

Statement of Purpose

of Zhonglin Liu (Ph.D. applicant for Fall 2026)

Zhonglin Liu u3597461@connect.hku.hk

My research interest lies in developing computational frameworks for modeling and controlling complex systems under uncertainty, with applications in computational biology and operations research. Building on substantial undergraduate research experience in probabilistic network modeling, machine learning, and therapeutic discovery, I am applying to [University Name]’s PhD in [Department] to advance interpretable AI systems for precision medicine and complex decision-making.

Research in Machine Learning and Financial Modeling My research journey began with investigating machine learning applications in financial decision-making. Under Professor Ching Wai Ki’s supervision, I led a collaborative project integrating LSTM and XGBoost models for online portfolio selection problems. Working with team members Zhao Y. and Lyu B., I developed predictive models that demonstrated significant improvements in portfolio performance across three datasets (NYSE-O’, NYSE-N’, and TSE’). Our comprehensive evaluation showed that LSTM-based models achieved superior risk-adjusted returns, with the LSTM+MV model reaching a Calmar ratio of 25.43 on the TSE dataset. This work, published in the International Conference on Applied Research in Business, Management and Economics, introduced me to the challenges of sequential decision-making under uncertainty and established my expertise in machine learning for time series analysis.

Research in Combinatorial Optimization Building on this foundation, I undertook a comprehensive comparative analysis of classical versus reinforcement learning approaches for the Traveling Salesman Problem under Professor Zang Wenan’s supervision. I implemented and evaluated multiple algorithms across varying problem scales, demonstrating that hybrid Actor-Critic agents integrated with classical heuristics could achieve competitive performance on large-scale instances. Most significantly, I discovered that providing structural hints from classical algorithms dramatically improved learning performance—the hybrid Actor-Critic model achieved solution quality statistically identical to the Christofides algorithm on 100-city problems while pure reinforcement learning failed to scale effectively. This project deepened my understanding of the synergy between traditional optimization and modern machine learning, establishing a foundation for hybrid algorithmic approaches.

Research in Computational Biology and Therapeutic Discovery My most impactful work emerged from applying computational methods to biological systems. During my exchange at NUS, I collaborated with Professor Louxin Zhang to develop the first application of probabilistic Boolean networks to model effective brain connectivity in Alzheimer’s disease. Using fMRI data from 59 subjects across the disease spectrum, we identified progressive disconnection patterns in critical neural pathways, specifically documenting linear decline in Default Mode Network to Medial Temporal Lobe connectivity. Our novel framework combined data-driven dynamics with neuroanatomical priors, revealing five significant connections that exhibited systematic degradation across disease stages. This work, published on bioRxiv and accepted for presentation at APBC 2025, demonstrated the power of probabilistic modeling for understanding complex biological phenomena.

This success motivated my most ambitious independent project: developing an integrated PBN-reinforcement learning-explainable AI framework for therapeutic discovery in melanoma. I constructed dynamic models from patient transcriptomic data to capture regulatory logic governing immunotherapy resistance, then employed reinforcement learning to systematically discover optimal intervention strategies. The analysis revealed that resistance corresponds to a fundamental network transition dominated by a JUN/LOXL2 regulatory axis. Most significantly, my approach discovered a non-obvious "hit-and-run" therapeutic strategy: a precisely timed, 4-step temporary inhibition of LOXL2 achieving 93.45

Current Research and Expanding Scope My current work spans multiple collaborative projects that are expanding both theoretical foundations and practical applications. I am working with Professor Ching Wai Ki on systematic analysis and control of probabilistic Boolean networks, developing scalable matrix-based methods for exact and approximate steady-state computation and formulating finite-horizon optimal control problems with therapeutic constraints. Simultaneously, I am collaborating with Professors Hong Ming Tan and Jussi Keppo at NUS on information acquisition and mechanism design, developing optimization models for pharmaceutical clinical trials and designing incentive mechanisms for large language model platforms.

Program Fit and Research Vision [University Name] represents the ideal environment to advance my research vision. Professor [A]'s work on [specific research area] aligns with my experience in probabilistic network modeling, while Professor [B]'s expertise in [specific area] resonates with my interests in reinforcement learning for adaptive control. I am particularly excited about the [specific lab/center] where I could contribute my expertise while learning from researchers working on [related areas]. My proven ability to bridge computational methods with biological applications positions me well to contribute to the department's research mission.

Teaching and Broader Impact Beyond research, I am committed to education and scientific communication. As team leader of the "Enhancing Mathematical Understanding via Manim" project, I have managed a team producing educational videos broadcast to over 5000 university students. My HKU Distinguished Service Award validates my commitment to making complex concepts accessible, preparing me to contribute meaningfully to graduate education.

Career Goals and Long-term Vision I am determined to pursue a research career developing interpretable AI systems for precision medicine, with the goal of establishing an independent research group bridging computational biology, machine learning, and therapeutic discovery. My publications demonstrate capability for high-impact research, while my interdisciplinary collaborations show ability to work across traditional boundaries. I aim to develop decision support systems that can discover therapeutic strategies while maintaining clinical interpretability.

Thank you for your consideration. I look forward to contributing to [University Name]'s research community and advancing the frontiers of computational biology and interpretable machine learning.