

Perceptual Compression for Video Storage and Processing Systems

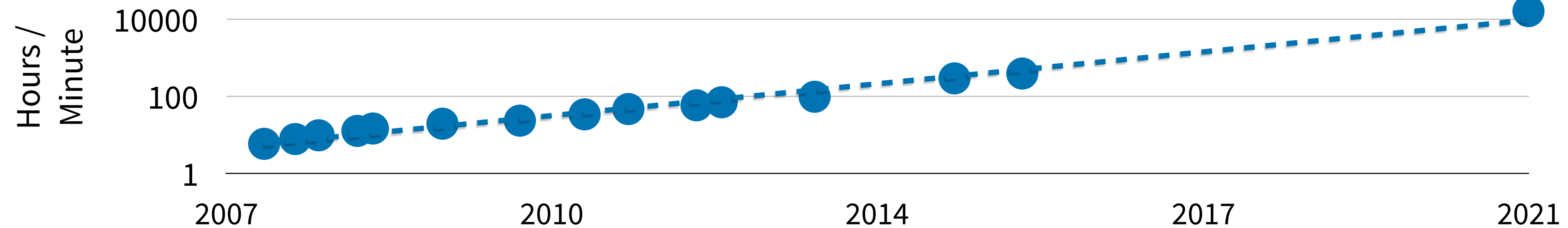
Amrita Mazumdar, Brandon Haynes, Magda Balazinska,
Luis Ceze, Alvin Cheung*, Mark Oskin

University of Washington

**University of California, Berkeley*

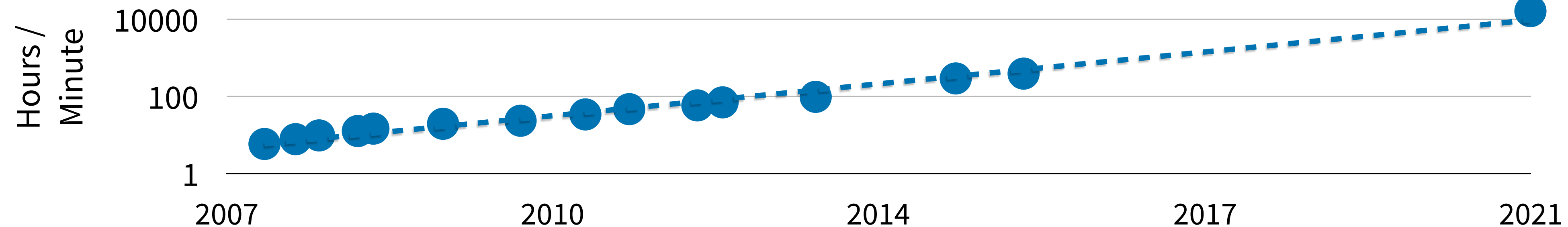
Video data is a fast-growing form of digital content

Hours of Video Uploaded Per Minute to YouTube

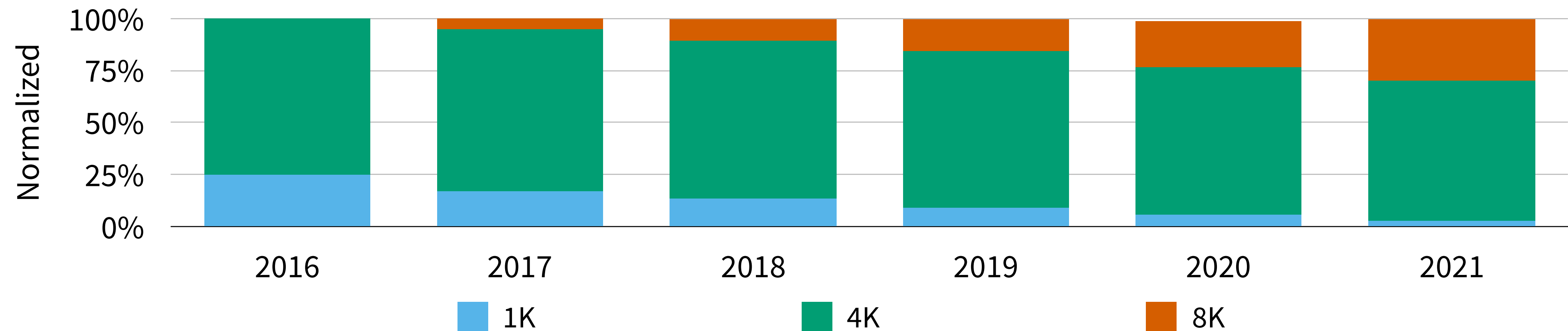


Video data is a fast-growing form of digital content

Hours of Video Uploaded Per Minute to YouTube



Exabytes (EB) uploaded per month



Video applications use compression to trade visual redundancy for file size



Baseline codec (HEVC) @ 20 Mbps
4 hours video playback

Video applications use compression to trade visual redundancy for file size

**fine details (noise,
high frequencies)**

color perception

fast motion



Baseline codec (HEVC) @ 20 Mbps
4 hours video playback

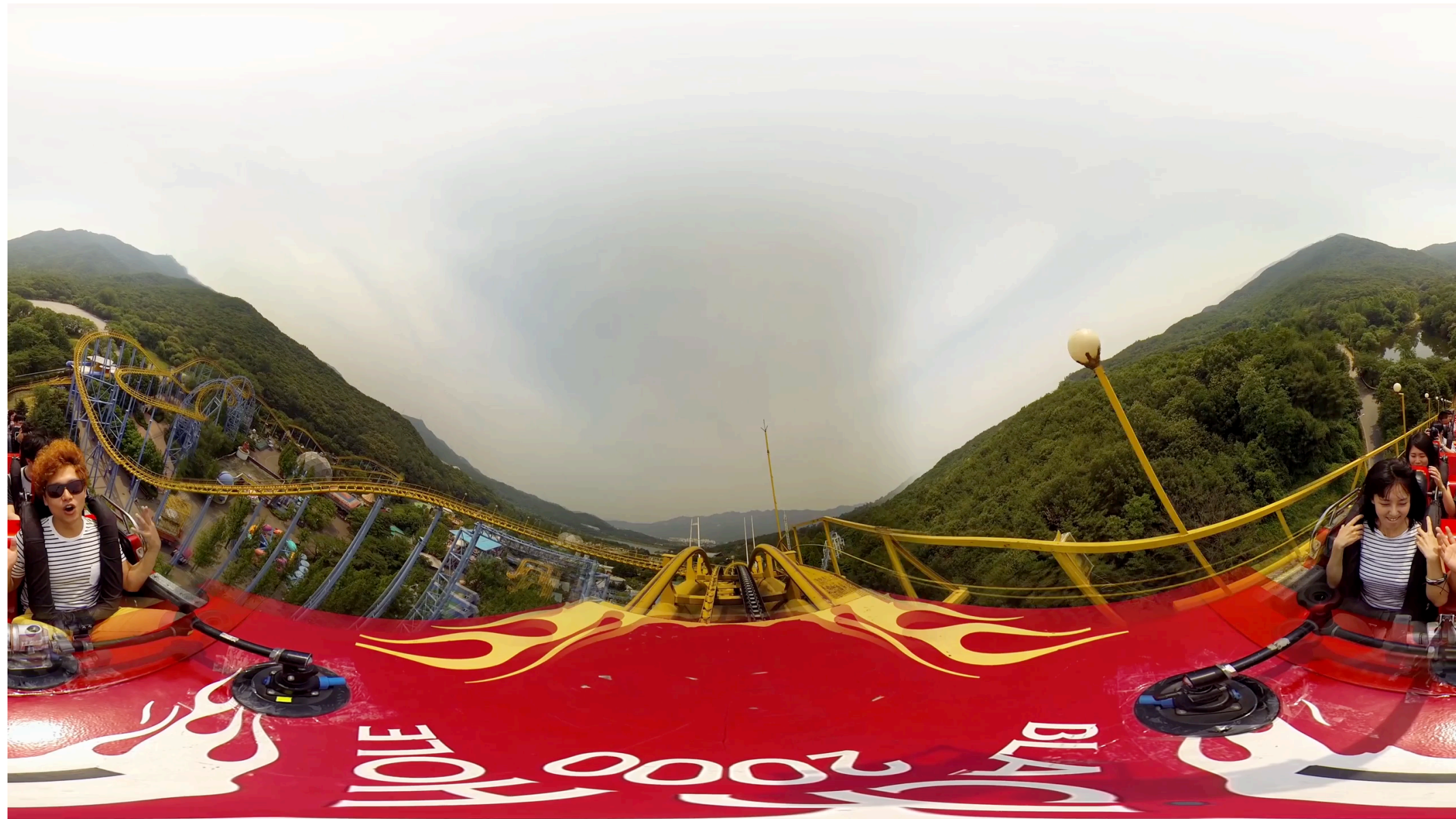
This work: Integrating new perceptual cues with video distribution systems for reduced video sizes



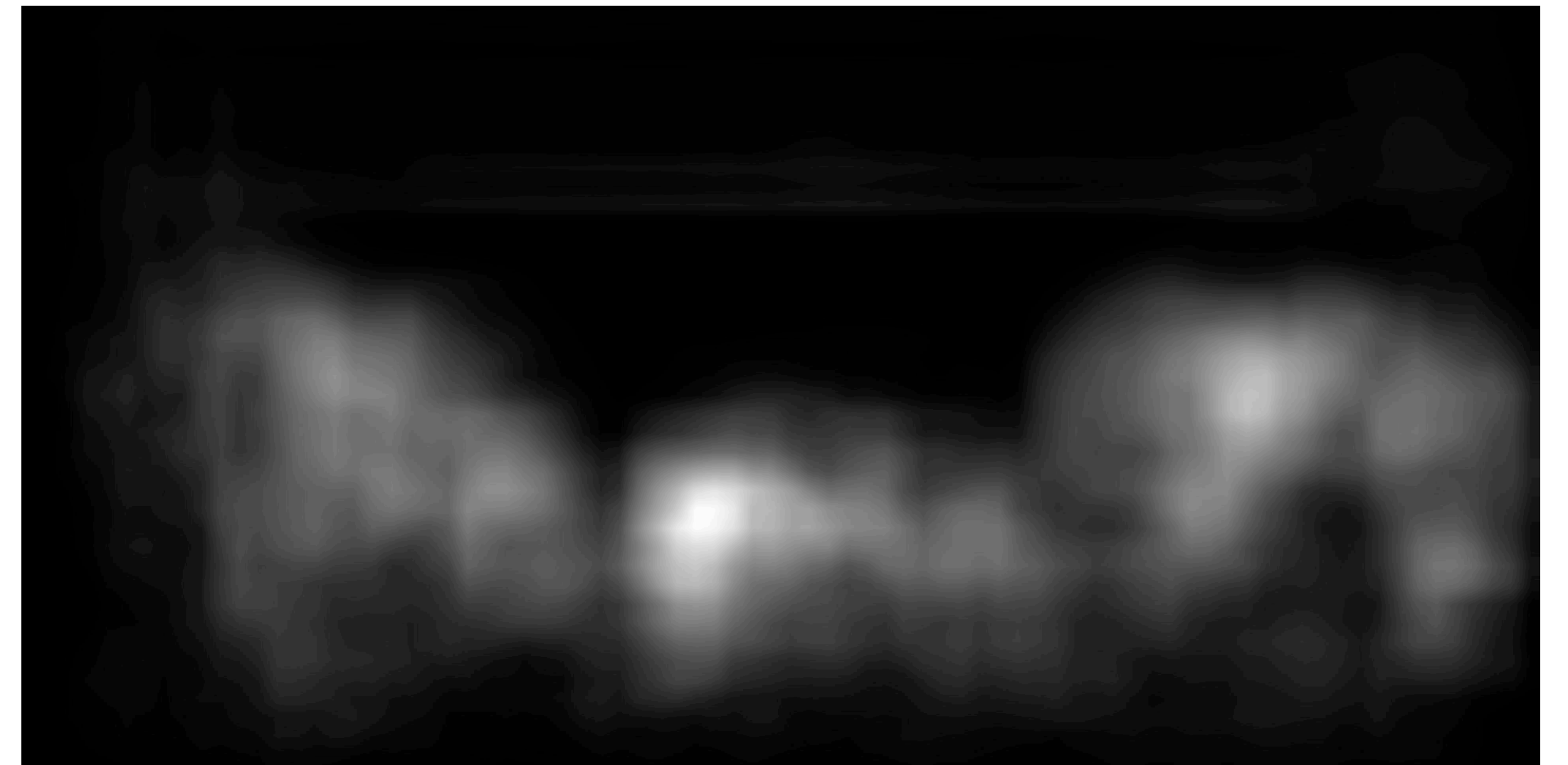
Baseline HEVC @ 20 Mbps
4 hours video playback

