Preface

I am glad to introduce *Multicomponent and Multiscale Systems: Theory, Methods and Applications in Engineering*.

When I started this book project, I proposed to write a book about my recent advances in mathematical modelling problems to multicomponent and multiscale systems. I considered the upcoming areas in material modelling, which include transport and reaction flow simulations and also electronic applications with electromagnetic fields.

I organized this book in combining theoretical and also application to practical problems. While multicomponent and multiscale systems are very new problems, the early stage of such a field needs such a book to explain in a theoretical and also a practical manner the tools and methods to solve such problems.

I have tried to fill the gap between numerical methods and the applications to real problems. I present rigorously the fundamental aspects of the numerical methods with their underlying analysis and applying such schemes to real-life.

This monograph is in the field of technical and physical simulation problems in engineering and sciences. Based on the theoretical framework in methods and structures of applied mathematics, it concludes with numerical approximations of multi-component and multi-scale problem. A main motivation of the book came from students and researchers in different lectures and research projects.

In this monograph, we describe the theoretical and practical aspects of solving complicated and multi-component and multi-scale systems, which are applied in engineering models and problems.

In the book, we are motivated to describe numerical receipts, based on different multi-scale and multi-component methods, that allow to apply truly working multi-scale and multi-component approaches. Nowadays, one of the main problems in multi-scale and multi-component systems is the gap between several models based on different time- and spatial-scales. Often the drawback of applying standard numerical methods, e.g. explicit time-discretization schemes, instead of working multi-scale approaches, e.g. multi-scale expansion methods, is, that we have a dramatic limiting factor, e.g. very small time- or spatial steps (due to resolving the finest scale). Such limiting factors did not allow to solve engineering complexity and industrial advancement is impossible to obtain. Here, we fill the gap between numerical methods and their applications to engineering complexities of real-life problems.

Such engineering complexities are delicate and need extraordinary treatment with special solver and tools to overcome the difficulties and restrictions of time- and spatial steps.

Therefore, we discuss the ideas of solving such multi-component and multi-scale systems with the help of non-iterative and iterative methods. Often such methods can be related to splitting multi-scale methods to be taken into account to decompose such problems to simpler ones. Such decomposition allows to treat the complex systems in simpler ones and skip the restriction of the finest scale to the solver methods, while we can apply individual scale to the decomposed system.

We discuss analytical and numerical methods in time and space for evolution equations and also nonlinear evolution equations with respect to their linearization and relaxation schemes.

All problems are related to engineering problems and their applications. I have started from reactive flow and transport models, which are related to bioremediation, combustion and various CFD applications, to delicate electronic models, which are related to plasma transport and flow processes in technical apparatus.

The main motivation is to embed novel multiscale approaches to complex engineering problems such that it is possible to apply a model-reduction. Thus, it is possible that parts of the model can be reduced or for those based on multiscale or multicomponent approaches, the data-transfer between fine and coarse grid is done, in a way that each scale is considered.

The outline of the monograph is given as:

1. Introduction (outline of the book)
2. General principles for multi-component and multiscale systems
   a. Multi-component Analysis (separating of components)
   b. Multiscale analysis (separating of scales)
   c. Mathematical methods
3. Theoretical part: functional splitting:
   a. Decomposition of a global multi-component problem
   b. Decomposition of a global multiscale problem
4. Algorithmic part
   a. Iterative methods
   b. Additive methods
   c. Parallelization

5. Models and applications
    a. Multicomponent applications
        i. Application of multicomponent fluids
        ii. Application of multicomponent kinetics
        iii. Analytical methods for a multicomponent transport model
    b. Multiscale applications
        i. Additive splitting method for Maxwell-equations
        ii. Nonuniform grids for particle in cell methods
6. Engineering applications (real-life models)
    a. Multicomponent applications
        i. Application of a multicomponent model in a plasma-mixture problem
        ii. Application of a multicomponent model in a biological problem (glycolysis)
    b. Multiscale applications
        i. Application of a multiscale model in a stochastic problem
        ii. Application of a multiscale model in a code-coupling problem
        iii. Application of a multiscale model in a dynamical problem
        iv. Application of a multiscale model in a particle transport problem
        v. Application of a multiscale model in plasma applications
        vi. Application of a multiscale model in complex fluids
7. Conclusion (fields of application and future ideas)

Based on the outline of the book, we hope that we could increase the attention of both industry and scientists; theoretical and practical aspects are illustrated and considered in an equal way.

Dallgow-Doeberitz Juergen Geiser
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