

Build, Train, Save, Deploy and Test a Convolutional Neural Network Model using MNIST

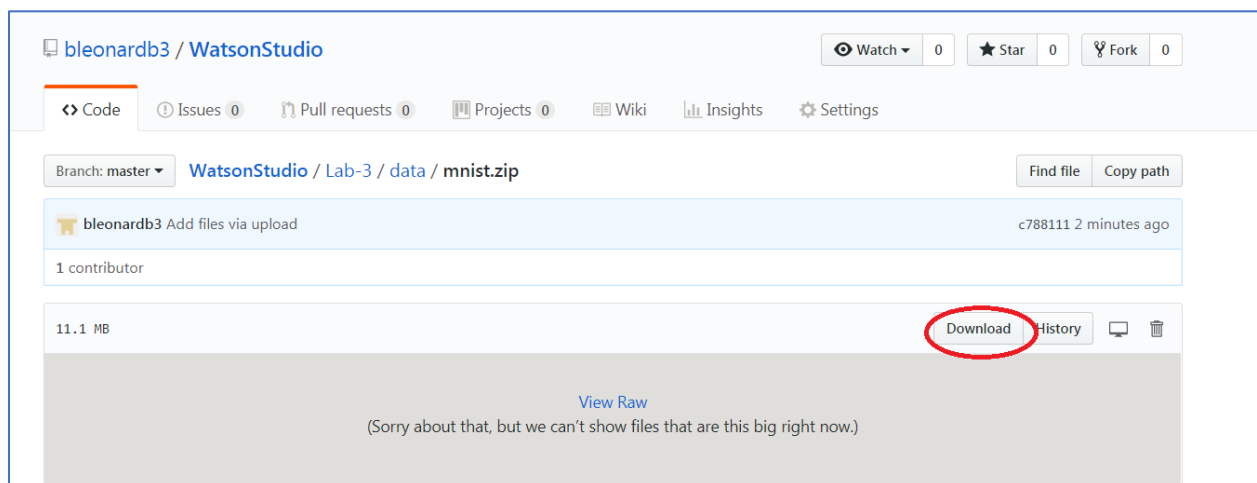
This lab will use the [MNIST](#) computer vision data set to train a deep learning model to recognize handwritten digits. A single layer convolutional neural network will be built in the Watson Studio neural network designer, and then trained using the Watson Studio Experiment Builder. The trained model will be saved in the model repository, deployed, and then tested with sample image data. The lab consists of the following steps:

1. Set up the data files in IBM Cloud Storage.
2. Design the neural network
3. Train the model
4. Monitor the training progress and results
5. Save and Deploy the Trained Model
6. Test the Deployment

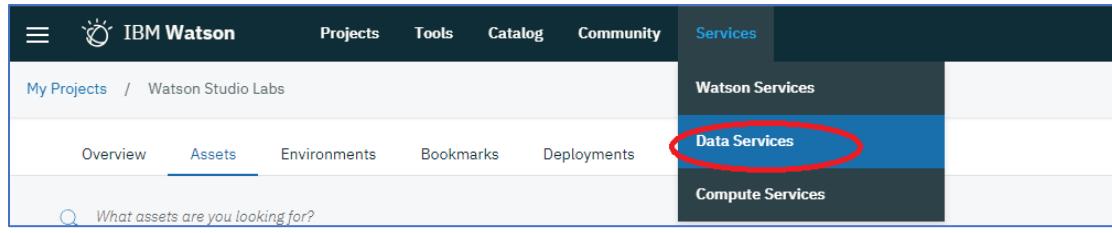
Step 1: Set up the Data Files in IBM Cloud Storage

Training a deep learning model using Watson Machine Learning relies on using Cloud Object Storage for reading input (such as training data) as well as for storing results (such as log files.)

1. Download the [mnist.zip](#) file. Extract the 3 files - a training file (mnist-tf-train.pkl), test file (mnist-tf-test.pkl), and a validation file (mnist-tf-valid.pkl) in pickle format.



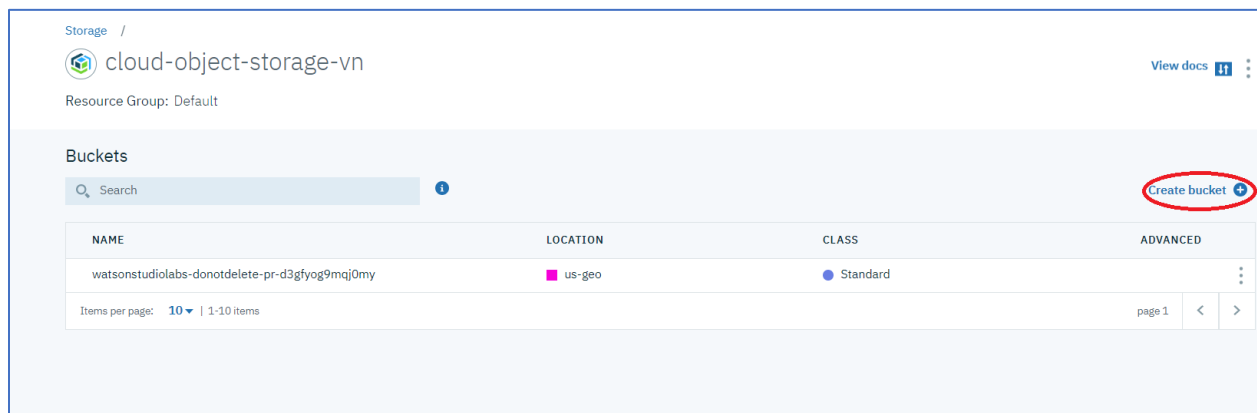
2. Select the **Services** tab and the click on **Data Services**



