

Model Monitoring

MLflow, Tensorboard, Weights & Biases

Credit to TA.Cheetah & TA.Phu

Outline

- MLflow
- Tensorboard
- Weights & Biases

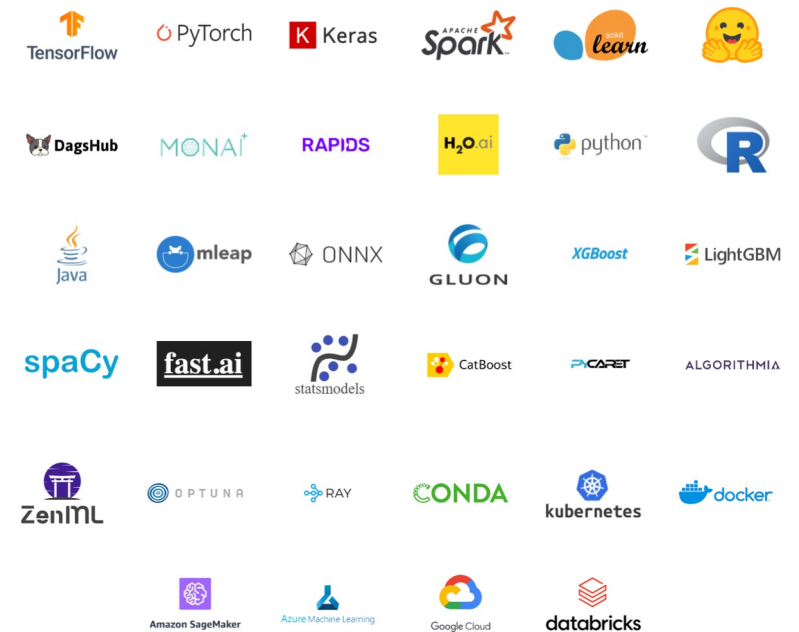
MLflow

What is MLflow?

- MLflow makes it simple to construct end-to-end Machine Learning pipelines **in production**, and this article will teach you all you need to know about the platform. This implies that at the conclusion of this tutorial, you'll be able to utilize MLflow for Machine Learning pipelines from model experimentation through model deployment.



Integrations with:



How to run MLflow

- Install mlflow

```
!pip install mlflow --quiet
```

Python

- Import libraries

```
# Importing all Libraries
import mlflow
import mlflow.sklearn

import numpy as np
import pandas as pd
from sklearn.tree import DecisionTreeClassifier
from sklearn.datasets import load_breast_cancer
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, classification_report
```

Python

- Load dataset and define evaluation metrics

```
# Load and split dataset
X, Y = load_breast_cancer(return_X_y=True)
X_train, X_test, y_train, y_test = train_test_split(X, Y, test_size=0.2, random_state=0)
print("Training Data Shape: ", X_train.shape, y_train.shape)
print("Testing Data Shape: ", X_test.shape, y_test.shape)

def eval_metrics(actual, pred):
    accuracy = accuracy_score(actual, pred)
    return accuracy
```

Model tracking

1. Start an experiment using **mlflow.start_run()** which switches the context of your existing model code to enable mlflow tracking.
2. We log the run parameters with **mlflow.log_param()**
3. We log the model metrics (mean accuracy on the training set in this case) with **mlflow.log_metric()**.
4. After model training and evaluation, I have logged the model using **mlflow.sklearn.log_model()**.

```
def train_model(criterion, max_depth):  
    # Starting the Experiment  
    with mlflow.start_run():  
        # Model building  
        model = DecisionTreeClassifier(criterion=criterion, max_depth=max_depth, random_state=0)  
        model.fit(X_train, y_train) # Model Training  
        y_pred = model.predict(X_test) # Model Prediction on Testing data  
        (accuracy) = eval_metrics(y_test, y_pred)  
  
        print('Decision tree (criterion=%s, max_depth=%d):'%(criterion, max_depth))  
        print('Accuracy: {:.4f}'.format(accuracy))  
  
        # Logging Parameters  
        mlflow.log_param("criterion", criterion)  
        mlflow.log_param("max_depth", max_depth)  
  
        # Logging Metrics  
        mlflow.log_metric("accuracy", accuracy_score(y_test, y_pred))  
  
        # Model Logging  
        mlflow.sklearn.log_model(model, 'model') #input_example=input_example  
  
    return model
```

