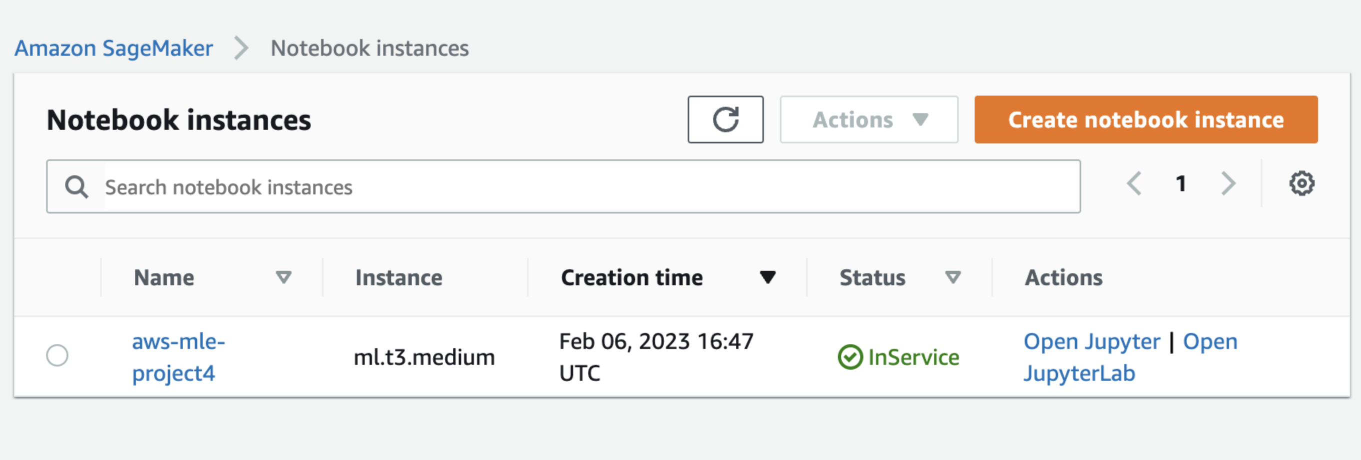
Operationalizing an AWS Machine Learning Project

Initial Set Up


Amazon SageMaker > Notebook instances
Notebook instances
Actions ▼
Create notebook instance
Search notebook instances
1

	Name	Instance	Creation time	Status	Actions
○	aws-mle-project4	ml.t3.medium	Feb 06, 2023 16:47 UTC	✓ InService	Open Jupyter | Open JupyterLab

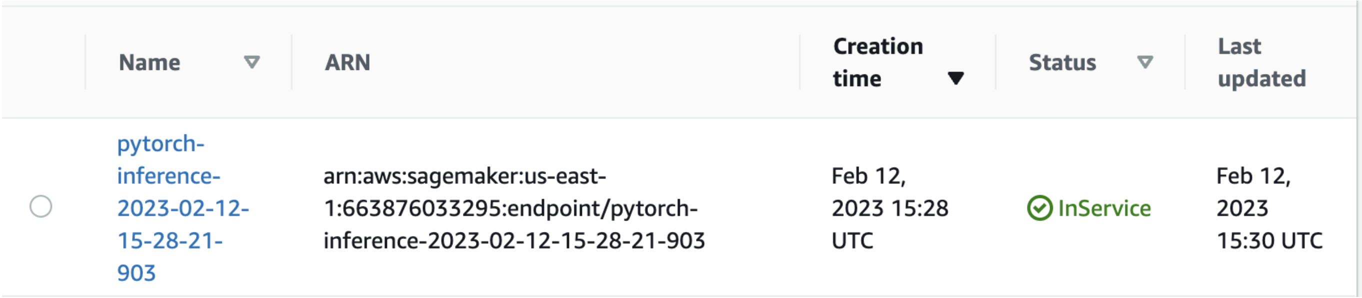
The ml.t3.medium is the cheapest among Sagemaker's standard instances at $0.05 per hour. It has 5 GiB of memory and runs on 2 vCPU. Optimized to start within 2 minutes, this instance would mean less waiting time in between starting and stopping the instance. This is important as one way of sticking to a limited budget is to work remotely and locally simultaneouly, requiring starting and ending the instance repetitively.

Although there are other instance types with the same fast launch feature, like the more powerful ml.g4dn.xlarge, which allows GPU-based capabilities, it is best to start conservatively with a smaller instance before moving on to a bigger instance should a faster performance be required for the workload, considering that this is a small, personal project.

