Massively Parallel Deep Learning with MMLSpark

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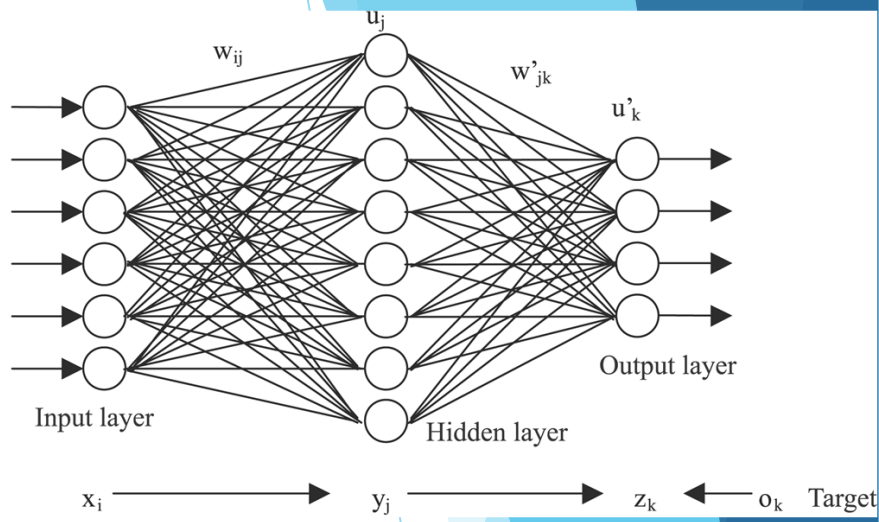
MMLSpark
aka.ms/mmlspark

Agenda

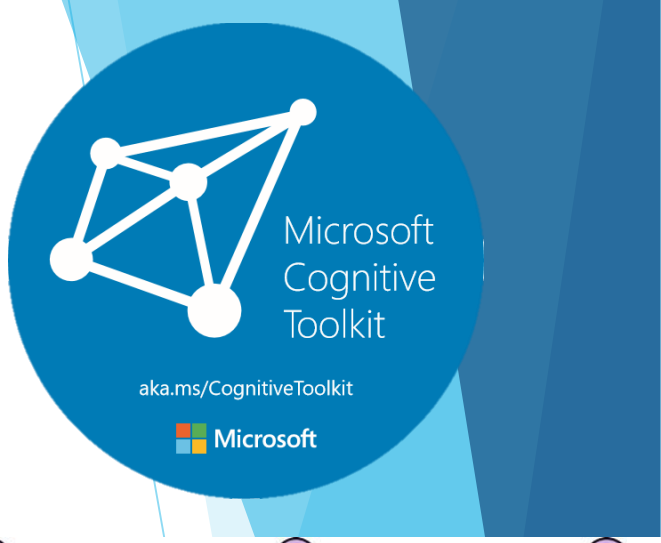
- Background
  - Deep Learning
  - Cognitive Toolkit (CNTK)
  - Apache Spark and SparkML
- MMLSpark
  - Integrating Cognitive Toolkit and Spark
  - OpenCV Spark integration
  - PySpark Wrapper Generation
- Snow Leopard Conservation
  - Transfer Learning
  - MMLSpark Serving
- Future Work
  - Local Interpretable Model Agnostic Explanations

Deep Learning

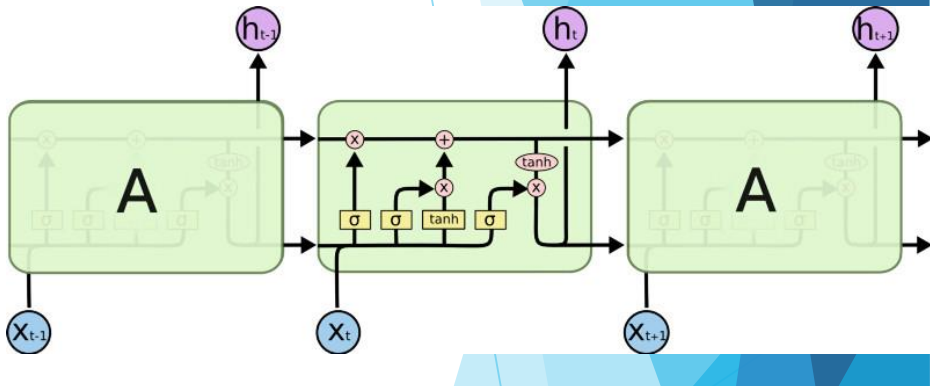
- Originally referred to learning neural networks with many layers
- Now refers to any suitably complicated statistical model trained with gradient descent
- Has become a recent favorite because:
  - Spectacular performance in many domains
  - Quick training w/ gradient descent
  - Low memory footprint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

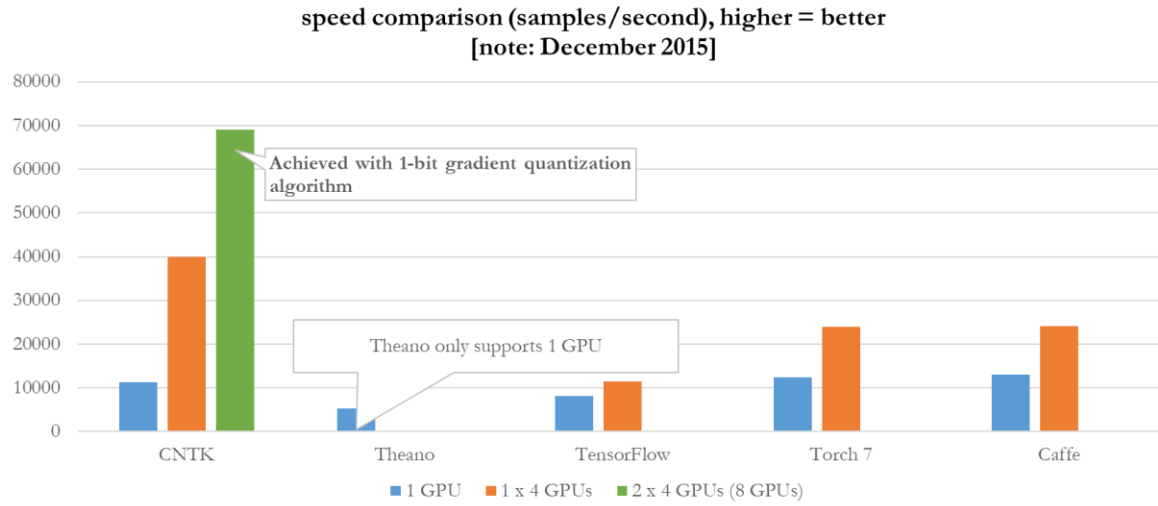


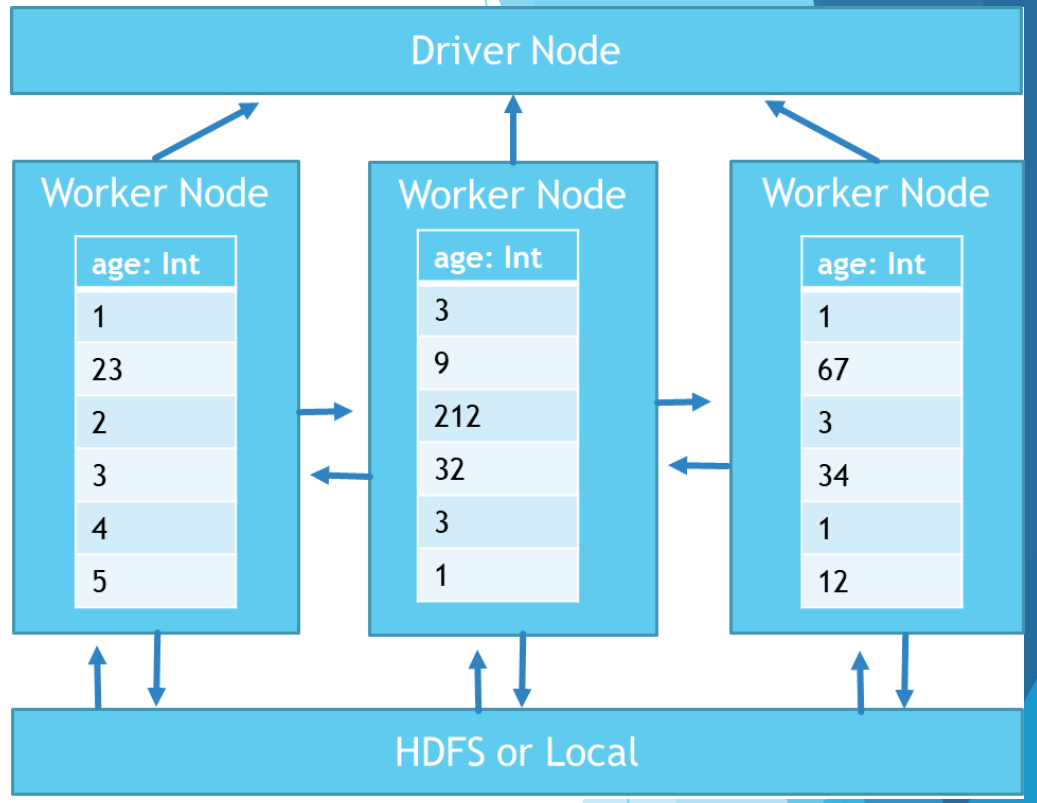
Microsoft Cognitive Toolkit (formerly CNTK) (Dong Yu et al. 2012)



