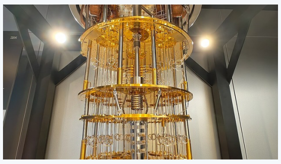
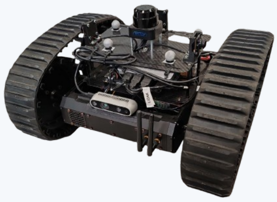
[QuaRob-1] – Quantum Meets Robotics: New Algorithms for Planning, SLAM, and Learning

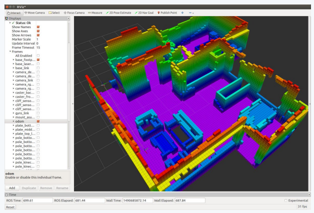
Thesis sheet · PRISMA Lab



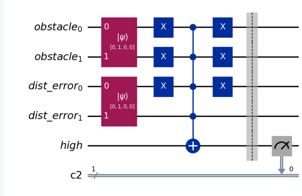
Quantum Computer



Prisma Rover



SLAM



QFIE circuit

THESIS OVERVIEW

Quantum and quantum-inspired computing is an emerging direction for optimisation, learning, and decision-making problems. In robotics, its practical impact is still exploratory, so this thesis will investigate which robotic subproblems may benefit from these methods and how they compare with classical baselines.

The student will focus on one selected track in planning, navigation, perception, learning, or parameter optimisation, formulate the problem within a suitable mathematical and computational framework, and validate the proposed approach in realistic simulation environments. When feasible, experimental tests on laboratory platforms may also be included. Quantum and quantum-inspired methods will be evaluated through circuit simulators and, when appropriate, real quantum backends, considering both robotic performance and practical aspects such as scalability, noise sensitivity, resource requirements, and deployability on current quantum hardware. The emphasis will be on rigorous comparison, without assuming a quantum advantage a priori.

TOOLS

Simulation & Middleware: ROS2 (Humble), Gazebo GZ, MuJoCo, Matlab/Simulink
Languages & Libraries: Python, C++, OpenCV (for vision-based tracks), Qiskit or PennyLane, NumPy/SciPy
Other: GitHub, Docker

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KEYWORDS

Quantum robotics; planning; SLAM; fuzzy; Q-learning; hybrid algorithms

EXAMPLES / POSSIBLE ACTIVITIES

• **Track 1 – Quantum and Quantum-Inspired Methods for Smooth Trajectory Planning**
Development of quantum or quantum-inspired approaches for smooth trajectory generation in mobile robotics. The activity will focus on formulating spline generation and trajectory smoothing as linear-system optimization problems, followed by the implementation and comparison of quantum-based methods against classical planning techniques in representative robotic navigation scenarios.
• **Track 2 – Quantum-Enhanced Modules for SLAM**
Investigation of quantum and quantum-inspired algorithms for specific subproblems arising in SLAM pipelines, such as data association, loop closure detection, feature matching, or pose-graph optimization. The goal is to evaluate potential improvements in computational efficiency, robustness, and localization accuracy compared with conventional methods.
• **Track 3 – Quantum Fuzzy and Artificial Potential Field Navigation**
Design of advanced navigation strategies integrating fuzzy logic, artificial potential fields, and quantum fuzzy inference mechanisms. The research will address tasks such as adaptive online gain tuning, obstacle avoidance, local-minimum escape strategies, and coordination/formation control in multi-robot systems.
• **Track 4 – Quantum and Quantum-Inspired Reinforcement Learning for Mobile Robotics**
Comparative study between classical Q-learning and hybrid quantum/quantum-inspired reinforcement learning approaches for autonomous robot navigation in complex environments characterized by dynamic obstacles, narrow passages, and trap regions. The work will focus on action-selection policies, exploration strategies, and navigation performance.

PREREQUISITES / NOTES

Recommended courses: Foundation of Robotics, Robotics Lab, Field and Service Robotics.
Recommended skills: Python/C++, basic linear algebra, familiarity with ROS2, quantum computing knowledge or willingness to learn it.
Target degree: Master's in Automation and Robotics Engineering.
Note: The final thesis will focus on one selected track or possibly another track discussed with the supervisor; hardware validation may be included depending on platform availability and on the selected track.

RELATED BIBLIOGRAPHY

• ROS2 Documentation – https://docs.ros.org/en/humble/
• Gazebo Simulator – https://gazebosim.org/
• Qiskit – https://quantum.cloud.ibm.com/docs/en/guides
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• G. Acampora, R. Schiattarella and A. Vitiello, "On the Implementation of Fuzzy Inference Engines on Quantum Computers," in IEEE Transactions on Fuzzy Systems.
• Harrow, Hassidim, Lloyd, "Quantum Algorithm for Linear Systems of Equations," Phys. Rev. Lett.
• Adel Rastkhiz et al., "A fuzzy set-based methodology for autonomous navigation", Fuzzy Sets and Systems.
• Sannia et al., "A hybrid classical-quantum approach to speed up Q-learning", Scientific Reports.