

Applied Machine Learning for Business Analytics

Lecture 10: Model Deployment in Machine Learning

Logistics

- Appreciate if you keeps video on!

Agenda

1. From Notebooks to Python Scripts
2. Interfaces of ML Systems
3. MLOps
4. Building ML Pipelines with better tools

1. From Notebooks to Python Scripts

Virtual Environment

- Virtual Environment is required to isolate the packages necessary for applications from our other projects that may have different dependencies
- `requirements.txt`
 - Set up the development environment
 - `pip freeze` will dump all dependencies of all our packages into the file
 - Try `pipreqs`, `pip-tools`
- `setup.py`
 - Redistribute the whole packages
 - Contains metadata, requirements and entry points

<https://stackoverflow.com/questions/43658870/requirements-txt-vs-setup-py>

Organized Code

- Code should be **readable, reproducible, scalable** and **efficient**,
- Notebooks are only suitable for POC
- The code can be organized based on utility i.e., working pipeline components

```
In [1]: # Widen width of notebook
from IPython.core.display import display, HTML
display(HTML("<style>.container { width:90% !important; }</style>"))
```

ML Practice Part 1

Agenda

1. Reading in and exploring the data
2. Feature engineering
3. Model evaluation using `train_test_split` and `cross_val_score`
4. Making predictions for new data
5. Searching for optimal tuning parameters using `GridSearchCV`
6. Extracting features from text using `CountVecorizer`
7. Chaining steps into a `Pipeline`

```
In [2]: # for Python 2: see print only as a function
from __future__ import print_function
```

```
In [3]: import pandas as pd
pd.set_option('max_colwidth', 100)
```

Part 1: Reading in and exploring the data

```
In [4]: train = pd.read_json('data/train.json')
train.head()
```

```
Out[4]:
```

	id	cuisine	ingredients
0	10299	green	[bruschetta lettuce, black olives, grape tomatoes, garlic, pepper, purple onion, seasoning, garlic...
1	25693	southern_us	[lean flour, ground pepper, salt, tomatoes, ground black pepper, thyme, eggs, green tomatoes, y...
2	20130	filipino	[eggs, pepper, salt, mayonaisse, cooking oil, green chilies, grilled chicken breasts, garlic powder...
3	22213	indian	[onion, vegetable oil, wheat, salt]
4	13162	indian	[black pepper, shalots, coriander, cayenne pepper, onions, garlic paste, milk, butter, salt, h...

```
In [5]: train.shape
```

```
Out[5]: (39774, 3)
```

```
In [6]: # count the number of null values in each column
train.isnull().sum()
```

```
Out[6]:
```

id	0
cuisine	0
ingredients	0
dtype:	int64

Cookiecutter Data Science Template

- One of templates we can use is:
 - <https://drivendata.github.io/cookiecutter-data-science/>

Cookiecutter Data Science

A logical, reasonably standardized, but flexible project structure for doing and sharing data science work.

Cookiecutter Data Science Template

```
pip install cookiecutter
cookiecutter https://github.com/drivendata/cookiecutter-data-science
cd churn_model
```

```
(churn_model) ruizhao@Ruis-MBP ~$ cookiecutter https://github.com/drivendata/cookiecutter-data-science
You've downloaded /Users/ruizhao/.cookiecutters/cookiecutter-data-science before. Is it okay to delete and re-download it? [yes]: yes
project_name [project_name]: churn_model
repo_name [churn_model]: churn_model
author_name [Your name (or your organization/company/team)]: BT5153
description [A short description of the project.]: ML Pipeline Demo
Select open_source_license:
1 - MIT
2 - BSD-3-Clause
3 - No license file
Choose from 1, 2, 3 [1]: 1
s3_bucket [[OPTIONAL] your-bucket-for-syncing-data (do not include 's3:/' )]:
aws_profile [default]:
Select python_interpreter:
1 - python3
2 - python
Choose from 1, 2 [1]: 1
```

Metadata

Cookiecutter Template

- The folder will be generated following the template
- Easier for us to understand and modify the code base

```
├── LICENSE
├── Makefile          <- Makefile with commands like 'make data' or 'make train'
├── README.md        <- The top-level README for developers using this project.
├── data
│   ├── external     <- Data from third party sources.
│   ├── interim      <- Intermediate data that has been transformed.
│   ├── processed     <- The final, canonical data sets for modeling.
│   └── raw           <- The original, immutable data dump.
├── docs              <- A default Sphinx project; see sphinx-doc.org for details
├── models            <- Trained and serialized models, model predictions, or model summaries
├── notebooks         <- Jupyter notebooks. Naming convention is a number (for ordering),
│                       the creator's initials, and a short '-' delimited description, e.g.
│                       '1.0-jqp-initial-data-exploration'.
├── references         <- Data dictionaries, manuals, and all other explanatory materials.
├── reports
│   └── figures        <- Generated graphics and figures to be used in reporting
├── requirements.txt   <- The requirements file for reproducing the analysis environment, e.g.
│                       generated with 'pip freeze > requirements.txt'
├── setup.py          <- Make this project pip installable with 'pip install -e'
├── src               <- Source code for use in this project.
│   ├── __init__.py   <- Makes src a Python module
│   ├── data          <- Scripts to download or generate data
│   │   └── make_dataset.py
│   ├── features       <- Scripts to turn raw data into features for modeling
│   │   └── build_features.py
│   ├── models         <- Scripts to train models and then use trained models to make
│   │                   predictions
│   │   ├── predict_model.py
│   │   └── train_model.py
│   └── visualization  <- Scripts to create exploratory and results oriented visualizations
│       └── visualize.py
└── tox.ini           <- tox file with settings for running tox; see tox.readthedocs.io
```

Config

Config directory or file should be created for the following:

- Hyper-parameters for training
- Specifications for model locations, logging and other hand-coded information
- Running a small test for training

Config Template

params.yaml

```
external_data_config:
  external_data_csv: data/external/train.csv

raw_data_config:
  raw_data_csv: data/raw/train.csv
  model_var: ['churn', 'number_vmail_messages', 'total_day_calls', 'total_eve_minutes', 'total_eve_charge', 'total_intl_minutes', 'number_customer_service_calls']
  train_test_split_ratio: 0.2
  target: churn
  random_state: 111
  new_train_data_csv: data/raw/train_new.csv

processed_data_config:
  train_data_csv: data/processed/churn_train.csv
  test_data_csv: data/processed/churn_test.csv

mlflow_config:
  artifacts_dir: artifacts
  experiment_name: model_iteration1
  run_name: random_forest
  registered_model_name: random_forest_model
  remote_server_uri: http://localhost:1234

random_forest:
  max_depth: 30
  n_estimators: 42

model_dir: models/model.joblib

model_webapp_dir: webapp/model_webapp_dir/model.joblib
```

Logging is important for ML Sys

- Life is short. You need logs
- Do not rely too much on print statements
 - For example, `print('aaaaaa')`
- Logging is the process of tracking and recording key events that occur in the applications
 - Inspect processes
 - Fix issues
 - More powerful than print statement

Logging 101

- **Logger:**
 - The main object that emits the log messages from the whole project
 - Can be specified to each module
- **Handler:**
 - Used for sending log records to a specific location and specifications for that location (name size, etc)
 - Different handlers have different rules to save logs in local files
- **Formatter**
 - Used for style and layout of the log records
- **Levels (according to different priorities)**
 - CRITICAL
 - ERROR
 - WARNING (Default setting for root logger)
 - INFO
 - DEBUG

