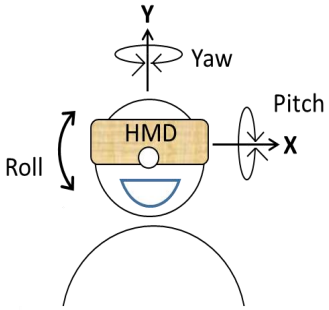
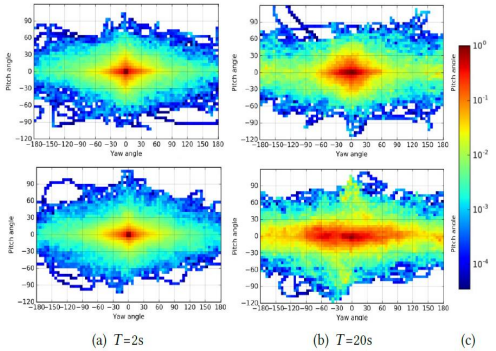
Had You Looked Where I'm Looking? Cross-user Similarities in Viewing Behavior for 360-degree Video and Caching Implications

Niklas Carlsson, ***Linköping University***

Derek Eager, *University of Saskatchewan*

LINKÖPING UNIVERSITY

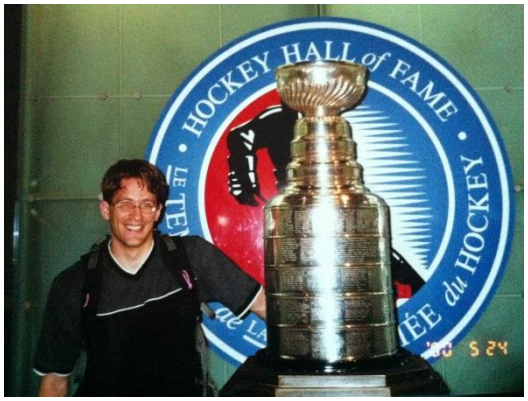




Proc. ACM/SPEC ICPE, April 2020

Before I start ...

The 360-degree experience ...



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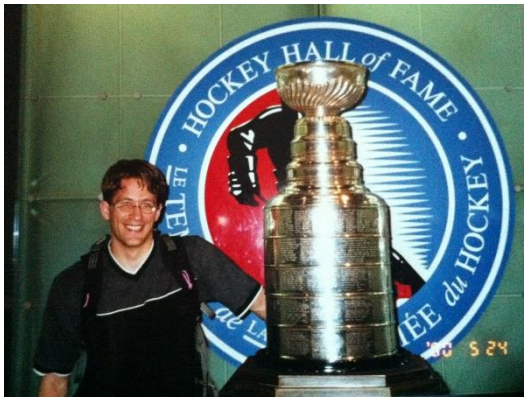

- Put the user in control of their experience

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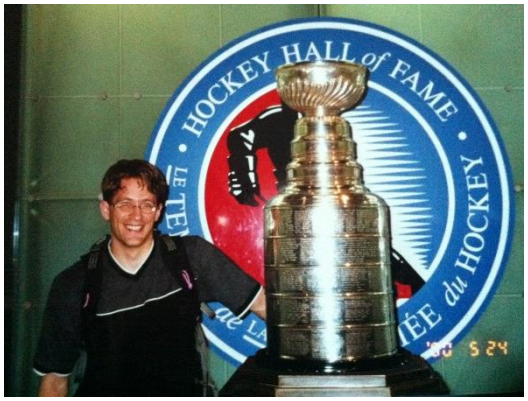

- Put the user in control of their experience
- Opportunity to revolutionize the viewing experience

Highly bandwidth intensive ...

- 360-degree video streaming highly bandwidth intensive

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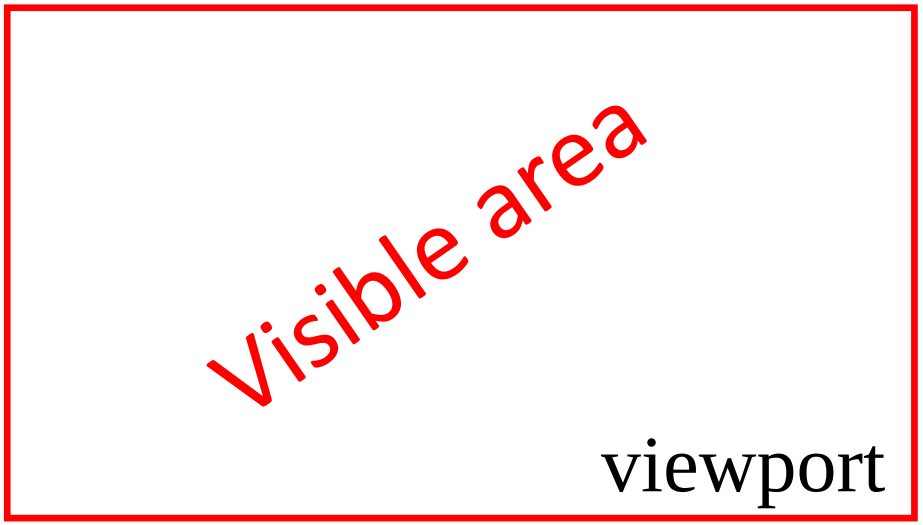
- Important to identify and understand bandwidth saving opportunities

Saving bandwidth ...

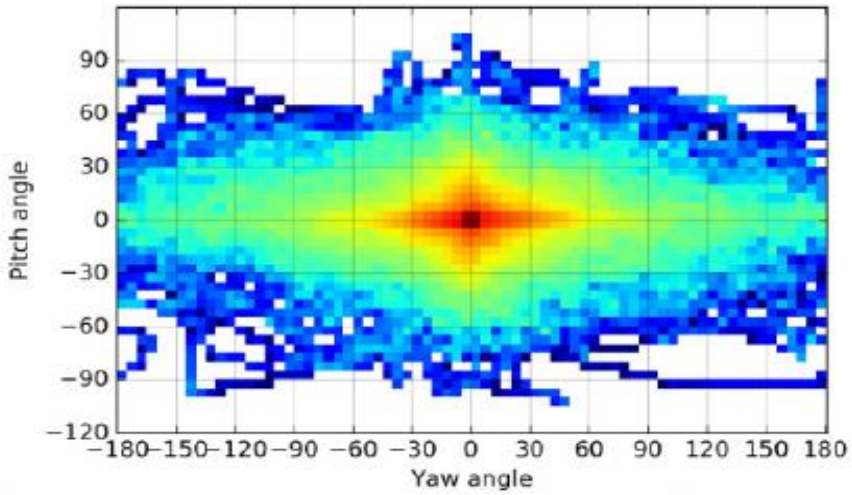


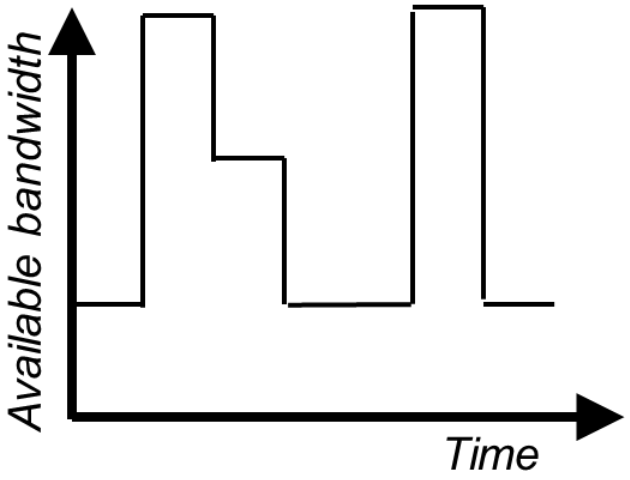
- Users only see what is in the viewport

Saving bandwidth ...

- Users only see what is in the viewport
- Many techniques prioritize the region visible to the user

Uncertainty in both ...





… and want to avoid stalls ...

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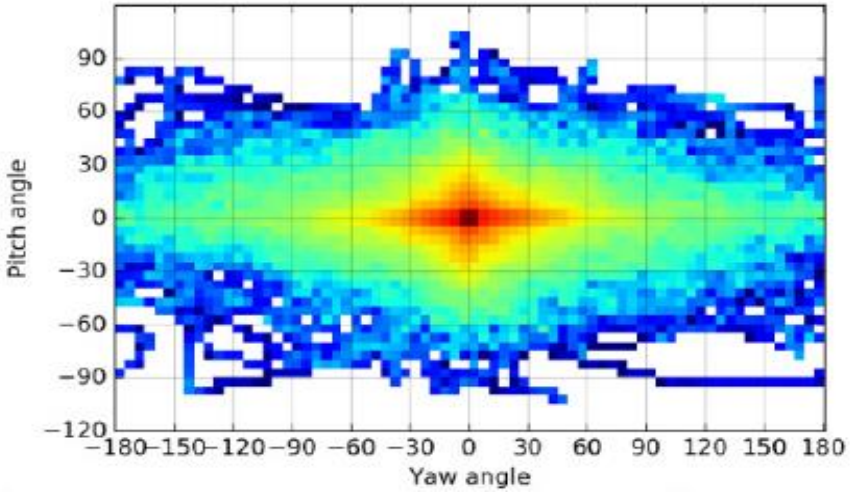
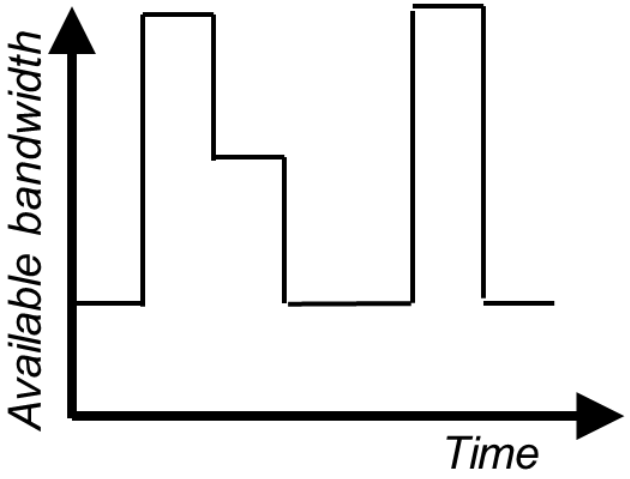
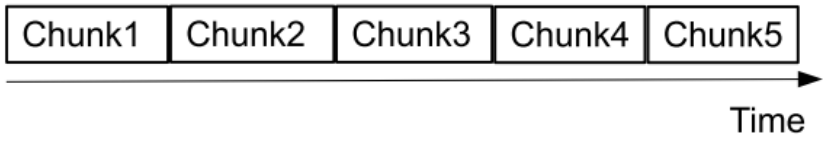




… and want to avoid stalls ...

HAS/DASH + Tiling

HTTP-based Adaptive Streaming (HAS)



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  - Video is split into chunks
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  -

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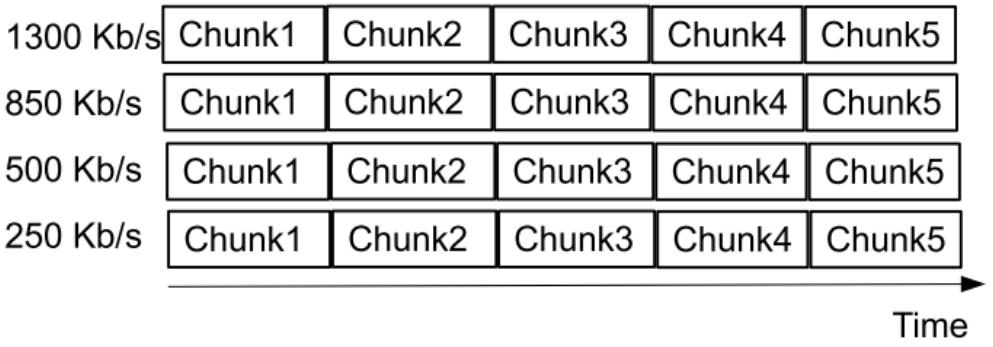

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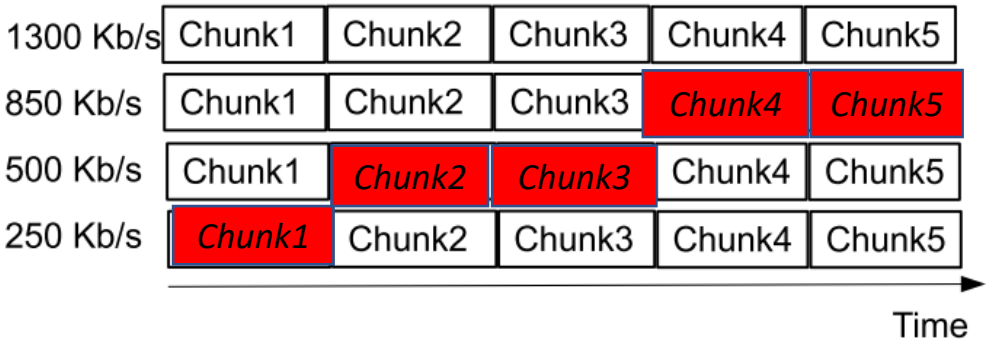

- HTTP-based **adaptive** streaming
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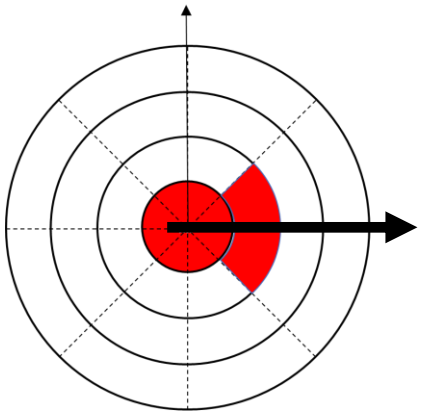
  - Clients adapt quality encoding based on buffer/network conditions

360 HAS with tiles



“Chunk 1”

- In addition to chunks, we have
  - Tiles of different quality in each direction
-
  -
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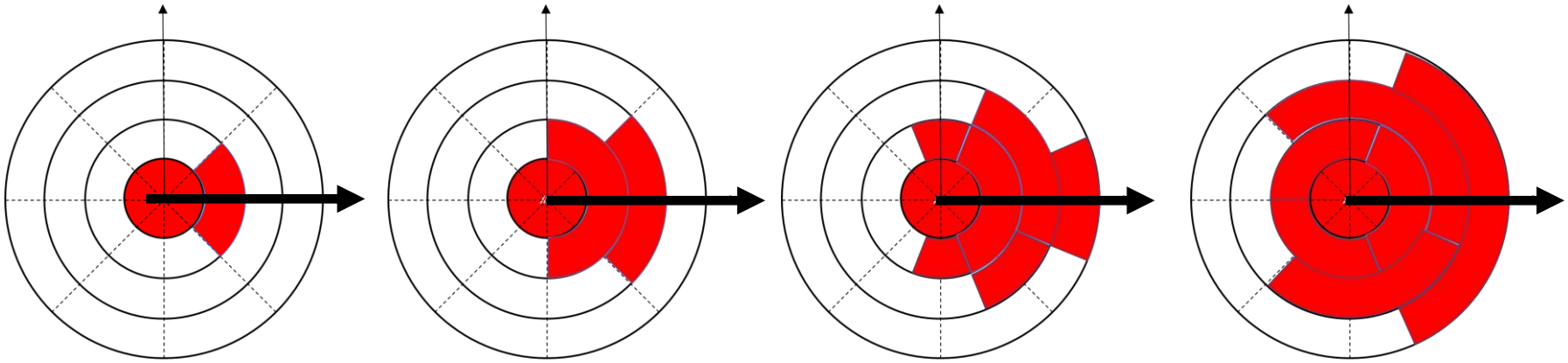
360 HAS with tiles



"Chunk 1" "Chunk 2" "Chunk 3" "Chunk 4"

- In addition to chunks, we have
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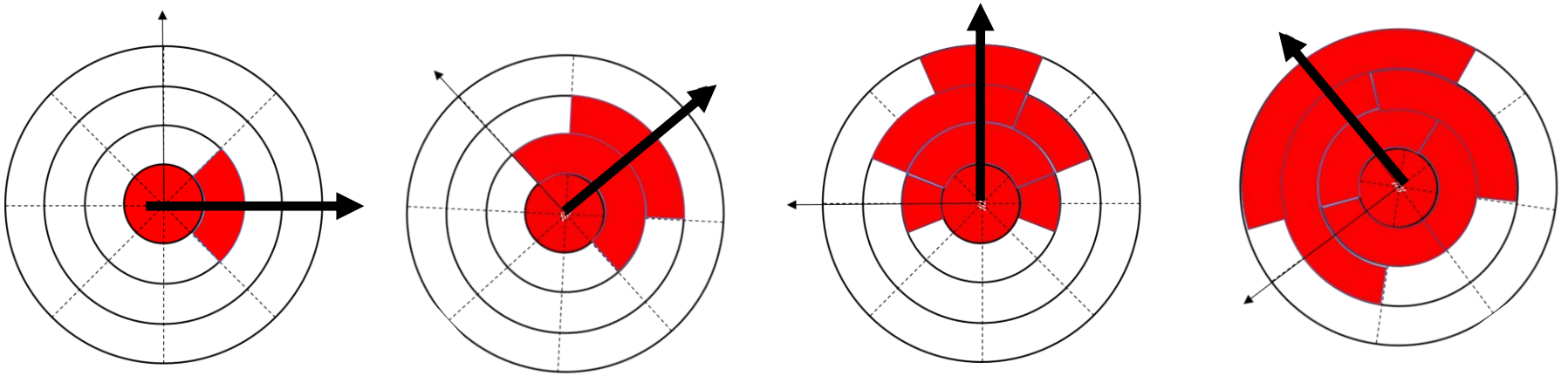

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- We present the first characterization of
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  - the potential cache hit rates for different video categories and network conditions.

