Quantum Computing Weather Forecasting

Team #5 weather forecasting

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Overview

-The challenge focuses on utilizing quantum computing to enhance **weather forecasting** accuracy in Egypt, specifically in Cairo.

-Weather forecasting is considered a challenge due to the chaotic nature of atmospheric systems, requiring significant computational power to process large datasets and patterns.

-Traditional forecasting methods often struggle with the intensity and precision on the long-term predictions. On the other hand, quantum computing handles complex optimization, pattern recognition, and probabilistic modeling, improving the accuracy and efficiency of weather predictions.

Our goal is: to utilize quantum algorithms in analyzing weather data, based on temperature, precipitation, or wind speed. So we can develop a quantum model which identifies patterns, optimizes forecasting algorithms, and reduce computational time compared to classical methods.

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Data Preprocessing

Processing Data

1. Loading the data
2. Exploring data
3. Handling missing values
4. Removing identical columns
5. Fixing data types
6. Saving cleaned data

03

Classical Model

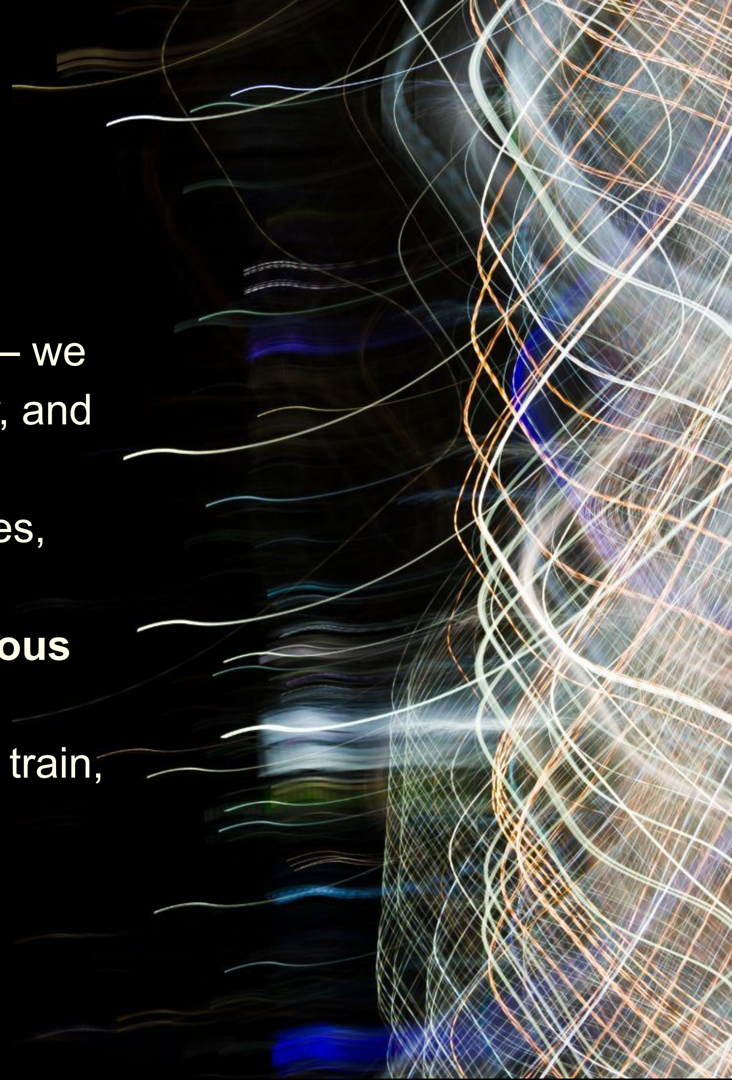
Multiple Linear Regression

Multiple Linear Regression

- Is a ML method used to model the relationship between one dependent variable (target) and two or more independent variables (features).
- It's an extension of simple linear regression, which only involves one independent variable.
- MLR tries to minimize the squared errors between actual and predicted values.

WHY Multiple Linear Regression?

