Predicting Compressive Strength of Concrete Using IBM Watson Auto AI Experiment

FINAL REPORT

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INTRODUCTION

Machine learning (ML) is a highly multidisciplinary field and consists of various methods for obtaining new information. ML is most often used for prediction. Predicting the categorical variable values is called classification, whereas predicting the numerical variable values is called regression. Regression is the process of analysing the relationship between one or more independent variables and a dependent variable. ML methods have become popular as they allow researchers to improve the prediction accuracy of concrete properties and are used for various engineering applications. The ML methods have been used to increase the prediction accuracy of concrete properties, and the data derived from the literature sources were used.

Prediction of the concrete compressive strength (f_c) and slump (S) is important in terms of the desirability of concrete and its sustainability. The goals of this study were (i) to determine the most successful normalization technique for the datasets, (ii) to select the prime regression method to predict the f_c and S outputs, (iii) to obtain the best subset with the ReliefF feature selection method, and (iv) to compare the regression results for the original and selected subsets. Experimental results demonstrate that the decimal scaling and min-max normalization techniques are the most successful methods for predicting the compressive strength and slump outputs, respectively.

1.1 Overview

Concrete is a complex composite material. Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate.

The predictability of concrete strength is extremely low. Therefore, it is challenging to create a model with the dependent variables of the concrete. One of the biggest challenge is to consider too many independent variables precisely and get a relation between them.

In this project, we are considering 8 independent variables for predicting the concrete strength. This is dataset can be trained and tested using Regression Model which comes under Supervised Machine Learning. We are building and evaluating multiple Machine Learning Models, and finding the lowest RMSE to understand which model has higher accuracy.

For making we will use Watson Studios Auto AI Experiment feature. We just have to input the data and Auto AI will generate the model according to it. Then we can deploy the model and use Node Red to make a web application.

1.2 Purpose

To predict the concrete strength of using the composition of its mixture and age of the concrete. Concrete has been widely used in recent years because its production compliments environmental conservation. It is a standard industrial practice that the concrete is classified based on grades. This grade is nothing but the Compressive Strength of the concrete cube or cylinder. Cube or Cylinder samples are usually tested under a compression testing machine to obtain the strength of concrete. The test requisites differ country to country based on the design code. The prediction of the strength of concrete using non-destructive techniques is of great interest to engineers worldwide. This is mainly because. It saves a lot of money by determining the concrete strength without destruction of any real sample.

LITERATURE SURVEY

The ultimate goal of design mix is to estimate the content of cement, aggregate and water (and admixture if used) for a specific grade of concrete. A review of the literature involving well accepted conventional methods (codes) for design mix. The concrete mixes can be classified into three types first is nominal mix, second is standard mix and third is design mix.

2.1 Existing problem

Concrete's composition is getting complex day by day. It is mainly because engineers are trying to replace of existing composition with more durable and less expensive one to increase the strength and reduce the overall cost of production. Now, this increases the difficulty in predicting the strength as the number of nonlinear independent variables keeps on increasing day by day. In earlier days, the concrete strength is measure through other traditional methods like using drill holes, weight spring, or using sensors. But that requires a significant destruction of test sample and thereby increasing the cost. And the accuracy was also hardly 70%.

2.2 Proposed solution

With the use of Machine Learning Model, there will be no limitation of the complexity increasing number of variables. This Model and train and test the given population of concrete and with the best performing machine learning model it can effortlessly predict the strength of the concrete with much higher accuracy than traditional methods.

For making we will use Watson Studios Auto AI Experiment feature. We just have to input the data and Auto AI will generate the model according to it. Then we can deploy the model and use Node Red to make a web application. We will also be using normal python notebook to make a Machine Learning model which can also be deployed in Watson studio and then can also be used to make an app or a web application.