Python

Train model and search best 5 runs

- Train 10 models with different hyperparameters

```
train_model('gini', 1)
```

Python

Decision tree (criterion=gini, max_depth=1):
Accuracy: 0.9035

```
DecisionTreeClassifier  
DecisionTreeClassifier(max_depth=1, random_state=0)
```

```
#Search best 5 runs  
best_run_df = mlflow.search_runs(order_by=['metrics.accuracy DESC'], max_results=5)  
best_run_df
```

Python

INFO [alembic.runtime.migration] Context impl SQLiteImpl.
INFO [alembic.runtime.migration] Will assume non-transactional DDL.

artifact_uri	start_time	end_time	metrics.accuracy	params.max_depth	params.criterion	tags.mlflow.sour
./mlruns/1/5d63abf908a643ac93724bd076496e19/ar...	2023-08-23 01:47:10.328000+00:00	2023-08-23 01:47:10.584000+00:00	0.964912	3	gini	/usr/local/lib/python3 packages
./mlruns/1/d845b4259e634b5cb8485012cc6bc01b/ar...	2023-08-23 01:47:10.014000+00:00	2023-08-23 01:47:10.263000+00:00	0.964912	2	gini	/usr/local/lib/python3 packages
./mlruns/1/4746bcfe0a5b4936b3350514515e0536/ar...	2023-08-23 01:47:10.639000+00:00	2023-08-23 01:47:10.961000+00:00	0.956140	4	gini	/usr/local/lib/python3 packages
./mlruns/1/09ad160ad4734e68a6044e59228c805a/ar...	2023-08-23 01:47:11.931000+00:00	2023-08-23 01:47:12.131000+00:00	0.947368	3	entropy	/usr/local/lib/python3 packages
./mlruns/1/d16fe0518d2d4bff80f343f9a58be6b4/ar...	2023-08-23 01:47:11.200000+00:00	2023-08-23 01:47:11.406000+00:00	0.947368	5	gini	/usr/local/lib/python3 packages

Load best model (MLflow models)

artifact_uri	start_time	end_time	metrics.accuracy	params.max_depth	params.criterion	tags.mlflow.sour
./mlruns/1/5d63abf908a643ac93724bd076496e19/ar...	2023-08-23 01:47:10.328000+00:00	2023-08-23 01:47:10.584000+00:00	0.964912	3	gini	/usr/local/lib/python3 packages
./mlruns/1/d845b4259e634b5cb8485012cc6bc01b/ar...	2023-08-23 01:47:10.014000+00:00	2023-08-23 01:47:10.263000+00:00	0.964912	2	gini	/usr/local/lib/python3 packages
./mlruns/1/4746bcfe0a5b4936b3350514515e0536/ar...	2023-08-23 01:47:10.639000+00:00	2023-08-23 01:47:10.961000+00:00	0.956140	4	gini	/usr/local/lib/python3 packages
./mlruns/1/09ad160ad4734e68a6044e59228c805a/ar...	2023-08-23 01:47:11.931000+00:00	2023-08-23 01:47:12.131000+00:00	0.947368	3	entropy	/usr/local/lib/python3 packages
./mlruns/1/d16fe0518d2d4bff80f343f9a58be6b4/ar...	2023-08-23 01:47:11.200000+00:00	2023-08-23 01:47:11.406000+00:00	0.947368	5	gini	/usr/local/lib/python3 packages

```
# Load model as a PyFuncModel.
loaded_model = mlflow.pyfunc.load_model(model_uri=f"runs://{run_id}/model") # run_id of best model

# Predict on a Pandas DataFrame.
predicted = loaded_model.predict(pd.DataFrame(X_test))
print(classification_report(y_test, predicted, target_names=['Non-DD', 'DD'], digits=4))
```

Python

	precision	recall	f1-score	support
Non-DD	0.9778	0.9362	0.9565	47
DD	0.9565	0.9851	0.9706	67
accuracy			0.9649	114
macro avg	0.9671	0.9606	0.9636	114
weighted avg	0.9653	0.9649	0.9648	114

Model registry

- The MLflow Model Registry component is a centralized model store, set of APIs, and UI, to collaboratively manage the full lifecycle of an MLflow Model. It provides model lineage, [model versioning](#), stage transitions (for example from staging to production), and annotations.

```
#Register best model
mlflow.register_model(model_uri=model_uri, name="breast_cancer")
```

Python

Successfully registered model 'breast_cancer'.
2023/08/23 14:12:33 INFO mlflow.tracking._model_registry.client: Waiting up to 300 seconds for model version to finish creation. Model name: breast_cancer, Created version '1' of model 'breast_cancer'.

