

# Machine Learning for CI

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# The Team



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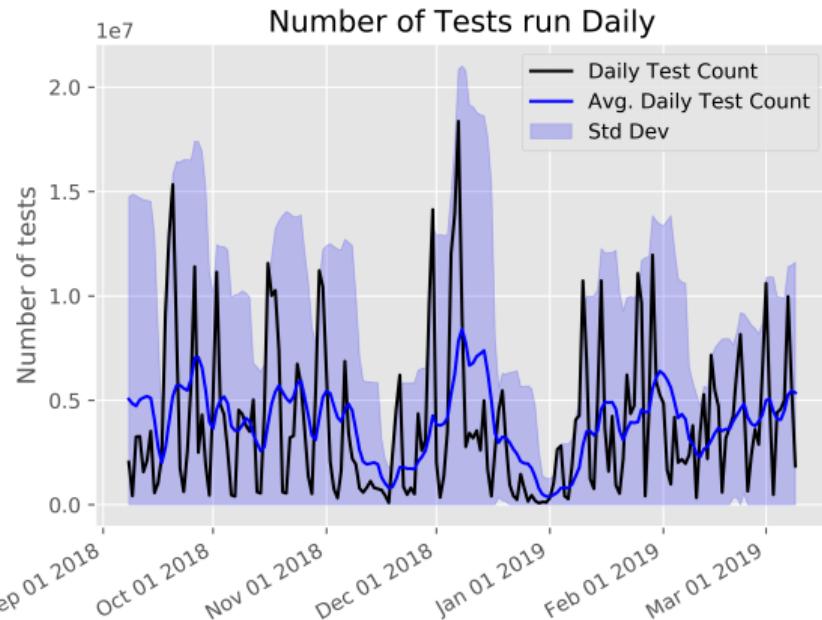
Andrea Frittoli  
*andrea.frittoli@gmail.com*

# Data Sourcing



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# CI at Scale



Source: subunit2sql-graph dailycount

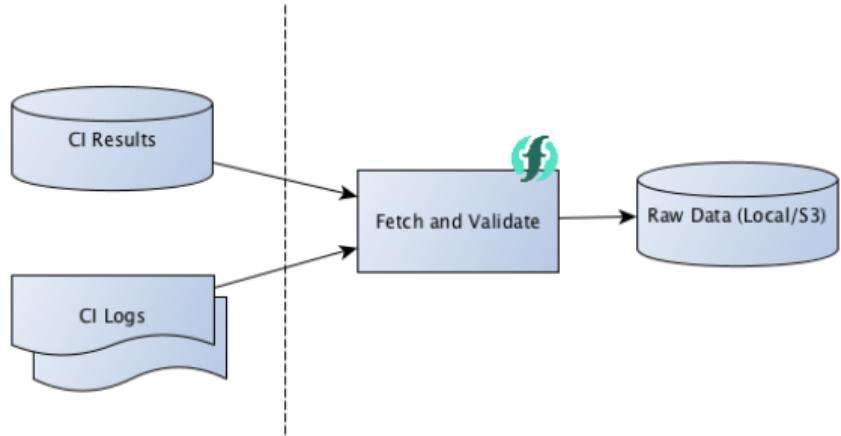
- Continuous Integration
- Continuous Log Data
- Lots of data, little time
- Triaging failures?
- AI to the rescue!

# The OpenStack use case

- Integration testing in a VM
- System logs, application logs
- Dstat data
- Gate testing
- Not only OpenStack

Normalized system average load for different examples

# Collecting data



- Automation and repeatability
- Light-weight data validation
- Object storage for data
- Periodic Action on OpenWhisk

Data caching diagram

# — Data Preparation

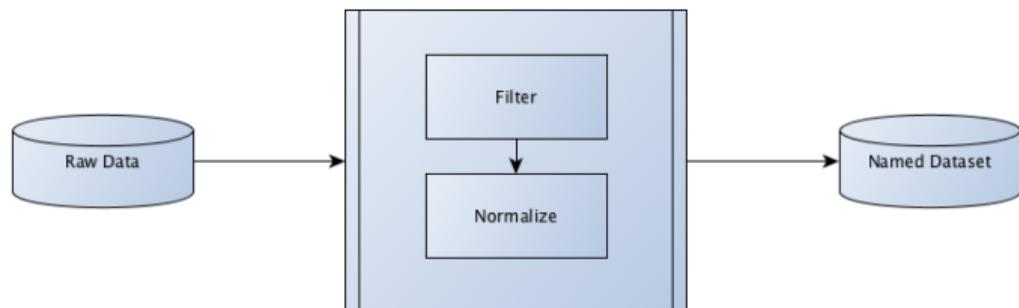


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# Experiment Workflow

- **Visualize data**
- **Define a dataset**
- Define an experiment
- Run the training
- Collect results

```
# Build an s3 backed dataset
ciml-build-dataset --dataset cpu-load-1min-dataset \
--build-name tempest-full \
--slicer :2000 \
--sample-interval 10min \
--features-regex "(usr|1min)" \
--class-label status \
--tdt-split 7 0 3 \
--data-path s3://cimlrawdata \
--target-data-path s3://cimldatasets
```



