3D lexicon for Human and Social Sciences

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Huma-Num CONSORTIUM 3D

RECOMMENDATIONS OF THE "CONSORTIUM 3D" FOR THE HUMANITIES

3D VOCABULARY

3D LEXICON FOR HUMAN AND SOCIAL SCIENCES

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TABLE OF CONTENTS

1. INDEX

2. PREAMBLE

This document is the result of an ongoing effort to enable SSH and 3D actors to interact around a common vocabulary. This lexicon is intended to accompany the different deliverables of the 3D consortium. It is also intended to help enrich TaDiRAH[1], "Taxonomy of Digital Research Activities in the Humanities", which is part of the European consortium DARIAH. This continuous nature of this process is illustrated by the fact that this is the second version of this document [1].

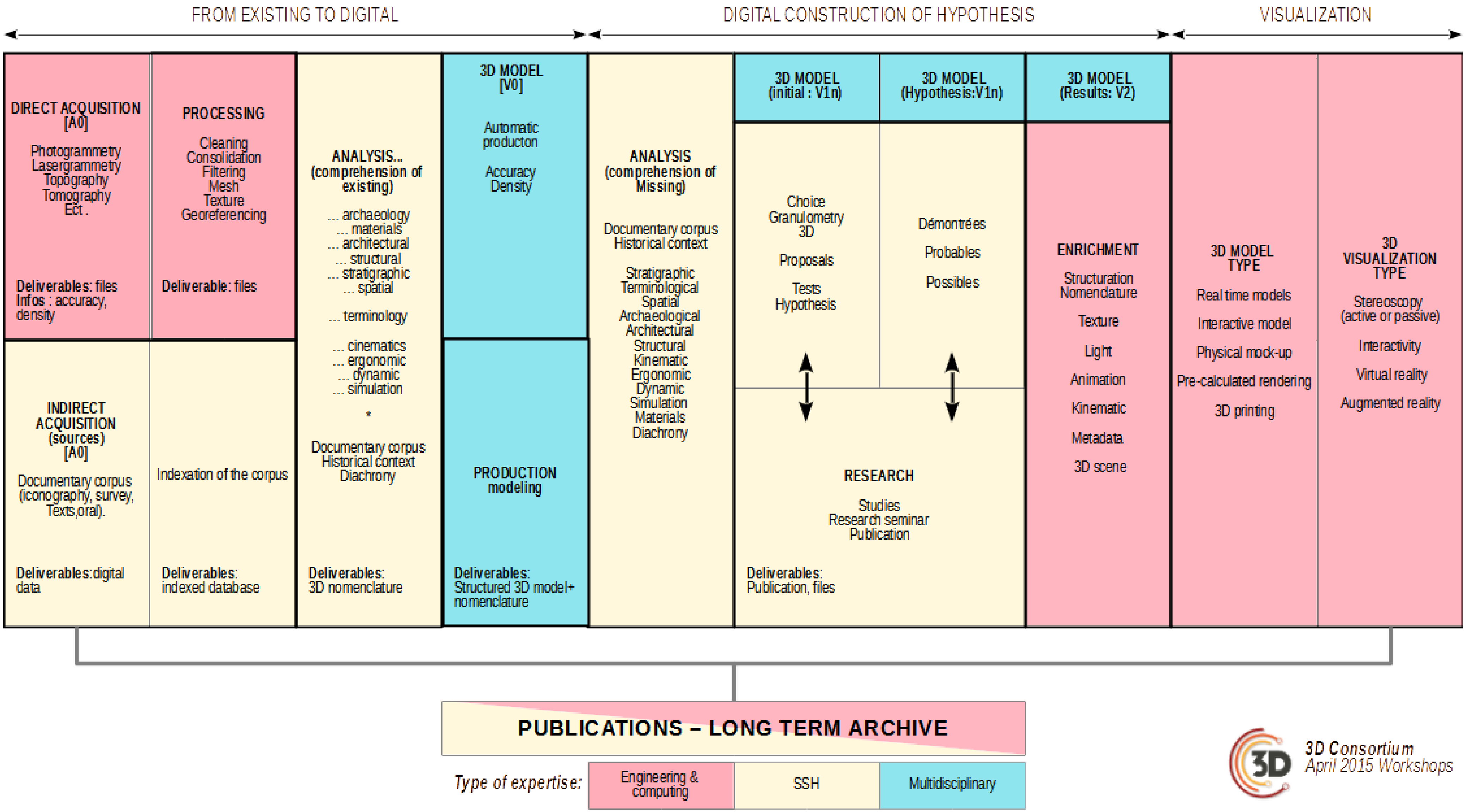
This effort to define common concepts is based on two tools. The first is the 3D data sequence graph (Figure 2). It presents the steps of the production process in a simplified way. The system of the graph has been defined to follow a logical path with notably the use of loops to express the recursive aspect of the work on data, especially during the hypothesis and restitution stages. The archiving, which is the subject of the white paper dedicated "Perennial archiving of 3D digital data for humanities and social sciences", is present at all levels.

The lexicon that we are proposing has been built with the aim of clarifying and specifying, and not to entirely redefine the notions related to digital heritage. Existing definitions have thus been adapted to the practice of 3D in SSH, and more specifically to heritage. The aim was to focus on a few essential definitions, categorized by steps and sub-steps, in accordance with the sequential graph rather than to rebuild a complete dictionary.

