# GPU-Based Lighting and Shadowing of Complex Natural Scenes

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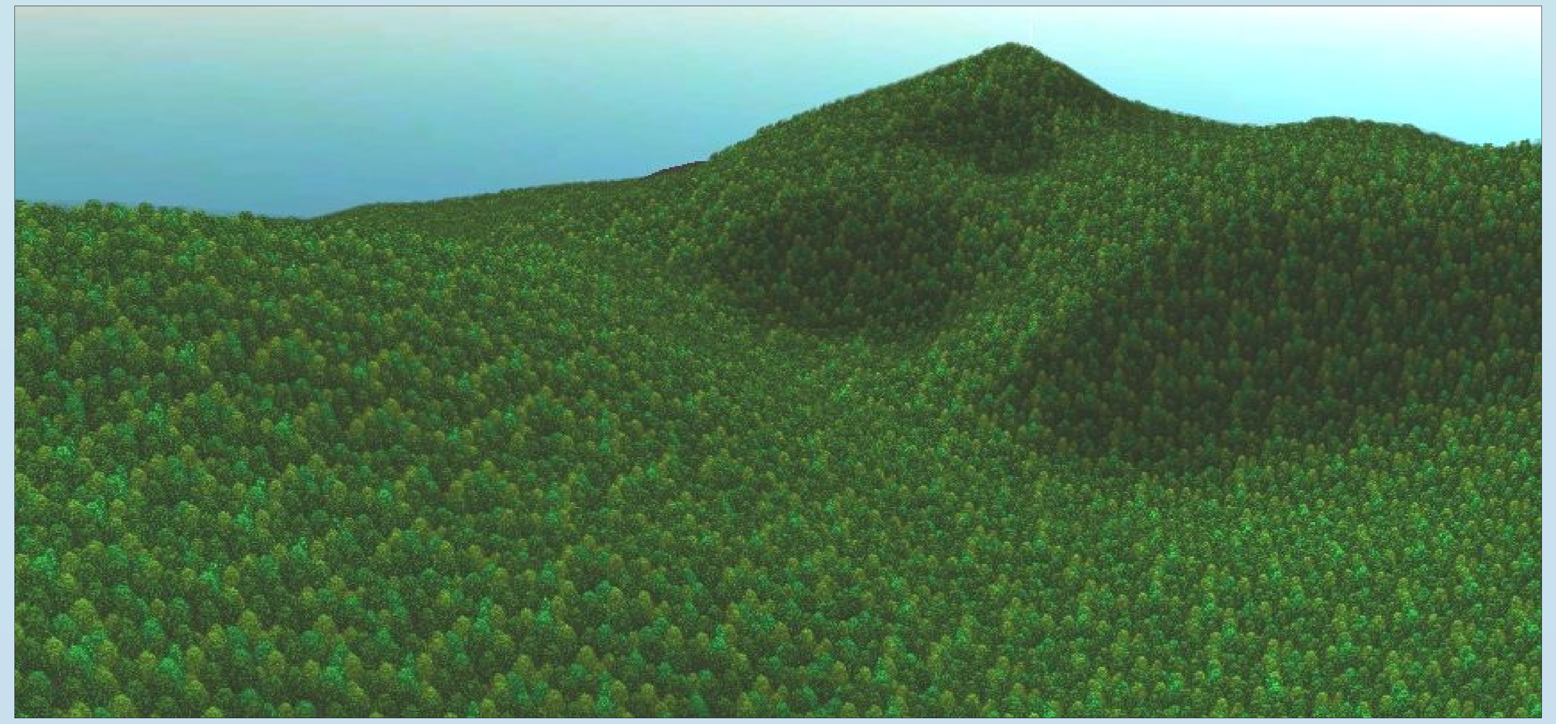
## Goals and motivations

We want to render in real-time scenes that contain complex shapes like forests or vegetation. Such scenes can be rendered efficiently using alternative representations such as point-based or volumetric texture-based approaches. But dynamic shading remains challenging.