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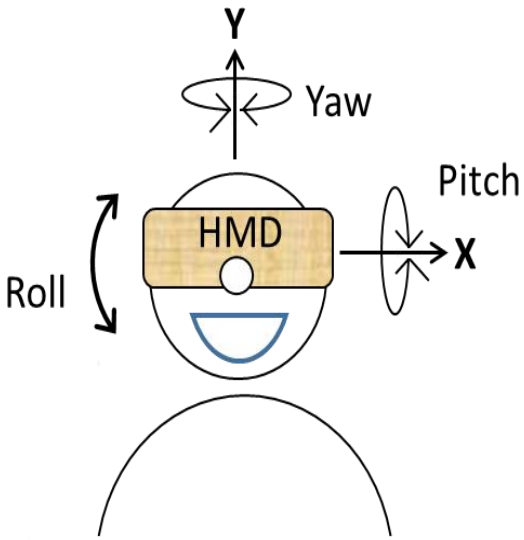
  - the overlap in viewports of these users (both instantaneously and on a per-chunk basis), and
  - the potential cache hit rates for different video categories and network conditions.

- Results provide insights into the conditions under which overlap can be considerable and caching effective, and can inform the design of new caching system policies tailored for 360° video.

Almquist et al. "The Prefetch Aggressiveness Tradeoff in 360 Video Streaming", Proc. ACM MMSys, 2018.

Head movement traces



- Oculus rift
- YouTube 360 videos with 4K resolution

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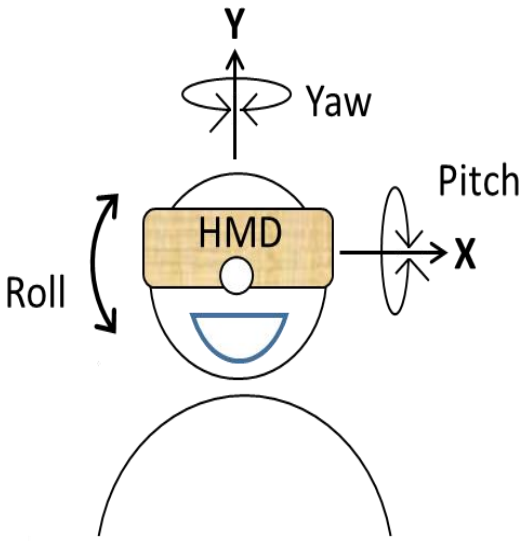

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- YouTube 360 videos with 4K resolution
- Five categories
  - Rides: “virtual ride ...”
  - Exploration: “no particular focus ...”
  - Static focus: “main focus of attention static ...”
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  - Miscellaneous: “unique feel ...”
- Focus on “representative” videos
  - Viewed by 32 views per video
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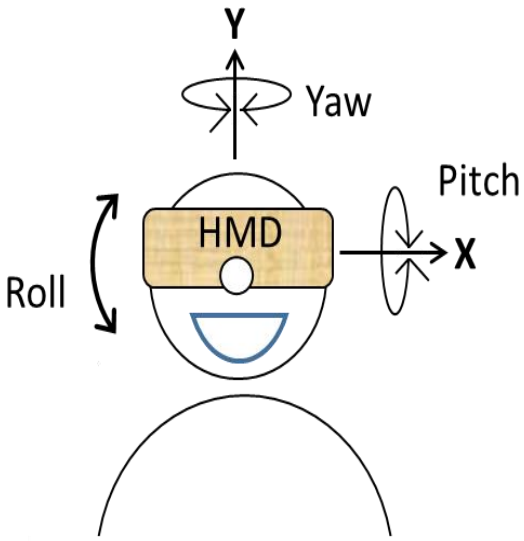

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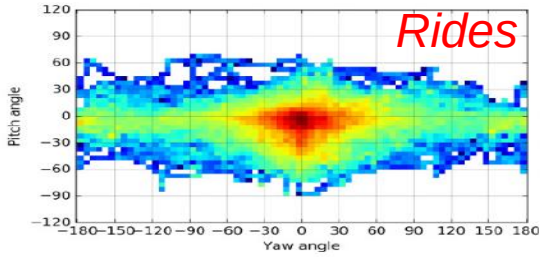

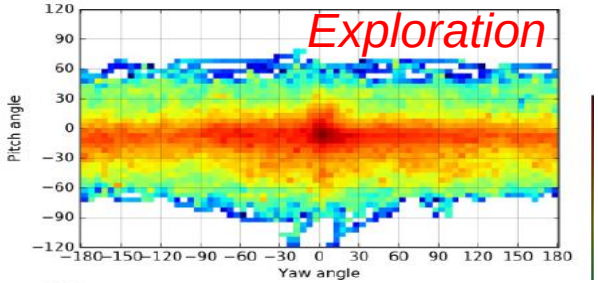

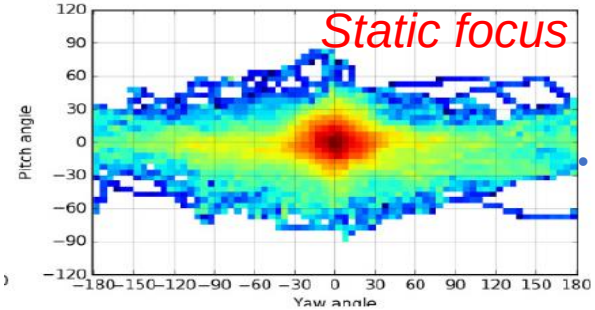

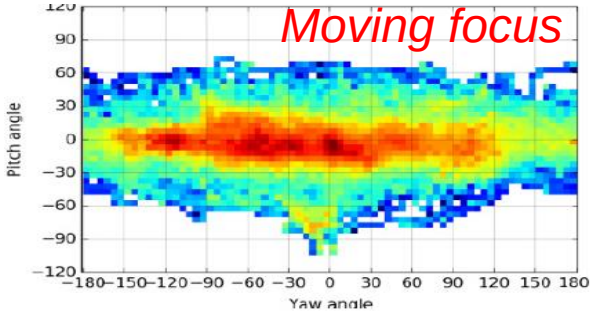

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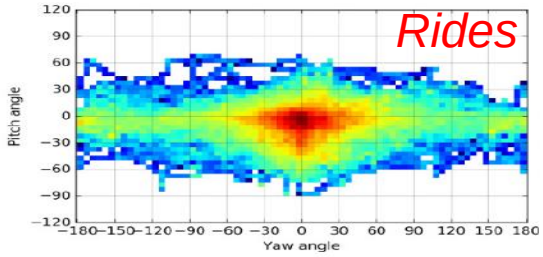

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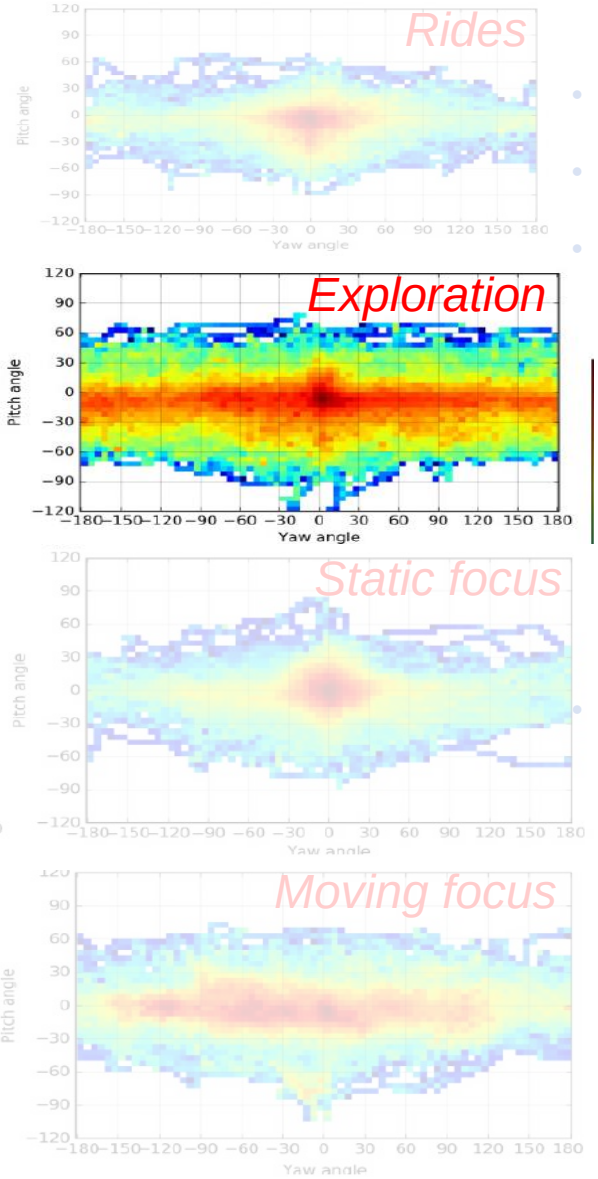

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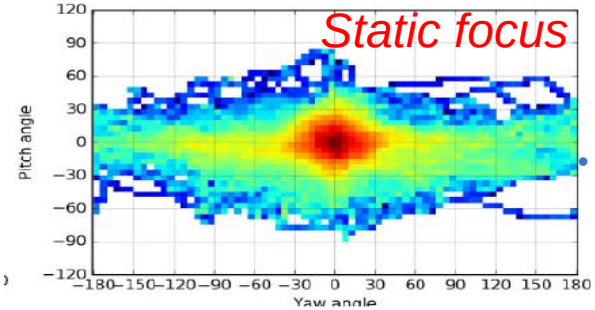

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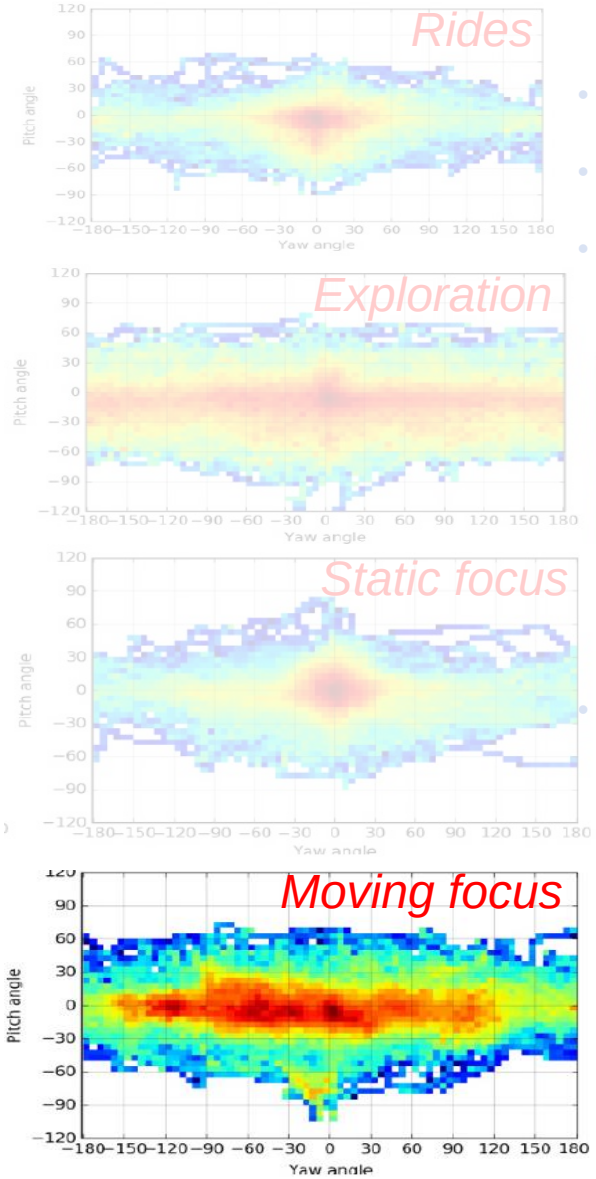

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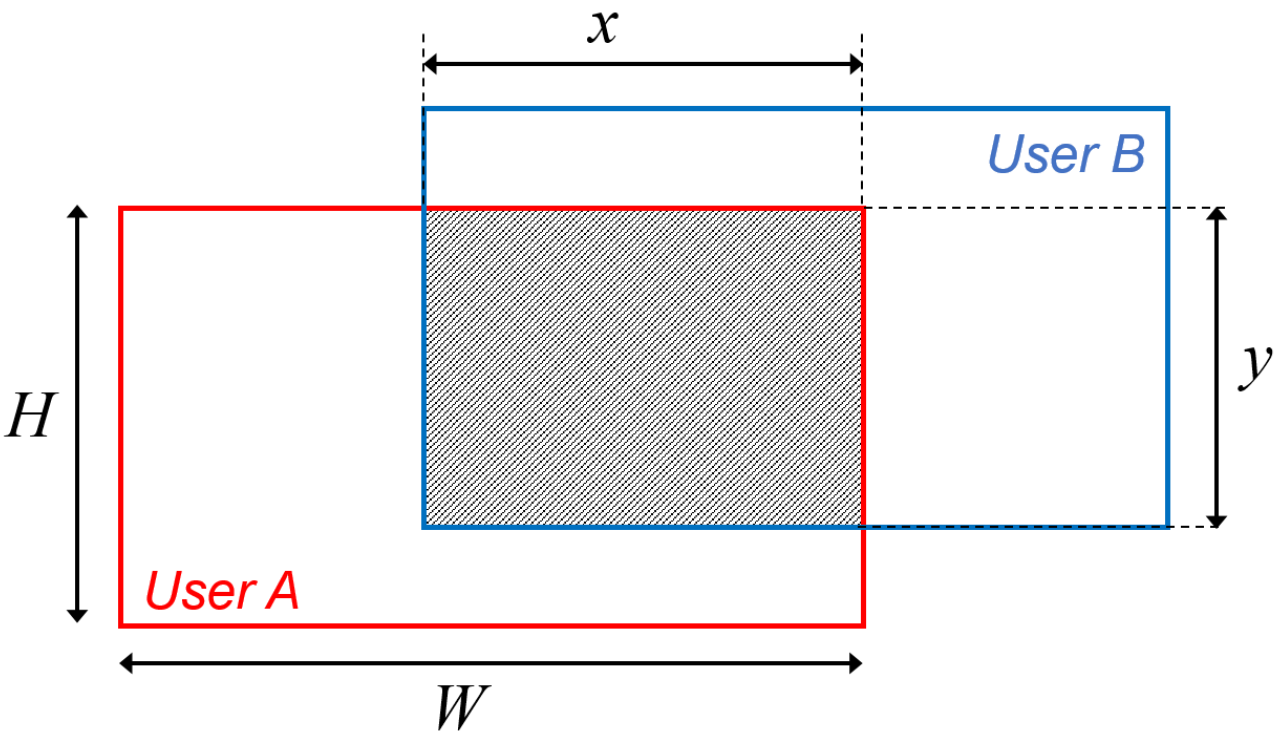
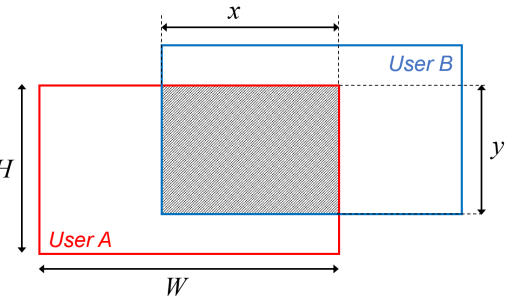


Pairwise viewport overlap

Part 1: Instantaneous similarities



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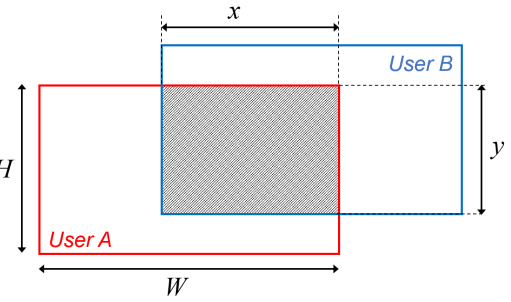

