Flexible and Scalable Deep Learning with MMLSpark

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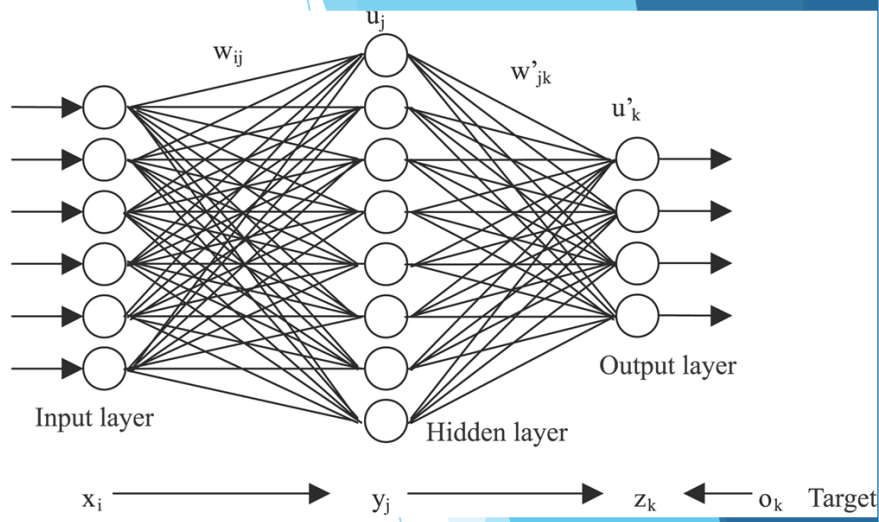
MMLSpark
aka.ms/mmlspark

Agenda

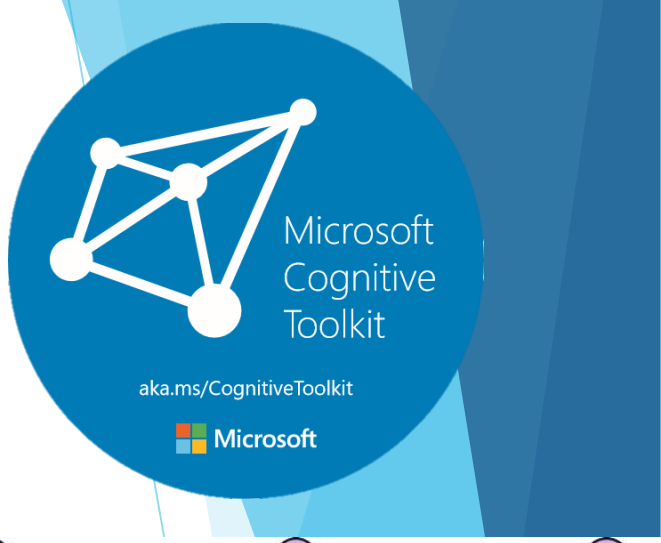
- Background
  - Deep Learning
  - Cognitive Toolkit (CNTK)
  - Apache Spark and SparkML
- MMLSpark
  - Integrating Cognitive Toolkit and Spark
  - OpenCV Spark integration
  - PySpark Wrapper Generation
- Snow Leopard Conservation
  - Transfer Learning
- Future Work
  - CNTK Training
  - Text Analytics

Deep Learning

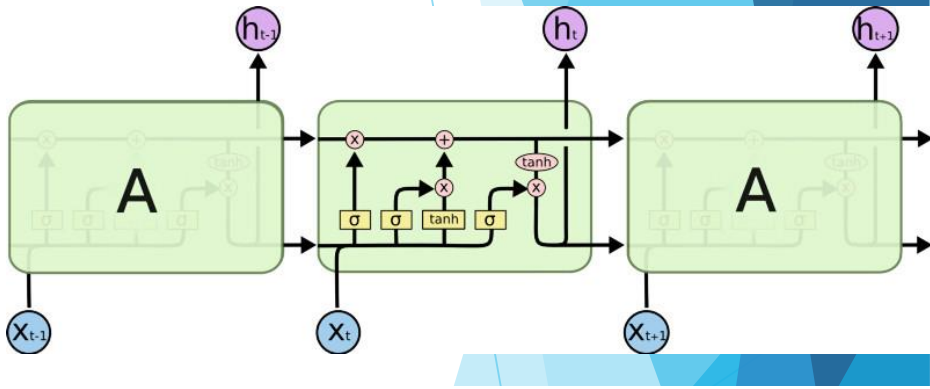
- Originally referred to learning neural networks with many layers
- Now refers to any suitably complicated statistical model trained with gradient descent
- Has become a recent favorite because:
  - Spectacular performance in many domains
  - Quick training w/ gradient descent
  - Low memory footprint w/ Stochastic Gradient Descent (SGD)
  - Large space of possible model architectures
  - Automatic differentiation software and APIs

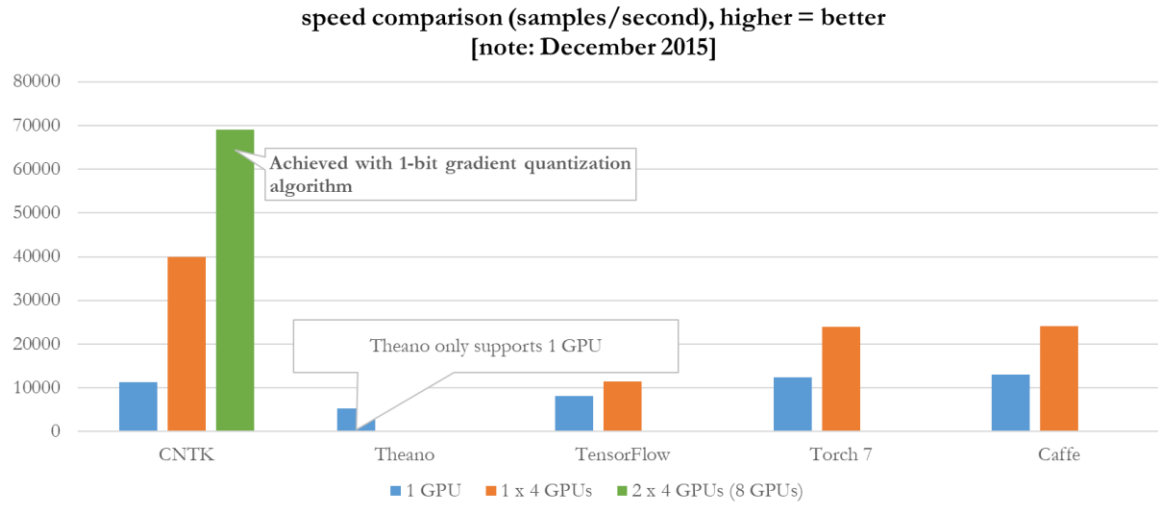


Microsoft Cognitive Toolkit (formerly CNTK) (Dong Yu et al. 2012)

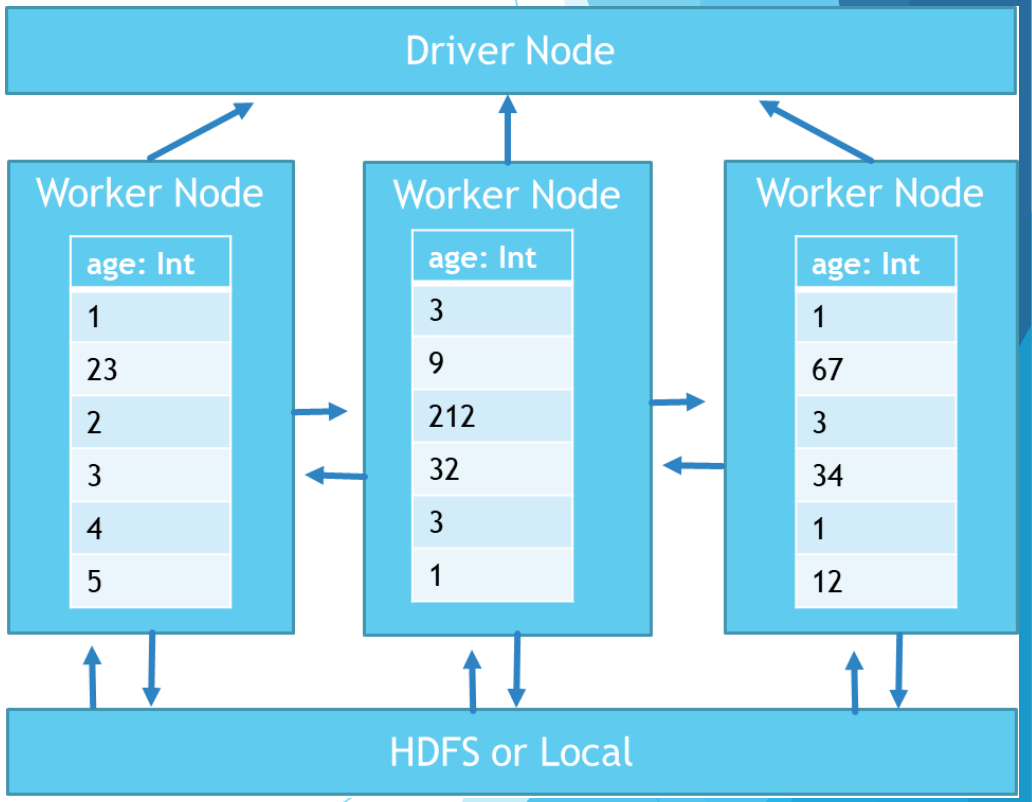


- Microsoft's open-source deep-learning toolkit
- https://github.com/Microsoft/CNTK
- Written in C++, bindings in Python, C#
- Runs over 80% Microsoft internal DL workload
- Can express a huge variety of deep architectures
  - LSTMS, ConvNets, RL, Gans, etc….
- Automatic differentiation
- Compute Agnostic: Compiles down to performant machine code
- Fast!





