Presentation Slides N009-Sasan.Ansarian

Vilnius University

Doctoral student:

Sasan Ansarian Najaf Abadi

Title of the dissertation:

Design and Optimisation of Quantum-Based and Hybrid Machine Learning Algorithms for Real-World Data Analysis Problems

Supervisor:

Dr. Ernestas Filatovas

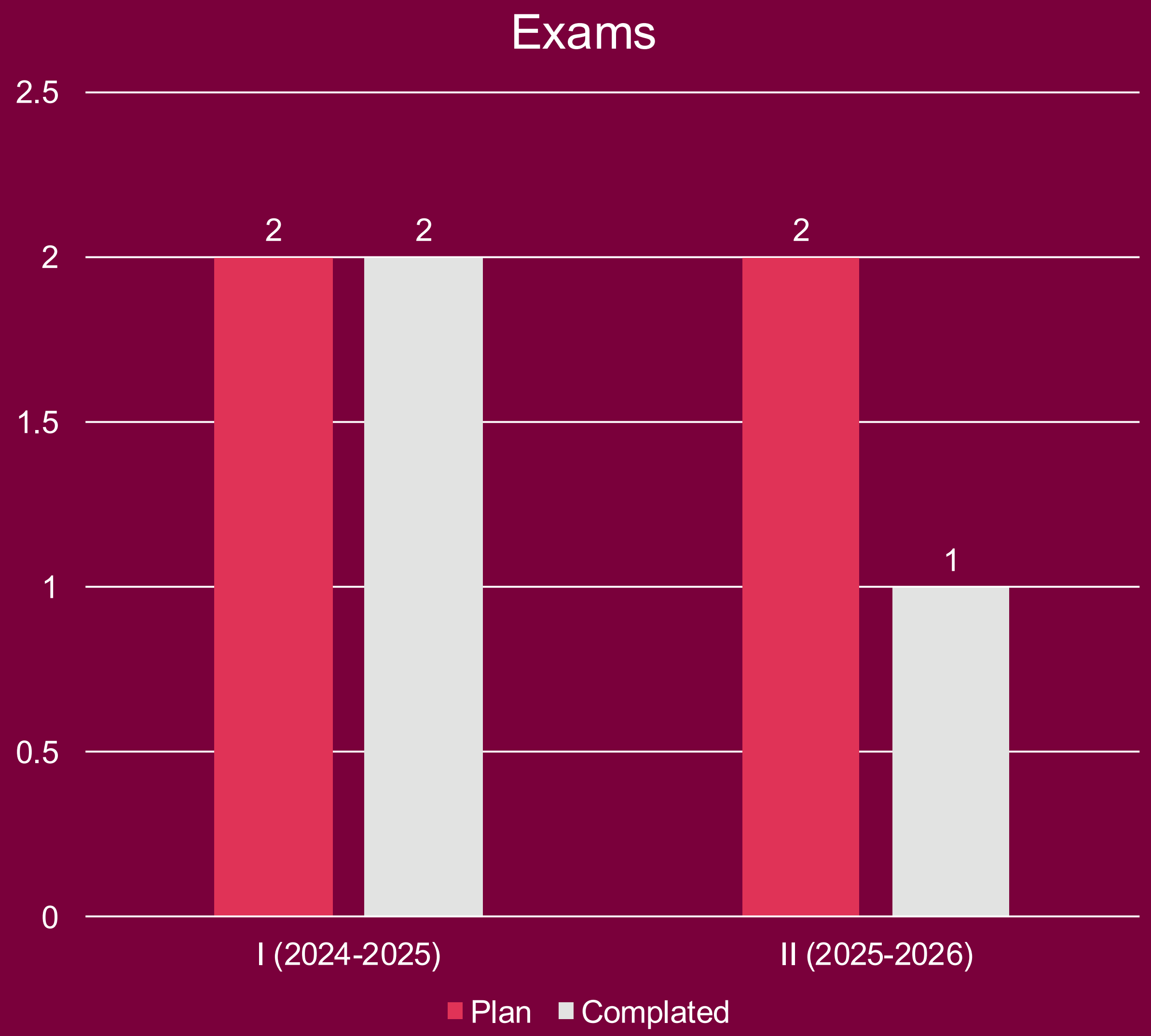
Start and End year of doctoral studies:

From 1 October 2024 To 30 September 2028.

Year of study:

2025-2026 (Third semester)

The plan of all doctoral studies and research, and a summary of its implementation (Table 1).