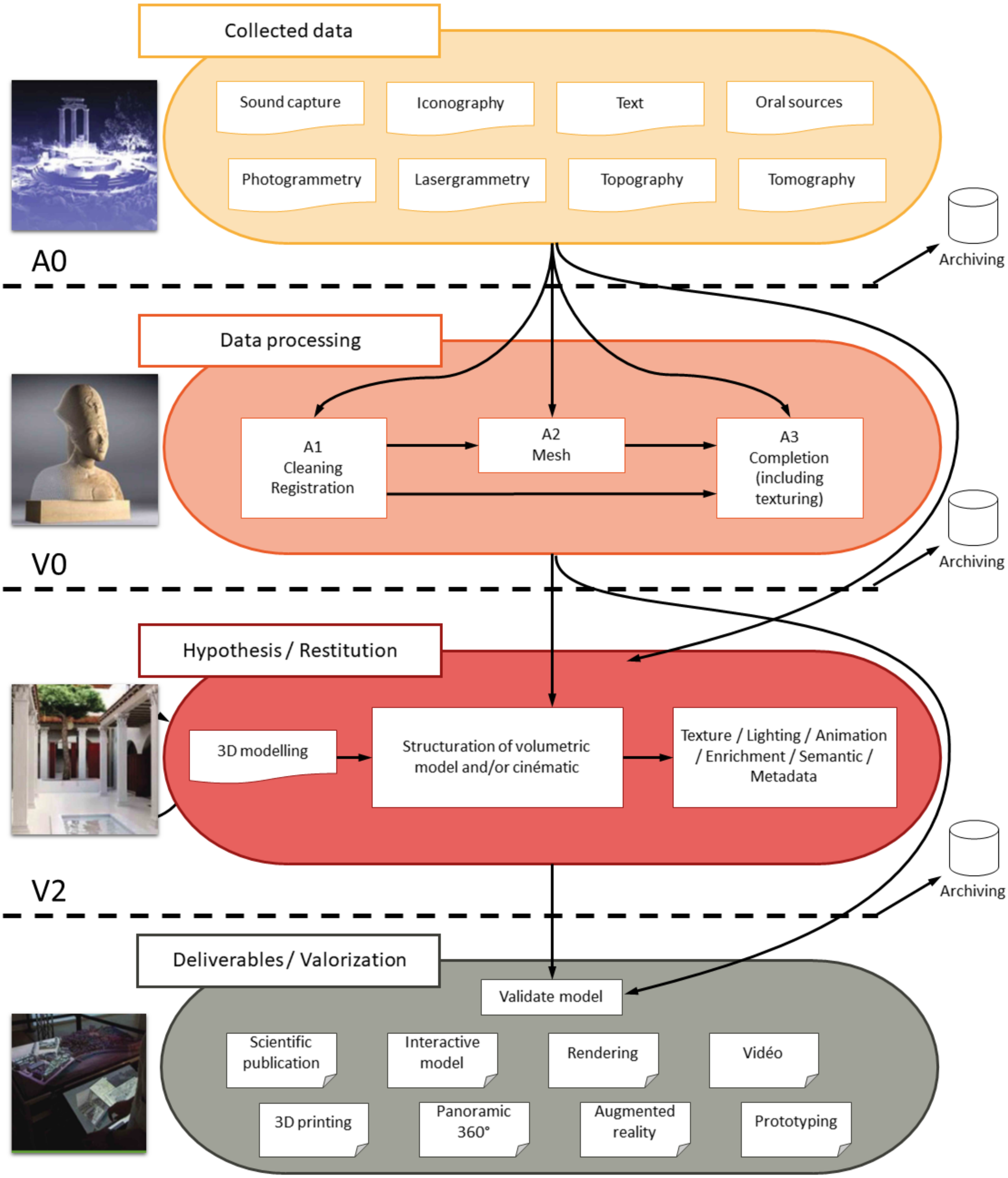
Questions arise when working on such a document. For example, it is necessary to recapitulate the objectives of SSH research by specifying the notions of recording and scientific study, as understood in the digitization of heritage. It is also necessary to try to remove semantic ambiguities such as, for example, the one that exists that between virtual reality and 3D with the necessary distinction between interactive mock-up and pre-calculated rendering. We also wanted to distinguish the stages of the model creation process by defining the terms consolidation and cleaning. The need emerged to clarify terms that are increasingly used in our domains like metadata or paradata, in order to avoid their use in a roundabout or misunderstood sense. Finally, we tried to clarify other terms and adapt definitions to the world of 3D in SSH, such as the notion of restitution.

[1] http://tadirah.dariah.eu/vocab/index.php

Table of 3D pratices in SSH



Sequential graph of 3D data production



3. FUNDAMENTAL 3D CONCEPTS

3.1 Geometry

In this section, we first discuss all the properties that define an object by the position and volume it occupies in a 3D environment. For original definitions in Computer Graphics and 3D, the reader may refer to the book "Computer Graphics: Principles and Practice" [2]

3D point:

A 3D point corresponds to a position in a 3 dimensional space (i.e. with three values or coordinates, often denoted by X, Y and Z). This 3D point can also be associated with other information valued at this position (see normal, color)

Point cloud:

A simple list of 3D points without creating any structure to link them (Figure 3).

