A Predictive Analytics Workflow on DICOM Images using Apache Spark

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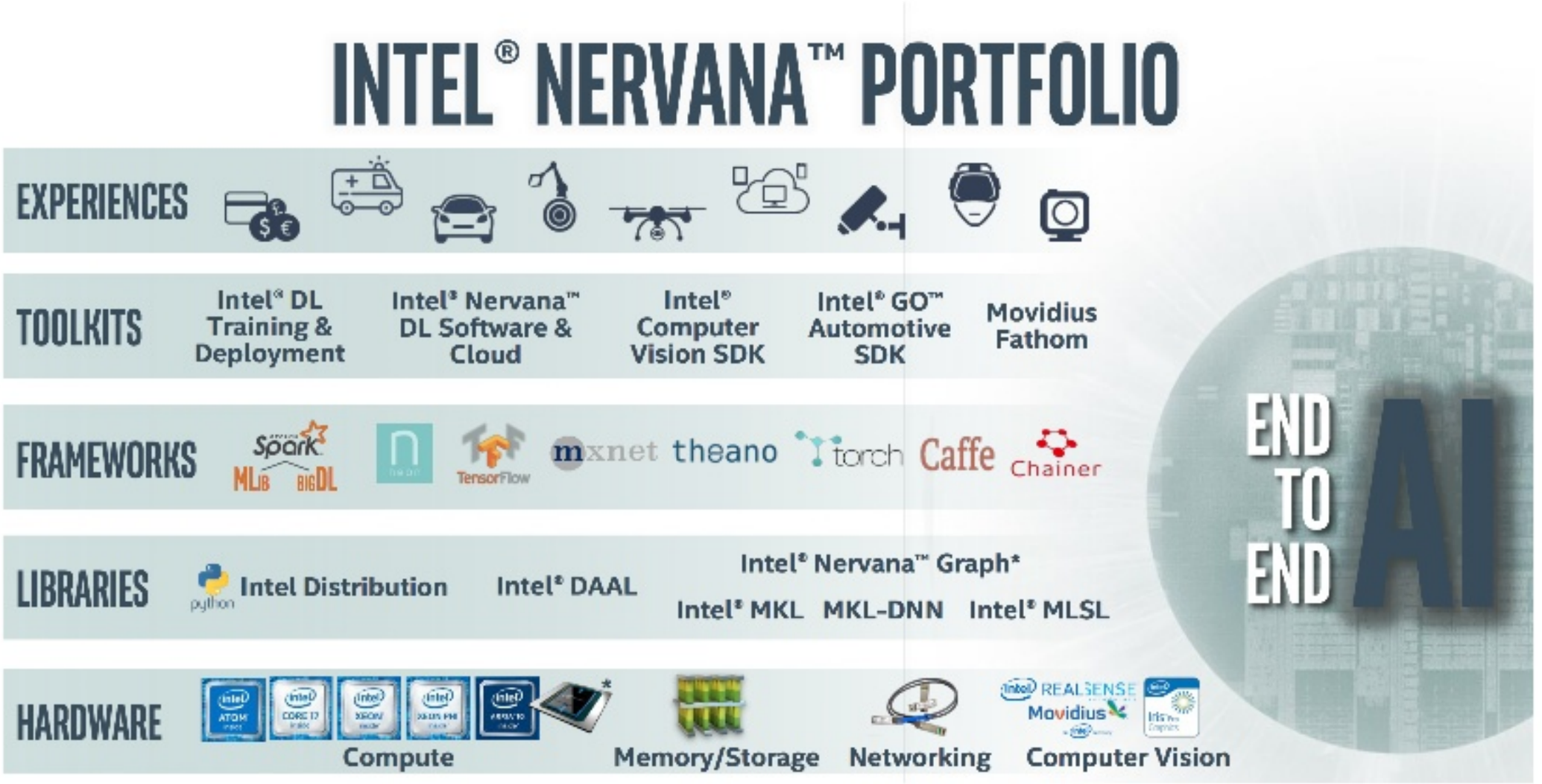
Who we are?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Agenda

- Use-case overview
- Challenges
- What is our data?
- Deriving Insights
- Machine Learning
- Tools
- Spark-tk
- Demo
- spark-tensorflow-connector
- Performance

Use-case overview

- Vast amount of medical image data available
- Meta-data accompanying the image
  - Patient information
  - Status of condition
  - Method of image capture
  - Time to events(if part of a study)

Create distributed technology needed to efficiently store, scan and analyze data in healthcare.

