Object Detection with Vertex AI and AutoML

Daniel Bank

https://github.com/danielbank/object-detection

Scope of This Talk

- Brief history of object detection solutions
- Build an object detection model using Vertex AI
- Run object detection on an Android device (no network calls)
- A little TensorFlow Lite along the way

TL;DR:
It is incredibly easy* to build an object detection model with Vertex AI and deploy it on Android

* assuming you are willing to spend time labeling your data and money training a model

What is Object Detection?

Image classification (Single-label)

Predict the one correct label that you want assigned to an image.

Image classification (Multi-label)

Predict all the correct labels that you want assigned to an image.

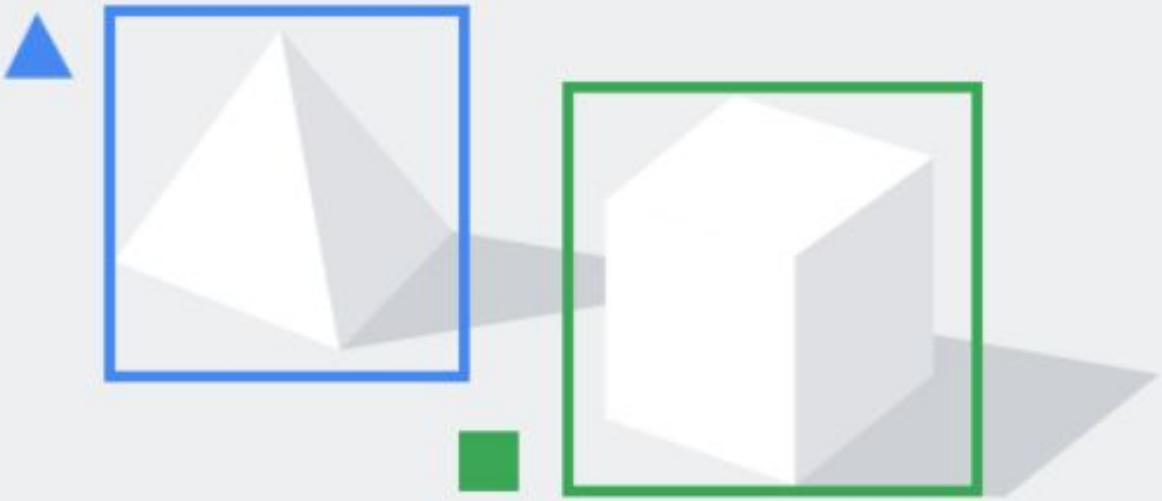


Image object detection

Predict all the locations of objects that you're interested in.

