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Multidisciplinary Contributions

Vol. XVII A

Edited by Andrea Siniscalco

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Color consistency in BIM systems and in the visualization of the project in Real Time - An overview of possible solutions

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Abstract

In today's panorama of tools available to the professional in architectural design field, the BIM methodology has recently spread more and more widely than in the past. This is also due to an increasingly stringent regulatory imposition in public procurement, especially concerning the estimated amount of the works.

Furthermore, in the 2000s the visualization of the project was mainly linked to photorealistic static renderings or popular films obtained from sequences of static images. Nowadays, the computing power of the available hardware and the evolution of the raytrace rendering engines have led to an increasingly frequent use of virtual reality and augmented reality, which therefore become renewed tools available to the designer to visualize and make the project better understood by the client and other professional actors involved in the design.

In both cases, once the color of a finish has been acquired through correctly calibrated devices and standardized procedures, the problem of its correct representation arises here. The theme appears complex and needs to be explored carefully. This text is therefore intended to be an overview of the currently available solutions, thus analyzing how the currently available applications address the issue of color consistency in the context of BIM and virtual reality.

Keywords: colormanagement, virtualreality, BIM.

Introduction

The BIM software on the market, which in recent times has been adopted more and more frequently by designers, has tools that facilitate the collection and sharing of project information and allow to build a virtual prototype of the building or the space to design. This model must be accompanied by detailed information relating to all construction elements. However, it cannot have a too high level of detail in terms of number of triangles and polygons used, since this would negatively affect the weight of the file in terms of bytes. Furthermore, the BIM methodology does not require the search for great graphic detail, as its focus is on other areas. Nevertheless, all BIM software are equipped with a module for visualizing the project. The images produced by this module can never be of a professional type, since the functions present are intuitive but minimal and simplified, and in addition, the model, for the reasons explained above, cannot have a solid graphic detail, especially on the furnishing elements. The BIM model's detail is appropiate only for general external architectural visualization.

At the same time, Virtual Reality and Augmented Reality applications are now having a great diffusion in indoor architectural visualization. Through these, photorealism in Real-Time has made significant progress, thanks to the evolution of rendering engines, AR / MR techniques (Alhakamy and Tuceryan, 2020) and the hardware capacity of modern video cards (Thoman *et al.*, 2022). In addition, some studies have shown that, especially in daylight simulations, the perception of space by the end user was particularly accurate (Chamilothori, Wienold and Andersen, 2019). Also in artificial lighting scenarios, the theme of visualization of the BIM model in VR visualization techniques has been studied, and good results have been obtained (Natephra *et al.*, 2017). For these reasons, the presentation of the project to the customer is experiencing a natural integration and evolution of static rendering towards these new visualization techniques.

Therefore, the need to find a way to present the BIM model through these new ways arises, improving the quality of the model without affecting the weight in bytes of the native file. As this is a continuous and rapid evolution field, the possible solutions are numerous and often different in the approach. Some already proposed in the past involve using multiple software applications (Wong *et al.*, 2019). Let us see here which tools can be used and if in these the theme of color fidelity is taken into account or not.

Preliminary Procedures

Regardless of the Real-Time solution that the designer chooses to use, the constancy of the color that he will want to verify cannot ignore two factors: a correct acquisition of the finish of the material sample and a faithful reproduction of the designed lighting scenario.

Most of the time, textures to use in CAD systems must have a standard sRGB color profile. As far as possible, the designer should avoid using textures downloaded from the internet, as it is rarely known: a) how they were acquired; b) if a standard procedure was followed; c) if the conversion of the relative color profile of the device to the absolute sRGB profile has been done and correctly. The designer should therefore opt for a live acquisition.

The possible procedures are two, one photographic and one via scanner. In both cases, the devices must be calibrated and have a relative color profile, periodically updated in the case of the scanner (Guarini, 2020) and obtained at the time of shooting in the case of the camera (Guarini and Rossi, 2021). The procedure, as well as the environmental conditions, must be standard and reproducible. Taking this last point into account, scanner acquisition is perhaps preferable in the case of thin material samples. The final image of the acquired texture must then be converted, using a dedicated program equipped with a CSM Manager, into the absolute sRGB color space. If the texture has to be repeated several times on a surface, it will then be refined in a photo editing program to be used as seamless.

The lighting conditions to carry out design simulations where it is possible to evaluate the color rendering of materials are basically two: natural light and artificial light.