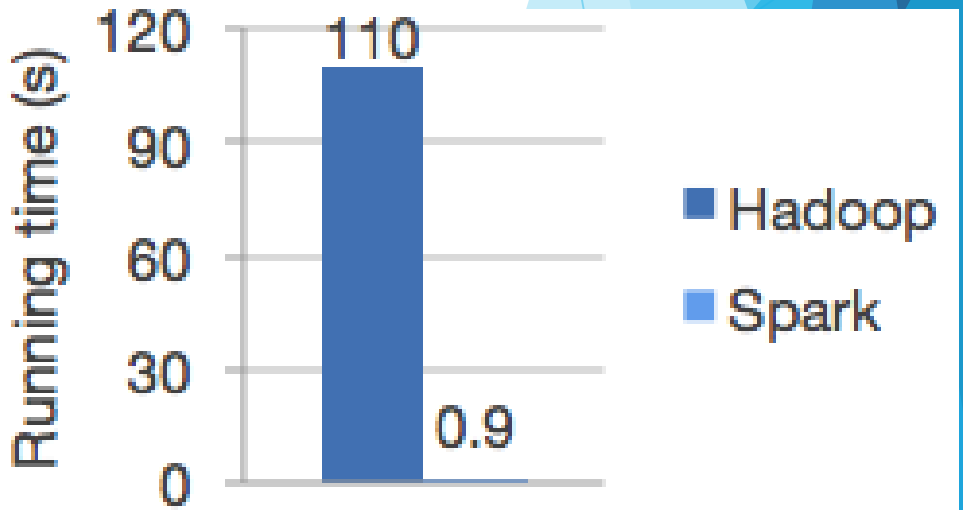
- Microsoft's open-source deep-learning toolkit
- https://github.com/Microsoft/CNTK
- Written in C++, bindings in Python, C#
- Runs over 80% Microsoft internal DL workload
- Can express a huge variety of deep architectures
  - LSTMS, ConvNets, RL, Gans, etc….
- Automatic differentiation
- Compute Agnostic: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







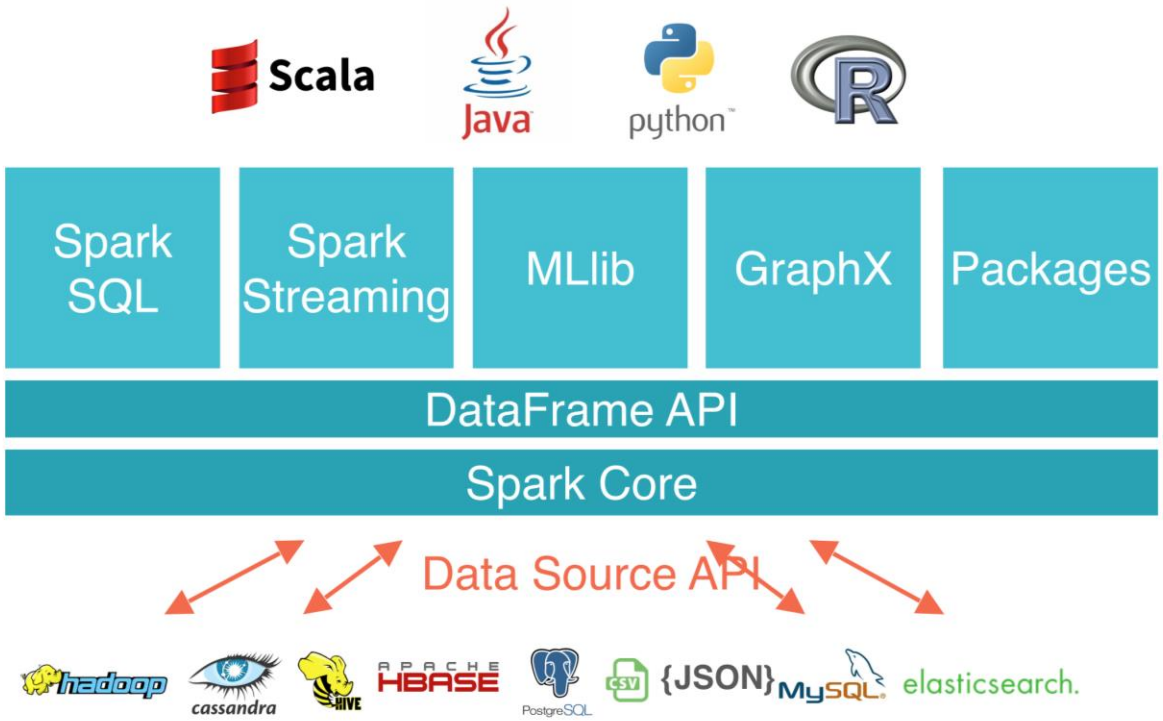
- A **fault-tolerant distributed** computing framework
- Generalizes, optimizes, and combines Map-Reduce and SQL style-operations
- Scales to thousands of machines
- Functional API
- Built in Scala, but has bindings in Python, R, Java, C#, F#
- Has a flourishing community
  - SparkML
  - GraphX
  - Structured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



Spark/SparkML

- Large scale parallelism
- Fault tolerance
- Auto-scaling/ elasticity
- High throughput streaming
- Operates in Scala (On the JVM) with bindings

CNTK

- High speed GPU/CPU computations
- Automated gradient calculations
- Flexible language for defining cutting edge models
- Operates in C++ with bindings

Microsoft Machine Learning For Apache Spark

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

https://aka.ms/mmlspark

MMLSpark

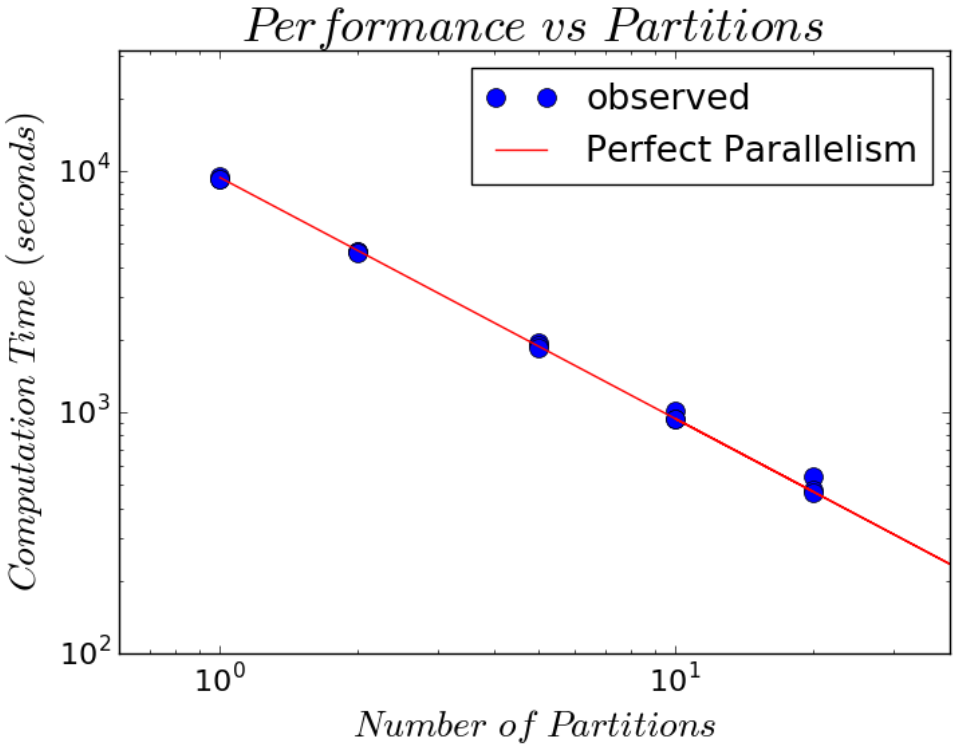
aka.ms/mmlspark

- Open Source
  - Contributions welcome!
  - Get started with our docker image + data science examples/course **aka.ms/mmlspark**
- **Integrates and unifies Spark, CNTK, and OpenCV, LightGBM, HTTP, and more**
- Tons of other useful abstractions and tools:
  - **Automatic Python/R code generation**, Auto-Featurization, Trained DNN Repository, High Performance Web Deployments

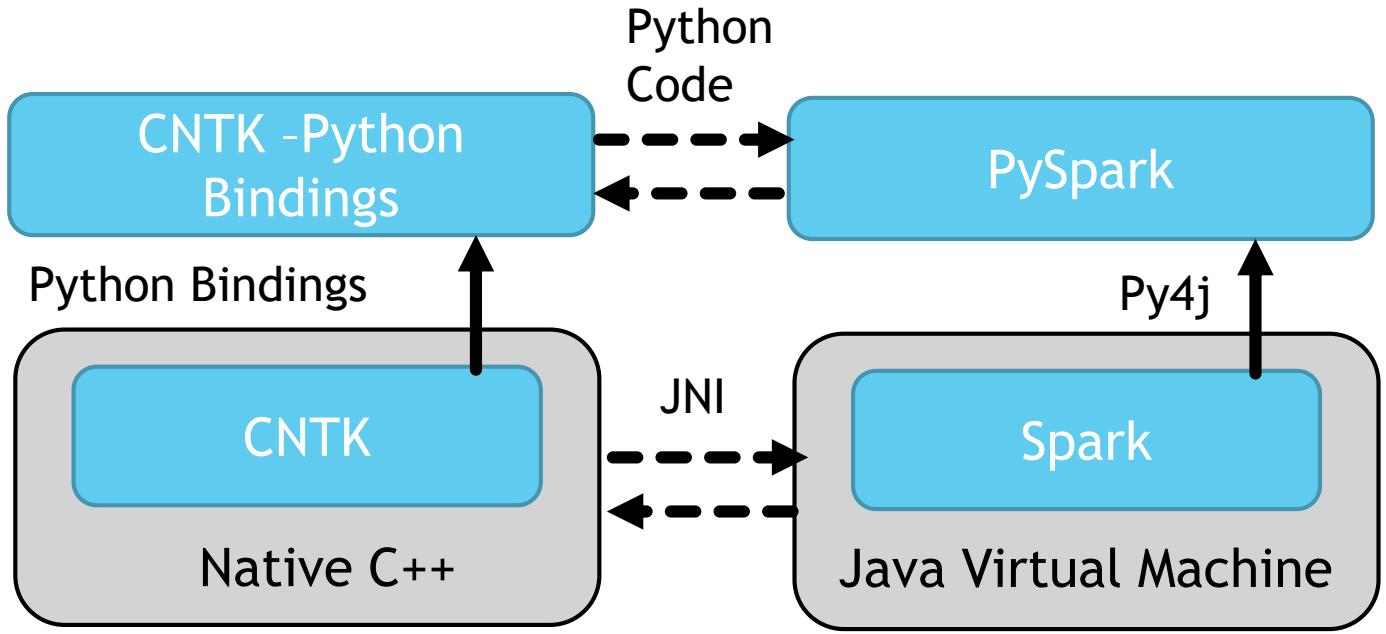
Cognitive Toolkit on Spark

- We have created a SparkML transformer for evaluating ***any*** CNTK computation graph on a spark cluster
- We take care of
  - Distributing + loading native libraries
  - Distributing model to all workers
  - Feeding the network using Spark's data
  - Minibatching for computational efficiency
- Performance scales near perfectly with Nodes
- Integrates naturally with SparkML + Spark Streaming ecosystem

```
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)
```



