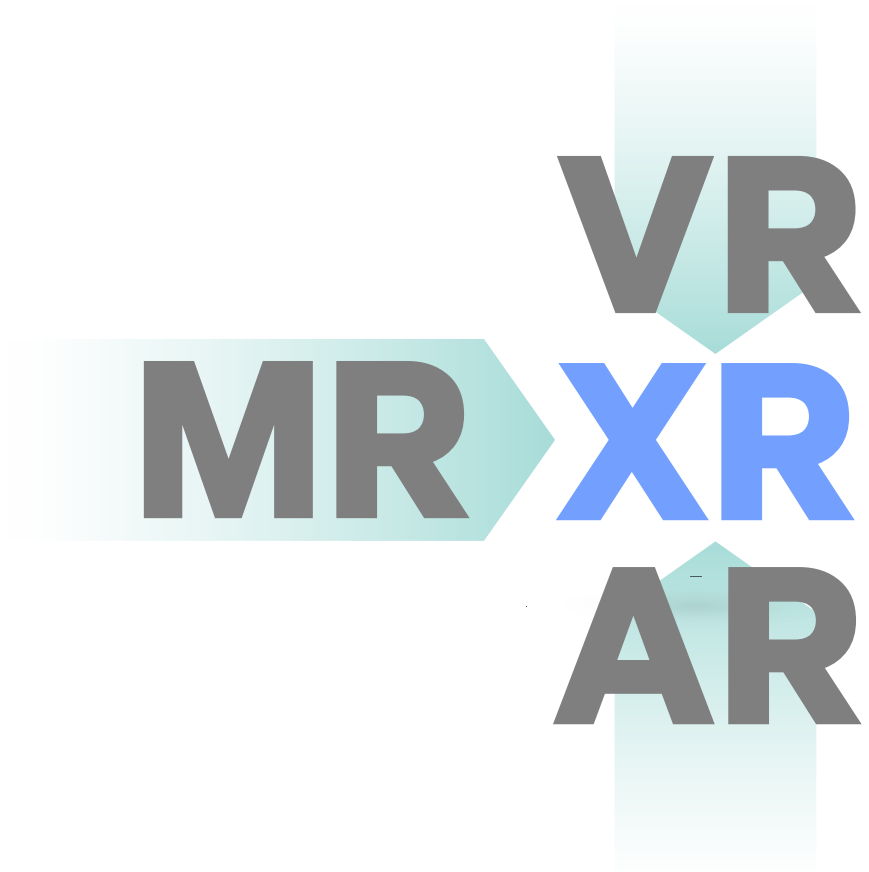
On-device motion tracking for immersive mobile VR