THEORITICAL ANALYSIS

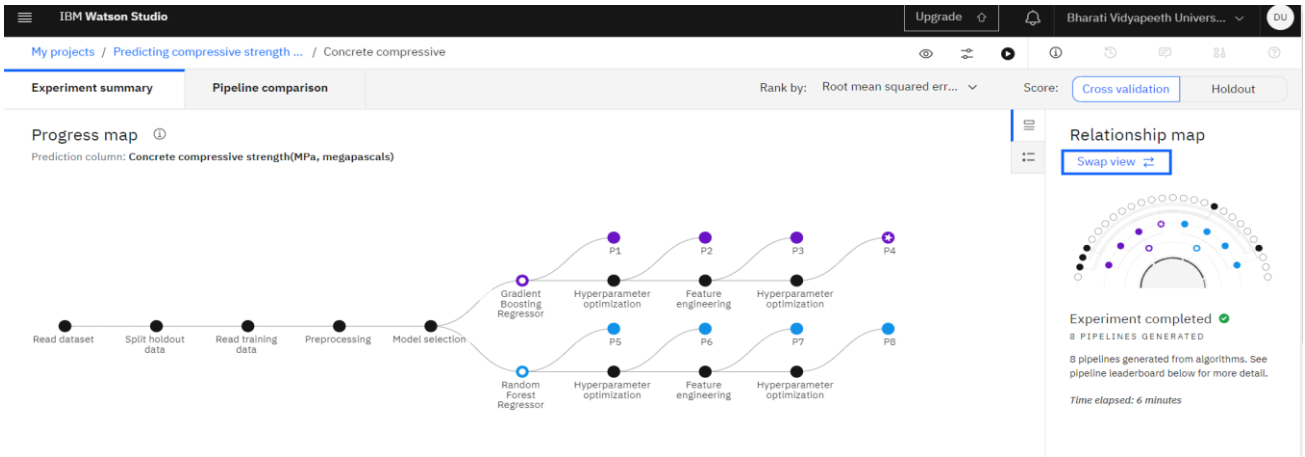
Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate.

Compressive strength is one of the most important engineering properties of concrete. It is a standard industrial practice that the concrete is classified based on grades. This grade is nothing but the Compressive Strength of the concrete cube or cylinder. Cube or Cylinder samples are usually tested under a compression testing machine to obtain the compressive strength of concrete. The test requisites differ country to country based on the design code.

The concrete compressive strength is a highly nonlinear function of age and ingredients .These ingredients include cement, blast furnace slag, fly ash, water, superplasticizer, coarse aggregate, and fine aggregate.

The actual concrete compressive strength (MPa) for a given mixture under a specific age (days) was determined from laboratory. Data is in raw form (not scaled). The compressive strength of concrete can be calculated by the failure load divided with the cross sectional area resisting the load and reported in pounds per square inch in US customary units and mega pascals (MPa) in SI units. Concrete's compressive strength requirements can vary from 2500 psi (17 MPa) for residential concrete to 4000psi (28 MPa) and higher in commercial structures. Higher strengths up to and exceeding 10,000 psi (70 MPa) are specified for certain applications.

3.1 Block diagram



3.2 Hardware / Software designing

For Auto AI solution:

- Strategy: matching the problem with the solution.
- Dataset preparation and pre-processing. Data collection.
- Adding Dataset to the Watson Machine Learning.
- Doing Auto AI analysis to find out the best model.
- Model deployment.
- Making Node Red flow.
- Deploying the machine learning model through that Flow Application.

For own ipynb Notebook solution:

- Strategy: matching the problem with the solution.
- Dataset preparation and pre-processing. Data collection. Data visualization. Labelling. Data selection. Data pre-processing. Data transformation.
- Dataset splitting into train data and test data.
- Modelling. Model training. Model evaluation and testing. Improving predictions with ensemble methods.
- Model deployment.
- Making Node Red flow.
- Deploying the machine learning model through that Flow Application.

