
Information technology — Computer graphics, image processing and environment data representation — Object/environmental representation for image-based rendering in virtual/mixed and augmented reality (VR/MAR)

Technologies de l'information — Infographie, traitement d'images et représentation des données environnementales — Représentation d'objets/environnements pour l'habillage à partir d'images réelles dans la réalité virtuelle/mixte et augmentée (VR/MAR)

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Foreword

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Introduction

As virtual reality (VR) and augmented reality (AR) expand to applications in entertainment and education industries, many methods of augmenting reality to virtual space have been developed. Because of this expansion, the technology of capturing and representing objects in real environments is in high demand.

One of the proposed methods of capturing the real world is image-based representation. Image-based representation is a technique that can be used in various applications that require 3D model rendering at an arbitrary viewpoint, including virtual reality, augmented reality and video stabilization. Since image-based representation is a predominant alternative to using 3D models in the growing VR/MAR market, due to its realism, scalability, accuracy and efficiency, creating a standard for image-based representation is required.

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1 Scope

This document specifies an image-based representation model that represents target objects/environments using a set of images and optionally the underlying 3D model for accurate and efficient objects/environments representation at an arbitrary viewpoint. It is applicable to a wide range of graphic, virtual reality and mixed reality applications which require the method of representing a scene with various objects and environments.

This document:

- defines terms for image-based representation and 3D reconstruction techniques;
- specifies the required elements for image-based representation;
- specifies a method of representing the real world in the virtual space based on image-based representation;
- specifies how visible image patches can be integrated with the underlying 3D model for more accurate and rich objects/environments representation from arbitrary viewpoints;
- specifies how the proposed model allows multi-object representation;
- provides an XML based specification of the proposed representation model and an actual implementation example (see [Annex A](#)).

2 Normative references

There are no normative references in this document.

3 Terms and definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

camera parameter

extrinsic/external and intrinsic/internal attribute value of a (virtual or real) camera that describes the mathematical relationship between the 3D coordinates of a point in the world space and the 2D coordinates of its projection onto the image space

3.1.2

image patch

set of connected pixels of an image that has the same visibility information

Note 1 to entry: Image patch is synonymous to image.

3.1.3

tessellation

process of dividing a face into sub-faces using sub-sampled vertices to attain enhanced visibility detection

3.1.4

viewpoint

rotation and position with respect to the reference coordinate system that determines visible parts of a 3D model in a representation system

Note 1 to entry: “Viewpoint” is different from “Camera (parameters)” in that it only includes the camera position and pose, where as the “Camera” has more information such as the internal *camera parameters* (3.1.1) including the focal length, field of view, near/far planes and skew parameters.

3.1.5

virtual image

image at an arbitrary *viewpoint* (3.1.4) that is generated by collecting visible photo information from real images

3.1.6

world reference frame

coordinate reference frame used to express positions/orientations of the camera, 3D models and other objects for a given scene

3.2 Abbreviated terms

IBR	image-based rendering
XML	extensible markup language
XSD	XML schema definition

4 Domain and concepts

4.1 General

This clause describes the domain and key concepts. This includes the domain of image-based representation of objects/environments and overall description of its details.

4.2 Domain

Geometric and optionally photometric information is essential when representing target objects/environments as is done in ISO/IEC 19775-1. In this document, an alternative representation method, image-based, is pursued in which the objects/environments are represented only using the photogrammetric information (e.g. set of images and other related information) and optionally the underlying 3D geometric information.

Therefore, the image-based representation of objects/environments first requires a set of images and their photogrammetric information of the target objects/environments taken at various locations, and the 3D model represented using vertices and faces and the association between these two (if needed). [Figure 1](#) shows the overall scene as represented a set of images (below), which have association to the 3D model (top). Note that with photogrammetric information alone, it is possible to render the target objects/environments from an arbitrary viewpoint by using and blending the sampled images around.

The association to the underlying 3D model, if it exists, can make the rendering output more accurate by helping to resolve visibility issues and registration errors.

