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**Editor: Mary-Luc Champel (mary-luc.champel@technicolor.com)**

**Rob Koenen (rob.koenen@tno.nl)**

**Gauthier Lafruit (gauthier.lafruit@ulb.ac.be)**

**Madhukar Budagavi (m.budagavi@samsung.com)**

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**Contents**

[1 Scope 2](#_Toc512352879)

[2 Terminology and Definitions 3](#_Toc512352880)

[3 Introduction 4](#_Toc512352881)

[4 Use Cases 8](#_Toc512352882)

[5 Architectures and Interfaces 10](#_Toc512352883)

[6 Quality Considerations for Immersive Services 11](#_Toc512352892)

# Scope

This document is a draft of a technical report on the coded representation of Immersive Media, and constitutes the first part of the MPEG-I standard for the coded representation of immersive media.

This report:

* Defines a body of terminology - a vocabulary to be used across the MPEG-I.
* Defines the elements of an immersive experience in production and consumption, documenting minimum quality requirements as well as quality objectives for an uncompressed immersive media experience as a whole.
* Breaks down the elements that contribute to a full immersive media experience and assign quality requirements as well as quality and design objectives for those, and provides measurable metrics.
* Provides architectural views on how these elements contribute to an overall immersive experience and how they are combined.
* Defines architectural views on the compression and coded representation of elements of immersive experiences as well as the coded representation and delivery of a full media experience, taking into account the individuality of the experience, while enabling scalable and efficient individual delivery as well as mass distributiontaking into account the rendering capabilities of consumption devices. This will ensure that the various technologies to be specified in the Project can integrate seamlessly. This Technical Report can possibly lead to a normative specification.
* Documents use cases for end-to-end interoperability, including Audio, Video, Graphics and Systems aspects with capture and rendering, as well as appropriate interfaces with sensors that record navigation in the immersive audiovisual space. It also addresses suitable formats for cost-conscious delivery to mass markets.

# Terminology and Definitions

**Degrees of Freedom (DoF)** : describes the number of independent parameters used to define movement of a viewport in the 3D space.

**3DoF** : Three rotational and un-limited movements around the X, Y and Z axes (respectively pitch, yaw and roll). A typical use case is a user sitting in a chair looking at 3D 360 VR content on an HMD (see Figure 1 – 3DoF).

**3DoF+** : 3DoF with additional limited translational movements (typically, head movements) along X, Y and Z axes. A typical use case is a user sitting in a chair looking at 3D 360 VR content on an HMD with the capability to slightly move his head up/down, left/right and forward/backward (see Figure 2 - 3DoF+).

**6DoF** : 3DoF with full translational movements along X, Y and Z axes. A typical use case is a user freely walking through 3D 360 VR content (physically or via dedicated user input means) displayed on an HMD (see Figure 5 - 6DoF).

**Windowed 6DoF** : 6DoF with constrained rotational movements around X and Y axes (respectively pitch and yaw) and constrained translational movements along Z axis. A typical use case is a user watching a windowed VR content; the user cannot look outside the window frame and cannot walk through the window (see Figure 3 – Windowed 6DoF).

**Omnidirectional 6DoF** : 6DoF with constrained translational movements along X, Y and Z axes (typically, a couple of steps walking distance). A typical use case is a user freely walking through VR content (physically or via dedicated user input means) displayed on an HMD but within a constrained walking area (see Figure 4 – Omnidirectional 6DoF).

**monoscopic 360 video** : 360 video in which, at any time instant, a single image is displayed (e.g. on a web-based viewer) or both the left and right images displayed to the viewer are the same (e.g. on a head mounted display)

**stereoscopic 360 video** : a pair of 360 videos (one for the right eye and one for the left eye) which provide a natural 3D representation and support head rotation in 2 specific rotational axes (pitch and yaw).

**full 3D 360 video** : 360 video which provides a natural 3D representation (correct disparity) and supports head rotation in all three rotational axes (roll, pitch and yaw).

