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Thèse de doctorat en sciences de l'Université Joseph Fourier

Représentations d'arbres réalistes et efficaces pour la synthèse d'images de paysages

Alexandre Meyer

Résumé : Cette thèse, située dans le cadre de la synthèse d'images de paysages, est consacrée à des représentations d'arbres adaptées soit au rendu de haute-qualité, soit au rendu temps réel. Les techniques de modélisation d'arbres donnent à ce jour de bons résultats en termes de diversité d'espèces et de formes représentables. Cependant, leur représentation géométrique nécessite une multitude de polygones représentant des détails fins, source d'un coût de calcul important et de gros problèmes d'aliassage lors du rendu de l'image. Pourtant, la construction de niveaux de détails par simplification de maillage ne peut s'appliquer à un arbre sans en modifier l'opacité et l'illumination globale, à cause du caractère disparate et non continu du feuillage. En suivant l'idée de représenter un ensemble de primitives (feuilles ou branches) par paquet intégrant les aspects géométriques et photométriques, nous avons conçu deux nouvelles représentations.

La première, destinée au rendu haute-qualité, est basée sur le calcul analytique du modèle d'illumination global d'une géométrie représentant un rameau d'aiguilles de conifère. En nous servant des connaissances a priori concernant la distribution géométrique des aiguilles, nous avons mis au point une hiérarchie de trois *shaders* capables de représenter à une échelle donnée les effets cumulés des niveaux plus fins, sans avoir à les échantillonner, et en tenant compte de l'auto-ombrage et de la visibilité. Le caractère analytique de ces *shaders* permet à la fois d'accélérer considérablement les temps de calcul et d'obtenir des images de qualité, en particulier avec très peu d'aliassage.

La deuxième, destinée au rendu temps réel, se compose d'une hiérarchie d'images correspondant à l'échantillonnage des directions de vue et de lumière, que nous affichons à l'aide de *billboards* en interpolant les images. Nous y associons une structure de visibilité pré-calculée, basée sur des *cubes de visibilité*, pour traiter l'auto-ombrage et l'ombrage en temps interactif. Notre implémentation permet l'affichage interactif d'une forêt de 1000 arbres avec illumination, auto-ombrage, ombrage, et avec possibilité de déplacer interactivement la source de lumière.

Mots-Clés : Synthèse d'Images, Scènes Naturelles, Modèles d'Illumination, Lancer de Rayons, Niveaux de Détails, Rendu Temps Réel, Réalisme, Visibilité, Ombrage.

Abstract : This PhD thesis is dedicated to the representation of trees for high quality or real time landscapes rendering. Techniques of tree modeling give good results in terms of diversity of species and shapes. However, the multitude of polygons of their geometrical representations generates a high computing cost and important problems of aliasing at rendering. Mesh simplification in order to build levels of details is not adapted to trees since it alters global illumination and opacity, because of the discontinuous repartition of the leaves. With the idea of representing groups of primitives (leaves or branches) using packets combining geometric and photometric appearance, we have introduced two new representations.

The first, intended to high quality rendering, is based on the analytic computation of the global illumination model of a geometric branch of needles. By using the knowledge of the geometric distribution of needles, we computed analytically a hierarchy of three *shaders* able to represent effect of lower levels, without sampling and with self-shadowing and visibility. The analytic aspect of these *shaders* allows in the same time the acceleration of computing time and good image quality, particularly with little aliasing.

The second, intended to real time rendering, is based on hierarchical sets of images corresponding to the sampling of view and light directions, which we render using *billboards* by interpoling images. We associate a precomputed visibility structure, based on visibility cubes maps, for self-shadowing and shadows. Our implementation allows the interactive rendering of a forest of 1000 trees with shading, self-shadowing, shadowing and the capability of moving light position interactively.

Key words : Computer Graphics, Natural Scenes, Shaders, Ray-tracing, Levels of Details, Real-Time Rendering, Realism, Visibility, Shadowing.