- **Multiple Features** → Matches our dataset structure — we use several weather variables like rain, wind, humidity, and sunshine.
- **Numerical Inputs** → All features are continuous values, which is ideal for regression models.
- **Single Output**→ We are predicting only **one continuous target**: **temperature**,.
- **Performs Well on Large Datasets**→ Efficient, fast to train, and scalable to thousands of records



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Quantum Model

Quantum Machine Learning

Quantum Machine Learning

Developed a hybrid quantum–classical regression model using Quantum Neural Network (QNN) to predict Cairo’s average temperature using two features:

- apparent_temperature_mean (°C)
- et0_fao_evapotranspiration (mm)

Quantum Architecture:

- Feature Map: ZZFeatureMap (1 repetition)
- Ansatz: EfficientSU2 with circular entanglement
- Simulator: Local backend via Qiskit Estimator
- QNN Type: EstimatorQNN integrated with PyTorch

Training Setup:

- Training Sample: 365 data points
- Loss Function: HuberLoss
- Optimizer: AdamW with StepLR learning rate scheduler
- Early stopping enabled after 20 stagnant epochs
- Preprocessing: MinMax scaling to range [-1, 1]

Insights

Observations:

- High predictive accuracy using only two features
- Strong correlation between predicted and actual values
- Quantum modeling demonstrated effectiveness even with limited data.
- Visual graph representations that confirm prediction reliability

Future Direction:

- Potential improvements with an additional complementary feature

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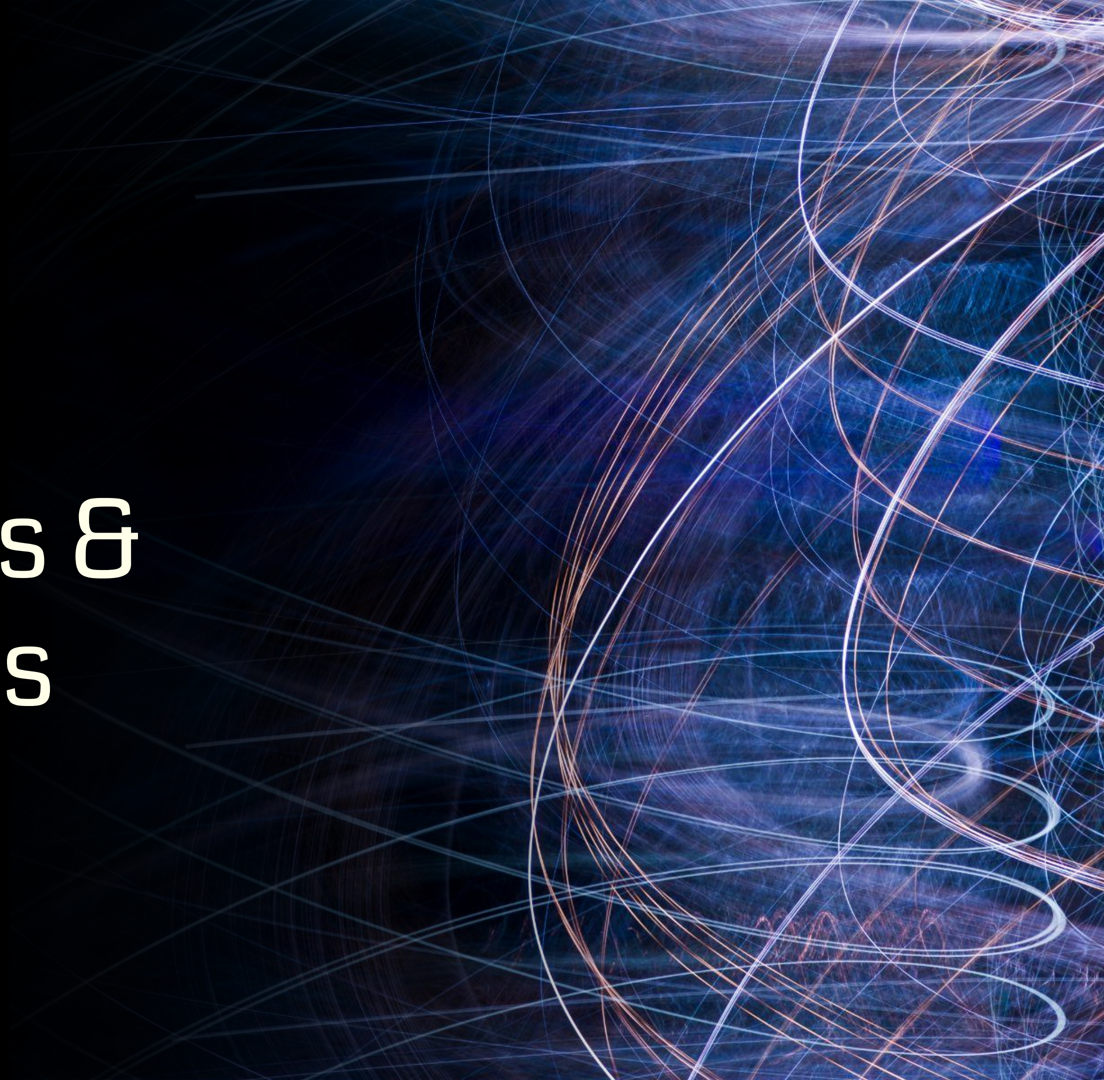
Challenges & Solutions



