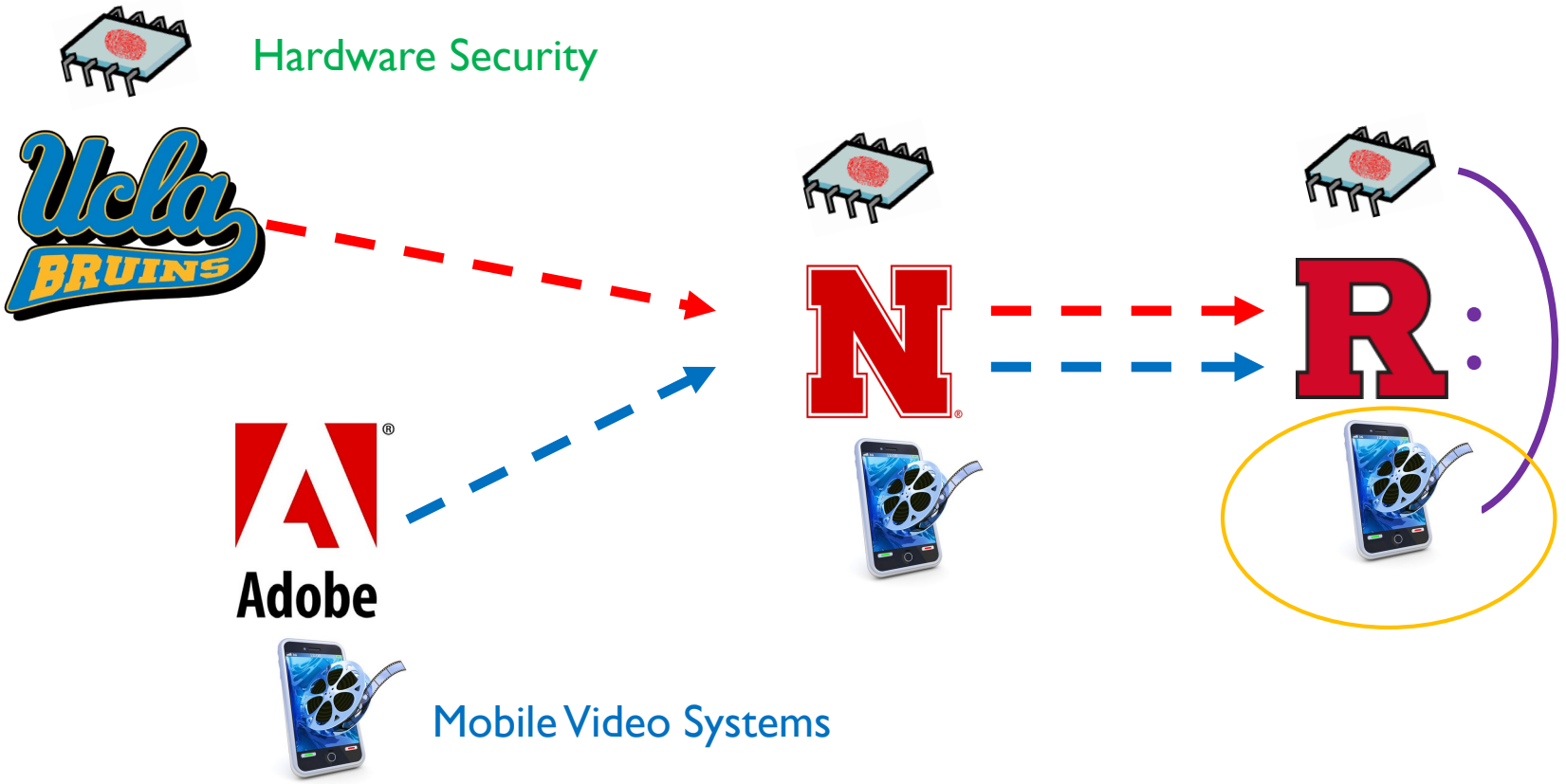
Power and Bandwidth Optimization in 360-Degree Immersive Mobile Video Streaming

Sheng Wei, Assistant Professor

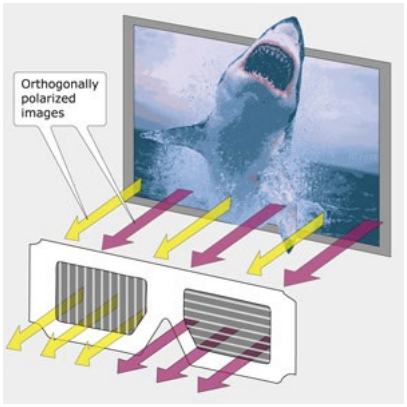
Rutgers ECE

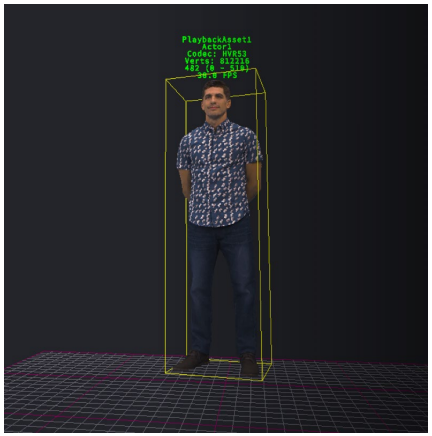
May 2019

Context: Research Paths



All about Videos





(VR)

(AR)

