Activity Report 2019

Project-Team MAVERICK

Models and Algorithms for Visualization and Rendering

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

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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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A5.5.1. - Geometrical modeling
A5.5.2. - Rendering
A5.5.3. - Computational photography
A5.5.4. - Animation

Other Research Topics and Application Domains:

B5.5. - Materials
B5.7. - 3D printing
B9.2.2. - Cinema, Television
B9.2.3. - Video games
B9.2.4. - Theater
B9.6.6. - Archeology, History

1. Team, Visitors, External Collaborators

Research Scientists

Nicolas Holzschuch [Team leader, Inria, Senior Researcher, HDR]
Fabrice Neyret [CNRS, Senior Researcher, HDR]
Cyril Soler [Inria, Researcher, HDR]

Faculty Members

Georges-Pierre Bonneau [Univ Grenoble Alpes, Professor, HDR]
Joëlle Thollot [Institut polytechnique de Grenoble, Professor, HDR]
Romain Vergne [Univ Grenoble Alpes, Associate Professor]

PhD Students

Alban Fichet [Inria, PhD Student]
Morgane Gerardin [Univ Grenoble Alpes, PhD Student]
Nolan Mestres [Univ Grenoble Alpes, PhD Student, from Oct 2019]
Ronak Molazem [Inria, PhD Student]
Vincent Tavernier [Univ Grenoble Alpes, PhD Student]
Sunrise Wang [Inria, PhD Student]

Interns and Apprentices

Mohamed Amine Farhat [Inria, from Jun 2019 until Jul 2019]
Anmol Hanagodimath [Inria, until Jul 2019]
Maxime Isnel [Inria, from Feb 2019 until Jul 2019]

Administrative Assistant

Diane Courtiol [Inria, Administrative Assistant]

Visiting Scientist

Hugo Rens [Univ Paul Sabatier, from May 2019 until Jul 2019]

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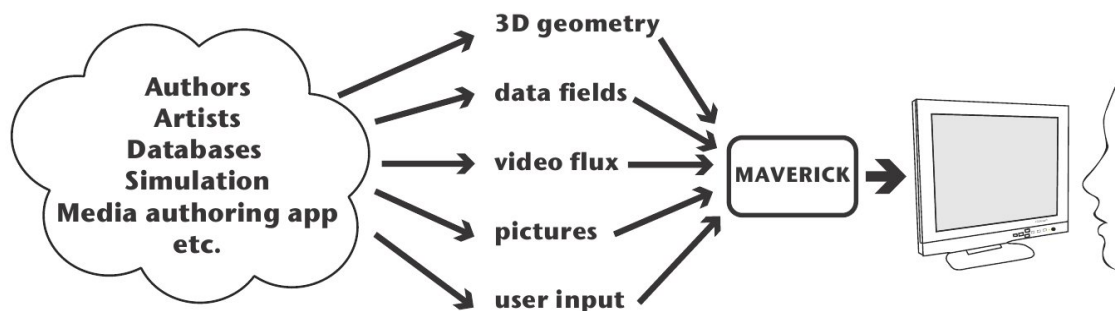
Figure 1. Position of the Maverick research team inside the graphics pipeline.

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 experience of collaboration with industrial partners. These collaborations bring us new problems to solve, with short-term or medium-term transfer 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. Application Domains

4.1. Application Domains

The natural application domain for our research is the production of digital images, for example for movies and special effects, virtual prototyping, video games... Our research have also been applied to tools for generating and editing images and textures, for example generating textures for maps. Our current application domains are:

- Offline and real-time rendering in movie special effects and video games;
- Virtual prototyping;
- Scientific visualization;
- Content modeling and generation (e.g. generating texture for video games, capturing reflectance properties, etc);
- Image creation and manipulation.

5. New Software and Platforms

5.1. 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 and Romain Vergne
- Partner: UJF
- Contact: Romain Vergne
- URL: http://gratin.gforge.inria.fr/

5.2. 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 developpement 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

5.3. libylm

LibYLM

KEYWORD: Spherical harmonics

FUNCTIONAL DESCRIPTION: This library implements spherical and zonal harmonics. It provides the means to perform decompositions, manipulate spherical harmonic distributions and provides its own viewer to visualize spherical harmonic distributions.

