

Hit and Render: Teaching CAD Visualization to Product Designers

Daniel Saakes

Delft University of Technology, d.p.saakes@io.tudelft.nl

ABSTRACT

Computer Aided Design takes in a central role in product presentations. In order to create visualizations of product concepts, designers need to have thorough knowledge of computer graphics algorithms, just as they need knowledge of solid modeling for creating engineering drawings.

At the faculty of Industrial Design Engineering we teach a course on creating 3D product rendering that comprises the entire process from modeling to rendering. This overview is deemed necessary for students to get insight in the effort versus quality decisions and contribution of each step to the final image.

In this paper we describe our course and identify three fundamental themes: amount of control over the image, the differences in approach between painting and photography, and a comparison between materials in design practice and computer graphics rendering.

Keywords: Computer Education, Design Tools and Techniques, User Interface, Interaction Style

1. INTRODUCTION

Computers have taken a prominent place in the way consumer products are designed. In a contextual inquiry about tool use in creative work practice held in 1993 [10], Pasman found almost no computer use in the design firms they consulted, ten years later, Keller repeated the study [8] and found a radical and rapid change towards computer tools. One area where computer graphics has entered is product visualization. Product visualization plays a major part in the work of Industrial Design Engineers. It helps the designer's thinking process in the iterative design cycles of generating, expressing and interpreting, evaluating. Visualizing is also essential for sharing ideas in design teams and presentations to clients. Design teams are becoming increasingly multi-disciplinary and visualizations ask for various graphic styles to communicate various aspect of the 3D shape [7]. While early in the process the graphic style often expresses an unfinished look, in the final stages photorealistic images are made to convince clients of the design solution. In a survey at design studios, van Dijk [5] found that nearly all product visualizations to clients were made using 3D computer visualization.

Design students in Delft typically encounter 3D tools for engineering in documenting design and running flow line analyses. Almost all 2D shape documentation is nowadays created out of 3D solid models. Engineering tools provide basic visualization facilities but these are not sufficient for creating renderings for presentations. Most design students who enroll in our master programmes have insight in creating visual material, have excellent drawing skills and CAD experience, but are not familiar with the techniques of computer graphics rendering.

In this paper we present how we teach product presentation skills using 3D computer graphics in the master programmes of industrial design engineering. The objective of the course is to give insight in the fundamental concepts of 3D computer graphics, insight in the use of 3D computer graphics in design visualization and being able to apply those insights in practical way when creating product presentations.

While teaching we found three fundamental aspects that need consideration in a course on computer aided visualization for design engineers. First the amount of control over the image; how much control is necessary to suit the visualization needs for product designers and which aspects are important to gain understanding of creating visualizations. Second, the differences in approach between photography and drawing, while visualization tools resemble a photographers' studio containing lights and backdrops, designers approach creating imagery as painting a canvas. Third is a comparison how designers think and work with expressive materials in design practice on the one hand, and render algorithms on the other hand.

2. THE COURSE LAYOUT: MIXING MEDIA

Our course runs twice a year and consists of 80 hours work in a 10 week schedule. We use the Maya software from Alias with NURBS as primary modeling tool and Mental Ray as renderer, similar to other courses on computer graphics [6,9].

The main of the course consists of hands-on experience in a project that runs through all the steps from modeling to the actual presentational renderings.

Having all steps in one project gives insights in the necessity and effort of each step, and the intertwining of the different steps. Changing parameters in the lighting for instance has to be compensated by adjusting choices for the render settings and material settings. The quality of the model's shape affects the experience of material attributes.

Having an overview also keeps the focus on the end result, the image of the product. It is tempting to zoom in on details or spend a lot of time creating the most convincing looking materials, while these might only contribute little to the overall quality of the image.

Although we follow the commonly accepted workflow of surfaces, shaders, lighting to rendering, we also feel that a concurrent process of all steps mixed in an iterative process of small adjustments in all steps might better reflect the practice. However in our experience the amount of new techniques and jargon that needs to be mastered by the students is best taught subject by subject.



Fig. 1. Typical models in the course are small handheld (electronic) products.

A typical project consists of modeling an existing product and using existing visual material in the presentations. Using real products and imagery, rather than creating new designs, focuses students' minds on the techniques, and keeps the assignments close to the designers' practice. It also brings up real problems that will be encountered in practice, that require insight in problem-solving strategies. We found that a tool and technique course can quickly turn into a design assignment instead of mastering a technique.

