Indian Institute of Science Education and Research, Mohali

Progress Report

Course Code - PHY312

Monte Carlo simulations of polarised light transport into scattering media

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1 Introduction

Monte Carlo methods are a broad class of algorithms that use randomness to simulate a model of interest. In this project, we use Monte Carlo methods to simulate light propagation through a scattering media. Since these topics are new to us, we start with a very simple model in which we consider an isotropic medium with absorption and scattering effects.

2 Implementation of the model

In our model, photons are successively emitted, and their individual paths are computed and tracked one by one. In light propagation through the medium, the photon propagation is simultaneous. But, we consider successive emission of photons for simplicity and finally merge the individual trajectories to simulate the propagation of light through the medium and obtain the desired data such as relative fluence rate and relative photon concentration. This doesn't affect the final data obtained, as the properties of the medium remain unchanged during photon propagation and photon-photon interactions are absent.

3 Absorption and Photon survival

Survival of a photon in the medium, as given by Beer's Law, is $\exp(\mu L)$, where μ is the absorption co-efficient and L is the path length of the photon.

One method to incorporate the effects of absorption of photons by the media is to check whether the photon is absorbed during each timestep. We use an alternate method in which we first obtain the maximum path L_{max} that the photon travels before it is absorbed, where L_{max} is a random variable that follows the distribution given by Beer's Law of photon survival.

4 Henyey-Greenstein scattering function

The scattering effects of the medium can be studied by checking whether scattering occurs at each timestep. In our model, we compute stepsize – the path travelled by a photon before it is scattered. Step size is determined by the scattering coefficient with lower stepsizes for a higher amount of scattering.

The deflection angle of the photons by scattering is described by the Henyey-Greenstein scattering function. The distribution of deflection angles for different values of anisotropy (g) of the medium can be obtained using this function. We spent hours trying to sample the deflection angle using the inverse CDF method, but our attempts were unsuccessful. We suspect that this is due to floating-point errors. Another possible reason that we suspect is that the inverse CDF method isn't appropriate in this case. We are planning to look into this matter and resolve it as soon as possible. We recently came across a module Miepython which could possibly help us resolve this issue. However, we have attached our attempts at simulating the HG function.

As we couldn't generate samples using the HG function, we have considered an isotropic medium with $g = 0$. The deflected angles were computed for $g = 0$, and the photon trajectories were obtained.

5 Results

We have attached animations of the trajectories of photons in 2-D for 10, 100 and 500 photons. The programs and the output info files have also been attached.