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

5.4. ShwarpIt

KEYWORD: Warping

FUNCTIONAL DESCRIPTION: ShwarpIt is a simple mobile app that allows you to manipulate the perception of shapes in images. Slide the ShwarpIt slider to the right to make shapes appear rounder. Slide it to the left to make shapes appear more flat. The Scale slider gives you control on the scale of the warping deformation.

- Contact: Georges-Pierre Bonneau
- URL: http://bonneau.meylan.free.fr/ShwarpIt/ShwarpIt.html

5.5. Vrender

KEYWORDS: 3D - Vector graphics

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://maverick.inria.fr/Software/VRender/

5.6. X3D TOOLKIT

X3D Development pateform

KEYWORDS: X3D - Geometric modeling

FUNCTIONAL DESCRIPTION: X3DToolkit is a library to parse and write X3D files, that supports plugins and extensions.

- Participants: Gilles Debunne and Yannick Le Goc
- Contact: Cyril Soler
- URL: http://maverick.inria.fr/Software/X3D/

5.7. 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: Cyril Soler, François Sillion and George Drettakis
- Contact: Cyril Soler

6. New Results

6.1. Texture synthesis

6.1.1. *Procedural Phasor Noise*

Participants: Thibault Tricard, Semyon Efremov, Cédric Zanni, Fabrice Neyret, Jonàs Martínez, Sylvain Lefebvre.

Procedural pattern synthesis is a fundamental tool of Computer Graphics, ubiquitous in games and special effects. By calling a single procedure in every pixel – or voxel – large quantities of details are generated at low cost, enhancing textures, producing complex structures within and along surfaces. Such procedures are typically implemented as pixel shaders. We propose a novel procedural pattern synthesis technique that exhibits desirable properties for modeling highly contrasted patterns, that are especially well suited to produce surface and microstructure details. In particular, our synthesizer affords for a precise control over the profile, orientation and distribution of the produced stochastic patterns, while allowing to grade all these parameters spatially. Our technique defines a stochastic smooth phase field – a phasor noise – that is then fed into a periodic function (e.g. a sine wave), producing an oscillating field with prescribed main frequencies and preserved contrast oscillations. In addition, the profile of each oscillation is directly controllable as shown Figure 2. Our technique builds upon a reformulation of Gabor noise in terms of a phasor field that affords for a clear separation between local intensity and phase. Applications range from texturing to modeling surface displacements, as well as multi-material microstructures in the context of additive manufacturing.

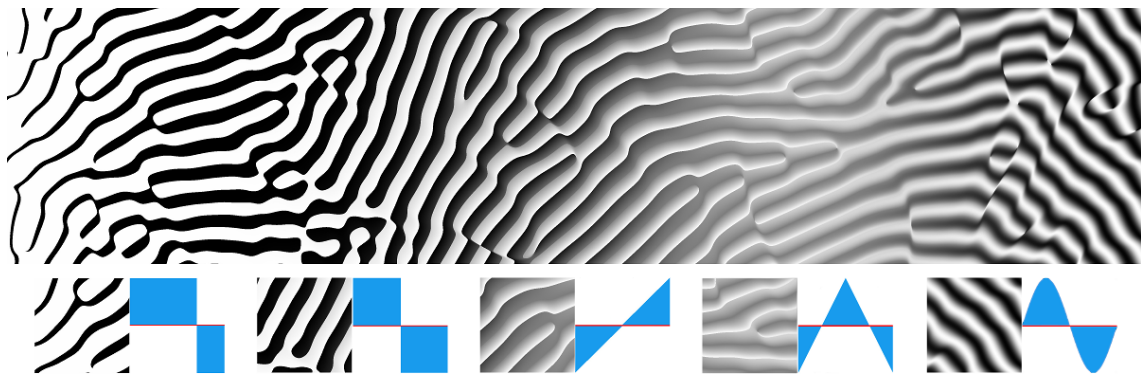This paper was published in ACM TOG [6] and presented at Siggraph 2019.

Figure 2. High-contrast patterns produced by our approach. Note how the profile of the oscillations smoothly transition from a rectangular wave (20% black), to a square wave, to a triangular profile and finally a sine wave. At the same time, the orientation of the waves changes from left to right. The field visualized here is purely procedural. It is obtained by feeding our phasor noise into periodic profile functions (shown in blue), that are interpolated from left to right.

6.1.2. *Making Gabor Noise Fast and Normalized*

Participants: Vincent Tavernier, Fabrice Neyret, Romain Vergne, Joëlle Thollot.