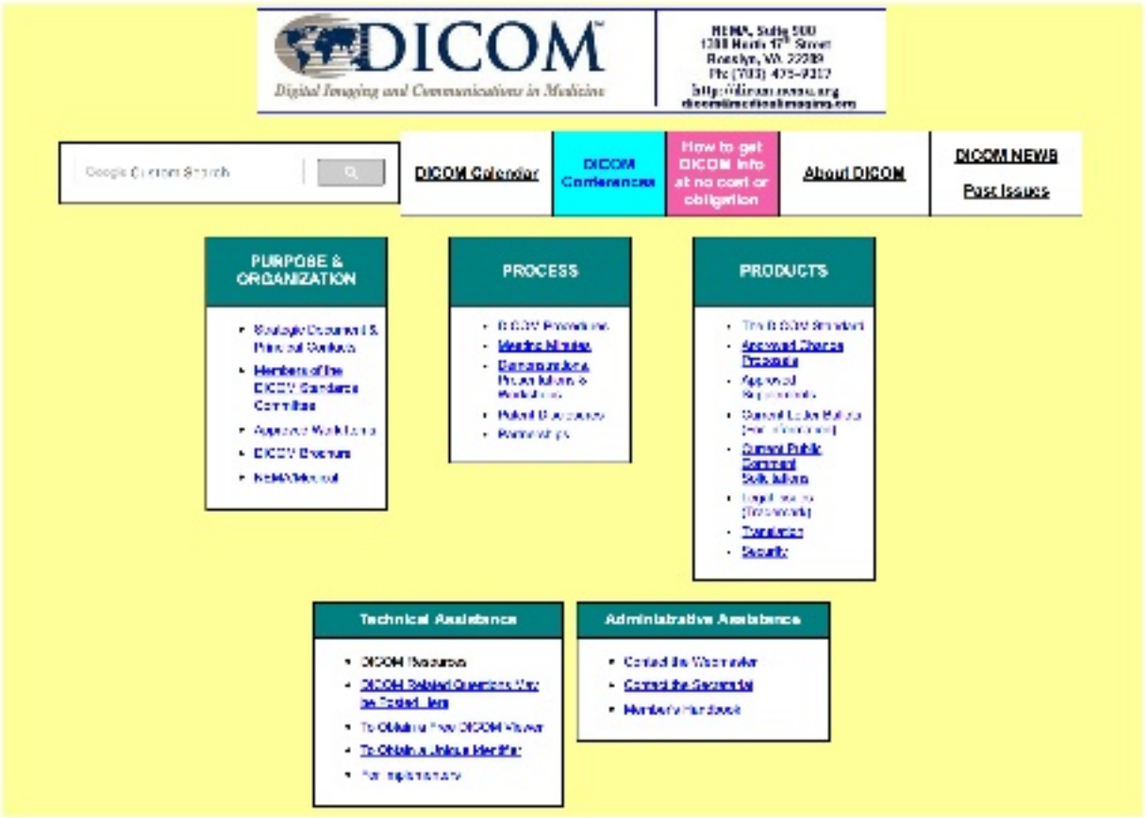
Challenges

- Getting data for experimentation is hard!
- Combine data from multiple public sources for simulation
- Multiple tools – image processing libraries, visualization tools, distributed engines, ML libraries
- Compatibility across different tools

How do we make Machine Learning easy to use?

Data: DICOM

- **D**igital **I**maging and **COM**munications in Medicine
- International standard format to store, exchange, and transmit medical images
- Standards for imaging modalities - radiography, ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), and radiation therapy.
- Protocols for image exchange, image compression, 3-D visualization, image presentation etc.



Data: Meta-data

- **Image** related: storage, date, relevant parts of the image etc.
- **Patient** related: age, weight, height, DOB, medical history
- **Device** related: manufacturer information, operator, method of capture

Deriving insights

- Can we develop smart filtering techniques based on image meta-data?
- Can we conclude and predict certain conditions based on patient meta-data?
- Can we classify image capture techniques and suggest improvements based on device meta-data?
- Can we combine image & patient meta-data to conclude and predict?
- Can analytics help automate/improve image capture techniques?