Qualcomm Technologies, Inc.
August 2017

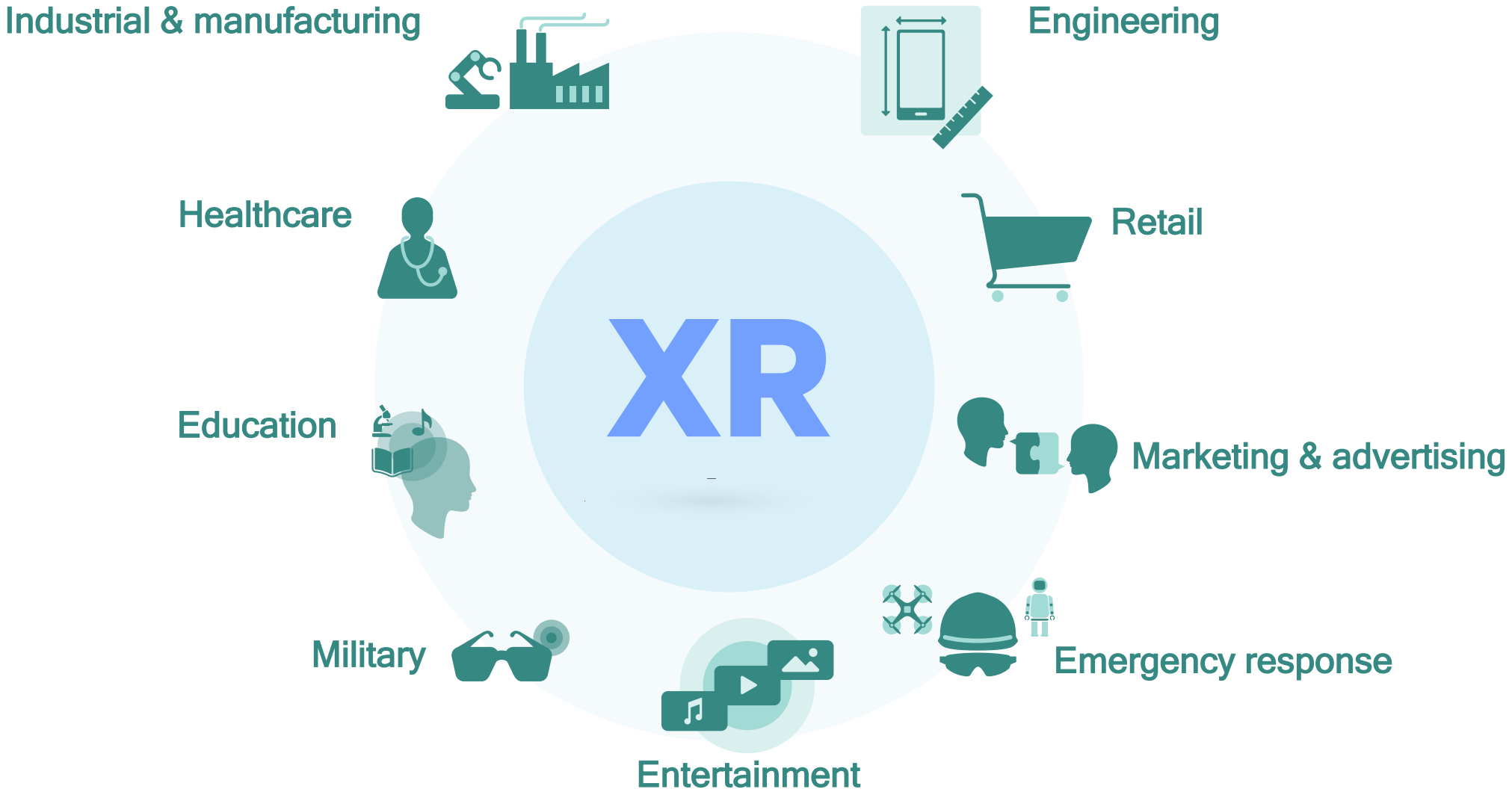
Taking the lead in XR

Building on our mobile VR/AR innovation and leadership



Taking the lead in XR

Building on our mobile VR/AR innovation and leadership



XR technologies and use cases evolve from mobile

VR usage primarily comes from console/TV/PC, but it's also moving towards AR

Landline

PDA

Handheld gaming

Camera

Laptop

Smartphone

TV

Desktop PC

Gaming consoles

AR glasses

VR HMD

VR will provide the ultimate level of immersion

Creating physical presence in real or imagined worlds: Intuitive interactions required

Visuals

So vibrant that they are eventually indistinguishable from the real world

Interactions

So intuitive that they become second nature

Sounds

So accurate that they are true to life

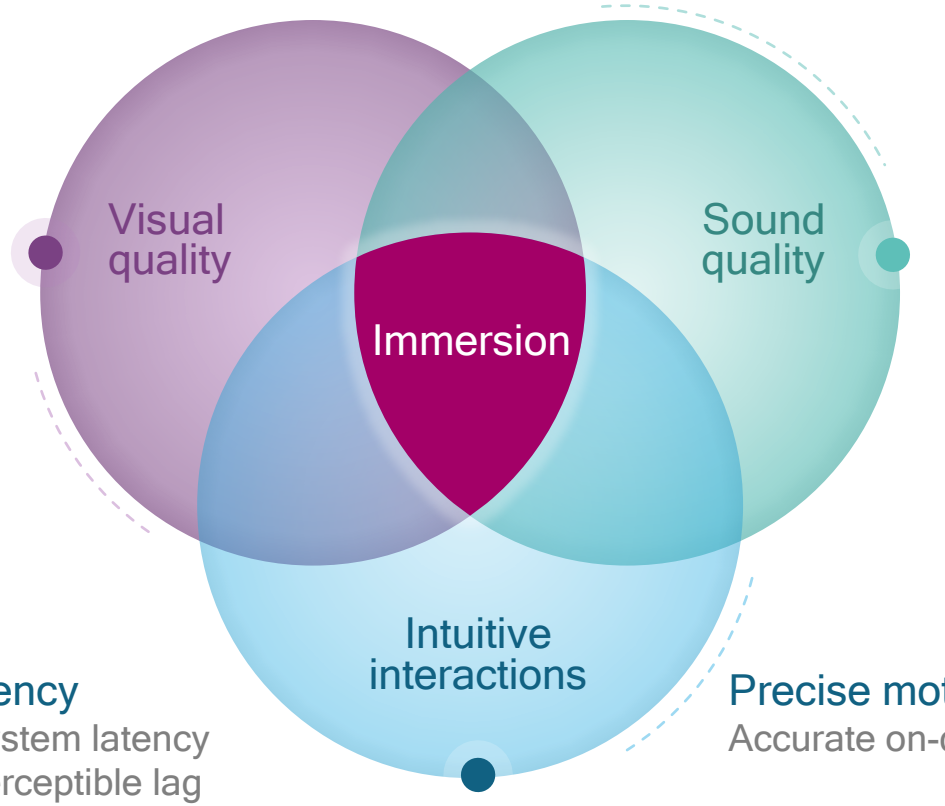
Immersive virtual reality has extreme requirements

Achieving full immersion at low power to enable a comfortable, sleek form factor

Extreme pixel quantity and quality
Screen is very close to the eyes

Spherical view
Look anywhere with a full 360° spherical view

Stereoscopic display
Humans see in 3D



High resolution audio
Up to human hearing capabilities

3D audio
Realistic 3D, positional, surround audio that is accurate to the real world

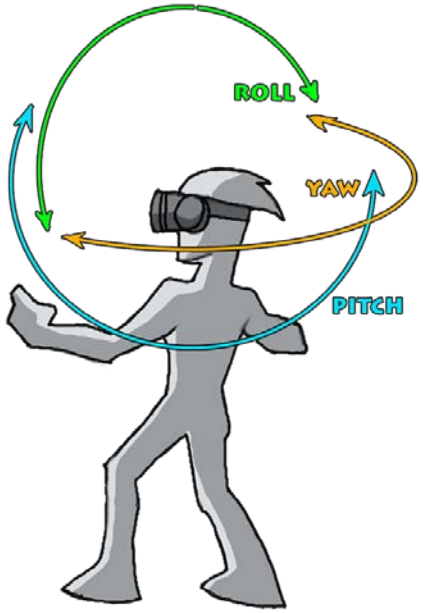
Minimal latency
Minimized system latency to remove perceptible lag

