

REVIEW

by Prof. Dr. Todorka Atanasova Glushkova

of a dissertation thesis submitted for the award of the educational and scientific degree “Doctor”

in: Field of higher education 4. Natural Sciences, Mathematics and Informatics,

Professional field 4.6. Informatics and Computer Science,

Doctoral program: Informatics

Author: **Pavel Aleksandrov Kyurkchiev**

Title: *“Methods and Architectural Approaches for Semantic Indexing and Simulation of Dynamic Processes in a Cloud Environment”*

Scientific supervisor: Prof. Dr. Anton Iliev, Paisii Hilendarski University of Plovdiv

1. General Description of the Submitted Materials

By Order No. ПД-22-1415/17.07.2026 issued by the Rector of Paisii Hilendarski University of Plovdiv, Prof. Dr. Rumen Mladenov, in accordance with Article 4 of the Law on the Development of Academic Staff in the Republic of Bulgaria, Article 2(2), Article 30(3) of the Regulations for the Implementation of the Law on the Development of Academic Staff in the Republic of Bulgaria, and Article 37(1) of the Regulations for the Development of Academic Staff at Paisii Hilendarski University of Plovdiv, and in connection with the decision of the Faculty Council of the Faculty of Mathematics and Informatics, recorded in Protocol No. 34/15.07.2026, I have been appointed as a member of the Scientific Jury for the defense of the dissertation thesis entitled “Methods and Architectures Suitable for Semantic Indexing and Simulation of Dynamic Processes in a Cloud Environment” for the award of the educational and scientific degree “Doctor” in the field of higher education 4. Natural Sciences, Mathematics and Informatics, professional field 4.6. Informatics and Computer Science, doctoral program Informatics.

The author of the dissertation thesis is Pavel Aleksandrov Kyurkchiev, a PhD student at the Department of Computer Technologies of the Faculty of Mathematics and Informatics, with scientific supervisor Prof. Dr. Anton Iliev from Paisii Hilendarski University of Plovdiv.

The set of materials submitted by doctoral student Pavel Kyurkchiev in both paper and electronic format complies with Article 36(1) of the Regulations for the Development of the Academic Staff at Paisii Hilendarski University of Plovdiv and includes the following documents:

- an application addressed to the Rector of Paisii Hilendarski University of Plovdiv for opening a procedure for the defense of a dissertation thesis;
- a curriculum vitae (CV) in European format;

- minutes from the preliminary discussion at the Department of Computer Technologies and an opinion from the scientific supervisor regarding the readiness for the preliminary discussion of the dissertation thesis;
- an abstract of the dissertation thesis (in Bulgarian and English);
- a list of scientific publications related to the topic of the dissertation thesis;
- copies of the publications related to the dissertation thesis;
- a declaration of originality and authenticity of the submitted documents;
- a report on compliance with the minimum national requirements.

The doctoral student has submitted three publications related to the research topic of the dissertation thesis. All documents included in the dissertation defense package have been prepared accurately and precisely in accordance with the requirements of the Regulations for the Implementation of the Law on the Development of Academic Staff in the Republic of Bulgaria and the Regulations for the Development of Academic Staff at Paisii Hilendarski University of Plovdiv.

2. Brief Biographical Information about the Doctoral Student

Pavel Aleksandrov Kyurkchiev possesses an academic and professional background that forms the foundation for the applied value of the dissertation thesis. He obtained his Bachelor's degree (2012) and Master's degree (2013) from Paisii Hilendarski University of Plovdiv. His professional career has developed through key positions in the IT industry – from a Software Developer at BS Technologies to Technical Lead and Capability Lead at Prime Holding. In his role as a Capability Lead, the doctoral student was responsible for establishing technical standards and supporting the development of engineering teams, which directly corresponds to his scientific interests in the field of knowledge management and advanced information processing approaches. Particular attention should be given to his experience in the migration of online platforms from monolithic (SOA) architectures to microservice-based architectures, which provided the foundation for the development of the prototype presented in the dissertation – the Alpha Cloud Data Hub.

Since 2018, Pavel Kyurkchiev has been an Assistant Professor at the Faculty of Mathematics and Informatics of Paisii Hilendarski University of Plovdiv, where he successfully applies his extensive business and technological experience in an academic environment.