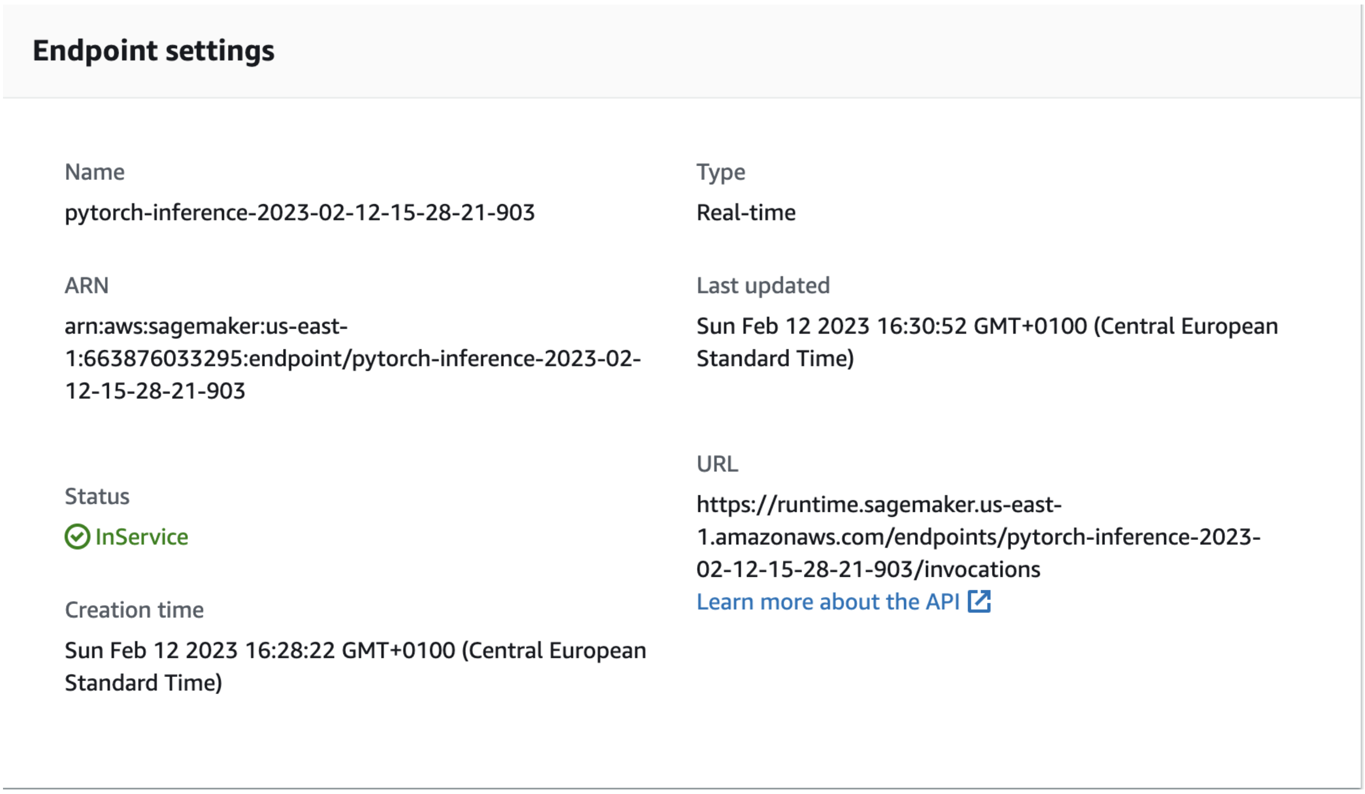
Initial Training & Deployment

```
hyperparameters = {'batch_size': 64, 'learning_rate':
'0.037260043722494224'}
estimator = PyTorch(
    entry_point='hpo.py',
    base_job_name='dog-pytorch',
    role=role,
    instance_count=1,
    instance_type='ml.m5.xlarge',
    framework_version='1.4.0',
    py_version='py3',
    hyperparameters=hyperparameters,
    ## Debugger and Profiler parameters
    rules = rules,
    debugger_hook_config=hook_config,
    profiler_config=profiler_config,
)
```

```
INFO:botocore.credentials:Found credentials from IAM Role: BaseNotebookInstanceEc2InstanceRole
INFO:sagemaker:Creating model with name: pytorch-inference-2023-02-12-15-28-21-386
INFO:sagemaker:Creating endpoint-config with name pytorch-inference-2023-02-12-15-28-21-903
INFO:sagemaker:Creating endpoint with name pytorch-inference-2023-02-12-15-28-21-903
------!
```



	Name ▽	ARN	Creation time ▼	Status ▽	Last updated
○	pytorch-inference-2023-02-12-15-28-21-903	arn:aws:sagemaker:us-east-1:663876033295:endpoint/pytorch-inference-2023-02-12-15-28-21-903	Feb 12, 2023 15:28 UTC	✓ InService	Feb 12, 2023 15:30 UTC



Endpoint settings

Name
pytorch-inference-2023-02-12-15-28-21-903

Type
Real-time

ARN
arn:aws:sagemaker:us-east-1:663876033295:endpoint/pytorch-inference-2023-02-12-15-28-21-903

Last updated
Sun Feb 12 2023 16:30:52 GMT+0100 (Central European Standard Time)

URL
https://runtime.sagemaker.us-east-1.amazonaws.com/endpoints/pytorch-inference-2023-02-12-15-28-21-903/invocations
Learn more about the API

