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Information technology — Computer graphics, image processing and environmental data representation — Mixed and augmented reality (MAR) reference model

Technologies de l'information — Infographie, traitement de l'image et représentation des données environnementales — Modèle de référence en réalité mixte et augmentée

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 24, *Computer graphics, image processing and environmental data representation*.

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Introduction

This document contains annexes:

— Annex A gives examples of existing MAR solutions and technologies and how they fit into the MAR reference model.

— Annex B gives examples of representative MAR systems and how their architecture maps to the MAR reference model.

Information technology — Computer graphics, image processing and environmental data representation — Mixed and augmented reality (MAR) reference model

1 Scope

This document defines the scope and key concepts of mixed and augmented reality, the relevant terms and their definitions and a generalized system architecture that together serve as a reference model for mixed and augmented reality (MAR) applications, components, systems, services and specifications. This architectural reference model establishes the set of required sub-modules and their minimum functions, the associated information content and the information models to be provided and/or supported by a compliant MAR system.

The reference model is intended for use by current and future developers of MAR applications, components, systems, services or specifications to describe, compare, contrast and communicate their architectural design and implementation. The MAR reference model is designed to apply to MAR systems independent of specific algorithms, implementation methods, computational platforms, display systems and sensors or devices used.

This document does not specify how a particular MAR application, component, system, service or specification is designed, developed or implemented. It does not specify the bindings of those designs and concepts to programming languages or the encoding of MAR information through any coding technique or interchange format. This document contains a list of representative system classes and use cases with respect to the reference model.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
augmentation
virtual object (3.1.24) data (computer-generated, synthetic) added on to or associated with target *physical object* (3.1.15) data (live video, real world image) in an *MAR scene* (3.1.9)

Note 1 to entry: This equally applies to physical object data added on to or associated with target virtual object data.

3.1.2
augmented reality
type of *mixed reality system* (3.1.13) in which *virtual world* (3.1.25) data are embedded and/or registered with the representation of *physical world* (3.1.16) data

3.1.3
augmented virtuality system
type of *mixed reality system* (3.1.13) in which *physical world* (3.1.16) data are embedded and/or registered with the representation of *virtual world* (3.1.25) data

3.1.4
display
device by which rendering results are presented to a user using various modalities such as visual, auditory, haptics, olfactory, thermal, motion

Note 1 to entry: In addition, any actuator can be considered display if it is controlled by MAR system.

3.1.5
feature
primitive geometric element (e.g. points, lines, polygons, colour, texture, shapes) and/or attribute of a given (usually physical) object used in its detection, recognition and tracking

3.1.6
MAR event
trigger resulting from the detection of a condition relevant to MAR content and *augmentation* (3.1.1)

EXAMPLE Detection of a marker.

3.1.7
MAR execution engine
collection of hardware and software elements that produce the result of combining components that represent on the one hand the real world and its objects, and on the other those that are virtual, synthetic and computer generated

3.1.8
MAR experience
human visualization and interaction of an *MAR scene* (3.1.9)

3.1.9
MAR scene
observable spatio-temporal organization of physical and *virtual objects* (3.1.24) which is the result of an *MAR scene representation* (3.1.10) being interpreted by an *MAR execution engine* (3.1.7) and which has at least one *physical* (3.1.15) and one virtual object

3.1.10
MAR scene representation
data structure that arranges the logical and spatial representation of a graphical scene, including the *physical* (3.1.15) and *virtual objects* (3.1.24) that are used by the *MAR execution engine* (3.1.7) to produce an *MAR scene* (3.1.9)

3.1.11
marker
metadata embedded in or associated with a *physical object* (3.1.15) that specifies the location of a super-imposed object

3.1.12
MAR continuum
spectrum spanning physical and virtual realities according to a proportional composition of physical and virtual data representations

Note 1 to entry: Originally proposed by Milgram et al.[1].

3.1.13
mixed reality system
mixed and augmented reality system
system that uses a mixture of representations of *physical world* (3.1.16) data and *virtual world* (3.1.25) data as its presentation medium

3.1.14
natural feature
feature (3.1.5) that is not artificially inserted for the purpose of easy detection/recognition/tracking

3.1.15
physical object
real object
object that exists in the real world

3.1.16
physical world
physical reality spatial organization of multiple *physical objects* (3.1.15)

3.1.17
point of interest
single or collection of target locations

Note 1 to entry: Aside from location data, a point of interest is usually associated with metadata such as identifier and other location specific information.