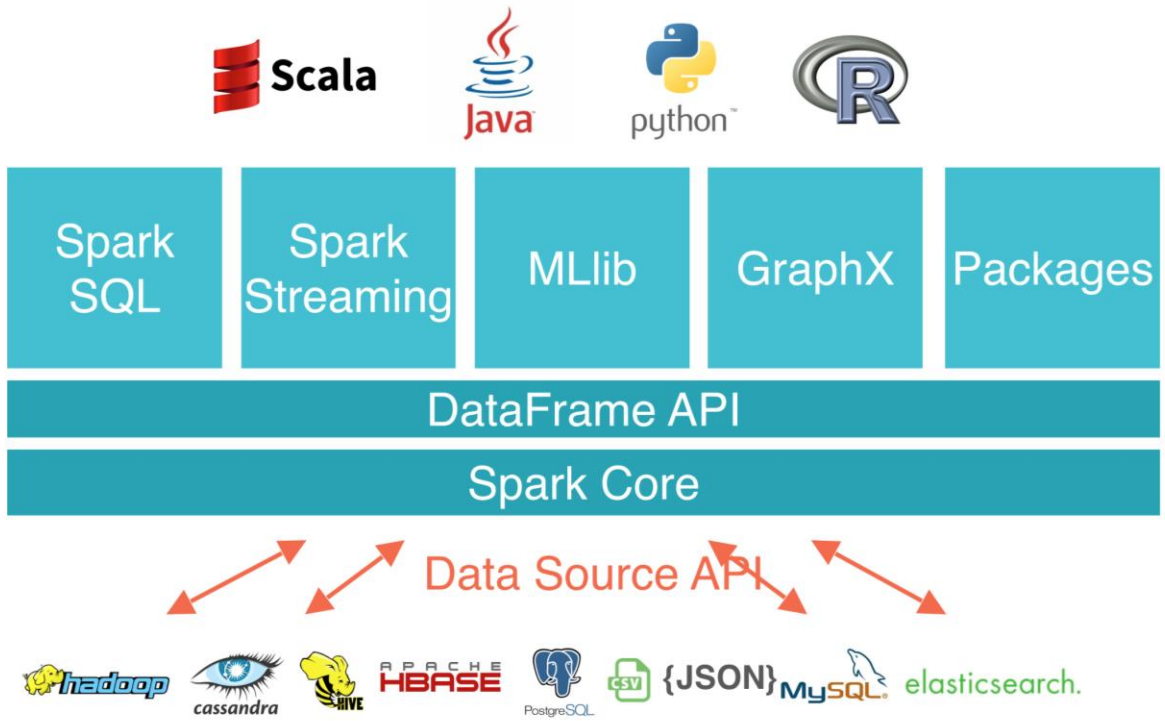
- A **fault-tolerant distributed** computing framework
- Generalizes, optimizes, and combines Map-Reduce and SQL style-operations
- Scales to thousands of machines
- Functional API
- Built in Scala, but has bindings in Python and R
- Has a flourishing community
  - SparkML
  - GraphX
  - Structured Streaming



Spark ML: Machine Learning at Scale

- High level library for machine learning
- Similar abstraction to SciKit Learn (But waaaaay better API)
- Written in Scala but has wrappers in Python
- Models all have a uniform interface: PipelineStage
  - Classification: logistic regression, naive Bayes, ...
  - Regression: generalized linear regression, survival regression, ...
  - Decision trees, random forests, and gradient-boosted trees
  - Recommendation: alternating least squares (ALS)
  - Clustering: K-means, Gaussian mixtures (GMMs), ...
  - Topic modeling: Latent Dirichlet Aallocation (LDA)

```
data = spark.read.csv("hdfs://...")
train, test = data.randomSplit([.5,.5])
model = LogisticRegression().fit(train)
predictions = model.transform(test)
```



Drawbacks:

Spark/SparkML

- Only “conventional” algorithms
  - Difficult to add new models, tons of boilerplate, restricted to certain kids of operations
  - All gradient based algorithms use custom SGD code
- No support for complex datatypes like images
- Need to manually write wrappers to get code into PySpark and SparkR

CNTK

- CNTK could not be scaled with fault tolerance
  - required expensive and dedicated HPC machines
- No support for elasticity or autoscaling
- No support for high throughput parallel streaming
- Mainly support for gradient based models

Microsoft Machine Learning For Apache Spark

Distributed Deep Learning, Image Analysis, Text Analytics, and Much More

https://aka.ms/mmlspark

MMLSpark

aka.ms/mmlspark

- Open Source
  - Contributions welcome!
  - Get started with our docker image + data science examples/course aka.ms/mmlspark
- **Integrates and unifies Spark, CNTK, and OpenCV**
- Tons of other useful abstractions and tools:
  - **Automatic Python/R code generation**, Auto-Featurization, Trained DNN Repository, Multi-Column support, Serialization, Fuzzing etc.

Cognitive Toolkit x Spark Step 1: Java Bindings

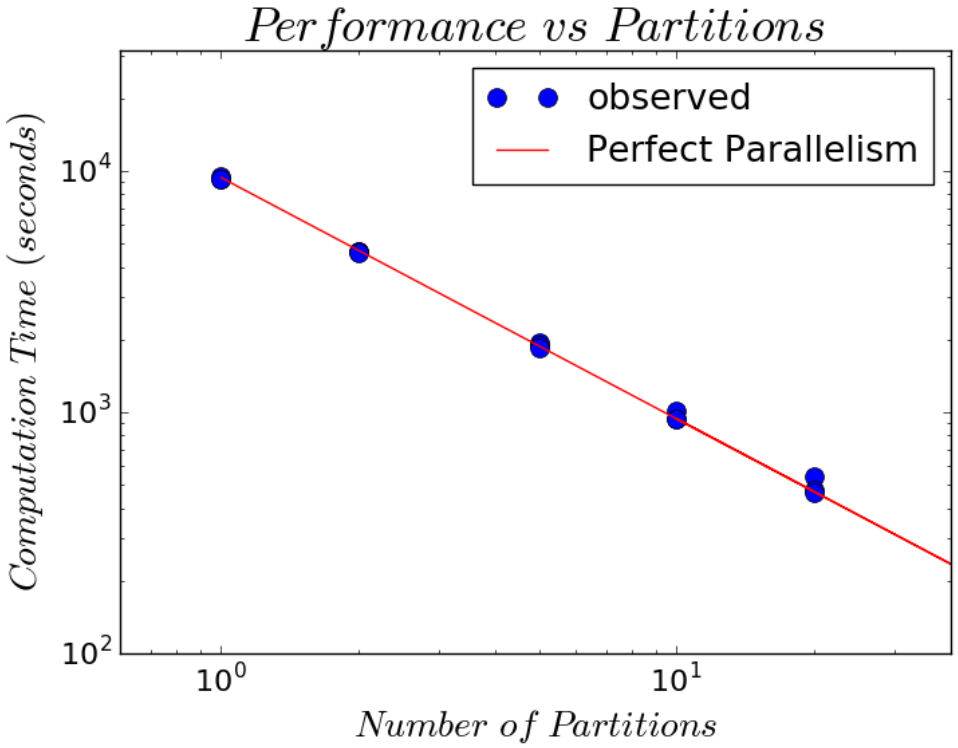
- Cognitive Toolkit is written in C++ but has bindings in Python, Brainscript, and C#
- We use the Simple Wrapper and Interface Generator (SWIG) to expose CNTK's Evaluation library to Java
- All Java bindings are machine generated so they require very little maintenance!
- Try them out in Cognitive Toolkit's > 2.0

```
Function modelFunc = Function.load(new File("resnet20_cifar10_python.dnn"), device);
Variable outputVar = modelFunc.getOutputs().get(0);
Variable inputVar = modelFunc.getArguments().get(0);
```

Cognitive Toolkit x Spark Step 2: Spark Transformers

- Spark is built on Scala (inter-ops with Java), allowing us to use our new CNTK Java Bindings
- Spark allows users to execute custom Scala code on each machine
- We automatically distribute, load, and run the CNTK model on all machines
- Each machine maps a small portion of the total dataset, so performance scales with machines

```
1  val model = new CNTKModel()
2    .setModelLocation(session, modelPath)
3    .setInputCol("images")
4    .setOutputCol("features")
5    .setOutputNodeName("z")
6
7  val result = model.transform(data)
```



