# Best Practice Checklists for 3D Museum Model Publication

## Quality Chart for Museum Photogrammetric 3D Asset

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**Abstract:** This article highlights good formatting practices in 3D assets publication and challenges the way those museums share this kind of content. Observations of more than 200 assets have been made through various museums 3D models, uploaded in open access WebGL platforms and published on a large scale cultural recognized institutions official accounts to determine the best keys to judge the model quality requirements.

The produced checklists will take into account various specific criteria about the acquisition to the presentation of the final asset in the web viewers. The analysis grid first takes into account the topology quality evaluation by explaining the different relative problems encountered in mesh construction and treatments. The texture quality evaluation gives information about how to judge colorimetric and details aspects needed by a museum digital copy. PBR shader quality evaluation part intends to explain the different layers of a Physically Based Rendering shader and how to combine correctly and without confusion those layers to mimic the reality produced by the light incidence on an asset.

Those three first technical checklists are completed by three important presentation aspects leading to high grade 3D experience for the public: the lighting quality evaluation; the enhancement options and their utilities and the asset context.

Shortcomings are identified and explained for each table in order to improve the delivery process of digital reproductions. This quality chart through its six tables wishes to give a better knowledge of assets creation, especially if models are not produced by a specialised inhouse technician.

Online museum visitors, students or professionals need the best numerical reproduction quality to be able to perfectly understand all the complexity of a masterpiece as in reality, and even more by the ability to manipulate those digital objects and to observe them from every viewpoint.

**Purpose of the Checklists to Enhance Public Museum 3D Assets Quality**

The quality checklists are based on the observation of 244 models[1] - two assets by museum or official collection account, uploaded on open access WebGL platforms and published on their official accounts - and aims to evaluate the intrinsic (topology, texture, and shaders) and extrinsic (lighting, post-effects, and context layout) quality of 3D models taking into account the point of Bennett (2015). From this assertion, it is possible to analyse 3D models production workflow based on published results.

WebGL viewers, Real Time viewers or CAD software can deliver information through the analysis of the mesh. The checklist entries depend on the asset's final goal and must be discussed and validated before the acquisition beginning. The proposed quality charts deliver a global view of asset's purposes making and follow the quality asked in a linear workflow of game development and 3D cinematic rendering.

All the observations and findings define a complete specification chart aiming to specify at best the expectations of all the actors – museum and producers – in terms of world heritage collection publication. Through this article the analysis intends to give a better experience and scientific analyses possibilities for students and researchers who do not have access to the real artefacts. We divide the model quality checklist in six parts. Each checklist studies specific model specifications as validation steps.

**Topology Quality Evaluation**

Mesh treatment, corrections, and aspects, reflecting its topology, are transcribed in Table 1. The checklist takes into account the size of the 3D asset into real world and details information: The model weight determined by the polygonal density according to its surface, the respect of its real dimension in a virtual space environment, its position into space (initial position and rotation centre), the surface cleaning process used to enhance the model (like denoising, smoothing, filling holes, outliers polygons cleaning) and the retopology requirements needed to alleviate the polygon count and adapt the texture (single or differentiated definition, limitation, or composite mesh).

- *Mesh weight:* It depends on the 3D player rendering capacity, the quality requirement and the viewing technologies (desktop, smartphone, ...). For a web purpose, the model needs to be as light as possible (best quality weight report) depending on its real size as explained in McGuire (2018). The delivery has to be tested with the generated texture and have to show any artifact before upload (ie: a statue nose over-decimated presents any relief at all). The decimation process must take into account the borders and the volume of the model to avoid any unfortunate deformations.

- *Measure:* The asset measurement needs to reflect the real subject. The size can be measured in CAD or into the WebGL player inspector. This data has to be precise when visitors use VR headset.

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[1] The complete models list can be asked to the writer of this article because it is in constant evolution.

- **_Presentation into 3D space:_** The asset position into the 3D space needs to be assigned in the viewer back office: the asset has to be placed on its gravity centre, on the virtual floor of the viewer and in a natural position.