# Introduction

A first set of specifications is required in time for a market launch of products and services in 2018. It is highly likely that MPEG can deliver solutions that are more optimised in a longer time frame, which allows for more experiments and development. Since many believe that major market launch of VR 360 services will happen in 2020, a next set of specifications can be delivered in 2019. At the same time it is clear that there is a strong need for longer term work, notably in the video area, but possibly also in the Audio space, on 6-degrees-of-freedom content.

## MPEG-I phases

Given these results, MPEG is planning standards in support of Immersive Media, including those for 360º Audiovisual Media, to be developed in the following phases:

|  |  |  |  |
| --- | --- | --- | --- |
| Phase 1a  * Timing is what guides this phase * Goal: to deliver a Final Draft International Standard for up to 3 degrees of freedom 360 VR by end 2017. * This phase aims to deliver a complete distribution system * Audio: a 3D Audio profile of MPEG-H geared to a 360 Audiovisual experience with 3 DoF, * Transport: Basic 360 streaming, and if possible optimizations (e.g., Tiled Streaming) * Video: Adequate tiling support in HEVC (may already exist) and projection, monoscopic and stereoscopic | | cid:image001.jpg@01D2725F.2A10A840  Figure 1 – 3DoF | |
| Phase 1b  * This phase is mainly motivated by desire by a significant part of the market to launch commercial services in 2020 * It is intended for systems and services that deploy in 2020; the specification must be ready in 2019 (which may match 5G deployments) * Phase 1b will be published as an extension of the Phase 1a specification; it will focus on VR 360 with 3 DoF, with some additional depth clues, that would, for instance, allow moving the viewpoint in a limited space. (Like in phase 1a, including monoscopic and stereoscopic). * In addition, this phase is thought to comprise elements like:   + Optimization in projection mapping   + Further motion-to-photon delay reductions   + Optimizations for person-to-person communications * Unlike phase 1a, phase 1b should have some quality definition and verification | | cid:image002.jpg@01D2725F.2A10A840  Figure 2 - 3DoF+ | |
| Phase 2  * A specification that is ready in 2021 or maybe 2022 * Goal is support for windowed 6DoF, omnidirectional 6DoF and 6DoF. * Most important element probably new video codec with support for 6 DoF * Audio support for 6 degrees of freedom * Systems elements required in support of 6 DoF, as well as 3D graphics. * Support for interaction with the virtual environment | |  | |
| Figure 3 – Windowed 6DoF | Figure 4 – Omnidirectional 6DoF | | cid:image003.jpg@01D2725F.2A10A840  Figure 5 - 6DoF |

## MPEG-I parts

Different technologies are used together to build immersive services. Consequently MPEG has structured MPEG-I as a suite of standards focusing on such specific technologies. The 5 parts of MPEG-I suite of standards are:

* Part 1 – Technical Report on Immersive Media (this present document)
* Part 2 – Application Format for Omnidirectional Media
* Part 3 – Immersive Video
* Part 4 – Immersive Audio
* Part 5 – Point Cloud Compression
* Part 6 – Immersive Media Metrics
* Part 7 – Immersive Media Metadata
* Part 8 – Network-Based Media Processing (NBMP)

**Part 1 – Technical Report on Immersive Media**

This report forms the basis of the Project and investigate aspects of Immersive Media, which includes Virtual Reality, that are relevant to understand the needs for standardisation by WG11. This part is envisaged to be approved within one year.

The Technical Report will:

* Define a body of terminology - a vocabulary to be used across the Project.
* Define the elements of an immersive experience in the production and the consumption. The Technical Report will document minimum quality requirements as well as quality objectives for an uncompressed immersive media experience as a whole.
* Break down the elements that contribute to a full immersive media experience and assign quality requirements as well as quality and design objectives for those, preferably developing measurable metrics.
* Provide one or more integrated and architectural views on how these elements contribute to an overall immersive experience and how they are combined.
* Define an architectural view on the compression and coded representation of elements of immersive experiences as well as the coded representation and delivery of a full media experience, taking into account the individuality of the experience, while enabling scalable and efficient individual delivery as well as mass distribution. The representation and delivery will need to be mindful of rendering capabilities of consumption devices. This will ensure that the various technologies to be specified in the Project can integrate seamlessly. This Technical Report can possibly lead to a normative specification.
* Document standardization requirements to create interoperability in end-to-end systems. Such aspects are expected to include Audio, Video, Graphics and Systems with capture and rendering, as well as appropriate interfaces with sensors that record navigation in the immersive audiovisual space, as well as suitable formats for cost-conscious delivery to mass markets.