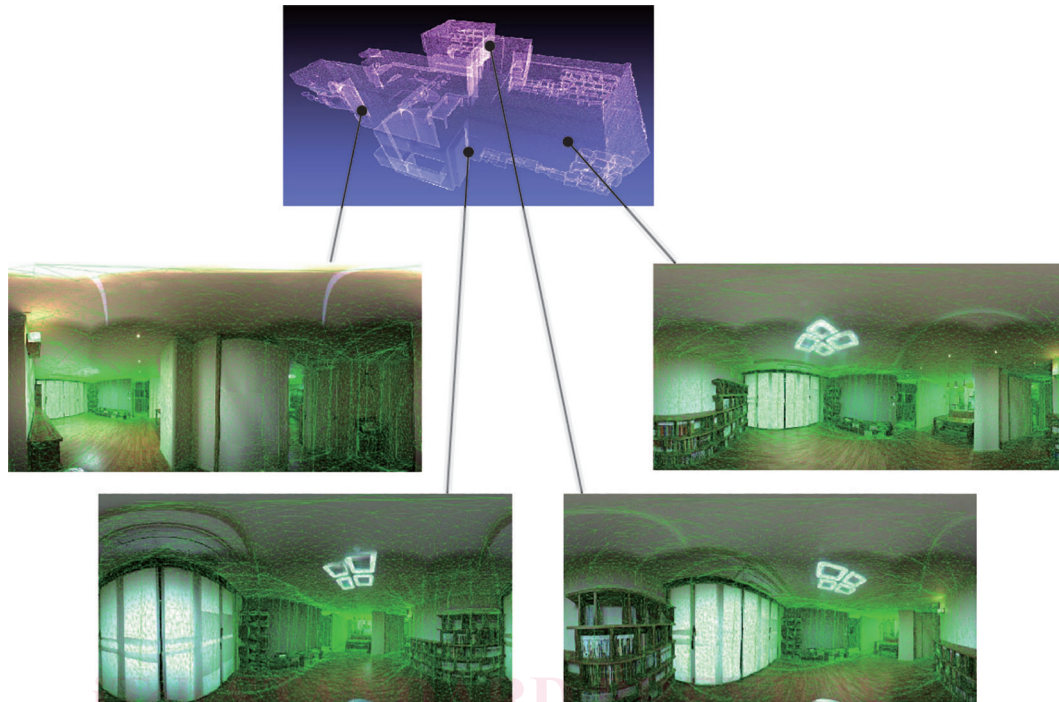


Figure 1 — Example of a 3D model and image set for target environment representation

To be more specific, because there are multiple blind spots in a wide and large environment that a single image cannot display, a combination of images is necessary to fully represent the whole target objects/environments without any such blind spots. Thus, to accurately associate the 3D model with the image set, each face of the 3D model is verified to be visible or not in each image of the image set. Then, the target objects/environments can be represented at an arbitrary viewpoint using only the visible image patches from different images^{[6],[7]}. Specifically, the colour value of each face of the 3D model is determined from the corresponding visible image patches. After that, the determined colour values can be blended into a single virtual image to represent the target objects/environments at any arbitrary viewpoint.

In this regard, this document concerns the basic image-based objects/environments representation approach that uses only the images (or photogrammetric information) but also the usage and association of multiple images to the underlying 3D model for resolving the visibility of each face from where the images are taken and thereby making the rendering system more accurate and efficient. If the 3D model is used along with the image-based one, the resulting virtual or mixed reality world can be not only more photorealistic, but with the 3D depth information, more interesting interaction becomes possible.

4.3 Concepts

A key part of image-based representation is representing the photogrammetric information of target objects/environments which is the basis of the proposed information model. Then the next is the optional part as how to associate each face of the 3D model with visible image patches of the image set. By associating each face with visible image patches, the photometric information of the visible image patches can be accurately overlaid to each face of 3D model.

For this purpose, visibility of the 3D model's vertex/face at each image, which can be acquired using a visibility/occlusion detection algorithm like z-buffering^[4], is first computed ahead of time (and added to the representation). Regarding visibility detection, the vertices/faces can be tessellated to improve visibility detection results in the case that the 3D model consists of sparse vertices.

Then, with the computed visibility information, objects/environments can be represented by connecting each face of the 3D model with the corresponding visible image patches. If a face has multiple visible image patches that can be mapped as texture, the photometric information of the face can be computed by, for example, selecting the best image patch among the candidates or by weighting the photometric information of multiple visible image patches. For the former case, to select one source image for the given face, the distance to the position where the image is captured, the area of the image, the texture quality (how well focused or blurriness) of the image can be considered. For the latter case, the aforementioned criteria can be used to derive relative weights in blending them into a virtual image texture as seen from an arbitrary viewpoint (see [Figure 2](#)).