3. Relevance of the Topic and Appropriateness of the Defined Goals and Objectives

The dissertation thesis of Pavel Kyurkchiev is dedicated to a current and significant scientific and applied problem related to the “vocabulary mismatch” problem, which hinders the reuse of knowledge and transforms repositories into unstructured archives where valuable data, knowledge, and models remain undiscoverable.

The main goal of the dissertation thesis is to research and apply the “System Dynamics” formalism through contemporary methods for semantic analysis and vector-based search. The author defends the hypothesis that the integration of a microservice cloud architecture with methods for vector semantic analysis will enable overcoming the problem of “vocabulary mismatch” in dynamic models, thereby improving search accuracy through a transition from syntactic comparison (based on variable labels) to semantic comparison (based on topological and functional structure).

The topic fully corresponds to Professional Field 4.6 “Informatics and Computer Science”, as it includes: modeling of information processes; development of software systems; integration of AI technologies; data analysis and processing; and design of information architectures.

To achieve the defined goal, four main objectives have been formulated, which are logically connected to the overall aim and lead to its realization. They include analysis of the current state and definition of an architectural model, development of a methodology for transformation and search, design and software implementation of a prototype environment, and experimental evaluation and validation of the proposed solutions.

The research topic of the dissertation thesis is undoubtedly relevant and significant both from scientific and practical perspectives, while the formulated goal and objectives are appropriate, specific, and adequate to the subject of the research.

4. Knowledge of the Problem, Style, and Language

The author demonstrates a high level of knowledge of the research area, identifying the existing limitations related to “semantic blindness” and closed formats. The dissertation thesis is characterized by a high academic style and precise use of terminology from the fields of NLP, system dynamics, and cloud architectures.

The bibliography contains 146 literary and online sources. All references are correctly cited in the text. It is noteworthy that the literature review covers both classical studies and a significant number of recent scientific publications from the last few years. This demonstrates the doctoral student’s effort to follow and critically evaluate contemporary trends and to position the research within the context of the latest technological developments.

The principles of good language use and scientific writing style for research works have been followed. The text of the dissertation thesis is clear, precise, and analytical.

5. Research Methodology

The methodology used in the dissertation thesis is comprehensive and appropriate to the defined objective. It combines fundamental theoretical, analytical, experimental, and applied research approaches. The study follows the principles of the Constructive Research Method, in which a theoretical model for solving the problem (the lack of semantic connectivity) is defined and

subsequently materialized through the creation of an innovative artifact (the Alpha Cloud Data Hub software prototype).

A Deductive Approach is applied in the analysis of architectural models – from the general principles of microservice architectures and Domain-Driven Design (DDD) to the specific implementation of specialized services for simulation and search. Through the decomposition of the research domain, individual subdomains (Domain, Infrastructure, Application Services) are isolated, enabling their independent development and testing.

6. Characteristics and Evaluation of the Dissertation Thesis

The main text of the dissertation thesis has a volume of 140 pages and consists of an introduction, five chapters, a conclusion, a list of the author’s publications related to the dissertation thesis, three appendices, and a list of references. The thesis contains 18 figures and 12 tables.

The **Introduction** substantiates the practical significance of the topic. The author justifies the relevance of the problem by identifying the “paradox of abundance” and “vocabulary mismatch” as the main barriers to the reuse of dynamic models in cloud infrastructure. The goal, objectives, and working hypothesis are defined, focusing on the integration of a microservice architecture with vector semantic analysis.

The **first chapter** has a theoretical and analytical character. It examines the evolution of simulation environments from desktop applications to Simulation-as-a-Service. The author compares discrete-event modeling, agent-based modeling, and system dynamics, selecting the latter due to its mathematical rigor. The platforms Stella, AnyLogic, and Matlab are analyzed, highlighting their limitations as “black boxes” with closed formats that are difficult to search semantically. The Missing Middle is defined – the need for a cloud ecosystem that combines system dynamics with AI-based analysis.

The **second chapter** examines the theoretical foundations and the mathematical formalism used. The concepts of causal loop diagrams and stock-and-flow diagrams are explained. Regarding numerical methods, the explicit Euler method is selected for solving differential equations due to its semantic clarity in a cloud environment. Vector representations (Embeddings), the BERT architecture, and the ONNX standard for portability of machine learning models are discussed. The use of specialized repositories (such as Qdrant) and approximate search algorithms is justified.