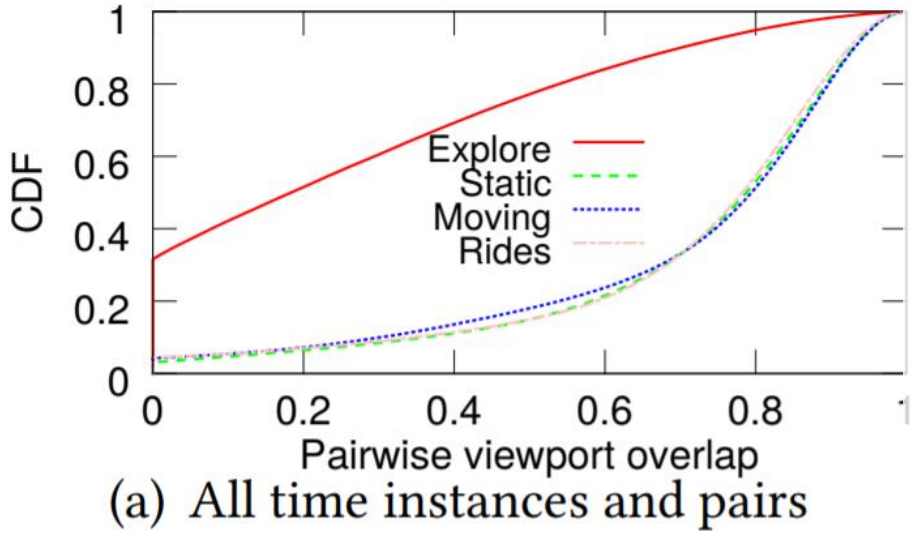

Explore category has **much smaller** pairwise overlap than other categories

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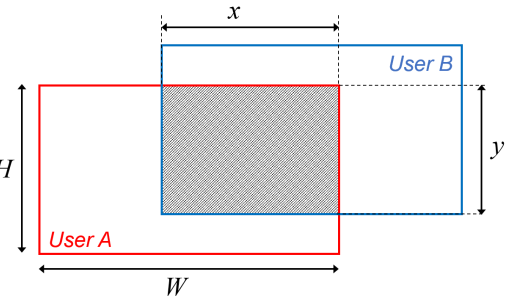

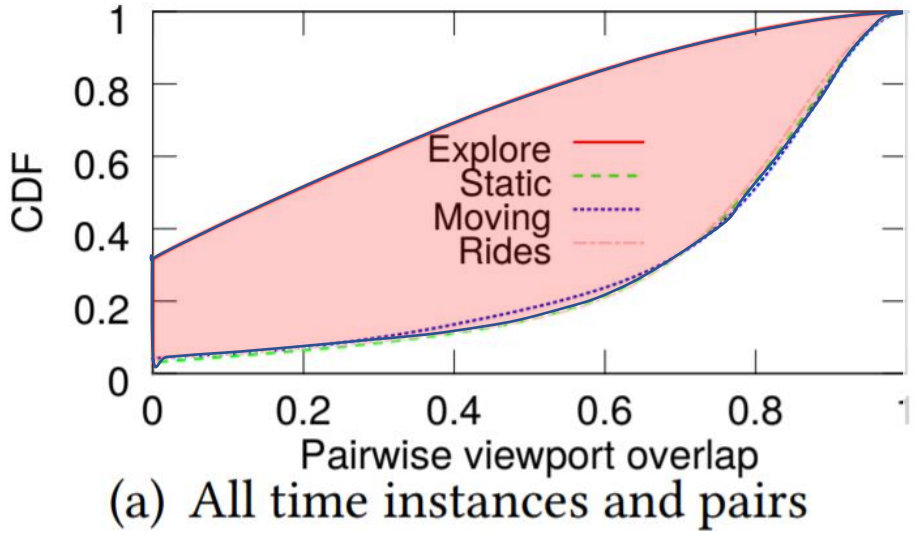

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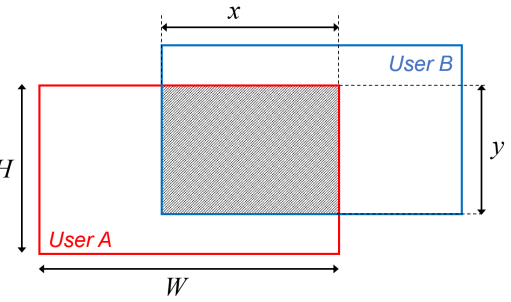

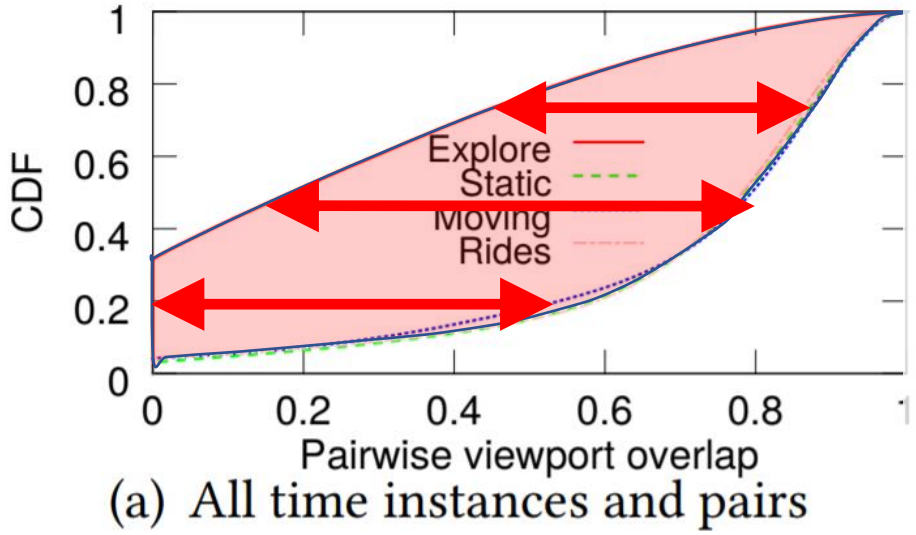

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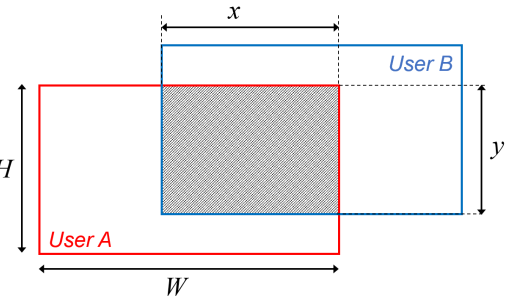

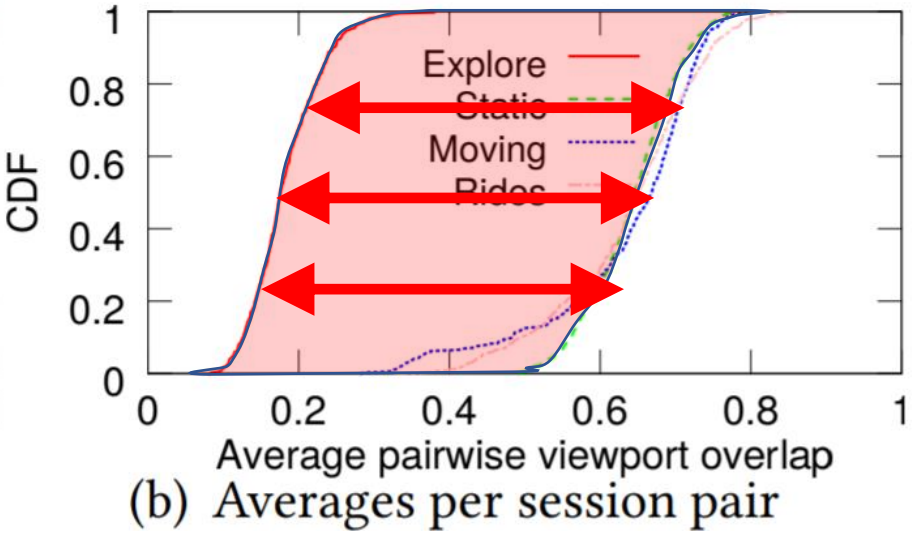

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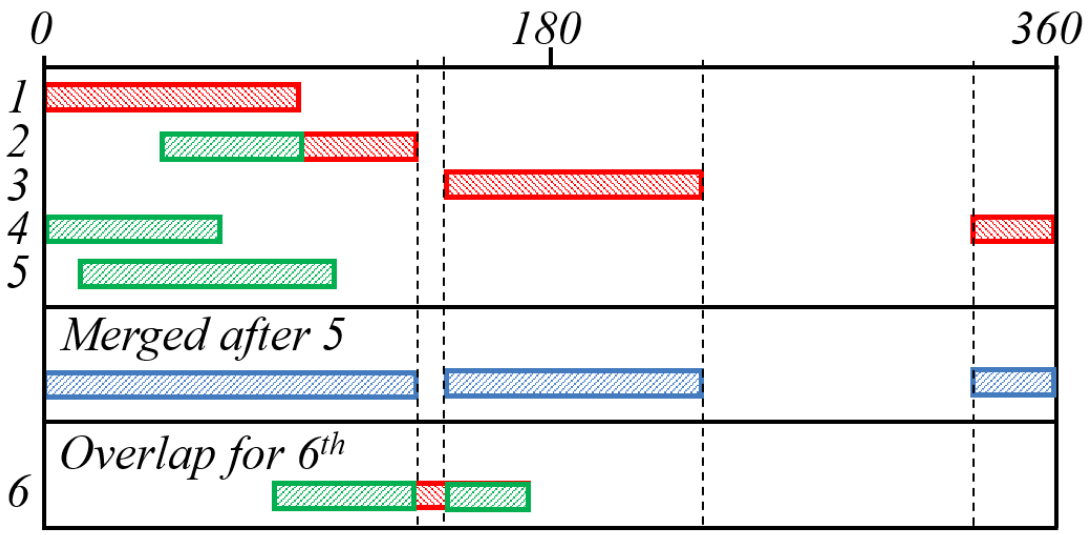
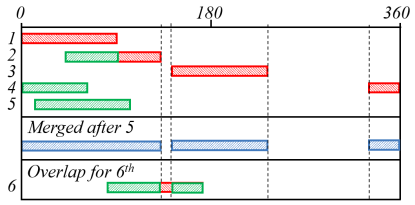


Multi-user scenario

Part 1: Instantaneous similarities



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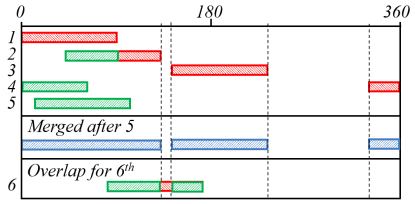
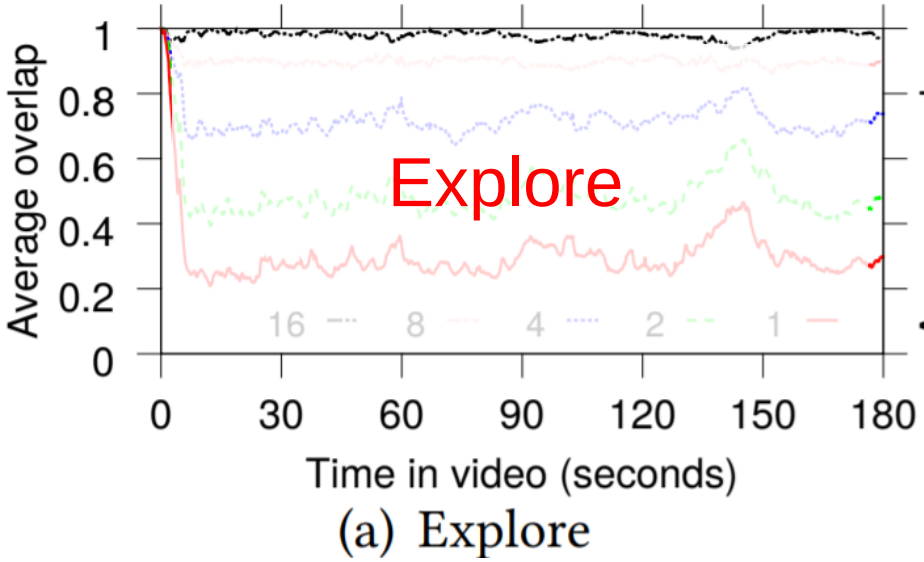
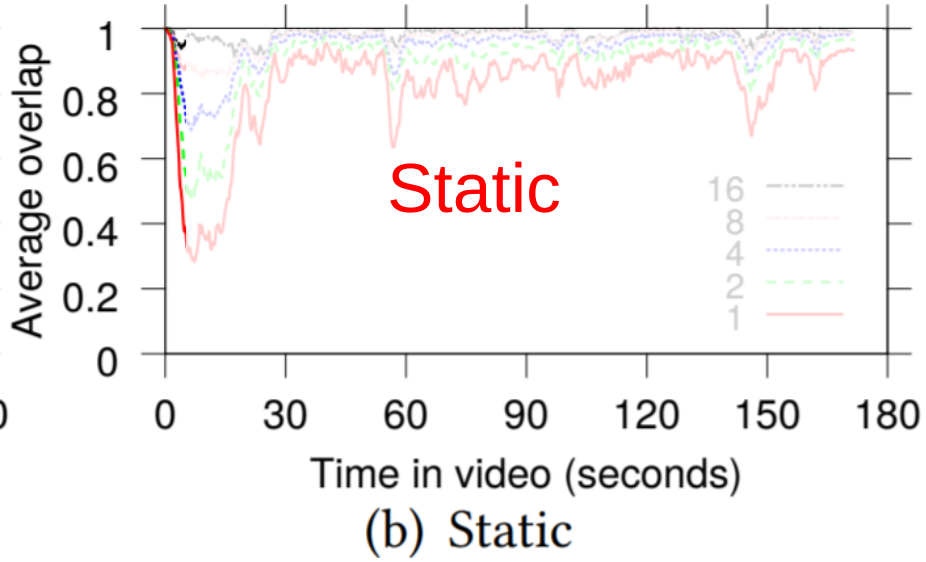




(a) Explore



(b) Static

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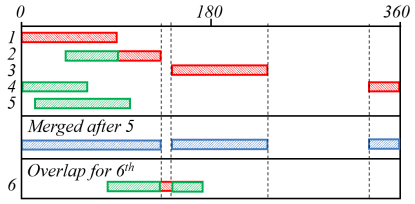
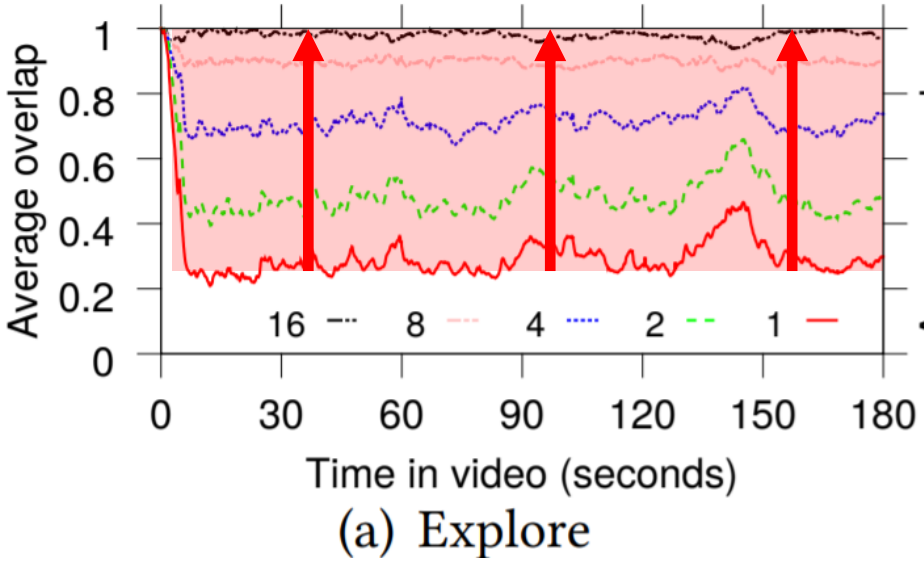
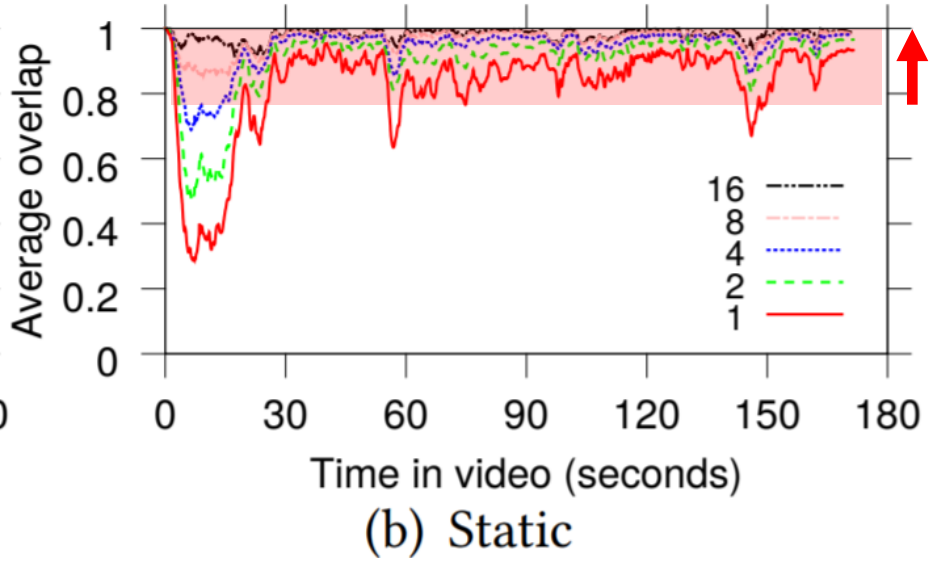




