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Neural networks for aerosol particles characterization

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ABSTRACT

Multilayer perceptron neural networks with one, two and three inputs are built to retrieve parameters of spherical homogeneous nonabsorbing particle. The refractive index ranges from 1.3 to 1.7; particle radius ranges from 0.251 μm to 56.234 μm. The logarithms of the scattered radiation intensity are used as input signals. The problem of the most informative scattering angles selection is elucidated. It is shown that polychromatic illumination helps one to increase significantly the retrieval accuracy. In the absence of measurement errors relative error of radius retrieval by the neural network with three inputs is 0.54%, relative error of the refractive index retrieval is 0.84%. The effect of measurement errors on the result of retrieval is simulated.

1. Introduction

Analysis of concentration and optical properties of aerosols is an urgent problem for many scientific and technological applications: the study of climate change, remote sensing, medicine [1,2], etc. Therefore, the development of optical sensors to analyze aerosols is a vital issue in the engineering and instrument-making industry. There is a growing interest in developing particle counters, which are based on the measurement of radiation scattered by a single particle [3–13]. These devices (nephelometers) allow to measure size and concentration of particles.Two main types of design of polar nephelometers can be differentiated [4]. The first one uses a single detector adjustable to different angles [4–7]. The second one measures simultaneously the light scattered at a set of angles with a set of detectors, positioned around the test space [8–12] (see Fig. 1). The first type has variable angular resolution, whereas the second type has limited angular resolution but it possesses high operation speed.

The intensity of the scattered light depends on the size and the refractive index of the particles [13]. For aerosol particles, the last varies within a range from about 1.3–1.7 [14]. To reduce errors and increase the reliability of the assessment of particle sizes typically involve the measurement of radiation scattered at several angles. It is important to select the most informative scattering angles. For example, in [15] it is found that particulate minimum dependence of the refractive index is achieved if the measured radiation is scattered at intervals from 10° to 30° and from 150° to 170°.

In most studies on the problem of retrieval of size and refractive index of particles based on the nephelometric measurements, homogeneous spherical particles are considered. Several approaches are proposed.

In [16] a theoretically rigorous solution of size and refractive index retrieval of spherical particles by the angular dependence of the scattered radiation in the range of angles from 0° to 180° is obtained. However, it is practically impossible to implement the system of measurement of the scattered radiation in such a wide range of angles.

In [4,17–19] the trial and error method is used. Typical for inverse problems instability manifested in the existence of many local minima of the objective function. Thus, it is necessary to solve the problem of finding the global extremum of a function of many variables. This is a difficult

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