IN PARTNERSHIP WITH:
CNRS

Institut polytechnique de Grenoble

Université Joseph Fourier (Grenoble)

Activity Report 2015

Project-Team MAVERICK

Models and Algorithms for Visualization and Rendering

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Interaction and visualization

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Project-Team MAVERICK

Creation of the Team: 2012 January 01, updated into Project-Team: 2014 January 01

Keywords:

Computer Science and Digital Science:

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5.5.1. - Geometrical modeling
5.5.2. - Rendering
5.5.3. - Computational photography
5.5.4. - Animation

Other Research Topics and Application Domains:

5.5. - Materials
5.7. - 3D printing
9.2.2. - Cinema, Television
9.2.3. - Video games
9.2.4. - Theater
9.5.6. - Archeology, History

1. Members

Research Scientists

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Fabrice Neyret [CNRS, Senior Researcher, HdR]
Cyril Soler [Inria, Researcher, HdR]

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Joelle Thollot [INP Grenoble, Associate Professor, HdR]
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2. Overall Objectives

2.1. Overall Objectives

Computer-generated pictures and videos are now ubiquitous: both for leisure activities, such as special effects in motion pictures, feature movies and video games, or for more serious activities, such as visualization and simulation.

Maverick was created as a research team in January 2012 and upgraded as a research project in January 2014. We deal with image synthesis methods. We place ourselves at the end of the image production pipeline, when the pictures are generated and displayed (see figure 1). We take many possible inputs: datasets, video flows, pictures and photographs, (animated) geometry from a virtual world... We produce as output pictures and videos.

These pictures will be viewed by humans, and we consider this fact as an important point of our research strategy, as it provides the benchmarks for evaluating our results: the pictures and animations produced must be able to convey the message to the viewer. The actual message depends on the specific application: data visualization, exploring virtual worlds, designing paintings and drawings... Our vision is that all these applications share common research problems: ensuring that the important features are perceived, avoiding cluttering or aliasing, efficient internal data representation, etc.

Computer Graphics, and especially Maverick is at the crossroad between fundamental research and industrial applications. We are both looking at the constraints and needs of applicative users and targeting long term research issues such as sampling and filtering.

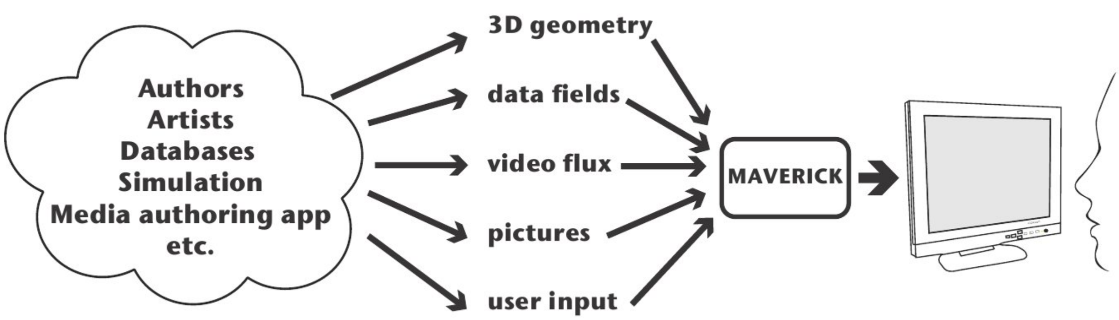


Figure 1. Position of the Maverick research team inside the graphics pipeline.

The Maverick project-team aims at producing representations and algorithms for efficient, high-quality computer generation of pictures and animations through the study of four *Research problems*:

- *Computer Visualization*, where we take as input a large localized dataset and represent it in a way that will let an observer understand its key properties,
- *Expressive Rendering*, where we create an artistic representation of a virtual world,
- *Illumination Simulation*, where our focus is modelling the interaction of light with the objects in the scene.
- *Complex Scenes*, where our focus is rendering and modelling highly complex scenes.

The heart of Maverick is *understanding* what makes a picture useful, powerful and interesting for the user, and designing algorithms to create these pictures.

We will address these research problems through three interconnected approaches:

- working on the *impact* of pictures, by conducting perceptual studies, measuring and removing artefacts and discontinuities, evaluating the user response to pictures and algorithms,
- developing *representations* for data, through abstraction, stylization and simplification,
- developing new methods for *predicting* the properties of a picture (*e.g.* frequency content, variations) and adapting our image-generation algorithm to these properties.

A fundamental element of the Maverick project-team is that the research problems and the scientific approaches are all cross-connected. Research on the *impact* of pictures is of interest in three different research problems: *Computer Visualization*, *Expressive rendering* and *Illumination Simulation*. Similarly, our research on *Illumination simulation* will gather contributions from all three scientific approaches: impact, representations and prediction.

3. Research Program

3.1. Introduction

The Maverick project-team aims at producing representations and algorithms for efficient, high-quality computer generation of pictures and animations through the study of four **research problems**:

- *Computer Visualization* where we take as input a large localized dataset and represent it in a way that will let an observer understand its key properties. Visualization can be used for data analysis, for the results of a simulation, for medical imaging data...
- *Expressive Rendering*, where we create an artistic representation of a virtual world. Expressive rendering corresponds to the generation of drawings or paintings of a virtual scene, but also to some areas of computational photography, where the picture is simplified in specific areas to focus the attention.
- *Illumination Simulation*, where we model the interaction of light with the objects in the scene, resulting in a photorealistic picture of the scene. Research include improving the quality and photorealism of pictures, including more complex effects such as depth-of-field or motion-blur. We are also working on accelerating the computations, both for real-time photorealistic rendering and offline, high-quality rendering.
- *Complex Scenes*, where we generate, manage, animate and render highly complex scenes, such as natural scenes with forests, rivers and oceans, but also large datasets for visualization. We are especially interested in interactive visualization of complex scenes, with all the associated challenges in terms of processing and memory bandwidth.

The fundamental research interest of Maverick is first, *understanding* what makes a picture useful, powerful and interesting for the user, and second *designing* algorithms to create and improve these pictures.