Machine Learning

- **Patient data**
  - Train classifier model on patient data to predict presence of a condition
    - Logistic Regression, Random Forest, Naïve Bayes
  - Train regressor model on patient data to predict probability of a condition
    - Linear Regression, Random Forest
  - Train survival analysis model on patient data to predict time to event, compare risk of populations
    - Accelerate Failure Time Model, Cox Proportional Hazards Model

Machine Learning

- **Image data**
  - Compute the Eigen decomposition of the image
  - Compute the Covariance Matrix of the image
  - Compute the Principal Component Analysis of the image pixel data

Machine Learning

- **Device data:**
  - Predict trends in image capture techniques
    - Classification/Regression techniques
  - Predict device time to failure
    - Cox Proportional Hazards Model, Accelerated Failure Time
  - Recommendations to device capture methods
    - Collaborative filtering

Tools

- **pydicom**
  - Python package for working with DICOM files such as medical images, reports, and radiotherapy
  - Single threaded
- **dcm4che**
  - Collection of open source applications and utilities for the healthcare enterprise.
  - Developed in the Java programming language for performance and portability, supporting deployment on JDK 1.6 and up
- **matplotlib**
  - Python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms.
  - Can be used in Python scripts, Python and IPython shell, jupyter notebook, web application servers
- **Machine Learning libraries**
  - Classifiers, regressors, failure analysis analysis
  - Eigen decomposition

Spark-tk Introduction

- Open source library enhancing the Spark experience
- APIs for feature engineering, ETL, graph construction, machine learning, image processing, scoring
- Abstraction level familiar to data scientists; removes complexity of parallel processing
- Lower level Spark APIs seamlessly exposed
- Easy to build apps plugging in other tools/libraries

https://github.com/trustedanalytics/spark-tk
http://trustedanalytics.github.io/spark-tk/

Spark-tk components

- **Frames**
  - Scalable data frame representation
  - More intuitive than low level HDFS file and Spark RDD/DataFrame/DataSet formats; schema inference
  - APIs to manipulate the data frames for feature engineering and exploration, such as joins and aggregations
  - Run user-defined transformations and filters using distributed processing
  - Input to our models
  - Easy to convert to/from Spark-tk Frames - Spark representations

Spark-tk components

- **Graphs**
  - Scalable graph representation based on Frames for vertices and edges
  - In house distributed algorithms for graph analytics using GraphX
  - Supports importing/exporting to OrientDB's scalable graph databases – visualize, real-time graph querying
  - Store massive graphs

Spark-tk components

- **Machine Learning & Streaming**
  - Time series analysis
  - Recommender systems
  - Topic Modeling
  - Clustering
  - Classification/Regression
  - Image processing
  - Scikit Models
  - Streaming via Scoring engine

How Spark-tk helps

- Brings in support for image analytics to Spark
  - Support for ingesting and processing DICOM images in a distributed environment
  - Queries, filters, and analytics on image collections
  - Integrated & distributed **dcm4che3** via. Spark
  - Tested against **pydicom**
  - Used matplotlib for visualization
- Machine learning for image and health records
  - Created distributed Cox Survival Proportional Hazards Model to compare sets of populations
  - Recommend algorithm and hyper-parameters

