THE ABSTRACT OF DOCTORAL THESIS

I. Summary of the Introduction

- Authors: Phạm Thị Quỳnh Trang
- Title: Mitigating Catastrophic Forgetting in Continual Learning via Memory Replay, Knowledge Transfer, and Adaptive Architecture Optimization
- Field of study of the dissertations: Doctor of Philosophy in Information Systems.
- Major: Information Systems Code: 9480104
- Name of the training institution: University of Engineering and Technology, Vietnam National University (UET-VNU).

II. Contents of the Abstract

1. Research objectives and subjects of the dissertation

   The dissertation focuses on the following objectives:

   - Objective 1: To develop and evaluate novel memory-based continual learning frameworks that integrate prototype augmentation techniques, aiming to achieve a significant reduction in catastrophic forgetting while maintaining computational efficiency comparable to baseline methods.
   - Objective 2: To investigate and implement advanced knowledge transfer mechanisms, specifically contrastive learning and knowledge distillation techniques, to enhance feature preservation and facilitate effective adaptation across sequential tasks, with measurable improvements in forward transfer performance.
   - Objective 3: To develop and validate adaptive architecture strategies with dynamic parameter allocation that effectively balance stability, plasticity, and computational efficiency across diverse continual learning scenarios, demonstrating state-of-the-art performance in mitigating catastrophic forgetting while enabling scalable, privacy-preserving, and resource-efficient sequential learning.

2. Research methods

   This dissertation adopts a mixed-methods research approach combining qualitative and quantitative methodologies:

   - Qualitative analysis involves: (i) a critical review of state-of-the-art continual learning methods and their underlying principles; (ii) the systematic identification of existing limitations and research

opportunities; (iii) the synthesis and development of novel approaches that build upon and extend current techniques.

- Quantitative evaluation includes: (i) Curation and preprocessing of benchmark datasets; (ii) systematic experimental design and implementation; (iii) performance assessment and comparative analysis of proposed frameworks; and (iv) peer-reviewed publication for community validation and reproducibility.

3. Main Results and Conclusions

This dissertation offers significant contributions in different aspects:

- Research memory-based approaches by developing methods that utilize memory

without storing actual samples. Instead, these methods approximate the data distri-

bution and generate random pseudo-samples, thus addressing both memory storage limitations and privacy issues.

- Since memory-based approaches are impractical in real-world scenarios, this dissertation investigates knowledge transfer methods that employ knowledge distillation techniques from previously learned models for new task learning and knowledge retention from pre-trained models to leverage their capabilities, consequently enhancing performance on both new and previously learned tasks.
- The dynamic parameter allocation strategies efficiently manage model capacity during continual learning by integrating multi-head architectures with adaptive prototype mechanisms and parameter fusion techniques. This dissertation enables selective parameter updates and knowledge preservation while maintaining computational efficiency across sequential tasks, achieving superior performance compared to static parameter allocation approaches in mitigating catastrophic forgetting.

For each of the proposed models, the dissertation conducts a series of experiments and compares the results with those of the baseline continual learning models. Through experimental findings, the dissertation highlights the impact of the proposed model components in comparison to those of the original models. This PhD dissertation contributes to both the scientific and practical areas.

List of scientific publications related to the thesis:

1. **Quynh-Trang Pham Thi**, Anh-Cuong Pham, Ngoc-Huyen Ngo, and Duc-Trong Le. Memory-Based Method using Prototype Augmentation for Continual Relation Extraction. In 2022 RIVF International Conference on

Computing and Communication Technologies (RIVF), pp. 1-6. IEEE, 2022. Scopus.

2. Thanh-Hai Dang, **Quynh-Trang Pham Thi**, Duc-Trong Le, and Tri-Thanh Nguyen. Contrastive Learning for Boosting Knowledge Transfer in Task-Incremental Continual Learning of Aspect Sentiment Classification Tasks. VNU Journal of Science: Computer Science and Communication Engineering 40, no. 1 (2024).
3. Duc-Hung Nguyen, Tri-Thanh Nguyen, Thanh-Hai Dang and **Quynh-Trang Pham Thi**. ZeroRFF: A Random Fourier Features and Analytic Learning Method for Generalized Class Incremental Learning. The 21st International Conference on Advanced Data Mining and Applications 2025. Scopus
4. **Quynh-Trang Pham Thi**, Duc-Hung Nguyen, Thanh Hai Dang, Duc-Trong Le, Tri-Thanh Nguyen, and Quang-Thuy Ha. "Towards Robust Continual Learning: A Multi-Head Approach with Online Prototype Equilibrium and Adaptive Prototypical Feedback." In Asian Conference on Intelligent Information and Database Systems, pp. 275-286. Singapore: Springer Nature Singapore, 2024. Scopus.
5. **Quynh-Trang Pham Thi**, Duc-Hung Nguyen, Anh-Duc Nguyen-Tran, Hung-Dung Nguyen, Tri-Thanh Nguyen, Quang-Thuy Ha and Thanh Hai Dang. "Addressing Catastrophic Forgetting in Continual Learning using Multihead Approach and Latent Alignment via Energy-Based Model." Vietnam journal of computer science. (Accepted). WoS Q3.
6. **Quynh-Trang Pham Thi**, Van-Truong Le, Thanh-Huyen Pham, Thanh-Nga Hoang Thi and Duc-Trong Le. DAKTA: Directional Kolmogorov-Arnold Classifier for Task Arithmetic in Continual Learning. SOICT 2025
7. **Quynh-Trang Pham Thi**, Quang-Dat Mac, Thanh-Ha Nguyen and Duc-Trong Le. SOLoRA: Sparse Orthogonal LoRA for Parameter-Efficient Continual Learning. In 2026 IEEE International Conference on Multimedia and Expo (ICME 2026).