Machine Learning Systems Design

Lecture 7: Versioning & experiment tracking

CS 329 | Chip Huyen

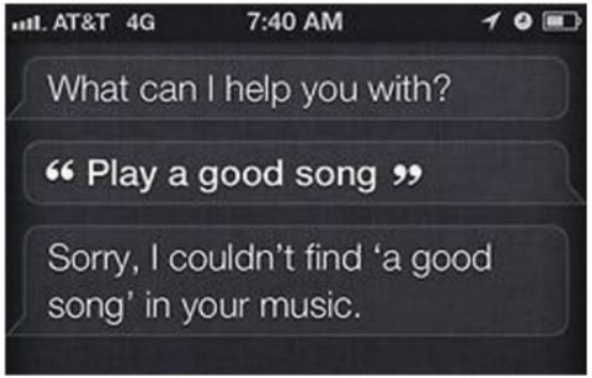
PSET collaboration policy

You can work in a group of 2 people, but

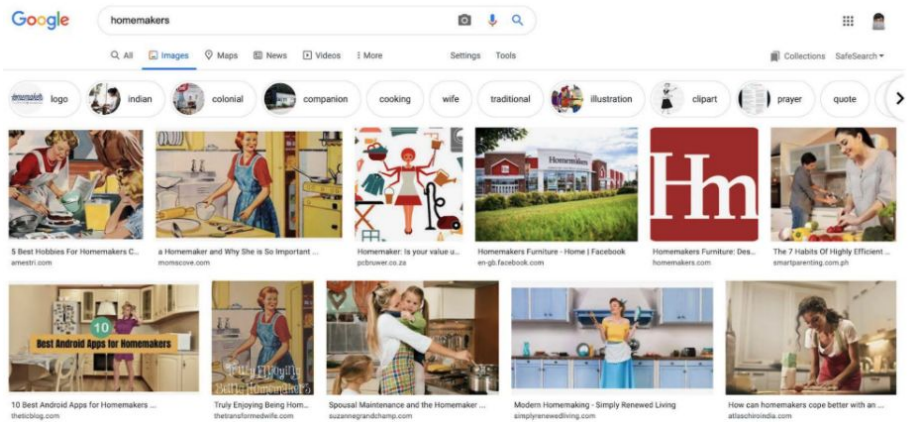
EACH MUST WRITE ANSWERS INDIVIDUALLY

PSET 1 highlights

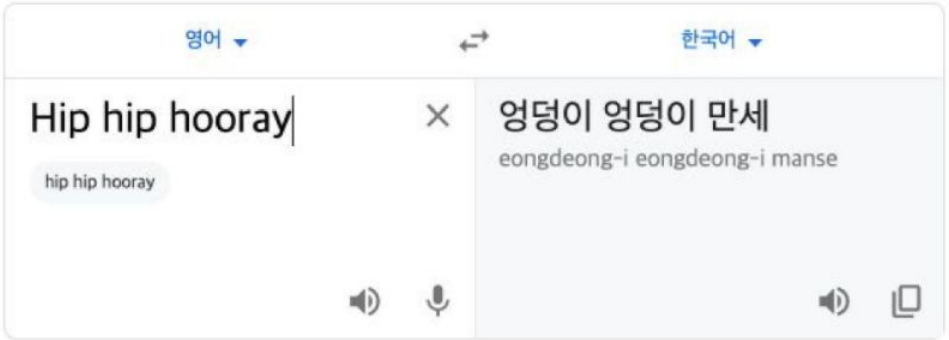
- Spam filter for search ≠ spam filter for emails
- Fraud detection for online transaction (interesting read)
  - False positives: immediate loss
  - False negatives: delayed loss



When Siri thinks your music is trash



Google Translate: The term / idiom “Hip hip hooray” is commonly used as a celebration / congratulation. However, its translated Korean counterpart “엉덩이 엉덩이 만세" literally means “Buttocks buttocks hooray”.



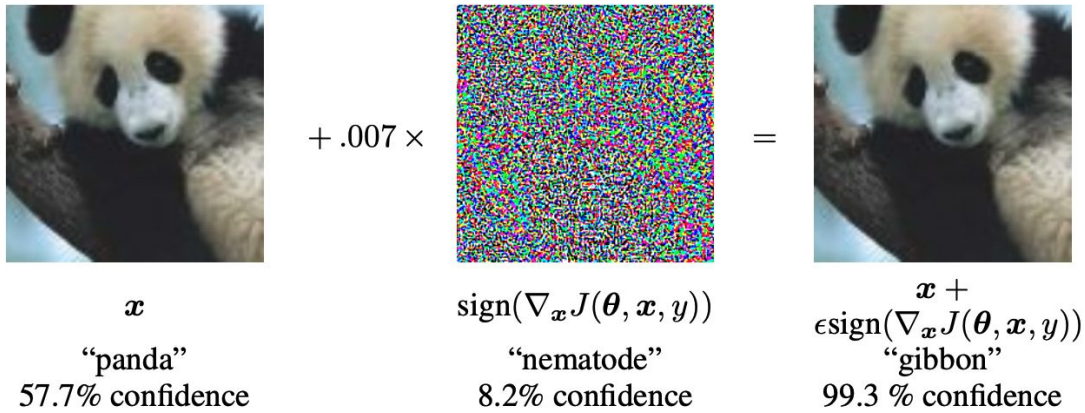
Perturbation evaluation

Perturbation evaluation

- Randomly add small noise to data to see how much outputs change
  - User inputs might contain noise
    - Speech recognition: background noise
    - Object detection: different lighting
    - Text inputs: typos, intentional changes (e.g. looooooooong)
  - Do small changes in inputs lead to big changes in outputs?

Perturbation evaluation

- Randomly add noise to data to see how much outputs change
- The more sensitive the model is to noise:
  - The harder it is to maintain
  - The more vulnerable the model is to adversarial attacks



EXPLAINING AND HARNESSING ADVERSARIAL EXAMPLES (Goodfellow et al., 2015)

Invariance tests

- Some input changes shouldn’t lead to changes in outputs
  - Changing race/gender info shouldn’t change predicted approval outcome
  - Changing name shouldn’t affect resume screening results

> The Berkeley study found that both face-to-face and online lenders rejected a total of 1.3 million creditworthy black and Latino applicants between 2008 and 2015. Researchers said they believe the applicants "would have been accepted had the applicant not been in these minority groups." That's because when they used the income and credit scores of the rejected applications but deleted the race identifiers, the mortgage application was accepted.

Disparity in home lending costs minorities millions, researchers find (CBS News, 2019)

Directional expectation tests

- Some changes to inputs should cause predictable changes in outputs
  - E.g. when predicting housing prices:
    - Increasing lot size shouldn’t decrease the predicted price
    - Decreasing square footage shouldn’t increase the predicted price

Ablation study

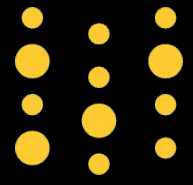
- Systematically removing parts of your model to see which ones are relevant to the model's performance
  - Features
  - Model components: e.g. regularizations

⚠️ Short-term results ≠ long-term results ⚠️

- Identical results short-term don’t mean identical results long-term
- Superior models now don’t mean superior models a week from now on

Agenda

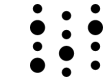
1. Weights & Biases tutorials
2. DVC tutorials



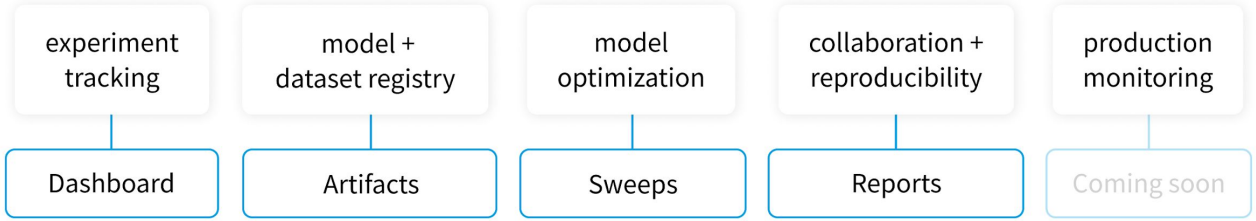
Weights & Biases

Developer tools for machine learning

ML Developer Tools for the entire ML workflow

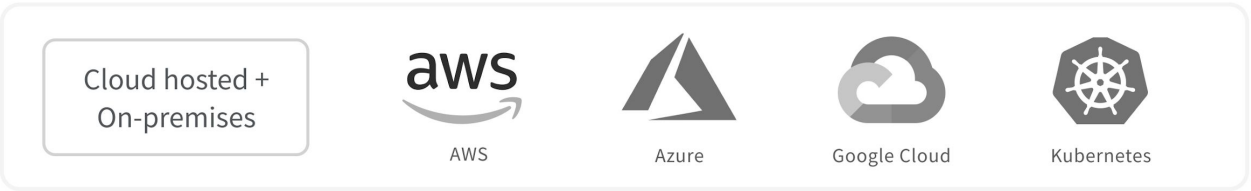


MODULAR TOOLS



FRAMEWORK AGNOSTIC

ENVIRONMENT AGNOSTIC



PROBLEM

Massive developer tools gap for ML

SOFTWARE 1.0 - WRITE CODE

Design	Version Code	Code & Collaborate	Deploy to Infra	CI/CD	Production Monitoring
Figma	GitHub	Jira	HashiCorp	circleci	PagerDuty
Sketch	GitLab	VS Code	puppet	Jenkins	DATADOG

SOFTWARE 2.0 - TRAIN MODELS

Prep & Visualize Data	Version Data & Models	Experiment Tracking	Manage Model Pipeline	Model CI/CD	Production monitoring
Custom apps Notebooks	Files in S3	Text files Screenshots	Text files	Custom scripts	Nothing

W&B Company

Chris Van Pelt
Co-Founder, CVP
Powerset, Figure Eight

Lukas Biewald
Co-Founder, CEO
Powerset, Figure Eight, OpenAI

Shawn Lewis
Co-Founder, CTO
Google

Customers

US Federal

Pacific Northwest National Laboratory

BERKELEY LAB
Lawrence Berkeley National Laboratory

Enterprise

OpenAI, lyft, Toyota Research Institute, GitHub, BlueCross BlueShield, NVIDIA, salesforce, SAMSUNG, Pfizer, pwc, Walmart, John Deere, Qualcomm, FUJIFILM SonoSite, GRAPHCORE, TELEDYNE CARIS, insitro, magic leap, illumina

Academia

Stanford, MIT, Berkeley University of California, Cornell University Founded A.D. 1865, NYU, UC San Diego, Carnegie Mellon University, Caltech

Investors

COATUE

Bloomberg BETA

Trinity VENTURES

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Nat Friedman
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CTO, OpenAI

Vladlen Koltun
Chief Scientist, Intel

Jeff Hammerbacher
Founder, Cloudera

Weights & Biases

1. Install the lightweight library
2. Track metrics and artifacts
3. Compare experiments fast
4. Optimize hyperparameters easily
5. Collaborate on reproducible models

Light integration

Try W&B in 5 minutes:

- Intro notebook
  bit.ly/intro-wb
- Quickstart docs
  docs.wandb.com

PYTORCH

```
import torch

model.train()
```

```
import torch
import wandb

wandb.watch(model)
model.train()
```

TENSORFLOW

```
import tensorflow as tf

classifier.train()
```

```
import tensorflow as tf
import wandb

wandb.init(sync_tensorboard=True)

classifier.train()
```