2D Video → 3D Video → Immersive Video → Volumetric Video

NETFLIX

IMAX 3D

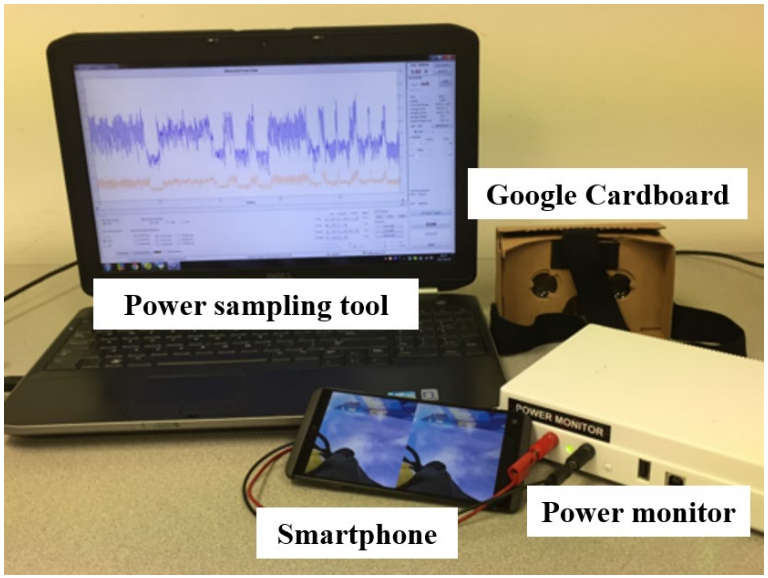
YouTube 360-Degree Video

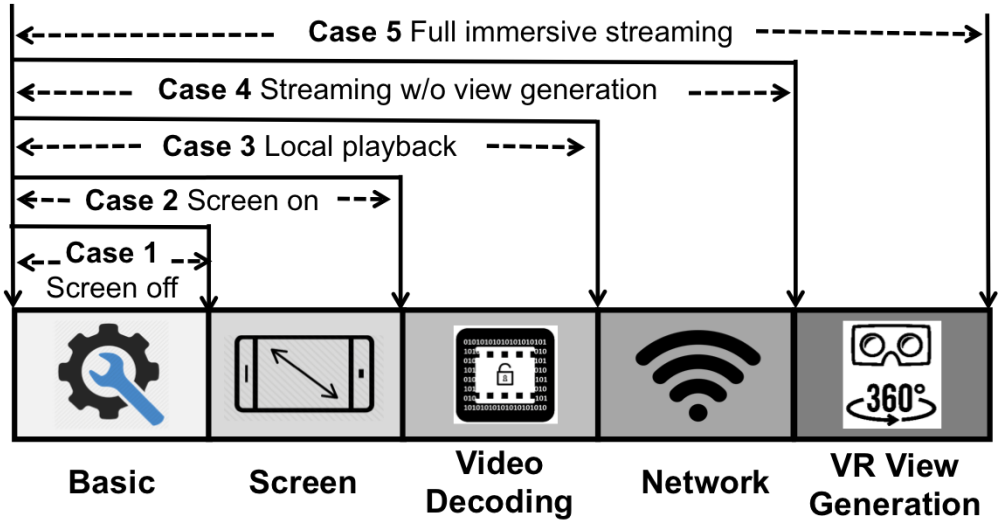
The 360-degree Challenges

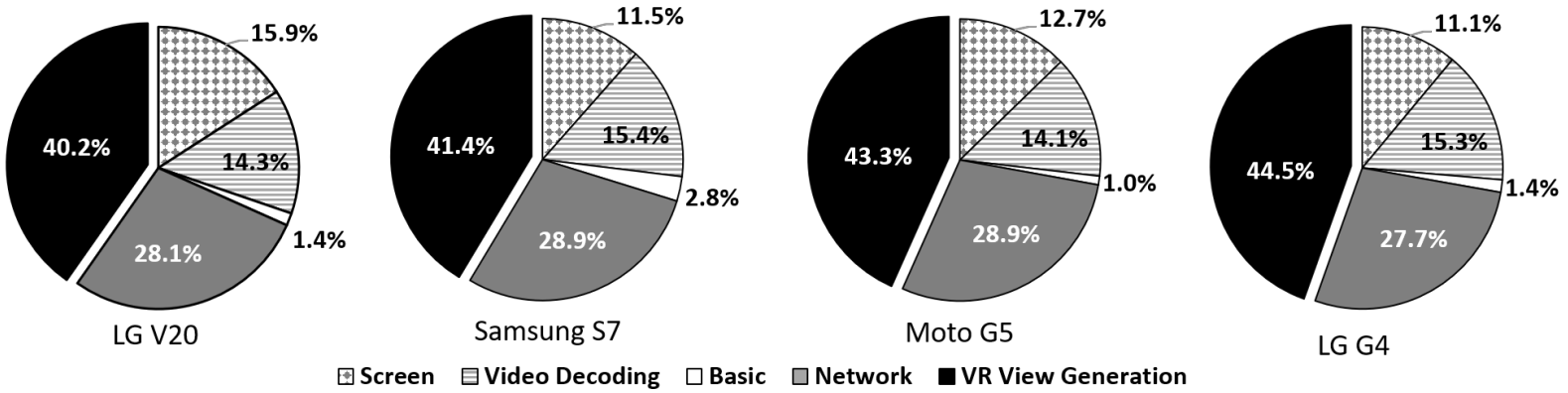
Power

Bandwidth

Power Profiling

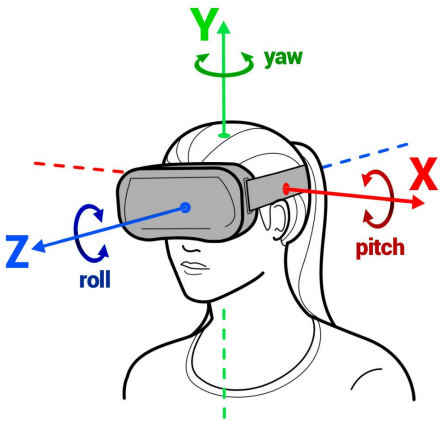






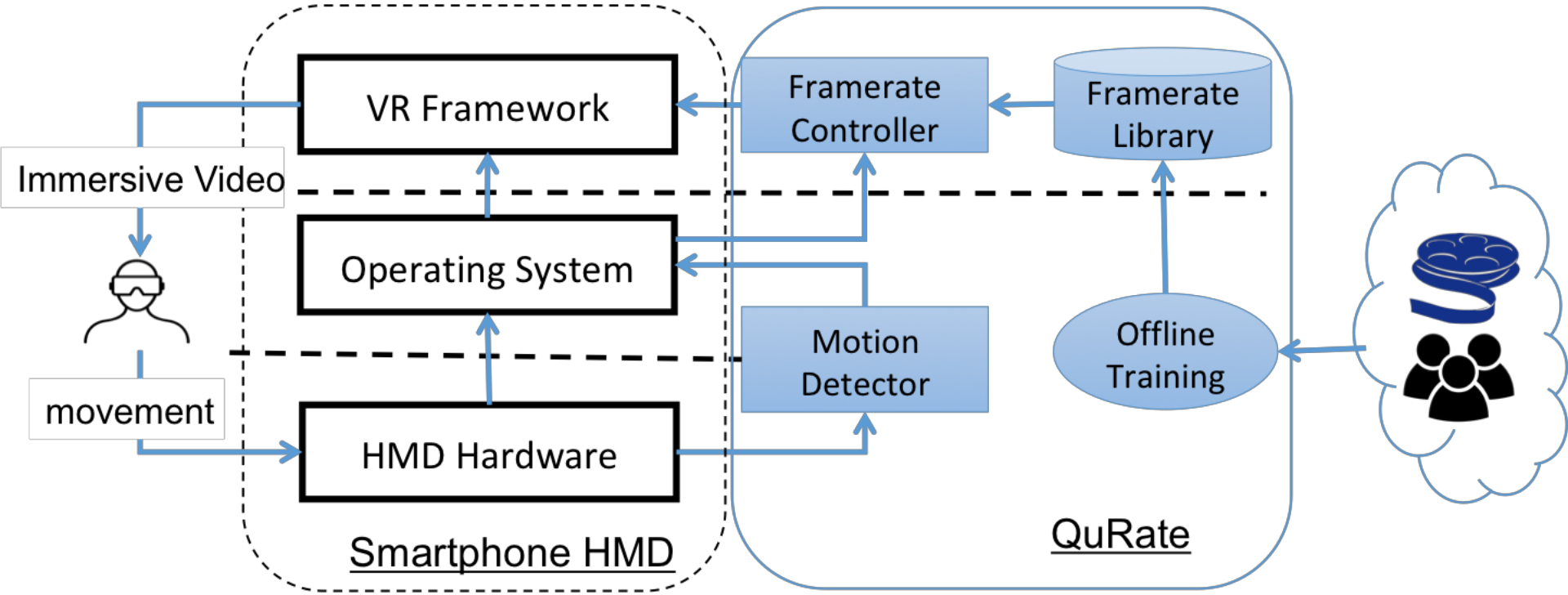
Power Optimization Solution

- Key Idea: Reducing the framerate