3.2. Research approaches

We will address these research problems through three interconnected research approaches:

3.2.1. Picture Impact

Our first research axis deals with the *impact* pictures have on the viewer, and how we can improve this impact. Our research here will target:

- *evaluating user response:* we need to evaluate how the viewers respond to the pictures and animations generated by our algorithms, through user studies, either asking the viewer about what he perceives in a picture or measuring how his body reacts (eye tracking, position tracking).
- *removing artefacts and discontinuities:* temporal and spatial discontinuities perturb viewer attention, distracting the viewer from the main message. These discontinuities occur during the picture creation process; finding and removing them is a difficult process.

3.2.2. Data Representation

The data we receive as input for picture generation is often unsuitable for interactive high-quality rendering: too many details, no spatial organisation... Similarly the pictures we produce or get as input for other algorithms can contain superfluous details.

One of our goals is to develop new data representations, adapted to our requirements for rendering. This includes fast access to the relevant information, but also access to the specific hierarchical level of information needed: we want to organize the data in hierarchical levels, pre-filter it so that sampling at a given level also gives information about the underlying levels. Our research for this axis include filtering, data abstraction, simplification and stylization.

The input data can be of any kind: geometric data, such as the model of an object, scientific data before visualization, pictures and photographs. It can be time-dependent or not; time-dependent data bring an additional level of challenge on the algorithm for fast updates.

3.2.3. Prediction and simulation

Our algorithms for generating pictures require computations: sampling, integration, simulation... These computations can be optimized if we already know the characteristics of the final picture. Our recent research has shown that it is possible to predict the local characteristics of a picture by studying the phenomena involved: the local complexity, the spatial variations, their direction...

Our goal is to develop new techniques for predicting the properties of a picture, and to adapt our image-generation algorithms to these properties, for example by sampling less in areas of low variation.

Our research problems and approaches are all cross-connected. Research on the *impact* of pictures is of interest in three different research problems: *Computer Visualization*, *Expressive rendering* and *Illumination Simulation*. Similarly, our research on *Illumination simulation* will use all three research approaches: impact, representations and prediction.

3.3. Cross-cutting research issues

Beyond the connections between our problems and research approaches, we are interested in several issues, which are present throughout all our research:

sampling is an ubiquitous process occurring in all our application domains, whether photorealistic rendering (*e.g.* photon mapping), expressive rendering (*e.g.* brush strokes), texturing, fluid simulation (Lagrangian methods), etc. When sampling and reconstructing a signal for picture generation, we have to ensure both coherence and homogeneity. By *coherence*, we mean not introducing spatial or temporal discontinuities in the reconstructed signal. By *homogeneity*, we mean that samples should be placed regularly in space and time. For a time-dependent signal, these requirements are conflicting with each other, opening new areas of research.

filtering is another ubiquitous process, occuring in all our application domains, whether in realistic rendering (*e.g.* for integrating height fields, normals, material properties), expressive rendering (*e.g.* for simplifying strokes), textures (through non-linearity and discontinuities). It is especially relevant when we are replacing a signal or data with a lower resolution (for hierarchical representation); this involves filtering the data with a reconstruction kernel, representing the transition between levels.

performance and scalability are also a common requirement for all our applications. We want our algorithms to be usable, which implies that they can be used on large and complex scenes, placing a great importance on scalability. For some applications, we target interactive and real-time applications, with an update frequency between 10 Hz and 120 Hz.

coherence and continuity in space and time is also a common requirement of realistic as well as expressive models which must be ensured despite contradictory requirements. We want to avoid flickering and aliasing.

animation: our input data is likely to be time-varying (*e.g.* animated geometry, physical simulation, time-dependent dataset). A common requirement for all our algorithms and data representation is that they must be compatible with animated data (fast updates for data structures, low latency algorithms...).

3.4. Methodology

Our research is guided by several methodological principles:

Experimentation: to find solutions and phenomenological models, we use experimentation, performing statistical measurements of how a system behaves. We then extract a model from the experimental data.

Validation: for each algorithm we develop, we look for experimental validation: measuring the behavior of the algorithm, how it scales, how it improves over the state-of-the-art... We also compare our algorithms to the exact solution. Validation is harder for some of our research domains, but it remains a key principle for us.

Reducing the complexity of the problem: the equations describing certain behaviors in image synthesis can have a large degree of complexity, precluding computations, especially in real time. This is true for physical simulation of fluids, tree growth, illumination simulation... We are looking for *emerging phenomena* and *phenomenological models* to describe them (see framed box “Emerging phenomena”). Using these, we simplify the theoretical models in a controlled way, to improve user interaction and accelerate the computations.

Transferring ideas from other domains: Computer Graphics is, by nature, at the interface of many research domains: physics for the behavior of light, applied mathematics for numerical simulation, biology, algorithmics... We import tools from all these domains, and keep looking for new tools and ideas.

Develop new fondamental tools: In situations where specific tools are required for a problem, we will proceed from a theoretical framework to develop them. These tools may in return have applications in other domains, and we are ready to disseminate them.

Collaborate with industrial partners: we have a long experiment of collaboration with industrial partners. These collaborations bring us new problems to solve, with short-term or medium-term transfert opportunities. When we cooperate with these partners, we have to find *what they need*, which can be very different from *what they want*, their expressed need.

4. Highlights of the Year

4.1. Highlights of the Year

Three software platforms based on our research were released as open-source distributions in 2015. These platforms contain the result of several years of research, and have been supported by Inria through engineering support:

- Gratin, a node-based compositing software for creating, manipulating and animating 2D and 3D data. It uses an internal direct acyclic multi-graph and provides an intuitive user interface that allows to quickly design complex prototypes.
- Proland, a platform for real-time quality rendering and editing of large landscapes. All features can work with planet-sized terrains, for all viewpoints from ground to space.
- Gigavoxel, a software platform for real-time quality rendering of very large and very detailed scenes which couldn’t fit memory. Performances permit showing details over deep zooms and walk through very crowded scenes (which are rigid, for the moment).

5. New Software and Platforms

5.1. Diffusion curves

KEYWORDS: Vector-based drawing - Shading

FUNCTIONAL DESCRIPTION

Diffusion Curves is a vector-based design tool for creating complex shaded images. This prototype is composed of the Windows binary, along with the required shader programs (ie. in source code).

