ANSI
American National Standards Institute

ISO
International Organization for Standardization

Market Acceptance of JPEG 2000
Medical, Digital Cinema, GIS

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Where IT all begins
InterNational Committee for Information Technology Standards

Presentation Overview

- Presentation was developed under INCITS/L3.2
  - Shared with the JPEG committee for use by all JPEG members
  - **Medical**, Alexis Tzannes, Ph. D, Aware Inc. Alexis@aware.com
  - **Digital Cinema**, Mr. Walt Husak, Dolby Labs, WJH@dolby.com
  - **GIS/Remote Sensing**, Bernie Brower, ITT Geospatial Systems
  - **Cultural Heritage**, Robert Buckley, U of R/NewMarket Imaging
- Focus on three markets that JPEG 2000 has gained market acceptance
  - Medical Imaging
  - Digital Cinema
  - GIS/Remote Sensing
- Will not focus on other JPEG 2000 markets
  - Cultural Heritage
  - HD Digital TV Capture (before editing and dissemination)
  - IP Security Cameras

JPEG2000: Requirements and Profiles

Original Requirements for JPEG 2000

- Internet applications (World Wide Web imagery)
  - Progressive in quality and resolution, fast decode
- Mobile applications
  - Error resilience, low power, progressive decoding
- Digital photography
  - Low complexity, compression efficiency
- Hardcopy color facsimile, printing and scanning
  - Compression efficiency, strip or tile processing
- Digital library/archive applications
  - Metadata, content management
- Remote sensing
  - Multiple components, fast encoding, region of interest
- Medical applications
  - Region of interest coding, lossy to lossless

Note: No Digital Cinema, Digital TV

Medical Imaging Market

Medical Imaging

- History: Medical Imaging
  - Unlike cinema, consumer imaging, and remote sensing – Medical imaging has been one of the leaders in digital capture of imaging data
  - Several digital technologies were developed well before the first digital camera
    - Ultrasound imaging was developed in the 1960s
    - Computed Tomography (CT) scanning was developed in the early 1970s
    - Digital Radiography was develop in 1978
    - Magnetic Resonance Imaging (MRI) was developed in 1980
    - The 3D image processing techniques were developed in the early 1980s
    - Computer networks enabling digital transmission of CT scans in the late 1980s
    - Most of the digital captured data was still printed onto film until the 1990s (mainly because of user preference – doctors were used to looking at film and not monitors – as those doctors were replaced with younger radiologists – the monitors have become common place)

Medical Imaging

- Why Digital Medical Imaging
  - Reduced cost, footprint, materials
    - Digital capture saves the cost of film, processing and diagnostic centers no longer require to have film processing systems located on sight
    - The maintenance and operation of a film processing system is expensive and requires the handling of hazardous material
    - The storage of digital data requires significantly less footprint than the storage of film X-rays (and less requirements for environmental control of film type systems)
  - Reduced time to diagnostics and increased collaboration
    - Previous medical examinations would require the film to be processed and the radiologist to be at the same location (or the film was shipped to them)
    - With digital radiology once the image is captured and processed the data can be shipped to multiple radiologist for review
    - Digital medical imagery can be shared across contents to experts in certain types of issues or simply shared across a given hospital or hospital to a family physician
  - Enhancement and Image Processing
    - X-Rays commonly have poor dynamic range and sharpness – image processing techniques can provide enhancements to the image that enable quicker and more accurate diagnoses
  - Digital Archive
    - Digital data can be organized in several different ways
    - Search, discover and access to historical data can be quicker than trying to find physical film files

Medical Imaging

- Advantages of JPEG 2000 over other DICOM allowed methods (JPEG, Lossless JPEG)
  - More flexible than the current standards – can achieve better quality than the previous standards (JPEG and JPEG-LS), with greater capability and functionality
  - Resolution scalability and Region of Interest Access was key
  - Lossless requirements
  - For medical storage and high quality exploitation – lossless compression is required
  - Bit Depth
    - Common medical images are greater than 8 bits, 12-16 bits is most common.
  - Multiple band/component data
    - Several of the systems have multiple bands which do not correspond to the common visual bands (red, green, blue)
    - 3D data (temporal or actual slices through a body). Part 2 of JPEG 2000 (Multi-component transformations) improves the compression efficiency of 3D data sets.