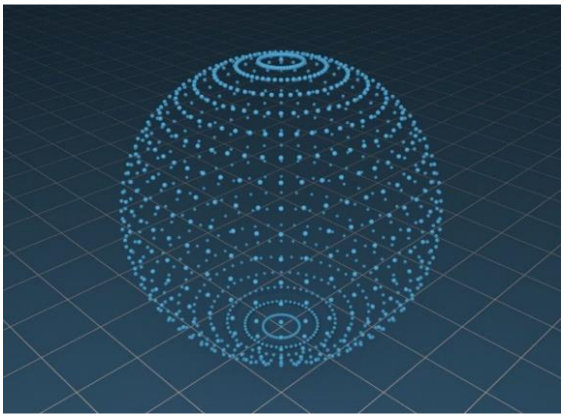


Figure 3 – Point cloud on a sphere

Mesh:

A mesh is a list of 3D polygons that are a set of linked 3D points spanning on a common plane. The 3D points are thus named vertices (Figure 4). The most common polygon is a triangle with three vertices. The links between the points give a structured version of the 3D point cloud.

It is important to note that there are several possibilities for creating a mesh from a given set of points (Figure 5): the result of the meshing process of a point cloud depends on a number of implicit assumptions. Some choices can be left to the user a priori or a posteriori to opt for more relevant solutions than the automatic ones.

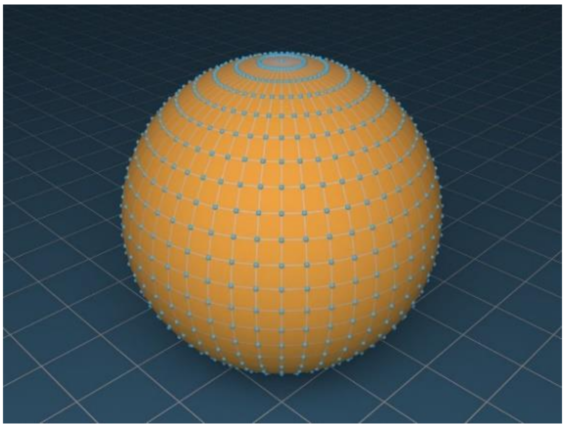


Figure 4– Mesh obtained from the point cloud from figure 3

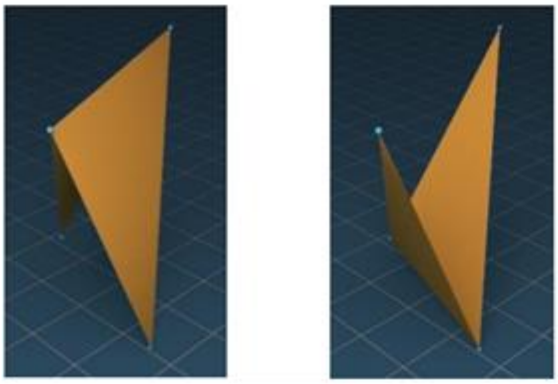


Figure 5 – Two meshes of the same quality obtained from the same four 3D points.

Normal of 3D point:

Orientation of the surface passing through a 3D point. For a manifold surface, it points outwards (Figure 6).

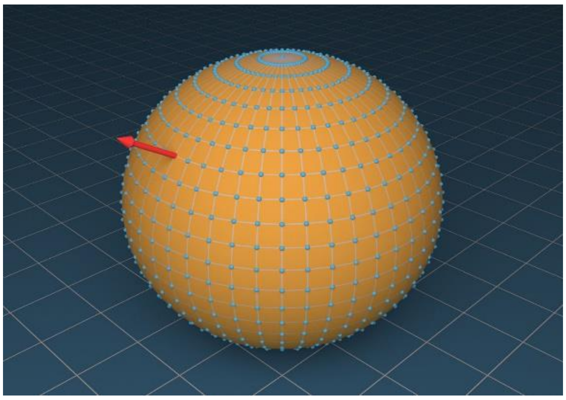


Figure 6 – The normal (red vector) indicates on the selected point the orientation of the surface (here a sphere).

Volume:

In Computer Graphics, a volume is a 3D data that is not simply characterized by its surface, but by all the variations that can occur within this surface (see tomography). For the SSH, volume often refers to the occupation of an object in space.

3.2 Appearance & Color

Everything that helps to define what we see of an object beyond its position in space and, in its digitized version, all the data that allows us to produce a visualization of it once again, beyond simple geometry (for example, for the restitution of polychromy - Figure 7). Basically, this can be the color associated with each 3D point.

Color:

According to Lexico from Oxford, color includes many notions, ranging from the sensation on an eye of the reflected light on an object, to the pigments. In the 3D community, the notion of color mainly refers to the value that can be displayed on a screen or measured with a camera. It is often a red-green-blue (RGB) triplet.

Color by vertex:

A color can be associated with each 3D point. It represents either a directly displayable color or a reflection property (mainly an albedo).

Figure 7 – Colored 3D model of a Madonna and Child (Musée des Augustins - Toulouse) for the restitution of various polychromies. (Digitization and restitution by Archeovision Production - 2005)

Albedo:

Albedo, a fundamental concept in radiometry [3], is the proportion of the received light power (or light flux) that is reflected. It is therefore a value between 0 and 1.

Reflectance:

Reflectance is often synonymous with albedo and generalises this notion by extending it to a ratio of power received in one direction and reflected in another.

BRDF:

Bidirectional Reflection Distribution Function was introduced in 1977 [4] and represents how a surface reflects the received light (irradiance) coming from one direction to another (radiance). Compared to reflectance, BRDF is limited to 1, but simply a positive radiometric quantity.

Shader:

For the 3D field, the term Shader [5], [6] refers to a small program used to produce the final appearance of an object in the process of computing an image. This program can simply modify the final color, calculate the light reflection to obtain this color, or even modify the shape of an object.

(2D) Texture:

In Computer Graphics, a texture is a function that attributes a value (in general a color) to each position on a 3D object. In this document, a texture defines an image used to map part of, or an entire object (Figure 8).

