ECE 3340 – Programming Assignment 2
Monte-Carlo Integration

This assignment is designed to teach you how to generate and use random numbers. You will implement a Monte-Carlo integrator that can compute the definite integral of spherical functions.

The problem
Your application will take a series of command-line arguments as floating point values:

$[s_0, s_1, \ldots, s_{n-1}, s_n, \alpha, N]$

The values s_0 through s_n are coefficients of a degree n spherical harmonic function $f(\theta, \phi)$. Spherical harmonics are a set of basis functions that can be used to build functions in spherical coordinates. **I will provide a C function that will return the value of $f(\theta, \phi)$ given a set of coefficients and a sample point (θ, ϕ).**

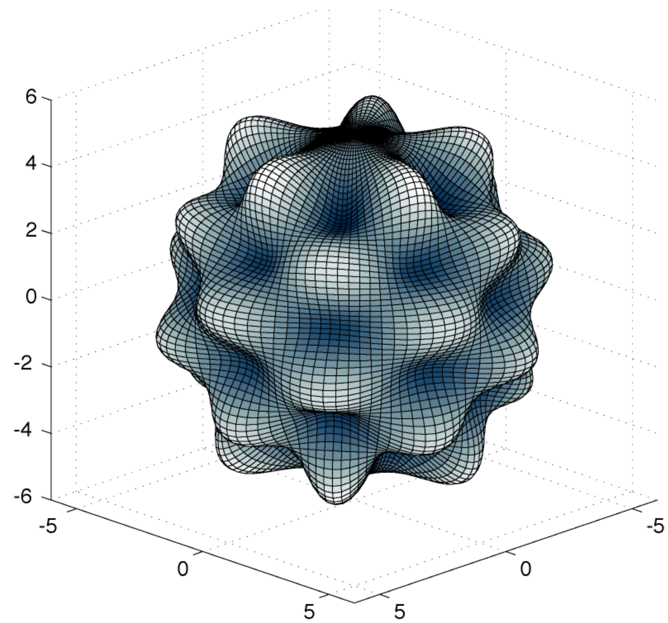


Figure 1: Demonstration of a spherical function (Pickwick, Wikimedia Commons)

Your job is to calculate the integral:

$$\int_0^{\alpha} \int_0^{2\pi} f(\theta, \phi) \sin\phi \, d\theta \, d\phi$$

where α is a solid angle and N is the number of Monte-Carlo samples.

This is extremely difficult to compute analytically, however these types of integrals are used routinely when simulating electromagnetic field propagation. This type of analysis is particularly useful when estimating light scattered from particles or spheres – a topic known as Mie scattering.

Your implementation is required to have the following functions (implemented separately):

- a 32-bit uniform pseudo-random number generator
  - Use a linear congruential generator with a period of at least 2^{32}
  - Speed is important, so minimize the number of arithmetic operations used in the LCG
- 2D Monte-Carlo integrator - draw from a set of random 2D samples of $f(\theta, \phi)$

Output the following things in this order:

1) The LCG parameters that you used, including
   a. modulus m
   b. multiplier a
   c. increment c
   d. your seed value x_0
2) The value of $f(\theta, \phi)$ at $(0, 0)$ and $(0, 2\pi)$
3) The integral evaluated using N samples

Turning in your code
Your code must be written in C or C++ using a single file. Upload your code to Blackboard. You'll want to run large tests using VS "Release" mode. This implements optimization and removes debug symbols.