(a) Explore

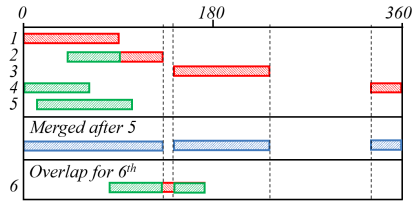


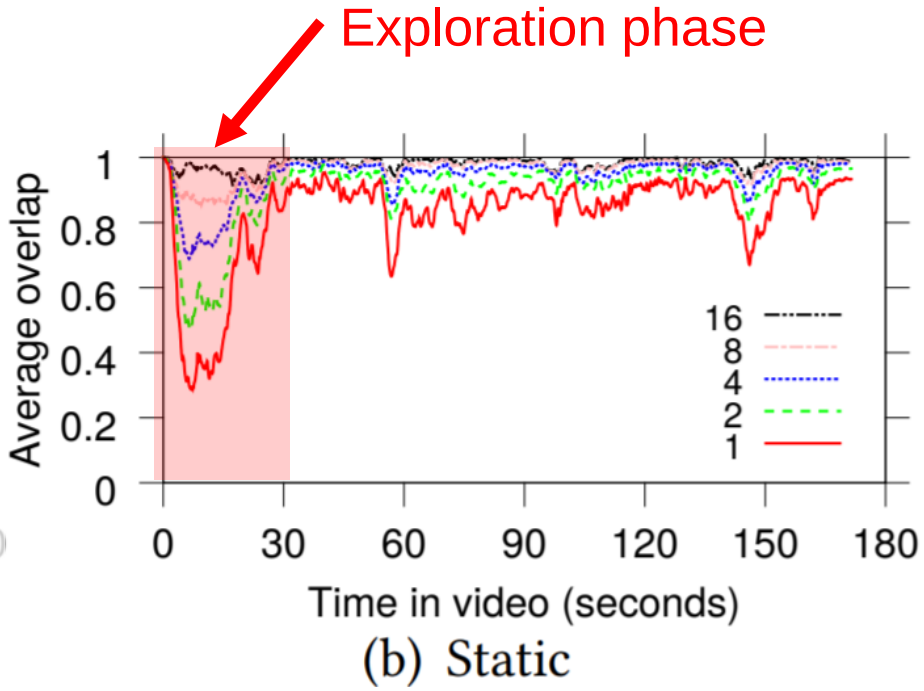
(b) Static

Substantial differences in how quickly overlap increase with more clients

- Explore vs static (above)

Part 1: Instantaneous similarities





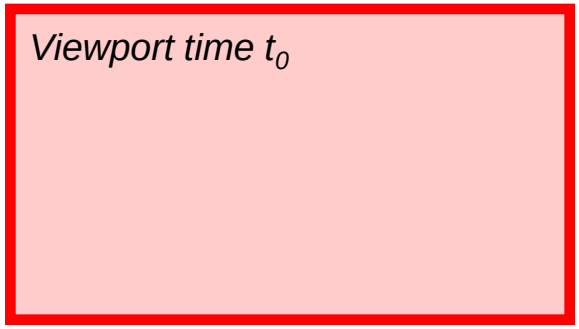
Substantial differences in how quickly overlap increase with more clients

- Explore vs static (above)

Exception: Initial exploration phase for static

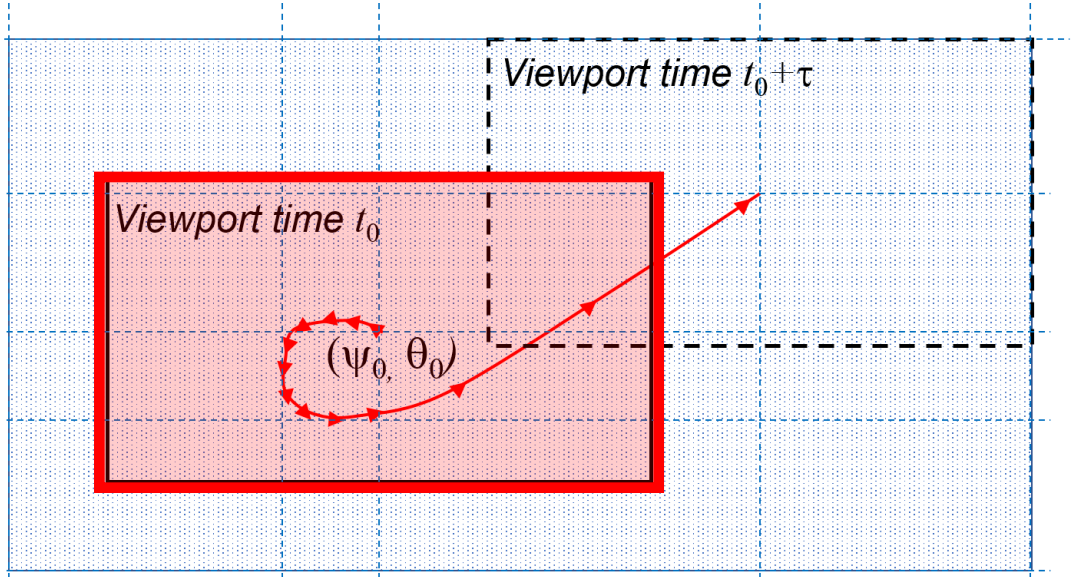
Part 2: Per-chunk similarities

Part 2: Per-chunk similarities



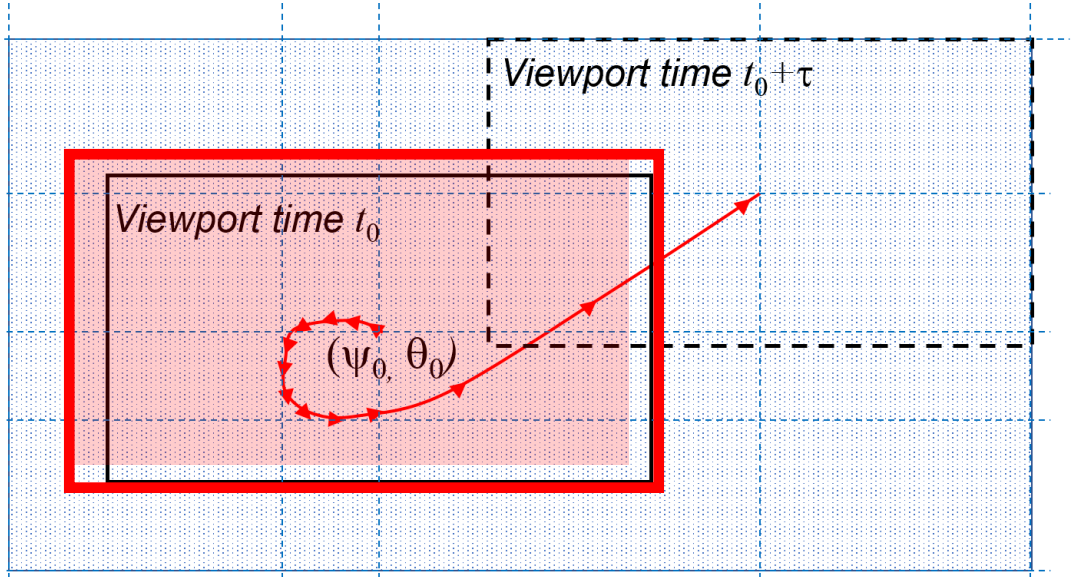
Define per-chunk coverage

Part 2: Per-chunk similarities



Define per-chunk coverage

Part 2: Per-chunk similarities



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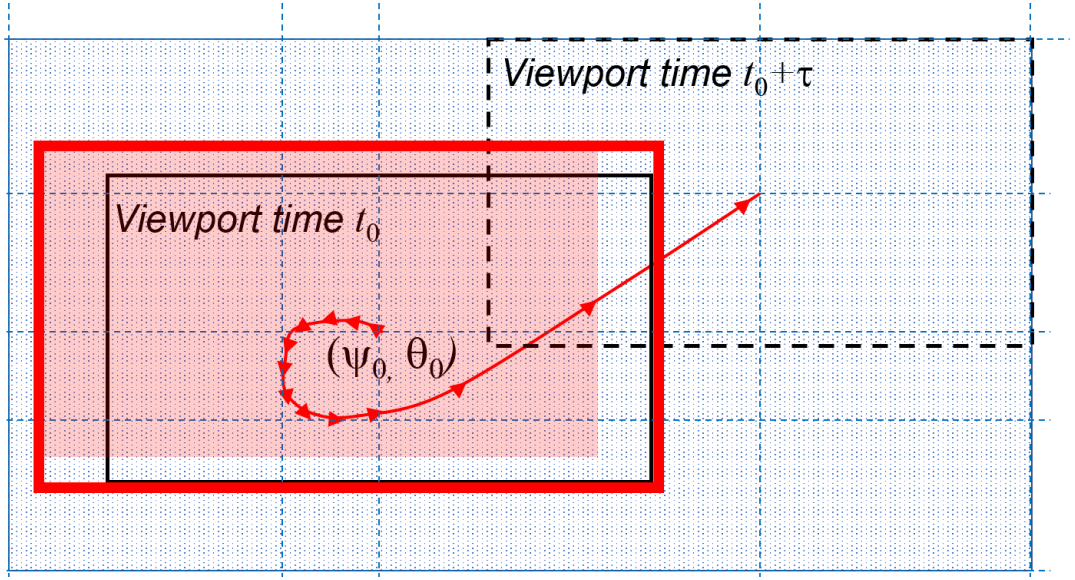
Part 2: Per-chunk similarities



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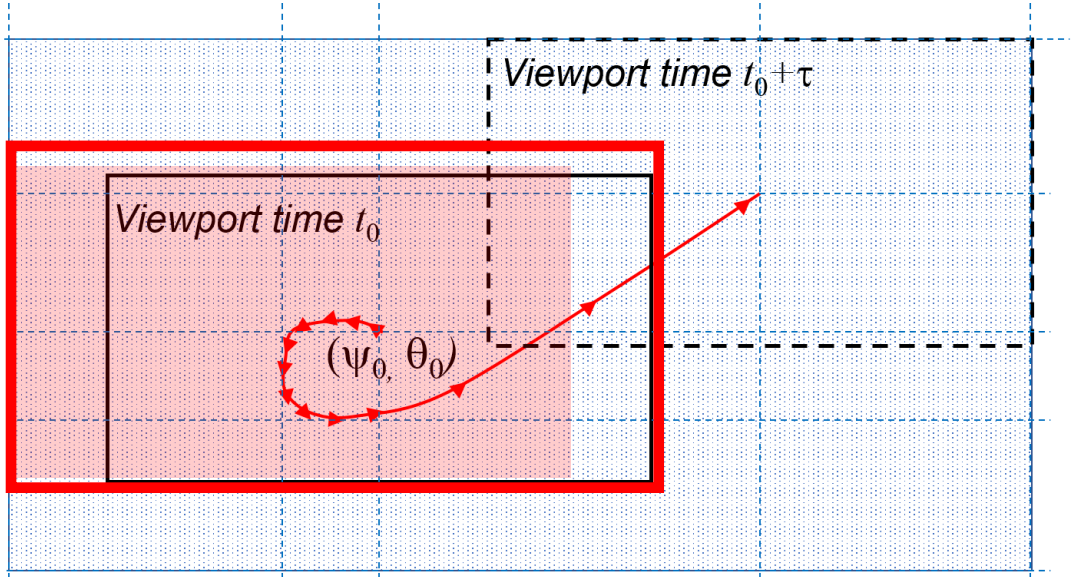

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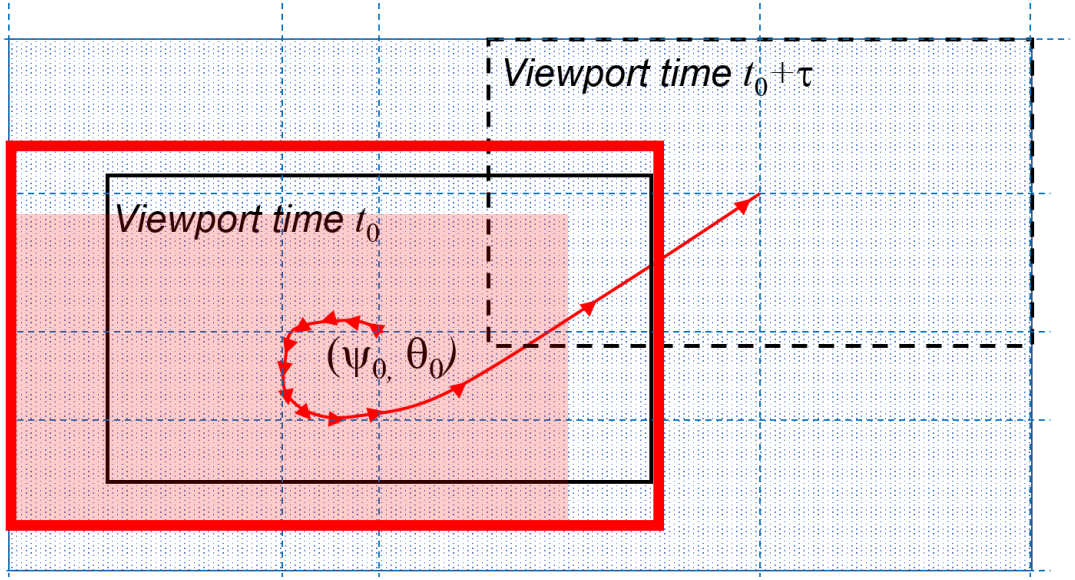
Part 2: Per-chunk similarities



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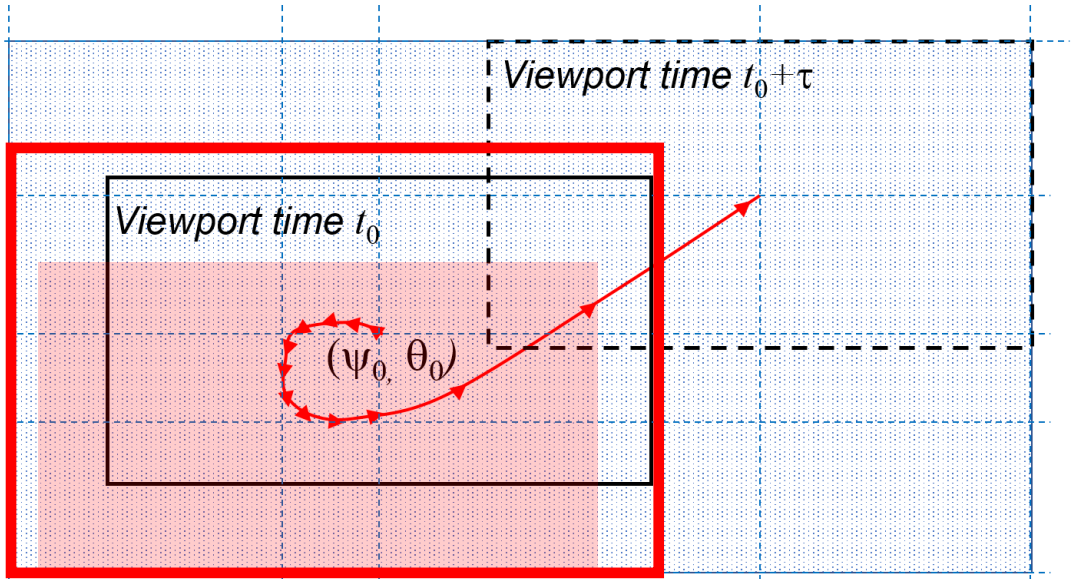
Part 2: Per-chunk similarities



