Implementation of Textures Inside of the Laser engraving Environment

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Abstract. *The technology of laser engraving is possible within a transparent glass crystal where it is possible to engrave various prepared computer models. Computer models can be simple so that the engraved model uniform in the crystal. Realistic engraved models are achieved by using different methods of texturing. There are several methods for generating UV projections individually that give good results in computer 3D tools. Preparation, processing and conversion of computer models in the "cloud of dots" is conducted by 3DVision, professional 3D tools, which do not achieve good results for most of the UV projections, regardless of the manner and quality of modelling objects. The study was conducted on several typical groups of models. Test model has been proven that the best results are obtained with planar UV map that is suitable for the symmetric models. In the case of asymmetrical models, details can't be achieved only through a single planar map. It should set aside a small part of the map to which it adds new information about the details.*

Keywords. CECIIS2011, Laser engraving; 3DVision; Texturing, UV maps, UV projections

1 Introduction

Technology of laser engraving inside glass allows user a wide discretion in choosing which elements to engrave. Considering that the desired result is planned and prepared with a computer model; the level of detail is significant element which can be accessed in three ways. The first way is computer modelling that requires the highest preparation for production. This approach results in a huge number of polygons where is very difficult to create realistic image with small details. This method is used for global modelling .
Another way is texturing the previously created models. With textures, there is an easy way to achieve desired effects on surface details. The third way is to prepare the final environment in which the model and textures are transformed into clouds of dots. In this environment it is possible to assign certain elements with more or less dots and cause differences in density and shades of the final results. The best results are obtained using all the above methods. It is good to pay attention to the creation of layers which makes separated objects one entity.

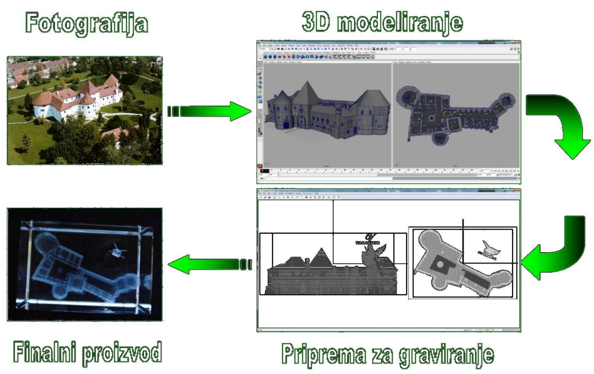

Figure 1. Preparation, analysis and modelling in the process of laser engraving

The final product of three-dimensional (3D) modelling is a 3D model. The level of detail that the model has, determines its purpose and usefulness. Computer systems that use rendering images in real-time 3D models are favoured by the smaller number of polygons.
Still images and rendering in the presentation and advertising purposes are using models with a very high degree of detail. In addition to modelling, texturing is a common appearance to obtain details. With textures, there are shown some details which can't be done in a simple way by pure modelling. Access to texturing is determinate by geometry of models. The basic geometry of model or the one that prevails in the model is what defines the process of texturing and creating a UV point. The position of the

texture maps point is controlled by UVs on the 3D model. Texture assigned to 3D model that does not contain the correct UV point will not display the texture properly. Such a view is impossible to use and it's often very deformed. Primitive models have the UV points that are assigned automatically, but during subsequent changes to the 3D model, UV texture coordinates location remains the same, not accompanied by changes in the model. Depending on the application, 3D models can be modelled in two basic ways; polygonal and with Non-uniform rational basis spline (NURBS) curve. Textural mapping of these ways of modelling is different. For NURBS surfaces, each surface of the network is defined as four paging surface which has a specific U and V directions. Texture coordinates which control the position of the texture are the basic settings which are implicitly linked to the control vertex. Any texture mapped on the surface is also affected. Move the vertex points will affect how is texture maps appears on NURBS surfaces.

2 **UV mapping**

UV mapping is a process that create and manipulate the dots shown in the UV plane. The result is the interconnection images and UV spots. To obtain the desired texture, the display model requires precise selection and installation of UV points on 2D grid model. According to the complexity and form of the model the UV mapping is selected. UV mapping of UV points distributed properly by the model, and subsequently UV points can adapt, merge, split and moved. On the model can be applied various types of UV mapping depending on the needs of the display. For polygonal type model, which has a free distribution of a vertex on the model, UV points may be specially designed and modified to create the texture mapping.

