When Virtual Reality Editing Meets Network Streaming

Lucile Sassatelli

Université Côte d'Azur

Eurographics Workshop on Intelligent Cinematography and Editing, Keynote, May 25, 2020

About me and my collaborators

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- Networking and Multimedia networking: video and immersive
  - Lucile Sassatelli

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- Project:
  - AI4Media: one of the 4 EU networks of excellence centers in AI, targeted at media







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2. A review of attention-driving techniques in 360° videos

3. New levers to improve VR streaming:
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    2. Virtual walls

4. Conclusions

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    → How to stream over the Internet?

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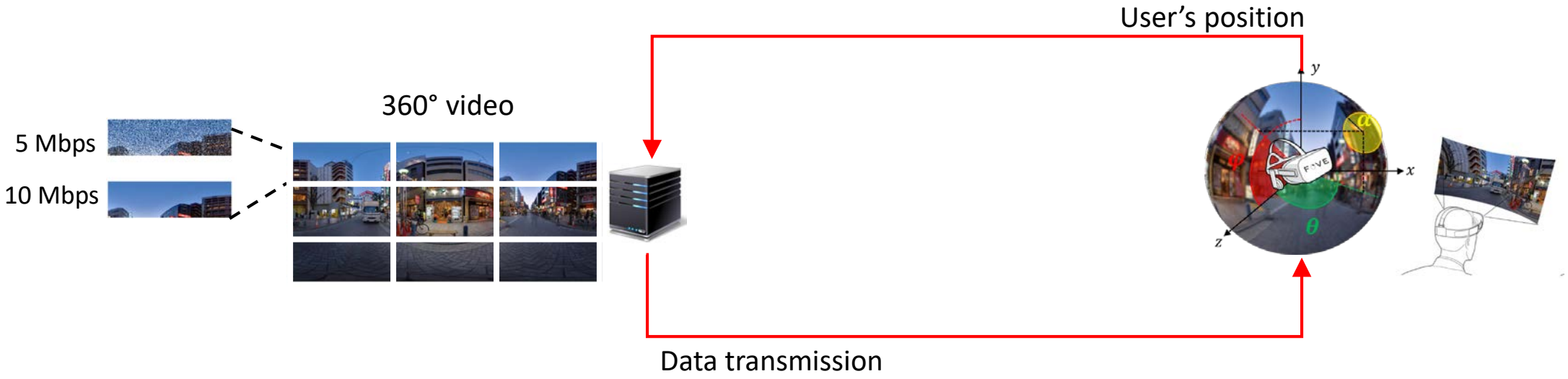

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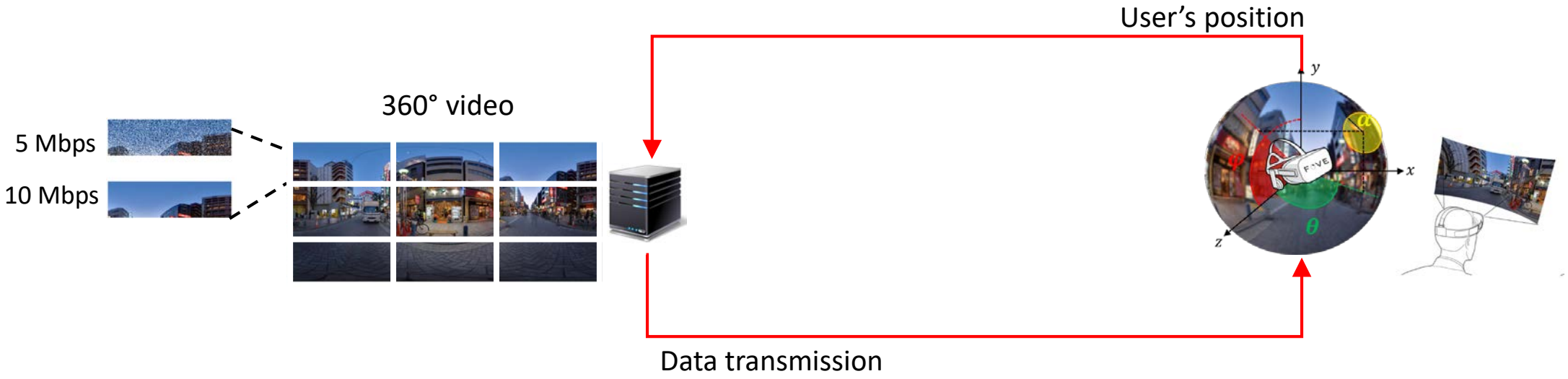

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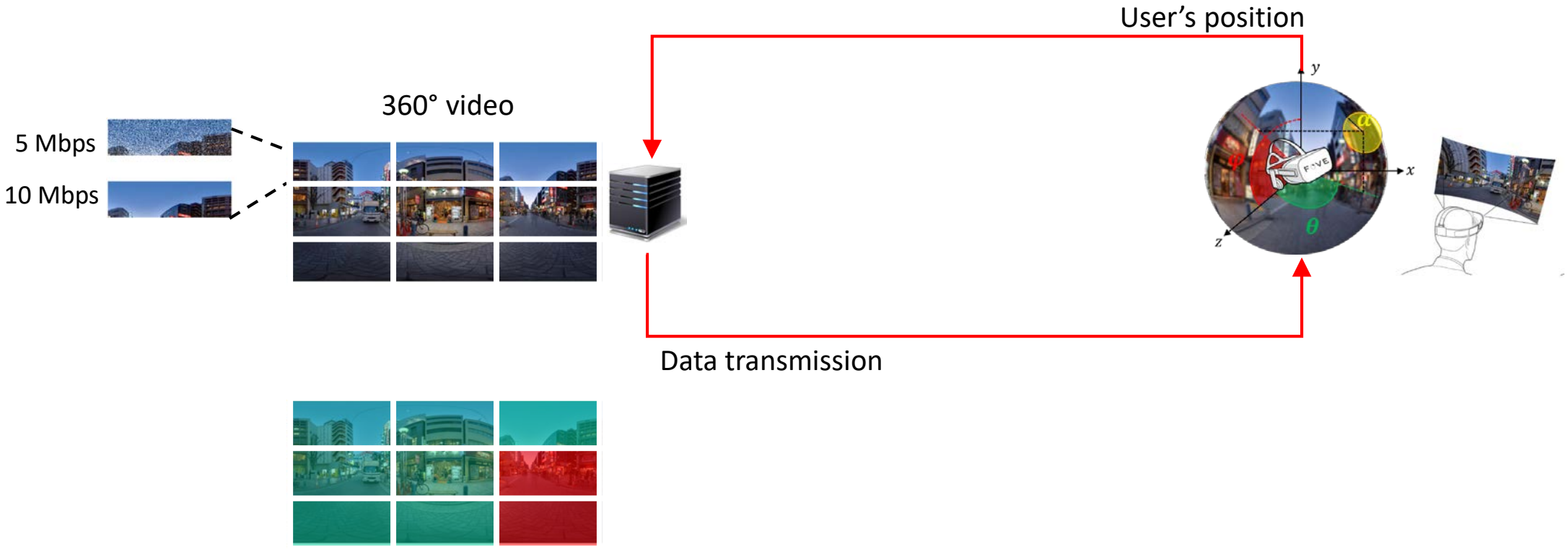

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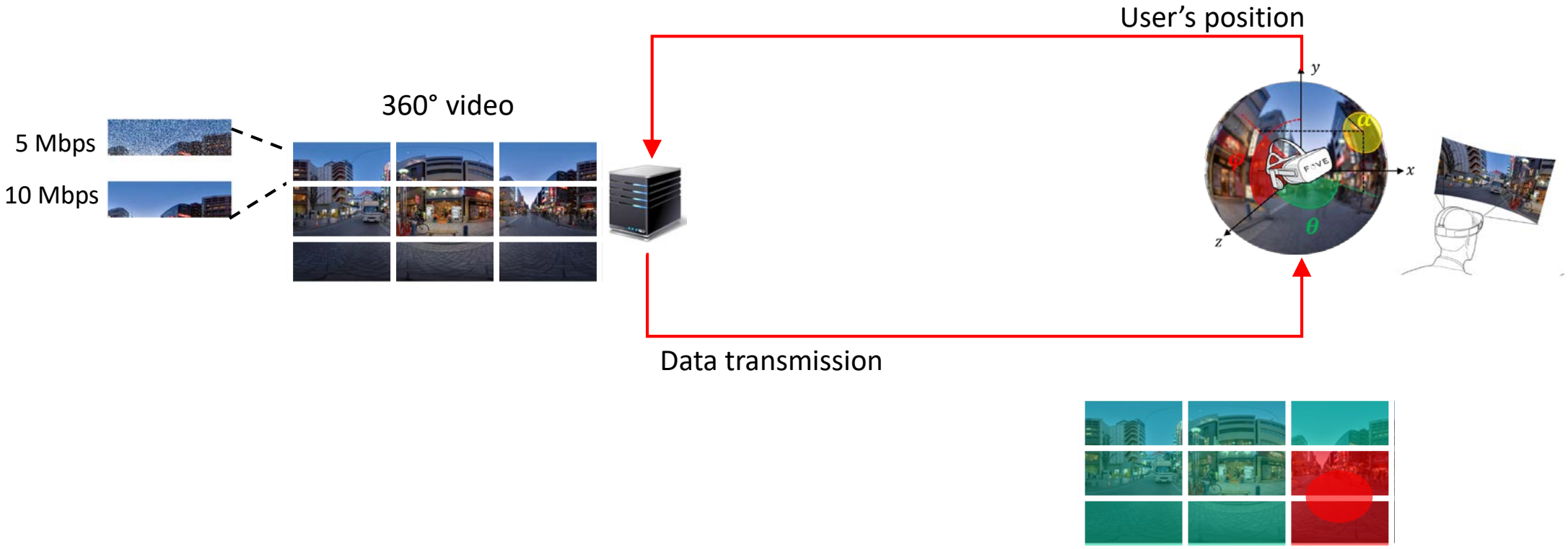

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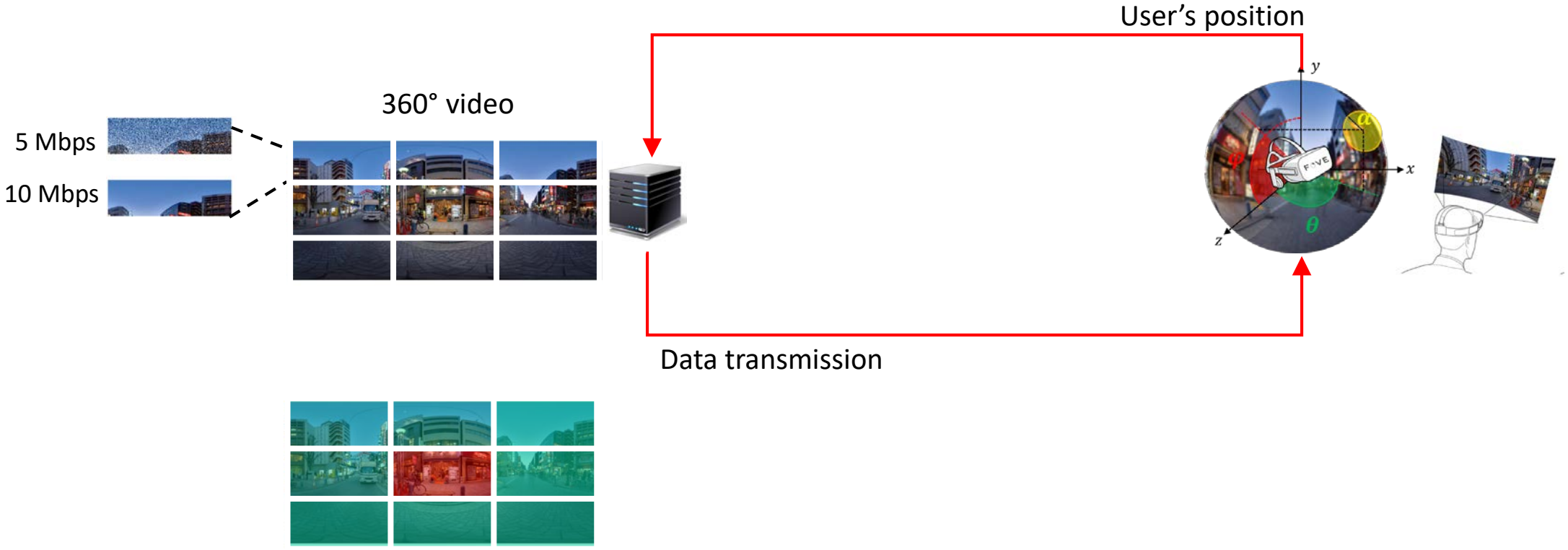

