

Digital Visualization of a Luminaire: From blueprint to Photorealistic Representation

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ABSTRACT

In this article we will discuss how to closely digital represent the aspect of a Luminaire and the photometric distribution of the light emitted by it. You will find a comparison of different modeling techniques used to obtain in a quick and efficient way a clean 3D model of a lighting fixture. A model that should also be, with minimum settings, scalable in terms of level of detail depending from the visual importance of the product in the scene. This will avoid too long rendering times and heavy geometry that could be difficult to manage. We will also investigate what could be an optimal procedure to couple the 3D model with photometric data taken from manufactures or measured in a laboratory.

KEYWORDS

Light, Color, Luminaire, Visualization, Digital Representation, 3D, Photometry

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1. INTRODUCTION

The continuous increase of the computational power of today's computers and the possibility to get fast results, contributed to the diffusion of 3D representation software used by designers to produce the so-called photo realistic renderings. The goal of these images, usually, is to show what should be the final appearance of the project.

Very often, unfortunately, these representations are the result of empirical graphic representation based in the best cases, on the experience of the designer and his ability to achieve images that should be similar enough to what he plans to realize. However, when these forecast images are produced without a precise methodology in the management of virtual materials or the importing and integration of technical data of lighting products usually the resulting digital images, although their strong visual impact, do not match the final appearance of the project a once put in place.

Having a beautiful image to present to the clients may help the designer to get the job, but in the end, if the real scene, with all of its luminaires, finishes and materials, is too different from the virtual image presented, there can be problems with the clients.

This article is part of a wider work on representation and is meant as a help for designers willing to apply modelling and representation techniques that are quick, efficient and that should better represent the appearance of selected lighting fixture.

Our aim is to describe some practical techniques of modeling and representation of lighting fixtures itself in virtual projects, rather than their impact in the whole space, while maintaining both photo-realism and photometric accuracy. To create a correct digital duplicate of the luminaire in terms of geometry, material, aspect and distribution of light is not a simple task.

These procedures can be used in the most common 3D software for modeling and representation.

2. MODELING THE LUMINAIRES

Considering the fact that there are few studies often designers, in order to speed up the modeling process, makes use of 3D models available online from the manufacturer's website or portal/libraries dedicated to 3D computer graphics.

Unfortunately, these models are not always optimized for the production of forecast images, for various reasons. Some time they are conversion of models that have been created for the CNC (Computer Numerical Control) of the objects, so with the purpose of the realization of

a physical model; or maybe with a completely different set of features. This can result in the first case in a model with excessively many polygons and in the second, a model that can have "inverted Normals", that results in visible "holes" in the surfaces of the objects.

If the model of the product found is not suitable, the better choice is to rebuild it, starting by defining the desired level of detail and therefore the modelling technique that allows the designer to obtain good results in an efficient way, always thinking to the final representation since early modelling.

The level of detail of the geometries is fundamental in order to not to waste time, needed for modeling and for rendering. The designer should be aware of the visual importance of the geometries in the images that he wants to produce, whether the objects will be represented in the foreground, the background or in an intermediate situation. A good approach is that the modelling techniques used may allow changes in the resolution of the 3D mesh of the model, increasing the detail of the geometry in relation to the importance of the model in the scene, using for instance subdivision modelling techniques.

The choice of the best modelling technique depends mainly from the geometry of the luminaire that can be made of one single piece or by multiple components. In this case it is possible to use more than one technique. If the model can be assimilated to basic geometries, it might be enough to use the CSG (Constructive Solid Geometry) modelling. The primitives available in most of the software, such as cubes, spheres, cylinders, cones, toroid, etc., are transformed with basic operations like move, rotate, scale, copy, etc.

If the model turns out to be more complex, but still can be built with operations of addition, subtraction or intersection between two or more solids, it is possible to use the so-called Boolean operations. These are very fast in order to obtain complex geometries even if they can cause two order of problems: visual continuity between the polygons that appear as unwanted shadows on the surfaces and issues in the organization of the polygonal structure of the model, the topology.

The modelling based on 2D shapes is ideal in case of long, flat, thick objects, so extrusion or taper operations can be effective.

Many lighting fixtures can be assimilated to 2D profiles that can be revolved around a specific axis. The "lath" command, present in most of the modeling software, may allow the designer to obtain these geometries quite easily.

For parts such as cables, filaments, springs, it is possible to use modeling tools such as Sweep or Loft (D'Agnano, 2008).

Sweep allows the creation of 3D geometries by

making a profile, that can be generated by the user or sometimes available on a library, "run" along a curve path keeping its perpendicular aligned to the tangent of the path itself.

The operation done by the Loft tool is similar to the one of the Sweep tool, but with more options. It is possible to change the profile, scale, rotate or twist it, along the path, modifying the resulting geometry. If no one of the previous tools can be used efficiently, the modelling technique that allow the designer to reproduce the most complex shape is the Polygonal modelling (Daniele, 2008).