For NURBS models with a rectangular arrangement, texture UV coordinates are constant. UV point is arranged by the same location as the controlled-vertex and so they have a natural relationship with a rectangular texture map.

Aim to generate 2D projections from the 3D topology is preservation of the polygon vertices. Mapping is usually done by triangulation flated models. In practice there are several algorithms that projects 3D mesh on the 2D plane where each of them is trying to have a minimal number of distortions.

This paper will discuss a few algorithms that makes possible texturing 3D model within the system of laser engraving crystal. The result of using algorithms ranges where the emphasis be placed on a logical or physical structure of the projection. If we observe the logical structure it leads to distinct parts of a complex model, which are separated along the boundary points. Such a projection is most useful for editing UV maps because at first glance it can read all elements and the position of 3D models. The question is how will program for laser engraving interpret the same projection. The physical structure of the projection is based on the exploitation of UV space. The emphasis is on minimal fragments of projections, which means the minimum number of errors when rendering textures at a later stage of preparing the model of laser engraving.

Algorithms that generate 2D projections from 3D models are as follows:

- Eckov[11] algorithm treats the model as a system of springs that are located on the boundary lines of the model and are subject to the laws of physics. The projection is realized with harmonic maps which sets initial 2D position. The inner peaks are calculated with respect to the overall energy system. The result is a metric dispersed networks.
- Maillotov[12] algorithm divides the model into several partitions using the information about curvature. Assigned harmonic maps and represents a compromise between the continuous mapping and distorted images.
- Bennisov[13] algorithm works on the principle where the first isoparame curve is flattened to the surface in relation to the curvature and length, and then draw an area around it. In this way, there is some threshold where the distortion is not present.
- Floaterov[14] algorithm first sets the limits of boundary points along the boundaries of flat convex polygons (rectangle, circle). The next step is to move the inner boundary points to the position of convex combinations of nearest neighbors, provided to retain as much as possible the primary length of the edges. These constraints define a linear system of equations for all the positions of boundary points of the polygon.

These techniques are focused on the behavior of local networks to prevent stretching and deformation of texture. Relations between the neighboring triangles is very important. If we want to achieve a free projection of any triangleit needs to add a special mapping with respect to the desired position in space.

Most of the algorithms tries to generate a minimum number of separated parts.

Very often one part is not sufficient for the complex geometry of the polygons and there is the problem of re-connecting the projection in a later work.

The way the algorithm creates a UV projection depends on how the user wants to separate 3D model. Because of the need for standardization, there are five techniques to generate UV map:

- Automatic UV mapping

- Planar UV mapping
- Cylindrical UV mapping
- Spherical UV mapping
- Camera based UV mapping

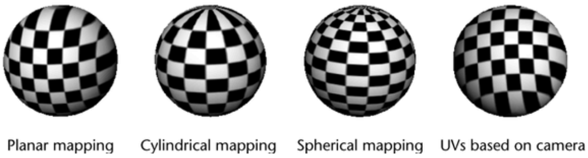

Figure 2. Techniques of UV texture coordinates

Each technique of UV Mapping produces UV texture coordinates that are projected onto a surface model. UV texture coordinates containing the original 2D areal distribution based on vertex information in a 3D space coordinate system. Initial UV mapping typically does not meet the final distribution of UV that is required for the texture. Often times it will be used for further processing by using UV-point tools for editing UV points.

Automatic UV mapping produces polygonal UV network trying to find the best UV position projected from multiple views. Creates six UV networks that were subsequently merged into a unit, where rotation and adjusting of the texture is possible . The method is used on complex shapes where other projections doesn't make applicable view of the UV point.
Planar UV mapping projects UV to the network through a flat surface. This projection is best for objects that are relatively flat and are fully visible only from one angle. Can be used on individual elements of the 3D model, and is generally one planar map that is used on a separate models.
Cylindrical UV mapping makes UV points for objects on the basis of cylindrical projections, and generated net wrap around the object. This projection is best for the objects that are completely sealed in a cylindrical shape. Application of the complex model is omitted.
Spherical UV mapping creates a network using UV projection that is based on a spherical envelope around the model. This projection is best for the shapes which can be completely closed, spherical shape and the visible part of the round object. The result is a map without a projection of empty or incorrect parts made from one piece.
Camera based UV mapping is a method that is most similar to planar mapping with the possibility of free positioning camera around the model. The application has a simple geometry of the models observed through one of three orthogonal projections.