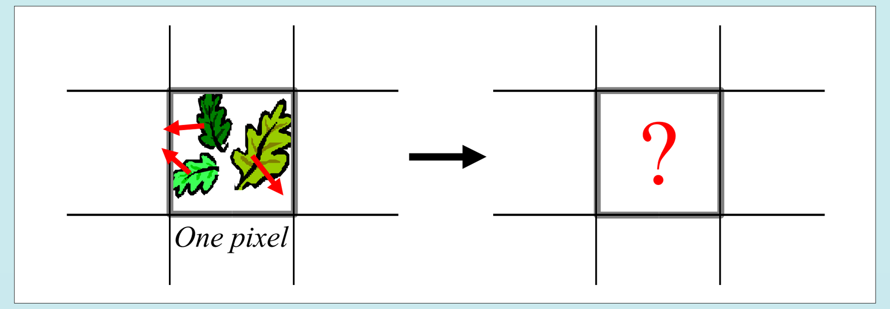


We propose lighting and shadowing techniques adapted to these representations as well as to the GPU, in order to achieve real-time framerates.

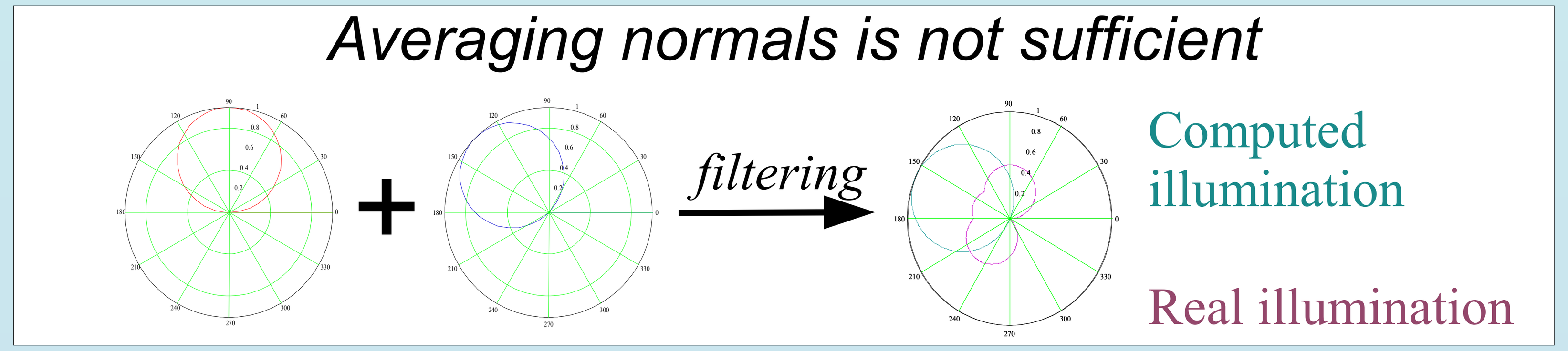
## Lighting

Lighting should be calculated per-pixel in order to highlight complex scenes.