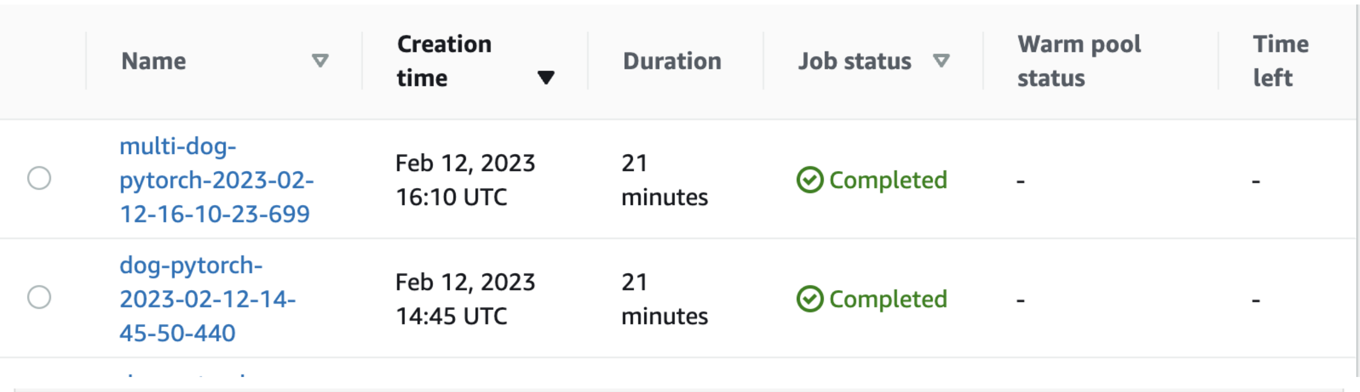
Status
✓ InService

Creation time
Sun Feb 12 2023 16:28:22 GMT+0100 (Central European Standard Time)

Multiple Instance Training & Deployment

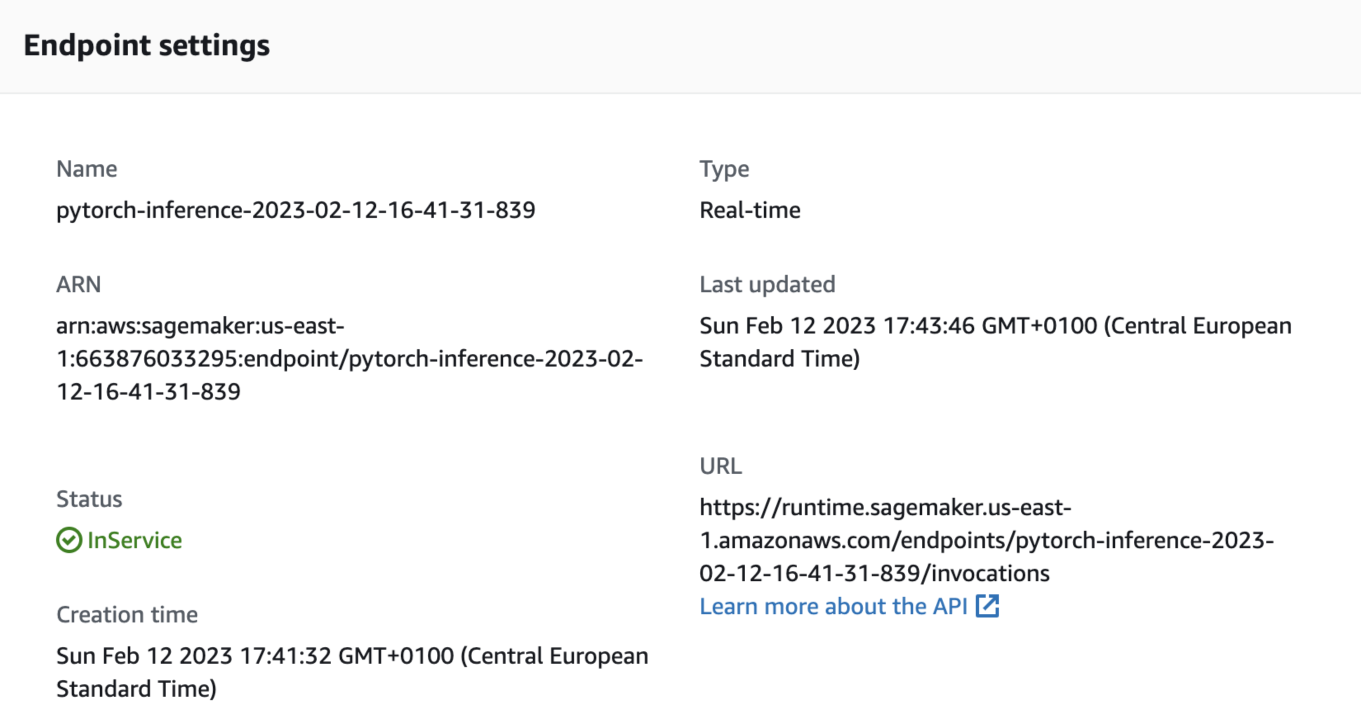
The time it took for the model to be trained was no different from that of the singular instance, however, the model with 3 instances did a better job at classifying the image, considering that the actual image has a label of 11.

```
mi_estimator = PyTorch(
    entry_point='hpo.py',
    base_job_name='multi-dog-pytorch',
    role=role,
    instance_count=3,
    instance_type='ml.m5.xlarge',
    framework_version='1.4.0',
    py_version='py3',
    hyperparameters=hyperparameters,
    ## Debugger and Profiler parameters
    rules = rules,
    debugger_hook_config=hook_config,
    profiler_config=profiler_config,
)
```