YEAR OF STUDY	EXAMS	
	Plan	Completed
I (2024-2025)	2	2
II (2025-2026)	2	1
III (2026-2027)	-	-
IIII (2027-2028)	-	-
Total	4	3

The plan of all doctoral studies and research, and a summary of its implementation (Table 1).

Study years	Participation in conferences				Publications					
	International		National		With citation rate			Without citation rate		
	Plan	Completed	Plan	Completed	Plan	Completed	Status	Plan	Completed	Status
I (2024-2025)										
II (2025-2026)			1	Attended the 16th Conference on Data Analysis Methods for Software Systems, November 27 - 29, 2025.						
III (2026-2027)	1				1					
IIII (2027-2028)	1				1					
Total	3		1	1	2					

The work plan for the reporting semester and its implementation (Table 2), detailing what has been done this semester.

Exams 2024/2026 (3rd semester)

Plan	Completed	Status
Machine Learning (2025 y. I quarter)	Machine Learning	Passed
How to Sell Your Research? (2025 y. I quarter)	How to Sell Your Research?	Passed
Research Methods in Informatics (2025 y. II quarter)	Research Methods in Informatics	Passed
Fundamental Methods of Informatics (2026 y. I quarter)	Fundamental Methods of Informatics	Passed

Conference participation 2025/2026 (Third Semester)

Plan	Completed	Conference type
1	Attended the 16th Conference “Data Analysis Methods for Software Systems”, November 27 - 29, 2025.	National

Publications 2025/2026 (Third Semester)

Plan	Completed	Status	Publication type

Information about international events and publications that present the main results of the dissertation (Table 3).

Participation in international conferences	
	Description
1.	

Publications (with citation rate only)		
	Bibliographic description	Condition
1.		

The stages of all doctoral research and dissertation preparation (see Table 4, it can be shortened slightly to fit 1–2 slides), detailing what has been done this semester.

	Title of the work	Due dates	Notes
1.	Review and analysis of scientific research related with the theme of doctoral thesis (in Lithuania and abroad):		
1.1.	Understanding the Foundations: Literature Review: Conducting a comprehensive review of existing research on Quantum and hybrid machine learning approaches.	2025 I quarter	• Implementation: Conducted a systematic literature review of QML in healthcare; a review article was prepared and submitted.
1.2.	Quantum Computing Fundamentals: Grasping the basic principles and concepts of quantum mechanics, such as superposition, entanglement, and measurement, and studying essential quantum algorithms like Grover's search, Shor's factoring, and quantum Fourier transform. familiarising yourself with different types of quantum hardware (e.g., superconducting qubits, trapped ions) and their limitations.	2025 II quarter	•Quantum basics studied • Key algorithms reviewed • Hardware surveyed
1.3.	Machine Learning Basics: Exploring traditional machine learning techniques (e.g., linear regression, decision trees, neural networks) and their applications, and Exploring hybrid models that combine classical and quantum components	2025 III quarter	•Classical ML implemented •Hyperparameters tuned •Hybrid models explored
2.	Prosecution of scientific research:		
2.1.	Formation of study methodology:		
2.1.1.	Designing effective quantum feature maps to encode classical data into quantum states.	2025 IV quarter	• Feature maps reviewed • Encoding techniques identified

	Title of the work	Due dates	Notes
2.2.	Theoretical study: Experimenting with different feature maps to optimise performance for specific tasks.	2026 I quarter	Exploring hybrid quantum-classical architectures and quantum variational circuits for machine learning.
2.3.	Empirical study: Implementing quantum variational circuits for training and optimisation, and exploring techniques to mitigate noise and improve the efficiency of variational algorithms	2026 II quarter	Initiated experimental evaluation of a Hybrid Quantum-Classical CNN for medical image classification with the DermaMNIST dataset.
2.4.	Analysis of facts, summing up, drawing conclusions: Developing hybrid models that leverage the strengths of both classical and quantum computing, and considering using quantum computing for specific subtasks within larger classical models.	2026 III quarter	
3.	Preparation of separate parts of doctoral thesis (study methodology, got facts, defended propositions, inferences, etc.):		
3.1.	Industry Selection and Problem Identification: Choosing a specific industry to explore how quantum machine learning can be applied and Identify problems or challenges in that industry that could be solved or improved with quantum solutions.	2026 IV quarter	
3.2.	Data Preparation: Collecting and preparing relevant data for training and testing quantum machine learning models.	2027 I quarter	
3.3.	Model Development and Evaluation: Developed and evaluated quantum-based and hybrid models for the selected applications.	2027 II quarter	
3.4.	Benchmarking: Benchmarking, researching, comparing, and applying best practices to evaluate and enhance products, methods, and services to measure success and improve performance.	2027 III quarter	
3.5.	The summarizing of the findings and discusses:Summarizing and highlighting the new achievement insights and the impact of its ability to influence future research and practice.	2028 I quarter	
4.	Preparation of doctoral thesis and debating at the department:	2028 II quarter	
5.	Defending of doctoral thesis:	2028 III quarter	