- Load model from registered model

```
model_name = "breast_cancer"
model_version = 1
# Load model as a PyFuncModel.
loaded_model = mlflow.pyfunc.load_model(model_uri=f"models:{model_name}/{model_version}")

# Predict on a Pandas DataFrame.
predicted = loaded_model.predict(pd.DataFrame(X_test))
```

Python

```
print(classification_report(y_test, predicted, target_names=['Non-DD', 'DD'], digits=4))
```

Python

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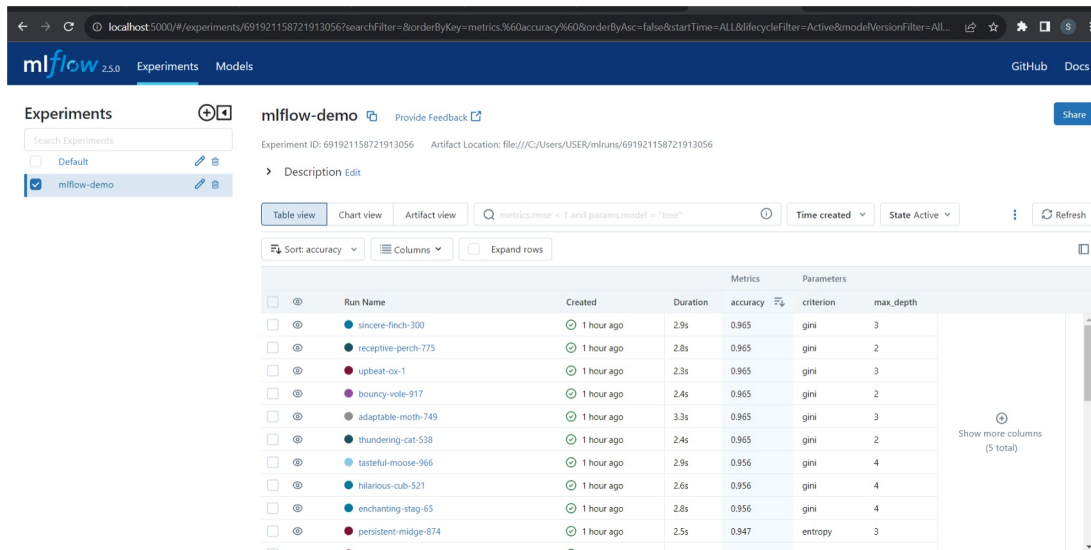
MLflow UI

- View MLflow runs and experiments

```
!mlflow ui
# Access this link: http://localhost:5000/
```

Python

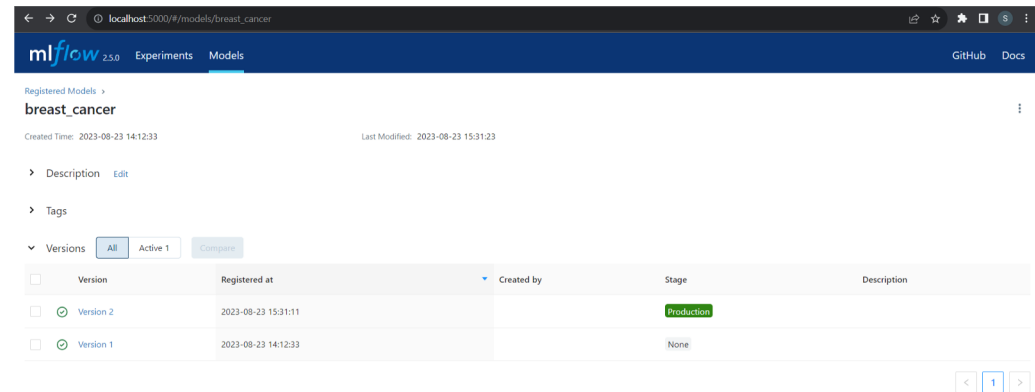
Compare performance



The screenshot shows the MLflow UI Experiments page. The left sidebar has a search bar and a list of experiments, with 'mlflow-demo' selected. The main area shows the 'mlflow-demo' experiment details, including the experiment ID and artifact location. Below this is a table of runs, sorted by accuracy. The table has columns for Run Name, Created, Duration, Metrics (accuracy, criterion, max_depth), and Parameters. The runs are listed in descending order of accuracy.