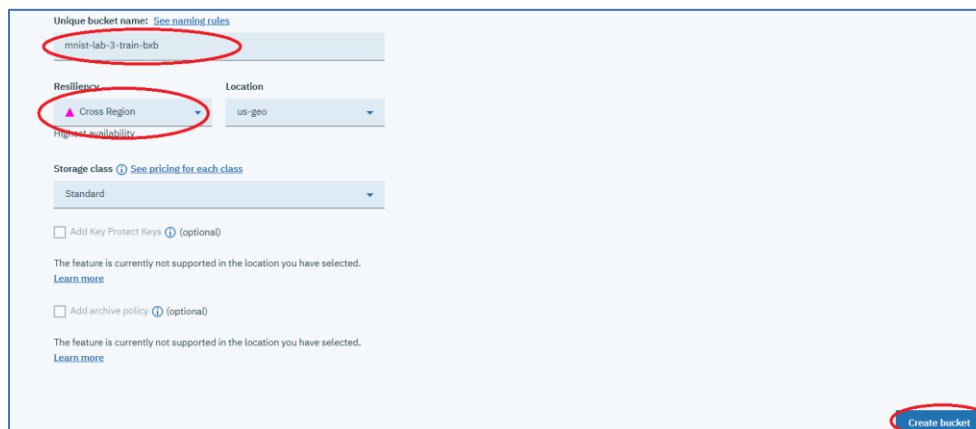
3. Select the vertical **ellipse** on the right hand side of the cloud object storage entry, and then click on **Manage in IBM Cloud**



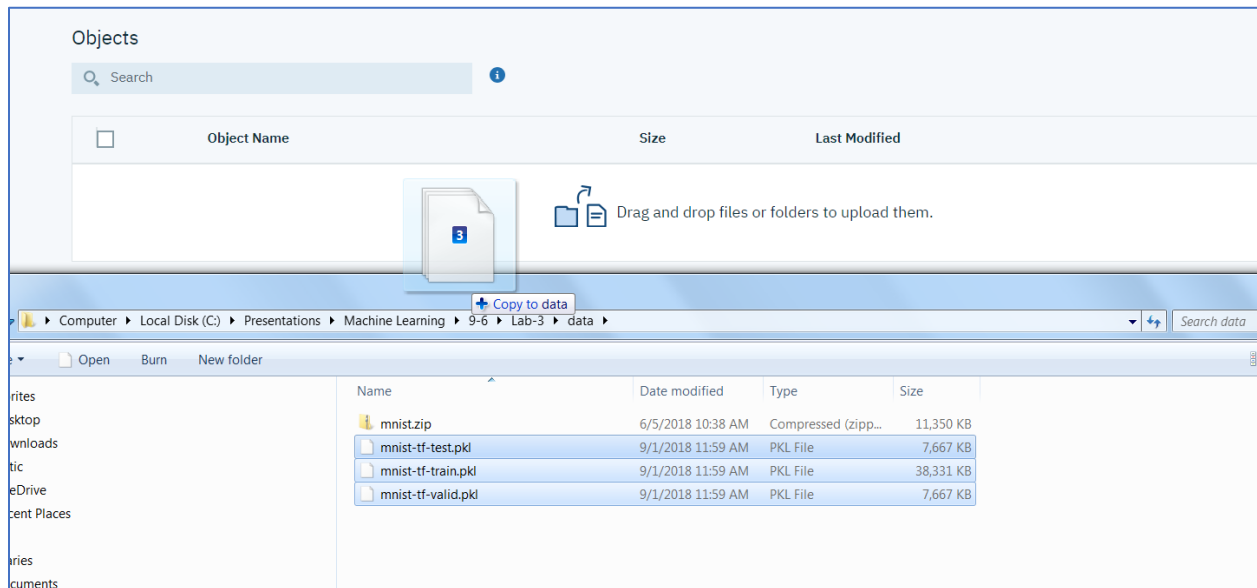
4. Click on **Create Buckets**



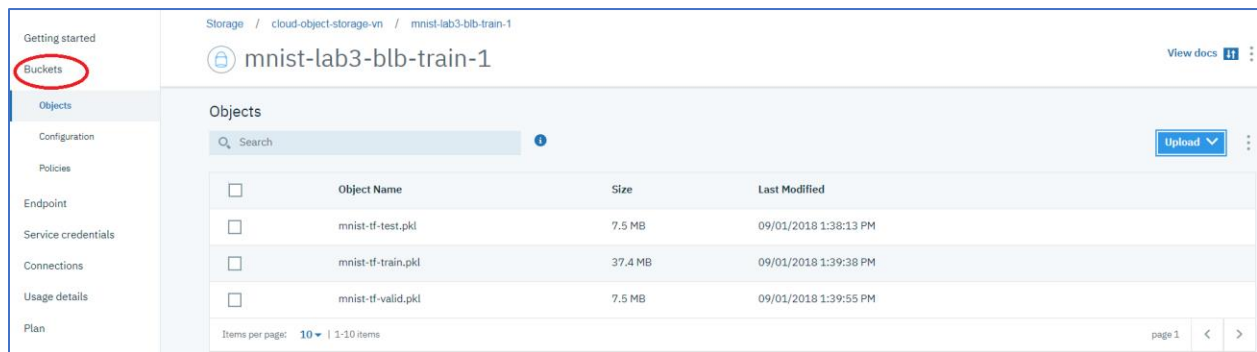
5. Enter a unique name for the bucket - mnist-lab-3-train-xxx (replace xxx with your initials), click on **Cross-Region** for the Resiliency and click **Create**.