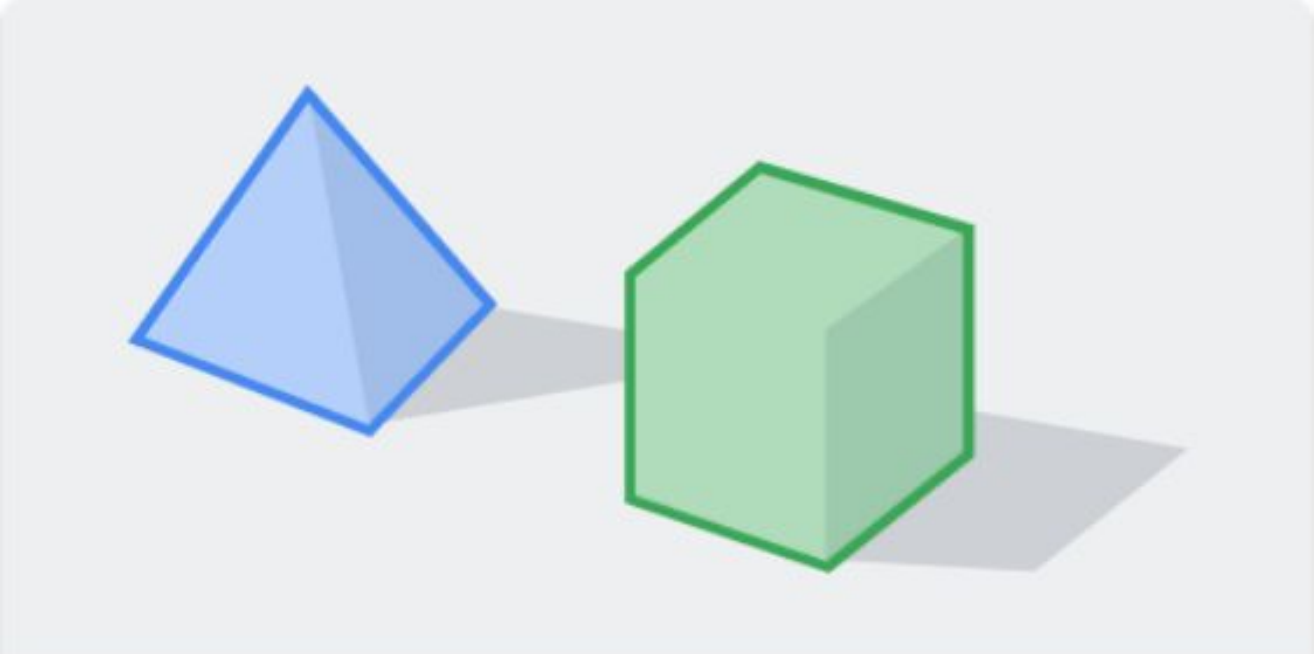
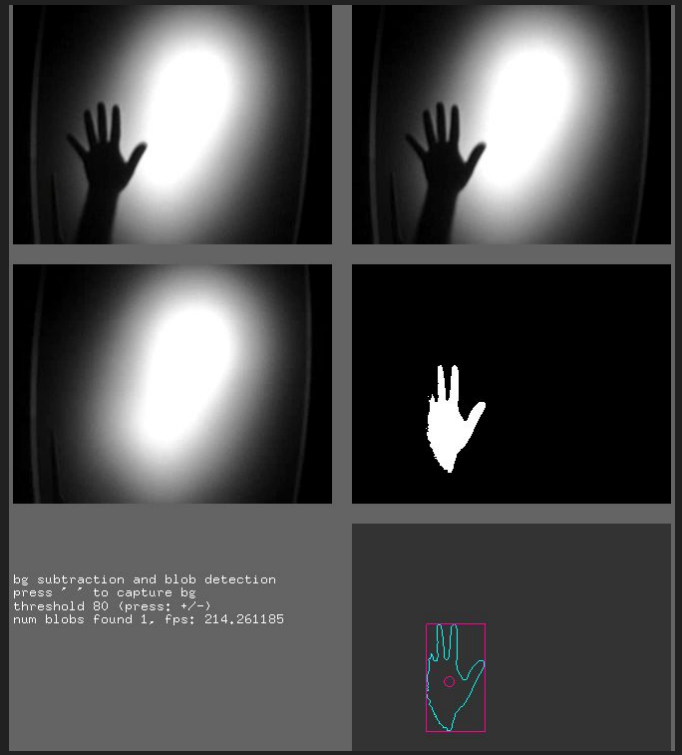