3.1.18
recognizer
MAR component (hardware and software) that processes *sensor* (3.1.19) output and generates *MAR events* (3.1.6) based on conditions indicated by the content creator

3.1.19
sensor
device that returns detected values related to detected or measured condition or property

Note 1 to entry: Sensor may be an aggregate of sensors.

3.1.20
spatial registration
establishment of the spatial relationship or mapping between two models, typically between *virtual object* (3.1.24) and target *physical object* (3.1.15)

3.1.21
target image
target object (3.1.22) represented by a 2D image

3.1.22
target object
physical (3.1.15) or *virtual object* (3.1.24) that is designated, designed or chosen to allow detection, recognition and tracking, and finally *augmentation* (3.1.1)

3.1.23
tracker
MAR component (hardware and software) that analyses signals from *sensors* (3.1.19) and provides some characteristics of tracked entity (e.g. position, orientation, amplitude, profile)

3.1.24
virtual object
computer-generated entity that is designated for *augmentation* (3.1.1) in association with a *physical object* (3.1.15) data representation

Note 1 to entry: In the context of MAR, it usually has perceptual (e.g. visual, aural) characteristics and, optionally, dynamic reactive behaviour.

3.1.25
virtual world
virtual environment
spatial organization of multiple *virtual objects* (3.1.24), potentially including global behaviour

3.2 Abbreviated terms

Abbreviated term	Definition
API	Application program interface
AR	Augmented reality
AVH	Audio, visual, haptic
GNSS	Global navigation satellite system
MAR	Mixed and augmented reality
MAR-RM	Mixed and augmented reality reference model
MR	Mixed reality
POI	Points of interest
PTAM	Parallel tracking and mapping
SLAM	Simultaneous localization and mapping
UI	User interface
VR	Virtual reality

