DEVELOPMENT OF CROSS-PLATFORM SOFTWARE COMPLEX FOR DETERMINING OPTICAL RADIATION EXTINCTION AND TRANSMISSION

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Introduction

Nowadays, the task of monitoring and investigating marine areas is given a large amount of attention [1]. The reason is growing necessity of environmental control and rational management of natural resources. For such task, it is very prospective to use optical methods based on determining the properties of radiation transformed by a medium.

This work describes the principles and algorithms behind the development of software complex, implementing a numerical model for studying extinction and transmission of optical radiation passing through a medium containing various particles. The software complex in question allows to easily perform a large number of calculations for a variety of input data and display the results in a way that is convenient for conducting research.

Method of calculation

To study the properties of the incident radiation passed through a medium, a numerical model has been developed [2]. Modelling the extinction process of radiant energy requires considering the extinction coefficient. For a system of particles, it can be defined as following:

$$\alpha_{ext} = C \cdot \langle S_{ext} \rangle . \quad (1)$$

Here $\langle S_{ext} \rangle$ is the average extinction cross-section; C is the volume concentration of particles.

When radiation beam transmits through a layer of medium with particles, radiation intensity decreases. The transmission function is determined as

$$T = \exp(-\alpha_{ext} \cdot h) , \quad (2)$$

where h is medium layer thickness.

To compute the extinction characteristics, it is necessary to use the dimensionless value such as extinction efficiency factor:

$$Q_{ext} = \frac{S_{ext}}{S_{sq}}, \quad (3)$$

where Ssq is the area of particle geometrical projection on the detector surface crystal shadow.

The software complex uses two methods to compute Qext among many other incident radiation scattering and extinction properties. First method utilizes Bohren-Huffman-Mie algorithm for solving the scattering problem of the plane wave on the sphere [3]. This algorithm returns a precise solution and is not compute-intensive. However, its application is limited to simple highly-symmetric shapes. This work uses the most common Mie algorithm for spheres only.

The second method is discrete dipole approximation (DDA) [4]. By using DDA method, it is possible to solve the problem of plane wave scattering on a particle of arbitrary shape and composition. While conceptually easy, the algorithm is iterative and computation-intensive. Nonetheless, it can solve the task with any specified accuracy given sufficient computational resources.

The software complex utilizes both of these methods as a part of its calculation routine. However, for a proper study of spectral-wave dependence of extinction, it is necessary to use a priori information on particle nature and select acceptable wavelength ranges for laser sensing. The numerical model uses a non-absorbent medium with particles that can absorb and scatter light to a varying extent.

Software complex model

To calculate the optical characteristics of the medium, we should consider a number of input parameters. They include wavelength of the incident radiation, the refractive index and thickness of the medium layer, particle sizes, particle concentration and spectral dependence of the complex refractive index.

The software complex designed for studying optical radiation extinction and transmission should satisfy a number of requirements. Such requirements include modularity, usage convenience, possibility of using custom input data sets and ability to record output data as well as change its visual appearance. The functional scheme of the developed software complex is shown in Figure 1.

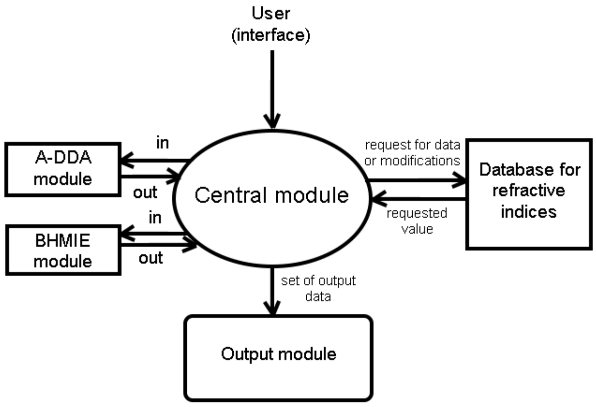

Figure 1. Software complex functional scheme

The central module acts as a pivot of the complex, receiving input data via user interface, sending commands to computation modules and sending the results to the output module. The user can specify whether to calculate a single value or a range of values with a varying parameter. In the case of varying parameter, a set of the resulting data in sent to the output module.

The user can specify which computation module needs to be used – BHMIE or A-DDA. The modules use Mie or discrete dipole approximation methods, respectively. The input data is received via user interface and collected by central module after processing. Since A-DDA module calculations can require a considerable amount of time, it is run in a separate thread with a separate window that displays computation progress as well as processing log.