	Name ▽	Creation time ▼	Duration	Job status ▽	Warm pool status	Time left
○	multi-dog-pytorch-2023-02-12-16-10-23-699	Feb 12, 2023 16:10 UTC	21 minutes	✓ Completed	-	-
○	dog-pytorch-2023-02-12-14-45-50-440	Feb 12, 2023 14:45 UTC	21 minutes	✓ Completed	-	-

```
INFO:botocore.credentials:Found credentials from IAM Role: BaseNotebookInstanceEc2InstanceRole
INFO:sagemaker:Creating model with name: pytorch-inference-2023-02-12-16-41-31-338
INFO:sagemaker:Creating endpoint-config with name pytorch-inference-2023-02-12-16-41-31-839
INFO:sagemaker:Creating endpoint with name pytorch-inference-2023-02-12-16-41-31-839
-----!
```



Endpoint settings

Name
pytorch-inference-2023-02-12-16-41-31-839

Type
Real-time

ARN
arn:aws:sagemaker:us-east-1:663876033295:endpoint/pytorch-inference-2023-02-12-16-41-31-839

Last updated
Sun Feb 12 2023 17:43:46 GMT+0100 (Central European Standard Time)

URL
https://runtime.sagemaker.us-east-1.amazonaws.com/endpoints/pytorch-inference-2023-02-12-16-41-31-839/invocations
Learn more about the API

Status
✓ InService

Creation time
Sun Feb 12 2023 17:41:32 GMT+0100 (Central European Standard Time)

```
pred[0]
# single instance => 28
# multiple instance => 11
```

EC2 Training

Unlike the demo shown in the module, there were only 3 choices for Deep Learning AMIs and only 2 of them have an environment that supports Pytorch packages and dependencies.

Unlike the AMI used in the demo, the Pytorch environment cannot be activated using instances other than: G3, P3, P3dn, P4d, G5, G4dn.

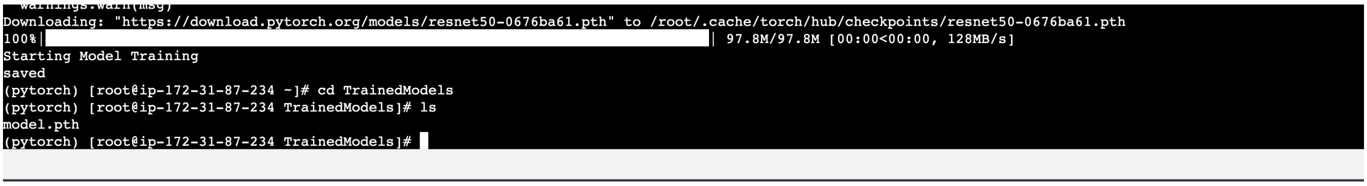
AWS Deep Learning AMI GPU PyTorch 1.12 (Amazon Linux 2)

AWS Deep Learning AMI GPU PyTorch 1.13 (Amazon Linux 2)

After going through the prices of these options and keeping in mind the budget given for this module, the best option was a g4dn.xlarge instance which costs $0.3418 for on-demand instances and $0.1578 for spot instances.

