Development of a software architecture concept for solving singularly perturbed problems in semiconductor electronics

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Andrii Bomba
National University of Water and Environmental Engineering
Rivne, Ukraine
a.ya.bomba@nuwm.edu.ua

Igor Moroz
Rivne State University of Humanities
Rivne, Ukraine
igor_moroz@yahoo.com

Zakhar Listiev
National University of Water and Environmental Engineering
Rivne, Ukraine
z.c.listiev@nuwm.edu.ua

Abstract **– The software architecture for automated solving of singularly perturbed problems in semiconductor electronics is presented. The system is based on the boundary correction method and domain-driven design (DDD). The developed software architecture integrates an artificial neural network for analyzing types of mathematical subproblems and selecting the most suitable method for solving them. The use of modern information technologies such as parallelization, cloud computing, and symbolic computations enables a new level of automated modeling. The research results demonstrated the effectiveness of the proposed approach in solving complex mathematical problems with singular perturbations.**

Keywords **– Singularly perturbed problems, domain-driven design; artificial neural network; automated modeling; boundary correction method; symbolic computations.**

I. Introduction

Singularly perturbed problems are common in the theory of differential equations, especially in physics and electronics, where they are used to model processes in complex technical systems such as plasma diodes. These problems include small parameters that significantly affect the behavior of solutions, particularly their asymptotic properties [1,2]. Solving such problems using classical numerical methods is inefficient due to sharp transitions in the solution, requiring extensive computational resources. The boundary correction method, one of the asymptotic methods, allows approximate solutions by expansions in small parameters. With advancements in computing resources and the emergence of new information technologies, such as artificial intelligence and cloud computing, etc. [3-6], solving singularly perturbed problems can be simplified and optimized.

II. Software Architecture

The developed architecture is based on domain-driven design (DDD) principles [4,5], ensuring efficient organization of the software system for solving singularly perturbed problems. The system decomposes the primary problem into subproblems using the boundary correction method. Each subproblem is analyzed by an artificial neural network, which determines the optimal method—analytical or numerical—for solving it. The software architecture consists of several interconnected blocks. The symbolic transformation block ensures the formal transformations of the initial problem and builds recurrent subproblem sequences. The numerical solution block applies modern computational methods to find exact or approximate solutions for each subproblem. The intelligent analysis block is responsible for identifying the type of mathematical problem and selecting the appropriate solution method using artificial neural networks. Finally, the result aggregation block consolidates the subproblem results into a single solution for the main problem.

The implementation of the software system uses modern tools such as the .NET framework for parallelized computations [3] and the Math.NET library for symbolic and numerical computations. An important component is the use of Microsoft Azure cloud technologies to scale computational resources. The architecture is modular, allowing new methods to be easily added or adapted for solving other problems. Interaction between different modules, such as symbolic transformations and numerical solutions, is achieved through clearly defined interfaces, making the system flexible and extendable.

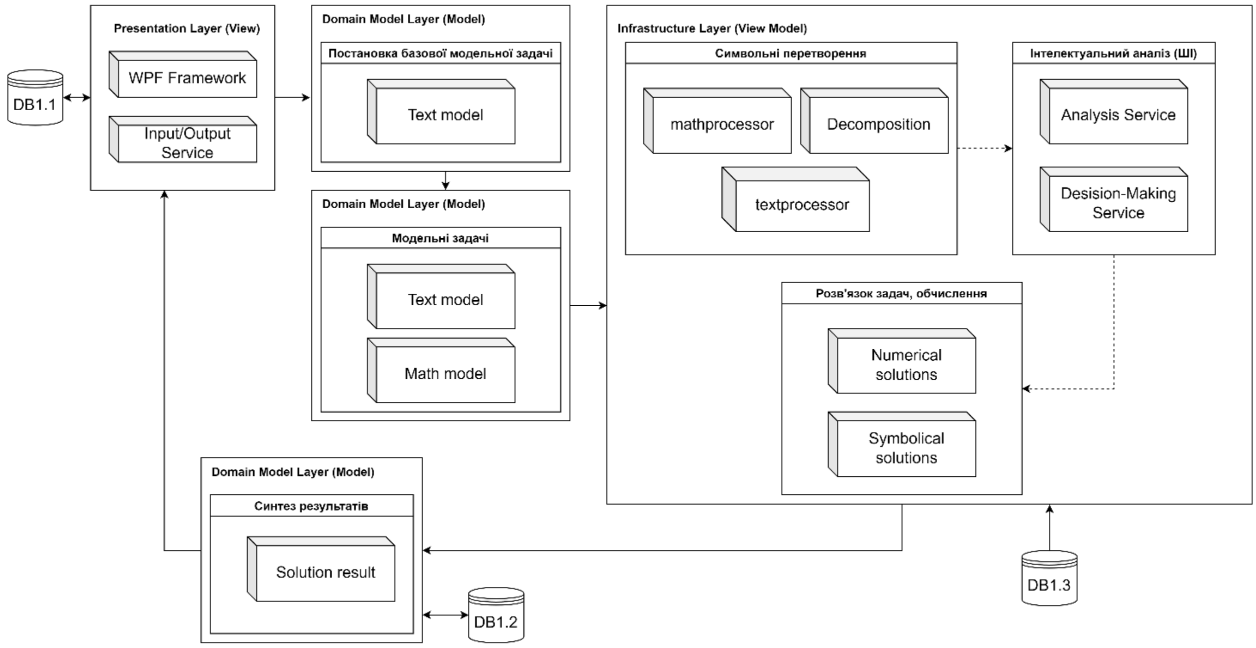

Fig. 1. Modeling and analysis software architecture using WPF, domain models, and infrastructure services

CONCLUSION

The proposed software architecture demonstrates significant effectiveness in solving singularly perturbed problems using the boundary correction method and modern information technologies. The inclusion of artificial neural networks for the automatic selection of solving methods greatly enhances the system's capability by improving both the accuracy and speed of computations. This approach minimizes manual intervention, allowing the system to adapt dynamically to various problem types by choosing the most appropriate computational technique, whether analytical or numerical. Such automation not only reduces computational overhead but also increases the overall efficiency of the process, making it particularly valuable for complex and resource-intensive problems.

The modular nature of the architecture is another key advantage, allowing for continuous improvement and adaptation. New methods and technologies can be integrated into the system as they emerge, ensuring that the architecture remains relevant and capable of tackling future challenges in computational modeling. This modularity also supports cross-disciplinary applications, as the architecture can be extended to solve problems in fields outside semiconductor electronics, such as physics, engineering, and other areas that involve differential equations with singular perturbations.

In conclusion, this software architecture represents a significant advancement in automated problem-solving for singularly perturbed systems. By combining advanced computational methods, artificial intelligence, and cloud computing, the architecture provides a robust, scalable, and flexible framework that can be adapted to a wide range of complex mathematical problems. Future work could focus on expanding the system's capabilities by integrating more sophisticated machine learning techniques and exploring its applications in other domains, such as fluid dynamics or material science, where singularly perturbed problems frequently arise. This architecture sets the stage for future innovations in computational modeling, providing a powerful tool for researchers and engineers in multiple fields.

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