

OPERATIONALIZING AN AWS ML PROJECT

Udacity AWS Machine Learning Engineer Nanodegree

1. SAGEMAKER SETUP

1.1. Sagemaker instance selection

Sagemaker's region is `us-east-1` (N.Virginia). There are many machine learning instances available in that region. The instance was chosen based on cost and capacity. Since the size of the data and training model is not large, it doesn't require to have high CPU and memory. Therefore, the most cost efficient instance that can process the data for the project is `ml.t3.medium` with 2 vCPU and 4GiB of memory.

Below is the snippet of available instances in US East region.

Region: US East (N. Virginia) ▾

Standard Instances	vCPU	Memory	Price per Hour
ml.t3.medium	2	4 GiB	\$0.05
ml.t3.large	2	8 GiB	\$0.10
ml.t3.xlarge	4	16 GiB	\$0.20
ml.t3.2xlarge	8	32 GiB	\$0.399
ml.m5.large	2	8 GiB	\$0.115

1.2. Data loading and uploading

The data was downloaded from `https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/dogImages.zip` to personal `s3://project4-us-files1/`.

The data contains `train`, `test` and `valid` folders with subfolders indicating dog breed.

2. MODEL TRAINING

2.1. Hyperparameter tuning

The following hyperparameters were tuned.

```
`hyperparameter_ranges = { "learning_rate": ContinuousParameter(0.001, 0.1),  
                           "batch_size": CategoricalParameter([32, 64, 128, 256, 512]) }`
```

The tuning job was successfully.

Training job status counter					
Completed 2 In Progress 0 Stopped 0 Failed 0 (Retryable: 0, Non-retryable: 0)					
Training jobs					
Sorting by objective metric value will display only jobs that have metric values. ↺ ↻ View logs View instance metrics Stop Create model					
<input type="text" value="Search training jobs"/>					
	Name	Status	Final objective metric value	Creation time	Training Duration
<input type="radio"/>	pytorch-training-230403-1945-002-c3844d24	Completed	53	4/3/2023, 4:06:15 PM	18 minute(s)
<input type="radio"/>	pytorch-training-230403-1945-001-4c875c46	Completed	39	4/3/2023, 3:45:35 PM	19 minute(s)

2.2. Best model training

The best hyperparameters from tuning job are below:

```
`{"batch_size": "32", "learning_rate": "0.0018776517232838084"}`
```

The parameters were used to train the model.

Job settings			
Job name dog-pytorch-2023-04-03-20-28-37-819	Status ✔ Completed View history	SageMaker metrics time series Enabled	IAM role ARN arn:aws:iam::694326168705:role/service-role/AmazonSageMaker-ExecutionRole-20230313T161989
ARN arn:aws:sagemaker:us-east-1:694326168705:training-job/dog-pytorch-2023-04-03-20-28-37-819	Creation time Apr 03, 2023 20:28 UTC	Training time (seconds) 1091	
	Last modified time Apr 03, 2023 20:48 UTC	Billable time (seconds) 1091	
		Managed spot training savings 0%	

The best model was used to deploy end point.

Endpoints

Search endpoints

Update endpoint

Actions

Create endpoint

<1>

	Name	ARN	Creation time	Status	Last updated
<input type="radio"/>	pytorch-inference-2023-04-03-20-55-03-732	arn:aws:sagemaker:us-east-1:694326168705:endpoint/pytorch-inference-2023-04-03-20-55-03-732	4/3/2023, 4:55:04 PM	✔ InService	4/3/2023, 4:57:30 PM

2.3. Multi-instance training

The same model as best estimator was used for multi-instance training with ``instance_count=3`` and ``instance_type=ml.m5.xlarge``.

dog-pytorch-2023-04-04-14-50-48-970				Clone	Create model package	Stop	Create model
Job settings							
Job name dog-pytorch-2023-04-04-14-50-48-970	Status ✔ Completed View history	SageMaker metrics time series Enabled	IAM role ARN arn:aws:iam::694326168705:role/service-role/AmazonSageMaker-ExecutionRole-20230313T161989				
ARN arn:aws:sagemaker:us-east-1:694326168705:training-job/dog-pytorch-2023-04-04-14-50-48-970	Creation time Apr 04, 2023 14:50 UTC	Training time (seconds) 1106					
	Last modified time Apr 04, 2023 15:10 UTC	Billable time (seconds) 1106					
		Managed spot training savings 0%					

The best model was used to deploy end point.

the best model has used to deploy endpoint.