- Participants: Joëlle Thollot, Pascal Barla, Adrien Bousseau and Alexandrina Orzan
- Partners: CNRS - LJK - INP Grenoble - Université Joseph-Fourier
- Contact: Joëlle Thollot
- URL: http://maverick.inria.fr/Publications/2008/OBWBTS08/index.php

5.2. Freestyle

FUNCTIONAL DESCRIPTION

Freestyle is a software for Non-Photorealistic Line Drawing rendering from 3D scenes. It is designed as a programmable interface to allow maximum control over the style of the final drawing: the user "programs" how the silhouettes and other feature lines from the 3D model should be turned into stylized strokes using a set of programmable operators dedicated to style description. This programmable approach, inspired by the shading languages available in photorealistic renderers such as Pixar's RenderMan, overcomes the limitations of integrated software with access to a limited number of parameters and permits the design of an infinite variety of rich and complex styles. The system currently focuses on pure line drawing as a first step. The style description language is Python augmented with our set of operators. Freestyle was developed in the framework of a research project dedicated to the study of stylized line drawing rendering from 3D scenes.

- Participant: Joëlle Thollot
- Contact: Joëlle Thollot
- URL: http://freestyle.sourceforge.net

5.3. GRATIN

FUNCTIONAL DESCRIPTION

Gratin is a node-based compositing software for creating, manipulating and animating 2D and 3D data. It uses an internal direct acyclic multi-graph and provides an intuitive user interface that allows to quickly design complex prototypes. Gratin has several properties that make it useful for researchers and students. (1) it works in real-time: everything is executed on the GPU, using OpenGL, GLSL and/or Cuda. (2) it is easily programmable: users can directly write GLSL scripts inside the interface, or create new C++ plugins that will be loaded as new nodes in the software. (3) all the parameters can be animated using keyframe curves to generate videos and demos. (4) the system allows to easily exchange nodes, group of nodes or full pipelines between people.

- Participants: Pascal Barla, Gautier Ciaudo and Romain Vergne
- Partner: UJF
- Contact: Romain Vergne
- URL: http://gratin.gforge.inria.fr

5.4. GigaVoxels

FUNCTIONAL DESCRIPTION

Gigavoxel is a software platform which goal is the real-time quality rendering of very large and very detailed scenes which couldn't fit memory. Performances permit showing details over deep zooms and walk through very crowdy scenes (which are rigid, for the moment). The principle is to represent data on the GPU as a Sparse Voxel Octree which multiscale voxels bricks are produced on demand only when necessary and only at the required resolution, and kept in a LRU cache. User defined producer lays accross CPU and GPU and can load, transform, or procedurally create the data. Another user defined function is called to shade each voxel according to the user-defined voxel content, so that it is user choice to distribute the appearance-making at creation (for faster rendering) or on the fly (for storageless thin procedural details). The efficient rendering is done using a GPU differential cone-tracing using the scale corresponding to the 3D-MIPmapping LOD, allowing quality rendering with one single ray per pixel. Data is produced in case of cache miss, and thus only whenever visible (accounting for view frustum and occlusion). Soft-shadows and depth-of-field is easily obtained using larger cones, and are indeed cheaper than unblurred rendering. Beside the representation, data management and base rendering algorithm themself, we also worked on realtime light transport, and on quality prefiltering of complex data. GigaVoxels is currently used for the quality real-time exploration of the detailed galaxy in ANR RTIGE.

- Participants: Cyril Crassin, Fabrice Neyret, Paul Gannay, Prashant Goswami, Jérémy Sinoir, Pascal Guehl and Eric Heitz
- Contact: Fabrice Neyret
- URL: http://gigavoxels.imag.fr

5.5. HQR: High Quality Renderer

KEYWORDS: Lighting simulation - Materials - Plug-in

FUNCTIONAL DESCRIPTION

HQR is a global lighting simulation platform. HQR software is based on the photon mapping method which is capable of solving the light balance equation and of giving a high quality solution. Through a graphical user interface, it reads X3D scenes using the X3DToolKit package developed at Maverick, it allows the user to tune several parameters, computes photon maps, and reconstructs information to obtain a high quality solution. HQR also accepts plugins which considerably eases the development of new algorithms for global illumination, those benefiting from the existing algorithms for handling materials, geometry and light sources.

- Participant: Cyril Soler
- Contact: Cyril Soler
- URL: http://artis.imag.fr/~Cyril.Soler/HQR
- URL: https://launchpad.net/~csoler-users/+archive/ubuntu/hqr

5.6. Spherical harmonic library

KEYWORDS: Lighting simulation - Materials - Plug-in

FUNCTIONAL DESCRIPTION

The spherical harmonic library regroups a set of tools to decompose spherical functions in to spherical and rotated zonal harmonics. It also implements two spherical harmonic rotation formulas (Jan Kautz' ZXZXZ method, and the rotation formula derived in Cyril Soler's PhD thesis). A graphical tool called `shdisplay` is also included and allows to visualize and manipulate distributions of spherical harmonics.

- Participants: Cyril Soler
- Contact: Cyril Soler
- URL: https://launchpad.net/~csoler-users/+archive/ubuntu/ylm

5.7. MobiNet

KEYWORD: Simulation

FUNCTIONAL DESCRIPTION

The MobiNet software allows for the creation of simple applications such as video games, virtual physics experiments or pedagogical math illustrations. It relies on an intuitive graphical interface and language which allows the user to program a set of mobile objects (possibly through a network).

- Partners: CNRS - LJK - INP Grenoble - Inria - IREM - Cies
- Contact: Fabrice Neyret
- URL: http://mobinet.imag.fr/index.en.html

5.8. PLANTRAD

KEYWORDS: Bioinformatics - Biology
FUNCTIONAL DESCRIPTION

PlantRad is a software program for computing solutions to the equation of light equilibrium in a complex scene including vegetation. The technology used is hierarchical radiosity with clustering and instantiation. Thanks to the latter, PlantRad is capable of treating scenes with a very high geometric complexity (up to millions of polygons) such as plants or any kind of vegetation scene where a high degree of approximate self-similarity permits a significant gain in memory requirements.

- Participants: George Drettakis, François Sillion and Cyril Soler
- Contact: Cyril Soler
- URL: no URL available

5.9. PROLAND

PROcedural LANDscape
KEYWORDS: Real time - 3D - Realistic rendering - Masses of data - Atmosphere - Ocean
FUNCTIONAL DESCRIPTION

The goal of this platform is the real-time quality rendering and editing of large landscapes. All features can work with planet-sized terrains, for all viewpoints from ground to space.

