IN PARTNERSHIP WITH:
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Institut polytechnique de Grenoble

Université de Grenoble Alpes

Activity Report 2017

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:

A5.2. - Data visualization
A5.5. - Computer graphics
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
B9.5.6. - Archeology, History

1. Personnel

Research Scientists

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Romain Vergne [Univ Grenoble Alpes, Associate Professor]

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Interns

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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.

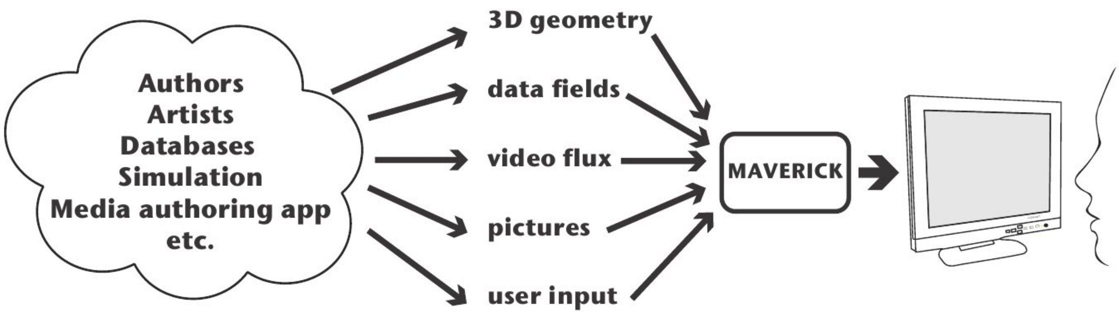

Figure 1. Position of the Maverick research team inside the graphics pipeline.

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. 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. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Presentations at Siggraph

The paper “Programmable 2D Arrangements for Element Texture Design” co-authored by Joëlle Thollot and Romain Vergne was presented at SIGGRAPH 2017 [3] (see Section 7.5.1).

The paper “A Two-Scale Microfacet Reflectance Model Combining Reflection and Diffraction” co-authored by Nicolas Holzschuch was presented at SIGGRAPH 2017 [2] (see Section 7.3.2).

The work on “Direct 3D stylization pipelines” co-authored by Joëlle Thollot and Romain Vergne was presented at SIGGRAPH 2017 real-time live! [13] (see Section 7.1.2)

5.1.2. Awards

The paper "Shape from sensors: Curve networks on surfaces from 3D orientations" [6], co-authored by Tibor Stanko, Stefanie Hahmann, Georges-Pierre Bonneau and Nathalie Saguin-Sprinsky, published in the journal Computer and Graphics, has received the "Best Paper Award" during the conference Shape Modeling International in June 2017.

6. New Software and Platforms

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

6.2. 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.

- Participants: Emmanuel Turquin, François Sillion, Frédo Durand and Stéphane Grabli
- Contact: François Sillion

6.3. 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. Ongoing researches are addressing animation. GigaVoxels is currently used for the quality real-time exploration of the detailed galaxy in ANR RTIGE. Most of the work published by Cyril Crassin (and al.) during his PhD (see http://maverick.inria.fr/Members/Cyril.Crassin/) is related to GigaVoxels. GigaVoxels is available for Windows and Linux under the BSD-3 licence.

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

6.4. 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/

6.5. 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 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

6.6. 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

6.7. MobiNet

KEYWORDS: Co-simulation - Education - Programmation
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). It is available in public domain for Linux,Windows and MacOS.

- Participants: Fabrice Neyret, Franck Hétroy-Wheeler, Joëlle Thollot, Samuel Hornus and Sylvain Lefebvre
- Partners: CNRS - LJK - INP Grenoble - Inria - IREM - Cies - GRAVIR
- Contact: Fabrice Neyret
- URL: http://mobinet.imag.fr/index.en.html

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

6.9. PROLAND

PROcedural LANDscape
KEYWORDS: Atmosphere - Masses of data - Realistic rendering - 3D - Real time - 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. Most of the work published by Eric Bruneton and Fabrice Neyret (see http://evasion.inrialpes.fr/Membres/Eric.Bruneton/) has been done within Proland and integrated in the main branch. Proland is available under the BSD-3 licence.

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

6.10. 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

6.11. 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/

6.12. X3D TOOLKIT

X3D Development pateform

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://artis.imag.fr/Software/X3D/

7. New Results

7.1. Expressive rendering

7.1.1. Edge- and substrate-based effects for watercolor stylization

Participants: Santiago Montesdeoca, Hock Soon Seah, Pierre Bénard, Romain Vergne, Joëlle Thollot, Hans-Martin Rall, Davide Benvenuti.

We investigate characteristic edge-and substrate-based effects for watercolor stylization. These two fundamental elements of painted art play a significant role in traditional watercolors and highly influence the pigment's behavior and application. Yet a detailed consideration of these specific elements for the stylization of 3D scenes has not been attempted before. Through this investigation, we contribute to the field by presenting ways to emulate two novel effects: dry-brush and gaps & overlaps. By doing so, we also found ways to improve upon well-studied watercolor effects such as edge-darkening and substrate granulation. Finally, we integrated controllable external lighting influences over the watercolorized result, together with other previously researched watercolor effects. These effects are combined through a direct stylization pipeline to produce sophisticated watercolor imagery (see Figure 2), which retains spatial coherence in object-space and is locally controllable in real-time. This work has been published in Expressive'2017 [9].

7.1.2. Direct 3D stylization pipelines

Participants: Santiago Montesdeoca, Hock Soon Seah, Pierre Bénard, Romain Vergne, Joëlle Thollot, Hans-Martin Rall, Davide Benvenuti.