Dataset preparation diagram

# Data Selection

- What is dstat data?
- Experiment reproducibility
- Dataset selection
  - Dstat feature selection
  - Data resolution (down-sampling)

Sample of dstat data

time	usr	used	writ	1m
16/02/2019 21:44:52	6.1	$7.36 \cdot 10^8$	$5.78 \cdot 10^6$	0.97
16/02/2019 21:44:53	7.45	$7.43 \cdot 10^8$	$3.6 \cdot 10^5$	0.97
16/02/2019 21:44:54	4.27	$7.31 \cdot 10^8$	$4.01 \cdot 10^5$	0.97
16/02/2019 21:44:55	1	$7.43 \cdot 10^8$	4,096	0.97
16/02/2019 21:44:56	0.5	$7.44 \cdot 10^8$	$1.5 \cdot 10^7$	0.97
16/02/2019 21:44:57	1.75	$7.31 \cdot 10^8$	4,096	0.97
16/02/2019 21:44:58	0.88	$7.43 \cdot 10^8$	4,096	0.9
16/02/2019 21:44:59	1.39	$7.31 \cdot 10^8$	$4.51 \cdot 10^5$	0.9
16/02/2019 21:45:00	1.01	$7.44 \cdot 10^8$	4,096	0.9
16/02/2019 21:45:01	0.75	$7.46 \cdot 10^8$	61,440	0.9
16/02/2019 21:45:02	1.26	$7.31 \cdot 10^8$	4,096	0.9
16/02/2019 21:45:03	1.13	$7.44 \cdot 10^8$	4,096	0.82
16/02/2019 21:45:04	5.77	$7.77 \cdot 10^8$	$1.72 \cdot 10^5$	0.82
16/02/2019 21:45:05	9.85	$8.31 \cdot 10^8$	$4.99 \cdot 10^6$	0.82
16/02/2019 21:45:06	3.88	$8.46 \cdot 10^8$	$8.25 \cdot 10^7$	0.82

# Data Normalization

- Unrolling
- Normalizing

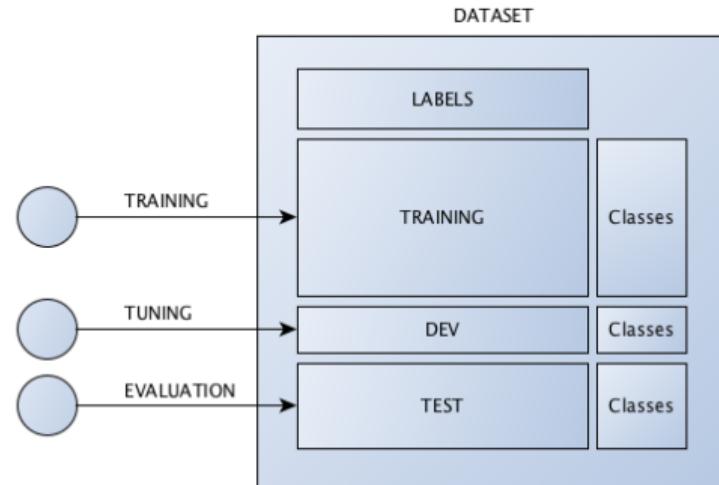
Sample of unrolled data

usr1	usr2	usr3	1m1	1m2	1m3
6.1	1.75	1.26	0.97	0.97	0.9
5.9	1.5	3.1	0.9	0.92	0.97
5.8	1.76	2.2	0.89	0.91	0.94

Sample of normalized data

usr1	usr2	usr3	1m1	1m2	1m3
0.6	0.3	-0.5	0.6	0.6	-0.5
-0.1	-0.7	0.5	-0.3	-0.2	0.5
-0.4	0.3	0	-0.4	-0.4	0

# Building the dataset



Structure of a dataset

- Split in training, dev, test
- Obtain classes
- Store normalized data on s3
- Input function for training
- Input function for evaluation

# Experiment Workflow

- Visualize data
- Define a dataset
- **Define an experiment**
- **Run the training**
- **Collect results**

```
# Define a local experiment
ciml-setup-experiment —experiment dnn—5x100 \
    —estimator tf.estimator.DNNClassifier \
    —hidden-layers 100/100/100/100/100 \
    —steps $(( 2000 / 128 * 500 )) \
    —batch-size 128 \
    —epochs 500 \
    —data-path s3://cimldatasets
```

