Interactive Grass Rendering in Real Time Using Modern OpenGL Features

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Problem Statement
There are only few sophisticated algorithms for rendering grass in real time due to the high amount of geometrical complexity. As a result, most algorithms visualize grass as a collection of billboards or use other image-based methods, which have problems concerning realistic appearance, physical interaction or different viewing angles. In addition, most grass rendering techniques are not able to react according to their environment.

Contributions
1. Rendering each blade of grass as geometrical object in real time
2. Distribution of the blades on arbitrary 3D models
3. Evaluation of a physical model for each blade of grass
4. Different culling methods are performed on each blade
5. The shape of a blade of grass is defined by analytic functions

Algorithm

Preprocessing
1. The blades of grass are distributed on the surface of arbitrary 3D models. We introduce different distribution techniques, which either distribute single blades of grass or whole tufts of grass.
2. Patches are formed out of blades of grass. Best performance is achieved if patches have an equal amount of blades and are compact in their spatial extent. We propose an algorithm solving the generation problem accurately and also fast algorithms providing reasonable results.

Rendering
1. We use an indirect rendering approach, which enables the dynamic adaption of the rendering pipeline to the changing number of visible blades.
2. Each blade of grass is rendered as tessellated geometric object, which enables smooth blade shapes defined by analytic functions.

Physical Model
Each blade of grass reacts to its environment according to a physically based model, implemented using a compute shader. This model includes the influence of:
1. Natural forces (gravity, wind, stiffness)
2. Collision forces (with simple and complex objects)

Visibility Culling
1. The bounding boxes of the patches are tested against the view frustum.
2. The visibility of each blade is evaluated in a compute shader depending on:
   - Orientation of the blade
   - View frustum
   - Distance to the camera
   - Occlusion

Results
1. Our rendering technique is capable of drawing dense fields of grass in real time.
2. In common scenarios, the culling methods are able to cull up to 75% of all blades of grass without noticeable difference of the density of the field of grass.
3. The calculation of the physical model requires only a few milliseconds for a dense field of grass and hundreds of collision spheres.
4. Different wind functions can simulate various natural effects, like light breezes, strong airflows or even tornados.
5. By using differently shaped blades of grass, the meadow has a more natural and heterogenous appearance.

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