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Best Practices for VR Applications

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Best Practices for VR Applications			
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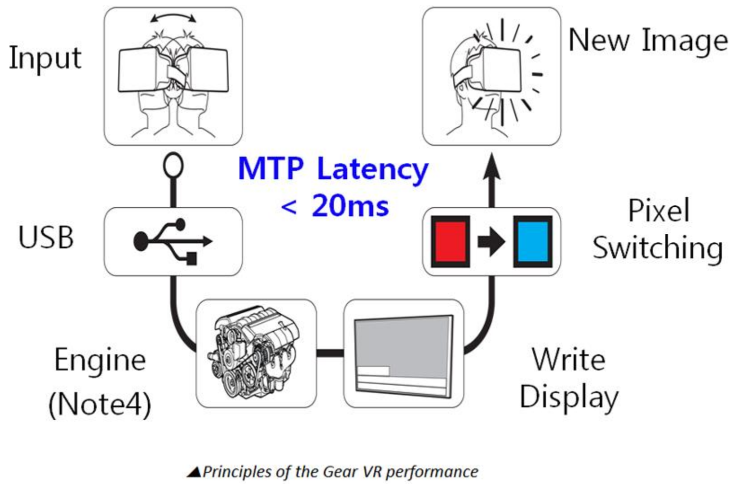
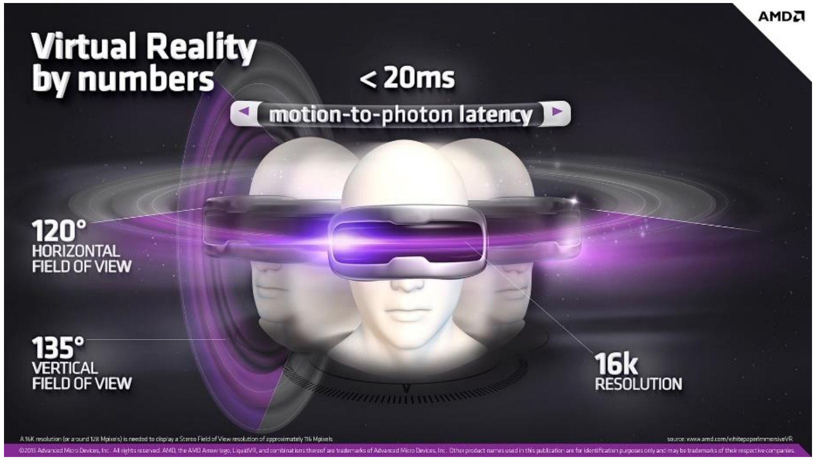
Best Practices for VR (1)

Latency Minimization

VR latency should not exceed 20 ms



<2015, Kostov G.>



<Graphics processing requirement for immersive VR(2015, AMD)>

■ VR Latency(Motion-to-Photon Latency)

- Mobile VR latency= Display Response + Head Tracking + Network Transmission + VR Rendering
- PC based VR latency= Display Response + Head Tracking + VR Rendering

■ Head-tracking performance varies among VR HMDs

Device	Samsung GearVR	HTC Vive VR	Oculus Rift CV	PlayStation VR
Head tracking	> 20ms	13ms	18ms	18ms

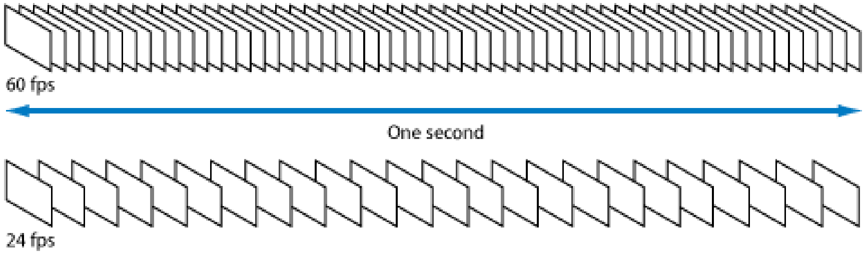
Best Practices for VR (2)

Frame Rate Optimization

Frame rate of VR content should be synchronized with the refresh rate of VR HMD, maintaining above 90 FPS for interactive VR applications

