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Modeling the Accumulation of Wind-Driven Snow

Technical Sketch

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1 Introduction

This technical sketch presents a method for modeling the appearance of snow drifts formed by the accumulation of wind-blown snow near buildings and other obstacles. Our method combines previous work on snow accumulation [Fearing] with techniques for incompressible fluid flows [Fedkiw et al.]. By computing the three-dimensional flow of air in the volume around the obstacles our method is able to model how the snow is convected, deposited, and lifted by the wind. The results demonstrate realistic snow accumulation patterns with deep windward and leeward drifts, furrows, and low accumulation in wind shadowed areas. (See figure.)

2 Methods

The first step of our method is to compute a steady flow field for the wind around the obstacles. As the snow accumulates, this flow field will be treated as constant until a significant amount of snow has accumulated. As large amounts of snow accumulate we periodically recompute the flow to reflect resulting changes in wind patterns.

The space around the obstacles is discretized into a uniform Eulerian grid. Cells within the obstacles are marked as impermeable. Cells directly above upward facing horizontal surfaces are marked as landing sites.

We compute the flow fields using the Naiver-Stokes equations for three-dimensional inviscid, incompressible flow. The cells on the boundary of the three-dimensional grid are initialized with the desired average wind velocity. A sequence of alternating mass-conserving and momentum-conserving steps are computed using a semi-Lagrangian integration scheme. (See [Fedkiw et al.].) The sequence terminates when the flow field has converged so that the maximum magnitude change in wind velocities from one time step to the next is below a threshold.

Once the flow field has been computed, the next step requires computing how snow moves through the flow and accumulates on the landing sites. Snow is injected into the scene by setting the border cells to contain an amount of snow equal to $\rho\hat{\boldsymbol{n}} \cdot \boldsymbol{v}$ where ρ is the density of snowfall, $\hat{\boldsymbol{n}}$ is the inward facing normal of the cell's exterior face(s), and $\boldsymbol{v}$ is the average velocity of the falling snow away from the obstacles. If this quantity is negative, then snow is not injected at that border cell.

The snow inside the grid is convected by moving it in a direction which is the sum of the local fluid velocity and a downward gravitational term. A landing cell removes a portion of its snow and stores it as resting on the corresponding horizontal surface. If the wind velocity in a landing cell is large, then a portion of snow will be removed from the horizontal surface and returned to the flow field.

The amount of snow at each landing site is compared to its neighbors to ensure that some critical slope is not exceeded. If the critical slope is exceeded between a site and its neighbor, the neighbor is checked to see if it can receive the snow. Impermeable cells cannot receive snow. If a neighbor is free to accept the snow, it receives a quantity proportional to the amount the critical slope is exceeded plus some small amount to ensure convergence. Neighboring open sites have the avalanched snow injected into the flow, while neighbor landing sites add the avalanched snow to the corresponding surface. The process repeats until all landing sites are stable.

The snow convection process proceeds until a suitable amount of snow has accumulated in the scene. If large drifts that might alter the wind flow form, then the flow field may be recomputed.

Once we have a final distribution of accumulated snow, the accumulation on the horizontal surfaces is used to generate a height field. The height field is rendered as a Catmull-Clark subdivision surface.

3 Results

We have tested our method on the simple scene shown in the figure. While this scene is much simpler than those shown in [Fearing], the use of a flow field to compute the snow's motion allows us to capture effects that were not producible by the previous method. Some of these effects include long windward drifts, furrows at the sides of obstacles, and leeward gullies and drifts. The top image shows a perspective view of a large amount of snow accumulating on and around 3 m tall obstacles. The lowers images show a top view of the same scene and a top view of a set of streamlines through the flow field. Approximately three hours were needed to generate these results with matlab on a laptop PC.

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References

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