<i>Phase</i>	<i>Duration</i>	<i>Objective</i>
tutorials	2 days	Getting familiar with the software
modeling	2 days	Model a product in a surface modeler
materials	3 days	Create a range of materials
presentation	3 days	Render presentations.

Tab. 1. Phases in the course.

2.1 Modeling

Students work in pairs and model a product of their choice, within constraints on complexity and suitability assessed by the tutors. Most product shapes have to be simplified before they can be visualized. Choosing what to simplify is a good exercise to see what level of detail is required in a rendering. Just as in drawing products on paper, details such as transitions between surfaces are important while not all the split lines between the mould parts need to be shown to convey the product's intended shape.

For most students, surface modeling is new and requires an approach of lines and surfaces rather than solids with booleans in a parametric model. Surface modeling and the sculpting techniques extend their knowledge of creating shapes.

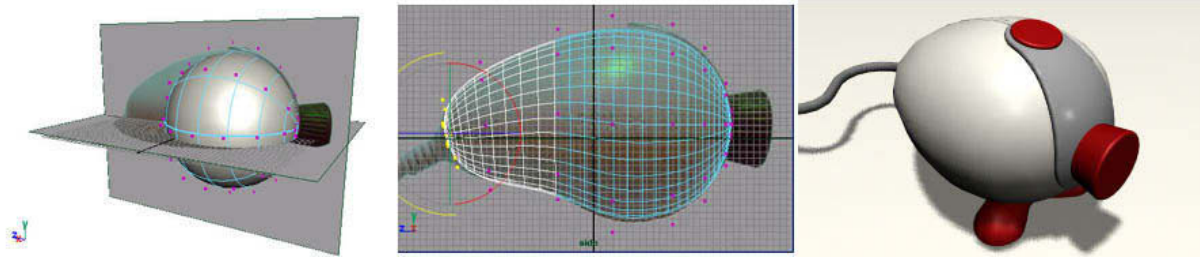


Fig. 2. Photos of the product are used as templates while modeling. In this way models are based on proportions rather than measuring the existing product, which speeds up the modeling process.

At the start of the course, we take digital photos of the product to be used as templates. Having an image of the product as a backdrop in the modeling view, as shown in figure 2, propagates modeling on proportions rather than exact measurements. Measuring a product and entering exact values in the software tended to slow down this phase. The imprecision introduced by using photos will in most cases not affect the final image.

We also experienced that having the real product at hand during the modeling helps understanding the shape and helps the discussion between the students and tutors about the modeling approach.



Fig. 3. The materials of these minidisc players match the theme of the background images.

2.1 Materials

The second part of our course consists of creating expressive materials, shown in figure 3. We ask students to bring a set of inspirational images, such as stock photos, advertisements or moodboards to theme their visualizations. The material expression should fit both the product and the style of the theme. Often it is interesting to fit a product in a theme that is out of the obvious, for instance: how to fit a game controller on a sunny beach? Which evokes questions about colors, patterns and the roughness of the surface.

We found that having a context gives focus and thereby accelerates the search for materials. Playing with materials without a goal can result in endless tweaking of parameters, driven by what's possible in the software. Often we found products rendered in a black space or on a checker floor to show off the reflections of a raytracer with no reference to the product's intended use environment.

We also feel that the overall quality of the visualization improved by using inspirational images, and that can be so simple as just having an image as a backdrop. The techniques of creating and judging materials in a context relates to the design practice where moodboards are used to express moods and environments with colors and textures.

2.1 Rendering

The final phase of the course consists of rendering the themed products into presentations. We ask to create a small number of renderings in a poster format. The portfolio should address various aspects of presenting products: compositing the 3D product model into environments, showing details, and a range of products varying in material or color.



Fig. 4. These presentational renderings are composed of stock photos and the 3d renderings.

When compositing virtual models into stock photos, the virtual lighting and reflection environments have to match to the ones in the photos. It requires an understanding of the complex relations of cause and effect involved in various settings. However it extends the understanding of lighting in general learned in drawing classes, such as the length and contrast of casted shadows and the point of view.

Sometimes presentations need to be processed by photo editing tools to match the image quality. We propagate that because it's part of the real-world problem solving.

3. HOW THE TOOLS FIT THE PRODUCT DESIGNER

The course 'computer visualization for designers' has been taught for more than ten years now. In the first years creating a 3D model was already an achievement; nowadays the focus has shifted to creating special materials and mixing multiple media. The complexity of the products modeled in the course increased over the years, not only because improvements in the tools, but also students acquire earlier and more extensive experience of 3D computer tools in their bachelor courses.