Figure 2. Our methods allow new and improved edge- and substrate-based effects for watercolor stylization: edge darkening (red), overlaps (green) and dry-brush (yellow). Still life, model by Dylan Sisson ©Pixar Animation Studios.

Using 3D computer graphics to emulate watercolor presents a special challenge. Complex stylizations are commonly processed offline, by combining multiple passes in compositing, where art directing is slow and non-intuitive because the stylized result is not immediate. This direct 3D stylization pipeline allows art direction to happen in real time (Figure 3). Using the framework, artists can assign their desired local and global effects directly in the 3D scene, see the stylized results immediately, and intuitively adapt them to fit their stylized vision. The technique can be used and applied in 3D animations, games, VR, visualizations, illustrations, and interactive art. This work was presented at the SIGGRAPH real-time live session [13].

Figure 3. This rendering is stylized and animated in real-time using our tool.

7.2. Computer-aided image manipulation

7.2.1. Local texture-based color transfer and colorization

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

This work targets two related color manipulation problems: Color transfer for modifying an image's colors and colorization for adding colors to a grayscale 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 (see Figure 4). This work is an extended version of an Expressive' 2016 paper and was published in the C&G journal [1].

Color transfer Colorization

Figure 4. Our framework allows for automatic local color transfer (left) and colorization (right).

7.2.2. Texture Transfer Based on Texture Descriptor Variations

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

(a) (b) (c)

Figure 5. The bark texture of the input tree (a) is replaced by the bark texture of the reference (b) in the final result (c). Alpha masks (bottom right) are used to define the input and reference textures in the images.

We tackle the problem of image-space texture transfer which aims to modify an object or surface material by replacing its input texture by another reference texture. The main challenge of texture transfer is to successfully reproduce the reference texture patterns while preserving the input texture variations due to its environment such as illumination or shape variations. We propose to use a texture descriptor composed of local luminance and local gradients orientation and magnitude to characterize the input texture variations. We then introduce a guided texture synthesis algorithm to synthesize a texture resembling the reference texture with the input texture variations. The main contribution of our algorithm is its ability to locally deform the reference texture according to local texture descriptors in order to better reproduce the input texture variations. We show that our approach is able to produce results comparable with current state-of-the-art approaches but with fewer user inputs. Preliminary results of this work are shown in a research report [14].

7.3. Illumination Simulation and Materials

7.3.1. Point-Based Rendering for Homogeneous Participating Media with Refractive Boundaries

Participants: Beibei Wang, Nicolas Holzschuch.

Illumination effects in translucent materials are a combination of several physical phenomena: refraction at the surface, absorption and scattering inside the material. Because refraction can focus light deep inside the material, where it will be scattered, practical illumination simulation inside translucent materials is difficult. We present an a Point-Based Global Illumination method for light transport on homogeneous translucent materials with refractive boundaries. We start by placing light samples inside the translucent material and organizing them into a spatial hierarchy. At rendering, we gather light from these samples for each camera ray. We compute separately the sample contributions for single, double and multiple scattering, and add them. We present two implementations of our algorithm: an offline version for high-quality rendering and an interactive GPU implementation. The offline version provides significant speed-ups and reduced memory footprints compared to state-of-the-art algorithms, with no visible impact on quality (Figure 6). The GPU version yields interactive frame rates: 30 fps when moving the viewpoint, 25 fps when editing the light position or the material parameters. This work has been published in IEEE Transactions on Visualization and Computer Graphics [7].

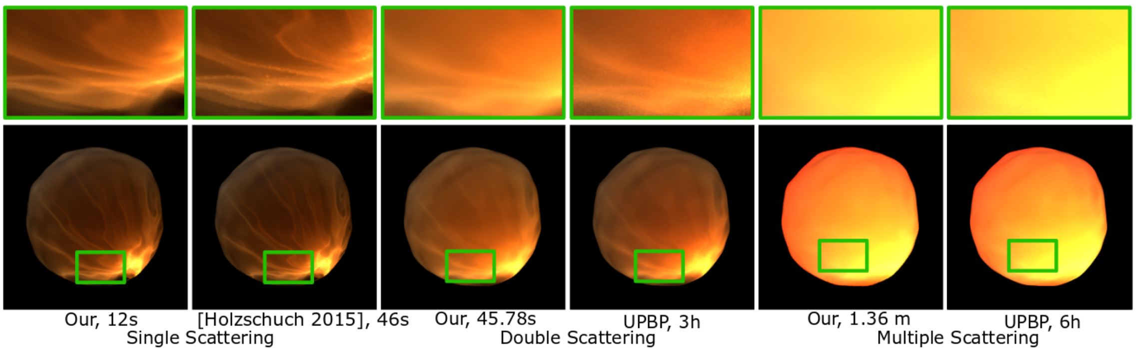

Figure 6. Individual component validation on the Bumpy Sphere scene, high-quality offline rendering.

7.3.2. A Two-Scale Microfacet Reflectance Model Combining Reflection and Diffraction

Participants: Nicolas Holzschuch, Romain Pacanowski.

Adequate reflectance models are essential for the production of photorealistic images. Microfacet reflectance models predict the appearance of a material at the macroscopic level based on microscopic surface details. They provide a good match with measured reflectance in some cases, but not always. This discrepancy between the behavior predicted by microfacet models and the observed behavior has puzzled researchers for a long time. In this work, we show that diffraction effects in the micro-geometry provide a plausible explanation. We describe a two-scale reflectance model, separating between geometry details much larger than wavelength and those of size comparable to wavelength. The former model results in the standard Cook-Torrance model. The latter model is responsible for diffraction effects. Diffraction effects at the smaller scale are convolved by the micro-geometry normal distribution. The resulting two-scale model provides a very good approximation to measured reflectances (Figure 7). This work has been published in TOG [2] and presented at SIGGRAPH 2017. It was also presented at the "tout sur les BRDF" day in Poitier (France) [17].

