LevelUp: A Thin-cloud Approach to Game Livestreaming

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Game Livestreaming

• Twitch
  • Average >2m concurrent viewers and >90k concurrent channels
  • >65m hours streamed and >1.5b hours watched per month

• Market size $40b, expected to grow 18% per year
Game Livestreaming
Cloud-based Video Transcoding Is Expensive

- $300+ to transcode 100 hours of video on Azure
- <$20 to livestream 100 hours of single-bitrate video on Wowza

- Reason: Video transcoding is resource demanding, usually requires hardware accelerators in the cloud
Mobile Hardware Trends

• The edge is ready to play a more central role in video livestreaming
Overview of the paper

• Idea
  • Offload cloud-based transcoding by encoding multi-bitrate videos on broadcasters’ smartphones
  • In case of bandwidth constraints, viewers boost reduced-resolution video quality with super-resolution using ML
  • Adopt game-specific CNN models to improve quality

• Contributions
  • Implementation of LevelUp prototype
  • Evaluation on COTS mobile devices

• Key Results
  • 88% improvement for low-resolution game streams
  • Only 5% battery usage for 30 mins video
LevelUp Design
LevelUp Design – bandwidth constrained
Broadcasters’s video pipeline

Capture screen

Resize to 3 resolutions

Send to HW encoder queue

Upload to server

Encode Segments
Viewer’s video pipeline – without SR

Download video segment

Decode

Display
Viewer’s video pipeline – with SR

1. Download video segment
2. Decode
3. Separate grayscale, chroma
4. Bicubic interpolate
5. Merge, display
How it builds on previous works

• Incremental work on DNN-based video super resolution (e.g., NAS)
• Similar to Dejavu which is used for video conferencing
• Orthogonal to other advances in codecs, compression, bitrate adaption
Game stream super-resolution

# of improvements with SR

PSNR: per-pixel, SSIM: structural, VMAF[1]: ML model of human perception

480p + SR

270p + SR

[1] https://github.com/Netflix/vmaf
Game stream super-resolution

VMAF improved 15-20%

VMAF improved 61-88%

[1] https://github.com/Netflix/vmaf
Game stream super-resolution

Interpolated, 480x270
LevelUp, 480x270
Game stream super-resolution

Interpolated, 480x270

LevelUp, 480x270
Quality vs. Bitrate
Quality vs. Bitrate

![Graph showing VMAF vs. Bitrate for various games with a VMAF boost by LevelUp.]
Quality vs. Bitrate

Super-resolution can greatly improve game stream quality w/o extra bandwidth consumption

Low+SR vs. Medium Bitrate: 70% lower bandwidth, 3-20% VMAF loss

Medium+SR vs. High Bitrate: 90% lower bandwidth, 10-20% VMAF loss
Can broadcaster encode multi-bitrate streams?

• Encode 3 2-second segments (1080p, 480p, 270p) at the same time
• Test on iPhone 11 Pro, the iPhone Xs, iPhone 8, iPhone 7, and iPhone 6s
• All devices can encode in realtime

• Multi-bitrate encoding is feasible on modern smartphones
Can viewers super-resolve video?

Recent smartphones equipped with ML accelerators can super-resolve gaming streams in realtime.
Energy overhead

LevelUp has small energy overheads even with super-resolution enabled.

} -5% after 30 min streaming
Conclusion

• Game livestreaming is expensive due to realtime transcoding
• LevelUp can greatly reduce game livestreaming costs by leveraging smartphones for transcoding
• LevelUp uses super-resolution to boost quality for reduced-resolution videos by up to 88%
• LevelUp can transcode and super-resolve game streams in realtime using recent smartphone hardware accelerators
Discussion

• Strengths
  • Clean and novel approach
  • Evaluation is extensive and relevant
  • Tradeoffs are well studied

• Weaknesses
  • Too much background information
  • System should be hybrid: cloud can still be helpful
  • Simple cost analysis could be included
    • Mobile bandwidth and resources are costly