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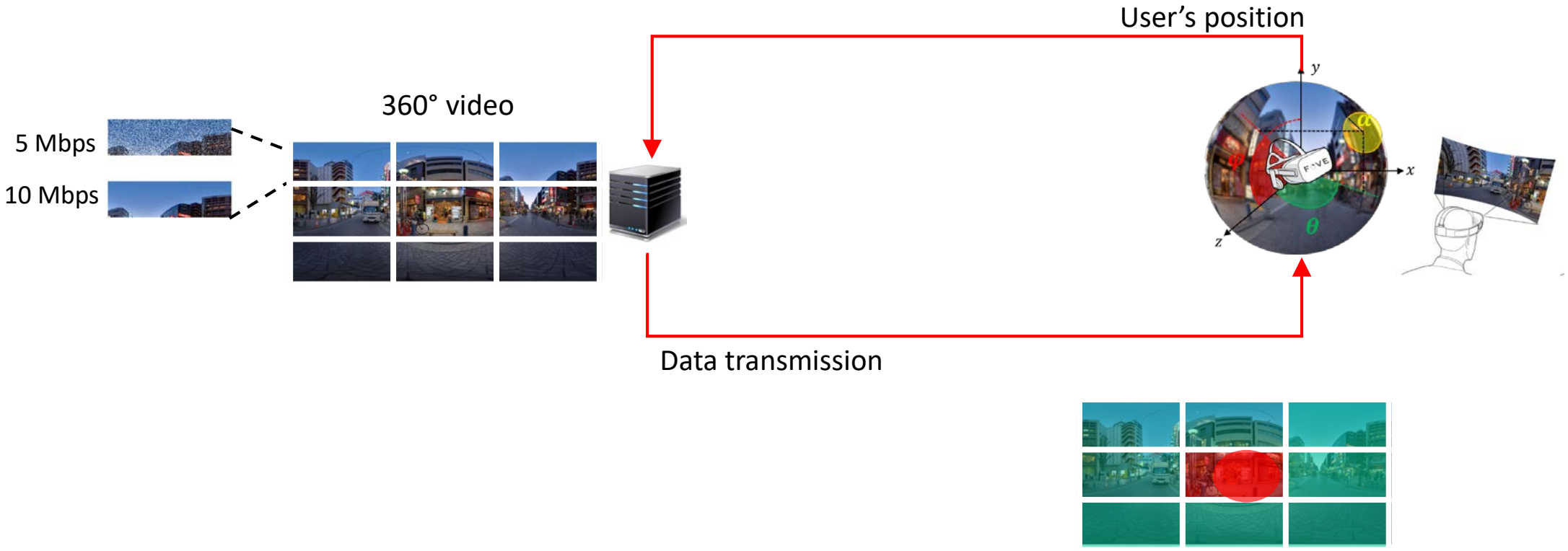

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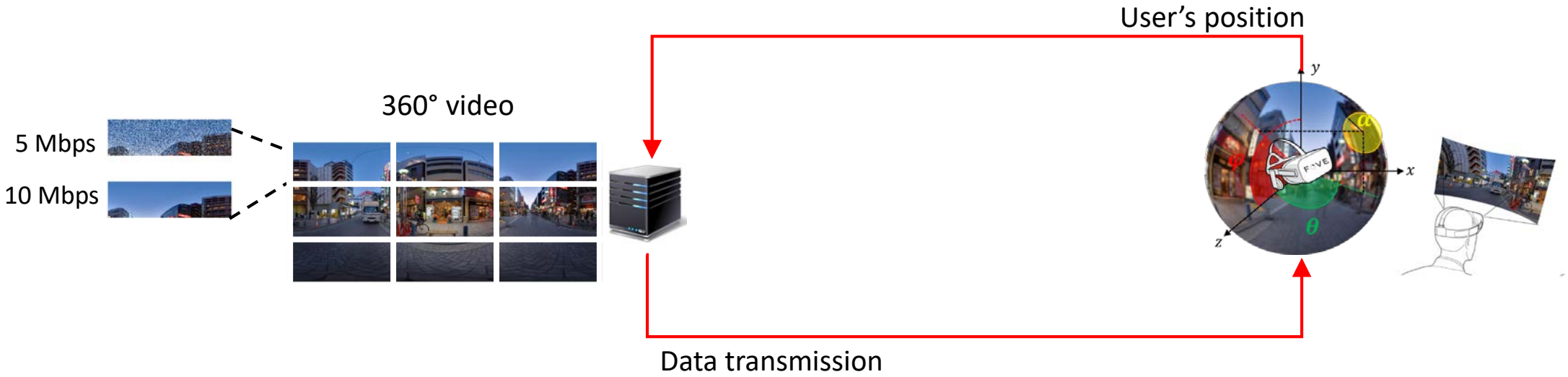

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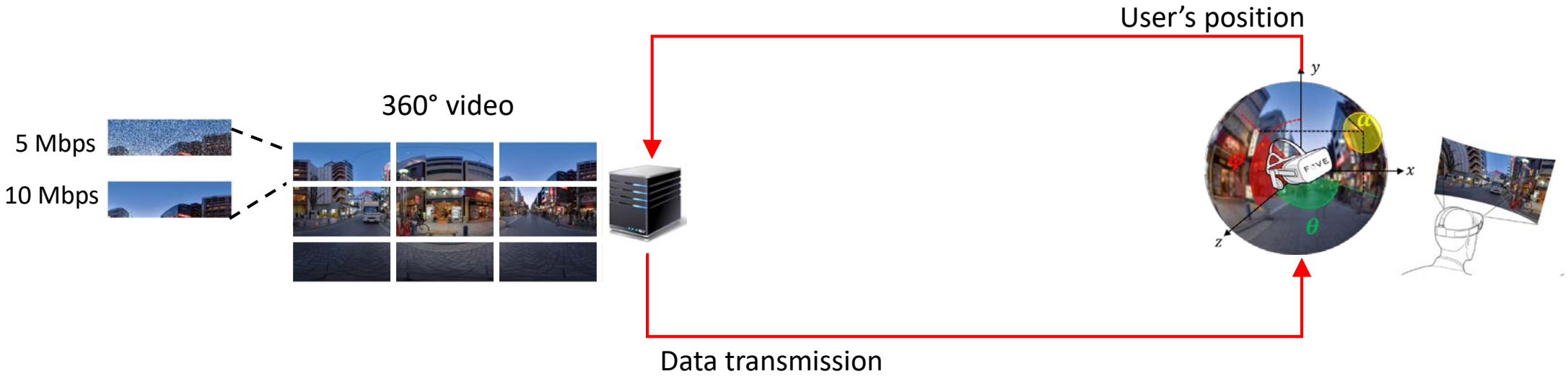

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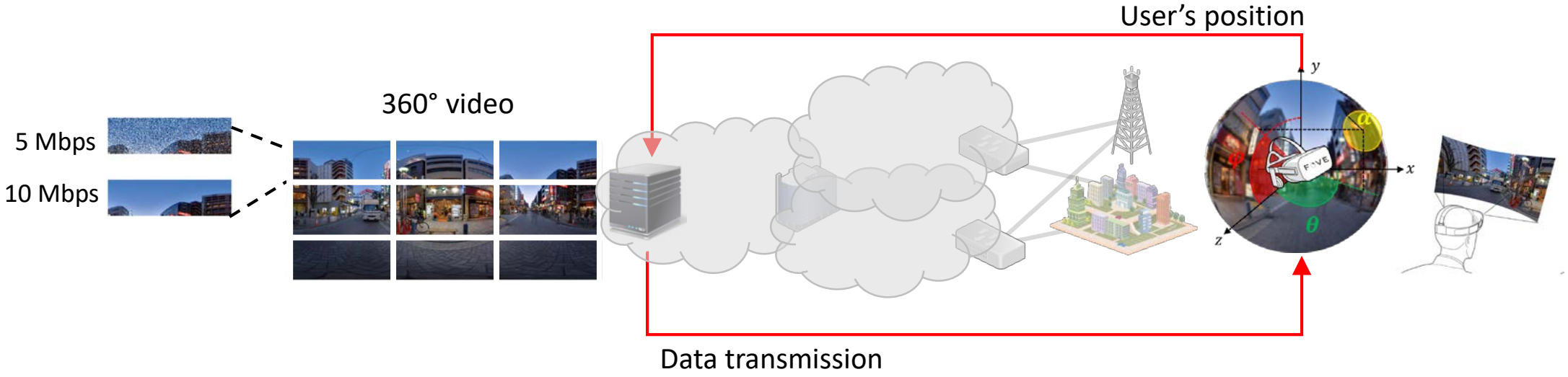

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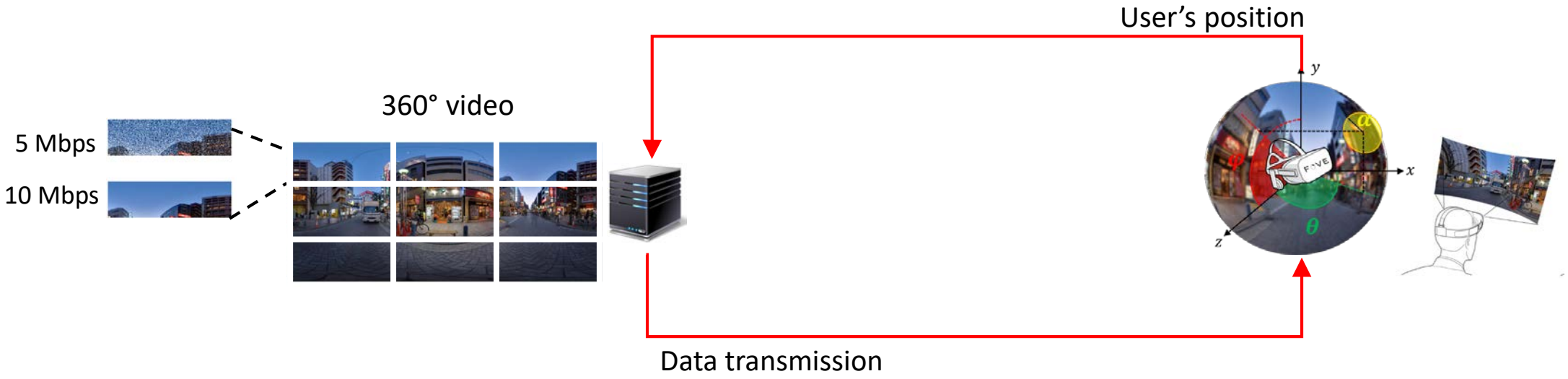

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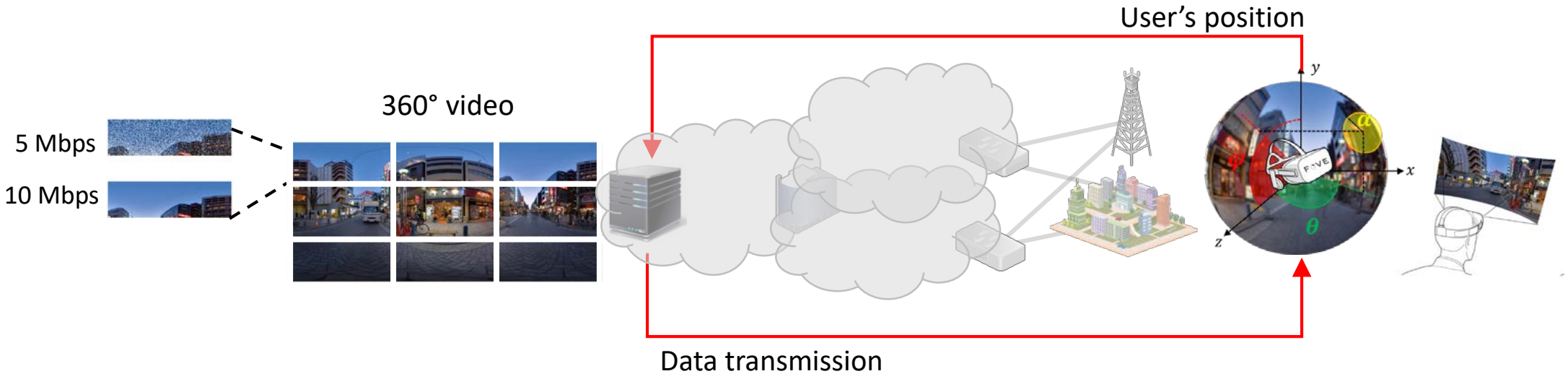