This work: 1 Mbps
6.5 hours video playback

Saliency is a powerful perceptual cue for reducing video size



4K 360° video
300 MB



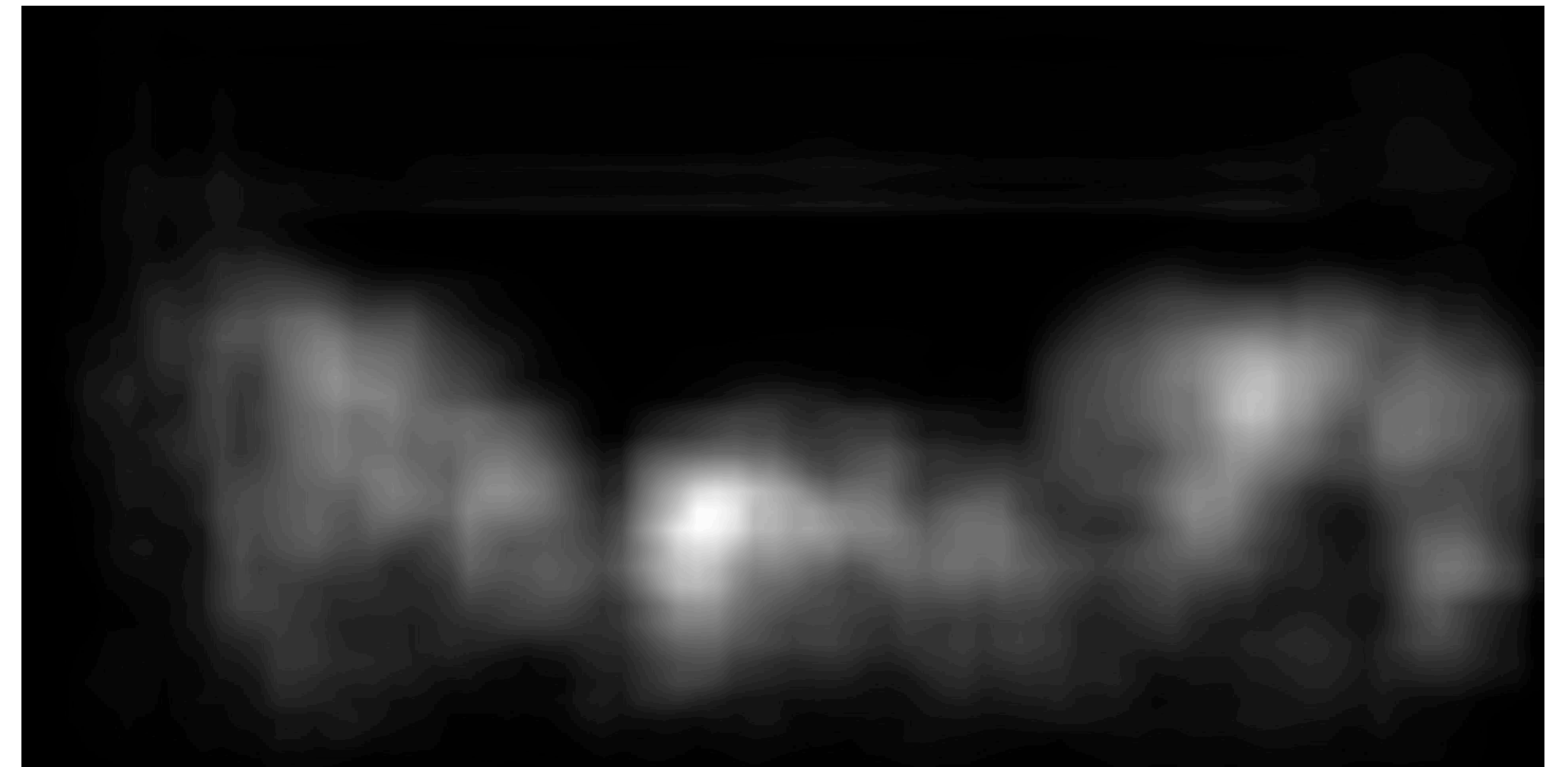
AI-generated saliency map
only 15% of pixels are important

Saliency is a powerful perceptual cue for reducing video size

Saliency is one of many new perceptual metrics

How can video services take advantage of them?

Can we leverage perception in cloud-scale video services for better storage and performance?



AI-generated saliency map
only 15% of pixels are important

Leveraging perceptual cues at scale is difficult

Requires custom, outdated codecs

Recent work:

- outdated codec
- 1,500 lines of code
- already worse by newer codecs w/o saliency compression

Leveraging perceptual cues at scale is difficult

Requires custom, outdated codecs

No integration with storage manager

Video storage manager concerns:

- How big is a file?
- How can I compress it?
- How do I control quality?

Leveraging perceptual cues at scale is difficult

Requires custom, outdated codecs

No integration with storage manager

No interface for applications

Video app concerns:

- Can I process this like any other video?
- Do I have to re-package this video for standard players?

Leveraging perceptual cues at scale is difficult

Requires custom, outdated codecs

No integration with storage manager

No interface for applications

Goals



Modern codecs



API for storage



Application portable

Vignette: a system for perceptual compression and storage

Vignette Compression

codec-free perceptual video compression framework

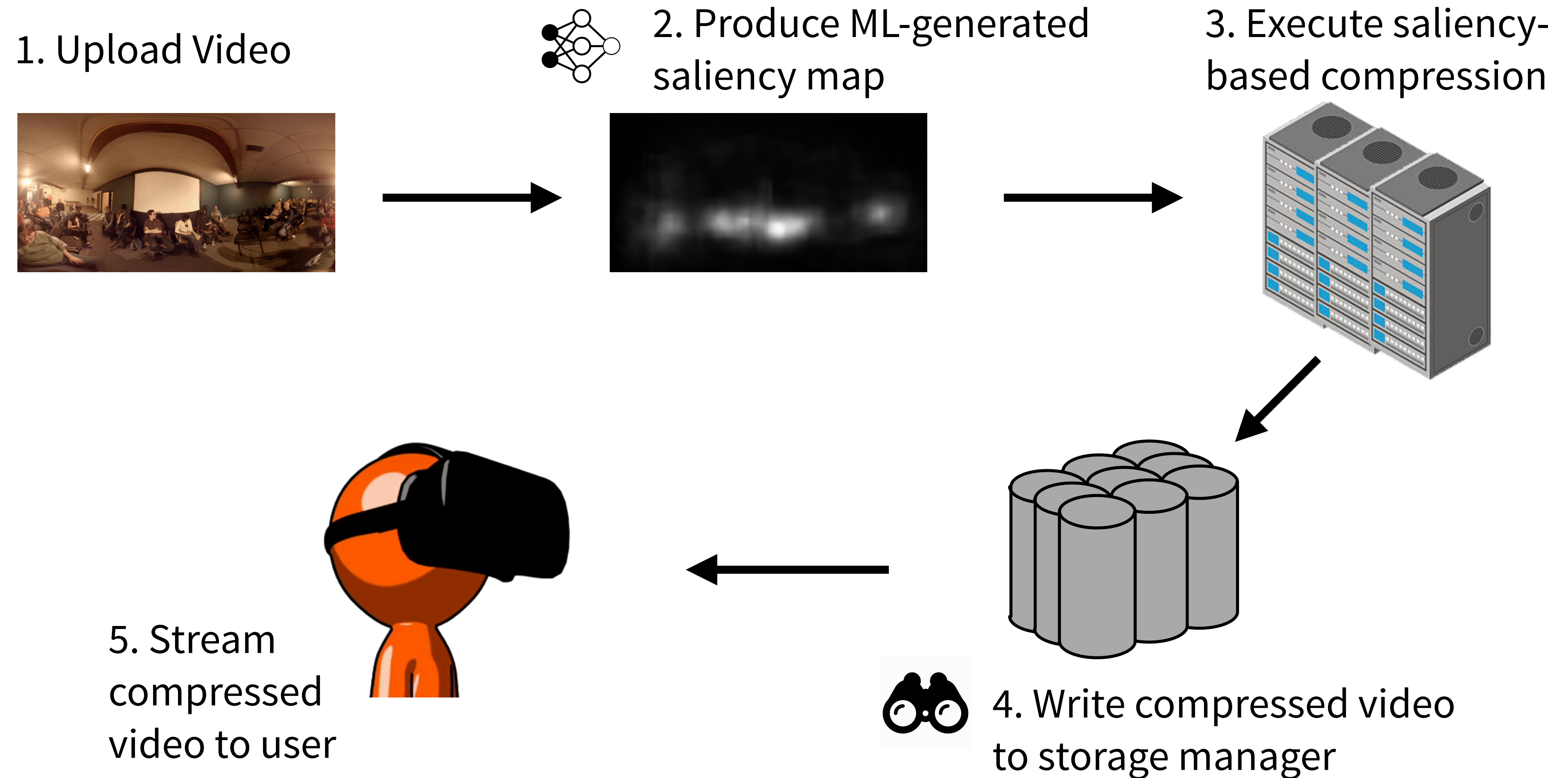
Vignette Storage

storage manager for perceptually-compressed videos

Reduces storage by up to 75-95% with little quality loss

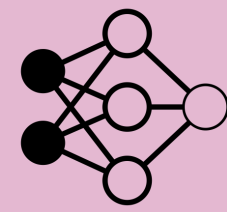
Resulting videos use 50% less power on mobile phones

Vignette system architecture



Vignette system architecture

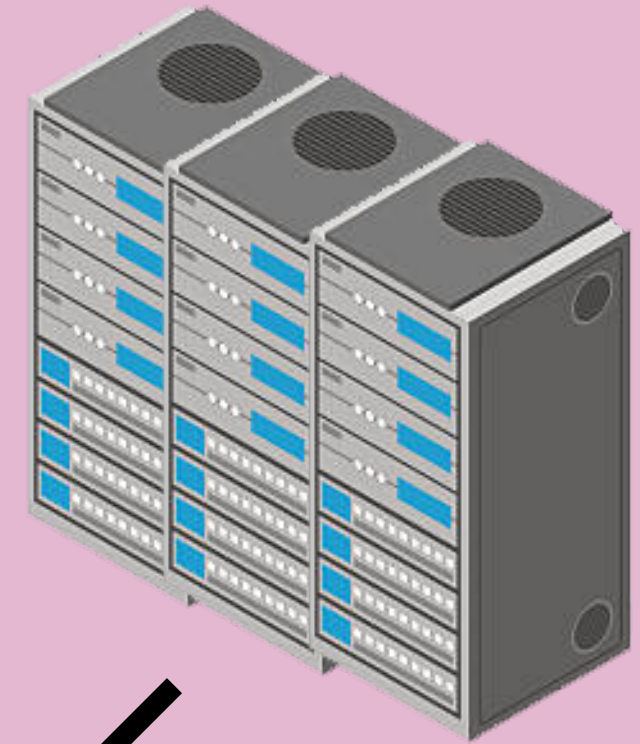
1. Upload Video



2. Produce ML-generated saliency map



3. Execute saliency-based compression

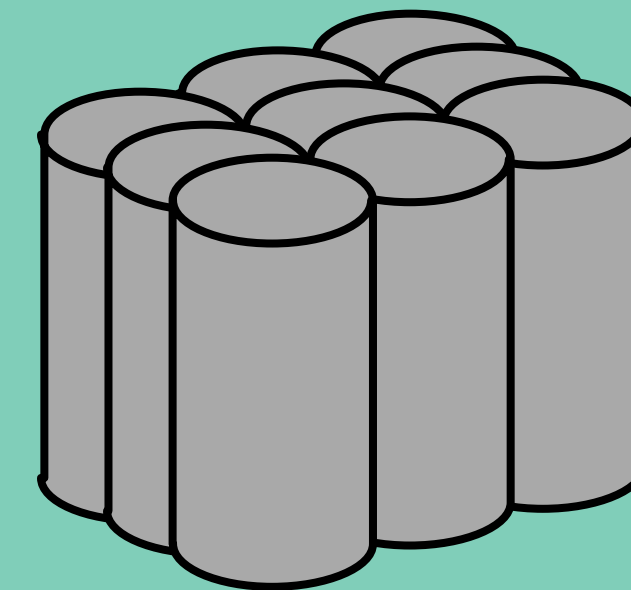


Vignette Compression

Vignette Storage



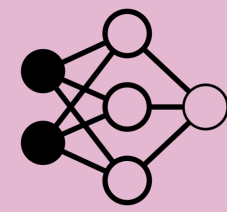
5. Stream compressed video to user



4. Write compressed video to storage manager

Vignette system architecture

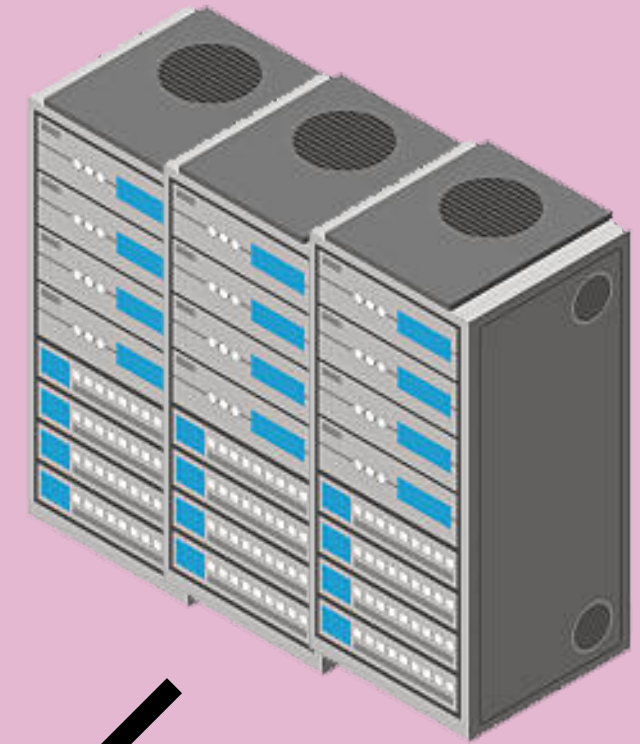
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Vignette Compression