The first is easier to manage, as each real-time simulation software has simplified commands that reproduce daytime or nighttime lighting. The parameters to set up are not numerous and essentially concern the simulation's date and time, the project's position and orientation, and the atmospheric conditions of the simulation. The designer must always take care not to modify the preset physical parameters, such as the sun's intensity and the solar disk's size, to avoid incorrect simulations in terms of the quantity of light and the visualization of shadows.

The artificial light condition requires more attention, as the designer should use the accurate photometric data of the luminaires he wants to use in the environment. The manufacturers of the appliances can supply these. The survey and acquisition techniques are constantly evolving. However, at present, the most widespread methodology consists in entering the data relating to the light intensity through photometric files (Siniscalco and Guarini, 2018) downloaded from the manufacturers' websites and the data relating to the color temperature of the sources by entering them manually from the technical data sheets of the device. Almost all real-time viewing software supports the insertion and the use of these files and these color temperatures. It is also necessary to verify that the software has available options or tools that allow using the real intensity distribution given by the file, without this being occluded or modified by the 3D geometry of the device itself.

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PBR Materials

Almost all the proposed solutions we will list later and which deal with the Real-Time visualization of the projects use PBR materials (McDermott, 2018). Revit has recently introduced this type of material, even if they are still hidden and not easily accessible by the user. When assigning materials in Revit, it is preferable to use these directly to facilitate compatibility and reduce the work in Real-time Rendering applications. If on the sample present in the library there is an exclamation point on a yellow triangle, the Revit material is not a PBR material (Fig. 1). If you want to create a PBR material from scratch, the "Asset Browser> Appearance Library> Base Materials" library must be installed, where you can find five base PBR materials to start from (Fig. 2).