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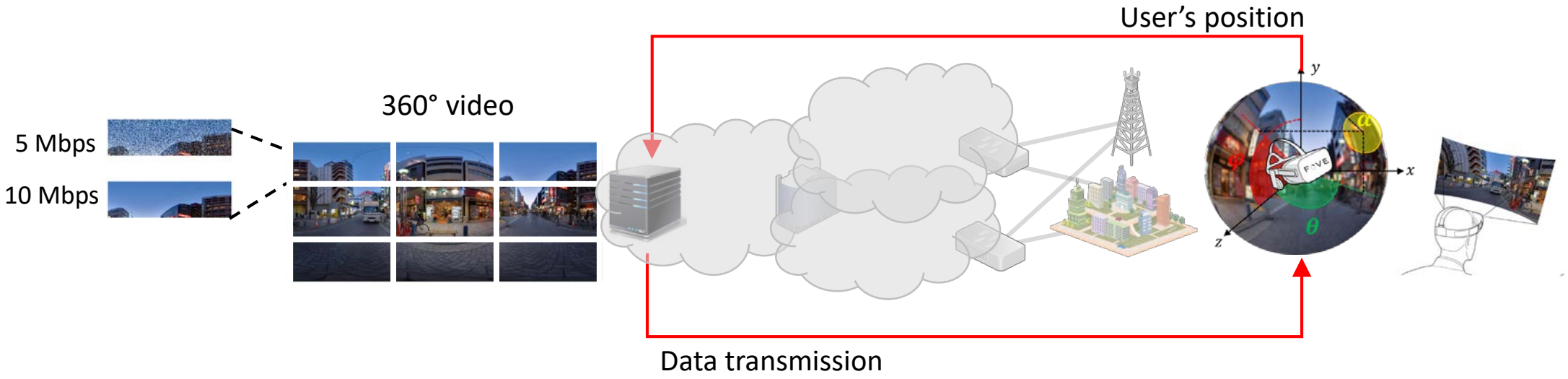

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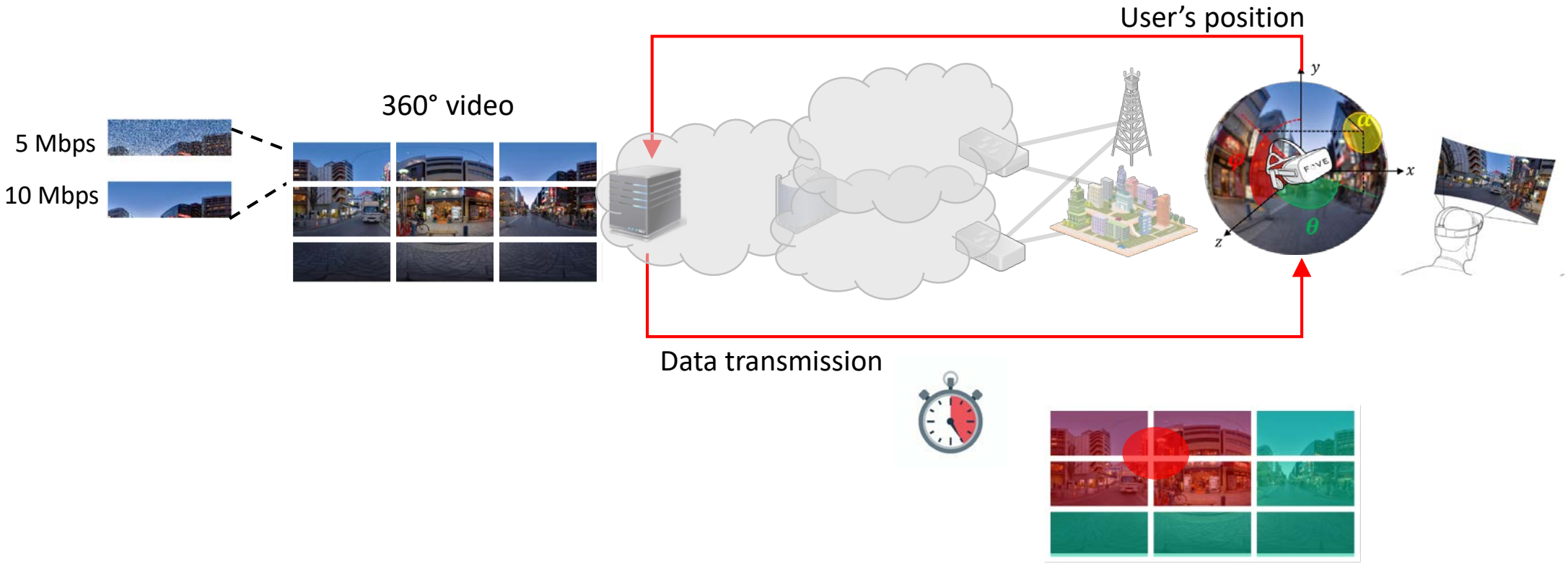

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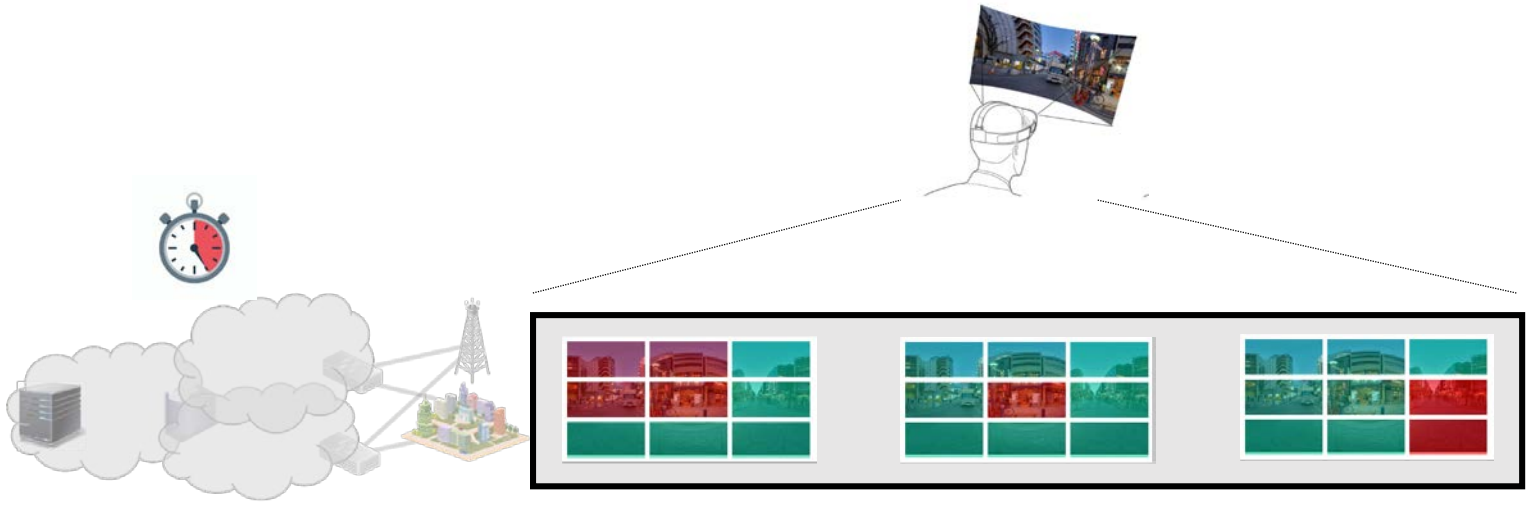

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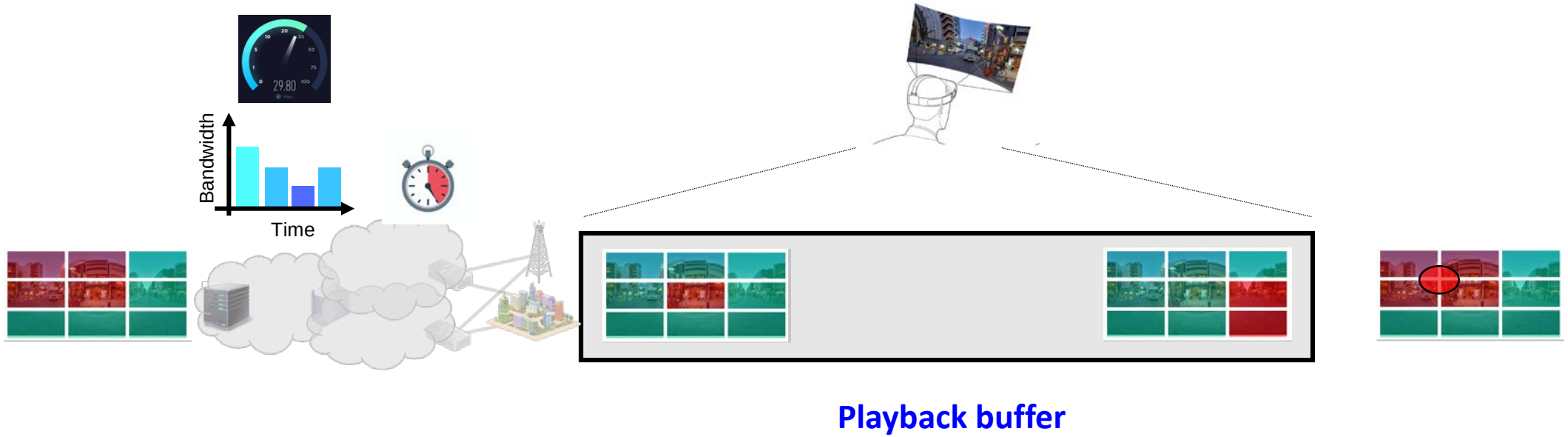

- A playback buffer is crucial to absorb network latency and bandwidth variations.

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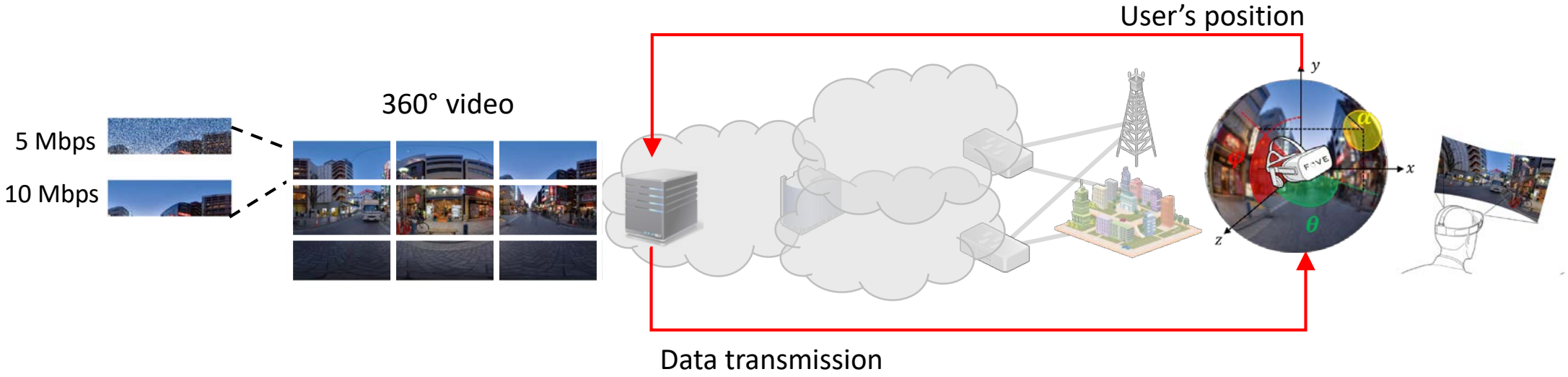

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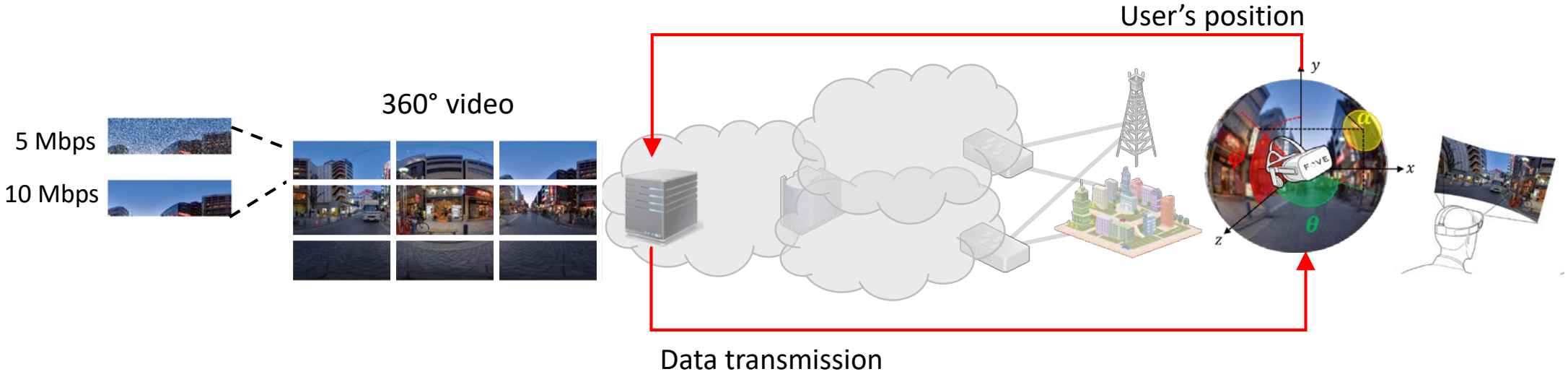

→ Visual quality and consumed rate get dependent on human motion

→ Solid groundwork for interdisciplinarity

Handling the user’s freedom

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- General strategy: predict the motion – *passive* and *reactive*

M. Romero, L. Sassatelli, R. Aparicio-Pardo, and F. Precioso. TRACK: A Multi-Modal Deep Architecture for Head Motion Prediction in 360-Degree Videos. IEEE ICIP 2020.