Levels in Logs

```
1 import logging
2 import sys
3
4 # Create super basic logger
5 logging.basicConfig(stream=sys.stdout, level=logging.INFO)
6
7 # Logging levels (from lowest to highest priority)
8 logging.debug("Used for debugging your code.")
9 logging.info("Informative messages from your code.")
10 logging.warning("Everything works but there is something to be aware of.")
11 logging.error("There's been a mistake with the process.")
12 logging.critical("There is something terribly wrong and process may terminate.")
```

PROBLEMS 3 OUTPUT TERMINAL DEBUG CONSOLE

```
(base) ruizhao@Ruis-MBP ~/Desktop python test.py
INFO:root:Informative messages from your code.
WARNING:root:Everything works but there is something to be aware of.
ERROR:root:There's been a mistake with the process.
CRITICAL:root:There is something terribly wrong and process may terminate.
(base) ruizhao@Ruis-MBP ~/Desktop
```

Best Practices in Logging

- Logger in each module
 - Examples:

```
| app.py  
| package_a  
|     module_a.py
```

```
# app.py  
import logging  
logging.basicConfig(format='%(asctime)s - %(name)s - %(levelname)s: %(message)s')  
from package_a import module_a  
  
logger = logging.getLogger(__name__)  
logger.warning('from app')  
  
# module_a.py  
import logging  
  
logger = logging.getLogger(__name__)  
logger.warning('from module_a')  
$ python app.py  
2019-12-24 21:53:21,915 - package_a.module_a - WARNING: from module_a  
2019-12-24 21:53:21,916 - __main__ - WARNING: from app
```

Best Practices in Logging

- Logger in each module
 - Easy to identify the error source
 - But at the same time: it is important to throw the pot



甩锅

"甩锅" ("throw the pot/pass the buck")



"你背" ("let you carry the pot", i.e., "lay the blame on you")



你的锅

你的锅

"你的锅" ("it's your pot"/ "it's for you to get the blame")

Best Practices in Logging

- Log all the details that you want to generate from the inside
 - It could be useful during development and model running check
- Should log messages outside of small functions and inside larger workflow
 - Logger could be placed within main.py and train.py since the smaller functions defined in other scripts are used here

Logging Configuration

- Coding directly in scripts
- Using a config file
 - `logging.config.fileConfig()`
- Using the dictionary type
 - `logging.config.dictConfig()`
 - Can be put in `config/config.py`

Suitable for complex projects

Documenting Your Code

- Document our code is a way to organize our code
- What is more, make others and ourselves in the future to easily use the code base
- Most common documenting types:
 - Comments
 - Typing
 - Docstrings
 - Documentation

When it's been 7 hours and you still can't understand your own code



Comments

- Good code should not need comments because it is readable
- When do you need comments:



Ayush Goel, Learner, Worker

Answered Nov 21, 2013



Found this in the production code we use currently :

```
1 // This is black magic
2 // from
3 // *Some stackoverflow link
4 // Don't play with magic, it can BITE.
```

4.6K views · View 39 upvotes

Typing

- Make our code as explicit as possible
 - Naming for variables and functions should be self-explaining
- Typing: Define the types for our function's inputs and outputs

Starting from Python 3.9+, common types are **built in**

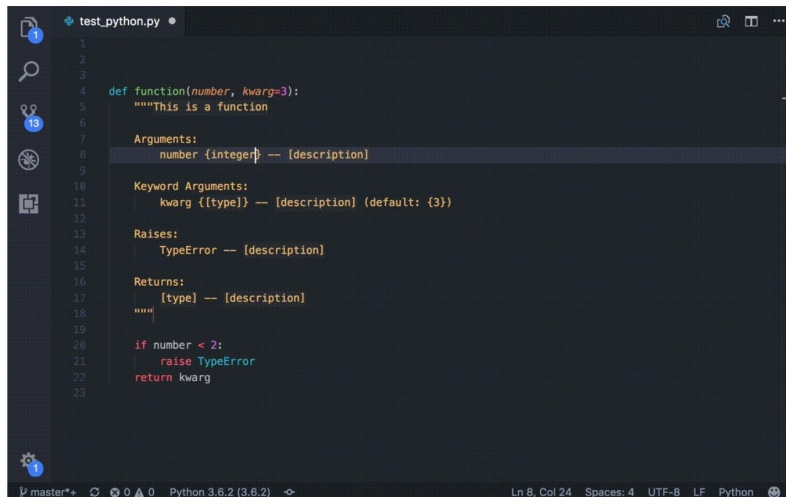
```
from typing import List, Tuple, Dict
def add(a: int, string: str, f: float, b: bool) -> Tuple[List, Tuple, Dict, bool]:
    list1 = list(range(a))
    tup = (string, string, string)
    d = {"a": f}
    bl = b
    return list1, tup, d, bl
print(add(5, "hhhh", 2.3, False))
```

Docstrings

- Docstrings could be placed in functions and classes
- Use Python Docstrings Generator extension in VS Code

autoDocstring: VSCode Python Docstring Generator

Visual Studio Code extension to quickly generate docstrings for python functions.

A screenshot of the Visual Studio Code editor interface. The editor window shows a file named 'test_python.py'. The code defines a function 'function(number, kwarg=3)'. The docstring for this function is generated and displayed, including sections for 'Arguments:', 'Keyword Arguments:', 'Raises:', and 'Returns:'. The function body contains a conditional check 'if number < 2:' followed by 'raise TypeError' and 'return kwarg'. The status bar at the bottom indicates the file is on 'master' branch, the cursor is at line 8, column 24, and the Python version is 3.6.2 (3.6.2).

```
1
2
3
4 def function(number, kwarg=3):
5     """This is a function
6
7     Arguments:
8     number {integer} -- [description]
9
10    Keyword Arguments:
11    kwarg {[type]} -- [description] (default: {3})
12
13    Raises:
14    TypeError -- [description]
15
16    Returns:
17    [type] -- [description]
18    """
19
20    if number < 2:
21        raise TypeError
22    return kwarg
23
```

<https://marketplace.visualstudio.com/items?itemName=njpwerner.autodocstring>

Documents

- The above are all placed inside scripts. The documentation is a separated doc.
- Some open-source packages could be used to automatically generate the documentation
 - [mkdocs](#) (generates project documentation)
 - [mkdocs-material](#) (styling to beautiful render documentation)
 - [mkdocstrings](#) (fetch documentation automatically from docstrings)

Styling

- Code is read more often than it is written
- Follow consistent style and formatting conventions -> make code easy to read
- Most conventions are based on PEP8 conventions.
- We have lots of pipeline tools in place to automatically and effortlessly ensure that consistency

PEP 8 -- Style Guide for Python Code

PEP:	8
Title:	Style Guide for Python Code
Author:	Guido van Rossum <guido at python.org>, Barry Warsaw <barry at python.org>, Nick Coghlan <ncoghlan at gmail.com>
Status:	Active
Type:	Process
Created:	05-Jul-2001
Post-History:	05-Jul-2001, 01-Aug-2013

