If you haven’t already, please pull the image:
docker pull cmusei/juneberry:vignette1

Juneberry - Tutorial

Naval Applications of Machine Learning 2022

MARCH 22, 2022

Andrew Mellinger
Nick Winski
Nathan VanHoudnos (van-HOD-ness)
docker pull cmusei/juneberry:vignette1

Copyright 2022 Carnegie Mellon University.

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

NO WARRANTY. THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN "AS-IS" BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

[DISTRIBUTION STATEMENT A] This material has been approved for public release and unlimited distribution. Please see Copyright notice for non-US Government use and distribution.

This material may be reproduced in its entirety, without modification, and freely distributed in written or electronic form without requesting formal permission. Permission is required for any other use. Requests for permission should be directed to the Software Engineering Institute at permission@sei.cmu.edu.


DM22-0250
Juneberry reproduces results

**Reproducibility** helps ML research and evaluation teams to:
- build ML capability,
- maintain capability, and
- evaluate existing ML.

No other framework directly addresses reproducibility:
- write less boilerplate code (PyTorch Lightning; TensorFlow)
- optimize hyper-parameters (Weights and Biases; Grid.AI)
- label and manage data (Labelstud.io)
- et cetera

Juneberry is a reproducible research framework to build, maintain, and evaluate ML with declarative configs.

Managing code is hard.
Managing configs is easier.

docker pull cmusei/juneberry:vignette1
By the end of this tutorial you will be able to ...

reproduce the CIFAR 10 results* from the original ResNet paper (He et al., 2015):

1. Get CIFAR-10 (torchvision/cifar10.json)
2. Implement the “original” 6N + 2 ResNet (resnet_simple.py)
3. Write a Juneberry wrapper class (resnet_simple.ResNet32x32)
4. Write a Juneberry model training config (models/cifar_R20)
5. Train the model (jb_train_cifar_R20)
6. Write an experiment to vary layers (experiments/cifar_layer)
7. Run the experiment to replicate the paper (jb_run_experiment_cifar_layer)

*ish: 2 epochs of training, fewer layers, and CPU only. For full replication with GPUs, see “Replicating a Classic Machine Learning Result with Juneberry” on our GitHub.
Juneberry Overview
Juneberry

https://github.com/cmu-sei/Juneberry

Juneberry is an open source Python tool that improves the experience of machine learning experimentation by providing a framework for automating the training, evaluation and comparison of multiple models against multiple datasets, reducing errors and improving reproducibility.

Juneberry is focused on *experiments* such as:

- Example 1: Compare the interaction of model architecture vs training data vs hyper parameters.
- Example 2: Compare the impact of various defensive strategies (robust models) against a variety of adversarial attacks.

Key features:

- **declarative** – Experiment, model and dataset configuration are done via json isolating the science from execution details
- **portable and extensible** – Juneberry is designed to rest on top of a wide variety of backends and tools supporting the latest in machine learning research, in particular adversarial machine learning
- **determinism and reproducibility** – By capturing all the configuration Juneberry strives for maximum reproducibility, experiment maintainability and *user scalability*
- **interoperability** – Juneberry experiments are designed to be invoked by scalable workflow and pipeline systems
Juneberry – What it isn’t...

- A math or statistics package like numpy or pandas
- A machine learning package like pytorch, tensorflow, or scikit-learn
- An object detection package like torchvision, detectron2, or mmdetection
- An adversarial machine learning toolkit like ART
- An interactive platform like Jupyter notebooks
- A workflow engine like doit, snakemake or airflow
- A python environment

Instead it uses, extends and supports all these together to ease the burden of managing and executing experiments.
Juneberry – Trainer and Evaluator

Introduction

Trainer
- Model config (json)
- Model code (python)
- Training data config (json)
- Training data
- Trained model (binary)
- Metrics (json)
- Metrics chart (png)
- Logs (text)