Parallel Image Processing with OpenCV

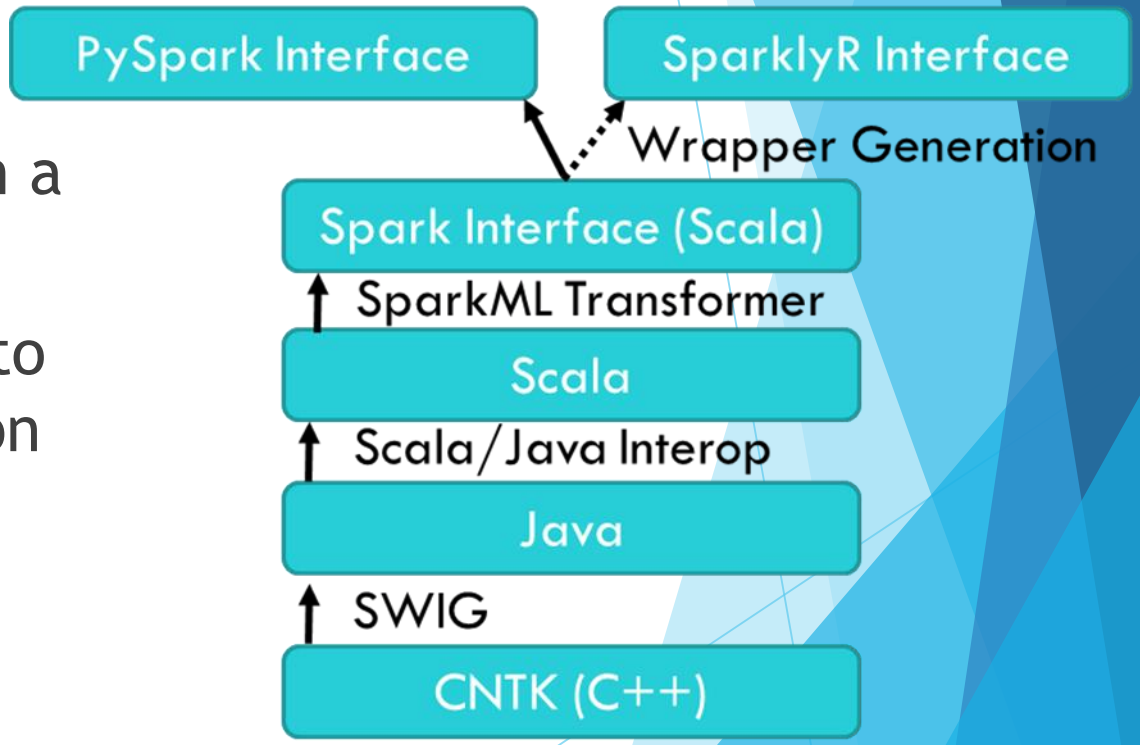
- DNNs are often picky about their input data shape and normalization.
- We provide bindings to OpenCV image processing operations, exposed as SparkML PipelineStages:

```
tr = ImageTransform().setOutputCol("transformed")
    .resize(height = 200, width = 200)
    .crop(0, 0, height = 180, width = 180)

smallImages = tr.transform(images).select("transformed")
```

PySpark Bindings…For Free!

- Our core code is written in Scala
- Python is too hot to forget
- Spark has a exposed bindings to python in a package called PySpark
- We automatically expose all of our work to python through generating SparkML python APIs
- Now also support SparklyR, Spark's R bindings




Snow
Leopard
Trust

Snow Leopard Conservation

- 3,900-6,500 individuals left in the wild
- Little known about their ecology, behavior, movement patterns, survival rates
- More data required to influence survival

Mining

Poaching

Retribution Killing

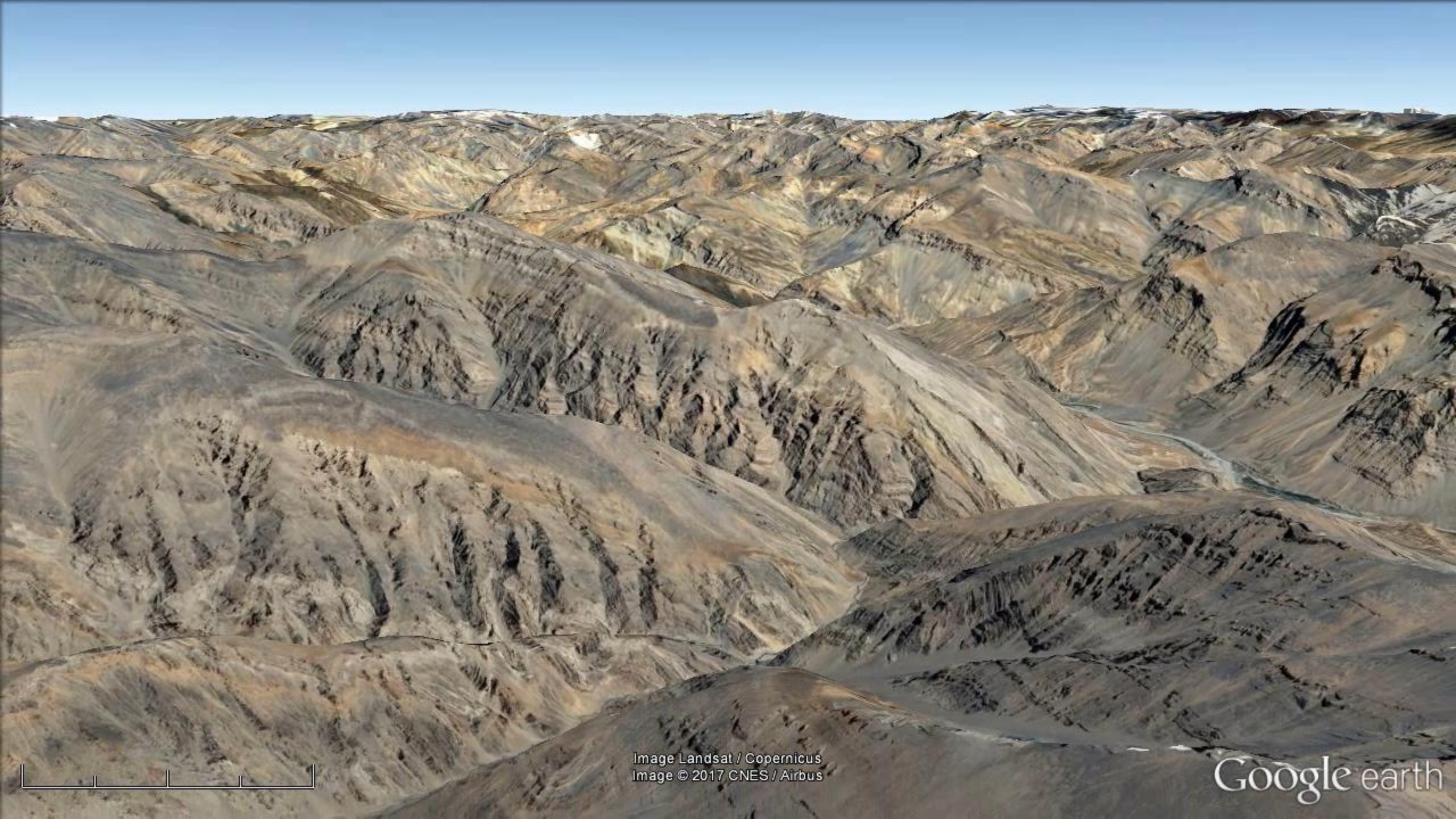
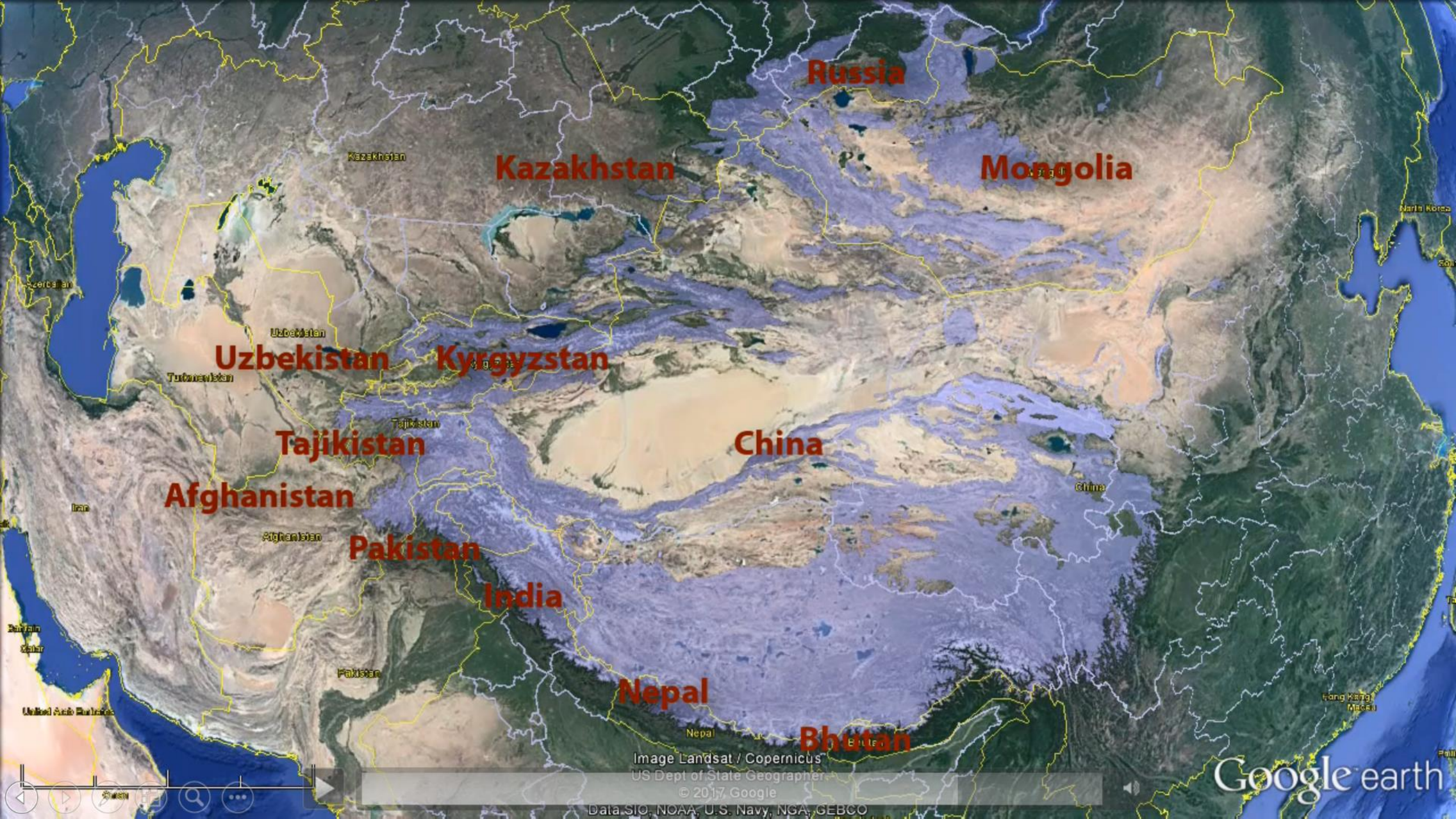