Run Name	Created	Duration	accuracy	criterion	max_depth
sincere-finch-300	1 hour ago	2.9s	0.965	gini	3
receptive-perch-775	1 hour ago	2.8s	0.965	gini	2
upbeat-ox-1	1 hour ago	2.3s	0.965	gini	3
bouncy-vole-917	1 hour ago	2.4s	0.965	gini	2
adaptable-moth-749	1 hour ago	3.3s	0.965	gini	3
thundering-cat-538	1 hour ago	2.4s	0.965	gini	2
tasteful-moose-966	1 hour ago	2.9s	0.956	gini	4
hilarious-cub-521	1 hour ago	2.6s	0.956	gini	4
enchanting-stag-65	1 hour ago	2.8s	0.956	gini	4
persistent-midge-674	1 hour ago	2.5s	0.947	entropy	3

Registered model



The screenshot shows the MLflow UI Registered Models page for the 'breast_cancer' model. The page displays the model's name, creation time, and last modified time. Below this is a table of model versions. The table has columns for Version, Registered at, Created by, Stage, and Description. The versions are listed in descending order of creation time.

Version	Registered at	Created by	Stage	Description
Version 2	2023-08-23 15:31:11		Production	
Version 1	2023-08-23 14:12:33		None	

For run mlflow ui on google colab

```
# Load and split dataset
X, Y = load_breast_cancer(return_X_y=True)
X_train, X_test, y_train, y_test = train_test_split(X, Y, test_size=0.2, random_state=0)
print("Training Data Shape: ", X_train.shape, y_train.shape)
print("Testing Data Shape: ", X_test.shape, y_test.shape)
```

```
local_registry = "sqlite:///mlruns.db"
mlflow.set_tracking_uri(local_registry)
experiment_id = mlflow.set_experiment('test_experiment')
```

add 3 lines before with `mlflow.start_run()`:

```
def eval_metrics(actual, pred):
    accuracy = accuracy_score(actual, pred)
    return accuracy
```

Get authToken from <https://dashboard.ngrok.com/auth>

```
!pip install pyngrok --quiet
```

Python

```
from pyngrok import ngrok
ngrok.kill()

#Setting the authToken (optional)
#Get your authToken from https://dashboard.ngrok.com/auth
NGROK_AUTH_TOKEN = '' # Your authToken
ngrok.set_auth_token(NGROK_AUTH_TOKEN)

# Open an HTTPS tunnel on port 5000 for http://localhost:5000
ngrok_tunnel = ngrok.connect(addr='5000', proto='http', bind_tls=True)
print("MLflow Tracking UI: ", ngrok_tunnel.public_url)
```

Python

```
WARNI [pyngrok.process-ngrok] t-2023-08-23T01:47:21.0000 lvl=warn msg="ngrok config file found at legacy location, move to XDG location" xdg_path=/root/.con
MLflow Tracking UI: https://79c5-34-136-157-242.ngrok-free.app
```

access from this link

```
!mlflow ui --backend-store-uri sqlite:///mlruns.db
```

