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Class of 2011

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Figure 1: In Antarctica the temperatures are cold and the air is dry, so snow crystals grow very slowly. This slow growth tends to produce very clean hexagonal prisms, which are well suited for producing beautiful atmospheric displays. The above example is a halo at the south pole showing a rich variety of arcs and halos. [1]

Title: Towards the Interactive Simulation of Ice Halos in the Open Sky

Purposes: A halo is an optical phenomenon that appears near or around the Sun or Moon, and sometimes near other strong light sources such as street lights. The purpose of this research is to simulate the visualization of ice halo under different atmospheric environments with algorithms more efficient than existing versions. Ice halo are created by ice crystals in the cold cirrus cloud by refracting and reflecting light [1]. Some of the existing software that simulates the formation of ice halo are HaloSim by Les Cowley and Michael and HaloSky by Stanley David Gedzelman. HaloSim creates simulation by accurately tracing up to several million light rays through mathematical models of ice crystals but requires a huge amount of computation. HaloSky simulates halo with dot models using a Monte Carlo approach and in his paper "Simulating halos and coronas in their atmospheric environment" described how halos vary with atmospheric turbidity, solar zenith angle, and cloud height, width, and optical depth [2]. These two programs require a huge amount of computation to simulate a scene. Generating each image therefore takes several minutes. The long-term goal of my research is using modern parallel processing to speed up the simulation time while maintaining physical accuracy. The resulting product will be useful to researchers, educators and students of atmospheric optics as they will be able to interact with the model and viewpoint, building an intuitive mental model of how the physics work.

Background: I will conduct my research in summer with Professor Steinhurst from the computer science department. As an independent study course in the Spring of 2009, Professor Steinhurst and I have carried out a detailed survey on the previous work including the mathematical models and simulation of atmospheric effects such as rainbow, halo and glories. We have collected a number of papers related to Halo and rainbow simulation and gathered information on the theoretical aspects of this research. This information is being pulled together into a literature review currently. In order to ensure the successful implementation of our simulation, Professor Steinhurst has guided me in understanding several important concepts in computer graphics by weekly meetings and reading assignments from "Ray Tracing from the Ground Up". I have also learnt how to use other important tools such as c/c++, subversion and using Trac to maintain an electronic lab notebook during a semester. This research will be significant to those who wish to study natural phenomena occurring in the atmosphere, specifically Halo under different weather situations. In addition, the long term goal of this research is to provide a more efficient and accurate way of simulating and exploring the natural environment through a computer program.

Work Plan:

1. Conduct a thorough literature review on the amount of work that has been done on Halo simulation and different atmospheric effects. Document in a professional document using conventions of conference papers in the field.
2. Develop an understanding of the mathematical techniques used to model ice halo formation and visualization.
3. Create a basic simulation of refraction and reflection by ice-crystals using the concepts I learnt during the Spring 2009 independent study to learn how HaloSim and HaloSky are implemented. The focus on this implementation is not speed, but ensuring that my understanding of the simulation techniques is correct. We may also use the Matlab environment as a protoype platform as it is easy to debug.

4. Carefully analyze different stages of our software development and decide the features to be included in our interactive simulator that will be developed during the 2009-2010 academic year. The focus of that follow on project will be leveraging the lessons of this summer into an interactive simulation suitable for the long-term goals of the project.

Timetable:

Week 1: Using the literature review, design the architecture of the simulator May 10 - 16
Week 2: Implementation May 17 - 18
Personal Vacation May 19 - 24
Week 3: Implementation and debugging May 25 - 31
ILTM program June 1 – July 16
Week 4: Implementation and debugging July 17 – 23
Week 5: Analyze results and gather data July 24 - 30
Week 6: Prepare final reports and poster for Sigma Xi Session July 31 – 6
Week 7: Complete final report and plan work for 2009-2010 year Aug 7 - 13

Research Environment: This research will take place at Bucknell University during the summer of 2009. I will be conducting this research mainly in May, July and August but not in June and early July as I am participating in the ILTM program which runs from June 1st to July 16th. At the beginning, Professor Steinhurst and I will meet on a daily basis and this schedule would taper to no less than two formal meetings a week. In addition to being available in his office, Professor Steinhurst will be available via email and instant messaging during his short planned trips off campus.

Outcome and deliverables: A complete literature and simulation review on ice halo in technical paper format will be done by the end of this semester. A working prototype simulation will be created during the summer to help us learn the physics and mathematical concepts underlying ice halo formation. All these works will lead to next year's research on a more efficient algorithm and real-time simulation of the optical phenomena under study.

References:

[1] Kenneth G. Libbrecht, http://www.its.caltech.edu/~atomic/snowcrystals/halos/halos.htm
[2] Les Cowley, http://www.atoptics.co.uk/halosim.htm
[3] Philip Laven, Simulation of Rainbows, Coronas and Glories by use of Mie Theory. Walter Tape and Gu¨ nther P. Ko¨ nnen, A General Setting for Halo Theory
[4] Gunther P. Ko¨ nnen, Herman R. A. Wessels, and Jaap Tinbergen, Halo Polarization Profiles and Sampled Ice Crystals: Observations and Interpretation.
[5] Stanley David Gedzelman, Simulating Halos and Coronas in their Atmospheric Environment.