Image Landsat / Copernicus
Image © 2017 CNES / Airbus
Google earth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US Dept of State Geographer
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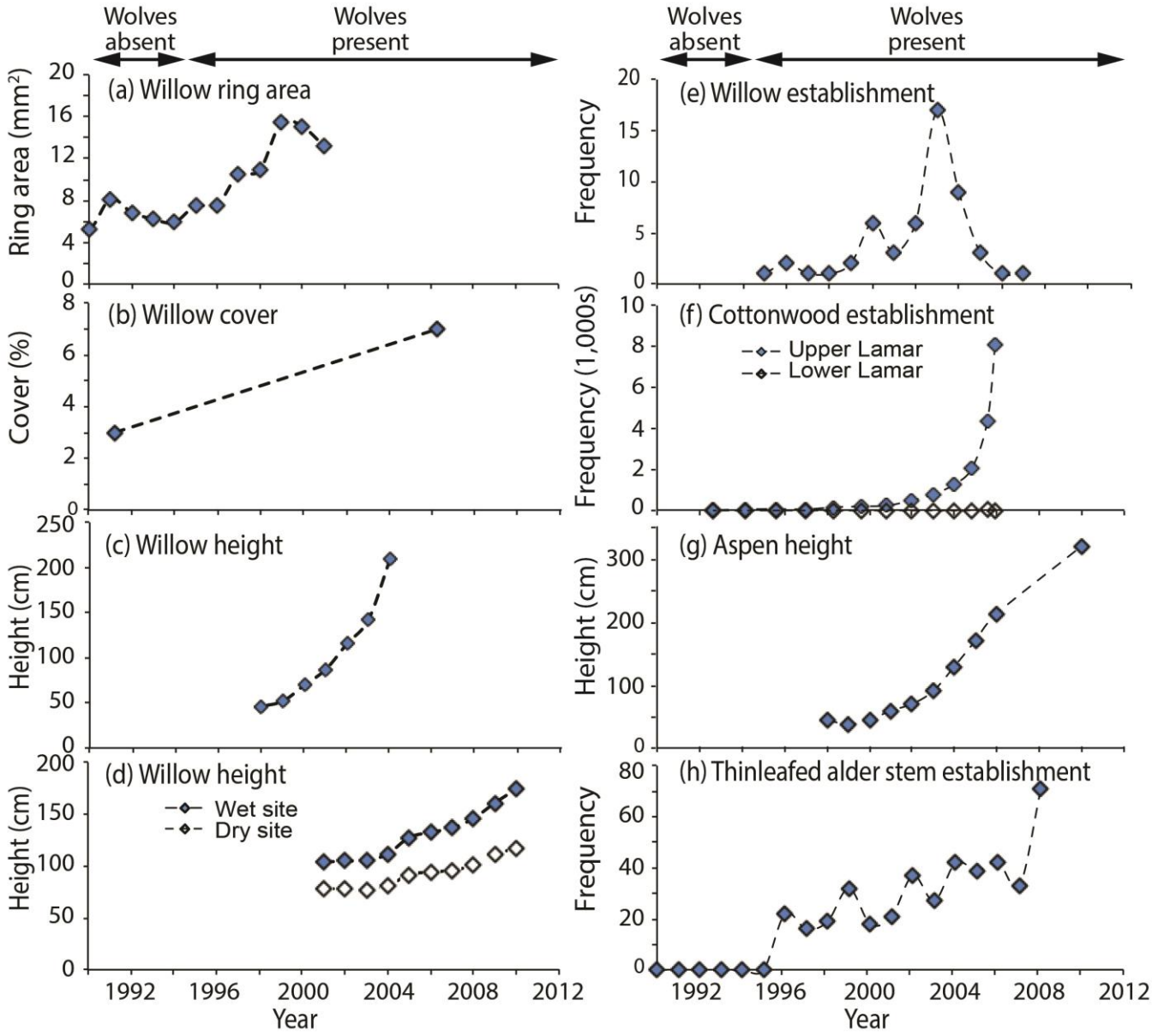
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

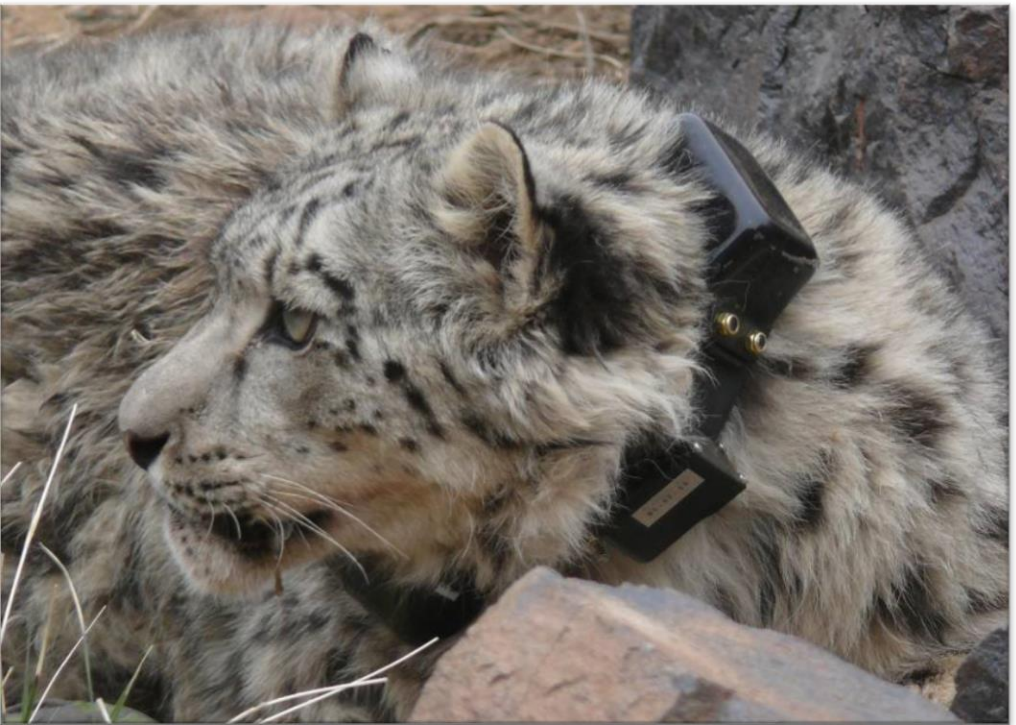
The Impact of Apex Predators

Beschta, Robert L., and William J. Ripple. "Riparian vegetation recovery in Yellowstone: The first two decades after wolf reintroduction." *Biological Conservation* 198 (2016): 93-103.



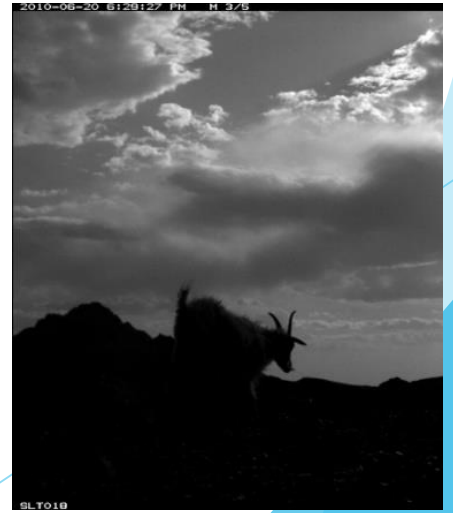
Gathering Leopard Data

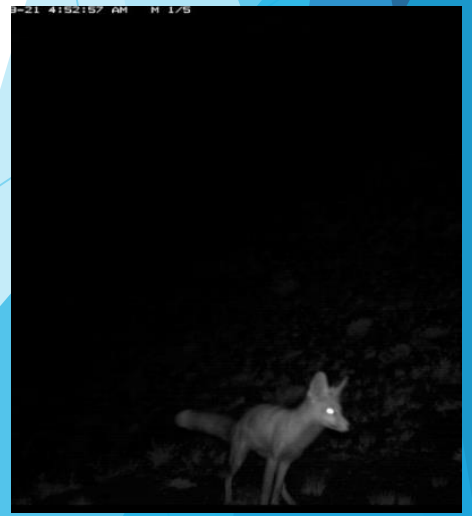
- 42 camera traps over 1,700 sq km
- ~1.3 mil images
- 23 leopards collared in 9 years