Unifying CNTK and Spark: What's under the hood



- Can either integrate at the python level
- Or at the deeper Java level
- Java level allows CNTK to target all spark bindings
- Direct Java integration means less data transfer

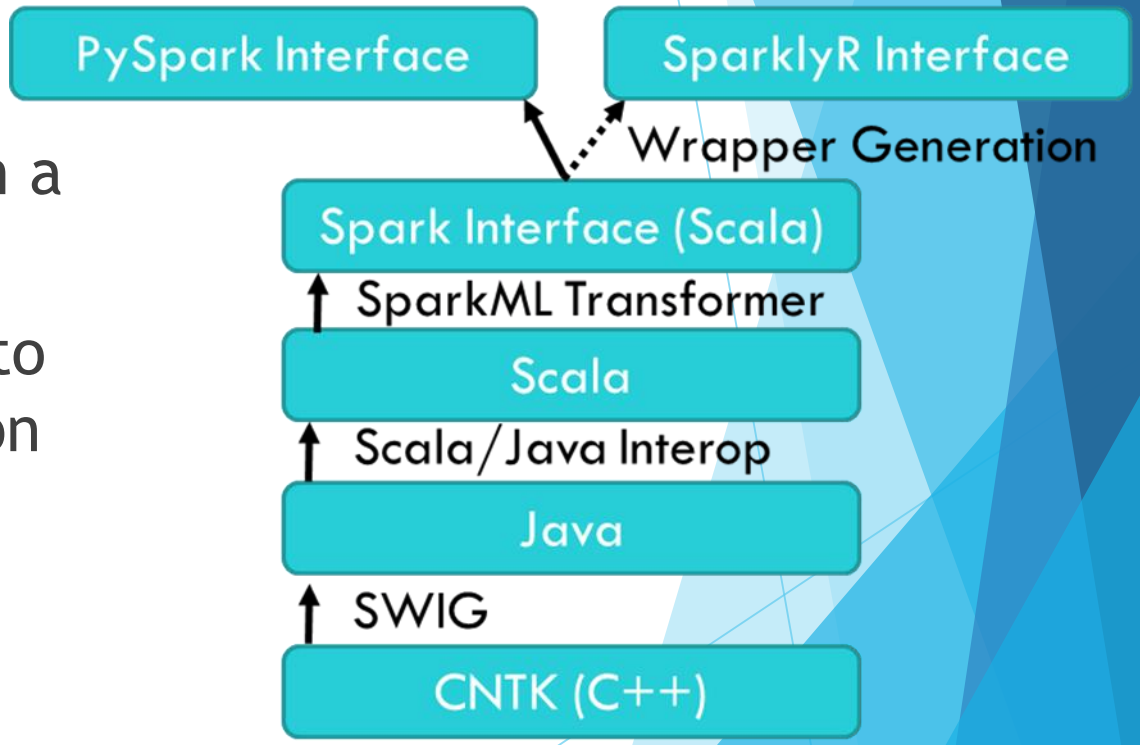
Cognitive Toolkit's Java Bindings

- Cognitive Toolkit is written in C++ but has bindings in Python, 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);
```

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

Snow leopard no longer 'endangered'

14 September 2017 Share

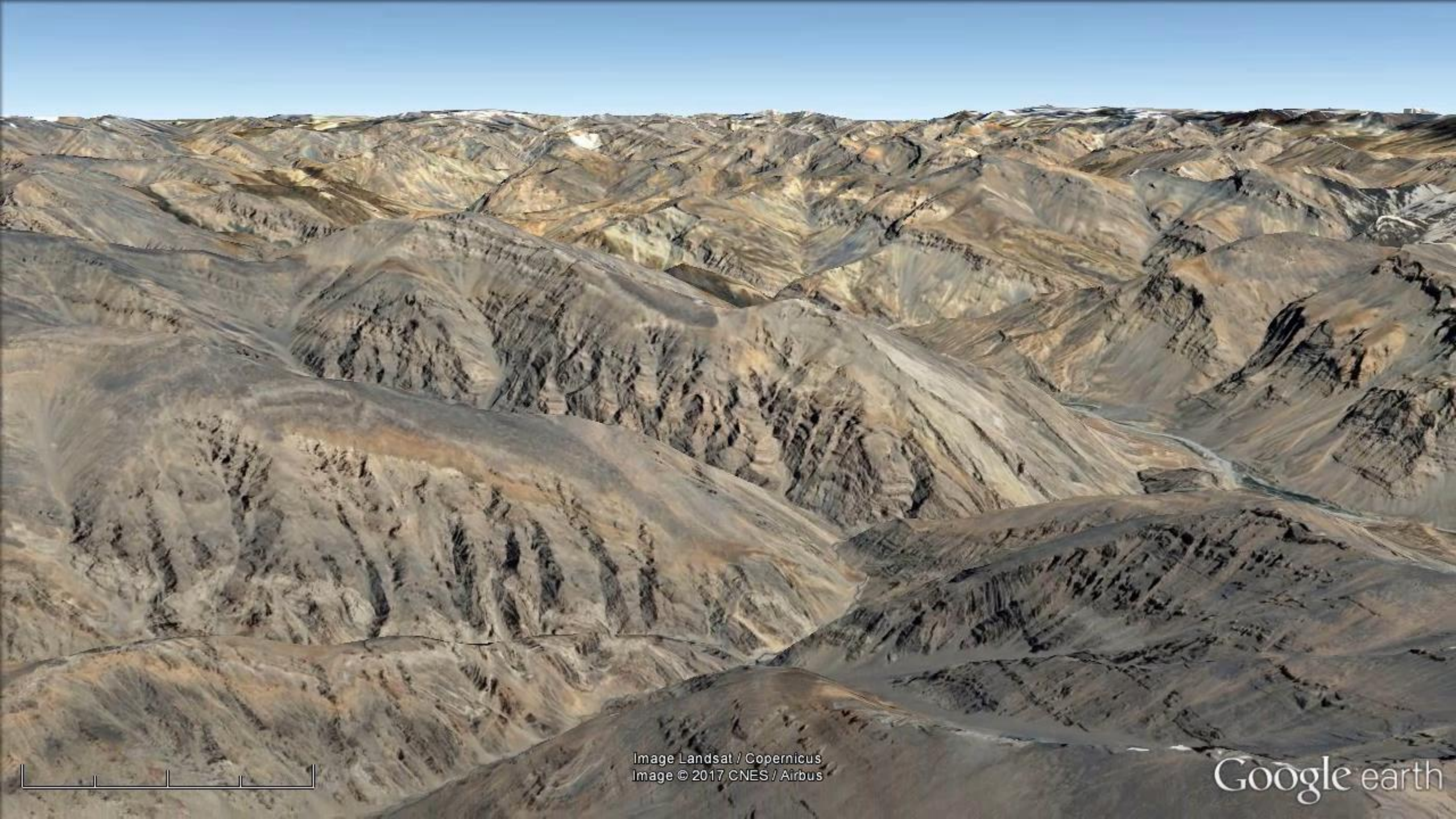
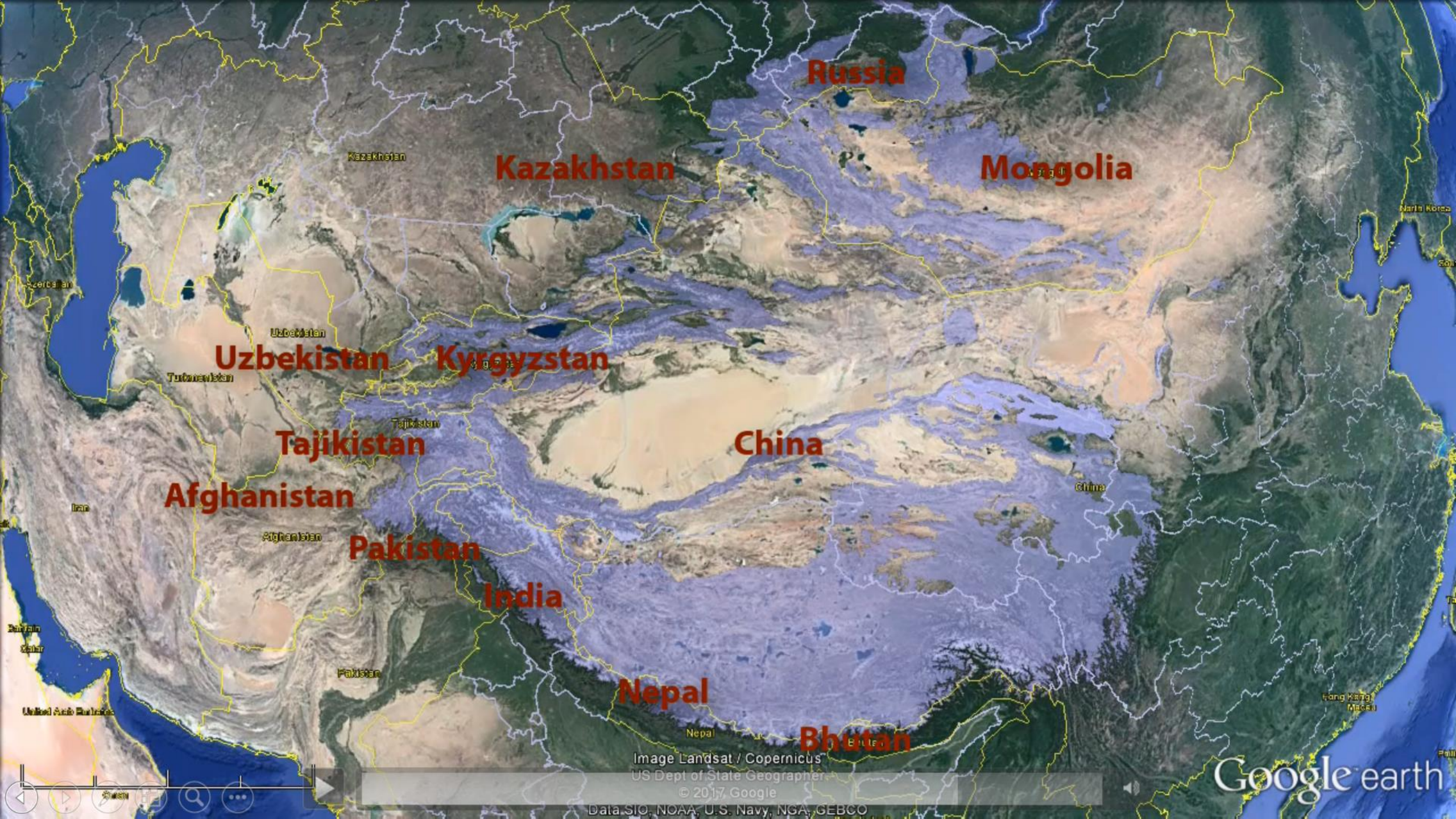


Image Landsat / Copernicus
Image © 2017 CNES / Airbus
Google earth


Russia