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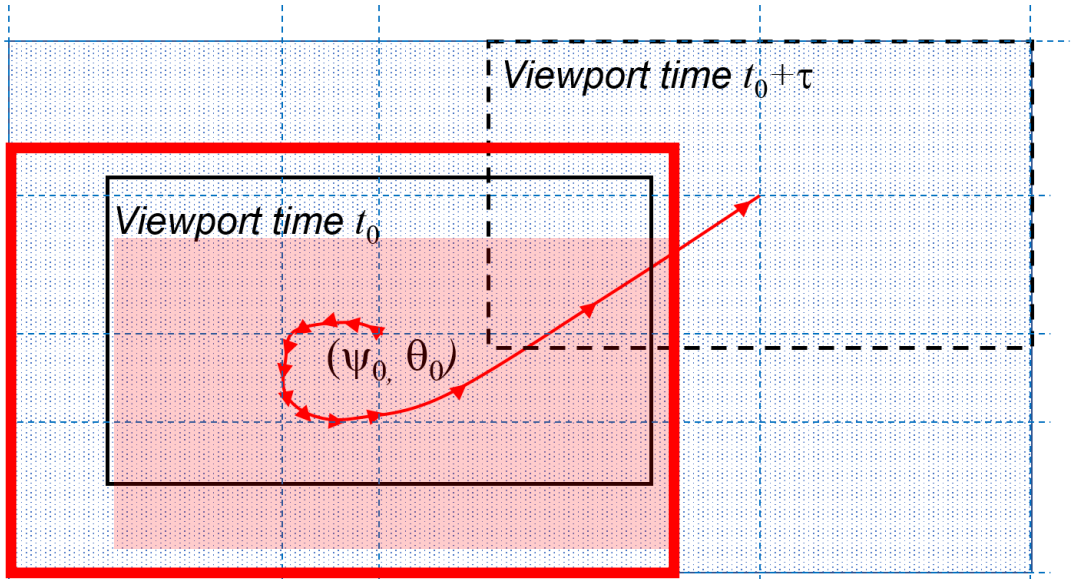
Part 2: Per-chunk similarities



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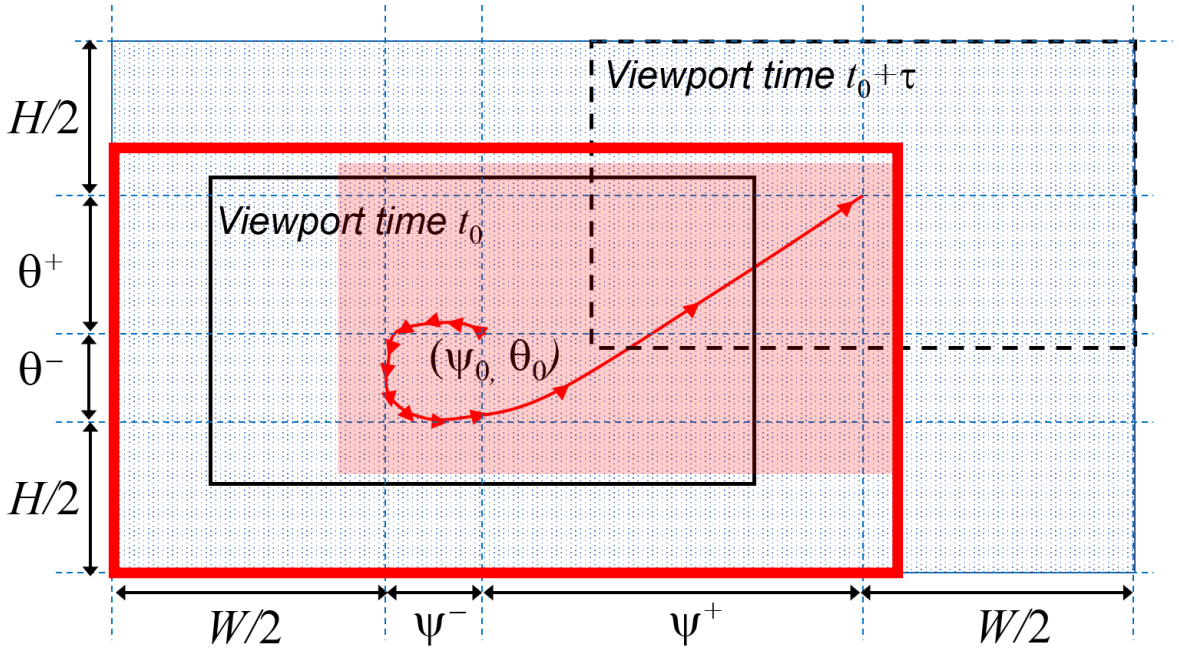
Part 2: Per-chunk similarities



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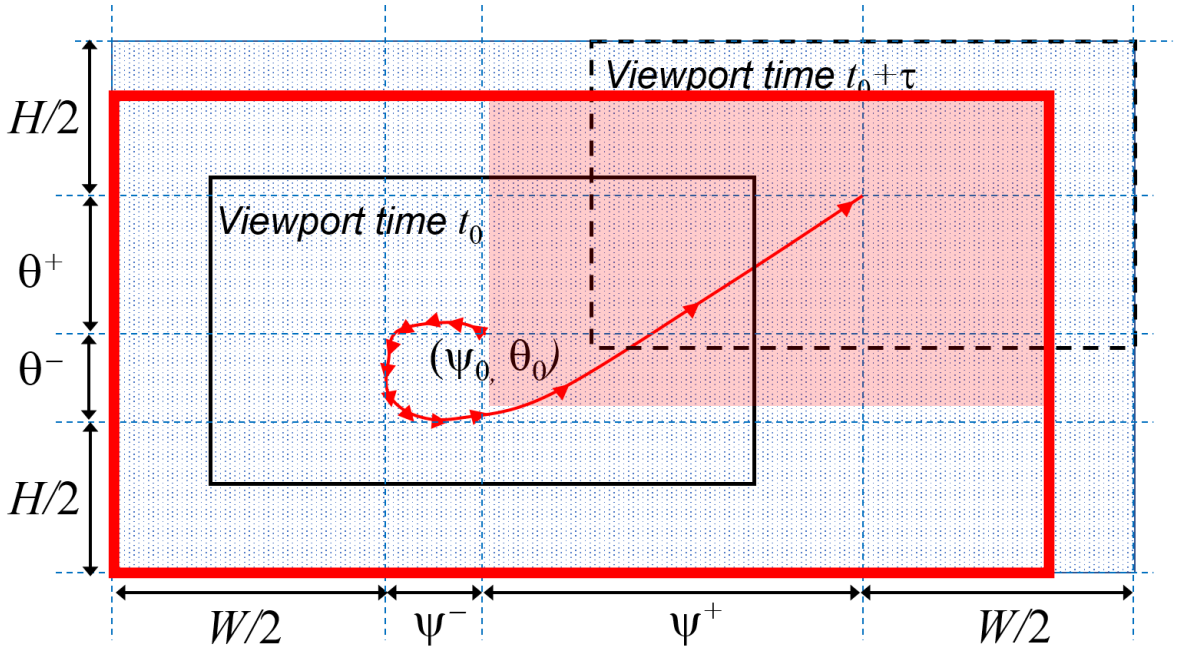

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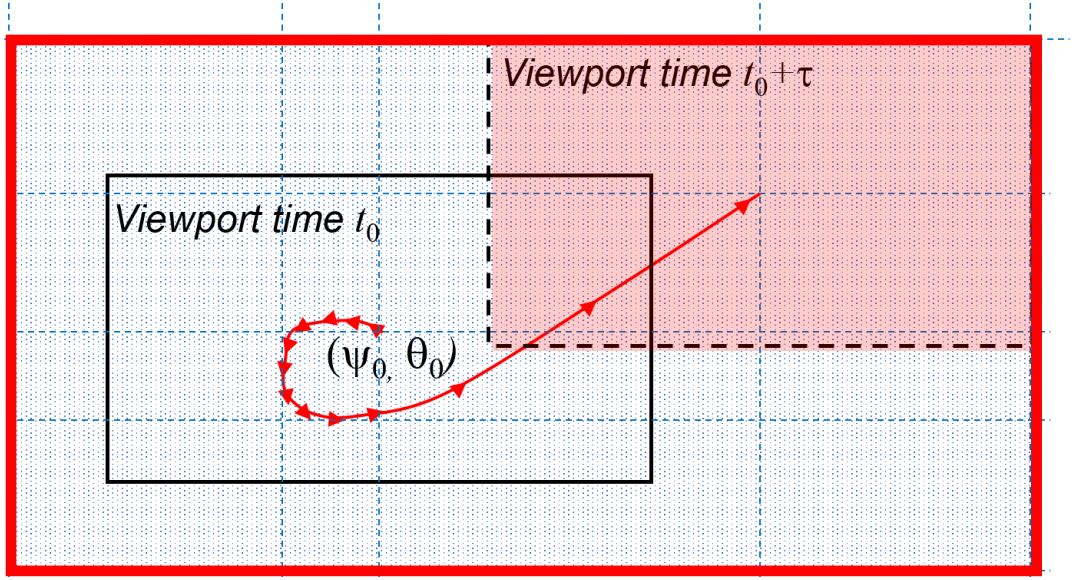
Part 2: Per-chunk similarities



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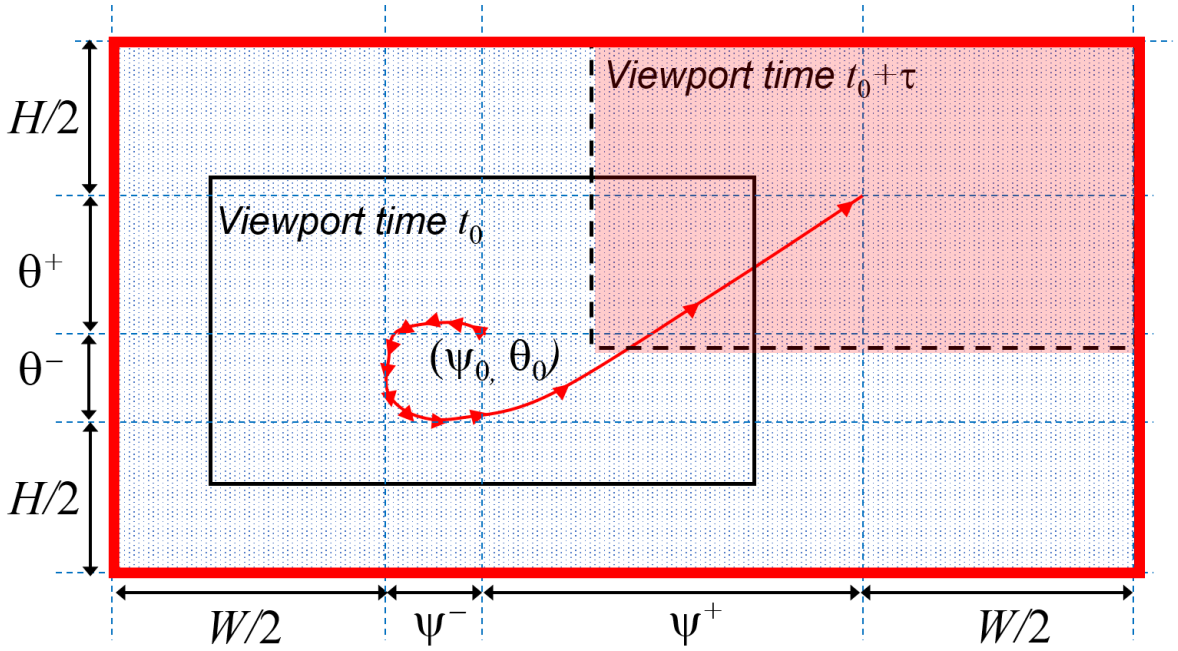
Part 2: Per-chunk similarities



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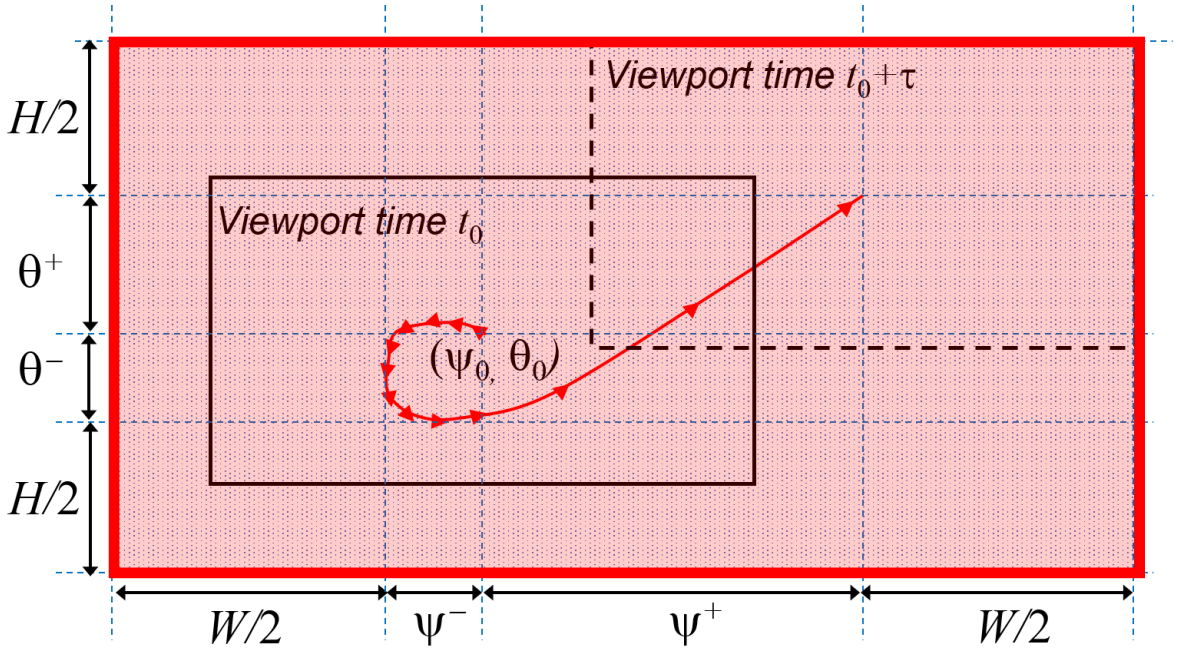
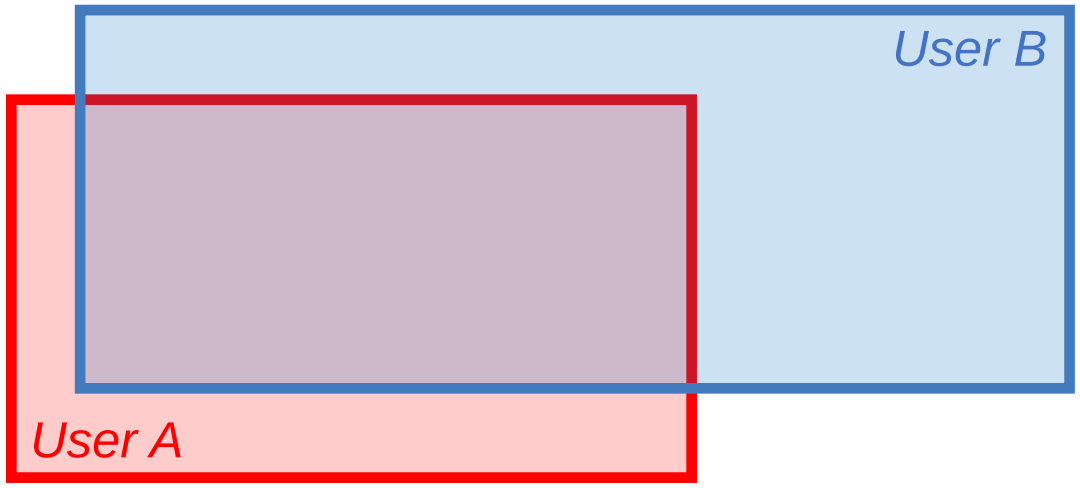