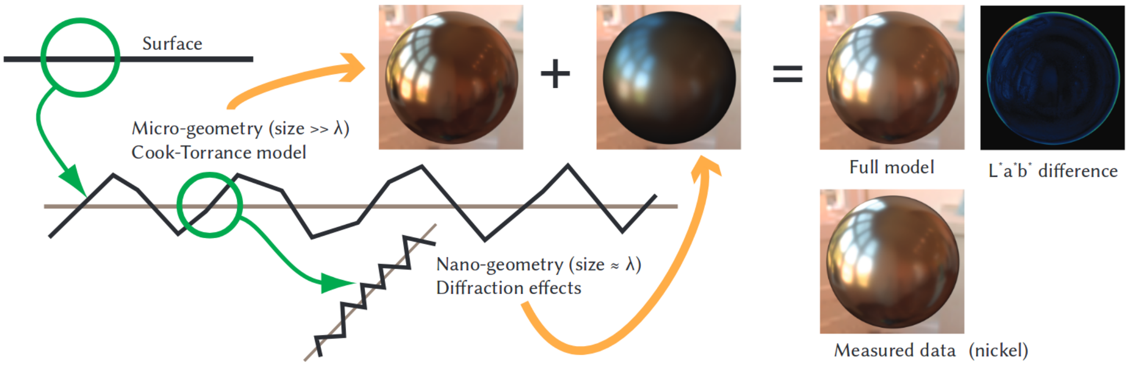

Figure 7. Material reflectance properties are caused by small variations in surface geometry. We separate these surface variations into micro-geometry, of size larger than the wavelength of visible light, and nano-geometry, of size comparable to the wavelength. The latter produces diffraction effects, with wavelength-dependent effects. The former corresponds to the classical Cook-Torrance lobe. We explain how these two levels interact and show that combined together, they reproduce measured materials faithfully, including subtle color shifts.

7.3.3. Precomputed Multiple Scattering for Light Simulation in Participating Medium

Participants: Beibei Wang, Nicolas Holzschuch.

Illumination simulation involving participating media is computationally intensive. The overall aspect of the material depends on simulating a large number of scattering events inside the material. Combined, the contributions of these scattering events are a smooth illumination. Computing them using ray-tracing or photon-mapping algorithms is expensive: convergence time is high, and pictures before convergence are low quality. In this work, we precompute the result of multiple scattering events, assuming an infinite medium, and store it in two 4D tables. These precomputed tables can be used with many rendering algorithms, such as Virtual Ray Lights (VRL), Unified Point Beams and Paths (UPBP) or Manifold Exploration Metropolis Light Transport (MEMLT), greatly reducing the convergence time (Figure 8). The original algorithm takes care of low order scattering (single and double scattering), while our precomputations are used for multiple scattering (more than two scattering events). This work was presented at SIGGRAPH [12].

7.3.4. The Effects of Digital Cameras Optics and Electronics for Material Acquisition

Participants: Nicolas Holzschuch, Romain Pacanowski.

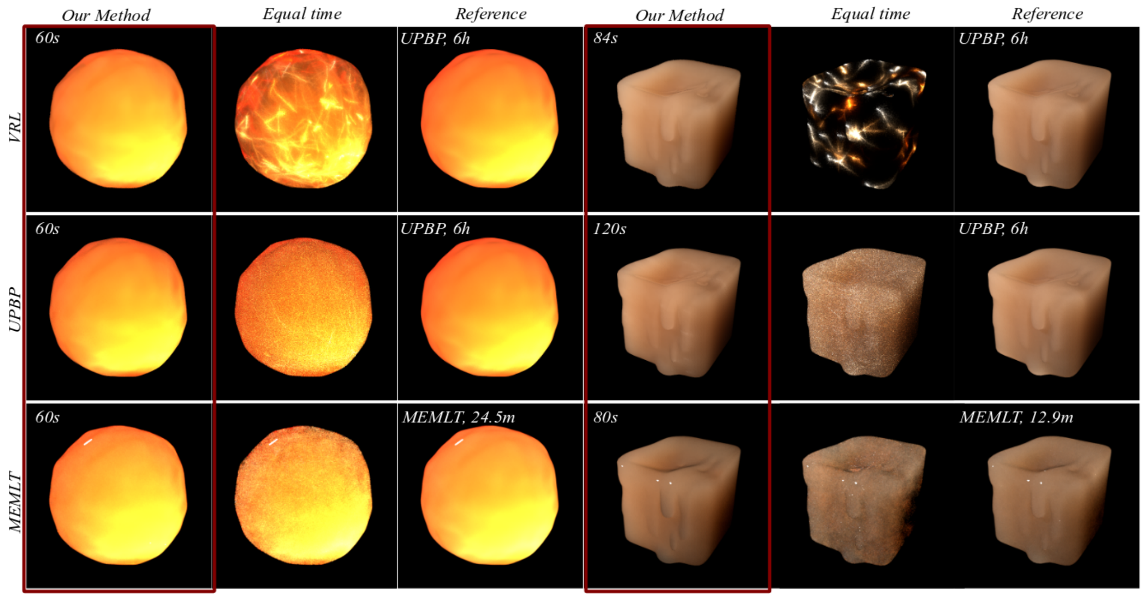

Figure 8. Our precomputed multiple scattering accelerates the convergence of existing algorithms for participating media.