Medical Imaging

- For 3D image data, Part 2 of JPEG 2000 (Multi-component Transformations) was adopted as part of DICOM in 2005.
  - Examples of improved compression efficiency in next slides.

- For image streaming, JPIP was adopted by DICOM in January 2006.
  - describes a mechanism for using JPIP to transmit partial or full image data as part of a DICOM interaction between a server and a client.
  - Image pixel data only, all metadata is transmitted using DICOM.

- JPIP was adopted in DICOM based on the following 4 use cases:
  - Large single image navigation (uses region of interest scalability)
  - Thumbnail view of different imaging studies (uses resolution scalability)
  - Navigation of a stack of CT or MR images (uses resolution scalability)
  - Navigation of 3D volume of CT or MR images (uses resolution scalability in all 3 directions, creating a sub-resolution volume)

Medical Imaging

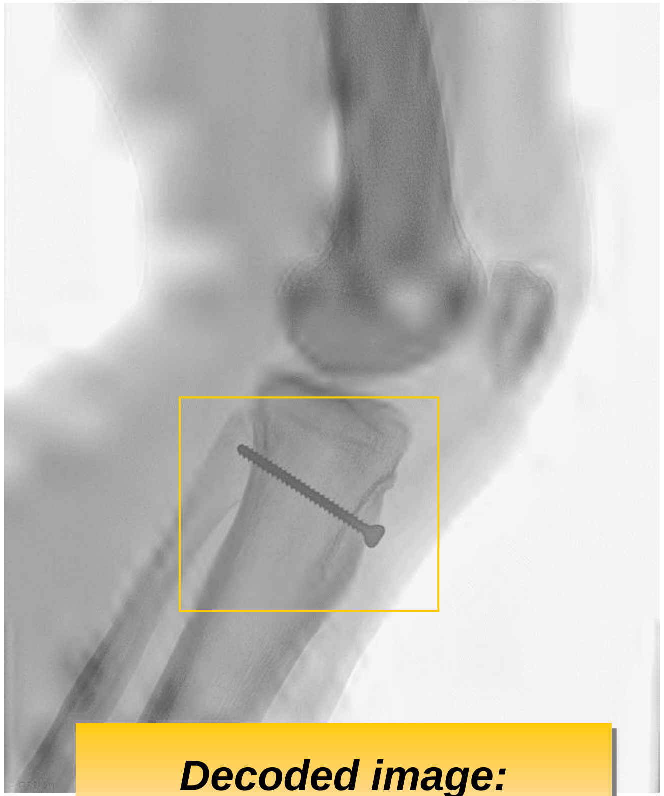
- Standards Organizations
- Some Data Providers

- Some of the Data Users/Software

- Standards Adopted
  - Part 1 JPEG 2000 Baseline
  - Part 2 Multiple Component
  - Part 9 JPIP

Region of Interest Example

Original Image



Decoded image: rectangular ROI centered on screw

Digital Cinema Market

Digital Cinema

- History: Digital Cinema
  - Digital cinema is in the processes of replacing film projection for theaters across the world
  - The technology started in the late 1990s that this capability would be viable replacement for the current production of multiple copies of film
  - Before digital cinema – Alternate content was being provided through digital applications – this enabled quicker and more flexible alternate content to be included into the movie going experience
    - Pre-movie commercials
    - Movie trailers
  - The migration to digital cinema really started in 2005
    - The migration is slow because of the capital investment and the current economical situation

Digital Cinema

- Why switch to digital cinema
  - Significant savings in distribution
    - Film copies cost over $1,000 per film for bulk copies
    - Hard-drives for digital release are as low $40
    - For a world wide release of 4,000 films – this could be a savings of over $4 Million per film
  - Greater Protection for content
    - World Wide release – this reduced cost enables world wide releases (in different languages) which reduces possibilities of pirated copies showing up in places that are part of the staggered releases.
  - **Increased 3D capability**
    - Digital Cinema enables cheaper and easier display of 3D content with better quality, commonly using the same base of technology
  - Quality
    - Reduces “flicker”, quality does not change over time like film (scratches, fading)
  - **Alternative content**
    - Digital cinema enables high quality alternate content to be display at a large venue (sporting events, political events, meetings, . . .)