Define per-chunk coverage

Part 2: Per-chunk similarities

Per-chunk coverage overlap

Part 2: Per-chunk similarities



Per-chunk coverage overlap

Part 2: Per-chunk similarities

Per-chunk coverage overlap

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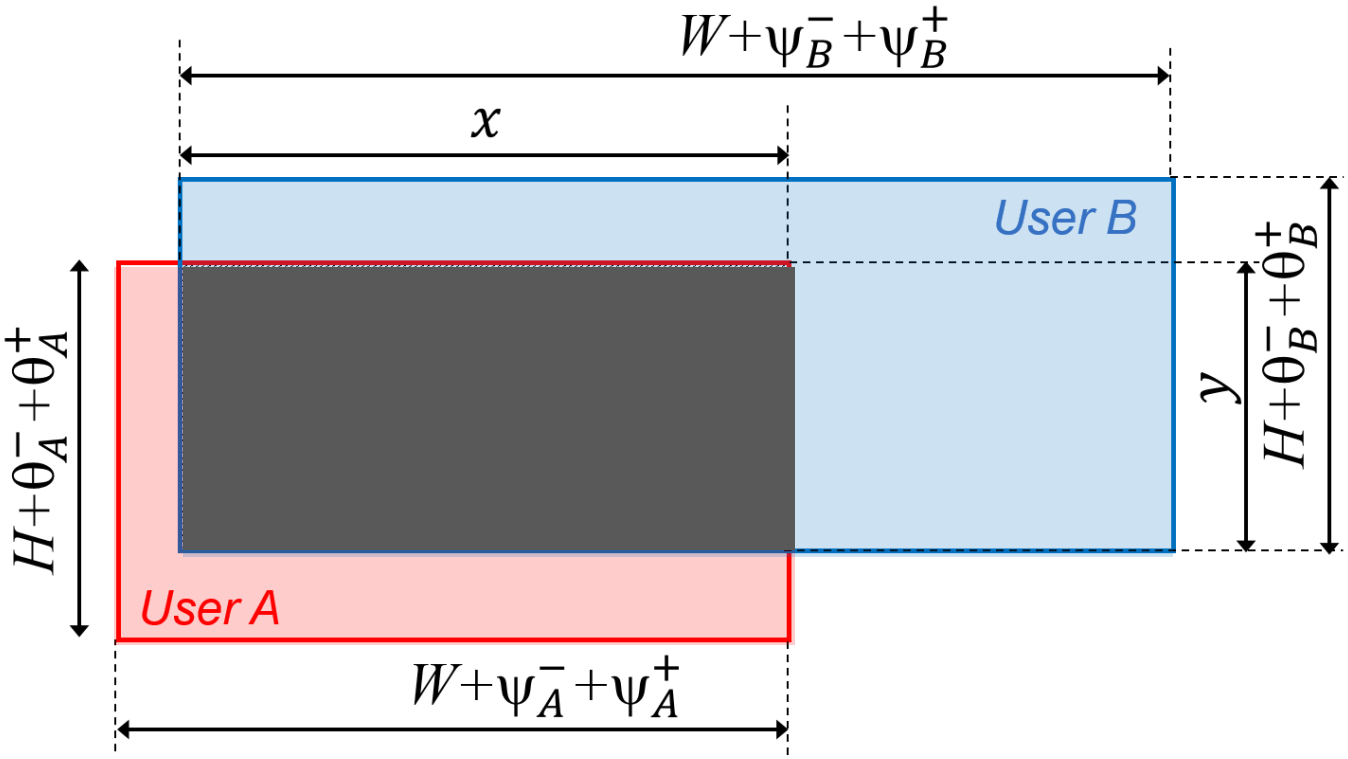
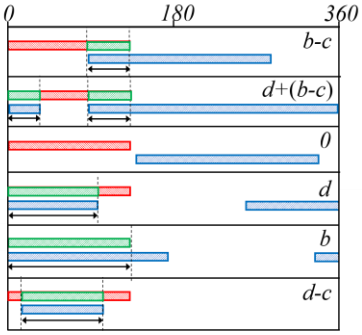


Per-chunk coverage overlap

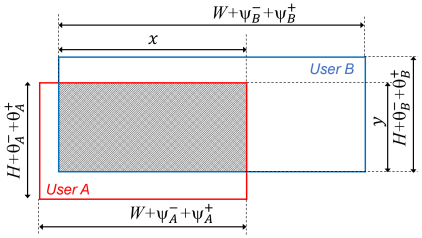
Part 2: Per-chunk similarities

Per-chunk coverage overlap

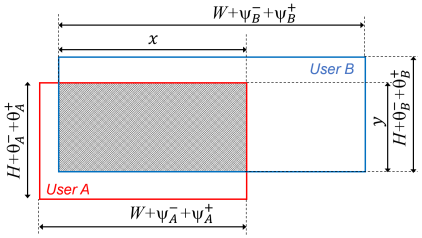
Also, some details for handling wraparound ...

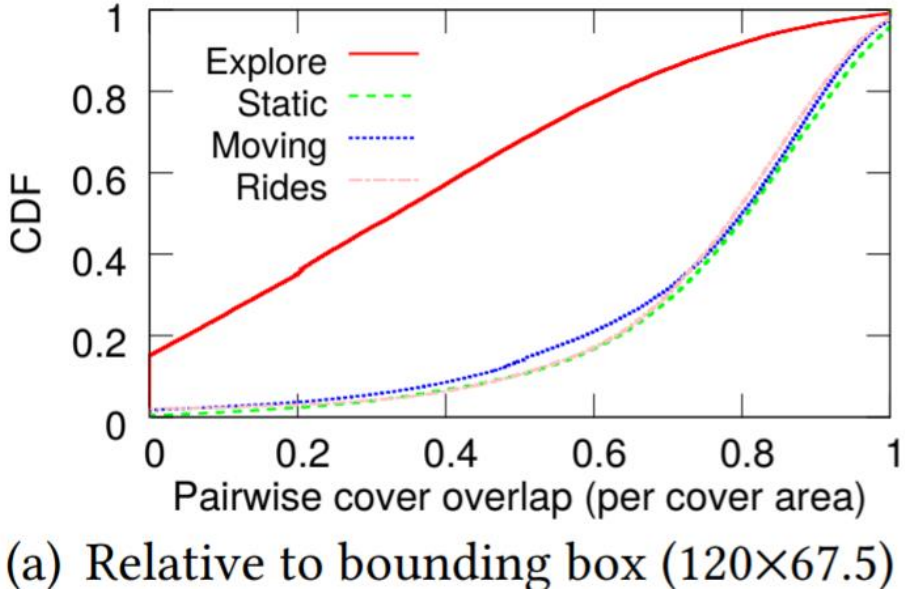


Part 2: Per-chunk similarities



Part 2: Per-chunk similarities



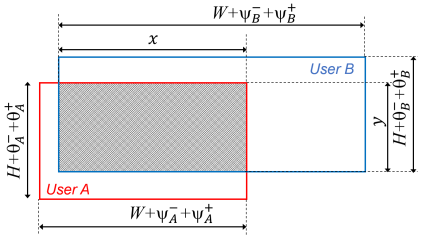


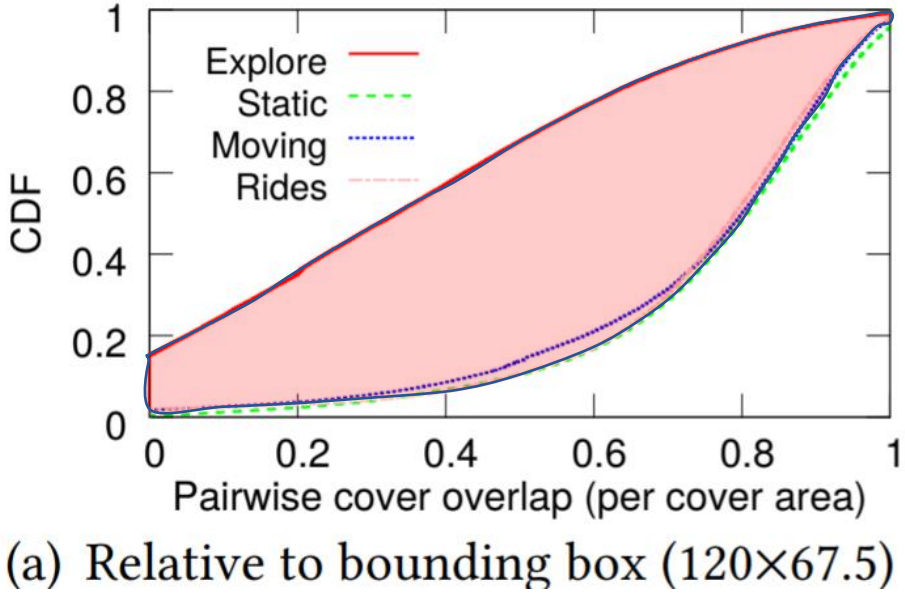
(a) Relative to bounding box (120×67.5)

(b) Relative to viewport (120×67.5)

Explore category has **much smaller** pairwise overlap than other categories

Part 2: Per-chunk similarities





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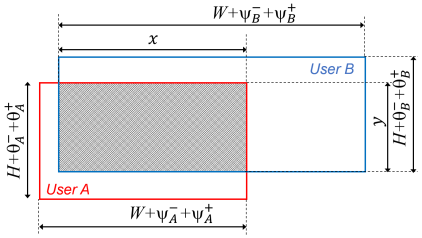

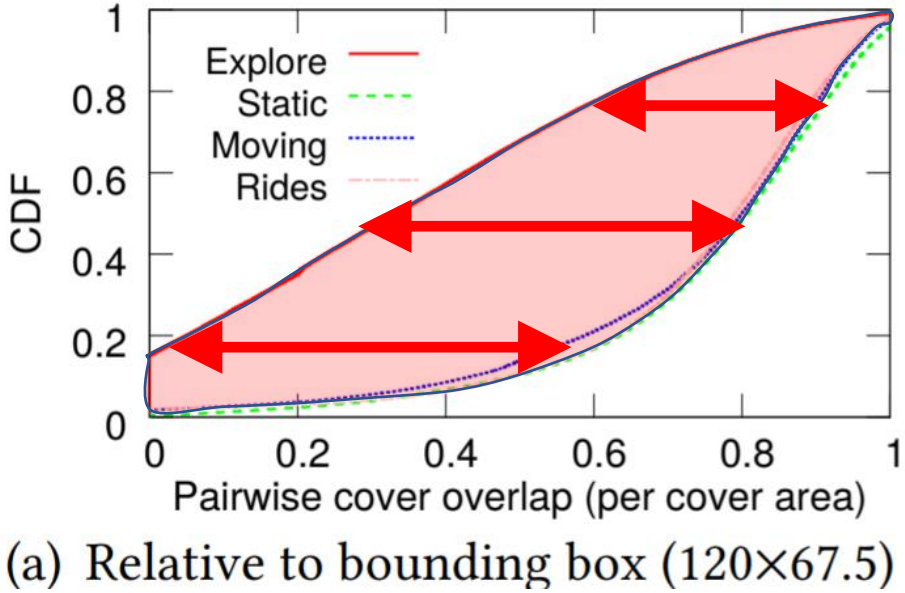

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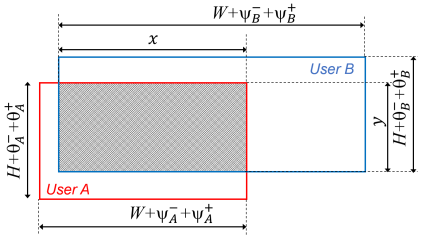

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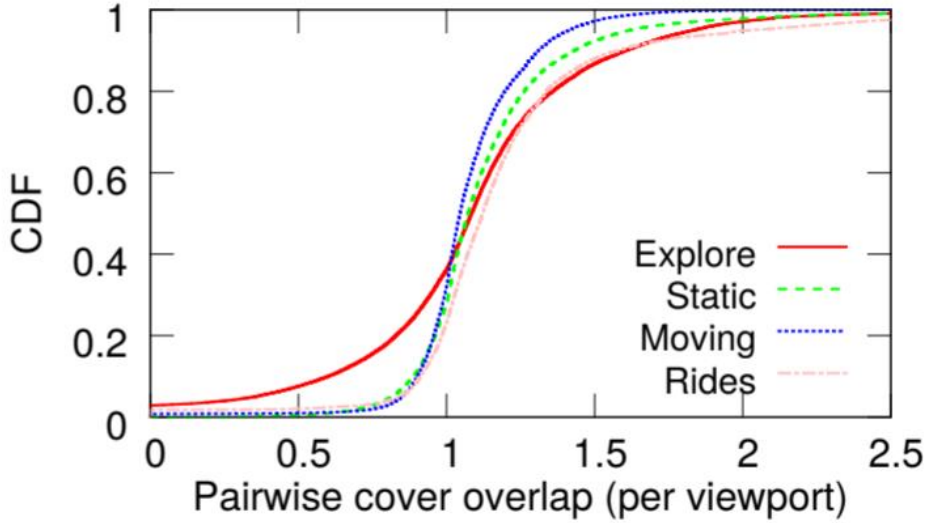
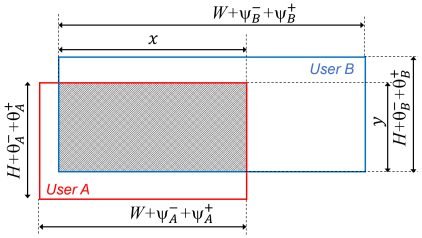


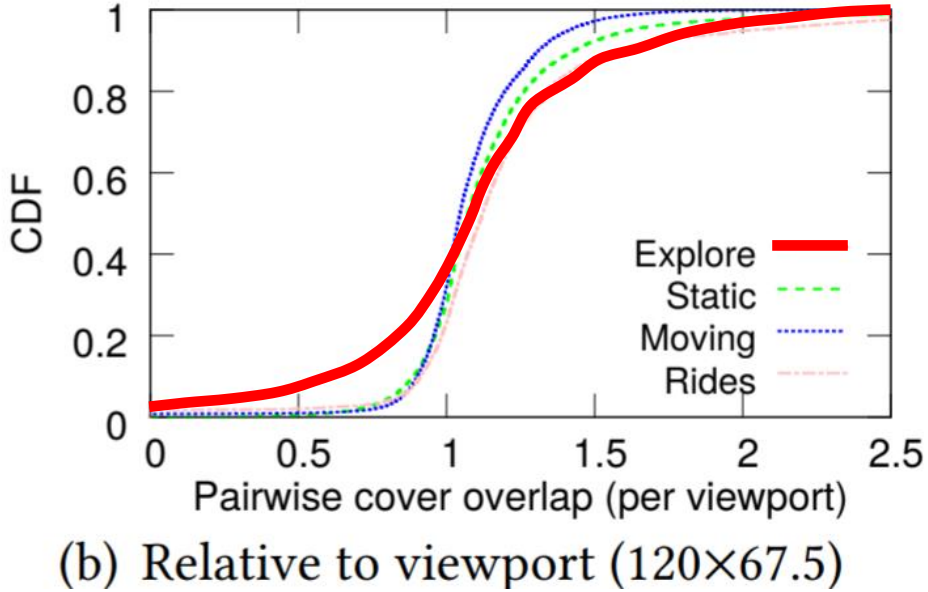
(b) Relative to viewport (120×67.5)

Explore category has **much smaller** pairwise overlap than other categories

Explore category has **much bigger** variation (due to larger head movements)

Part 2: Per-chunk similarities





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Part 3: Cache simulations

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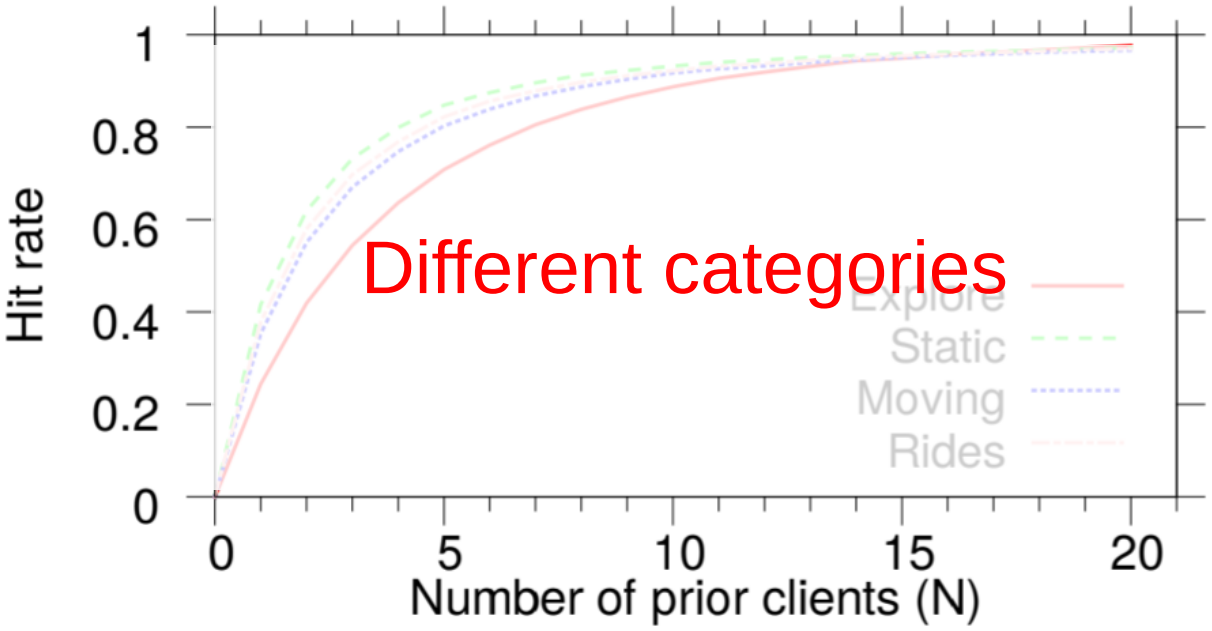