Texel:

Pixel of a 2D texture.

Colorimetry:

Colorimetry can have many different definitions. According to the “CIE Fundamentals for Color Measurements”, it is "the science and technology used to quantify and describe physically the human color perception." For 3D data in the SSH field, this definition is extended to include all the information about the conditions in which the color measurements were made in order to best calibrate the process [28] [29].

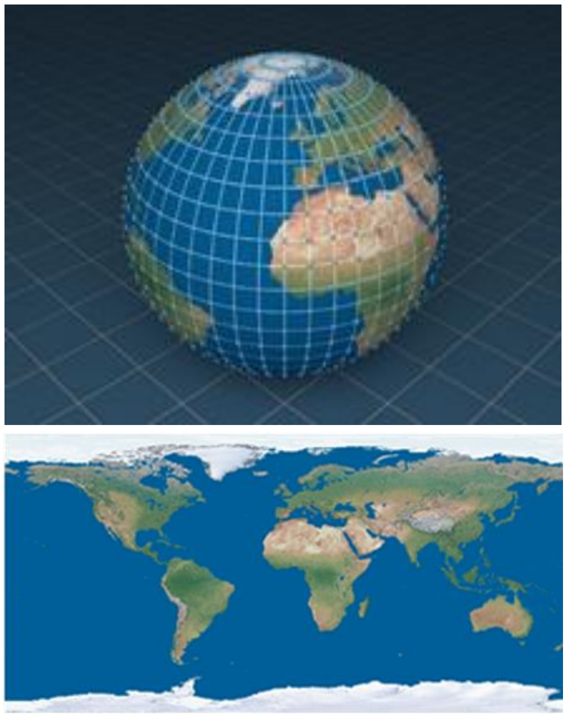


Figure 8 – 2D texture (bottom) mapped on a sphere.

Point light (source):

Digital light source corresponding to a 3D point that emits energy or assimilated in all directions. The distribution is uniform in all directions for a Lambertian source [3]. A goniometric diagram allows the definition of the distribution in other cases. Real point light sources are rare and this model remains an approximation used for small sources such as candle flames or light bulbs.

Directional light (source):

A digital, sizeless light source that is characterized by a single direction of reception of an energy or assimilated. The sun's illumination is often approximated by a directional light.

Area light (source):

Digital light source defined by a finite surface area. Ceiling lights can be approximated by area lights.

3.3 3D Model and Scene

3D Model:

A set of digital data that are linked to a single object of study and that are obtained after 3D acquisition or modelling. It is a synthetic digital document intended to evolve with the state of research knowledge. The model can thus have several versions after each step of the sequential graph of data life cycle (Figure 2) until a final version is delivered for a specific purpose. The terms 3D model - virtual model - digital model are considered to be synonyms.

3D scene:

In Computer Graphics, a 3D scene contains one or more 3D objects in the same 3D referential, associated with other data such as light sources.

4. DATA QUALITY

The concepts presented in this section correspond to those commonly used for writing specifications when digitization is requested. They are presented to help standardize their use.

Outliers:

Outliers [8] are data whose values seem too far away or inconsistent with the whole or a sub-set of the data set (Figure 9). Out-of-frame points are an example of this.

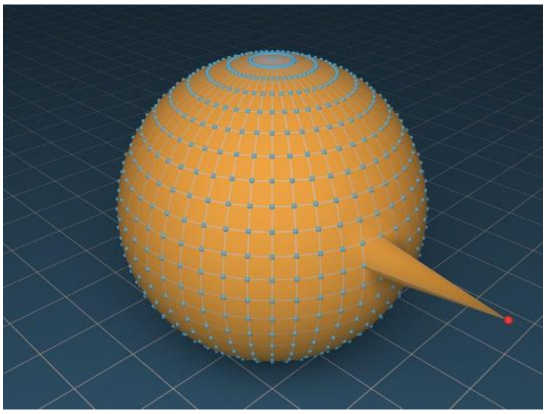


Figure 9 – Example of outliers: the point in red is very different from the other points in blue and certainly corresponds to a measurement error.

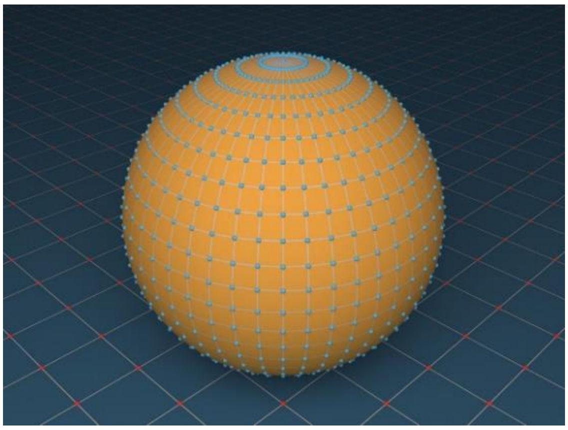


Figure 10 – Not relevant data. If the object of study is the sphere, the blue dots are relevant and the red dots on the ground are not relevant

Un-relevant data:

Data that does not belong to the object of study. An example is the support on which the object is placed, which may be in the measurements at the same time as the object itself (Figure 10).

Redundant data:

Over acquisition of very similar points according to the chosen resolution or accuracy.

Measurement noise:

Deviation (Figure 11) of the measurements by a non-repeatable or random phenomenon that results in a difference between the measured value and the true quantity value. The most well known is the noise or chromatic grain obtained in a photographic shoot under low light conditions with long exposure time and high gain.