**Part 2 – Application Format for Omnidirectional Media**

This part defines a Media Application Format that enables storage and delivery of media content for an omnidirectional viewing experience. This part is envisaged to reach FDIS status at the end of 2017.

This part will reference technologies that include:

* Video coding profile(s), and a list of projection technologies that can be used for conversion of omnidirectional video content into a two-dimensional rectangular video;
* Immersive audio profile(s);
* Metadata for rendering and interaction;
* Encapsulation format that enable delivery using DASH and MMT

**Part 3 – Immersive Video**

This part represents the progression in visual coding technologies, to support the emerging and growing demand for higher efficiency video coding capabilities. In addition to the coding of traditional video content, this part will also address the new challenges presented by immersive video content by taking into account visual information that provides an increased sense of immersion beyond what existing video coding standards can provide. Immersion will be enabled by support of features that provide the viewer with the freedom to experience visual content with full parallax that is coherent to the movement of the user’s viewing position and point of view, as well as to the motion of the objects in the scene – that is, the standard will provide up to 6 degrees of freedom of movement for the user. These features will be supported using coding technologies that facilitate the transmission and storage over networks whose deployment are envisaged to align with the completion of this standard.

**Part 4 – Immersive Audio**

The goal of this Part is to provide audio coding for 6 degrees of freedom. Technologies may include ad-hoc sampled audio scenes that contain environmental meta-data (e.g. pertaining to acoustic characteristics) and compressed audio signals (e.g. ambient audio scenes or local audio sound sources). A more forward-looking stage is to investigate whether the capture, compressed representation and reproduction of audio sound fields is a means to providing a more realistic user experience of virtual audio presentations.

**Part 5 – Point Cloud Compression**

This Part will address compression of 3D visual media, in the form of point clouds. Point clouds can have attributes such as colors, material properties and/or other attributes. Point Clouds are typically captured using multiple cameras and depth sensors in various set-ups, however the acquisition is outside of the scope of this standard.

Point clouds typically have thousands up to billions of points to represent realistically reconstructed scenes.

The standard targets efficient geometry as well as attribute compression, scalable/progressive coding, and coding of sequences of point clouds captured over time. In addition, the compressed data format should support random access to subsets of the point cloud. The standard targets lossy compression useful for real-time communications, and lossless compression for, e.g., Geographical Information Systems, Computer-Aided Design, and cultural heritage applications. When combined with video, it enables immersive experiences that combine natural and synthetic content, and mixed reality applications.

**Part 6 – Immersive Media Metrics**

This part specifies immersive media metrics and measurement framework to enhance the immersive media quality and experiences. This part also includes a client reference model with observation and measurement points to define the interfaces for the collection of the metrics.

**Part 7 – Immersive Media Metadata**

This part specifies immersive media metadata that can be consistently used in different application and system environments. The metadata includes definition of coordinate systems, projection formats, texture-to-sphere mappings, coverage definitions, or rotation parameters.