4 Mixed and augmented reality (MAR) domain and concepts

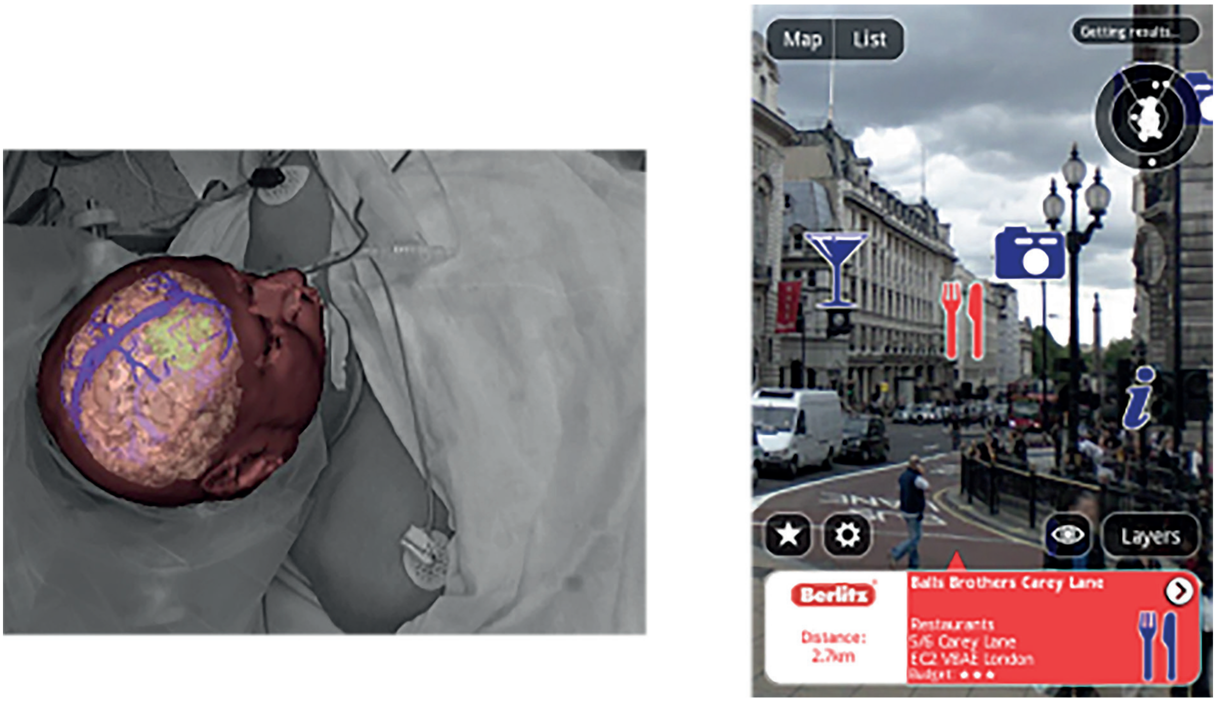
4.1 General

MAR refers to a spatially coordinated combination of media/information components that represent on the one hand the real world and its objects, and on the other those that are virtual, synthetic and computer generated. The virtual component can be represented and presented in many modalities (e.g. visual, aural, touch, haptic, olfactory) as illustrated in Figure 1. The figure shows an MAR system in which a virtual fish is augmented above a real world object (registered by using markers), visually, aurally and haptically.

SOURCE Magic Vision Lab, University of South Australia, reproduced with the permission of the authors

Figure 1 — The concept of MAR as a combination of representations of physical objects and computer mediated virtual objects in various modalities (e.g. text, voice and force feedback)

Through such combinations, the physical (or virtual) object can be presented in an information-rich fashion through augmentation with the virtual (or real) counterpart. Thus, the idea of spatially-coordinated combination is important for highlighting the mutual association between the physical and virtual worlds. This is also often referred to as registration and can be done in various dimensions. The most typical registration is spatial, where the position and orientation of a real object are computed and used to control the position and orientation of a virtual object. Temporal registration can also occur when the presence of a real object is detected and a virtual object is to be displayed. Registration can have various precision performances; it can vary in its degree of tightness (as illustrated in Figure 2). For example, in the spatial dimension, it can be measured in terms of distance or angles; in the temporal dimension, in terms of milliseconds.



NOTE Virtual brain imagery tightly registered on a real human body image is shown on the left-hand side[2] and tourist information overlaid less tightly over a street scene[3] is shown on the right-hand side.

Figure 2 — The notion of registration precision at different degrees

An MAR system refers to real-time processing[4]. For example, while a live close-captioned broadcast would qualify as an MAR service, an offline production of a subtitled movie would not.

4.2 MAR continuum

Since an MAR system or its contents combines real and virtual components, an MAR continuum can be defined according to the relative proportion of the real and virtual, encompassing the physical reality ("All physical, no virtual") on one end and the VR ("All virtual, no physical") on the other end (as illustrated in Figure 3). A single instance of a system at any point on this continuum[1] that uses a mixture of both real and virtual presentation media is called an MR system. In addition, for historical reasons, MR is often synonymously or interchangeably used with AR, which is actually a particular type of MR (see Clause 7). In this document, the term "mixed and augmented reality" is used to avoid such confusion and emphasize that the same model applies to all combinations of real and digital components along the continuum. The two extreme ends in the continuum (the physical reality and the VR) are not in the scope of this document.