Styling Tools

- Those tools could be used with configurable options:
 - **Black**: an in-place reformatter that (mostly) **adheres** to PEP8.
 - **isort**: sorts and formats import statements inside Python scripts.
 - **flake8**: a code linter with stylistic conventions that adhere to PEP8.

```
# Black formatting
[tool.black]
line-length = 100
include = '\.pyi?$'
exclude = '''
/(
    \.eggs          # exclude a few common directories in the
    | \.git          # root of the project
    | \.hg
    | \.mypy_cache
    | \.tox
    | \.venv
    | _build
    | buck-out
    | build
    | dist
)/
'''
```

Formatting done by Black

```
# in:

def very_important_function(template: str, *variables, file: os.PathLike, engine: str, header: bool = True, debug: bool = False):
    """Applies `variables` to the `template` and writes to `file`."""
    with open(file, 'w') as f:
        ...

# out:

def very_important_function(
    template: str,
    *variables,
    file: os.PathLike,
    engine: str,
    header: bool = True,
    debug: bool = False,
):
    """Applies `variables` to the `template` and writes to `file`."""
    with open(file, "w") as f:
        ...
```

Makefile

- Makefile is an automation tool that organizes our commands
- Syntax:

```
# Makefile
target: prerequisites
<TAB> recipe
```

Styling

.PHONY: style

style:

black .

flake8

isort .

In the command Line, call “make style”

Makefile

- Different rules can be configured here

```
Makefile M X
11 PYTHON_INTERPRETER = python3
12
13 ifeq ($(shell which conda))
14 HAS_CONDA=False
15 else
16 HAS_CONDA=True
17 endif
18
19 #####
20 # COMMANDS
21 #####
22
23 ## Install Python Dependencies
24 requirements: test_environment
25     $(PYTHON_INTERPRETER) -m pip install -U pip setuptools wheel
26     $(PYTHON_INTERPRETER) -m pip install -r requirements.txt
27
28 ## Code styling using flake8, black, isort
29 style:
30     black src
31     flake8 src
32     isort src
33
34 ## Make Dataset
35 data: requirements
36     $(PYTHON_INTERPRETER) src/data/make_dataset.py data/raw data/processed
37
38 ## Delete all compiled Python files
39 clean:
40     find . -type f -name "*.py[co]" -delete
41     find . -type d -name "__pycache__" -delete
```

```
(churn_model) ✖ ruizhao@Ruis-MBP ~/churn_model main ± make
Available rules:

clean          Delete all compiled Python files
create_environment Set up python interpreter environment
data           Make Dataset
requirements   Install Python Dependencies
style          Code styling using flake8, black, isort
sync_data_from_s3 Download Data from S3
sync_data_to_s3 Upload Data to S3
test_environment Test python environment is setup correctly
```

https://github.com/rz0718/churn_model/blob/main/Makefile


2.2 Interfaces of ML Systems

Batch prediction vs. online prediction

- Batch prediction:
 - Generate predictions periodically
 - Predictions are stored somewhere (e.g. SQL tables, CSV files)
 - Retrieve them as needed
 - Allow more complex models
- Online prediction:
 - Generate predictions as requests arrive
 - Predictions are returned as responses

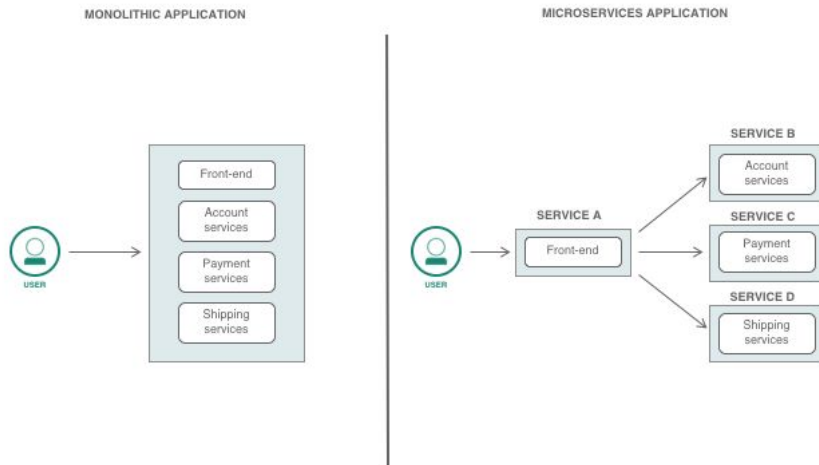
	Batch prediction	Online prediction
Frequency	Periodical	As soon as requests come
Useful for	Processing accumulated data when you don't need immediate results (e.g. recommendation systems)	When predictions are needed as soon as data sample is generated (e.g. fraud detection)
Optimized	High throughput	Low latency
Input space	Finite: need to know how many predictions to generate	Can be infinite
Examples	<ul style="list-style-type: none"> • TripAdvisor hotel ranking • Netflix recommendations 	<ul style="list-style-type: none"> • Google Translation • Tiktok feed

Hybrid: batch & online prediction

- Online prediction is default, but common queries are precomputed and stored
-  **DOORDASH**
 - Restaurant recommendations use batch predictions
 - Within each restaurant, item recommendations use online predictions
- **NETFLIX**
 - Title recommendations use batch predictions
 - Row orders use online predictions

Monolith vs Microservices

- Monolith: all application logics in one instance
- Microservices:
 - break application logics into smaller services
 - each service in its own container

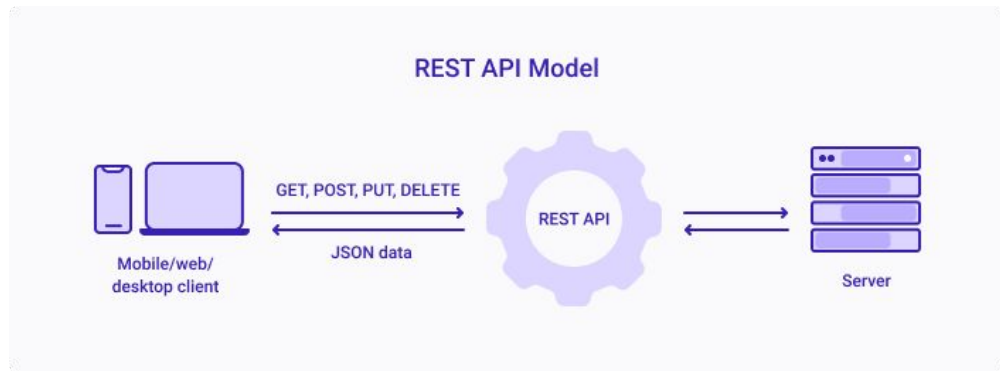
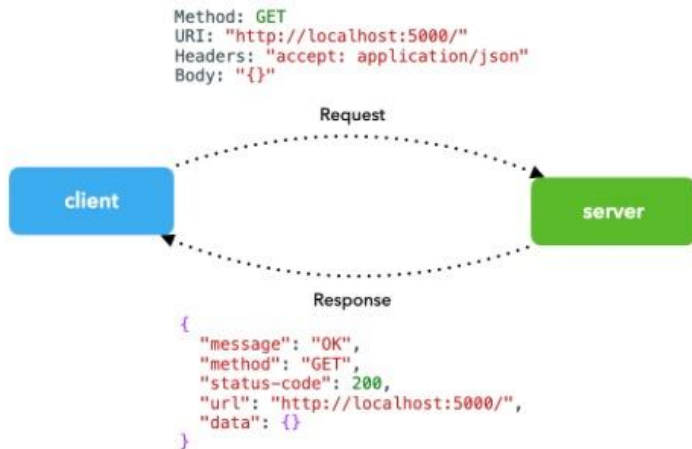


Microservices

- **Reduced complexity:** each developer works on a smaller codebase
- **Faster development cycle:** easier review process
- **Flexible stack:** different microservices can use different technology stacks

Deploy ML model in RestAPI

- Wrap ML Models in a Rest API
- Deploy them as a **Microservice**



Export a model

- Train models
- Turn models into binary formats
 - scikit-learn, XGBoost -> joblib, pickle
 - TensorFlow -> .save()
 - PyTorch -> .save()
 - Here, MLflow is recommended that is a board project focused on improving the lifecycle of machine learning projects.
- How to deploy the model?

