Delft University of Technology

Laser Swarm

Simulator Report

Design Synthesis Exercise

Authors:
S. Billemont
L.S. Boersma
B. Buyens
S.R. Finck
J.P. Florijn
T.C. Goossens
N.S. Oborin
A.J. Vorobiev
G.J. van der Wel
Z. Zhou

Tutor:
Ben Gorte

Coaches:
Prem Sundaramoorthy
Mathieu Willaert

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Abstract

As part of a laser swarm feasibility study, this document preliminarily describes the design and workings of a simulator. This simulator simulates a satellite swarm with a single emitter and multiple receivers flying in formation for the purpose of mapping the Earth's surface. The how and why of the simulator is discussed in this document.

Contents

List of Acronyms

BRDF Bidirectional Reflection Density Function

DEM Digital Elevation Model

Chapter 1

Introduction

This report preliminarily discusses the design and workings of a software tool developed with the purpose of guiding and validating the results of the tradeoff done in the main laser swarm project, as well as demonstrating the feasibility of the concept of the laser swarm.

Generally speaking, the simulator program is divided into two parts. The first part is the simulation of the physical path of the photons in the laser pulse up to the point were they are received by the receiving satellites. This part has been documented in chapter 2, page 4.

The second part is the analysis of the received photon data, to determine terrain height and Bidirectional Reflection Density Function (BRDF). Obtaining this data is what the software and in general this feasibility study is about. This part is described in chapter 3, page 6.

Chapter 2

Simulation

In this chapter the simulation of the satellites moving through space and sending and receiving laser pulses is discussed. In section 2.1 the emitter and receiver satellite orbits are considered. In section 2.2 the way the Earth's surface was modeled is explained. The in section 2.4 the introduction of noise into the signal is disclosed, whereas in section 2.3 the path of the signal is examined.

2.1 Orbit

2.2 Earth Model

The earth model is the digital representation of the earth surface. It stores **DEM0!** (**DEM0!**), and of the scattering characteristics of the local terrain. In section 2.2.1, the Digital Elevation Model (DEM) implementation will be elaborated and in section 2.2.2 describes the way incoming radiation is scattered.

2.2.1 Digital Elevation Model

2.2.2 Scattering Model

Scatter is the physical process where incident radiation is absorbed and reflected back into the atmosphere. To this end a scattering model is used. This scattering model is a way to construct a BRDF. A BRDF is a distribution of the incident light over the hemisphere [Rees(2001), pages 47-49]. An example is shown in figure 2.2.2, page 5.

The most basic example of a BRDF is the Lambertian model [Rees(2001), pages 49-50]. This model assumes a homogeneous perfectly rough surface, causing a homogeneous scattering distribution. Apart from the index of refraction of the air, the incident radiation vector and the exittant radiation vector (which are all known) use of Snell's law is needed to find Fresnel's coefficients, thereby requiring the index of refraction of the ground.

A modification that can be made to take into account the tendency of surfaces to scatter more in the direction of the surface normal, is called the Minnaert model [Rees(2001), page 50]. It causes a more elliptical BRDF. It depends on the Minnaert parameter κ.

Another important modification is the Henyey-Greenstein term. It accounts for the tendency of surfaces to back- or forwardscatter [Rees(2001), page 51]. This rotates and deforms the elliptical BRDF obtained from the Minnaert model. The Henyey-Greenstein term is parameterized by Θ. The final result is shown in figure 2.2.2, page 5.

This is the scattering model used in the program. Because there is no data from which all three parameters can be accurately determined, a coefficient map was made up. It does not matter much what the precise form of the BRDF used in the simulation is, so long as it can be retrieved.

With the help of the formulae from [Rees(2001), pages 43-51], the incidence vector can be taken and the number of photons radiated in a specific direction can be calculated. Note that the program does not integrate over part of the sphere: because the angle of the cone is very small, the BRDF is assumed to be constant over the cone. The error induced here is worth avoiding the computationally expensive integration.

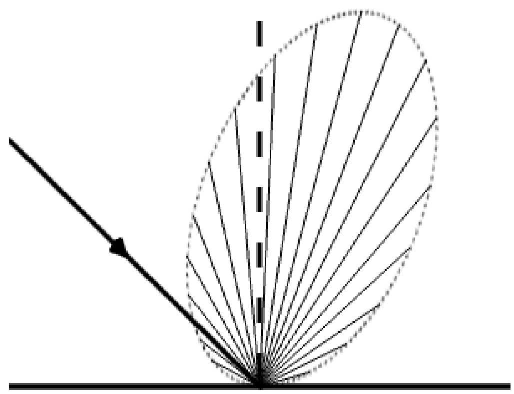

Figure 2.1: Example of a BRDF

2.3 Signal Path

2.4 Noise Introduction

Chapter 3

Data Analysis

In this chapter the analysis of the received photon data taken care of in the software tool is elaborated on. The analysis consists of two parts: the terrain altitude determination and the BRDF determination. The first is expounded in section 3.1, the second in 3.2.

3.1 Altitude Determination

3.2 Bidirectional Reflection Density Function Determination

Bibliography

[Rees(2001)] W. G. Rees. *Physical Principles of Remote Sensing.* Cambridge University Press, Cambridge, second edition, sixth printing edition, 2001. ISBN 9780521669481.