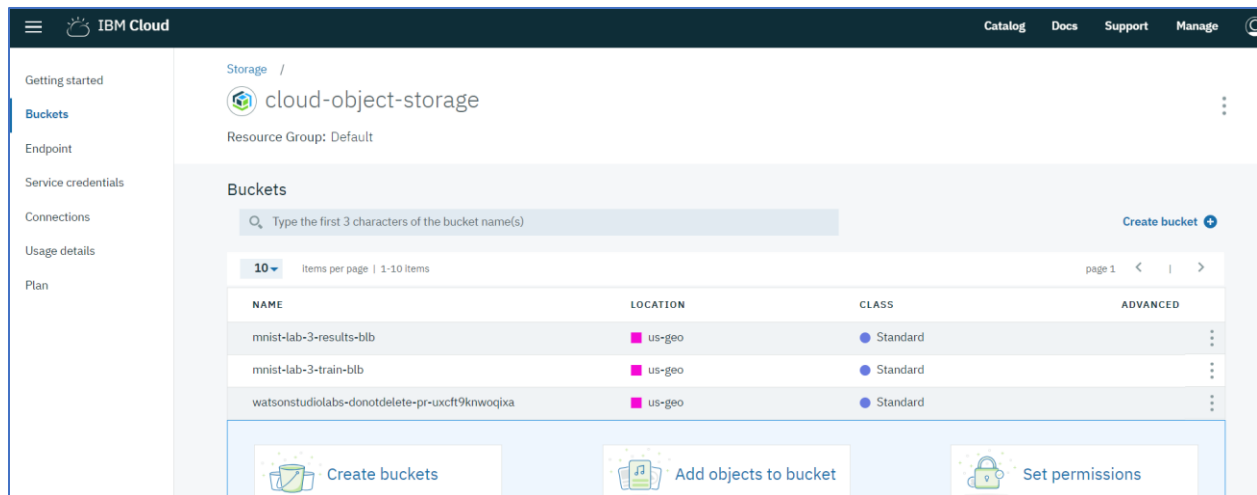
6. Navigate to the directory where the 3 mnist files are stored. Select these 3 files and drag and drop where indicated.



7. Click on Buckets to add a second bucket.

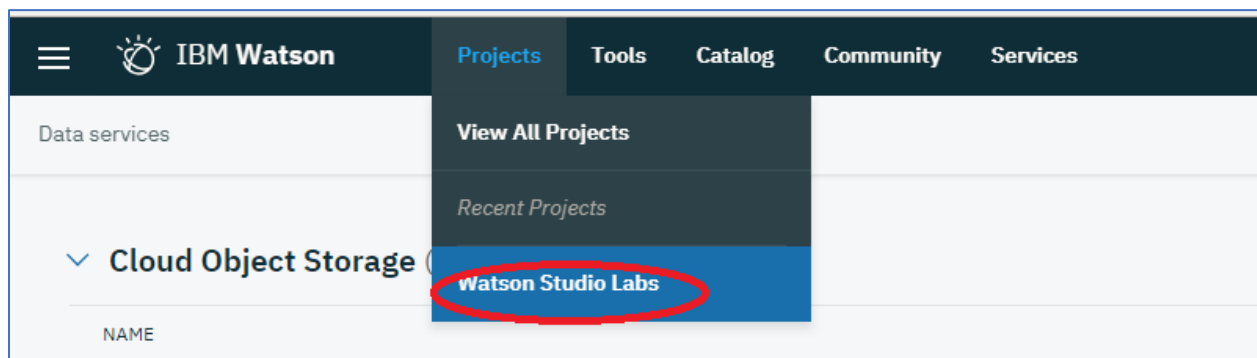


8. Name it mnist-lab-3-results-xxx, where xxx are your initials. Follow the procedure above to create the second bucket. No files need to be added.
9. The Cloud Object Storage panel should appear as below.