Gabor Noise is a powerful procedural texture synthesis technique, but it has two major drawbacks: It is costly due to the high required splat density and not always predictable because properties of instances can differ from those of the process. We bench performance and quality using alternatives for each Gabor Noise ingredient: point distribution, kernel weighting and kernel shape. For this, we introduce 3 objective criteria to measure process convergence, process stationarity, and instance stationarity. We show that minor implementation changes allow for 17-24× speed-up with same or better quality.

This paper has been presented at Eurographics-short 2019 [11].

6.2. Illumination simulation and materials

6.2.1. *Harmonic Analysis of the Light Transport Operator*
Participants: Ronak Molazem, Cyril Soler.

In this work we study the eigenvalues and eigenfunctions of the light transport operator. While computing the spectrum of the light transport operator is a simple task in Lambertian scenes by applying a traditional eigensolver to the linear system obtained from discretized geometry, it becomes a real challenge in general environments where discretizing the geometry is not possible anymore. "Diagonalizing" light transport however can be a very effective way to perform re-lighting and rapidely compute light transport solutions.

In this work we propose an analysis of the properties of the spectrum of the light transport operator, connecting the calculation of eigenvalues to resolvent theory. We show that the eigenfunctions are generally not orthogonal nor positive, but they can still be used to efficiently represent light distributions.

We analyse the performance of different methods to compute eigenvalues and images of their eigenfunctions using path tracing. We prove in particular that it is possible to compute the eigenfunctions of the light transport operator by integrating "circular" light paths of various lengths accross the scene.

This work is part of the PhD of Ronak Molazem and is funded by the ANR project "CaLiTrOp". At the time of writing this (Dec. 2019), we're about to submit a paper to ACM Transactions on Graphics.

$$\Lambda_0 \qquad\qquad\qquad \Lambda_1 \qquad\qquad\qquad \Lambda_2 \qquad\qquad\qquad \Lambda_{144}$$
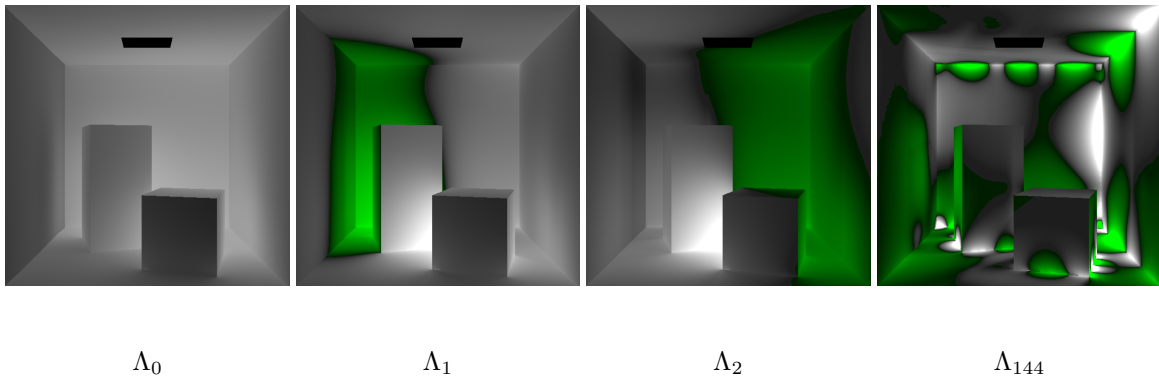
Figure 3. Path-traced images of four eigenfunctions of the light transport operator in the Cornell Box. A green scale is used to represent negative values.

6.2.2. *Low Dimension Approximations of Light Transport*
Participants: Ronak Molazem, Cyril Soler.

Light transport is known to be a low rank linear operator: the vector space formed by solutions of a light transport problem for different initial conditions is of low dimension. Approximating this space using appropriate bases is therefore of primordial help to efficiently compute solutions to light transport problems.

In this work, we're interested into generating such approximations using *ad-hoc* methods that rely on deep learning. The goal is to be able to efficiently generate a sensible basis for light transport solutions on which we can efficiently project a noisy image. Other applications of this work include relighting pictures, in which an approximate geometry is used to project the illumination in the image, that can further be manipulated while staying in the space of expected light transport solutions.

This work is an ongoing collaboration with Unity Research Grenoble, and part of the PhD of Ronak Molazem, currently in her second year of PhD, and is funded by the ANR project "CaLiTrOp".