Generally, the easiest approach is to start from flat surfaces mapped with a raster image of the technical drawings; the so called "blueprints" used as planes of projection. It is possible to begin from a primitive solid or even a single polygon and rebuild the entire object by moving and/or adding vertices and polygons. When possible it is good practice to begin by realizing a low-poly model and then increasing the complexity of the geometry at will, by using a "Subdivision tool". This procedure split up the interested polygons in four parts and allow the user to "relax" the adjacent polygons, also divided, creating a smoother appearance of the surfaces. The process can be repeated more times intervening on the number of iterations. It is necessary to pay attention to the number of iterations applied, because for each one, the number of polygon of geometry quadruplicates, increasing exponentially the weight of the 3D model and the time needed to calculate the renders.

In order to decide how many iterations are

needed for a model, as previously mentioned, the designer should know the importance of the object in the scene; for close objects, the number of iterations will be much greater than for objects in the background.

3. PHOTOMETRY

Once achieved the goal of a balanced 3D model in term of quality and weight, it is necessary to transform the obtained geometry into an actual light source that can be used to render the final scene.

A desirable thing should be to use the software as a verification tool and not just to produce attractive images; for instance, how my project will look like if I choose one luminaire instead of another. In order to do so, it is necessary that the software in use comes with calculation algorithms that approximate in a plausible manner, the real light distribution in space. This is possible only when indirect light is actually calculated by the interaction of the emitted light and the surfaces of the scene, and not simulated with hypothetic parameters that modulate the amount of light diffused in the scene, such as ambient light, for example.

In software used to do lighting verification, these calculations were once made by the algorithm of Radiosity, which allowed the simulation of light evenly diffused by Lambertian surfaces and soft shadows. The results, were integrated by Ray tracing algorithms that were dedicated to calculate specular reflections and sharp, defined shadows. More recently, software specialized in

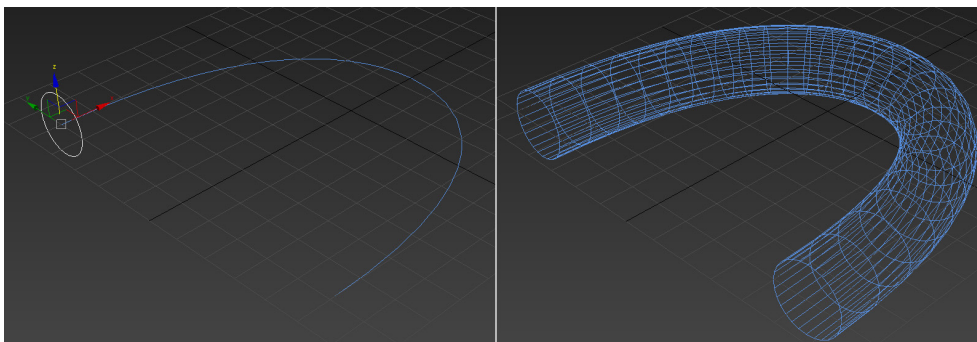


Figure 1 - SWEEP TOOL - Example of the use of the Sweep tool. On the right, it is possible to see the circle that will act as profile running on the path (in this case a curve). On the left the resulting geometry

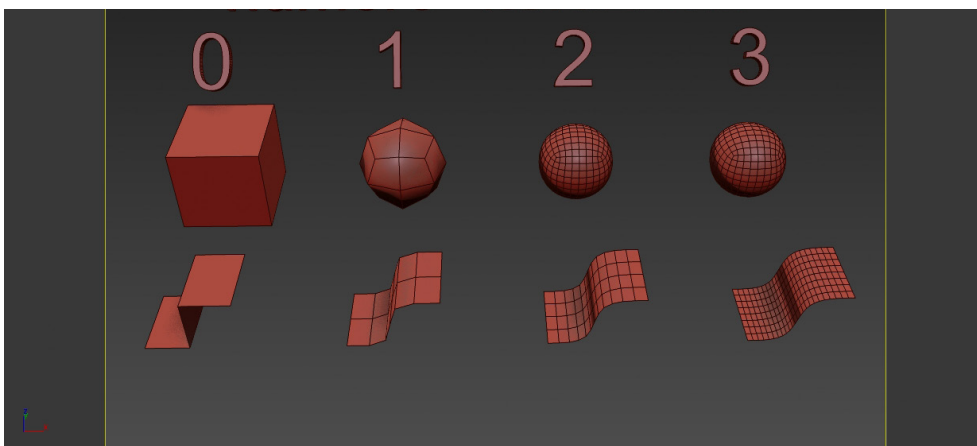


Figure 2 - ITERATIONS - Example of increase in the number of polygons in relation to the number of iterations choices for the object

light calculations have been updated with more recent algorithms such as Photon mapping or the rapidly diffusing Physically based algorithms. That said it must be clear to the designer that it is not possible to get reliable results by using the "classic" light sources of computer graphics (such as OpenGL Ambient, Point, Directional, Spot). Real luminaires, in most cases, have a spatial distribution of the lighting intensity more complex than those achievable through OpenGL lights. As an example, it is very easy to understand that the light distribution in space of a road luminaire has nothing to do with the one of a table lamp or a retail premise spotlight. Each luminaire has a specific light intensity distribution, which is the result of interaction between the lamp and the optical system of the device, generally designed to meet specific project requirements.