3D modelling and texturing is having an important role in the practical application of laser engraving. Each real object is modelled in three dimensions and the texture is assigned to it. Method of allocation the texture depends on the complexity and appearance of the model. Texturing in the environment of making 3D model is supported and allows the correct display of images on the models. Environment that is used for final processing and conversion of 3D models in a format that can laser engrave, does not possess the advanced display options and so the specific texture projection is not drawn correctly.
Test was conducted based on all the above methods of UV texture coordinates. The model is universal with regular geometry. Due to the simplicity of presentation texture is like a chessboard with black and white rectangles on which the observed irregularities are viewed.

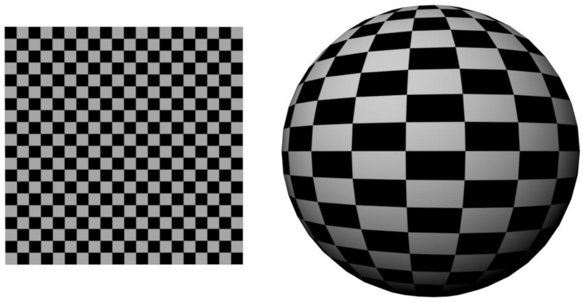

Figure 3. Sneak preview of the texture

3 Tested projections

Test model passes control within the program by which was created in terms of normalization and layout of polygons. The need of this step has proved to be necessary for two reasons. Irregular geometry contains information that is not beyond the standardized development environment and as such represent a problem in the next step, which refers to converting the model into a cloud of dots that is engraved in the glass. Systems for the conversion polygons into a cloud of dots becomes unstable and the process is experiencing problems in terms of efficiency, accuracy and quality of work. Another reason is the interpolation of polygons that lead to deformation of the entire model. Systems for the conversion works correctly, but the target object is deformed to such an extent that is not usable in practical situations.
By controlling and adjusting the geometry it is necessary to take consideration of all polygons that have more than four marginal points.
Polygons which belongs to this category are diagonal divided into smaller units up to the point where the model is not reduced to a polygon with four or three points edge. Correction is necessary for polygons that have holes within them as well as to those who are not aligned in the same plane. The process of control and correction information associated with the modelling of the object through the log records all the steps. Studying of the log note ways of modelling , it can be seen where the error occurred. It is not advisable to

use the modified log notes due to new deformation that will follow.
Corrected model is ready of next step of granting the texture.

Planar map is a two-dimensional view that ignores the back of the model. The result is a symmetrical appearance of the front and rear. The usefulness of this approach is that the map was quickly finished, and aligned within the space of texturing. Symmetrical objects in nature are easy to show because it is only important one side. The second part will automatically filled and adjusted to the correct format. The problem can occur if the second part has a minor change in it's appearance. These changes can not be achieved by a single planar map, and it is needed to set aside a small part of the map to which it adds new information about the details.

Cylindrical map generates the front and back of the model within a UV projection. The problem with details of non symmetrical side planar maps, has been resolved and preview gives very good results. A negative side of cylindrical maps is present in it's two cases. First refers to connecting the beginning and end of the UV projection. The texture it is properly aligned and displayed within a development environment where the model is created, but in an environment where the models and textures are transformed into a cloud of dots, the texture is deformated. Deformations are exactly at the points that correspond to the connection of UV projection. Another problem is deformed preview of polygons that the camera did not notice during creation of UV maps. These are typically upper and lower polygons. Since the cylindrical map covers only one plane, three-dimensional object always has a deformed part of its UV projection. The result is not satisfactory and requires an alternative approach.

Spherical map generates UV screening in it's all planes. At first glance, works as the approach to the problem, but very soon it's noticed which elements should be corrected. First part is related to the merging of boundary points as well as the cylindrical maps. The problem is most pronounced at the top of the model where things are infinite curves at which is texture placed incorrectly. The solution is not possible to achieve in a classic creation of such projection, but must be combined with a planar projection above showing only the deformed upper part. The result, within the environment of create a cloud of dots, is not acceptable and is even worse than the cylindrical mapping because there is more room of merging texture.