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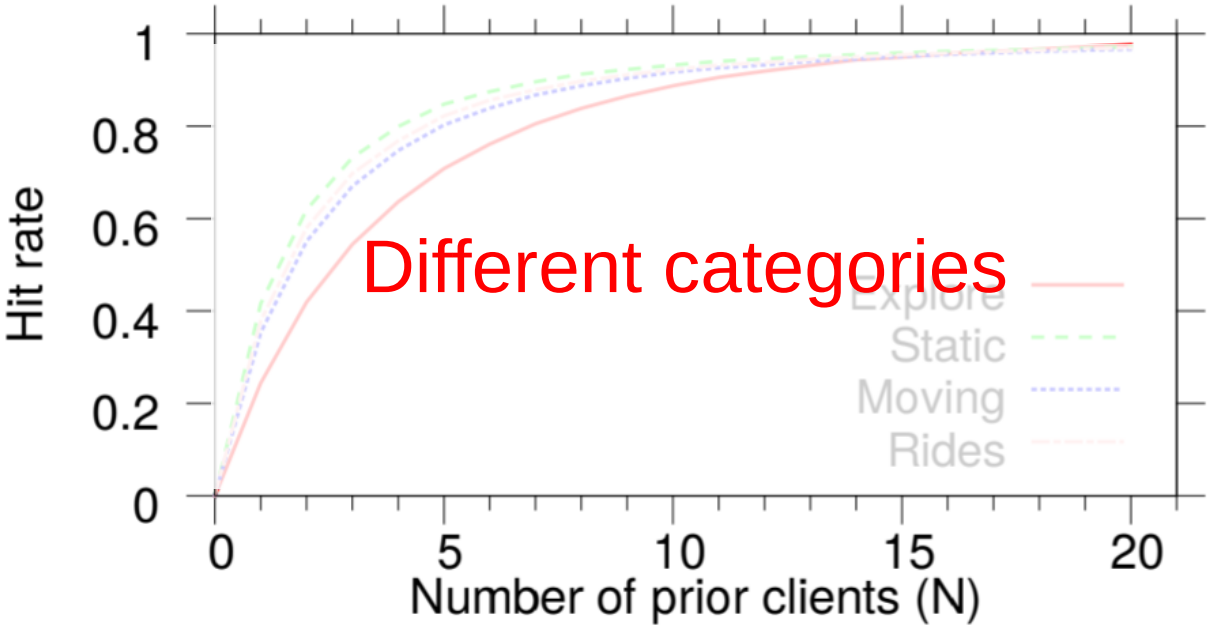

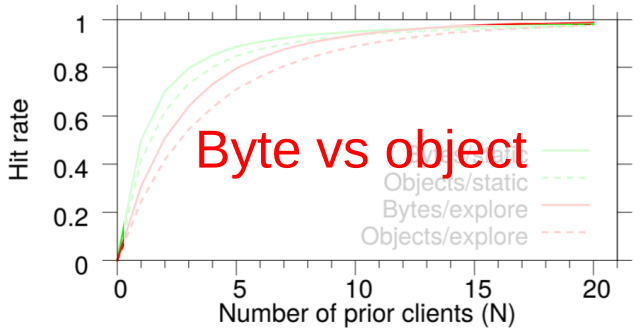

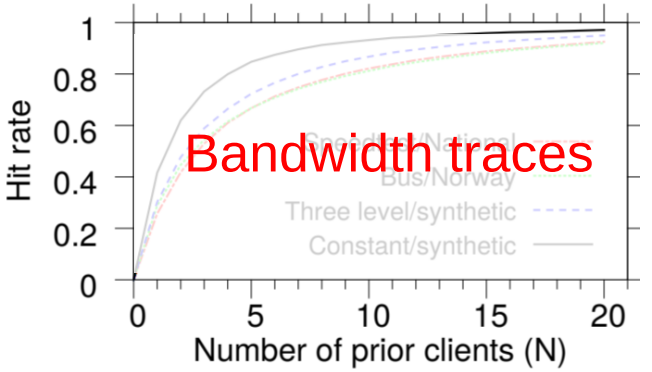

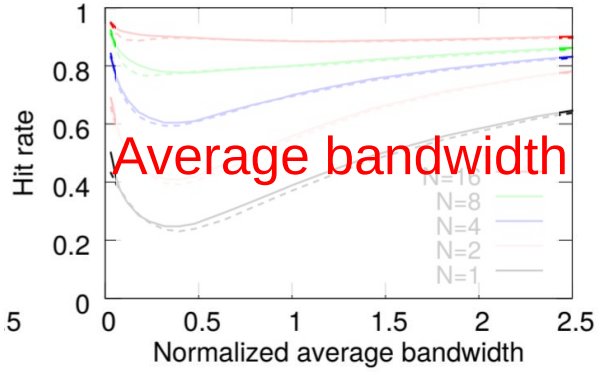

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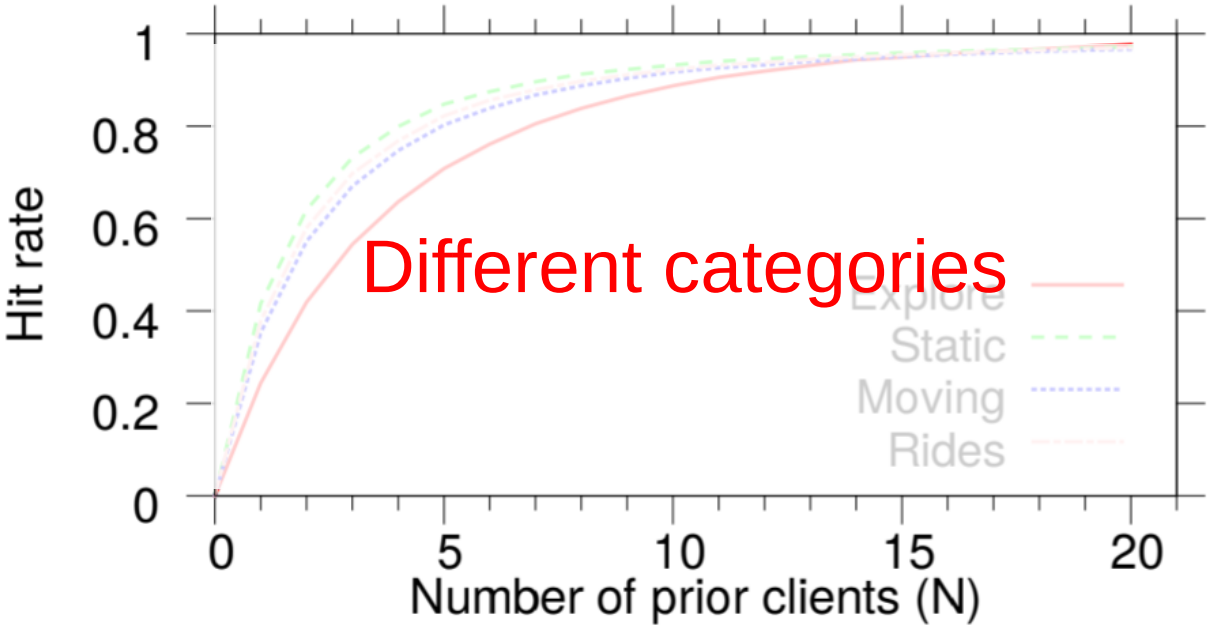
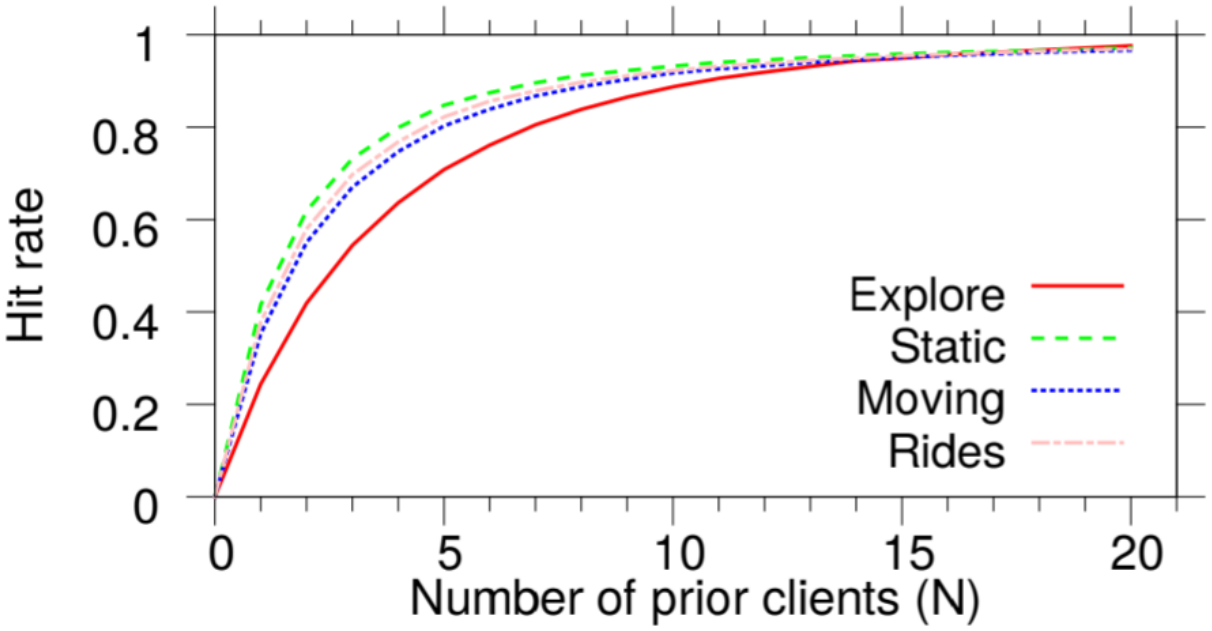


- Significant differences in bandwidth usage

Part 3: Cache simulations



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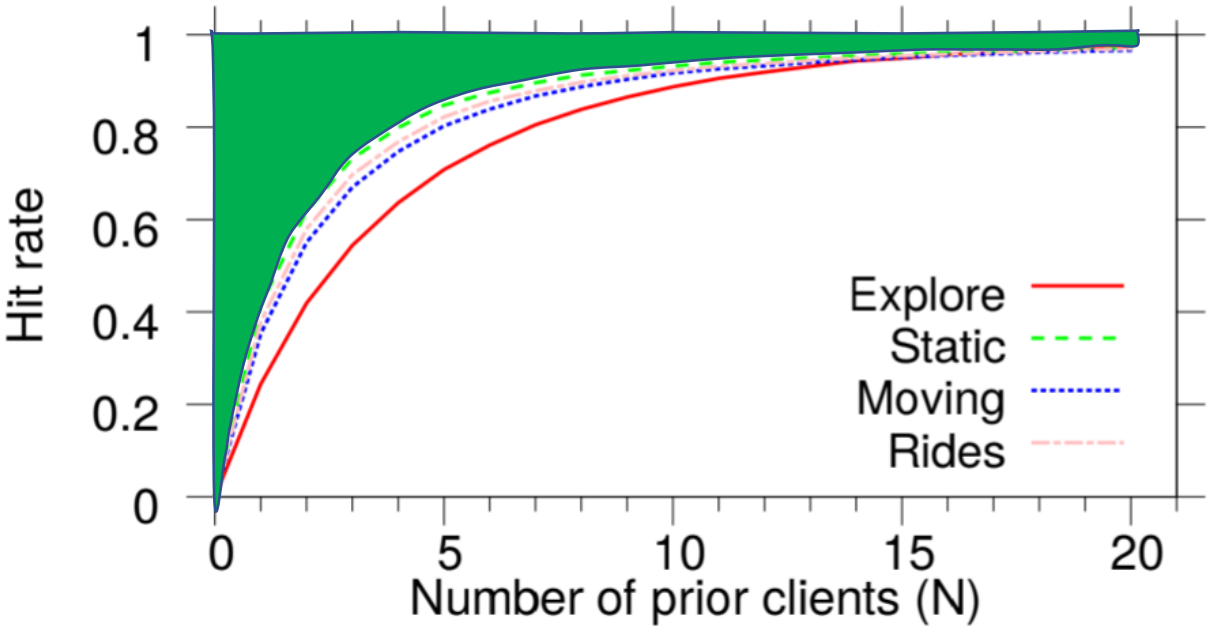

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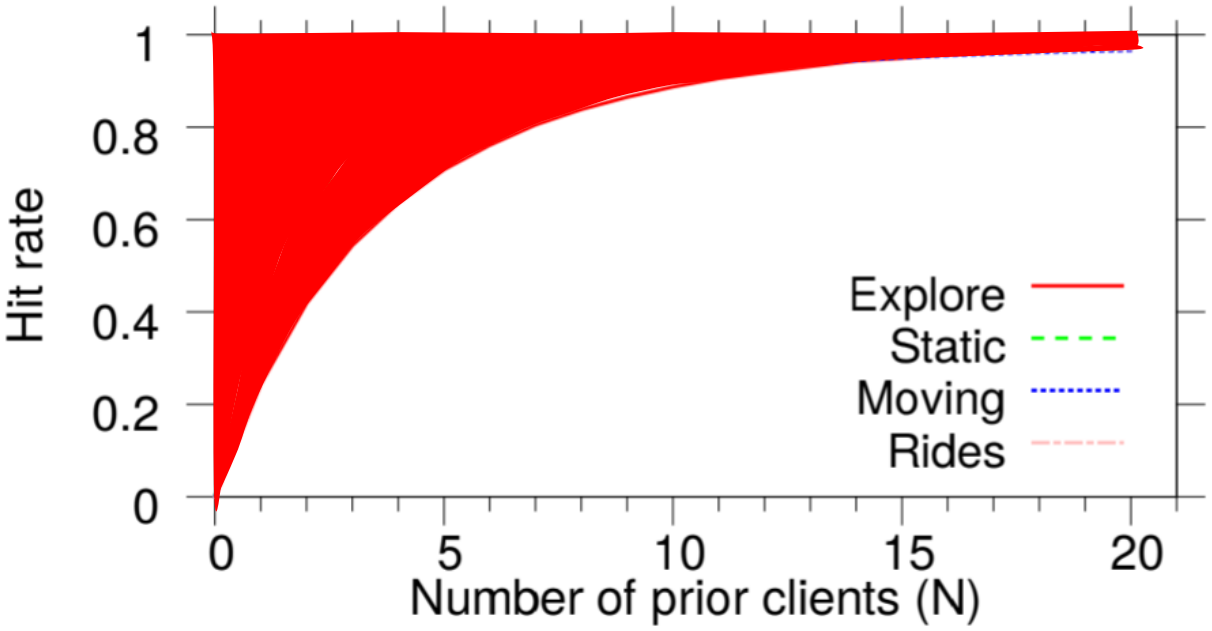

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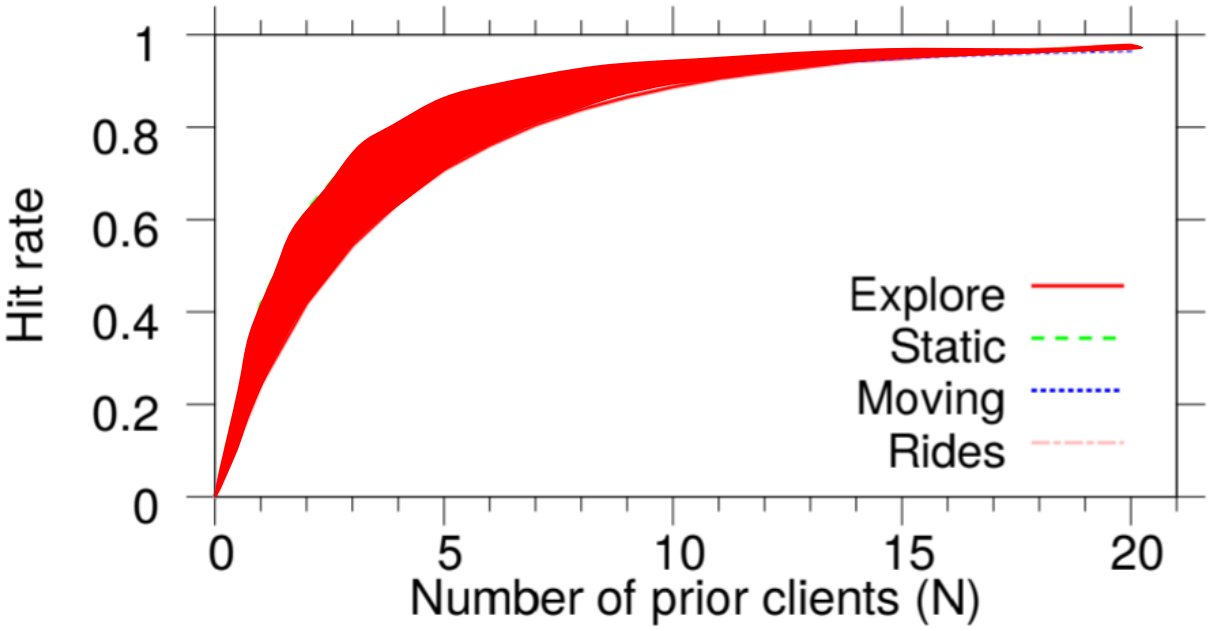

