Multimedia Communication

Zhu Li
http://l.web.umkc.edu/lizhu

Outline

- Background
- Objective of the class
- Prerequisite
- Lecture Plan
- Course Project
- Q&A

Video Growth

- Better and Bigger Video:
  - Moving to UHD 4K resolution
  - HDR – High Dynamic Range
  - Much higher data rate

- Mobile Video:
  - 25X growth predicted over the next 5 years (source Cisco Visual Networking Index)
  - Low power encoding/decoding on devices
  - Mobile network capacity gap

- Internet Video:
  - Already accounts for more than half the internet traffic
  - Netflix alone 70% of ISP traffic at peak time.
  - Need better coding efficiency

Video Signal
Video Compression

- Uncompressed 1080p high definition (HD) video at 24 frames/second
  - Pixels per frame: 1920x1080
  - Bits per pixel: 8-bits x 3 (RGB)
  - 1.5 hours: 806 GB
  - Bit-rate: 1.2 Gbits/s
- Blu-Ray DVD
  - Capacity: 25 GB (single layer)
  - Read rate: 36 Mbits/s
- Video Streaming or TV Broadcast
  - 1 Mbits/s to 20 Mbits/s
- Require 30x to 1200x compression

Compression Approaches

- Basics of Video Compression
  - Remove redundancy from the signal – brain to eye connection is estimated to have only several hundred bits/sec capacity.
- Video Signal Redundancy:
  - Spatial Redundancy
  - Perceptual Redundancy
  - Temporal Redundancy
  - Symbol Statistical Redundancy

Spatial Redundancy Removal

- Intra Prediction – predict within the frame

Spatial Redundancy Removal

- Block Transform:
  - Block Transforms
    - Typically matrix operations
    - Used for correlation reduction and energy compaction in the block
  - 8x8 2D Discrete Cosine Transform (DCT)
Perceptual Redundancy

- Human Visual System (HSV) is more sensitive to changes in low freq. areas than high freq.
- Capitalize on this by allow for coarser quantization at different texture areas.

Temporal Redundancy

- Exploit redundancy among successive frames
  - Inter prediction
  - Frame difference coding
    - Difference can be encoded using DCT + Quantization + Entropy Coding

Motion Compensation

- Block based motion compensation for Temporal Redundancy removal
  - Inter prediction using Motion compensated prediction
    - Divide the frame into blocks and apply block motion estimation/compensation
    - For each block find out the relative motion between the current block and a matching block of the same size in the previous frame
    - Transmit the motion vector(s) for each block
Video Motion Prediction Structure

- I, P, B, b Frames...

- Intra Picture (I)
  - Picture is coded without reference to other pictures

- Inter picture (P, B, b)
  - Uni-directionally predicted (P) Picture
    - Picture is predicted from one prior coded picture
  - Bi-directionally predicted (B, b) Picture
    - Picture is coded from two prior coded pictures

Symbol Stats Redundancy

- Not all pixel values have the same frequency
  - Say if 128 appears 90% of time, we can use short bits to represent, and longer bits to represent the rest of symbols
  - Entropy coding!

  - Original image: 8 bits/pixel, Entropy coding: 7.14 bits/pixel

  - Results more dramatic when entropy coding is applied on transformed and quantized image: 1.82 bits/pixel

Video Compression in Summary

- Intra Prediction and Inter Prediction

- Transform and Quantization of residual (prediction error)
  - many pixels → few coefficients

- Entropy coding on syntax elements
  - e.g. prediction modes, motion vectors, coefficients

Video Coding Standard

- Why Standard?
  - Ensures inter-operability between encoder and decoder
  - Support multiple use cases and applications
    - Levels and Profiles
  - Video coding standard specifies decoder: mapping of bits to pixels
  - ~2x improvement in compression every decade
Video Coding Standard History

- **Pre-HEVC**
  - MPEG: Moving Picture Experts Group (ISO/IEC)
  - VCEG: Video Coding Experts Group (ITU-T)
  - Other standards: VC1, VP8/VP9, China AVS, RealVideo

HEVC – High Efficiency Video Coding

- **Objective of HEVC**
  - Achieves 2x higher compression compared to H.264/AVC
  - High throughput (Ultra-HD 8K @ 120fps) & low power
    - Implementation friendly features (e.g. built-in parallelism)
  - Benefits include
    - reduce the burden on global networks
    - easier streaming of HD video to mobile devices
    - account for advancing screen resolutions (e.g. Ultra-HD)

  "HEVC will provide a flexible, reliable and robust solution, future-proofed to support the next decade of video"

Rate-Distortion Performance

- **Pre-HEVC**

HEVC History

- **Very brutal…**
  - Chairs
    - G. J. Sullivan (Microsoft)
    - J. R. Ohm (Aachen University)
  - Meet Quarterly
    - 1st meeting (A) [January 2010]
    - 12th meeting (L) [January 2013]
  - 250 attendees per meeting representing ~70 companies
  - Several hundred contributions per meeting
    - Each meeting is around 9 - 10 days (14+ hours/day)
    - Multiple parallel tracks
HEVC Performance