Digital Cinema

- Why was JPEG 2000 Selected
  - The first digital cinema systems were based on MPEG-2 but were not interoperable – there were issues in sharing content to these different systems
  - The Digital Cinema Initiative (DCI) was brought together to define stands that would enable interoperability across the market – they selected JPEG 2000 over other techniques because of the following issues
    - DCI studied different compression techniques
      - Studies showed at the highest quality JPEG 2000, MPEG-2, and MPEG-4 did not show significant visual quality difference at the bit rates required for applications in digital cinema
    - DCI also evaluated the Cost impact of different standards
      - JPEG 2000 does not require license fees
      - MPEG-2 and MPEG-4 have license fees that would increase the cost of distribution and may also require cost per "showing" of each movie for each screen
    - Separation from Digital Television and HDTV content
      - The movie industry does not want the high quality movies to be confused or easily converted to consumer based technology (DVD, BlueRay)
    - Bit Depth (digital cinema was 36 bit color)
    - Scalability (current Digital cinema systems are either 2K-by-1K or 4K-by-2K

Digital Cinema

- Current Status
  - There are about 36,000 digital cinema “screens”
  - The number of screens more than doubled in 2010
  - Projects are at 120,000 digital screens by 2015
  - In the US it is about 45% of screens in North America
    - Most of the major theaters have at least one digital screen
  - Each year there are about 200 major Hollywood titles and the top 30 to 40 releases are released in both digital and film
  - 3D theater experiences are increasing significantly - most “animated” movies come out in 3D and several mainstream movies are starting to come out in 3D
    - AVATAR
    - Alice in Wonderland
    - TRON Legacy
    - Toy Story 3

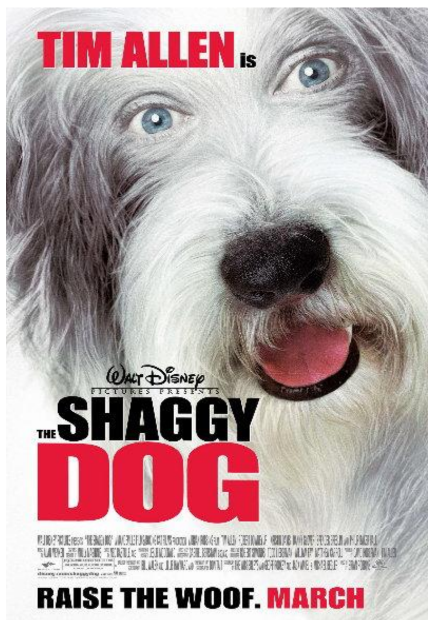
Digital Cinema

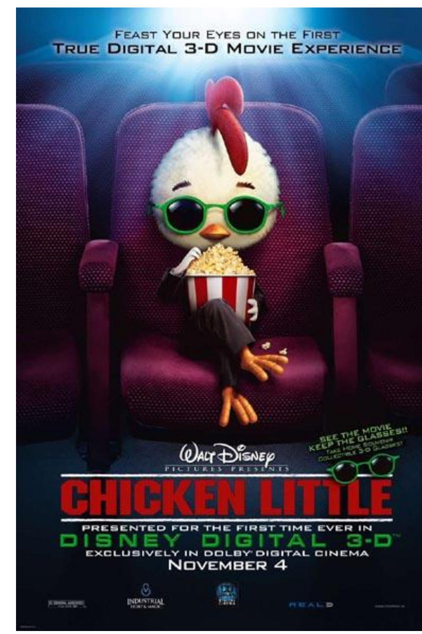
- Standards Organizations
- Data Providers
- Some of the Data Users/Software
- Standards Adopted
  - Part 1 JPEG 2000 Baseline
  - Digital Cinema Profile