The **third chapter** is dedicated to the development of a methodology for transformation, simulation, and intelligent search and presents the author’s main contributions from an algorithmic perspective. The following are discussed: the translation algorithm (describing how visual graph models are transformed into mathematical equations through topological sorting), semantic linearization (an original method for converting graph topology into linear text through depth-first traversal), cycle tokenization, and the introduction of an appropriate marker for preserving information about feedback loops in the model.

The **fourth chapter** presents the architecture of the Alpha Cloud Data Hub platform and describes the software implementation of the proposed prototype. The architectural framework of the microservice model is designed according to the principles of DDD (Domain-Driven Design) and Event-Driven Design, using RabbitMQ for asynchronous communication. The main components are presented: Angular SPA (interface), Hermes Processor (vectorizer), and hybrid storage (Polyglot Persistence) in MongoDB and Qdrant. The proposed local execution approach provides a solution for running AI models locally through ONNX, ensuring independence from external services and data protection.

The final, **fifth chapter**, examines experimental validation and analysis of the results. The test corpus includes 63 models from different domains (economics, ecology, epidemiology). The validation of the simulator demonstrates proven accuracy of calculations through the SIR and Lotka–Volterra models. The semantic approach achieves F1-Score = 1.00 at a similarity threshold of 0.72, completely eliminating the noise inherent in traditional keyword-based search. A search latency of approximately 1.9 seconds was measured, which is acceptable for user experience (UX).

The **Conclusion** presents the main contributions of the dissertation thesis. A table summarizes the relationship between the contributions, objectives, dissertation structure, and publications. The doctoral student's formulated perspectives for future development of research on the topic make a positive impression. The dissertation thesis includes information about participation with two presentations at scientific conferences, as well as the doctoral student's involvement in projects funded by the Scientific Research Fund at Paisii Hilendarski University of Plovdiv.

7. Contributions and Significance of the Research for Science and Practice

The contributions are consistent with the goals and objectives defined in the dissertation thesis and can be summarized in two main areas – scientific-applied and applied contributions.

Scientific-applied contributions:

- Development of an algorithm for semantic linearization of graph models, transforming nonlinear topology into a sequential context aligned with the requirements of modern NLP models.
- Definition of a serialization strategy with explicit tokenization of cyclic dependencies to prevent information loss during vectorization.

Applied contributions:

- Design and software implementation of the Alpha Cloud Data Hub cloud platform based on a microservice architecture.
- Integration of vector databases for intelligent knowledge retrieval and overcoming terminological differences between scientific domains.

I consider that the stated contributions are real, well-argued, and to a significant extent proven in the dissertation thesis. They can be attributed to the categories of enrichment of existing scientific knowledge and scientific achievements in practice, as well as the creation of new and modification of existing methods, approaches, and models for solving the tasks defined in the dissertation thesis. I consider that the objective of the doctoral research has been achieved.

Overall, the development perspectives proposed by the PhD student are realistic, relevant, and demonstrate potential for further advancement of the achieved scientific and applied results.

8. Evaluation of the Publications Related to the Dissertation Thesis

Doctoral student Pavel Kyurkchiev has submitted a total of three publications related to the topic of the dissertation thesis, of which two are independent publications and one publication in which he is the first author. Publication No. 3 is indexed in Web of Science (WoS) and Scopus, with IF = 4.6 and quartile Q2. This confirms the relevance of the dissertation topic, the significance of the achieved results, and their applicability. I consider that the results of the dissertation have been adequately presented to the scientific community.

The Minimum National Requirements under Article 2b, paragraphs 2 and 3, respectively the requirements under Article 2b, paragraph 5 of the Law on the Development of Academic Staff in the Republic of Bulgaria, as defined in the Regulations for the Implementation of the Law on the Development of Academic Staff in the Republic of Bulgaria for the acquisition of the educational and scientific degree “Doctor” in Professional Field 4.6, have been fulfilled. According to these requirements, at least 30 points are required in Group of Indicators G, while the doctoral student has achieved 60 points, representing 200% fulfillment of the requirements.

