Quantum kernel learning Model constructed with small data

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Introduction & Datasets

We are researching anomaly detection (image and time series) in the viewpoint of social implementation [1-3)]. We recognize the importance of building learning models using real data, not toy data. Here, we researched SVM with quantum kernel with a small image data. training & testing data are 24 & 9 for normal & anomaly data. This time we detect apples with internal vine cracks as shown in Figure 1, which is difficult.

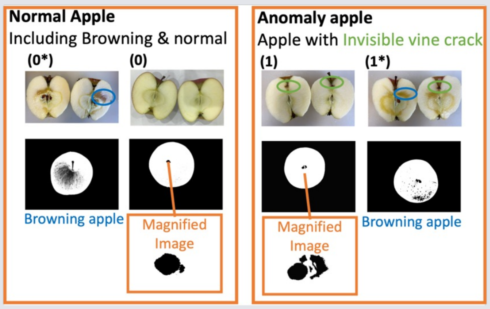

Figure 1. binarized image of apples after illumination

Quantum Kernel

In this study, we investigated the performance of SVMs using multiple quantum kernels in separating normal and anomaly data. Qiskit & IBM_Osaka are used as quantum simulator & computer.

E-mail address

Research Activities

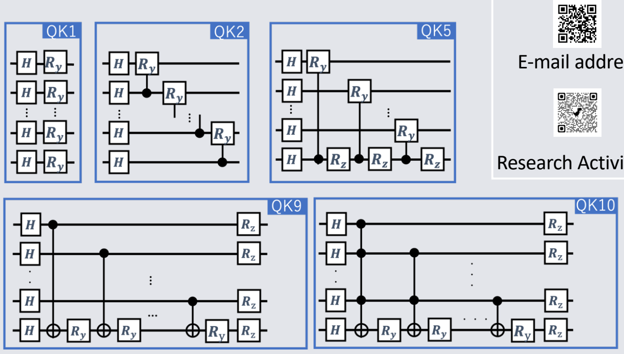

Figure 2. Quantum circuits diagram for SVM embedded quantum kernel

Results

The quantum kernels that showed higher performance indices than the classical kernels were QK1, QK9, and QK10.
The quantum kernels QK2 and QK5, which use the rotation control gate Ry, were higher than the classical kernels when the feature amount was small. But when the feature amount increased to 6 and 7, the values were almost the same as the classical kernels.

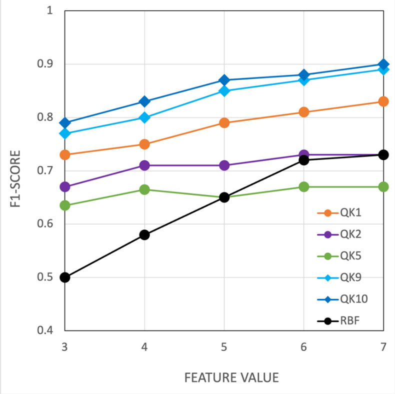

Figure 3. Features value v.s. F1-score for each quantum kernel compared to classical kernel RBF.

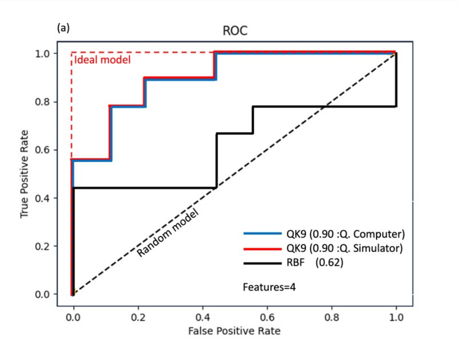

Figure 4. ROC-AUC curve for QK9.

Figure 4 shows the ROC-AUC curves of RBF, QS, and QC on QK9, and the right figure shows the ROC-AUC curves of RBF QS and QC on QK10. The AUC of the classical RBF is drawn close to the random model, and the numerical data is 0.62. On the other hand, in the case of QK9, the behavior of the AUC curve of the quantum computer was the same as that of the quantum simulator. The numerical data of the AUC at that time was 0.90 for both, as shown in the figure.

As shown in Figure 5, in the case of QK10, the behavior of the ROC-AUC curve of the quantum computer was lower than that of the classical computer. As shown in the figure, the numerical data of the AUC value at that time was 0.89 for the quantum simulator and 0.59 for the quantum computer. For QK10, the behavior and numerical data on the quantum computer were significantly different from those on the quantum simulator.

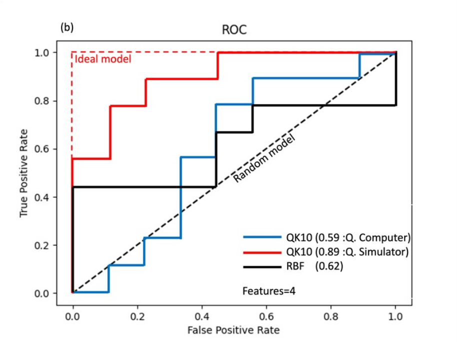

Figure 5. ROC-AUC curve for QK10.

Discussion

To investigate the cause of the difference between the quantum simulator and the quantum computer in QK10, we investigated the circuit depth of the quantum circuit. The results are shown in Table 2. Since there was no difference between the quantum simulator and the quantum computer for QK9, it is considered that there is no problem up to a circuit depth of 32, but since a problem occurred at a circuit depth of 273, it is considered that an error occurred between 32 and 273. This suggests that the depth of the quantum circuit affects the occurrence of errors in the quantum computer [4)], and that noise, Barren plateaus [5)], etc. are possible causes.

Acknowledgements

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