### The problem: Filtering

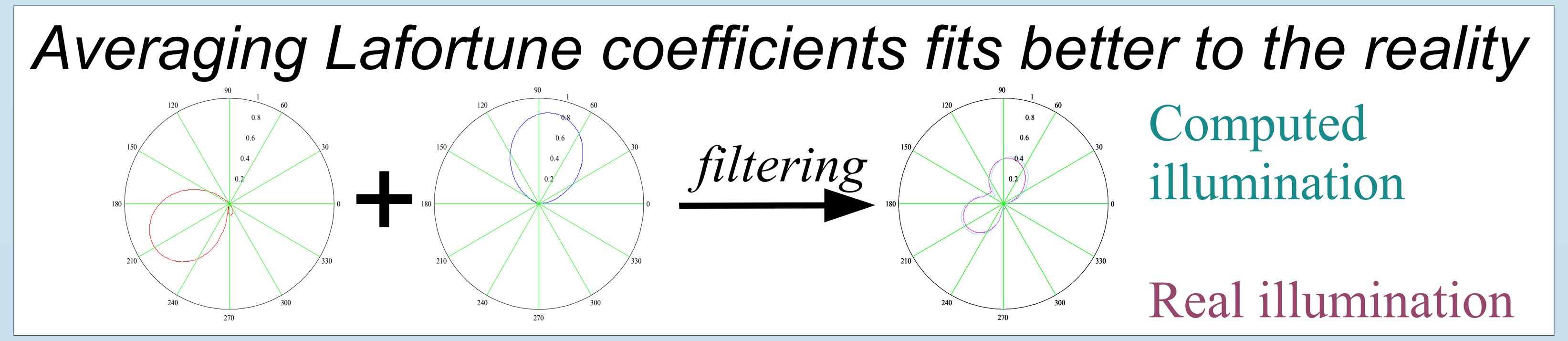



Many elements (e.g., many leaves for a forest scene), each one with its own illumination function, are projected onto the same pixel, and everything acts as if there is only one element with a new illumination function.

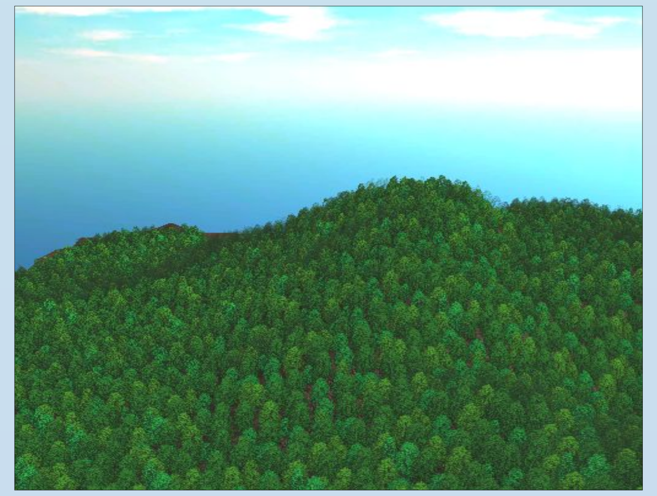



### Our solution: Adapted Lafortune lighting model

Lafortune et al. **[2]** have introduced a model, which allows us to filter the illumination functions.




We encode the Lafortune coefficients into textures and to use a fragment program so that the GPU computes the Lafortune-illumination model quickly, as we can see on this screenshot.