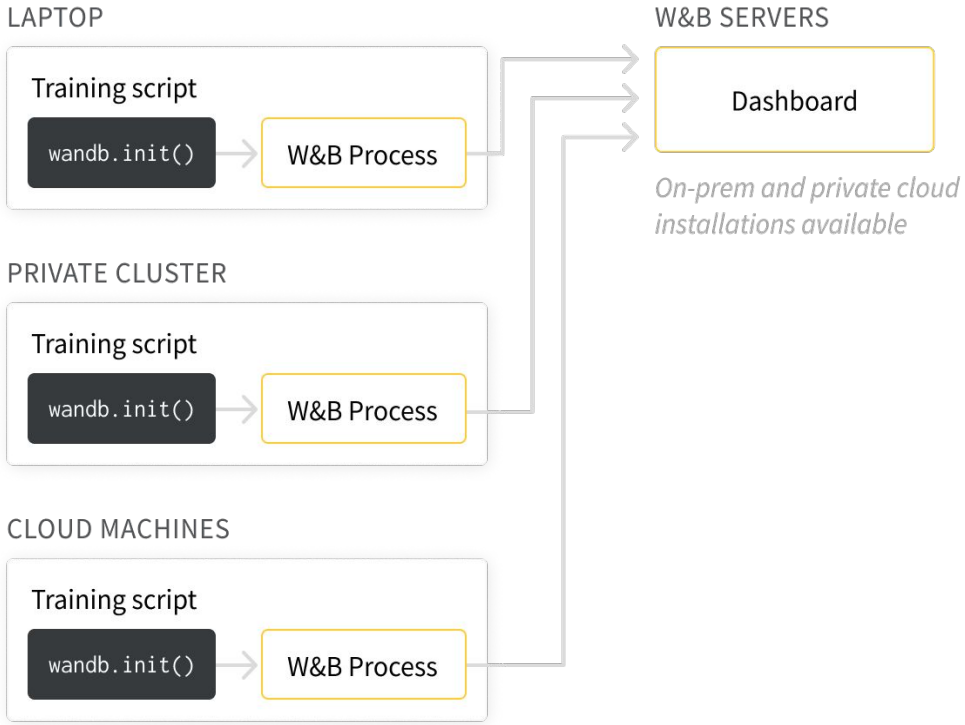
KERAS

```
from tensorflow import keras

model.fit(X, y)
```

```
from tensorflow import keras
import wandb

model.fit(X, y,
callbacks=[WandbCallback()])
```

Infra agnostic

Get started quickly with W&B in our hosted cloud, private cloud, or on-prem



Weights & Biases

1. Install the lightweight library
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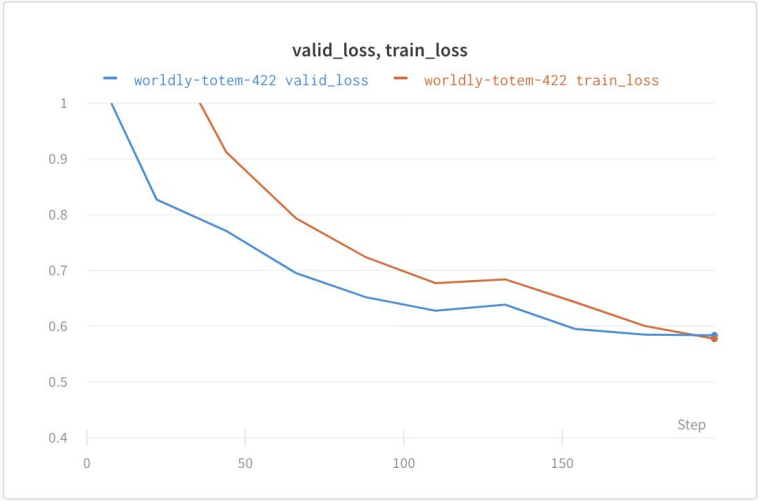
bit.ly/demo-run

Track experiments

See live updates on model performance, check for overfitting, and visualize how a model performs on different classes.



Track experiments – Before W&B

```
Layer (type)                 Output Shape              Param #     Connected to
==================================================================================================
conv2d_1_input (InputLayer)  (None, 299, 299, 3)  0
__________________________________________________________________________________________________
lambda_1 (Lambda)            (None, 299, 299, 3)  0           conv2d_1_input[0][0]
__________________________________________________________________________________________________
lambda_2 (Lambda)            (None, 299, 299, 3)  0           conv2d_1_input[0][0]
__________________________________________________________________________________________________
sequential_1 (Sequential)    (None, 10)            910922      lambda_1[0][0]
                                                               lambda_2[0][0]
__________________________________________________________________________________________________
activation_7 (Concatenate)   (None, 10)            0           sequential_1[1][0]
                                                               sequential_1[2][0]
==================================================================================================
Total params: 910,922
Trainable params: 910,922
Non-trainable params: 0
__________________________________________________________________________________________________
None
Found 49999 images belonging to 10 classes.
Found 8000 images belonging to 10 classes.
Epoch 1/50
39/39 [==============================] - 270s 7s/step - loss: 2.3153 - acc: 0.1178 - val_loss: 2.2428 - val_acc: 0.1589
Epoch 2/50
39/39 [==============================] - 263s 7s/step - loss: 2.2588 - acc: 0.1538 - val_loss: 2.1890 - val_acc: 0.2174
Epoch 3/50
39/39 [==============================] - 262s 7s/step - loss: 2.2060 - acc: 0.1827 - val_loss: 2.1767 - val_acc: 0.2096
Epoch 4/50
39/39 [==============================] - 263s 7s/step - loss: 2.1640 - acc: 0.2107 - val_loss: 2.1133 - val_acc: 0.2357
Epoch 5/50
39/39 [==============================] - 261s 7s/step - loss: 2.0827 - acc: 0.2432 - val_loss: 2.1499 - val_acc: 0.2344
Epoch 6/50
39/39 [==============================] - 262s 7s/step - loss: 2.0810 - acc: 0.2508 - val_loss: 2.0289 - val_acc: 0.2604
Epoch 7/50
39/39 [==============================] - 262s 7s/step - loss: 2.0575 - acc: 0.2602 - val_loss: 1.9912 - val_acc: 0.2865
Epoch 8/50
39/39 [==============================] - 261s 7s/step - loss: 2.0355 - acc: 0.2734 - val_loss: 2.0319 - val_acc: 0.2409
Epoch 9/50
39/39 [==============================] - 263s 7s/step - loss: 2.0254 - acc: 0.2829 - val_loss: 1.9364 - val_acc: 0.3307
Epoch 10/50
39/39 [==============================] - 262s 7s/step - loss: 2.0056 - acc: 0.2804 - val_loss: 1.9934 - val_acc: 0.2773
Epoch 11/50
39/39 [==============================] - 256s 7s/step - loss: 1.9678 - acc: 0.3048 - val_loss: 1.9048 - val_acc: 0.3352
Epoch 12/50
39/39 [==============================] - 260s 7s/step - loss: 1.9634 - acc: 0.3109 - val_loss: 1.8758 - val_acc: 0.3568
```

Table 3: Detection results on **PASCAL VOC 2007 test set**. The detector is Fast R-CNN and VGG-16. Training data: "07": VOC 2007 trainval, "07+12": union set of VOC 2007 trainval and VOC 2012 trainval. For RPN, the train-time proposals for Fast R-CNN are 2000. †: this number was reported in [2]; using the repository provided by this paper, this result is higher (68.1).

method	# proposals	data	mAP (%)
SS	2000	07	66.9†
SS	2000	07+12	70.0
RPN+VGG, unshared	300	07	68.5
RPN+VGG, shared	300	07	69.9
RPN+VGG, shared	300	07+12	**73.2**
RPN+VGG, shared	300	COCO+07+12	**78.8**

Table 4: Detection results on **PASCAL VOC 2012 test set**. The detector is Fast R-CNN and VGG-16. Training data: "07": VOC 2007 trainval, "07++12": union set of VOC 2007 trainval+test and VOC 2012 trainval. For RPN, the train-time proposals for Fast R-CNN are 2000. †: http://host.robots.ox.ac.uk:8080/anonymous/HZJTQA.html. ‡: http://host.robots.ox.ac.uk:8080/anonymous/YNPLXB.html. §: http://host.robots.ox.ac.uk:8080/anonymous/XEDH10.html.

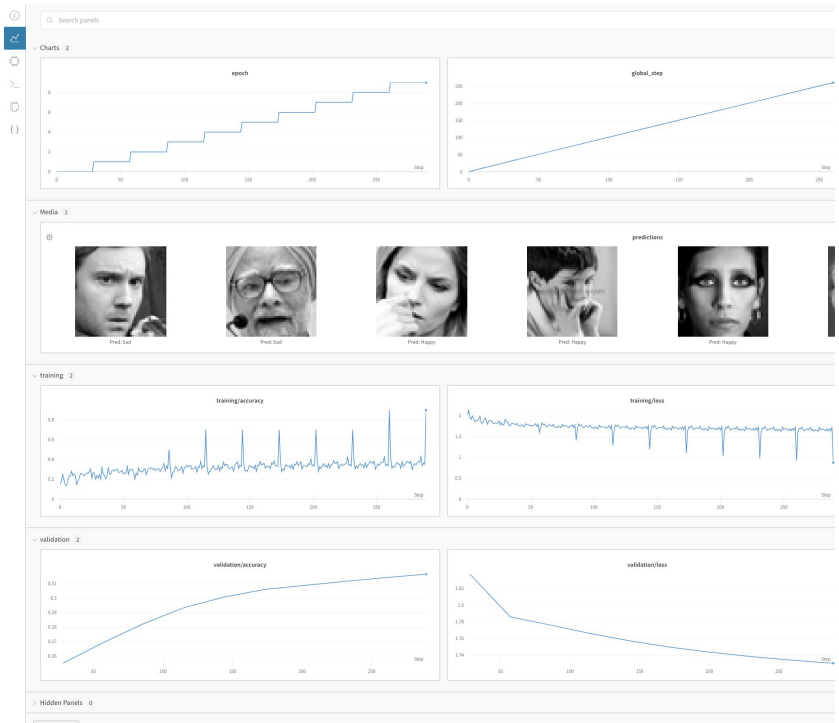
method	# proposals	data	mAP (%)
SS	2000	12	65.7
SS	2000	07++12	68.4
RPN+VGG, shared†	300	12	67.0
RPN+VGG, shared‡	300	07++12	**70.4**
RPN+VGG, shared§	300	COCO+07++12	**75.9**

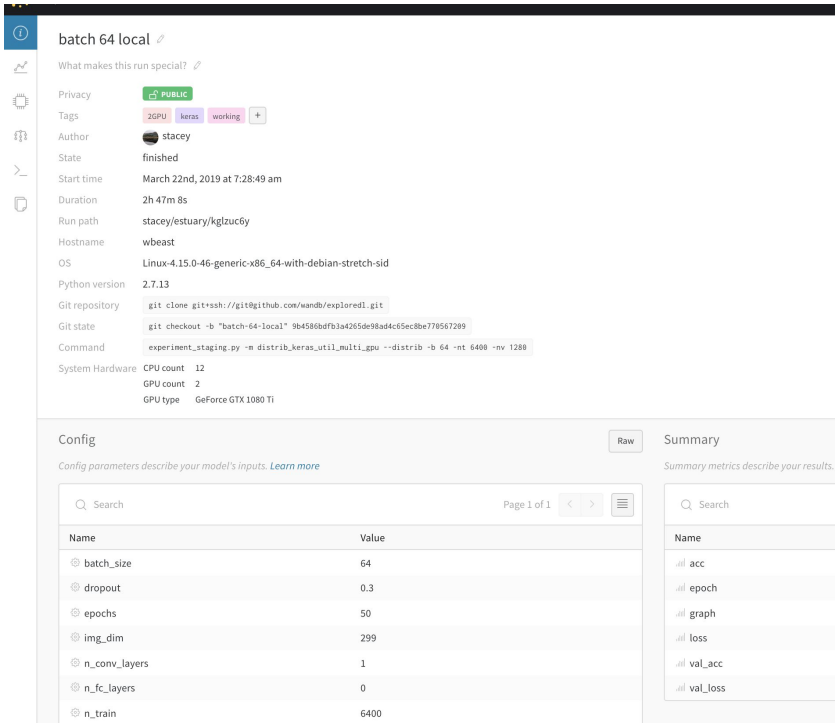
Table 5: **Timing** (ms) on a K40 GPU, except SS proposal is evaluated in a CPU. "Region-wise" includes NMS, pooling, fully-connected, and softmax layers. See our released code for the profiling of running time.