- The Problem: Video quality degradation
- Solution: Reducing framerate during switching only



(Courtesy of F. Qian et al.)

Power Optimization Framework: QuRate



$$STVQM = SVQM \cdot \frac{1 + a \cdot TI^b}{1 + a \cdot TI^b \cdot \frac{30}{FR}},$$

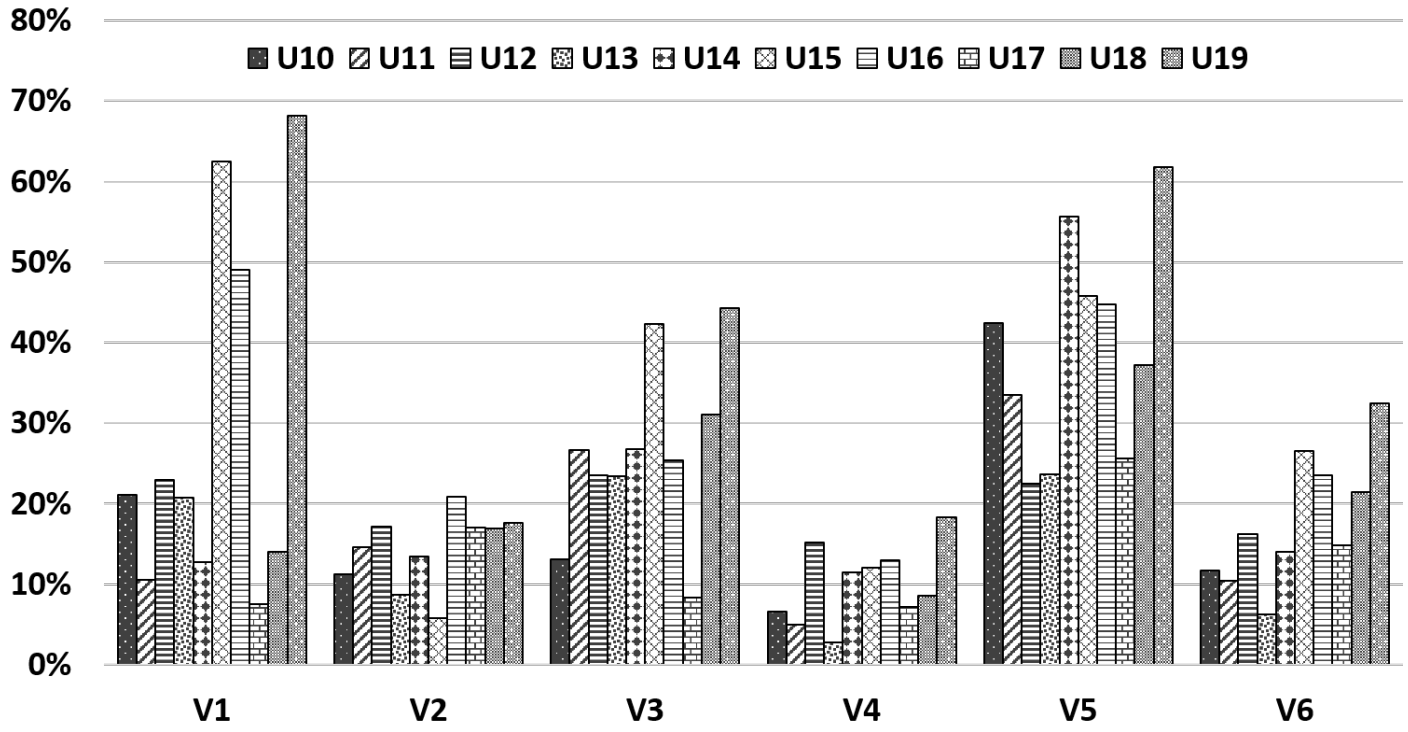
Video Quality

Framerate

$$FR = \frac{30 \cdot a \cdot TI^b \cdot STVQM}{SVQM \cdot (1 + a \cdot TI^b) - STVQM}.$$