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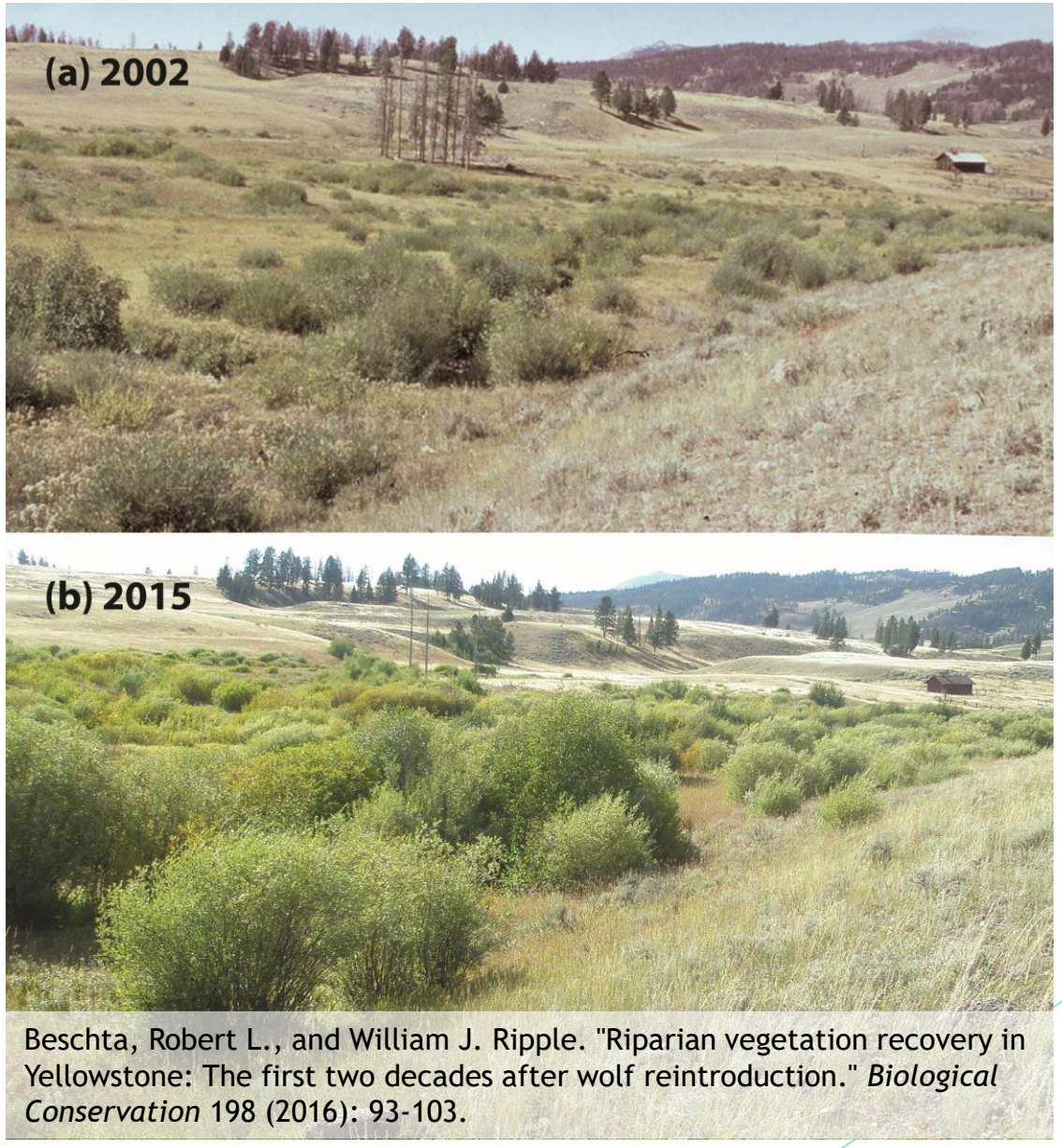
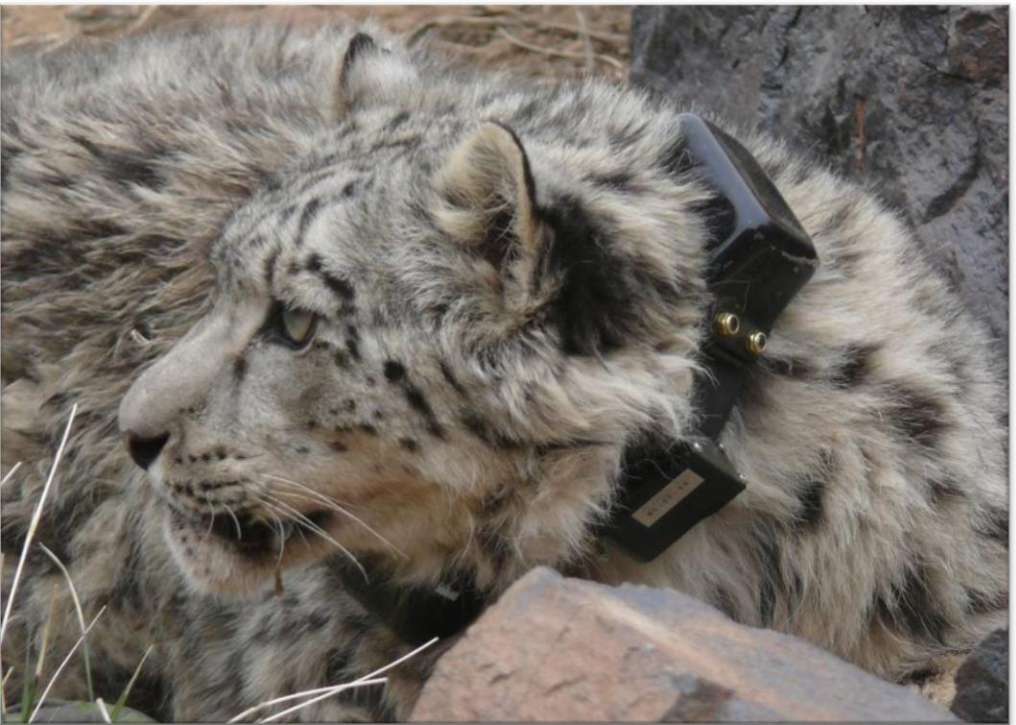
The Impact of Apex Predators



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.

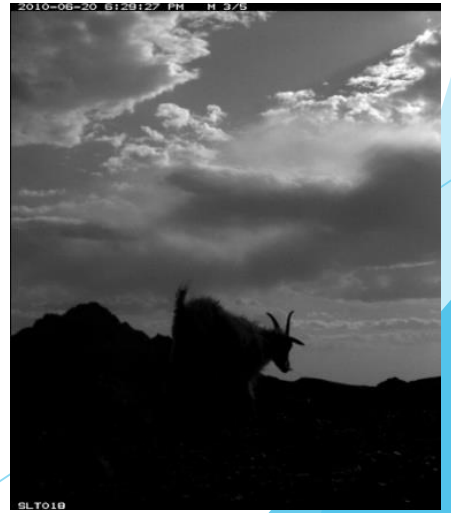
Gathering Leopard Data

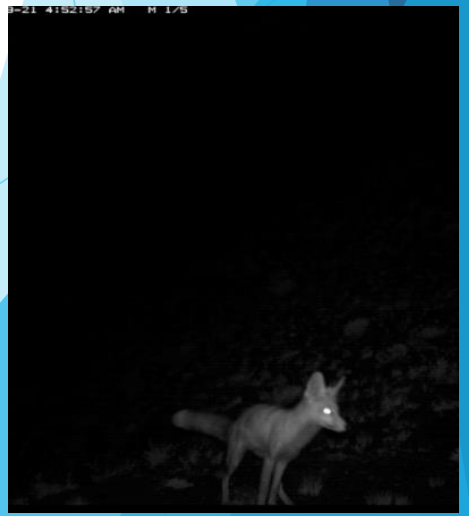
- 23 leopards collared in 9 years
- 42 camera traps over 1,700 sq km
- ~1.3 mil images

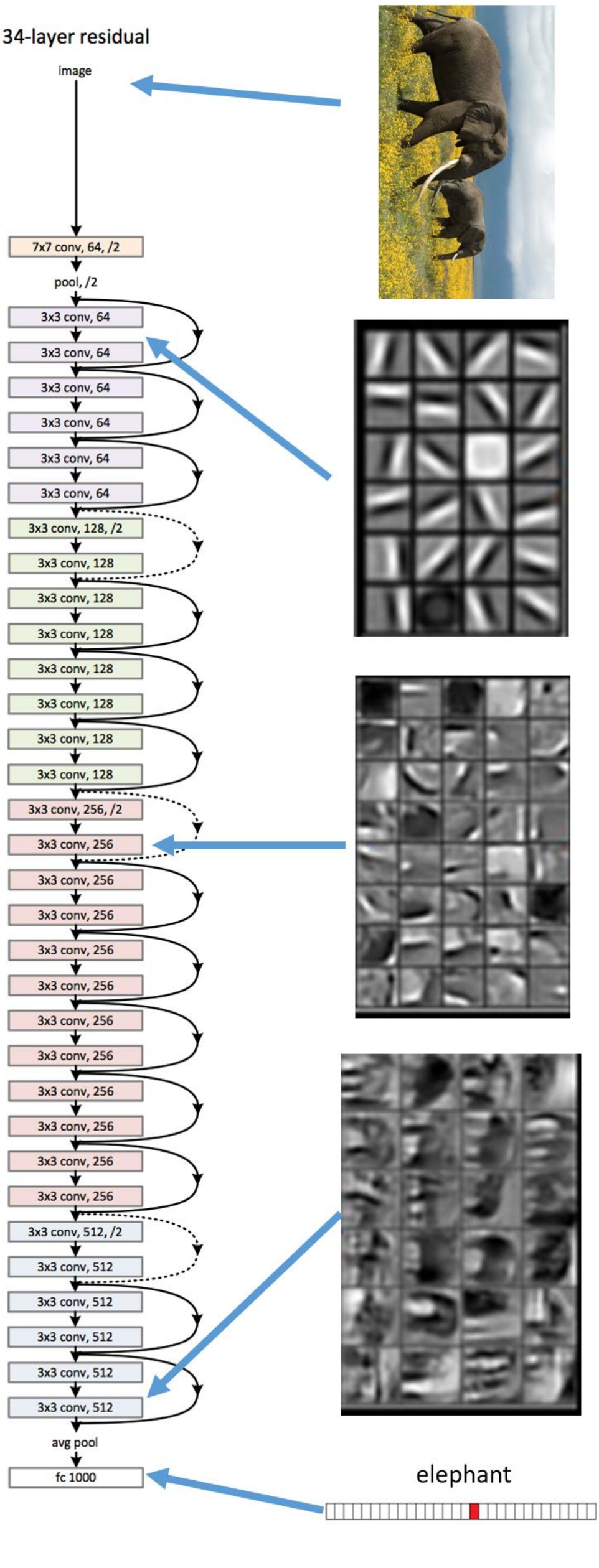


Camera Trap Images

Manually classifying 20k images took 300 hours → 1.3 million will take 19,500 hours



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pool, /2
3x3 conv, 64
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3x3 conv, 128
3x3 conv, 128