3.1 PHOTOMETRIC FILES

The shape of light emission in luminaires, is generally measured by using a laboratory instrument called Goniophotometer that performs an angular emission investigation and saves the results in ASCII files containing, along with other parameters, a set of coordinates and values, that put in relation spatial angles with the light intensity emitted by the luminaire. These files are generally called Photometric files or Photometric webs.

These shapes are eventually more complex than the basic OpenGL lights.

The photometric files are generated in different formats (mostly in relation to the nation in which they are acquired/created) such as Eulumdat - *.ldt - Europe (Stockmar, 1999), IESNA - *.ies - America (ANSI/IESNA, 2008), CIBSE TM14 - *.cib - United Kingdom (CIBSE, 1988), LTLI - *.lil - Denmark (UNI EN 13032-1, 2012).

In addition to these standard files there are also several proprietary formats used by specific lighting design software, such as the format *.uld of Dialux (DIAL GmbH, 2018), the format *.oxl of Litestar (Oxytech Srl, 2018) or the format *.rolfz of Relux (Relux Informatik AG, 2018), that are often integrated with a 3D model that is usually given by the luminaire manufacturer, and unfortunately, not always properly modelled.

Obviously these latter formats are read only by their software, whose main purpose is not really the photorealistic rendering, but rather the photometric verification, and cannot be opened with the most common software used for photorealistic renderings.

The choice given to the designer is to import common photometric files such as Eulumdat, or other open formats like IESNA, CIBSE, LTLI, which can simulate the actual light distribution of the luminaire, but still, not their physical appearance.

In order to reproduce the appearance of a lighting fixture it is necessary to couple the geometric model to its corresponding photometric web that usually is available from the manufacturer or measured with a goniophotometric relief in a laboratory.

3.2 PAIRING 3D MODELS AND PHOTOMETRIC FILES

After modelling the geometry of the luminaire with the methods suggested in paragraph 2, it is necessary to place a light source whose emission properties will be those of the photometric solid. The photometric files are related to a point in space that emits light with different intensities as vectors in space.

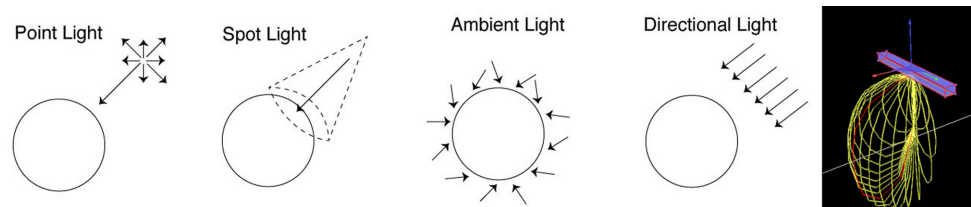
In the physical reality, these intensities are the result of the interaction between the light emitted by sources like discharge in gas, burner or LED and the optical system of the luminaire, for example: reflector, refractor, lenses, filters, etc. It is necessary to remember that the measured photometric file already considers these interactions.

Consequently, it is important that the three-dimensional model of the luminaire, does not alter the emission of the photometric web, like for instance, by cutting her off. In many software, this is possible by editing the properties of the light source so that some objects do not interact with the light; specifically, by not casting any shadow. An example of object that may be set with these properties are those of the part of the luminaire that emits light, in which the photometric web will probably be placed.

In order to complete this task correctly, the designer need to place the photometric web in a correct way according the modelled geometry. Logic would suggest placing the photometric web in the same position where the light source is found in the real luminaire. In reality, the solution is not so simple.

Considering that photometric webs are considered to be points; where to place them when the light source is widespread? What is the correct placement position when inside of the luminaire there are multiple lights sources, such in the case of LED lighting fixtures?

Figure 3 - LIGHT SOURCES - From left to right, different generic light sources commonly used in 3D software: Point, Spot, Ambient and Directional. The far right shows the photometric web of a real lighting fixture (Mellow Light IV by Zumtobel)



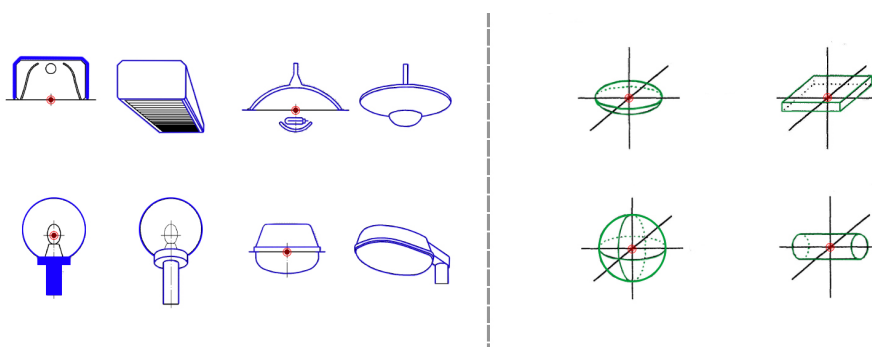


Figure 4 - PHOTOMETRIC CENTER - To the left (in blue) some guidelines for the identification of the photometric center (also called photometric zero), marked in red, as prescribed by the European standard UNI EN 13032-1. To the right (in green), some of the prescription provided by the American standard IESNA LM-63-02.