<30 FPS>

<60 FPS>

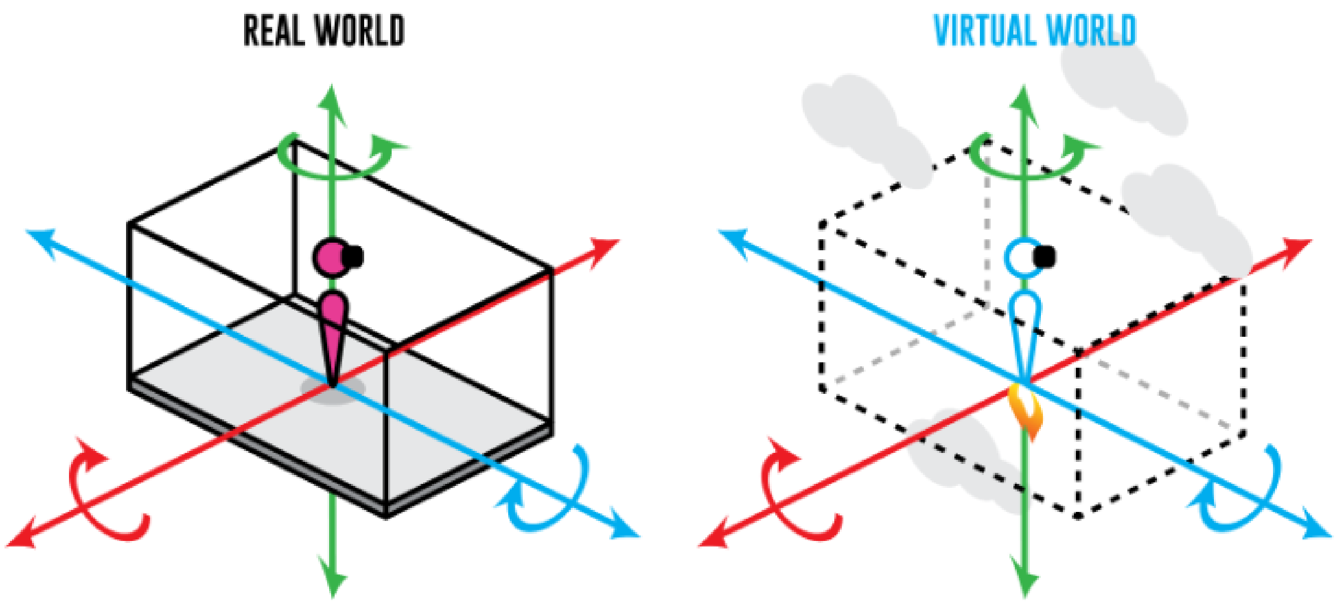


- Low frame rate generates flickering/motion blurring/juddering in the VR image, causing headache, eye strain and seizure(ala Nintendo epileptic)
- Normal video and interactive video should have frame rate of at least 30 fps and 90 fps, respectively
- Most off-the-shelf VR HMDs have refresh rate of above 90 Hz
- Oculus best practice is above 75 fps
- High-contrast or high-sharpness VR content may have flickering even for high frame rates

Best Practices for VR (3)

Camera Motion

Frequency and magnitude of the accelerated camera motion(back/forth, left/right, rotation, zoom) should be minimized, and should move at constant speed if possible



- Abrupt camera movement causes VR sickness for the users, since it changes the cFoV(camera Field of View)
  - The huge amount of pixel information change at an instant causes discomfort to users
- Human vestibular system is very sensitive to the change of speed of visual objects, either being a camera and an object

Best Practices for VR (4)

Rig Construction

For 360° VR, rig system should be manufactured in a way that cameras are aligned with the nodal point (a.k.a. no parallax point)