model	system	conv	proposal	region-wise	total	rate
VGG	SS + Fast R-CNN	146	1510	174	1830	0.5 fps
VGG	RPN + Fast R-CNN	141	**10**	47	**198**	**5 fps**
ZF	RPN + Fast R-CNN	31	**3**	25	**59**	**17 fps**

	backbone	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L
Two-stage methods							
Faster R-CNN+++ [5]	ResNet-101-C4	34.9	55.7	37.4	15.6	38.7	50.9
Faster R-CNN w FPN [8]	ResNet-101-FPN	36.2	59.1	39.0	18.2	39.0	48.2
Faster R-CNN by G-RMI [6]	Inception-ResNet-v2 [21]	34.7	55.5	36.7	13.5	38.1	52.0
Faster R-CNN w TDM [20]	Inception-ResNet-v2-TDM	36.8	57.7	39.2	16.2	39.8	**52.1**
One-stage methods							
YOLOv2 [15]	DarkNet-19 [15]	21.6	44.0	19.2	5.0	22.4	35.5
SSD513 [11, 3]	ResNet-101-SSD	31.2	50.4	33.3	10.2	34.5	49.8
DSSD513 [3]	ResNet-101-DSSD	33.2	53.3	35.2	13.0	35.4	51.1
RetinaNet [9]	ResNet-101-FPN	39.1	59.1	42.3	21.8	42.7	50.2
RetinaNet [9]	ResNeXt-101-FPN	**40.8**	**61.1**	**44.1**	**24.1**	**44.2**	51.2
YOLOv3 608 × 608	Darknet-53	33.0	57.9	34.4	18.3	35.4	41.9

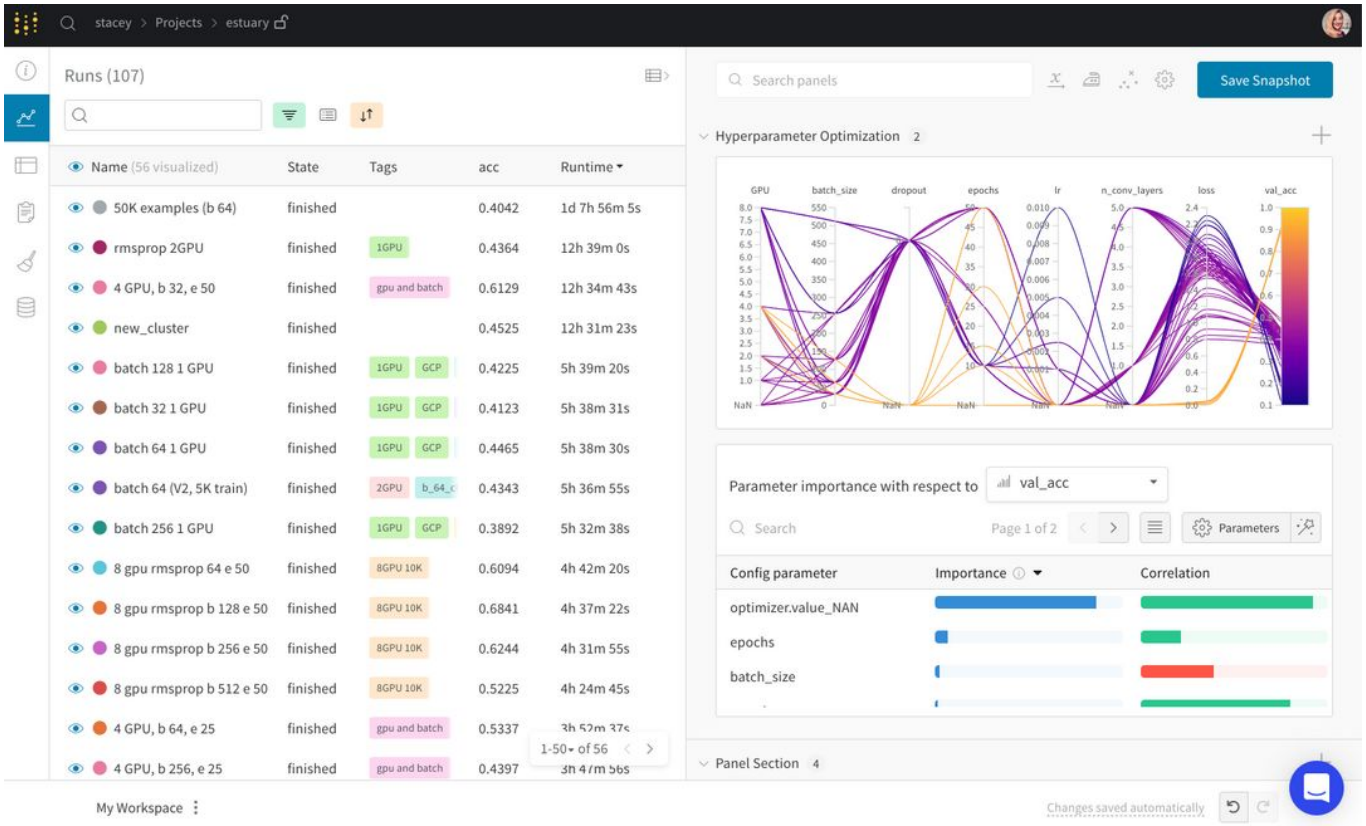
Track experiments – After W&B





[Live Dashboard]

Track experiments – After W&B

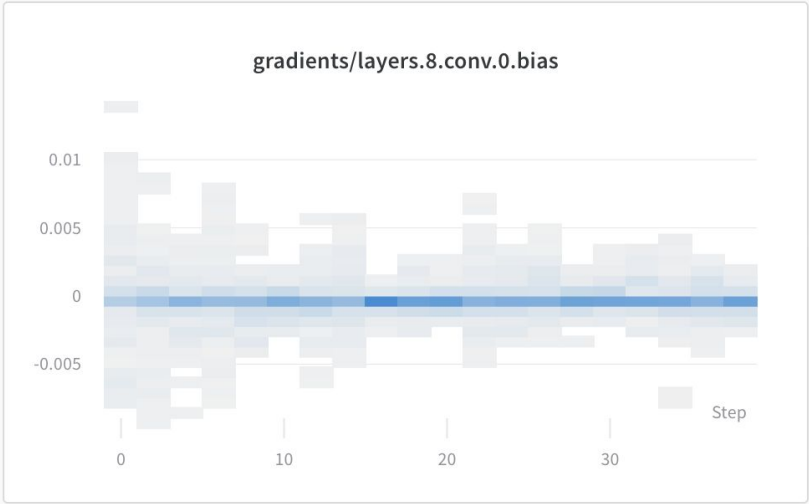


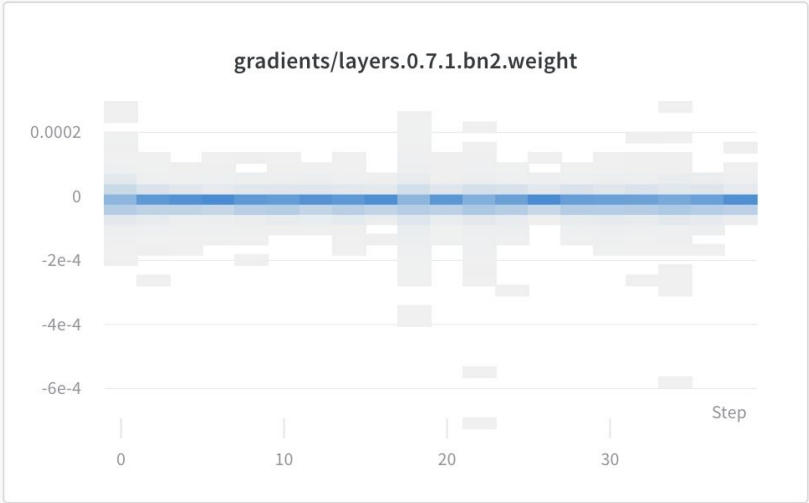
[Live Dashboard]

bit.ly/demo-run

Visualize gradients

See the inner workings of your model, look for convergence during training, and check for exploding gradients.

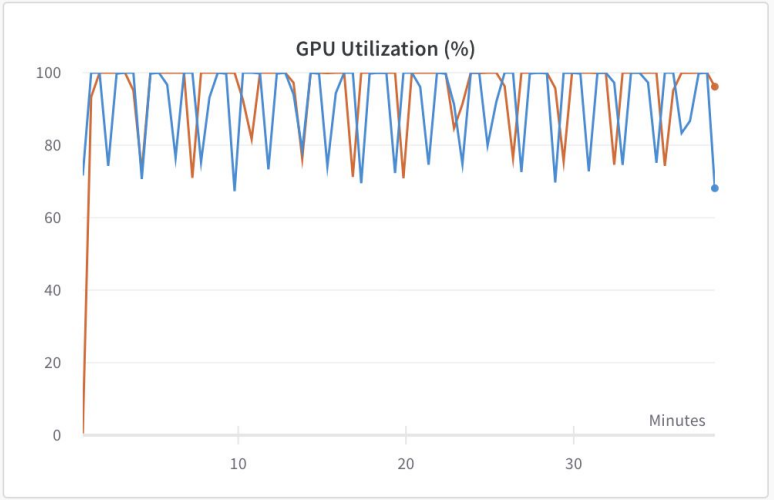


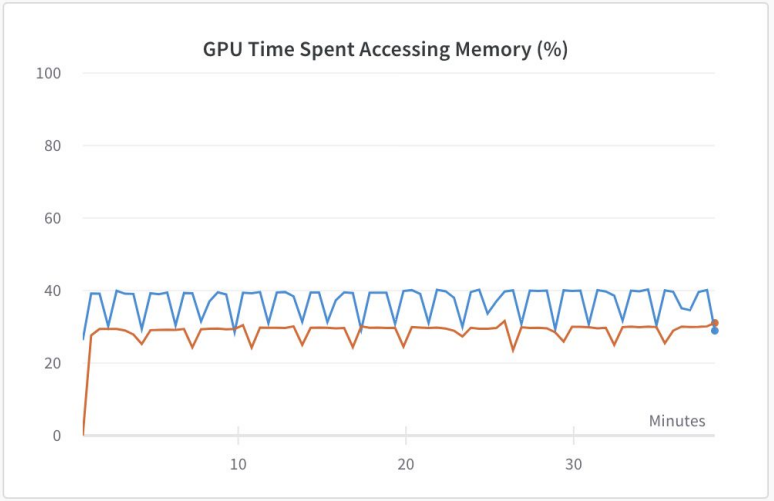


bit.ly/demo-run

System metrics

Get the most out of your GPUs and identify opportunities for optimizing hardware utilization.



