Riemannian Ray Tracing

The Turing architecture of *Nvidia RTX GPUs* enabled the implementation of *ray tracing* in real-time with a high degree of photo-realism giving rise to many applications in games. RTX GPUs are starting a major revolution in Computer Graphics, comparable with the breakthrough when programmable GPUs were introduced. We believe Ray Tracing GEMs 2 will be of utmost importance, not only to present real-time algorithms for ray tracing effects but also to discuss non-trivial and more general applications using such new architecture.

In part, the success of Nvidia RTX architecture is due to its generic definition that employs hierarchical grouping of scene primitives to speed up the ray tracing. For rapid prototyping, there is the open-source *Falcor* which uses traditional representations of surfaces by triangles meshes and accelerates the ray tracing using classic hierarchical structures. It is still a long way to fully understand and optimize *RTX GPUs* use and this task itself is a fertile field for scientific research. However, we consider another path: the challenge of tracing *curved* rays in Non-Euclidean spaces.

Ray tracing works intrinsically in space geometry since light travels along lines minimizing lengths (geodesics). Thus, unlike in rasterization, no tricks to compute information based on the global physical behavior of light are required. In particular, ray tracing could be extended to not necessarily be restricted to Euclidean geometry tracing straight lines. We believe *Riemannian geometry* is the right setting for this extension since it generalizes the required concepts: metric and rays.

Riemannian space construction has *topology* as a global geometric constraint. In [reference], the authors define Riemannian shading to explore Nvidia RTX GPUs to visualize Non-Euclidean spaces endowed with non-trivial topology (dating back to Thurston's geometrization conjecture). Instead, this work firstly focuses on time/user-dependent Riemannian metric constructions on the classic space to explore special effects like *warping, mirages* [Stam] and *scene deformation* [Bar]. This implies spaces with trivial topology, but with generic Riemannian geometry. Then, we define *Riemannian ray tracing* to compute the global illumination of scenes endowed with such effects. Our first results use graphs of functions and diffeomorphisms to construct the metrics, allowing the modeling of expressive effects. Finally, gaussian bump functions restrict these constructions providing local deformations.

That approach opens many geometric questions concerning new ways of representing rays and space. Thus, the goal of this paper is to establish the basis of a new line of research based on employing Riemannian geometry in ray-tracing techniques. We believe curved rays can advance the state of the art in many areas, not restricted to rendering only.