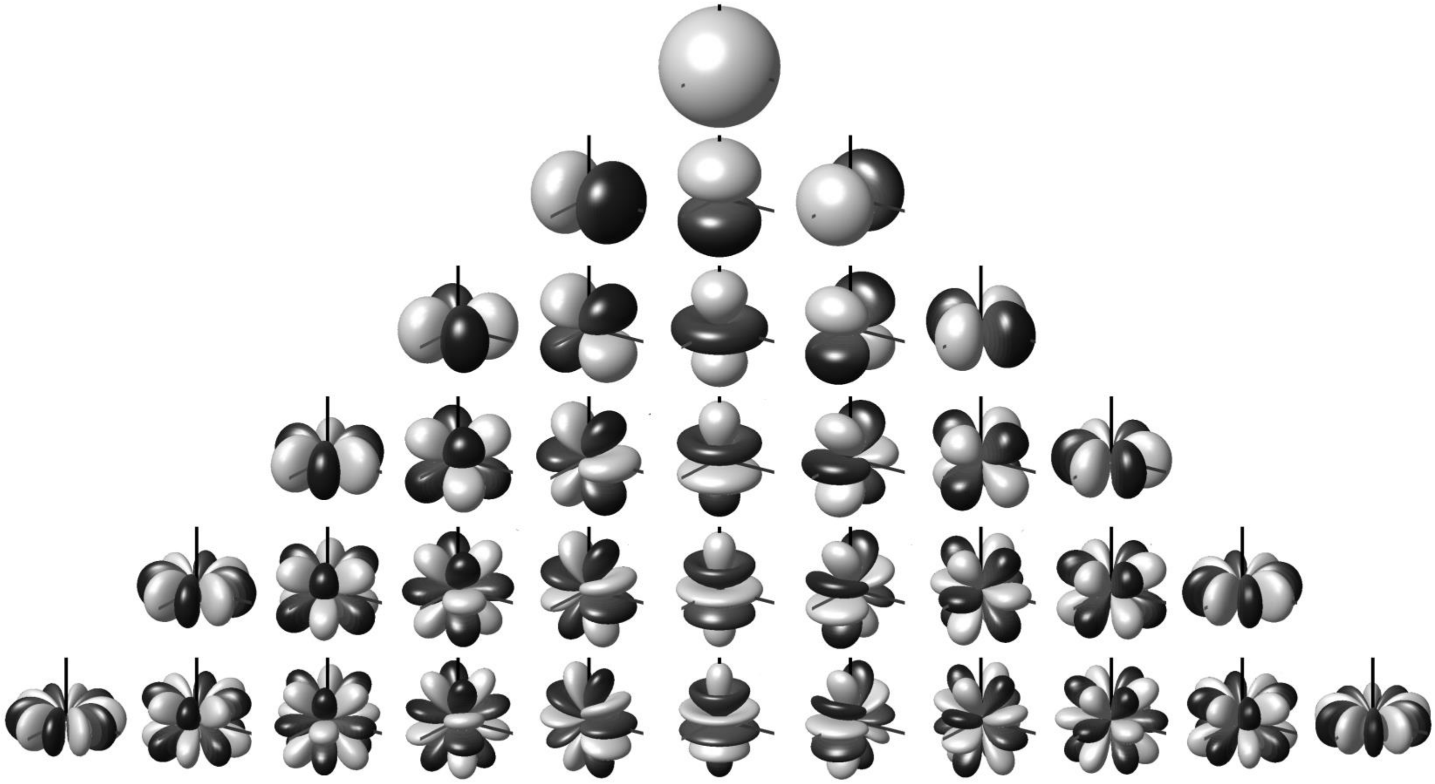


Figure 2: The set of spherical harmonic basis functions up to degree-5 (by Franz Zotter)

Examples

I have written code that you can use to visualize your functions given a set of spherical harmonic coefficients. This code is available on the course website: http://stim.ee.uh.edu/education/ece-3340-numerical-methods/

harmonics: **1, 0, 0, 1, 2, 3**

$\alpha =$ **0.5 radians**

integral: **0.21694**

harmonics: **1, 0, 0, 1, 2, 3**

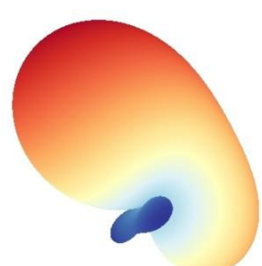
$\alpha =$ **0.75 radians**

integral: **0.98192**

harmonics: **1, 0, 1, 0.5, 2, 0, 3**

$\alpha = 0.5$ **radians**

integral: **1.769**



harmonics: **0.84, 0.39, 0.78, 0.8, 0.91**

$\alpha =$ **1.5 radians**

integral: **2.5756**

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Rubric

Name_____________________________

input format		**__________ / 5**
output format (1 or 2 decimal values)		**__________ / 5**
correct interface with SH code		**__________ / 5**
LCG		**__________ / 45**
parameters optimize period	__________ / 10	
correct implementation	__________ / 10	
minimum number of operations	__________ / 15	
input and code commented	__________ / 10	
2D Monte-Carlo integrator		**__________ / 40**
sample distribution computed correctly	__________ / 10	
integrand computed correctly	__________ / 10	
samples scaled correctly	__________ / 10	
input and code commented	__________ / 10	
Total		**__________ / 100**