<360° Camera Rig>

<Vertical Camera Rig>

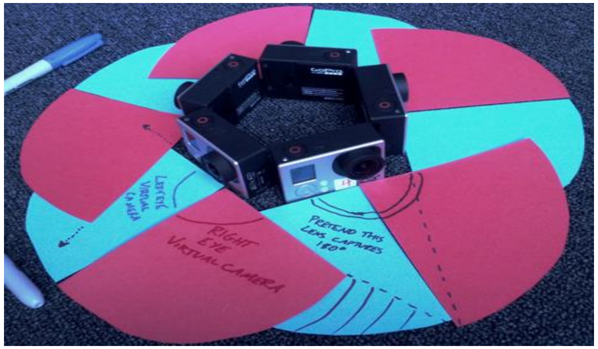
<Various 360° VR Camera Rig>

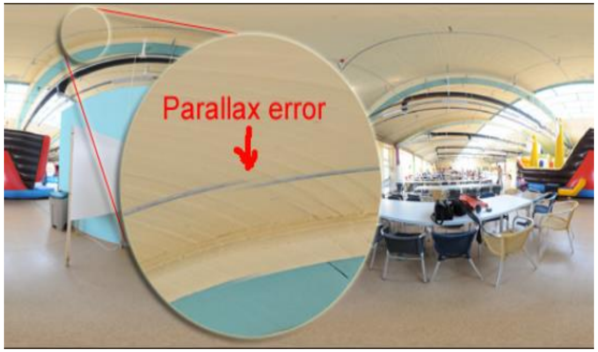
- There exists some gaps between cameras for 360° VR due to its physical bulkiness
- Proper design of camera-rig system is needed to overcome the problems due to inherent defection caused by the camera-rig structure
- Deviations from the nodal point causes a uncomfortable parallax, which in turn aggravates the stitching errors

Best Practices for VR (5)

Stitching Optimization

Adjustments need to be done for camera placement, lens distortion, camera sync, and stitching algorithm in order to reduce the errors for 360° VR capturing and post processing





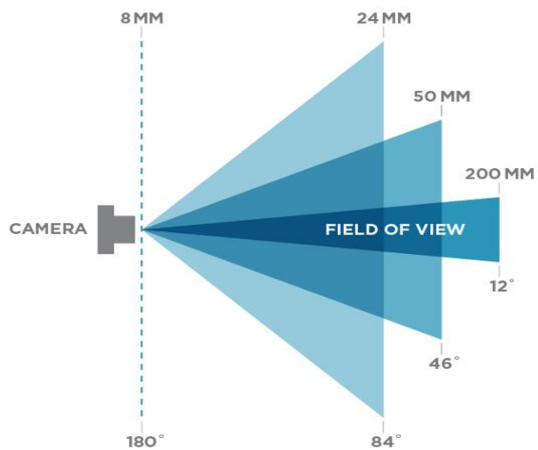
<Stitching errors (e.g.)>

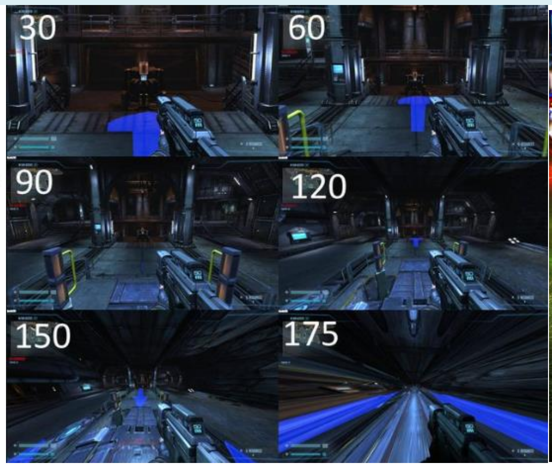
- Image distortion due to stitching errors prevents user's immersion, eventually leading to VR sickness
- Stitching errors occur due to camera differences in optical focal length, horizontal disparity, lens curvature, etc.
- Specific guidelines needed for corrections:
  - camera placement to handle disparity
  - distortion due to lens curvature
  - proper use of stitching SW

Best Practices for VR (6)

FoV Adjustment

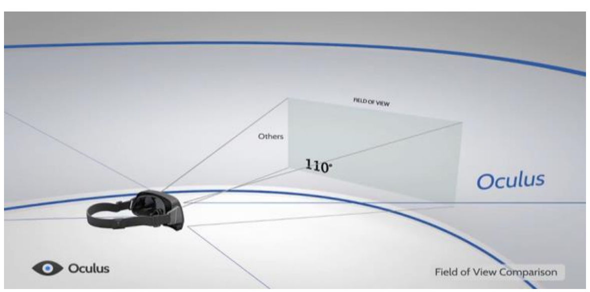
cFoV (Camera's FoV) must match the fixed dFoV (display FoV)

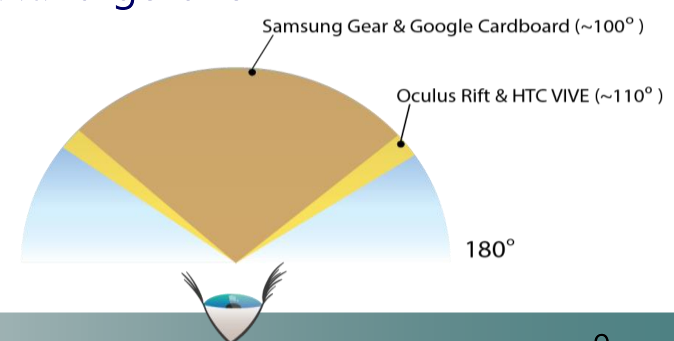




- A discrepancy between cFoV and dFoV causes a discomfort due to distortion on displayed image and degraded resolution

