Appendix 12b

REPORT

of dissertation for the acquisition of:

educational and scientific degree " **doctor** "	X
scientific degree **"Doctor of Science"**	
	the true is indicated by the sign "X"

Author of the dissertation:

		Junhong		Xie	UCTM
academic position	scientific degree	name	middle name	last name	workplace

Topic of the dissertation:

Intelligent Model-Based Control of Nonlinear Systems

Scientific area:

5	Technical Sciences
code	name

Professional area:

5.2.	Electrical engineering, electronics and automation
code	name

Scientific specialty:

Automatic control theory

The report was written by:

Prof.	Dr. Eng=	Elena	Georgieva	Koleva	UCTM, IE-BAS
academic position	scientific degree	name	middle name	last name	workplace

1. Meeting the minimum requirements under the Regulations:

A) The candidate meets the minimum requirements	20 points	X
B) The candidate doesn't meet the minimum requirements	0 points	
		one of the answers given is marked with the sign "X"

It is mandatory to fill in if answer B is marked. The publication activity of the candidate is analyzed. The response of the results achieved (quoted) is analyzed.
PhD student Junhong Xie presents a dissertation (worth 50 points) and 4 scientific publications related to the dissertation, which, according to the Regulations for the Application of the Law on the Development of Academic Staff in the Republic of Bulgaria (RALDASRB), receive 60 points, while the minimum required is

30 points. The candidate significantly exceeds the minimum requirements set by the Regulations. The research results have been validated through participation in international scientific forums with research presentations highlighting the main scientific contributions, as well as through a poster session at the University of Chemical Technology and Metallurgy (UCTM). Some of the results have also been utilized in two UCTM projects.

No data has been provided regarding citations of the 4 submitted publications. Notably, the candidate has demonstrated high publication activity during the period 2021–2024, with a total of 8 scientific publications indexed in Scopus.

2. The relevance of the topic of the dissertation:

A) The topic is relevant and new (there are no known results on the topic by other authors)	8 points	
B) The topic is relevant and results from other authors are known	6 points	X
C) The topic is not relevant, but results from other authors are known	2 points	
D) The topic is not relevant and no results from other authors are known	1 point	
E) The topic does not correspond to the level of dissertation	0 points	
		one of the answers given is marked with the sign "X"

The evaluation of the relevance of the dissertation must be substantiated

The relevance of the dissertation stems from the increasing complexity and nonlinearity of real-world systems in modern engineering and industry. More and more frequently, engineering and technological objects are characterized by dynamics that cannot be adequately described using linear models, especially in the presence of external disturbances, parametric uncertainty, and limited resources. This renders traditional control methods ineffective or even inapplicable in many real-world situations. Nonlinear systems such as neural networks, chemical reactors, and chaotic dynamic structures require a new generation of control approaches capable of adapting to changing conditions while ensuring high accuracy and stability.

In this context, intelligent control, which combines elements of model predictive control, adaptive control, and techniques from the field of machine learning, offers promising solutions. The application of deep neural networks and Gaussian processes in modeling and control of nonlinear systems is particularly relevant, as it enables automatic learning from data, flexible adaptation to new conditions, and a high level of optimization. This is essential not only for industrial applications with strict safety and efficiency requirements but also for broader scientific and technological fields, including biomedicine, chemical technologies, and industrial automation across various production sectors.

Therefore, the research presented in the dissertation addresses a real and growing need for intelligent methods in the control of nonlinear systems and makes a significant scientific and applied contribution to modern control theory and practice.

The bibliography includes 179 English-language sources, of which 85 publications are dated after 2010. These include scientific articles, conference papers, and books, with a substantial number from the past few years, including 2023 and 2024. This highlights the relevance of the literature used, the availability of recognized results on the topic, and the overall significance and timeliness of the research at an international level.

3. Type of research:

A) Theoretical	4 points	
B) Applied	4 points	
C) Theoretical with application elements	4 points	X
D) It does not correspond to the level of dissertation	0 points	

		one of the answers given is marked with the sign "X"

The level of research must be substantiated if answer D is marked.
The level of research in the dissertation can be substantiated through several key aspects: scientific and methodological depth, theoretical contribution, applicability and validation of the results, publication activity, and the relevance and practical significance of the research. The dissertation presents novel intelligent control methods that integrate classical approaches such as model predictive control, sliding mode control, and adaptive control with modern machine learning techniques—specifically, deep neural networks and Gaussian processes. This interdisciplinary integration demonstrates a high degree of complexity and innovation in the research. The stability of the newly synthesized controllers, including an exponentially perturbed controller based on neural networks, has been proven. Mathematical models and controllers have been developed for nonlinear and chaotic systems, which requires a solid analytical foundation and deep understanding of complex system dynamics. The proposed methods go beyond theoretical development—they have been validated through simulations on specific classes of real systems, such as the Hindmarsh–Rose neuronal model, master-slave systems, and chemical reactors. The results show the superiority of the proposed intelligent approaches compared to classical methods like PI controllers or standard SMC control. Part of the results have been presented at reputable international conferences (e.g., IEEE International Conference on Intelligent Systems, indexed in Scopus), indicating the scientific significance and originality of the research. The research addresses real-world challenges in industry and automation, where the need for managing nonlinear, uncertain, and highly dynamic systems is increasingly critical. The methods are oriented towards embedded systems and real-time applications, emphasizing their practical applicability. Thus, through a combination of theoretical achievements, innovative methodology, successful experimental validation, and international visibility, the high level of the conducted research is convincingly demonstrated.