Precise motion tracking
Accurate on-device motion tracking

Natural user interfaces
Seamlessly interact with VR using natural movements, free from wires

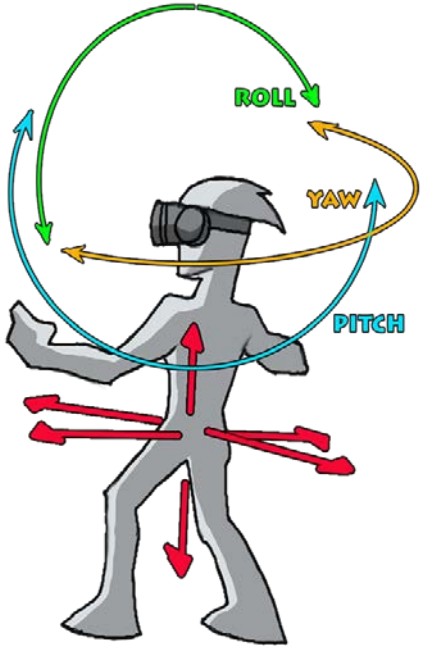
3-DoF vs. 6-DoF

3 degrees of freedom (3-DoF)



- “In which direction am I looking”
- Detect rotational head movement
- Look around the virtual world from a fixed point

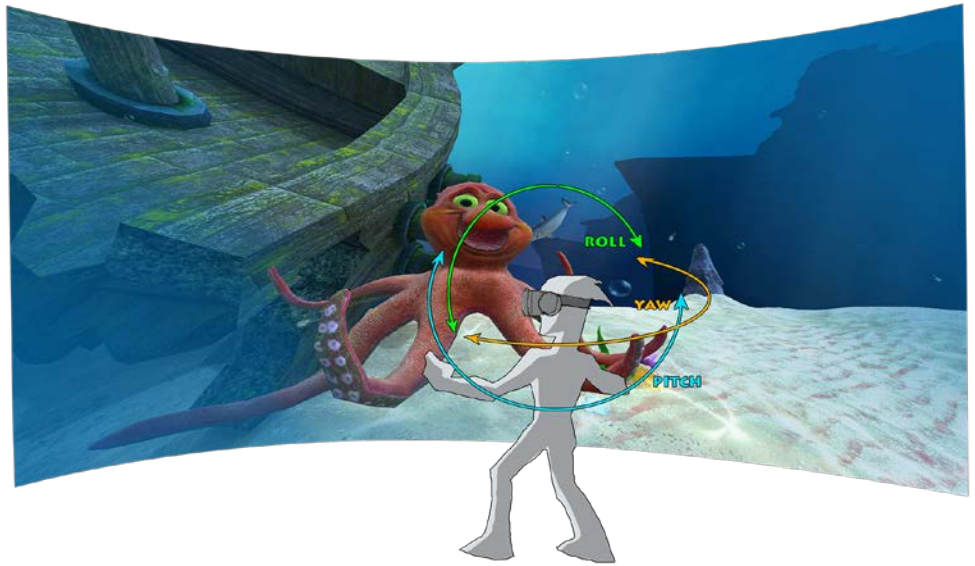
6 degrees of freedom (6-DoF)



- “Where am I and in which direction am I looking”
- Detect rotational movement and translational movement
- Move in the virtual world like you move in the real world

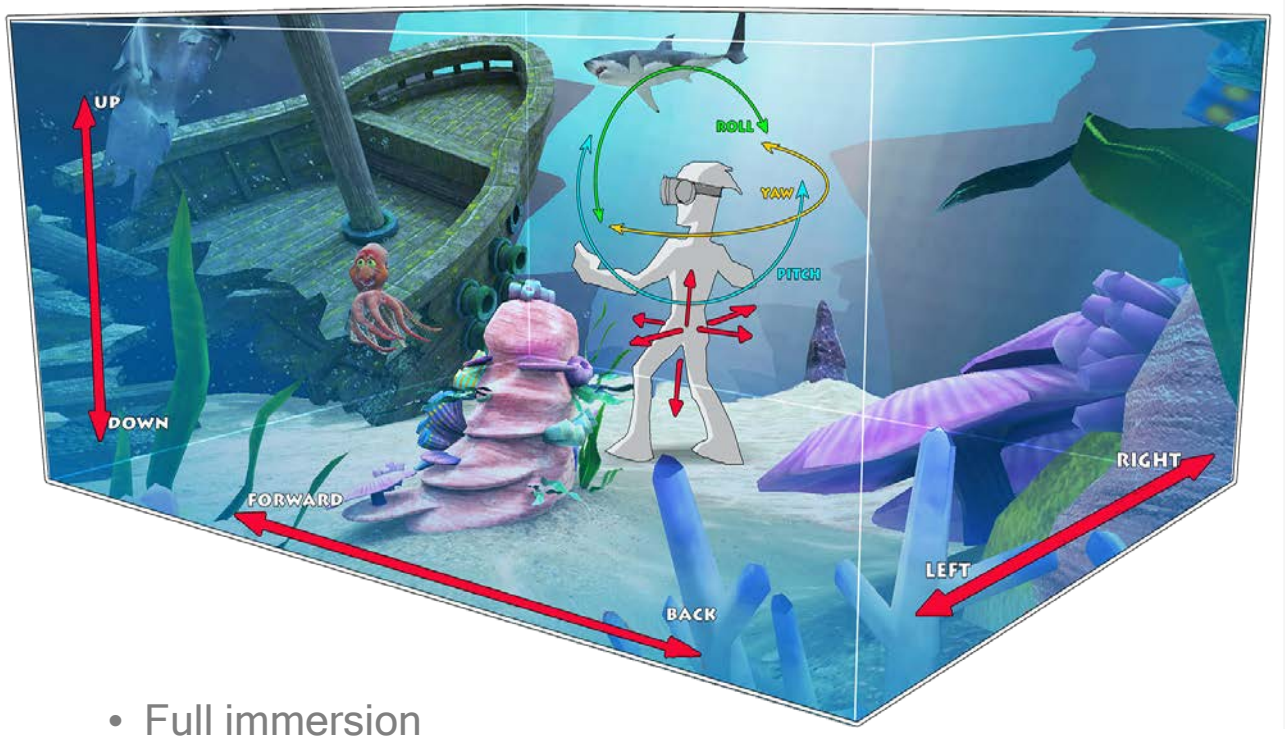
6-DoF allows developers to bring the user into their story