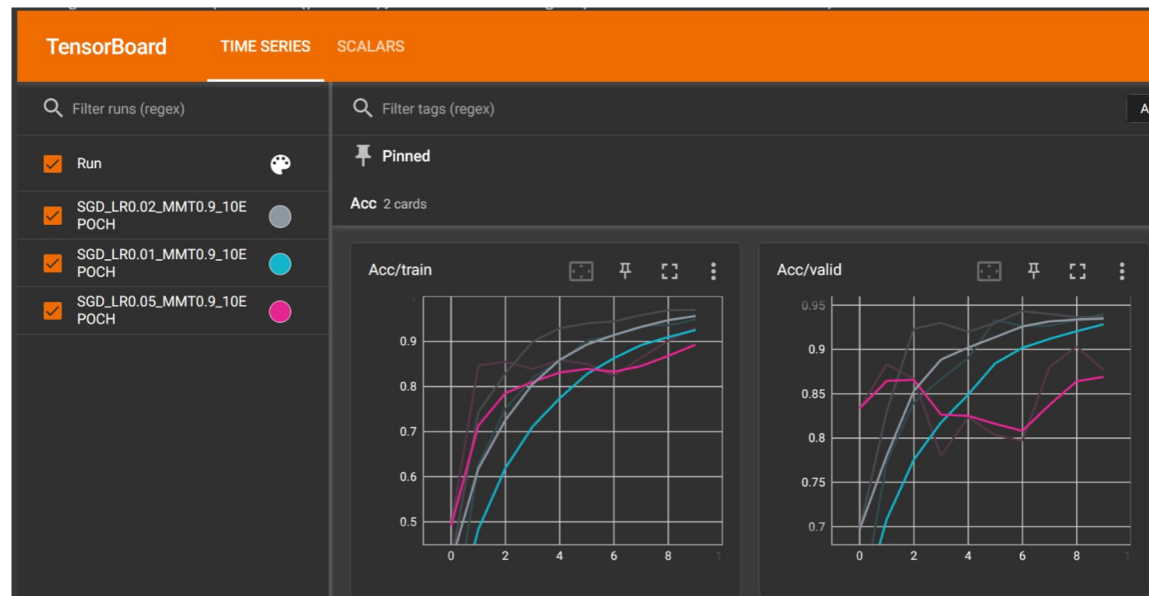
Python

Tensorboard

Guide

What is tensorboard

- 1) Visualization toolkit for machine learning training
- 2) Can visualize train/validate loss, accuracy etc.
- 3) Benefits in comparing between runs (adjust hyperparameters)



Tensorboard steps

- 1) install `pip install -qq tensorboard`
- 2) import summarywriter
`from torch.utils.tensorboard import SummaryWriter`
- 1) create directory to save log files e.g. `/content/runs/run1/`
- 2) instantiate writer `writer = SummaryWriter(log_dir="./runs/run1/")`
- 3) add scalar `writer.add_scalar("Name", value, round)`
- 4) write on disk `writer.flush()`
- 5) close `writer.close()`
- 6) launch tensorboard
`%load_ext tensorboard`
`%tensorboard --logdir runs`

References

- [1] <https://www.tensorflow.org/tensorboard>
- [2] https://pytorch.org/tutorials/recipes/recipes/tensorboard_with_pytorch.html

WandB

Guide

What is WandB

- Special tools by Weights & Biases for
 - *experiments tracking*
 - results visualization
 - *hyperparameter adjustment (sweep)*
 - reproduce models
 - and more!
- Create account <https://wandb.ai/site>
- Get API key (Need when login) <https://wandb.ai/authorize>

Steps: Dashboard

```
1) install    !pip install wandb
2) import    import wandb
3) login      wandb.login()  # this one is for the imported wandb library
4) initiate   wandb.init(
                    project="Animal-EfficientNetB0",
                    config={"learning_rate": 0.02,
                            "architecture": "EfficientNetB0",
                            "dataset": "Animal2",
                            "epochs": 10}
                )
5) log        wandb.log({"acc": acc, "loss": loss})
6) finish     wandb.finish()
```

Steps: Sweep

1) install

```
!pip install wandb
```

2) import

```
import wandb
```

3) login

```
wandb.login()
```

4) create config (dict)

5) write your own training function

6) write WandB training function on top

7) initiate sweep (via wandb agent)

8) get results at your account page

```
sweep_config = dict()
```

```
train()
```

```
trainer()
```

```
wandb.agent(sweep_id, train)
```

