VIETNAM NATIONAL UNIVERSITY, HANOI
VNU UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SOCIALIST REPUBLIC OF VIETNAM
Independence – Freedom – Happiness

INFORMATION ON DOCTORAL THESIS

1. Full name : TRUONG XUAN HUNG 2. Sex: Male

3. Date of birth: April 23, 1979 4. Place of birth: Hanoi

5. Admission decision number: 358/QĐ-ĐT Dated May 18, 2022

6. Changes in academic process:

- Decision No. 1296/QD-DHCN dated June 20, 2025, by the Rector of the VNU University of Engineering and Technology regarding the 12-month (1-year) study extension.

- Decision No. 894/QD-DHCN dated May 5, 2026, by the Rector of the VNU University of Engineering and Technology regarding the adjustment of the doctoral dissertation title.

7. Official thesis title: Research on Artificial Bee Colony Algorithm in Path Planning and Dynamic Clustering for Multi-Robot Systems

8. Major: Engineering Mechanics 9. Code: 9520101

10. Supervisors: Assoc. Prof. Dr. Pham Manh Thang

11. Summary of the **new findings** of the thesis:

The overarching purpose of this thesis is to address the dual challenges of path planning and operational management for large-scale multi-robot systems (MRS) consisting of ten or more units operating in complex environments. Specifically, the research focuses on two key contributions:

i. Developing a path planning framework based on the Artificial Bee Colony algorithm, which is designed to secure global optimality in trajectory generation while maintaining the requisite search flexibility to adapt to dynamic local variations.

ii. Proposing a partitioning strategy to enhance system scalability. By subdividing the robot population into smaller clusters with localized data-sharing protocols, the system effectively reduces the total communication overhead and the volume of operational data required for real-time management.

The scope of this research subjects encompasses two fundamental components. The first is centralized multi-robot systems characterized by a high density of homogeneous

agents. These robots possess environmental awareness and the capacity for information exchange, enabling them to execute independent tasks, manifested by distinct start-and-goal configurations for each unit. The second component involves the mathematical models and algorithms investigated, ranging from classical methods to swarm intelligence-based approaches as well as specialized clustering or partitioning methodologies.

The thesis employs an integrated research methodology, which includes (1) a comprehensive theoretical survey of MRS and path planning to identify existing research gaps and establish a strategic research direction; (2) the utilization of mathematical tools to formalize the proposed technical solutions; (3) computer-based simulations using MATLAB to validate algorithmic performance across diverse scenarios. Statistical analysis is further applied to substantiate the evaluation of the results.

The thesis presents significant contributions to the field of MRS through two core solutions: the ElasticABC algorithm and the Dynamic Clustering Method (DCM). The ElasticABC variant introduces a structural optimization framework characterized by a dual-operator pair combined with a heuristic initialization strategy. These improvements enable the algorithm to effectively balance exploration and exploitation, allowing the system to autonomously adapt the path structure and the number of waypoints to environmental constraints. Furthermore, the DeZigzagPath technique is successfully integrated with ElasticABC to eliminate the local zigzag phenomenon, thereby enhancing trajectory quality and ensuring practical feasibility for real-world robotic operations. Concurrently, the DCM is developed to optimize system management through a soft clustering approach based on Gaussian Mixture Models. This method establishes a flexible probability distribution that allows for overlapping cluster boundaries, ensuring that robotic agents are distributed across groups in a balanced and automated manner. The DCM utilizes the set of trajectory intersection points as its primary input data, allowing the system to partition the operational space based on the density of potential agent interactions.

12. Practical applicability: The proposed framework demonstrates high practical feasibility; however, further empirical evaluations on multi-robot platforms are required to validate its real-world applicability.

13. Further research directions, if any:

- Investigating an adaptive mechanism to determine K-factor (number of clusters) in the DCM, leveraging quantitative input data metrics for model optimization.

- Evaluating the performance of ElasticABC algorithm in environments with complex obstacle geometries, such as concave polygons, U-shapes or V-shapes, to address the local minimum problem.

- Validating the operational performance of both DCM and ElasticABC algorithm when applied to multi-robot systems under real-world operating conditions.

14. Thesis-related publications:

Hung Truong Xuan, Pham Manh Thang and Thuc Nguyen Van, "Digitizing Working Space of the Multi Mobile Robots System Using an Approximate Cell Decomposition Method", Proceedings of the 7th International Conference on Engineering Mechanics and Automation (ICEMA7), pp. 3-8, 2023, ISBN: 978-604-357-241-4, doi: 10.15625/vap.2023.0110.

Trương Xuân Hùng (VN); Nguyễn Thị Hồng Hạnh (VN); Trịnh Thăng Long (VN); Nguyễn Văn Thức (VN); Bằng độc quyền giải pháp hữu ích số 3615 "Phương pháp xác định trạng thái chuyển động của robot di động vận chuyển hàng hoá để phục vụ điều khiển và giám sát robot", 2024.

Nguyễn Thị Hồng Hạnh (VN); **Trương Xuân Hùng (VN)**; Nguyễn Đức Minh (VN); Bằng độc quyền sáng chế số 48666 "Cụm cơ cấu điều chỉnh hướng và robot vận chuyển hàng hoá trong nhà kho bao gồm cụm cơ cấu điều chỉnh hướng này", 2025.

Hung Truong Xuan, Thang Pham Manh, Nha Nguyen Quang, Hanh Nguyen Thi Hong Hanh, “Dynamic Clustering of Multi-Mobile Robot System using Gaussian Mixture Model”, J. Robot. Control, vol. 6, no. 5 SE-Articles, pp. 2129–2140, Aug. 2025, doi: 10.18196/jrc.v6i5.27184.

Hung X. Truong, Thang M. Pham, Nha Q. Nguyen, Hanh T. H. Nguyen and Viet A. Dang, "Evaluation of Spatial Stability and Adaptability in a Dynamic Clustering Method for Multi-Robot Systems", Proceedings of the 8th International Conference on Engineering Mechanics and Automation (ICEMA8), pp. 12-18, 2025, doi: 10.15625/vap.2026.0003. ISBN: 978-604-357-500-2.

Hung X. Truong, Thang M. Pham, Nha Q. Nguyen, Hanh T. H. Nguyen and Viet A. Dang, "Artificial Bee Colony for Multi-Robot Path Planning: A Comparative Study of Population Structures", Proceedings of the 8th International Conference on Engineering Mechanics and Automation (ICEMA8), pp. 19-25, 2025, doi: 10.15625/vap.2026.0004. ISBN: 978-604-357-500-2.

Date: June 29, 2026	Date: June 29, 2026
Signature: ……	Signature: ……
Full name: Assoc. Prof. Dr. Pham Manh Thang	Full name: Truong Xuan Hung