**Part 8 – Network-Based Media Processing (NBMP)**

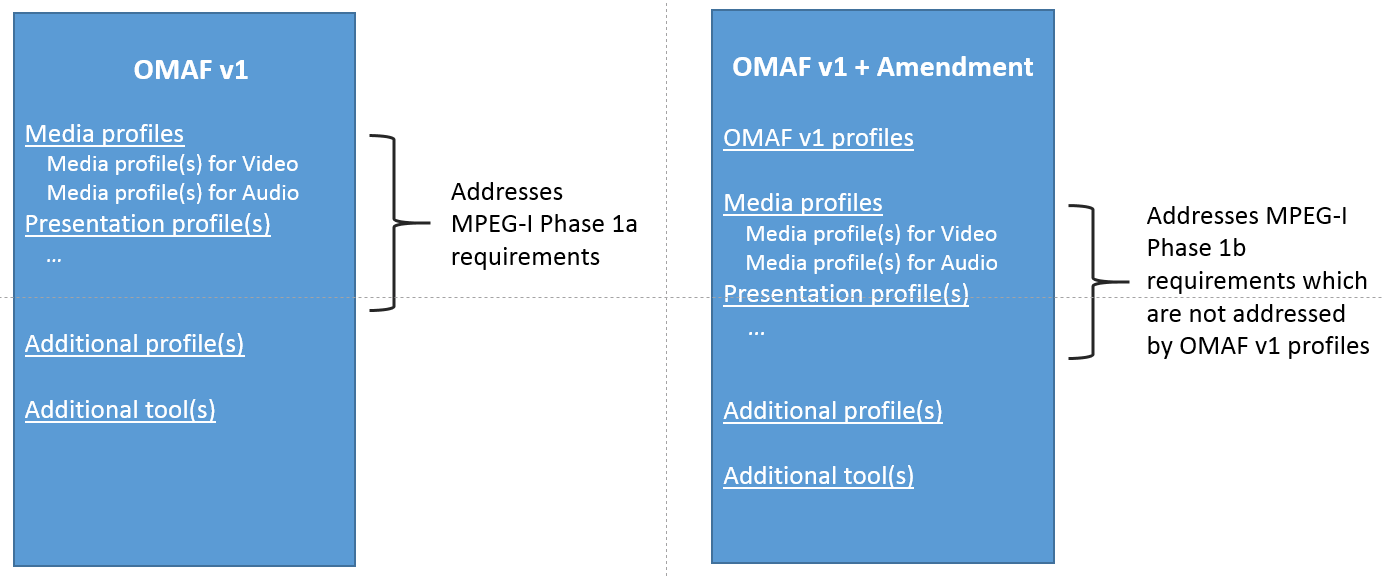
With the development of immersive technologies in MPEG-I, such as 6DoF and AR/MR, the need for extensive media processing grows significantly. To address this challenge, part 8 will specify formats and interfaces to enable offloading of resource intensive immersive media processing tasks to the network. The Network-Based Media Processing framework will define external interfaces between the Media Source and the Media Processing Entities, that will allow users of the framework to access the framework, configure media processing tasks, upload/stream media data to the network for media processing, and access the processed media and the resulting metadata in real-time or in a deferred way. Workflow management that is used to configure media processing entities and to compose media processing services as a pipeline of media processing entities, is in scope of NBMP. The media and metadata formats that are used between Media Processing Entities in a media processing pipeline are also within scope.

## Correlation between MPEG-I phases and MPEG-I parts

MPEG-I phases convey two sorts of information: a timeline and a set of requirements that needs to be addressed by MPEG-I specifcations (MPEG-I parts).

MPEG-I parts are the actual standard specifications that forms the MPEG-I suite. Consequently, device or service conformance with regards to MPEG-I shall be done with regards to specific MPEG-I parts. MPEG-I parts are likely to have their own naming. For instance, MPEG-I part 2 is known as OMAF. Finally, MPEG-I parts may contain additional technologies that are not requested by MPEG-I Phases requirements but how MPEG-I Phases requirements are met in MPEG-I parts shall be clearly identified, for instance through profiles definitions.

The following figure shows, as an example, how MPEG-I part 2 (OMAF) and MPEG-I Phase 1a and Phase 1b would relate to each other. While MPEG-I Phase 1a requirements would be addressed by media profiles and at least one presentation profile in OMAF, additional profiles and tools that are not required by Phase 1a requirements could also be defined. Similarly, Phase 1b requirements would be addressed by additional profiles in a future amendment of OMAF.