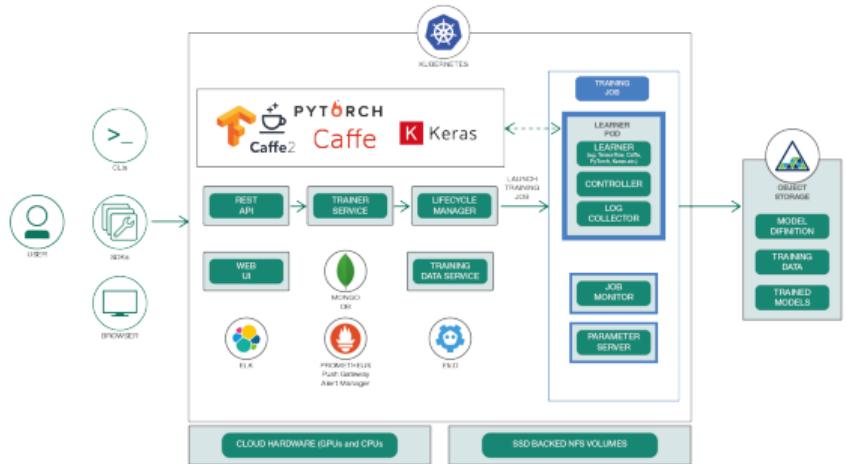
```
# Train the model locally based on the dataset and experiment
# Store the evaluation metrics as a JSON file
ciml-train-model —dataset cpu-load—1min—dataset \
    —experiment dnn—5x100 \
    —data-path s3://cimldatasets

# Train the same model in a FfDL cluster
ffdl_train.sh cpu-load—1min—dataset dnn—5x100
```

# Data Pipelines



# Training Infrastructure



- TensorFlow Estimator API
- CIML wrapper
- ML framework interchangeable
- Training Options:
  - Run on a local machine
  - Helm deploy CIML, run in containers
  - Submit training jobs to Ffdl
  - Kubeflow

FfDL Architecture - Source: <https://developer.ibm.com/code/>

# Prediction

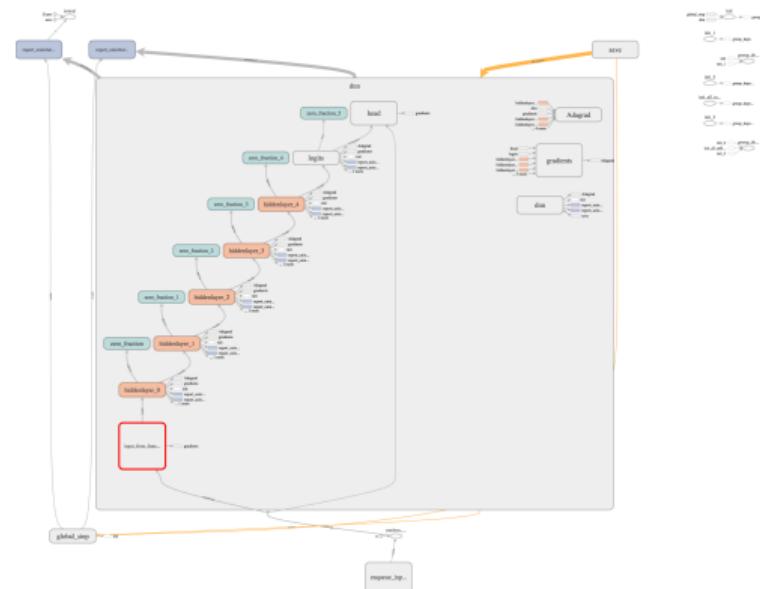
- Event driven: near real time
  - No request to serve the prediction to
  - MQTT Trigger from the CI system
  - CIML produces the prediction
  - Trusted Source: Continuous Training
- 
- CIML kubernetes app components:
    - MQTT Client receives events
    - Data module fetches and prepares data
    - TensorFlow wrapper issues the prediction
    - Example: comment back on Gerrit/Github

# — Experiments



## DNN - Binary Classification

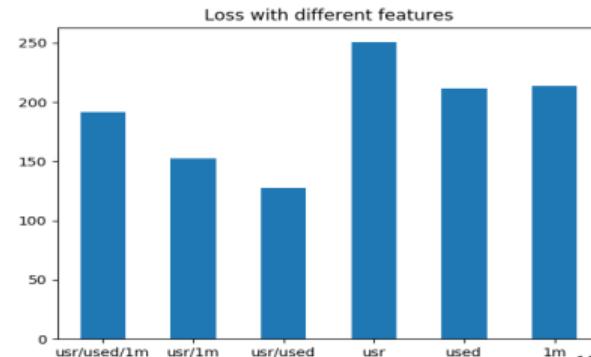
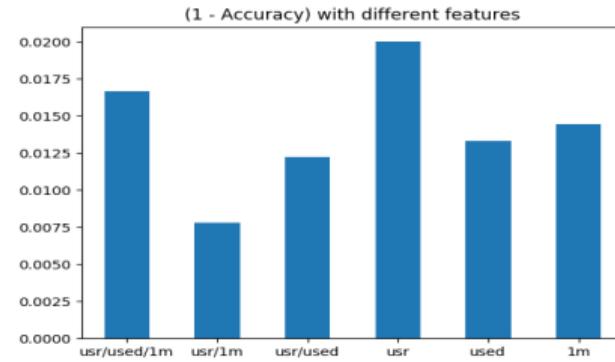
- Classes: Passed or Failed
  - Supervised training
  - TensorFlow *DNNClassifier*, classes=2
  - Dataset:
    - CI Job "tempest-full"
    - Gate pipeline only
    - 3955 examples split in 60% training, 20% dev and 20% test
  - Hyper-parameters:
    - Activation function: ReLU
    - Output layer: Sigmoid
    - Optimizer: Adagrad
    - Learning rate (initial): 0.05
    - 5 hidden layers, 100 units per layer
    - Batch Size: 128, Epochs: 500



