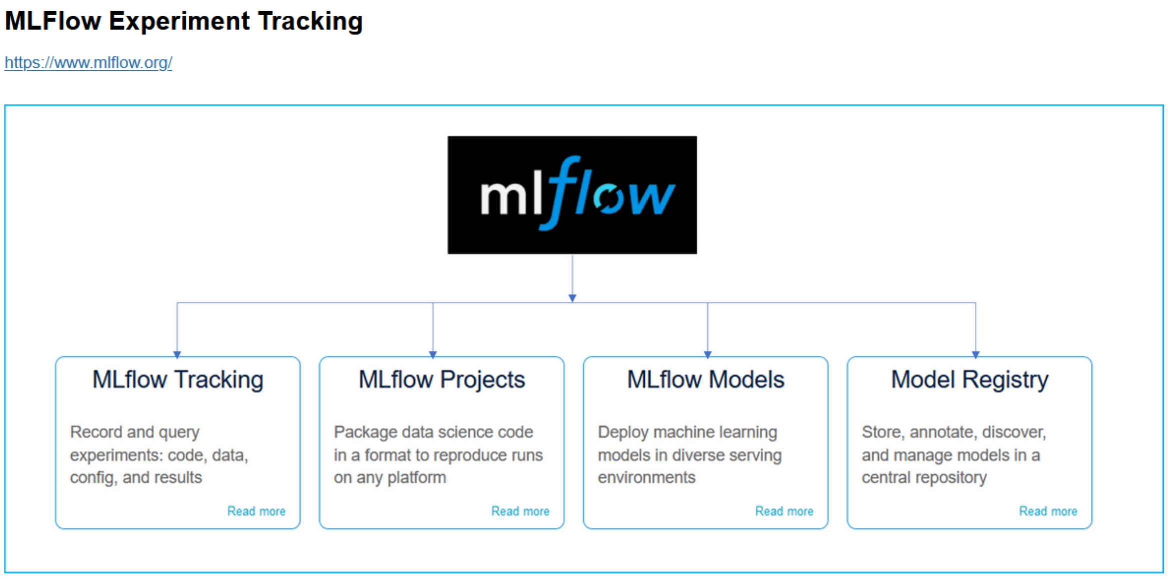

MLFlow Experiment Tracking

https://www.mlflow.org/

MLflow Tracking

Record and query experiments: code, data, config, and results

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MLflow Projects

Package data science code in a format to reproduce runs on any platform

Read more

MLflow Models

Deploy machine learning models in diverse serving environments

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Model Registry

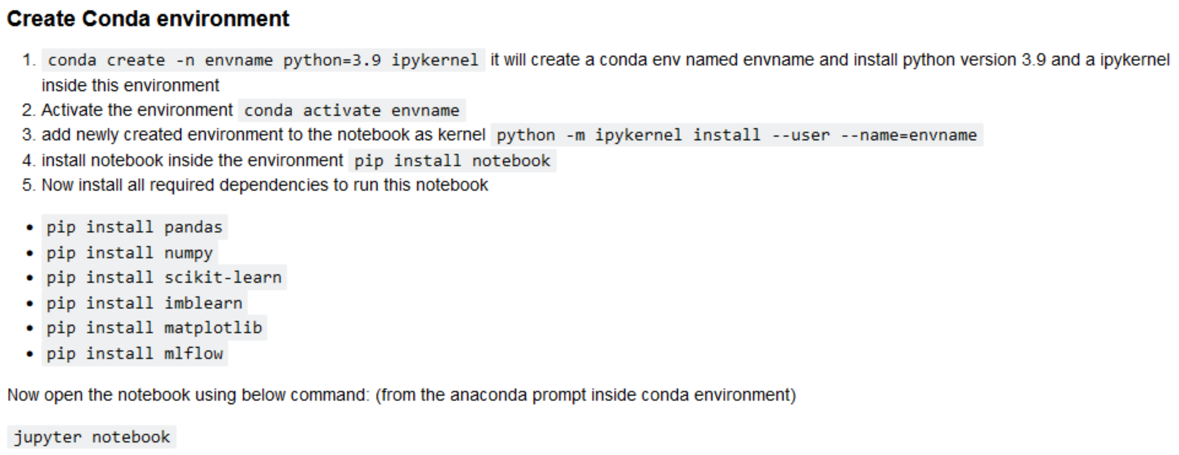
Store, annotate, discover, and manage models in a central repository

Read more

Topics Covered:

- Conda Environment Creation
- Model training important steps written as python function
- Train basic classifier and log it as an experiment
- Do Model hyperparameter tuning and again log the tuned model as another experiment
- log various parameters, model metrics, model itself and other artifacts like charts etc.