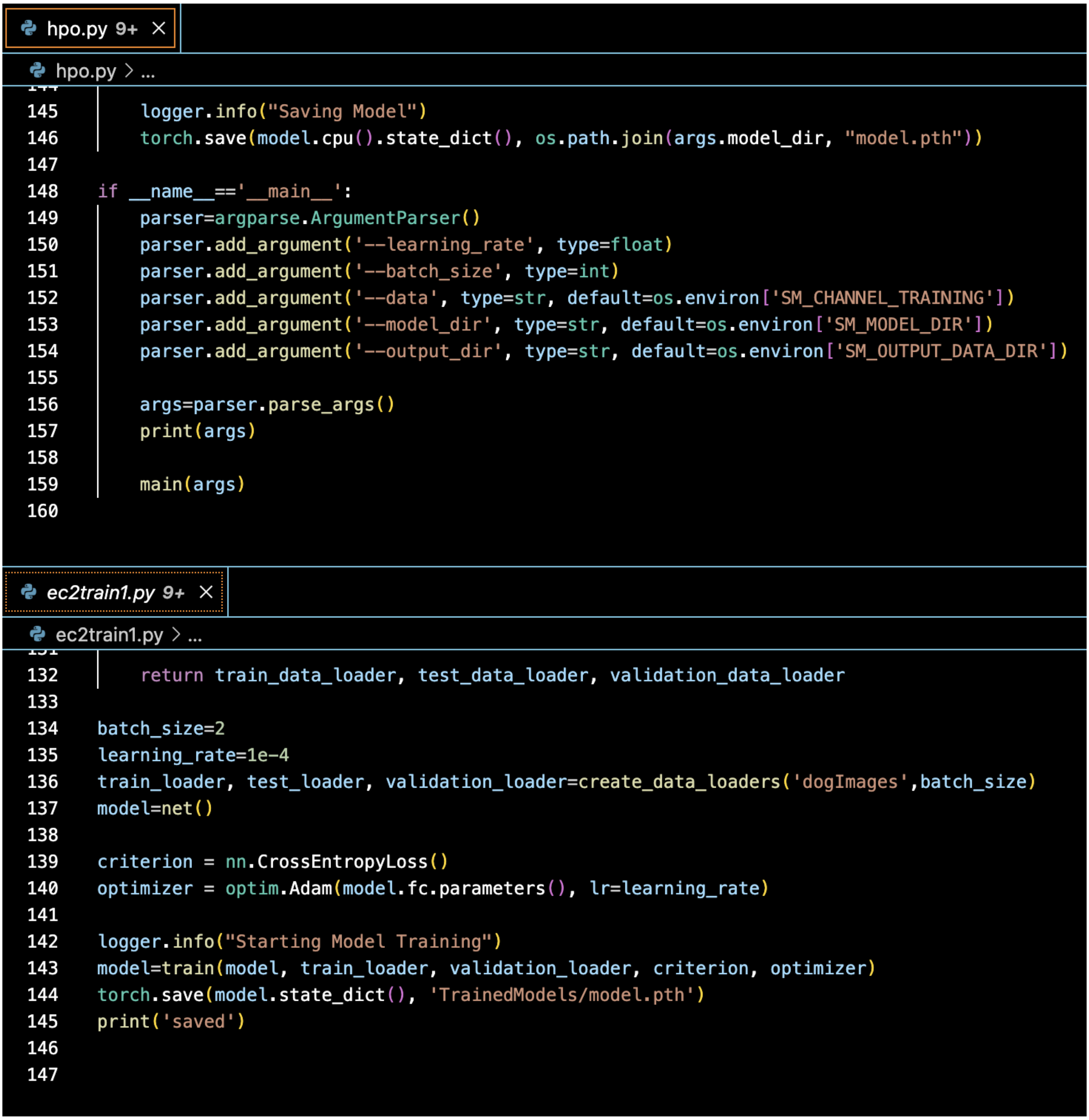
Among all the instances that is required by the AMI, this has the lowest cost for both on-demand and spot instances. As the use of spot instances have a limit and requesting for an increase takes time, having the option to use either spot or on-demand instances for a project that has a tight deadline without breaking the budget is of high importance.

See "Spot vs on-demand pricing"



```
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet50-0676ba61.pth" to /root/.cache/torch/hub/checkpoints/resnet50-0676ba61.pth
100%|██████████████████████████████████████████████████| 97.8M/97.8M [00:00<00:00, 128MB/s]
Starting Model Training
saved
(pytorch) [root@ip-172-31-87-234 ~]# cd TrainedModels
(pytorch) [root@ip-172-31-87-234 TrainedModels]# ls
model.pth
(pytorch) [root@ip-172-31-87-234 TrainedModels]# █
```

EC2 script vs hpo script



```
    logger.info("Saving Model")
    torch.save(model.cpu().state_dict(), os.path.join(args.model_dir, "model.pth"))

if __name__=='__main__':
    parser=argparse.ArgumentParser()
    parser.add_argument('--learning_rate', type=float)
    parser.add_argument('--batch_size', type=int)
    parser.add_argument('--data', type=str, default=os.environ['SM_CHANNEL_TRAINING'])
    parser.add_argument('--model_dir', type=str, default=os.environ['SM_MODEL_DIR'])
    parser.add_argument('--output_dir', type=str, default=os.environ['SM_OUTPUT_DATA_DIR'])

    args=parser.parse_args()
    print(args)

    main(args)

```

```
    return train_data_loader, test_data_loader, validation_data_loader

batch_size=2
learning_rate=1e-4
train_loader, test_loader, validation_loader=create_data_loaders('dogImages',batch_size)
model=net()

criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.fc.parameters(), lr=learning_rate)

logger.info("Starting Model Training")
model=train(model, train_loader, validation_loader, criterion, optimizer)
torch.save(model.state_dict(), 'TrainedModels/model.pth')
print('saved')