Network Graph - Source: TensorBoard

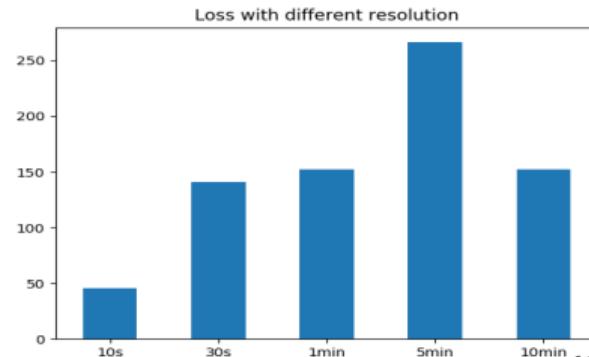
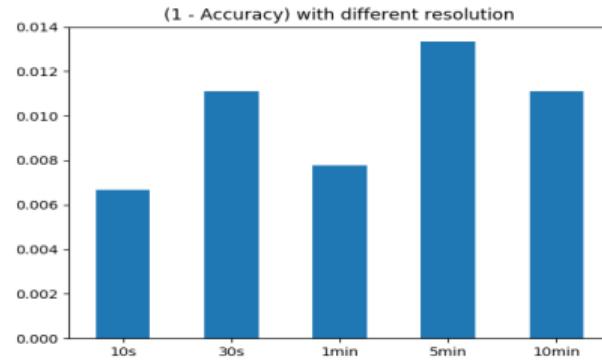
# DNN - Binary Classification

- Selecting the best feature set
- Primary metric: accuracy
- Aim for lower loss, caveat: overfitting
- Key:
  - **usr**: User CPU
  - **used**: Used Memory
  - **1m**: System Load - 1min Average
  - Data Resolution: **1min**
  - Source: TensorFlow evaluation
- Winner: (**usr, 1m**) tuple
- Accuracy achieved: **0.992**
- 6 mistakes on a 791 test set



# DNN - Binary Classification

- Selecting the data resolution
- Primary metric: accuracy
- Aim for lower loss, caveat: overfitting
- Note: careful with NaN after down-sampling
- Key:
  - Original data frequency: 1s
  - x-axis: new sampling rate
  - Features: (**usr, 1m**)
  - Source: TensorFlow evaluation
- Winner: **10s**
- Accuracy achieved: **0.993**
- 6 mistakes on a 791 test set



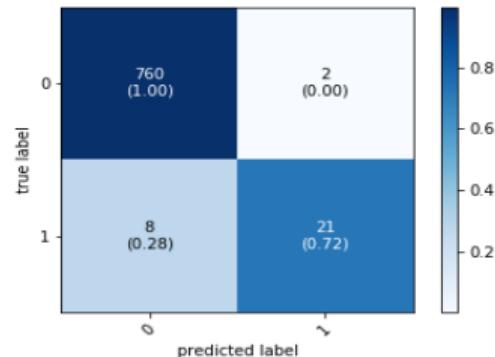
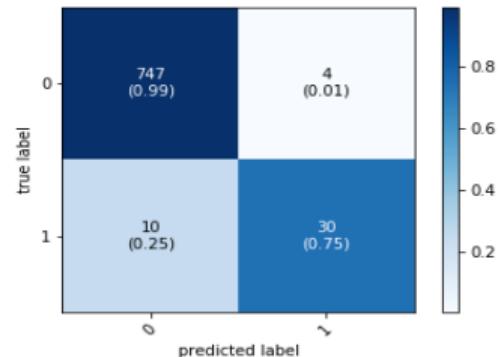
# DNN - Binary Classification - Metrics report

Metrics report for usr 1m and 1min

status	precision	recall	f1-score	support
passed	0.99	0.99	0.99	751
failed	0.88	0.75	0.81	40
accuracy		0.98	791	

Metrics report for usr 1m and 10s

status	precision	recall	f1-score	support
passed	0.99	1	0.99	762
failed	0.91	0.72	0.81	29
accuracy		0.99	791	