- **_Denoising:_** Depending on the camera sensor, the object material and the acquisition lightings, and the numerical reconstruction, the mesh can present some noise. When the asset needs to be very precise because it contains micro-topology, this noise must be polished in specialised software such as Meshlab, ZBrush, 3Dcoat or Rhino3D.

- **_Manifold_**: Some mesh presents artifacts such as scars, shrinks, distortions, tunnels, spikes, self-intersections or ripples also defined by Fei Dai et al. (2014) due to bad acquisition pictures or bad pictures processing. The corrections or mesh modifications must be written into the model description. In the case of 3D printing of the model, the mesh must pass through a _non-manifold_ rectification process to avoid polygonal intersections.

- **_Mesh correction_**: Some models are presenting a lack of details or some missing parts due to a bad picture shooting coverage or an incorrect pictures processing. As for manifold observations, It is possible to correct those artifacts by taking more or better pictures, by applying picture corrections or by making a post-processing of the mesh before its publication.

- **_Filling holes_**: Depending on the subject and the pictures acquisition, some 3D mesh can present some holes. Those holes must be filled during the 3D post-production process.

- **_Retopology:_** It's a way to rationalize the topology of a subject to make it more suitable for its use or to be able to easily make some corrections in 3D post-processing. Movie productions (high standard) use _Pure Quad_ mesh topology to let the shaders move correctly on the mesh while the subject surface is rigged/animated. The obtained photogrammetric topology could be transformed in _Tri_, _Quad_ or _Ngon_ (non-suitable). Some 3D players recreate automatically triangles from a _Quad_ mesh topology just for speed rendering optimization dividing the quadrangles polygons by two.

- **_Normal inversion_**: _Normal_ polygon inversion can cause wrong interpretation by CAD softwares or WebGL players (if in single-side projection) or discoloured polygons on the 3D asset surface. This kind of problem must be corrected to avoid viewing inconsistencies of the 3D model.

| Topology Quality | OK | NOK | Comments |
|---|---|---|---|
| Mesh weight | | | Under or over a reasonable number of polygons |
| Measure | | | Smaller than original / Greater than original |
| Presentation into 3D space | | | Gravity centre / Native position |
| Denoising | | | Smoothed mesh / Not smoothed |
| Manifold | | | Scars / Shrinks / Distortions / Ripples / Spikes / Tunnels / ... |
| Mesh correction | | | Lack of details / Missing parts |
| Filling holes | | | Holes filled / Not filled |
| Retopology | | | Triangle / Quad mesh / Ngons polygons |
| Normal inversion | | | Create hole where polygon normal is inverted |

*Table 1. Topology quality evaluation.*

The most common problems observed in these assets topological observations were principally the lack of retopology into quad mesh topology, practically any mesh corrections but also the presence of holes, shrink or noise and the lack of intentional decimation process. From those topological mesh observations, it can be defined that a lot of 3D museum collection assets are the result of a "*one pushed button*" automated photogrammetry process with practically any post-processing. Those productions can't lead to a multipurpose and correctable models: some of those errors depend on the photogrammetric acquisition process while others prevent any precise human rectifications on a topological view. In some cases, during this analysis, some museums published some new assets made by professional 3D agencies that passed all the requirements of our topological quality checklist.

**Texture Quality Evaluation**

The colorimetric quality and the sustainability of this data presented in Table 2 are able to help a better stylistic comprehension of the real object and the possibility to have a better view on the corresponding craftship technique. This evaluation will be made on: the texture size according to a suitable texel ratio, definition and quality of the unfolding process and its usability (*UV Unwrap*, *UV mapping*, *UV packing* or the use of *texture atlas*), the respect of the real subject colorimetry, the presence of a delighting process (shadows suppression) and its implication in rendering (production of an *Albedo map* in addition of a *Colour map*) as well as the overall clarity in the 3D asset manipulations such as a zoom on particular model details.

- *Colourimetry:* photogrammetric assets colourimetry depends on the acquisition context and if the photographer used a colour chart to rectify the white balance and the colour tones during the post processing. The realistic colours rendering and the realistic light reactions depends on those rectifications.