Power Optimization Results

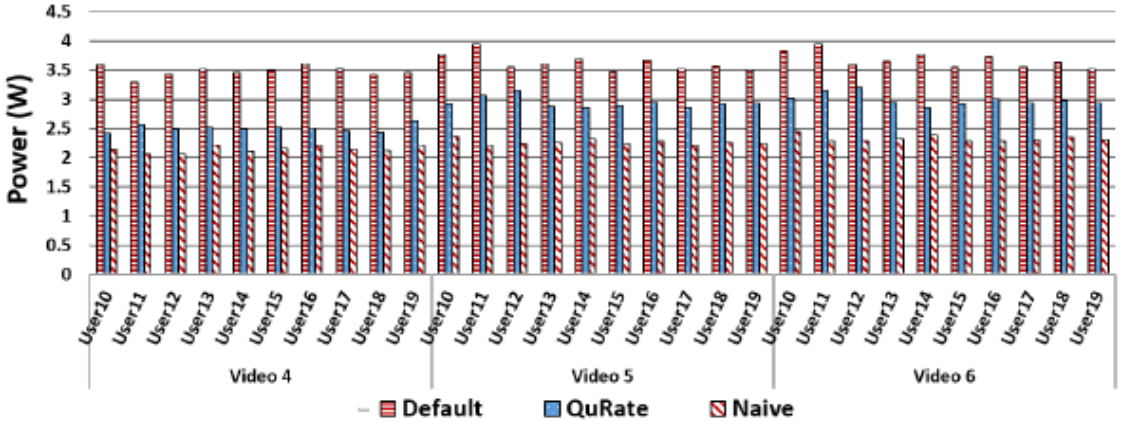
- 6-video, 59-user head movement dataset