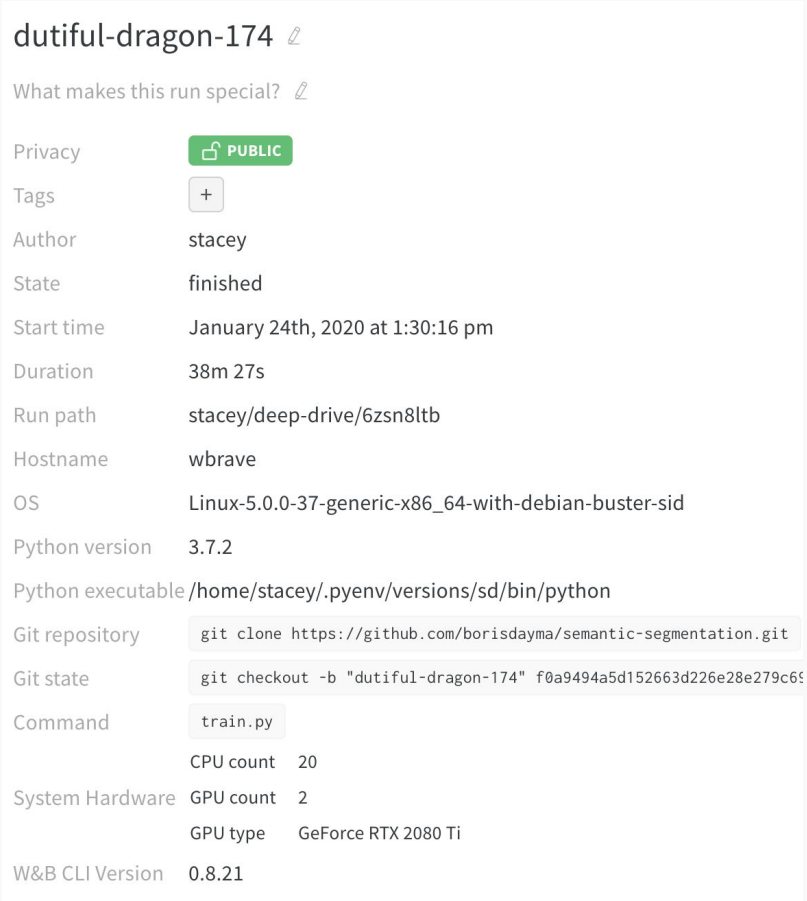


bit.ly/demo-run

Capture the code

Save the most recent git commit, the command and args, and system hardware setup.

W&B also saves a patch file with uncommitted changes so you can reproduce the exact code that trained the model.



dataset /
pedestrians-at-night

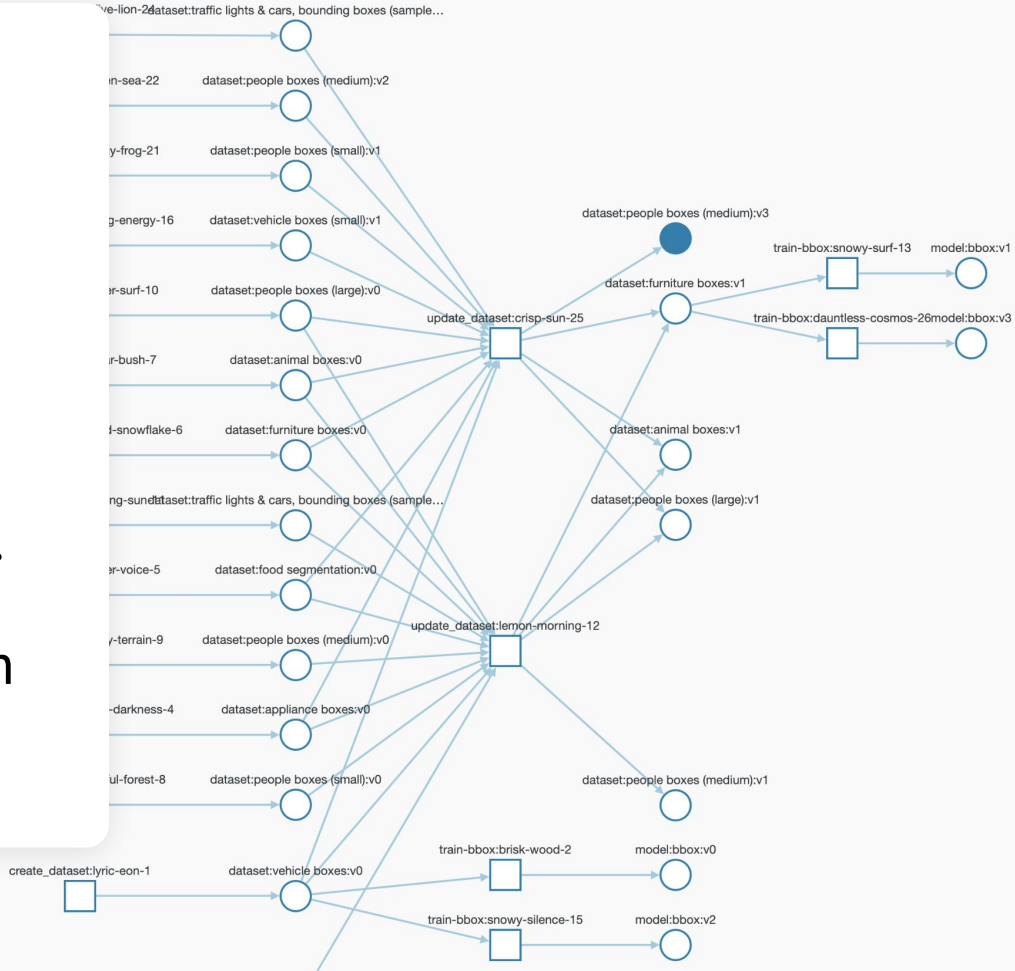
Overview API Metadata Files Graph view

Track artifacts

Get a bird's eye view of every step of model development.

Automatically checksum and version datasets and models.

Host your files anywhere with our infra-agnostic tracking.



INSTALL • TRACK • COMPARE • OPTIMIZE • COLLABORATE

Weights & Biases

1. Install the lightweight library
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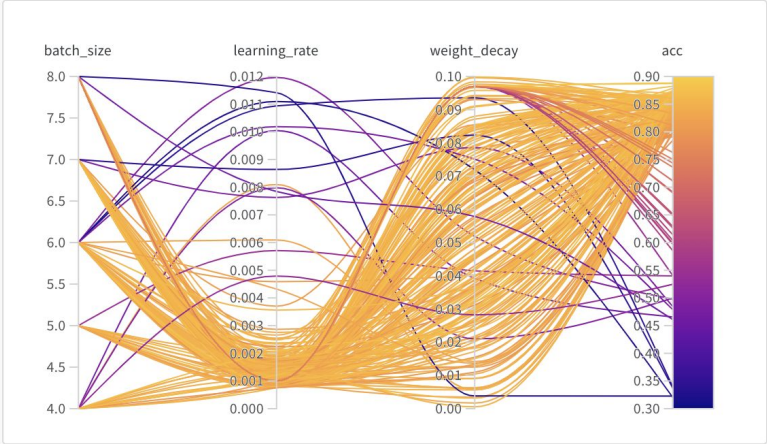
bit.ly/deep-drive

Iterate quickly

Use the interactive dashboard to spot issues in real time.

Stop underperforming runs early to optimize resource utilization.

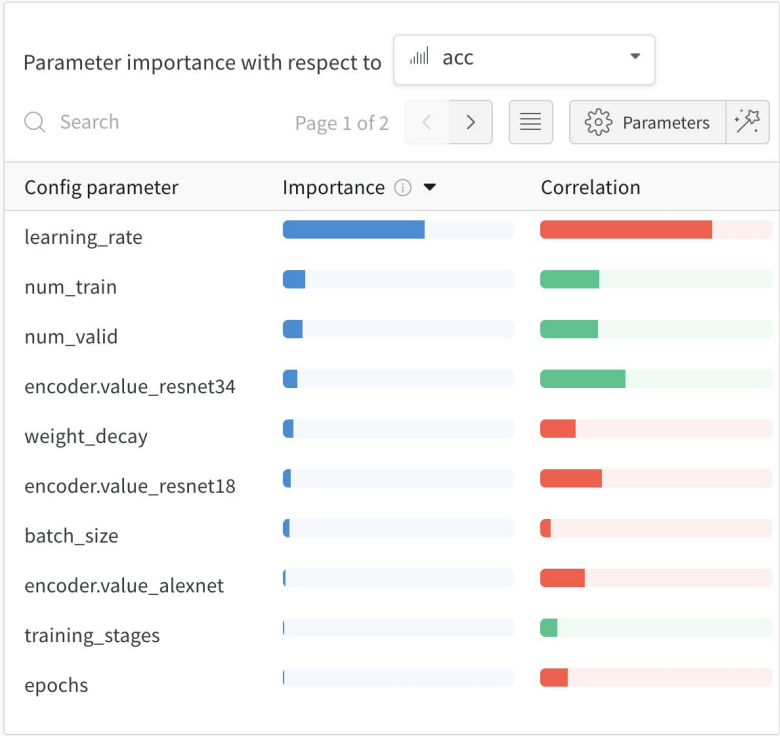


bit.ly/deep-drive

Compare runs

Visualize the relationships between hyperparameters and model metrics.

Explore the space of possible models quickly, without getting bogged down setting up manual visualizations.



bit.ly/deep-drive

Persistent system of record

Query and filter across thousands of runs, and easily keep projects organized.

Runs (395)

3 Filters | Group | Sort | Tag | Move | Columns

Name (228 visualized)	Tags	Runtime	batch_size	encoder	learning_ra	num_train	num_valid	weight_dec	iou	train_loss	valid_loss	acc	traffic_acc	road
best car acc (50% data)	seg_masks	47m 52s	6	resnet34	0.001311	3524	492	0.08173	0.7997	0.5375	0.4427	0.8823	0.8664	0.93
best traffic acc (50% data))	seg_masks	46m 42s	8	resnet18	0.001	3523	492	0.097	0.8073	0.4919	0.4203	0.888	0.8718	0.94
best human iou (50% data)	seg_masks	31m 34s	7	alexnet	0.0009084	1405	190	0.097	0.716	0.6222	0.6259	0.8334	0.8042	0.9
best overall IOU (20% data)	seg_masks	20m 23s	7	resnet34	0.001367	1376	205	0.06731	0.7948	0.5096	0.4659	0.8726	0.8593	0.93
vibrant-cherry-426		6m 12s	8	resnet34	0.001	347	42	0.097	0.752	0.7114	0.6055	0.8474	0.8282	0.95
worldly-totem-422		12m 54s	8	resnet34	0.001	682	97	0.097	0.7523	0.5774	0.5836	0.8566	0.8349	0.91
jumping-voice-421		11m 59s	8	resnet34	0.001	725	92	0.097	0.7449	0.5633	0.5334	0.8504	0.8296	0.91
logical-energy-420	test_only	2m 14s	8	resnet34	0.001	66	10	0.097	0.4297	1.459	1.221	0.626	0.5958	0.76

