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A Machine Learning Approach to Climate Forecasting

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Abstract

Climate change poses a major threat, with impacts including water scarcity, extreme weather, and rising sea levels. Machine learning offers a powerful approach for climate modeling and prediction to support policymaking. This research developed a machine learning model to investigate climate variables in Saudi Arabia. Historical data on temperature, precipitation, pressure, and wind from 1980-2015 was used to train a Random Forest model, which then predicted temperature from 2016-2020 based on the other variables. After preprocessing and compatibility checks, the model achieved a 2.69% mean-squared error, demonstrating its accuracy. The unifunctional model successfully uncovered interdependencies between variables. Next steps involve integrating it into a multifunctional tool with broader predictive capabilities. Overall, this work produced an accurate machine learning model for a key climate variable. With further development, such models can generate actionable insights and early warnings related to weather disasters, agriculture, air quality, sea level rise, and other impacts in Saudi Arabia and beyond.

Introduction

Climate change plays a major role in environmental problems. Over 1.9 billion people lack sufficient water due to changing weather, while more than 400 extreme weather events have occurred recently, up from about 200 in the 1980s. Furthermore, Climate change led to shifts in weather patterns, contributing to more frequent and severe dust storms. Increased desertification and reduced vegetation cover can enhance the generation and transport of dust particles, leading to worsened air quality leading to air pollution. For these reasons the problem should be taken seriously and treated accordingly. Part of tackling climate change is modeling to it to make future predictions and then those models can be used for policy assessment, impact assessment, economic assessment, etc. Most climate models are Physical and mathematical Climate models ,but they struggle with long-term predictions due to complexity in data. Machine learning excels at understanding complex data and patterns, making it ideal for climate modeling. This research examines connections between temperature, precipitation, surface pressure, and wind, using the Random Forests machine learning Algorithm to predict the temperature using the others, focusing on Saudi Arabia's climate. For future plans this model will be integrated with other models to develop a multifunctional machine learning model for climate forecasting. Applications include early warnings for weather disasters, insights into the effect of climate change on agriculture etc.

Methodology

A System model was developed to construct the overall system view. Ontological modeling was used as the modeling approach. after Modeling the system, chronological satellite data for the climate was retrieved from the 'ERA5 Monthly Aggregates' via Google Earth Engine. The data was preprocessed, and Random Forest Algorithm was then implemented to make predictions for the temperature based on the other climate variables. The model was then tested using the mean squared error test.

The training data is for the years 1980-2015

Testing data is for the years 2016-2020

Tools in use:

Google Earth Engine Python API (figure 1), via Google Collab

```
[ ] #Predictioyns using the model and testing it
x_train = independent_array
y_train = dependent_array
x_test = test_indarray
rf = RandomForestRegressor()
rf.fit(x_train, y_train)
y_pred = rf.predict(x_test)

mse = mean_squared_error(y_true, y_pred)
print("Mean Squared Error:", mse)
mape = mean_absolute_percentage_error(y_true, y_pred)
mape_percentage = mape * 100
print("MAPE: {:.2f}%".format(mape_percentage))

Mean Squared Error: 2.690080638827671
MAPE: 0.45%
```

Figure 1: Mean Square error testing

Results

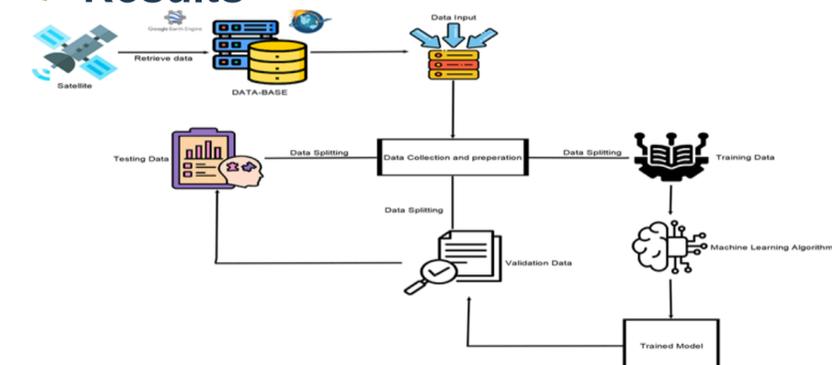


Figure 2: System Overview

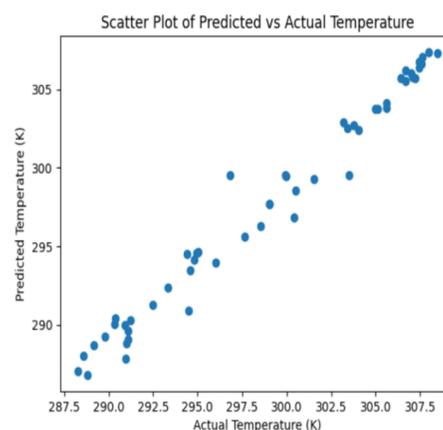


Figure 3: Scatter plot of predicted vs Actual temperature

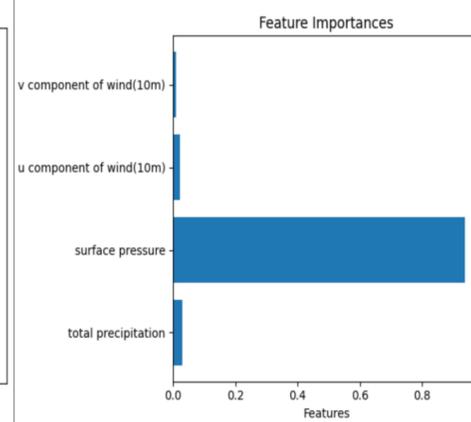


Figure 4: Histogram for level of dependency

Conclusion

- 01 The scatter plot (figure 3) displayed a linear relationship between the predicted and actual values of the temperature, which suggests accurate predictions
- 02 The accuracy was tested through the use of the mean square error method, (figure 1) which yielded 2.69% meaning that the model is accurate.
- 03 The Model was also able to identify the relationship between the variables, as demonstrated by the histogram (figure 4)
- 04 Future plans involve integrating the current uni-functional model with others and expanding data to include more variables, like greenhouse gases, creating a multifunctional machine learning model for climate forecasting. This aims to offer comprehensive insights into climate change dynamics, leading to more practical applications including early warnings for weather disasters, insights into the effect of climate change on agriculture, air pollution, sea levels etc.

References

- 01 Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalysis of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), (date of access), <https://cds.climate.copernicus.eu/cdsapp#!/home>