4.4 Basic components

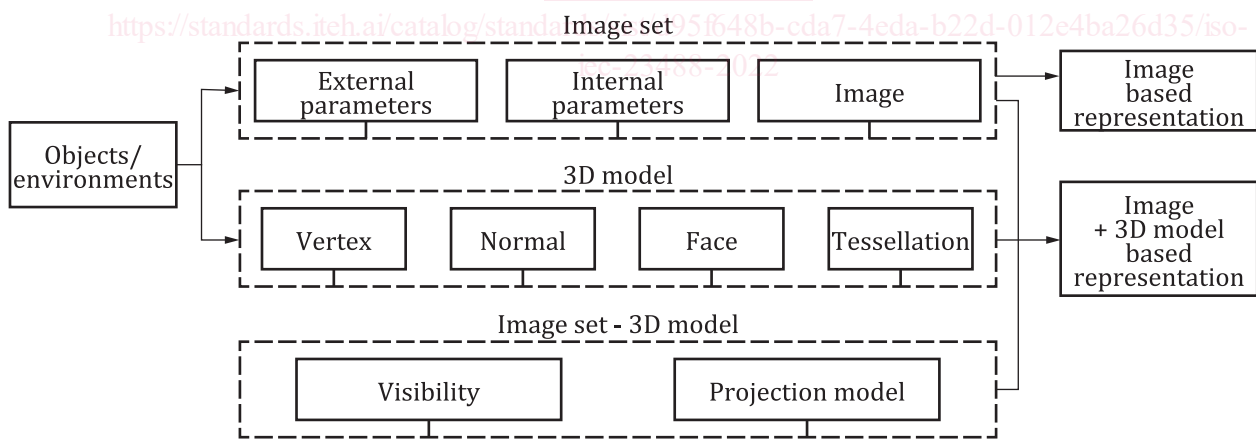
4.4.1 General

This subclause describes details of image-based representation. This includes explanation of the two key elements of image-based representation (image set and underlying 3D model), and their integration as in [Figure 2](#).

4.4.2 Image set

4.4.2.1 General

An image set consists of images capturing the photometric information of target objects/environments at different locations. The images can be taken by different entities using different hardware, allowing the usage of virtual and real images. Also, to project the images to a 3D model, it shall be augmented with the external parameters (rotation and translation) and the camera's internal parameters (focal length, resolution, aspect ratio, etc.). Using the external and internal parameters, a vertex or face of the 3D model can be projected onto the image and visibility information can be acquired, all of which are used to visualize a 3D model with multiple textures at an arbitrary viewpoint.



Visibility should be changed according to changing viewpoint and visibility of a candidate patch considered for the final image blend would be determined by a visibility/occlusion algorithm like z-buffering^[4] and back-face culling.

Figure 2 — Abstraction of image-based representation

4.4.2.2 Image

An image contains the photometric information of the target objects/environments. The photometric information can be depicted using any image format, including PNG, JPG, JPEG and TIFF. The photometric information also includes a colour model, which can be represented as RGB, HSL, or HSV. To acquire an image, there shall be no limits on the camera model, including pinhole, fisheye, cubemap, spherical and

cylindrical models, as long as a projection model between the image and the 3D model can be formed. Further description of the projection model is given in [4.4.4.3](#).

4.4.2.3 Camera external parameters

Camera external parameters are the rotation and translation of a camera when it captures an image with respect to the world reference frame. Thus, the number of camera external parameter sets is equal to the number of images used in rendering system. The camera external parameters transform the vertices of a 3D model to the camera coordinate system. Explicitly, the camera external parameters can be represented as a 3-by-4 matrix using floating points where the left 3-by-3 matrix represents a rotation matrix and the right 3-by-1 vector represents a translation^[5].

4.4.2.4 Camera internal parameters

Camera internal parameters geometrically describe how the target objects/environments around the camera are projected to an image. Thus, they can be used to project vertices of a 3D model, with respect to the camera coordinate system, to the image. The set of internal parameters depends on the projection model of the camera, which can be pinhole, fisheye, cubemap, spherical and cylindrical models, depending on the hardware characteristics of the camera. Each camera in the IBR capture system has a single set of internal parameters associated with one lens. Thus, for an IBR capture system with n cameras, where each camera has one or multiple lenses, there can be a total of n or more internal parameter sets.

4.4.3 3D model

4.4.3.1 General

A 3D model contains the geometric information of the target environment as stated in [4.2](#). In this document, a 3D model is represented by a 3D mesh which consists of four main parts: vertex, normal, face, and tessellation. The vertex and normal values together mark a single point in the 3D space. These points are connected as triangles to form the face of the mesh structure. If a face is not occluded by other faces at a viewpoint, the face and the corresponding vertices are considered visible at the viewpoint. If tessellation is necessary, each face is split into sub-faces and the visibility at a viewpoint is recalculated.

4.4.3.2 Vertex

A vertex refers to a point in two or three dimensional space. Among its attributes, the vertex position is written in floating points with respect to the world reference frame. A vertex can be projected to an image through external and internal camera parameters as in [4.4.4.3](#).

4.4.3.3 Face

A face represents a polygon formed by a collection of vertices. A face requires all vertices in the polygon to be coplanar. The simplest polygon is the triangle with three vertices which are guaranteed to be coplanar. A face can be projected to an image through external and internal parameters as in [4.4.4.3](#).

4.4.3.4 Normal

A vertex normal at a vertex of a polyhedron is a directional vector associated with a vertex, intended as a replacement to the true geometric normal of the surface. Commonly, it is computed as the normalized average of the surface normals of the faces that contain that vertex. Thus, there shall be the same number of vertex normal values as the number of vertices. This vertex normal can be used to shade a 3D model when rendering a target object/environment. It also allows compression of the object's surface. Face normal vectors perpendicular to a face can be computed using the vertex normals of the face. Multiple faces whose normal vectors are similar (relatively flat and almost coplanar) can be simplified into a single larger face with the averaged normal vector.