Pavel Kyurkchiev has submitted a declaration of originality and authenticity. No plagiarism has been established, according to the legally prescribed procedure, in the submitted dissertation thesis and scientific publications.

9. Personal Contribution of the Doctoral Student

The personal contribution of the doctoral student and his ability to define research tasks, solve problems, and derive logically justified conclusions are clearly evident from the presented work. I have no doubts that the dissertation thesis and the obtained results are the work of the doctoral student, or, when they have been achieved within the framework of collaborative research, the contribution of the doctoral student is clearly distinguishable.

10. Abstract

The abstract complies with the requirements of the Regulations for the Implementation of the Law on the Development of Academic Staff in the Republic of Bulgaria. Its volume is 32 pages, it is

very well structured, and it accurately reflects the content of the dissertation thesis, the main aspects of the research, and the achieved results.

11. Critical Remarks and Questions

The dissertation thesis is characterized by the relevance of its topic, good practical orientation, and a significant amount of research and scientific-applied activity. Alongside its undeniable merits, the following remarks can be made:

- The research focuses primarily on deterministic systems (ODEs), without providing a detailed consideration of stochastic processes, which could further expand the scope of the simulation core.
- Although the thesis is excellently structured and visually well presented, the extensive use of English terminology directly within key conceptual figures is noticeable (for example, Figure 1, Figure 4.1, and Figure 4.3), where terms such as “Vocabulary Mismatch,” “Semantic Discovery,” “Inference,” and “Mean Pooling” are presented without Bulgarian equivalents. Although this is a standard practice in the IT industry, a more complete adaptation of the graphical materials into Bulgarian would improve the accessibility of the presentation for a broader academic audience.
- The achieved perfect result (F1-Score = 1.00) represents an exceptionally high achievement. However, it should be noted that this result was obtained on a controlled corpus of 63 models, selected by the author as a “Gold Standard”. As the doctoral student correctly points out in the analysis of limitations, when transitioning to real industrial systems containing thousands of models, the density of the vector space will increase significantly, which would require the implementation of more complex and adaptive similarity thresholds.

These remarks are mainly of a discussion-oriented nature and do not diminish the high scientific and applied value of the dissertation thesis.

Question: Considering the cloud architecture, how would the latency change when transitioning from the Euler method to a more precise but computationally intensive method such as Runge-Kutta 4 (RK4) in real-time execution?

12. Recommendations for Future Use of the Dissertation Contributions and Results

I recommend the further development of the Alpha Cloud Data Hub as an open-source platform and the integration of Large Language Models (LLMs) for the automatic generation of textual descriptions of models based on their topology.

The remarks and recommendations made do not diminish the scientific value of the achieved results but rather outline opportunities for further development and improvement of the research.

13. Personal Impressions

I have personally known Pavel Kyurkchiev in his role as an Assistant Professor at Paisii Hilendarski University of Plovdiv since 2018, and I highly appreciate him as an exceptionally well-prepared professional and a dedicated lecturer.

His ability to successfully combine academic activities with his extensive practical experience gained through key positions in the IT industry – as a software architect, technical lead, and Capability Lead – is truly impressive.

Through the systematic preparation of teaching resources and assignments, fully based on real-world industry practices, he successfully introduces students in IT-related programs to contemporary challenges in the software development process..

CONCLUSION

The dissertation thesis of Pavel Aleksandrov Kyurkchiev represents a completed scientific study offering innovative solutions at the intersection of system dynamics, cloud technologies, and AI. The defined goal and objectives have been successfully achieved. The obtained results have a scientific-applied and applied character and meet the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria, the Regulations for the Implementation of the Law, and the relevant Regulations of Paisii Hilendarski University of Plovdiv. Pavel Kyurkchiev possesses in-depth theoretical knowledge in the field of Informatics and demonstrates the ability to conduct independent scientific research.

All of the above provides sufficient grounds for me to give a **positive evaluation** of the dissertation thesis and to propose that the respected Scientific Jury award the educational and scientific degree “Doctor” to Pavel Aleksandrov Kyurkchiev in the field of higher education 4. Natural Sciences, Mathematics and Informatics, professional field 4.6 Informatics and Computer Science, doctoral program **Informatics**.

06.08.2026 г.

Reviewer:

/prof. Todorka Glushkova, PhD/