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

J. McCarthy, M. A. Sasse and D. Miras

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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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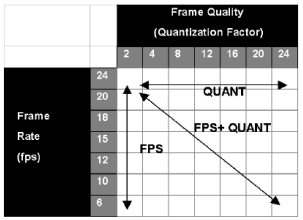
Method

- 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

Clip	Content
A	Match Intro and opening 3 minutes of play
B	Highlights of Manchester United chances
C	Highlights of Arsenal chances, final whistle and Arsenal celebration

- 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

F = fps *Q = quant*	Source Clip			Source Clip		
	A	B	C	A	B	C
	Decreasing Quality			Increasing Quality		
Group 1A	*F*	*Q*	*F+Q*	*F*	*Q*	*F+Q*
Group 2A	*Q*	*F+Q*	*F*	*Q*	*F+Q*	*F*
Group 3A	*F+Q*	*F*	*Q*	*F+Q*	*F*	*Q*
study 2	Increasing Quality			Decreasing Quality		
Group 1B	*F*	*Q*	*F+Q*	*F*	*Q*	*F+Q*
Group 2B	*Q*	*F+Q*	*F*	*Q*	*F+Q*	*F*
Group 3B	*F+Q*	*F*	*Q*	*F+Q*	*F*	*Q*

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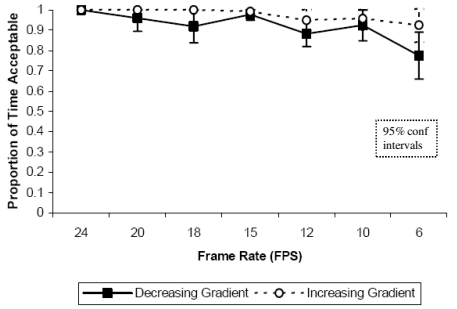
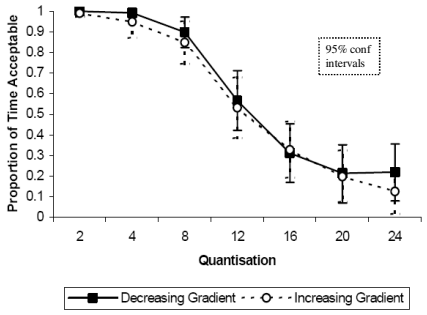
Perceived Quality and Frame Rate

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)



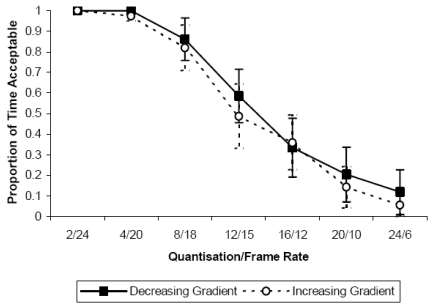
- ANOVA test says all different
- At 6 FPS, quality is acceptable 80% of the time

Perceived Quality and Quantization



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

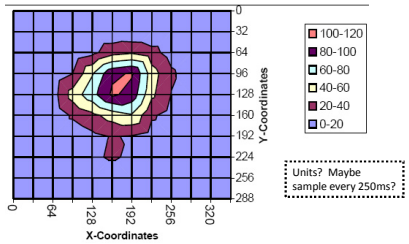
Quantization and Frame Rate



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

Eye Movements

Averaged over all clips



Units? Maybe sample every 250ms?

- 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

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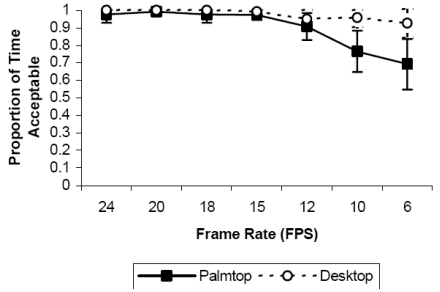
Study 2 – Study on Palmtop

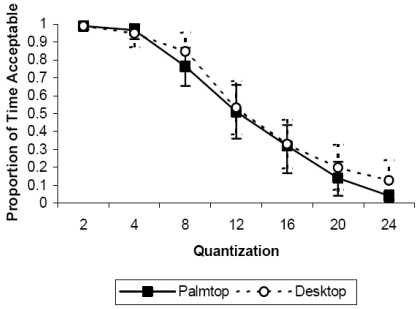
- 37 participants (31 male, 6 female)
  - Mean age 22
- Paid 5 pounds (about $8)
- Tried to recruit those who liked football (soccer) and watched regularly
  - 65% one+ per week, 84% rooted for some team with 38% supporting one team in clip
  - (Me: not clear of participant overlap between studies)
-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

Perceived Quality and Frame Rate



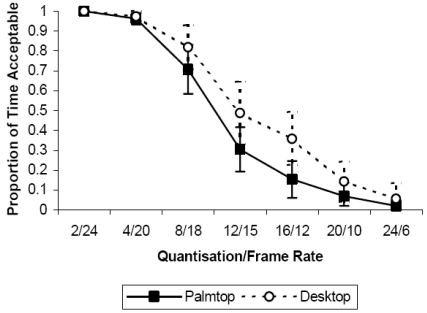
- Low FPS less acceptable on palmtop than desktop
- Driven by one clip (B) with panning and action
- Still acceptable at least 50% of time at 6 FPS

Perceived Quality and Quantization



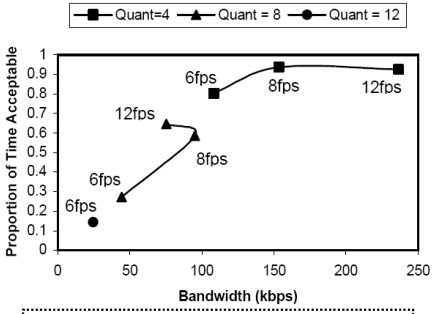
- Similar for both
- Again, critical value at 8 quantization

Quantization and Frame Rate



- Again, palmtop appears slightly more sensitive
- May be because of frame rate

Critical Values, Acceptability and Bandwidth



- Study relationship with 4th clip
- Examine only critical values from previous study
- For low quality, drop in frame rate may compound?
- Me: quantization *dominates* for bandwidth

(was not comparing "apples to apples" before)

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)