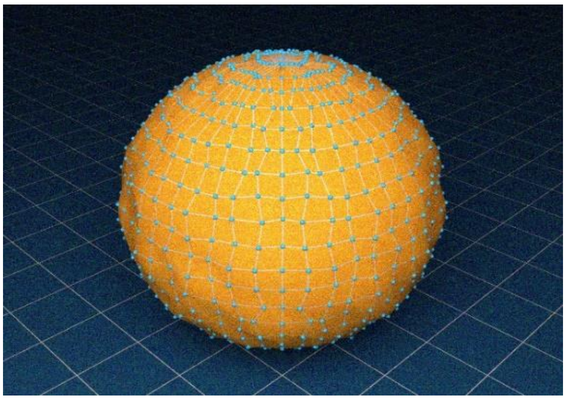


Figure 11 - Measurement noise. The measured position is randomly offset from the exact position on the sphere.

Measurement bias:

Systematic deviation of the measurements by a repeatable phenomenon which results in a difference between the measured data and the actual value (Figure 12). This can be for example an error in the size of the object or a constant deviation between measured and actual values. The measurement bias can often be corrected by calibrating the measuring system.

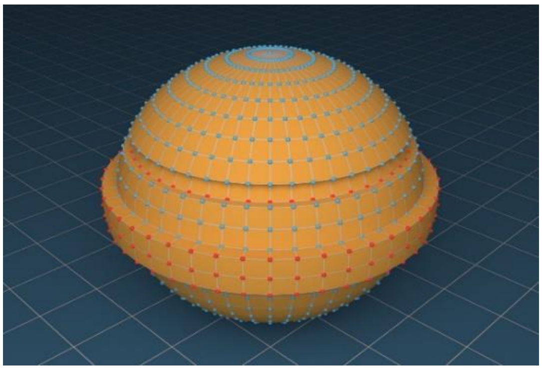


Figure 12 – Example of measurement bias: the measuring device has introduced on certain areas (red dots) a constant offset with respect to the actual position on the sphere.

Accuracy:

Maximum deviation between measured value and true quantity value. It is either absolute (e.g. a deviation of ±1mm) or relative (e.g. a deviation of ±1%)

Scale	Scanning Interval (mm)	Precision (mm)	Max.Object Size (M)
1 :10	2	2	5x5
1 :20	4	4	10x10
1 :50	15	15	20x30
1 :100	25	25	40x60

Tableau 1 - Example of accuracy for lasergrametry. Source: GIM - Terrestrial Laser Scanning - http://bit.ly/2wjeAcp

(Spatial) Resolution:

In general, the resolution is the spacing between two measurements. This corresponds to the minimum detail of the model.

- For a subject this corresponds to the distance between two adjacent measuring points.
- For a scanned image this is related to the pixel density of an image (e.g. number of pixels per centimeter)[2].
- For a screen this depends both on the number of pixels and the size of the screen. [10].
- For any other image, the resolution depends on the size of the projection of a pixel on the study object (e.g. a texture).
- For a photograph, the resolution therefore depends on the number of pixels (reference to the notion of definition), the distance between the subject and the camera, the size of the subject and/or the field of view.
- In the context of aerial photography, we speak of ground sampling distance or GSD [11])

(Image) Definition:

The definition of an image is the total number of pixels that a sensor can acquire to form an image.

[2] http://www.pixelvalley.com/appareil-numerique/definition-resolution.php

HDR or "High Dynamic Range":

HDR [12] refers to both an image format and a set of techniques for creating and manipulating such images. In the case of HDR images, this corresponds to an increase in dynamics, i.e. the ratio between the maximum and minimum value per pixel. and per color, by comparison with conventional images such as BMP, JPEG, GIF, etc. These images allow values closer to the light power of a real scene to be captured thus limiting under- and over-exposures.

When we talk about HDR in terms of processing (as on most of today's cameras), it means that the software and/or the acquisition peripheral will multiply the shots with different exposures and recombine them in order to limit under- and over-exposures. However, it is important to remember that colorimetric treatments such as white balance do not have comparable behavior on an image resulting from such a process although the image format remains a classical one.

(a) *image LDR sous exposée temps d'ouverture = 0.25 sec* (b) *image LDR temps d'ouverture = 2 sec* (c) *image LDR sur exposée temps d'ouverture = 3.2 sec* (d) *image HDR reconstruite*

Figure 13 – Sequence (a-c) of photographs of the "memorial church" of Harvard University for different exposure times which, once merged, allows to reconstruct an HDR image (d) containing details in the previously under- or over-exposed areas. Images from the article by Debevec and Malik (ACM SIGGRAPH 1997).

5. GOALS

Recorded data:

Survey of characteristic information of the state of what remains of a heritage object (topographic survey, architectural survey, orthophotography, photogrammetry, lasergrammetry, etc.). The purpose is to provide later dematerialised access to the heritage object. It is also a backup, within the limits of what has been recorded.

Communication:

Dissemination of scientific knowledge and methodologies resulting from the study of the object to a scientific public and/or the general public.

Valorization:

According to the Collins dictionary, valorization is the action of "conferring a value upon something". For the data we are dealing with in this document, it is any action that makes use of them in a context other than a scientific study, such as the production of a popularisation document.

Figure 14 Example of valorization: interactive visit of ancient Rome by night (University of Caen Normandy, CIREVE, Map of Rome)

6. RAW DATA - ACQUISITION: A0

Scientific 3D reconstruction must be based on existing documents using different techniques for survey and representation. We shall discuss the vocabulary for these two aspects.