Explanation with live demo is also available at: https://www.youtube.com/watch?v=r0do1KVEGqM



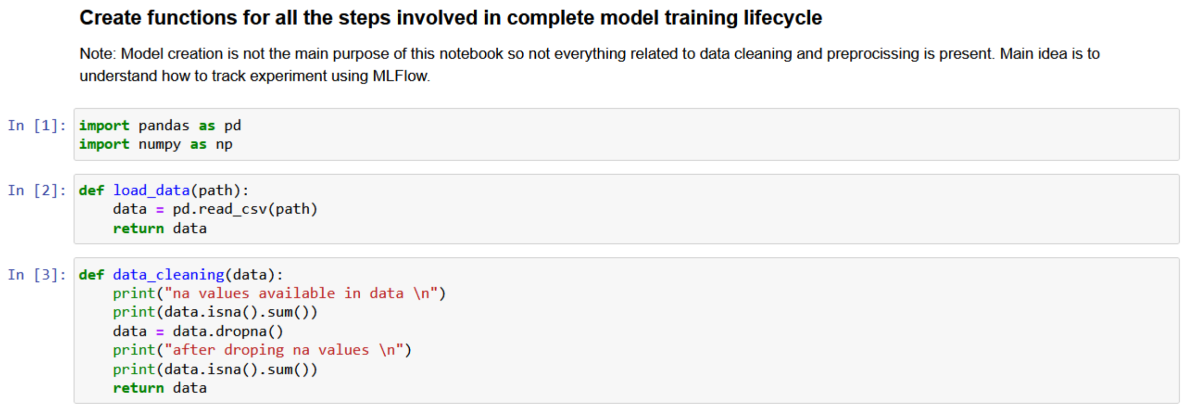
Create Conda environment

1. `conda create -n envname python=3.9 ipykernel` it will create a conda env named envname and install python version 3.9 and a ipykernel inside this environment
2. Activate the environment `conda activate envname`
3. add newly created environment to the notebook as kernel `python -m ipykernel install --user --name=envname`
4. install notebook inside the environment `pip install notebook`
5. Now install all required dependencies to run this notebook

- `pip install pandas`
- `pip install numpy`
- `pip install scikit-learn`
- `pip install imblearn`
- `pip install matplotlib`
- `pip install mlflow`

Now open the notebook using below command: (from the anaconda prompt inside conda environment)

```
jupyter notebook
```



Create functions for all the steps involved in complete model training lifecycle

Note: Model creation is not the main purpose of this notebook so not everything related to data cleaning and preprocessing is present. Main idea is to understand how to track experiment using MLFlow.

In [1]:
```
import pandas as pd
import numpy as np
```

In [2]:
```
def load_data(path):
    data = pd.read_csv(path)
    return data
```