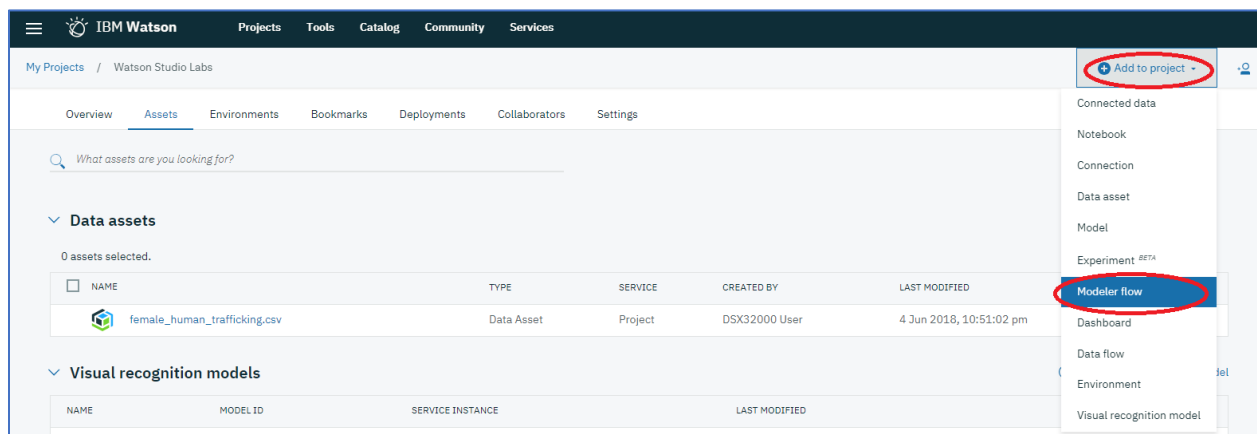


Step 2: Design the Neural Network and Publish Training Definition

1. Return to Watson Studio, and click on the **Projects** tab, and **Watson Studio Labs**.



2. Click on the **Add to project** and then click on **Modeler Flow**.



3. Click on **From example**.

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Modeler

New From file **From example**

Name*
Type name here. 50

Description
Type description here. 500

Select flow type

☒ Modeler Flow ☐ Neural Network Modeler BETA

Runtime

☒ IBM SPSS Modeler ☐ Scala Spark 2.1 BETA

4. Click on the **Single Convolution Layer on MNIST** and then click on **Create**

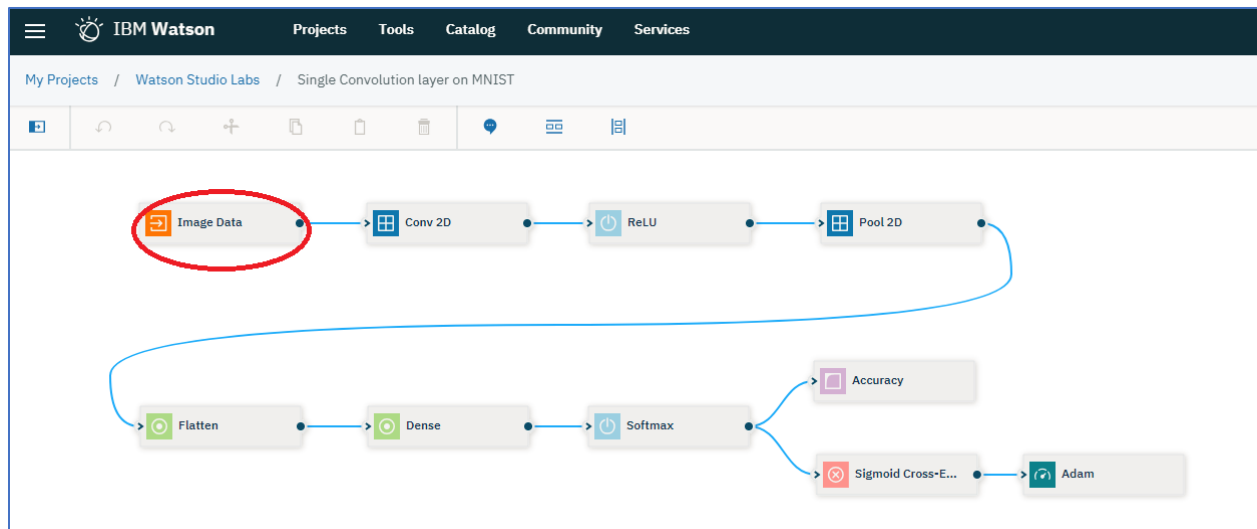
New From file From example

Select one of the samples below to get started with an existing stream that suits the kind of modeling you want to do. When you create the stream it will be added to your project, allowing you to modify and save your changes.

<p>SPSS MODELER Drug Study Example Use neural network and C5.0 algorithms to build classification models that allow you to predict the correct type of drug for a patient based on various health metrics.</p>	<p>SPSS MODELER Sales Promotion Study Use neural network and CART algorithms to predict the effect of advertising promotions on the sale of various items. Input data of sales before and after a sales promotion are used to train the model to predict the effectiveness of advertising.</p>	<p>NEURAL NETWORK DESIGN Single Convolution layer on MNIST Classification of MNIST dataset with a simple deep Convolutional Neural Network containing one single convolutional and dense layer.</p>	<p>NEURAL NETWORK DESIGN CNN on CIFAR10 Classification of CIFAR-10 dataset with a simple deep Convolutional Neural Network.</p>
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Cancel **Create**

5. A standard convolution neural network (CNN) architecture is displayed. We need to configure the Image Data node. Double-click on Image Data.



6. Optionally change the default **Connection Name**, and then click on **Create a connection**.

Image Data

ALERTS (2) ▼

DATA (2) ▲

There are no data connections in this project.
Would you like to connect your default COS instance to your project?