Main Academic and Research Activities (Third Semester)

Review Article:

- A systematic review of QML studies in healthcare (2020–2025).
- Analysed algorithms, models, datasets, and methods.
- Identified research gaps and methodological limitations.
- Manuscript submitted to an international journal.

Experimental Research:

- Implementing an HQCNN.
- Utilised the DermaMNIST medical image dataset.
- Compared classical and hybrid quantum models.
- Comparison of CNN and HQCNN under the same conditions.

DAMSS Conference:

Attending the Data Analysis Methods for Software Systems Conference, Druskininkai, Lithuania, November 27–29, 2025

Purpose:
- Presentation poster of the review article.

Quantum Autumn School:

Quantum Autumn School Stockholm, Sweden, November 3–7, 2025

Activities:
- Learning Quantum Computing Fundamentals
- Understanding basic principles of quantum mechanics
- Familiarising with quantum hardware and its limitations

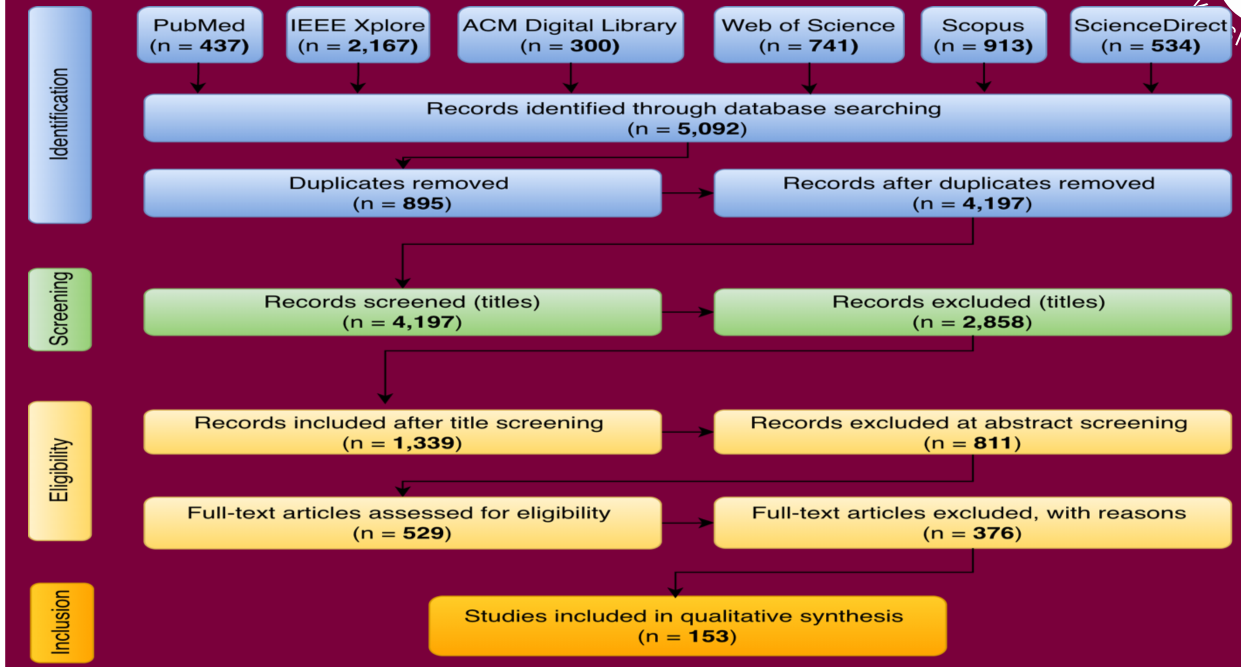
Systematic Review of Quantum Machine Learning in Healthcare