Vignette Storage

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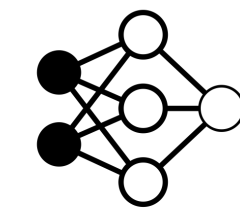
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Vignette Compression

ingest video

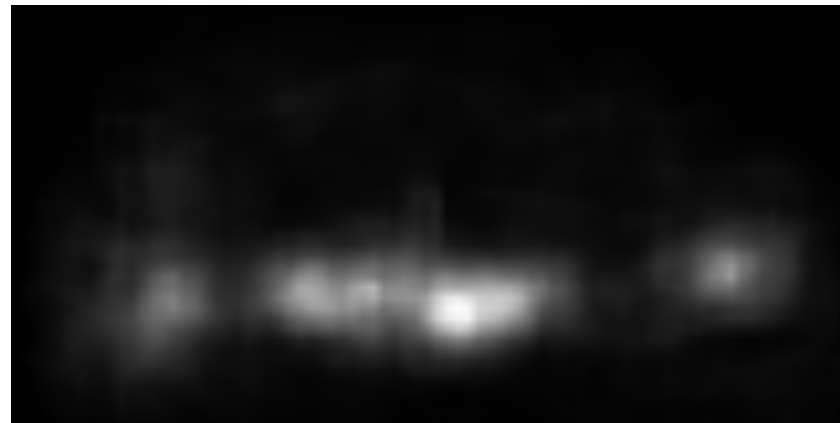


Vignette Compression

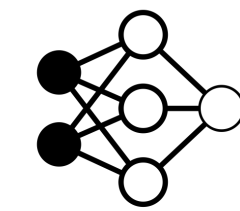


generate perceptual
map for the video

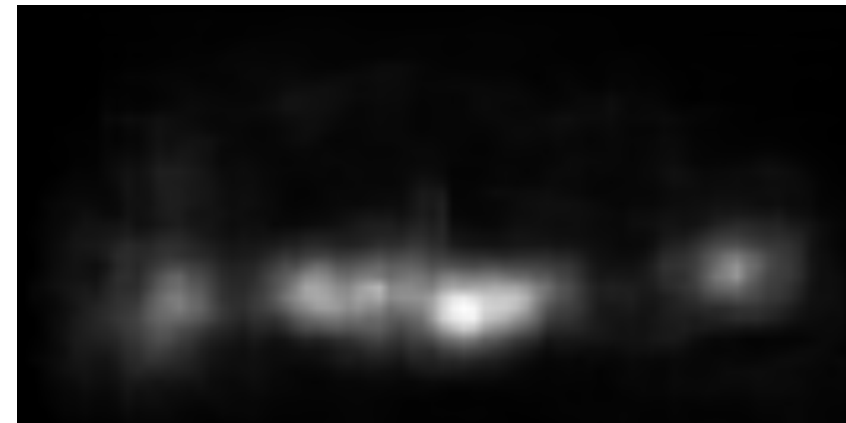
ingest video



Vignette Compression



generate perceptual
map for the video

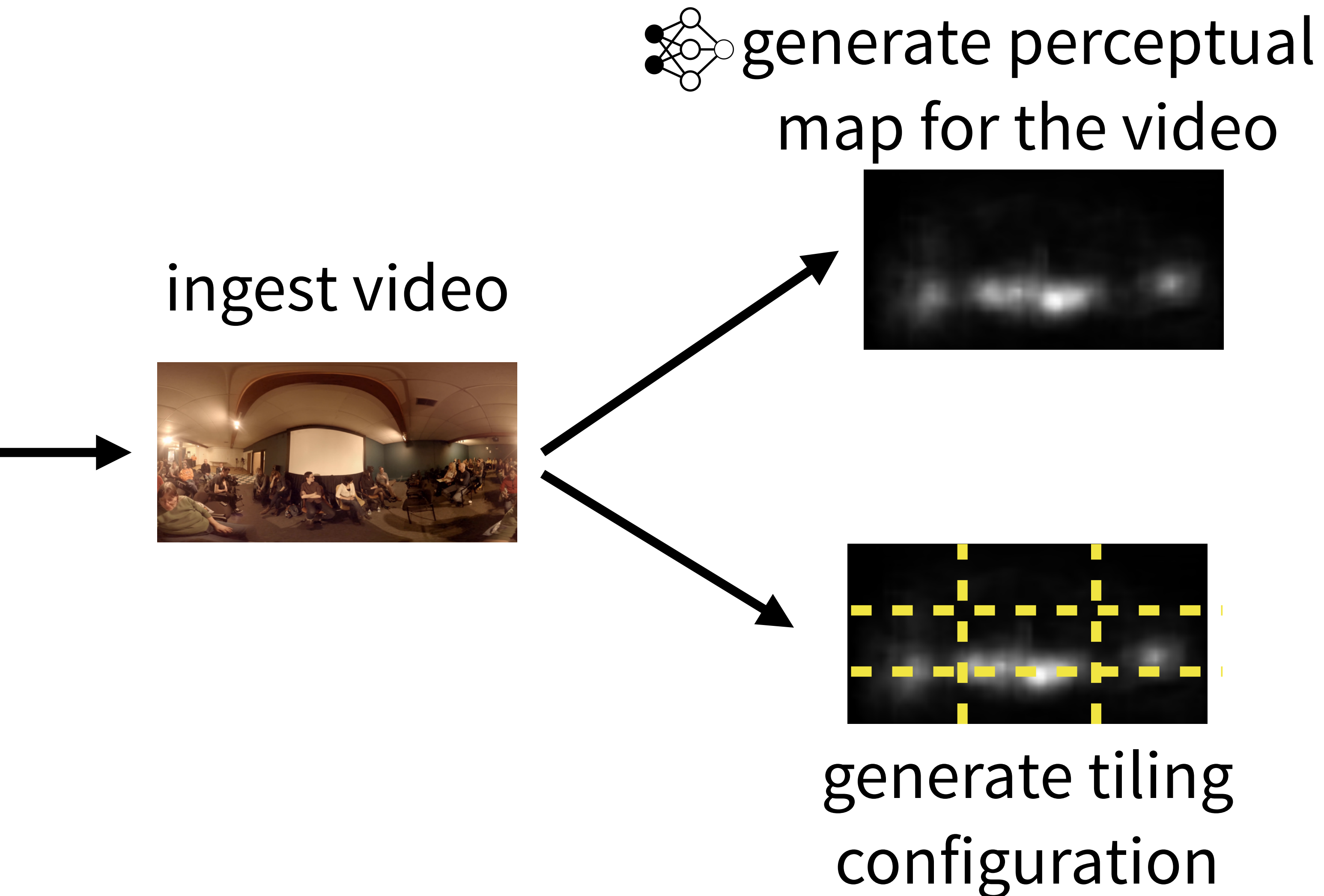


ingest video



- high-accuracy, compute-intensive neural network
- designed to easily switch to new models or perceptual metrics

Vignette Compression



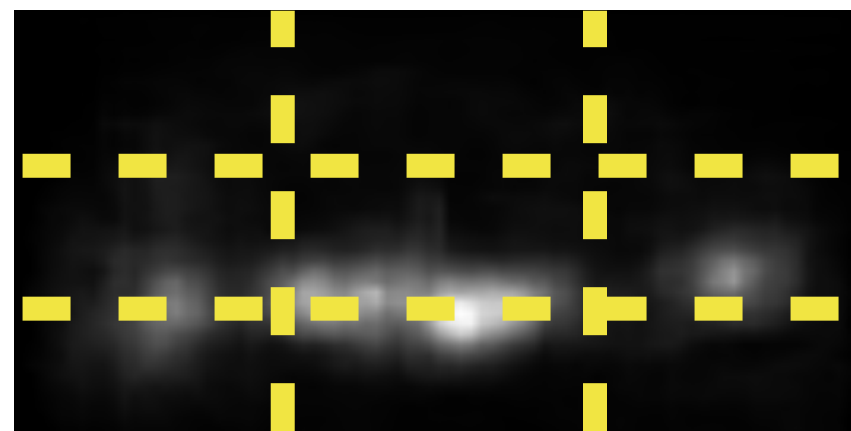
Vignette Compression

ingest video

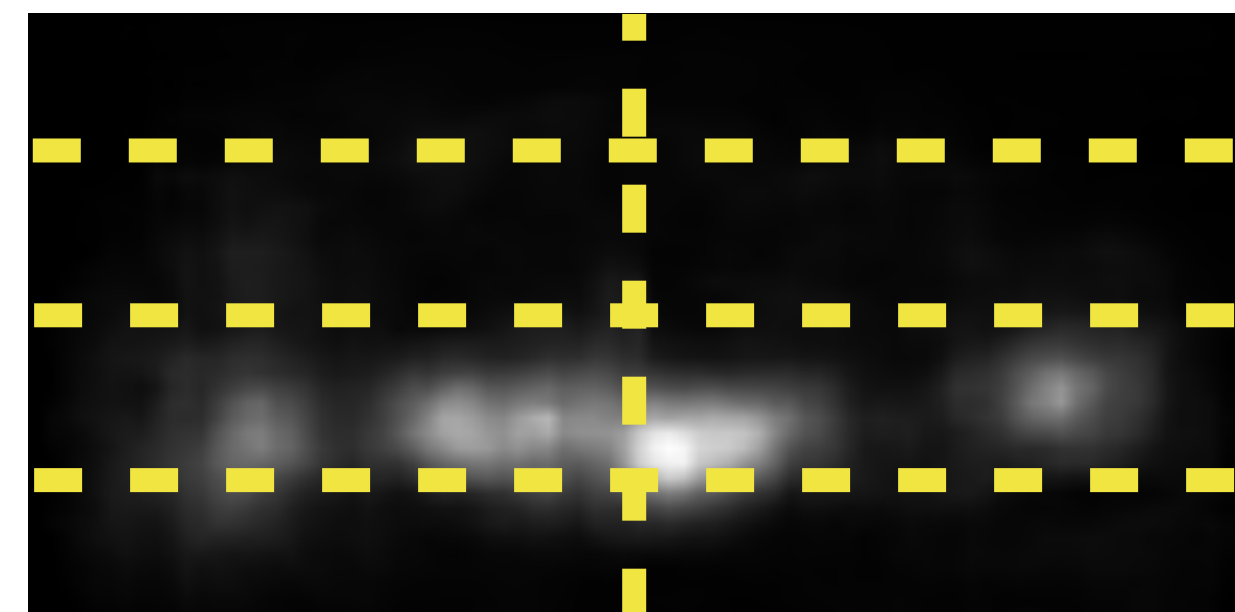
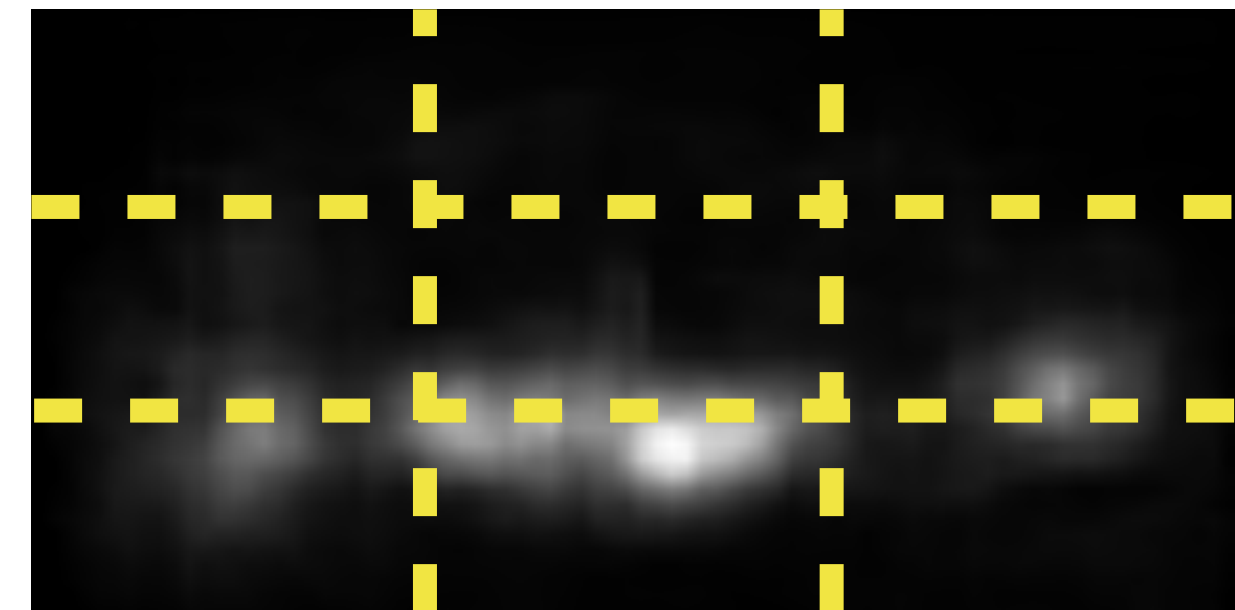
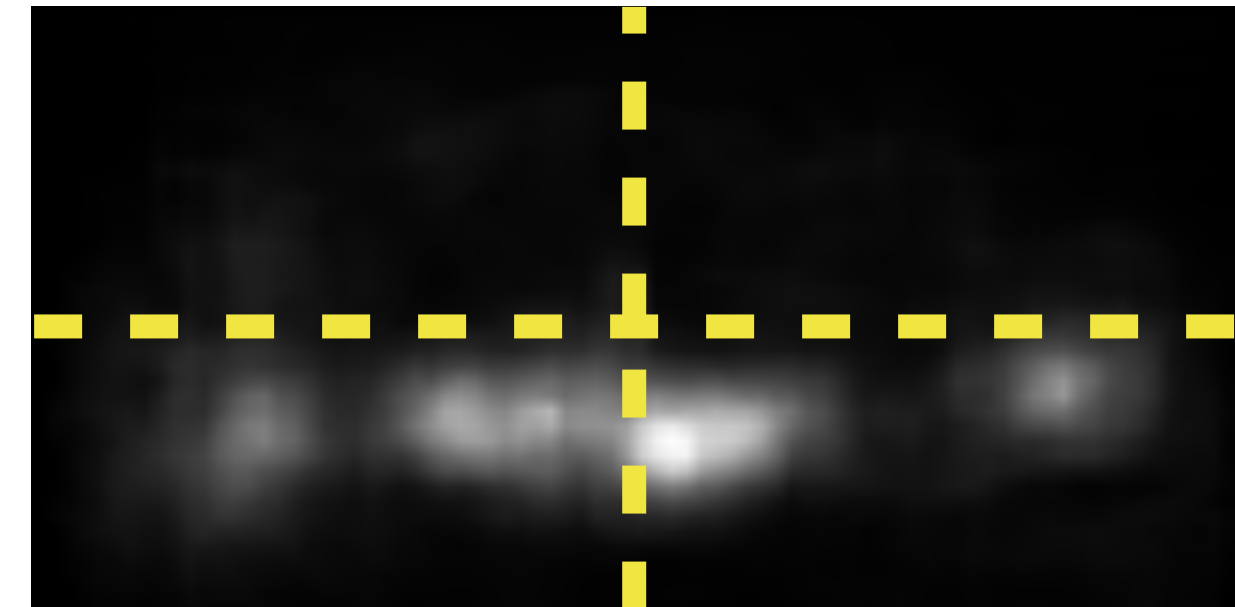