Connection Name

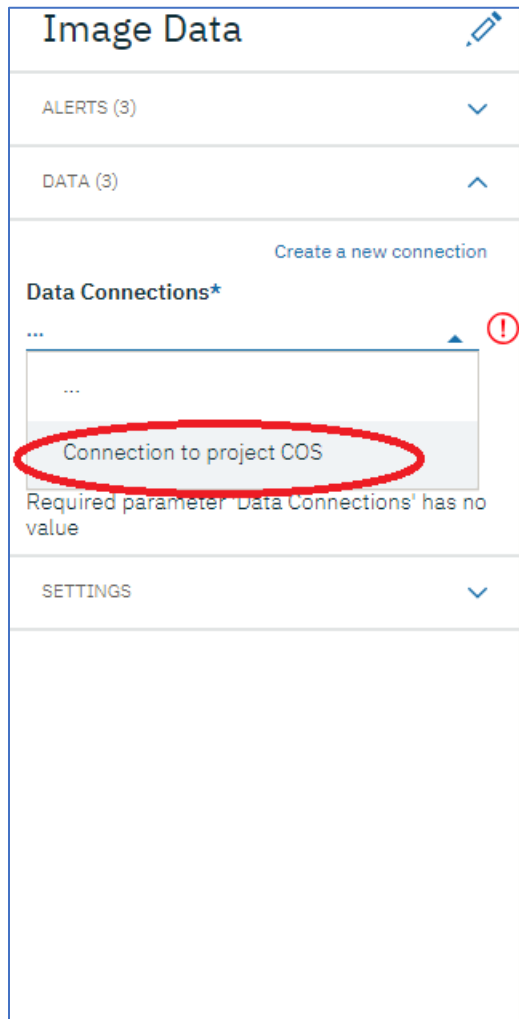
Connection to project COS

Create a connection

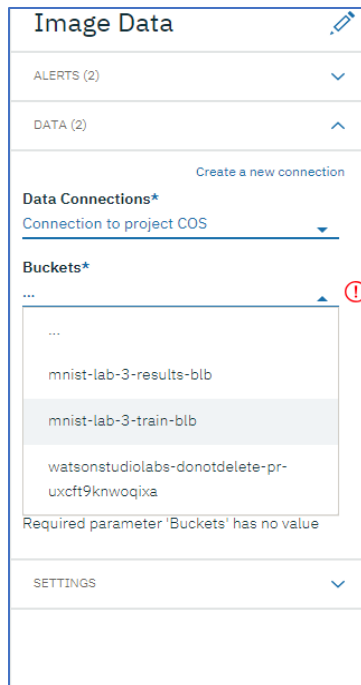
25

SETTINGS ▼

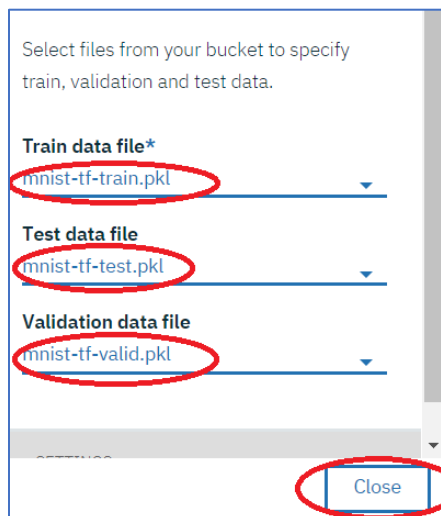
7. Click on the downward triangle icon ▼ underneath **Data Connections***. Click on the connection that was just created.





8. Click on the downward triangle icon ▼ underneath **Buckets***, and then click on the **mnist-lab-3-train-xxx** where “xxx” are your initials.

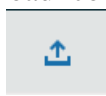


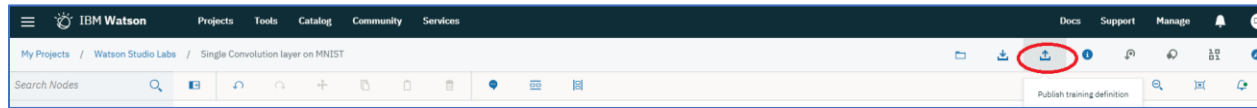
9. Click on the ▼ icon underneath **Train data file*** and select the **mnist-tf-train-pkl**. Assign the Test data file(mnist-tf-test-pkl), and Validation data files(mnist-tf-valid-pkl) in the same way and then click on **Close**.



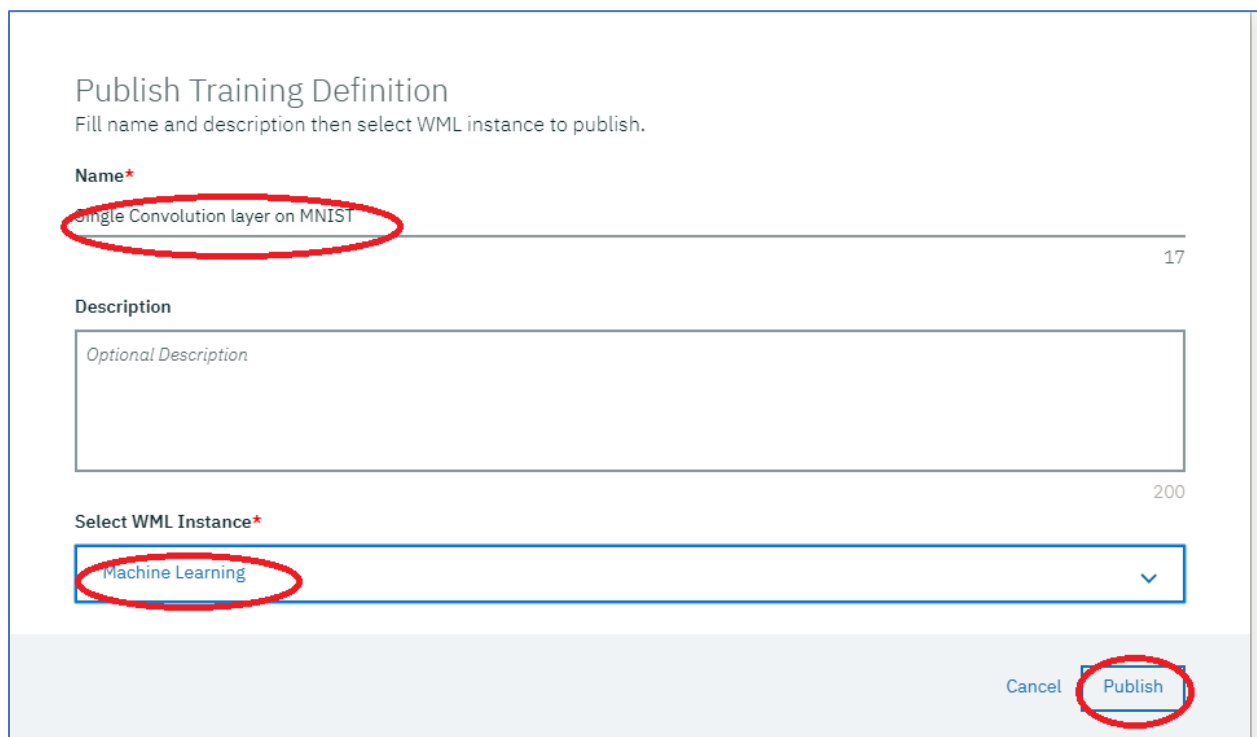
10. Explore the neural network flow modeler options
 1. Click on the  icon to see the list of neural network component categories that are available
 2. Explore the contents in each category. Hover over the components to get a pop-up description.
 3. Drag some nodes on the canvas and double-click to see the parameters. **Note remove these nodes before doing step 11.**