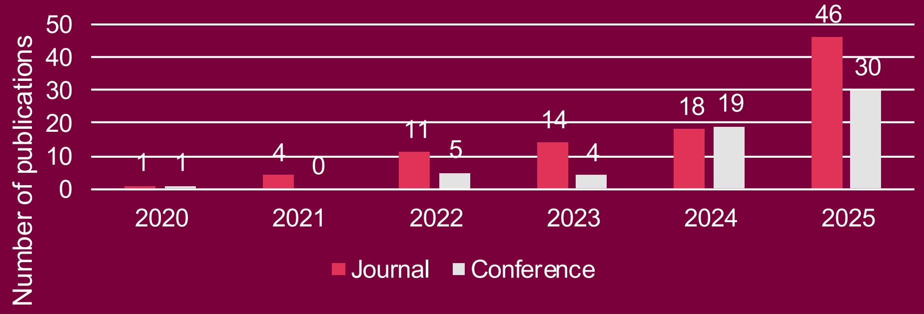
➢ **Content:**

- Conducted a PRISMA-aligned systematic review of 153 studies published between 2020 and 2025.
- Focused specifically on QML methods for medical image classification.
- Analysed studies using a multi-axis taxonomy, including:
  - QML mechanism family,
  - Integration role,
  - Representation strategy,
  - Clinical task type,
  - Claimed quantum advantage,
  - Hardware maturity.

➢ **Main output:**

Submitted a review article on the methodological landscape of QML in medical image classification.





Methodological Issues Observed in Existing QML Studies

- **Baseline mismatch:**

Classical and quantum models are often compared under different parameter budgets and preprocessing pipelines.

- **Lack of benchmarking standards:**

Studies use different datasets, evaluation metrics, and experimental setups, making comparisons difficult.

- **Limited optimisation analysis:**

Most work focuses on accuracy results, with limited analysis of training dynamics or optimisation behaviour.

Motivation and Objective of the Experimental Study

❖ **Motivation:**

- While analysing existing QML studies, several methodological issues were observed in the comparison between classical and quantum models.
- These issues motivated the need for a controlled experimental evaluation.

❖ **Objective:**

To perform a baseline comparison between classical and hybrid quantum–classical models under the same experimental conditions.