For material acquisition, we use digital cameras and process the pictures. We usually treat the cameras as perfect pinhole cameras, with each pixel providing a point sample of the incoming signal. In this work, we study the impact of camera optical and electronic systems. Optical system effects are modelled by the Modulation Transfer Function (MTF). Electronic System effects are modelled by the Pixel Response Function (PRF). The former is convolved with the incoming signal, the latter is multiplied with it. We provide a model for both effects, and study their impact on the measured signal. For high frequency incoming signals, the convolution results in a significant decrease in measured intensity, especially at grazing angles. We show this model explains the strange behaviour observed in the MERL BRDF database at grazing angles. This work has been presented at the Workshop on Material Appearance Modeling [8].

7.3.5. A Versatile Parameterization of Measured Material Manifolds

Participants: Cyril Soler, Kartic Subr, Derek Nowrouzezahrai.

A popular approach for computing photorealistic images of virtual objects requires applying reflectance profiles measured from real surfaces, introducing several challenges: the memory needed to faithfully capture realistic material reflectance is large, the choice of materials is limited to the set of measurements, and image synthesis using the measured data is costly. Typically, this data is either compressed by projecting it onto a subset of its linear principal components or by applying non-linear methods. The former requires prohibitively large numbers of components to faithfully represent the input reflectance, whereas the latter necessitates costly algorithms to extrapolate reflectance data. We learn an underlying, low-dimensional non-linear reflectance manifold amenable to the rapid exploration and rendering of real-world materials. We show that interpolated materials can be expressed as linear combinations of the measured data, despite lying on an inherently non-linear manifold. This allows us to efficiently interpolate and extrapolate measured BRDFs, and to render directly from the manifold representation. To do so, we rely on a Gaussian process latent variable model of reflectance. We demonstrate the utility of our representation in the context of both high-performance and offline rendering with materials that interpolated from real-world captured BRDFs. This work has been accepted for publication at the Eurographics 2018 conference.

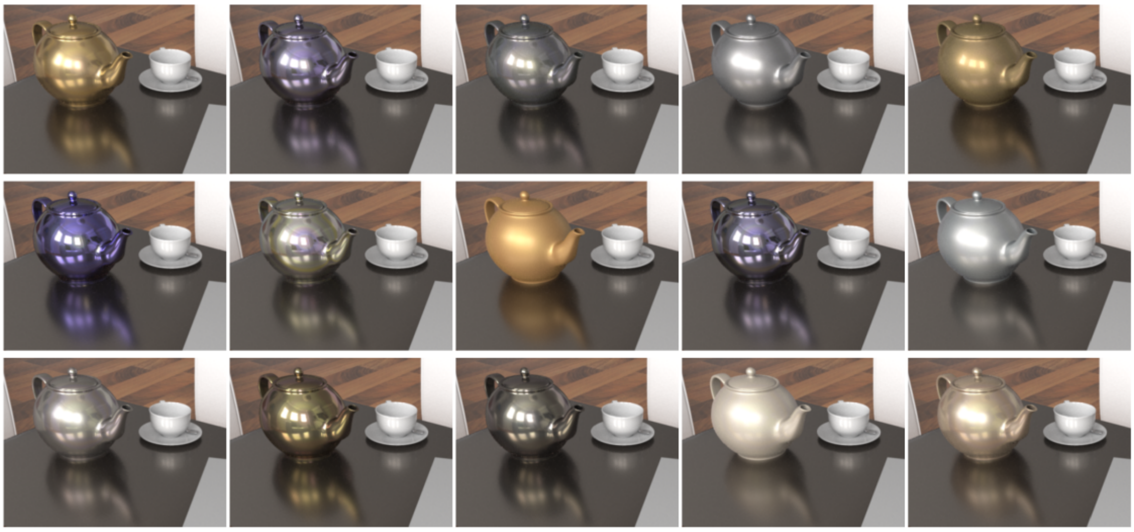

Figure 9. Four of the images above (Number 2,4,6 and 12 in reading order) are rendered with measured BRDFs from the MERL dataset [MPBM03a], the remaining 11 being rendered with BRDFs randomly picked from our parameterization of the non-linear manifold containing MERL materials. We explore this manifold interactively to produce high-quality BRDFs which retain the physical properties and perceptual aspect of real materials.

7.4. Complex Scenes

In order to render both efficiently and accurately ultra-detailed large scenes, this approach consists in developing representations and algorithms able to account compactly for the quantitative visual appearance of a regions of space projecting on screen at the size of a pixel.

7.4.1. Appearance pre-filtering

Participants: Guillaume Loubet, Neyret Fabrice.

We address the problem of constructing appearance-preserving level of details (LoDs) of complex 3D models such as trees and propose a hybrid method that combines the strength of mesh and volume representations. Our main idea is to separate macroscopic (i.e. larger than the target spatial resolution) and microscopic (sub-resolution) surfaces at each scale and to treat them differently, because meshes are very efficient at representing macroscopic surfaces while sub-resolution geometry benefit from volumetric approximations. We introduce a new algorithm based on mesh analysis that detects the macroscopic surfaces of a 3D model at a given resolution. We simplify these surfaces with edge collapses and provide a method for pre-filtering their BRDFs parameters. To approximate microscopic details, we use a heterogeneous microflake participating medium and provide a new artifact-free voxelization algorithm that preserves local occlusion. Thanks to our macroscopic surface analysis, our algorithm is fully automatic and can generate seamless LoDs at arbitrarily coarse resolutions for a wide range of 3D models. We validated our method on highly complex geometry and show that appearance is consistent across scales while memory usage and loading times are drastically reduced (see Figure 10). This work has been accepted at EG2017 [4].