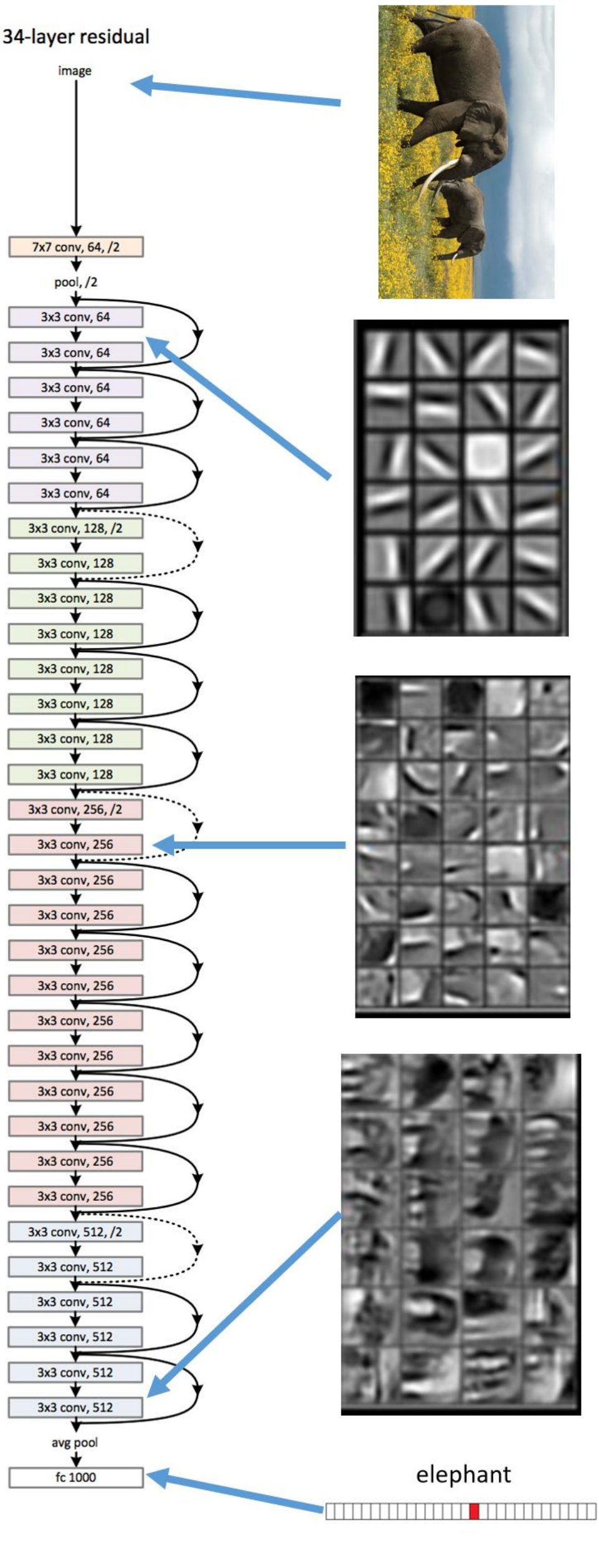


Camera Trap Images

Manually classifying images averages 300 hours per survey



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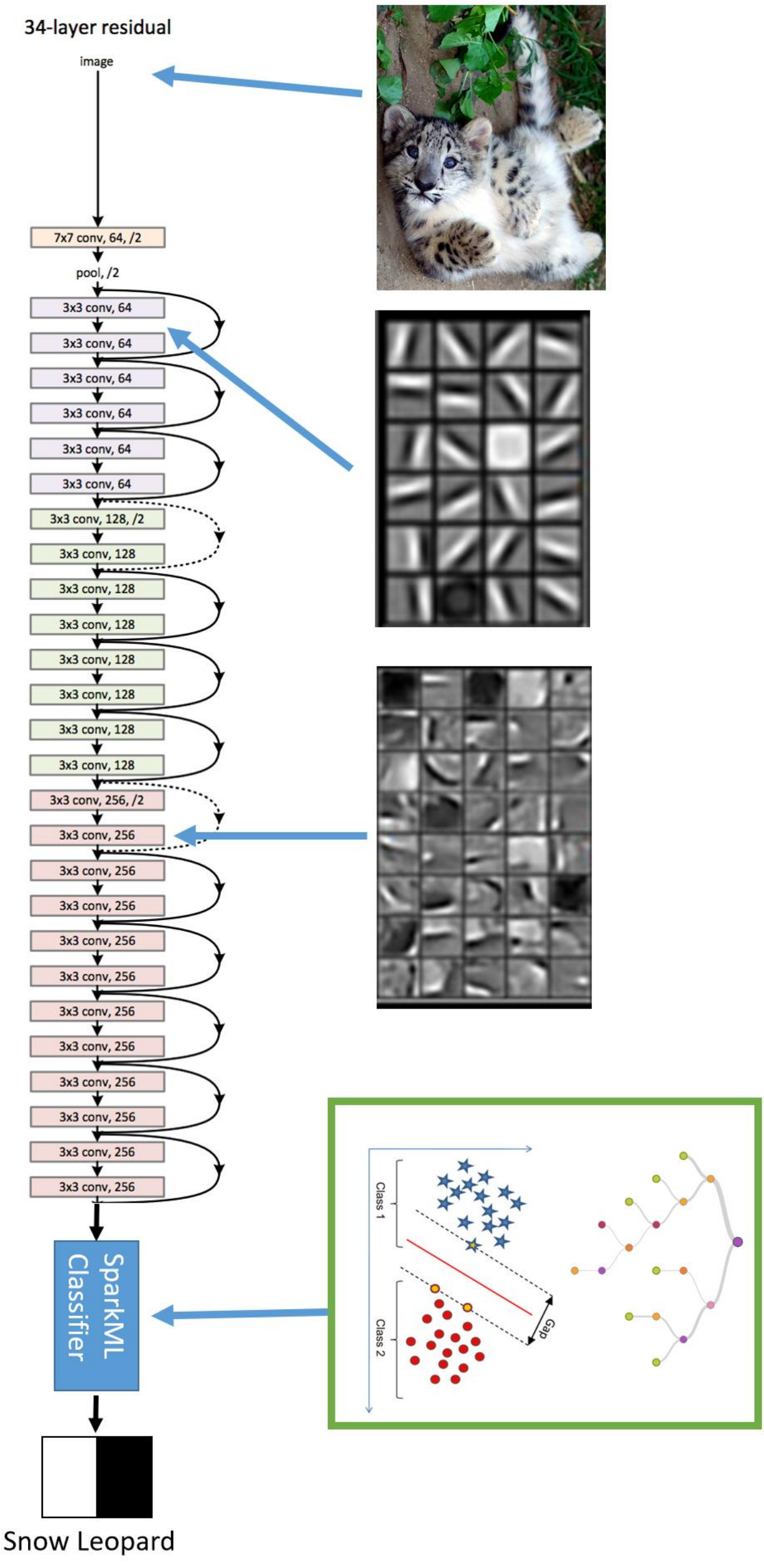
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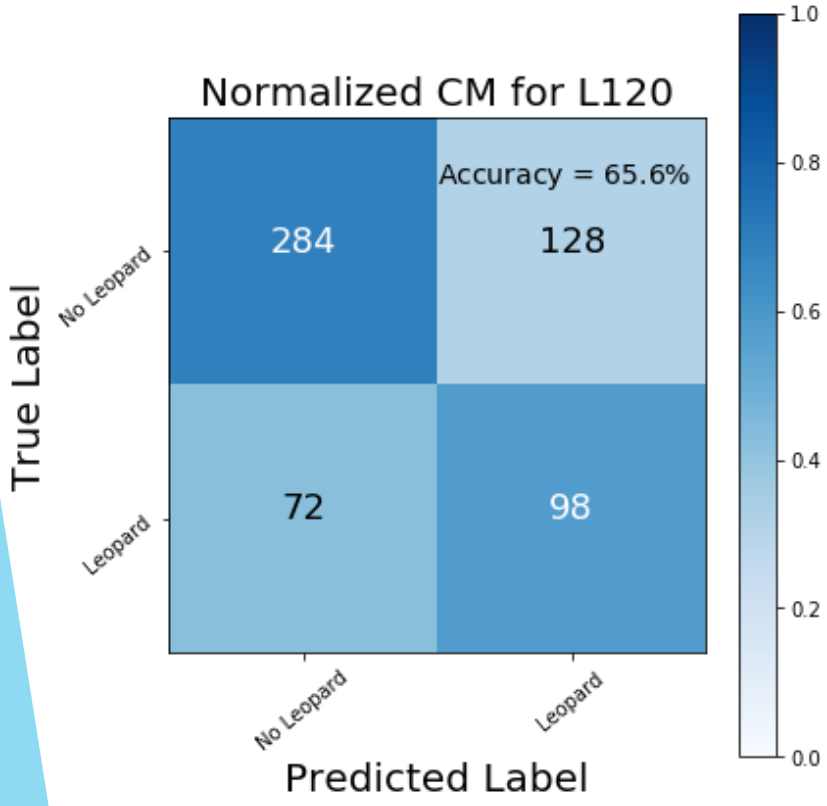
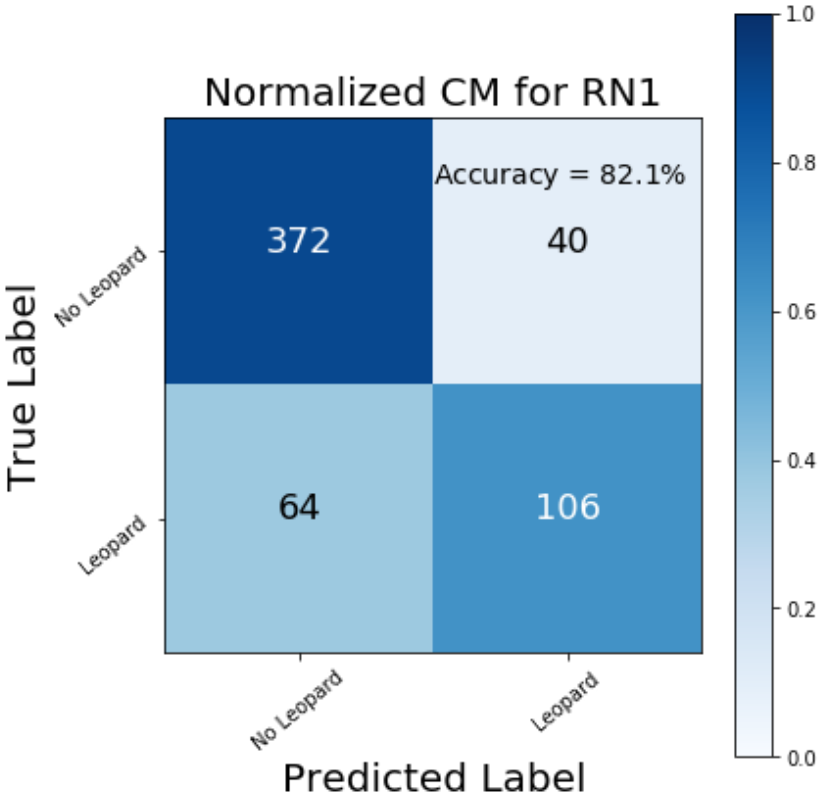
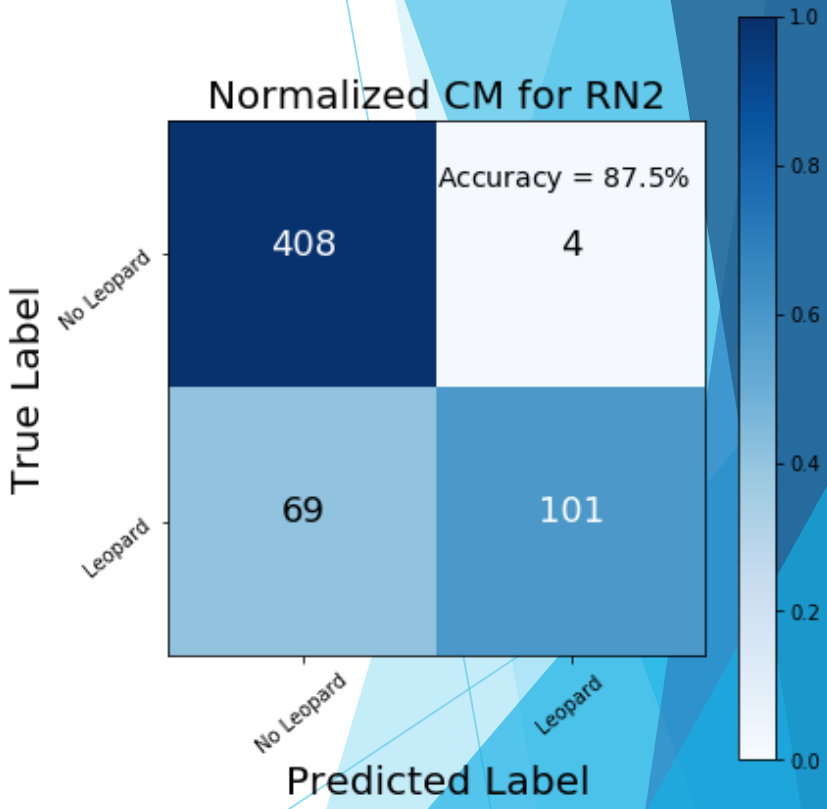
SparkML Classifier
Class 1
Class 2
Gap
Snow Leopard