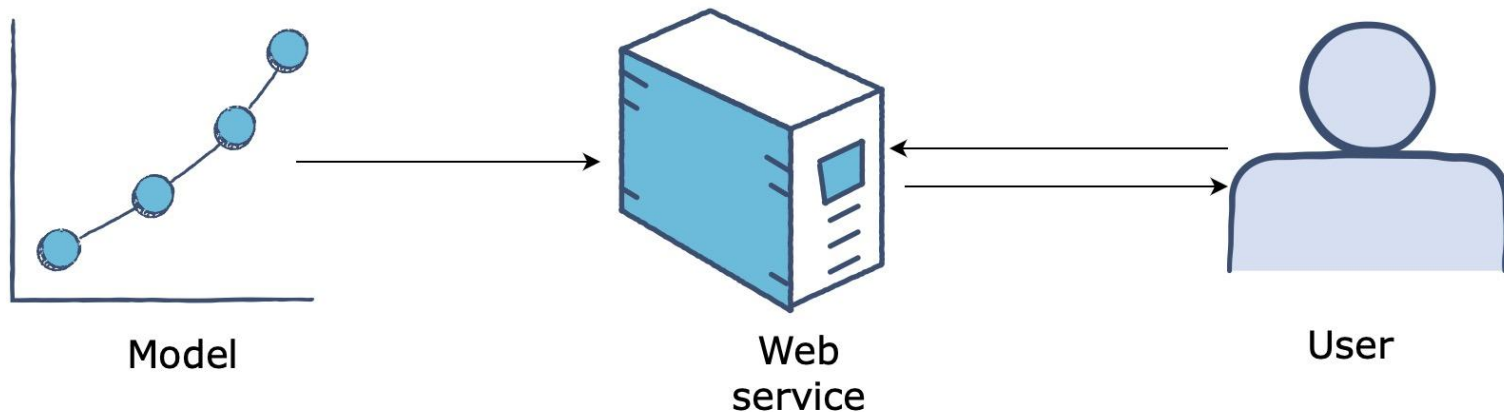
```
import mlflow.keras

model_path = "models/keras_games_v1"
mlflow.keras.save_model(model, model_path)

loaded = mlflow.keras.load_model(model_path, custom_objects={'auc': auc})
loaded.evaluate(x, y, verbose = 0)
```

Model as a web endpoint

- A model as an endpoint:
 - Prediction in response of a set of parameters
 - Here, parameters are feature vectors, images or model inputs
 - Other systems can easily use the predictive model which provides a real-time result



SKLearn Model Endpoint using Flask

```
import flask

model_path = "models/logit_games_v1"
model = mlflow.sklearn.load_model(model_path)

app = flask.Flask(__name__)

@app.route("/", methods=["GET", "POST"])
def predict():
    data = {"success": False}
    params = flask.request.args

    if "G1" in params.keys():
        new_row = { "G1": params.get("G1"), "G2": params.get("G2"),
                    "G3": params.get("G3"), "G4": params.get("G4"),
                    "G5": params.get("G5"), "G6": params.get("G6"),
                    "G7": params.get("G7"), "G8": params.get("G8"),
                    "G9": params.get("G9"), "G10": params.get("G10")}

        new_x = pd.DataFrame.from_dict(new_row,
                                       orient="index").transpose()
        data["response"] = str(model.predict_proba(new_x)[0][1])
        data["success"] = True

    return flask.jsonify(data)

if __name__ == '__main__':
    app.run(host='0.0.0.0')
```

```
import requests

new_row = { "G1": 0, "G2": 0, "G3": 0, "G4": 0, "G5": 0,
            "G6": 0, "G7": 0, "G8": 0, "G9": 0, "G10": 1 }

result = requests.get("http://52.90.199.190:5000/", params=new_row)
print(result.json()['response'])
```

Python Web Frameworks

- Flask
 - Suitable for quickly prototype
- Django
 - First choice to build robust full-stack websites
- FastAPI
 - Good at speed or scalability but quite new

A proper deployment also need a WSGI server that provides scaling, routing and load balancing.



Model as a serverless function

- Reduces the DevOps overhead of deploying models as web services.
- GCP Cloud Functions or AWS Lambda
- With serverless function environments,
 - Write a function that the runtime supports
 - Specify a list of dependencies
 - Deploy the function to production
 - The rest is fully managed by cloud platform such as provisioning servers, scaling up more machines to match demand, managing load balancers, and handling versioning.

