PhD position – Campaign 2016

Title: Extraction and analysis of the geometric and photometric properties for the classification of the materials of 3d objects acquired in uncontrolled lighting conditions

Host team: IGG (Computer Graphics and Geometry group) at ICube Lab

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Starting date: September 2016

Ending date: 3 years from the starting date

Funding: About 1500 euros per month, net salary

Location: Strasbourg area, France

Prerequisites: Computer graphics and geometric modeling

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1. Context and problem statement

The media content production industry is experiencing a boom thanks to the massive development of 3d acquisition and display devices. This industry is in increasing demand of tools for creating complex geometric models with realistic appearances more rapidly and more efficiently. For reasons of cost-effectiveness, the representations of the output models must be compatible with commercially available edition software and rendering engines, and should also be as inexpensive as possible in memory. These representations are most often based on triangle meshes equipped with parameterizations (also called UV maps) and multiple texture layers simulating the relief of a surface (normal map) as well as its photometric properties (diffuse map, specular map, ambient occlusion map, etc.).

Current 3d digitization technologies for real objects considerably simplify the process of creating 3d models. While the techniques for reconstructing geometry from samples are more and more reliable, there is a lot of room for improvement in the field of appearance processing and representation. In an industrial context, it is highly desirable that photometric acquisitions be performed in an uncontrolled lighting environment, which may significantly reduce the cost of the required equipment, as well as the necessary time and skills. It is also desirable to be able to visualize a reconstructed model in a realistic fashion in a lighting environment that differs from the acquisition one. As a last requirement, the appearance of the models should be represented by as compact as possible texture layers. These multiple constraints involve many difficulties that are not addressed or only partially addressed by the current literature.

For several years now our group has been developing a 3d digitization platform for real objects including both geometry and appearance acquisition and processing [PNIGG]. It aims at providing a complete set of automatic tools for the production of detailed geometric models [Lar08] as well as the reconstruction of the photometric properties of the surface of the objects from photographs in the form of surface light fields [VSG+13]. A surface light field only depends on the direction of the point of

view, and hence does not make it possible to visualize a reconstructed model in a lighting environment that differs from the one of the acquisition. This representation is also limited by the huge amount of data that have to be stored in memory, as well as by the requirement of specific rendering methods.
In order to perform realistic rendering with variable lighting conditions, the common approach consists in estimating the parameters of a Bidirectional Reflectance Distribution Function (BRDF) model that characterizes the optical properties of a material, possibly taking spatial variations into consideration (i.e. Spatially Varying BRDF, or SVBRDF) [LKG+01]. Most existing methods for the estimation of the parameters however rely on photometric acquisitions performed in perfectly controlled lighting environments. When the lighting environment is controlled, the estimation of specularity is in particular made easier. This property indeed depends on both the direction of the point of view and the directions of the light sources. Palma et al. [PCD+12], and more recently Dong et al. [DCP+14] proposed two methods for the reconstruction of an approximate SVBRDF in uncontrolled, but fixed, lighting conditions. The method proposed by Palma et al. [PCD+12] uses a Phong model that benefits from only a few parameters, but that is unable to take into account too complex specular reflections. The method proposed by Dong et al. [DCP+14] relies on a microfacet reflectance model that is closer to the physical reality, but the estimation of the parameters is highly sensitive to blur effects resulting from camera motion or focusing. In both cases the classification of the materials only takes into account the variation of the diffuse color. For example, the variations of the geometry, or the presence of shadows are not taken into account, which artificially increases the number of detected material classes; last but not least, the SVBRDF model is not compatible with a standard representation by texture layers. The conversion of a SVBRDF-based representation into a representation based on texture layers is a very challenging research topic. There has been only little work in this field. Let us also cite works on *Intrinsic Images* [LBP+12], that deal with the separation of diffuse color and illumination effects, but that apply to single images.
The IGG group has also been interested in example-based texture synthesis [VSL+13, GSV+14] and texture analysis [LSA+16] for three years, with the goal of reproducing realistic appearances from images by resorting to very compact parametric and procedural representations. Nonetheless, only the diffuse color property has been taken into account till now. In order to synthetize textures associated to other geometric or photometric properties, data from material represented by texture layers are required.

2. Thesis goal

The goal of this thesis is to tackle the scientific bottlenecks that have just been presented. The project consists in studying and devising a new processing pipeline to enrich the previous work of the group, which includes: 1. the automatic and accurate extraction of the geometric and photometric properties of a 3d object acquired in uncontrolled lighting conditions from a collection of photographs (geometry, normal, diffuse color, specularity, shadows) as well as the storage of the extracted data in texture maps; 2. the analysis of the extracted data in order to obtain a classification of the materials as close as possible to the reality over the whole surface of a digitized object, taking into account spatial variations jointly with the inter-property variations. This classification of the materials of a digitized object, together with the associated texture layers, will be used as input for the instantiation of parametric and procedural material models based on texture synthesis techniques developed in the IGG group.
The first stage of the thesis will consist in evaluating existing methods for the classification of the materials of a digitized object, especially Palma et al.'s method [PCD+12] and Dong et al.'s method [DCP+14]. In order to improve the extraction of the geometric and photometric properties, a robust statistical approach will be considered, in which both the reconstructed 3d model and the collection of photographs will be taken into account. Particular attention will be paid to the coherency between the variations of the different properties (e.g. the influence of the shadows on measured diffuse color). The detection of the various materials of a digitized object will be first considered in a user-assisted way. The user will provide material examples selected on the object itself or on some other objects. The segmentation of the surface of an object according to its materials will then be performed through texture analysis [LBP+12, LSA+16]. The chosen descriptors will have to be as robust as possible to noise,

varying lighting conditions as well as to scale variations. The method will be validated through a comparison protocol between hand-made segmentations, serving as ground-truth, and automatic segmentations. The developed framework will also include material editing tools (e.g. to modify the diffuse color or the relief of a surface) preserving the coherency between the geometric and photometric properties of each material. The implementation will be done in C++ and will be part of the digitization platform of the IGG group.

Keywords: computer graphics, geometric modeling, computer vision, appearance reconstruction, real-time visualization, BRDF, SVBRDF, GPU, material editing.

3. References

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