In [3]:
```
def data_cleaning(data):
    print("na values available in data \n")
    print(data.isna().sum())
    data = data.dropna()
    print("after droping na values \n")
    print(data.isna().sum())
    return data
```

```
In [4]: def preprocessing(data):
            data['education']=np.where(data['education'] =='basic.9y', 'Basic', data['education'])
            data['education']=np.where(data['education'] =='basic.6y', 'Basic', data['education'])
            data['education']=np.where(data['education'] =='basic.4y', 'Basic', data['education'])

            cat_vars=['job','marital','education','default','housing','loan','contact','month','day_of_week','poutcome']
            for var in cat_vars:
                cat_list='var'+'_'+var
                cat_list = pd.get_dummies(data[var], prefix=var)
                data1=data.join(cat_list)
                data=data1

            cat_vars=['job','marital','education','default','housing','loan','contact','month','day_of_week','poutcome']
            data_vars=data.columns.values.tolist()
            to_keep=[i for i in data_vars if i not in cat_vars]

            final_data=data[to_keep]


            final_data.columns = final_data.columns.str.replace('.','_')
            final_data.columns = final_data.columns.str.replace(' ','_')
            return final_data
```

```
In [5]: def train_test_split(final_data):
            from sklearn.model_selection import train_test_split
            X = final_data.loc[:, final_data.columns != 'y']
            y = final_data.loc[:, final_data.columns == 'y']

            X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3,stratify = y, random_state=47)
            return X_train, X_test, y_train, y_test
```

```
In [6]: def over_sampling_target_class(X_train, y_train):
            ### Over-sampling using SMOTE
            from imblearn.over_sampling import SMOTE
            os = SMOTE(random_state=0)

            columns = X_train.columns
            os_data_X,os_data_y=os.fit_resample(X_train, y_train)

            os_data_X = pd.DataFrame(data=os_data_X,columns=columns )
            os_data_y= pd.DataFrame(data=os_data_y,columns=['y'])
            # we can Check the numbers of our data
            print("length of oversampled data is ",len(os_data_X))
            print("Number of no subscription in oversampled data",len(os_data_y[os_data_y['y']==0]))
            print("Number of subscription",len(os_data_y[os_data_y['y']==1]))
            print("Proportion of no subscription data in oversampled data is ",len(os_data_y[os_data_y['y']==0])/len(os_data_X))
            print("Proportion of subscription data in oversampled data is ",len(os_data_y[os_data_y['y']==1])/len(os_data_X))

            X_train = os_data_X
            y_train = os_data_y['y']

            return X_train, y_train
```

```
In [7]: def training_basic_classifier(X_train,y_train):
            from sklearn.ensemble import RandomForestClassifier
            model = RandomForestClassifier(n_estimators=101)
            model.fit(X_train, y_train)

            return model
```

```
In [8]: def predict_on_test_data(model,X_test):
            y_pred = model.predict(X_test)
            return y_pred
```

```
In [9]: def predict_prob_on_test_data(model,X_test):
            y_pred = model.predict_proba(X_test)
            return y_pred
```

```
In [10]: def get_metrics(y_true, y_pred, y_pred_prob):
             from sklearn.metrics import accuracy_score,precision_score,recall_score,log_loss
             acc = accuracy_score(y_true, y_pred)
             prec = precision_score(y_true, y_pred)
             recall = recall_score(y_true, y_pred)
             entropy = log_loss(y_true, y_pred_prob)
             return {'accuracy': round(acc, 2), 'precision': round(prec, 2), 'recall': round(recall, 2), 'entropy': round(entropy, 2)}
```

```
In [11]: def create_roc_auc_plot(clf, X_data, y_data):
             import matplotlib.pyplot as plt
             from sklearn import metrics
             metrics.plot_roc_curve(clf, X_data, y_data)
             plt.savefig('roc_auc_curve.png')
```

```
In [12]: def create_confusion_matrix_plot(clf, X_test, y_test):
             import matplotlib.pyplot as plt
             from sklearn.metrics import plot_confusion_matrix
             plot_confusion_matrix(clf, X_test, y_test)
             plt.savefig('confusion_matrix.png')
```

```
In [13]: url = 'https://raw.githubusercontent.com/TripathiAshutosh/dataset/main/banking.csv'
         data = load_data(url)
```

```
In [14]: cleaned_data = data_cleaning(data)
```

```
na values available in data

age               0
job               0
marital           0
education         0
default           0
housing           0
loan              0
contact           0
month             0
day_of_week       0
duration          0
campaign          0
pdays             0
previous          0
poutcome          0
emp_var_rate      0
cons_price_idx    0
```

```
In [15]: final_data = preprocessing(cleaned_data)
```

```
C:\Users\Ashutosh Tripathi\AppData\Local\Temp\ipykernel_41232\4067079169.py:20: FutureWarning: The default value of regex will
change from True to False in a future version. In addition, single character regular expressions will *not* be treated as liter
al strings when regex=True.
  final_data.columns = final_data.columns.str.replace('.','_')
```

```
In [16]: X_train, X_test, y_train, y_test = train_test_split(final_data)
```

```
In [17]: X_train, y_train = over_sampling_target_class(X_train, y_train)
```

```
length of oversampled data is  51166
Number of no subscription in oversampled data 25583
Number of subscription 25583
Proportion of no subscription data in oversampled data is  0.5
Proportion of subscription data in oversampled data is  0.5
```

```
In [18]: model = training_basic_classifier(X_train,y_train)
```

```
In [19]: y_pred = predict_on_test_data(model,X_test)
```

```
In [20]: y_pred
```

```
Out[20]: array([0, 0, 0, ..., 0, 0, 0], dtype=int64)
```

```
In [21]: y_pred_prob = predict_prob_on_test_data(model,X_test) #model.predict_proba(X_test)
```

```
In [22]: y_pred_prob
```

```
Out[22]: array([[1.        , 0.        ],
                [0.97029703, 0.02970297],
                [0.92079208, 0.07920792],
                ...,
                [1.        , 0.        ],
                [0.71287129, 0.28712871],
                [0.99009901, 0.00990099]])
```