Rapidly moving from prototype to production for your prediction models

<https://towardsdatascience.com/data-science-in-a-serverless-world-d04632e07a67>

3. MLOps

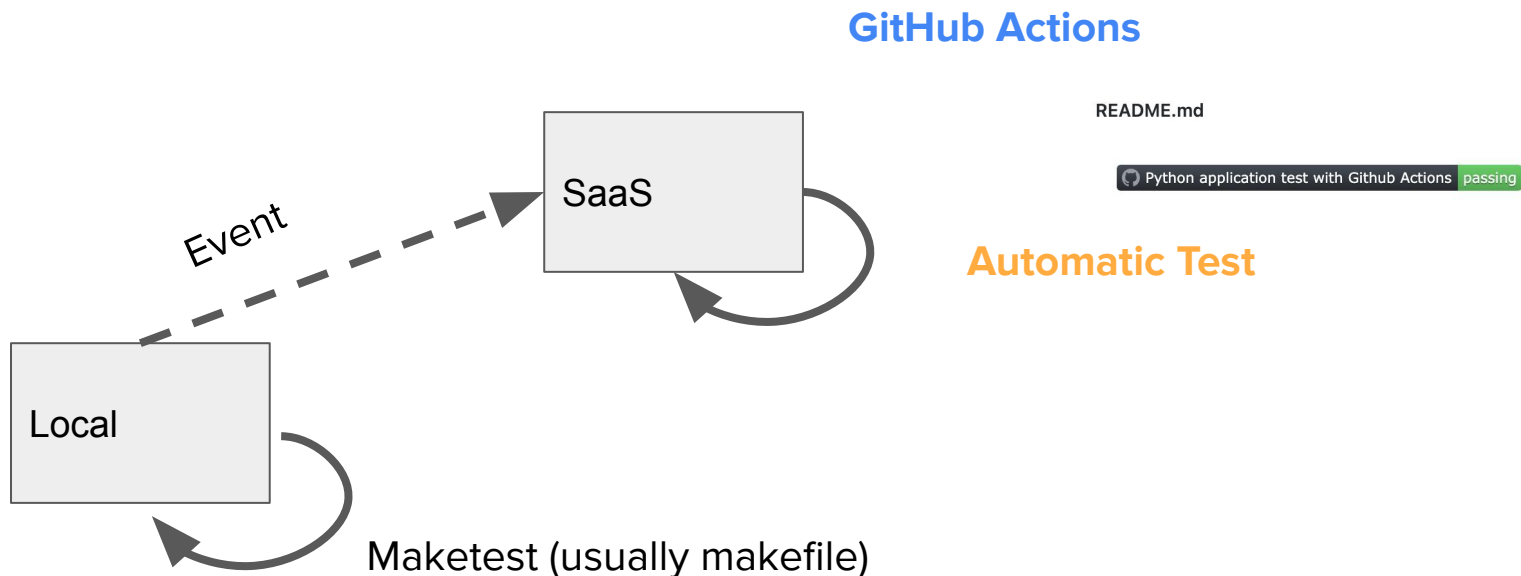
MLOps=ML + DevOps

- MLOps:
 - Apply DevOps principles to ML systems (MLOps)
 - Implement and automate:
 - ContinUous Integration (CI)
 - Continuous Delivery (CD)
 - Continuous Training (CT)

} DevOps

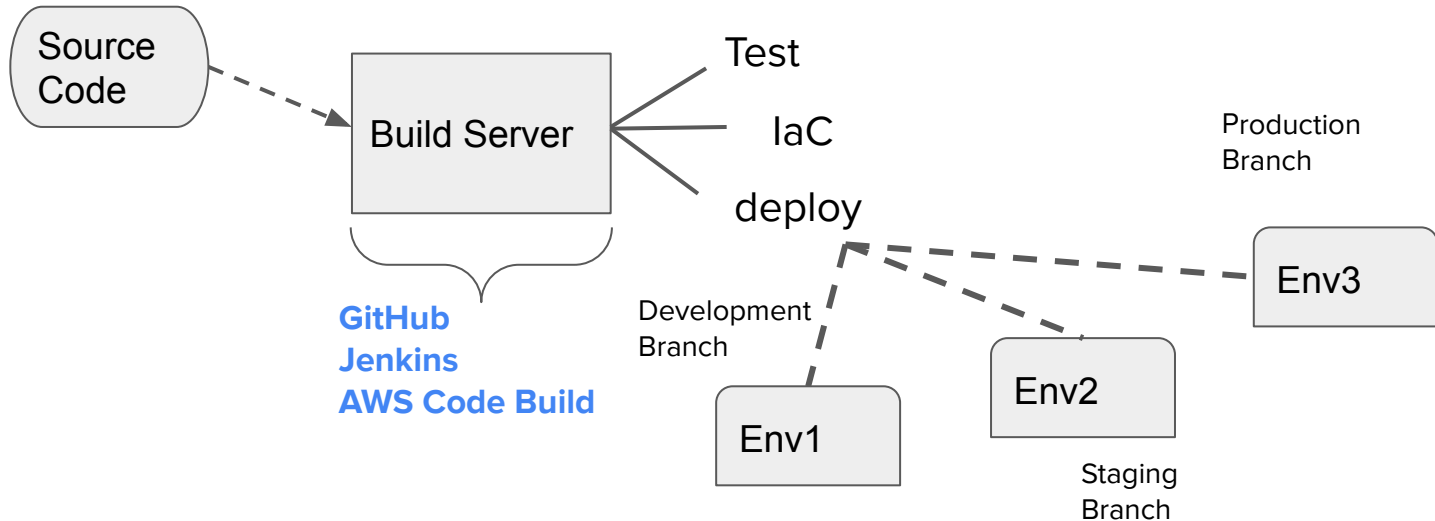
CI

- A testing factory that automatically test your code and repeats it
- In ML, not only code, but also **data**, **data schema** and **models** should be tested and validated.



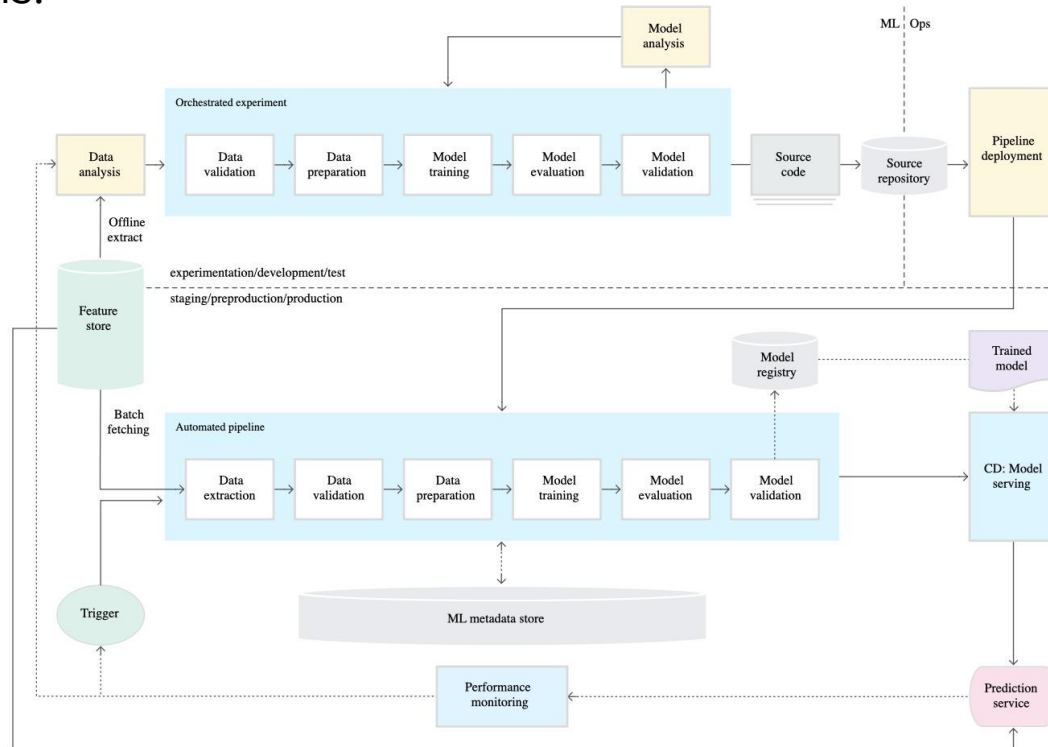
CD

- Make sure the code is always in a deployable state, both in terms of the application software and the infrastructure needed to run the code.
- In ML, it is a system consisting of machine learning training pipeline and prediction services



CT

CT is unique to MLOps. It try to automatically retrain and serve machine learning models.