Tiles:

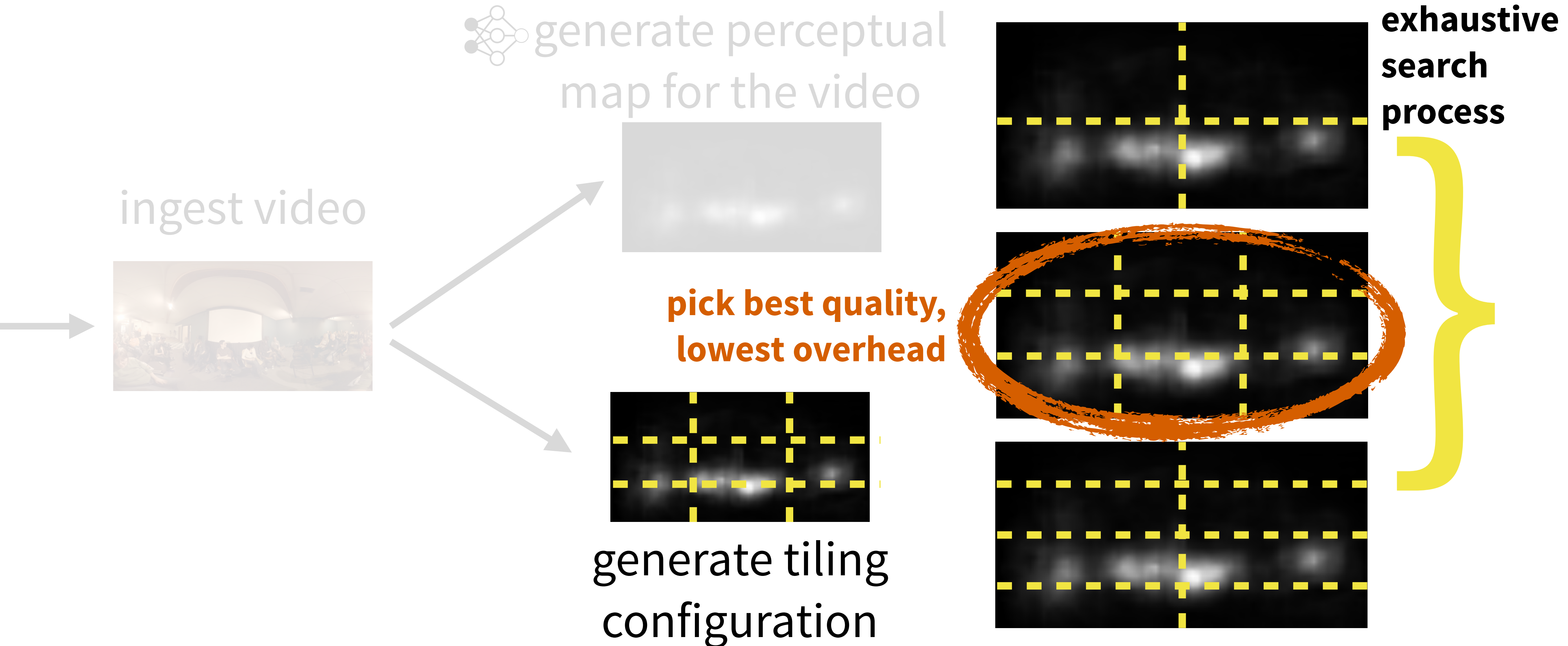
- codec-standard feature
- divide video into smaller regions (some overhead)
- drive quality per-tile



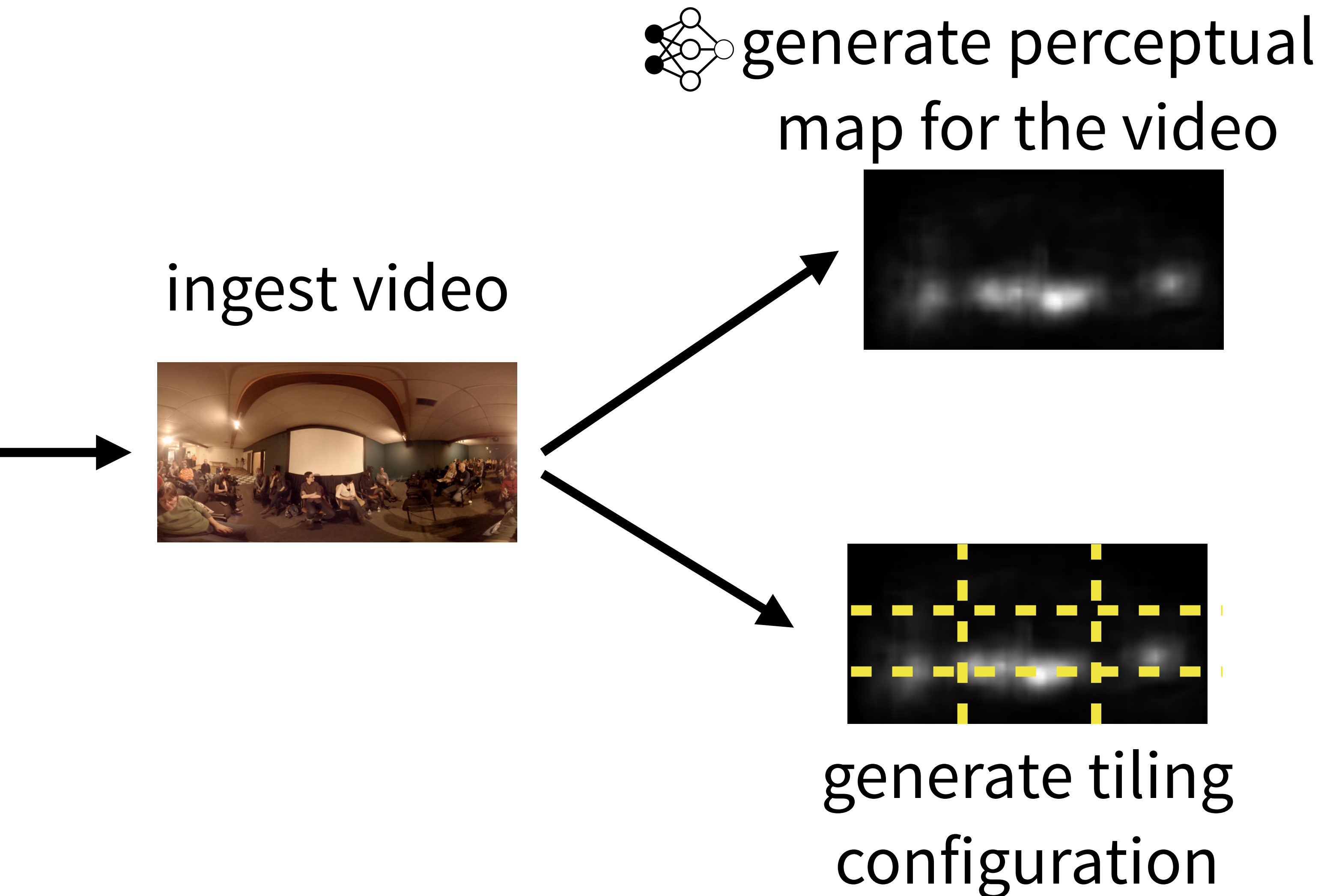
generate tiling
configuration



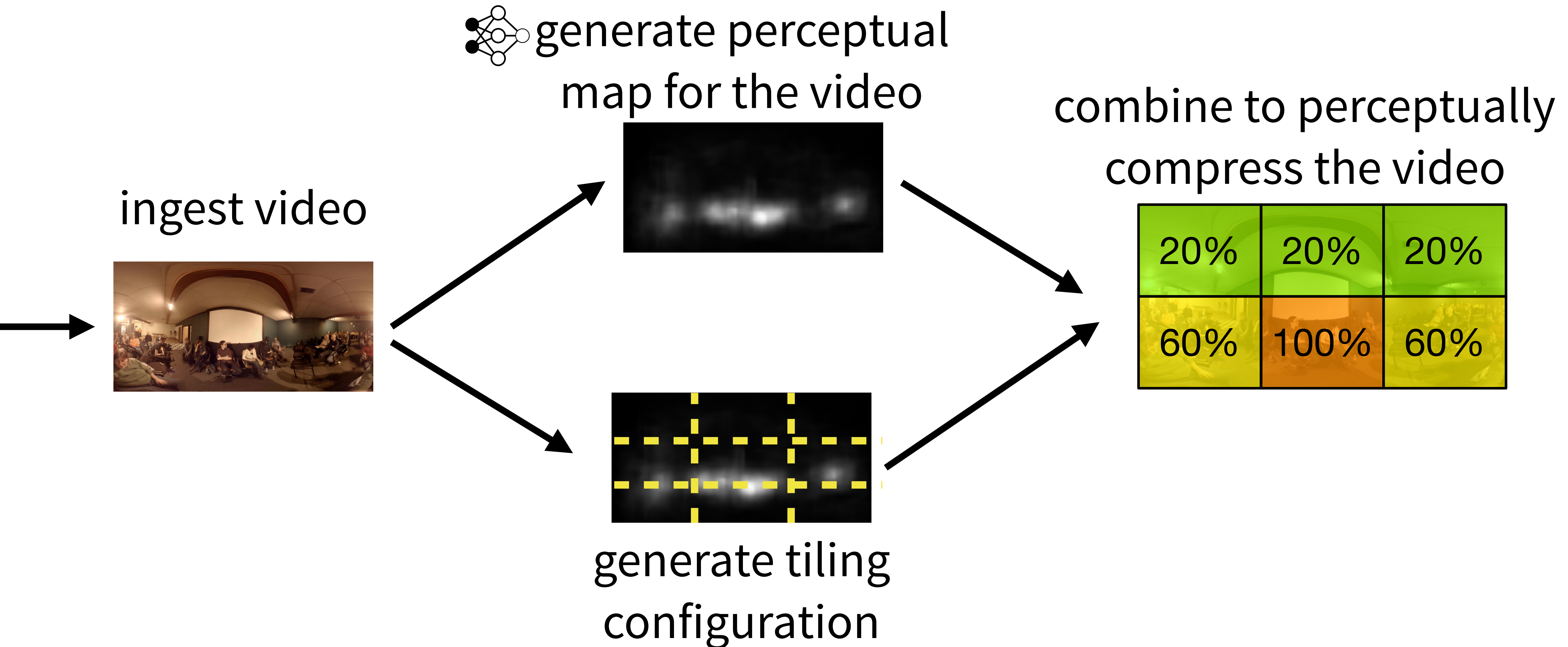
Vignette Compression



Vignette Compression

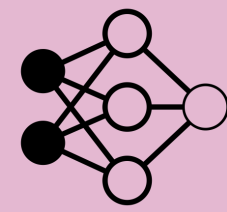


Vignette Compression



Vignette system architecture

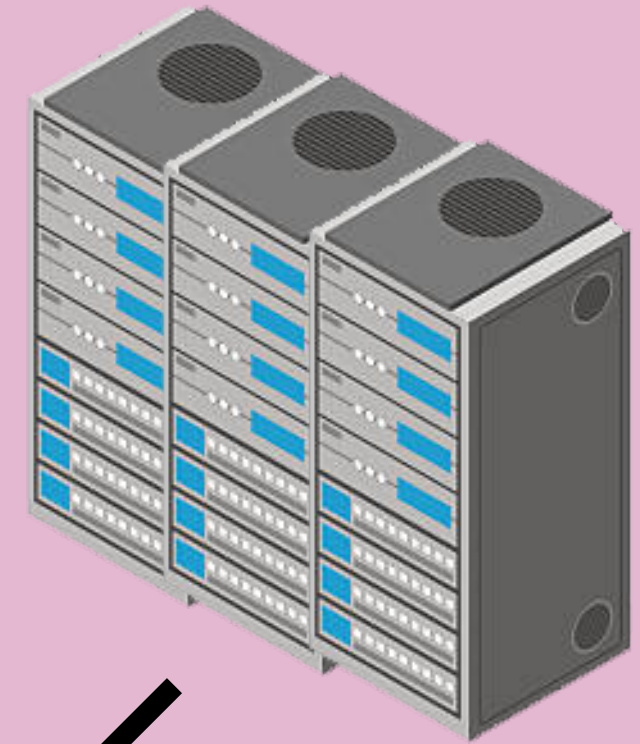
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3. Execute saliency-based compression