# Use Cases

This section describes main use cases for immersive media. They are used to derive requirements for immersive applications and services.

|  |  |
| --- | --- |
| Distributing 360 A/V content library in 3GPP | |
| Introduction: content library and target devices A Service provider has access to a library of 360 A/V content which is a mixture of content formats from user generated content, documentaries, promotional videos, as well as highlights of sports events. The content enables to change the field-of-view based on user interaction. The Service provider wants to create a portal to distribute the content to Head Mounted Displays that are powered by mobile devices. The service provider wants to target two types of applications:   * View on a screen with the field-of-view for the content adjusted by manual interaction (e.g. mouse input or finger swipe) * View in a HMD with head motion tracking. The Service provider expects different types of consumption and rendering devices with different capabilities in terms of decoding and rendering.   The Service provider has access to the original footage of the content and may encode and transcode it to appropriate formats. The footage includes different types of VR content, including   * For video:   + Monoscopic video, i.e. a spherical video without real depth perception.   + Stereoscopic video, i.e., a spherical video using a separate input for each eye.   + Different spatial and temporal resolutions, e.g. up to 16K and 240fps with 10 bit and 12bit as well as different colour spaces and transfer characteristics. * For audio:   + Channel-based audio | * + Object-based audio   + Scene-based audio   + Mixtures of the above   The service provider wants to reach as many devices as possible and wants to minimize the amount of different formats that need to be produced while ensuring that the content is presented in highest quality on the different devices. Specifically, the content provider wants to target existing and emerging mobile phones, for example powered by Snapdragon 821 and 835.  The service provider also wants to ensure that the original content provides consistent information that can be used by the encoding and decoding to maintain the artistic intent of the content producer. Downloading content The service provider wants to enable that a certain amount of the content can be downloaded to devices through HTTP and is played back on the device after downloading. The service provider wants to ensure that a device downloads only content that it can decode and render while providing the best user experience for the device capabilities. Non real-time broadcast distribution of VR content Many of the devices support broadcast file delivery services. The service provider agrees with a mobile network operator that certain content is pre-cached on mobile devices for offline consumption using an MBMS file delivery services. The service provider wants to ensure that MBMS delivered content can be consumed by as many devices as possible. Streaming content For certain contents, the service provider wants to ensure that content is rendered instantaneously after selection, so a DASH-based streaming is considered. The service provider wants to ensure that a device accesses only content that it can decode and render while providing the best user experience for the device's capabilities. The service provider also wants to ensure that the available bandwidth for the user is used such that the rendered content for the user is shown in the highest quality possible. |
| **Overlap with other use cases** | |
| Overlaps with OMAF objectives | |
| **Target Phase (1a, 1b, 2) :** Phase 1a, Phase 1b | |
| **Required features** | |
| * Consistent formats of the original footage including metadata * Audio and video encoding tools for 360 video and 3D audio that do not exceed capabilities of existing and emerging devices * Encapsulation tools to annotate and distribute content through ROI streaming and for broadcast * Reference decoder to rendering interfaces in order to enable rendering of 360 video and 3D audio | |
| **Identified Gaps and Optimization Potentials** | |
| * Consistent metadata for encoding * Specification for collection of audio and video encoding tools for 360 video and 3D audio that do not exceed capabilities of existing and emerging devices * Encapsulation tools to annotate and distribute content through ROI streaming and for broadcast * Reference decoder to rendering interfaces in order to enable rendering of 360 video and 3D audio | |







|  |
| --- |
| 360 3DoF+ video with depth |
| While still sitting, the user can experience full 3DoF VR experience (the three head rotation degrees of freedom are fully supported) with the addition of constrained degree of freedom on translation axis (heave, sway and surge). Such 3DoF+ experience allows the user to benefit from a true 3D experience thanks to the support of motion parallax. |
| **Overlap with other use cases** |
| Overlap with : 360 3DoF video with depth. The present use case adds the capability to have constrained movement along heave, sway and surge axis. The constraints reproduce the actual physical constraints experienced by a sitting user. |
| **Target Phase (1a, 1b, 2) :** Phase 1b |
| **Required  features** |
| 3DoF+ navigation  Depth information  Motion parallax support |
| **Identified Gaps and Optimization Potentials** |
| Quality of motion parallax perception  Experience shall not rely on heave , sway and surge sensors but benefit from them when present.  Composition of video objects with different depths. |