<https://cloud.google.com/architecture/mlops-continuous-delivery-and-automation-pipelines-in-machine-learning>

4. Building ML Pipelines with better tools

ML Pipeline for Churn Prediction

- Machine learning models are trained to predict churn
 - Kaggle data: <https://www.kaggle.com/c/customer-churn-prediction-2020>
- Tools used for the ML pipeline
 - [Flask](#): create API as interfaces of models
 - [Pytest](#): To implement the unit tests
 - [MLFlow](#): for model registry
 - [Github](#): for code version control
 - [Data Version Control \(DVC\)](#): version control of the datasets and to make pipeline
 - [Cookiecutter](#): Project templates



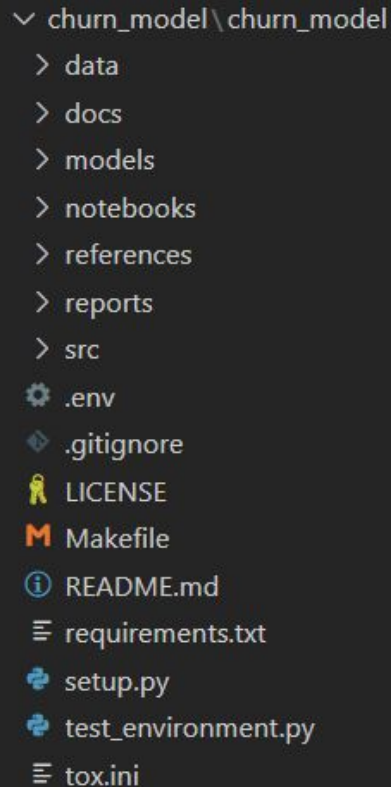
Git Repo: https://github.com/rz0718/churn_model

Create Virtual Environment

```
conda create -n churn_model  
conda activate churn_model
```


Create Project Structure using the cookiecutter

```
pip install cookiecutter
cookiecutter https://github.com/drivendata/cookiecutter-data-science
cd churn_model
```



The screenshot shows a file explorer window with a dark background. The root directory is 'churn_model\churn_model'. It contains several subdirectories and files. The subdirectories are 'data', 'docs', 'models', 'notebooks', 'references', 'reports', and 'src'. The files are '.env', '.gitignore', 'LICENSE', 'Makefile', 'README.md', 'requirements.txt', 'setup.py', 'test_environment.py', and 'tox.ini'. Each file has a small icon to its left: a gear for '.env', a diamond for '.gitignore', a yellow ribbon for 'LICENSE', an orange 'M' for 'Makefile', a blue 'i' in a circle for 'README.md', a hamburger menu for 'requirements.txt', a blue Python logo for 'setup.py', a blue Python logo for 'test_environment.py', and a hamburger menu for 'tox.ini'.

- ▼ churn_model\churn_model
 - > data
 - > docs
 - > models
 - > notebooks
 - > references
 - > reports
 - > src
 - ⚙ .env
 - 💎 .gitignore
 - 📜 LICENSE
 - 📄 Makefile
 - 📖 README.md
 - ☰ requirements.txt
 - 🐍 setup.py
 - 🐍 test_environment.py
 - ☰ tox.ini

Create a Github repo

```
git init -b main
git add .
git commit -m "Init project"
git remote add origin <your_github_repo>
git branch -m main
git push -u origin main
```

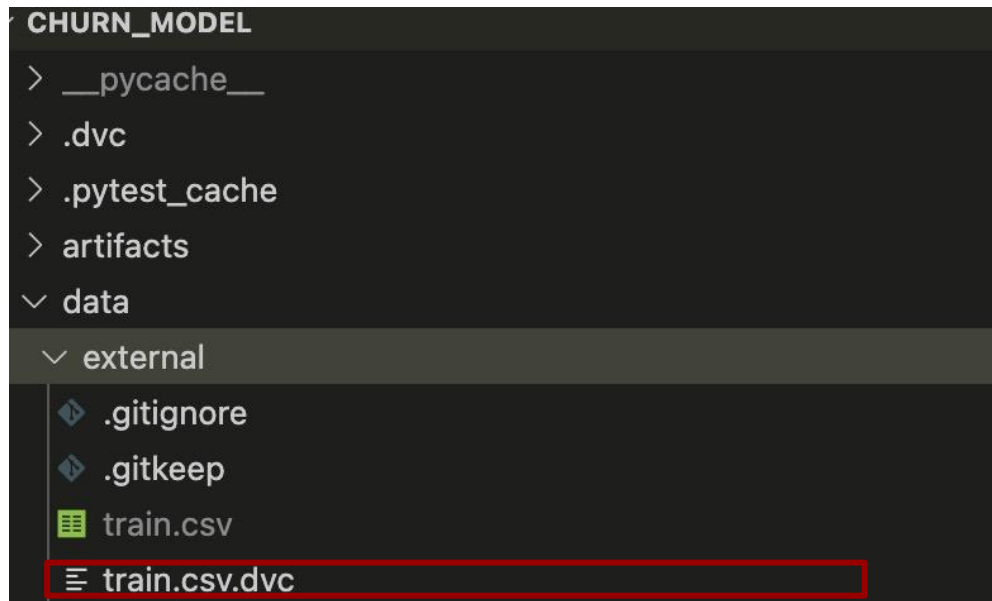
Code Version Control

rz0718 add lib list		d23e7b6 3 hours ago	3 commits
📁 .dvc	finish local deploy	3 hours ago	
📁 artifacts/1	finish local deploy	3 hours ago	
📁 data	finish local deploy	3 hours ago	
📁 docs	Init Repo with template	4 hours ago	
📁 models	finish local deploy	3 hours ago	
📁 notebooks	Init Repo with template	4 hours ago	
📁 references	Init Repo with template	4 hours ago	
📁 reports	Init Repo with template	4 hours ago	
📁 src	finish local deploy	3 hours ago	
📁 tests	finish local deploy	3 hours ago	
📁 webapp	finish local deploy	3 hours ago	
📄 .dvcignore	finish local deploy	3 hours ago	
📄 .gitignore	Init Repo with template	4 hours ago	
📄 LICENSE	Init Repo with template	4 hours ago	
📄 Makefile	Init Repo with template	4 hours ago	
📄 README.md	Init Repo with template	4 hours ago	
📄 app.py	finish local deploy	3 hours ago	
📄 dvc.lock	finish local deploy	3 hours ago	
📄 dvc.yaml	finish local deploy	3 hours ago	
📄 params.yaml	finish local deploy	3 hours ago	
📄 requirements.txt	add lib list	3 hours ago	
📄 setup.py	Init Repo with template	4 hours ago	
📄 test_environment.py	Init Repo with template	4 hours ago	

Track data version with DVC

```
pip install dvc  
dvc init  
dvc add <path_for_the_data_file>
```

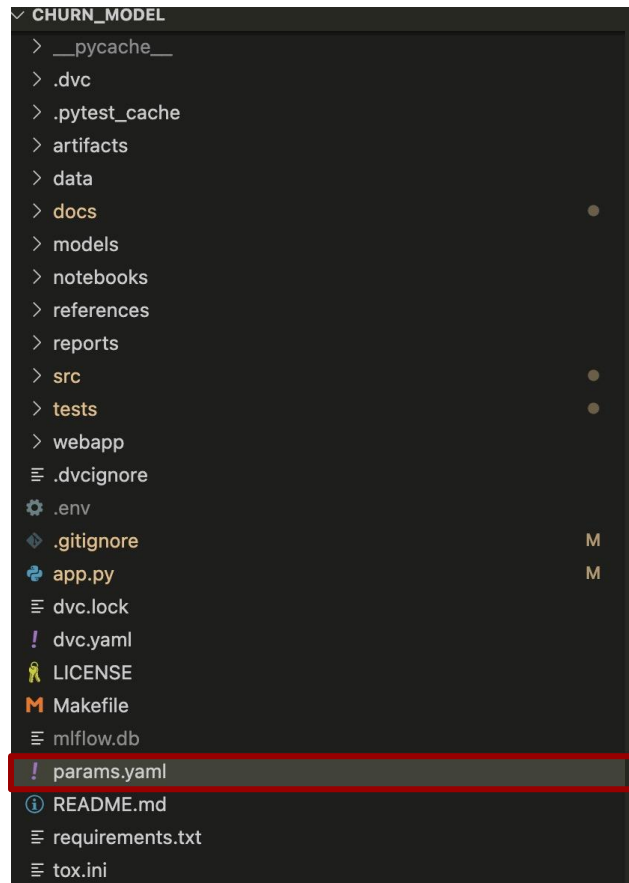
Data Version Control



Used by dvc to track train.csv

Write config file: params.yaml

- Store all the configurations related to this project
- Put the yaml file under main folder