4. Click on the download icon  to see the multiple options for code generation.

11. Click on the **Publish** icon  to create a training definition.



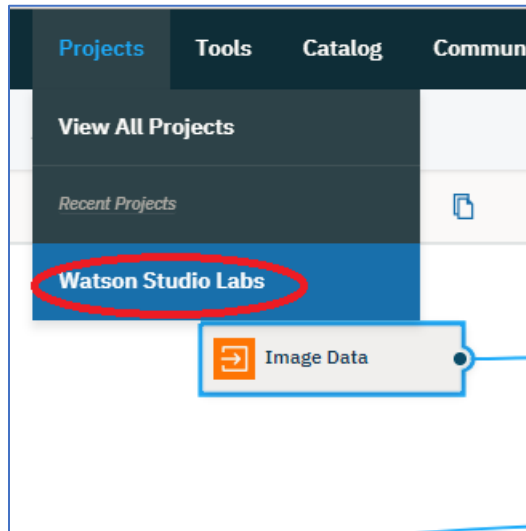
12. Enter a name for the training definition (or leave the default), and select the Machine Learning service that you created. Note, it will not be named Machine Learning unless that is the name that you used. Click on Publish.

A screenshot of the 'Publish Training Definition' form in IBM Watson Studio. The form has three main sections: 'Name*', 'Description', and 'Select WML Instance*'. The 'Name' field contains 'Single Convolution layer on MNIST' and is circled in red. The 'Description' field is empty and has a placeholder 'Optional Description'. The 'Select WML Instance' dropdown menu is set to 'Machine Learning' and is also circled in red. At the bottom right, there are 'Cancel' and 'Publish' buttons, with the 'Publish' button circled in red. Character counts '17' and '200' are visible next to the name and description fields respectively.

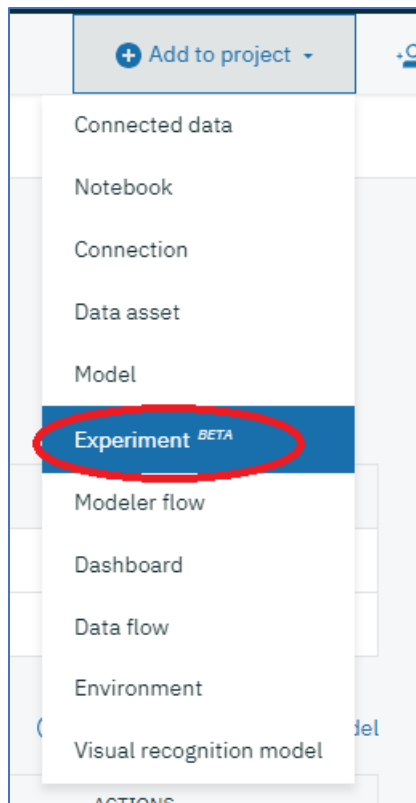
Step 3: Train the Model using Experiment Builder

As part of the model building process, we want to be able to compare different algorithms, and/or different algorithmic parameters to determine the best model. Experiment Builder is a facility in Watson Studio that supports this effort. Different training runs can be defined and run in parallel and their results can then be compared. In this lab, we will define only one training run to minimize the training time.

1. Return to the Watson Studio Labs Assets panel by clicking on the **Projects** tab and then **Watson Studio Labs**. Click on the **Assets** tab if the Assets panel is not displayed.



2. Click on **Add to project**, and then click **Experiment** to create a new Experiment.



3. Enter an Experiment **Name**, select the **Machine Learning** service, and then click on **Select** to assign a Cloud Storage bucket.

New experiment BETA

Define experiment details

Name

Single Convolution Layer on MNIST

67

Description

Experiment description

300

Machine Learning Service

Machine Learning

Cloud Object Storage bucket for storing training source and results files

Select

Associate training definitions

[+ Add training definition](#)

NAME	COMPUTE PLAN
No training definitions associated.	

☐ Use global execution command (override training definition values)

4. Select **Existing connections**, and then select the **Connection to project COS** connection.

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Cloud Object Storage bucket selection

Existing connections New connection

Cloud Object Storage connection

Select Cloud Object Storage connection

Connection to project COS

5. We now need to assign the Training and Results buckets. Select **Existing** underneath **Bucket containing training data**, and click on mnist-lab-3-train-xxx, where “xxx” are your initials. Click on **Select**.

Cloud Object Storage training source bucket selection

Existing connections New connection

Cloud Object Storage connection

Connection to project COS ▼

Bucket containing training source data

☒ Existing ☐ New

mnist-lab-3-train-bdb-3 ▼

Cancel Select

6. Click on **Select** underneath **Cloud Object Storage** for storing results.

New experiment ^{BETA}

Define experiment details

Name

Single Convolution on MNIST

73

Description


Experiment description

300

Machine Learning Service

Machine Learning ▼

Cloud Object Storage bucket for storing training source files

Source: [Connection to project COS / mnist-lab-3-train-b...](#)  Update

Cloud Object Storage bucket for storing results

Select

7. Follow the same procedure used to assign the training bucket to assign the results bucket. Assign bucket mnist-lab-3-results-xxx, where “xxx” are your initials, and then click on **Select**.