EXPERIMENTAL INVESTIGATIONS

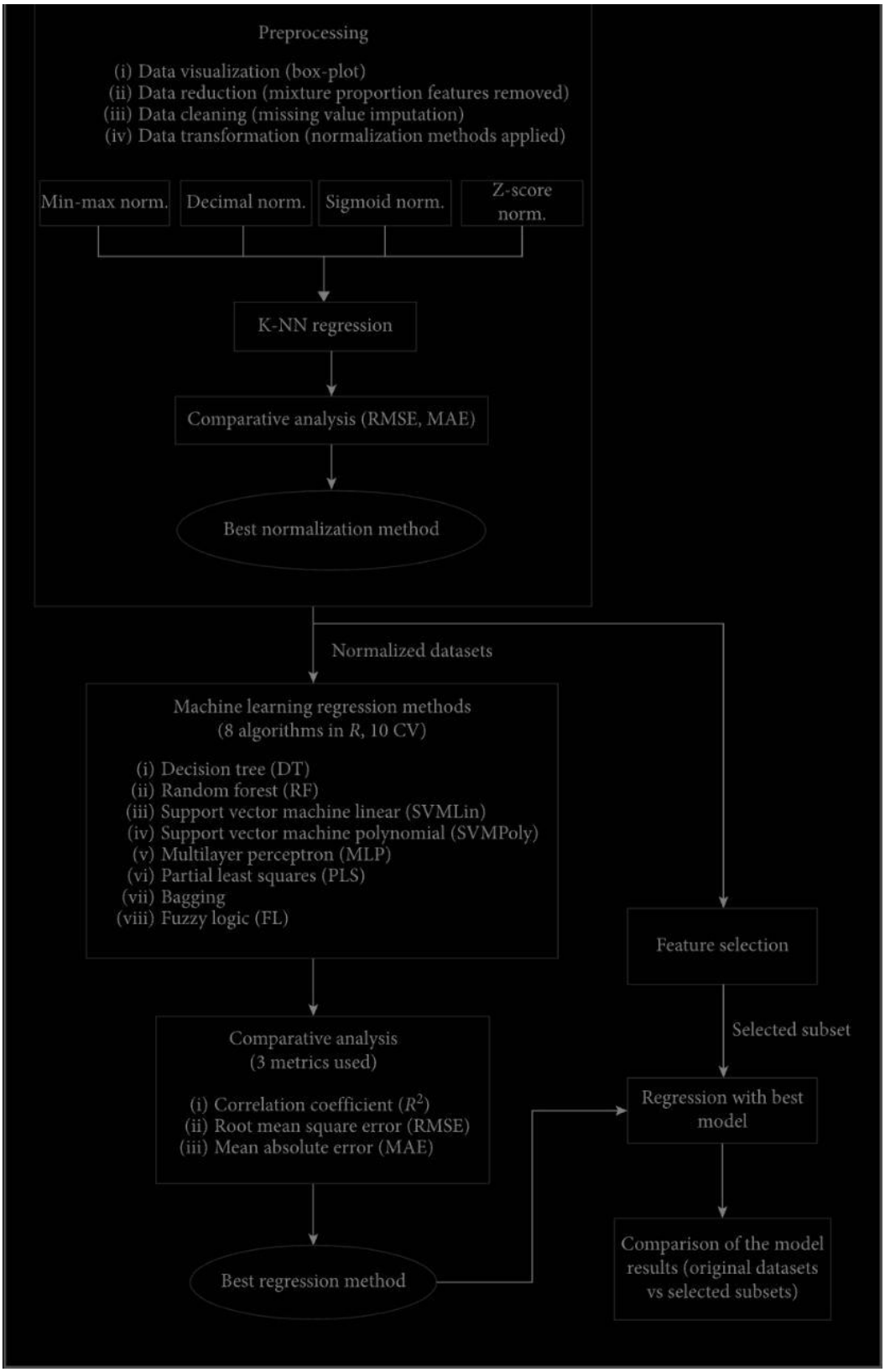
The compressive strength data for the present work was obtained from the experiments. For generating a reliable data bank on concrete compressive strength, he had considered five parameters, namely, water-cementitious material ratio, cementitious content, water content, workability, and curing ages in the experimental program. The casting and testing of specimens for generating the data bank were performed in controlled laboratory conditions.

Range of various parameters:

- Cement (component 1)(kg in a m^3 mixture) = 102 – 540
- Blast Furnace Slag (component 2)(kg in a m^3 mixture) = 0 – 359.4
- Fly Ash (component 3)(kg in a m^3 mixture) = 0 – 200.1
- Water (component 4)(kg in a m^3 mixture) = 121.75 - 247
- Superplasticizer (component 5)(kg in a m^3 mixture) = 0-32.2
- Coarse Aggregate (component 6)(kg in a m^3 mixture) = 801- 1145
- Fine Aggregate (component 7)(kg in a m^3 mixture) = 594 – 992.6
- Age (day) = 1 – 365

FLOWCHART

For own ipynb notebook model:



RESULT

Based on the 8 inputs entered by the user, the model predicts the strength of the concrete prepared and displays the predicted strength. And gives the output according to the entries in the Node red application. The correlation coefficient provides information on the effect level and direction of the linear relationship between two variables. The Pearson correlation is used when the dataset has a normal distribution, whereas the Spearman correlation is applied when the normal distribution cannot be reached.

ADVANTAGES & DISADVANTAGES

ADVANTAGES:

- Unlike traditional methods there is no wastage of test samples.
- Higher accuracy can reduces errors in wrong grading of concretes.
- Reduce the cost of finding out strength of concrete.
- Engineers might also be able to play around with the composition and mixture quantity and understand the desired outcome of the concrete strength.
- Easy user interface with straight forward prediction.

DISADVANTAGES:

- The construction mixtures of the concrete needs to be accurately found out before any prediction of concrete strength.
- The model is limited to predict the concrete strength for only those concretes which have exactly 8 compositions in their mixture.

APPLICATIONS

- It can be used to predict the strength of concrete that is made using several parameters.
- Assurance of concrete quality for manufacturing of optimal concrete.
- Implementable on the website.
- Can also be made into a phone app.

CONCLUSION

The goals of this study were (i) to determine the most successful normalization technique for the datasets, (ii) to obtain the prime regression method to predict the f_c and S values, (iii) to choose the best subset using the ReliefF feature selection method, and (iv) to compare the regression results for the original and selected subsets. The experimental designs with fewer effect variables are sufficient for estimating the concrete properties.