6.1 Instrumental acquisition

Acquisition:

In the context of this document, an acquisition is a measurement of 3D data using photogrammetry, lasergrammetry, tomography, a topographic survey, or any other technology or combination of technologies that allow this.

Photogrammetry:

The Collins dictionary defines photogrammetry [30] as "the process of making measurements from photographs". It is thus a technology that calculates a set of 3D points from a set of photographs or digital images. This set of 3D points is defined in a single reference and at a scale or size to be determined. Color information can be associated with each point by an extraction from the original images.

Lasergrammetry:

Lasergrammetry [31] brings together all the acquisition techniques that use a laser to calculate the distance between the object of study and a emission point of a laser in a given direction. The intensity of laser reflection can also be measured.

Laser scanning produces a set of 3D points. Some devices allow the acquisition of color information using an additional dedicated sensor.

Topography:

Study and description of the shape of a terrain on a map, with the details of the natural or artificial elements it contains, in order to determine the position and altitude of any point located in a given area. Often, a total station, tacheometer, satellite positioning (GPS) or laser telemeter is used to carry out a topographic survey. In the case of historical topography, according to the definition of the lexicon given by the French National Center for Textual and Lexical Resources (CNRTL), it is the set of methods using topography, toponymy, archaeology, etc., in a convergent way to identify ancient sites.

Figure 15 – 3D acquisition by lasergrammetry of a Gallic helmet found on the Tintignac-Naves archaeological site. The laser scanner is a Faro scan arm (Archeovision production - 2018)

Tomography:

These techniques are widely used in medical imaging [15] and allow the estimation of the internal characteristics of an object from images. Examples of these characteristics are density, absorption (X-ray imaging), refractive indices [16], etc. The resulting data are often in the form of a regular 3D grid of values. One of the most commonly used techniques in archaeology is CT scan (for X-ray computed tomography or Computed Tomodensitometry).

Sound recording:

In the context of 3D production, this is the recording of sounds produced by or which come from a heritage object (Figure 16).

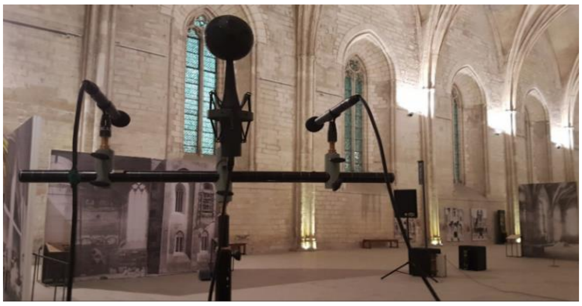


Figure 16 – Sound recording (Projet IMAPI porté par Julien Ferrando) https://www.prism.cnrs.fr/projets/projets-collaboratifs/imapi/

This recording is to be distinguished from the collection of oral or musical sources around a heritage object, which is a complementary collection of information by sources. We may cite for example, the sound recording of different materials (wood, concrete, stone, etc.) of an architectural ensemble, to determine its acoustics.

RTI or "Reflectance Transform Imaging":

This was originally designed to obtain textures that depend on light directions ("Polynomial Texture Map" - PTM [17]) and now refers to both (1) a setup to acquire images for a fixed view-point with different light directions or positions of light, and (2) the approximation of these data in the form of PTM with the corresponding visualization tools. These techniques were popularized in the field of SSH by the "Cultural Heritage Imaging" association. In terms of visualization, this allows offsite replays of changes due to lighting variations and, manipulations to improve the appearance of studied object [18]. Approximation is generally carried out using standard functions (e.g., polynomials) chosen a-priori and without relation to the properties of the considered surfaces.

6.2 Documentation and sources of information

These are the different categories of iconographic sources (photographs, drawings, paintings, engravings) that bear witness to the state of a building or object at a particular moment of its history.

Iconography:

A collection of images related to the object to be portrayed in 3D (surveys, sketches, photographs, mosaics, numismatics, paintings, etc.).

Texts:

All forms of writing related to the studied object: primary literature (ancient texts, inscriptions), secondary literature (excavation reports, excavation journals, scientific publications, etc.). Examples of the form of these writings are manuscripts, prints, engravings, etc.

Oral sources:

Documentation which comes directly from individuals, groups concerned by the studied object. It is recorded in audio format or transcribed.

7. PREPROCESSED DATA / PREPROCESSING: V0

These are the data resulting from a series of technical operations involving cleaning, consolidation, completion and semantic enrichment of the raw acquisition. This processed data constitutes an initial version of the 3D model (V0). In the case of an acquisition, the V0 is the first complete model with the minimum of human intervention. As soon as the scientist acts, we name this "processing". Each level of pre-processing should go with metadata that details (1) the algorithms/ methodologies/etc. used, (2) the chosen value of the parameters and, (3) a quality level.

Cleaning:

A cleaning step consists of removing irrelevant, redundant or aberrant data. It can also consist of reducing measurement noise and correcting measurement bias. Cleaning can be automatic or manual. It is important to know the parameters of the measuring instrument and to take them into account to avoid removing useful information. It is equally important that those involved in the acquisition (1) either perform this task or, at least, work in close collaboration with the team performing the pre-processing and (2) validate the result together with the scientists that asked for digitization to be carried out.