# Architectures and Interfaces

The following is an architecture that addresses applications that provide up to 3 degrees of freedom navigation in VR360 audiovisual media:

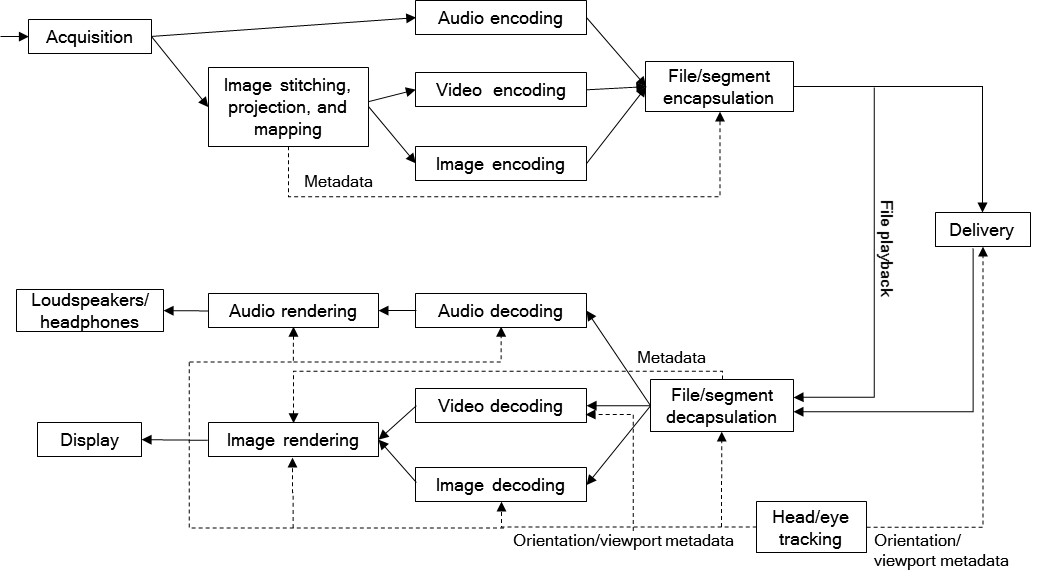


Figure 6 - Architecture for up to 3 DOF content

Figure 7 shows an architecture for navigation with 3 degrees of freedom and limited room for the user to move their head laterally. A few elements, identified in red in the figure, are added to the architecture in Figure 6

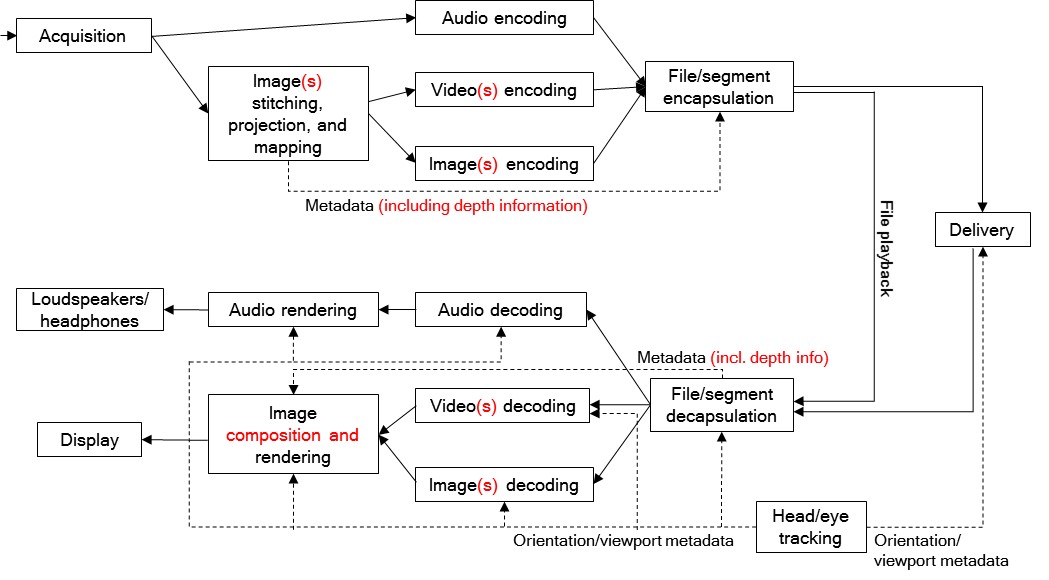


Figure 7 - Architecture for 3+ degrees of freedom media

# Quality Considerations for Immersive Services

It is well understood that VR quality builds on visual, audio and immersion quality and specific metrics in each of these three fields need to be defined to assess the overall quality of VR.