- *Pixel peeping:* it's the ability to zoom on the asset without reaching blurry or pixelated texture. The texture definition depends on the texel ratio and the choice between quality and rendering time of the real-time renderer. Museum asset texture must be sharp when zooming in to be perfectly understood and studied.

- *Rectification:* texture maps may have been rectified or modified in 3D post-processing. For this purpose the asset maker has to check if there are no differences between the texture

layers, for example between colour/albedo maps and normal maps. Each asset must be verified for seems presence, artifacts, blurry parts coming from bad photography focus, flying polygons or uncoloured parts.

- *Reprojection:* the camera photogrammetric reprojection creating the asset texture is judged by observing presence of texture misalignment causing blurriness or doubling details between the mesh and the texture.

- *Unlighting:* if shadows persist on the colour map, the texture was not properly delighted and cannot be realistically relighted by the 3D rendering process.

- *Unwrap quality:* the unwrapping process develops in 2D the 3D asset texture such as a taxidermy. By this process, the operator produces a humanly understandable picture that can be rectified in CAD software. Without this step, it will be practically impossible to rectify the texture ad posteriori due to the deformations and the subdivisions in the texture.

- *UV mapping / packing:* UV mapping and UV packing are reorganisation of the islands (texture patches onto UV surface) composing the asset texture in a 2D representation. It intends to optimize the space through the size assigned to the texture and by the way it's definition (like 4K, 8K, 16K).

- *Texel density:* an asset couldn't have the same texel density all over its parts but it's possible to increase or decrease the scale of the UV texture parts called islands. Increasing the scale of an island gives more definitions to certain texture parts of an asset, giving more importance to some detail parts.

| Texture Quality | OK | NOK | Comments |
|---|---|---|---|
| Colorimetry | | | Realistic / Unrealistic |
| Pixel peeping | | | Blurry / Pixelated when zooming on the asset |
| Rectification | | | Seems / Artifacts / Blurry parts / Uncoloured parts |
| Reprojection | | | Reprojection inconsistency / Misalignment |
| Unlighting | | | Unlighted / Not unlighted |
| Unwrap quality | | | Humanly understandable / Raw from software |
| UV mapping / packing | | | Organised / Not organised / Mesh cut |
| Texel density | | | Respected or not (2k, 4k, 8k, 16k) |

*Table 2. Texture quality evaluation.*

Concerning the textures quality, the 3D models analysis reveals some recurring problems : usage of blurry pictures or misalignment during the photogrammetry process introducing blurry parts in the generated texture, UV Unwrapping process with no real texel ratio to conserve the highest picture definition, too few texture post-rectification in CAD software but also the use of low texture definition giving pixelated or blurry rendering texture when zooming into the models details. Some of those problems came from a lack of filtering or post-processing before the picture importation into the photogrammetry software or just an optimisation process misunderstanding on how to prepare and correct a 3D model.

**PBR Shader Quality Evaluation**

This part of the quality checklist looks at the appropriate presence and use of the different texture maps used for creating a realistic rendering experience. The grid takes into account the subject's materials and the light influences to look how artefact materials interact in the real world but also some effects based on those materials. As defined in Deshmukh et al. (2017) real-time renderers use, Physically Based Rendering (PBR) shaders require several specific maps in order to fully render the appearance of the subject into realistic experience. Production of those necessary maps depends on the real materials subject in order to provide to the shader the information needed to work properly. The lack or the erroneous uses of those texture maps in the shader configuration will obviously imply an uncontrolled data or a confusion in the rendering player. To perfectly understand how works the layer construction of a shader, it is necessary to explain each one:

- *Albedo map:* need the presence of a real Albedo Map. The Albedo map is the Diffuse map – the camera reprojected texture – without shadows (underexposure) and hot spots (overexposure). It can be obtained by using cross-polarisation acquisition technique, by treating all the pictures by removing highlights and shadows or by delighting the photogrammetric obtained colour map in a software such as Agisoft De-Lighter.