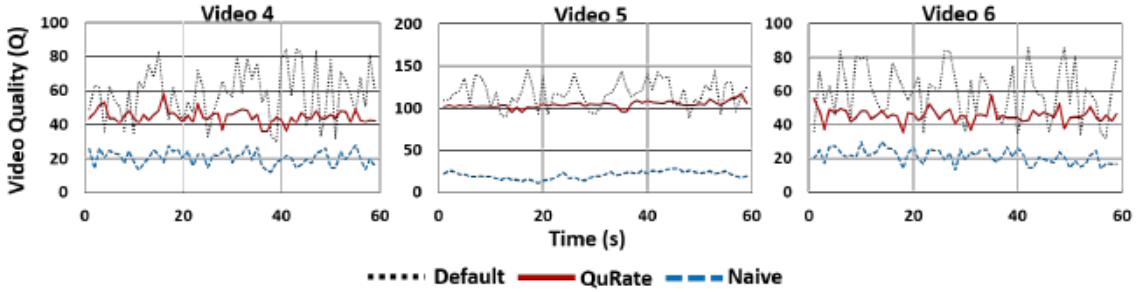
Frequency of View Switching

Power Optimization Results

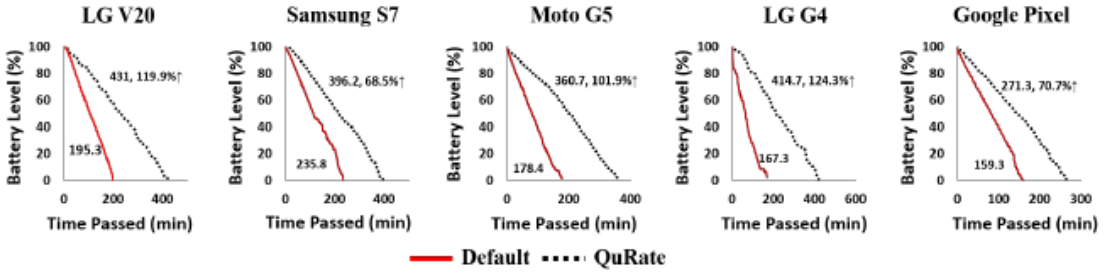
Power



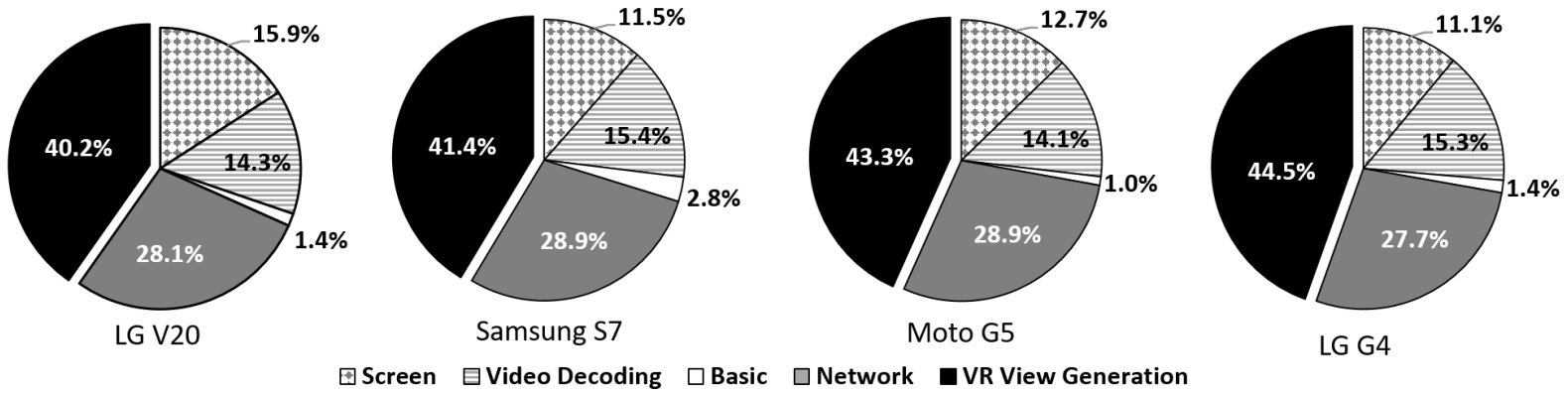
Quality

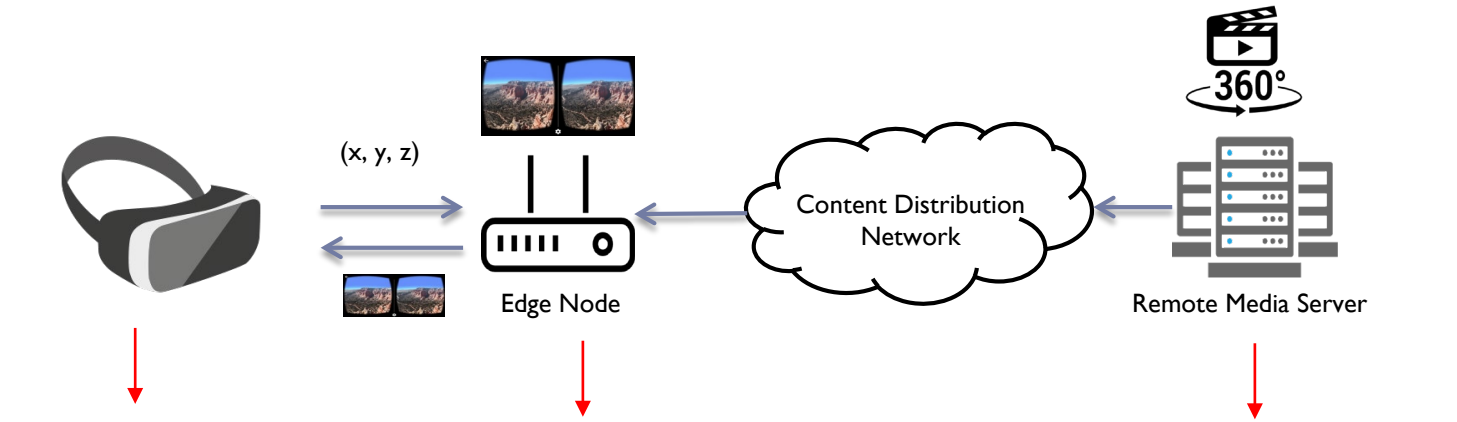


Battery Life



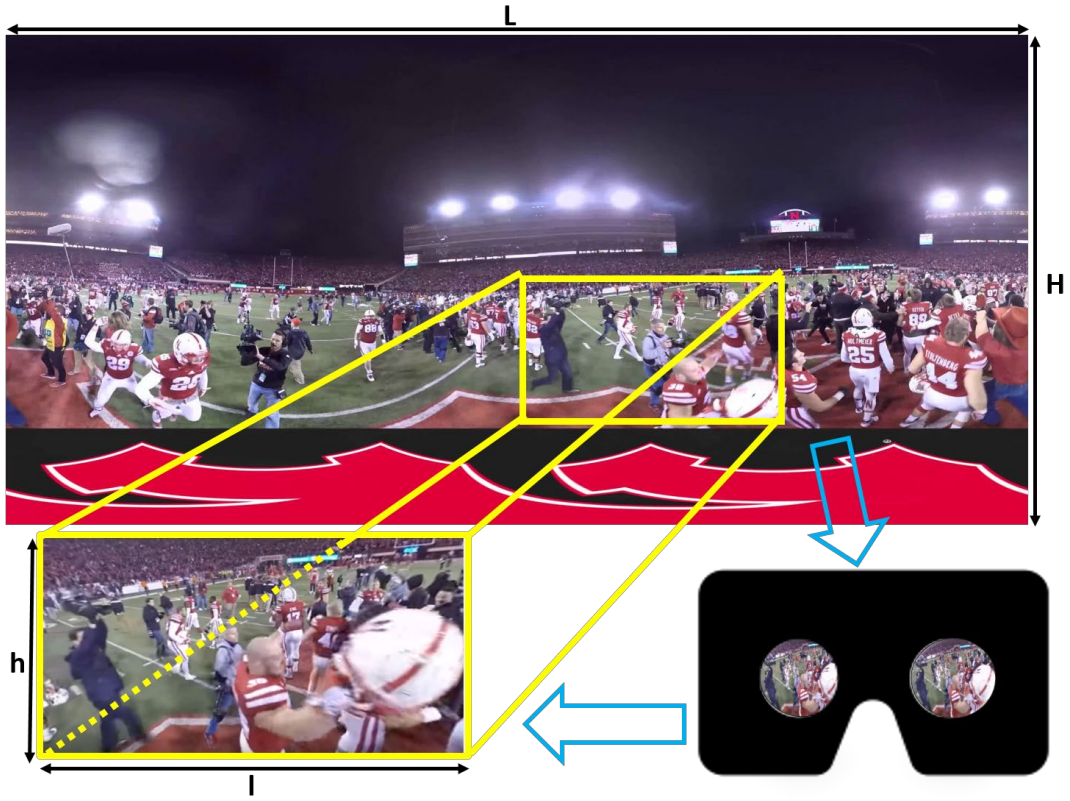
Future Work


15.9%
40.2%
14.3%
28.1%
1.4%
LG V20
11.5%
41.4%
15.4%
28.9%
2.8%
Samsung S7
12.7%
43.3%
14.1%
28.9%
1.0%
Moto G5
11.1%
44.5%
15.3%
27.7%
1.4%
LG G4
Screen
Video Decoding
Basic
Network
VR View Generation


360°
(x, y, z)
Content Distribution Network
Edge Node
Remote Media Server
Hardware Acceleration
Edge Computing
Viewport Prediction