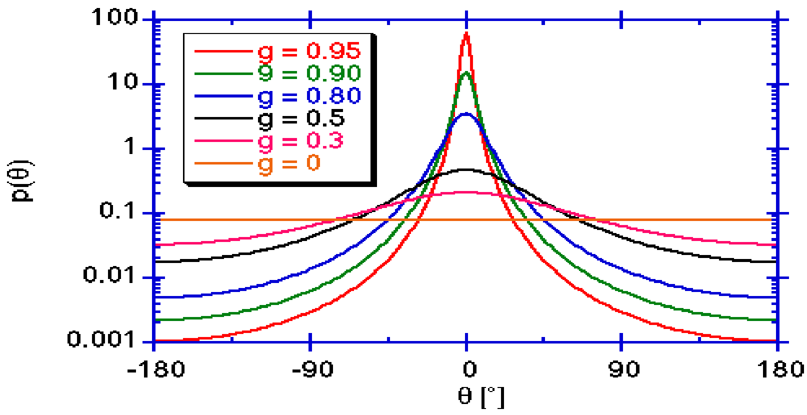

Figure 1: Expected distribution

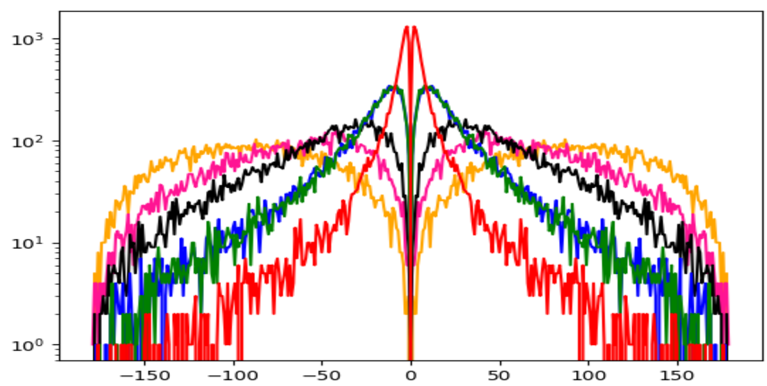

Figure 2: Simulated distribution

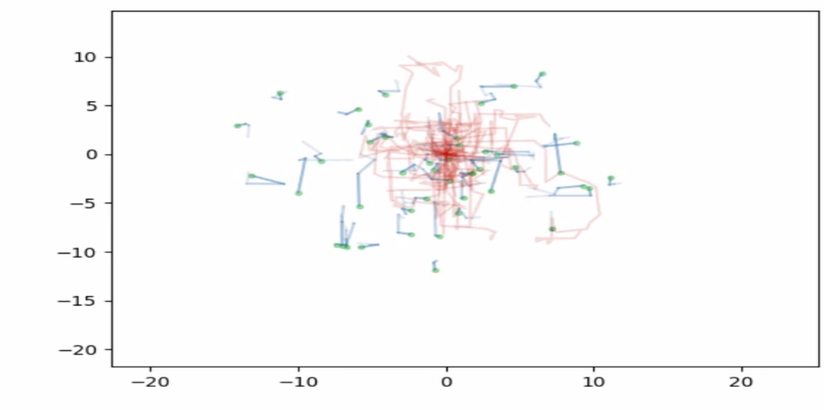

Figure 3: Link to animation given in the appen

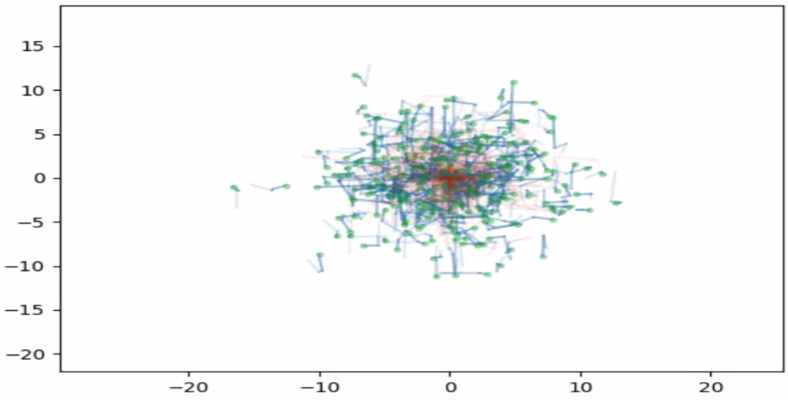

Figure 4

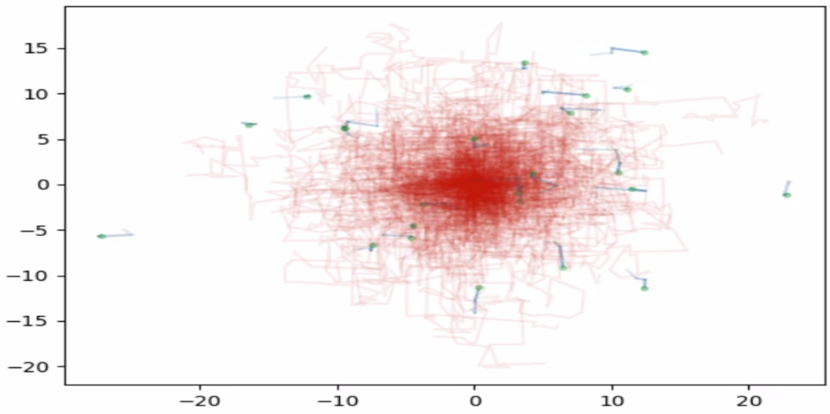

Figure 5: The red trajectory corresponds to dead (absorbed) photons

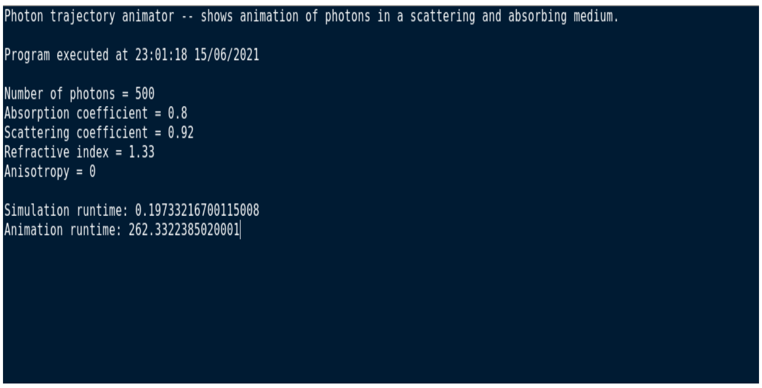

Figure 6: Output info file

6 Limitations

- Since animating 3-D models require more knowledge on data visualisation and computational resources, we have chosen a 2-D model for the animation of trajectory alone.
- The 3-D model in which we track the trajectories and the radial photon concentration is incomplete. We are working on it and will update soon.

- Since this is our first attempt, we have not accounted for polarisation.

7 Link

Link to the project folder
`https://drive.google.com/drive/folders/14BsjDYSstjd1JVj6r0wjMHvYo43ORwmu?usp=sharing`