- *Geometric normal map:* presence or not of a geometric normal map such as explained in Glassner (1990) generated by extracting geometric information from the High-Definition model shape. The normal map uses RGB information corresponding to the X, Y, Z axes in 3D space indicating the exact direction of the normals of each element and its orientation indicates how the shading should be performed.

- *Texture normal map:* Normal map texture is extracted from the High-Definition model Albedo or colour Map. Definition is the same as the geometric normal map but the source of the information comes out from the details of the colour map texture.

- *Blended normal map:* Ameliorated normal map resulting from the combination of the geometric normal map and the texture normal map by blending those two maps. This crossover map contains the global relief information of the geometric model data blended with the micro-details contained in the texture map.

- *Ambient Occlusion map:* Ambient Occlusion (AO) map is a shadow simulation caused by objects blocking ambient light. It allows dark areas that are difficult to access by the light producing reliefs on the subject.

- *Glossiness / Roughness or Metalness map*: The Glossiness or Roughness map defines how the light rebound on the surface depending on its nature.

- *Specular / Reflection map:* Specular map defines the brightness and the highlight colour of a surface. The higher is the value, the brighter the surface will be. This map has to be hand painted depending on the reflexion of the materials on the subject.

- *Cavity Map:* Cavity map represents dark shading in the crevices of a subject accentuating the details. The black parts represent the recesses and the white ones the high points.

- **_Transparency / Opacity map:_** Transparency or opacity map (Grayscale Relief Texture) defines the material transparency level. Those maps can be hand painted to give this propriety to some parts of a 3D model.

- **_Subsurface Scattering map:_** Subsurface Scattering (SSS) map defines the light penetration and the diffusion level inside a translucent material such as skin.

| PBR Shader | OK | NOK | Comments |
|---|---|---|---|
| Albedo map | | | Erroneous use of maps |
| Geometric normal map | | | Erroneous use of maps |
| Texture normal map | | | Erroneous use of maps |
| Blended normal map | | | Geometric + Texture Normal map blending |
| Ambient Occlusion map | | | Erroneous use of maps |
| Glossiness / Roughness or Metalness map | | | Erroneous use of maps / Uniform / Handmade |
| Specular / Reflection map | | | Erroneous use of maps / Uniform / Handmade |
| Cavity map | | | Erroneous use of maps |
| **Transparency / Opacity map** | | | Erroneous use of maps / Handmade / Uniform |
| **Subsurface Scattering map** | | | Erroneous use of maps / Handmade / Uniform |

*Table 3. PBR shader quality evaluation.*

Through the observation of the different analysed models, various negative points and shortcomings emerge such as a majority of assets published in PBR material mode only containing the Colour map without any Normal map – limiting real lighting simulation of the subject or reflecting details lost if the model is decimated – but also a real confusion between different maps composing this PBR shader:

- Confusion between Albedo map (colour without light and shadow) and colour map,

- Confusion between Metalness and Specular in PBR shader,

- Confusion between Roughness and Glossiness in PBR shader.

The major problems come from the misunderstanding usage of the PBR shader production.

**Lighting quality evaluation**

The light incidence on a model and its visual presentation as a collection part in a museum and how the museum curator wants to present this digital model for the public is evaluated in Table 4. The entries explain the light quality though the selected shader type in the real-time render engine, the model lighting needs for its presentation, the use of different lighting types (spot light, HDRI, shadeless, etc.) implementation and complexity and the light impact on the subject rendering.

- **_Lit / Shadeless:_** WebGL players and real time renderer give the ability to enlighten assets scenery but also to produce lighting effects without any shade to offer a flat view of all the details. This point is a representation choice of the publisher and can be commented upon depending on the whole 3D Scenery offering to the visitor another way to understand the masterwork produced on the artefact without any shadow disturbances.

- **_Lighting rig:_** 3D renderer offers a very flexible way to enlighten scenery. Lighting rigs are composed, at least for giving a realistic representation, of a key light (direct light), of one or more fill lights (to model the shapes of the subject) and of one or more backlights to give consistency to the details. Each of those lights possess different colour temperatures to enhance the composition. WebGL players such as Sketchfab only offer three lights. The quality chart takes into account the use of those lights when such lighting is used.