7.4.2. Appearance pre-filtering of self-shadowing and anisotropic occlusion

Participants: Guillaume Loubet, Neyret Fabrice.

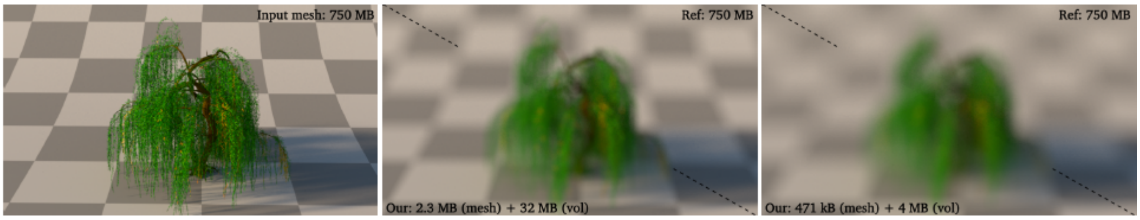

Figure 10. A weeping willow 3D model pre-filtered with our method. Our LoDs use meshes for representing macroscopic surfaces and a volumetric representation to approximate sub-resolution geometry. This approach allows for accurate preservation of the appearance of complex geometry across scales while memory usage is drastic reduced. These images have been rendered with 256spp and a thin lense camera model in Mitsuba (http://www.mitsuba-renderer.org/).

This year, we addressed the problem of representing the effect of internal self-shadowing in elements about to be filtered out at a given LOD, in the scope of volume of voxels containing density and phase-function (represented by a microflakes).

Naïve linear methods for downsampling high resolution microflake volumes often produce inaccurate results, especially when input voxels are very opaque. Preserving correct appearance at all resolutions requires taking into account inter- and intravoxel self-shadowing effects (see Figure 11). We introduce a new microflake model whose parameters characterize self-shadowing effects at the microscopic scale. We provide an anisotropic self-shadowing function and a microflake distribution for which scattering coefficients and phase functions of our model have closed-form expressions. We use this model in a new downsampling approach in which scattering parameters are computed from local estimations of self-shadowing in the input volume. Unlike previous work, our method handles datasets with spatially varying scattering parameters, semi-transparent volumes and datasets with intricate silhouettes. We show that our method generates LoDs with correct transparency and consistent appearance through scales for a wide range of challenging datasets, allowing for huge memory savings and efficient distant rendering without loss of quality. This work has been accepted at EG2018.

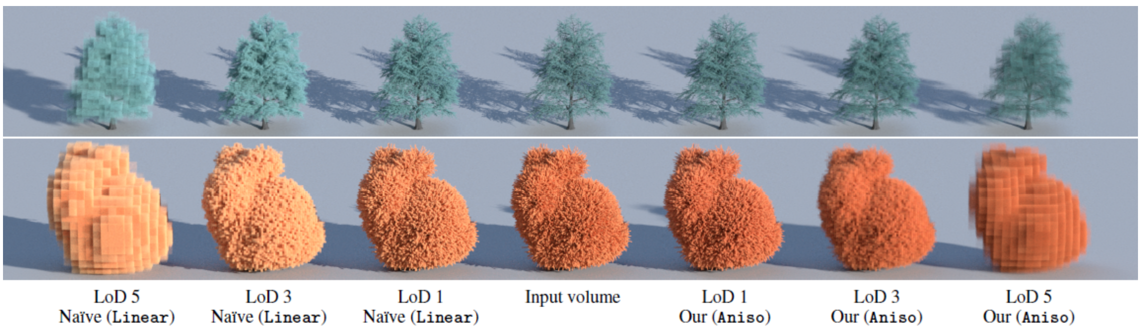

Figure 11. Comparison between naïve downsampling of microflake volumes and our method ("Aniso"). Naïve dowsampling of volumes with dense voxels often lead to inaccurate results due to the loss of inter- and intra-voxel self-shadowing effects. Our method is based on a new participating medium model and on local estimations of self-shadowing. It generates LoDs with correct transparency and consistent appearance through scales. Rendered with volume path tracing in Mitsuba (http://www.mitsuba-renderer.org/): the trunk of the cedar is a mesh.

7.5. Texture Synthesis

7.5.1. Programmable 2D Arrangements for Element Texture Design

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

Figure 12. Some textures obtained using our operators and mapped onto 3D surfaces.

This work introduces 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 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 such as 3D texturing, as shown in Figure 12. This work has been published in TOG [3] and presented at SIGGRAPH 2017.

7.6. Visualization and Geometric Design

7.6.1. Activelec: an Interaction-Based Visualization System to Analyze Household Electricity Consumption

Participants: Jérémy Wambecke, Georges-Pierre Bonneau, Romain Vergne, Renaud Blanch.

Everyone can now record and explore the evolution over time of his/her personal household electricity consumption. However understanding what links this data to our behavior remains a challenge. In this work, we present a visualization tool based on the direct manipulation, by the users, of their behavior (see Figure 13). Users can select and modify their actions over time, evaluating the results on the data with the visualization. We also conduct a user study, showing that our method allows users to understand the links between actions and data, and to use this knowledge in order to test and evaluate changesin their behavior. This work has been published in Visualization In Practice (VIP) [11].

