Enabling Space Exploration by Using AI to Improve Data Communication

Lara Suzuki, Ph.D.
Technical Director, Office of the CTO
Google
AI History

AI Birth
- A generation of Scientists

AI Hype
- UNIMATE (assembly line)
- Eliza (chatbot)
- STUDENT (Algebra)

AI Winter
- Compute limitations
- Data Limitations

AI Rebirth
- 1997 Chess: Deep Blue vs Kasparov
- 2011 Watson wins Jeopardy
- 2017 Go: AlphaGo vs Ke Jie
AI History

Areas of dramatic improvement

Vision
Language
Translation
Speech
Events
Artificial Intelligence

Industry Applications

- Aerial inspections
- Precision manufacturing
- Healthcare / medical image analysis
- Retail / inventory management
- Robotics / warehouse automation
- Agricultural crop/pest analysis
The same technology that knows your cat from your dog

Google Photos uses AI to organize your images and help you quickly find what you are looking for. And for doctors who are working to prevent blindness in 415 million diabetics worldwide, AI is also being used to quickly identify damaged blood vessels in retina scans.

Empowering doctors through diagnosis, with a little help from Google.

ai.google/healthcare
DTN Architecture

- UK
- Madrid-Spain
  - GCP
- London - UK
  - GCP
- Canberra - AU
  - AWS
- Goldstone - US
  - Azure

Contact plan
Anomaly Detection

AstoPi signal processing and anomaly detection using TensorFlow

Google Cloud
Stellar Classification

Transfer Learning

Define your data schema and target
Analyze your input features
Feature engineering
Model selection
Hyperparameter tuning
Train your model
Evaluate your model behavior
Deploy your model to get predictions

Hyperparameter tuning

Feature engineering

Model selection

Train your model

Evaluate your model behavior

Deploy your model to get predictions

Google Cloud

<table>
<thead>
<tr>
<th>True label</th>
<th>Predicted label</th>
</tr>
</thead>
<tbody>
<tr>
<td>GALAXY</td>
<td>98% 1% 1%</td>
</tr>
<tr>
<td>STAR</td>
<td>0% 100% –</td>
</tr>
<tr>
<td>QSO</td>
<td>6% – 94%</td>
</tr>
</tbody>
</table>
From Models to Production

Writing the ML code is just a small part of the job

Source: Sculley et al.: Hidden Technical Debt in Machine Learning Systems
From Data Preparation to Model Evaluation
A combinatorial explosion of things to worry about

Model Training

<table>
<thead>
<tr>
<th>Data preparation</th>
<th>Feature engineering</th>
<th>Architecture selection</th>
<th>Parameter selection</th>
<th>Tuning strategy</th>
<th>Model evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properly handling:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Imbalanced data</td>
<td>● Selecting right preprocessing for:</td>
<td>● Selecting the best model architecture from dozens available</td>
<td>● For each architecture, selecting the right values for each hyperparameter</td>
<td>● Choose efficiently from O(1000s) of combinations.</td>
<td></td>
</tr>
<tr>
<td>● Outliers</td>
<td>● Numbers</td>
<td>● Linear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Missing values</td>
<td>● Classes</td>
<td>● Feed forward</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● High cardinality features</td>
<td>● Strings</td>
<td>● Random forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Highly correlated features</td>
<td>● Dates</td>
<td>● Decision tree</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Target leakage</td>
<td>● Lists</td>
<td>● Residual nets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Inconsistent feature definition</td>
<td>● Nested fields</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Data that doesn’t fit local memory</td>
<td>● ...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>● ...</td>
<td>Multiple options per column, 100s of columns in table</td>
<td>Keeping up with the onslaught of newest state of the art</td>
<td>Potentially more than a dozen values to set</td>
<td>Evaluating model at</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● Dataset-level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● Feature-level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>● Prediction-level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ensuring behavior is fully understood before deployment</td>
<td></td>
</tr>
</tbody>
</table>