Source ISO/WG 1 JPEG committee

Digital Cinema

- There are over 16,000 DCI Projectors in North America
  - 1st JPEG 2000 based digital film Stealth at the Tokyo Film Festival
  - Serenity was the fist fully compliant DCI packaged film
  - The Shaggy Dog was first digital cinema delivered by Satellite
  - Corpse Bride is the first 4Kx2K distribution of a digital cinema (2Kx1K is the common now)
  - Chicken Little first major 3-D Digital Movie





GIS and Remote Sensing Market

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GIS and Remote Sensing

- History: GIS and Remote Sensing
  - Mapping has been around for ever
  - Aerial Photography has been around since the late 1800s
  - GIS and Remote sensing was mainly used by government and military applications
    - Mapping cities, mapping troops, mapping roads, city development plans, utility plans, . . .
  - GIS and Remote sensing became consumer based with the advent of the consumer GIS applications (MapQuest, Google Maps, Google Earth, Microsoft’s Bing Maps, . . .)
  - The collection of massive data to feed these consumer based GIS applications has grown – aerial photographic companies have grown, two commercial remote sensing companies (commercial satellite companies) have been started

GIS and Remote Sensing

- Why was JPEG 2000 Selected
  - JPEG DCT was not meeting the needs of the GIS market – several different proprietary compression algorithms (mainly wavelet based) were gaining popularity
  - What is different from consumer based imaging (JPEG DCT)
    - Larger images (commonly larger than 10 megapixels)
    - Greater bit depth (images are commonly greater than 10 bits and sometimes greater than 14 bits deep)
    - Number of bands/multiple resolutions – the current satellite systems provide five bands and one is 4X different than the other
  - Large images with access to region of interest based on user's needs
  - Users will access data over different level of bandwidth capability
  - Open Standard – (not limited to proprietary compression – and the costs associated with that)

GIS and Remote Sensing

- Commercial Remote Sensing (Satellite Collections)
  - Sensors continue to become more capable
- GeoEye
  - IKONS – the first commercial remote sensing satellite was launched in September of 1999
    - 1 Meter resolution (Ground Sample Distance) in Panchromatic and 4 meter resolution in 4 spectral bands (red, green, blue, and Near Infrared)
    - Linear scanner camera over 13,000 pixels across in Panchromatic (3,000 for each color)
    - Since 1999 it has collected over 300 Million square kilometers of data (375 million megapixels)

IKONOS Satellite
Picture from GeoEye

GIS and Remote Sensing

- WorldView-2
  - GeoEye-2 – most recent commercial remote sensing satellite – launched in October of 2009
    - 0.46 meter GSD Panchromatic, 1.84 Meter resolution spectral (8 bands – Coastal Blue, Blue, Green, Yellow, red, red edge, near infrared 1, near infrared 2)
    - Linear scanner – over 36,000 pixels across Panchromatic (9,000 pixels across spectral bands)
    - Capable of collecting 975 thousand square kilometers per day

WordView-2 Satellite
Picture from Digital Globe

Over 4 Million Megapixels per day available via JPEG 2000

WorldView-2 Image – Tuscaloosa, Al

GIS and Remote Sensing

- Example: JPEG 2000/JPIP GIS Application
- **Norwegian Coast Guard** (**Kystvakten**) is delivering satellite imagery to ships over low bandwidth while navigate through the ice-infested waters of the Arctic Ocean
  - European Space Agency's Envisat Satellite and Canada's Radarsat-1 are collected, processed, and sent to the ships within 30 minutes
  - The data is compressed with JPEG 2000 and served via Iridium Satellite Phones
  - Enables ships to get updated information that can save time, money and possible ships

Information from Werner, Debra, "Navigating Arctic Ice with an Assist from an Iridium Phone", *Space News*, January 2009.

GIS and Remote Sensing

- Example: JPEG 2000/JPIP Data Sharing Application
- HiRISE (High Resolution Imaging Science Experiment) is camera is a camera on board the Mars Reconnaissance Orbiter.
- NASA/JPL/UofA process the images and share them with the world through the University of Arizona (UofA) department of Planetary Sciences web site
  - http://hirise.lpl.arizona.edu/nea.php