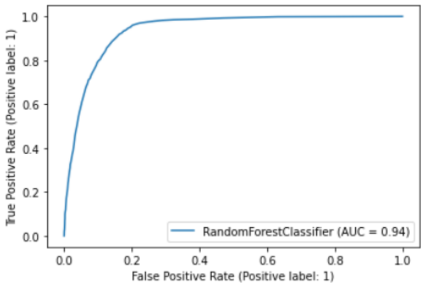
```
In [23]: run_metrics = get_metrics(y_test, y_pred, y_pred_prob)
```

```
In [24]: print(run_metrics)
```

```
{'accuracy': 0.91, 'precision': 0.63, 'recall': 0.51, 'entropy': 0.2}
```

```
In [25]: create_roc_auc_plot(model, X_test, y_test)
```

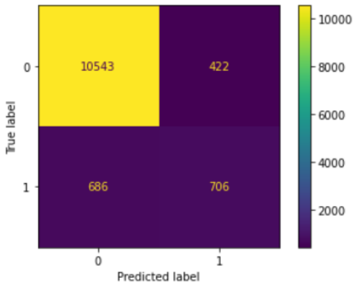
```
C:\Users\Ashutosh Tripathi\anaconda3\envs\mlops\lib\site-packages\sklearn\utils\deprecation.py:87: FutureWarning: Function plot
_roc_curve is deprecated; Function :func:`plot_roc_curve` is deprecated in 1.0 and will be removed in 1.2. Use one of the class
methods: :meth:`sklearn.metric.RocCurveDisplay.from_predictions` or :meth:`sklearn.metric.RocCurveDisplay.from_estimator`.
  warnings.warn(msg, category=FutureWarning)
```



In [26]:

```
create_confusion_matrix_plot(model, X_test, y_test)
```

```
C:\Users\Ashutosh Tripathi\anaconda3\envs\mlops\lib\site-packages\sklearn\utils\deprecation.py:87: FutureWarning: Function plot
_confusion_matrix is deprecated; Function `plot_confusion_matrix` is deprecated in 1.0 and will be removed in 1.2. Use one of t
he class methods: ConfusionMatrixDisplay.from_predictions or ConfusionMatrixDisplay.from_estimator.
  warnings.warn(msg, category=FutureWarning)
```



MLFlow work Starts from here

Function to create an experiment in MLFlow and log parameters, metrics and artifacts files like images etc.

In [27]:

```
def create_experiment(experiment_name,run_name, run_metrics,model, confusion_matrix_path = None,
                      roc_auc_plot_path = None, run_params=None):
    import mlflow
    #mlflow.set_tracking_uri("http://localhost:5000") #uncomment this line if you want to use any database like sqlite as backend
    mlflow.set_experiment(experiment_name)

    with mlflow.start_run():

        if not run_params == None:
            for param in run_params:
                mlflow.log_param(param, run_params[param])

        for metric in run_metrics:
            mlflow.log_metric(metric, run_metrics[metric])

        mlflow.sklearn.log_model(model, "model")

        if not confusion_matrix_path == None:
            mlflow.log_artifact(confusion_matrix_path, 'confusion_materix')

        if not roc_auc_plot_path == None:
            mlflow.log_artifact(roc_auc_plot_path, "roc_auc_plot")

        mlflow.set_tag("tag1", "Random Forest")
        mlflow.set_tags({"tag2":"Randomized Search CV", "tag3":"Production"})

    print('Run - %s is logged to Experiment - %s' %(run_name, experiment_name))
```