Prepare Source Code Inside the Src Folder

- Add data loading related scripts into the folder of data
- Add modeling related scripts into the folder of models

```
src          <- Source code for use in this project.
├── __init__.py  <- Makes src a Python module
├── data          <- Scripts to download or generate data
│   └── make_dataset.py
├── features      <- Scripts to turn raw data into features for modeling
│   └── build_features.py
├── models        <- Scripts to train models and then use trained models to make
│                   predictions
│   ├── predict_model.py
│   └── train_model.py
```


Data Folder

✓ src

✓ data

 __init__.py

 .gitkeep

 load_data.py

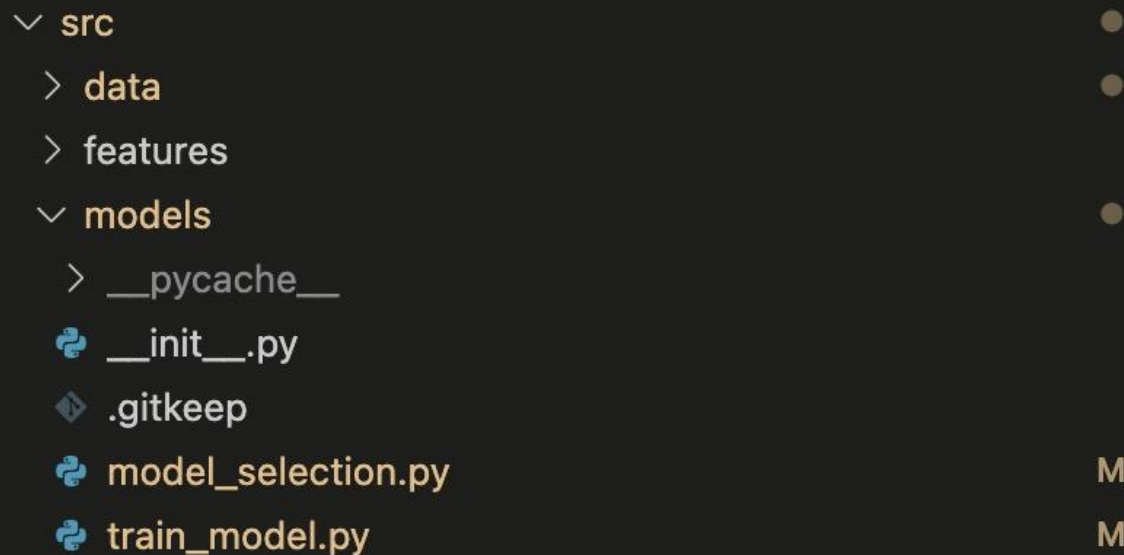
Copy external train.csv into the data/raw folder

 split_data.py

Split the train.csv in raw folder to new train vs test in processed folder

Model Folder

- MLflow is used to track the model performances
- `model_selection.py` is used to select the best model from model registry and save the best model in the `root/model` directory

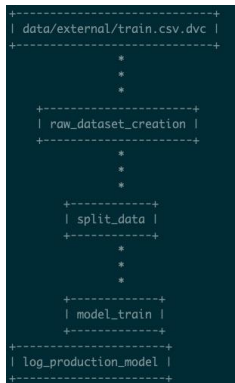


A screenshot of a file explorer interface with a dark theme. The 'src' directory is expanded, showing subdirectories 'data' and 'features', and a 'models' directory. Below these are files: '__pycache__' (expanded), '__init__.py', '.gitkeep', 'model_selection.py' (marked with a blue Python icon and an 'M'), and 'train_model.py' (marked with a blue Python icon and an 'M').

```
✓ src
  > data
  > features
  ✓ models
    > __pycache__
    __init__.py
    .gitkeep
    model_selection.py M
    train_model.py M
```

Pipeline Creation with DVC

- With all scripts in src folder, create the dvc.yaml to define the pipeline
- Each stage in yaml files contains:
 - **cmd**: bash command to execute the script
 - **deps**: the dependencies to execute the step
 - **outs**: output from the cmd line (model or data)
 - **params**: parameters used in the script
- With deps, we can create DAG
 - Call “dvc dag”



```
stages:
  raw_dataset_creation:
    cmd: python src/data/load_data.py --config=params.yaml
    deps:
      - src/data/load_data.py
      - data/external/train.csv
    outs:
      - data/raw/train.csv

  split_data:
    cmd: python src/data/split_data.py --config=params.yaml
    deps:
      - src/data/split_data.py
      - data/raw/train.csv
    outs:
      - data/processed/churn_train.csv
      - data/processed/churn_test.csv
```

```
model_train:
  cmd: python src/models/train_model.py --config=params.yaml
  deps:
    - data/processed/churn_train.csv
    - data/processed/churn_test.csv
    - src/models/train_model.py
  params:
    - random_forest.max_depth
    - random_forest.n_estimators
```

```
log_production_model:
  cmd: python src/models/model_selection.py --config=params.yaml
  deps:
    - src/models/model_selection.py
  params:
    - random_forest.max_depth
    - random_forest.n_estimators
  outs:
    - models/model.joblib
```

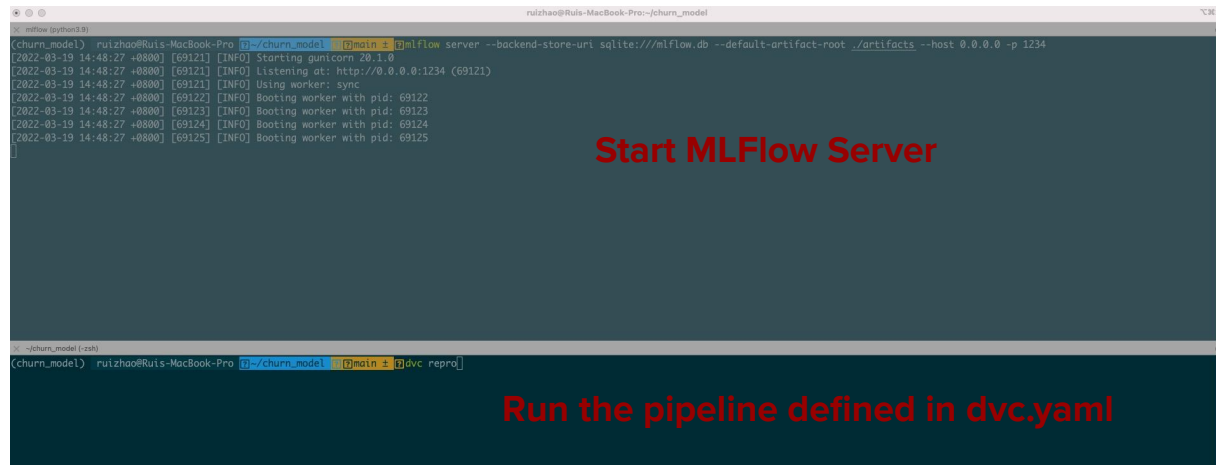
https://github.com/z0718/churn_model/blob/main/dvc.yaml