Cloud Object Storage results bucket selection

Existing connections New connection

Cloud Object Storage connection

Connection to project COS

Bucket containing results data

Existing New

mnist-lab-3-results-bxb-1

Cancel Select

8. We now need to associate a Training Definition. Click on **Add Training Definition**.

IBM Watson Projects Tools Catalog Community Services Docs Support Manage

New experiment BETA

Define experiment details

Name
Single Convolution Layer on MNIST

Description
Experiment description

Machine Learning Service
Machine Learning

Cloud Object Storage buckets for storing training source and results files
Source: Connection to project COS / mnist-lab-3-train...
Results: Connection to project COS / mnist-lab-3-resul...
Update

Associate training definitions

Add training definition

NAME COMPUTE PLAN

No training definitions associated.

☐ Use global execution command (override training definition values)

9. Click on **Existing training definition**, and select **Single Convolution Layer on MNIST**, select **1/2 x NVIDIA Tesla K80 (1 GPU)** for the compute plan, and then click **Select**.

Add training definition

new training definition **existing training definition**

Select training definition

Existing training definitions

Single Convolution layer on MNIST

Training definition attributes

Compute plan

1/2 x NVIDIA® Tesla® K80 (1 GPU)

Hyperparameter optimization method

None

Cancel **Create**

10. Click **Create and run**.

New experiment BETA

Define experiment details

Name

Single Convolution Layer on MNIST

67

Description

Experiment description

300

Machine Learning Service

Machine Learning

Cloud Object Storage buckets for storing training source and results files

Source: Connection to project COS / mnist-lab-3-train... [🔗](#)

Results: Connection to project COS / mnist-lab-3-resul... [🔗](#) [Update](#)

If your connection is authorized for dashboard access, click the bucket name above to launch the dashboard. It may take a few seconds for the dashboard link to work for newly created buckets. Alternatively, reference the Cloud Object Storage APIs [🔗](#).

Associate training definitions

[+ Add training definition](#)

NAME	COMPUTE PLAN
Single Convolution layer on MNIST	1/2 x NVIDIA® Tesla® K80 (1 GPU) 🔗 🗑️

☐ Use global execution command (override training definition values)

Cancel **Create and run**

Step 4: Monitor the Training Progress and Results

Training runs will be first queued, then in-process, and then completed. Use the **Training Runs** tab to keep track of progress.

Queued Status

My Projects / Watson Studio Labs / Single Convolution Layer on MNIST

Single Convolution Layer on MNIST

Cancel runs in progress Add training runs

Training Runs Compare Runs Overview

1 Runs in total 0 hr, 0 min, 0 sec Total running time

Queued

NAME	SUBMITTED
Single Convolution layer on MNIST	0 hr, 0 min, 6 sec ago

In progress

NAME	DURATION
No training runs found.	

Completed

NAME	STATUS	DURATION	ACTIONS
No training runs found.			

In-Process Status

My Projects / Watson Studio Labs / Single Convolution Layer on MNIST

Single Convolution Layer on MNIST

Cancel runs in progress Add training runs

Training Runs Compare Runs Overview

1 Runs in total 0 hr, 0 min, 43 sec Total running time

Queued

NAME	SUBMITTED
No training runs found.	

In progress

NAME	DURATION
Single Convolution layer on MNIST	0 hr, 0 min, 43 sec

Completed

NAME	STATUS	DURATION	ACTIONS
No training runs found.			

Completed Status

Single Convolution Layer on MNIST

Cancel runs in progress Add training runs

Training Runs Compare Runs Overview

1 Runs in total 0 hr, 2 min, 45 sec Total running time

Queued

NAME	SUBMITTED
No training runs found.	

In progress

NAME	DURATION
No training runs found.	

Completed

NAME	STATUS	DURATION	ACTIONS
Single Convolution layer on MNIST	completed	0 hr, 2 min, 45 sec	

1. Click on the Single Convolution layer on MNIST link to check the results.

My Projects / Watson Studio Labs / Single Convolution Layer on MNIST

Single Convolution Layer on MNIST

Training Runs Compare Runs Overview

1 Runs in total 0 hr, 2 min, 45 sec Total running time

Queued

NAME	SUBMITTED
No training runs found.	

In progress

NAME	DURATION
No training runs found.	

Completed

NAME	STATUS	DURATION	ACTIONS
Single Convolution layer on MNIST	completed	0 hr, 2 min, 45 sec	

2. Click on **Logs**

My Projects / Watson Studio Labs / Single Convolution Layer on MNIST / Single Convolution layer on MNIST

Single Convolution layer on MNIST

Monitor Overview **Logs**

✓ completed 0 hr, 2 min, 45 sec
Training status Total running time

3. Scroll down to the bottom to check accuracy measure.

My Projects / Watson Studio Labs / Single Convolution Layer on MNIST / Single Convolution layer on MNIST

Single Convolution layer on MNIST

Monitor Overview **Logs**

```
> i 8352/10000 [=====>.....] - ETA: 0s
> i 9120/10000 [=====>...] - ETA: 0s
> i 9856/10000 [=====>.] - ETA: 0s
> i 10000/10000 [=====] - 1s 68us/step
> i /usr/local/lib/python3.5/dist-packages/h5py/__init__.py:36: FutureWarning: Conversion of the second argument of issubdtype from `float` to `np.float64` is deprecated. In future, it will be treated as `np.float64` or `np.float_` depending on the context.
> i from ._conv import register_converters as _register_converters
> i Using TensorFlow backend.
> i [0.0704007319975819, 0.9811]
> i Saving the model...
> i Model saved in file: /mnt/results/mnist-lab-3-results-blb/training-yGqyOKImg/model/Single-Convolution-layer-on-MNIST.h5
> i Done!
> i -----
```

Most recent 500 logs are displayed.

Step 5: Save and Deploy the Trained Model

We will now save the trained model to the Watson Machine Learning repository.