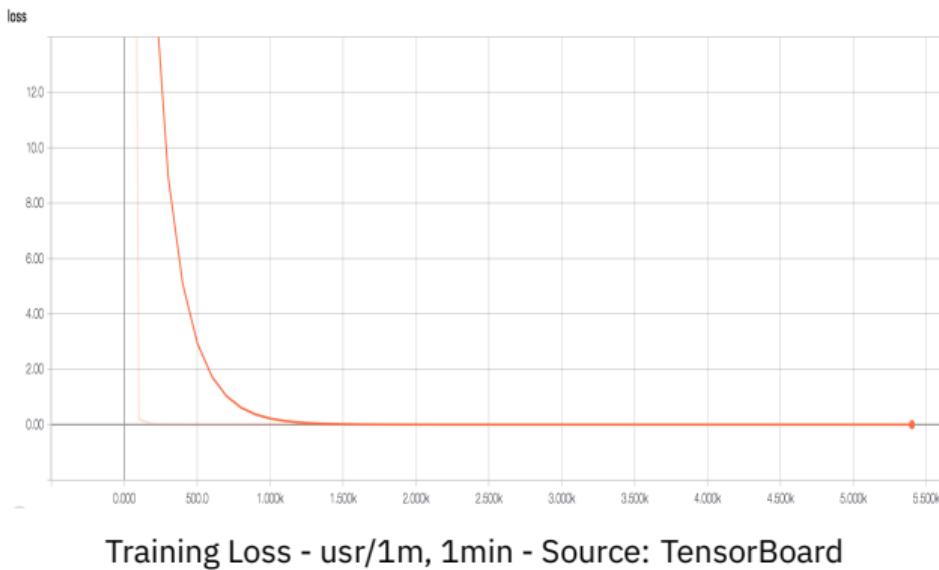
# Changing test job

metric	tempest-full	tempest-full-py3
accuracy	0.994	0.953
loss	47.176	86.873
auc_precision_recall	0.949	0.555

- Train with "tempest-full"
- Evaluating with "tempest-full-py3"
  - Similar setup, uses python3
  - It does not include swift and swift tests
  - 600 examples evaluation set
- Dataset and training setup:
  - Features: (usr, 1m)
  - Resolution: 1min
  - Same hyper-parameters

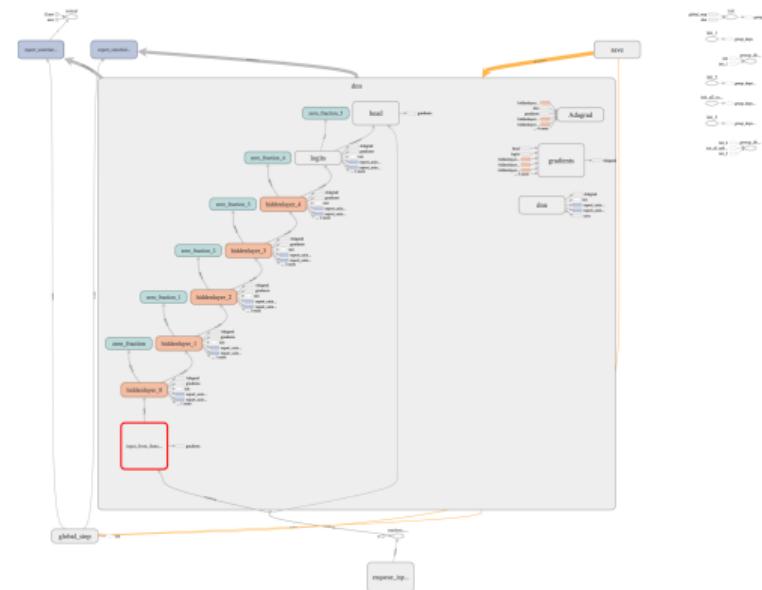
# Binary Classification - Summary

- Features: User CPU and 1min Load Avg
- Resolution: 10s best, 1 minute may be enough
- High accuracy: **0.993**
- High precision, recall and F1-score
- A trained model might be applicable to similar CI jobs