Automatic map creates the projection of model with considering on the six views. From each view are taken only those polygons which lie approximately in the same plane with the camera. It is not necessary that elements are parallel. The resulting projection has a large number of separate elements and is considering on the previous research, a result that will appear in the next stage we can already assume. Number of deformation is equal to the product of the number of parts of texture and boundary points by which are connected into a single unit. It usually generates twenty parts which brings us to one of the worst display ever.

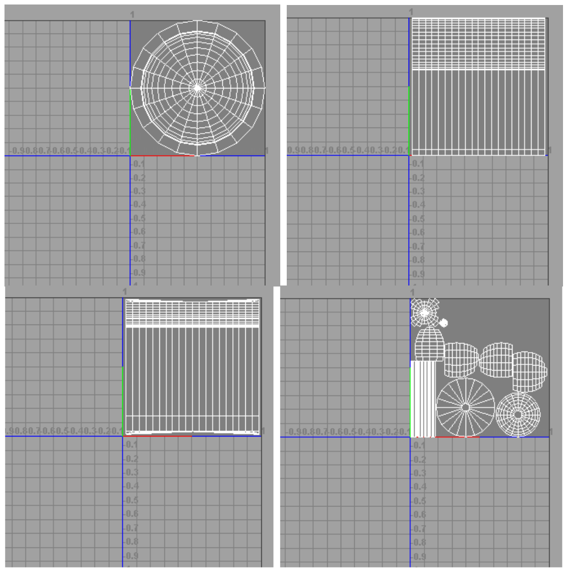

Figure 4. Test UV projection: planar, cylindrical, spherical, Automatic

From the above it is obvious that the planar mapping is the best. The entire projection it is one UV map without additional separate elements. Alternative is in it's form of polishing maps because details are possible but desirable to avoid them. Within the testing it is also observed that UV projection must be placed strictly within the boundaries of the first quadrant. The reason is that otherwise we would be losing the correct information about the location of boundary points. This situation be solved by reducing UV projection which distorts the quality of detail of textures or redistribution of additional elements within the projection. Due to, the necessary details is recommended to use textures that exceed 512x512 pixels where the upper limit could fit on a 2048x2048 pixel.

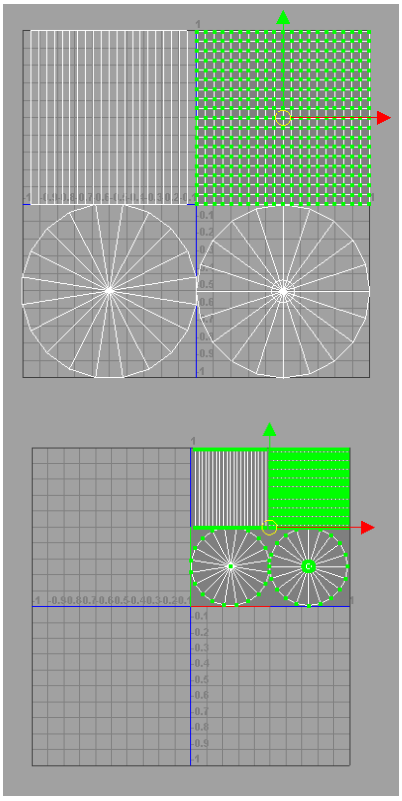

Figure 5. Positioning of the UV projection

Listed example shows the UV projection distributed throughout all four quadrants. The basic rule is to position only in it's the first quadrant. The obvious problem is placing all the elements in the first quadrant due to the arrival of overlapping UV projection. The assumption is that all of the elements are different which implies that each element must be on the second part of the UV maps. The only way to reduce this proportion of projection is the moment where every projection will be arranged into first quadrant without overlapping.

4 Practical implementation and comparative preview

For the purposes of this study it is created three types of models. Their use shows the relation between UV maps and the final product.

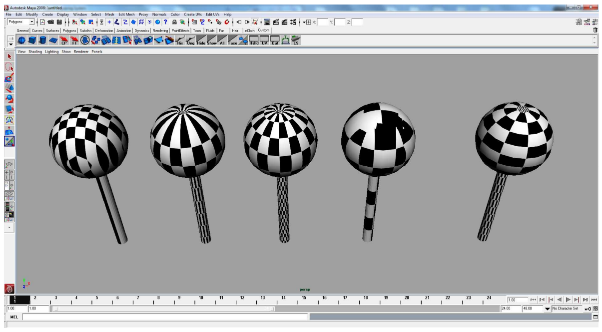

Figure 6. Models and a comparative overview of UV projection

The same model that is used same texture has different layouts for different UV projection. First model on itself has a planar UV projection that is generated according to the Y axis. The second model has a cylindrical projection. A third spherical, and the fourth automatic projection. The fifth model is composed of several projections which were performed logically, depending on the design of certain parts of the model.