- Participants: Antoine Begault, Eric Bruneton and Guillaume Piolet
- Contact: Fabrice Neyret
- URL: http://proland.imag.fr/

5.10. Vrender

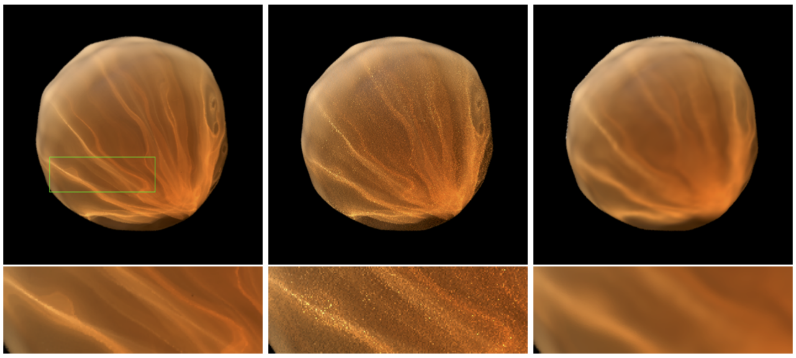
FUNCTIONAL DESCRIPTION

The VRender library is a simple tool to render the content of an OpenGL window to a vectorial device such as Postscript, XFig, and soon SVG. The main usage of such a library is to make clean vectorial drawings for publications, books, etc.

In practice, VRender replaces the z-buffer based hidden surface removal of OpenGL by sorting the geometric primitives so that they can be rendered in a back-to-front order, possibly cutting them into pieces to solve cycles.

VRender is also responsible for the vectorial snapshot feature of the QGLViewer library.

- Participant: Cyril Soler
- Contact: Cyril Soler
- URL: http://artis.imag.fr/Software/VRender/



(a) Our algorithm (169 s) **(b)** Point samples [WZHB09] (27 samples, 170 s) **(c)** Photon mapping (650 000 photons, 167 s)

Figure 2. Single scattering: comparison between our algorithm and existing methods (equal computation time) on a translucent sphere illuminated by a point light source from behind.

6. New Results

6.1. Single Scattering in participating media with refractive boundaries

Participant: Nicolas Holzschuch [contact].

Volume caustics are high-frequency effects appearing in participating media with low opacity, when refractive interfaces are focusing the light rays (see Figure 2). Refractions make them hard to compute, since screen locality does not correlate with spatial locality in the medium. We have developed a new method for accurate computation of single scattering effects in a participating media enclosed by refractive interfaces. Our algorithm is based on the observation that although radiance along each camera ray is irregular, contributions from individual triangles are smooth. Our method gives more accurate results than existing methods, faster. It uses minimal information and requires no precomputation or additional data structures. This paper was published in the *Computer Graphics Forum* journal [3] and presented at the *Eurographics Symposium on Rendering*.

6.2. Diffraction effects in reflectance properties

Participant: Nicolas Holzschuch [contact].

Reflectance properties express how objects in a virtual scene interact with light. They control the appearance of the object: whether it looks shiny or not, it has a metallic or plastic appearance. The reflectance model (BRDF) is essential for photorealistic pictures. Measured reflectance provide high realism, at the expense of memory cost. Parametric models are compact, but it is difficult to find the right parameters from measured reflectance.

Many parametric models are based on a physical representation of the surface micro-geometry and how it interacts with incoming light. The Cook-Torrance model assumes that light follows the principles of optical geometry: it is reflected by the surface micro-geometry but also potentially occluded. The diffraction model assumes that the micro-geometry diffracts the incoming light. This reflectance model has an intrinsic wavelength dependency. Previous experiments have shown that fitting measured materials to parametric models is hard. Heuristic models based on either Cook-Torrance or diffraction are complex, with many parameters. Our research has shown that both effects (optical geometry and diffraction) are present in most

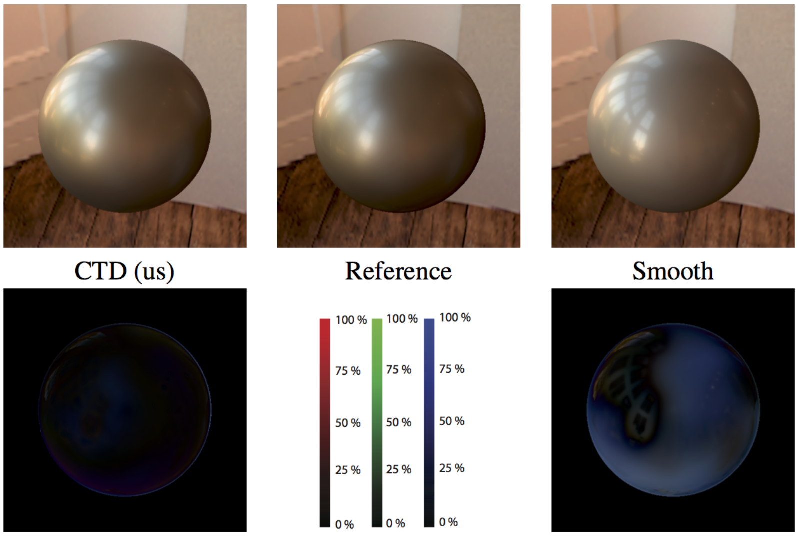


Figure 3. Comparison between our model combining reflection and diffraction (left), measured data (center) and state-of-the-art model (right).

measured materials [6]. Based on this knowledge, we have proposed a new reflectance model, that accurately represents measured reflectance [10]. This model combines optical geometry for the specular peak and diffraction effects for wide-angle scattering.

6.3. Efficient and Accurate Spherical Kernel Integrals using Isotropic Decomposition

Participant: Cyril Soler [contact].

Spherical filtering is fundamental to many problems in image synthesis, such as computing the reflected light over a surface or anti-aliasing mirror reflections over a pixel. This operation is challenging since the profile of spherical filters (e.g., the view-evaluated BRDF or the geometry-warped pixel footprint, above) typically exhibits both spatial-and rotational-variation at each pixel, precluding precomputed solutions. We accelerate complex spherical filtering tasks using isotropic spherical decomposition (ISD), decomposing spherical filters into a linear combination of simpler isotropic kernels. Our general ISD is flexible to the choice of the isotropic kernels, and we demonstrate practical realizations of ISD on several problems in rendering: shading and prefiltering with spatially-varying BRDFs, anti-aliasing environment mapped mirror reflections, and filtering of noisy reflectance data. Compared to previous basis-space rendering solutions, our shading solution generates ground truth-quality results at interactive rates, avoiding costly reconstruction and large approximation errors. This paper was published in *ACM Transactions on Graphics* [4] and presented at Siggraph Asia 2015.