## DNN - Multi Class

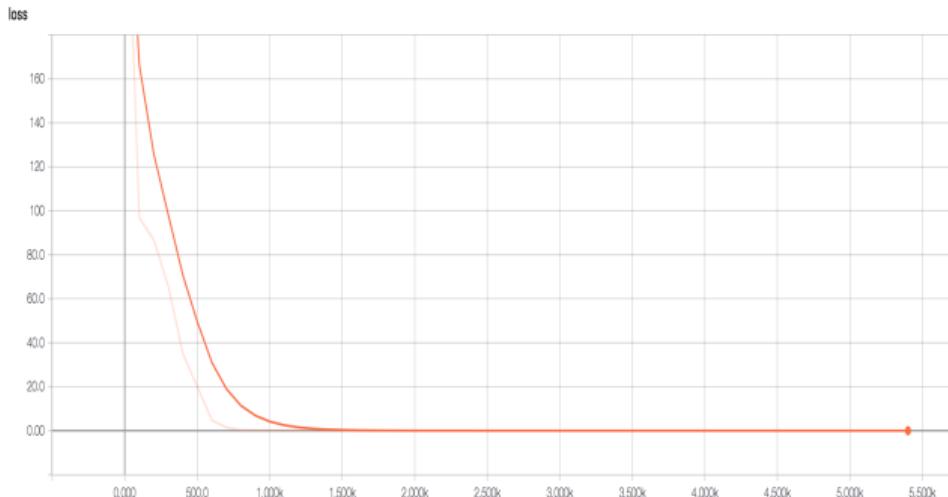
- Classes: Hosting Cloud Provider
  - Supervised training
  - TensorFlow *DNNClassifier*, classes=10
  - Dataset:
    - CI Job "tempest-full"
    - Gate pipeline only
    - 3000 examples, 2100 training, 900 test
  - Hyper-parameters:
    - Activation function: ReLU
    - Output layer: Sigmoid
    - Optimizer: Adagrad
    - Learning rate (initial): 0.05
    - 5 hidden layers, 100 units per layer
    - Batch Size: 128, Epochs: 500



Network Graph - Source: TensorBoard

# DNN - Multi Class

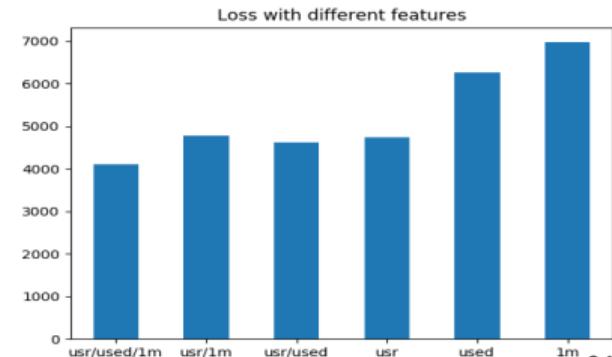
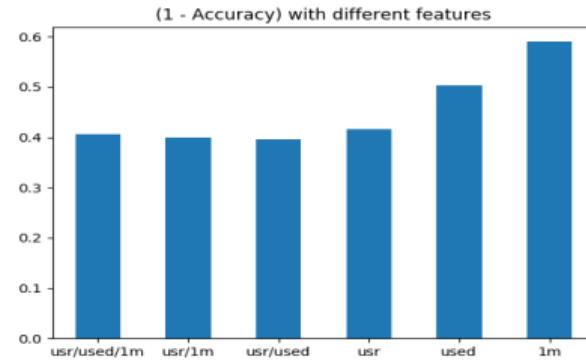
- Features: (usr, 1m)
- Resolution: 1min
- Loss converges, but...
- Evaluation accuracy achieved:  
**0.601**
- Not good!



Training Loss - usr/1m, 1min - Source: TensorBoard

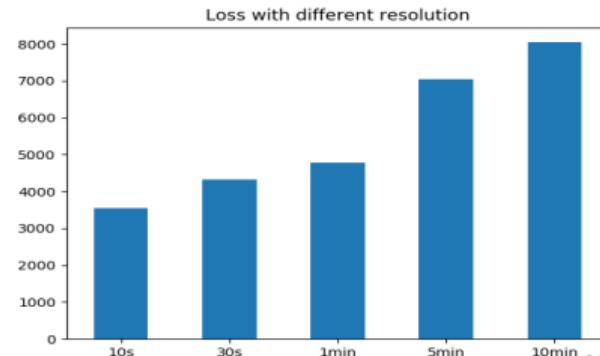
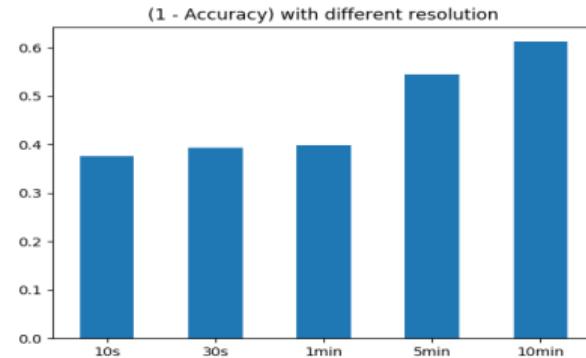
# Multi Class - Different Features

- Try different combinations of features
- Primary metric: accuracy
- Aim for lower loss, caveat: overfitting
- Key:
  - **usr**: User CPU
  - **used**: Used Memory
  - **1m**: System Load - 1min Average
  - Data Resolution: **1min**
  - Source: TensorFlow evaluation output
- No real improvement
- Best accuracy achieved: **0.603**
- Adding Disk I/O or process data does not help either