Vignette Compression

Vignette Storage



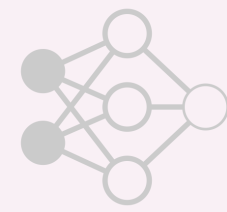
5. Stream compressed video to user



4. Write compressed video to storage manager

Vignette system architecture

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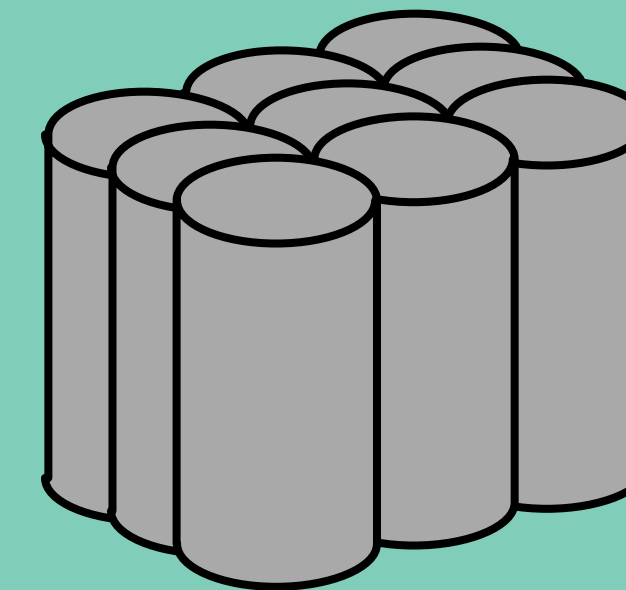


Vignette Compression

Vignette Storage

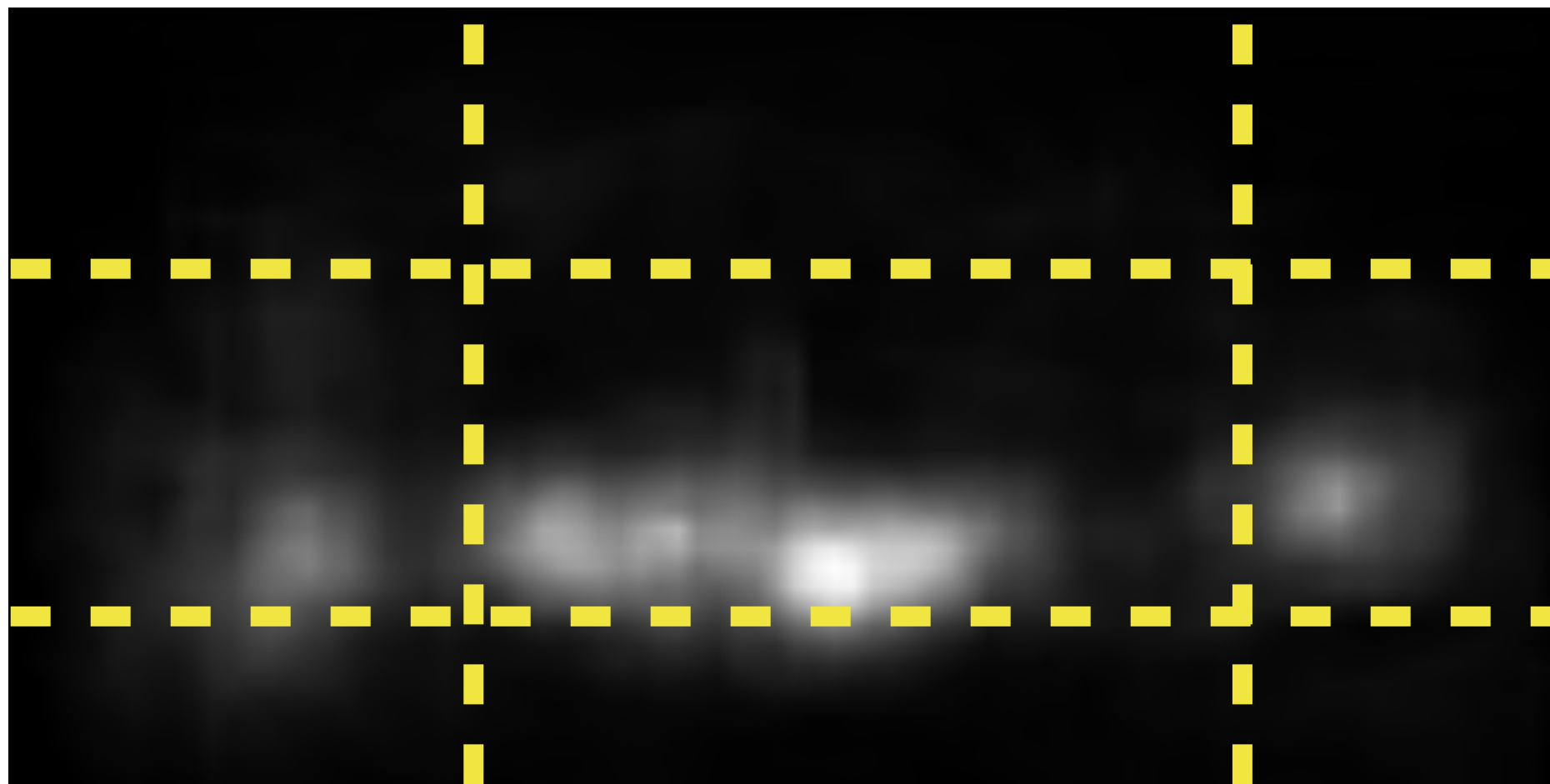


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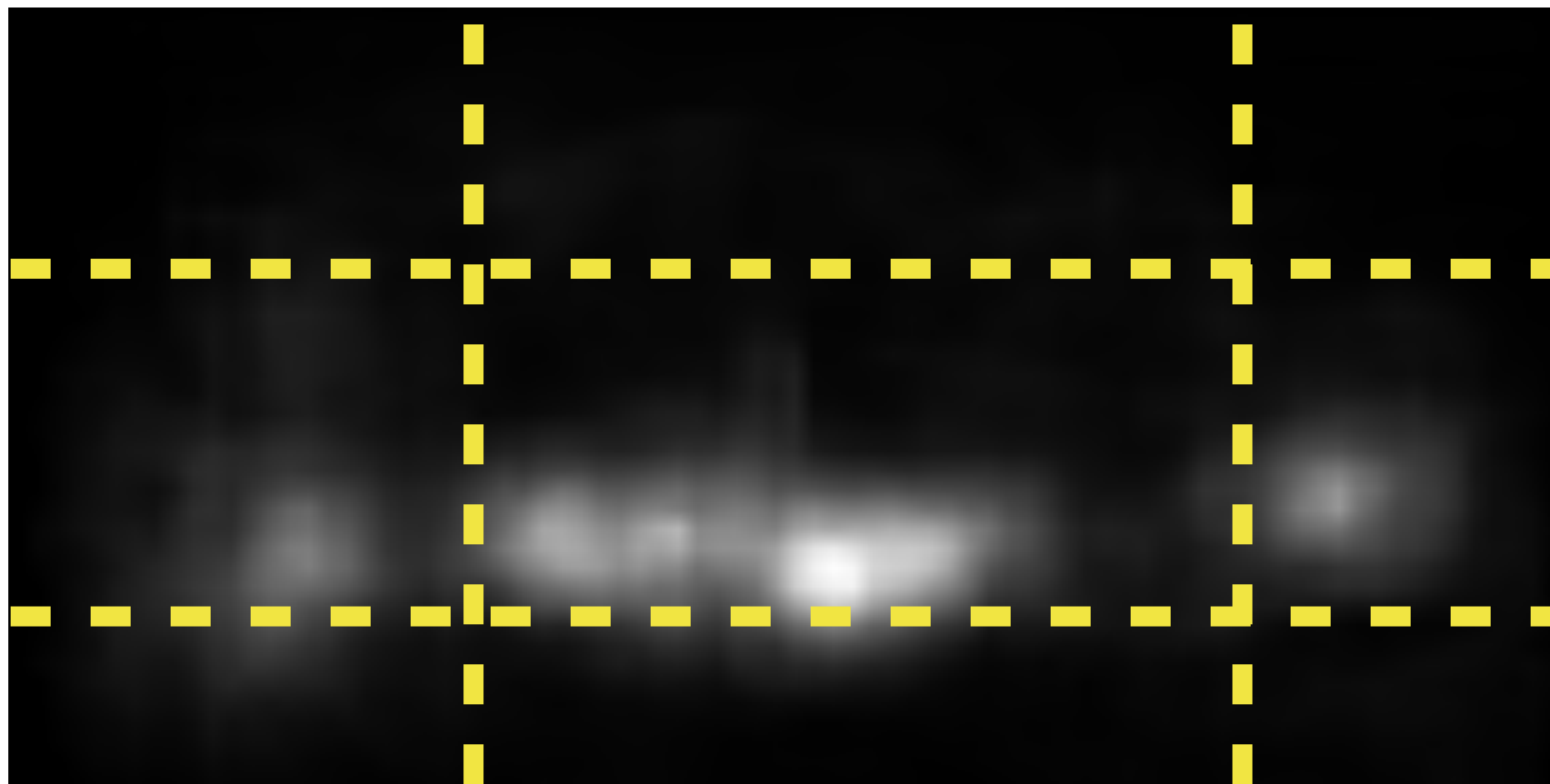
4. Write compressed video to storage manager

Vignette Storage uses compressed metadata to communicate tile configurations



up to 1.75x compressed video size

Vignette Storage uses compressed metadata to communicate tile configurations



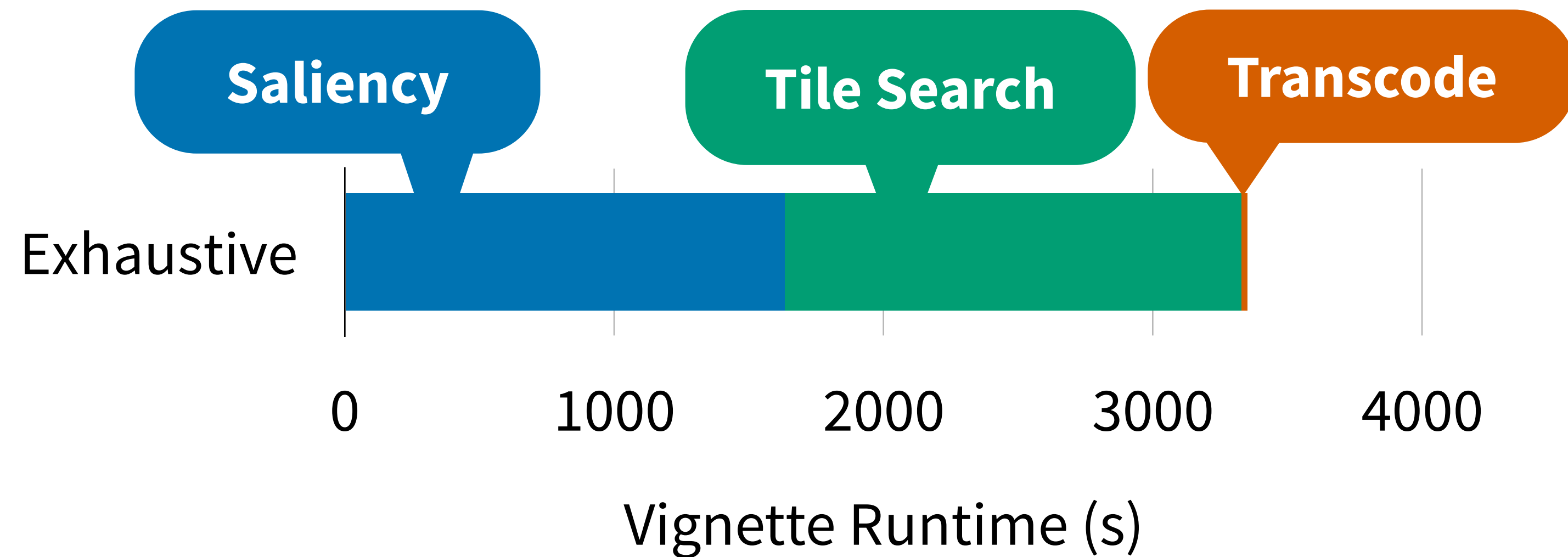
up to 1.75x compressed video size

this work: video + low-overhead metadata



metadata: tile config & qualities (8-100 B)

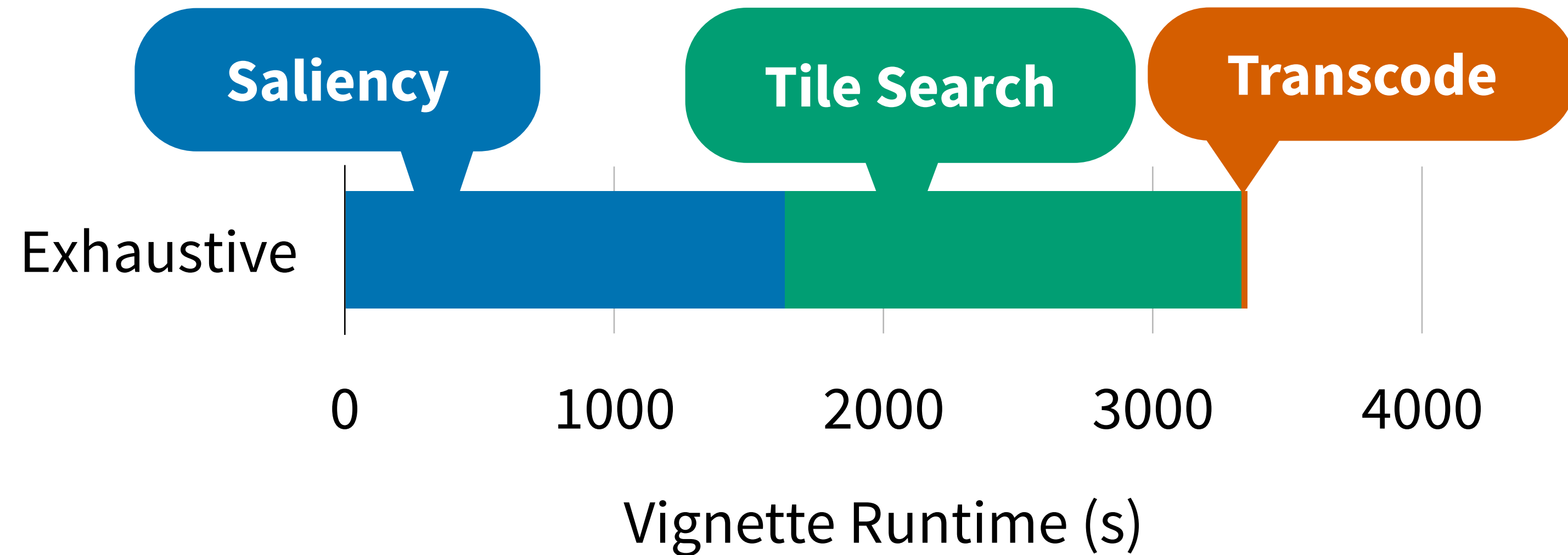
Vignette Storage provides a faster heuristic search to find tile configurations