Performance





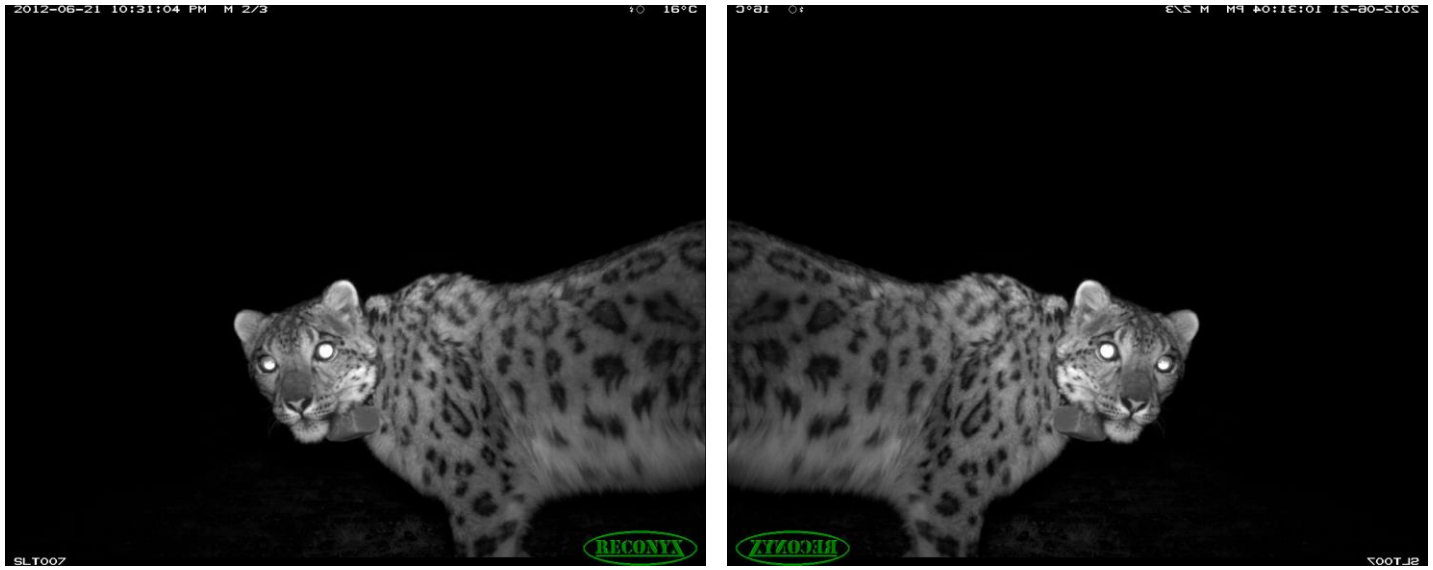


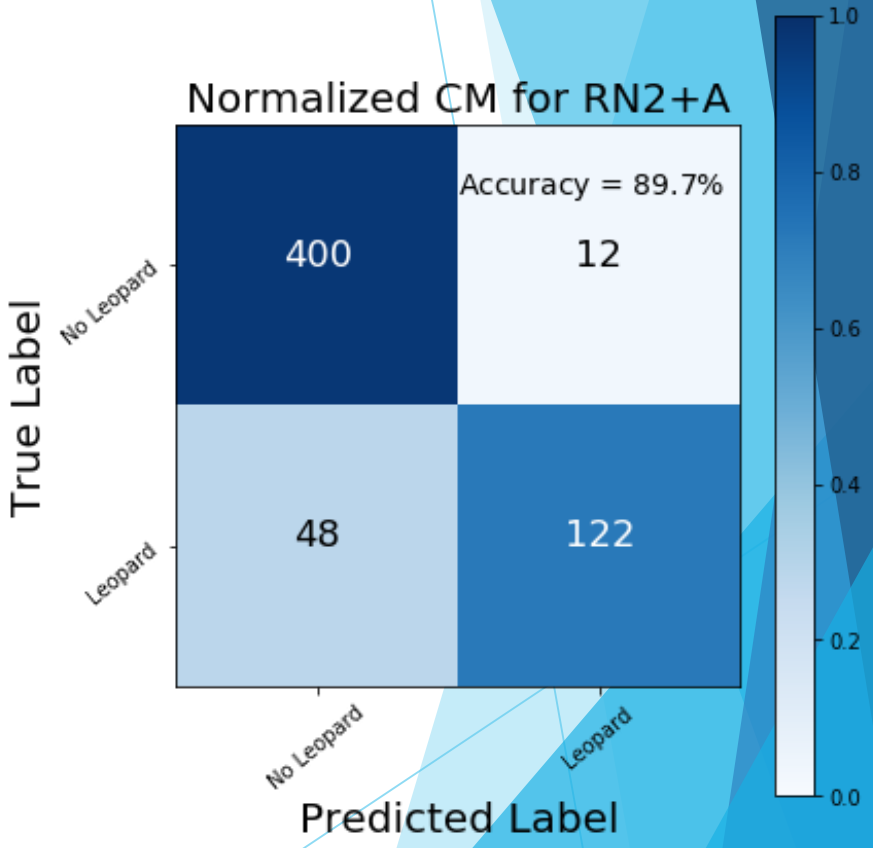
Without Deep Featurization

With Deep Featurization

Further Refinements

- Dataset Augmentation



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2012-06-30 9:03:11 PM M 2/5
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SLT017