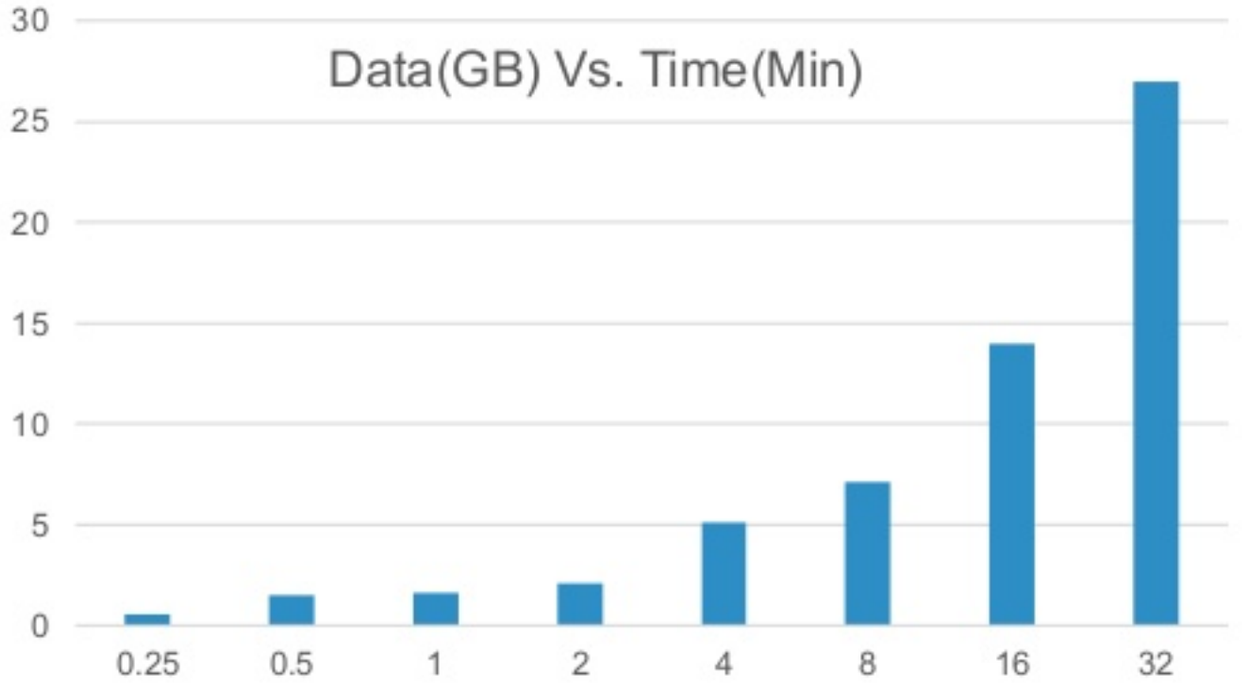
Live Demo

spark-tensorflow-connector

- Developed library for loading and storing TensorFlow records with Apache Spark
- Implements data import from the standard TensorFlow record format (TFRecords) into Spark SQL DataFrames, and data export from DataFrames to TensorFlow records

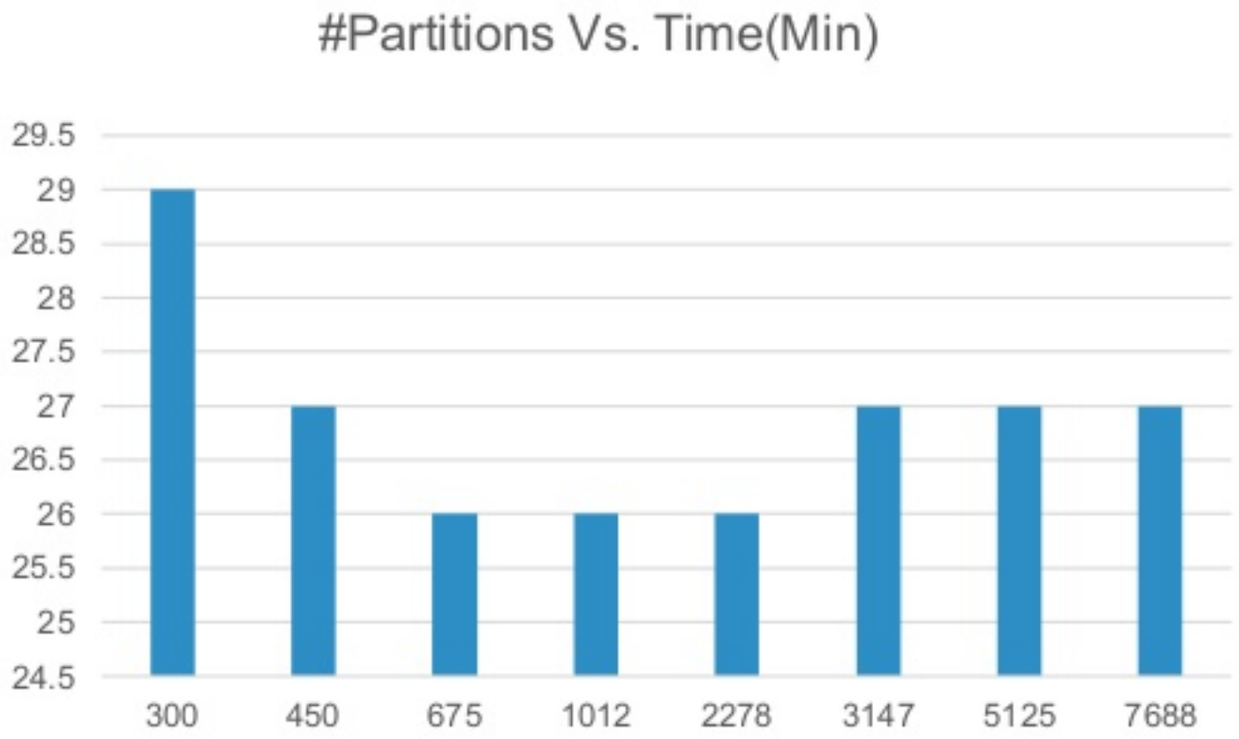
https://github.com/tensorflow/ecosystem/tree/master/spark/spark-tensorflow-connector