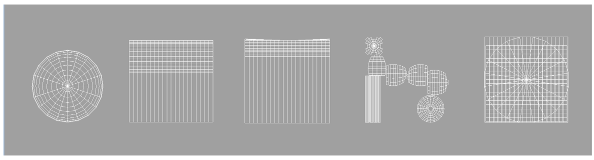

Figure 7. Comparative presentation of UV projection

It may be observed that planar projection and automatic form only respect the form where is no overlapping UV points. Despite a regular schedule, there is a problem with the automatic projection because the environment that transforms the texture in the cloud of dots is very difficult to handle transitions in connections texture. All other UV maps have gaps and overlaps because of UV and merging points on the final boundary of projection.

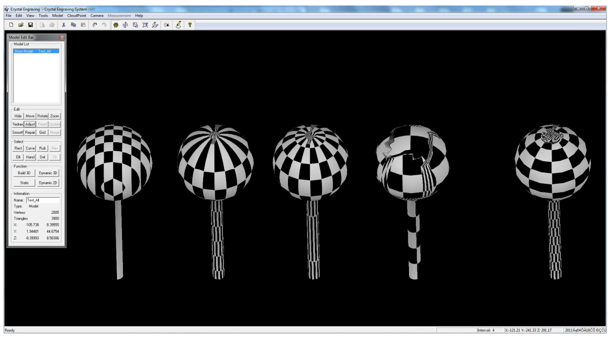

Figure 8. Comparative preview of textures in the environment of 3D laser engraving

Planar projection is the only correct preview of textures.

All of the others minimally deform the texture on the places that connects the start and end of projection. The worst score is tied to automatic mapping what is assumed because of the largest number of independent parts.

The following model shows excellent texture and model. Listed product can be widely used because it has correct geometry and texture does not contain any overlap between elements. The problem of this model is that it contains non planar UV projection and for these reasons distorts the appearance of textures.

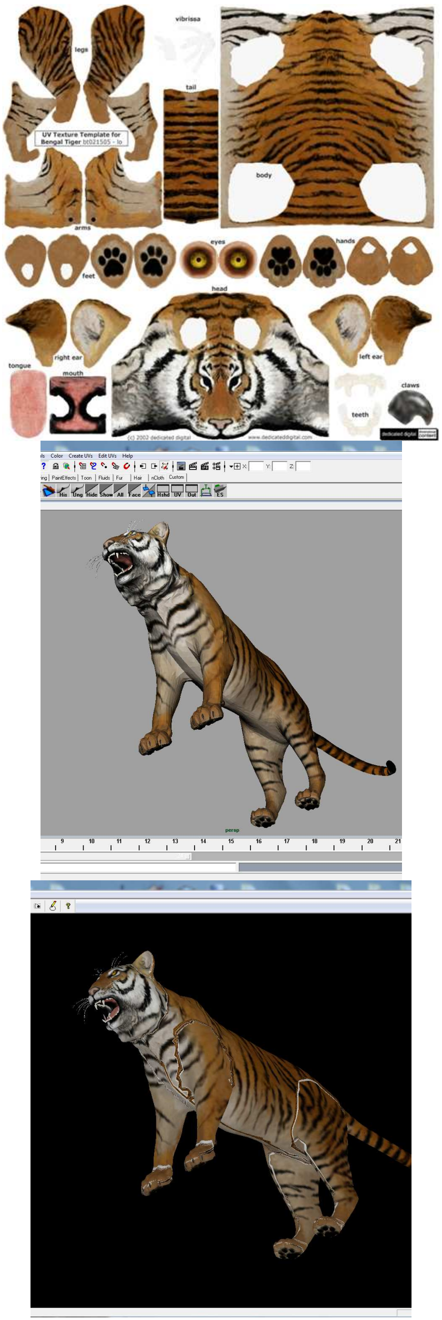

Figure 9. Tiger texture using a non planar projection

These figures show the deformated that occurs with UV projection. At the joint adjacent picture elements occurs infinitely repeating boundary line which are causing difficulties and problems for future work. A possible solution is to apply to the existing model planar UV map but in the this case the texture that is made is no longer usable and is needed to create a new texture on the new UV projection. The level of detail are reduced because of two symmetrical sides of the tiger, but that solved the problem with deformation.