- **_HDRI:_** another way to enlighten a scenery is to use a High-Dynamic-Range Imaging (HDRI). A HDRI is a spherical picture containing the whole lighting information made by stacking a wide range of aperture stops. It is possible to choose the angle of the lighting parts of this spherical projection and its intensity. It can also be used as a background or to make realistic reflexions and caustics on a reflexive material. Most of the WebGL players and Real Time renderer furnish common HDRI to illuminate 3D scenery. The chart takes into account the shadows quality resulting from a default or a specified purpose made HDRI, reproducing the real environment and the lighting of the artefact in its place in its own museum.

- **_Shadow catcher / Baked light:_** those two points represent technical points for loading time or for fluidity. Shadow catcher and backed light are pre-calculated shadow textures avoiding a real time process. Those techniques are used when in the scenery the subject lay down on a support or on the ground.

| Lighting Quality | OK | NOK | Comments |
|---|---|---|---|
| Lit / Shadeless | | | Lit / Shadeless |
| Lighting rig | | | Use of …. light |
| HDRI | | | Common / In House |
| Shadow catcher / Baked light | | | If there is support for the subject (ground, pillar, column, …) |

*Table 4. Lighting quality evaluation.*

The lighting quality of the whole 3D model composition has a drastic impact on its comprehension. Following problems which affect the representation of the observed models can be raised such as:

- The misplacement of the lights (spot light misplacement or HDR angle),

- The use of a default HDRI causing inconsistent or unrealistic shadows,

- The use of unlit scenery with texture already presenting shadows,

- The configuration of a wrong Shadow Bias.

**Post effect evaluation**

The global composition and rendering enhancement options within a WebGL 3D player such as Sketchfab2 gives the ability to enhance the model presentation with photographic filters and various effects in order to highlight its details or compose a staging to emphasize. Used wisely, those additional options and effects can significantly enhance the visibility of details or highlight a specific

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[2] Sketchfab is a platform to publish, share, discover, buy and sell 3D, VR and AR content. It provides a viewer based on the WebGL and WebVR technologies that allows users to display 3D models on the web, to be viewed on any mobile browser, desktop browser or Virtual Reality headset.

presentation context. On the other hand, in some cases, they can hinder a good scan by digitized artifacts. The evaluation list is presented in Table 5 and describes the different effects and their impact on a model.

- **Screen Space Reflection:** Screen Space Reflection (SSR) is a technology to simulate lower quality reflections and to limit the specular light leaking. The use of SSR is logically limited for low configuration rendering. Its use needs to be justified because it was implemented for performance mode over quality.

- **Screen Space Ambient Occlusion:** Screen Space Ambient Occlusion (SSAO) is used to defer the Ambient Occlusion in real time and is taken in charge by the graphic card. If there is already the presence of a baked Ambient Occlusion in the shaders, this option is not needed at all.

- **Sharpness:** check the usage or not of the texture sharpening enhancement if it is needed. The lack of Sharpening could give a blurry texture details but if it is used too extremely it can produce noises or artifacts on the texture when moving around the model.

- **Grain:** this effect result inserts a film grain filter in the viewer. The quality chart considers that this kind of filter degrades the quality of the 3D work.

- **Chromatic aberrations:** result of inserting chromatic aberrations filter. The quality chart considers that this kind of filter degrades the quality of the visualisation.

- **Vignette:** Vignette is a reduction of the brightness or saturation towards the periphery to catch the eye on the model or on a particular detail of the composition. However, the use of vignette can harm the overall composition and particularly the background information.

- **Bloom:** this effect inserts a chromatic aberrations filter. The quality chart considers that this kind of filter degrades the quality of the visualisation.

- **Tone mapping:** tone mapping is a technique created to enhance the textures by offering a way to raise the dynamic range of the pictures. This option can be used to enhance the colorimetry, but used too low or too far, the model colours will be degraded.

- **Colour balancing:** this option permits colour rectification directly in the real-time renderer. When the base colour is not rectified in post-production, this effect is able to more or less do it. The chart takes into account a comparison between the non-optimised colour map and the real-time renderer post-treatment result.