Registration:

In the case of point cloud registration, a single acquisition (e.g., from a single point of view) is never sufficient to record a heritage ensemble regardless of the acquisition device that was used. Different acquisitions are thus required , especially when the goal is to record an entire building, or a site, at several levels of detail. It is therefore necessary to transform point clouds collected separately into a single coordinate system in order to prepare their fusion. Consolidation is therefore the controlled fusion of several acquisitions into a unique representation. An example is the alignment of different acquisitions from an object from different points of view thanks to the estimation of points sharing the same position on the object [19]. The process can be carried out automatically, manually or semi-automatically (a first manual registration is carried out and then automatically optimized).

Georeferencing:

Position and geographic orientation of 3D models without modifying the original source data. This operation consists of moving from a relative location of 3D data to an absolute location in a recognized geographic coordinate system [32]

Completion:

The process of adding absent or missing information into a point cloud or a mesh to complete the original data.

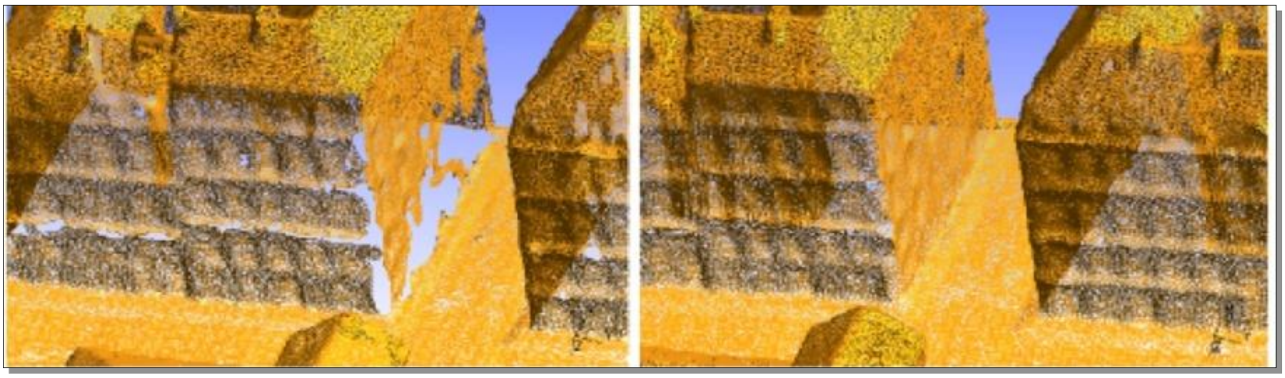


Figure 17: Completion of a mesh: (left) Mesh acquired (right) mesh holes completed - Nantes 1900 Project - F. Laroche (Epotec-LS2N UMR 6004)

8. HYPOTHESIS / RESTITUTION: FROM V0 TO V2

Processing:

Steps of scientific involvement on a 3D model, starting from the initial structured model (V0) to all the resulting processed models (V1n). Processing performed to move from one state to another must be recorded in the paradata.

Restitution[3]:

Restitution is a digital reconstruction based on scientific data used in the cultural heritage community. It consists of representing a given state in time of an archaeological site, building or object from archaeological or historical sources. It can be a set of drawings, digital 3D models, scale or full-size models, etc. Restitution helps researchers gain better understanding of remains and can also help them validate archaeological and/or architectural hypotheses. Restitution is thus continuously ongoing work since it takes into account research in the field and also the evolution of technologies.

Structuring the 3D model:

The creation of a digital object that contains all 3D data and metadata, prior to any educational, scientific use or conservation. From this stage, the model can take kinematics aspects (movements, mechanical actions) into account.

Semantic enrichment

Added information at the 3D data level [22]. This enrichment is an interpretation of the acquired data and is often necessary to understand the object of study. This information can be added by coloring a point cloud or applying a texture, adding text, or filtering or classifying a point cloud or a sub-part of it.

Textual semantic enrichment may use thesauri and ontologies to structure the relationships between terms used in the text.

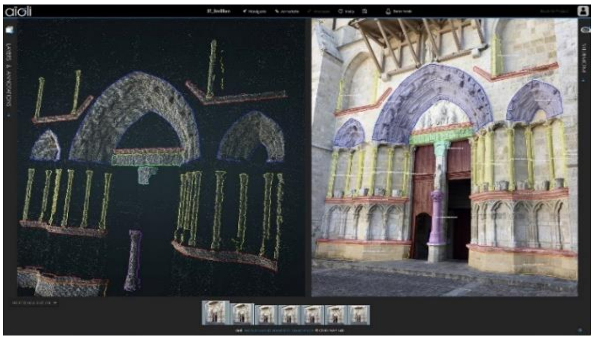


Figure 18: Aioli a reality-based annotation platform for collaborative semantic enrichment (UMR MAP 3495)

Kinematics:

Description of movements from different parts of a 3D model together with the mechanical movements they may maintain between them. By adding the temporal dimension to the kinematics, a dynamic model can be obtained which enables simulations to be made.

3 In French *Selon le traité de la réalité virtuelle [27], "Les modèles fournis (…) comportent régulièrement trop de polygones pour «être utilisés dans une application de réalité virtuelle*"

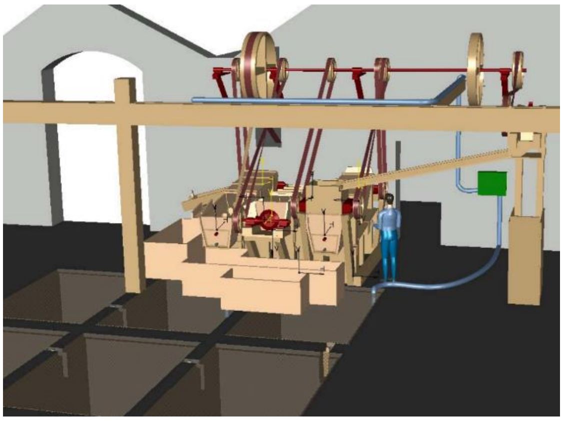


Figure 19 – Example of a kinematic case study of the BERTRAND Company in BATZ-SUR-MER (44): dynamic 3D modeling of the factory and the salt washing machine (1914-1966) (F. Laroche - LS2N)

Simulation:

Computation based on the 3D model to recover or estimate one or several parameters of a model in order to validate hypotheses (kinematics of the model [35], [36], restitution of texture, lighting [34], movement of crowds in a given space [33], etc.)