6.2.3. *Precomputed Multiple Scattering for Rapid Light Simulation in Participating Media*
Participants: Nicolas Holzschuch, Liangsheng Ge, Beibei Wang.

Rendering translucent materials is costly: light transport algorithms need to simulate a large number of scattering events inside the material before reaching convergence. The cost is especially high for materials with a large albedo or a small mean-free-path, where higher-order scattering effects dominate. In [7], we present a new method for fast computation of global illumination with participating media. Our method uses precomputed multiple scattering effects, stored in two compact tables. These precomputed multiple scattering tables are easy to integrate with any illumination simulation algorithm. We give examples for virtual ray lights (VRL), photon mapping with beams and paths (UPBP), Metropolis Light Transport with Manifold Exploration (MEMLT). The original algorithms are in charge of low-order scattering, combined with multiple scattering computed using our table. Our results show significant improvements in convergence speed and memory costs, with negligible impact on accuracy.

6.2.4. *Fast Computation of Single Scattering in Participating Media with Refractive Boundaries using Frequency Analysis*

Participants: Nicolas Holzschuch, Yulin Liang, Lu Wang, Beibei Wang.

Many materials combine a refractive boundary and a participating media on the interior. If the material has a low opacity, single scattering effects dominate in its appearance. Refraction at the boundary concentrates the incoming light, resulting in an important phenomenon called volume caustics. This phenomenon is hard to simulate. Previous methods used point-based light transport, but attributed point samples inefficiently, resulting in long computation time. In [3], we use frequency analysis of light transport to allocate point samples efficiently. Our method works in two steps: in the first step, we compute volume samples along with their covariance matrices, encoding the illumination frequency content in a compact way. In the rendering step, we use the covariance matrices to compute the kernel size for each volume sample: small kernel for high-frequency single scattering, large kernel for lower frequencies. Our algorithm computes volume caustics with fewer volume samples, with no loss of quality. Our method is both faster and uses less memory than the original method. It is roughly twice as fast and uses one fifth of the memory. The extra cost of computing covariance matrices for frequency information is negligible.

6.2.5. *Reparameterizing discontinuous integrands for differentiable rendering*

Participants: Nicolas Holzschuch, Wenzel Jakob, Guillaume Loubet.

Differentiable rendering has recently opened the door to a number of challenging inverse problems involving photorealistic images, such as computational material design and scattering-aware reconstruction of geometry and materials from photographs. Differentiable rendering algorithms strive to estimate partial derivatives of pixels in a rendered image with respect to scene parameters, which is difficult because visibility changes are inherently non-differentiable.

We propose [5] a new technique for differentiating path-traced images with respect to scene parameters that affect visibility, including the position of cameras, light sources, and vertices in triangle meshes. Our algorithm computes the gradients of illumination integrals by applying changes of variables that remove or strongly reduce the dependence of the position of discontinuities on differentiable scene parameters. The underlying parameterization is created on the fly for each integral and enables accurate gradient estimates using standard Monte Carlo sampling in conjunction with automatic differentiation. Importantly, our approach does not rely on sampling silhouette edges, which has been a bottleneck in previous work and tends to produce high-variance gradients when important edges are found with insufficient probability in scenes with complex visibility and high-resolution geometry. We show that our method only requires a few samples to produce gradients with low bias and variance for challenging cases such as glossy reflections and shadows. Finally, we use our differentiable path tracer to reconstruct the 3D geometry and materials of several real-world objects from a set of reference photographs.

6.3. Expressive rendering

6.3.1. *Procedural Stylization*

Participants: Maxime Isnel, Mohamed Amine Farhat, Romain Vergne, Joëlle Thollot.