Rinse & repeat up to 10s of times per use case
From Models to Production

Writing the ML code is just a small part of the job

Source: Sculley et al.: Hidden Technical Debt in Machine Learning Systems
Architecture Selection of ML Models

Automating the design of machine learning models

Sample architecture A with probability p

Trains a child network with architecture A to get accuracy R

Compute gradient of p and scale it by R to update the controller

Using Machine Learning to Explore Neural Network Architecture - Quoc Le & Barret Zoph, Research Scientists, Google Brain team
Feature Extraction and Prediction Output

Automating the design of machine learning models

Feature extraction part

Edges
Shapes
Objects
Hot Dog
Not Hot Dog
Complex Objects
Classification part

Just Tweak This!

Convolution
AvgPool
MaxPool
Concat
Dropout
Fully connected
Softmax

Google Cloud
## Object Classification

### Some models for object detection

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster R-CNN</td>
<td>Based on Region Proposal Network (RPN) to reduce compute intensity</td>
<td><a href="https://arxiv.org/abs/1506.01497">https://arxiv.org/abs/1506.01497</a></td>
</tr>
<tr>
<td>SSD</td>
<td>Single neural network generates scores for possible objects and produces adjustments to the box to better match the object shape</td>
<td><a href="https://arxiv.org/pdf/1512.02325.pdf">https://arxiv.org/pdf/1512.02325.pdf</a></td>
</tr>
<tr>
<td>YOLO</td>
<td>A single neural network predicts bounding boxes and class probabilities directly from full images in one evaluation</td>
<td><a href="https://arxiv.org/pdf/1506.02640.pdf">https://arxiv.org/pdf/1506.02640.pdf</a></td>
</tr>
<tr>
<td>Mask R-CNN</td>
<td>Extension of R-CNN by adding a branch for predicting an object mask in parallel with the existing branch for bounding box recognition.</td>
<td><a href="https://arxiv.org/abs/1703.06870">https://arxiv.org/abs/1703.06870</a></td>
</tr>
</tbody>
</table>
R-CNN, or Region-based Convolutional Neural Network, makes 3 simple steps:

1. Scan the input image for possible objects using an algorithm called Selective Search, generating ~2000 region proposals.
2. Run a convolutional neural net (CNN) on top of each of these region proposals.
3. Take the output of each CNN and feed it into:
   A) an SVM to classify the region
   B) a linear regressor to tighten the bounding box of the object, if such an object exists.
Object Classification

Crater Detection
Federated Learning and Analytics over DTN

**DTN-ML** is to be an end-to-end network service and federated computations capabilities providing cloud-based AI services and communications in and/or through environments characterized by one or more of the following:

1. Intermittent Connectivity
2. Variable delays
3. High bit error rates
4. Asymmetric and simplex links
Choose an option:
ION event: Payload delivered.
   payload length is 5.
   'Water'
ION event: Payload delivered.
payload length is 18.
   '0.8288546808491491'
ION event: Reception interrupted.
yzION event: Payload delivered.
yz payload length is 9.
   'Carnivore'
yzyION event: Payload delivered.
yz payload length is 17.
   '0.8214439844855202'
yzION event: Payload delivered.
payload length is 13.
   'Companion dog'
ION event: Payload delivered.
payload length is 18.
   '0.81868066825696'
ION event: Payload delivered.
payload length is 4.
   'Fawn'
ION event: Payload delivered.
payload length is 18.
   '0.8157362938647485'
zyzION event: Payload delivered.
   payload length is 5.
   'Smile'
ION event: Payload delivered.
payload length is 18.
   '0.97842763485443115'
ION event: Payload delivered.
payload length is 3.
   'Dog'
ION event: Payload delivered.
payload length is 18.
   '0.9581359861947351'
ION event: Payload delivered.
payload length is 17.
   'Facial expression'
ION event: Payload delivered.
payload length is 18.
   '0.952884467078166'
ION event: Payload delivered.
payload length is 5.
   'Couch'
ION event: Payload delivered.
payload length is 18.
Thank you
Questions?

Lara Suzuki
larissasuzuki@google.com