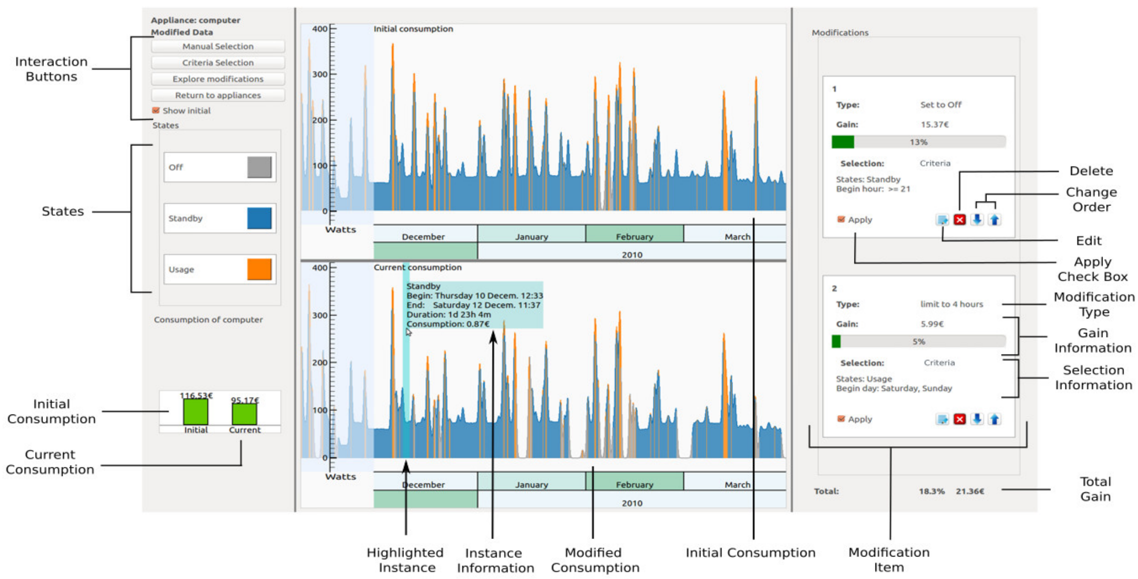

Figure 13. Interface of our visualization tool.

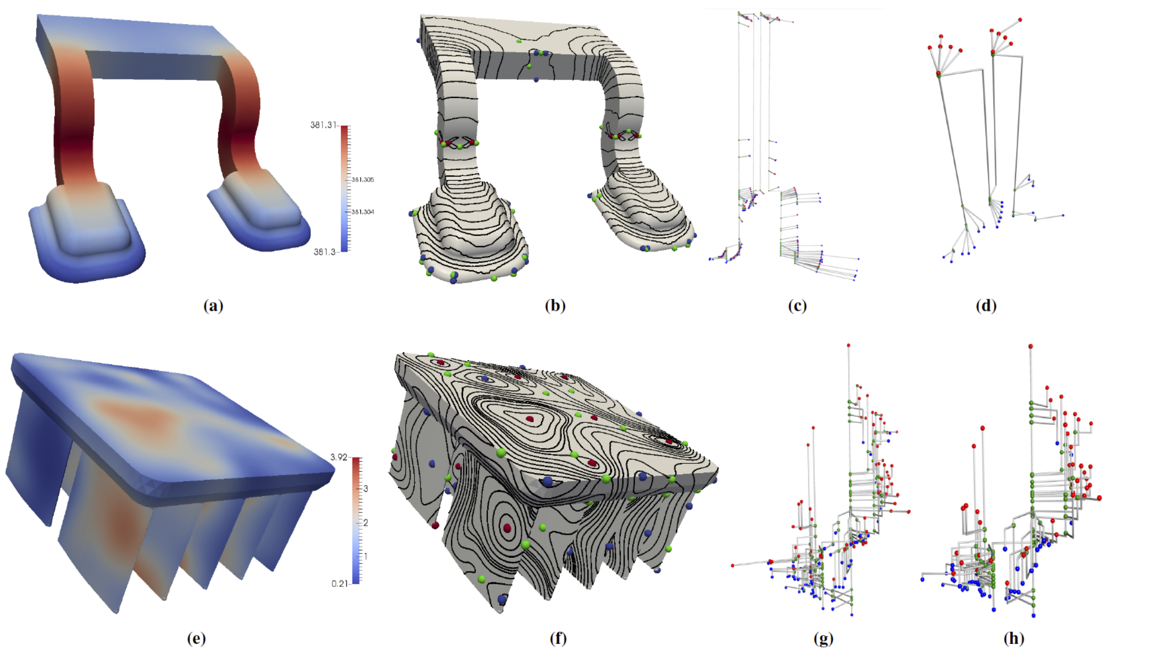

Figure 14. From left to right: quadratic (top) and cubic (bottom) scalar function visualized by a colormap, critical points of the scalar function, exact contour tree, simplified contour tree.

7.6.2. Computing Contour Trees for 2D Piecewise Polynomial Functions

Participants: Georges-Pierre Bonneau, Stefanie Hahmann, Girijanandan Nucha, Vijay Natarajan.

This work is a result from a collaboration with Vijay Natarajan from the Indian Institute of SCience (IISc), Bangalore, and team-project IMAGINE (Stefanie Hahmann). Contour trees are extensively used in scalar field analysis. The contour tree is a data structure that tracks the evolution of level set topology in a scalar field. Scalar fields are typically available as samples at vertices of a mesh and are linearly interpolated within each cell of the mesh. A more suitable way of representing scalar fields, especially when a smoother function needs to be modeled, is via higher order interpolants. We propose an algorithm to compute the contour tree for such functions. The algorithm computes a local structure by connecting critical points using a numerically stable monotone path tracing procedure. Such structures are computed for each cell and are stitched together to obtain the contour tree of the function. The algorithm is scalable to higher degree interpolants whereas previous methods were restricted to quadratic or linear interpolants. The algorithm is intrinsically parallelizable and has potential applications to isosurface extraction. Figure 14 shows examples of contour trees for quadratic and cubic scalar functions defined on 3D meshes. The results have been published in Computer Graphics Forum [5].