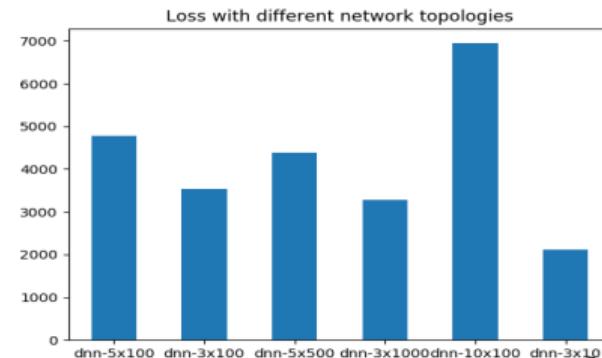
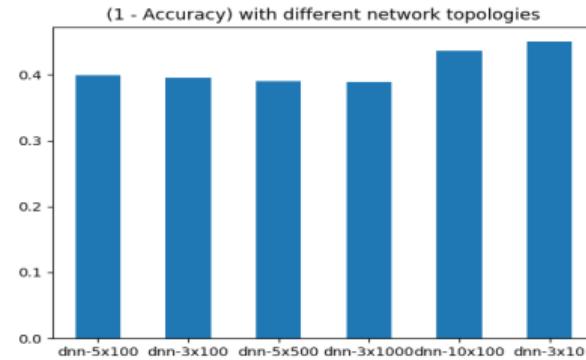
# Multi Class - Changing Resolution

- Trying to change the data resolution
- Primary metric: accuracy
- Aim for lower loss, caveat: overfitting
- Key:
  - Original data frequency: 1s
  - x-axis: new sampling rate
  - Features: (**usr, 1m**)
  - Source: TensorFlow evaluation
- No real improvement
- Best accuracy achieved: **0.624**



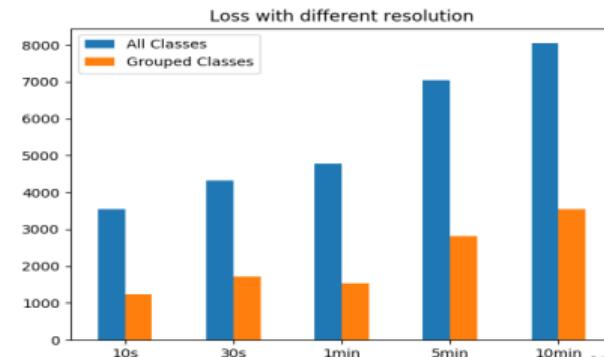
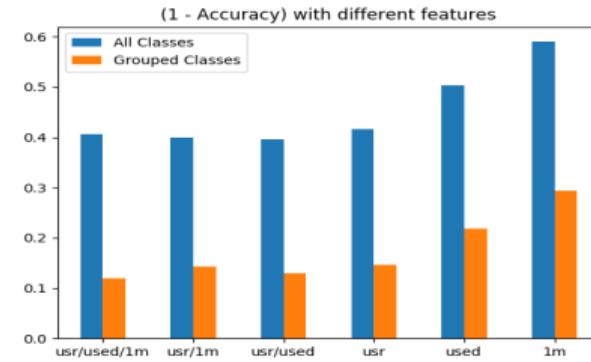
# Multi Class - Network topology

- Trying to change the network depth
- Trying to change number of units per layer
- Primary metric: accuracy
- Aim for lower loss, caveat: overfitting
- Key:
  - x-axis: units and hidden layers
  - Features: (**usr**, **1m**)
  - Resolution: **1min**
  - Source: TensorFlow evaluation
- No real improvement
- Best accuracy achieved: **0.668**



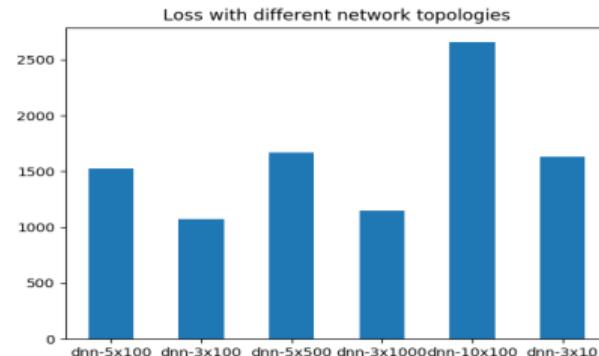
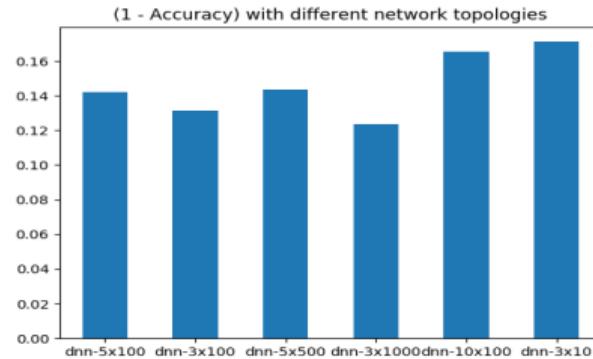
# Multi Class - Reducing the number of classes

- Reducing the number of classes
  - Different regions from a Cloud Operator
  - Consider as a single class
  - New number of classes is **7**
- Experiments:
  - Train with different feature sets
  - Train with different resolutions
  - Source: TensorFlow evaluation
- Significant improvement!
- Best accuracy achieved: **0.902**
- What does that mean?