The course started with the Electrogig software on dedicated CAD computers. Electrogig was mainly used as a solid modeler and models of products were created with only a few geometric primitives and boolean operations. The simplicity and beauty of this type of modeling is that it is quickly learned and easy to understand, but a parametric tree of boolean operations quickly gets too large to handle when modeling complex products. Nowadays we use Maya and have seen the complexity of the tools increase in all the parts of the workflow.

The renderings made with Electrogig were high quality raytraced images and still are, but a rendering could take up to multiple hours to calculate. The speed of renderings increased enormously and thereby allows almost interactive

tuning. The iterative cycles of expressing and interpreting that have emerged are a key benefit for the user's ability to search the high-dimensional parameter spaces for the desired expression.

3.1 Amount of Control

Whereas the shaders in Electrogig consisted of a few types with a small number of tweakable values, in Maya the shader system contains a complete visual programming language. Also the rendering techniques have evolved from a single raytracing or scanline algorithm to a stack of algorithms that are all used in a single rendering to address specific needs ranging from soft shadows to caustics.

The designer's need for quick visualizations is fulfilled with the new designer-orientated tools that hide most of the details of computer graphics. These tools, such as Photoworks and Alias Image Studio, ease the necessary tweaking of parameters and support designers to focus on the result. Alias image studio provides libraries not only for organizing materials but also for lights and environments. But by hiding most details under the hood, these tools might limit the richness of expression.

In order to experiment, customize and play with visualizations designers have to rely on professional artist tools such as 3D studio MAX and Maya. The multiplicity of graphical styles that these tools offer also accommodates the often very specific visualization needs in different design situations. Thereby these tools come closest to the designer's need for expressive style and realistic rendering. Developing an individualistic style is a key freedom that designers want from a computer tool, as found in the contextual inquiries mentioned in the introduction.

However because these tools are made for the cinema and game industries, they are optimized for rendering speed and their interfaces are close to the computer graphics algorithms, including extensive sets of parameters. In order to use these tools designers have to get familiar with the vocabulary and techniques of computer graphics that differs from the vocabulary of perception and physical properties designers tend to use. Another issue of our choice for a complex professional tool is that often students have difficulties using the tool in the later stages of their studies, because they are not using them on a daily basis, as do the professionals for whom the tools are intended.

3.2 The Interface Metaphor: Drawing Versus Photographing

Although 3D tools support direct manipulation for creating 3D shapes, other aspects of computer graphics, such as controllers for shadows and materials, are still indirectly manipulated through sliders and controls. Early versions of 3D studio MAX contained a feature named "place highlight", a highlight could be set by selecting both a light source and a point on a surface. The selected light source would move according to the surface normal and camera settings. This approach is very similar to sketching where the specular highlight can be painted directly on the paper.

The common approach requires a direct manipulation of the light source with the highlight as an indirect effect and quickly turns into a sequence of trial, error and adjustments from multiple points of view. Pellacini [11] showed a similar approach by manipulating shadows as 3D objects that indirectly manipulate the light sources to match the shadows.

The direct manipulation approach to shadows and highlights fits in our view the industrial design engineer while it addresses the designers' familiarity with sketching, and keeps the focus on the image.

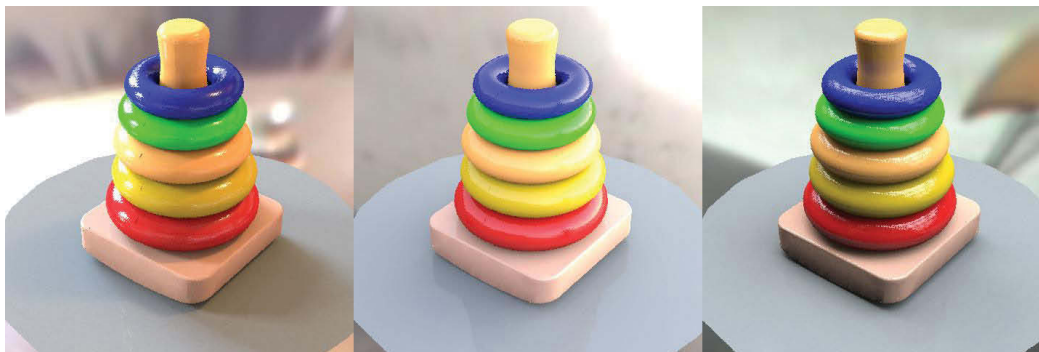


Fig. 5. This fisherprice toy is rendered using three light environments from HDRI pictures. In this way the complex setup of lights can be avoided.

