Sharp or Smooth? Comparing the Effects of Quantization vs. Frame Rate for Streamed Video

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Introduction (1 of 2)

• Streaming sports (football) are popular Internet service
  – The NFL ... but they mean soccer
  – Key business for mobile services
• Little known about quality levels required
  – Minimum for acceptable quality?
• For given constraint, what is best?
  – Note, constraint may be bitrate capacity or power or...
• Recent IBM QoS policy says:
  – “The priority for smooth video is higher than the priority for frame quality”
• Yet, available evidence suggests sports are relatively insensitive to changes in frame rate

Introduction (2 of 2)

• Discover functions relating physical quality to perceived quality
  – Graphs give service providers knowledge to manage resources
• New methodology
  – Test sports on sports enthusiasts (may buy)
  – Gradually increase or decrease video perf within clip to determine acceptability edge
  – Investigate effects of frame rate and quality (quantization) on acceptability
  – Get subjective responses and eye movements
  – Examine palmtop and desktop

Outline

• Introduction (done)
• Background
• Method
• Study 1 (Desktop)
• Results
• Study 2 (Palmtop)
• Results
• Conclusions
Background – Perceived QoS

• Typically, show short (~10 second) clip and measure with 5-point rating [11]
  – Problematic when network conditions vary over time
  – Problematic when content changes over time
• Continuous quality evaluation using slider [3,4,8,14]
  – But can be intrusive for real-time tasks

Background – Physical QoS

• Physical metrics impacting quality: resolution, frame rate, frame quality (quantization) [6]
  – For MPEG type compression, quantization of DCT coefficient dominates
• Other metrics that impact quality: size of display, distance between observer and display
• For service provider, primary factors they can control are frame rate and frame quality
  – Focus on those in this study

Background – Service Providers and Acceptability

• Service providers need metric to relate physical quality to perceived quality
  – Neither MOS nor slider give good indication of acceptability (Ex: is MOS of 3 acceptable?)
• Some researchers have used 5-point acceptability scale [5,9]
• Draw upon this work for new metric:
  – Easy to understand
  – Less disruptive than continuous techniques
  – Can be used with variable video quality
  – Is more relevant to service providers

Background – Relevant Studies

• Most related work shows sports insensitive to frame rate changes
  – Apteker et al. [2] study frame rates 5, 10, 15 fps and show acceptability of sports highlights little difference
  – Ghinea and Thomas [7] show information content same for 5, 15, 25 fps
  – Wang et al. [15] manipulate frame rate and quantization for 8 second video (American football)
    • “Quantization distortion is generally more objectionable than motion judder”
• All run against intuition that higher motion needs higher frame rate
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Method

- Method of Limits (Fechner in [5]):
  - Gradually increase stimulus in steps until it is just detectible
  - Give subject binary (yes/no) to detect
  - Also run in reverse (decrease stimulus in steps)
- Authors:
  - Variant of this: ask users if acceptable or not
- Use 210 second clips, increase/decrease quality every 30 seconds (7 types)
  - But don’t tell users, only “varied in quality”

Quality Gradients

- Three types
  - Temporal: Frame rate (fps)
  - Quality: Quantization
  - Both
- Each has 7 levels
  - (30 seconds x 7 = 210 s)
- User free to say “acceptable” or “unacceptable” as much as want

Eye Tracking

- Measure where users looked using remote eye-tracking camera
  - Measure with EyeGaze from LC technologies [13]
  - Record where looking with EyeSpy (open source)
- Help identify regions of interest → could, someday, make compression use info
  - More detail for area user looking at (ex: ball and person kicking)
  - Less detail for background (ex: pitch, fans)
Source Material

• Sourced from DVD of recent match between Manchester United and Arsenal

<table>
<thead>
<tr>
<th>Clip</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Match intro and opening 2 minutes of play</td>
</tr>
<tr>
<td>B</td>
<td>Highlights of Manchester United chances</td>
</tr>
<tr>
<td>C</td>
<td>Highlights of Arsenal chances, floodlights and Arsenal celebrations</td>
</tr>
</tbody>
</table>