Endpoints

Update endpoint



Actions

Create endpoint

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Search endpoints

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	Name ▾	ARN	Creation time ▾	Status ▾	Last updated
<input type="radio"/>	pytorch-inference-2023-04-04-16-01-04-164	arn:aws:sagemaker:us-east-1:694326168705:endpoint/pytorch-inference-2023-04-04-16-01-04-164	4/4/2023, 12:01:05 PM	 InService	4/4/2023, 12:04:38 PM
<input type="radio"/>	pytorch-inference-2023-04-03-20-55-03-732	arn:aws:sagemaker:us-east-1:694326168705:endpoint/pytorch-inference-2023-04-03-20-55-03-732	4/3/2023, 4:55:04 PM	 InService	4/3/2023, 4:57:30 PM

3. EC2 TRAINING

3.1. EC2 instance setup

The data is small and the model doesn't require large resource. `Deep Learning AMI GPU PyTorch 1.13.1 (Ubuntu 20.04) 20230326` AMI was chosen, however, `t3.small` instance type was not supported by AMI. Although `t3.small` is the most cost efficient, it is a general-purpose instance and not suitable for accelerated computing such as GPU. The suitable instance types were P and G instance types. From the [instance types](#), G3 had the lowest GPUs and reasonable CPUs which would be suitable for our application. Therefore, `g3s.xlarge` was chosen.

3.2. Model training

1. Download and unzip the data

```
`wget https://s3-us-west-1.amazonaws.com/udacity-aind/dog-project/dogImages.zip`  
`unzip dogImages.zop`
```

2. Make directory
`mkdir TrainedModels`
3. Created `solution.py` model training script from `ec2train1.py`
4. Activated pytorch environment
`conda activate pytorch`
5. The model training
`python solution.py`

```
(pytorch) ubuntu@ip-172-31-92-25:~$ python solution.py  
/opt/conda/envs/pytorch/lib/python3.9/site-packages/torchvision/models/_utils.py:208: UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be removed in the future, please use 'weights' instead.  
warnings.warn(  
/opt/conda/envs/pytorch/lib/python3.9/site-packages/torchvision/models/_utils.py:223: UserWarning: Arguments other than a weight enum or `None` for 'weights' are deprecated since 0.13 and may be removed in the future. The current behavior is equivalent to passing `weights=ResNet50_Weights.IMAGENET1K_V1`. You can also use `weights=ResNet50_Weights.DEFAULT` to get the most up-to-date weights.  
warnings.warn(msg)  
Downloading: "https://download.pytorch.org/models/resnet50-0676ba61.pth" to /home/ubuntu/.cache/torch/hub/checkpoints/resnet50-0676ba61.pt  
0% | 0.00/97.8M [00:00  
21% | 20.7M/97.8M [00:00<00:00,  
43% | 42.2M/97.8M [00:00<00:00,  
66% | 64.2M/97.8M [00:00<00:00,  
89% | 86.7M/97.8M [00:00<00:00,  
100% | 97.8M/97.8M [00:00<00:00,  
228MB/s)  
Starting Model Training  
saved  
(pytorch) ubuntu@ip-172-31-92-25:~$ ls  
BUILD_FROM_SOURCE_PACKAGES_LICENSES  LINUX_PACKAGES_LIST  THIRD_PARTY_SOURCE_CODE_URLS  dogImages  solution.py  
LINUX_PACKAGES_LICENSES  PYTHON_PACKAGES_LICENSES  TrainedModels  dogImages.zip  
(pytorch) ubuntu@ip-172-31-92-25:~$ cd TrainedModels  
(pytorch) ubuntu@ip-172-31-92-25:~/TrainedModels$ ls  
model.pth
```