```

The main difference between the hpo.py script and the ec2train1.py script lies in the way the arguments and hyperparameters are introduced to the model. In the ec2train1.py script, the hyperparameters and arguments are declared at the end of the script whereas the arguments and hyperparameters of the hpo.py script are declared within the Sagemaker notebook instance and are introduced to the script using `parser.argparse.ArgumentParser()` and a main function.

```
if __name__=='__main__':
    parser=argparse.ArgumentParser()
    parser.add_argument('--learning_rate', type=float)
    parser.add_argument('--batch_size', type=int)
    parser.add_argument('--data', type=str,
default=os.environ['SM_CHANNEL_TRAINING'])
    parser.add_argument('--model_dir', type=str,
default=os.environ['SM_MODEL_DIR'])
```

```
    parser.add_argument('--output_dir', type=str,
default=os.environ['SM_OUTPUT_DATA_DIR'])

    args=parser.parse_args()
    print(args)

    main(args)
```

Lambda

Lambda, Amazon's serverless compute service, is the ideal solution for small tasks that are frequently used as it executes code without underlying infrastructures like operating system or hardware specifications that can sometimes impede the smooth implementation of programs.

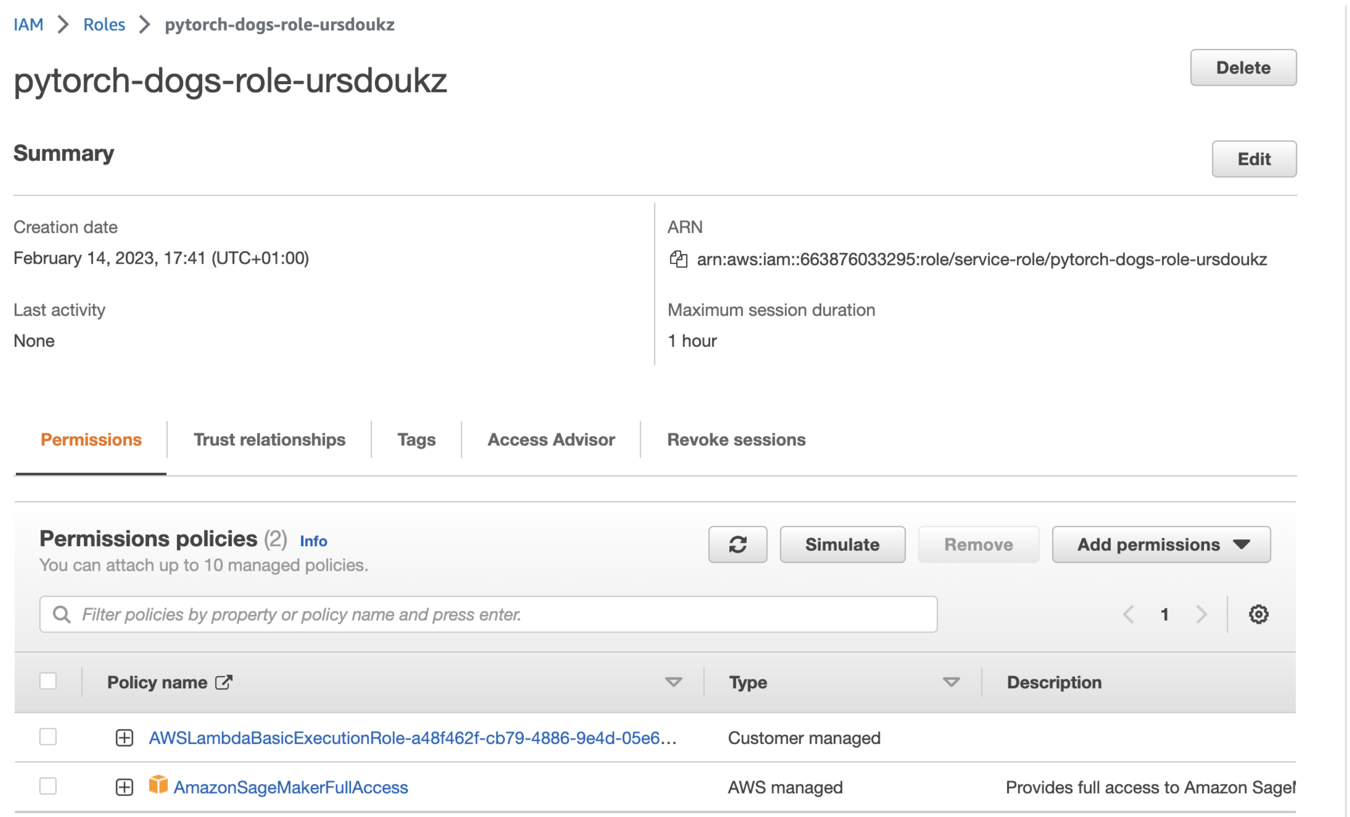
It is developed using Python code through Boto3, an AWS SDK that allows the function to interact with and manage AWS services, provided that it has the correct policies and execution role. This is done through the client as specified in the code shown below:

```
runtime=boto3.Session().client('sagemaker-runtime')
```

The code is executed by the handler function which is usually contained in a file called lambda_function.py. When a payload in the form of a JSON object is delivered, the Lambda function executes the code defined by the endpoint using the invoke_endpoint() method.

