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Womanium Quantum+AI 2024

Fraunhofer <> Womanium

Quantum Machine Learning for Conspicuity Detection in Production

1. Project Overview:

The project focuses on conspicuity detection in production, which makes it possible to identify improvement measures for individual work steps or sub-processes at an early stage and thus optimize the production process. To do this, we analyze process data such as image data or time series to uncover deviations and weak points in production. Classical methods for analyzing such data are very time-consuming.

Therefore, our project attempts to explore the potential of hybrid quantum computing in accelerating this process. Our primary focus lies in implementing the necessary hybrid quantum algorithms and rigorously benchmarking them against classical approaches, including machine learning and statistical methods.

Firstly, the students are asked to make themselves familiar with PennyLane and the integration of JAX. They are requested to implement and to present the tutorial of PennyLane x JAX. Subsequently, the students are requested to tackle QNNs (Quantum Neural Networks) with different scaling approaches. The goal for them is to implement these prototypes in these frameworks and present their results using standard metrics and visualization.

2. Project Duration:

- 4 weeks
- Teams start working on July 5, 2024
- Teams submit their project solutions on August 9, 2024

3. Team Guidelines:

- Team size - Maximum 2 participants per team.
- All team participants must be enrolled in Womanium Quantum+AI 2024.
- Everyone is eligible to participate in this project and win Womanium grants.
- Get selected for Womanium QSL fellowships with Fraunhofer ITWM.

4. Project Tasks/ Deliverables:

1) Familiarize yourself with Pennylane. The tutorials in the Pennylane codebook are a good way to get started. We recommend the codebooks from the sections "Introduction to Quantum Computing", "Single-Qubit Gates" and "Circuits with Many Qubits", which can be found on the following page (registration is required): Pennylane Codebook.
2) (necessary to pass the project) To familiarize yourself with the basic workflow in Quantum Machine Learning, work through the tutorial on Variational Classifier. Implement and present the usual steps in this workflow and explain in your own words the purpose of each step.
3) (necessary to pass the project) Consider a more sophisticated model using an interesting real-world dataset (here the MNIST dataset), Quanvolutional Neural Networks. Work through the example, Implement and present your steps in a notebook and comment on the important steps.
4) (challenging sub-task) The goal of this subtask is to develop your own model and use it to learn the sine function on the interval $[0, 2\pi]$. Discretize the interval with a suitable number of points (of your choice) and use the values of the sine function at these discretization points as labels. Implement a Quantum Machine Learning model which reproduces the values of the sine function.
5) (very challenging sub-task) We change the data set from the sine function to real-word data-set from the industry. Download the following data-set from kaggle: data. You can find more information about the data set in the following paper.
   Implement a Quantum Machine Learning model to detect a defective production part. The implementation includes the preprocessing of the data, the implementation of a model and the visualization of the results. You can use one of the models above. Further, you can also use only a subset of the downloaded data. The final deliverable should be a notebook in which all the necessary steps have been carried out and documented.

5. Quantum Hardware Credits / Platform:

- Participants may use any quantum SDK or platform of their choice.

6. Judging Criteria:

- The implementation of Task 4 & 5 would be given the most weight.
- It is important that people show initiative themselves and not just repeat the tutorials from Task 2 and 3. In addition to a technically clean implementation with detailed commentary, we positively rate the independent research and

implementation of a new model. We give higher ratings to models that do not simply originate from another Pennylane tutorial.

- Completing Tasks 1-3 is necessary to pass the project, and earn the Womanium Quantum+AI Project Certificate.
- Completing Tasks 4 & 5 also, makes you eligible to compete for QSL fellowships. Finalists for QSL fellowships will be decided on the basis of Highest cumulative scores from all 4 tasks, Technical Merit, Novelty, Communication and Presentation Skills.

7. Resources:

- Further sources for various QML models: Link.
- The kaggle data set for Task 5: data.
- The paper for Task 5: paper.