Challenge	Solution
Long Quantum Simulation Time: Simulating quantum circuits on classical hardware is computationally expensive and time-consuming.	We selected the two most important features to reduce input dimensionality.
Training Quantum Models: The quantum model training was unstable and sometimes got stuck in local minima.	We used **AdamW optimizer** with **Huber Loss** and a **learning rate schedule** to help the model learn smoothly.

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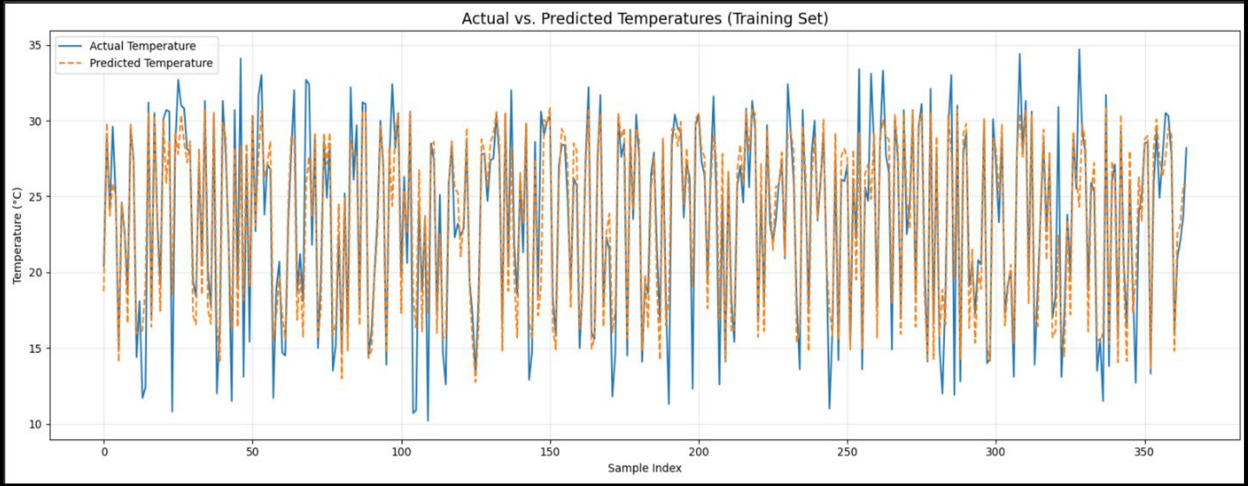
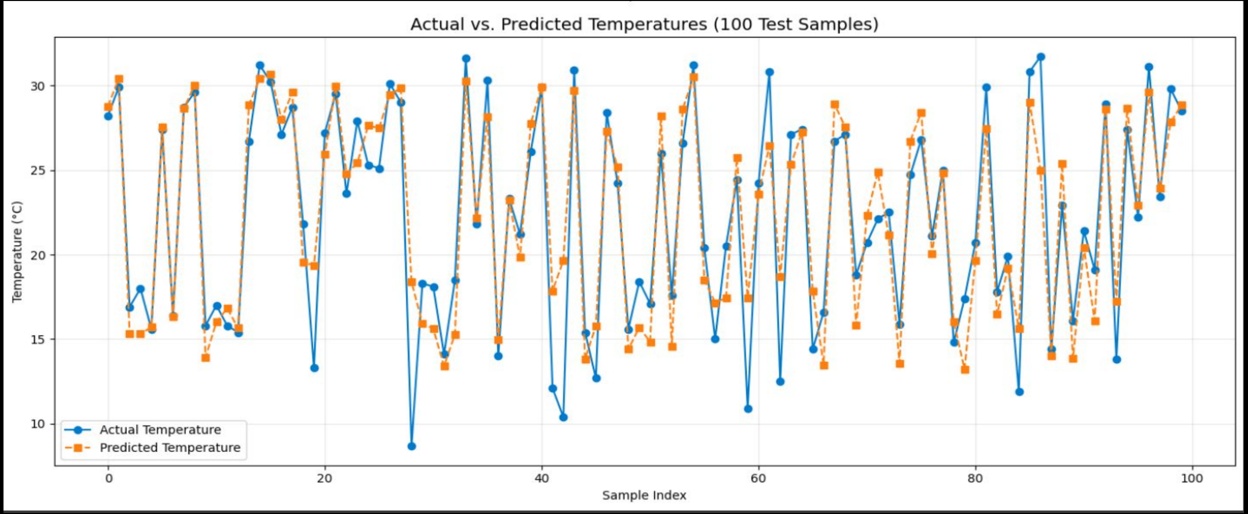
Results