Likewise the new image-based lighting techniques [4] might also change the way the process of product rendering is conceived. The approach to create a rendering resembles taking a picture with a camera. The light setup, often composed of multiple sources, is similar to those used by a photographer in a studio. Image-based lighting techniques employ a prefixed environment around the model providing both a reflection environment and a light setup. So rather than changing the studio environment around the model, the model and camera are placed within the environment. The complexity moved from the light setup to a picture, a HDRI panoramic image. Nowadays these images are widely available in stock libraries.

3.3 Material Fit

Early computer visualization tools could convincingly depict a few materials with mathematically simple reflection properties: shiny metals, plastics and elastomers. Nowadays, more and more materials can be convincingly rendered within an acceptable time frame; methods are available for hair, fur, and translucent materials.

But with this freedom, the rendering algorithms have become increasingly complex. Creating materials in visualization software also needs a considerable amount of knowledge of the inner workings of rendering algorithms. Materials are often described [3] inseparable from the rendering algorithms.

Computer graphics materials deal mainly with surface properties whilst in industrial design materials also involve considerations of manufacturing technology and shape shown in Ashby's interaction diagram [1], shown in figure 7.

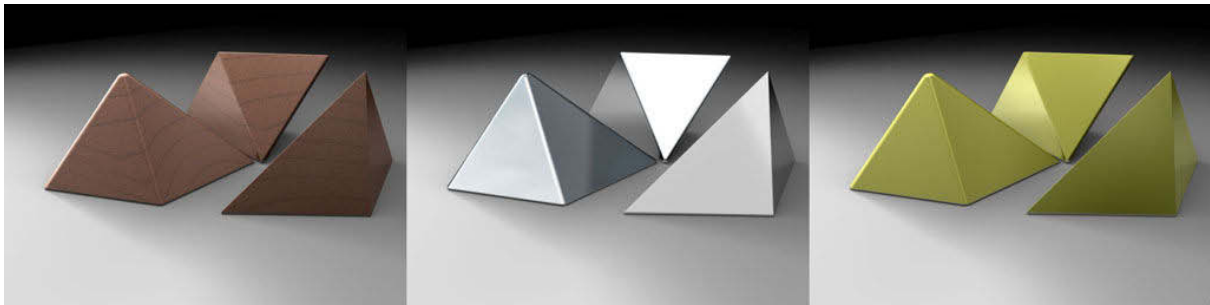


Fig. 6. The perception of the material varies with the transition between the faces. A sharp transition might fit a metal product while a round one might better fit the injection molding detailing of a plastic product.

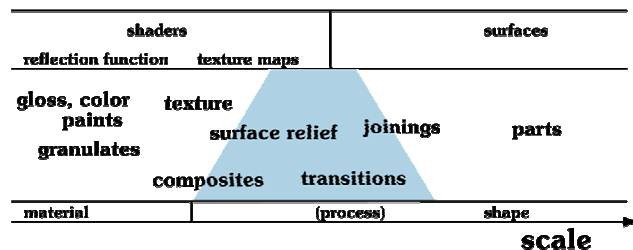
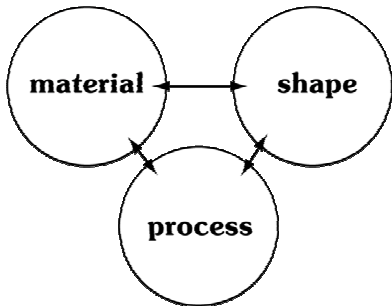


Fig. 7. On the left Ashby's interaction diagram of material, shape and manufacturing technology (process) in a product. On the right the interaction diagram mapped to computer graphic concepts. The gliding scale from material to shape, spans both shaders and surfaces.

A designer's material cannot be separated from shape and the choice of a material also influences the choice of how parts are joined down to the little details that come from the manufacturing process such as sharp or rounded edges, figure 6.

A product that is commonly made of plastic shows a shape language and contains details that are typically found in thin shell injection molded plastic. Only applying a wood shader is not sufficient to convey that the product is made out of wood.