Security and Testing a Lambda Function

Once the Lambda function has been written and deployed, a test case can be configured by creating a JSON object that matches which contains the arguments specified in the function. As AWS Lambda is provided with its own execution role, it is imperative that the correct policies are attached to it so that the one can test the function successfully.



pytorch-dogs-role-ursdoukz

Summary

Creation date
February 14, 2023, 17:41 (UTC+01:00)

ARN
arn:aws:iam::663876033295:role/service-role/pytorch-dogs-role-ursdoukz

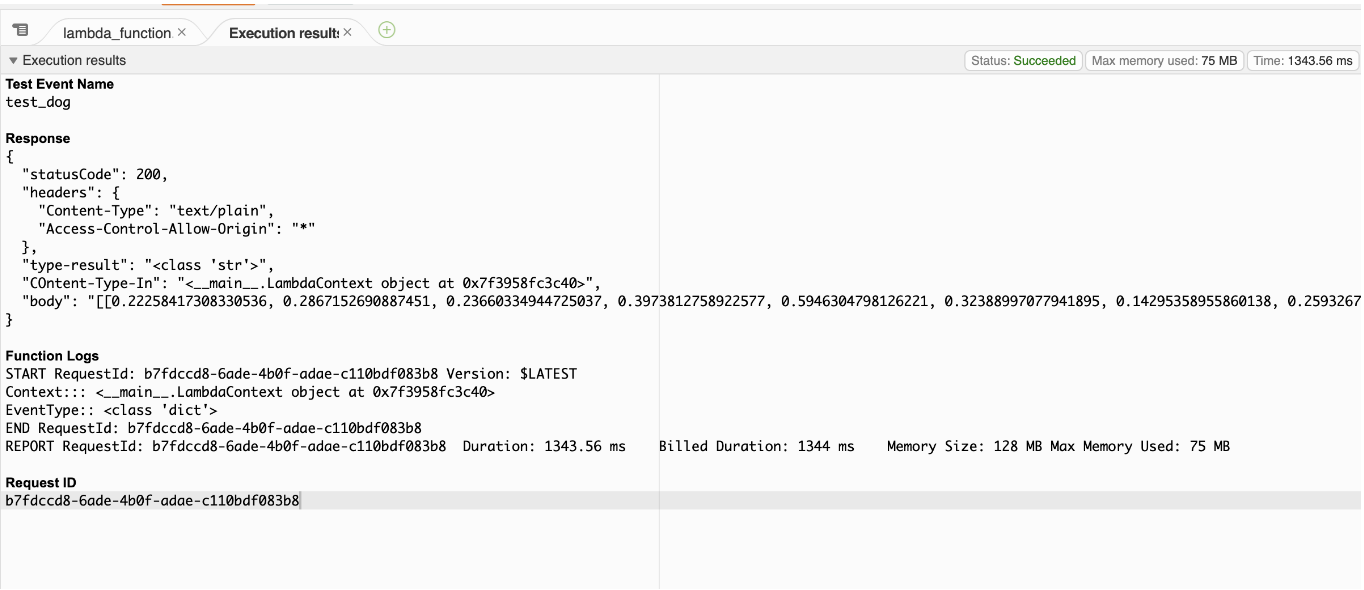
Last activity
None

Maximum session duration
1 hour

Permissions policies (2) Info
You can attach up to 10 managed policies.

□	Policy name	Type	Description
□	⊞ AWSLambdaBasicExecutionRole-a48f462f-cb79-4886-9e4d-05e6…	Customer managed	
□	⊞ AmazonSageMakerFullAccess	AWS managed	Provides full access to Amazon Sagel

If this is done correctly, it will result to a response with a status code of 200 and the values specified in the return statement will be found in the body of the response as shown below.



Status: Succeeded | Max memory used: 75 MB | Time: 1343.56 ms

Test Event Name
test_dog

Response

```
{
  "statusCode": 200,
  "headers": {
    "Content-Type": "text/plain",
    "Access-Control-Allow-Origin": "*"
  },
  "type-result": "<class 'str'>",
  "COntent-Type-In": "<__main__.LambdaContext object at 0x7f3958fc3c40>",
  "body": "[[0.22258417308330536, 0.2867152690887451, 0.23660334944725037, 0.3973812758922577, 0.5946304798126221, 0.32388997077941895, 0.14295358955860138, 0.2593267
}
```

Function Logs

```
START RequestId: b7fdccd8-6ade-4b0f-adae-c110bdf083b8 Version: $LATEST
Context::: <__main__.LambdaContext object at 0x7f3958fc3c40>
EventType:: <class 'dict'>
END RequestId: b7fdccd8-6ade-4b0f-adae-c110bdf083b8
REPORT RequestId: b7fdccd8-6ade-4b0f-adae-c110bdf083b8  Duration: 1343.56 ms    Billed Duration: 1344 ms    Memory Size: 128 MB Max Memory Used: 75 MB
```