Weights & Biases

1. Install the lightweight library
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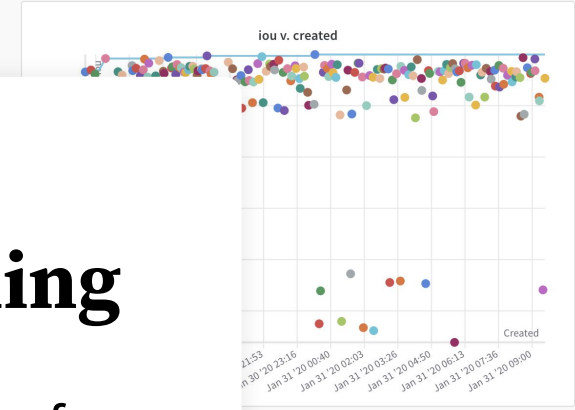
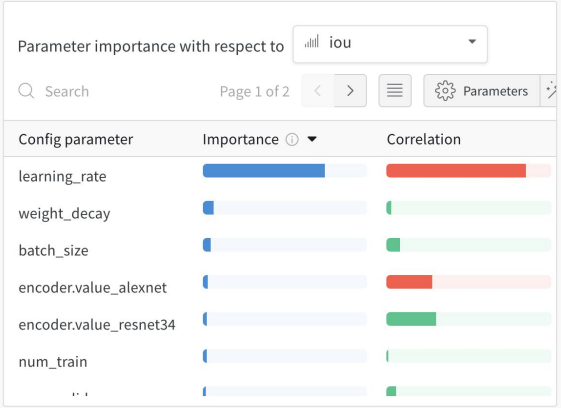
bit.ly/deep-drive-sweep

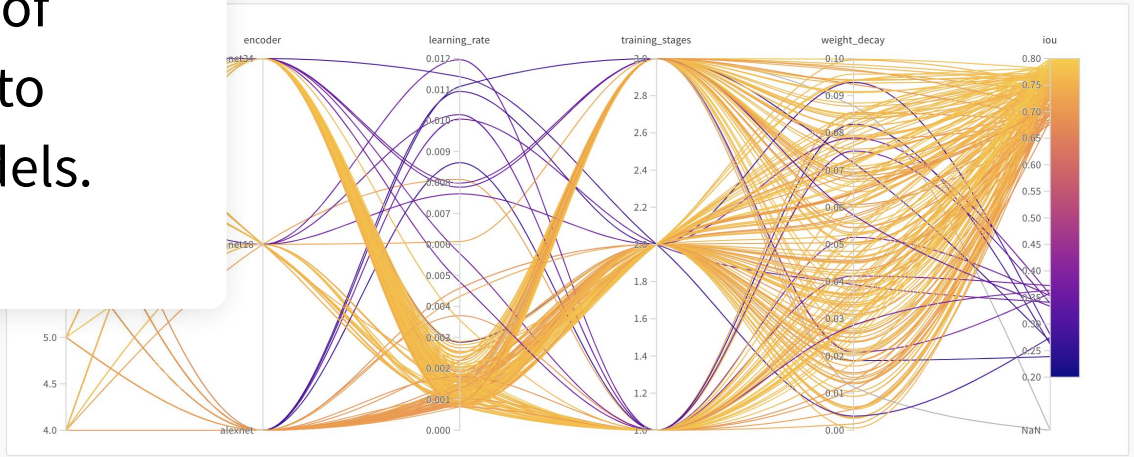
HYPERPARAMETER SWEEPS

Scale up training

Easily launch dozens of parallel experiments to quickly optimize models.





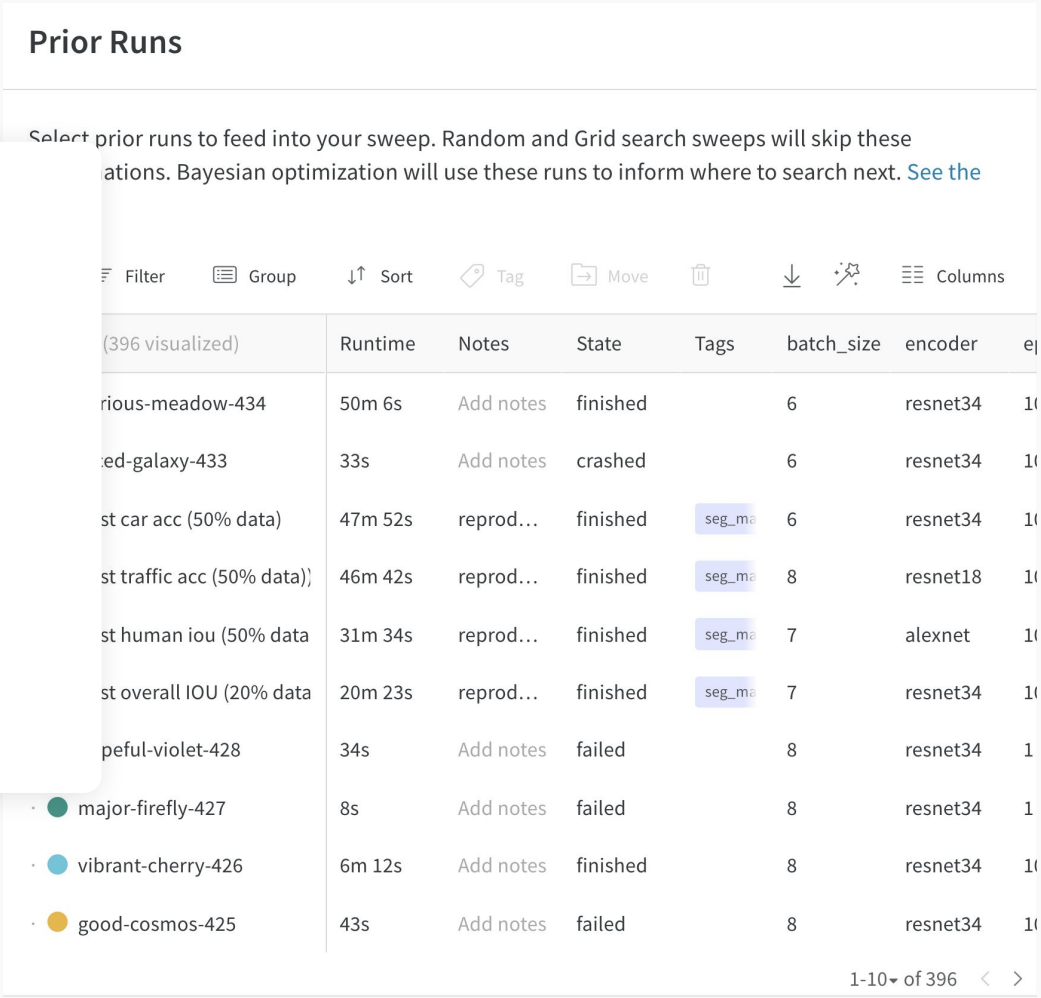


bit.ly/deep-drive-sweep

HYPERPARAMETER SWEEPS

Iterate + explore

Use manual experiments and previous sweeps to seed new searches.

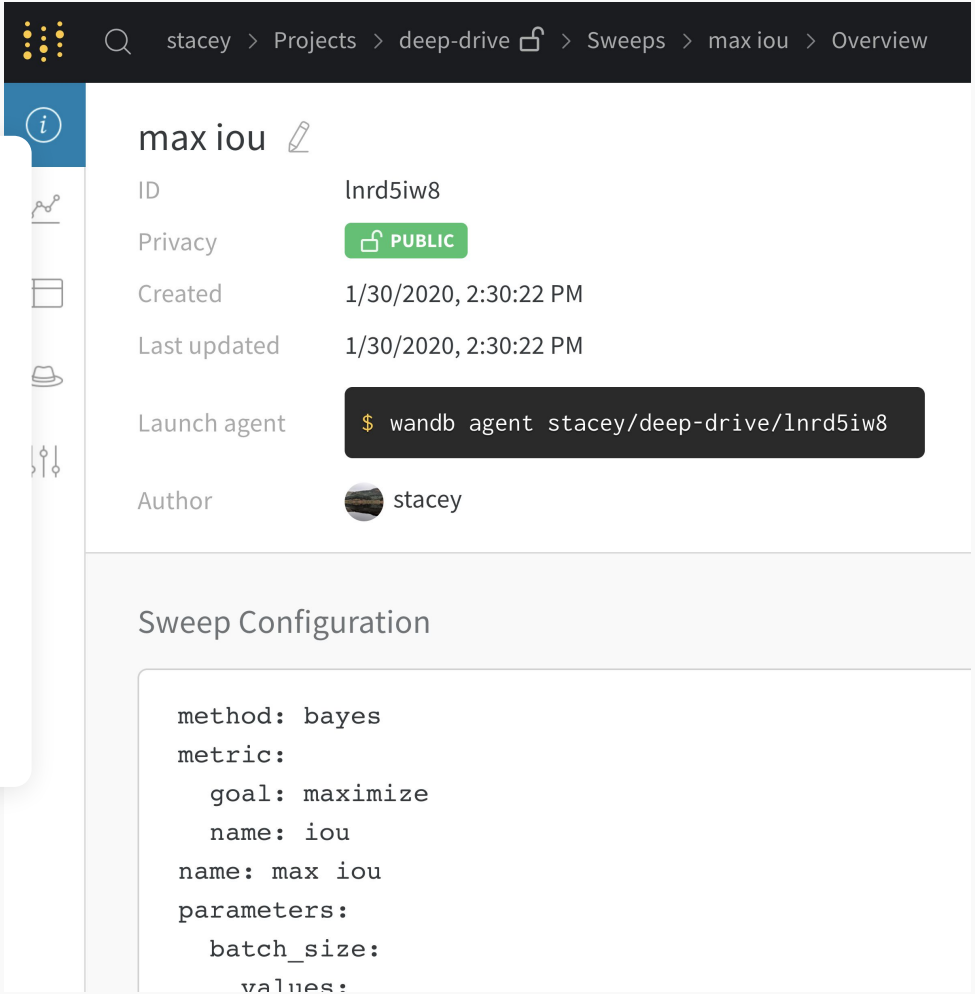


bit.ly/deep-drive-sweep Sweeps docs

HYPERPARAMETER SWEEPS

Fast setup

Use Bayesian sweeps and early stopping without writing custom code.



