Optik 158 (2018) 725–736

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Computation of intersection volume using discrete quadrature algorithm

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ARTICLE INFO

Article history:
Received 29 November 2017
Accepted 28 December 2017

Keywords:
Quasi Monte Carlo algorithm
Discrete quadrature algorithm
Irregularity intersection volume
Light source

ABSTRACT

Quasi Monte Carlo algorithm is one of the most famous particle method, which is used to solve intersection volume computation problem. Inspired by the quasi Monte Carlo algorithm, a discrete quadrature algorithm is proposed to calculate the intersection volume. First, the three dimensional entity with unknown function is divided into a series of random sequences points using the quasi Monte Carlo algorithm. Second, calculating the common point set in terms of a given function three dimensional entity. Finally, both the intersection volume and irregularity intersection volume are approximated by the number of the common point set. Simulation shows that the proposed method has the advantages in estimation accuracy and computational load.

1. Introduction

Intersection volume computation (IVC) problem is critical in almost all fields of scientific endeavor [1]. For example, in optical research, the intersection volume (IV) between two light sources is usually needs to be calculated in order to obtain the number of the light source. Furthermore, the volume of the four dimensional space should be calculated to measure the Etendue of Light Emitting Diode (LED) [2]. Especially, in the architectural lighting design, it needs to compute the intersection volume between the light source and the architectural for the room light design [3].

Generally speaking, there are several competitive classes of intersection volume computation method. Among these, the two most popular ones are the Delaunay Triangulation [4] and quasi Monte Carlo algorithm [5–10]. Usually, quasi Monte Carlo algorithm has received considerable attention, in that it has both a better exponent of convergence and a better assurance of error [11], for example, [12] proposed a new measure of irregularity to improve the Quasi Monte Carlo method. [13] used the quasi Monte Carlo sampling to the polarimetric SAR despeckling technique. And then, the quasi Monte Carlo method was proposed to solve probabilistic optimal power flow problem [14]. Therefore, in our opinion, the quasi Monte Carlo algorithm is still a popular tool for the intersection volume computation.

The main contribution of this work is that a discrete quadrature algorithm is proposed to calculate the intersection volume based on quasi Monte Carlo algorithm. First of all, the three dimensional entity with unknown function is divided into a series of random sequences points using the quasi Monte Carlo algorithm. Second of all, calculating the common point set

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https://doi.org/10.1016/j.ijleo.2017.12.154

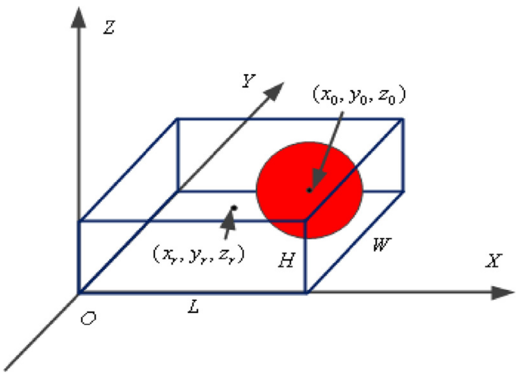

Fig. 1. The IV in Case 1.

in terms of a given function three dimensional entity. Finally, the above common point set is utilized to approximate the intersection volume or irregularity intersection volume.

This paper is organized as follows. The intersection volume computation problems are described in Section 2. In Section 3, a discrete quadrature algorithm is proposed to calculate the intersection volume. In Section 4, numerical examples are provided to demonstrate the effectiveness of the proposed algorithm. Finally, Section 5 concludes this paper.

2. Problem formulation

At first, we define the coordinate system as shown in Fig. 1. For simplify, the light source is a sphere, its center coordinates is (x_0, y_0, z_0), and the radius of the sphere is R. Furthermore, the size of the room is (L, W, H), and the central coordinates of the room is (x_r, y_r, z_r).

In this paper, we only discuss the condition that the central coordinates of the light source belong to the room, that is

$$\begin{cases} 0 \le x_0 \le L \\ 0 \le y_0 \le W \\ 0 \le z_0 \le H \end{cases} \tag{1}$$

From Fig. 1, we can see that the IV has the following cases between the light source and the room.

Case 1: The light source surrounds the room, which satisfy the following conditions

$$\begin{cases} (x_0, y_0, z_0) = (x_r, y_r, z_r) \\ \dfrac{\sqrt{L^2 + W^2 + H^2}}{4} \le R \end{cases} \tag{2}$$

and the relationship between the light source and the room is shown in Fig. 2(a)

Clearly, in Case 1, the IV between the light source and the room is the volume of the room, calculated as

$$V_e = L \times W \times H \tag{3}$$

Case 2: Similar to Case 1, let

$$\begin{aligned} &\text{Mix\_ d istense} = \min\left\{\frac{L}{2}, \frac{W}{2}, \frac{H}{2}\right\} \\ &\text{Max\_ d istense} = \max\left\{\frac{L}{2}, \frac{W}{2}, \frac{H}{2}\right\} \end{aligned} \tag{4}$$

then, if we have

$$\begin{cases} (x_0, y_0, z_0) = (x_r, y_r, z_r) \\ \text{Mix\_ d istense} \ge R \end{cases} \tag{5}$$

that is, the room surrounds the light source. To see this, Fig. 2(b) shows the relationship between the light source and the room in Case 2.

According to Eq. (3), the IV in Case 2 is given as

$$V_e = \frac{4}{3}\pi R^3 \tag{6}$$