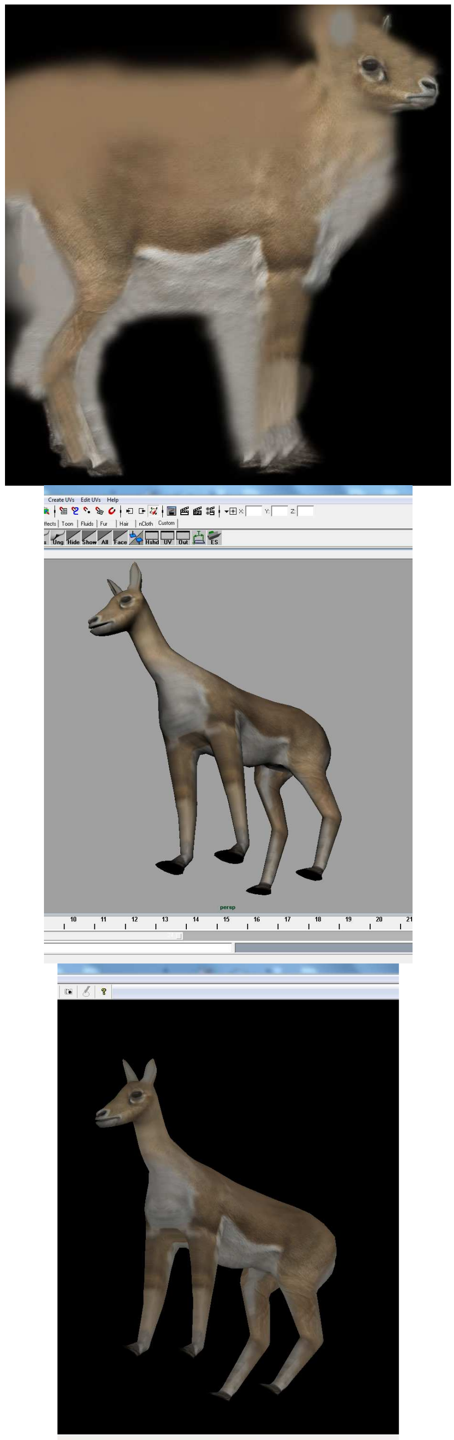

Figure 10. Texture gazelles using a planar projection

The texture of gazelles has made according to the planar projection models. On the model within the development environment textures is assigned to check the correctness. Deformations are not present and the same model is used in the environment for laser engraving. The model has the correct geometry and contains a planar UV map on which the textures is placed. Textures are properly distributed according to the model without distortions. In this preparation phase, the model is ready to conversion in the a cloud of dots that of laser engravings in the glass crystal. The density of clouds of dots does not depend on the model or the appearance of textures. Shall be determined separately and it is necessary to evaluate the optimal ratio between the number of dots and the size of crystals in the which of model engravings.

5 Conclusion

Development environment for the laser engraving is very sensitive on the format and structure of input data. A computer model must be very precisely and correctly modelled. Development environment for the manipulation of 3D models should correctly identify the key elements of the model or of textures. Restrictions that are placed for the user, prevents development of functionality in the 3D model and it can get to losing the quality of the final product. Textures that are attributed to UV projections should be correctly positioned and are added to the finished model. Preview of textures depends only on the UV projections that is generated in a production environment in which the model was created.
Research on the applicability of certain projection texture on different types of models was conducted in a professional software tool for the laser engraving of crystal glass 3DVision. Research shows that not all projection textures is applicable to 3DV and it is impossible to conduct the conversion of the image texture in the proper arrangement of dots on the model.
The results of planar texture mapping is displayed correctly without deformation. Results that were seen on the tested model is correct in the both work environment. Regardless of on UV spectrum that the projections can be generated, the choice of settings for the laser engraving is limited to a planar projection. The main advantage is ease of creating UV maps and its corresponding texture. The lack of it is reduction of detail in the case of asymmetrical layout model.

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