*Lafortune-illuminated forest*

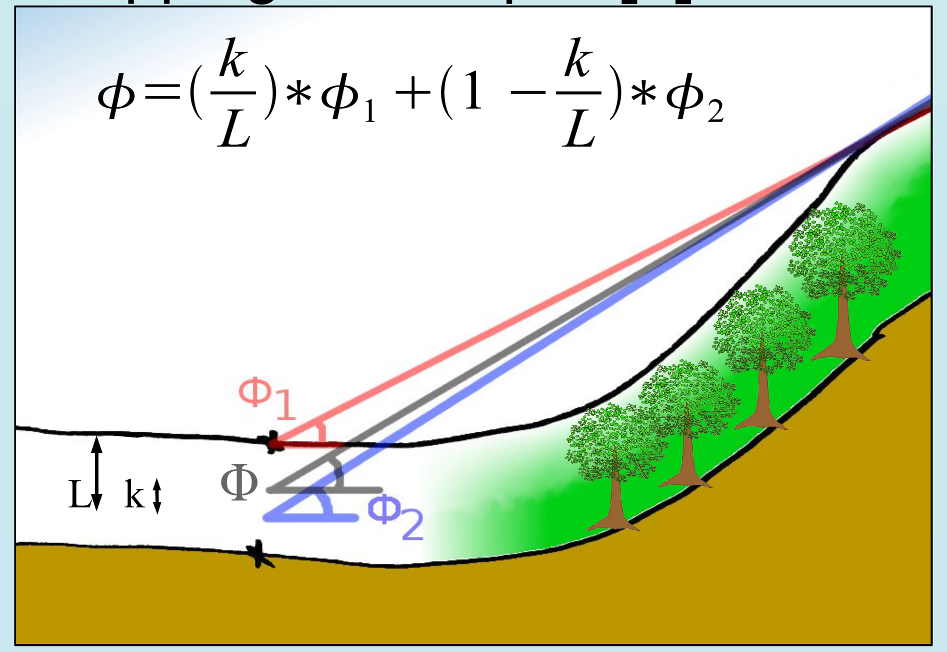
## Shadowing

### The problem: Scene complexity

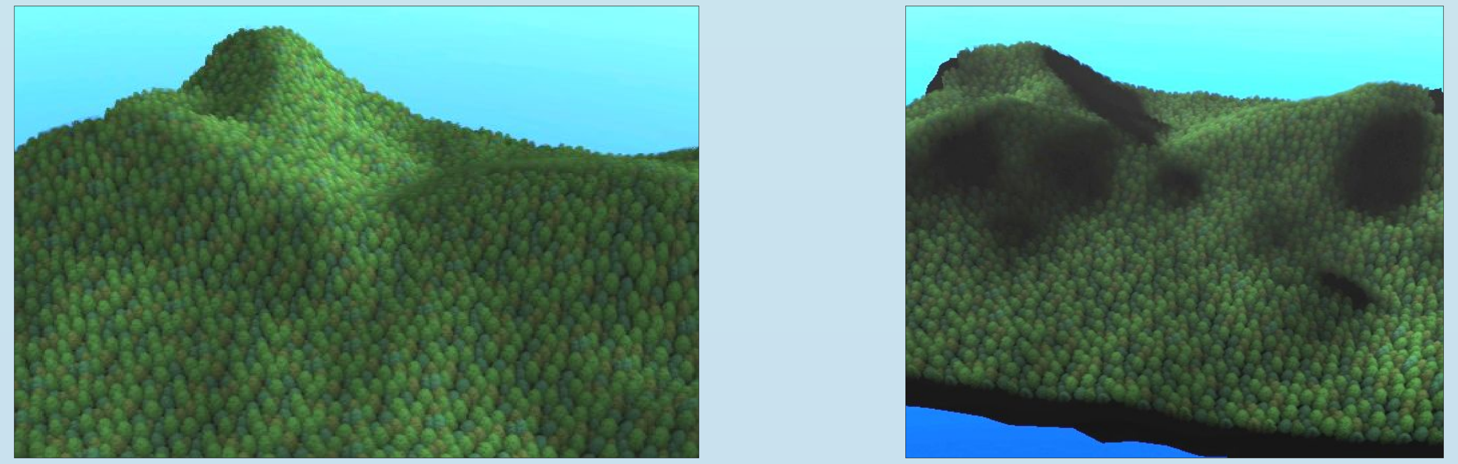
Processing the shadows on a per-object basis is often impractical since the amount of objects is very large.

### Our solution: Extended horizon-maps

We extend the horizon-mapping technique **[3]** in such a way that it is adapted to non - heightfield scenes: we pre-compute several horizon-maps at different heights above the surface.




These maps are then interpolated for each given fragment within the volumetric layer. Thus, shadows can be rendered at low costs compared to the visual complexity.