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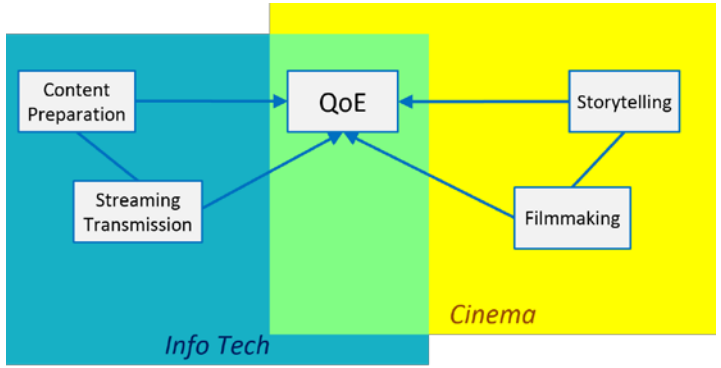
→How to design attention-based levers that we can instrument in a 360° streaming algorithm?



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Attention-driving techniques in 360° videos

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- Categories of attention-driving techniques:
  - Guidance with diegetic visual cues
  - Guidance with non-diegetic visual cues
  - Cuts for scene transitions
  - Directing change of Field of View (FoV)

Guidance with diegetic visual cues

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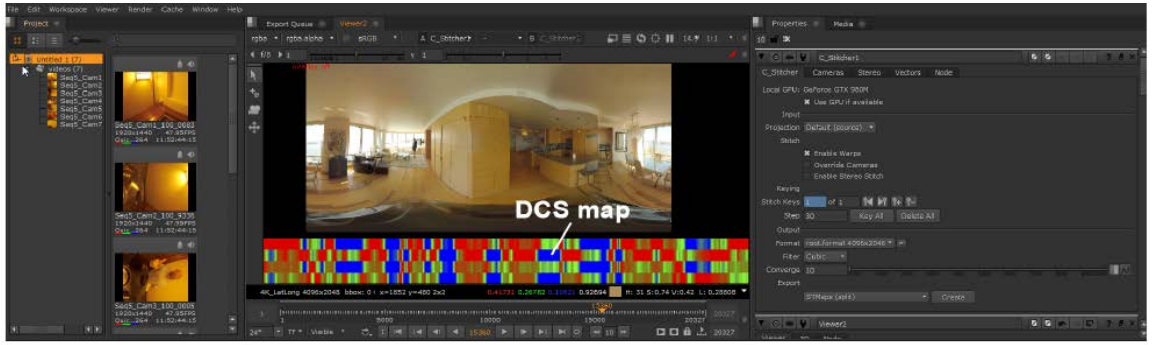
[1] Alia Sheikh, Andy Brown, Zillah Watson and Michael Evans. Directing Attention in 360° Videos. IBC 2016.
[2] Sebastian Knorr, Cagri Ozcinar, Colm O Fearghail, Aljosa Smolic. Director's Cut - A Combined Dataset for Visual Attention Analysis in Cinematic VR Content. ACM CVMP 2018.
[3] A. Kvisgaard et al.. Frames to Zones: Applying Mise-en-Scène Techniques in Cinematic Virtual Reality. IEEE WEVR 2019.

Guidance with diegetic visual cues

- In [2], Knorr et al.:
  - explore the efficacy of various directional cues (sounds, environment, actions)
  - by analyzing the difference between typical user's trajectories and the pre-determined director's trajectory of FoVs.



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[4] F. Danieau, A. Guillo and R. Doré. Attention guidance for immersive video content in head-mounted displays. IEEE VR 2017.
[5] Yung-Ta Lin, Yi-Chi Liao, Shan-Yuan Teng, Yi-Ju Chung, Liwei Chan, Bing-Yu Chen. Outside-In: Visualizing Out-of-Sight Regions-of-Interest in a 360° Video Using Spatial Picture-in-Picture Previews. ACM UIST 2017.
[6] S. Grogorick, M. Stengel, E. Eisemann and M. Magnor. Subtle Gaze Guidance for Immersive Environments. ACM SAP 2017.

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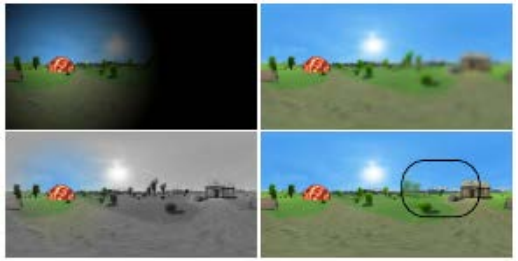

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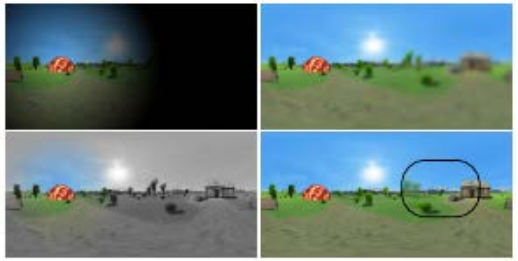

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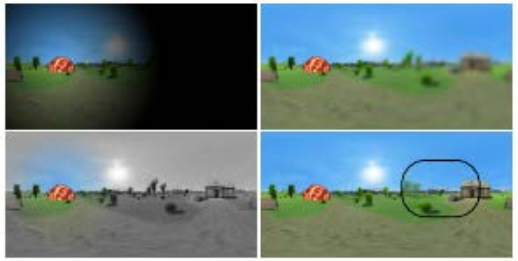

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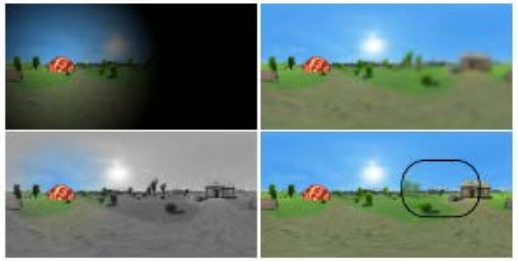

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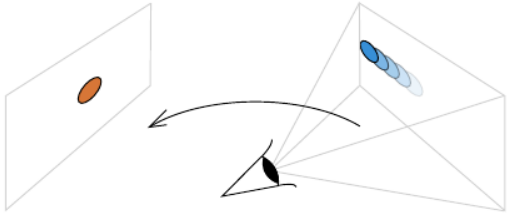

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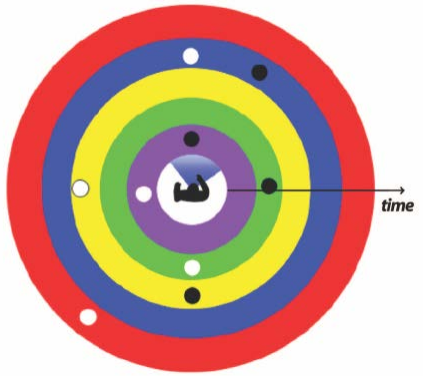
Cuts for scene transitions in VR



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[7] Ana Serrano, Vincent Sitzmann, Jaime Ruiz-Borau, Gordon Wetzstein, Diego Gutierrez, Belén Masiá. Movie Editing and Cognitive Event Segmentation in Virtual Reality Video. ACM ToG 2017.
[8] C. Maranes, D. Gutierrez, A. Serrano. Exploring the impact of 360° movie cuts in users' attention. IEEE VR 2020.
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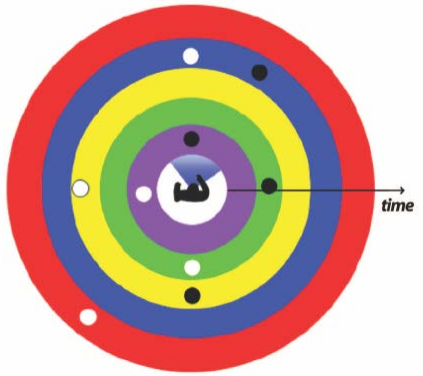

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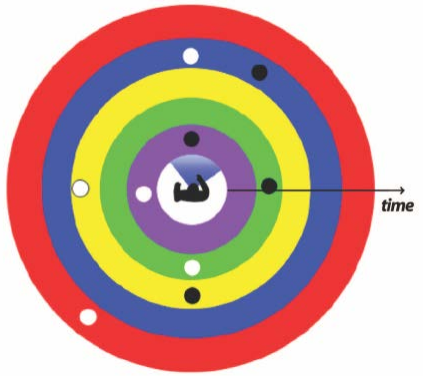

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- In [9], Lillelund et al.:
  - show that high editing cut frequency can be very well received, as long as the user's attention is appropriately guided at the point of cut.

[7] Ana Serrano, Vincent Sitzmann, Jaime Ruiz-Borau, Gordon Wetzstein, Diego Gutierrez, Belén Masiá. Movie Editing and Cognitive Event Segmentation in Virtual Reality Video. ACM ToG 2017.
[8] C. Maranes, D. Gutierrez, A. Serrano. Exploring the impact of 360° movie cuts in users' attention. IEEE VR 2020.
[9] C.B. Lillelund, M. Moth-Poulsen, N.C. Nilsson, R. Nordahl and S. Serafin. Can you cut it?: an exploration of the effects of editing in cinematic virtual reality. ACM VRST 2017.

Directing change of FoV: assist the user in moving

[10] R. Yu, W.S. Lages, M. Nabiyouni, B. Ray, N. Kondur, V. Chandrashekar and D.A. Bowman. Bookshelf and Bird: Enabling Real Walking in Large VR Spaces through Cell-Based Redirection. IEEE 3DUI 2017.
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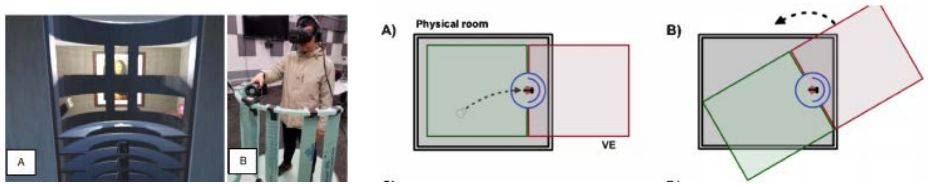

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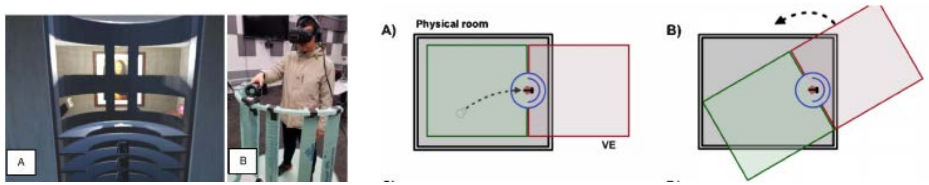

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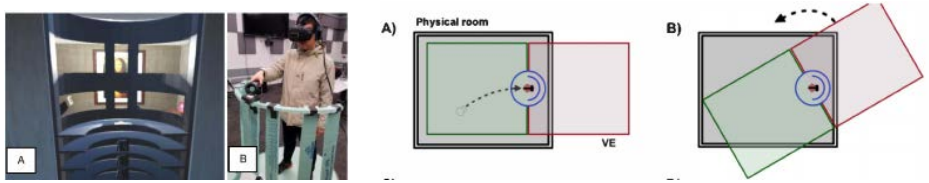

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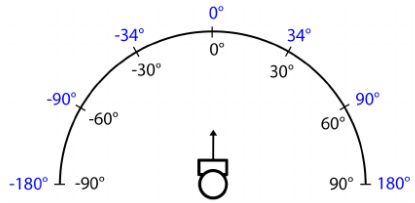

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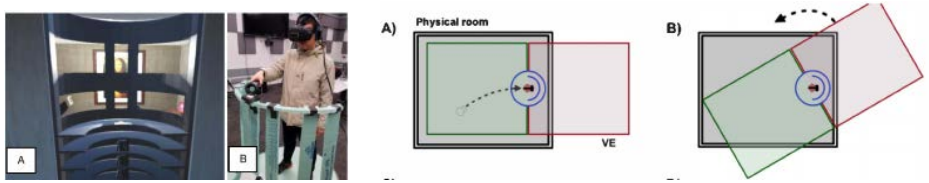