3 degrees of freedom (3-DoF)



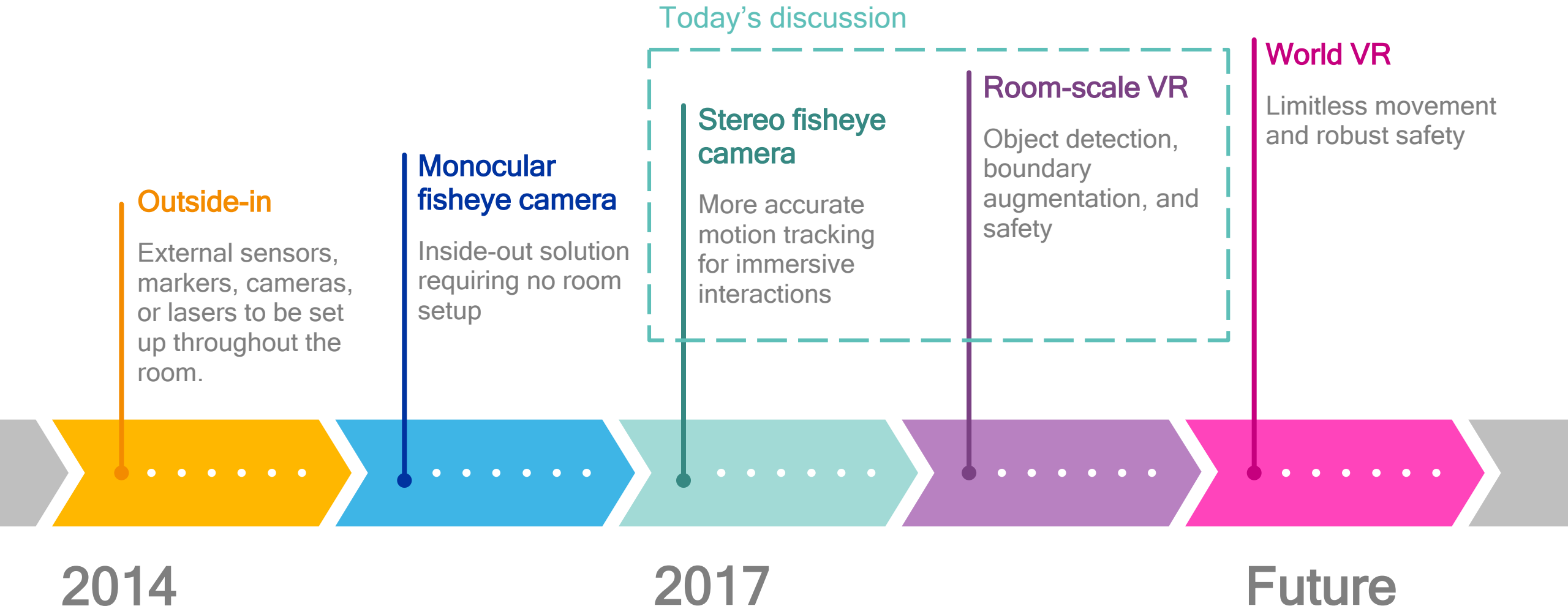
- Can only watch

6 degrees of freedom (6-DoF)