6.4. Color transfer guided by summary statistics

Participants: Benoit Arbelot, Thomas Hurtut, Romain Vergne [contact], Joëlle Thollot.

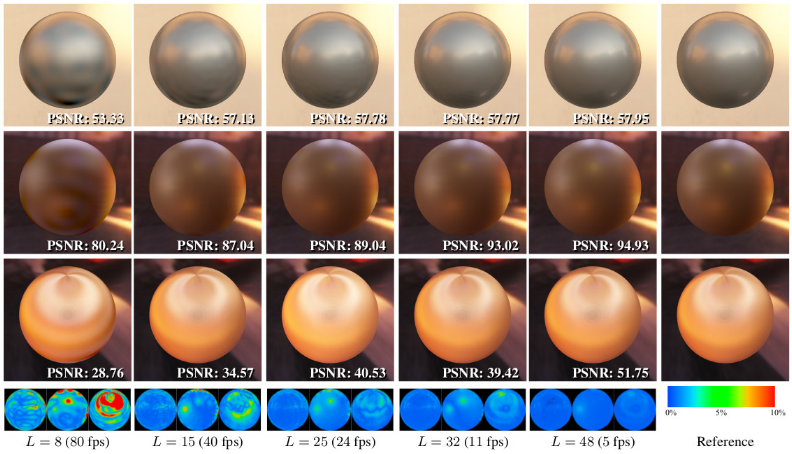


Figure 4. Convergence of spherical ISD shading for increasing L. Top to bottom: isotropic alum-bronze (with `pisa` illumination), isotropic gold-paint and anisotropic yellow-satin (both using `grace cathedral` illumination). Reference images were ray-traced using 300K samples per pixel. False color error images in the bottom row visually illustrate the convergence of our RZH approximation to the reference rendering. Note that the dark region in the center of the spheres on the last row of renderings is indeed part of the underlying reflectance input data.

Color transfer Colorization

Figure 5. Our framework allows for automatic local color transfer (left) and colorization (right) based on textural properties.

We have targeted two related color manipulation problems: *Color transfer* for modifying an image colors and *colorization* for adding colors to a greyscale image. Automatic methods for these two applications propose to modify the input image using a reference that contains the desired colors. Previous approaches usually do not target both applications and suffer from two main limitations: possible misleading associations between input and reference regions and poor spatial coherence around image structures. In this paper, we propose a unified framework that uses the textural content of the images to guide the color transfer and colorization. Our method introduces an edge-aware texture descriptor based on region covariance, allowing for local color transformations. We show that our approach is able to produce results comparable or better than state-of-the-art methods in both applications. This work was presented at the AFIG conference [7]. An extended version is available as a research report [9].

6.5. Programmable 2D Arrangements for Element Texture Design

Participants: Hugo Loi, Thomas Hurtut, Romain Vergne, Joëlle Thollot [contact].

We introduce a programmable method for designing stationary 2D arrangements for element textures, namely textures made of small geometric elements. These textures are ubiquitous in numerous applications of computer-aided illustration. Previous methods, whether they be example-based or layout-based, lack control and can produce a limited range of possible arrangements. Our approach targets technical artists who will design an arrangement by writing a script. These scripts are using three types of operators: partitioning operators for defining the broad-scale organization of the arrangement, mapping operators for controlling the local organization of elements, and merging operators for mixing different arrangements. These operators are designed so as to guarantee a stationary result meaning that the produced arrangements will always be repetitive. We show (see Figure 10) that this simple set of operators is sufficient to reach a much broader variety of arrangements than previous methods. Editing the script leads to predictable changes in the synthesized arrangement, which allows an easy iterative design of complex structures. Finally, our operator set is extensible and can be adapted to application-dependent needs. This work is available as a research report [11]

6.6. Piecewise polynomial Reconstruction of Scalar Fields from Simplified Morse-Smale Complexes

Participants: Léo Allemand-Giorgis, Georges-Pierre Bonneau [contact].

Morse-Smale (MS) complexes have been proposed to visualize topological features of scalar fields defined on manifold domains. Herein, three main problems have been addressed in the past: (a) efficient computation of the initial combinatorial structure connecting the critical points; (b) simplification of these combinatorial structures; (c) reconstruction of a scalar field in accordance to the simplified Morse-Smale complex. The present paper faces the third problem by proposing a novel approach for computing a scalar field coherent with a given simplified MS complex that privileges the use of piecewise polynomial functions. Based on techniques borrowed from shape preserving design in Computer Aided Geometric Design, our method constructs the surface cell by cell using piecewise polynomial curves and surfaces. We present the benefit and limitations of using polynomials for reconstruction surfaces from topological data. This research was published in a book chapter [8].

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

WetaFX (New-Zealand) has given us 30,000 euros in 2015, as a unilateral gift.