Note: The following quality considerations were established at the beginning of the MPEG-I project in early 2017 and therefore reflect what was considered at that time. With the eveolution of VR technologies and VR devices, it is likely such quality considerations need to be frequently updated. This will be done whenever a new version of this technical report is produced.

## Visual and Audio quality metrics

For traditional video, several metrics exist to assess the quality of the content: Resolution, framerate, color space, bit depth… While these metrics could be used for VR content too, they are not always appropriate and need to be adjusted to VR specificities.

Regarding video resolution, instead of using the number of pixels for an image or number of pixels per inch for a display, in VR environments the notion of number of pixels per degree is preferred. Indeed, since only a small fraction of the whole 360 environment can be seen at a time, what matters is how precisely that portion is presented to the user’s eye. The following table shows some measurements for the most popular HMDs (see http://doc-ok.org/?p=1414). For comparison, average values with traditional TV are also presented.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Device** | **Resolution** | **Maximum frame rate** | **min/max Field of View Horizontal & Vertical** | **min/max pixels per degree** |
| Samsung Gear VR | 2560x1440 | p60 | max 96° | min : 13 H & 15 V |
| Oculus Rift | 2160x1200 | p90 | 67°-96° H & 66°-107° V | 11-16 H & 11-18 V |
| HTC Vive | 2160x1200 | p90 | 76°-100° H & 77°-113° V | 11-14 H & 10.5-15.5 V |
| PlayStation®VR | 1920x1080 | p120 | max 100° | min: 9.5 H & 11 V |
| TF (Full HD) | 1920x1080 | p30 | avg : 45 H & 25 V | 43 H & 43 V |
| TV (4K) | 3840x2160 | p120 | avg : 45 H & 25 V | 86 H & 86 V |

Number of video pixels per degree (pix/deg) is indeed an essential metric for high quality VR. A minimum value of 20 pix/deg ensures that the content will always have a resolution higher than the display resolution (max is 18pix/deg with Oculus Rift). Nevertheless, compared to traditional TV this is still about 2 times less (perceived) resolution than 1080p or 4 times less than 4K.

While no HMD is capable of displaying 40pix/deg today, it is believed such a value is what would give a high quality VR perception to the user.

Another way to look at this requirement is to look at the video resolution of the image supporting the whole 4pi steradian space. Current solutions send 4K resolution to HMD which extracts a FOV that is much lower than HD (about 12-14% of the 4K image), and then upscales it to 1080 resolution for display on the HMD. That is why the perceived quality remains low today.

As shown in Figure 8, sending 4 times 4K resolution to the HMD would result in a visible viewport which surface is about 50% of a 4K image (assuming 12-14% of the 4pi steradian space is seen). This would convert in times 1080 vertical resolution for the visible viewport. While this is superior to the display resolution of current HMDs, we expect HMDs with 4K display resolution to hit the market soon.

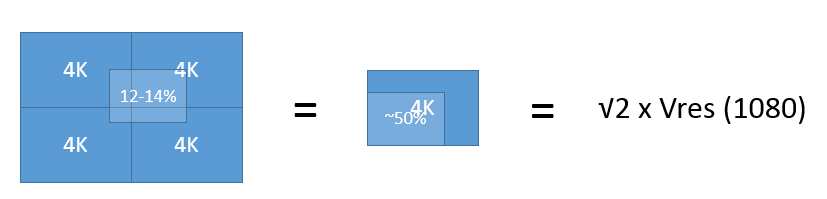


Figure 8 - video resolution & visible viewport resolution

As it is anticipated that high quality VR can be obtained when the resolution of the visible viewport is higher than the display resolution. Assuming that the visible viewport is about 12-14% of the total environment, and that the target is HMDs with a 4K display resolution, the vertical resolution of the image supporting the 4pi steradian space shall be at least about times the vertical resolution of 4K.