Since, any builder working on the concrete strength do not want to waste any of the physical resources for testing purpose. Our application helps in predicting the Strength of the concrete based on the past data without wasting any material.

FUTURE SCOPE

With this model now engineers would be able to determine the self-life of the concrete i.e. when will the concrete strength will be below average as per the age of the concrete. Based on this many would be able to advise when a construction with that particular grade of concrete should be renovated. This model can predict the outcome with many different inputs within seconds. The model will save a lot of time of the construction companies and the civil engineers. Experiment cost is also reduced with creates a bigger opportunity for construction companies in cost effectiveness work.

BIBILOGRAPHY APPENDIX

Source Code

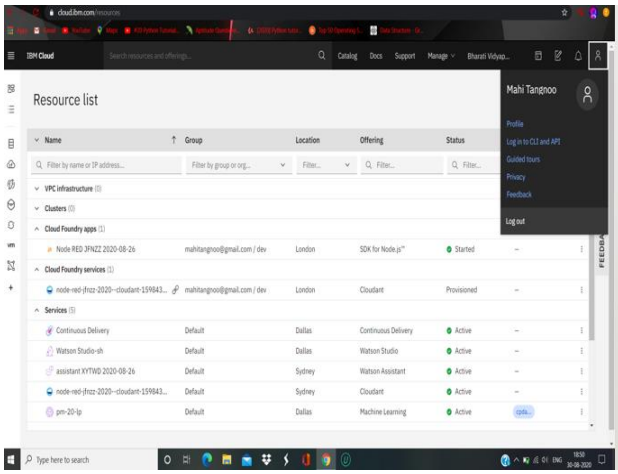
Model Building:

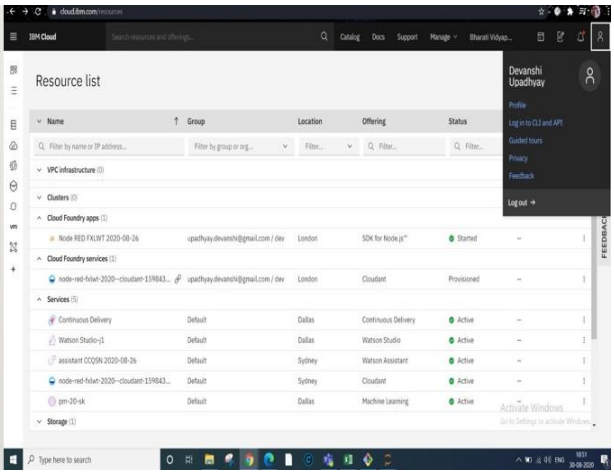
- Dataset
- Auto AI Notebook
- Own Model

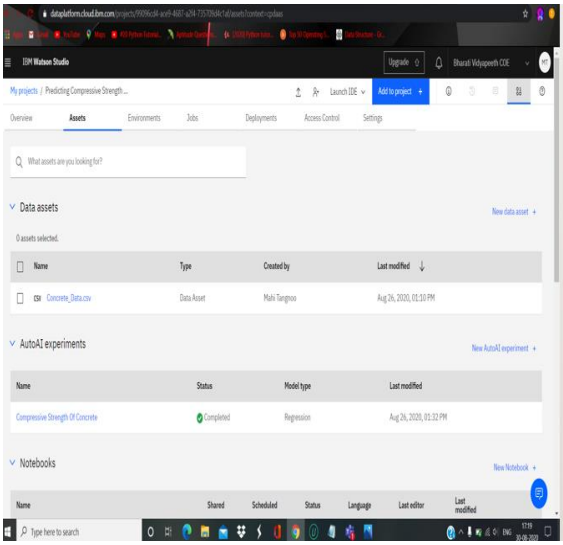
Application Building:

- Node-Red App
- App Link

UI Output Screenshot



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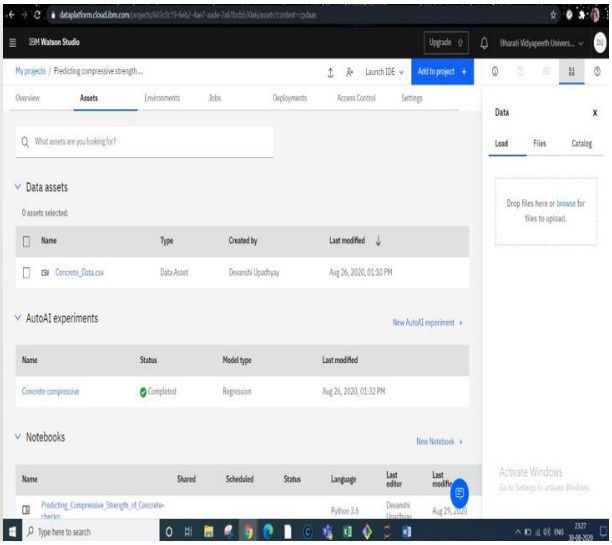
Data assets
AutoAI experiments
Notebooks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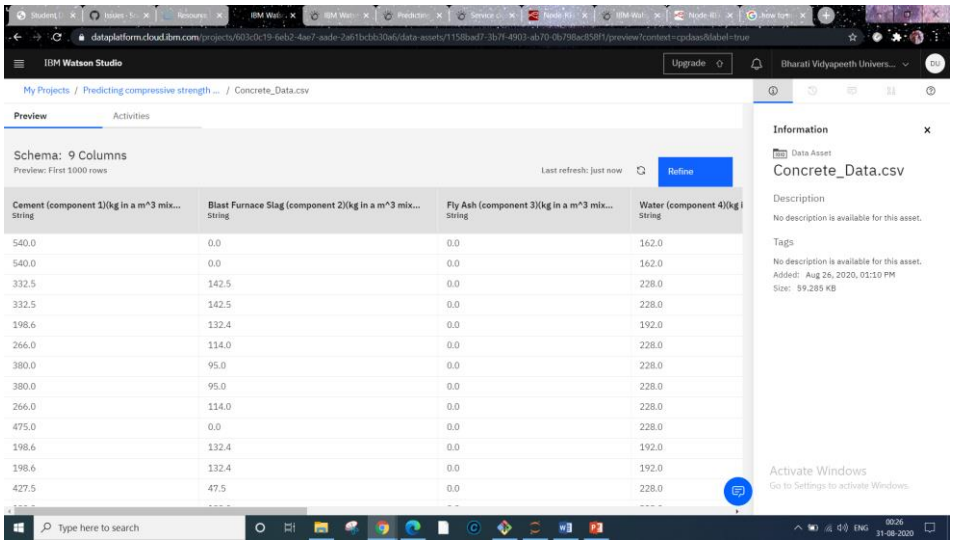
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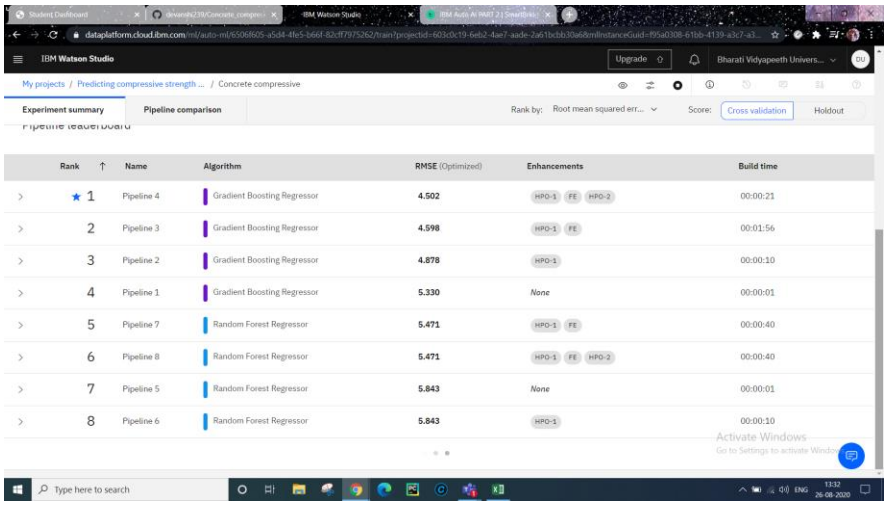
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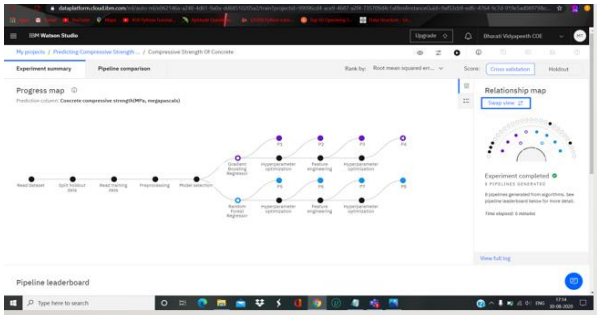
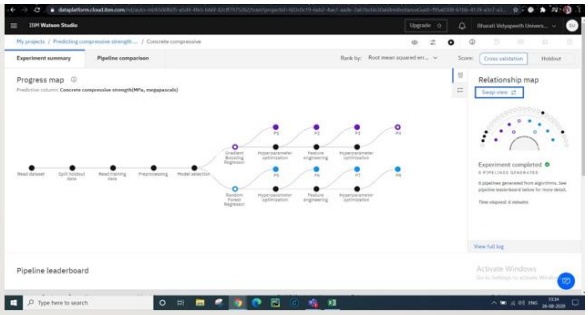
Concrete compressive