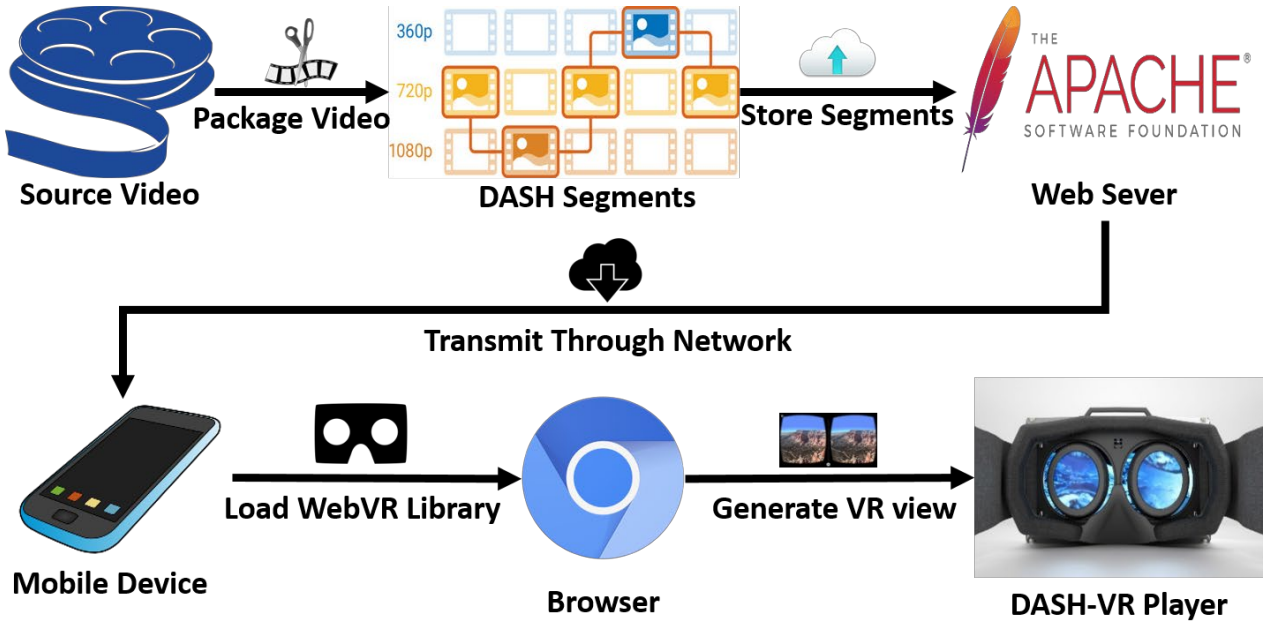
Viewport Prediction

- Bandwidth/Power Optimization Opportunity

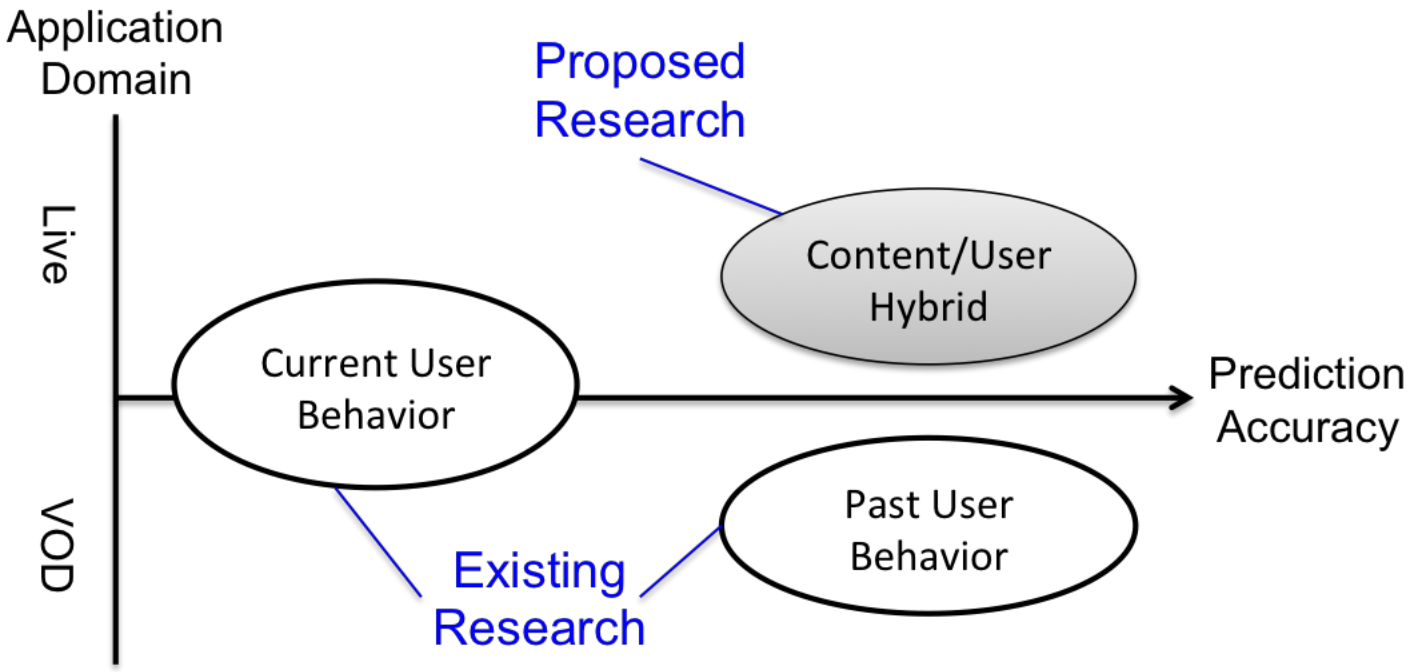


Problem Definition

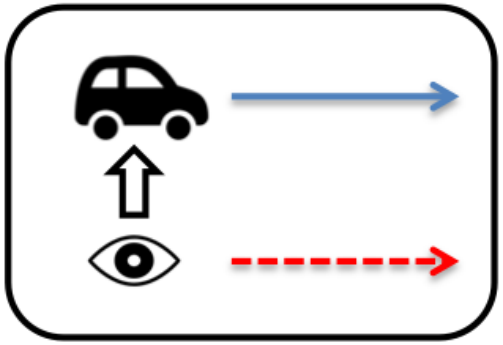
- Scenario: Live 360-degree Video Streaming
- Problem: Predict the user viewport for a few seconds



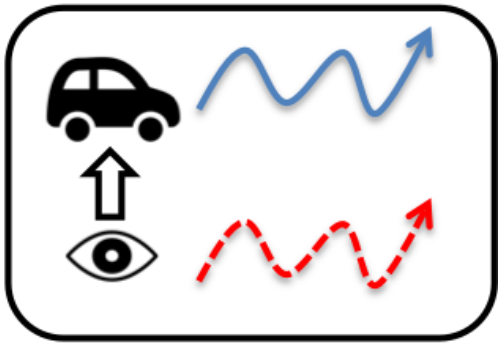
Solution Space



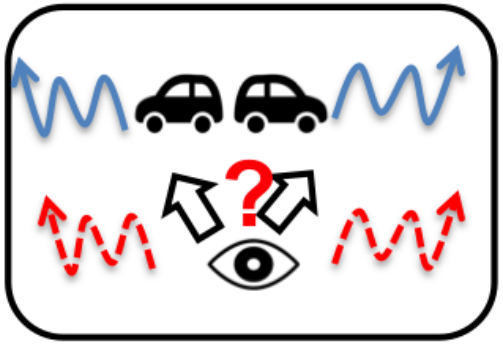
Challenges



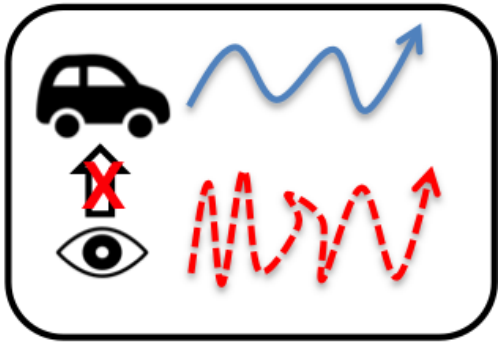
(a) 1-1 move



(b) 1-n move



(c) m-n move



(d) Arbitrary move

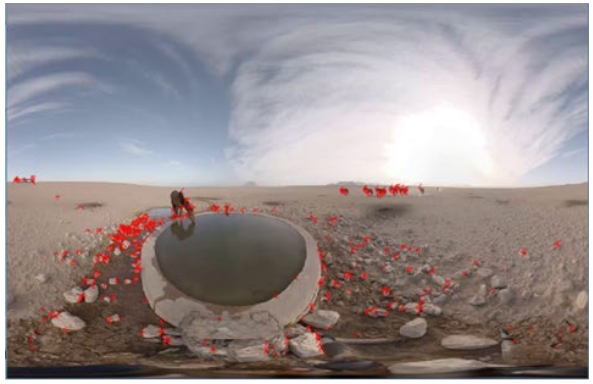
[Ubicomp 19]

