Using JPEG 2000 in Future Digital Cameras: Advantages and Challenges

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Abstract

The JPEG 2000 family of still-image compression standards promises to improve the usability and image quality of consumer digital photography systems. The new file standard uses the discrete wavelet transform with bit-plane encoding to provide both a multi-resolution representation and progressive coding of image data. The new standard will also allow digital cameras to save images in an extended range color space, along with instructions that allow conversion into the common sRGB metric.

Along with these opportunities for product improvements, however, come increased complexity and potential barriers to product interoperability. New initiatives within the international standards community are aimed at addressing these challenges for digital still cameras. The goal is to develop a new digital camera profile of supported image compression and format parameters within the larger framework of JPEG 2000.

JPEG 2000

Currently, most digital still cameras (DSC) compress and store digital images in the established JPEG file format. The JPEG standard defined a minimal file format for the exchange of compressed data but without color space specifications or metadata. Later, a *de facto* industry standard file format was developed around JPEG. Several years after the adoption of JPEG Part 1, ISO developed a complete file format, SPIFF.

In contrast with the early stages of JPEG 2000, developing the file format was given close attention. The JPEG 2000 standards[1,2] have incorporated several recent developments in digital image compression. They are based on discrete wavelet transforms in a multi-resolution format with progressive encoding. In addition, the format facilitates the storing of several forms of metadata,[3] which can be used to improve application-specific image processing after decompression.

The motivation for the development of the new standards was only in part to provide improved image compression over that delivered by the previous JPEG standard. At least as important was the desire to provide a new way to represent image information with features for current and future imaging systems and applications. Part 1 of the JPEG 2000 standard supports the following:

- Improved compression efficiency and error resilience
- Improved performance under multiple compression–decompression operations
- Multiple resolution representation
- Layer-progressive decoding, lossy to lossless
- Image tiling with spatially progressive decoding
- Region-of-interest (ROI) coding
- Random access and processing
- Improved format flexibility with improved color-space and ICC profile support.

Although several of these items are supported under JPEG, they are not included in the "Baseline" version used by most digital cameras.

For DSCs, the improved compression efficiency allows for either more images to be stored on the same memory card, or for the same number of images to be stored with a higher image quality. The multi-resolution feature allows the various segments of the bit stream to be decoded to provide multiple resolutions of the image, as needed for LCD display, e-mail, and digital printing. The progressive decoding method allows the selective discarding of image information. Figure 1 shows an example of increasing quality as an image is decompressed using increasing numbers of bit planes.

Another important aspect of progressive decoding is flexible rate control, which can be used for efficient memory allocation in the camera. Under JPEG, the user must decide the quality level of the images to be stored. JPEG 2000 enables initial image storage at high quality. If memory is needed for more images, it stores a selective reduction of the images' resolution and quality level.

Many digital cameras today are capable of capturing color data that has a wider dynamic range and larger color signal volume than provided by the common sRGB color space. They have to discard the additional data in order to convert it into a JPEG file that is compatible with equipment from other vendors. With JPEG 2000, digital cameras will be able to save an image in an extended range color space, along with instructions that allow it to be converted into sRGB. This can be used to create higher quality prints via exposure level and color adjustments of the decompressed images.

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Fig. 1. Reconstructed image after decoding bit-planes 2, 4, 6, and 8 (from Ref. 1)

Digital Camera Profile

Today's digital cameras enjoy a high level of compatibility between cameras and between the camera and the other parts of the system (such as printers and software). This interoperability is because digital camera makers worked together to determine how JPEG would be implemented in digital cameras and how the file must be organized on memory cards. While some of this work is still valuable in the larger scope of JEPG 2000, many new options are available which are not addressed by the current file exchange standards (Exif and DCF).

Image compression is one of several important image-processing operations performed by a DSC in delivering a digital image file. Figure 2 shows a common sequence of steps from sensor data to a finished file for current cameras.

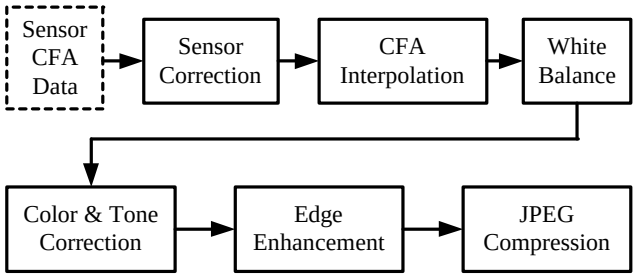

Fig. 2. Common digital still camera image processing operations

The raw-image detector data is usually modified to correct for sensor and color filter array (CFA) response. The fully populated color image is then generated by a CFA interpolation step. Following an estimate of the scene illumination or color bias to the image data, a white balance transformation is applied. Next, a color and contrast transformation conditions the image for the destination rendering, usually a CRT monitor. Finally, a modification of the spatial characteristics is introduced by an enhancement filter, which can be a simple or adaptive sharpening operation.

Each of the above steps is performed prior to image compression and, therefore, influences its performance. In addition, knowledge of the image capture and camera processing conditions can be used to improve the utility of decompressed digital images. This is the role of the metadata tags, supported under the JPEG 2000 standard.

If future DSCs are to maintain compatibility across imaging applications and products using the JPEG 2000 standard, it is important that a common set of supported parameters and functions is defined within the larger standard. The I3A/IT10 (International Imaging Industry Association) has begun studying the application of JPEG 2000 in future DSCs. An *ad hoc* group has also been formed within ISO/TC42/WG18 which will provide input to I3A/IT10 on this matter. If appropriate, it is anticipated that an application profile for DCSs will be developed. The group will be proposing an interoperability specification to address the following issues:

- Compression parameters (such as codeblock size, wavelet filter, number of resolutions)
- Use of the JP2 and JPX file formats
- Supported colorspaces
- Required and recommended metadata fields and format
- The integration of audio and JPEG 2000
- Ways to provide a minimal level of interoperability with JPEG based devices.

Conclusions

The transition from the current JPEG image format to JPEG 2000 presents opportunities for improved flexible-image acquisition and exchange. A natural next step for digital cameras is the definition and acceptance of requirements for creating and editing JPEG 2000 compatible image files. By addressing the specific needs of DSC image processing, a common set of compression and file format parameters can be established. It is likely that this will represent a subset of the new standards.

References

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