IBM Watson Studio
Progress map
Relationship map
Pipeline leaderboard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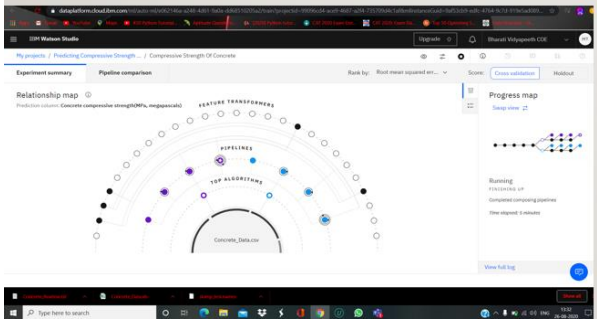
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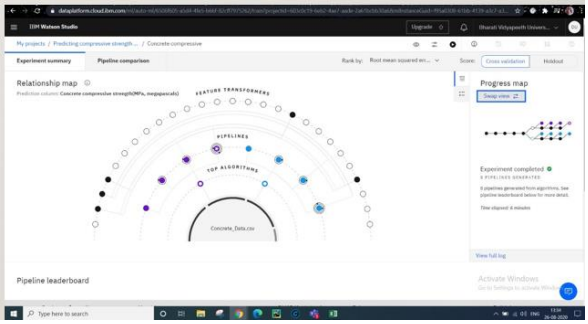
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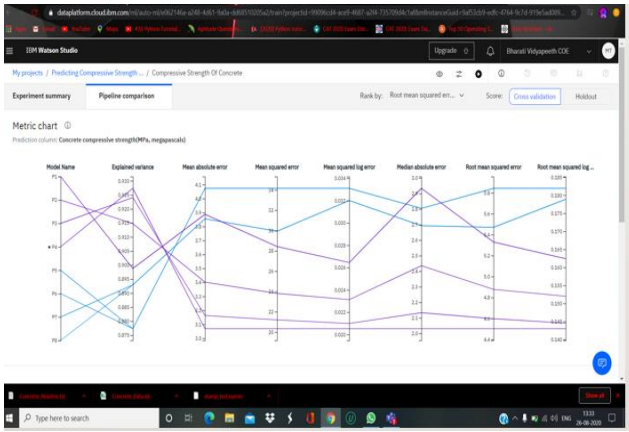