Evaluator
- Trained model (binary)
- Evaluation data config (json)
- Evaluation data
- Predictions (json)
- Metrics (json)
- Metrics chart (png)
- Logs

Viz
- Predictions
- Plots (png)
- Summaries (csv)
- Reports (md)

docker pull cmusei/juneberry:vignette1

TensorFlow
PyTorch
Detectron2
MMDetection
ONNX
Sample Experiment Context

Introduction

Model config A

Trainer

Model A

Evaluator

Eval Data 1

Predictions A1

Viz

Plots (png)

Metrics (csv)

Reports (md)

Pretrained Model

docker pull cmusei/juneberry:vignettel
Introduction

File Organization

```
docker pull cmusei/juneberry:vignette1
```
The Vignette Container
Obtaining the Container Image

Configuring Docker on your host OS is outside the scope of this presentation.

A Docker image built specifically for this vignette is available on Docker Hub.

Retrieve the image using the following command:

docker pull cmusei/juneberry:vignette1
Running a Shell Inside the Container

After obtaining the vignette image, the goal is to establish an interactive shell inside the container.

We also need to establish a shared directory between the host filesystem and the container.
- This will allow you to view files generated inside the container on your host OS.

The command to run a shell inside the container:

```
docker run -it -rm -v "directory on host":/shared cmusei/juneberry:vignette1 bash
```

Replace “directory on host” with the path to a directory on your host OS.
- Shared files will appear in this directory on your host OS.
Assembling Components for a Single Model
The Dataset Config

We'll be working with the CIFAR-10 dataset.
• Relatively small, commonly used

The CIFAR-10 data files (via torchvision) can be found inside /dataroot in the vignette-specific Docker container.

The goal is to create a “dataset config” that tells Juneberry how to use this data.
“Creating” the Dataset Config

Create a sub-directory for torchvision related dataset configs:

```bash
mkdir /juneberry/data_sets/torchvision
```

Copy the pre-built dataset config into the new directory:

```bash
cp /juneberry/docs/vignettes/vignette1/configs/cifar10.json /juneberry/data_sets/torchvision/cifar10.json
```

(Optional) Examine the contents of the dataset config:

```bash
cat /juneberry/data_sets/torchvision/cifar10.json
```
Assembling Components for a Single Model

The Model Architecture

Code that defines the layers of the Neural Network

Copy the pre-built architecture into the target directory:

cp /juneberry/docs/vignettes/vignette1/configs/resnet_simple.py /juneberry/juneberry/architectures/pytorch/resnet_simple.py

(Optional) Examine the contents of the architecture file:

cat /juneberry/juneberry/architectures/pytorch/resnet_simple.py | more

There’s a constraint on the number of layers in the ResNet.

• Number of layers must be \((6n + 2)\), where \(n\) is some integer (1, 2, 3, ...)
The Model Config

A model config defines various parameters of the model:
- Model architecture; training dataset
- Various training parameters
  - Learning rate
  - Optimizers
  - Validation split

Create a unique model directory for the model config:

```bash
mkdir /juneberry/models/cifar_R20
```
Assembling Components for a Single Model

"Creating" the Model Config

Copy the pre-built model config into the target directory:

```
cp /juneberry/docs/vignettes/vignette1/configs/config.json /juneberry/models/cifar_R20/config.json
```

Modify the contents of the pre-built config:

- Full training may take 4+ hrs; this is a 45 minute session
- Reduce training epochs for faster training (but worse model performance)

Open `cifar_R20/config.json`, change epochs to 2, save + close

```
vim /juneberry/models/cifar_R20/config.json
```
(nano and emacs are also available in the container)

Change (Line 4)

```
"epochs": 182, -> "epochs": 2,
```
Running Commands on a Single Model
The training command needs the name of a model inside the “models” directory.

```
jb_train cifar_R20
```

Once training finishes, examine the new files in the model directory:

```
ls /juneberry/models/cifar_R20
ls /juneberry/models/cifar_R20/train
```
Once you have a trained model, you can evaluate it.

