Hybrid Quantum–Classical Algorithms for High-Precision Sensor Fusion in Robotics Applications

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***Abstract*—The fusion of quantum computing and robotics represents a frontier in computational intelligence, promising to overcome the limitations of classical sensor fusion methods in precision, scalability, and real-time adaptability. This study proposes a hybrid quantum–classical framework designed to enhance the integration and synchronization of LiDAR, visual, and inertial sensor data, ultimately improving robotic perception and spatial awareness in complex environments. The model employs quantum-assisted optimization techniques to handle high-dimensional uncertainty, noise propagation, and data redundancy challenges inherent in multi-sensor processing. By leveraging variational quantum circuits and classical machine learning optimizers, the hybrid model achieves efficient data correlation and error minimization during sensor alignment. Benchmark experiments were conducted to evaluate the efficiency and precision of the proposed quantum-assisted sensor fusion system relative to conventional data integration algorithms. The findings reveal that hybrid quantum–classical systems yield substantial improvements in localization accuracy, temporal synchronization, and resilience to sensor noise, while maintaining computational feasibility within near-term quantum devices. This work highlights the potential of quantum-enhanced perception frameworks to accelerate the next generation of autonomous robotics, providing a foundation for adaptive control, intelligent navigation, and mission-critical decision-making under uncertainty.**

In the era of Industry 4.0 and autonomous systems, robotics has become increasingly reliant on accurate and robust sensor fusion to achieve intelligent environmental perception and decision-making [7]. Sensor fusion integrates data from multiple modalities—commonly LiDAR, vision-based cameras, and inertial measurement units (IMUs)—to construct coherent environmental representations necessary for navigation, mapping, and object recognition. Classical fusion algorithms, including Kalman filtering and deep learning-based integration, have advanced the field considerably. However, these methods often struggle with high-dimensional, nonlinear, and noisy data environments, particularly when robots operate under dynamic conditions such as urban traffic or variable terrain [8]. The computational cost of synchronizing asynchronous data streams in real time presents a persistent challenge, creating a

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