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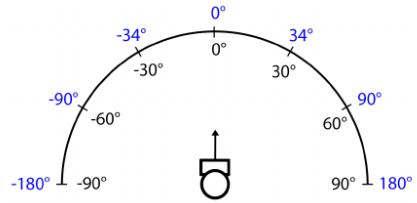

Taken from [11]

- In [12], Farmani et al.
  - rotation snapping to reduce sickness: above 25°/s, fast fading transition and viewpoint snapping by increments of 22.5°

Taken from [12]

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UNIVERSITÉ CÔTE D'AZUR

1. Streaming 360° videos: an interdisciplinary problem

2. A review of attention-driving techniques in 360° videos

3. New levers to improve VR streaming:
    1. Dynamic film editing
    2. Virtual walls

4. Conclusions

Our general approach

Our general approach

UNIVERSITÉ CÔTE D'AZUR

- **Research objective**:
  - Improve the quality of experience of 360° video streaming with new adaptation levers

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  - Design a wider set of levers, beyond compression,
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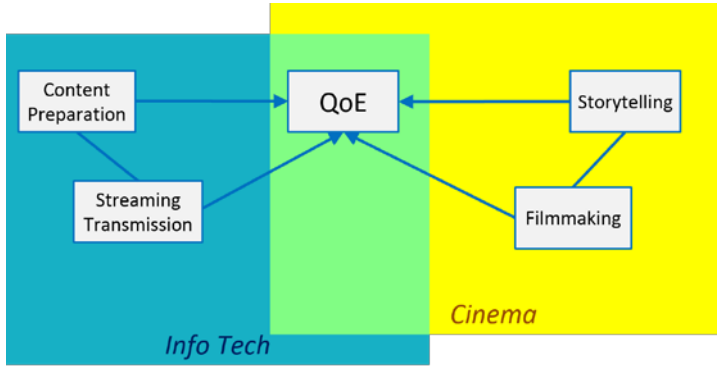
  - Higher rates, user's motion, different experience

- **Approach**:
  - Design a wider set of levers, beyond compression, to modulate the immersive content.
  - Build on interdisciplinarity: ex: HCI and filmmaking



Dynamic editing for 360° videos

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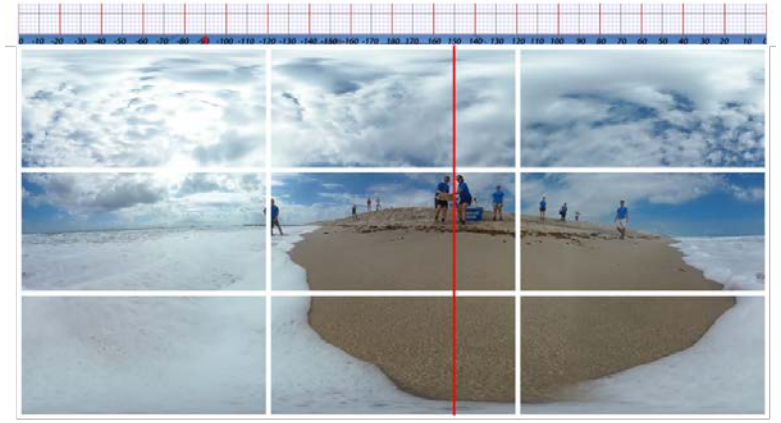
- Snap-change to control field of view:
  - Re-position user in front of a pre-defined area, in a snap
  - Defined by the art director
  - Enables bandwidth saving **AND** serves the content's objective



Identification of the Region of Interest: 140° at 6s

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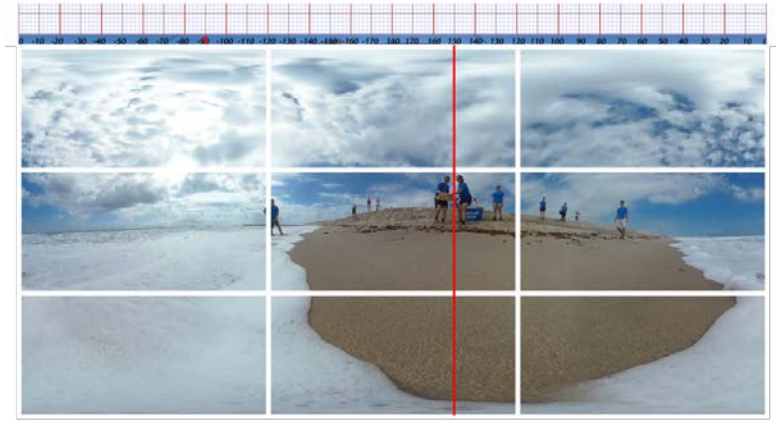

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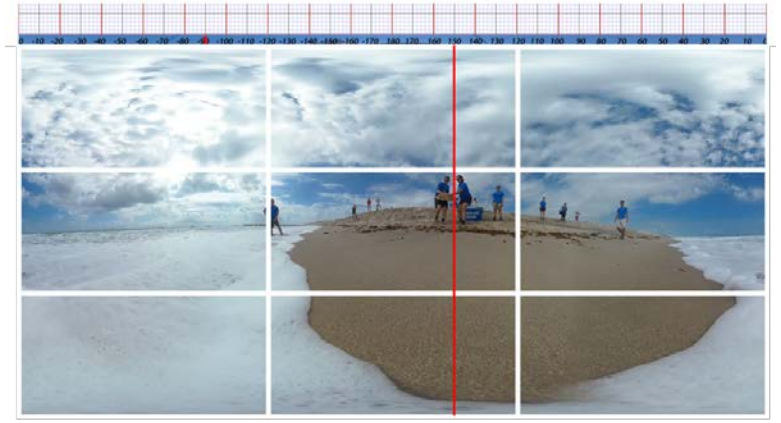

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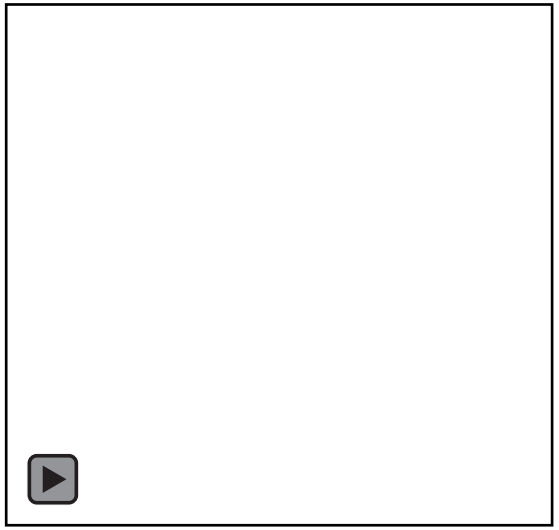

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Our 360° player: TOUCAN-VR

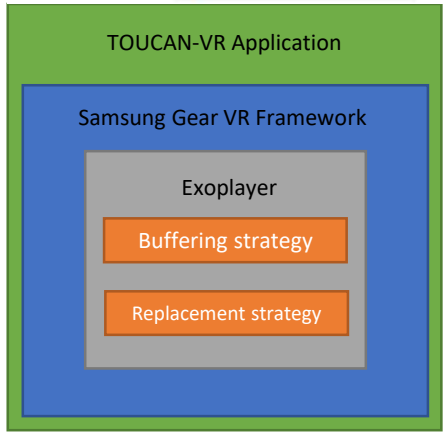
Identification of the region of interest

```
<?xml version="1.0"?>
<snapchange>
    <milliseconds>15000</milliseconds>
    <roiDegrees>-90</roiDegrees>
    <foVTile>1,2,4,5</foVTile>
</snapchange>
```

Description of a snap-cut :
xml file to download

ACM reproducibility badge:
https://github.com/UCA4SVR/TOUCAN-VR

App



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Components of the streaming app

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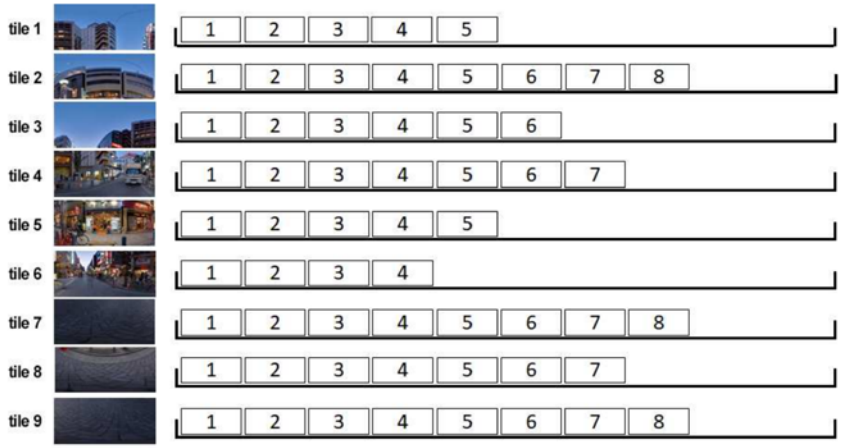
Buffering and quality selection



Qualities selected based on current FoV or next snap-change

→ Benefits from Dynamic editing

Replacements for responsiveness

No replacements to make before a snap-change occurs

→ Benefits from Dynamic editing

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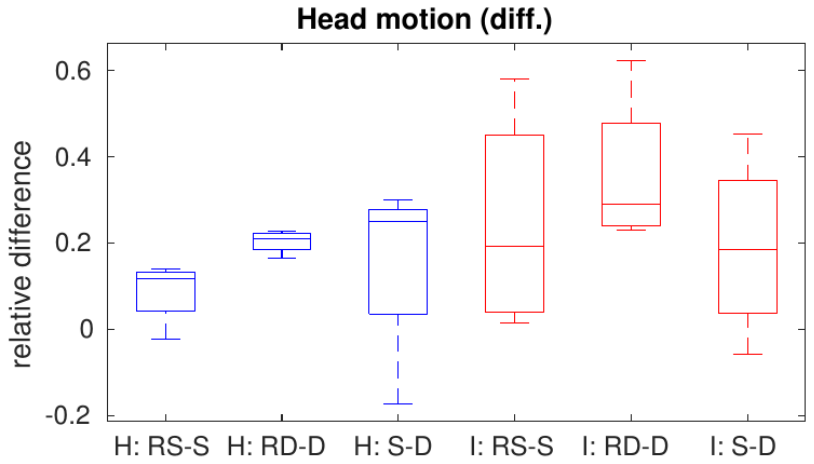
Dynamic movie editing helps streaming



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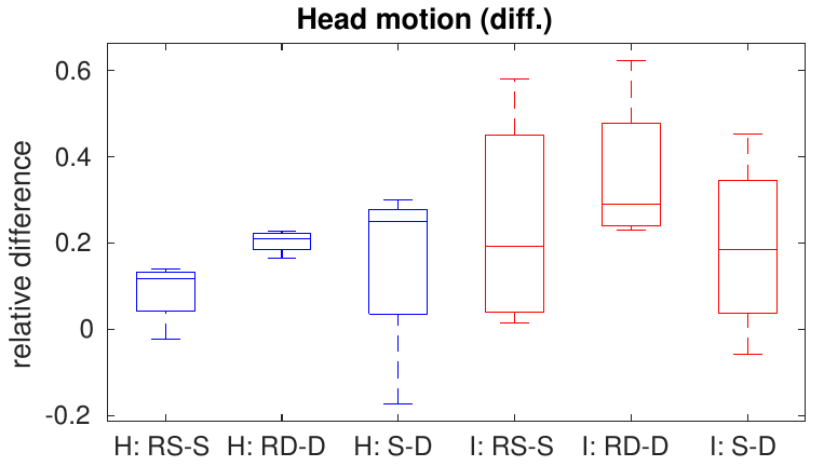
Dynamic movie editing helps streaming