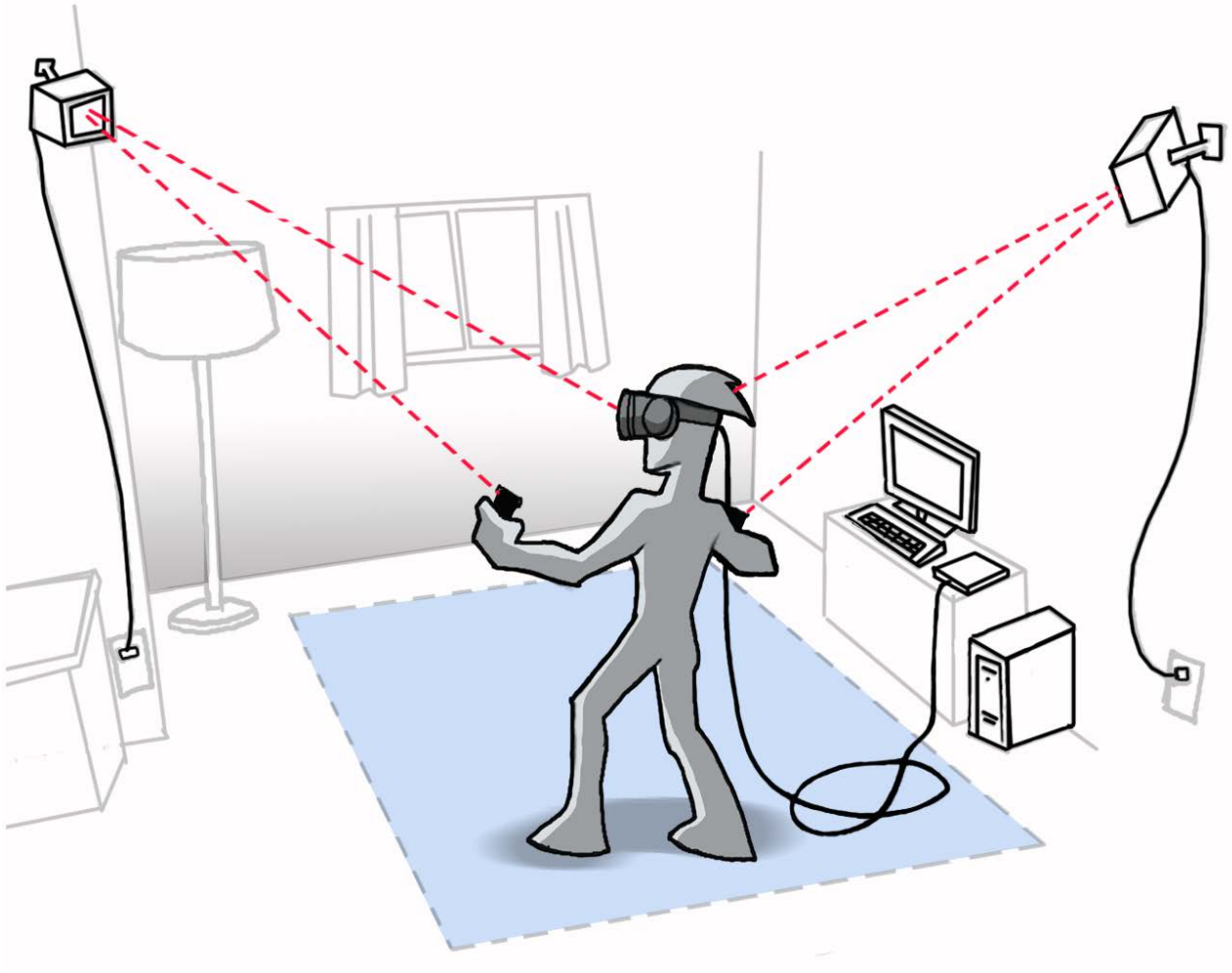
- Full immersion
- Can become part of the story
- Can now interact and change the story

6-DoF motion tracking evolution



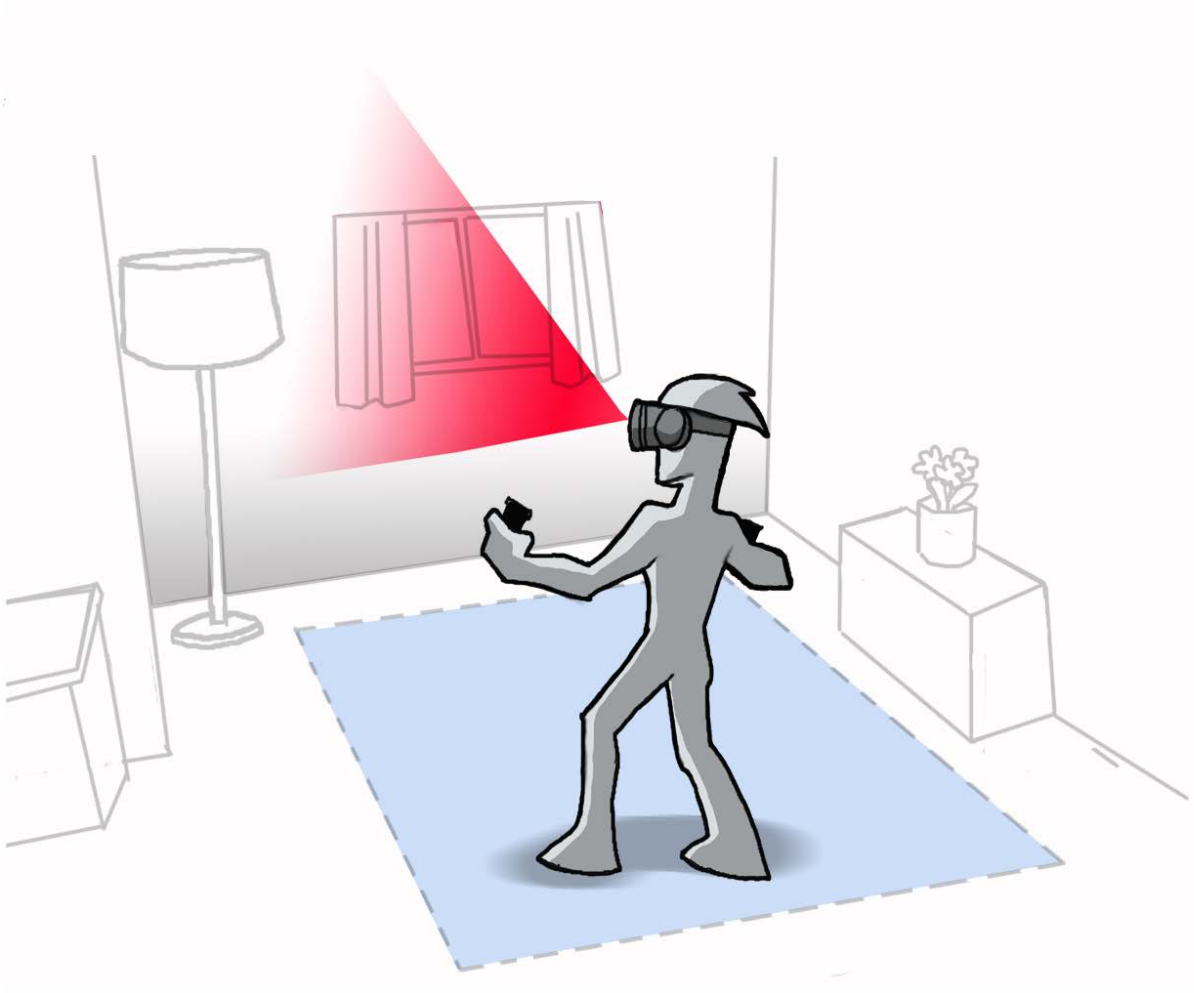
Conventional 6-DoF: “Outside-in” tracking