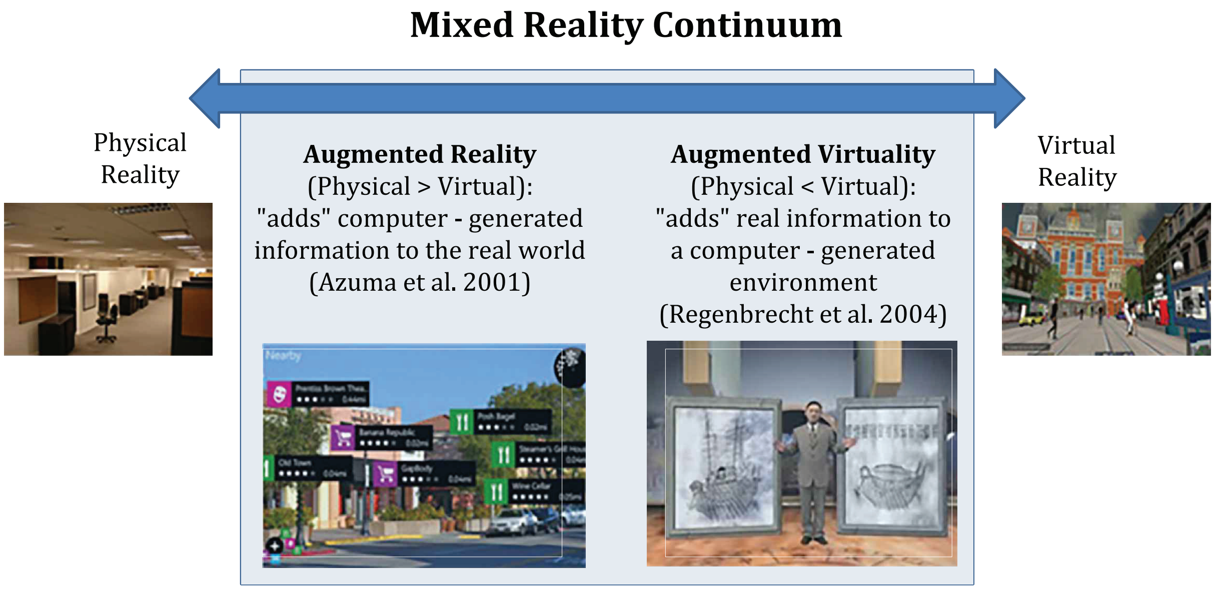


Figure 3 — The MAR (or reality-virtuality) continuum[1]: definition of different types of MR according to the relative portion between the real world representation and the virtual

Two notable types of MAR or points in the continuum are the AR and augmented virtuality. An AR system is a type of mixed reality system in which the medium representing the virtual objects is embedded into the medium representing the physical world (e.g. video). In this case, the physical reality makes up a larger proportion of the final composition than the computer-generated information. An augmented virtuality system is a type of MR system in which the medium representing physical objects (e.g. video) is embedded into the computer-generated information (as illustrated in Figure 3).

5 MAR reference model usage example

5.1 Designing an MAR application or service

The MAR reference model is a reference guide in designing an MAR service and developing an MAR system, application or content. With respect to the given application (or service) requirements, the designer may refer to and select the necessary components from those specified in the MAR reference architecture (see Clause 6). The functionalities, the interconnections between components, the data/information model for input and output, and relevant existing standards for various parts can be cross-checked to ensure generality and completeness. The component classification scheme described in Clause 7 can help the designer to specify a more precise scope and capabilities, while the specific system classes defined in Clause 8 can facilitate the process of model, system or service refinement.

5.2 Deriving an MAR business model

The MAR-RM document introduces an enterprise viewpoint with the objective of specifying the industrial ecosystem, identifying the types of actors and describing various value chains. A set of business requirements is also expressed. Based on this viewpoint, companies may identify current business models or invent new ones.

5.3 Extending existing or creating new standards for MAR

Another expected usage of the MAR-RM is in extending or creating new application standards for MAR functionalities. MAR is an interdisciplinary application domain involving many different technologies, solutions and information models, and naturally there are ample opportunities for extending existing technology solutions and standards for MAR. The MAR-RM can be used to match and identify components for those that can require extension and/or new standardization. The computational and information models can provide the initial and minimum basis for such extensions or for new standards. In addition, strategic plans for future standardization can be made. In the case when competing de facto standards exist, the reference model can be used to make comparisons and evaluate their completeness and generality. Based on this analysis and the maturity of the standards, incorporation of de facto standards into open ones may be considered (e.g. markers, API, POI constructs).

6 MAR reference system architecture

6.1 Overview

An MAR system requires several different components to fulfil its basic objectives: real-time recognition of the physical world context, the registration of target physical objects with their corresponding virtual objects, display of MAR content and handling of user interaction(s). A high-level representation of the typical components of an MAR system is given in Figure 4. The central pink area indicates the scope of the MAR-RM. The blue round boxes are the main computational modules and the dotted box represents the required information constructs. Arrows indicate data flow. Control signals are not explicitly shown, to avoid particular technical or implementation details in this document. Also, this reference system architecture should not to be taken as something rigid and unchangeable, but as a depiction of a typical case at the macro scale. Flexibility exists in actual application.