Enhancement can be needed to compensate deteriorated quality generated by the real-time rendering engine or by an unwanted texture compression. However, it is clear that some effects, in some cases, are improperly used such as:

- Too much sharpening causing noises or artifacts when moving into the scenery,

- Use of grain, chromatic aberration and bloom effects altering the colorimetry and the real aspect of the model,

- Need of tone mapping or colour balancing tweaking to manage colorimetric problems.

| Post effect | OK | NOK | Comments |
|---|---|---|---|
| Screen Space Reflection | | | Useless (backed AO map) |
| Screen Space Ambient Occlusion | | | Blurry / Sharp / Too sharp |
| Sharpness | | | Useless / Too much |
| Grain | | | Useless / Too much |
| Chromatic aberrations | | | Useless / Needed |
| Vignette | | | Not necessary / Too much |
| Bloom | | | None / Too much |
| Tone mapping | | | None / Too much |
| Colour balancing | | | Useless / Too much |

*Table 5. Post effect evaluation.*

## Context evaluation

Production quality also takes care of archiving each step of the work in order to be able to use the raw files and the intermediate data to improve a model ad posteriori, either to correct it or to complete it. 3D rectification gives a guarantee of compatibility through numerous modelling software and rendering engines or for different publication types but a model is nothing without context. Table 6 provides the information needed to complete the 3D models presentation context:

- **Background:** the presence or not of a specific background designed for or by the museum containing its logo and some contextual information. The background can be a 2D picture or a spherical one (HDRI) representing the real place of the subject in the museum room.

- **Reproduction authorisation(s):** presence of an annotation in the description part announcing if the 3D acquisition of the model was made with or without the museum authorisation.

- **Official model:** a text describing if the model presented is the original one or a 3D acquisition of a reproduction.

- **Author(s):** presence in the asset description of the artist attribution and a production date.

- **Collection name:** if the model is a part of a particular collection, does the description cites this one?

- **Description:** copy of the museum description card linked to the artifact if it is an official museum asset. This pasted description of the model is under copyright law. When the 3D model is not the museum propriety, this text needs a reproduction authorisation.

- **Inventory number:** presence or not of the museum inventory number in the description.

- **Picture(s) in place:** presence if possible, some real pictures of the real model in context.

- **Place in the museum:** localisation inside the museum building offering the possibility to visitors to rapidly reach the original subject seen in the 3D library.

- **POI('s):** integration or not of interactive Point of Interest (POI) in the 3D scenery.

- **Credit(s):** insertion in the asset description of all the credits such as photographer, 2D and 3D artist(s), etc...

| Context | OK | NOK | Comments |
|---|---|---|---|
| Reproduction authorisations | | | Authorised / Proprietary / No authorisation at all |
| Proprietary | | | Piece of the museum collection or not |
| Official model | | | Reproduction or original |
| Author and era | | | Attribution of the subject |
| Collection name | | | If part of a specific collection in the museum |
| Description | | | Historical and archaeological description of the subject |
| Inventory number | | | Related to the museum collection |
| Picture in place | | | Original picture of the subject |
| Situation in the museum | | | Room in the museum |
| POI | | | Presence of POI on the model |
| Credits | | | Credits of the photogrammetrist and/or 3D artist / 3D Society |

*Table 6. Context evaluation.*

The context checklist is made on a global observation of lacking information in model descriptions and in order to present some possible entries to add on each 3D asset. In this case, it is more of a checkbox list than a statement on the 3D models quality referenced during these inspection sessions. Nevertheless, this information makes it possible tot judge the attention paid to the subject and to the creation of its digital reproduction.

## Conclusions

Defining a quality chart based on intrinsic and extrinsic criteria of 3D museum models forces in a first step to review all the important points of the PANORAMA platform production pipeline for improving the internal quality of the assets made within the framework of research projects. In a second time, it offers to structure the photogrammetry training course initiated at the Université libre de Bruxelles in September 2019 and to adapt the different workflows for obtaining an easy way to produce 3D photogrammetric models by the students who never touch 3D software.

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