3x3 conv, 256, /2
3x3 conv, 256
3x3 conv, 256
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avg pool
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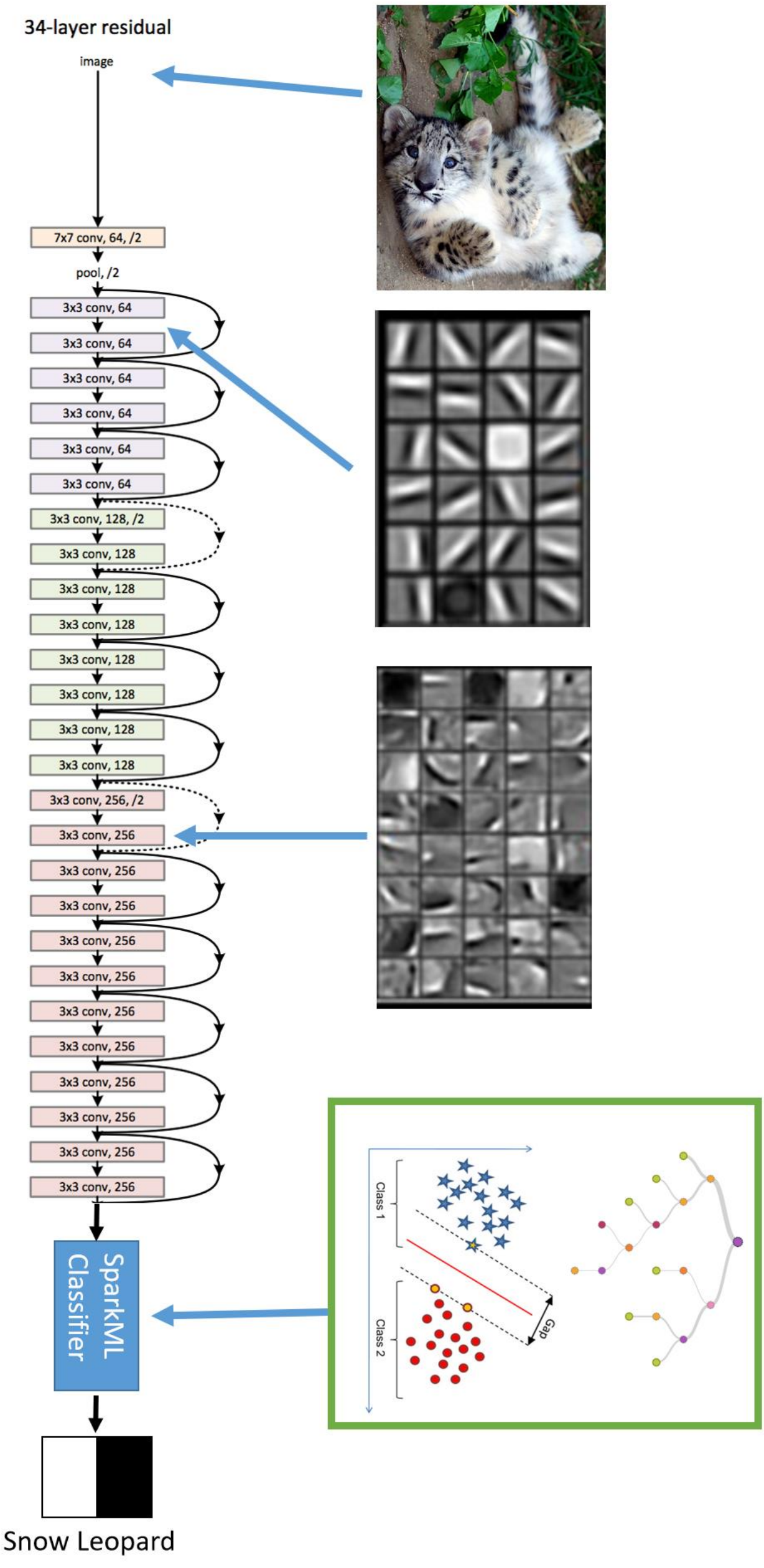
elephant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3x3 conv, 256
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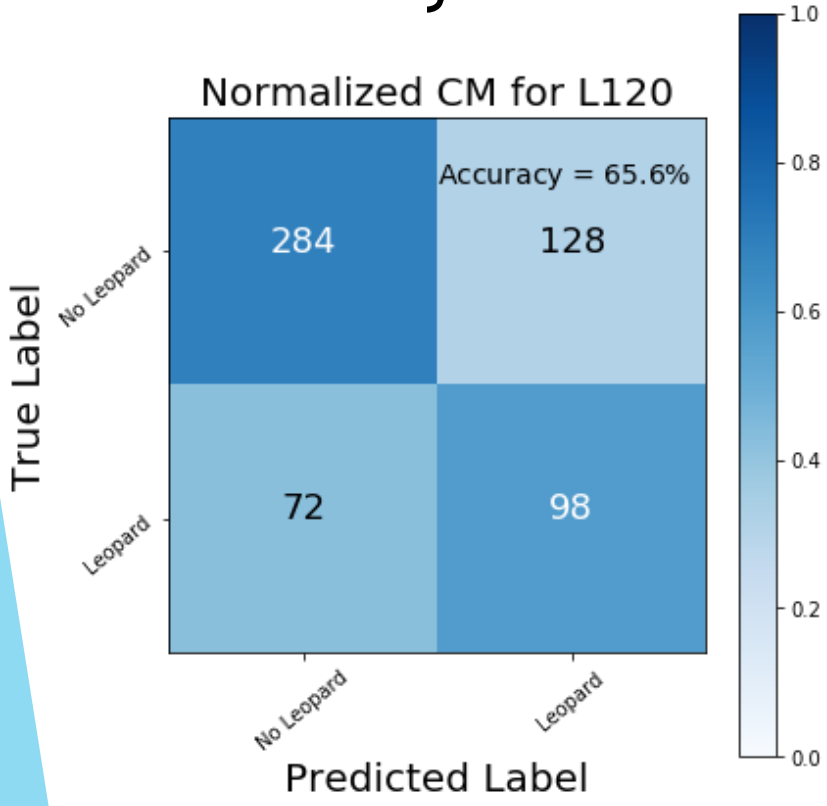
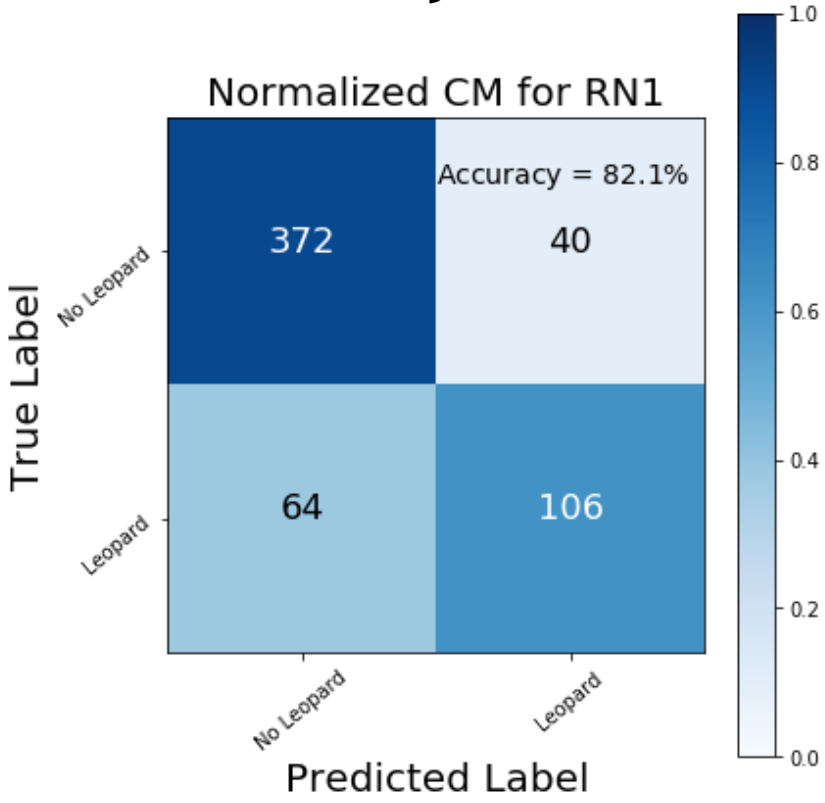
SparkML Classifier
Class 1
Class 2
Gap
Snow Leopard

Performance

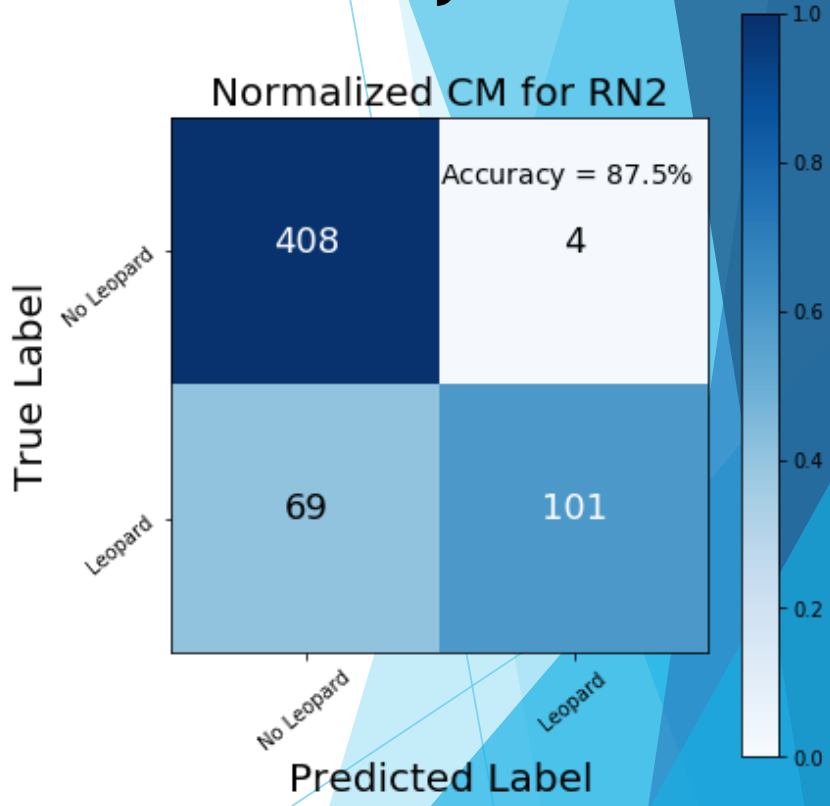
Accuracy 65.6%



Accuracy 82.1%



Accuracy 87.5%



Without Deep Featurization

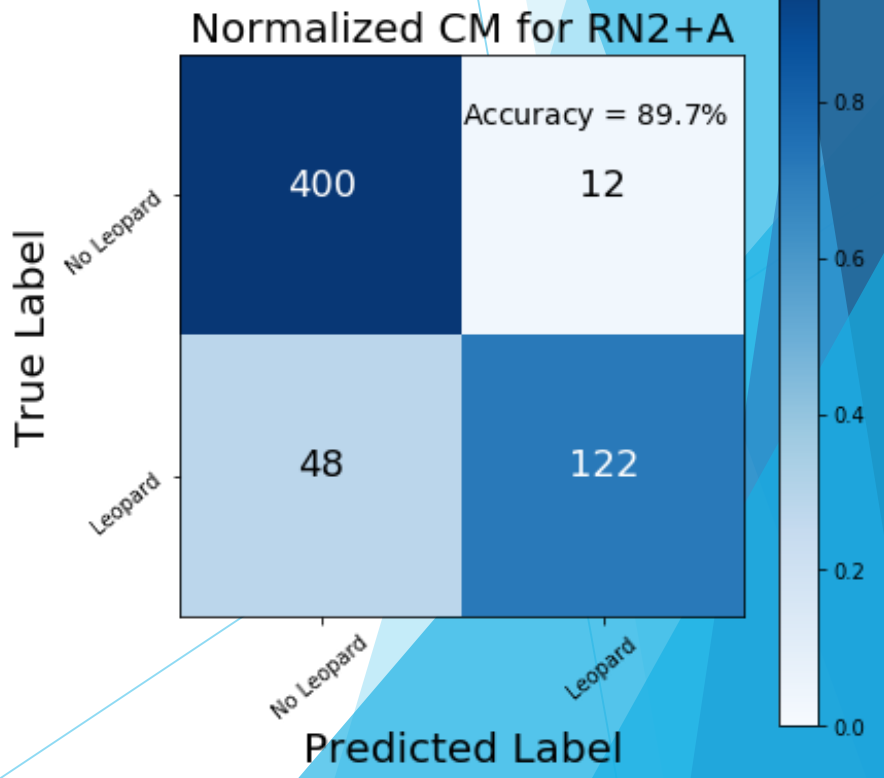
With Deep Featurization

Further Refinements

- Dataset Augmentation

