VII International Conference on Mathematics and its Applications in Science and Engineering
(ICMASE 2026)

ICMASE 2026

A Comparative Study of Classical and Quantum Support Vector Machine for Diabetic Foot Classification Using the Cluster Thermal Index

Pedro Teixeira[1], Vítor Filipe[1,2], Ana Teixeira[1,3*]

[1]*University of Trás-os-Montes e Alto Douro, Vila Real, Portugal*
[2]*INESC TEC—INESC Technology and Science, Porto, Portugal*
[3]*Centro de Matemática, Universidade do Minho – Polo CMAT-UTAD, Vila Real, Portugal*

Abstract

Diabetes mellitus is one of the most common chronic diseases in the world and is frequently associated with severe complications such as diabetic foot ulcers, which can lead to infection, hospitalization, and lower-limb amputation if not detected early. Infrared thermography has emerged as a promising non-invasive imaging modality for diabetic foot assessment, as changes in plantar temperature distributions can detect physiological abnormalities before they become visible clinical symptoms. Mathematical descriptors and machine learning techniques are increasingly used to characterize thermographic patterns and improve classification performance [3, 5].

Recent advancements in quantum computing have prompted the adaptation of well-known machine learning algorithms to quantum computational frameworks, resulting in Quantum Machine Learning and quantum-inspired learning approaches. These methods draw inspiration from principles of quantum mechanics, such as superposition and quantum state representations, to construct alternative data encodings and feature spaces. In particular, Quantum Support Vector Machine (QSVM) extend classical Support Vector Machine (SVM) through the use of quantum feature maps and quantum kernel functions, enabling data to be represented in Hilbert spaces generated by quantum circuits. From a mathematical perspective, these representations provide alternative formulations of kernel-based classification and may offer new possibilities for modelling complex data structures. As a result, quantum and quantum-inspired learning methods have attracted increasing attention in areas such as medical image analysis and pattern recognition [2, 4].

In this context, this paper proposes a comparative analysis between classical SVM and QSVM for diabetic foot classification using engineered thermographic features. The methodology is based on the Cluster Thermal Index (CTI), a mathematical descriptor that quantifies the deviation of an individual's plantar thermal profile from that of a healthy reference population through temperature clustering, together with additional global and regional statistical features extracted from thermograms [1]. These descriptors define a common feature space for both classical and quantum classifiers, enabling a direct comparison under equivalent conditions.

The performance of both approaches is measured using standard classification metrics such as accuracy, precision, recall, F1-score, specificity, and area under the ROC curve. The purpose of the study is to evaluate the applicability of the QSVM to CTI-based diabetic foot classification and to investigate its performance relative to the classical SVM in thermographic biomedical analysis. In addition to contributing to diabetic foot assessment and computer-aided diagnosis, the findings contribute to the emerging field of quantum machine learning in healthcare, emphasizing the importance of mathematical feature engineering for infrared thermography-based diagnostic systems.

Keywords Cluster Thermal Index · Kernel Methods · Quantum Machine Learning · Quantum Support Vector Machine · Support Vector Machine · Infrared Thermography · Diabetic Foot

[*]*Corresponding Author's E-mail: ateixeir@utad.pt*

References

[1] Filipe V., Teixeira P., and Teixeira A., Automatic Classification of Foot Thermograms Using Machine Learning Techniques, Algorithms, 15(7): 236, 2022. DOI: 10.3390/a15070236.

[2] Havlíček V., Córcoles A.D., Temme K., Harrow A.W., Kandala A., Chow J.M., and Gambetta J.M., Supervised Learning with Quantum-Enhanced Feature Spaces, Nature, 567(7747): 209–212, 2019. DOI: 10.1038/s41586-019-0980-2.

[3] Khandakar A., Chowdhury M.E.H., Reaz M.B.I., Ali S.H.M., Hasan M.A., Kiranyaz S., Rahman T., Alfkey R., Bakar A.A.A., and Malik R.A., A machine learning model for early detection of diabetic foot using thermogram images, Comput. Biol. Med., 137: 104838, 2021. DOI: 10.1016/j.compbiomed.2021.104838.

[4] Sar A., Kumar A., Roy S., Kaushish A., Choudhury T., Minakshi, Alqahtani S.S., and Abraham A., Quantum Machine Learning in Medical Image Analysis: From Diagnostics to Surgery Planning, IEEE Access, 14: 27690–27732, 2026. DOI: 10.1109/ACCESS.2026.3663498.

[5] Wu L., Huang R., He X., Tang L., and Ma X., Advances in Machine Learning-Aided Thermal Imaging for Early Detection of Diabetic Foot Ulcers: A Review, Biosensors, 14(12): 614, 2024. DOI: 10.3390/bios14120614.