*Double horizon-mapping*

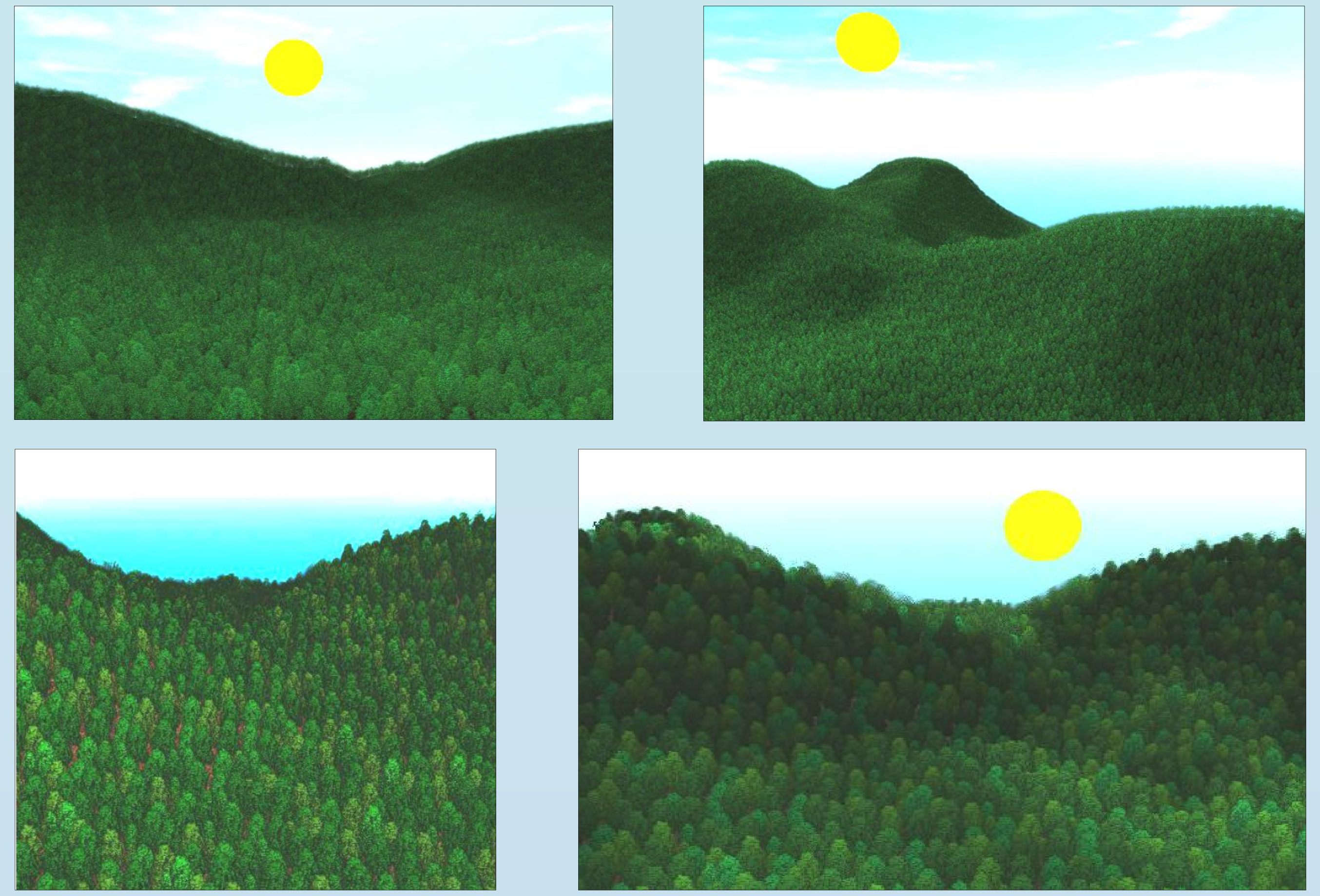
## GPU lighting and shading

In order to test and validate this approach, we implemented the techniques into the "texcells" representation for forest scenes **[1]**, in which precomputed lighting and shadows were used.

We pre-compute a 3D "texcell" containing the normals and Lafortune coefficients of each forest scene element.

In our implementation, for the shadows, we use only two horizon-maps (as on the left drawing).

We pre-compute the two horizon-maps at the top and bottom of the forest, and let the ordinary texture management interpolate them for each fragment.



Videos available at [www-imagis.imag.fr/Publications/2004/CDN04/](www-imagis.imag.fr/Publications/2004/CDN04/)

[1] DECAUDIN, P., AND NEYRET, F. 2004. Rendering forest scenes in real-time. In *Eurographics Symposium on Rendering 2004*.

[2] LAFORTUNE, E. P. F., FOO, S.-C., TORRANCE, K. E., AND GREENBERG, D. P. 1997. Non-linear approximation of reflectance functions. In *Proc. of SIGGRAPH 97*.

[3] MAX, N. L. 1988. Horizon mapping: shadows for bump-mapped surfaces. *The Visual Computer* 4, 2 (July), 109 117.

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