If the purpose is the photometric accuracy and the program allows you to exclude parts of the geometry from the lighting calculation, the correct position is that of the photometric center of the luminaire.

The photometric center is defined as the point where the luminaire is aligned with the goniophotometer during the relief in which the photometric file is generated. The correct position of this point is described by the standards for the measurement of light fittings, which may vary from country to country (for instance America and Europe) and result into the generation of different photometric files.

It is possible to consider the photometric center as the locus from which the light is emitted, and therefore, it should be considered as the point of junction between the geometry of the 3D model and the photometric files.

The operation of identification of the photometric center is easier for the categories described by the standard. Nevertheless, for some luminaires with very complex shapes, it is necessary to use some simplifications and adjustments, but this happens for the goni-photometric relief as well. For instance, a complex chandelier will hardly have a photometric file, but if the file exists, it will be hardly described in the standard. In this case, the designer should look at the shape of the photometric web, at the position of the light sources by looking to a catalogue or the brochure of the product, and deduce the position of the photometric center that in most cases, correspond to the center of the geometry of the light emitting part of the fixture.

4. COLOR

A fundamental problem in the representation of the luminaires and light in general, is related to the limits of the representation devices. The computer-generated images are mostly produced to be displayed on video; it can also happen that these images are printed, maybe with high resolution but still, the devices typically used for digital representation, are unable to compete with the dynamic of the physical reality and the human perception. This is true regarding both the luminance contrasts, and the spectral component of light.

Having to use a representation device as an example, a monitor, all of the colors usually are converted to RGB triplets.

A simple mix of three components it is not enough to compose light in physical reality; an electromagnetic radiation composed by different wavelengths of which, our visual system can perceive only the portion between 380 and 780 nanometers: violet, indigo, blue, green, yellow, orange and red.

Given this, it is also necessary to specify that often the light sources commonly used in luminaires, have nonlinear emission spectra that might be incomplete or in bands that peaks in certain colors; very different from that of the sun. For this reason, some light sources are less effective in color render. Under these light sources, some colors appear to be dull and grayish.

The chromaticity of a computer generated light source, must necessarily be converted into an RGB triplet in order to be represented by common monitors, which are matrices of RGB LEDs. Also, because the user have to decide the color of a light source within the modelling software, the most used method is still RGB.

Sometimes color presets are available in the software, for example relating to different sources or different color temperatures, but even if the chosen values recall the real physics in practice, the light is colored only by changing the RGB values and it is hardly able to represent different color rendering indexes.

Some rendering programs (RandomControl SLU, 2017) (Fluid Interactive Inc, 2015) (Glare Technologies Limited, 2018) (LuxRender, 2018) (NVIDIA, 2015) (Wenzel, 2010) (OTOY Inc, 2017) (Solid Iris Technologies. 2012) (Eclat-Digital Recherche, 2013) implement algorithms able to mimic the spectral behavior of light, displaying the color by simulating the spectral colors with a given spectral step, for example simulating the properties with steps of 10nm.

There are many ways to implement these algorithms, but generally, although they allow higher accuracy in the calculation of color simulating more correctly phenomena such as the spectral dispersion or the lower color-rendering index of some light sources, this cost globally in terms of greater complexity and the

need of longer computational times.

The same concepts are valid also for the materials applied in the scene, commonly called “shaders”, which by reflection, refraction and transmission, should affect the spectrum of light by dispersion or by reflecting or transmitting only certain wavelength and thus, changing the color of light.

If the will of the designer is to remain faithful to the physics of real world, it is necessary (Radziszewski et al., 2009) to use a software that calculates light and its interaction with materials with a full spectrum algorithm.

5. CASE STUDIES

Five case studies of digital representation of real luminaires will be described below, but before starting, a little premise is necessary: the described techniques, both for modelling and for rendering, are not the only ones that can be used. The focus is to achieve models that are clean, efficient and with a level of detail that can be increased or decreased at will.

The software used for these case studies purpose is 3D Studio Max 2016 by Autodesk, but these techniques can be easily reproduced in any compatible modelling software.

The choice fell on 3DSMax because it is one of the most diffuse modeling software for design visualization. It also offers a wide set of tools that allow the user to approach the modeling with different techniques. Moreover, a lot of reference and tutorial can be easily found on the web in order to help the user to learn how to use it.

Other specific software such as Dialux, Relux, Agi32 or LiteStar, specifically designed for lighting, are commonly used for the evaluation of the lighting project, but their modeling tools are very simplified and also, they usually have proprietary files that already implement the system 3D model – photometric file, as said in 3.1.

The first case is a very simple luminaire, that can be modelled with CSG, extrusion of spline and very simple polygonal modeling. The amount of detail is derived by the parameters embedded in the primitives

The second case shows how an inner part of a luminaire can be simplified because not directly and totally seen. Instead the numerous and external items are the most accurate and prepared for subdivision, done with a single instance of a sphere modified with poly modelling.

