Image compression practices and standards for geospatial information systems

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Outline

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  - ➔ JPEG 2000
  - ➔ JPEG-LS
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  - ➔ JPIP
- Conclusions

Motivation

On-board sensor → Image compression → TX

- Limited bandwidth
- Limited power
- Real-time
- Lossless/near-ls/lossy ?

- Limited bandwidth
- Limited storage?
- Not real-time
- Lossless/near-ls/ lossy ?

Ground station

Image processing → Image compression and archiving → Access and distribution

Application

Must take no more than few seconds

- *Access database, negotiate bandwidth and capabilities, start application*
- Query: Toulouse
- Response: SAR (ERS) + MS (Landsat,Aviris)
- Query: SAR+Landsat fusion
- Response: available (download thumbnail)
- Query: see associated metadata and precomputed features
- Response: see and download available features
- Query: refine feature extraction according to customized criteria (radiometric accuracy, feature type and nr., new signatures,...)
- Response: compute and download features
- Query: select data to buy and download
- Response: **prepare data** and redirect to secure server for transaction

Which compression ?

- Lossless
  - ➔ widely used in the past
  - ➔ low compression, not suitable for network-based access
  - ➔ Not used for SAR
- Lossy
  - ➔ partially avoided in the past due to the quality loss
  - ➔ now being adopted on major systems (SPOT 4/5, IKONOS)
  - ➔ maybe not very useful if lossy compression is used on-board
- Near-lossless
  - ➔ provides a bound on the error at each pixel
  - ➔ possible solution to the quality problem ?

DAD requirements

- Access to the data in a flexible way
  - ➔ variable resolutions, to optimize network access
  - ➔ random access to portions of the data
  - ➔ possibility of reordering the compressed data in various orders of importance (quality-wise, component-wise, resolution-wise,...)
- ⇨ Scalability: ability of generating a bitstream that contains the information in order of importance

DAD requirements (cont'd)

- Quality
  - ➔ for each application, quality requirements (resolution/accuracy) must be worked out
- ⇨ Image compression must support high to very high qualities
  - ➔ high coding efficiency
  - ➔ possibility to model the coding distortion
  - ➔ knowledge of how this distortion impacts on the applications

DAD requirements (cont'd)

- Integration
  - ➔ seamless access to the database, the data and all the associated information
- ⇨ File format technology must allow flexible use of data and associated metadata
  - ➔ contain auxiliary information and precomputed image analysis results (e.g. features) in a standardized format
  - ➔ contain links to other relevant information in the database
- ⇨ Compressed domain processing
  - ➔ allows to carry out image analysis directly on the compressed data

JPEG 2000 family of standards

- JPEG (1992)
  - ➔ lossy and lossless, DCT-based
- JPEG-LS (1997)
  - ➔ Lossless and near-lossless, prediction-based
- JPEG 2000 Part 1 (2002)
  - ➔ lossy and lossless, wavelet-based
- JPEG 2000 Part 2 (2002)
  - ➔ Provision for 3D extensions
- JP3D (started in 2002)
  - ➔ multicomponent and volumetric images

JPEG 2000 Part 1

- JPEG 2000: main features
  - released in 2002
  - high coding efficiency (20% more than JPEG)
  - wavelet-based compression (also good for compressed domain processing)
  - seamless lossy-to-lossless compression
  - highly scalable (in quality, resolution, component)
  - easy alteration of the progression order
  - region of interest coding
  - random access to codestream portions

JPEG 2000 Part 2

- JPEG 2000 Part 2 (extensions)
  - ➔ supports arbitrary wavelet filters
  - ➔ supports multicomponent transformations
- Multicomponent support:
  - ➔ Linear block transform (DCT, KLT,...)
  - ➔ 3D wavelet transform
  - ➔ predictive coding
- Must specify inverse transform, then store 2D wavelet-compressed components

JPEG-LS

- JPEG-LS: lossless and near-lossless compression
  - ➔ released in 1997
  - ➔ based on non-linear prediction and context-based Golomb-Rice coding
  - ➔ has low complexity
  - ➔ lossless compression is better than JPEG 2000
  - ➔ provides support for near-lossless compression
  - ➔ does not provide scalability
  - ➔ good choice for on-board compression, but not well suited to DAD

JPEG-LS Part 2

- JPEG-LS Part 2
  - ➔ has just been approved for publication by the ISO
- Provides a few add-ons over Part 1
  - ➔ Arithmetic coding (multiplication-free)
  - ➔ Adaptive peak error (based on image features)
  - ➔ Scan-based peak error (allows for rate control)
  - ➔ Modified prediction for images with spase histograms

JPEG 2000 file formats

- JPEG file format technology
  - ➔ codestream, JP2, JPX, MJ2, JPM
- File format: sequence of boxes, some for metadata and some for codestreams
  - ➔ it is possible to add custom boxes to enhance functionality of the file format
  - ➔ it is possible to use UUID boxes to embed vendor-specific information (e.g. URL of web page containing additional information)
  - ➔ The format of each extension must be user-defined
  - ➔ example: GeoJP2 file format

JPIP

- JPIP: interactive imaging protocol (http-like)
  - ➔ provides PUT and GET functions to access data from a remote system
  - ➔ provides the capability of selective access to the data (e.g. metadata, selected portions of the data)
  - ➔ can adapt the transmission mode to the bandwidth and to the client capabilities
  - ➔ can support several protocols (TCP/IP, UDP, ...)
  - ➔ is tailored to JPEG 2000, but extensions to other file formats can be devised

Open issues

- Quality
  - ➔ near-lossless is a general quality-preserving framework
  - ➔ it may be too conservative for certain applications
  - ➔ the effect of lossy compression is not thoroughly understood
  - ➔ in general, we do not know much about quality issues for remote sensing images

Open issues (cont'd)

- Compressed domain processing
  - ➔ May be very useful for the development of an integrated DAD system
  - ➔ May lead to lower complexity image analysis techniques
  - ➔ So far, we do not have many available techniques
- Standardization
  - ➔ We need to standardize more things, e.g. the metadata description

Lessons learned

- Network-based access does impose constraints on image compression
- We need more insight on image quality assessment for geospatial applications
- We need more integration
  - ➔ Compressed domain processing
  - ➔ Metadata description
- There are other relevant problems (privacy, security,…)