Animation:

Virtual movements of objects in a 3D scene (static or dynamic). This can include (Figure 20) the movement of people such as mechanical parts, falling objects, etc.

It should be noted that this movement can be defined either ad-hoc by trajectories in space without physical constraints (contrary to kinematics) or by the result of a physical simulation (like in kinematics: falling trajectory of an object under the influence of gravity, collisions, etc.). It is therefore up to the expert to take the time to validate such behavior.

Figure 20 – Restitution of a factory of the former Renault factory of Boulogne Billancourt (workshop C5) with animation of the work chain showing the production of the car chassis. (Factory project 3D-Archeovision Production)

Metadata:

Data used to describe a dataset, a 3D model (date of acquisition, authors, rights of use). The surrounding data (context) are filled in as paradata.

Paradata:

Data specific to the context, but not directly constituting metadata, such as the methodological report or the acquisition process (scientific choices, hardware, software and techniques). Term specific to statistics used to inform the survey process.

9. DELIVERABLES

Virtual Reality:

The concept of virtual reality encompasses all the technologies that make it possible to digitally recreate and render the world around us. It involves the use of digital models, algorithms for image synthesis (or any other signal that can stimulate the human senses as well as sound), displays such as screens, headphones, etc. in the context of images (or sound restitution peripherals for sound) as well as all the techniques and tools for interactions between humans and this data [37].

Augmented reality:

As in [38], the goal of AR is to enrich the perception and knowledge of a real environment by adding digital information relating to this environment. It thus includes all the techniques that make it possible to associate a real world with a virtual world. In the context of image creation, it often consists of superimposing real images and synthetic images on screens or with the help of dedicated devices such as augmented reality headsets/glasses.

Mixed Reality:

Extending the notion of augmented reality, mixed reality includes all the technologies [25] such as augmented reality that combine a greater or lesser proportion of real data with virtual data (Figure 21).

Interactive model:

A 3D scene in which users can interactively move or manipulate some 3D objects.

Precomputed rendering:

A 3D model containing some elements from lighting, animation, kinematics that are computed prior to the visualisation rather than directly. It can be for a fixed or a predefined path. An application can propose several pre-calculated renderings (user's choice) [39].

Stereoscopy:

As far as display is concerned, stereoscopy includes all the techniques that allow a user to have the impression of a 3D image by displaying a dedicated image for each eye.

Orthoimage:

A geometrically rectified and measurable image, projected on a reference plane (orthogonal, zenithal, etc.). When an orthoimage is recomposed from several photos, it is called mosaic orthophotography [40].

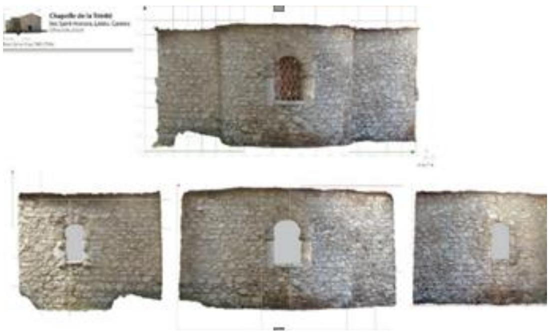


Figure 21– Ortho-image developed, from the chevet of the Chapel of the Trinity, Saint-Honorat Islands Cannes (S.Sorin - CEPAM)

Decimation:

As in [41], the aim of a decimation algorithm is to reduce the total number of triangles in a (..) mesh, preserving (..) a good approximation of the original geometry. Validation of the simplified model must be based on scientific advice to ensure the quality of the final model.

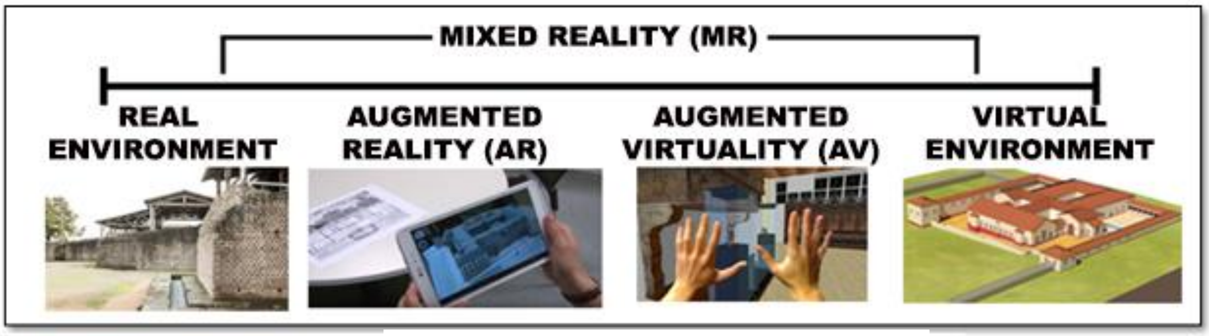


Figure 22– Milgram's continuum

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