The third one lends itself to the use of Boolean operation, refined with few steps of poly modeling to obtain clean results. Also the revolution tool (lathe) to curve primitives will be the best choice.

It will be evident, that to prefer one technique

more than another will be a decision driven by the shape of the object or of its main component. When possible an approximation with parametric primitives is to be preferred. When it is not, an analysis of the geometry will tell us how to proceed. If by combining or subtracting the geometry, extruding or revolving a curve, giving thickness to lines and curves. Where all of this techniques cannot help, direct polygonal editing is the suggested approach to solve the problem. A clean topology obtained with this technique is also the best starting point to have a scalable 3D object in terms of level of detail.

5.1 EVOLUZIONE BY DISANO ILLUMINAZIONE

Evoluzione is a very common luminaire that mount fluorescent linear lamp produced by Disano illuminazione. The simple, straightforward design is also reflected on the simplicity of the modelling process. The luminaire can be replicated with five geometric shapes: a parallelepiped for the external shell, an extruded profile for the aluminum reflectors, cylinders for the lamps, other parallelepipeds for the lamp-holders and the side abutment.

The external shell is obtained by a parallelepiped, where the lower face has been refined into a new smaller polygon that has been then removed. The thickness of the shell is obtained by using a command that create a series of polygons parallel to the existing ones for simulating the thickness of the element. Usually this command is called “Shell”.

The profile of the reflector is extruded for the length of the luminaire, and closed at the sides, by the abutments, created by two parallelepipeds. These two elements are placed inside of the external shell.

The fluorescent lamps are obtained with four cylinders. The use of the standard parametric primitive gives the possibility to easily increase or decrease the number of faces in the model.

A polygonal modification of a parallelepiped, allow the designer to create the lamp holders.

After the model is created, it is necessary to find the correct photometric file to couple with the model. As in most case, these files can be downloaded from the website of the manufacturer. To place the photometric web in the photometric center, the designer should look at the standard. In this case, both the American and European standards states that the photometric center is in the lower center of the luminaire. This means in the intersection of the median axes at the height of the lower face of the external shell. It is important not to modify the values of intensity inherited by the photometric file, even if the software allow the user to do so, because these are the actual measured values of the luminaire.

A problem should be very visible at this point:

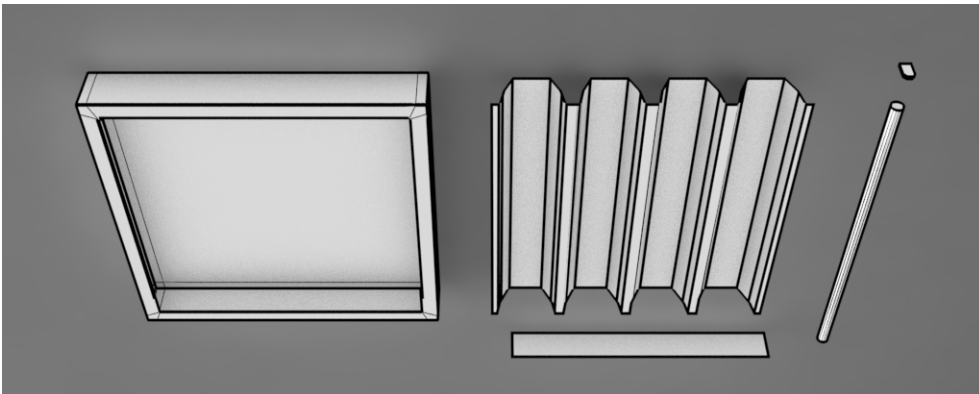


Figure 5 - EVOLUZIONE BASIC GEOMETRY - Basic geometric components for the 3D modelling of Evoluzione by Disano Illuminazione.

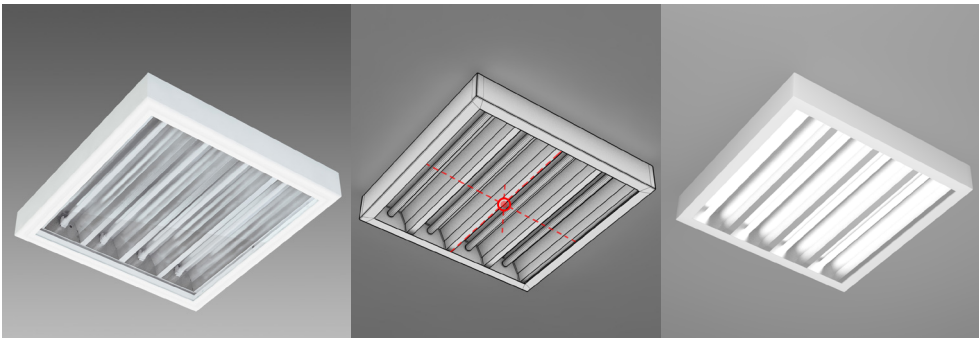


Figure 6 - EVOLUZIONE COMPARISON - From left to right: picture of the luminaire, geometric model of the luminaire (red sign indicates the photometric center) and production render of the luminaire.

how it is possible to simulate the appearance of the four luminous tubes with just one photometric file that, in this case, emits only downwards. Only by using the photometric file, this is impossible. The tubes appear dark, even if the luminaire is emitting light. To solve this, it is necessary to use a little trick. First, it is necessary to assign the correct materials to the geometry, paying attention to the energy balance of materials, because it is necessary to reproduce the right finishes and the right index of reflection/transmission/refraction of each part of the model. For Evoluzione, the external shell is a highly diffusive painted white metal with a small reflective component, around 65% diffusive and 5% reflective. Except the tubes, the other parts are made of brushed aluminum with 70% of specular reflection with glossiness lowered to 50%.

