

## ACADEMIC STATEMENT

**Concerning:** Dissertation for awarding an educational and scientific degree "Doctor" in professional field "Economics" 3.8, doctoral program "Analytical Research on Data (Data Science)", Sofia University "ST. KLIMENT OHRIDSKI"

**Author:** Sergey Sergeev Vichev

**Title:** Application of machine learning methods to solve business problems - multi-agent automated systems for solving complex tasks in databases using large language models.

**Reason for submitting the academic statement:** participation in the scientific jury, according to the Order RD38-220/24.04.2025 of the Rector of Sofia University "St. Kliment Ohridski".

The author Sergey Sergeyev Vichev has been studying as a full-time PhD student in the doctoral program "Analytical Research on Data (Data Science)", at the Department of Statistics and Econometrics, professional field 3.8 "Economics", from 2021 to 2024. In parallel, he is developing his professional career in software systems and data analysis (data science). This has a positive impact and contribution to the practical-applied quality of the submitted work.

The work has a total length of 171 pages and follows a structure in three chapters. A total of 118 literature sources are used, mostly in English. Mandatory attributes for this kind of research are correct and logically defined. Definitely, the topic has a high degree of relevance and importance in the context of the development of artificial intelligence-based systems. The work is structured in three chapters: 1) theoretical foundations; 2) methodology of building an automated system for solving in-depth business problems on database information, and 3) simulations and experiments with automated database decision systems.

The first chapter clarifies the theoretical foundations of the nature of large language models (LLMs) and their application in the business. Particular attention is paid to their multimodality, the retrieval augmented generation (RAG) systems, and the focused learning of LLMs. Prompts for training models and their thinking abilities are also covered. The basics of LLMs implementation in business are defined. The conceptual setting of the research is also featured in this section, motivating the focus on the SQL systems. The second chapter is about the methodology of building automated systems to solve business problems and

database information usage. In this part the focus is on forecasting methods with large language models as well as data embedding processes. The chapter also clarifies the architecture of RAGSQL, as well as various implementation selections for this system. In the last chapter, simulations and experiments are conducted with the developed software system. It presents the principal applications of the system and exploration of the critical components.

The scientific work achieves its goal and reaches the fundamentals of developing multi-agent automated systems based on large language models and their integration with databases. The author's practical experience and search for highly applied results is definitely evident in this part of the text. The general impression of the thesis is of a very good knowledge of the problems and of making a thorough analysis. After getting know the texts, there is no suspicions and doubt about the authorship.

A number of contributions can definitely be pointed out in the work. At the core is the architecture developed for an automated problem-solving analysis system based on multi-layer coordination between individual LLM agents and analysis of the resulting queries (RAGSQL). A novel approach for specialized model learning with semantic embedding is proposed in the context of BIRD. A practical application of ReAct-based systems is also proposed. Different simulated views of the system operation are presented using the SQL Murder Mystery methodology. For this particle solution, a simplified model is built at the beginning, then upgraded to the use of an LLM supervisor and several LLM database analyzers. In this way, the aim is to represent the system performance under different conditions and to track the working.

Three independent publications and a fourth one co-authored with the scientific supervisor are attached to the work. Overall, they promote the development, with some of them making further elaboration of the topic towards the logistics sector. The scientific abstract of the dissertation can also be evaluated positively.

Critical comments can be made to the work, and I will highlight some of them that are more fundamental by their nature. Overall, the link to business and management can be strengthened by going deeper into the functional areas management problems of the organization. In this way, areas of application in the business environment can be more clearly defined as specific processes within the organization. The topic can also be expanded into interdisciplinarity and linkage

between functional areas. Separately, the work would benefit if the motivation for choosing SQL databases is broadened and explained by the specific needs of business organizations.

In spite of the above-mentioned remarks, the work entitled "Application of machine self-learning methods for solving business problems - multi-agent automated systems for solving complex problems in databases using large language models", prepared by Sergey Sergeev Vichev, represents actual scientific research, The work has scientific and applied contributions to theory and practice. The evaluations made in the academic statement provide me with grounds to propose to the distinguished members of the scientific jury to vote "For" the award of the Sergey Sergeev Vichev the degree of Doctor in the professional field 3.8 "Economics", doctoral program "Analytical Research on Data (Data Science)".

May 29th 2025

Assoc. Prof. Dr. Nikolay Dragomirov Ivanov

Sofia

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