Weights & Biases

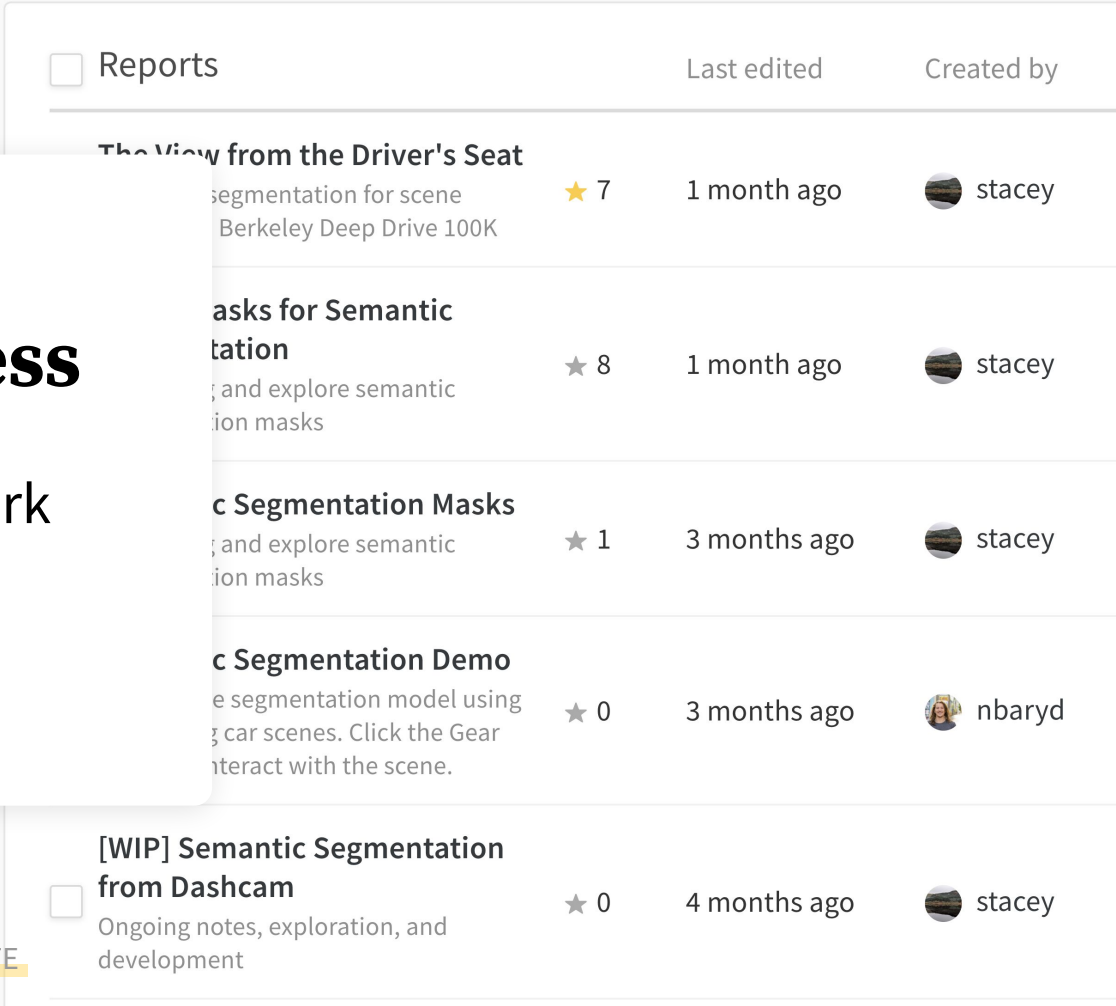
1. Install the lightweight library
2. Track metrics and artifacts
3. Compare experiments fast
4. Optimize hyperparameters easily
5. Collaborate on reproducible models

bit.ly/deep-drive-report

REPORTS

Annotate progress

Use reports to keep a work log and quickly pick up where you left off.



INSTALL • TRACK • COMPARE • OPTIMIZE • COLLABORATE

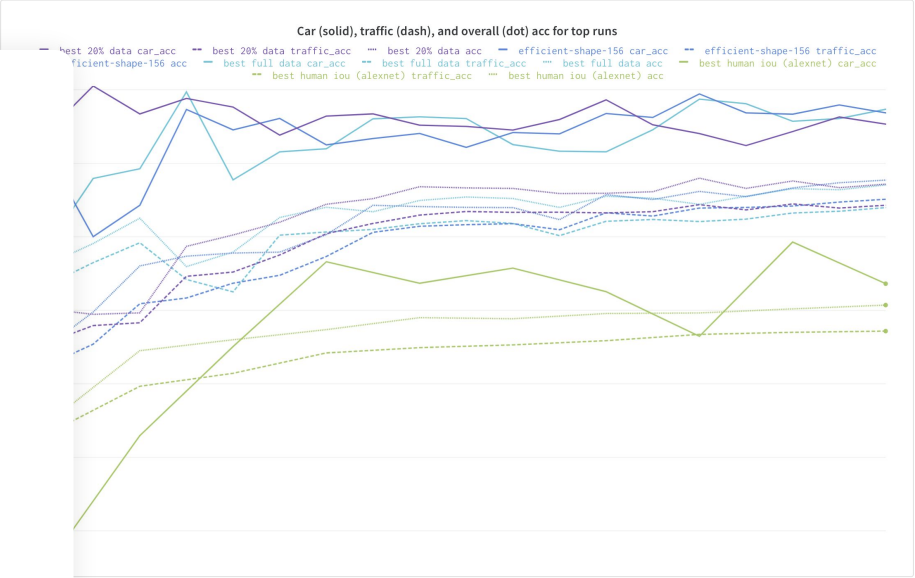
bit.ly/deep-drive-report

REPORTS

Live dashboards

Customize real-time views of model training and evaluation, and share auto-updating dashboards with your team to keep everyone in the loop.

Comparing per-class accuracies



top models 4

(isualized)	acc	car_acc	traffic_acc	train_loss	valid_loss	encoder	learning_ra	num_train	nur
est 20% data	0.8866	0.931	0.8724	0.4421	0.4284	resnet18	0.001	1421	183
efficient-shape-156	0.8863	0.9329	0.8739	0.4321	0.4394	resnet18	0.001	1409	200
best full data	0.8848	0.9356	0.8697	0.5218	0.4242	resnet18	0.001	7000	100
best human iou (alexnet)	0.8036	0.8181	0.7859	0.6373	0.708	alexnet	0.0009084	699	106

1-4 of 4

bit.ly/deep-drive-report

REPORTS

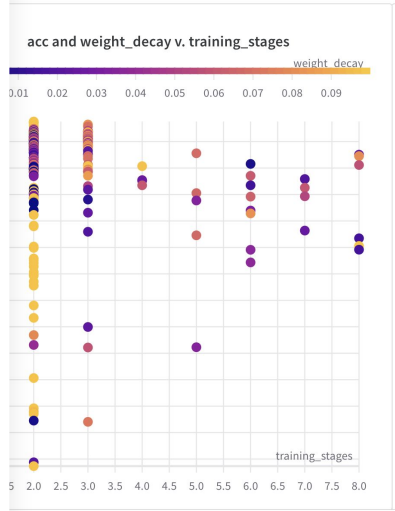
Collaborate easily

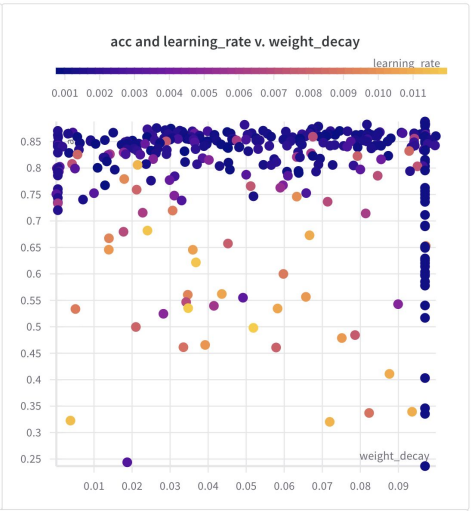
Give team members access to your exploratory results, sharing the context they need to quickly build on your work.

Weight decay: inconclusive

Initially increasing the weight decay 5X improved the accuracy by 9%. Increasing by 200X causes the same amount of improvement though.