<table>
<thead>
<tr>
<th>Encoding</th>
<th>PSNR (dB)</th>
<th>Bit-Rate Savings Relative to HEVC MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.264/AVC HP</td>
<td>35.4%</td>
<td>35.4%</td>
</tr>
<tr>
<td>H.264/AVC HP</td>
<td>63.7%</td>
<td>63.7%</td>
</tr>
<tr>
<td>H.264/AVC HP</td>
<td>65.1%</td>
<td>65.1%</td>
</tr>
<tr>
<td>H.264/AVC HP</td>
<td>70.8%</td>
<td>70.8%</td>
</tr>
<tr>
<td>MPEG-4 ASP</td>
<td>--</td>
<td>46.6%</td>
</tr>
<tr>
<td>MPEG-4 HVP</td>
<td>--</td>
<td>55.4%</td>
</tr>
<tr>
<td>MPEG-4 ASP</td>
<td>--</td>
<td>19.7%</td>
</tr>
<tr>
<td>H.264 HVP</td>
<td>--</td>
<td>16.2%</td>
</tr>
</tbody>
</table>

HEVC Resources

- **Overview Paper:**

- **Spec:** H265 High Efficiency Video Coding Specification
  - [http://sist.sysu.edu.cn/~isscwli/ref/h265.pdf](http://sist.sysu.edu.cn/~isscwli/ref/h265.pdf)

- **Reference Software:**
  - [https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/](https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/)

- **Python Tool:** HARP
  - [http://lms.lnt.de/HARP/](http://lms.lnt.de/HARP/)

New Media – 3D Image/Video

- **Point Cloud Capture & Compression**

Point Cloud Compression

- **Octa Tree Decomposition & Coding**

recursive sub-divisions: complexity $O(2^N)$
Limit level $N$ and differentially code of points in larger leafs for real-time coding [Kammerl12]
Prediction of subdivisions based on the previous level [Schnabel06, Huang06]
Context Adaptive Entropy encoding [Schnabel06, Huang06]
rangep coding [Kammerl12]
**Video Communication**

- The Dimension of the Video Communication Problem:
  - Content: managed vs UGC
  - Transport: managed IP networks vs Over The Top (OTT) networks
  - Devices: managed settop boxes, vs unmanaged devices

**Current Landscape**

- Managed vs Unmanaged:
  - From Totally Best-Effort to Fully-Managed Offerings
  - Challenge is to Provide a Solution that Covers All

**Traditional TV vs OTT Video**

- Services are converging…

**The Lines are Blurring between TV and the Web**

**Netflix Phenomena**

- Purely OTT Solution, very successful in user penetration
- Accounted for a large portion of ISP traffic between 8-10pm.
HBO

Internet is dominated by video traffic

- Top Down/ Bandaid approach:
  - CDN (Content Delivery Network) Solutions, mostly based on HTTP transport

- New Trend/Clean Slate Approach:
  - ICN (Info Centric Networking), design from layer 3 up to support video

Multimedia is Predominant on the Internet

- Real-time entertainment
  - Streaming video and audio
  - More than 60% of Internet traffic at peak periods

- Popular services
  - YouTube (14.0%), Netflix (34.9%), Amazon Video (2.6%), Hulu (1.4%
  - All delivered over the top

PSS over managed IP networks

- Managed mobile core IP networks

MPEG DASH – OTT

- HTTP Adaptive Streaming of Video
Quality of Experience (QoE)

- Spatial quality
- Temporal quality
- Viewing condition
- Packets received

Prerequisite & Text book

- Prerequisite
  - Good C and Python programming skills
  - Taken Digital Signal Processing and/or Digital Image Processing, or consent of the instructor
  - Will have different expectation for MS and undergrad students

- Textbook:
  - None required (saving $), will distribute relevant chapters, papers, and notes.

- Key References:
  - K. Sayood, Introduction to Data Compression, 3rd Edition

Tentative Plan

Video Coding
1) Entropy and Info Theory Background
2) Lossless Coding/Entropy Coding: Hoffman, Arithmetic
3) Lossy Image Coding: Transforms, Quantization, Wavelet/JPEG2000
4) Video Signal Processing: Sampling, Motion Compensation
5) Scalability and Super Resolution
6) Video Coding Standards: HEVC

Video Networking
1) QoE metrics, Source-Channel Coding and Error Resilience
2) Media Transport: RTP/RTSP/RVSP/RTCP, HTTP/Websocket, WebRTC
3) Congestion Measurement and Control: TCP, SCTP, SPDY, NADA
4) CDN, HTTP Cache, Cache Deduplication, and delivery acceleration
5) OTT Video Streaming Standards: DASH, MMT
6) Overlay networks and P2P video streaming

Course Outcome

- Upon completion of the course you will be able to:
  - Understand the basic compression theory and algorithms for media compression.
  - Familiar with the latest media compression and communication solutions and have hands on experiences.
  - Can apply the knowledge an algorithms to solve real world media communication problems
  - Have good job and internship prospect with both Semiconductor Makers like QCOM, MediaTEK, Samsung, Intel, Broadcom, and content provider and CDN/ISP operators like AKAMAI, Netflix, Youtube, COMCAST, HBO, Sprint, ATT.
Grading

- Homeworks (30%)
  - Lossless coding of symbols
  - Lossy image coding
  - Motion Compensation
  - Video codec exercise
  - Network simulation of video streaming
- Quiz (30%): relax, quiz is actually on me, to see where you guys stand
  - Quiz-1: On Video Coding
  - Quiz-2: On Video Communication
- Project (40%)
  - Original work leads to publication (1.25x factor), discuss with me by Spring break
  - Regular project: assign papers to read, implement certain aspect, and do a presentation

Logistics

- Office Hour:
  - Mon, Wed: 2:30-4:00pm, 560E FH
  - Or by appointment
- TA:
  - Lohith K. Vemula
  - Lab Sessions are planned to cover certain software tools aspects.
  - Office Hour: TBA
- Course Resources:
  - Will share a box.com folder with slides, references, data set, and software
  - Volunteer Course Web Master recruiting: count as 10% extra credit

Q&A

- ....