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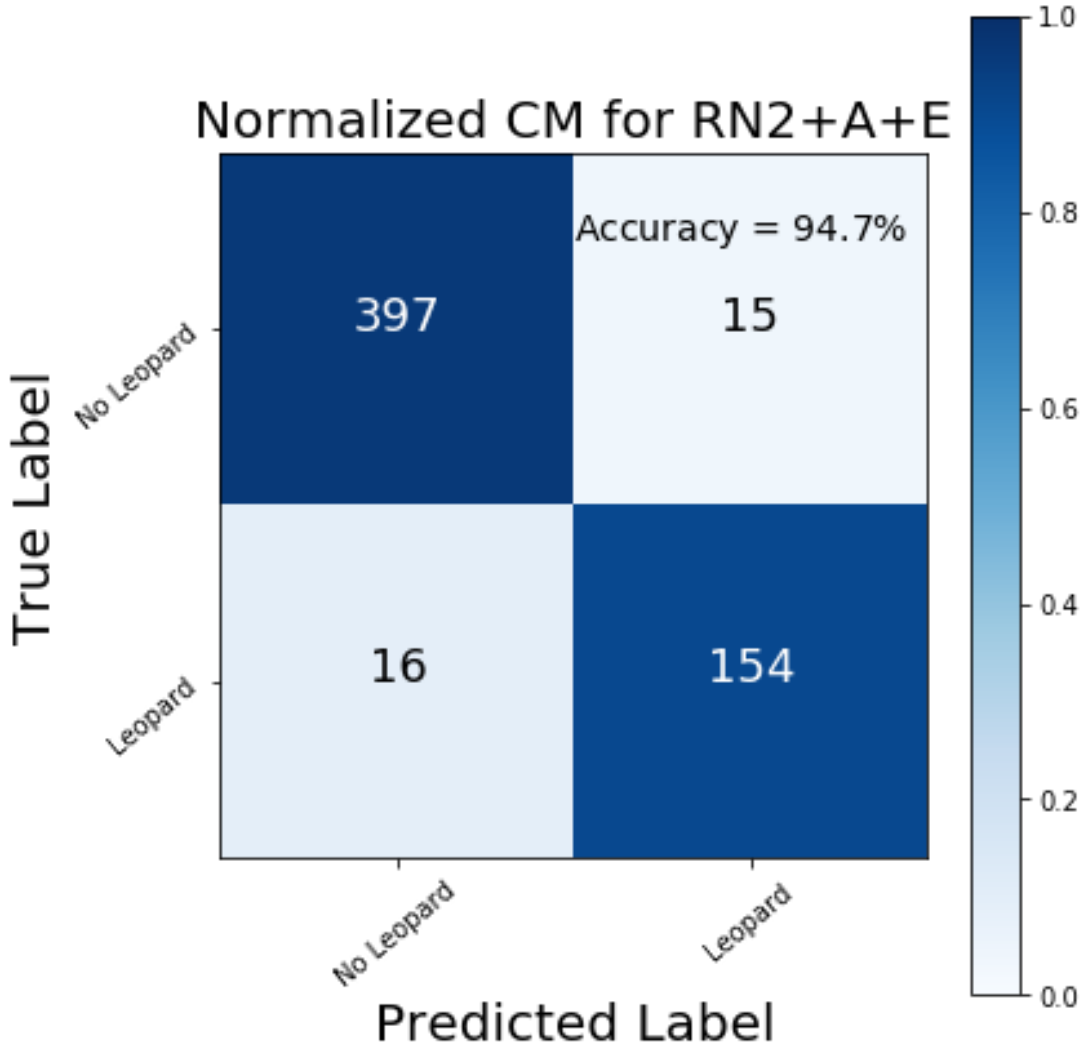
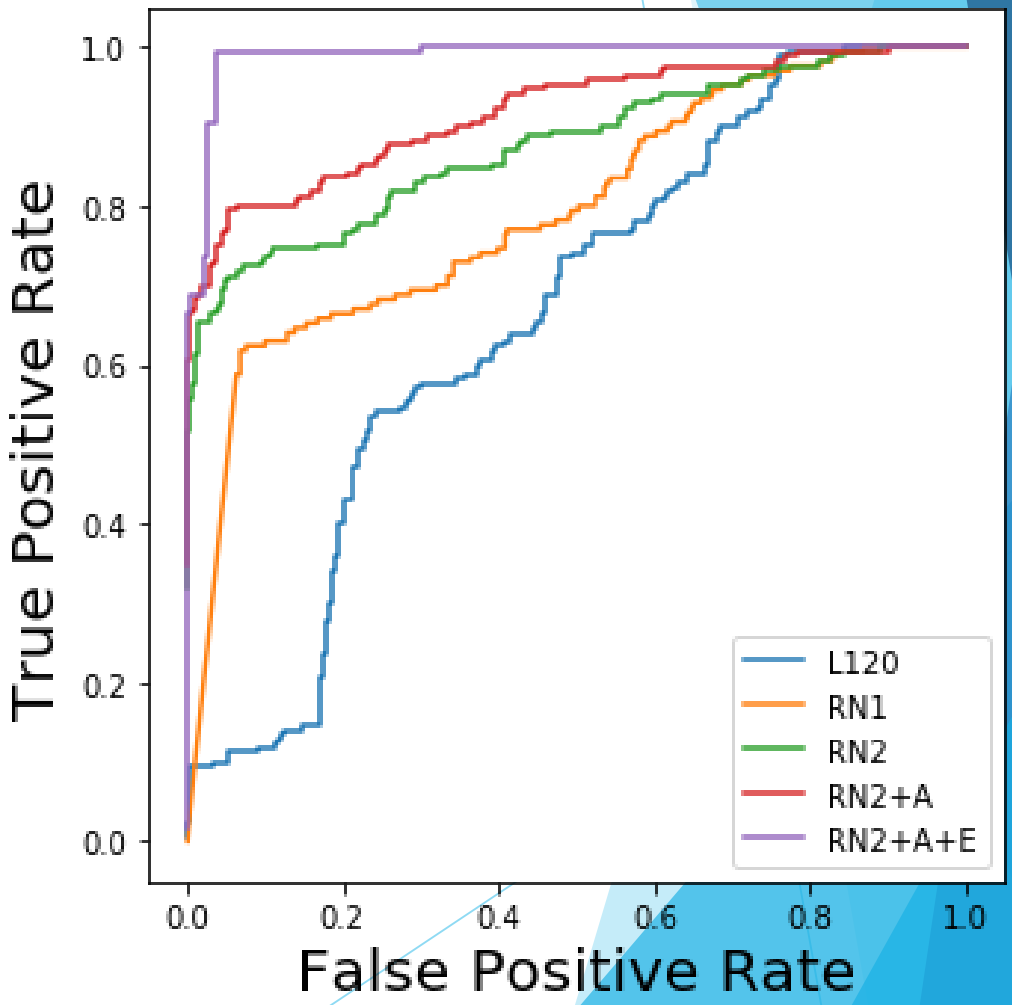
RECONYX
SLT017

Ensembling over Sequences



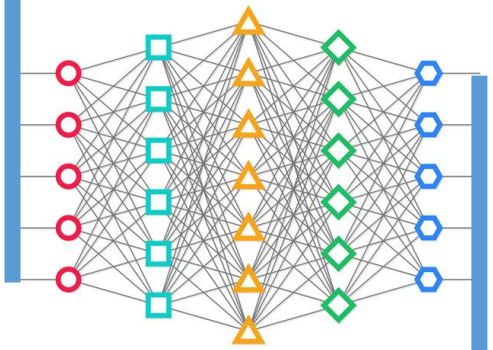
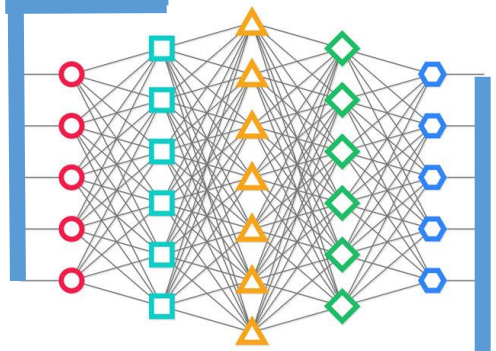