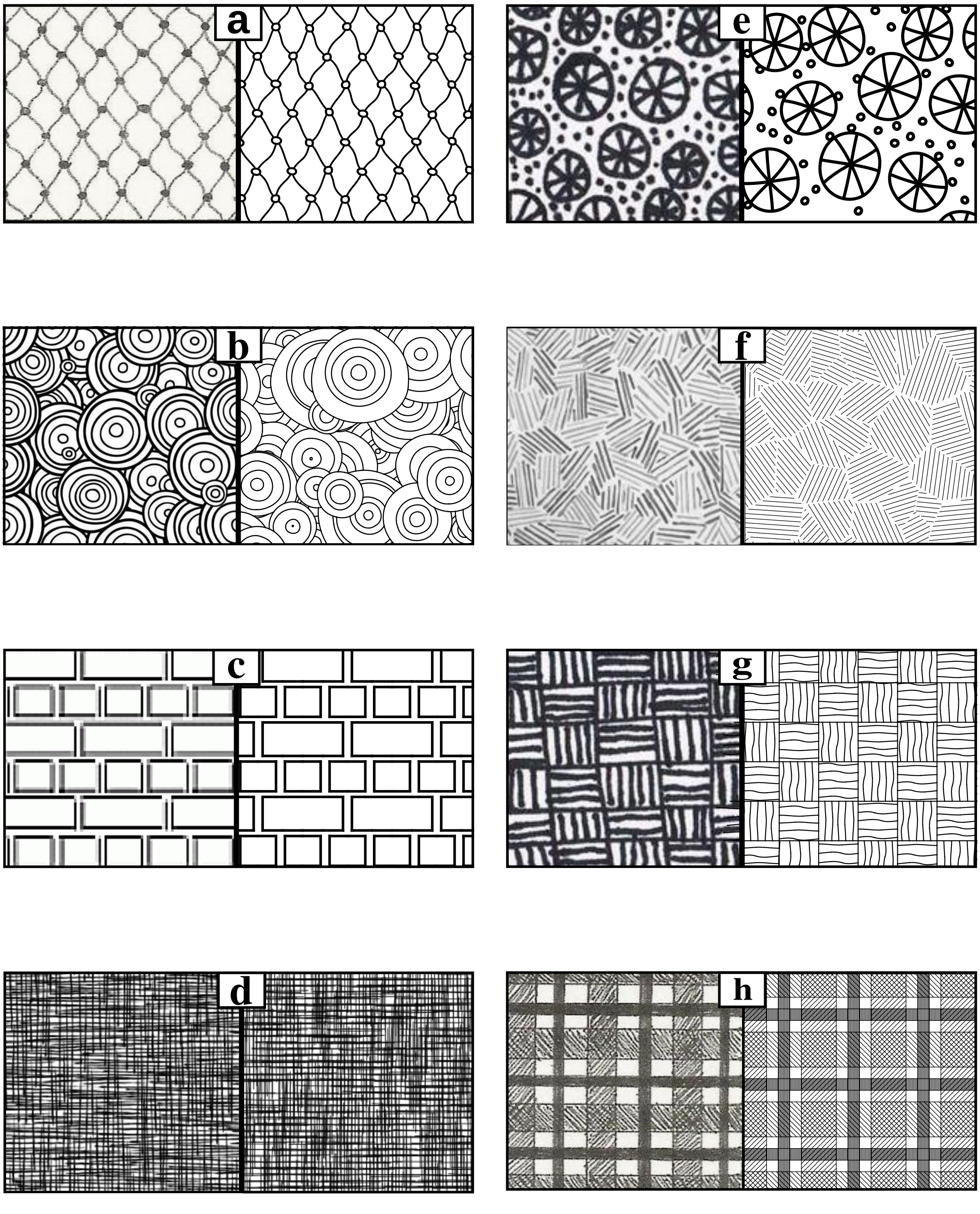


*Figure 6. **Element textures commonly used.** These textures can be found in professional art (d,g,h), casual art (a,e,f), technical productions such as Computer-Assisted Design illustration tools (c), and textile industry (b). For each example, we show a hand-drawn image (left), and our synthesized reproduction of its geometric arrangement (right). (a,b,c) Classic regular distributions with contact, overlap and no adjacency between elements respectively. (d) Overlap of two textures creating cross hatching. (e) Non overlapping combination of two textures. (f,g,h) Complex element textures with clusters of elements. — Image credit: (d,g,h) "Rendering in Pen and Ink: The Classic Book On Pen and Ink Techniques for Artists, Illustrators, Architects, and Designers" ; (a,e) Profusion Art [profusionart.blogspot.com]; (f) Hayes' Art Classes [hayesartclasses.blogspot.com]; (c) CompugraphX [www.compugraphx.com]; (b) 123Stitch [www.123stitch.com].*

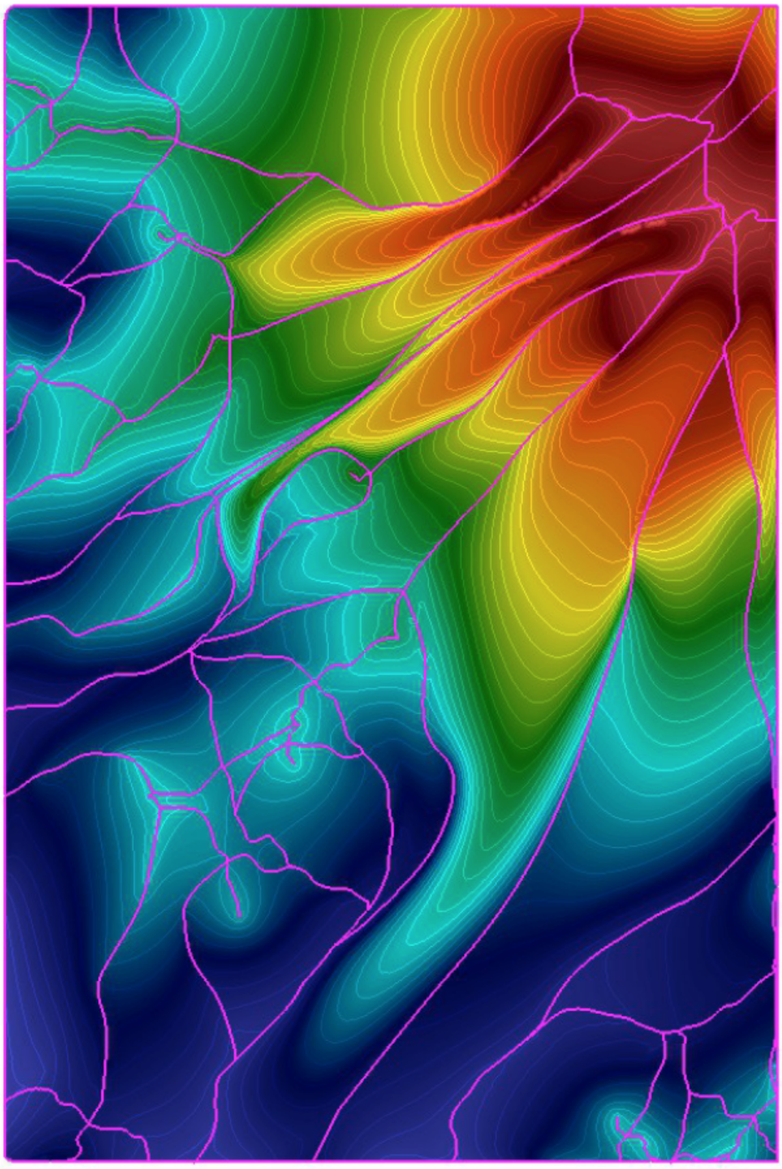


Figure 7. A function is reconstructed from its Morse-Smale complex (in purple). Inside the cells the function is monotonic so that no critical points are inserted, as can be seen from the isocontours in white. This technique is useful in Visualization whenever critical points in the data are important.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR BLANC: ALTA

Participants: Nicolas Holzschuch [contact], Cyril Soler.