To obtain the fluorescent tubes, it is necessary to use a self-illuminating material for the simulation of the light that comes out from the tubes. Fortunately, most of the rendering engines include this kind of shader. Two important elements must be considered while using such material: first, the self-illumination effect must be visible in the reflections of the other components and second, the light emitted by the self-illuminated material must be ignored in the global calculation of the scene. This because if the light of the self-illuminated material is computed, it will invalidate the luminous emission of the photometric file, producing incorrect results.

5.2 CABOCHÉ SUSPENSION BY FOSCARINI

Caboche is a quite complex suspension luminaire to model. It is composed by a structure made by arcs and circles, a central luminous body, many decorative refractive spheres, wires and cable and the ceiling strut.

The lattice of arcs and circle can be simulated and simplified with the use of a standard torus primitive. Once the center lower and upper faces of the toroid have been removed, the mesh topology can be converted in a wire cage with a thickness decided by the user. For example, in 3DS Max this can be done with the use of the "Lattice" modifier. In this command it is easy to fine tune the number of segments with a parametric value.

The decorative spherical elements can be modeled with the standard sphere primitive, with the lower part modified with few step of polygonal modeling. As the refraction of light trough these spheres is the core aspect of this luminaire, it is indispensable that these elements are calculated as solid thick geometry.

Since these refractive sphere are present in large amount, it is a good idea to use a subdivision technique to the instanced elements, in order to reduce the weight of the model with one single parameter in case of shoots with the luminaire far from the camera.

The luminous body is obtained with the lower part of a sphere primitive. Also in this case the polygon modeling technique helps refining the upper part of the object.

The same process defines the strut on the ceiling. The cuts in the geometry in which the electrical wires pass trough are done open chamfering a corresponding selected set of edges.

Figure 7 - CABOCHE BASIC GEOMETRY - Basic geometric components for the 3D modelling of Caboche by Foscarini.

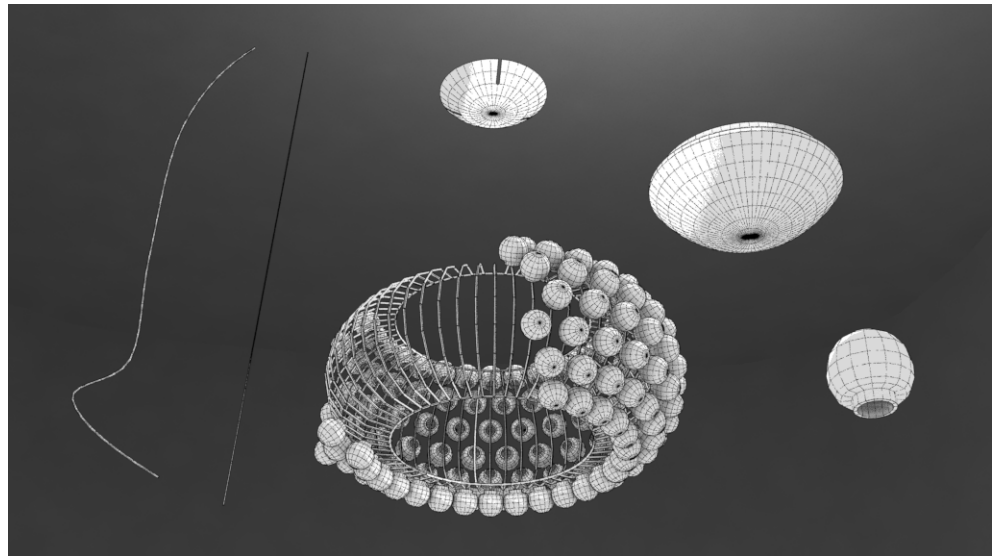
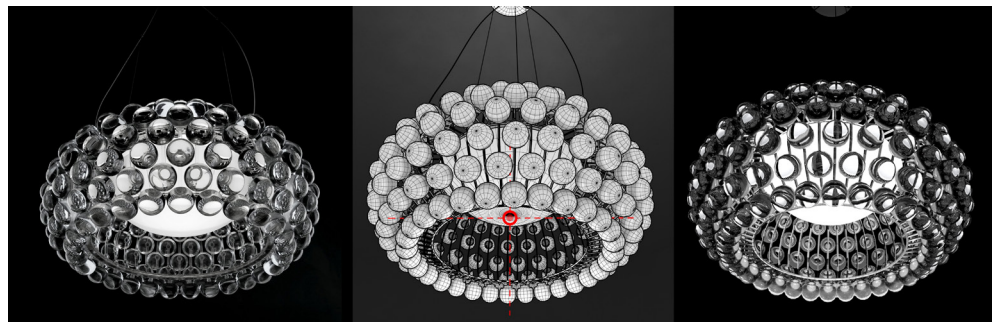


Figure 8 - CABOCHE COMPARISON - From left to right: picture of the luminaire, geometric model of the luminaire (red sign indicates the photometric center) and production render of the luminaire



Cables and suspension wires are created with linear lines and splines. It is possible to create these elements and then use a command to assign them a thickness of a given diameter or, in alternative, using the "Loft" tool.