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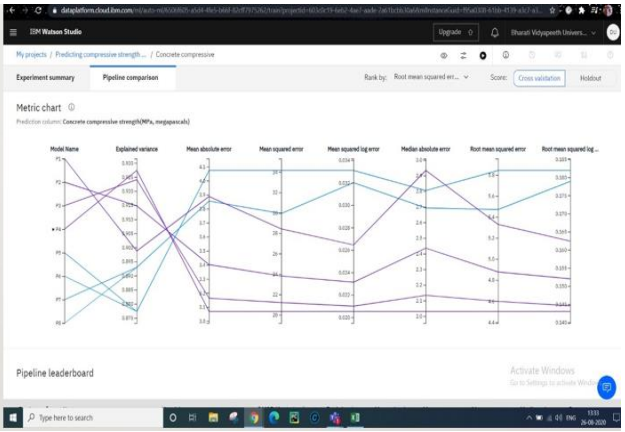
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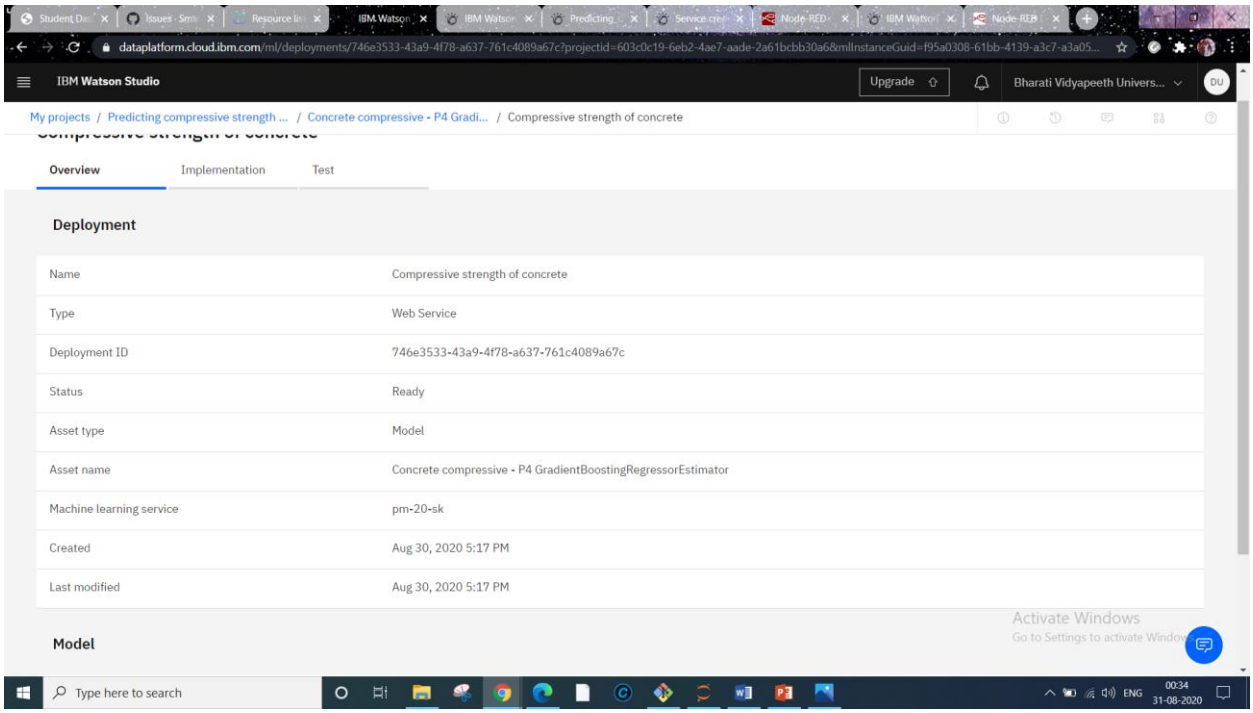
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My projects / Predicting compressive strength ... / Concrete compressive - P4 Gradi... / Compressive strength of concrete