To match the designer's concept of a material with its visual properties in computer graphics, materials have to be considered on multiple scales, not limited to the reflection function. As shown in figure 7 each scale addresses a distinct modeling technique ranging from parameters in the reflection function to applying textures and adding shape details for surface transitions. A concept as gloss can be expressed on all these scales, but does not necessarily match the tools for expressing gloss when creating the actual product. Just as reflection environment helps expressing a shiny metal, the joining and shape details also help to convey material expression.

The issues in the transition between shape and shader occur frequently in product renderings, which tend to zoom in on the product itself, and thereby requiring detailed material visualizations compared to architectural renderings that have a multitude of surfaces and materials.

4. CHALLENGES AND CONCLUSIONS

We have presented our approach to teach the fundamentals of creating visualizations with computer graphics. Most courses on CAD [2] and teaching effort focuses on creating shape, while we feel that the relation and intertwining of all the steps needs to be experienced as a whole. Our case study approach tries to give an overview of the whole process and shows the contributions and necessities of each step. The mixed media approach of using real, existing models of products and stock photos that provide a context for the presentation accelerates the process of creating visualizations and keeps it close to the design practice.

At our faculty our course fills in the gap between drawing classes and computer sketching course [12], and the engineering drawing classes using solid modelers. The tools we use in our course are not made for designers, but for professionals in the animation/simulation industry. There, issues of render speed and visual effects are more important than that they are for designers. Shortcuts that optimize render speed are often complex to set or too specialized and not necessary for industrial design purposes with more modest visualization needs. Saving a few seconds is less important if one only renders a single frame instead of thousands of frames.

However we feel that by being close on the techniques we give students a thorough knowledge of the fundamentals with which they can then learn the various "professional" and "designer orientated" packages quickly. The downside of this low level approach is the steep learning curve and that the ability to still use the software after a few months.

Over the years we found that the increased rendering speed is a key aspect that allows students to play, discover and get a feel for the various parameters and options. We feel however that there is still much to improve in the fit between the industrial designer and the computer graphics interfaces concerning lights and materials.

5. ACKNOWLEDGEMENTS

The author wants to thank the following students for their images in this paper: A. Peeters, C.S. de Jong, J.J. Vester, B.Loot, P. Costerus, H. Jacobs, J. Wiersma, S. van Heummen, K. Lambers, B.G. Meurs, W. van der Esker and A.D. de Lange. The light environments in figure 5 are courtesy of Paul Debevec. Results of the course can be found at <http://studiolab.io.tudelft.nl/compvis/>

6. REFERENCES

- [1] Ashby, J. and Johnson, K., *Materials and Design: the art and science of material selection in product design*, Butterworth and Heinemann, Oxford, 2002.
- [2] Asperl, A., How to teach CAD, *Computer Aided Design and Applications*, Vol. 2. Nos. 1-4, 2005, pp 459-468.
- [3] Birn, J., *[digital] lighting & Rendering*, New Riders, Indianapolis, 2000.
- [4] Debevec, P. E., Rendering Synthetic Objects into Real Scenes: Bridging Traditional and Image-Based Graphics with Global Illumination and High Dynamic Range Photography. *In ACM SIGGRAPH'98*, 1998.
- [5] van Dijk, J., *Material Explorer*, Unpublished master thesis, Delft University of Technology, Delft, The Netherlands, 2003.
- [6] Ebert, D. S. and Baily, D., An Interdisciplinary Approach to Teaching Computer Animation to Artists and Computer Scientists, *GVE '99*. 1999.

- [7] Kasik, D. J., Buxton, W. and Ferguson, D. R., Ten CAD challenges, *IEEE Computer Graphics and Applications*, Vol. 25, No 2, 2005.
- [8] Keller, A. I., Stappers, P. J. and Pasman, G. J., Collections designers keep: collecting visual material for inspiration and reference, submitted.
- [9] Nikolic, D. and Shene, C., GraphicsMentor: A tool for Learning Graphics Fundamentals, in *ACM SIGCSE '02*, 2002.
- [10] Pasman, G. J., *Designing with Precedents*, Delft University of Technology, Delft, The Netherlands 2003.
- [11] Pellacini, F., Tole, P. and Greenberg, D. P., A user interface for interactive cinematic shadow design, In *SIGGRAPH '02*, 2002.
- [12] Van den Herik, Y. and Eissen, K., Intuitive sketching - A new and explorative medium in generating Ideas, *CAID&CD 2005*, conference proceedings, 2005.