The materials for Caboche are an opaline blown glass for the luminous body, PMMA for the spheres, polycarbonate for the arches, stainless steel for the suspension cables and transparent electrical cable for the power supply.

The crucial element of this product is the crown of spheres that refract light coming from the luminous element placed in the center. To achieve this effect, the spheres must be considered as solid geometry so it will be possible to put in evidence the refraction; the index for the PMMA is around 1.49. Other materials should not be difficult.

The position of the photometric center, following the indications (figure 5, profile 10) of the European standard, is in the center of the suspended element and not inside of the luminous body as logic may suggest. It is also important to pay attention to the orientation of the photometric web. In this case, for example, the emission of the luminaire is both direct and indirect. The designer must identify the right orientation of the emission by looking at the polar diagrams of the luminaire on the catalogue or the manufacturer's website. In this case, the higher intensities are pointing downwards, so the photometric web must be oriented accordingly.

5.3 A0Y BY FLOS

This luminaire is made by one glass cylindrical main body, a goblet, a reflector and a light bulb. The glass cylinder can be obviously replicated with the corresponding standard primitive, paying attention to the amount of segments at the base circle section. Being the main and bigger body of the luminaire, the circumference of the body should be obtained at least with 32 segments. This should be the minimum choice for a foreground / medium distance camera view.

The arch at the base of the cylinder is obtained by subtracting with a boolean operation, a second cylinder primitive. In order to clean up the topology, the resulting object should be refined with polygonal modelling, removing the unnecessary polygons and vertices created by the subtraction.

To create a more correct model, the opaline goblet inside of the cylinder need to have the same amount of segments. A fast and easy way to obtain this result is to extrude the upper part of the glass cylinder downward and then detaching it from the rest of the body.

The upper reflector is created by revolving a curve along the vertical axis, this can be done with a "Lathe" tool, taking care of setting the number of segments equal to the ones of the other parts of the luminaires.

A revolution can be also used to create the two elements that form the light bulb.

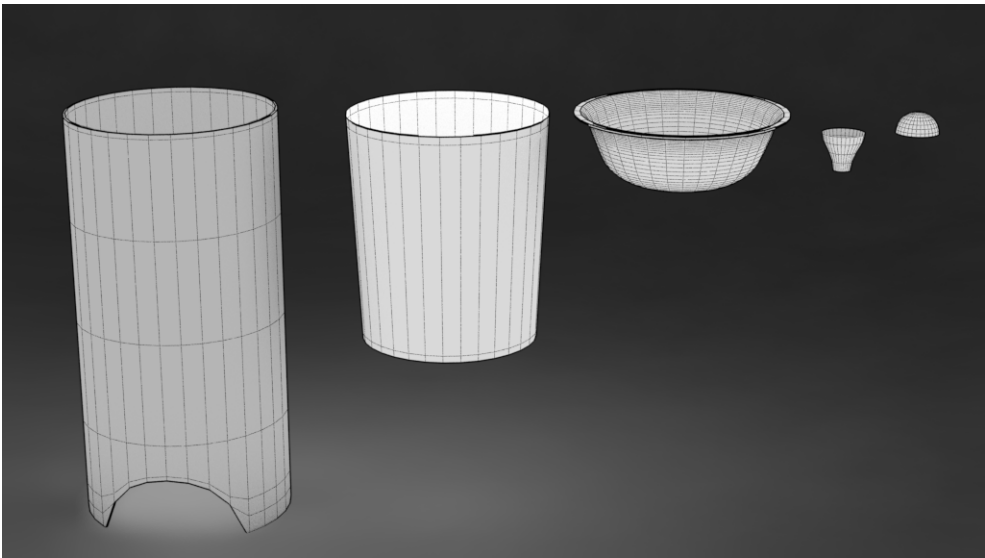


Figure 9 - AOY BASIC GEOMETRY - Basic geometric components for the 3D modelling of Aoy by Flos.

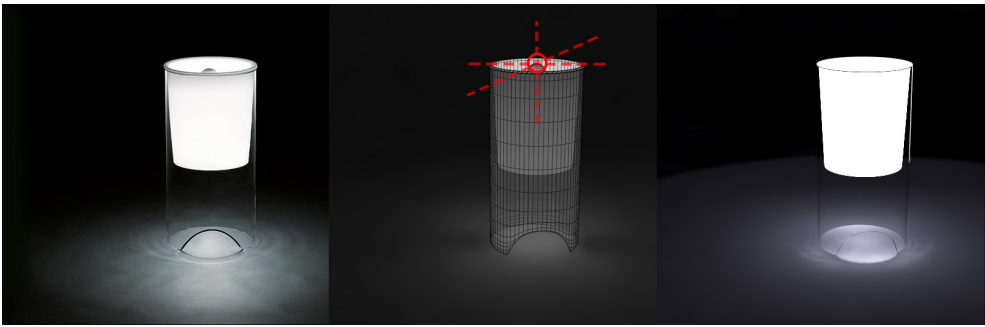


Figure 10 - AOY COMPARISON - From left to right: picture of the luminaire, geometric model of the luminaire (red sign indicates the photometric center) and production render of the luminaire

This last object aside, the first three elements need to have a certain thickness, so the *“Shell”* command must be used.