For practical resolutions, we propose to use 3 times the vertical 4K resolution: 11520x6480

**Quality factor #1 : pixels/degree**

**Threshold for high quality: 40 pix/deg** *(current HMDs are limited to max 20 pix/deg)*

**Quality factor #1 : video resolution for 4pi steradian space**

**Threshold for high quality: 3 times 4K vertical resolution = 11520x6480**

Regarding framerate, 90fps is what most of the HMD offer today (save from Samsung Gear VR which runs at 60fps) and is considered as a minimum. This is significantly higher than what is used for traditional video, but with HMDs, the display literally sits on the user’s nose, what makes him even more sensible to flicker. Additionally, a 90fps framerate offers a latency low enough to prevent nausea due to improper motion-to-photon latency (see Immersion metrics below).

**Quality factor #2 : framerate**

**Threshold for high quality: 90 fps**

When creating VR content, capture on a camera rig (a rigid array of cameras looking out from a central point) is often followed by a stitching process. The stitching step is one of the steps where impact on quality can be very important. Stitching consists in merging views from different cameras into a single view. Unfortunately, any glitch that may happen at the border of two adjacent views is easily spotted by the human eye and drastically lowers the perceived quality of the VR content. This step is often performed automatically by software and there are a variety of algorithms with different processing costs and quality results. From a delivery point-of-view it is important that on the receiver side no additional stitching error may be introduced.

**Quality factor #3 : stitching errors**

**Threshold for high quality: delivery and rendering processes shall not introduce additional stitching errors.**

Regarding audio quality for VR, the degree of immersion offered by various types of audio encoding is often used. At minimum, VR audio should follow head movements so that stationary sound sources appear stationary in the virtual environment, and not tied to the user’s head. Audio encodings which do support VR include: 360 surround sound, object-based audio (where audio source position is defined, and possibly updated, within the VR environment) and Ambisonics (environmental, or scene-based, audio).

**Quality factor #4 : 3D Audio**

**Threshold for high quality: support of scene-based and/or environmental audio**

## Immersion

Judging the quality of immersion is very specific to VR, and as noted above, this is with little doubt the most important metric for VR quality.

The first metric commonly used here is motion-to-photon latency. It describes how much time there is between the moment the user interacts with the content and the moment an image which responds to the interaction is presented to the user. For simple interactions, such as head movement, it defines how fast the head movement is taken into account on the display. A minimum motion-to-photon latency of 20ms is often defined today.

**Quality factor #5 : motion-to-photon latency**

**Threshold for high quality: maximum 20ms**

Similarly to video, audio 3D positioning shall have an immediate response to any user interaction (movement). Moreover, to prevent nausea, it is important to have the same responsiveness in audio as in video.

**Quality factor #5 : motion-to-audio latency**

**Threshold for high quality: maximum 20ms and same as motion-to-photon latency**

The quality of immersion can also be defined by the presence or not of techniques that strengthen the immersion of the user within a 3D Virtual environment. This is for instance the use or not of stereoscopic images or the simulation of parallax effect. Indeed by offering interactive parallax in the VR content, the user has the capability to look behind objects in the foreground as he would do in a real environment. Figure 9 shows how it is possible to look behind the figure in the foreground when interactive parallax is present whereas the same figure would seem stuck to the background when parallax is not present. Moreover, while objects in the foreground are undoubtedly improving the immersion, studies also revealed that if they are too close to the user (less than 3m) it is likely they can also become an important cause of nausea (see http://digital-library.theiet.org/content/conferences/10.1049/ibc.2016.0029;jsessionid=49ngjho83in95.x-iet-live-01). Proper balance shall be found here.

Figure 9 – Importance of parallax

Quality factor #6 : foreground & parallax

**Threshold for high quality: objects in the foreground shall be far enough to prevent nausea and interactive parallax with background shall be present for such objects**