4. Objectives of the research:

A) Realistic and of scientific and / or applied interest	8 points	X
B) Realistic, but not of scientific and / or applied interest	3 points	
C) Unattainable (unrealistic)	0 points	
		one of the answers given is marked with the sign "X"

Objectives must be specified. The type of the set objectives must be justified.
The objectives set in the dissertation reflect specific scientific problems in the control of nonlinear systems – an area known for its complexity and high theoretical significance. Each objective addresses particular shortcomings of existing methods. The goals encompass various classes of nonlinear systems – neural models, chaotic synchronized systems, and chemical reactors – demonstrating that they are not formulated in isolation but strategically, to cover a broad range of applications and to show the generalizability of the proposed methods. The dissertation is research- and innovation-oriented, as it does not merely apply existing methods but also synthesizes new controllers and combined methodologies – such as integrating deep neural networks with model predictive control. The formulated objectives correspond to real engineering challenges, such as control under limited resources, changing conditions, and disturbances. Each goal is defined in a way that makes it achievable through specific tasks and methods, including simulation experiments and analytical proofs. This allows for an objective evaluation of their fulfillment. Therefore, the type of goals can be defined as scientific and applied research goals with a high level of innovation and strong justification. The research in the dissertation addresses several key objectives: 1. Development of new intelligent control methods for nonlinear systems – through the synthesis of controllers based on deep neural networks and Gaussian processes, aiming for effective and optimal control of complex dynamic systems that cannot be managed by classical methods.

2. Improvement of control performance and robustness in nonlinear systems – by incorporating predictive and adaptive components, the dissertation aims to achieve faster response, lower error, and greater robustness in the presence of disturbances and uncertainties.
3. Overcoming the limitations of classical controllers – the goals include tackling shortcomings such as the need for precise models, lack of adaptability, and inability to handle nonlinearities and chaos, by implementing artificial intelligence methods.
4. Demonstration of the applicability of intelligent controllers in real and simulated systems – through simulations on models such as the Hindmarsh–Rose neuron, master-slave systems, and tubular chemical reactors, the practical relevance of the developed approaches is demonstrated.
5. Establishing a foundation for future embedded real-time applications – given their reduced computational complexity and the possibility of offline training, the proposed methods are suitable for implementation in real technological systems.

5. Contributions of the dissertation:

A) With lasting scientific and / or applied response, they form the basis for new research and applications	20 points	
B) They are of significant scientific and / or applied interest, complete and / or summarize previous research	16 points	X
C) They are of scientific and / or applied interest	12 points	
D) Lack of significant contributions	8 points	
E) Lack of contributions	0 points	
		one of the answers given is marked with the sign "X"

Contributions must be specified. The type of results achieved must be justified.

The dissertation contains scientific contributions related to the development of new control methods for nonlinear systems and applied scientific contributions related to the implementation of these methods in specific classes of such systems.

Scientific Contributions:

1. Development of new intelligent controllers for nonlinear systems:
   - A novel explicit nonlinear model predictive controller for the Hindmarsh–Rose neuronal model has been developed, based on deep neural networks (DNN).
   - A new control and synchronization scheme for master-slave systems has been proposed, utilizing an exponentially perturbed sliding mode controller based on a radial basis function neural network (RBF-NN).
2. Theoretical proof of stability of the proposed controllers has been established, including under the presence of external disturbances and parametric uncertainty.
3. Development of a methodology for modeling complex systems using Gaussian Processes (GP) - A new approach has been introduced for constructing NARX models for chemical reactors and their use in adaptive predictive controllers.

Applied Scientific Contributions:

1. Application of the proposed methods to specific systems - successful control and synchronization have been achieved for a chaotic neuronal model (Hindmarsh–Rose), chaotic master-slave systems, and nonlinear chemical reactors with distributed parameters.
2. High accuracy and efficiency in simulation experiments - the superiority of the proposed intelligent controllers has been demonstrated compared to classical controllers such as PI controllers and sliding mode controllers.
3. The developed methods provide a foundation for real-time embedded control system applications, owing to their low computational complexity during online execution.

These contributions form a solid basis for new research directions and practical applications.

6. Conclusion

A) The evaluation of the dissertation is **POSITIVE**	This evaluation is assigned to a total number of at least 40 points	X
B) The evaluation of the dissertation is **NEGATIVE**	This evaluation is assigned to a total number below 40 points	
		one of the answers given is marked with the sign "X"

To be filled in at the request of the member of the scientific jury
The dissertation entitled "Intelligent Model-Based Control of Nonlinear Systems", with authorship by PhD Student Junhong Xie, meets the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria and the Regulations on the Conditions and Procedure for Awarding Academic Degrees and Academic Positions of the University of Chemical Technology and Metallurgy for obtaining the educational and scientific degree "Doctor" in scientific field 5. "Technical Sciences", professional field 5.2 "Electrical Engineering, Electronics and Automation".

30.05.2025	The report was written by: **Prof. Dr. Eng. Elena Georgieva Koleva**	
date		signature