External sensors determine the user’s position and orientation



Mobile 6-DoF: “Inside-out” tracking

Visual inertial odometry (VIO) for rapid and accurate 6-DoF pose



Mobile 6-DoF: “Inside-out” tracking

Visual inertial odometry (VIO) for rapid and accurate 6-DoF pose

Mono or stereo camera data

Captured from tracking camera image sensor at ~30 fps

Accelerometer & gyroscope data

Sampled from external sensors at 800 / 1000 Hz

“VIO” subsystem on Qualcomm® Snapdragon™ Mobile Platform

- Camera feature processing
- Inertial data processing

Qualcomm® Hexagon™ DSP algorithms

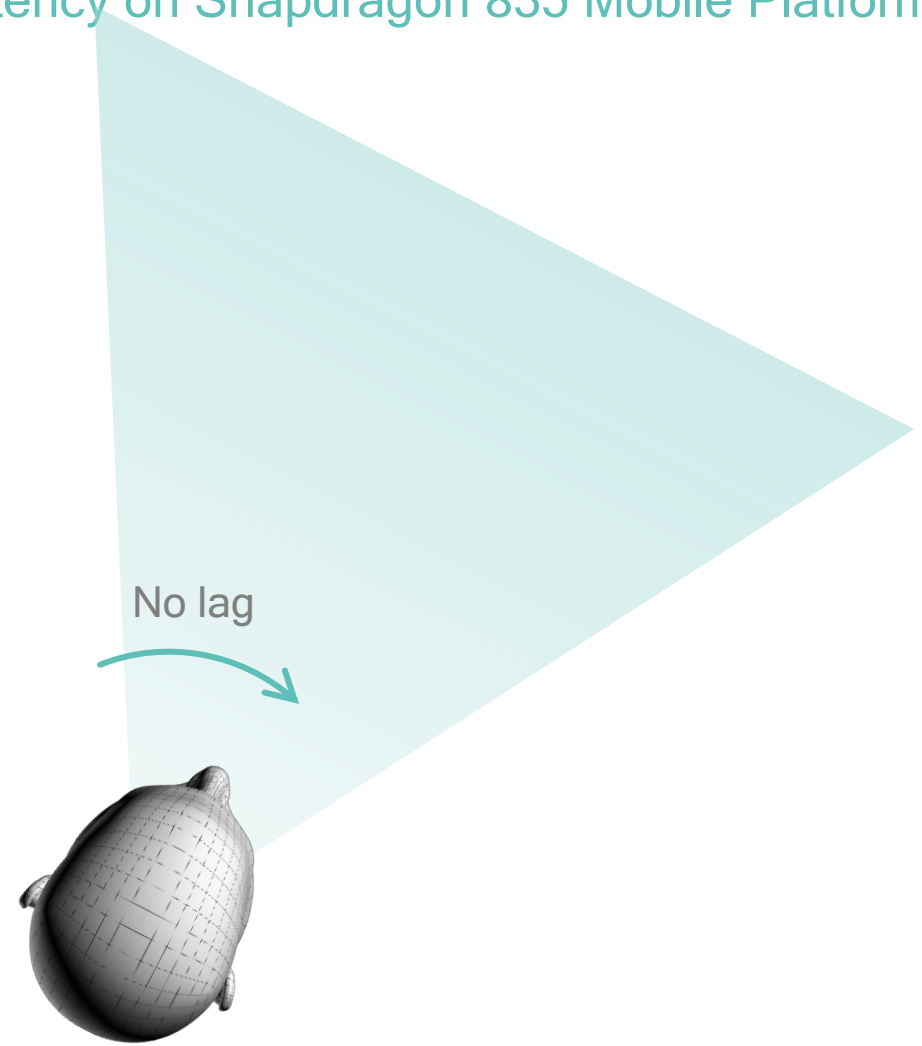
- Camera and inertial sensor data fusion
- Continuous localization
- Accurate, high-rate “pose” generation & prediction