Image segmentation

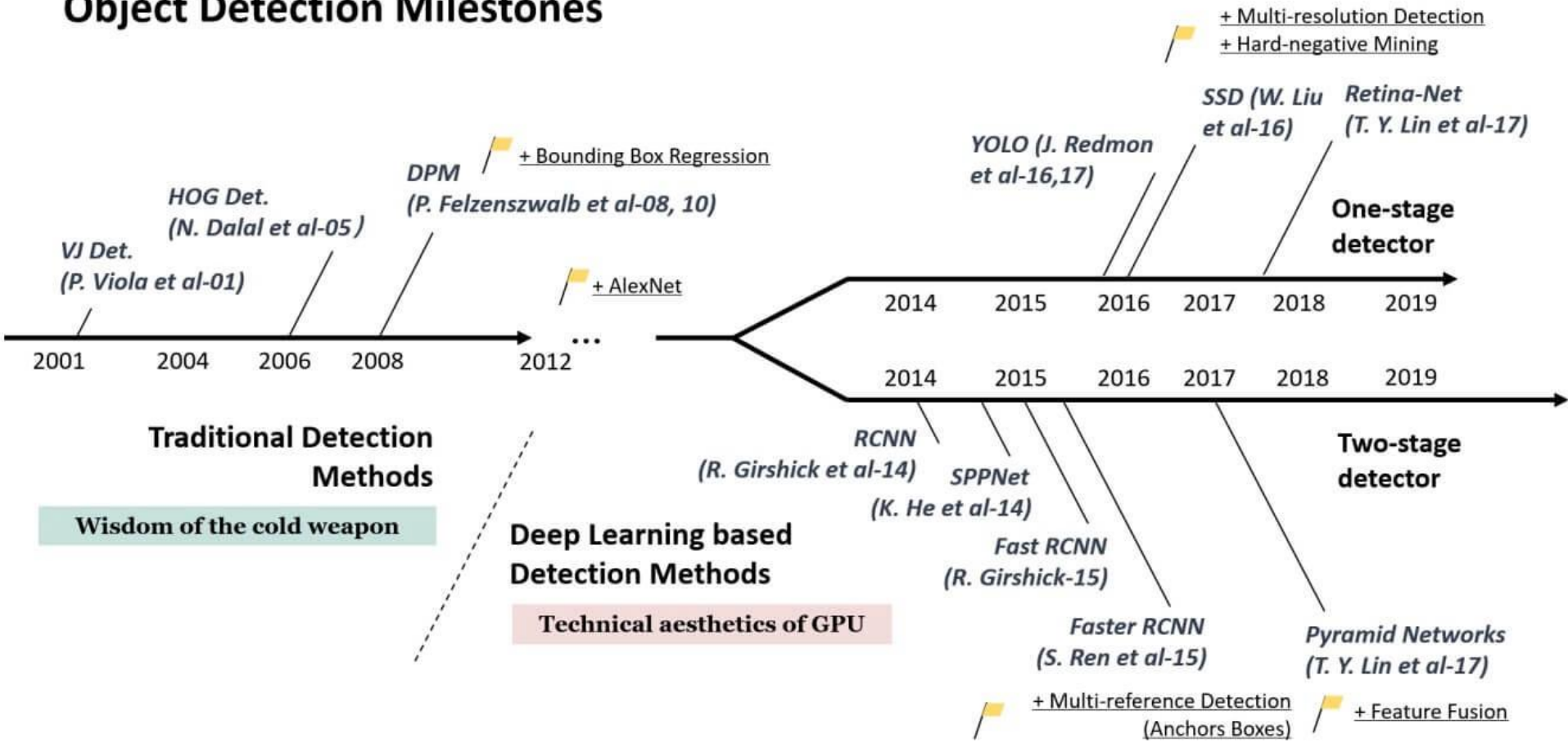
Predict per-pixel areas of an image with a label.

OpenCV

- C++ Library for computer vision
- Initially released in **2000**
- Image processing, video capture, and analysis
- DNN Module (Deep Neural Network) in **2015**