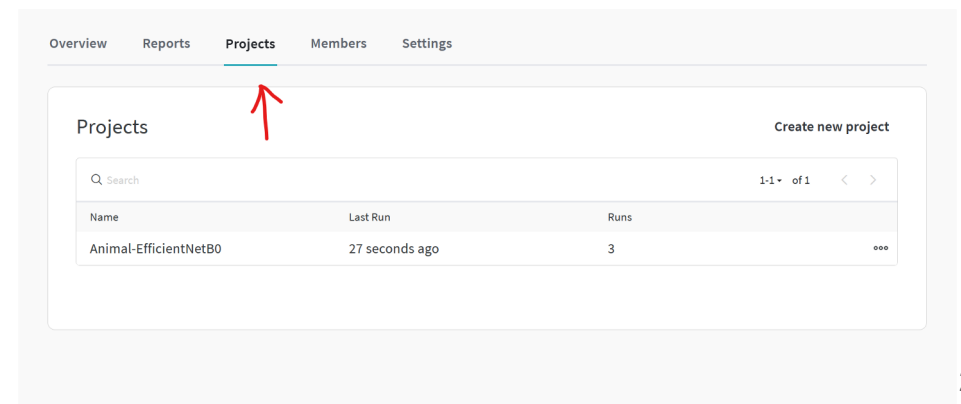
<https://wandb.ai/>

Results

- Run history and run summary in your notebook



- Full dashboard in your wandb profile



Runs (2)



👁 Name (2 visualized)

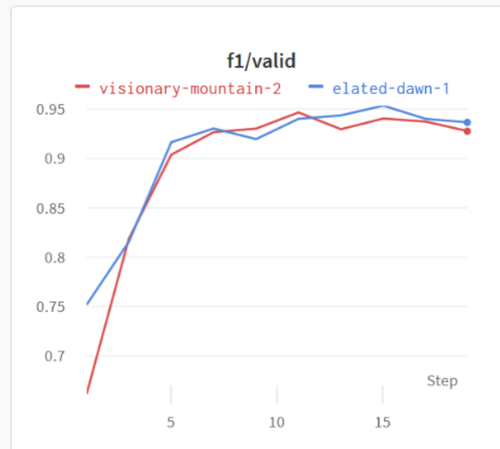
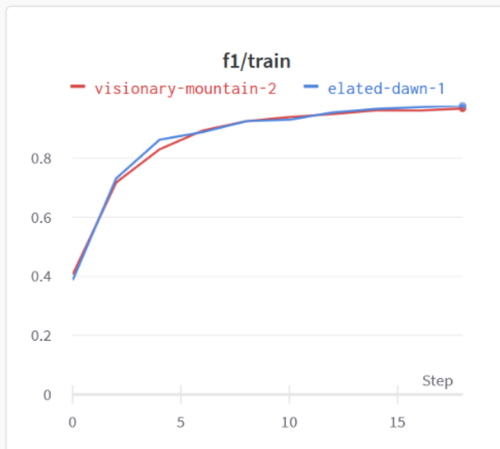
👁 ● visionary-mountain-2

👁 ● elated-dawn-1

1-2 of 2 < >

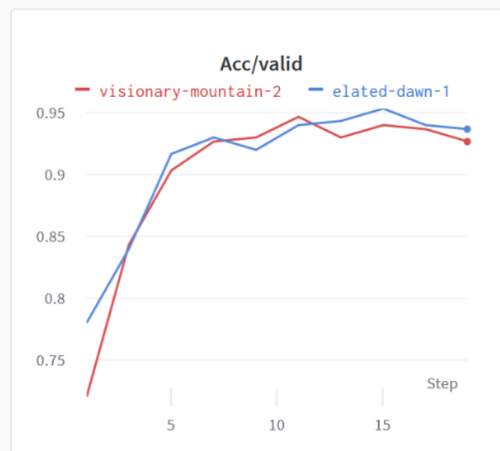
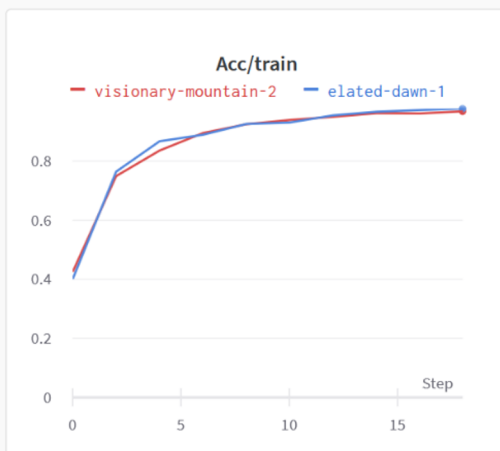


Create report



▼ Acc 2

Add panel



References

[1] <https://wandb.ai/home>