Create Experiment for basic classifier and log the artifacts

In [29]:

```
experiment_name = "basic_classifier" ##basic classifier
run_name="term_deposit"
run_metrics = get_metrics(y_test, y_pred, y_pred_prob)
print(run_metrics)
```

```
{'accuracy': 0.91, 'precision': 0.63, 'recall': 0.51, 'entropy': 0.2}
```

In [30]:

```
create_experiment(experiment_name,run_name,run_metrics,model,'confusion_matrix.png', 'roc_auc_curve.png')
```

```
Run - term_deposit is logged to Experiment - basic_classifier
```

```
C:\Users\Ashutosh Tripathi\anaconda3\envs\mlops\lib\site-packages\_distutils_hack\__init__.py:30: UserWarning: Setuptools is re
placing distutils.
  warnings.warn("Setuptools is replacing distutils.")
```

Model Tuning

In [31]:
```
def hyper_parameter_tuning(X_train, y_train):
    # define random parameters grid
    n_estimators = [5,21,51,101] # number of trees in the random forest
    max_features = ['auto', 'sqrt'] # number of features in consideration at every split
    max_depth = [int(x) for x in np.linspace(10, 120, num = 12)] # maximum number of levels allowed in each decision tree
    min_samples_split = [2, 6, 10] # minimum sample number to split a node
    min_samples_leaf = [1, 3, 4] # minimum sample number that can be stored in a leaf node
    bootstrap = [True, False] # method used to sample data points

    random_grid = {'n_estimators': n_estimators,
                   'max_features': max_features,
                   'max_depth': max_depth,
                   'min_samples_split': min_samples_split,
                   'min_samples_leaf': min_samples_leaf,
                   'bootstrap': bootstrap
                  }

    from sklearn.model_selection import RandomizedSearchCV
    from sklearn.ensemble import RandomForestClassifier
    classifier = RandomForestClassifier()
    model_tuning = RandomizedSearchCV(estimator = classifier, param_distributions = random_grid,
                   n_iter = 100, cv = 5, verbose=2, random_state=35, n_jobs = -1)
    model_tuning.fit(X_train, y_train)

    print ('Random grid: ', random_grid, '\n')
    # print the best parameters
    print ('Best Parameters: ', model_tuning.best_params_, ' \n')

    best_params = model_tuning.best_params_

    n_estimators = best_params['n_estimators']
    min_samples_split = best_params['min_samples_split']
    min_samples_leaf = best_params['min_samples_leaf']
    max_features = best_params['max_features']
    max_depth = best_params['max_depth']
    bootstrap = best_params['bootstrap']

    model_tuned = RandomForestClassifier(n_estimators = n_estimators, min_samples_split = min_samples_split,
                                         min_samples_leaf= min_samples_leaf, max_features = max_features,
                                         max_depth= max_depth, bootstrap=bootstrap)
    model_tuned.fit( X_train, y_train)
    return model_tuned,best_params
```

Create another experiment after tuning hyperparameters and log the best set of parameters for which model gives the optimal performance

In [32]:
```
import mlflow
experiment_name = "optimized model"
run_name="Random_Search_CV_Tuned_Model"
model_tuned,best_params = hyper_parameter_tuning(X_train, y_train)
run_params = best_params

y_pred = predict_on_test_data(model_tuned,X_test) #will return the predicted class
y_pred_prob = predict_prob_on_test_data(model_tuned,X_test) #model.predict_proba(X_test)
run_metrics = get_metrics(y_test, y_pred, y_pred_prob)
```

```
Fitting 5 folds for each of 100 candidates, totalling 500 fits
Random grid:  {'n_estimators': [5, 21, 51, 101], 'max_features': ['auto', 'sqrt'], 'max_depth': [10, 20, 30, 40, 50, 60, 7
0, 80, 90, 100, 110, 120], 'min_samples_split': [2, 6, 10], 'min_samples_leaf': [1, 3, 4], 'bootstrap': [True, False]}

Best Parameters:  {'n_estimators': 101, 'min_samples_split': 6, 'min_samples_leaf': 3, 'max_features': 'sqrt', 'max_depth
': 50, 'bootstrap': True}
```