Overview
Implementation
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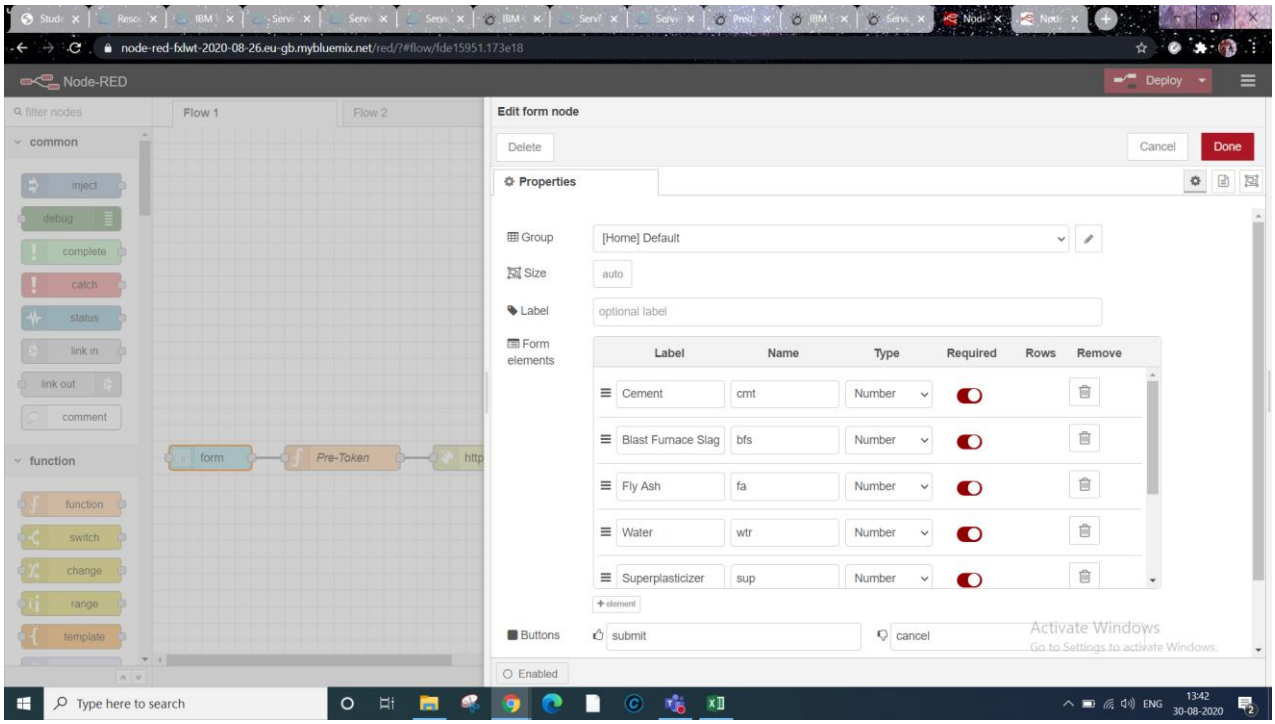
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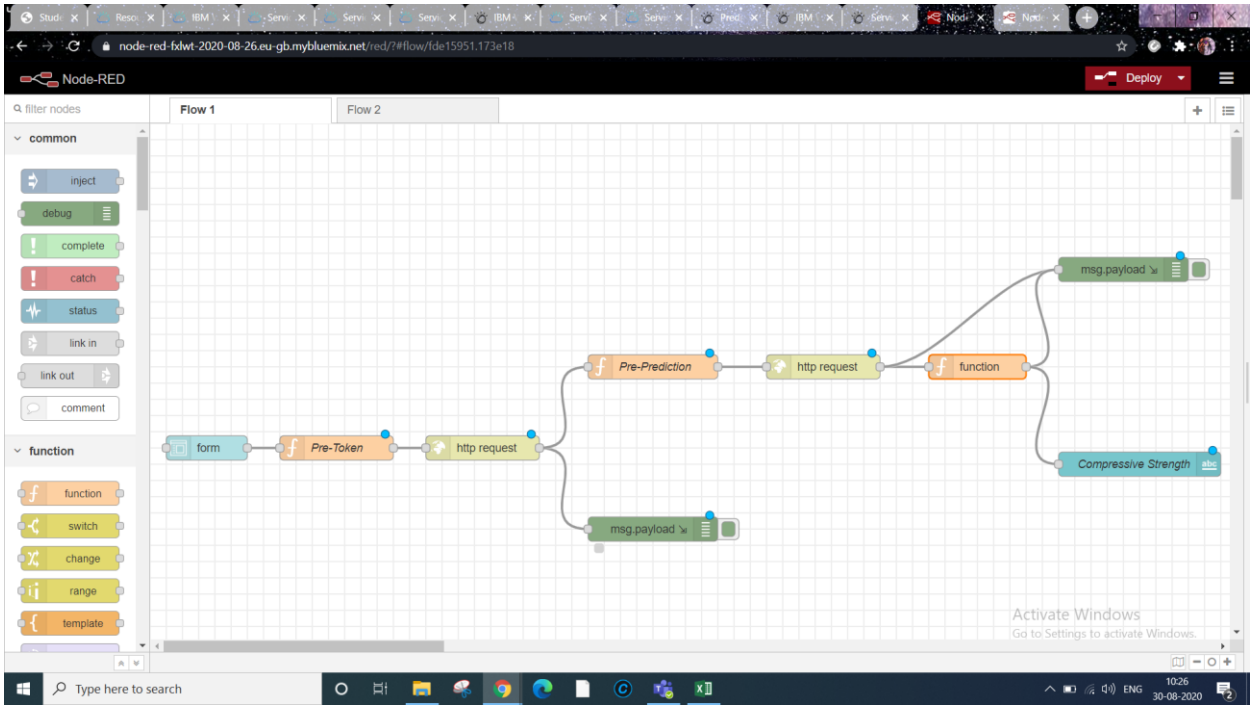
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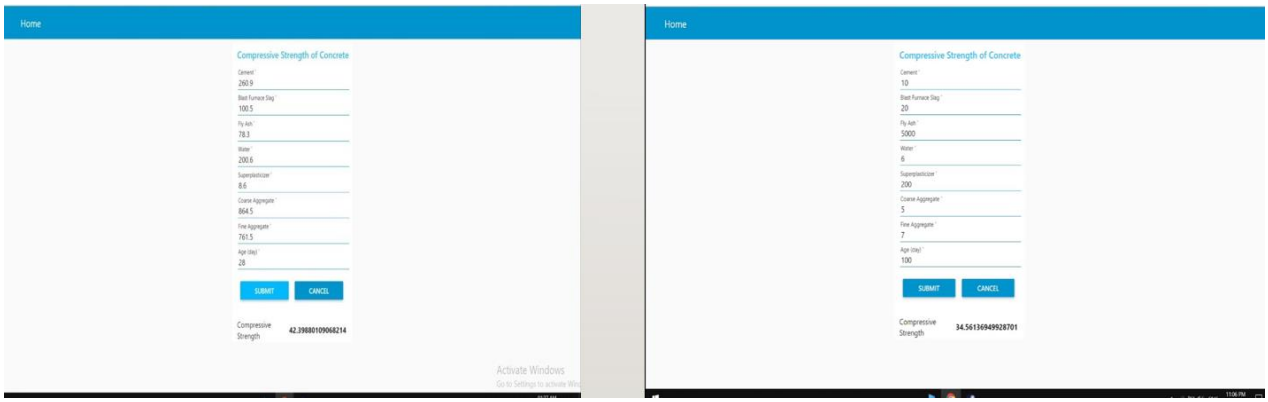
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