The evaluate command requires two components: the model name AND a dataset to evaluate

```
jb_evaluate cifar_R20 /juneberry/data_sets/torchvision/cifar10.json
```

Once the evaluation finishes, examine the new files in the model directory:

```
ls /juneberry/models/cifar_R20/eval
ls /juneberry/models/cifar_R20/eval/cifar10/
```

The predictions.json holds the raw data that will be useful for plotting.
ROC curves help visualize a model's performance.

The plot_roc command requires three components:

- A predictions file, the classes to plot, and the desired path for the output file

```
jb_plot_roc -f /juneberry/models/cifar_R20/eval/cifar10/predictions.json -p all /juneberry/models/cifar_R20/cifar10_roc.png
```

Move the output file to the shared directory and examine the image on your host OS.

```
cp /juneberry/models/cifar_R20/cifar10_roc.png /shared/
```
Designing an Experiment
The Experiment Outline

Experiments group models together for comparison.

Create a unique experiment directory for the experiment:

```bash
mkdir /juneberry/experiments/cifar_layer
```

Copy the pre-built experiment outline into the target directory:

```bash
cp /juneberry/docs/vignettes/vignette1/configs/experiment_outline.json /juneberry/experiments/cifar_layer/
```
Modify the Experiment Outline

We also need to modify the experiment outline so the models train faster.

Open the experiment outline for editing:

```bash
vim /juneberry/experiments/cifar_layer/experiment_outline.json
```

(nano and emacs are also available in the container)

An experiment outline can construct multiple model configs by substituting values for one (or more) variables into a baseline model config.

Remember the architecture’s layer constraint? \((6n + 2)\)

This will be the variable in our model config.

Change (line 24)

```
"vals": [ 20, 32, 44, 56 ] -> "vals": [ 8, 14, 20 ]
```
Running an Experiment
Running an Experiment

**jb_run_experiment**

The following command runs the experiment in commit mode:

```
jb_run_experiment cifar_layer -X
```

This experiment trains 3 models, evaluates each one, and then creates a report summarizing the results.

Output files will appear in two locations:

```
ls /juneberry/experiments/cifar_layer
ls /juneberry/models/cifar_layer
```
### Running an Experiment

**Experiment Results**

```
root@fdbf46cf5fe0+vignette1:/juneberry$ ls -ls /juneberry/experiments/cifar_layer/
total 44
 4 -rw-r--r-- 1 root root 586 Mar 17 15:51 'Experiment Summary.md'
 4 drwxr-xr-x 2 root root 4096 Mar 17 15:42 __pycache__
 4 -rw-r--r-- 1 root root 1229 Mar 17 15:42 config.json
 4 -rw-r--r-- 1 root root 717 Mar 17 15:42 experiment_outline.json
 4 -rw-r--r-- 1 root root 1219 Mar 17 15:42 log_experiment_creation.txt
 4 drwxr-xr-x 2 root root 4096 Mar 17 15:42 logs
 0 -rw-r--r-- 1 root root 5380 Mar 17 15:42 main_dodo.py
12 -rw-r--r-- 1 root root 10395 Mar 17 15:42 rules.json
root@fdbf46cf5fe0+vignette1:/juneberry$
root@fdbf46cf5fe0+vignette1:/juneberry$
root@fdbf46cf5fe0+vignette1:/juneberry$
cat /juneberry/experiments/cifar_layer/Experiment\ Summary.md
```