1. Click on the vertical ellipse under ACTIONS, and click **Save model**.

Completed			
NAME	STATUS	DURATION	ACTIONS
Single Convolution layer on MNIST	completed	0 hr, 2 min, 45 sec	<div><div></div><div>Save model</div></div>

2. Enter a **Name** for the model (Single Convolution layer on MNIST) and click **Save**.

Save Model

Name
Single Convolutional layer on MNIST 65

Description
Model description 300

Cancel Save

- Return to the Watson Studio **Assets** panel, by clicking on **Watson Studio Labs** in the breadcrumb path. Click on the **Assets** tab if the Assets panel is not showing.

IBM Watson Projects Tools Catalog Community Services

My Projects / Watson Studio Labs Single Convolution Layer on MNIST

✓ Model successfully saved. View model details [here](#).

- Click on the newly saved model

Models New model

NAME	STATUS	TYPE	RUNTIME	LAST MODIFIED	ACTIONS
<u>Single Convolutional Layer on MNIST</u>	trained	tensorflow-1.5	python-3.5	5 Jun 2018	

- Click on **Deployments**.

The screenshot shows the IBM Watson Studio interface. The top navigation bar includes 'My Projects', 'Watson Studio Labs', and 'Single Convolutional layer on MNIST...'. The main header shows 'Single Convolutional layer on MNIST' with a sub-header containing 'Overview', 'Evaluation', and 'Deployments' (circled in red). Below this is a 'Summary' section with a table of model details.

Property	Value
Machine learning service	Machine Learning
Model Type	tensorflow-1.5
Runtime environment	python-3.5
Training date	5 Jun 2018, 3:48 PM
Latest version	1c472928-e0ac-4146-9985-5b1c02bb8881

6. Click on **Add Deployment**.

This screenshot shows the 'Deployments' tab of the IBM Watson Studio interface. The 'Add Deployment' button, located in the top right corner of the deployment list area, is circled in red. Below the button is a table with columns for NAME, STATUS, DEPLOYMENT TYPE, and ACTIONS. The table currently shows a message: 'Your model is not deployed.'

7. Enter a **Name** (e.g. Single Convolution layer on MNIST Deployed), select **Web Service** (should be the default), and click on **Save**.

The screenshot shows the 'Create Deployment' form. The 'Name' field is filled with 'Single Convolutional layer on MNIST Deployed' and is circled in red. The 'Description' field is empty. Under the 'Deployment type' section, 'Web service' is selected with a radio button and is circled in red. At the bottom right, the 'Save' button is circled in red.

8. The model is successfully deployed.

Overview Evaluation Deployments Lineage			
			+ Add Deployment
NAME	STATUS	DEPLOYMENT TYPE	ACTIONS
Single Convolution Layer on MNIST Deployed	DEPLOY_SUCCESS	Web Service	⋮

Step 6: Test the Deployed Model

We will now test the deployed model using the sample image data contained in the file test.json that was extracted from the mnist.zip file previously.

1. Click on the vertical ellipse, and then click on **View**.

Single Convolution on MNIST 📄			
Overview Evaluation Deployments Lineage			
			+ Add Deployment
NAME	STATUS	DEPLOYMENT TYPE	ACTIONS
Single Convolution Layer on MNIST Deployed	DEPLOY_SUCCESS	Web Service	⋮ View Delete

2. Click on **Test**.

Single Convolution Layer on MNIST Deployed	
Overview Implementation Test	
Deployment	
Name	Single Convolution Layer on MNIST Deployed
Type	Web Service
Deployment ID	89cf10e5-bd95-4b56-a728-e8b65fa98d83



3. Go to the file directory where you have the “test.json” file stored, and double-click on the file.

Computer > Local Disk (C:) > Presentations > Machine Learning > 9-6 > Lab-3 > data				
Organize	Include in library	Share with	Burn	New folder
Favorites				
Desktop				
Downloads				
static				
OneDrive				
Recent Places				
Libraries				
Documents				
Name	Date modified	Type	Size	
._MACOSX	9/2/2018 10:40 AM	File folder		
mnist.zip	9/2/2018 11:46 AM	Compressed (zipp...	11,437 KB	
mnist-tf-test.pkl	9/2/2018 11:45 AM	PKL File	7,667 KB	
mnist-tf-train.pkl	9/2/2018 11:45 AM	PKL File	38,331 KB	
mnist-tf-valid.pkl	9/2/2018 11:45 AM	PKL File	7,667 KB	
mnistup.py	9/2/2018 10:50 AM	PY File	1 KB	
test.json	9/2/2018 11:36 AM	JSON File	14 KB	

4. Select the contents of the file by placing the cursor to the left of the { and pressing and holding the <Shift><Ctrl><End> keys.

Single Convolution Layer on MNIST Deployed

Overview Implementation **Test**



Enter input data  

```
{  
  "values":  
    [[[[ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0]]]]  
}
```

Predict

Single Convolution Layer on MNIST Deployed

Overview Implementation **Test**

Enter input data  

```
{  
  "values":  
    [[[[ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0],  
        [ 0]]]]  
}
```

Predict

6. Based on the confidence levels returned, we can see that the number 8 would be selected as the best fit for this sample image.

Single Convolution Layer on MNIST Deployed

Overview

Implementation

Test

Enter input data



```
{
  "values": [
    [[[[ 0],
      [ 0],
      [ 0],
      [ 0],
      [ 0],
      [ 0],
      [ 0]]]]
  ]
}
```

Predict

```
{
  "fields": [
    "prediction"
  ],
  "values": [
    [
      1.3815683352121771e-15,
      2.1411425399327925e-18,
      1.4536198037363307e-13,
      1.547869092014681e-13,
      3.484191859962678e-18,
      1.3316728982702908e-19,
      3.832952076167682e-23,
      1,
      1.7163898882906203e-13,
      4.053319832553193e-11
    ]
  ]
}
```