Vignette Storage provides a faster heuristic search to find tile configurations



motion vectors in video



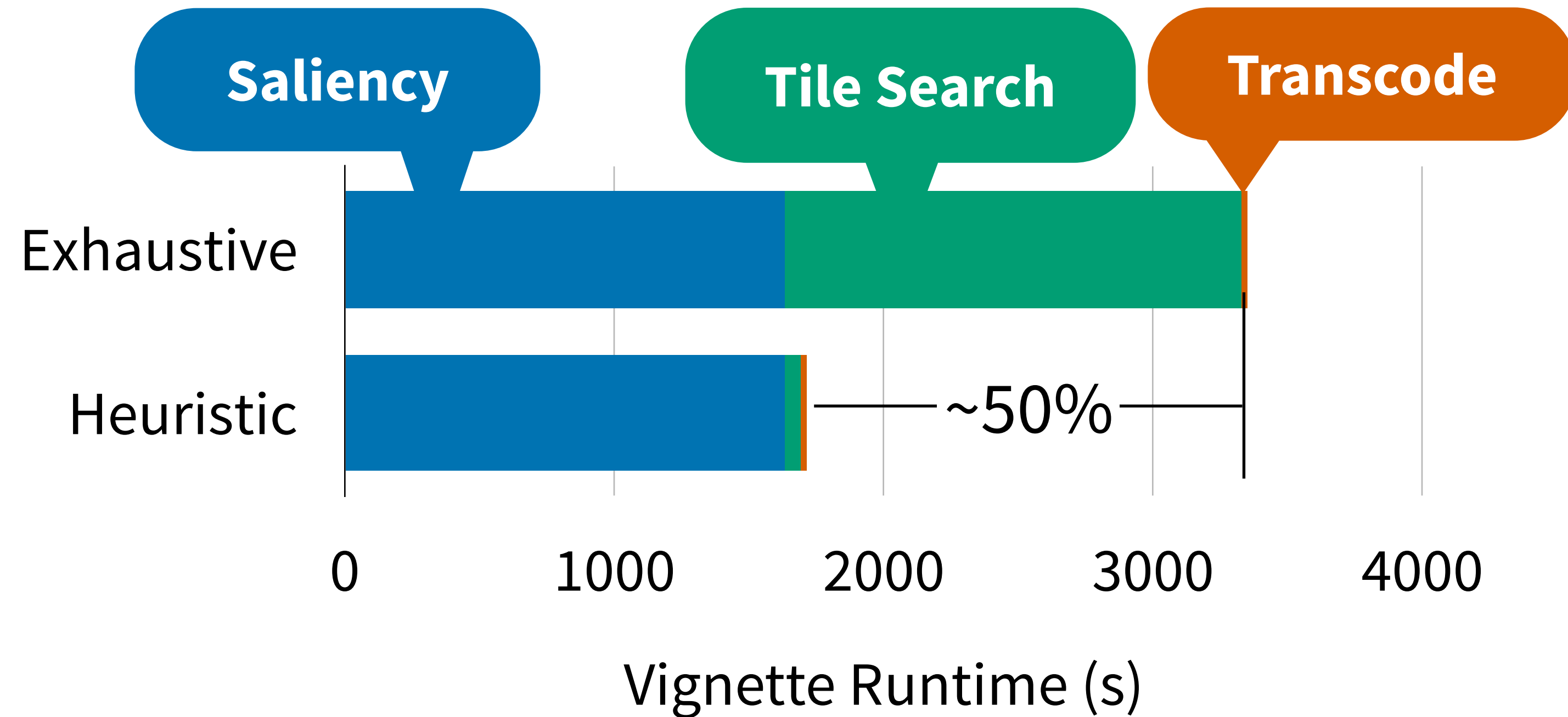
New algorithm using motion vectors to guide tile size

Key Insight: splitting motion vectors across tiles results in larger videos

Vignette Storage provides a faster heuristic search to find tile configurations

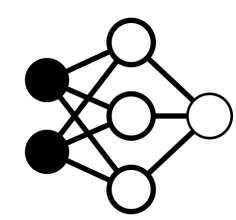


motion vectors in video

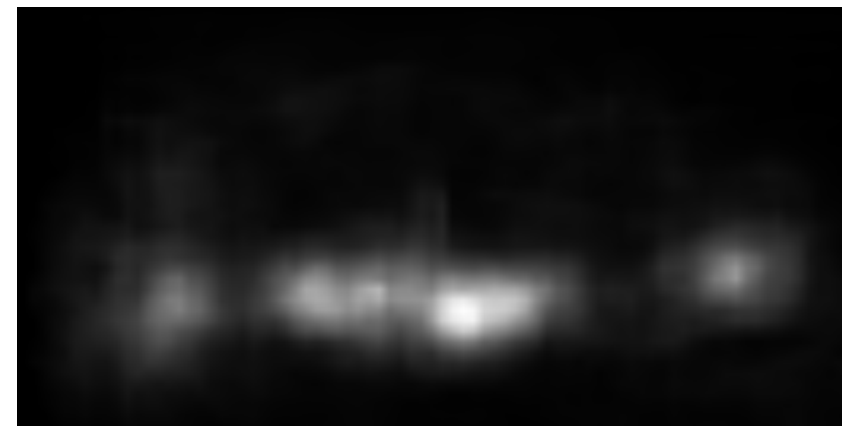


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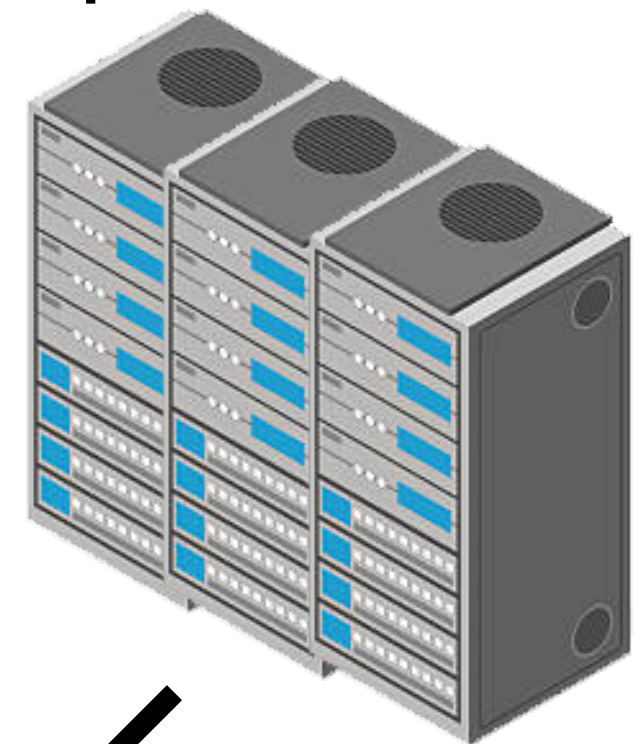
1. input video



2. ML-generated saliency map



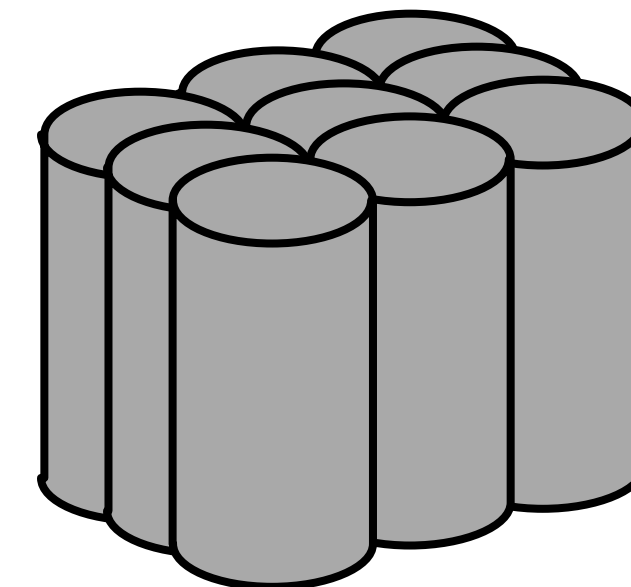
3. saliency-based compression



more details in
the paper!



5. streaming to user,
(optional) eye-tracker feedback



4. storage manager

Evaluation & Results



Baseline HEVC @ 20 Mbps
4 hours video playback



Vignette @ 1 Mbps
6.5 hours video playback

Evaluation & Results

Compression Performance and Quality

How small are Vignette videos?

How much quality loss is there?

Cloud Performance

Is Vignette practical to use in the cloud?

How does Vignette affect TCO?

Evaluation & Results

Compression Performance and Quality

How small are Vignette videos?

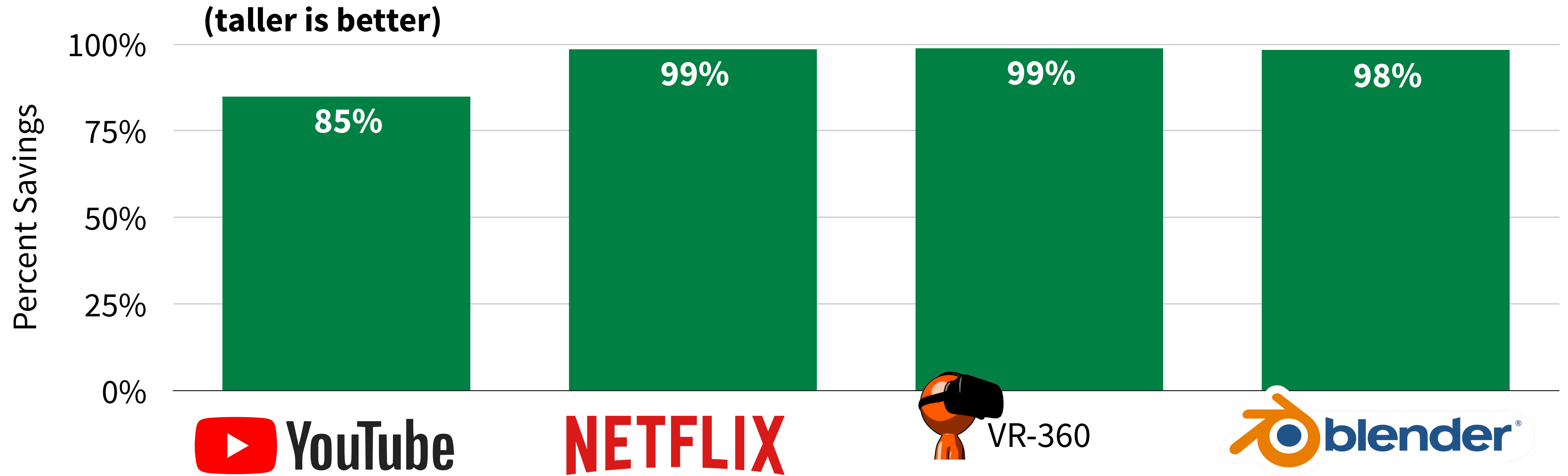
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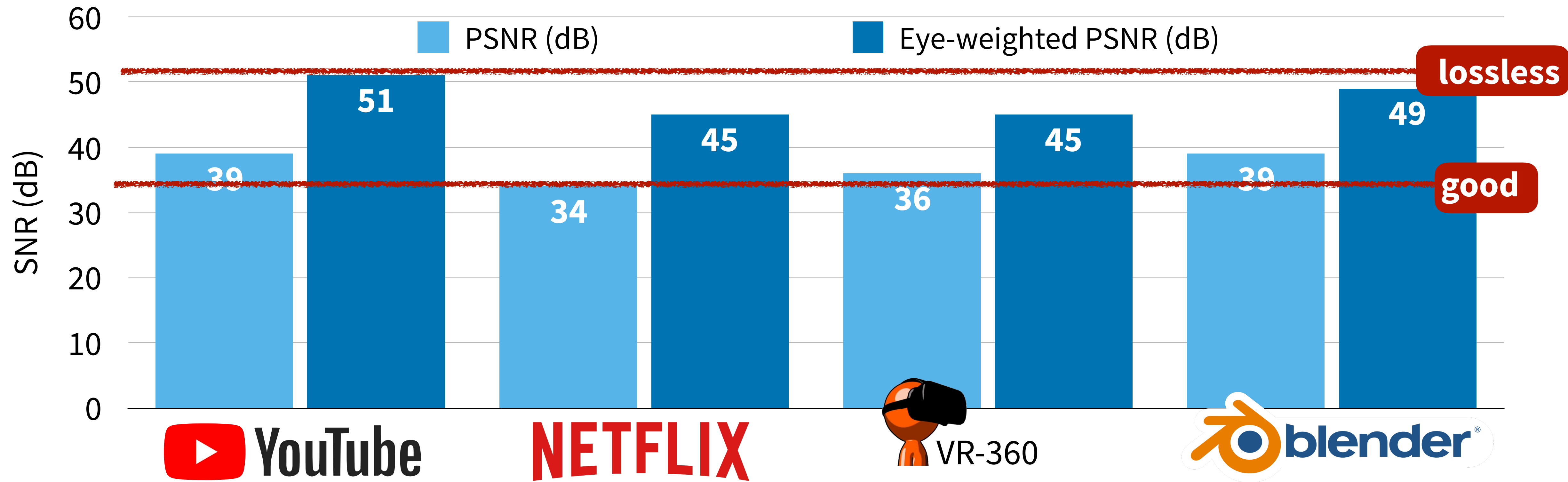
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Vignette Storage Savings



Vignette Quality




Vignette Perceptual Quality User Study

W Video Quality Study!


https://homes.cs.washington.edu/~amrita/form0.html

Video Compression User Study Questions? E-mail: amrita@cs.washington.edu

Question 1



0:00 / 0:06



0:00 / 0:06

Video A

Video B

Which video's quality did you prefer?