```
ia = mml.ImageSetAugmenter(inputCol="images", outputCol="images")
pipe = Pipeline(stages=[ia, featurizer,classifier])
```

Accuracy 89.7%



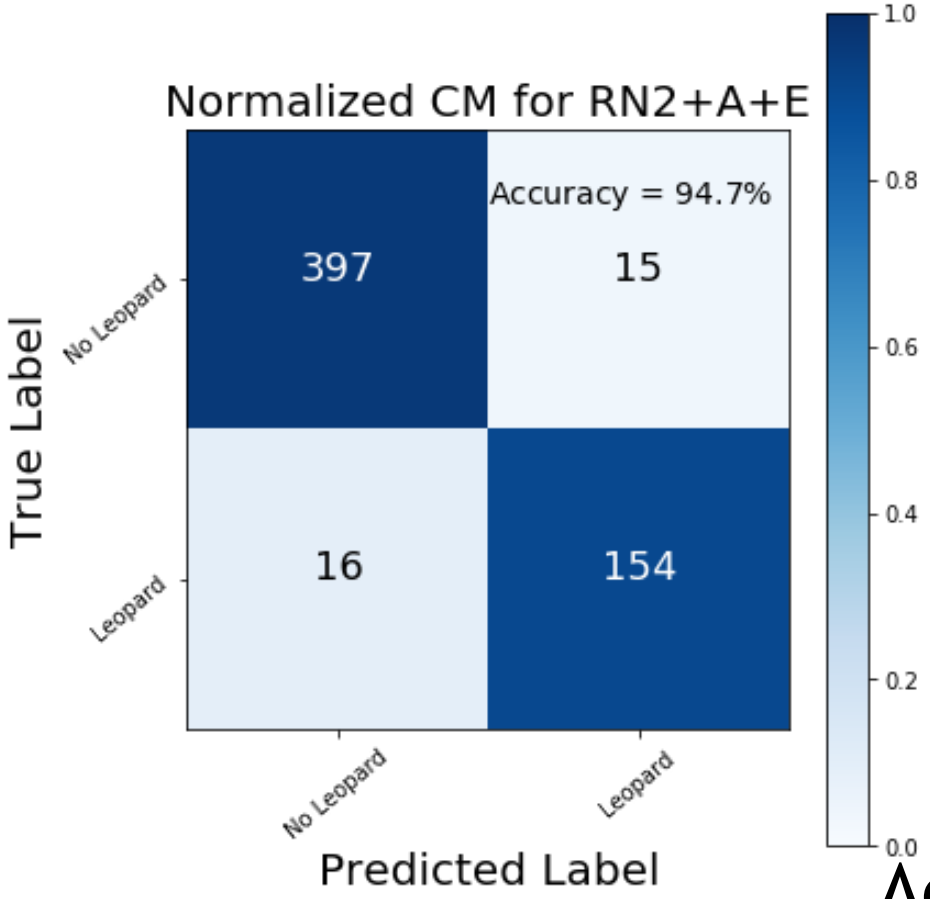

2012-06-30 9:03:10 PM M 1/5
24°C
RECONYX
SLT017

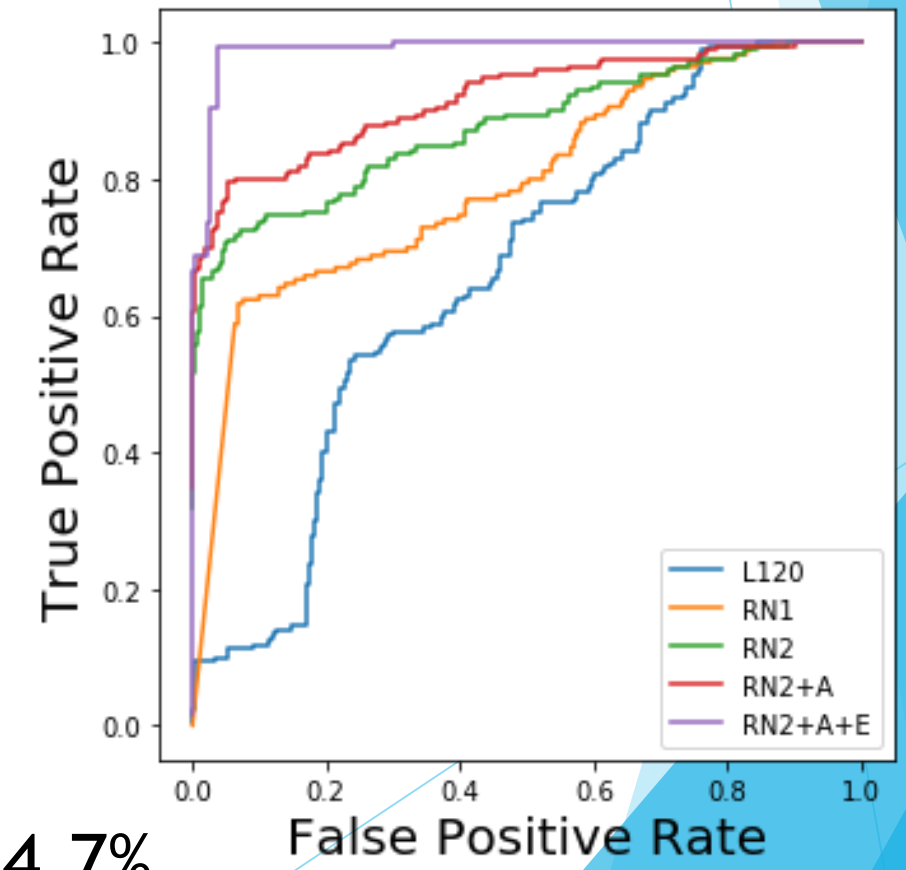

2012-06-30 9:03:11 PM M 2/5
24°C
RECONYX
SLT017


2012-06-30 9:03:12 PM M 3/5
24°C
RECONYX
SLT017

Ensembling over Sequences