6-DoF position & orientation

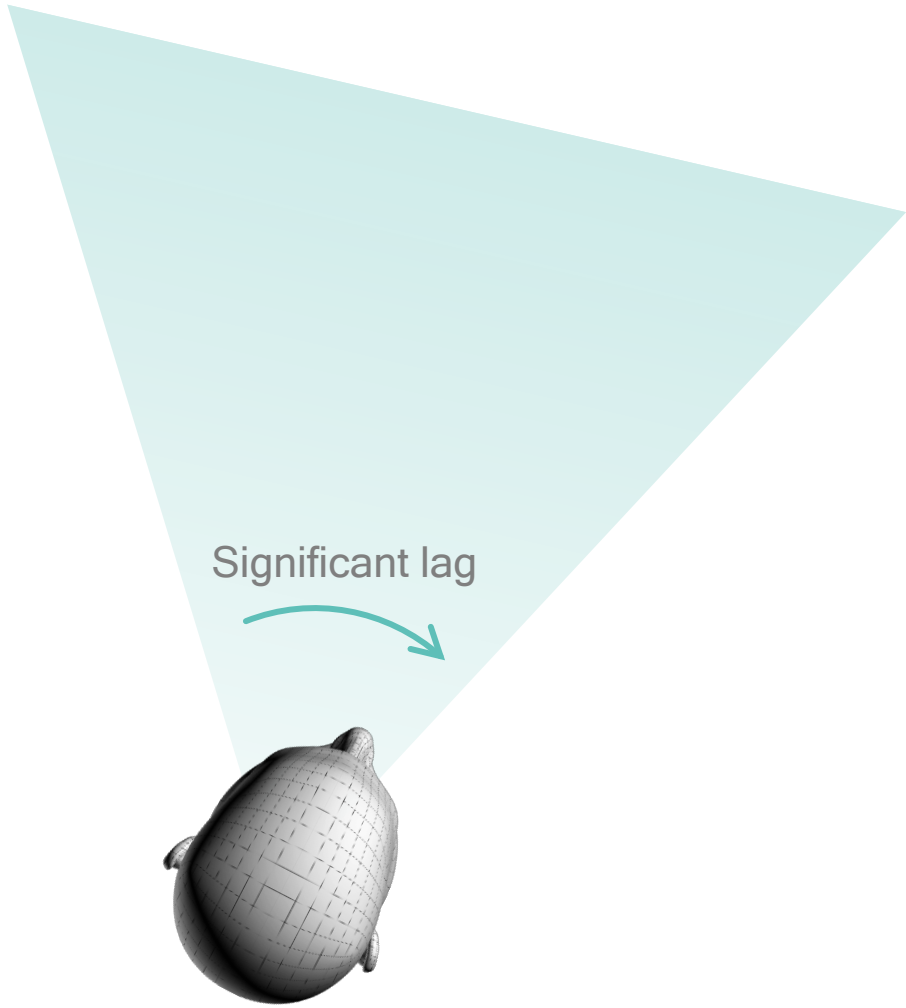
(aka “6-DoF pose”)

Minimizing motion to photon (MTP) latency is crucial

~15-16 ms MTP latency on Snapdragon 835 Mobile Platform shows our mobile VR leadership



Low latency



Noticeable latency

Low latency mobile 6-DoF inside-out tracking

Many workloads must run efficiently for an immersive VR experience

"Motion"

Motion detection

- Sensor sampling
- Sensor fusion

Visual processing

- View generation
- Render / decode

Display

- Image correction
- Quality enhancement and display

"Photon"

(new pixels' light emitted from the screen)

Total time (motion to photon latency) for all steps above must be less than 20 milliseconds

Stereo VIO for rapid, robust and accurate 6-DoF pose

Sensor fusion of stereo camera features and high rate IMU data

Stereo wide-angle lenses

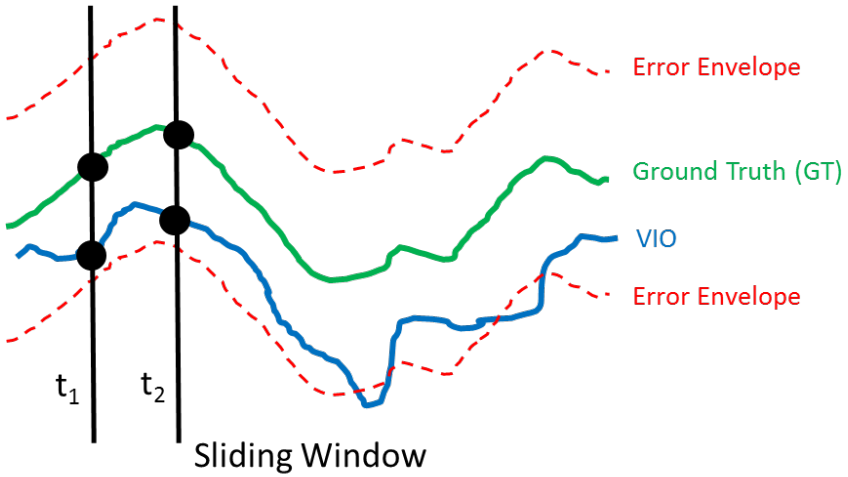
Benefits of stereo over monocular 6-DoF

- Instant accurate scene depth
- Faster initialization
- Better performance with quick and rotational motions
- Improved tolerance to camera occlusion

6-DoF key performance indicators (KPI)

KPI definitions

- Jitter: Defines the frame to frame changes in VIO pose when stationary.
- Absolute error: Defines the total instantaneous error in translation and rotation in VIO pose for the video sequence.
- Relative error: Defines frame to frame rotation and translation error in VIO pose.