☐ Video A ☐ Video B ☐ Can't Tell

Question 2

https://homes.cs.washington.edu/~amrita/vignette_socc19.html

Vignette Perceptual Quality User Study

Web form, mixed desktop/mobile users

Video Compression User Study Questions? E-mail: amrita@cs.washington.edu

Question 1

Baseline fixed at 20 Mbps

Vignette varied between 1 - 20 Mbps

Video A

Video B

Which video's quality did you prefer?

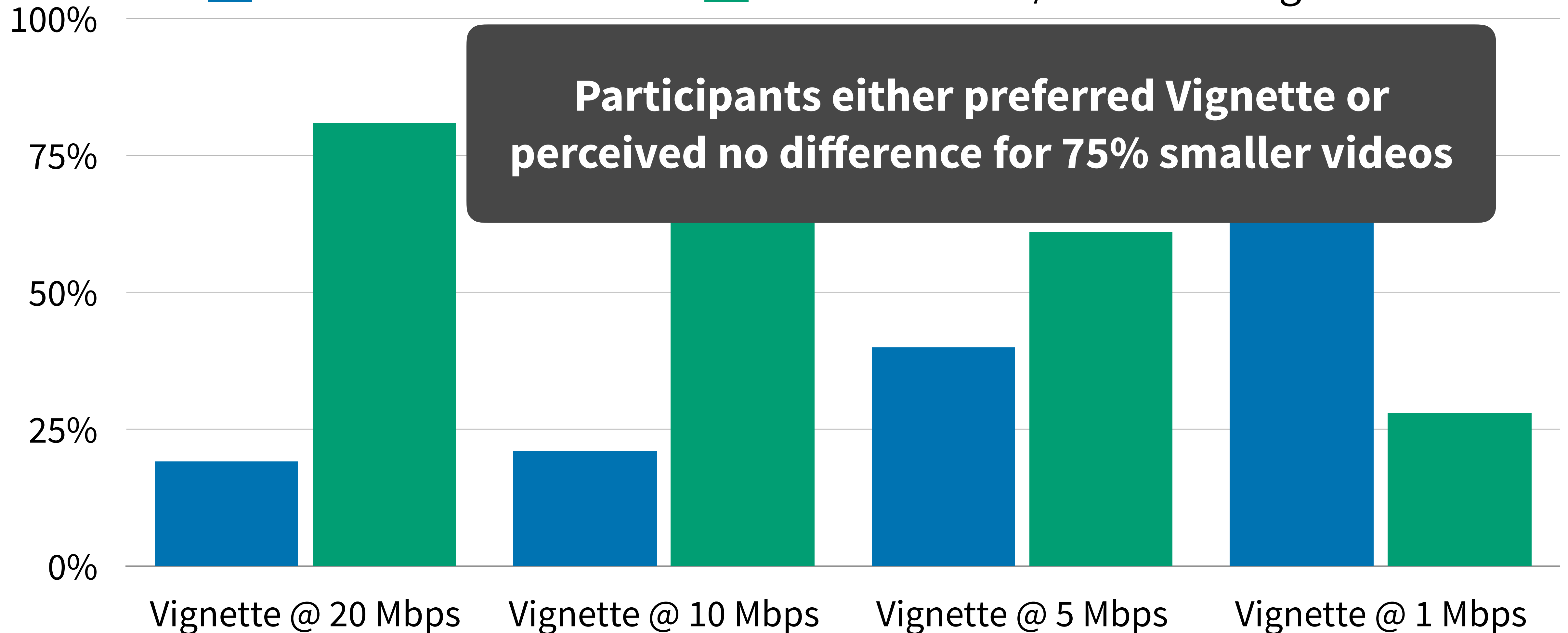
☐ Video A ☐ Video B ☐ Can't Tell

Question 2

https://homes.cs.washington.edu/~amrita/vignette_socc19.html

Vignette Perceptual Quality User Study

■ Preferred Baseline ■ No Difference / Preferred Vignette



Evaluation & Results

Compression Performance and Quality

Vignette videos are 85% smaller while maintaining quality.
For 75% smaller videos, users did not notice quality impact.

Cloud Performance

Is Vignette practical to use in the cloud?

How does Vignette affect TCO?

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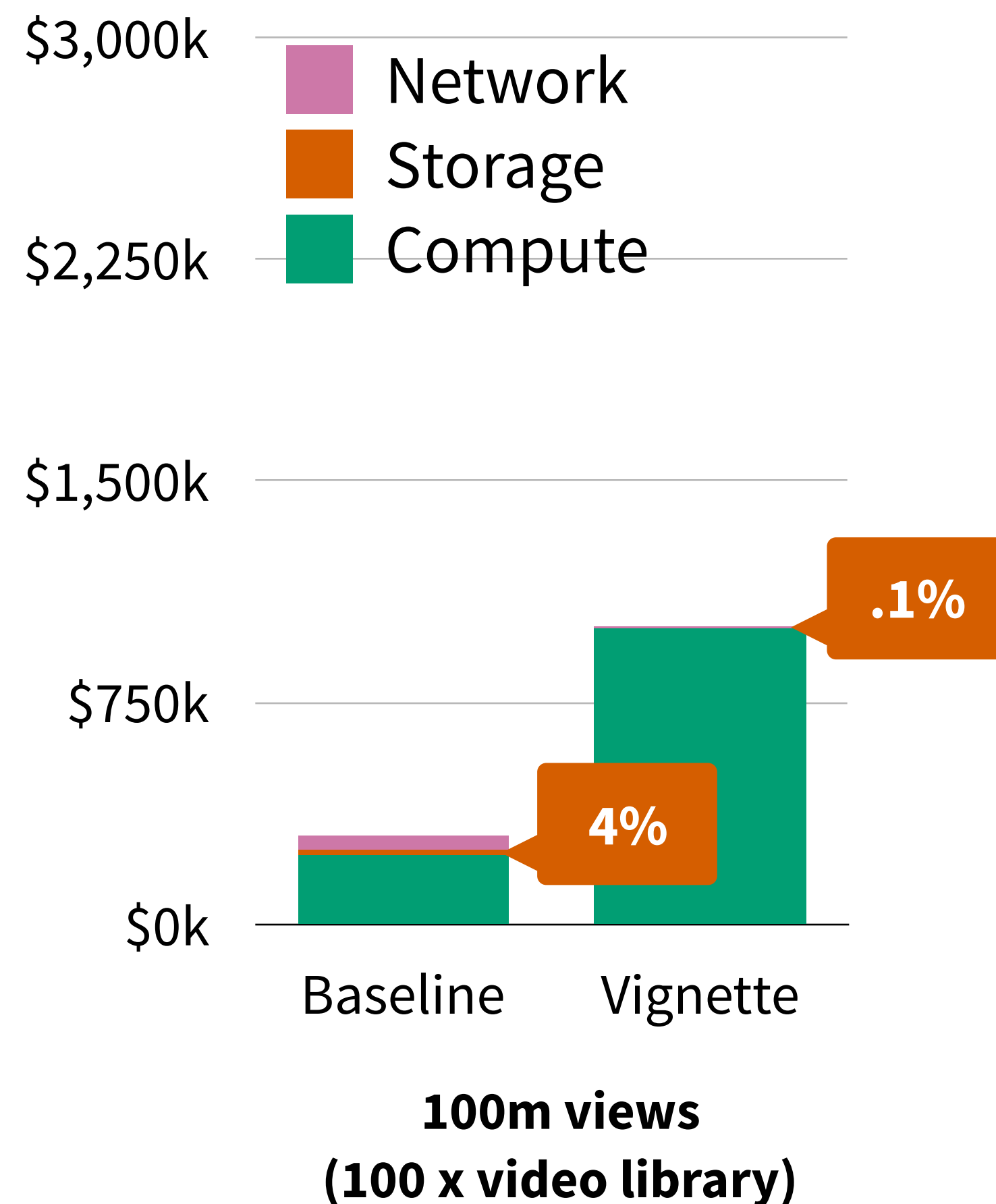
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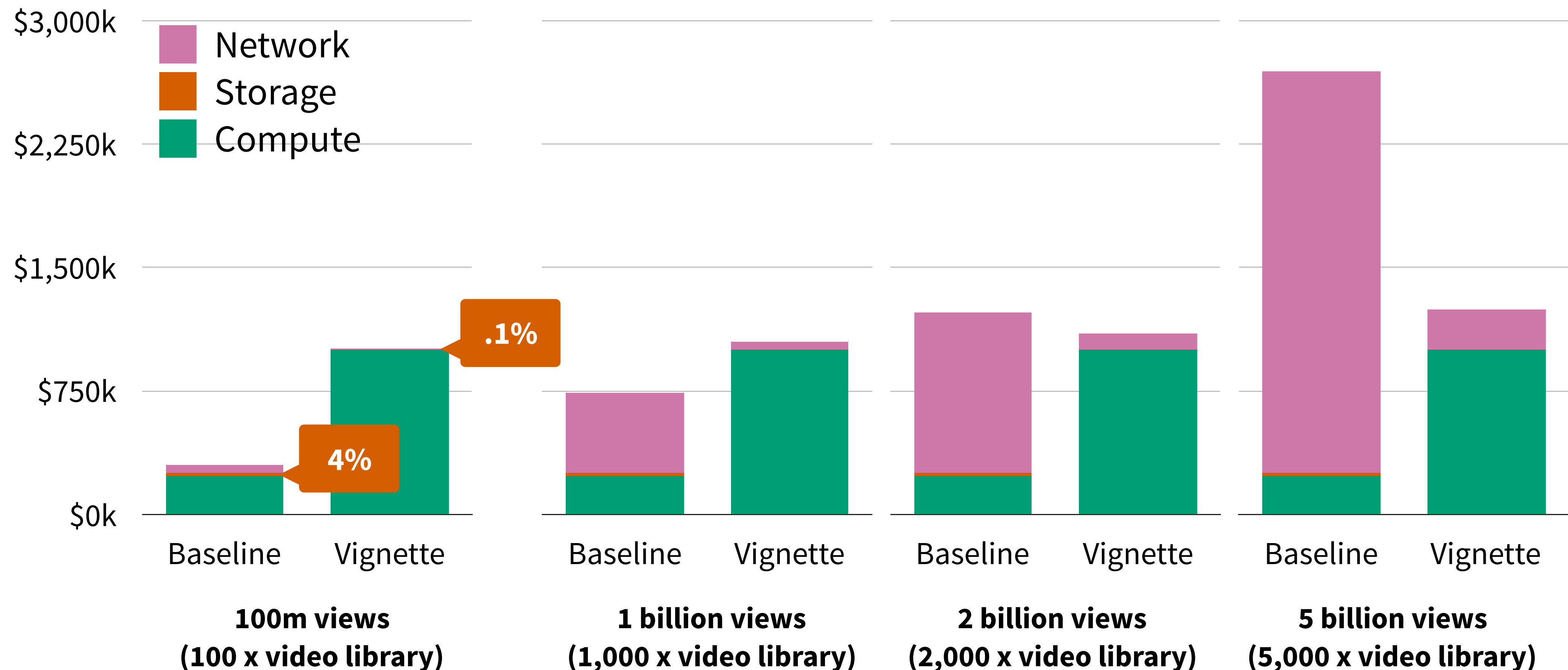
TCO analysis on AWS datacenter