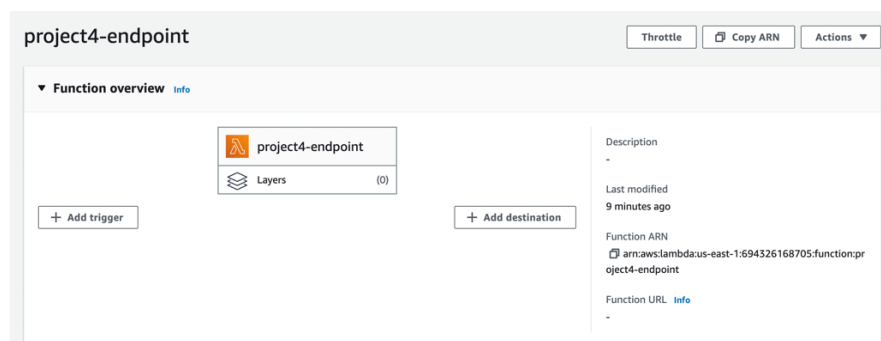
3.3. Code difference

The sagemaker code requires explicitly passing arguments such as train and test data locations, learning rate and epochs when fitting the model. On the other hand, EC2 training (`ec2train1.py`) had the arguments specified in the script.

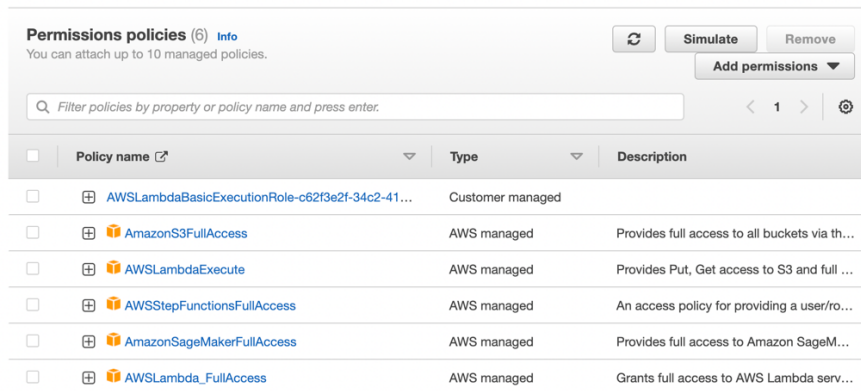
The dataset was accessed directly from `dogImages` folder when training on EC2 and the model is saved to `TrainedModels` folder. Working on EC2, we need to specify where the input is and where to save the output. Also, the data needs to be on the EC2 instance.

4. LAMBDA – ACCESS AND CONCURRENCE

`lambdafunction.py` script was used to invoke the endpoint. The endpoint name was changed to `pytorch-inference-2023-04-04-16-01-04-164` which is the endpoint for multi-instance trained model. In the script, `sagemaker-runtime` session was initiated through boto3 and the `lambda_handler` function uses the runtime to call `invoke_endpoint`. The response of the endpoint invocation is stored to `result` variable and the function returns `statusCode` 200 if successful and response of the invocation.



When the lambda function was created, following accesses were added to the role to perform invocation. If the full accesses were not granted, the lambda function can't invoke endpoint. Therefore, managing these policies are important first step to secure who can access the endpoint.

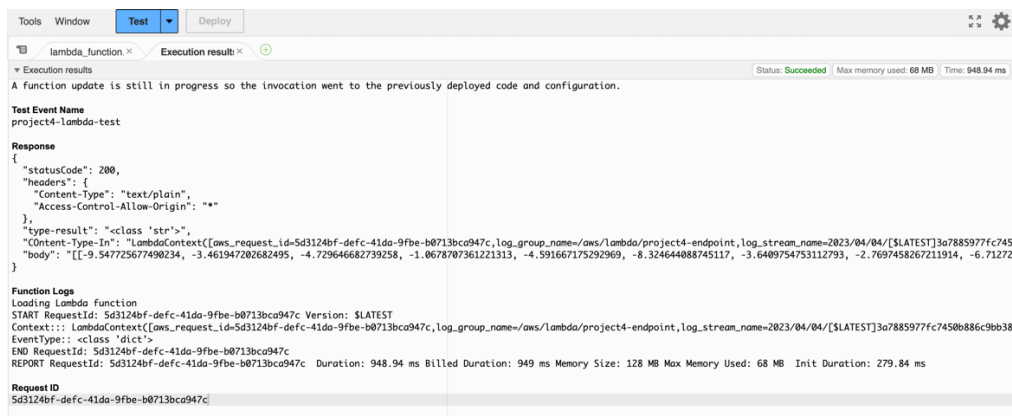


The screenshot shows the 'Permissions policies' section in the AWS IAM console. It lists six policies attached to a role. The policies are: AWSLambdaBasicExecutionRole-c62f3e2f-34c2-41..., AmazonS3FullAccess, AWSLambdaExecute, AWSStepFunctionsFullAccess, AmazonSageMakerFullAccess, and AWSLambda_FullAccess. The table includes columns for checkboxes, policy names, types (Customer managed or AWS managed), and descriptions.