The MAR execution engine has a key role in the overall architecture and is responsible for:

— processing the content as specified and expressed in the MAR scene, including additional media content provided in media assets;

— processing the user input(s);

— processing the context provided by the sensors capturing the real world;

— managing the presentation of the final result (aural, visual, haptic and commands to additional actuators); and

— managing the communication with additional services.

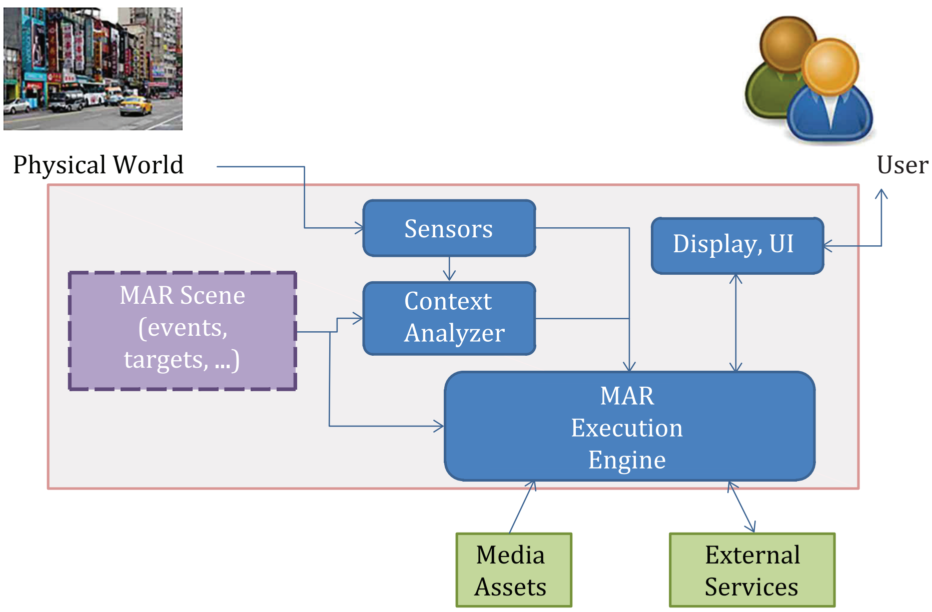


Figure 4 — Major components and their interconnection in an MAR system at a high macro level

6.2 Viewpoints

In order to detail the global architecture presented in Figure 4, the reference model considers three analysis angles, called viewpoints: enterprise, computation and information. This viewpoint-wise exposition permits readers, who can be interested in or focused on particular aspects or viewpoints, to better understand the MAR architecture. The definition of each viewpoint is provided in Table 1. In this subclause, the terms "view" and "viewpoint" are used in the context of information modelling and establishing a reference architecture. They should not be confused with the same term that refers to the location of the virtual camera in computer graphics or virtual environments.

The notion of view is separate from that of the viewpoint: a viewpoint identifies the set of concerns, representations and modelling techniques used to describe the architecture to address those concerns, and a view is the result of applying a viewpoint to a particular system[5].

Table 1 — Definitions of the MAR viewpoints

Viewpoint	Viewpoint definition	Topics covered by MAR-RM
Enterprise	Articulates the business entities in the system that should be understandable by all stakeholders. This focuses on purpose, scope and policies, and introduces the objectives of different actors involved in the field.	Actors and their roles. Potential business models for each actor. Desirable characteristics for the actors at both ends of the value chain (creators and users).
Computational	Identifies the functionalities of system components and their interfaces. Specifies the services and protocols that each component exposes to the environment.	Services provided by each AR main component. Interface description for some use cases.
Information	Provides the semantics of information in the different components in the views, the overall structure and abstract content type, as well as information sources. Describes how the information is processed inside each component. This view does not provide a full semantic and syntax of data but only a minimum of functional elements, and should be used to guide the application developer or standard creator for creating their own information structures.	Context information such as spatial registration, captured video and audio. Content information such as virtual objects, application behaviour and user interaction(s) management. Service information such as remote processing of the context data.

6.3 Enterprise viewpoint

6.3.1 General

The Enterprise viewpoint (see Figure 5) describes the actors involved in an MAR system, their objectives, roles and requirements. The actors can be classified according to their role. Several types of actors from the list in 6.3.2 can commercially exploit an MAR system.