14.9.2 JPEG–2000 compression

- DCT compression — basis for JPEG
- wavelet compression — basis for JPEG–2000

- JPEG–2000 — new international standard for still image compression
  - overcomes some limitations of original JPEG standard
  - not its extension
  - new, powerful, flexible environment for image compression
  - flexibility allows compression of different types of still images (bi-level, gray-level, color, multi-band) with different characteristics (natural images, scientific, medical, military imagery, text, rendered graphics) within a unified system
  - removes need for different compression mechanisms for lossless and lossy compression
  - represents lossless compression as cohesive extension of lossy compression

- $\Rightarrow$ important paradigm shift — allows compression of image data in a lossless manner and—at a later time—a selective data removal to represent images in a lossy fashion while increasing the compression ratio
- **quality scalability** — lossless and lossy behavior from the same compressed image data source
- **resolution scalability**— extraction of lower resolution images from the same data source
- **spatial scalability** — selective reconstruction of individually defined regions from compressed image data source

- JPEG 2000 standard creates unified image compression environment
- but – only specifies
  - decoder operations
  - bitstream syntax
  - file format
- this allows for future improvements and innovations of coding

- Encoding — two primary paths and several options
- RCT – reversible component transform is used with the 5×3 wavelet filter for lossless compression
- Decreased bit rates and increased compression ratios achieved by truncation during the quantization step (decrease in image quality)

- Purely lossy coding
- YCbCr transforms RGB signal to intensity component Y and two color components (blue/red)

$$\begin{aligned} Y &= +0.299\,R + 0.587\,G + 0.114\,B\,, \\ C_b &= -0.168736\,R - 0.331264\,G + 0.5\,B\,, \\ C_r &= +0.5\,R - 0.418688\,G - 0.081312\,B\,. \end{aligned} \tag{14.12}$$

- folloed by 9×7 wavelet transform
- then arbitrary quantization by division in addition to truncation

- such main paths have several options for identification of the region of interest, coding options to trade complexity and performance, and choices about the amount of scalability in the bitstream

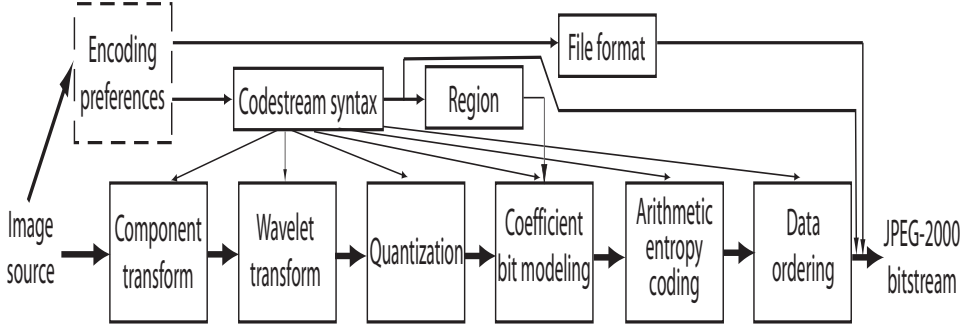

Figure 14.7: Main data path of JPEG–2000 data compression.

- image is divided into rectangular, non-overlapping tiles on a regular grid
- border tiles may be sized as needed
- arbitrary tile sizes allowed, up to using a single tile representing the entire image

- **component transform** block — input: original image data ... decorrelates image components of multi-band image—typically the R,G,B channels of the color image
- decorrelation yields improved compression performance
- allows for visually relevant quantization

- when lossy (irreversible) path is used the floating-point YCbCr transform is employed in the same way as it is used in the original color JPEG compression.

- **wavelet transform** is the heart of the JPEG–2000 compression
- can be performed in two ways
- both ways provide lower resolution images and spatial decorrelation of the images
  - 9×7 biorthogonal Daubechies filter – highest compression
  - Le Gall 5×3 filter is of lower complexity – lossless compression
- advanced parts of JPEG–2000
  - simultaneous use of multiple wavelets
  - including user-defined wavelet transforms for which coefficients are specified in bitstream
- blocky character of JPEG image - most typical artifact
- wavelet compression can be applied to the entire image converted into a series of wavelets
  ⇒ blockiness may be completely removed
- even if block-based wavelet transformation is employed, the blockiness is substantially decreased

- **quantization** step offers trade-off between compression ratio and image quality
- similar to JPEG, wavelet coefficients can be divided by a different value for each image subband
- some coded data can be discarded to increase compression ratio
- **codestream syntax** prescribes marker segments, which determine the location of the coded data with respect to a given spatial image location, resolution, and quality

Application 1

- web – JPEG–2000 allows initial and quick display of low resolution image (map)
- later, any part of image (map) can be requested via the region of interest selection, server only provides necessary additional data for that spatial region at the required resolution
- if user requests a printout of that region of interest, a higher resolution version that is matched to the printer resolution may be fetched
- based on gray-level or color printer capabilities, only grayscale or color information would be transferred.

- $\Rightarrow$ selective transmission of only necessary data by the specific application is an inherent and intriguing feature of the JPEG–2000 standard

Application 2

- storing high resolution digital photographs ... running out of space
- currently, one photograph must be deleted before we can store another image
- if stored using JPEG–2000, possible slightly to decrease quality of all stored images
  ... make space for that one more important photograph to be taken and stored, or archived

- JPEG–2000 is much better compression tool than JPEG when high image quality is demanded, even when using lossy compression

- for lossy compression, JPEG–2000 can typically compress images 20–200% more than JPEG

- JPEG–2000 can handle up to 256 image channels while original JPEG was, due to its common implementation, limited to only 3-channel color data

- JPEG–2000 compression ratios of about 2.5 are typical for lossless compression

- Replacing *Motion JPEG* (for editing production-quality video, but no international standard),
  JPEG–2000 includes standardized **Motion JPEG-2000** format

- JPEG–2000 shall be the compression standard of choice
- but – original JPEG standard is not likely to disappear quickly