Performance



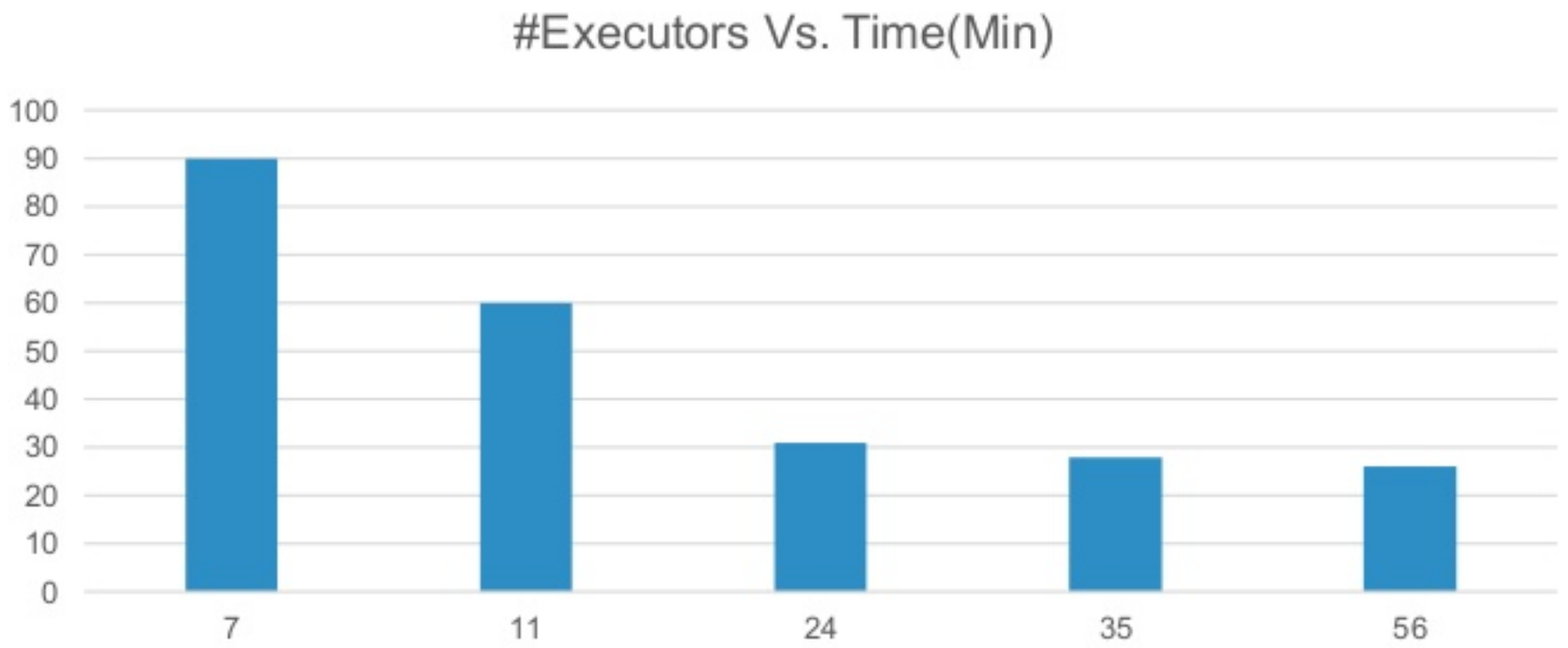
Processing time increases with data(Constant #Partitions=1000)

Performance



Increasing partitions reduced the time and then increased time(overhead)

Performance



Increasing number of executors reduces the time significantly

Performance

Increasing executor cores did not significantly change time

Thank You.

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