Stylizing 3D scenes is a long term goal for the expressive rendering community. During the master internship of Maxime Isnel we have worked on a procedurel approach based on a procedural solid noise used in image space to generate brush strokes or 2.5D visual primitives, such as fur. The overview of the approach is shown Figure 4. This project is still in progress and will continue with a post-doc in 2020.
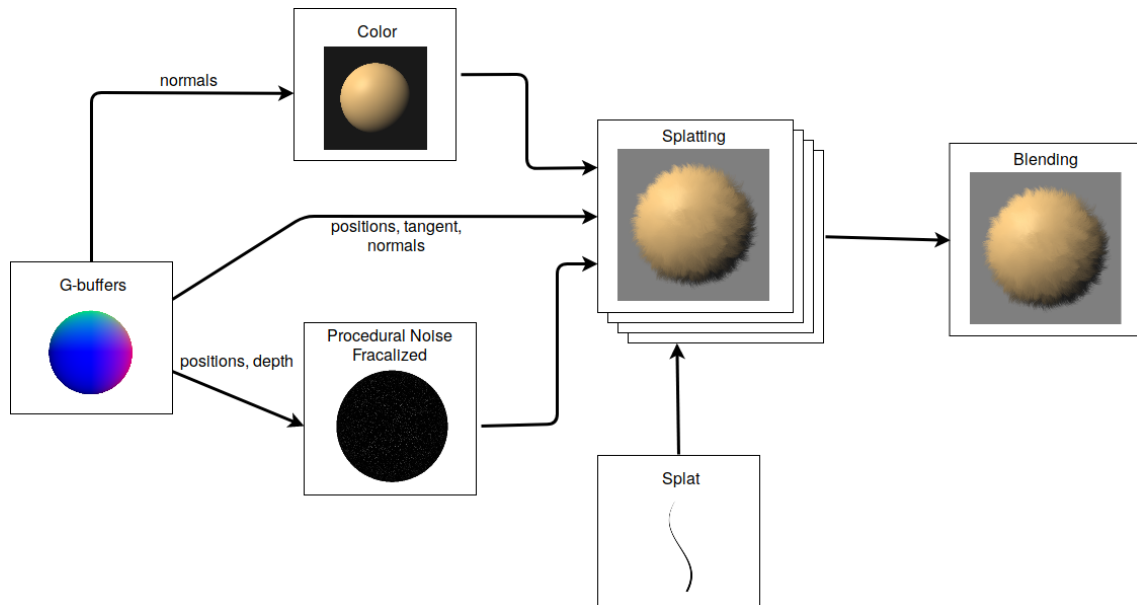

Figure 4. Based on a procedural solid noise and the use of geometry buffers, we propose an image-space approach to stylize a 3D object on the GPU.

7. Partnerships and Cooperations

7.1. Regional Initiatives

We have frequent exchanges and on-going collaborations with Cyril Crassin from nVIDIA-Research, and Eric Heitz, Laurent Belcour, Jonathan Dupuy and Kenneth Vanhoey from Unity-Research.

7.2. National Initiatives

7.2.1. 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. This project is in cooperation with Océ Print Logic technologies, the Museum of Ethnography at the University of Bordeaux and the Manao team at Inria Bordeaux. The grant started in October 2015, for 48 months.

7.2.2. CDP: Patrimalp 2.0

Participants: Nicolas Holzschuch [contact], Romain Vergne.

The main objective and challenge of Patrimalp 2.0 is to develop a cross-disciplinary approach in order to get a better knowledge of the material cultural heritage in order to ensure its sustainability, valorization and diffusion in society. Carried out by members of UGA laboratories, combining skills in human sciences, geosciences, digital engineering, material sciences, in close connection with stakeholders of heritage and cultural life, curators and restorers, Patrimalp 2.0 intends to develop of a new interdisciplinary science: Cultural Heritage Science. The grant starts in January 2018, for a period of 48 months.

7.2.3. *ANR: CaLiTrOp*

Participant: Cyril Soler [contact].

Computing photorealistic images relies on the simulation of light transfer in a 3D scene, typically modeled using geometric primitives and a collection of reflectance properties that represent the way objects interact with light. Estimating the color of a pixel traditionally consists in integrating contributions from light paths connecting the light sources to the camera sensor at that pixel.

In this ANR we explore a transversal view of examining light transport operators from the point of view of infinite dimensional function spaces of light fields (imagine, e.g., reflectance as an operator that transforms a distribution of incident light into a distribution of reflected light). Not only are these operators all linear in these spaces but they are also very sparse. As a side effect, the sub-spaces of light distributions that are actually relevant during the computation of a solution always boil down to a low dimensional manifold embedded in the full space of light distributions.

Studying the structure of high dimensional objects from a low dimensional set of observables is a problem that becomes ubiquitous nowadays: Compressive sensing, Gaussian processes, harmonic analysis and differential analysis, are typical examples of mathematical tools which will be of great relevance to study the light transport operators.

Expected results of the fundamental-research project CALiTrOp, are a theoretical understanding of the dimensionality and structure of light transport operators, bringing new efficient lighting simulation methods, and efficient approximations of light transport with applications to real time global illumination for video games.