We are funded by the ANR research program "Blanc" for a joint research project with two other Inria research teams, REVES in Sophia-Antipolis and Manao in Bordeaux. The goal of this project is studying light transport operators for global illumination, both in terms of frequency analysis and dimensional analysis. The grant started in October 2011, for 54 months.

8.1.2. ANR CONTINT: Galaxy/veRTIGE

Participants: Jean-Dominique Gascuel, Nicolas Holzschuch, Fabrice Neyret [contact].

RTIGE stands for Real-Time and Interactive Galaxy for Edutainment. This is an ANR CONTINT (Contents and Interactions) research program, for a joint research project with the EVASION Inria project-team, the GEPI and LERMA research teams at Paris Observatory, and the RSA Cosmos company. The goal of this project is to simulate the quality multi-spectral real-time exploration of the Galaxy with Hubble-like images, based on simulation data, statistical data coming from observation, star catalogs, and procedural amplification for stars and dust clouds distributions. RSA-Cosmos aims at integrating the results in digital planetariums. The grant started in December 2010, for 60 months.

8.1.3. ANR CONTINT: MAPSTYLE

Participants: Joëlle Thollot [contact], Hugo Loi.

The MAPSTYLE project aims at exploring the possibilities offered by cartography and expressive rendering to propose original and new cartographic representations. Through this project, we target two types of needs. On the one hand, mapping agencies produce series paper maps with some renderings that are still derived from drawings made by hand 50 years ago: for example, rocky areas in the series TOP25 (to 1/25000) of the French Institut Géographique National (IGN). The rendering of these rocky areas must be automated and its effectiveness retained to meet the requirements of hikers safety. On the other hand, Internet mapping tools allow any user to become a cartographer. However, they provide default styles that cannot be changed (GeoPortal, Google Maps) or they are editable but without any assistance or expertise (CloudMade). In such cases, as in the case of mobile applications, we identify the need to offer users means to design map styles more personalised and more attractive to meet their expectations (decision-making, recreation, etc.) and their tastes. The grant started on October 2012, for 48 months.

8.1.4. ANR: Materials

Participants: Nicolas Holzschuch [contact], Romain Vergne.

We are funded by the ANR for a joint research project on acquisition and restitution of micro-facet based materials.

two other Inria research teams, REVES in Sophia-Antipolis and iPARLA in Bordeaux. The goal of this project is studying light transport operators for global illumination, both in terms of frequency analysis and dimensional analysis. The grant started in October 2011, for 54 months.

8.2. International Initiatives

8.2.1. Inria International Partners

8.2.1.1. Informal International Partners

We have an ongoing cooperation with the Université De Montréal (Derek Nowrouzhezarai, Pierre Poulin), dealing with light transport and isotropic filter decomposition in the spherical domain, based on zonal harmonic basis.

We also have an ongoing cooperation with Polytechnique de Montréal (Thomas Hurtut) dealing with procedural texture design and color transfer.

8.3. International Research Visitors

8.3.1. Visits to International Teams

8.3.1.1. Sabbatical programme

Soler Cyril

Date: Aug 2015 - Jul 2016

Institution: Université de Montréal (Canada)

8.3.1.2. Research stays abroad

Neyret Fabrice

Date: Jan 2015 - Mar 2015 and Nov 2015 - Mar 2016

Institution: WETA Digital (New-Zeland)

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events selection

9.1.1.1. Chair of conference program committees

- Eurographics 2015 Tutorials: Cyril Soler (co-chair)

9.1.1.2. Member of the conference program committees

- Eurographics 2015: Nicolas Holzschuch
- Eurographics Symposium on Rendering 2015: Nicolas Holzschuch, Cyril Soler
- Interactive 3D Graphics 2015: Nicolas Holzschuch
- Interactive 3D Graphics 2016: Nicolas Holzschuch
- Expressive 2015: Joëlle Thollot
- Solid and Physical Modeling 2015: Georges-Pierre Bonneau
- Eurographics VisSym Short Papers: Georges-Pierre Bonneau
- Environmental Visualization: Georges-Pierre Bonneau
- Topology in Visualization (workshop): Georges-Pierre Bonneau
- Jury du meilleur papier à l'AFIG: Romain Vergne

9.1.2. Research administration

- Nicolas Holzschuch is an elected member of Inria *Evaluation Committee*, a reserve member of Inria *Scientific Board* and of Inria *Comité Technique*.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : Enseignant, titre du cours, nombre d'heures en équivalent TD, niveau (L1, L2, L3), université, pays

Licence: Joëlle Thollot, Théorie des langages, 27h, L3, ENSIMAG, France

Licence: Georges-Pierre Bonneau, Algorithmique, Polytech'Grenoble, France

Licence: Romain Vergne, Introduction à l'Algorithmique, 66.5, L1, Université de Grenoble, France
Licence: Romain Vergne, WebGL, 29, L3, IUT2 - Université de Grenoble, France
Master: Romain Vergne, Synthèse d'images, 32h, M1, Université de Grenoble, France
Master: Romain Vergne, Synthèse d'images avancée, 13.5h, M2, Université de Grenoble, France
Master: Romain Vergne, Reconstruction et géométrie algorithmique, 36h, M2, Université de Grenoble, France
Master: Georges-Pierre Bonneau, Synthèse d'Images, Polytech'Grenoble, France
Master: Georges-Pierre Bonneau, Visualisation Scientifique, Polytech'Grenoble, France
Master: Georges-Pierre Bonneau, Visualisation d'information, G-INP, France
Master: Georges-Pierre Bonneau, Scientific Visualization, G-INP, France
Master: Georges-Pierre Bonneau, Géométrie numérique, Université de Grenoble, France
Master: Georges-Pierre Bonneau et Nicolas Holzschuch, Computer Graphics II, 36 h, M2, Université de Grenoble, France
Master : Nicolas Holzschuch, Synthèse d'Images et Animation, 60 h, M2, ENSIMAG, France
Master: Joëlle Thollot, Responsable du cursus en alternance, 48h, M1-M2, ENSIMAG, France
Master: Joëlle Thollot, Tutorat d'apprentis, 70h, M1-M2, ENSIMAG, France
Master: Joëlle Thollot, Tutorat d'apprentis, 70h, M1-M2, ENSIMAG, France
Master: Romain Vergne, Responsable de stages, 27h, M1-M2, Polytech'Grenoble, France
Master: Romain Vergne, Tutorat, 16h; M1-M2, Polytech'Grenoble, France