LiveMotion: Motion-tracking-based Viewport Prediction

- Key Idea: User watches moving objects, so let's track the motion

(a) Original frame

(b) Motion detection



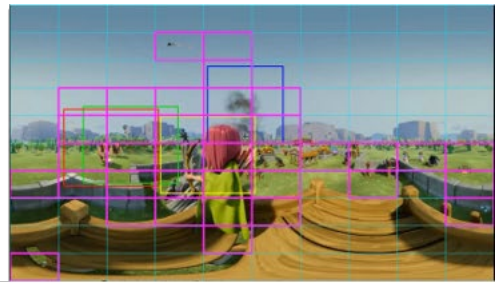
(c) Feature abstraction

(d) View prediction

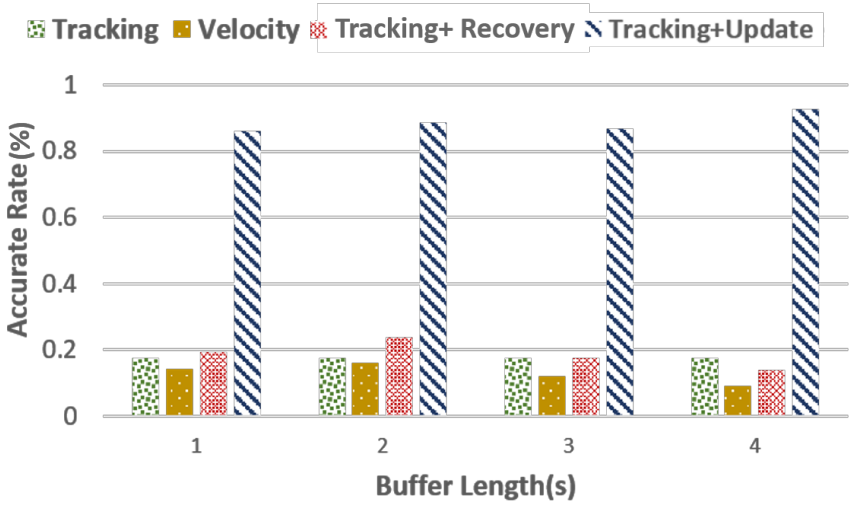
LiveMotion Results

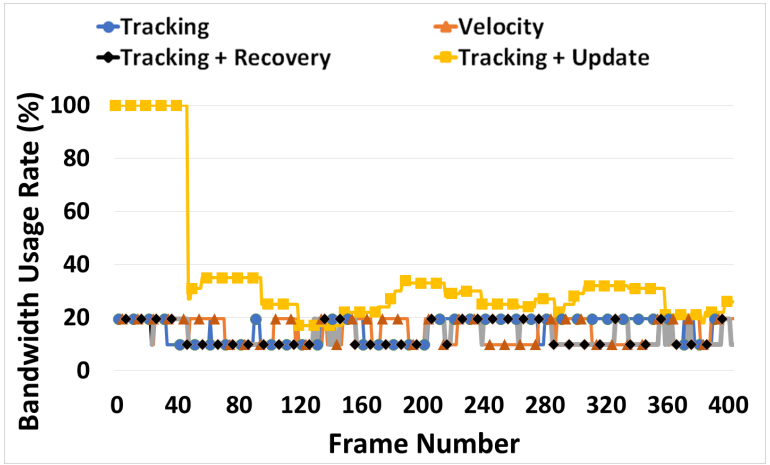
(a) Wild Horse

(b) Airbus



(c) Video Game





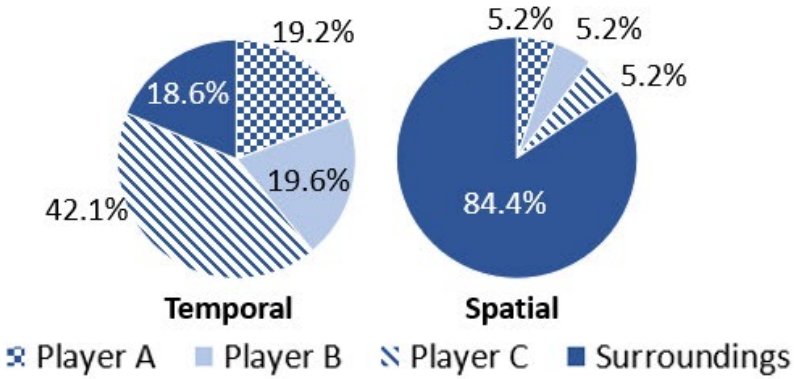
LiveMotion Limitations

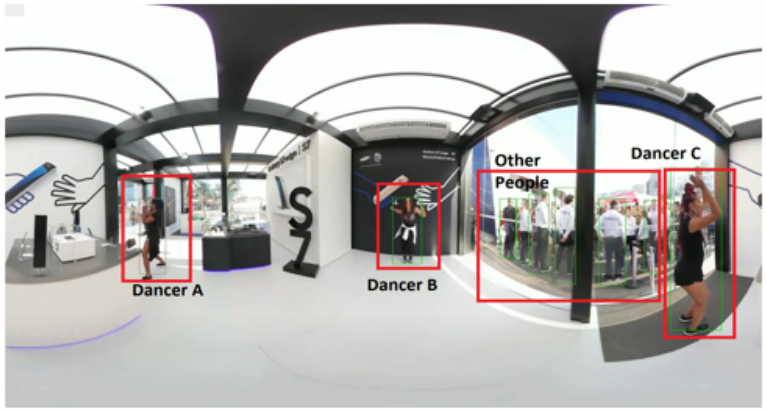
- Does not work for videos shot by moving cameras
- Does not work for complicated moving background
- User may want to watch non-moving objects