7.3. European Initiatives

Together with Stefanie Hahmann and Melina Skouras from project-team IMAGINE, Georges-Pierre Bonneau is part of the H2020 FET-Open Challenging Current Thinking project $ADAM^2$, grant ID 862025, accepted in June 2019 and starting officially January 1st 2020. The Imagine and Maverick teams at Inria are in charge of modelling of micro-structured geometries and design of meta-metarials. More information is available at www.adam2.eu.

7.4. International Initiatives

7.4.1. *ASICIAO: Erasmus+ capacity building project*

Joëlle Thollot is an active member of the ASICIAO Erasmus+ project. In this project four European higher education institutions support six schools from Senegal and Togo in their pursuit of autonomy by helping them to develop their own method of improving quality in order to obtain the CTI accreditation and the EUR-ACE label and, by doing so, to reach international standards.

7.5. International Research Visitors

7.5.1. *Visits of International Scientists*

7.5.1.1. *Internships*

Anmol Hanagodimath spent 6 months of internship in our team as part of his master thesis of Delft university. He was supervised by Romain Vergne and Joëlle Thollot in Grenoble and Elman Eisemann in Delft.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific Events: Selection

8.1.1.1. Member of the Conference Program Committees

- Romain Vergne: AFIG 2019
- Romain Vergne: SIBGRAPI 2019
- Joëlle Thollot: *Expressive* 2019.
- Nicolas Holzschuch: Eurographics 2020, Sibgrapi 2019, Eurographics Symposium on Rendering Steering Committee

8.1.2. Journal

All members of the Maverick team work as reviewers for the most prestigious journals, including ACM TOG, IEEE TVCG, CGF, etc.

8.1.3. Invited Talks

- Fabrice Neyret presented a 1 hour invited talk "Managing Ultra-high Complexity in Real-time Graphics: Some Hints and Ingredients" at HPG'2019 (ACM-SIGGRAPH-Eurographics Symposium on High-Performance Graphics) [9].
- Fabrice Neyret presented a 1 hour opening invited talk "Graphics vs Physics: the light and dark sides of the Force" [8] in pair with Emmanuel Delangre (Ladhyx - Ecole Polytechnique) at GraPhyz'2019, a new international workshop bridging Physics and Computer Graphics communities.
- Romain Vergne presented a 1 hour invited talk "ensuring congruency between shape and light" at IRIT: Institut de Recherche en Informatique de Toulouse.

8.1.4. Research Administration

- Georges-Pierre Bonneau is member of the "conseil du Laboratoire Jean Kuntzmann".
- Romain Vergne is member of the "conseil du Laboratoire Jean Kuntzmann".
- Romain Vergne is co-responsible of the Rendering Working Group of the French Association ofr Computer Graphics (AFIG).
- Romain Vergne is co-responsible of the PhD students of the Laboratoire Jean Kuntzmann.
- Nicolas Holzschuch is an elected member of CNESER (National Council for Higher Education and Research), 2019 — 2023.
- Nicolas Holzschuch is an elected member of Inria Evaluation Committee (CE), an elected member of Inria Comité Technique (CTI) and a reserve member of Inria Scientific Council (CS).
- Nicolas Holzschuch is responsible for the department "Geometry and Images" of the Laboratoire Jean Kuntzmann.
- Nicolas Holzschuch is co-head of the Inria International Laboratory "Inria - EPFL".
- Nicolas Holzschuch is an elected member of Conseil Académique of the COMUE Université Grenoble-Alpes

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

Joëlle Thollot and Georges-Pierre Bonneau are both full Professor of Computer Science. Romain Vergne is an associate professor in Computer Science. They teach general computer science topics at basic and intermediate levels, and advanced courses in computer graphics and visualization at the master levels. Joëlle Thollot is in charge of the MMIS ENSIMAG cursus (master level) with Stefanie Hahmann. Nicolas Holzschuch teaches advanced courses in computer graphics at the master level.

Licence: Joëlle Thollot, Théorie des langages, 45h, L3, ENSIMAG, France

Licence: Joëlle Thollot, Séminaire d'innovation, 10h, L3, ENSE3, France

Licence: Joëlle Thollot, MAP, 10h, L3, ENSIMAG, France

Master : Joelle Thollot, TD de créativité, 7h, M1, ENSIMAG, France.

Master : Joelle Thollot, English courses using theater, 18h, M1, ENSIMAG, France.