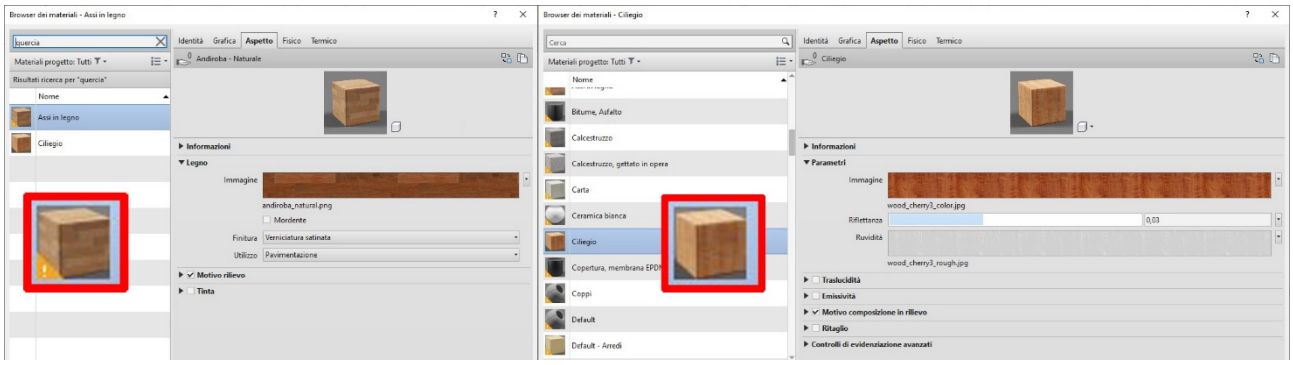

Fig. 1 - non PBR and PBR Materials in Revit

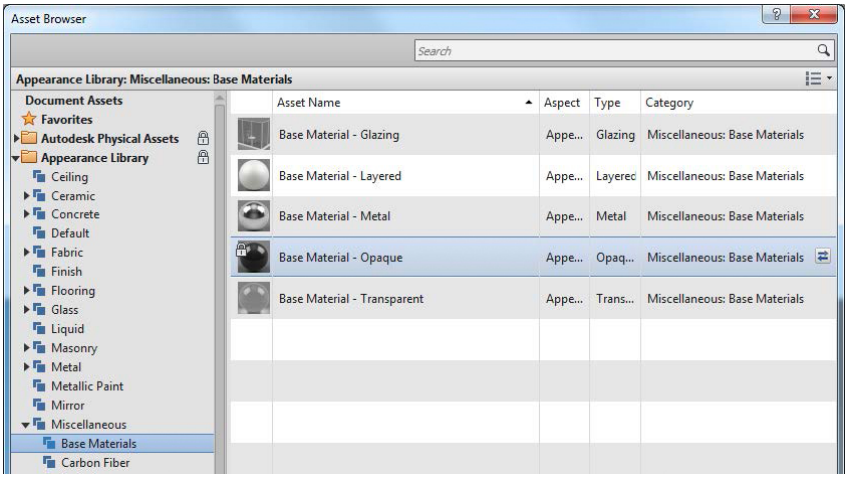

Fig. 2 - Base PBR Materials in Revit

These PBR materials are based on physical parameters, which can be set through values and preferably through specific texture images. These parameters in which to insert the maps are always the same, regardless of the software used. Once the designer has obtained the maps in question, he must connect them to the respective map channels of the application he wants to use. Among the most important, we mention the "Albedo" relating to the diffuse reflection of light, the "Roughness" relating to the surface imperfections of the surface and the "Height Map" relating to the bump.

Here the problem arises regarding how to obtain the textures related to these properties. Several sites offer pre-prepared textures for the various channels. However, as already explained, these should be avoided for a whole series of problems regarding the fidelity of the acquisition of the base color, which is why it would be advisable to use a texture acquired with known and standard procedures. Once obtained this, free software allows obtaining all the others textures from the first image. An example of this software is Materialize (*Bounding Box Software - Materialize*, no date).

However, we outline that the procedure for obtaining images with sRGB profile to be used in the Albedo property tries to return the color as faithfully as possible. Instead, this free software that renders the other maps helps to give a more realistic appearance to the final finish by acting on the gloss of the material and its roughness, but they work empirically and reproducing the type of finish is due to the designer's ability.

Available solutions

After following the preliminary procedures and using PBR materials where possible, a dedicated application or plugin is still required to easily view the project in real-time. The BIM software has a module for viewing the rendering of the project, which, however, has a limited set of tools and does not solve the problems related to the interaction of the photometric solid within the lighting fixture. Furthermore, they do not have a module for real-time viewing. Some integrated and cloud-based solutions were implemented but were subsequently discontinued, such as "Revit Live"(*Revit Live | Autodesk*, 2020).

However, several solutions are currently available, given the ever-increasing diffusion of Realtime Visualization and Augmented Reality. Among these, even professional rendering engines with years of experience in the visualization sector have developed additional real-time applications to import the scenes rendered through their plugin, such as VRay for Revit (*V-Ray for Revit*, 2021) and Chaos Vantage (*Chaos Vantage – Pure ray tracing in real-time | Chaos*, 2022).

There are also plugin solutions dedicated to the world of architecture, allowing, through live synch, to view the model easily. Some examples are Enscape and Lumion (*Lumion 3D Rendering Software | Architectural Visualization*, 2022).

Another possible solution is to import the BIM model using a standard file format into leading software in the sector, such as Unity (Unity, 2022a) and Unreal (*Unreal Engine 5*, 2004). Software houses are increasingly developing plugins to allow BIM users to take advantage of the Real-Time raytraced project visualization through simplified versions of their vertical software in the sector, simplifying the work of the designers. Unity Reflect (Unity, 2022b) is an example of this approach.

Revit VRay and Chaos Vantage

VRay for Revit is a plugin that expands the possibilities of Revit in terms of project visualization. It solves the interaction problems of the photometric solid within the luminaire and can perform lighting analysis on photometric quantities. It has photometrically correct materials, the VRay Materials, which allow importing textures acquired specifically with sRGB profile, thus guaranteeing color consistency in the representations. The software house that developed it has also implemented an application dedicated to real-time visualization, Chaos Vantage. From VRay for Revit, it is possible to export the entire model in a *.VRayscene format, which can then be imported into Chaos Vantage.

In this case, the materials and natural light are managed entirely within VRay for Revit, while the lighting fixtures and photometric files are set up in Revit. Once the file has been imported into Vantage, it is possible to explore the model in Realtime and with the same rendering quality as VRay. It is also possible to apply other materials to the scene, including those previously created and assigned within VRay for Revit. The lighting fixtures can also be switched off and dimmed.

Revit and Enscape

Enscape (*Enscape™*, 2022) is a Real-time Rendering Plugin that can be used in various software, including BIM software and Revit. Once the plugin is installed, it is possible to transport the BIM model to an Enscape instance, establishing a dynamic link between the model and its visualization. Therefore, the Enscape window acts as a Real-Time viewer of everything modified in Revit.