# Experiment Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>Duration (seconds)</th>
<th>Eval Dataset</th>
<th>Accuracy</th>
<th>Train Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>cifar_layer/layers_0</td>
<td>91.0</td>
<td>/juneberry/data_sets/torchvision/cifar10.json</td>
<td>50.00%</td>
<td><img src=".../models/cifar_layer/layers_0/train/output.png" alt="Training Chart" /></td>
</tr>
<tr>
<td>cifar_layer/layers_1</td>
<td>149.0</td>
<td>/juneberry/data_sets/torchvision/cifar10.json</td>
<td>60.87%</td>
<td><img src=".../models/cifar_layer/layers_1/train/output.png" alt="Training Chart" /></td>
</tr>
<tr>
<td>cifar_layer/layers_2</td>
<td>222.0</td>
<td>/juneberry/data_sets/torchvision/cifar10.json</td>
<td>47.16%</td>
<td><img src=".../models/cifar_layer/layers_2/train/output.png" alt="Training Chart" /></td>
</tr>
</tbody>
</table>
Running an Experiment

Experiment Results

```
root@fbdf46cf5fe0+viqnete1:juneberry$ ls -l /juneberry/models/
total 44
-dwrxr-x-- 4 root root 4096 Mar 18 12:37 cifar_R20
-dwrxr-x-- 5 root root 4096 Mar 17 15:42 cifar_layer
-dwrxr-x-- 2 root root 4096 Feb 16 17:09 imagenet_160x160_rgb_unit_test_pytf_resnet18
-dwrxr-x-- 2 root root 4096 Feb 16 17:09 imagenet_224x224_rgb_unit_test_tftf_resnet50
-dwrxr-x-- 5 root root 4096 Feb 9 13:37 model_tests
-dwrxr-x-- 3 root root 4096 Feb 9 13:37 onnx
-dwrxr-x-- 2 root root 4096 Feb 16 17:09 tabular_binary_sample
-dwrxr-x-- 2 root root 4096 Feb 16 17:09 tabular_multiclass_sample
-dwrxr-x-- 4 root root 4096 Feb 9 18:37 text_detect
-dwrxr-x-- 2 root root 4096 Feb 16 17:09 tf_mnist_simple
-dwrxr-x-- 2 root root 4096 Feb 16 17:09 torchvision_mnist_simple
root@fbdf46cf5fe0+viqnete1:juneberry$ root@fbdf46cf5fe0+viqnete1:juneberry$ ls -l /juneberry/models/cifar_layer/
total 12
-dwrxr-x-- 4 root root 4096 Mar 17 15:44 layers_0
-dwrxr-x-- 4 root root 4096 Mar 17 15:47 layers_1
-dwrxr-x-- 4 root root 4096 Mar 17 15:50 layers_2
root@fbdf46cf5fe0+viqnete1:juneberry$ root@fbdf46cf5fe0+viqnete1:juneberry$ root@fbdf46cf5fe0+viqnete1:juneberry$ ls -l /juneberry/models/cifar_layer/layers_0/
total 324
-rw-r----- 1 root root 3172 Mar 17 15:42 config.json
-dwrxr-x-- 3 root root 4096 Mar 17 15:50 eval
-rw-r----- 1 root root 31783 Mar 17 15:44 model.pt
-dwrxr-x-- 2 root root 4096 Mar 17 15:44 train
root@fbdf46cf5fe0+viqnete1:juneberry$ root@fbdf46cf5fe0+viqnete1:juneberry$ root@fbdf46cf5fe0+viqnete1:juneberry$ root@fbdf46cf5fe0+viqnete1:juneberry$ ls -l /juneberry/models/cifar_layer/layers_0/train/
total 60
-rw-r----- 1 root root 9384 Mar 17 15:44 log.txt
-rw-r----- 1 root root 1483 Mar 17 15:44 output.json
-rw-r----- 1 root root 41024 Mar 17 15:44 output.png
```
Questions and Feedback?

**AI ENGINEERING**

Juneberry

**AI FOR MISSION**

**DIGITAL TRANSFORMATION**

**CONTACT**
Andrew Mellinger
aomellinger@sei.cmu.edu

**GITHUB**
github.com/cmu-sei/Juneberry

**COME WORK WITH US**
sei.cmu.edu/careers/