storing and streaming a 1-million video library



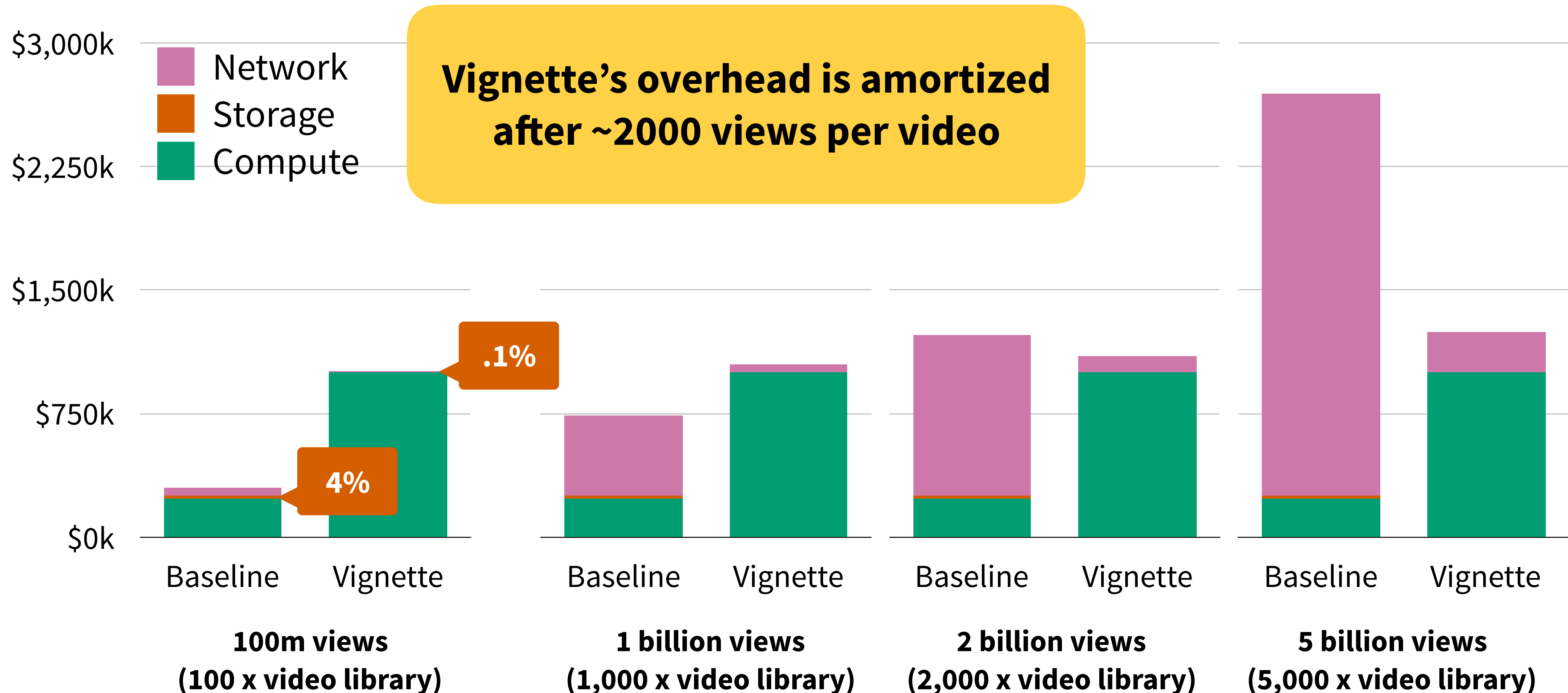
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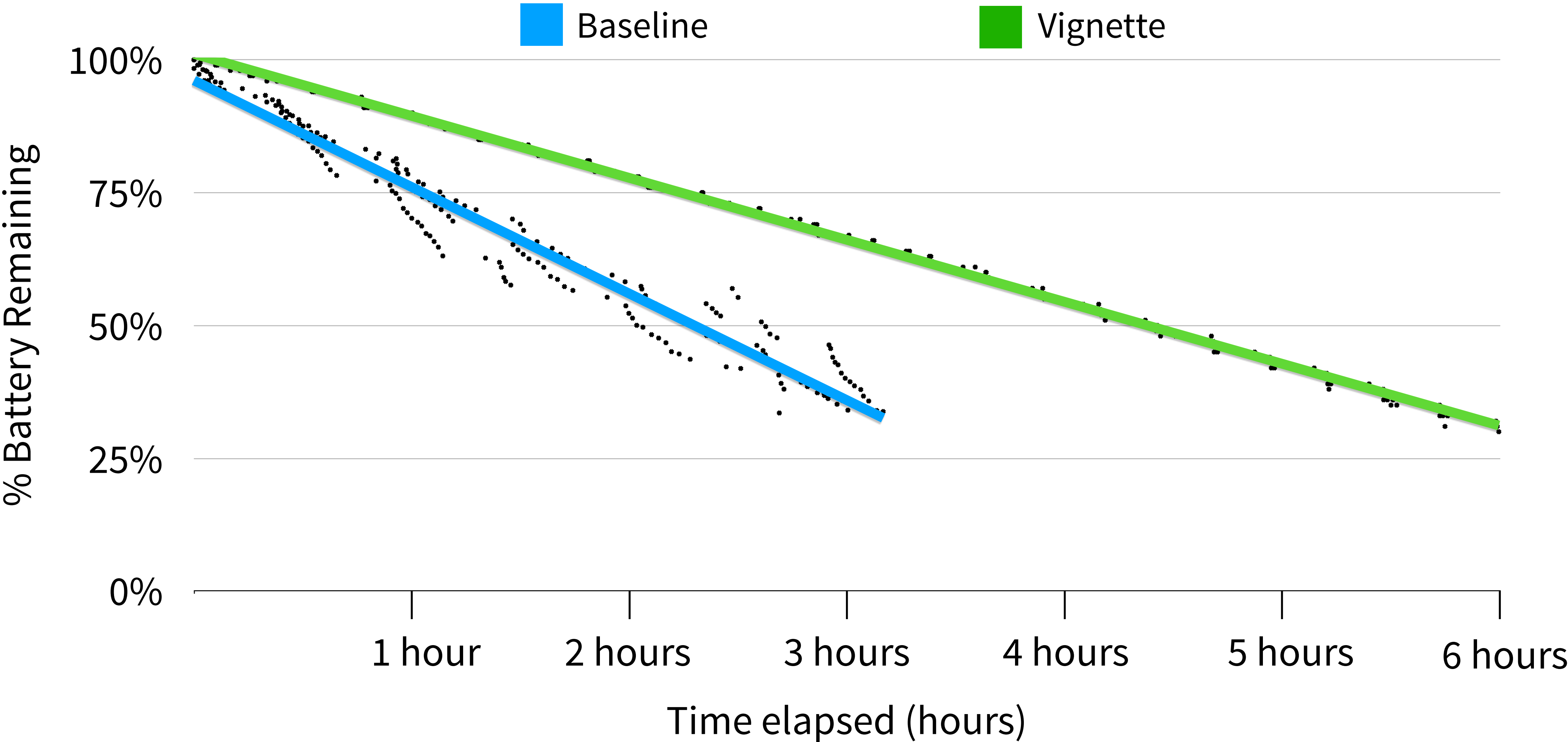
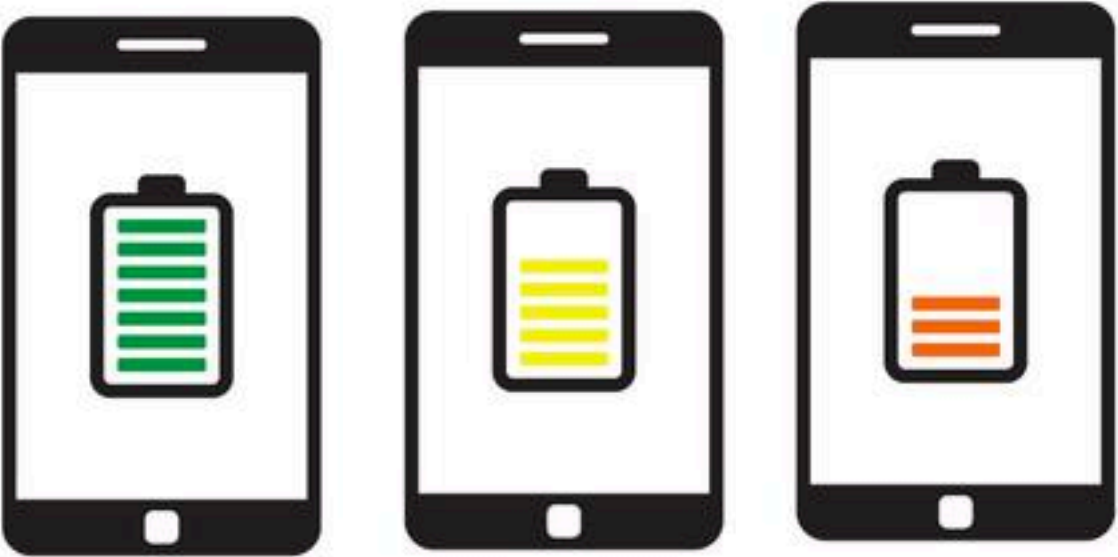


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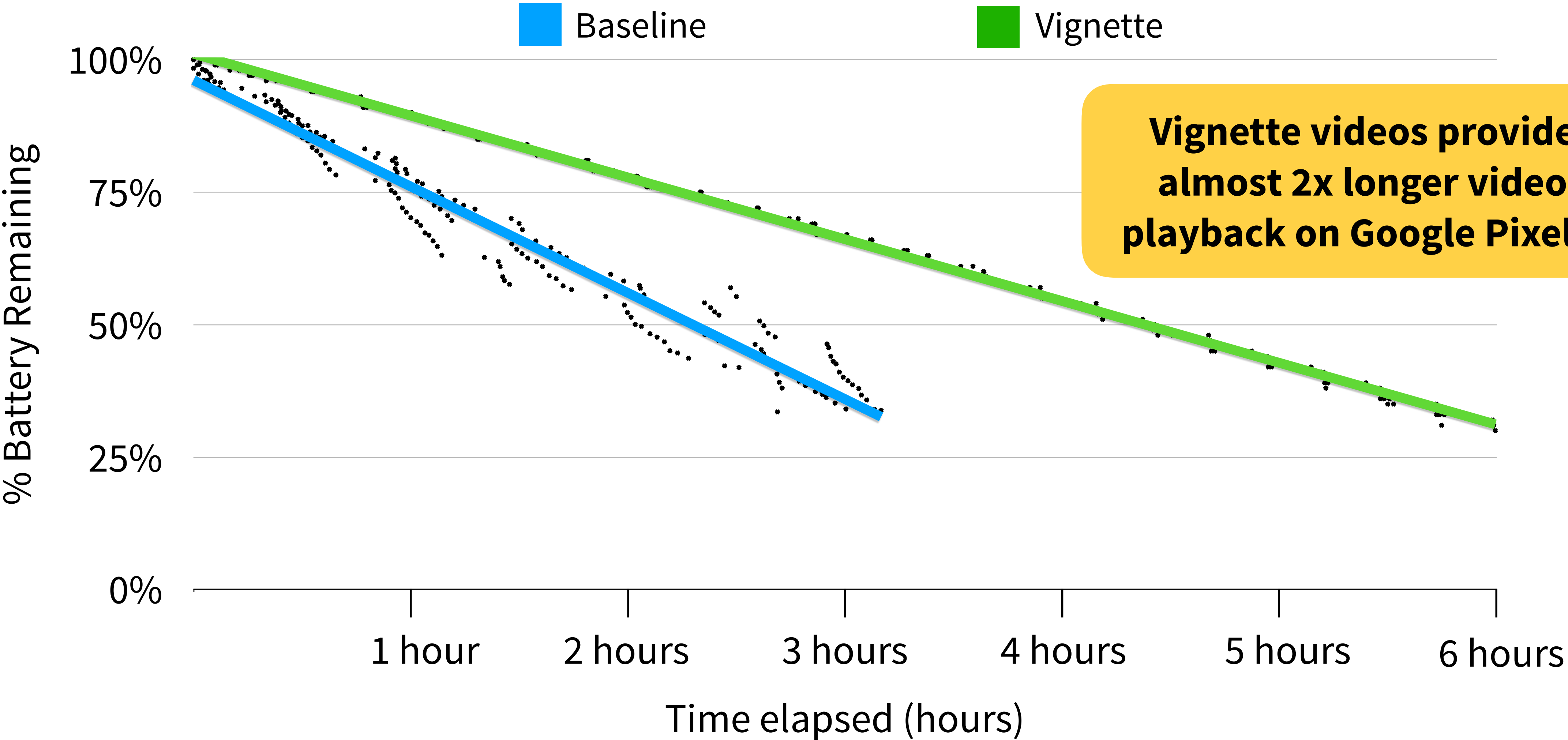
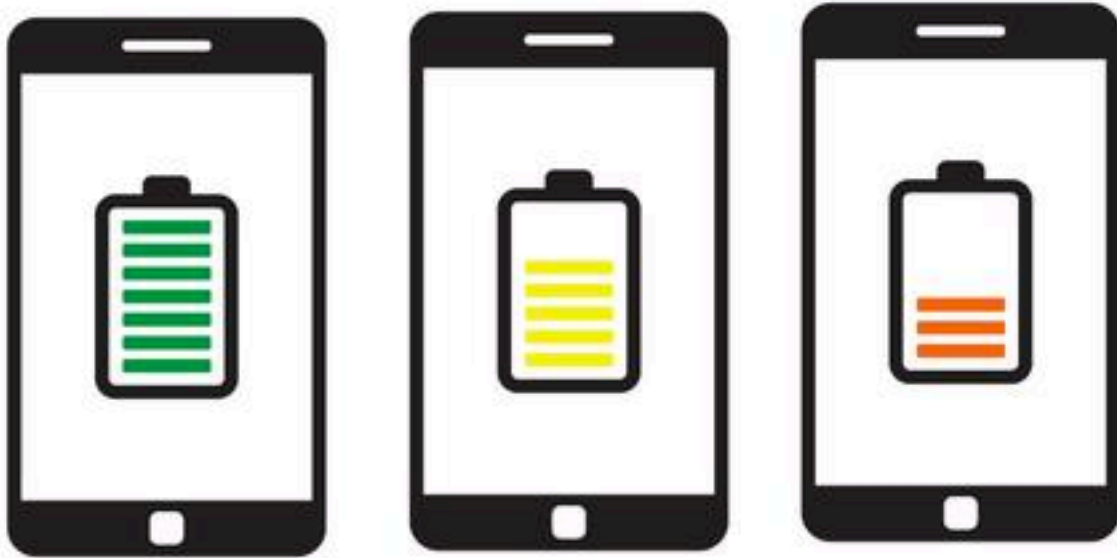
storing and streaming a 1-million video library



Results: Mobile Power Analysis



Results: Mobile Power Analysis



Evaluation & Results

Compression Performance and Quality

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Cloud Performance

Vignette amortizes large transcode costs in ~2000 streams / video.

Vignette videos also reduce power during mobile playback.

Vignette: a system for perceptual compression and storage

Thank you!

[https://
homes.cs.washington.edu/
~amrita/vignette_socc19.html](https://homes.cs.washington.edu/~amrita/vignette_socc19.html)

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codec-free perceptual video compression

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storage manager for perceptually-compressed videos

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