```
ebk = mml.EnsembleByKey(
    keys=["group", "filename"],
    cols=["prob"],
    colNames=["mean(prob)"])
pipe = Pipeline(stages=[ia, featurizer, classifier, ebk])
```

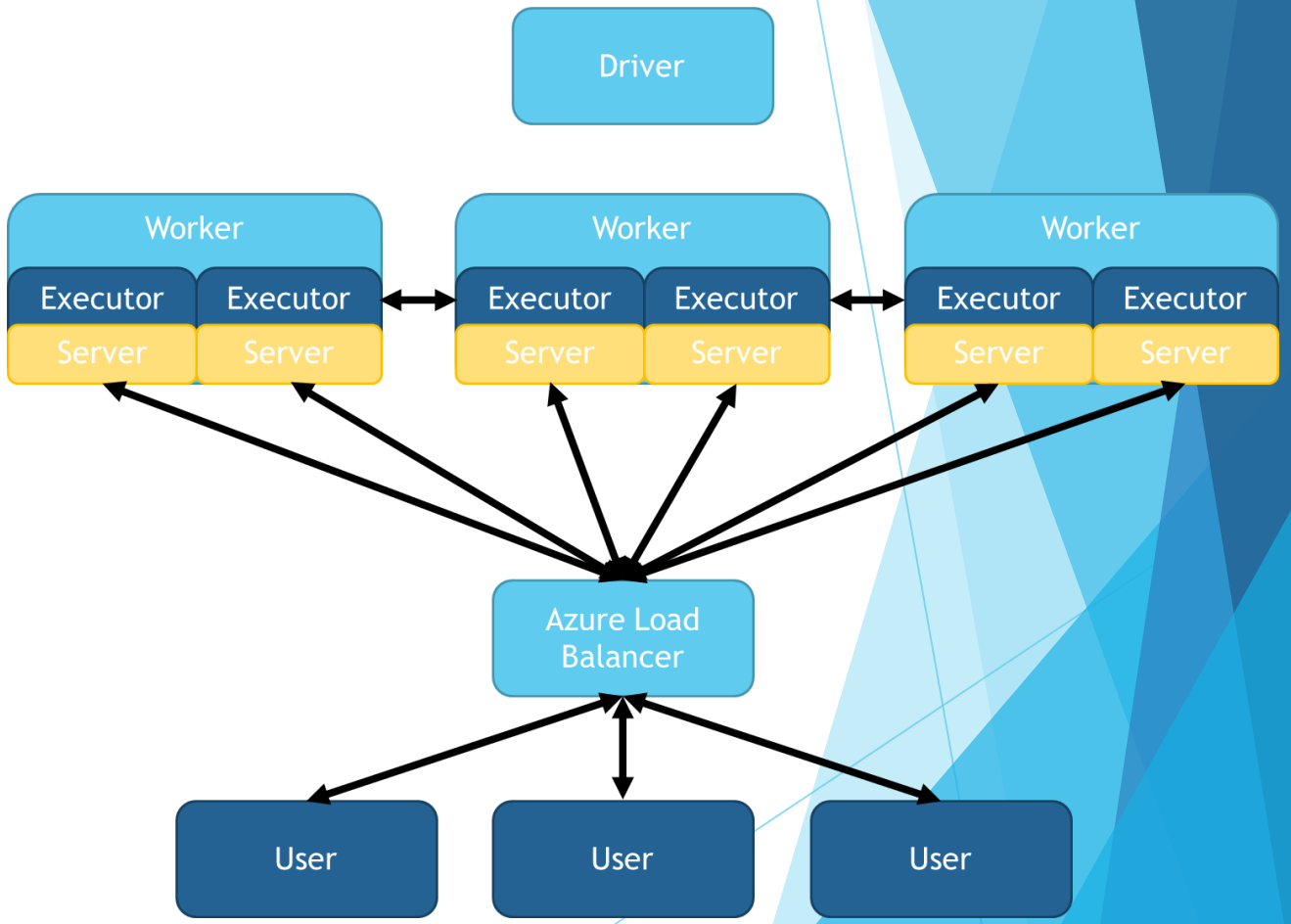




Accuracy 94.7%

MMLSpark Serving

- Scalable, fault-tolerant, and convenient RESTful services
- Simplest and most efficient way to operationalize spark models on any Spark platform
- Available in Python, Scala, and R
- Parallel at every level:
  - Multi-threaded, multi-JVM, multi-node

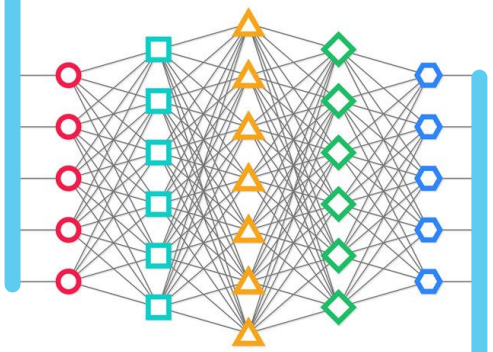


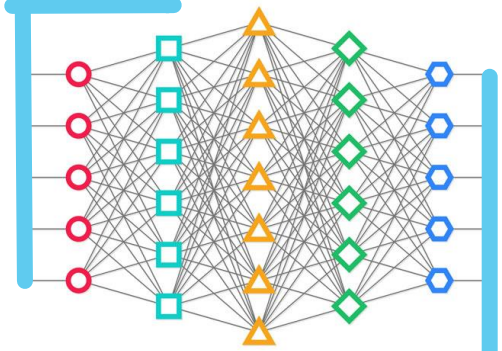



Time

1 2 3 4 5 6

CNTK Pipeline





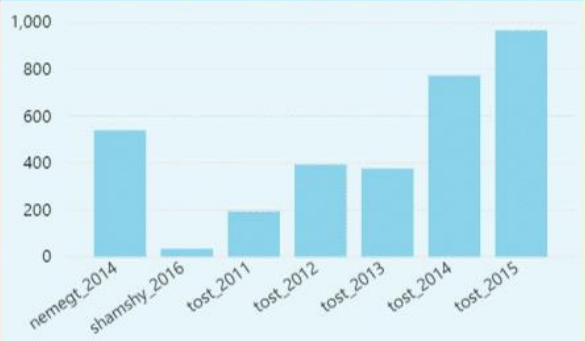
Time

1 2 3 4 5 6

Power BI | My Workspace > Snow Leopard Dashboard

File | View | Edit report | Explore | Refresh | Pin Live Page | Press F11 to exit full screen | Usage Metrics | View related | Subscribe

Total	Leopards	Other
51.88K	3274	48.61K