- Reduction of up to 30% in head motion speed with snap-changes



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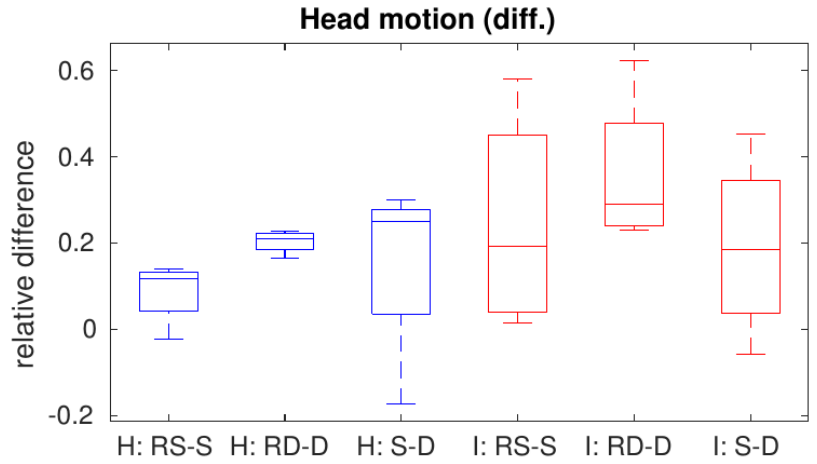
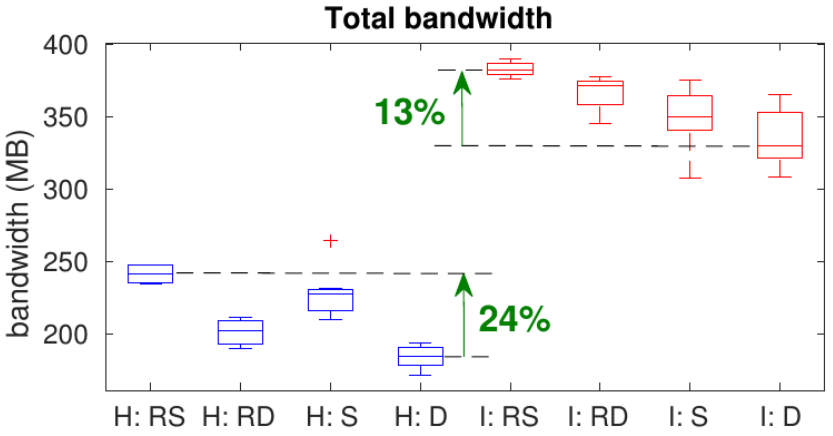


- Reduction of up to 24% in consumed data rate



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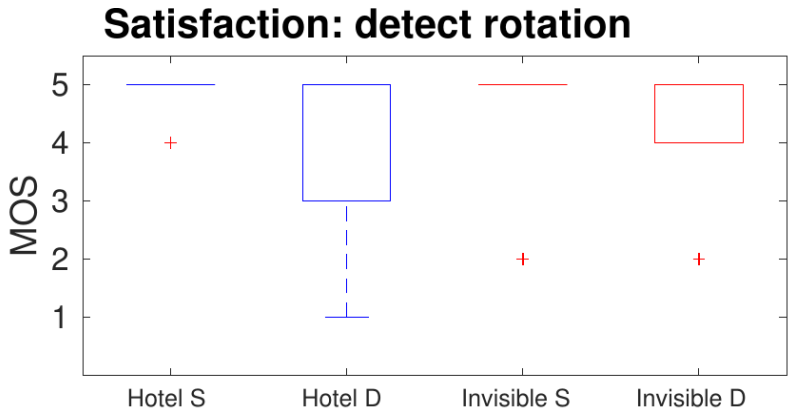
AND dynamic editing improves the user's experience

- Snap-cuts go unnoticed



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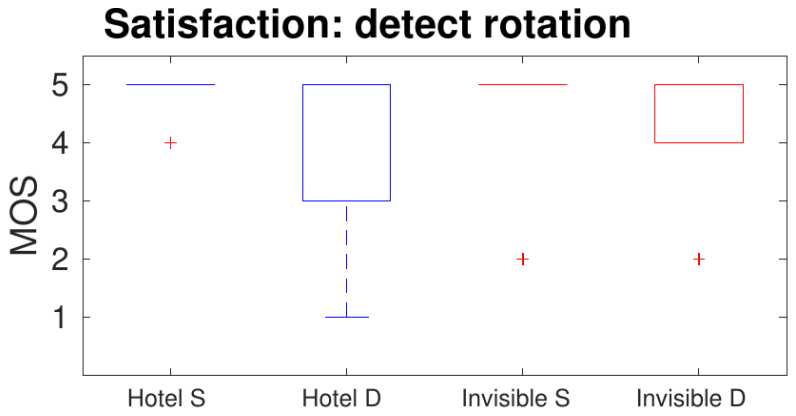
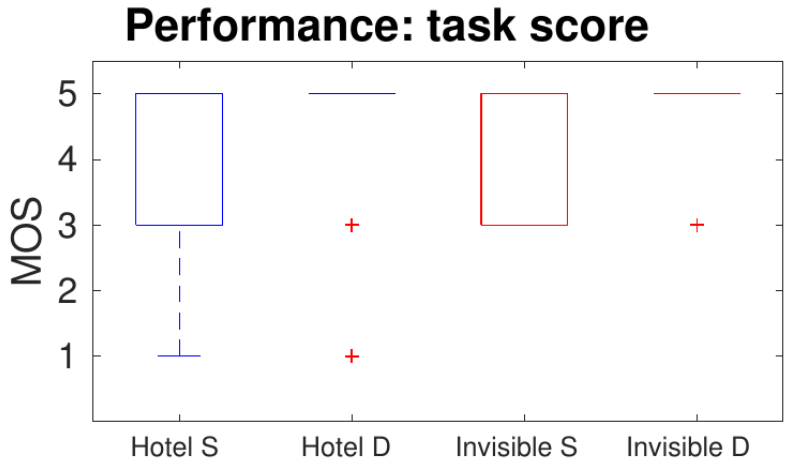


- The director can control what the user sees and remembers



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-> Virtual Wall: a new type of impairment allowing to preserve the visual quality

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-> Virtual Wall: a new type of impairment allowing to preserve the visual quality

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- Our hypothesis: Virtual Wall can improve the user's QoE compared with legacy FoV-based adaptation using compression only, for a given bandwidth budget.

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Motivation

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- Understanding the human attention to improve streaming
- Exploratory phase of about 20s [1]
- Different scene types yield users' behaviors [2]
  - Exploration, rides, static focus, moving focus

[1] V. Sitzmann, et al.. Saliency in VR: How Do People Explore Virtual Environments?. IEEE Trans. on Vis. and Comp. Graphics 2018.
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→ Is it possible to appropriately restrict the accessible angular sector to preserve visual quality?

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Design of Virtual Wall

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- Preventing access to an angular sector
- Placed after exploration in Static focus and Rides scenes
- When the longitude of the user's position reaches the limit of the visible sector, the FoV refreshes in latitude only
- Do not affect latitude to keep balance

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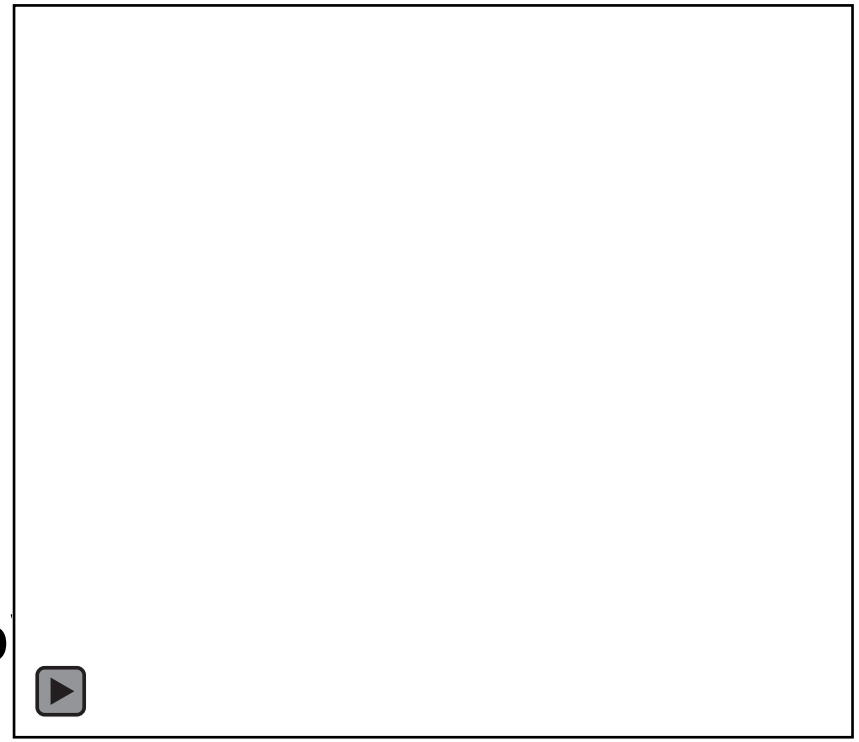

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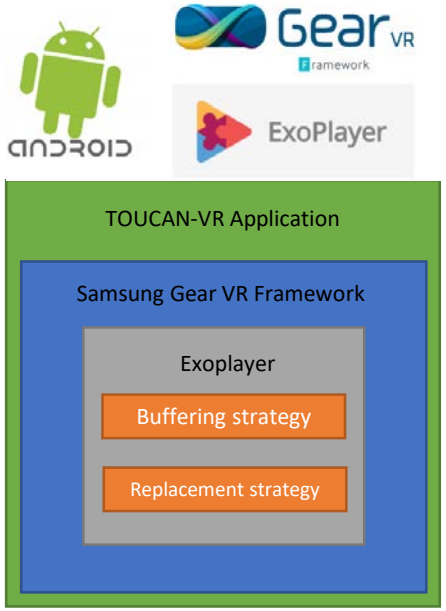
Implementation of Virtual Wall

- In our TOUCAN-VR app:

```
<?xml version="1.0"?>
<virtualwall>
  <milliseconds>18000</milliseconds>
  <roiDegrees>170</roiDegrees>
  <duration>13000</duration>
  <freedegreesy>180</freedegreesy>
  <hysteresisMargin>0</hysteresisMargin>
</virtualwall>
```

App



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Hypotheses to test

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L. Sassatelli, M. Winckler, T. Fisichella, A. Dezarnaud, J. Lemaire, R. Aparicio and D. Trevisan. New Interactive Strategies for Virtual Reality Streaming in Degraded Context of Use. Elsevier Computers & Graphics, Oct. 2019.

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- [H1] If the VW is positioned after the exploration phase in scenes with concentrated saliency (Static focus and Rides), a substantial fraction of users will seldom perceive it.

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- [H1] If the VW is positioned after the exploration phase in scenes with concentrated saliency (Static focus and Rides), a substantial fraction of users will seldom perceive it.

- [H2] Compared with a reference with no VW consuming the same amount of data, VW can be preferred.

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Experimental design - Videos to assess

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- Double-stimulus approach, 2 versions of each video, 18 users
- 2 video categories, 5 scenes
- Video rates chosen in accordance with the targeted scenario: VW triggered if bandwidth drop happens in focus phase

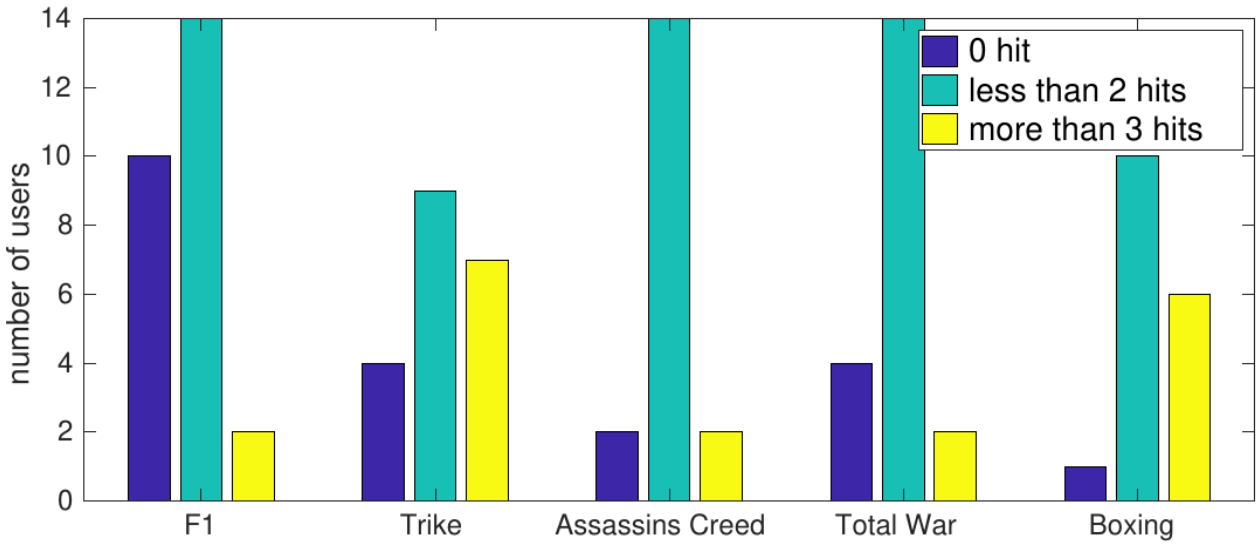
Class	Scene, duration	VW period	Rate outside the VW period (Mbps)	Rate in VW period for ref. (Mbps)	Rate in VW period for VW version (Mbps)
Ride	F1, 31s	18-31s	10	5	10
Ride	Trike, 51s	25-51s	10	5	10
Ride	Assassin, 51s	20-46s	10	5	10
Ride	Total War, 42s	22-42s	10	5	10
Static focus	Boxing, 85s	25-85s	12	3	6

H1: Users' interaction with Virtual Wall

- More than 50% of users do not hit a VW more than twice, 88% in Rides.