# Multi Class - Tuning network topology

- Tuning network topology
- Experiments:
  - x-axis: units and hidden layers
  - Features: (**usr, 1m**)
  - Resolution: **1min**
- Some improvement
- Winner: 3x100. Accuracy: **0.925**



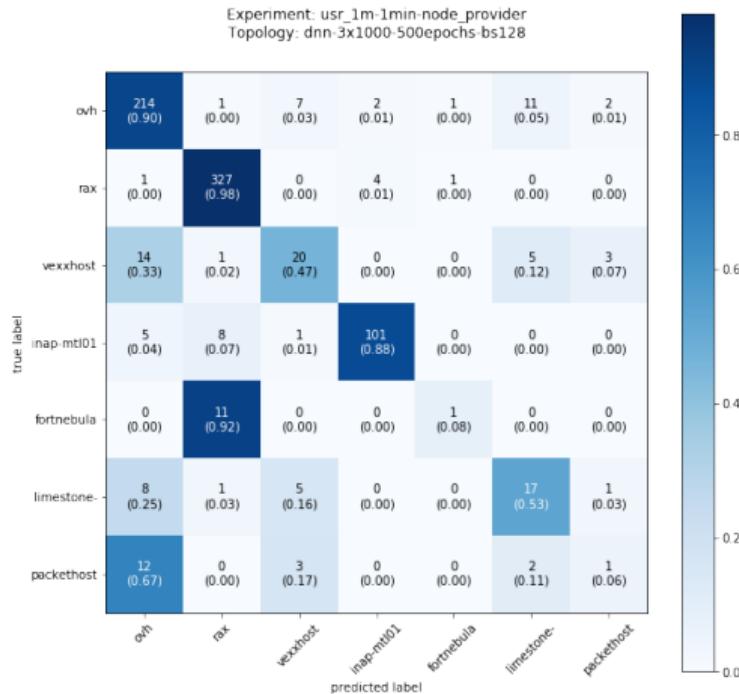
# Multi Class - Metrics report

## – Experiment:

- Dataset: 3955 examples split in 60% training, 20% dev and 20% test
- Features: User CPU and Load Avg
- Resolution: 1 minute
- Hyperparameters: 3 hidden layers, 1000 units each
- Cloud providers: 7

Metrics report for usr 1m and 1min

provider	precision	recall	f1-score	support
rax	0.94	0.98	0.96	333
inap-mtl01	0.94	0.88	0.91	115
ovh	0.84	0.9	0.87	238
vexxhost	0.56	0.47	0.51	43
limestone	0.49	0.53	0.51	32
fortnebula	0.33	$8 \cdot 10^{-2}$	0.13	12
packethost	0.14	$6 \cdot 10^{-2}$	$8 \cdot 10^{-2}$	18
accuracy			0.86	791



# Multi Class - Changing test job

metric	tempest-full	tempest-full-py3
accuracy	0.925	0.775
average_loss	0.978	3.271
loss	586.713	1,962.447

- Train with "tempest-full"
- Evaluating with "tempest-full-py3"
  - Similar setup, uses python3
  - It does not include swift and swift tests
  - 600 examples evaluation set
- Dataset and training setup:
  - Features: (usr, 1m)
  - Resolution: 1min
  - Same hyper-parameters (dnn-3x100)

# Multi Class - Summary

- User CPU and 1min Load Avg
- Resolution: 1 minute is enough
- Hyperparameters: 3 hidden layers, 100 units each
- Reasonable accuracy: **0.925**
- A trained model is not applicable to similar CI jobs



Training Loss - usr/1m, 1min, dnn3x100 - Source: TensorBoard

# Conclusions

# Conclusions

- Collect data
- Know your data
- Work with cloud tools
- Able to confirm that system load plays a role in failures
- Load profiles are consistent across regions in our cloud providers

## Future Work

- Look at adapting techniques for new models with different data
- Human curated dataset for supervised training
- Research clustering techniques for unsupervised training
- Explore job portability
- Use the pass/fail data to detect degradation in CI Jobs

# Questions?

- This talk: [https://github.com/afrittoli/ciml\\_talk](https://github.com/afrittoli/ciml_talk)
- CIML: <https://github.com/mtreinish/ciml>

# Thank You!