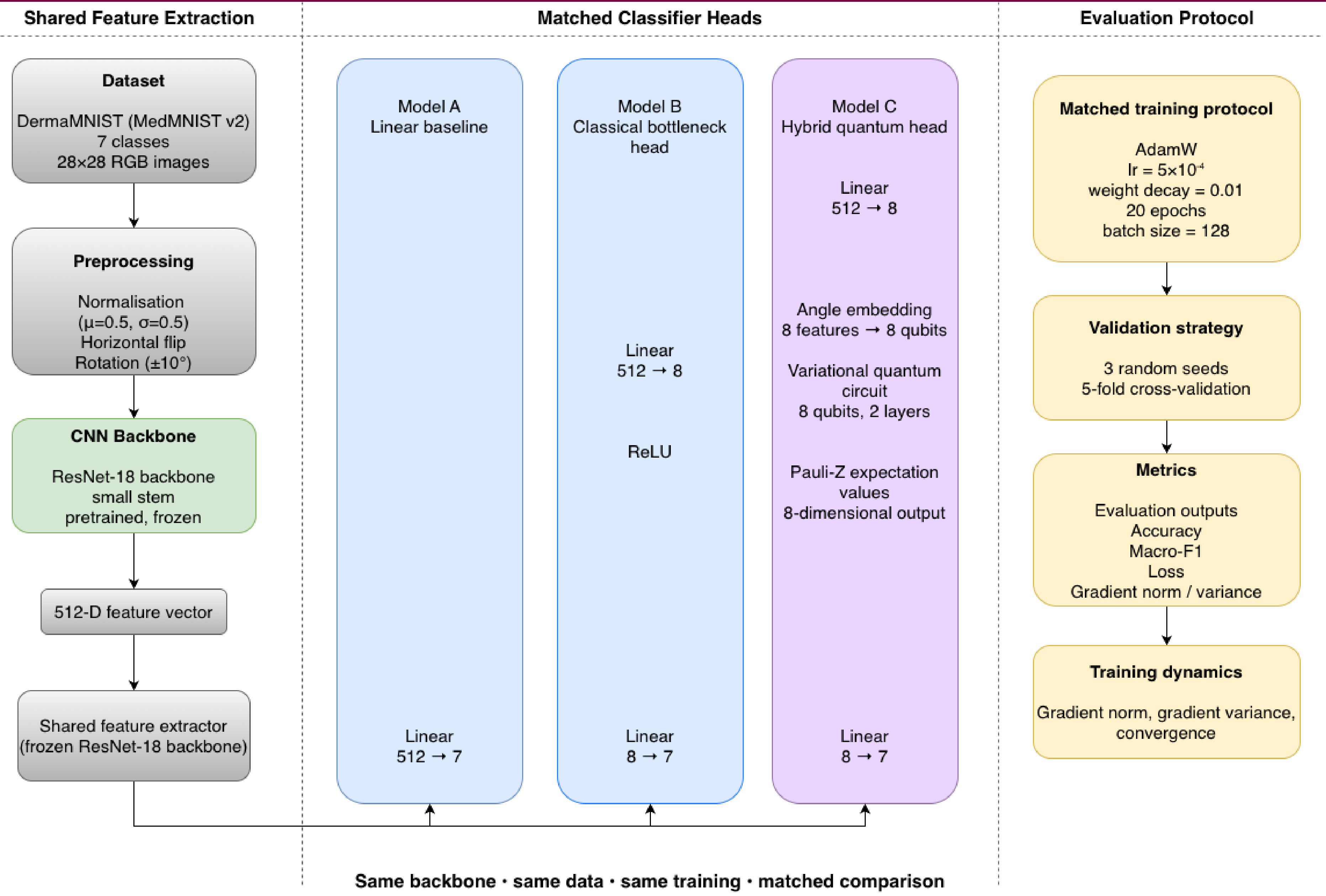
❖ **Key Questions:**

1) Can a hybrid quantum–classical model outperform a classical baseline when trained under comparable conditions?
2) How does a quantum classifier behave when integrated with deep neural network features?
3) What insights can be obtained regarding the conditions for potential quantum advantage?

❖ **Case Study:**

- Hybrid Quantum–Classical CNN
- Dataset: DermaMNIST

Controlled Experimental Setup for HQCNN



Introduction:

- ✓ Controlled comparison between classical and hybrid quantum–classical classifiers.
- ✓ All models use the same feature extractor, dataset, and training protocol.

Experimental Results

Key Observations

•The **linear baseline achieved the highest performance**.
•Introducing a **bottleneck layer reduced performance slightly**.
•The **hybrid quantum classifier did not outperform the classical models** under the tested configuration.

Interpretation

Under the tested conditions, the hybrid quantum–classical model **does not demonstrate a performance advantage over classical baselines**.

Model	Accuracy	Macro-F1
Model A – Linear baseline	**0.739**	**0.472**
Model B – Classical bottleneck	0.731	0.390
Model C – Hybrid quantum head	0.728	0.317

Interpretation and Next Research Direction

❖ **Interpretation of Results**

•Hybrid quantum–classical models are **feasible but do not automatically provide**

❖ **performance advantages**.

The results indicate that performance depends strongly on:

- feature representation
- quantum circuit design
- model integration strategy

❖ **Key Insight**

Quantum advantage is **not guaranteed** and must be investigated under specific conditions.

❖ **Research Direction**

•Explore different **quantum feature encoding methods**

•Investigate alternative **quantum circuit architectures**

•Analyse **training behaviour and optimisation dynamics**

•Study conditions where **quantum methods may provide advantages**

How These Results Support My Dissertation

Contribution of This Semester:

1 Theoretical Contribution:

- Conducted a **systematic review of QML for medical image classification**
- Identified **methodological issues and research gaps**
- Established a **research direction for hybrid QML**

2 Methodological Contribution:

- Designed a **controlled experimental framework**
- Ensured **fair comparison between classical and quantum models**
- Addressed baseline mismatch and benchmarking issues

3 Experimental Contribution:

- Implemented a **hybrid quantum–classical CNN architecture**
- Performed **comparative evaluation on medical image data**
- Established a **baseline result for future research**

Key Outcome

This work provides the **foundation for identifying conditions under which quantum advantages may emerge in real-world applications.**

Short-Term and Long-Term Research Plans

Short-Term Plans (Next Semester):

➢ Coursework
- Complete **Deep Neural Networks** course

➢ Research
- Improve hybrid quantum–classical model design
- Explore **quantum feature encoding methods**
- Extend experiments to additional datasets

➢ Publications
- Publish the **review article**
- Prepare a **research paper based on experimental results**

Long-Term Plans (Aligned with Study Plan):

➢ Methodology Development
- Design and optimise **quantum feature maps**
- Investigate **variational quantum circuits**

➢ Empirical Research
- Develop and evaluate **hybrid QML models**
- Analyse performance under different conditions

➢ Dissertation Progress
- Apply models to **real-world datasets**
- Benchmark against classical approaches
- Prepare and publish **journal papers**

Vilnius University

Thanks for your attention

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