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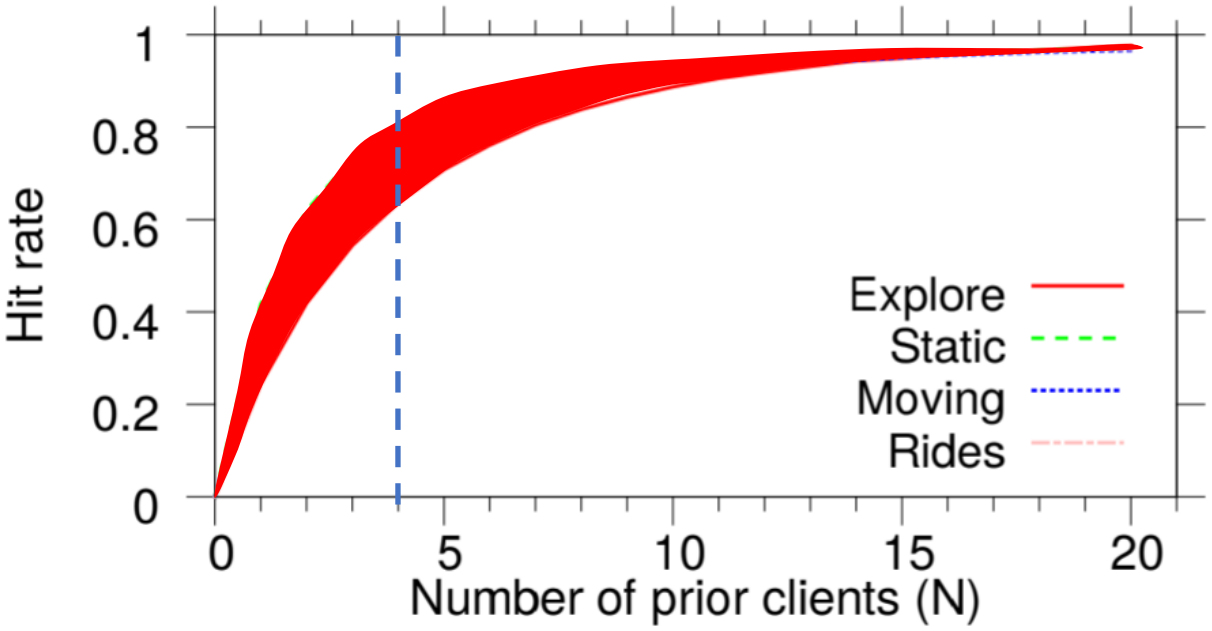
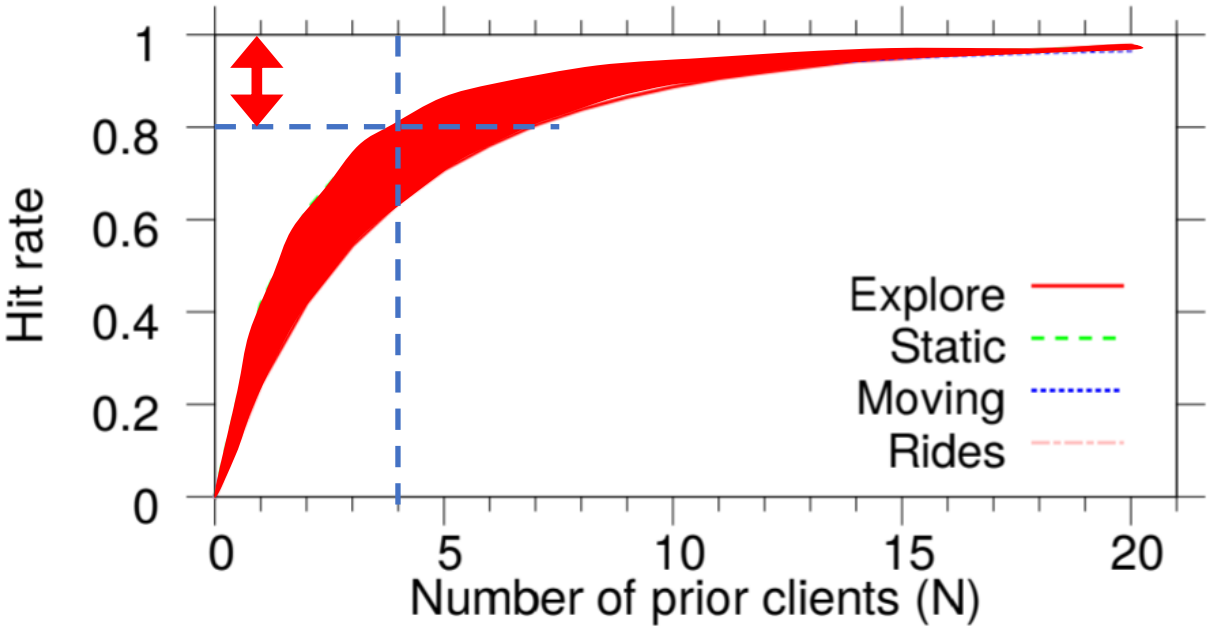


- Significant differences in bandwidth usage
  - E.g., for 4th client, ≈ 80% more misses

Part 3: Cache simulations



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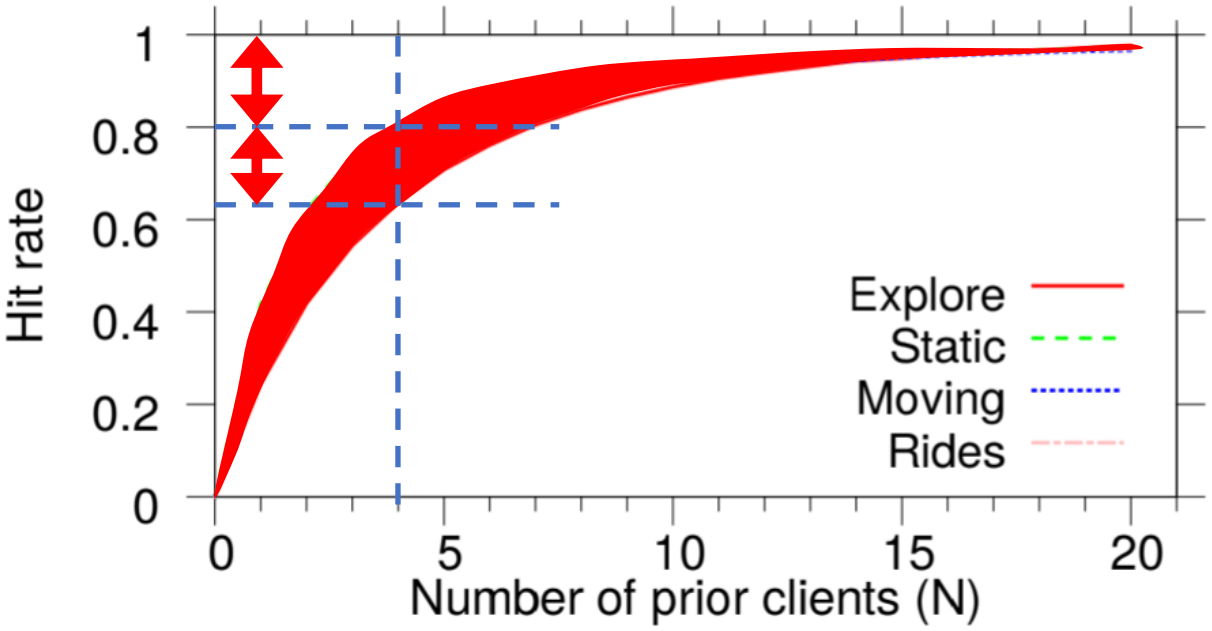

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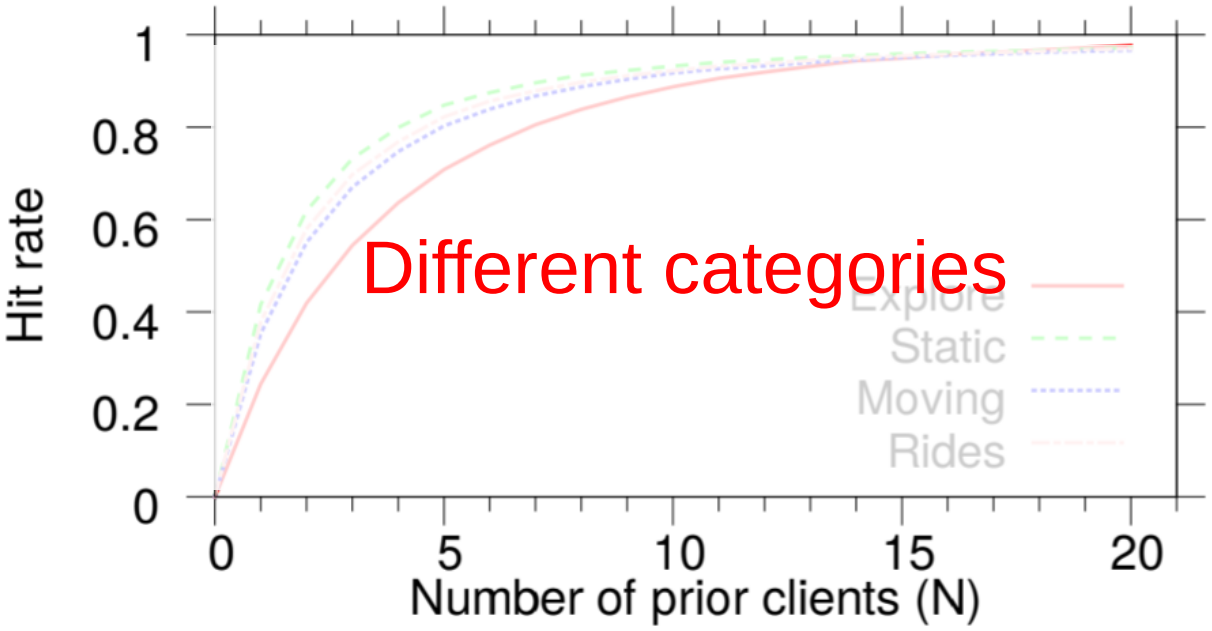

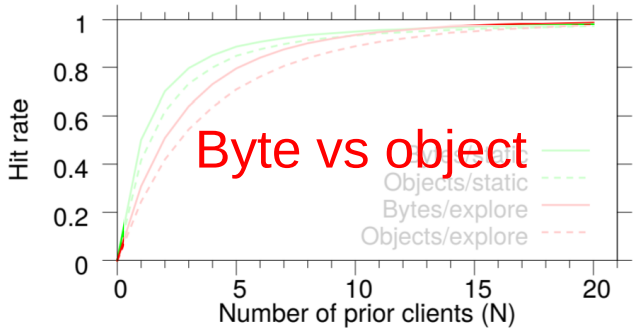

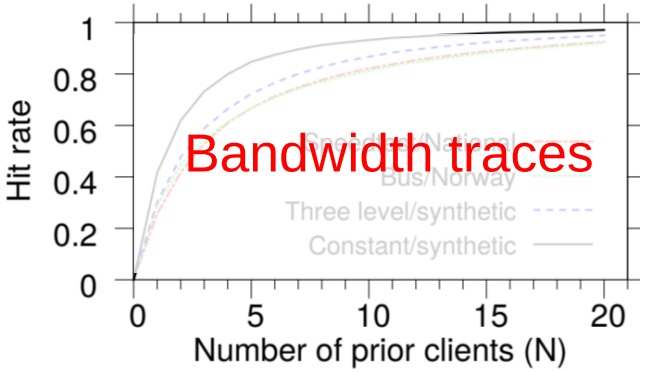

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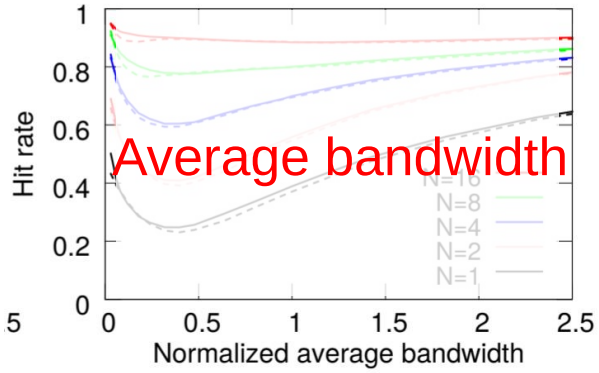

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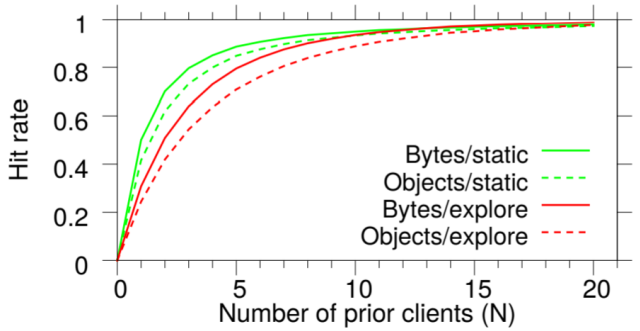

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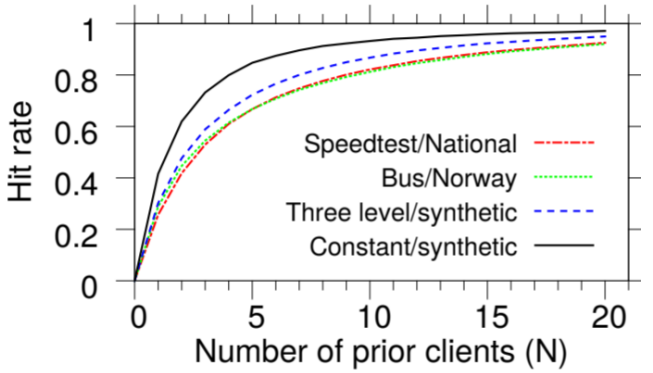
- Byte hit rates greater than object hit rates
  - Even greater bandwidth savings

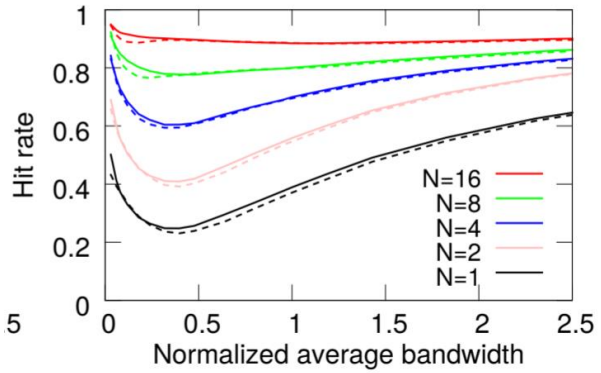
Part 3: Cache simulations



- Significant differences in bandwidth usage
  - E.g., for 4th client, ≈ 80% more misses
- Byte hit rates greater than object hit rates
  - Even greater bandwidth savings
- Greatest hit rates under stable network conditions

Part 3: Cache simulations

- Significant differences in bandwidth usage
  - E.g., for 4th client, ≈ 80% more misses
- Byte hit rates greater than object hit rates
  - Even greater bandwidth savings
- Greatest hit rates under stable network conditions
- Greatest hit rates at low/high bandwidth scenarios



Conclusions

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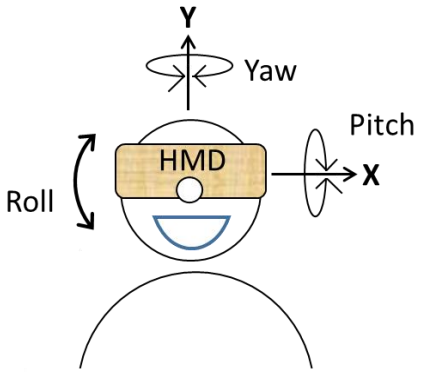
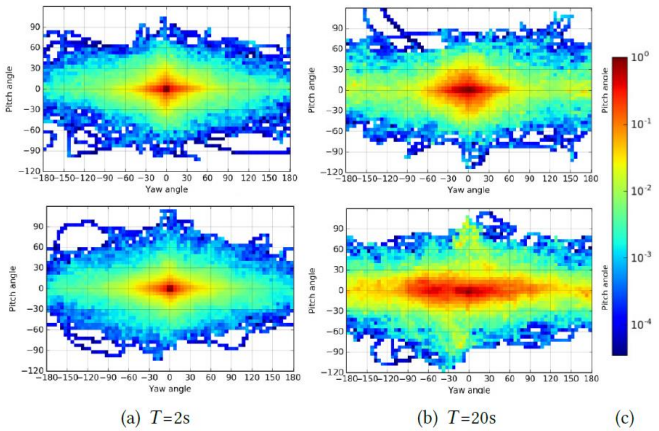
Conclusions

- First trace-driven characterization of caching opportunities
  - Category-based comparisons
- Substantial differences between different video categories
  - Overlap in viewports (both instantaneously and on a per-chunk basis)
  - Potential cache hit rates for different video categories and network conditions
- Some of the same things that improve user QoE without a cache also improve cache performance (e.g., as measured by cache hit rates)
  - Improved viewport prediction techniques (as provided in client-side)
  - Stable network conditions (motivating the use of cap-based network/server-side solutions) and less quality switches (suggesting less greedy client-side solutions)

Thanks for listening!





Had You Looked Where I'm Looking? Cross-user Similarities in Viewing Behavior for 360-degree Video and Caching Implications

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