Request ID
b7fdccd8-6ade-4b0f-adae-c110bdf083b8

```
Test Event Name
test_dog

Response
{
  "statusCode": 200,
  "headers": {
    "Content-Type": "text/plain",
    "Access-Control-Allow-Origin": "*"
  },
    "type-result": "<class 'str'>",
    "COntent-Type-In": "<__main__.LambdaContext object at 0x7f3958fc3c40>",
    "body": "[[0.22258417308330536, 0.2867152690887451, 0.23660334944725037,
  0.3973812758922577, 0.5946304798126221, 0.32388997077941895,
  0.14295358955860138, 0.2593267858028412, -0.2645488977432251,
  -0.0056010279804468155, 0.3683377206325531, 0.40309959650039673,
  -0.011438594199717045, 0.3243323266506195, 0.4832281768321991,
  0.11940720677375793, 0.3301726281642914, 0.016071753576397896,
  0.13358867168426514, 0.4334683120250702, 0.3398759961128235,
  -0.12303052097558975, 0.38373783230781555, 0.208574116230011,
  -0.17253750562667847, -0.13229110836982727, 0.41559934616088867,
  -0.3317200839519501, 0.5983749032020569, 0.15570591390132904,
  0.2418746054172516, 0.5634035468101501, -0.06630165129899979,
  0.260342001914978, 0.15422964096069336, 0.26249510049819946,
  0.05999879539012909, 0.17178316414356232, 0.28845247626304626,
  0.14137883484363556, 0.2950528860092163, 0.34624922275543213,
  0.1801588386297226, 0.37983566522598267, 0.1358564794063568,
  0.39831653237342834, 0.09975286573171616, 0.06437289714813232,
  0.20123106241226196, 0.2751830816268921, 0.3577496409416199,
  0.10020403563976288, 0.09287401288747787, 0.2717002034187317,
  0.10770490020513535, 0.19640129804611206, 0.40510982275009155,
  0.02587900683283806, -0.0023690317757427692, 0.05544339120388031,
  0.2715991735458374, 0.0018166087102144957, 0.1619286835193634,
  -0.12189028412103653, 0.04019118845462799, -0.28905490040779114,
  -0.18545860052108765, 0.35718852281570435, 0.02673361450433731,
  0.06363802403211594, 0.3299733102321625, 0.10386842489242554,
  -0.2123139351606369, -0.02947426214814186, 0.026548288762569427,
  0.33504170179367065, -0.09340201318264008, -0.23949125409126282,
  0.19283726811408997, -0.06110447272658348, -0.06545177847146988,
  0.1155146136879921, 0.05927373468875885, 0.28965985774993896,
  -0.19908912479877472, 0.05027751624584198, 0.3238394558429718,
  0.20499038696289062, 0.015548424795269966, 0.2560834586620331,
  0.25757649540901184, 0.024451695382595062, -0.1503819227218628,
  -0.037278901785612106, 0.10541312396526337, 0.116038016974926,
  -0.05723908543586731, -0.04249229282140732, -0.11206389963626862,
  -0.2917730212211609, -0.01494930312037468, -0.32105588912963867,
  0.3950178921222687, -0.3360593318939209, -0.322693407535553,
  0.0007147123105823994, -0.07922632992267609, -0.4352700412273407,
  -0.19211743772029877, -0.1981441080570221, -0.08153677731752396,
  0.18471316993236542, -0.0832882970571518, -0.27037137746810913,
  0.3735558092594147, -0.366347998380661, 0.0038887872360646725,
  0.2003762274980545, -0.21762414276599884, -0.048697978258132935,
  -0.3799019455909729, -0.37747669219970703, -0.14877746999263763,
  0.009409474208950996, -0.2609257102012634, -0.37330231070518494,
  -0.05776982381939888, -0.342445969581604, 0.03831148520112038,
  0.062469542026519775, -0.41384974122047424, -0.5424782037734985,
  -0.3256552815437317]]"
  }
```

As this is a course activity that does not involve private information, it does not require as much security as a project within a company. In this case, assigning any policy with full access, despite the requirements that it may fulfill in the execution of the code, can cause security issues. In this case, the additional protection by segmentation provided by the VPC can be useful. After all, giving the minimal access that is required to accomplish tasks in a certain role will be the best way to maintain a secure system.

Concurrency and Autoscaling

Concurrency decreases the latency of response during high-traffic situations. As this is a course project, it is quite easy to foresee that the function will not be exposed to a high amount of traffic. Needless to say that the traffic will be under the control of the coder, so a low value of 4 reserved concurrencies was chosen. With the project's low budget and very predictable traffic, there was really was no need for a provisioned currency.

The same considerations applied to the autoscaling configuration. It does not require a high target value as this was done for the purpose of a small-scale project. In this case, it was best to choose 3 instances as the maximum and to lower the cost, a target value of 50 was chosen. As for response time, 30 seconds was chosen for both scale in and scale out times.

This means that 30 seconds after the number of simultaneous invocations reaches 50, the instances will increase and will decrease after the same amount of time once number of invocations decrease. The shorter scale in and scale out time in this case increases the responsiveness which makes up for the higher target value.