9.2.2. Supervision

PhD: Hugo Loi, Synthèse programmable de textures vectorielles et application à la cartographie, Université de Grenoble, December 16, 2015, Joëlle Thollot, Romain Vergne, Thomas Hurtut.
PhD in progress: Leo Allemand-Giorgis, Visualisation de champs scalaires guidée par la topologie, October 1, 2012, Georges-Pierre Bonneau, Stefanie Hahmann.
PhD in progress: Benoit Arbelot, Statistical studies of shape, material, and environment for appearance manipulation, October 1, 2013, Joëlle Thollot, Romain Vergne.
PhD in progress: Alexandre Bleron, Stylization of animated 3D scenes in a painterly style, October 1, 2015, Joëlle Thollot, Romain Vergne.
PhD in progress: Alban Fichet, Efficient representation for measured reflectance, October 1, 2015, Nicolas Holzschuch.
PhD in progress: Aarohi Johal, Algorithmes de génération automatique d'arbres de construction à partir de modèles géométriques CAO B-Rep, September 2013, Jean-Claude Léon, Georges-Pierre Bonneau, thèse CIFRE EdF R&D.
PhD in progress: Guillaume Loubet, Représentations efficaces de l'apparence sous-pixel, October 1, 2014, Fabrice Neyret.
PhD in progress: Jeremy Wambecke, Data Visualization for non-experts, October 1, 2014, Renaud Blanch, Georges-Pierre Bonneau, Romain Vergne.
PhD in progress: Benoit Zupancic, Acquisition of reflectance properties, October 1, 2014, Cyril Soler.

9.2.3. Juries

- Nicolas Holzschuch has been a member of the jury for the PhD of Jonathan Dupuy (Lyon, Dec 2015), Adrien Pilleboue (Lyon, Nov 2015) and Gurprit Singh (Lyon, Sep 2015).
- Joëlle Thollot has been a member of the jury for the PhD of Martin Guay (Grenoble, Dec 2015).

9.3. Popularization

Every year, "MobiNet" (see section 5.7) classes are conducted with high school pupils of the large Grenoble area to practice initiation and intuition on Computer Science, Maths and Physics. Depending on the year, we have 2 to 4 groups in the scope of INP-Grenoble "Enginneering weeks", and 0 to 2 groups in the scope of Math-C2+ operations.

10. Bibliography

Major publications by the team in recent years

[1] F. DURAND, N. HOLZSCHUCH, C. SOLER, E. CHAN, F. X. SILLION. *A Frequency Analysis of Light Transport*, in "ACM Transactions on Graphics", August 2005, vol. 24, n^{o} 3, pp. 1115 - 1126 [*DOI :* 10.1145/1186822.1073320], http://hal.inria.fr/inria-00379363

[2] A. ORZAN, A. BOUSSEAU, H. WINNEMÖLLER, P. BARLA, J. THOLLOT, D. SALESIN. *Diffusion Curves: A Vector Representation for Smooth-Shaded Images*, in "ACM Transactions on Graphics", August 2008, vol. 27, n^{o} 3, pp. 92:1-8 [*DOI :* 10.1145/1399504.1360691], http://hal.inria.fr/inria-00274768

Publications of the year

Articles in International Peer-Reviewed Journals

[3] N. HOLZSCHUCH. *Accurate computation of single scattering in participating media with refractive boundaries*, in "Computer Graphics Forum", September 2015, vol. 34, n^{o} 6, pp. 48-59 [*DOI :* 10.1111/CGF.12517], https://hal.inria.fr/hal-01083246

[4] C. SOLER, M. BAGHER, D. NOWROUZEZAHRAI. *Efficient and Accurate Spherical Kernel Integrals using Isotropic Decomposition*, in "ACM Transactions on Graphics", November 2015, vol. 34, n^{o} 5, 14 p. [*DOI :* 10.1145/2816795.2818141], https://hal.inria.fr/hal-01187865

[5] R. VERGNE, P. BARLA. *Designing Gratin, A GPU-Tailored Node-Based System*, in "Journal of Computer Graphics Techniques", 2015, vol. 4, n^{o} 4, 17 p. , https://hal.inria.fr/hal-01254546

International Conferences with Proceedings

[6] N. HOLZSCHUCH, R. PACANOWSKI. *Identifying diffraction effects in measured reflectances*, in "Eurographics Workshop on Material Appearance Modeling", Darmstadt, Germany, June 2015, https://hal.inria.fr/hal-01170614

National Conferences with Proceedings

[7] B. ARBELOT, R. VERGNE, T. HURTUT, J. THOLLOT. *Transfert de couleurs et colorisation guidés par la texture*, in "28ème journées de l'Association Française d'Informatique Graphique", Lyon, France, LIRIS, November 2015, https://hal.archives-ouvertes.fr/hal-01245713

Scientific Books (or Scientific Book chapters)

[8] L. ALLEMAND-GIORGIS, G.-P. BONNEAU, S. HAHMANN. *Piecewise polynomial Reconstruction of Scalar Fields from Simplified Morse-Smale Complexes*, in "Topological Data Analysis", T. W. HAMISH CARR (editor), Springer, 2016, https://hal.inria.fr/hal-01252477

Research Reports

[9] B. ARBELOT, R. VERGNE, T. HURTUT, J. THOLLOT. *Color Transfer and Colorization based on Textural Properties*, Inria ; LJK, December 2015, n^{o} RR-8834, https://hal.archives-ouvertes.fr/hal-01246615

[10] N. HOLZSCHUCH, R. PACANOWSKI. *A physically accurate reflectance model combining reflection and diffraction*, Inria, November 2015, n^{o} RR-8807, 24 p. , https://hal.inria.fr/hal-01224702

[11] H. LOI, T. HURTUT, R. VERGNE, J. THOLLOT. *A Programmable Model for Designing Stationary 2D Arrangements*, Inria - Research Centre Grenoble – Rhône-Alpes ; Inria, April 2015, n^{o} RR-8713, https://hal.inria.fr/hal-01141869