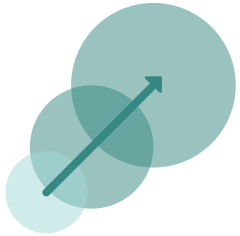


KPIs are captured for:

- Different environments (seated, standing)
- Lighting (low: 5-35 lux, high: 180-350 lux)
- Features (low, high)
- Head motions (slow, fast)

Developing 6-DoF content

Some key things to consider



Scale and space

- Issue: Untethered mobile allows for limitless movement, but available space could change between runs of app
- DO consider limits to amount of full body movement
- DO provide movement alternatives

Tracking

- Issue: Device cameras can become occluded or environment can be too dark
- DO fade to black or fixed image in event of lost head tracking to avoid nauseating jumps and judder
- DON'T fall back to tracking only orientation (3-DoF). Jumps in position or seeing virtual world respond differently to movement can be uncomfortable for users

Storytelling

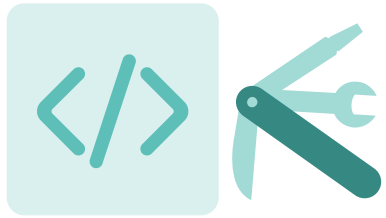
- Issue: Users may not be looking or positioned in desired location to advance story
- DO use audio and visual cues to guide user focus
- DON'T take over control of virtual camera in order to force focus on story element

We are accelerating the adoption of XR

Designed to make it easy to create premium mobile VR and AR experiences

Snapdragon Mobile VR Platform

Purpose built silicon for superior Mobile VR & AR



Snapdragon VR SDK

Access to advanced features to optimize applications and simplify development

Snapdragon Mobile VR HMD

Reference design to build and optimize applications

HMD Accelerator Program

Accelerating the development of standalone head-mounted displays

LTE/5G

5G will be required to take XR experiences to the next level

Ecosystem Collaboration

Advancing XR content development and technology advancements

Commercialize VR HMDs quickly with few resource constraints

HMD Accelerator Program

Commercialization

Allow OEMs to quickly design and manufacture standalone VR HMDs

High quality

Provide means for OEMs to track performance, monitor KPIs and promote them

Scale & harmonization

Standardizes a platform for the whole value chain to build on top and garner critical scale for VR to flourish

Snapdragon 835 VR Development Kit

Advanced VR features designed to optimize applications and simplify development

System on Chip (SoC)

Snapdragon 835 mobile platform

Memory

DRAM: 4GB LPDDR4

Flash: 64GB UFS

Display

AMOLED WQHD

~2MPix per eye

Connectivity

Wireless: Wi-Fi, Bluetooth

Other: USB3.1 type C (power)

Cameras & Other Sensors

Six degrees of freedom (6-DoF) motion tracking:

- Two monochromatic, one mega pixel (1280x800) global shutter cameras & fisheye lens
- Inertial measurement unit with fast interface to Snapdragon 835 integrated sensor core

Eye Tracking:

- Two monochromatic VGA global shutter cameras

Audio

Integrated WCD9335 CODEC

I/O

3-DoF controller support

Snapdragon VR SDK

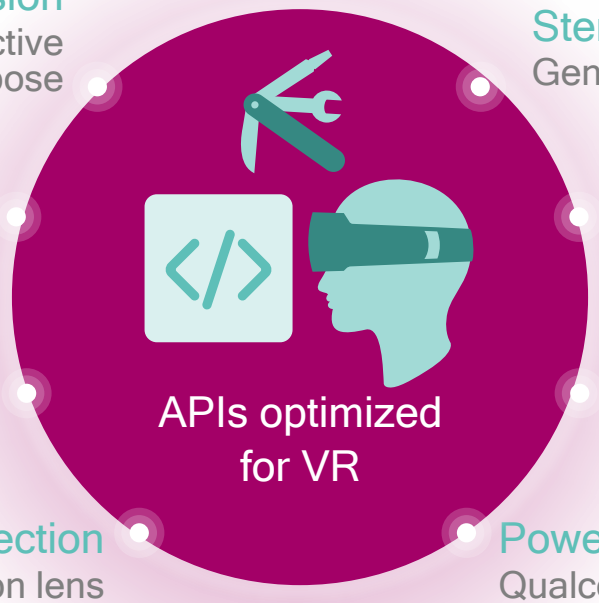
Access to advanced VR features to optimize applications and simplify development

DSP sensor fusion
Access to the latest and predictive head pose

Asynchronous time warp
Warp image based on the latest head pose just prior to scan out

Chromatic aberration correction
Correct color distortion based on lens characteristics

Lens distortion correction
Barrel warp image based on lens characteristics



Stereoscopic rendering
Generate left and right eye view

Single buffer rendering
Render directly to the display buffer for immediate display scan out

VR layering
Generate UI menus and text so that they render correctly in a virtual world

Power & thermal management
Qualcomm® Symphony System Manager provides CPU, GPU, and DSP power, thermal, and performance management

Benefits

Simplified development | Optimized VR performance | Power and thermal efficiency

Qualcomm Symphony System Manager is a product of Qualcomm Technologies, Inc.

Actively working with XR device manufacturers

XR products based on Snapdragon Mobile VR Platform

VR HMD

Baofeng Matrix

VR HMD

Coocaa Wondergate G1

VR HMD

iQiyi Adventure

Tango and Daydream

ASUS Zenfone AR

Daydream

Google Pixel

Daydream

Google Pixel XL

Tango

Lenovo Phab 2 Pro

VR HMD

Pico Neo

VR HMD

WhaleyVR

AR Glasses

ODG R8/R9

Daydream

ZTE Axon

Daydream

Moto Z

Gear VR

Samsung Galaxy S8

Gear VR

Samsung Galaxy S8 Edge

20+
Devices launched

Qualcomm snapdragon

20+
Devices in development

QUALCOMM® Developer Network

Snapdragon Mobile VR Development Kit

- Snapdragon VR SDK
- Snapdragon VR HMD

developer.qualcomm.com

Thank you

Follow us on:

For more information, visit us at:
www.qualcomm.com & www.qualcomm.com/blog