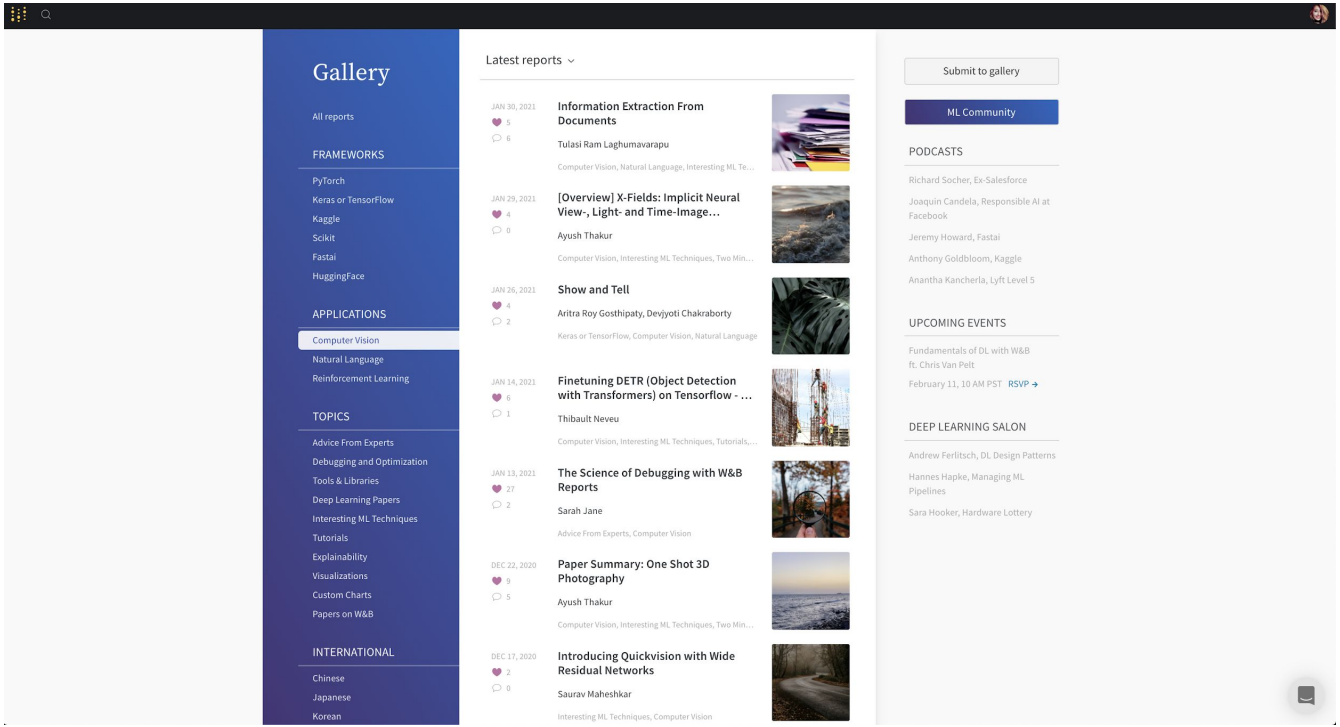
erparameter Sweep Insights



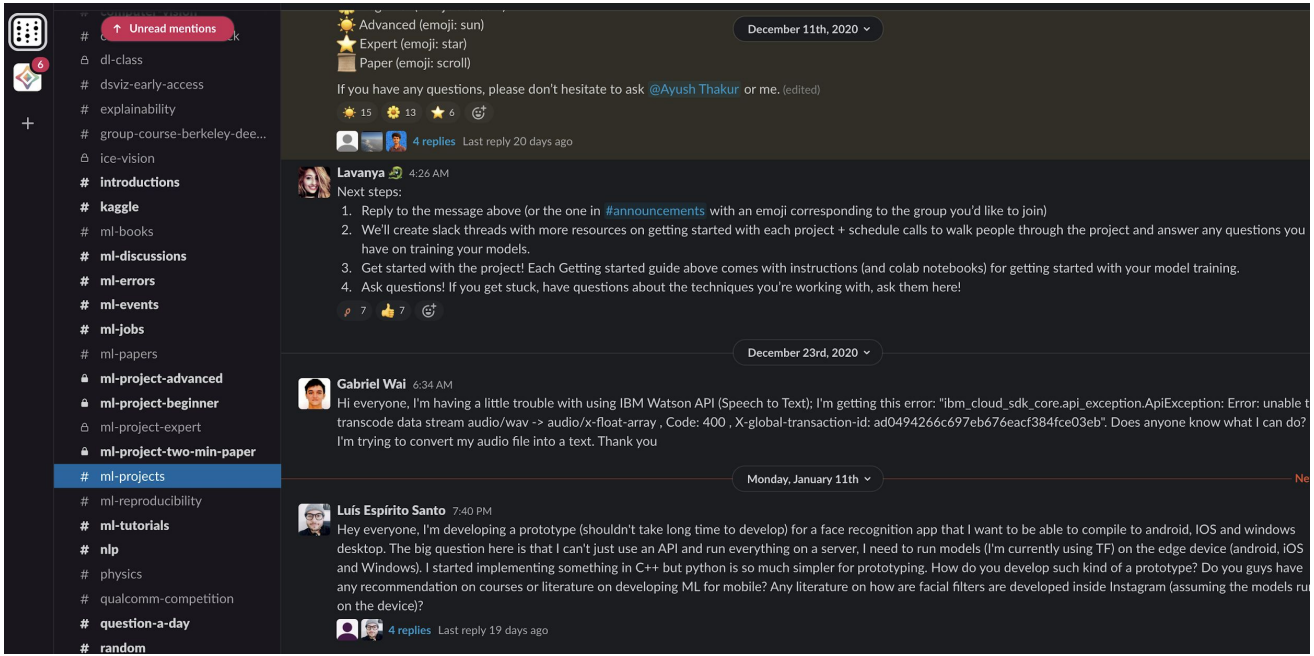


INSTALL • TRACK • COMPARE • OPTIMIZE • COLLABORATE

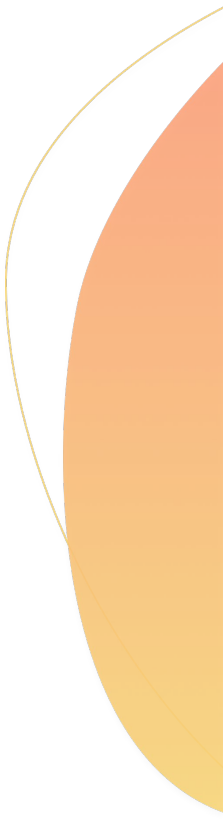
The Gallery


Gallery
All reports
FRAMEWORKS
PyTorch
Keras or TensorFlow
Kaggle
Scikit
Fastai
HuggingFace
APPLICATIONS
Computer Vision
Natural Language
Reinforcement Learning
TOPICS
Advice From Experts
Debugging and Optimization
Tools & Libraries
Deep Learning Papers
Interesting ML Techniques
Tutorials
Explainability
Visualizations
Custom Charts
Papers on W&B
INTERNATIONAL
Chinese
Japanese
Korean
Latest reports
JAN 30, 2021
Information Extraction From Documents
Tulasi Ram Laghumavarapu
JAN 29, 2021
[Overview] X-Fields: Implicit Neural View-, Light- and Time-Image…
Ayush Thakur
JAN 26, 2021
Show and Tell
Aritra Roy Gosthipaty, Devjyoti Chakraborty
JAN 14, 2021
Finetuning DETR (Object Detection with Transformers) on Tensorflow - …
Thibault Neveu
JAN 13, 2021
The Science of Debugging with W&B Reports
Sarah Jane
DEC 22, 2020
Paper Summary: One Shot 3D Photography
Ayush Thakur
DEC 17, 2020
Introducing Quickvision with Wide Residual Networks
Saurav Maheshkar
Submit to gallery
ML Community
PODCASTS
Richard Socher, Ex-Salesforce
Joaquin Candela, Responsible AI at Facebook
Jeremy Howard, Fastai
Anthony Goldbloom, Kaggle
Anantha Kancherla, Lyft Level 5
UPCOMING EVENTS
Fundamentals of DL with W&B ft. Chris Van Pelt
February 11, 10 AM PST RSVP →
DEEP LEARNING SALON
Andrew Ferlitsch, DL Design Patterns
Hannes Hapke, Managing ML Pipelines
Sara Hooker, Hardware Lottery

The Community: wandb.me/slack



Experiment Tracking In Practice



LatentSpace

the first fully AI-rendered 3D engine

- Reports
  - Communicate results internally
  - Build on top of each others work iteratively
  - As mini research papers, which then become a paper
- Debugging
  - Report

OpenAI

- Reports
  - Every experiment the OpenAI team tries starts as a Report
  - “The ability to mix real data from experiments with context and commentary on the results was the primary selling point for us”
  - From Google docs with screenshots to interactive reports.

- Workflow
  - Report
  - Create a new report with text at the top explaining the context, hypotheses under test, and experimental plan.
  - Launch one or more experiments aimed at testing the hypotheses.
  - Monitor the experiments. If enough data has been collected after the first set of experiments, add a conclusion to the top and share with the team. Otherwise, update the hypotheses and experimental plan and return to step 2.

Wadhwani

AI for Pest Monitoring – Intelligent autonomous spraying

- Model pipeline tracking
  - Blog Post
  - **Data versioning:**
    - As datasets continue to evolve over time, train/val/test splits cannot be static. Explicitly version data to take snapshots of samples used to train any given experiment.
  - **Experiment versioning:**
    - We store all our hyperparameters for each experiment in a config file along with the Git commit ID and the specific seed.

John Deere

Production machine learning for agriculture

- Debugging through reproducible model pipelines
  - Blog Post
  - **Interactive plots for debugging**
    - Parameter importance, Custom plots, Gradients
    - Model predictions
  - **Reproducible model training pipelines with Artifacts**
  - **Efficiency: “**As we develop new models, we need to experiment quickly and share results. W&B gives us the visibility we need to debug and improve our models.”
  - **Performance:** “At the end of the day, we need to build the most accurate and fastest models for our field machines. We have full visibility and transparency in the development process with W&B, making it easy to identify the most performant models.”

Weights & Biases System of Record

Unified toolset for Machine Learning

Reproducibility

- Data lineage and provenance
- ML pipeline version control
- Maintain a knowledge base + central registry of all trained models

Visualization

- Live dashboards for fast experimentation
- Collaboration in unified workspaces and reports
- Manage visibility of machine learning projects across research teams, stakeholders, and academic community

Fast integration

- Modular solutions with lightweight setup
- Flexible deployment, with both cloud and on-prem solutions available
- Intuitive user experience built in partnership with leading research institutions

Trusted by 50,000+ machine learning practitioners at 200+ companies and research institutions

Experiment Tracking in practice

wandb.me/emotion

Weights & Biases

Docs	docs.wandb.com
Instrument W&B in 5 mins	github.com/wandb/examples
Gallery	wandb.ai/gallery
Slack Community	wandb.me/slack
Questions?	twitter.com/lavanyaai
	lavanya@wandb.com

Thank You!

introduction

Dmitry Petrov, PhD

@FullStackML

dmitry@iterative.ai

Hello

Dmitry Petrov

PhD in Computer Science
Twitter: @FullStackML

Creator of
DVC.org project

Co-Founder & CEO > Iterative.AI > San Francisco, USA

ex-Data Scientist > Microsoft (BingAds) > Seattle, USA

ex-Head of Lab > St. Petersburg Electrotechnical University > Russia

1

DVC principles

What DVC does?

1. Data versioning
2. ML models versioning
3. ML pipeline versioning
4. * Data & models transferring

DVC principles

1. Git is a foundation
2. Use storage directly – speed!
    - S3, Azure Blob, GCS, GDrive, FTP
3. No services
    - Git server (like GitHub) + S3
    - Distributed (as Git)
4. Compatible with Git and Git-ecosystem
    - GitHub/GitLab/BitBucket issue trackers
    - CI/CD

DVC users

1. ML researcher & ML engineer
    - Create ML models
    - Tune models
2. DevOps & Engineers
    - Productionize models
    - Manage data and labels

DVC first step

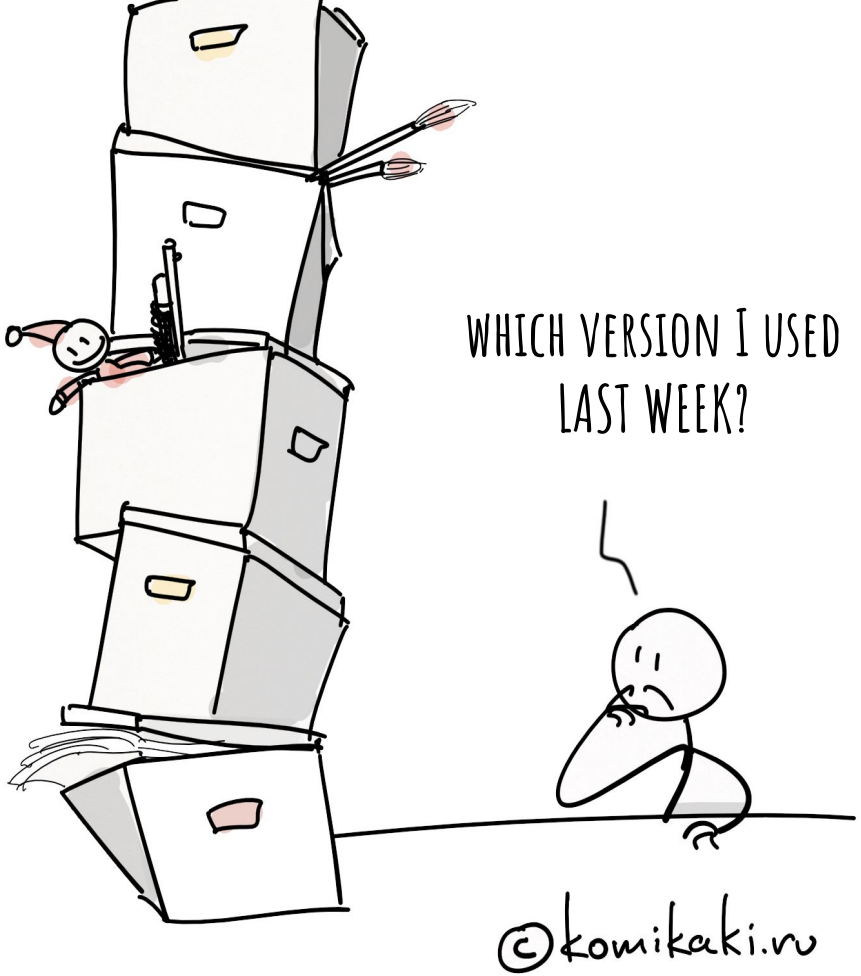
WebSite and Docs: **https://dvc.org**

Source code: **https://github.com/iterative/dvc/**

```
$ pip install dvc


# Init in a project
$ cd my-project
$ dvc init
```

Define storage - data remote

```
$ dvc remote add -d mys3 s3://dmpetrov/test
$ git add .dvc/config
```



2

Data versioning

Add data to your project

```
$ dvc add data/   # creates mata-file data.dvc

$ cat data.dvc
outs:
- md5: b8f4d5a78e55e88906d5f4aeaf43802e.dir
  size: 41149064
  nfiles: 1800
  path: data
```