• Three clips, include variety of camera angles and shots (including replays)
• CIF (252x288) for study 1, QCIF (176x144) for study 2
• H.263 encoded for quality gradients
• Re-encode to MPEG so could use commercial (e.g., RealPlayer)
• Audio for all clips is 64 kbps
• Total of 18 clips for study 1, Total of 9 clips for study 2

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Study 1 – Small Screen on Desktop

• 41 participants (29 male, 12 female)  
  – Average age 22
• Paid 5 pounds (about $8)
• Tried to recruit those who liked football (soccer) and watched regularly  
  – 59% one+ per week, 88% rooted for some team, 50% supported one team in clip
• 352x288 resolution on LCD with 1024x768
• RealPlayer set to theater mode (rest is black)

Study 1 – (Continued Design)

• Each saw 6 clips: FPS, Quant, FPS+Quant  
  – both increasing and decreasing gradients
• Counter-balance with “Greco Latin” squares design (no sequences appear more than once row or column)
• Participants briefed first  
  – Told Telecom company wanted acceptable region

Study 1 – (Continued Design)

<table>
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<tr>
<th>F</th>
<th>0.25</th>
<th>A</th>
<th>0</th>
<th>B</th>
<th>0</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>Quant</td>
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<td>FPS</td>
<td>Quant</td>
<td>FPS</td>
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<td>Quant</td>
<td>FPS</td>
<td>Quant</td>
<td>FPS</td>
</tr>
</tbody>
</table>

Group 1A | Group 2A | Group 3A | Group 4A
Group 1B | Group 2B | Group 3B | Group 4B
Group 5 | Group 6 | Group 7 | Group 8

Increasing Quality | Decreasing Quality | Increasing Quality | Decreasing Quality
---|---|---|---
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
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Perceived Quality and Frame Rate

- Transform binary (yes/no) to ratio by calculating which portion of 30 seconds acceptable (Ex: unacceptable at 20s of the 30 would be 0.667)
- ANOVA test says all different
- At 6 FPS, quality is acceptable 80% of the time

Perceived Quality and Quantization

- ANOVA test says difference
- Sharp drop after 8 quantization
- Interesting shape

Quantization and Frame Rate

- ANOVA test says difference
- Similar to quantization alone
- Suggest quantization dominates
Eye Movements

- Similar across all clips – focus is on center.
- May be because nature of video – action is in center.
- Could use this region of interest in compression
  + use more bits on area where gaze is focused

Averaged over all clips

Study 2 – Study on Palmtop

- 37 participants (31 male, 6 female)
  – Mean age 22
- Paid 5 pounds (about $8)
- Tried to recruit those who liked football (soccer) and watched regularly
  – 65% one+ per week, 84% rooted for some team with 38% supporting one team in clip
  – (Me: not clear of participant overlap between studies)
- 176x144 resolution, iPAQ h2210
- Additional clip to study critical values

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Perceived Quality and Frame Rate

- Low FPS less acceptable on palmtop than desktop
- Driven by one clip (B) with panning and action
- Still acceptable at least 50% of time at 6 FPS
Perceived Quality and Quantization

Quantization and Frame Rate

Critical Values, Acceptability and Bandwidth

Qualitative Comments

- When “unacceptable”, users give reasons:
  - 84% said recognizing players was impossible
  - 65% had problems following the ball
  - 35% said close up shots fine, but distant camera shots very poor
  - 21% cited jerky movement as one problem

- Summary statement:
  - “I’d rather have jerky video and better quality pictures”
Conclusions

- Limitations of approach
  - Additional degradations are not factored in (packet errors, changing capacity, etc.)
- Substantive findings
  - Response curve relating perceived quality to physical quality
  - Population of users with clear interest (i.e., would be consumers and pay for service)
  - At 6 fps, 80% of the time video is acceptable
  - Challenges assumption that sports must be high frame rate
- Methods of limits
  - Provides stable metric
  - Curves in line with ITU logistic with quality

Future Work?

Future Work

- Screen size (inches) and resolution (pixels)
  - Mobile device/player could pick if difference
- Other video content
  - Include measure of motion
- Investigate using eye tracking data for compression
  - Need computationally cheap way to save bandwidth without impacting quality
- Same bitrate for quality versus frame rate (versus resolution)