	Policy name	Type	Description
<input type="checkbox"/>	AWSLambdaBasicExecutionRole-c62f3e2f-34c2-41...	Customer managed	
<input type="checkbox"/>	AmazonS3FullAccess	AWS managed	Provides full access to all buckets via th...
<input type="checkbox"/>	AWSLambdaExecute	AWS managed	Provides Put, Get access to S3 and full ...
<input type="checkbox"/>	AWSStepFunctionsFullAccess	AWS managed	An access policy for providing a user/to...
<input type="checkbox"/>	AmazonSageMakerFullAccess	AWS managed	Provides full access to Amazon SageM...
<input type="checkbox"/>	AWSLambda_FullAccess	AWS managed	Grants full access to AWS Lambda serv...

The lambda function was tested by passing following image to the endpoint and it ran successfully.

```
` { "url": "https://s3.amazonaws.com/cdn-origin-etr.akc.org/wp-content/uploads/2017/11/20113314/Carolina-Dog-standing-outdoors.jpg" } `
```



The screenshot shows the AWS Lambda console 'Test' tab. It displays the execution results for a test event named 'project4-lambda-test'. The status is 'Succeeded'. The response is a JSON object with status code 200 and headers. The function logs show the loading of the lambda function and the execution details, including the request ID, context, and duration.

Execution results

A function update is still in progress so the invocation went to the previously deployed code and configuration.

Status: Succeeded Max memory used: 68 MB Time: 948.94 ms

Test Event Name
project4-lambda-test

Response

```
{
  "statusCode": 200,
  "headers": {
    "Content-Type": "text/plain",
    "Access-Control-Allow-Origin": "*"
  },
  "type-result": "<class 'str'>",
  "Content-Type-In": "LambdaContext[aws_request_id=5d3124bf-defc-41da-9fbe-b0713bca947c, log_group_name=/aws/lambda/project4-endpoint, log_stream_name=2023/04/04/[SLATEST]3a7885977fc745",
  "body": "[[-9.547725677490234, -3.461947202682495, -4.729646682739258, -1.0678707361221313, -4.591667175292969, -8.324644088745117, -3.6409754753112793, -2.7697458267211914, -6.71272
```

Function Logs

```
Loading Lambda function
START RequestId: 5d3124bf-defc-41da-9fbe-b0713bca947c Version: $LATEST
Context::: LambdaContext[aws_request_id=5d3124bf-defc-41da-9fbe-b0713bca947c, log_group_name=/aws/lambda/project4-endpoint, log_stream_name=2023/04/04/[SLATEST]3a7885977fc745
Event type:: <class 'dict'>
END RequestId: 5d3124bf-defc-41da-9fbe-b0713bca947c
REPORT RequestId: 5d3124bf-defc-41da-9fbe-b0713bca947c Duration: 948.94 ms Billed Duration: 949 ms Memory Size: 128 MB Max Memory Used: 68 MB Init Duration: 279.84 ms
```

Request ID
5d3124bf-defc-41da-9fbe-b0713bca947c

By setting up concurrency and autoscaling, we can handle high volume traffic without any performance issue.

We can setup reserved or provisioned concurrencies. Reserved concurrency guarantees a maximum number of instances at lower cost, but the traffic exceeds the maximum number of instances, then it can create latency. On the other hand, provisioned concurrency is always on regardless of the traffic but costly. Combination of concurrency and auto-scaling, we can handle sudden spikes in traffic without affecting the performance. The number of concurrency depends on the application and traffic. It's important to test before choosing any autoscaling or **concurrency** type to decide which is best for the project.

For this project, the traffic is unknown. Therefore, for the lambda function, 5 reserved concurrency instances and 3 provisioned concurrency instances were set.