Time

1 2 3 4 5 6

CNTK Pipeline

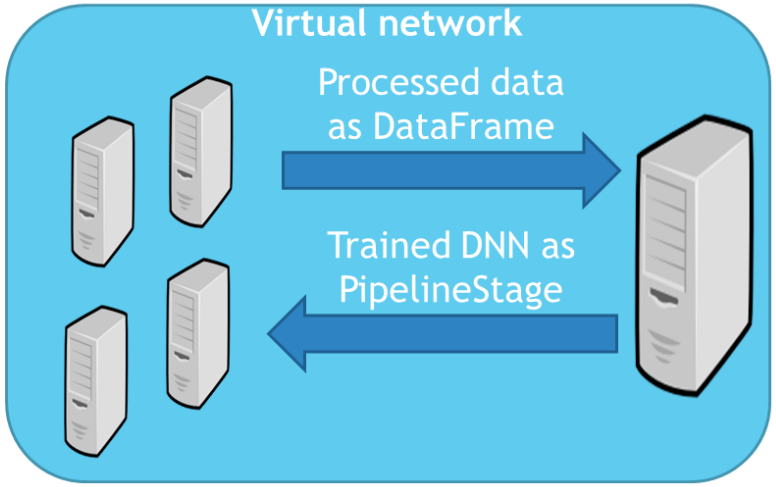



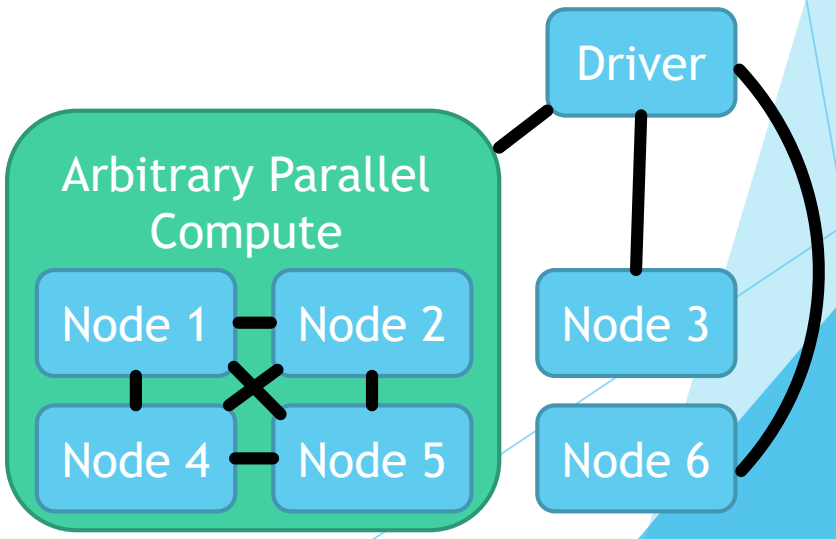
Time

1 2 3 4 5 6

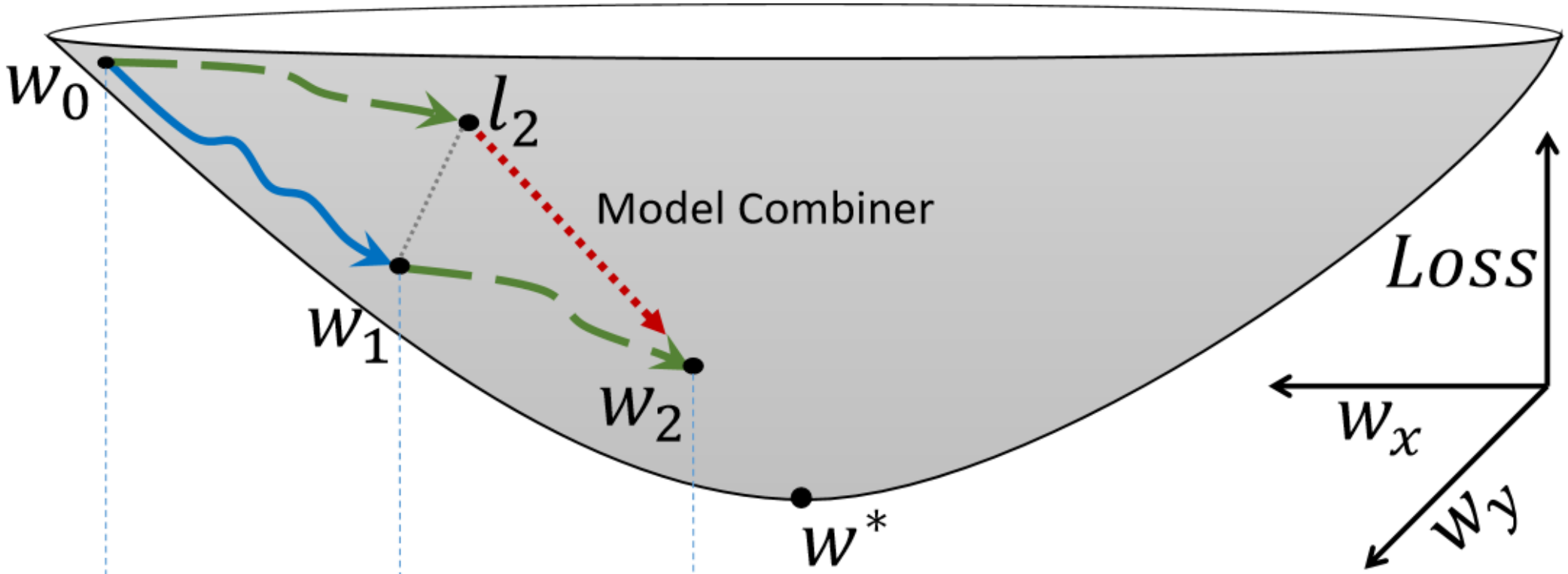
Training

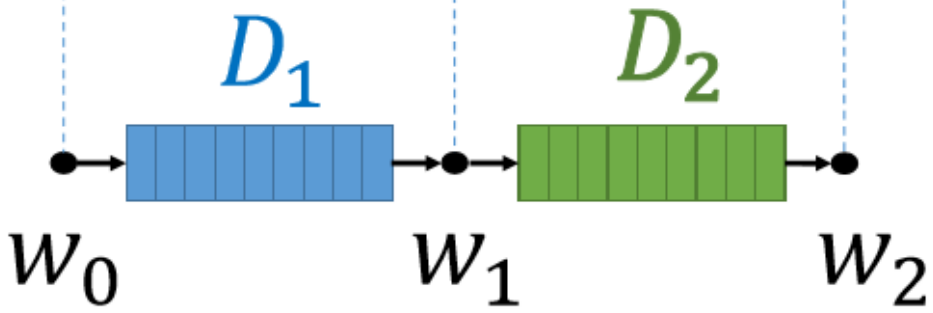
- https://github.com/Azure/mmlspark/tree/gpu
- GPU can give a 10x speedup for network training and eval
- Tether a GPU cluster to spark cluster
- Long Term Goal: Hook into Spark resource manager to request resources for custom jobs: CNTK, LightGBM, etc





Next Steps: Sym SGD and Parallel Training





Maleki, Saeed, Madanlal Musuvathi, and Todd Mytkowicz. "Parallel Stochastic Gradient Descent with Sound Combiners." *arXiv preprint arXiv:1705.08030* (2017).

How you can help

They need more camera surveys!

- 1,700 sq km surveyed of 1,500,000
- $500 will buy an additional camera
- $2,000 will fund a researcher
- Any amount helps!

www.snowleopard.org

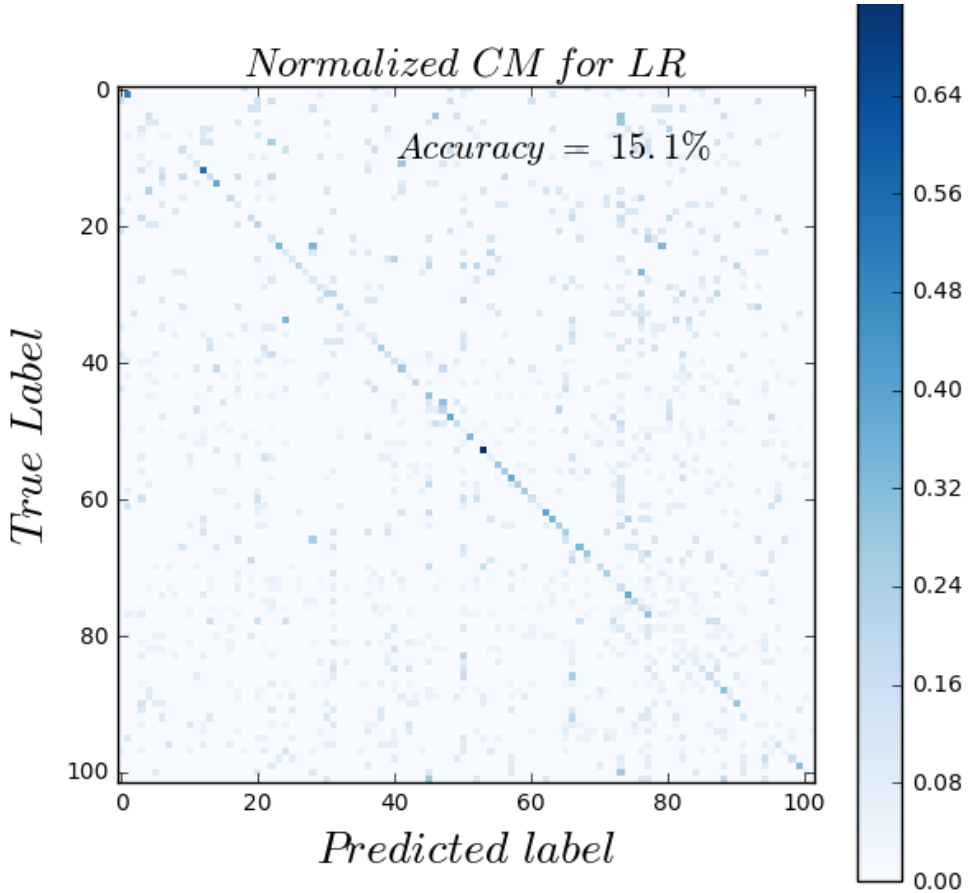
Thanks to

- MMLSpark Team:
  - Akshaya Annavajhala (AK), Danil Kirsanov, Eddie DeLeon, Eli Barzilay, Ilya Matiach, Joe Davison, Maureen Busch, Miruna Oprescu, Ratan Sur, Roope Astala, Sudarshan Raghunathan, Tong Wen, Young Park
- CNTK Team:
  - M. Hillebrand, N. Karampatziakis, W. Manousek, Z. Wang, C. Zhang, Liqun Fun

Where to Learn More

- Snow Leopard Blog Post:
  - https://blogs.technet.microsoft.com/machinelearning/2017/06/27/saving-snow-leopards-with-deep-learning-and-computer-vision-on-spark/
- MSJAR Article: “Massively Parallel Neural Networks with CNTK on Spark”
  - **http://aka.ms/msjar**
- Submitting to PMLR 2017: Flexible and Scalable Deep Learning with MMLSpark
- Sample Notebooks
  - https://github.com/mhamilton723/notebooks/blob/master/SnowLeopard.ipynb
  - https://github.com/Azure/mmlspark/blob/master/notebooks/samples/305%20-%20Flowers%20ImageFeaturizer.ipynb

Without Deep Featurization



With Deep Featurization