Also in this model, it is possible to use subdivisions in order to adapt the resolution of the polygonal mesh in relation to the position of the luminaire in the scene.

The external body is made of clear glass and the internal diffuser and reflector are made of white, opaline glass. The light source is a bulb, with the upper half with a chrome finish that serves as anti-glare system.

The position of the photometric web in this case is not in the center of the luminaire, but in correspondence of the light source. The European standard states that for luminaires with transparent sides or without side features, the photometric center corresponds to the lamp photometric center.

Another element to keep in consideration is that this fixture, in dark environments, creates a slight caustic effect at the base of the luminaire. In order to achieve so, the software used must have a render algorithm that is able to calculate caustics, and the effect has to be set up properly. The opaline diffuser and reflector may need a little improvement with a self-illuminated material. To achieve the caustic effect and for physical correctness, they also must be removed from the calculation of shadows together with the bulb.

6. CONCLUSIONS

The techniques described can change in relation to the software used and the shape of the luminaires as it can span from very simple to incredibly complicated. All the objects can be created in many ways, but the techniques described are efficient and allow the designer no to worry about the weight of the model, that can also directly affect the calculation time.

In synthesis, the important steps are:

- The study of the luminaire: geometry, photometry and materials, directly on the catalogues or manufacturer website.
- What to represent; hidden components, for instance, should not be modelled.
- Select the most efficient technique to model all the visible parts.
- Scalability: trying to grant the possibility to change the resolution in relation to the importance of the luminaire in the scene.
- Correct position of the light sources when coupling the photometric data with the geometry. Attention in placing the photometric web in the correct spot according with the standard in use.
- Creating the visual aspect of the object; materials and properties to set in order to respect the physics of the real world, and overcoming the limitations of the system geometry/photometry.

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CONFLICT OF INTEREST

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BIBLIOGRAPHY

- D'Agnano F. (2008), "3ds Max per l'architettura" Apogeo
- Daniele T. (2008), "Poly-Modelling with 3ds Max: Thinking Outside of the Box" Focal Press
- Stockmar A. (1999), EULUMDAT File Format Specification Available at: <http://www.helios32.com/Eulumdat.htm> (Accessed: 18 April 2018)
- Standard ANSI/IESNA LM-63-02 (R2008), "Standard File Format for Electronic Transfer of Photometric Data"
- CIBSE TM14 (1988), "Standard File Format for Transfer of Luminaire Photometric Data", Chartered Institution of Building Services Engineers
- UNI EN 13032-1 (2012), "Luce e illuminazione - Misurazione e presentazione dei dati fotometrici di lampade e apparecchi di illuminazione - Parte 1: Misurazione e formato di file"
- DIAL GmbH (2018). Available at: <https://www.dial.de> (Accessed: 18 April 2018)
- Oxytech Srl (2018). Available at: <http://www.oxytech.it/> (Accessed: 18 April 2018)
- Relux Informatik AG (2018). Available at: <http://www.relux.biz/> (Accessed: 18 April 2018)
- Arion - RandomControl, SLU (2017). Available at: <http://www.randomcontrol.com/arion> (Accessed: 18 April 2018)
- Fluid Interactive Inc. - FluidRay (2015). Available at: <http://www.fluidray.com/features/technical-specs/#tab-id-3> (Accessed: 18 April 2018)
- Glare Technologies Limited - Indigo renderer (2018). Available at: <http://www.indigorenderer.com/features/technical> (Accessed: 18 April 2018)

LuxRender (2018). Available at: http://www.luxrender.net/wiki/Features#Physically_based.2C_spectral_rendering (Accessed: 19 April 2018)

NVIDIA - Mental ray (2015). Available at: <http://docs.autodesk.com/MENTALRAY/2014/CHS/mental-ray-help/files/manual/spectral.html> (Accessed: 19 April 2018)

Wenzel J. - Mitsuba renderer (2010). Available at: <http://www.mitsuba-renderer.org/> (Accessed: 19 April 2018)

OTOY Inc. - Octane (2017). Available at: <https://home.otoy.com/render/octane-render/features/> (Accessed: 19 April 2018)

Solid Iris Technologies - Thea renderer (2012). Available at: <https://www.thearender.com/site/index.php/features.html> (Accessed: 19 April 2018)

Eclat-Digital Recherche - Ocean (2013). Available at: <http://www.eclat-digital.com/spectral-rendering/> (Accessed: 19 April 2018)

Radziszewski M., Boryczko K., Alda W. (2009), "An improved technique for full spectral rendering" Journal of WSCG - vol. 17, no. 1-3, Václav Skala - UNION Agency