Determining optical properties of the radiation transformed by a medium requires considering materials with spectral dependences of the complex refraction index. Therefore, it is very convenient to use a complex refraction index database. Once material database is loaded, its contents are added to the user interface. The screenshot of the central module displaying database contents is shown in Figure 2.

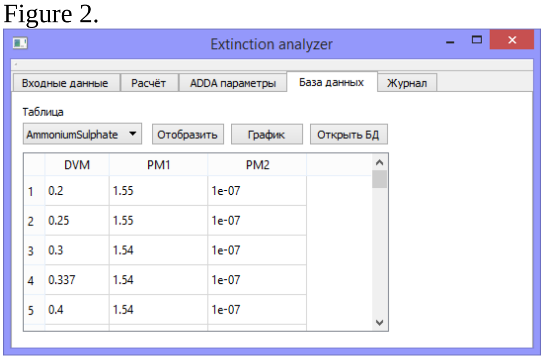

Figure 2. Screenshot of the database for refractive indices

When calculations are complete, central module gathers the output data into a single set and sends it to the output module. The output module stores the data received in this session and can display it in both text and graphical form. For research purposes, the data visualization is the most important aspect. The output module features a number of tools to display calculation results in a more convenient way, adding multiple data sets on a single graph or changing the curve style and color for visibility. The screenshot of the output module is shown in Figure 3.

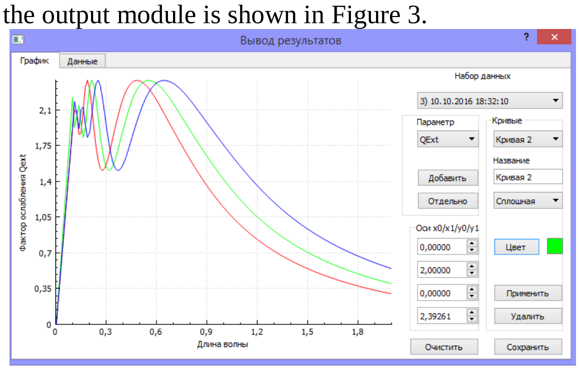

Figure 3. Screenshot of the output module graph

Implementation tools

The prototype version of the software complex for determining optical radiation extinction and transmission was written on C++ language and utilizes free Qt libraries. Qt allows to compile the source code for most of the known platforms, which can extend the application field of the software.

BHMIE calculation module uses classic Bohren-Huffman-Mie algorithm for solving the scattering problem of the plane wave on the sphere. The algorithm was rewritten for C++ programming language and further modified to fit the software complex.

Discrete dipole approximation calculation module uses free ADDA application designed by Maxim Yurkin. Software complex provides a basic interface that allows to generate a series of commands for ADDA running in background. After processing is complete, central module reads and stores the results.

Output module uses free QCustomPlot library [5] that provides a convenient way for customized graph visualization.

Conclusion

A software complex designed for determining optical radiation extinction and transmission was presented in this paper. Its modular architecture and ability of cross-platform code compilation allow for easy modification due to possible changes in requirements. The described software can run a number of calculations and visualize them in a way convenient to study and find useful dependences. The developed complex is a practical solution for researching optical radiation transformed by a medium containing particles of various sizes and natures.

References

1. Eastman R., Warren S.G. Variation in cloud cover and cloud types over the ocean from surface observations // J. Climate. – 2011. – V. 24. – pp. 5914-5934.

2. Shefer O.V., Loskutov V.V. Numerical model of water medium with methane inclusions // International Siberian Conference on Control and Communications, SIBCON-2016, Proceedings. – Moscow: Institute of Electrical and Electronics Engineers Inc., 2016.

3. Bohren C.F., Huffman D.R. Absorption and scattering of light by small particles. / Wiley-VCH Verlag, New York, 1983.

4. Yurkin M.A., Hoekstra A.G. The discrete-dipole-approximation code ADDA: capabilities and

known limitations // J. Quant.Spectr. Rad. Trans. – 2011. – V. 112. – pp. 2234-2247.

5. QCustomPlot - Introduction [Web resource] / Qt Plotting Widget QCustomPlot. – URL: http://qcustomplot.com/index.php/introduction (reference date: 11.10.2016).