Training Vs. Testing



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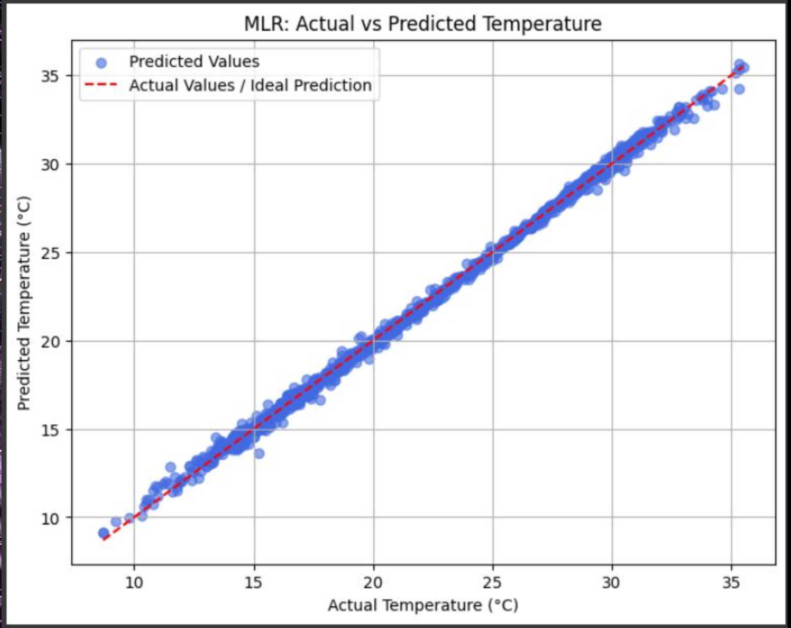
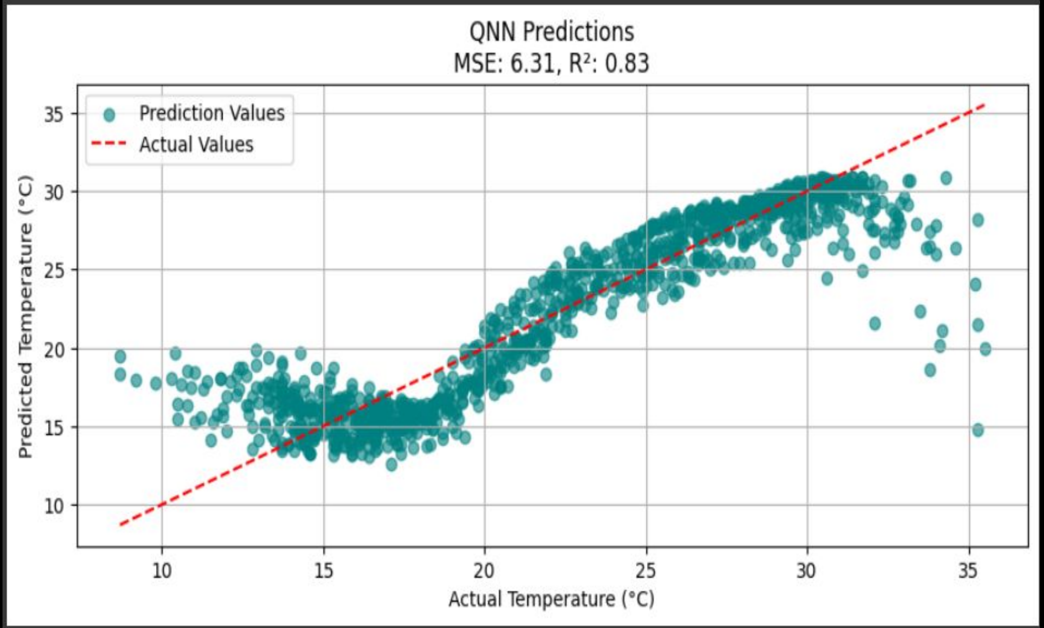
Final Evaluation:
Training MSE: 5.9581, R²: 0.8490
Testing  MSE: 6.3072, R²: 0.8338
```

Classical Model	Quantum Model
Multiple Linear Regression	**Quantum Neural Network (QNN) via EstimatorQNN**
📉 Mean Squared Error (MSE): 0.073 📈 R^2 Score: 0.998	📉Mean Squared Error (MSE): 6.2681 📏 RMSE: 2.5036 📈 R^2 score: 0.8348

Classical Vs. Quantum





Results

While classical model currently outperform in absolute metrics,The quantum model demonstrated promising results, especially in reducing overfitting and achieving competitive accuracy with fewer trainable parameters.

```
Enter apparent temperature mean (°C)( 3.9 ___ 36 ): 18
Enter et0_fao_evapotranspiration (mm)(1.1 ___ 12.7): 10

Predicted Mean Temperature: 22.44 °C

Closest 5 Real Data Points from Dataset:
Apparent Temp: 18.20 °C, Evapotranspiration: 8.58 mm, Real Temp: 22.80 °C
Apparent Temp: 18.60 °C, Evapotranspiration: 8.55 mm, Real Temp: 23.90 °C
Apparent Temp: 18.50 °C, Evapotranspiration: 8.44 mm, Real Temp: 22.80 °C
Apparent Temp: 19.70 °C, Evapotranspiration: 9.82 mm, Real Temp: 24.80 °C
Apparent Temp: 19.80 °C, Evapotranspiration: 9.56 mm, Real Temp: 24.80 °C
```

Quantum Weather Predictor

Predict mean temperature using quantum machine learning

Apparent Temperature (°C)

30

Range: 3.9 to 36 °C

Evapotranspiration (mm)

5

Range: 1.1 to 12.7 mm

Predict Temperature

Prediction Results

Predicted Mean Temperature: 29.54 °C

Closest Real Data Points from Dataset:

#1: Apparent Temp: 30.3 °C, Evapotranspiration: 5.2 mm, Real Temp: 30.5 °C

#2: Apparent Temp: 29.3 °C, Evapotranspiration: 5.1 mm, Real Temp: 28.9 °C

#3: Apparent Temp: 29.3 °C, Evapotranspiration: 5.1 mm, Real Temp: 27.8 °C

Thank you!