In [33]:
```
run_metrics
```

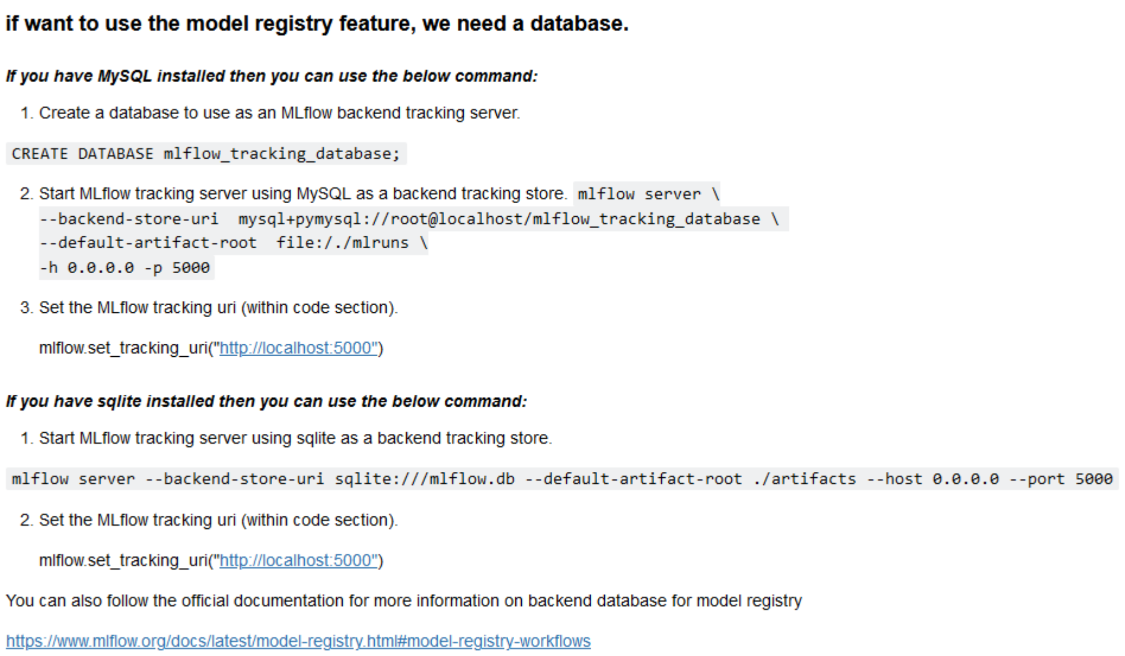
Out[33]:
```
{'accuracy': 0.91, 'precision': 0.62, 'recall': 0.54, 'entropy': 0.2}
```

In [34]:
```
for param in run_params:
    print(param, run_params[param])
```

```
n_estimators 101
min_samples_split 6
min_samples_leaf 3
max_features sqrt
max_depth 50
bootstrap True
```

In [35]:
```
create_experiment(experiment_name,run_name,run_metrics,model_tuned,'confusion_matrix.png', 'roc_auc_curve.png',run_params)
```

```
Run - Random_Search_CV_Tuned_Model is logged to Experiment - optimized model
```



if want to use the model registry feature, we need a database.

If you have MySQL installed then you can use the below command:

1. Create a database to use as an MLflow backend tracking server.

```
CREATE DATABASE mlflow_tracking_database;
```

2. Start MLflow tracking server using MySQL as a backend tracking store. `mlflow server \`

```
--backend-store-uri  mysql+pymysql://root@localhost/mlflow_tracking_database \
--default-artifact-root  file:/./mlruns \
-h 0.0.0.0 -p 5000
```

3. Set the MLflow tracking uri (within code section).

   mlflow.set_tracking_uri("http://localhost:5000")

If you have sqlite installed then you can use the below command:

1. Start MLflow tracking server using sqlite as a backend tracking store.

```
mlflow server --backend-store-uri sqlite:///mlflow.db --default-artifact-root ./artifacts --host 0.0.0.0 --port 5000
```

2. Set the MLflow tracking uri (within code section).

   mlflow.set_tracking_uri("http://localhost:5000")

You can also follow the official documentation for more information on backend database for model registry

https://www.mlflow.org/docs/latest/model-registry.html#model-registry-workflows

Notebook Explanation and MLFlow UI please watch the video:

https://www.youtube.com/watch?v=r0do1KVEGqM

Thank You