main component of the codec. The output are subbands consisting of wavelet samples which in turn represent horizontal and vertical spacial frequencies. Coding artifacts as they are encountered on DCT-based systems are hereby avoided (see Fig. 2).

(a) JPEG (b) JPEG2000

Figure 2: Lena detail, appr. equal bit rate of 0.25 bpp

Then, the samples are quantized, further grouped into logical blocks and entropy encoded by an adaptive arithmetic bit plane encoder using causal contexts, finally leading to the data being organized in packets. On the decoder side, the inverse operations according to the encoding process are done in reverse order.

Error resilience is accomplished by seven precautions. (1) The grouping of subband samples bounds the effects of channel errors to blocks. (2) The arithmetic codec is terminated after each coding pass. Further, (3) its contexts are reset at the same time. Both features enable the restarting capability after error occurance. (4) Raw bits are inserted without encoding. This prevents error propagation. (5) A special unique symbol is encoded at the end of each code segment for error detection purposes. If this symbols cannot be decoded, an error has affected the respective segment. Also, at a lower level, (6) the packet headers are copied from the code stream to the main header that is assumed to be transmitted error-free, maintaining this important information. Finally, (7) resynchronization markers are placed in front of every packet in a tile.

A visual evaluation of the standard's typical performance is offered by Fig. 3, considering a coding ratio of 160:1 and random bit errors during image transmission.

Figure 3: Performance at a bit error rate of 10^{-4}

4. OUTLOOK: JPEG2000 PARTS II–V

JPEG2000 Part I contains mandatory specifications, and all algorithms are license-free or at least royalty-free to implement. Part II of the standard consists of optional extensions like e.g. specifications addressing special markets. Part III (Motion JPEG2000) addresses e.g. short high-quality video streams found in consumer still image cameras, full-length professional video and animated Web images. Part IV will enable tools for verification of software implementations, while Part V will provide a reference implementation to help the understanding of the specifications (Part I–III).

After consensus was reached on the JPEG2000 basic algorithms (Part I), a Working Draft 1.0 was issued in March 1999. The algorithms could still be altered until the Committee Draft was published in December 1999. Now, modifications can only take place if technical defects are discovered, or through agreement of several National Bodies (each member country has its own NB — Norwegian Technology Centre is coordinating the Norwegian NB). During the year 2000, the baseline standard will be released as International Standard, after going through the stages Final CD, Draft IS and Final DIS. The emphasis of the development is currently put on Part II. The future project schedule is given in Tab. 1.

Part	Title	WD	CD	IS
I	Core system (Baseline)	1999/03	1999/12	2000/12
II	Extensions	2000/03	2000/08	2001/07
III	Motion JPEG2000	2000/03	2000/12	2001/11
IV	Conformance Testing	2000/07	2000/12	2001/11
V	Reference Software	2000/03	2000/07	2001/07

Table 1: JPEG2000 project schedule

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