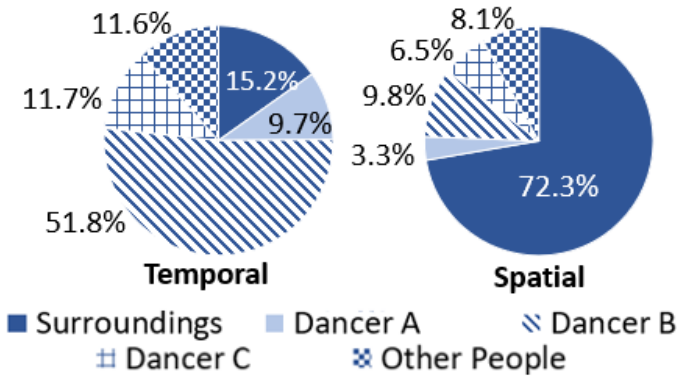
Solution: Let's understand the users better

LiveObj: Object-semantics-based viewport prediction

- Key Idea: user watches meaningful objects

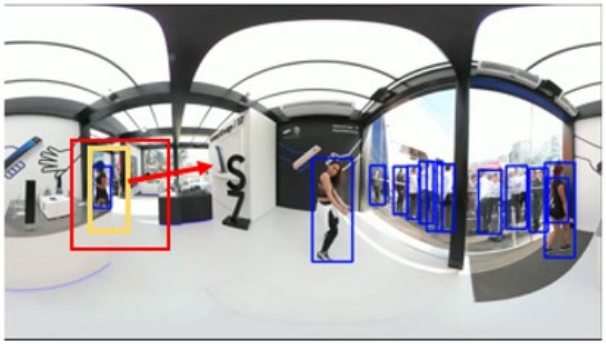




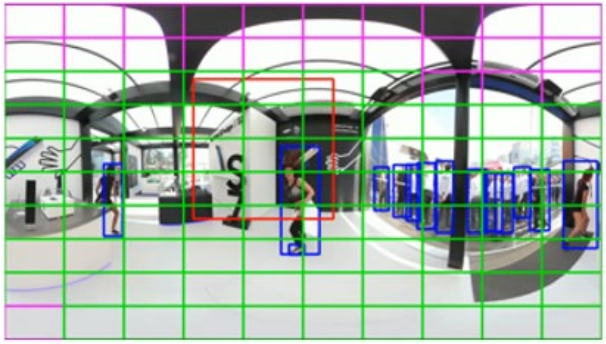


LiveObj Design

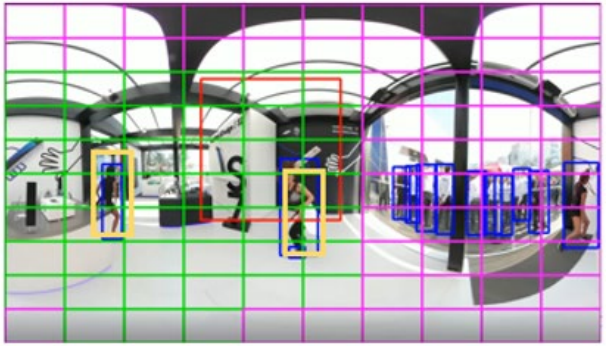
(a) Original frame



(b) Object detection & tracking & user feedback



(c) Over-Cover: comprehensive prediction



(d) LiveObj: tracking based prediction

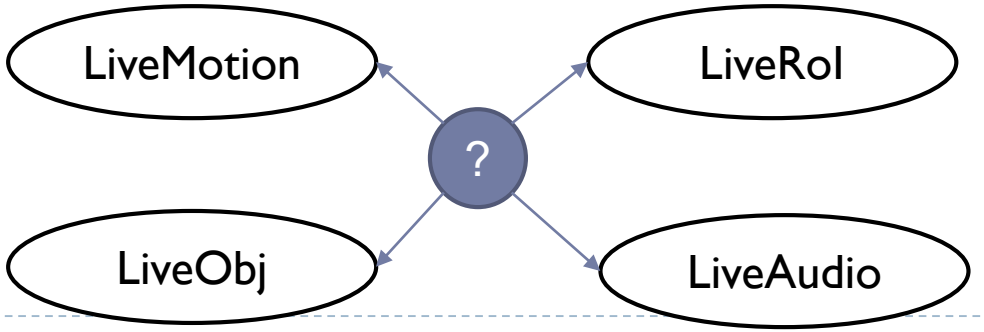
LiveObj Results

Public head movement dataset involving 48 users watching 10 videos

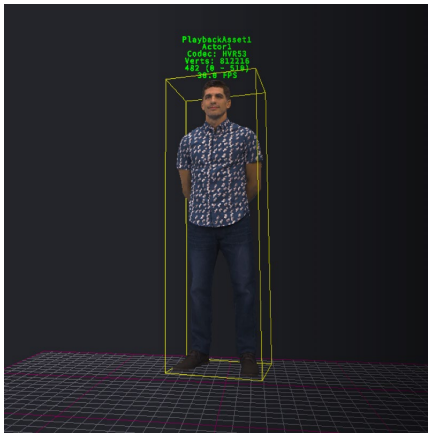
		Accuracy Rate (%)					Bandwidth Usage (%)				
NO	Video Name	Basic	Velocity	O-C	LiveObj	Motion	Basic	Velocity	O-C	LiveObj	Motion
1	Korean	25	20	95	93	97	17	14	78	50	58
2	Football	25	11	94	82	92	17	15	69	50	62
3	FemaleBasketball	18	11	95	88	92	19	14	75	53	55
4	Fighting	3	18	96	95	96	19	14	71	44	69
5	Anitta	2	9	94	71	92	19	15	72	44	52
6	Front	10	11	85	76	95	18	14	66	45	75
7	Cooking	14	14	96	81	91	18	15	69	43	42
8	Falluja	10	10	88	74	92	18	15	64	48	62
9	RioVR	25	14	96	88	93	17	15	72	42	41
10	Rhinos	22	12	86	80	93	17	14	48	41	57

Future work in viewport prediction

- Accomplished
  - User watches moving objects → LiveMotion [ubicomp19]
- In Progress
  - User watches meaningful objects → LiveObj
- Future Work
  - User watches meaningful actions → LiveROI
  - User watches video content based on audio guide → LiveAudio
  - User/Content-based adaptive viewport algorithm selection



Future work: Volumetric Video Security



Volumetric Video

- Security/Privacy concerns
- Threat model
  - Bypassing face ID authentication
- Solution
  - Encryption (too much overhead)
  - Proposed: Opposite use of adversarial attack

Acknowledgement


Project Repositories: gitlab.com/hwsel