7.6.3. Shape from sensors: Curve networks on surfaces from 3D orientations

Participants: Tibor Stanko, Stefanie Hahmann, Georges-Pierre Bonneau, Nathalie Saguin-Sprynski.

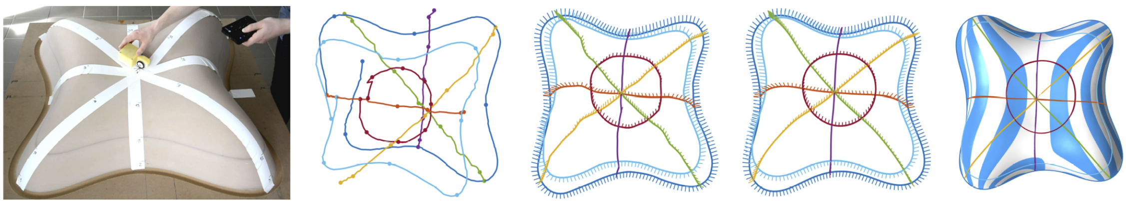

Figure 15. From left to right: curves are scanned on an object with a device measuring orientations, simple Euler integration of tangents, reconstruction of curve network with incoherent orientations, reconstruction of curve network with smooth and coherent orientations, surface reconstruction

This is a joint work with team-project IMAGINE (Tibor Stanko and Stefanie Hahmann) at Inria-Grenoble and CEA-Leti (Nathalie Saguin-Sprynski). This work introduces a novel framework for acquisition and reconstruction of 3D curves using orientations provided by inertial sensors. While the idea of sensor shape reconstruction is not new, we present the first method for creating well-connected networks with cell complex topology using only orientation and distance measurements and a set of user- defined constraints. By working directly with orientations, our method robustly resolves problems arising from data inconsistency and sensor noise. Although originally designed for reconstruction of physical shapes, the framework can be used for “sketching” new shapes directly in 3D space. We test the performance of the method using two types of acquisition devices: a standard smartphone, and a custom-made device. The results have been published in C&G [6]. This paper has been awarded "Best Paper" at the conference Shape Modeling International 2017.

7.6.4. Morphorider: Acquisition and Reconstruction of 3D Curves with Mobile Sensors

Participants: Tibor Stanko, Stefanie Hahmann, Georges-Pierre Bonneau, Nathalie Saguin-Sprynski.

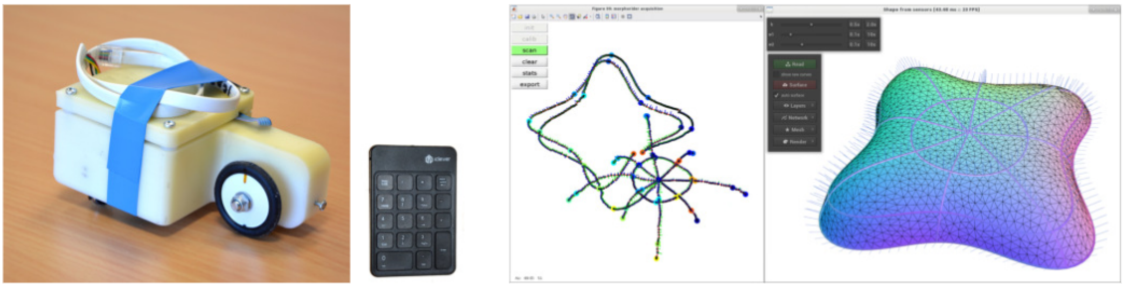

Figure 16. Left: the Morphorider and the wireless keypad used for marking nodes during acquisition. Right: screenshots of our acquisition and reconstruction applications.

This is a joint work with team-project IMAGINE (Tibor Stanko and Stefanie Hahmann) at Inria-Grenoble and CEA-Leti (Nathalie Saguin-Sprynski). In this work we introduce a new mobile device called the Morphorider, which is equipped with a 3A3M-sensor node and an odometer for distance tracking. Using this single inertial measurement unit (IMU), we propose a method to scan physical objects and to reconstruct digital 3D models. By moving the IMU along the surface, a network of local orientation data is acquired together with traveled distances and network topology. We then reconstruct a consistent network of curves and fit these curves by a globally smooth surface. This work has been published in IEEE Sensors [10].

8. Partnerships and Cooperations

8.1. Regional Initiatives

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

Maverick is part of the GPU Research Center labeled by nVIDIA at Inria Grenoble. Team contact: Fabrice Neyret.

8.2. National Initiatives

8.2.1. 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.

8.2.2. 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.

8.2.3. 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.

8.2.4. 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.

8.3. International Initiatives

8.3.1. Inria International Partners

8.3.1.1. Declared Inria International Partners

Title: "MAIS": Mathematical Analysis of Image Synthesis

International Partner (Institution - Laboratory - Researcher):

University of Montreal (Canada) - Département d'Informatique et Recherche Opérationnelle - Derek Nowrouzezahrai

Duration: 2015 - 2019

Start year: 2015

See also: http://diro.umontreal.ca/accueil/

8.3.1.2. Indo-French Center of Applied Mathematics

Topology-driven Visualization of Scientific Data

Title: Topology-driven Visualization of Scientific Data

International Partner (Institution - Laboratory - Researcher):

IISc Bangalore (India) - Deptartment of Science and Automation - Vijay Natarajan

Duration: Sept 2016 - Sept 2017

One of the greatest scientific challenges of the 21st century is how to master, organize, and extract useful knowledge from the overwhelming flow of information made available by today's data acquisition systems and computing resources. Visualization is the premium means of taking up this challenge. Topological analysis has recently emerged as a powerful class of methods for visualizing data. From the input data, these methods derive combinatorial structures capturing the essential features of the data. The goal of this project is to design new topological structures, study their properties, and develop efficient algorithms to compute them. In order to solve this challenge, we will combine our expertise in Topology for the Indian partner and in Geometric Modeling for the French partner. We plan to develop new geometric models that accurately and intuitively depict the topological combinatorial structures.