The materials and the lights are then set directly in the BIM software. For this reason, to obtain the consistency between the purchased color and the one represented, the procedure and the precautions

are the same to follow to import a color and a texture into the native materials of Revit (Guarini and Rossi, 2019) , taking care to use PBR materials as much as possible. On the influence of the correct simulation of artificial light on color, it is sufficient to follow the recommendations indicated at the beginning of the article. This is generally a valid prerequisite for a solid inserting of lights into the BIM software. On the other hand, the simulations of natural lighting are set directly and dynamically in Enscape.

To have a good representation of the project, the models should be in high detail, i.e. with a high number of polygons, to better represent the curved surfaces and the shades of color on the various finishes. This would, unfortunately, weigh up the BIM file. The Plugin solves this problem by replacing in the representation phase low-detailed Revit families with 3D models developed within an Enscape proprietary Editor. With this expedient, the BIM file is not thought of in terms of Bytes, while the Real-Time representation is shown in high quality.

The Plugin has a custom library containing ready-to-insert templates. If the designer wants to insert models that are not present, he can use the Enscape Editor to import different 3D file formats. This solution allows bypassing the mapping coordinate problems that are present in Revit. The BIM software has a limited set of tools for these purposes but importing a 3D model into the Enscape Editor also imports the mesh mapping coordinates of the imported surfaces, thus solving any problems.

Regarding the color rendering in Enscape, the Plugin can use the Revit materials. However, it also has tools to create dedicated materials, which replace the native materials in the Real-Time window or directly in Revit, if the designer decides to apply them permanently. These materials are configurable within the project and in the Enscape Editor for importing into objects. The basis of the materials that can be created in Enscape is the PBR Materials. Considering this, for the correct color rendering, the texture with the sRGB color profile to be used is the one that must be inserted in the slot generally called “Albedo”, which refers to the light reflected in a diffused way. In addition, if the designer opts to use Revit materials to view the project with Enscape without making any replacements, it is advisable to directly use the PBR materials, already present in Revit since 2019 and as explained at the beginning of this text.

Revit and exporting in dedicated di Real-Time Visualization Software

Another possible way to view the BIM model in interactive mode is the use of vertical applications in this sector, explicitly developed for Real-Time visualization, among which we can mention the best-known "Unity" and "Unreal".

These software also use PBR materials, which are, in fact, the standard for a physically correct representation of materials and their finishes. Taking up and completing what written at the beginning of this text, the parameters present in this type of material are different, but among the leading properties, we can mention: color (or Albedo), roughness and metalness, that is, if the material is a dielectric or metal. These three properties are present in every solution we are presenting here. Each of these affects the final color rendering by the observer, but the one that most significantly affects the perception is the first: the Albedo, which should always be entered with the sRGB color space in case it is assigned as a texture.

Each software may present these parameters differently. For example, in Unreal, the Albedo is named "Basic Color". The interface of the Unreal Material Editor shows an Editor of nodes, which are connected with a tree structure. The various parameters are the nodes, connected to the primary node that represents the material on which the designer is working. In the node relating to the

texture to insert "Texture Sample" and connect to the "Basic color" it is possible to choose the texture to use. In the texture properties, it is possible to specify whether the inserted texture should be in the sRGB color space (Fig. 3), and as explained at the beginning of this text, here this option must always be activated.