Execute the pipeline

- Use two terminals to execute:

```
mlflow server --backend-store-uri sqlite:///mlflow.db --default-artifact-root ./artifacts --host 0.0.0.0 -p 1234
```

```
dvc repro
```



The screenshot shows two terminal windows. The top window is titled 'mlflow (python3.9)' and shows the command `mlflow server --backend-store-uri sqlite:///mlflow.db --default-artifact-root ./artifacts --host 0.0.0.0 -p 1234` being executed. The output shows the server starting successfully and listening on port 1234. The bottom window is titled 'churn_model (-zsh)' and shows the command `dvc repro` being executed. The output shows the pipeline running successfully.

```
(churn_model) ruizhao@Ruiz-MacBook-Pro ~$ mlflow server --backend-store-uri sqlite:///mlflow.db --default-artifact-root ./artifacts --host 0.0.0.0 -p 1234
[2022-03-19 14:48:27 +0800] [69121] [INFO] Starting gunicorn 20.1.0
[2022-03-19 14:48:27 +0800] [69121] [INFO] Listening at: http://0.0.0.0:1234 (69121)
[2022-03-19 14:48:27 +0800] [69121] [INFO] Using worker: sync
[2022-03-19 14:48:27 +0800] [69122] [INFO] Booting worker with pid: 69122
[2022-03-19 14:48:27 +0800] [69123] [INFO] Booting worker with pid: 69123
[2022-03-19 14:48:27 +0800] [69124] [INFO] Booting worker with pid: 69124
[2022-03-19 14:48:27 +0800] [69125] [INFO] Booting worker with pid: 69125
```

Start MLFlow Server

```
(churn_model) ruizhao@Ruiz-MacBook-Pro ~$ dvc repro
```

Run the pipeline defined in dvc.yaml

Why DVC

- DVC only conduct the action if dependencies are changed
- For example, run dvc repro again

```
(churn_model) ruizhao@Ruis-MacBook-Pro ~/churn_model [main] dvc repro
'data/external/train.csv.dvc' didn't change, skipping
Stage 'raw_dataset_creation' didn't change, skipping
Stage 'split_data' didn't change, skipping
Stage 'model_train' didn't change, skipping
Stage 'log_production_model' didn't change, skipping
Data and pipelines are up to date.
```

- Change the hyper-parameters in params.yaml, the last two stages will be executed. We can use mlflow dashboard to track

model_iteration1

Track machine learning training runs in an experiment. [Learn more](#)

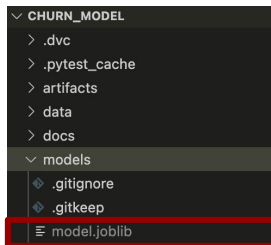
Experiment ID: 1

Description

Columns: Only show differences

Showing 6 matching runs

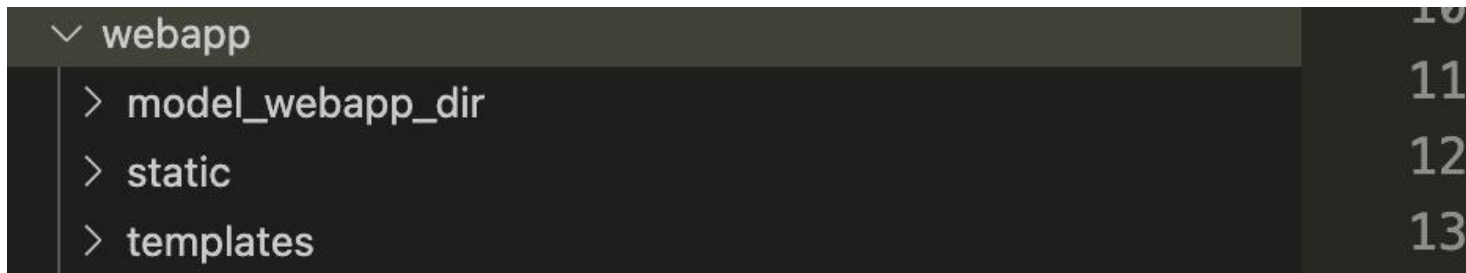
	Start Time	Duration	Run Name	Metrics	F1 score	precision	max_depth	n_estimators
<input type="checkbox"/>	11 minutes ago	1.2s	random_forest	accuracy	0.947	0.914	0.006	35
<input type="checkbox"/>	10 minutes ago	1.5s	random_forest	accuracy	0.948	0.916	0.009	30
<input type="checkbox"/>	9 minutes ago	1.3s	random_forest	accuracy	0.948	0.915	0.006	30
<input type="checkbox"/>	8 minutes ago	1.3s	random_forest	accuracy	0.948	0.917	0.001	10
<input type="checkbox"/>	8 minutes ago	1.3s	random_forest	accuracy	0.950	0.914	0.002	5
<input type="checkbox"/>	4 hours ago	1.6s	random_forest	accuracy	0.949	0.914	0.006	10



Update the model file

Build a web app using Flask

- Web App is able to:
 - Allow users to enter feature values
 - Call the backend ml model to take the inputs and predict the outcome
- Create a folder: webapp
 - Have required HTML, CSS and JS codes (front-end)
 - The model file (joblib) is required to be put in the model_webapp_dir



Create app.py

- Create app.py under the main folder
 - Connect backend to frontend
 - Send the responses to the UI after predicting the label

```
(churn_model) ruizhao@Ruis-MBP ~/churn_model [main] python app.py
* Tip: There are .env or .flaskenv files present. Do "pip install python-dotenv" to use them.
* Serving Flask app 'app' (lazy loading)
* Environment: production
  WARNING: This is a development server. Do not use it in a production deployment.
  Use a production WSGI server instead.
* Debug mode: on
* Running on all addresses.
  WARNING: This is a development server. Do not use it in a production deployment.
* Running on http://10.94.68.172:5000/ (Press CTRL+C to quit)
* Restarting with stat
* Tip: There are .env or .flaskenv files present. Do "pip install python-dotenv" to use them.
* Debugger is active!
* Debugger PIN: 475-850-310
10.94.68.172 - - [19/Mar/2022 15:17:36] "GET / HTTP/1.1" 200 -
10.94.68.172 - - [19/Mar/2022 15:17:36] "GET /static/css/main.css HTTP/1.1" 304 -
10.94.68.172 - - [19/Mar/2022 15:17:36] "GET /static/script/index.js HTTP/1.1" 404 -
10.94.68.172 - - [19/Mar/2022 15:17:36] "GET /static/css/main.css HTTP/1.1" 304 -
```

What we are missing

- Unit/Load tests
- Deploy the application in a real environment (not local env.)
- CI/CD
 - Push the change to git repo
 - It can be immediately deployed in production after passing the test
 - The answers from industries at this moment are:
 - Containers
 - Kubernetes
- Online Model Monitoring