  * Human FoV: 210°, Military HMD's FoV: 180°~210°
- Some tradeoff between the immersion and VR fatigue w.r.t. large dFoV

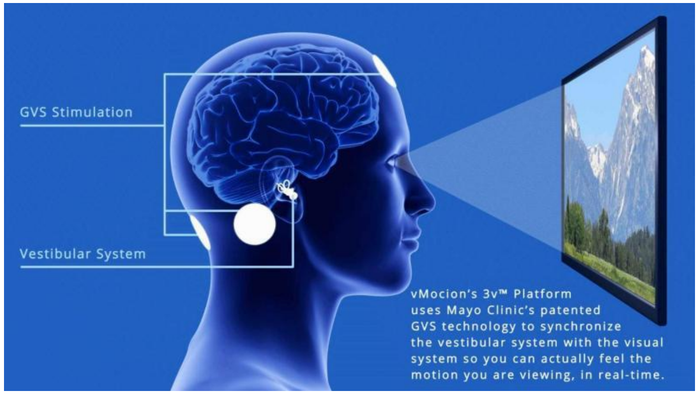




Best Practices for VR (7)

Synchronization of Sensory Conflicts

Synchronize the user's visual experience with the bodily sensation in order to reduce the VR sickness



Synchronization of vestibular system via GVS (Mayo Clinic, 2016)

<Synchronization of proprioceptive sense>

■ VR sickness occurs mainly by two reasons:

- User's visual cues doesn't match with that of the internal ear's vestibular sense
- User's visual cues doesn't match with that of the proprioceptive sense

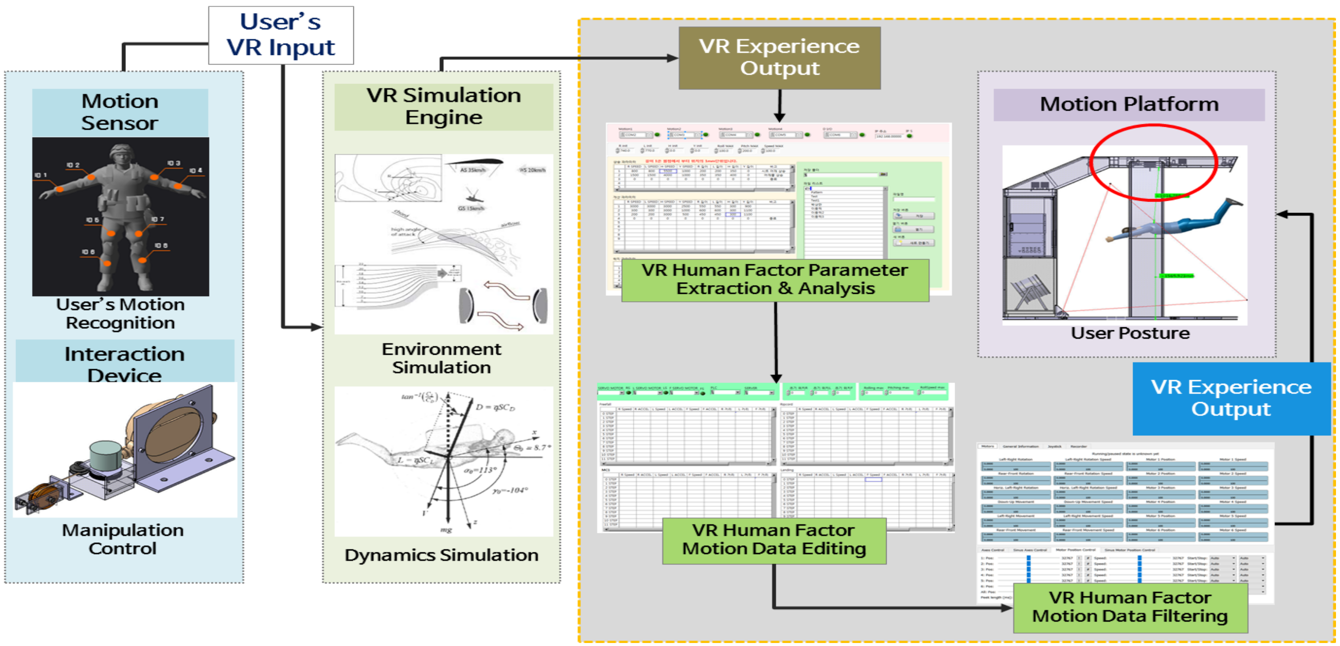
■ VR sickness could be partially handled by:

- having the user's VR experience to be expected
- using an avatar reflecting exact behaviors of the users
- artificial stimulation of the human vestibular system

Best Practices for VR (8)

Synchronization of Motion Platform

To synchronize the user's visual experience with the sensation of movement, the VR input-output latency should not exceed 150 ms



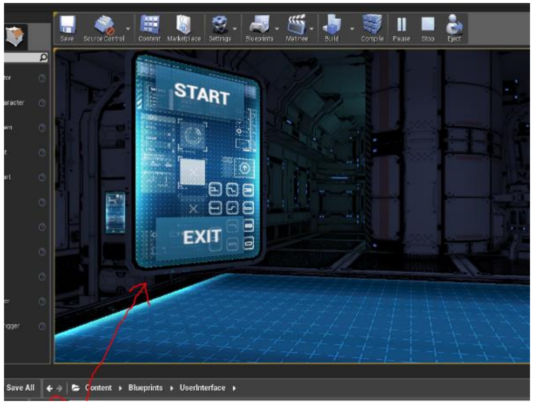
- VR sickness due to riding simulators (motion sickness) is mainly caused by the desynchronization between the user's visual cues and their sensation of movement
- Currently-recommended VR input-output latencies:
  - MLIT (Korea) : between 100ms~150ms(1st grade, 2nd grade, 3rd grade)
  - FAA (U.S.A.) : under 100ms
- Much more tricky to deal with the accuracy issues for riding simulators

Best Practices for VR (9)

UI Placement

Place UI in the 3D space in VR by making it a 3D object

<UI in the form of a HUD>



<UI as an 3D object in VR space>

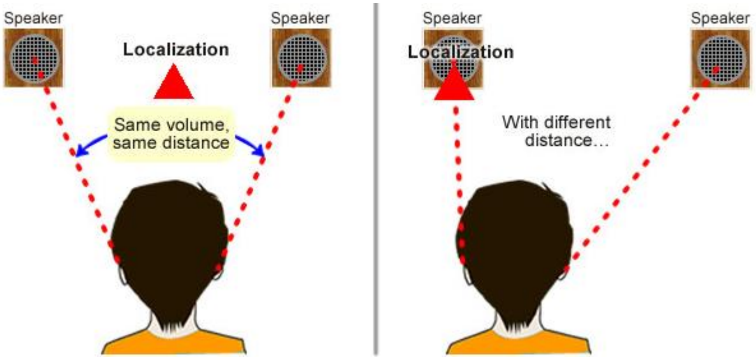
- Avoid attaching UI to camera, so called HUD, so as to avoid undesirable movements due to its tight-coupling with the camera's motion
  - Embed or integrate the information into the environment, forgoing the HUD
- Make UI visible whenever necessary or transparent using alpha value to avoid undesirable obtrusive view (occlusion)
- Place UI within user's effective Field of View
- Use gaze crosshair or reticle

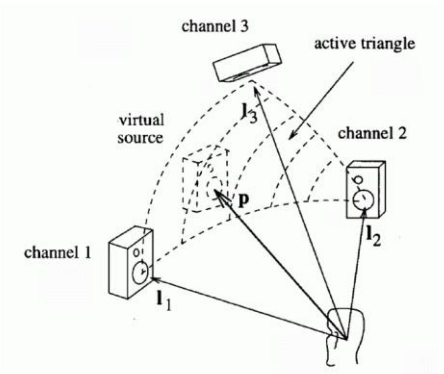
Best Practices for VR (10)

Sound

Adjust the incoming direction of the sound in synchronization with the head tracking of the users

<VR Sound>





<Binaural Effect>

- ■ Synchronizing the sound direction with the head tracking helps users to be situation-aware
- ■ Binaural rendering* can be used to create immersive sound
  - Synthesize the 3D sound into two-channel output, which is rendered in a way that reflects where the sound is coming from, taking into account the relative direction and distance between the sound source and the listener(user)

  * when two sound signals of two different frequencies are presented separately, the user's brain detects the phase variation and recognize it as a third sound signal