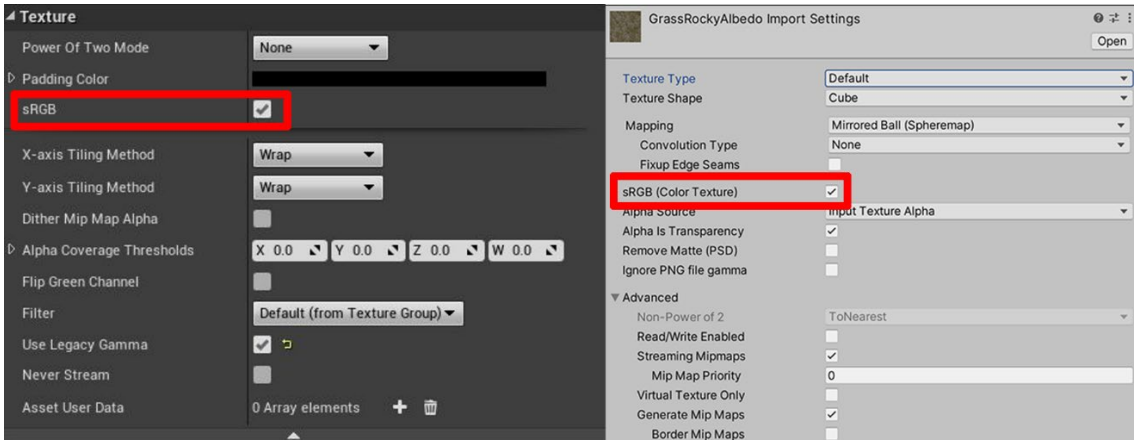

Fig. 3 – sRGB Option in the Texture Properties of Unreal Engine and of Unity

It is possible to develop the procedure for importing the BIM model into Unreal in several ways. The most straightforward and immediate one is using the *.fbx format. However, this is a geometric format, and its use can lead to the loss of many information in the project's BIM database. This problem can be solved using a third-party plugin, such as "Datamisth" (*Datasmith Exporter Plugins*, 2004), which allows to associate information not present after exporting the *.fbx file. This Plugin should be installed on Revit and enabled on Unreal. Using this Plugin, it is possible to keep track of the material replacements made during the import of the *.fbx file, and it is possible to reapply them automatically if it is needed to re-import the model following some modification or variant of the project. This procedure is longer and more complex compared to the Enscape Plugin alone, as it requires several steps and attention from the designer.

The visual render of the BIM model is not so sophisticated because the furniture's level of detail and development cannot have surface models composed of an excessive number of polygons. So even in Unreal, as with Enscape, it is possible to replace the Revit families with more complex geometries to enhance the visual result.

Another Vertical program dedicated to Real-Time Rendering, as Unreal, is Unity. Also in this application, the materials used are PBR, and here too, there is the possibility to specify whether the texture should be used with the sRGB color profile (Fig. 3). If the texture is assigned to the Albedo color, the sRGB profile must always be specified.

Revit and Unity Reflect

As shown in the previous paragraph, the use of vertical software in Real-Time representation guarantees, on the one hand, high-level performance and a great variety of tools for the designer. On the other hand, the export process can be non-intuitive for the designer and increase the number of skills he must acquire to obtain the desired result, discouraging their use. Considering this, some software houses have decided to develop specific versions of their applications dedicated to the BIM world, so that they interface directly with Revit and facilitate the use of these tools by BIM specialists. An example of these dedicated applications is "Unity Reflect", derived from the Unity application. The application installs a new tab in the Revit ribbon, from which it is possible to easily

export the BIM model to the Unity Reflect viewer. Any changes made in the Revit model, both in the geometry and the material, are automatically updated in the Unity Reflect model. The model imported into the viewer is completed with all BIM data, without the need of third-party export programs. The color properties of the materials, to be consistent, must therefore be correctly set directly in Revit with the advisable use of the PBR material, since Unity Reflect does not have the tools of the central Unity program; it is simply a 3D viewer of the BIM model.

Conclusions

This text illustrates some solutions available today to visualize a BIM model through Real-Time rendering, trying to maintain consistency between the actual colors chosen for the finishes and those represented in the design visualization. It has been explained that to achieve this result it is necessary to respect some preliminary procedures: a) acquire the textures of the materials with standard procedures and periodically calibrated tools, taking care to convert the relative color profile of the devices into the absolute sRGB color space; b) correctly simulate the possible lighting conditions; c) preferably use the recent PBR materials, if possible, already within the BIM software.

The BIM software does not have a module dedicated to Real-Time. A first solution could be using the VRay for Revit plugin, which in addition to creating traditional professional renderings, can export the scene to the Chaos Vantage Real-Time application of the same software house. Another solution is using other rendering engines such as Enscape or Lumion, which allow a live connection with the BIM software through a special plugin for Revit. It is also possible to export the BIM model to programs specifically dedicated to the Game Engine and Real-Time Visualization, such as Unreal and Unity. Finally, we can mention the possibility of using specific BIM versions of previously listed vertical Real-Time software, such as Unity Reflect.

These are just some of the possible solutions in the designer's toolset, which vary in terms of typology and applications available. Indeed, with the evolution of current technologies in a dynamic and rapidly expanding field, we hope that there will be a convergence towards a reduced number of solutions for professionals in the future.

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