8.4. International Research Visitors

8.4.1. Visits to International Teams

8.4.1.1. Research Stays Abroad

- Alexandre Bléron has made a 3 months internship to work with Hock Soon Seah on 3D stylization in the MAGIC group of Nanyang Technological University of Singapour.
- Alban Fichet is making a 12 months stay at Charles University in Prague, to work with Alexander Wilkie and Jaroslav Krivanek on material models.
- Guillaume Loubet has made a 3 months internship in the Hyperion group at Disney, Los Angeles.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Selection

9.1.1.1. Member of the Conference Program Committees

- Georges-Pierre Bonneau was a member of the International Program Committees of the conferences Solid and Physical Modeling 2017, Eurographics Visualization Symposium 2017 (short paper track) and EnvirVis 2017.
- Romain Vergne was a member of the Conference Program Commitee of SIBGRAPPI 2017.
- Joëlle Thollot was a member of the Conference Program Committee of Expressive 2017.
- Nicolas Holzschuch was a member of the Program Committee for the Symposium on Interactive 3D Graphics and Games (I3D) 2017.
- Nicolas Holzschuch is a member of the Steering Committee for the Eurographics Symposium on Rendering.

9.1.1.2. Reviewer

All members of the Maverick team work as reviewers for the most prestigious conferences, including Siggrah, Eurographics, the EG symposium on rendering.

9.1.2. Journal

9.1.2.1. Reviewer - Reviewing Activities

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

9.1.3. Invited Talks

- Romain Vergne, October 13, 2017. Blekinge Technology Institute (Karlskrona, Sueden).
- Joëlle Thollot, February 2, 2017. Loria - Inria Nancy.

9.1.4. 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 GT Rendu.
- Romain Vergne is co-responsible of the PhD students of the Laboratoire Jean Kuntzmann.
- 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.

9.2. Teaching - Supervision - Juries

9.2.1. 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. Nicolas Holzschuch teaches advanced courses in computer graphics at the Master level.

- Licence: Joëlle Thollot, Théorie des langages, 27h, L3, ENSIMAG, France.
- Licence: Joëlle Thollot, Séminaire d’innovation, 10h, L3, ENSE3, France.
- Master: Joëlle Thollot, Responsable du cursus en alternance, 48h, M1-M2, ENSIMAG, France.
- Master: Joëlle Thollot, Tutorat d’apprentis, 50h, M1-M2, ENSIMAG, France.
- Master: Joëlle Thollot, responsable de la filière MMIS, 24h, M1-M2, ENSIMAG, France.
- Licence : Romain Vergne, Introduction to algorithms, 64h, L1, UGA, France.
- Licence : Romain Vergne, WebGL, 29h, L3, IUT2 Grenoble, France.
- Master : Romain Vergne, Geometric modeling, 18h, M1, UGA, France.
- Master : Romain Vergne, Image synthesis, 27h, M1, UGA, France.
- Master : Romain Vergne, Image synthesis, 15h, M1, Polytech, 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.

9.2.2. Supervision

- PhD: Tibor Stanko, Reconstruction de surfaces lisses maillées à partir de capteurs inertiels, Friday december 8th, 2017, Stefanie Hahmann and Georges-Pierre Bonneau.
- PhD: Benoit Arbelot, Transferts d'apparence en espace image basés sur des propriétés texturelles, April 7, 2017, Joëlle Thollot, Romain Vergne.
- PhD in progress: Alexandre Bléron, Stylization of animated 3D scenes in a painterly style, October 1, 2015, Joëlle Thollot, Romain Vergne.
- PhD in progress: Vincent Tavernier, Procedural stochastic textures, October 1, 2017, Fabrice Neyret, Joëlle Thollot, Romain Vergne.
- PhD in progress: Guillaume Loubet, Efficient representations for sub-pixel appearence, October 1, 2014, Fabrice Neyret.
- PhD in progress: Jeremy Wambecke, Temporal Data Visualization in Natural Environments, September 2015, Georges-Pierre Bonneau, Romain Vergne and Renaud Blanch.
- PhD in progress: Alban Fichet, Efficient representation for measured reflectance, October 1, 2015, Nicolas Holzschuch.

9.2.3. Juries

- Fabrice Neyret was in the jury of the HDR of Pascal Barla on October 9th, 2017 (Bordeaux, France).
- Joëlle Thollot was in the jury of the PhD of Hristina Hristova (Univ. Rennes 1) and Jean Hergel (Inria Nancy).

9.3. Popularization

Every year, “MobiNet” (see section 4.5) 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.

Fabrice Neyret published a popularization article "Maths in special effects" in the magazine "Tangentes" #178 (sep-oct 2017).

Fabrice Neyret maintains the blog shadertoyunofficial (https://shadertoyunofficial.wordpress.com/) and various shaders examples on Shadertoy site (https://www.shadertoy.com/) to popularize GPU technologies as well as disseminates academic models within computer graphics, computer science, applied math and physics fields.

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