-> H1 confirmed:

the users seldom sense the VW, even more so in high camera motion rides.



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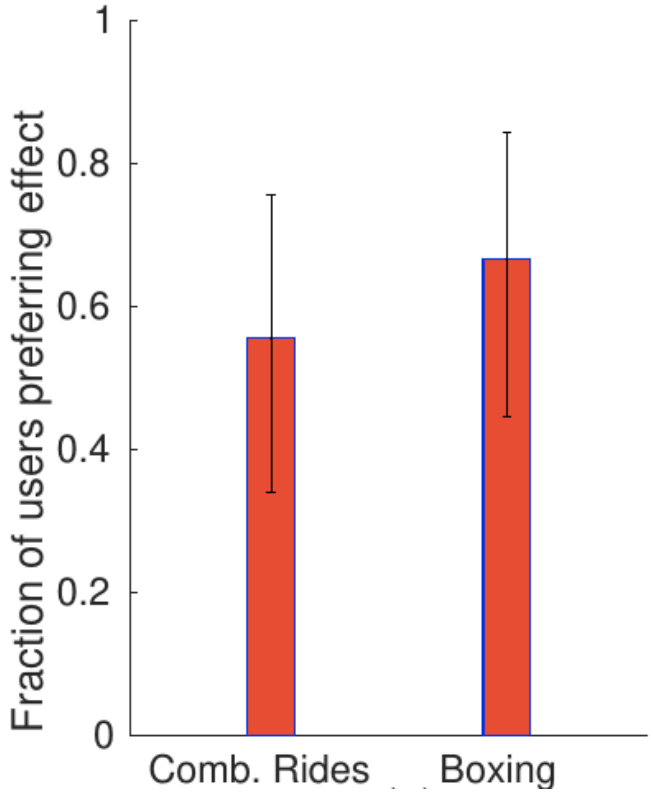
Subjective ratings: Preference

- VW version preferred by 58% users in Rides and 68% in Static focus.

-> H2 not confirmed but results are encouraging

- Breakdown analysis possible:



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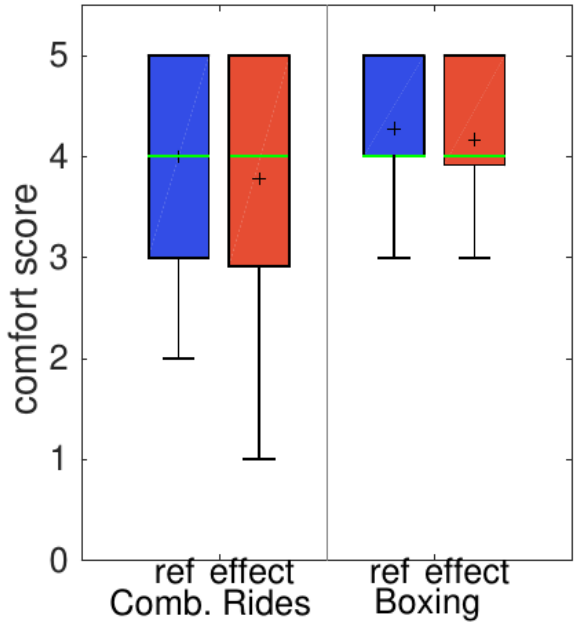
Subjective ratings: Comfort

- VW perceived as comfortable the reference

-> VW is acceptable



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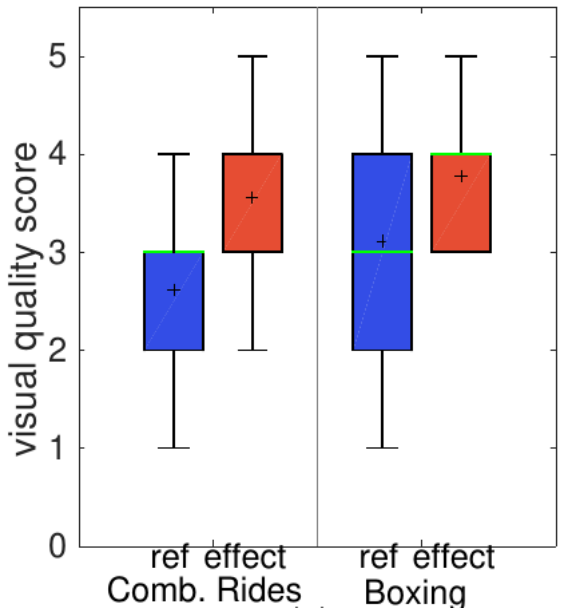
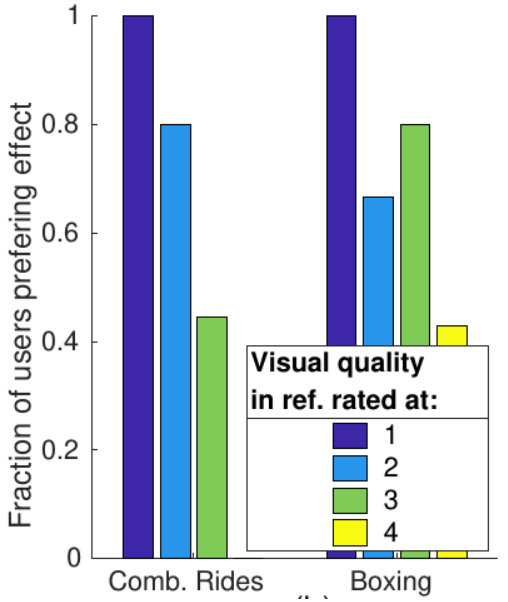
Subjective ratings: Visual quality

- Visual quality confirms to be a crucial parameter: it strongly correlates with the preference.





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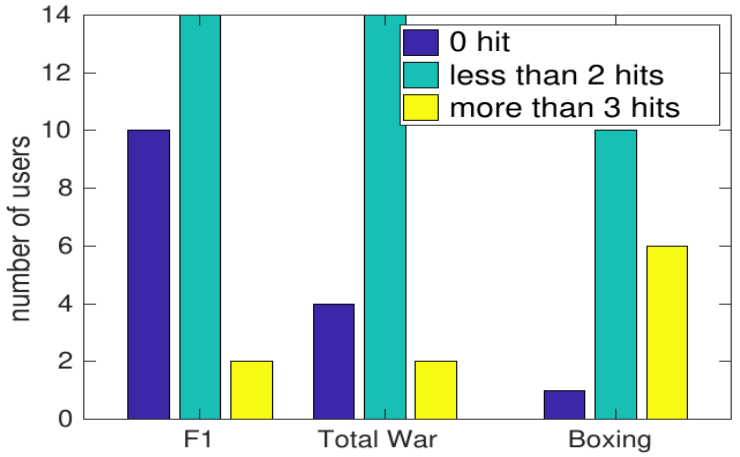
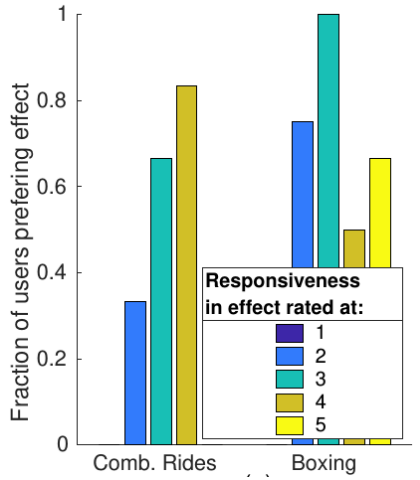
Subjective ratings: Responsiveness to head motion

- But: hits have a greater impacts on Rides

→ implementation of VW should consider camera motion





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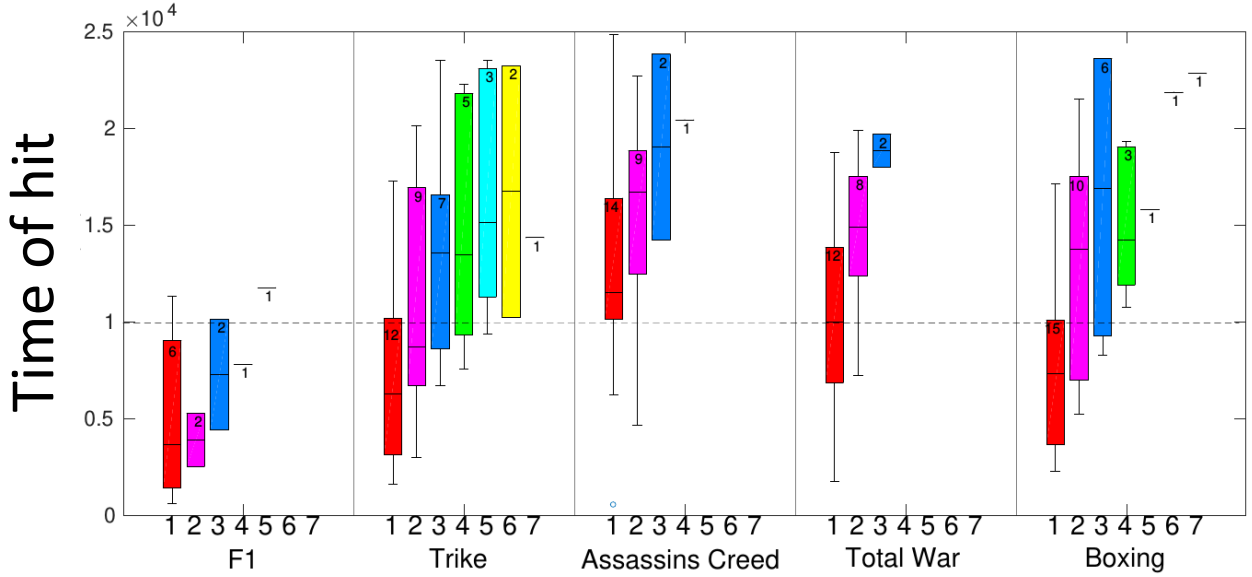
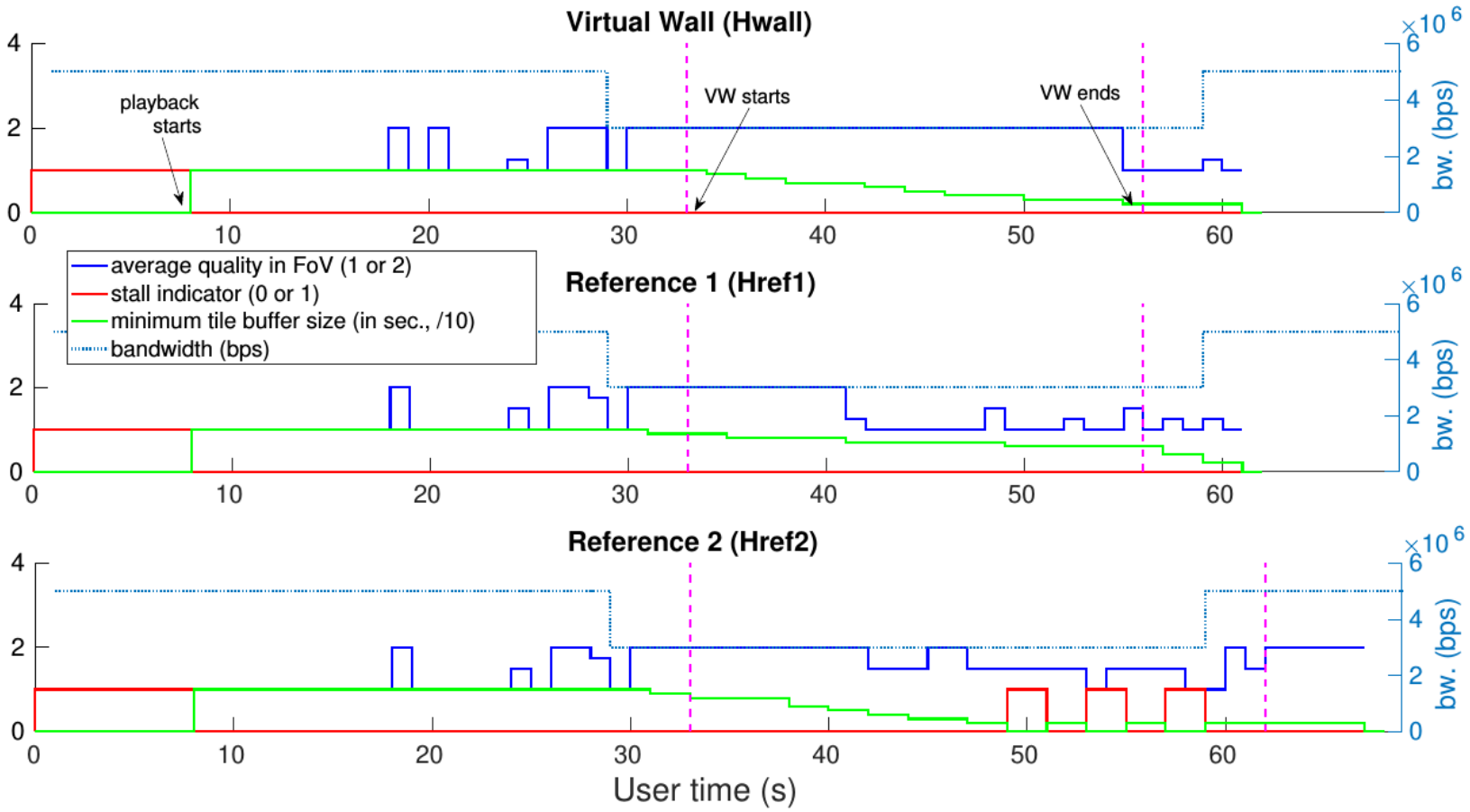
Synthesis: improving Virtual Walls

- Adapting the implementation to camera-motion (slow-down or dimming)
- Better adapting to attention: do not make the wall last more than 10 seconds if possible.



