Parallel Computational Technologies for Radiation Transfer Problem

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The research of radiation transfer processes is necessary in a lot of problems including engineering and astrophysical applications. Such problems arise, for example, at the description of processes occurring in stellar atmospheres, in plasma physics and plasma diagnostics, development of lasers [1,2]. The numerical modeling of these processes is connected to the large difficulties caused by non-linearity and non-locality of a problem, singular behaviour of researched values (boundary layers on various variable, large scales of values). It results in necessity to store the large files and to make the large volumes of calculations, that, in turn, results that the calculations of real problems become impracticable for acceptable time, and there is a urgent necessity of use of parallel technologies and multiprocessor computing systems.

The authors during a number of years carried out researches in this direction. For a case of the elementary geometry — flat layer, the effective enough technique of solving the equations of radiation transfer for multicomponent media combining numerical and analytical methods and using parallel algorithms for multiprocessor computer systems was created [3,4]. It includes a complex of the programs and user interface for the researcher.

The flat layer of thickness L is considered, in which all values depend on one coordinate x directed perpendicularly to a surface of a layer. Besides we consider a stationary case. In a layer there is a medium containing mixture from Γ component, γ — number components. The atoms by everyone γ -component of a mixture can be in several states with a different degree of excitation and ionization. Each condition is determined in pair of indexes (iI), where I — degree of ionization, i — number discrete exited condition for the given degree of ionization. The relative share of ions γ -substance staying in a condition with the data (iI), is designated through $c_{iI}^{(\gamma)}(x)$ and refers to as population of this state. Populations satisfy to system of the kinetic equations

$$-c_{iI}^{(\gamma)} \sum_{iI \neq jJ} W_{iI,jJ}^{(\gamma)} + \sum_{iI \neq jJ} c_{jJ}^{(\gamma)} W_{jJ,iI}^{(\gamma)} = 0,$$

where the summation is made for all types of states which are taken into account for γ -substance.

The substances in a mixture are connected only through a field of radiation: the coefficients $W_{jJ,iI}^{(\gamma)}$ are some functionals from radiation intensity $I(x,\mu,\varepsilon)$, where μ — cosine of an angle between a direction of flight of quantum and axis x, ε — energy variable.

The radiation transfer equation in a considered case accepts a kind

$$\mu \frac{dI}{dx} = -\kappa I + S,$$

thus factor of absorption $\kappa(x,\varepsilon,\mu)$ and source function $S(x,\varepsilon,\mu)$ by a rather complex depends on all populations $c_{iI}^{(\gamma)}(x)$.

The given nonlinear integro-differential system should be complemented by boundary conditions for function $I(x,\mu,\varepsilon)$: we prescribe intensity of radiation falling on boundary of layer.

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It is supposed, that the considered flat layer, generally speaking, is non-uniform: it can consist from several sublayers, and in each sublayers the medium can have the own characteristics.

For solving the problem the authors develop two various algorithms, one of which is based on a combination asymptotic representations and explicit representation of the solution of the transfer equation at known a source function and absorption coefficient, another is based on representation of the solution $I(x,\mu,\varepsilon)$ as an interpolational Lagrange polynomials on knots of interpolation —roots of Chebyshev polynomials.

The development of two various algorithms at the first stage of work was connected to various scientific interests of the co-authors, but further has appeared rather useful in different aspects. The opportunity of comparison of the calculations, which have been carried out on different techniques, essentially facilitated creation of the programs and their testing. For this rather difficult problem presence of two competitive methods, the coincidence of computations allows to receive more reliable and proved results of modeling. In process of development of a technique and transition to application of parallel technologies the presence of two algorithms has appeared useful to creation of the mobile parallel codes.

Now technique allows us to compute problems for multicomponent media in multiplayer region, the number of radiating transitions in model can achieve several tens. For both algorithms there are programs developed in MPI to system of parallel programming. Besides for one of algorithms the parallel code is developed with use of DVM-system.

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