Licence : Romain Vergne, Introduction to algorithms, 64h, L1, UGA, France.

Licence : Romain Vergne, WebGL, 29h, L3, IUT2 Grenoble, France.

Licence : Romain Vergne, Programmation, 68h. L1, UGA, France.

Master : Romain Vergne, Image synthesis, 27h, M1, UGA, France.

Master : Romain Vergne, 3D graphics, 15h, M1, UGA, France.

Master : Nicolas Holzschuch, Computer Graphics II, 18h, M2 MoSIG, France.

Master : Nicolas Holzschuch, Synthèse d'Images et Animation, 32h, M2, ENSIMAG, France.

Licence: Georges-Pierre Bonneau, Algorithmique et Programmation Impérative, 23h, L3, Polytech-Grenoble, France.

Master: Georges-Pierre Bonneau, responsable de la 4ième année du département INFO, 32h, M1, Polytech-Grenoble, France

Master: Georges-Pierre Bonneau, Image Synthesis, 23h, M1, Polytech-Grenoble, France

Master: Georges-Pierre Bonneau, Data Visualization, 40h, M2, Polytech-Grenoble, France

Master: Georges-Pierre Bonneau, Digital Geometry, 23h, M1, UGA

Master: Georges-Pierre Bonneau, Information Visualization, 22h, Mastere, ENSIMAG, France.

Master: Georges-Pierre Bonneau, Scientific Visualization, M2, ENSIMAG, France.

Master: Georges-Pierre Bonneau, Computer Graphics II, 18h, M2 MoSiG, UGA, France.

8.2.2. Supervision

PhD: Alban Fichet, Efficient representation for measured reflectance, UGA, 13/12/2019, Nicolas Holzschuch.

PhD in progress: Vincent Tavernier, Procedural stochastic textures, 1/10/2017, Fabrice Neyret, Joëlle Thollot, Romain Vergne.

PhD in progress: Sunrise Wang, Light transport operators simplification using neural networks, 1/9/2018, Nicolas Holzschuch

PhD in progress: Morgane Gérardin, Connecting physical and chemical properties with material appearance, 1/10/2018, Nicolas Holzschuch

PhD in progress: Ronak Molazem, Dimensional Analysis of Light Transport, 1/09/2018, Cyril Soler

PhD in progress: Nolan Mestre, Rendering of panorama maps, 1/10/2019, Joëlle Thollot, Romain Vergne.

8.2.3. Juries

Romain Vergne, member of the jury, PhD of Julien Fayer, University of Toulouse, 19/04/2019.

Joëlle Thollot, president of the jury, PhD of Geoffrey Guingo, Université Grenoble-Alpes, 3/12/2019

Joëlle Thollot, president of the jury, PhD of Maxime Garcia, Université Grenoble-Alpes, 19/12/2019

Georges-Pierre Bonneau, reviewer, PhD of Yohann Bearzi, Université Claude Bernard Lyon 1, 8/11/2019

Georges-Pierre Bonneau, reviewer, PhD of Maxime Soler, Sorbonne Universités, 20/06/19

8.3. Popularization

8.3.1. Articles and contents

- Fabrice Neyret maintains the blog shadertoy-Unofficial and various shaders examples on Shadertoy site to popularize GPU technologies as well as disseminates academic models within computer graphics, computer science, applied math and physics fields. About 26k pages viewed and 12k unique visitors (87% out of France) in 2019.

- in 2019, Fabrice Neyret launched the blog desmosGraph-Unofficial to popularize the use of interactive grapher DesmosGraph for research, communication and pedagogy. For this year, about 1k pages viewed and 800 unique visitors (95% out of France).

8.3.2. Interventions

In the scope of MathC2+ (partnership with French ministry of Education and "Fondation Sciences mathématiques de Paris") Inria Rhône-Alpes hosted in June, 2019 a selection of about 30 motivated high-school students (level "second") for a day of presentations, demos and discussions. Fabrice Neyret did a 1h presentation on "Math and Physics in special effects and video games" plus discussions about his curriculum and questions.

9. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] H. DENG, B. WANG, R. WANG, N. HOLZSCHUCH. *A Practical Path Guiding Method for Participating Media*, in "Computational Visual Media", February 2020, https://hal.inria.fr/hal-02486014

[2] L. GE, B. WANG, L. WANG, X. MENG, N. HOLZSCHUCH. *Interactive Simulation of Scattering Effects in Participating Media Using a Neural Network Model*, in "IEEE Transactions on Visualization and Computer Graphics", January 2020 [*DOI :* 10.1109/TVCG.2019.2963015], https://hal.archives-ouvertes.fr/hal-02486039

[3] Y. LIANG, B. WANG, L. WANG, N. HOLZSCHUCH. *Fast Computation of Single Scattering in Participating Media with Refractive Boundaries using Frequency Analysis*, in "IEEE Transactions on Visualization and Computer Graphics", April 2019, pp. 1-9, forthcoming [*DOI :* 10.1109/TVCG.2019.2909875], https://hal.inria.fr/hal-02089988

[4] W. LIN, B. WANG, L. WANG, N. HOLZSCHUCH. *A Detail Preserving Neural Network Model for Monte Carlo Denoising*, in "Computational Visual Media", February 2020, https://hal.inria.fr/hal-02488602

[5] G. LOUBET, N. HOLZSCHUCH, W. JAKOB. *Reparameterizing Discontinuous Integrands for Differentiable Rendering*, in "ACM Transactions on Graphics", November 2019, vol. 38, n° 6, pp. 228:1 - 228:14 [*DOI :* 10.1145/3355089.3356510], https://hal.inria.fr/hal-02497191

[6] T. TRICARD, S. EFREMOV, C. ZANNI, F. NEYRET, J. MARTÍNEZ, S. LEFEBVRE. *Procedural Phasor Noise*, in "ACM Transactions on Graphics", July 2019, vol. 38, n° 4, Article No. 57:1-13 [*DOI :* 10.1145/3306346.3322990], https://hal.archives-ouvertes.fr/hal-02118508

[7] B. WANG, L. GE, N. HOLZSCHUCH. *Precomputed Multiple Scattering for Rapid Light Simulation in Participating Media*, in "IEEE Transactions on Visualization and Computer Graphics", 2019, pp. 1-14, forthcoming [*DOI :* 10.1109/TVCG.2018.2890466], https://hal.inria.fr/hal-01970399

Invited Conferences

[8] F. NEYRET, E. DELANGRE. *(keynote) Graphics vs Physics : the light and dark sides of the Force*, in "GraPhyz 2019 - Workshop physique/mécanique/informatique graphique", Grenoble, France, October 2019, https://hal.inria.fr/hal-02333788

[9] F. NEYRET. *(keynote) Managing Ultra-high Complexity in Real-time Graphics: Some Hints and Ingredients*, in "HPG 2019 - High-Performance Graphics", Strasbourg, France, July 2019, https://hal.inria.fr/hal-02333768

International Conferences with Proceedings

[10] M. GERARDIN, N. HOLZSCHUCH, P. MARTINETTO. *Rendering transparent materials with a complex refractive index: semi-conductor and conductor thin layers*, in "MAM 2019 - 7th annual Workshop on Material Appearance Modeling", Strasbourg, France, July 2019, pp. 1-4, https://hal.inria.fr/hal-02191534

[11] V. TAVERNIER, F. NEYRET, R. VERGNE, J. THOLLOT. *Making Gabor Noise Fast and Normalized*, in "Eurographics 2019 - 40th Annual Conference of the European Association for Computer Graphics", Gênes, Italy, T. E. ASSOCIATION (editor), Eurographics 2019 - Short Papers, 2019, pp. 37-40 [*DOI :* 10.2312/EGS.20191009], https://hal.inria.fr/hal-02104389

[12] A. VODA, O. MARTIN, P. R. NAVES NETO, J.-D. GASCUEL, S. SCHMERBER. *Visual-vestibular compensation in balance recovery: A transfer function model-based analysis*, in "FOSBE 2019 - 8th IFAC Conference on Foundations of Systems Biology in Engineering", Valencia, Spain, October 2019, pp. 1-6, https://hal.archives-ouvertes.fr/hal-02371059

Other Publications

[13] L. CIAVALDINI RIVIERE, E. CHALMIN, M. DUVAL, P. MARTINETTO, P. BORDET, K. FROMENT, C. DEJOIE, N. BLANC, N. HOLZSCHUCH, D. ZIÉBELIN, P.-A. DAVOINE. *Patrimalp, Science of Heritage : perspectives on cultural artworks*, February 2019, World meeting « Heritage Sciences and Technologies, 13-16 Février 2019, Paris, Poster, https://hal.archives-ouvertes.fr/hal-02416129