Simulation results: application-level metrics



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Outline

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2. A review of attention-driving techniques in 360° videos

3. New levers to improve VR streaming:
    1. Dynamic film editing
    2. Virtual walls

4. Conclusions

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For a joint approach to transmission and content design?

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→ Opens the path to define new degrees of freedom for VR streaming

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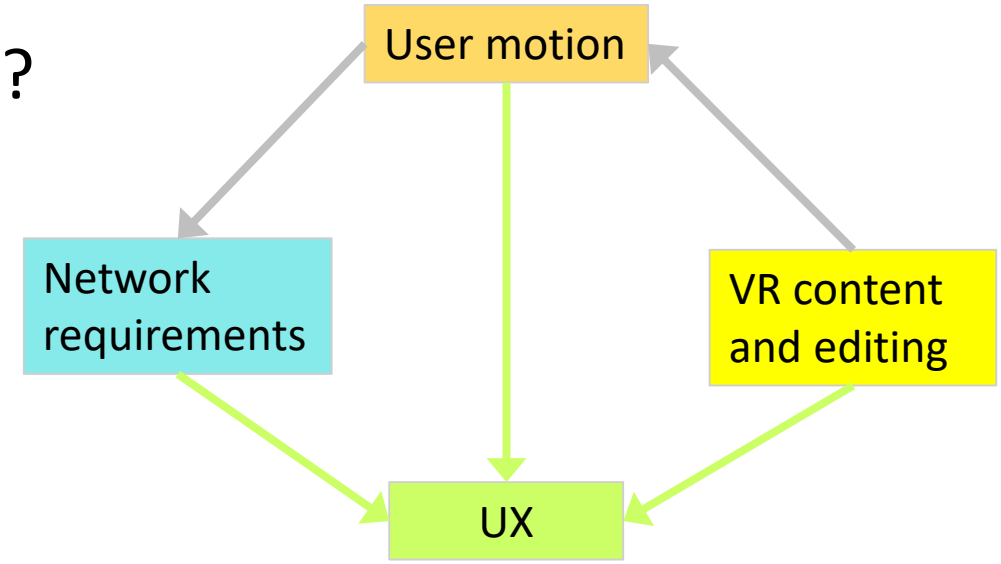

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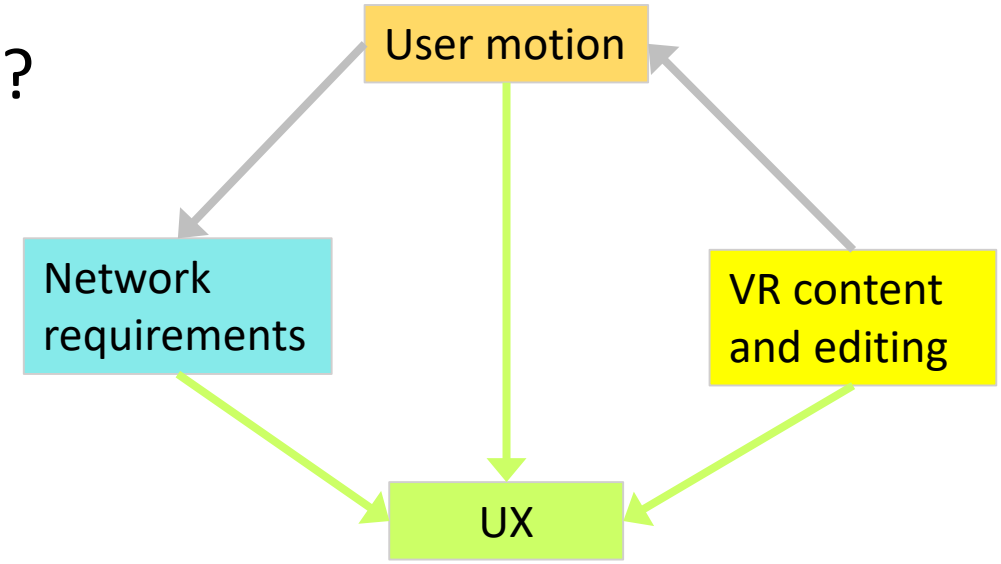

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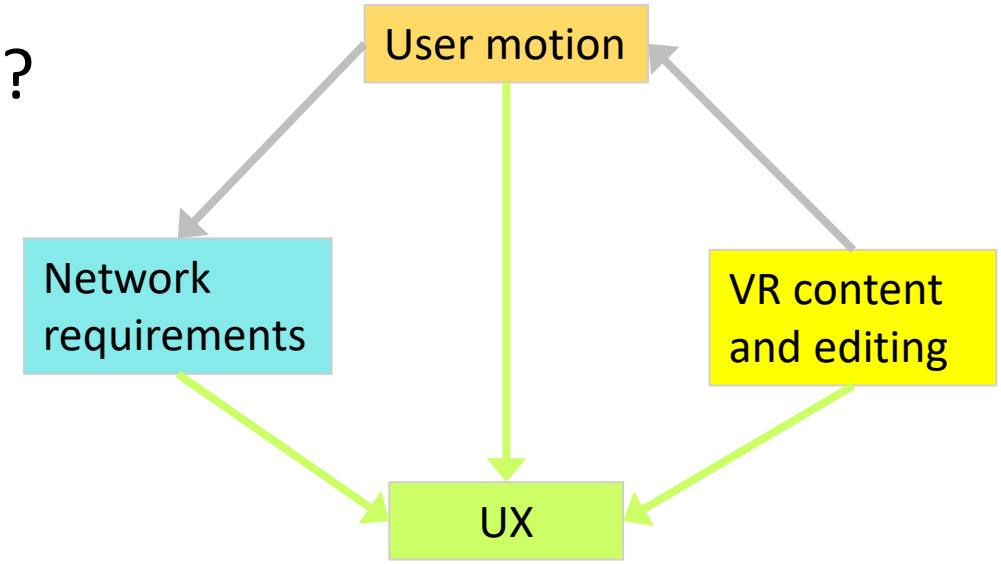
→ A more global approach can benefit the user's experience

→ Wide research perspectives



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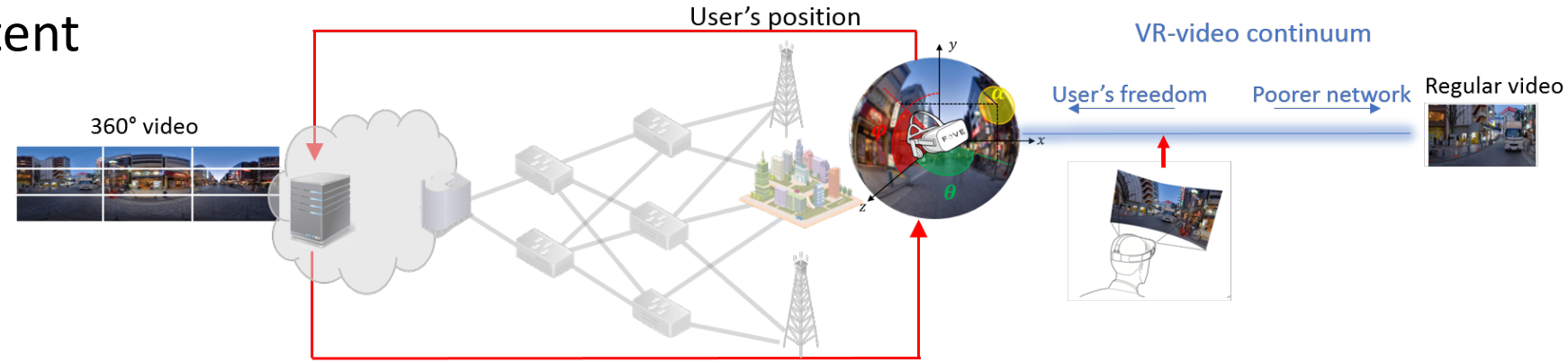
  - the content



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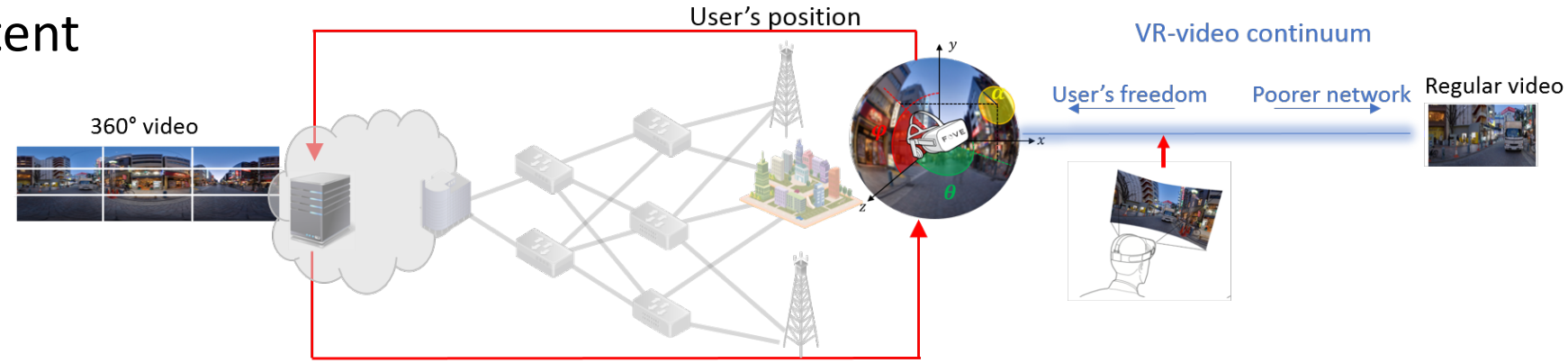

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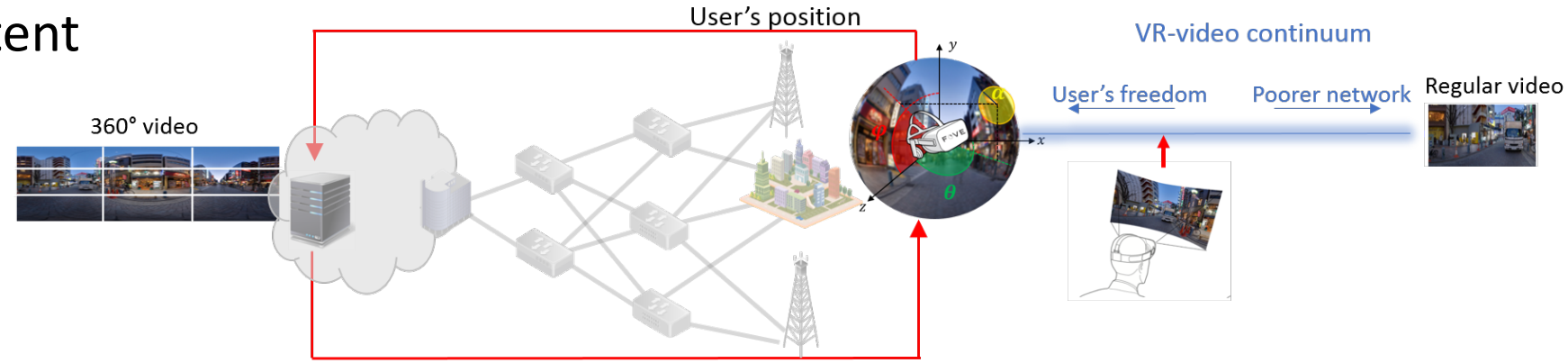

- Methods:
  - Machine Learning for dynamic decision-making
  - Reinforcement and Imitation Learning: the user into the loop

Thank you!

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