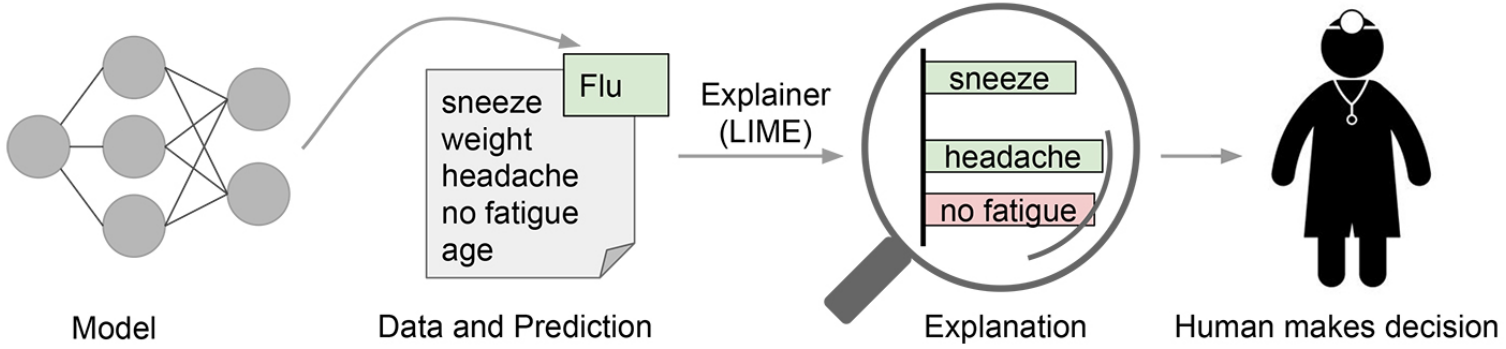
Survey Selector

- Select All
- nemegt_2014
- shamshy_2016
- tost_2011
- tost_2012
- tost_2013
- tost_2014

FILTERS

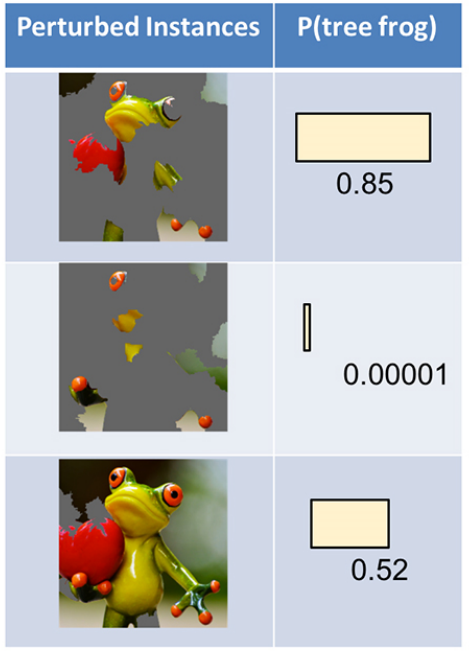
Page 1

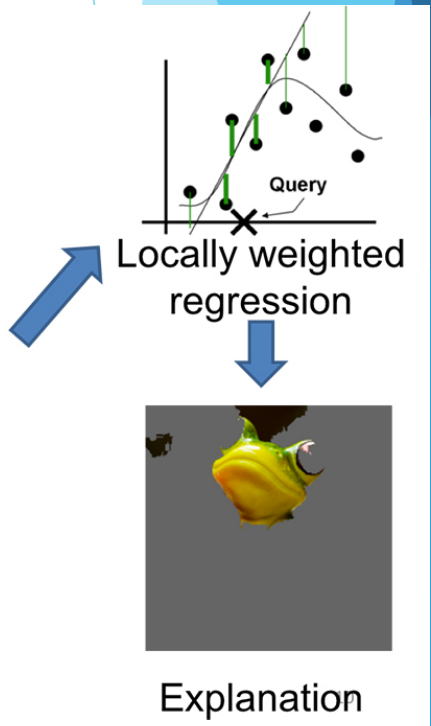
Ongoing work: Local Interpretable Model-Agnostic Explanations (LIME)



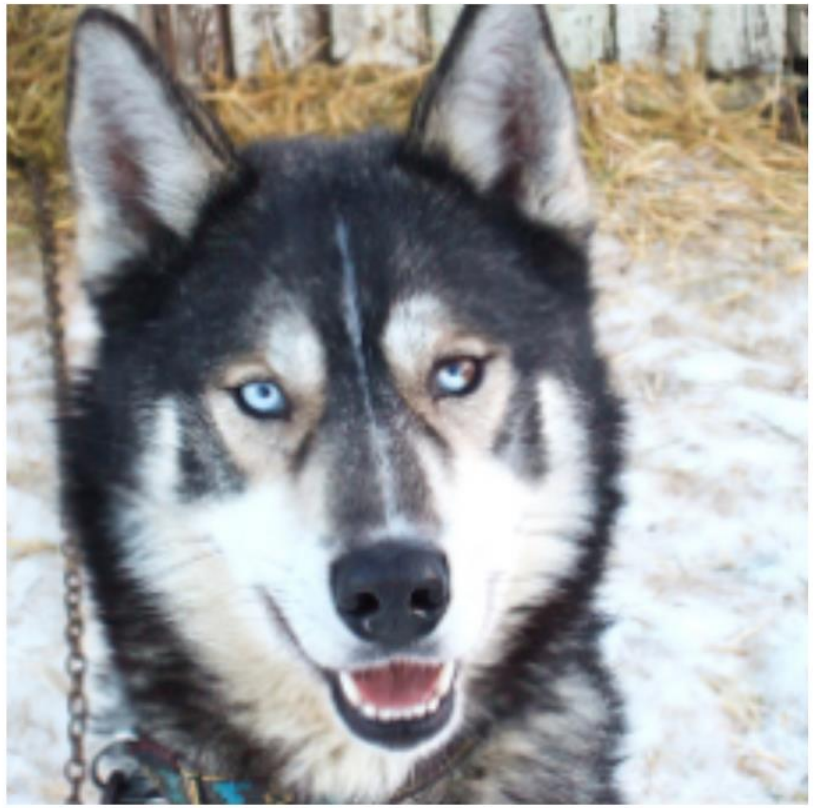
Interpretable Components

Original Image
P(tree frog) = 0.54





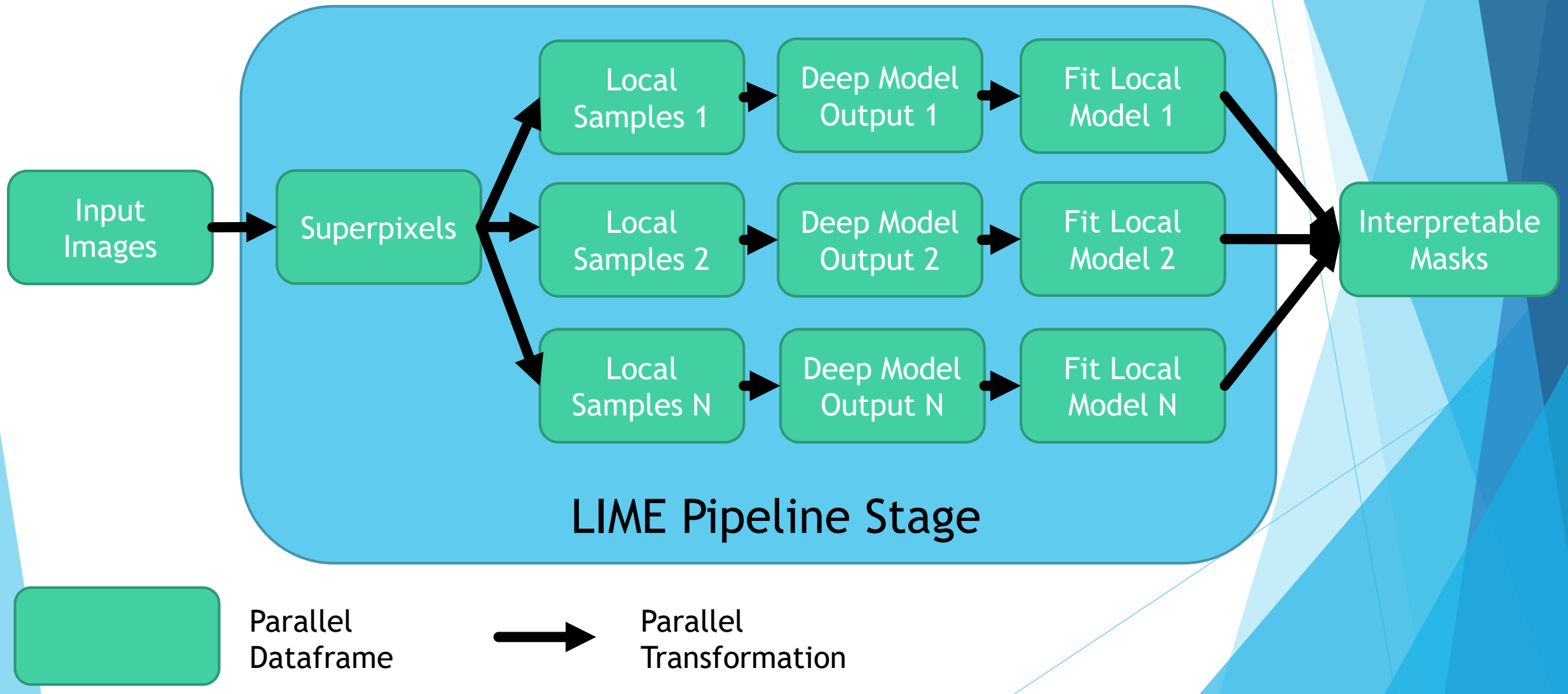
Error Detection



(a) Husky classified as wolf

(b) Explanation

LIME on Spark



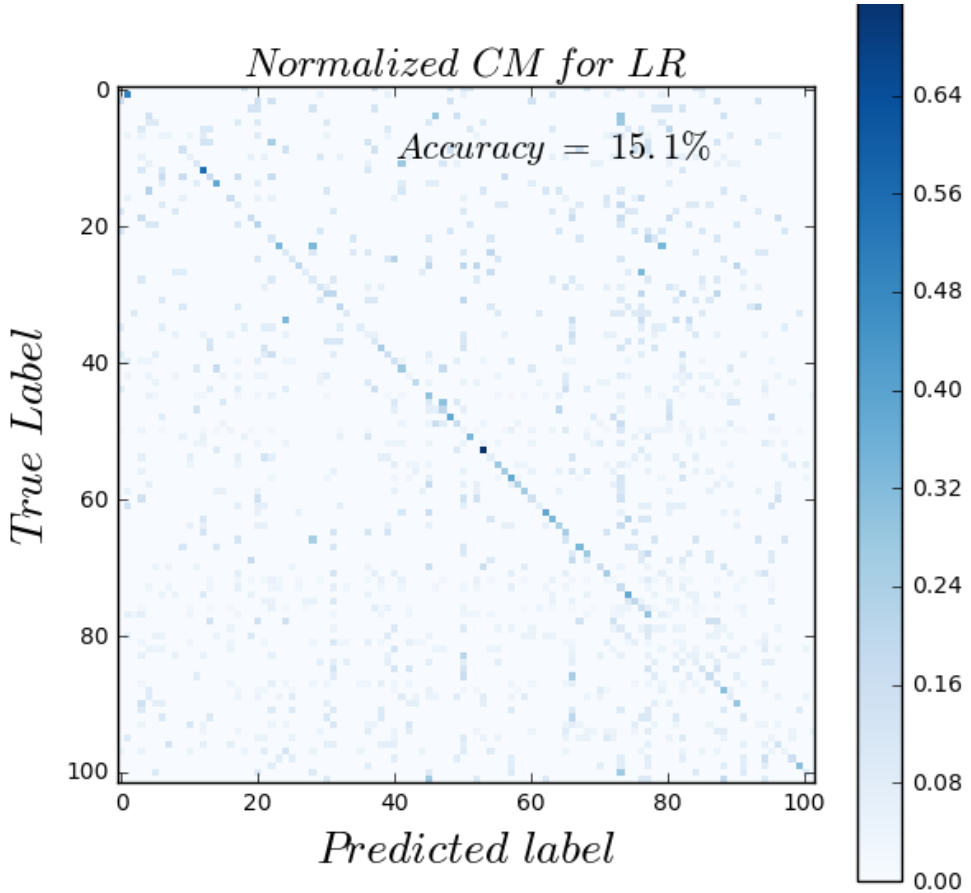
Thanks to

- MMLSpark Team:
  - **Ben Brodsky**, 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, Manik Jindall

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**
- Flexible and Scalable Deep Learning with MMLSpark (in review in PMLR):
  - https://arxiv.org/abs/1804.04031
- 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