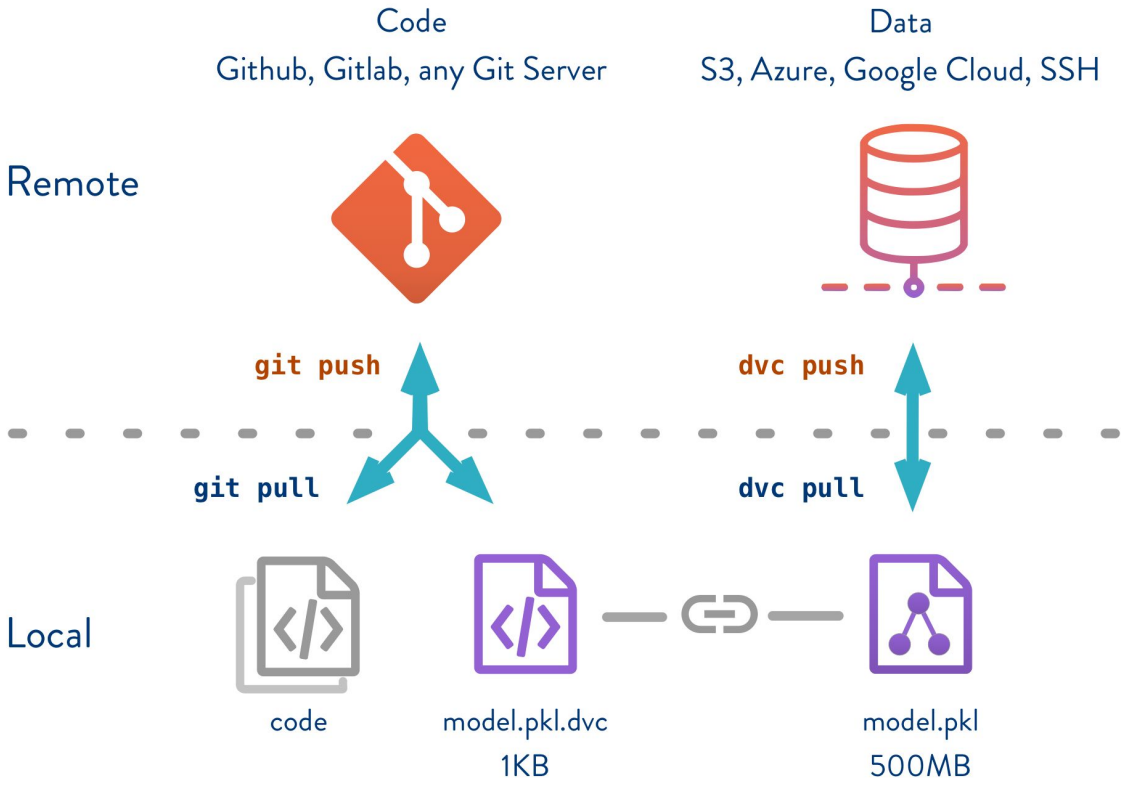
Commit meta-data

```
$ cat data.dvc
outs:
- md5: b8f4d5a78e55e88906d5f4aeaf43802e.dir
  size: 41149064
  nfiles: 1800
  path: data

$ git add data.dvc
$ git commit -m “1st dataset”
$ dvc push  # push dataset to the storage
```

Transfer projects

```
$ git clone https://github.com/dmpetrov/test
$ cd test
$ ls
…
data.dvc

$ dvc pull            # transfers data
$ du -sh data
43M       data.tsv
```

DVC: data meta-info



3

ML pipeline versioning

Define pipeline and metrics file

```
$ dvc run -n my_train          \
      -d data/ -d train.py     \   # dependencies
      -o model.h5              \   # model file
      -M metrics.json          \   # model metrics file
      python train.py          \   # command to run

$ cat metrics.json
{"step": 2, "loss": 2.142695903778076,
 "accuracy": 0.2135166748523712,
  "val_loss": 2.102356910705564,
  "val_accuracy": 0.25060001015663147
}
```

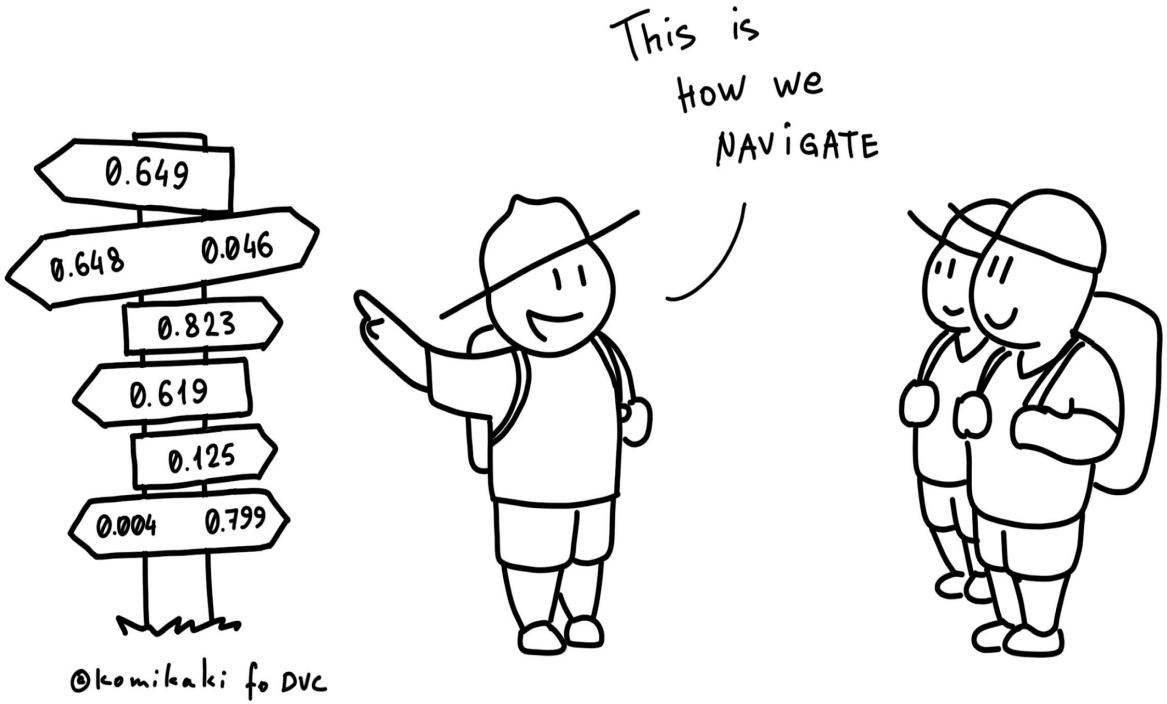
Pipeline meta-file

```
$ cat dvc.yaml
stages:
  my_train:
    cmd: python train.py
    deps:
    - data
    - train.py
    outs:
    - model.h5
    metrics:
    - metrics.json:
        cache: false
```

Reproduce pipeline

```
$ dvc repro
'data.dvc' didn't change, skipping
Stage 'cats-and-dogs' didn't change, skipping
Data and pipelines are up to date.
```

4
Model versioning



Metrics diff

```
$ dvc metrics diff
Path                Metric        Value         Change
metrics.json        accuracy      0.213516      0.023528
metrics.json        loss          2.142695      -0.382401

Also:
$ dvc metrics diff HEAD^^
$ dvc metrics diff master
$ dvc metrics diff v2.1 v2.3
...
```

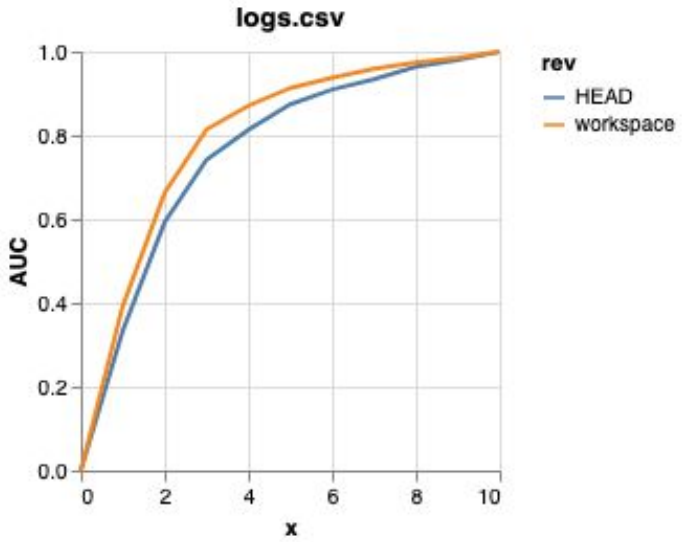
Plots file

```
$ dvc plots diff
file:///Users/dmitry/
src/exp4/plots.html →
```

Also:

```
$ dvc plots diff HEAD^^
$ dvc plots diff master
$ dvc plots diff v2.1 v2.3
```

...



Getting ML model (to production)

```
$ dvc list https://github.com/iterative/myproject
model.h5
train.py
...

$ dvc get https://github.com/iterative/myproject model.h5
$ du -sh model.h5
4.7M   model.h5

OR in Python
Import dvc.api
```

Getting ML model (to production) - Python API

```python
import dvc.api

with dvc.api.open(
        'get-started/data.xml',
        repo='https://github.com/iterative/dataset-registry'
        ) as fd:
    # ... fd is a file descriptor that can be processed normally.
```

5

Integration and compatibility CI/CD

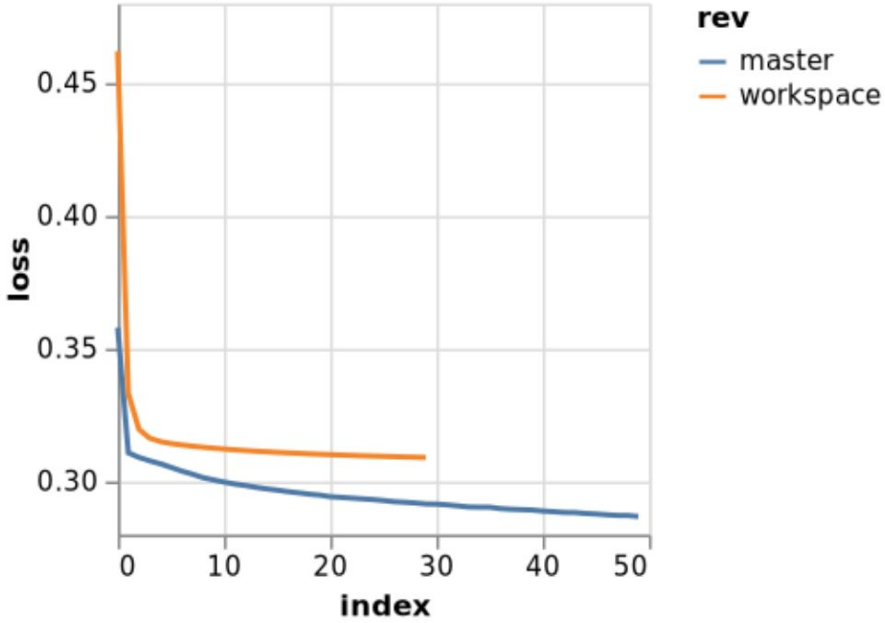
CML – Continuous Machine Learning

CML is CI/CD for Machine Learning Projects.

https://cml.dev/

github-actions bot commented on 591b626 on Jul 2, 2020

Path	Metric	Value	Change
metrics.json	accuracy	0.86944	-0.00292
metrics.json	precision	0.86923	0.00504
metrics.json	recall	0.87185	-0.01382



GitHub Action CI/CD workflow

```
dvc pull data
pip install -r requirements.txt
dvc repro

git fetch --prune
dvc metrics diff --show-md master >> report.md

dvc plots diff \
     --target loss.csv --show-vega master > vega.json
vl2png vega.json | cml-publish --md >> report.md
cml-send-comment report.md
```

Conclusion

Data codification, not versioning

DVC “codifies” data: data → meta-data

Git does the versioning (of meta-info).

Is Git version control system?

Data codification, not versioning

DVC “codifies” data: data → meta-data

Git does the versioning (of meta-info).

Is Git version control system?

```
$ man git
NAME
       git - the stupid content tracker
SYNOPSIS
...
```

Important

1. Keep track of data, ML models and pipelines
2. Efficiently transfer data
3. Be a part of the entire software engineering stack

Thank you!

Dmitry Petrov, PhD

Twitter: @FullStackML

Tutorial: dvc.org/doc/use-cases/versioning-data-and-model-files/tutorial

Machine Learning Systems Design

Next class: Deployment