Object Detection Milestones



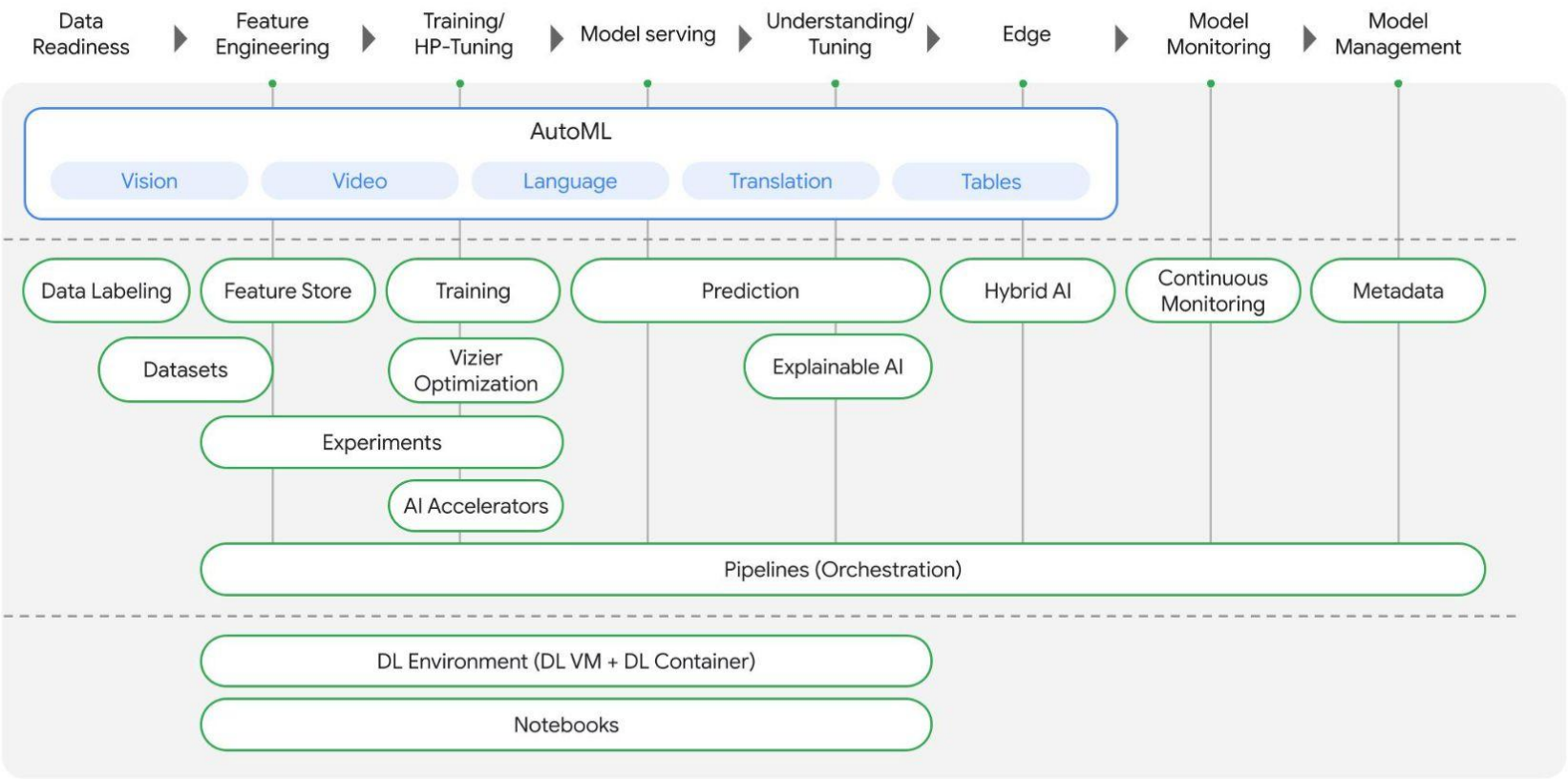
TensorFlow Object Detection API

- An open source framework built on top of TensorFlow that makes it easy to construct, train and deploy object detection models
- Released in **2017**
- Includes a Detection Model Zoo, a collection of pre-trained models
  - Model Zoo only has two-stage detectors

Vertex AI and AutoML

- Vertex AI
  - Google’s Managed ML Platform
  - Launched in **2021**
- Neural Architecture Search (NAS) a.k.a AutoML
  - AI that generates other Neural Networks
  - Developed by Google Brain in **2017**
  - Vertex AI NAS
    - Available for Qualcomm Technologies Neural Processing SDK, optimized for Snapdragon 8

What's included in Vertex AI?



Building a Dataset

Detecting Dice

- Six-sided Dice Dataset: https://www.kaggle.com/nellbyler/d6-dice
  - 250 images
  - 1-25 six-sided dice per image
  - Images and annotations (YOLO format)
- Dice Detection Tutorial: https://github.com/nell-byler/dice_detection

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Create dataset

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Image classification (Multi-label)

Predict all the correct labels that you want assigned to an image.

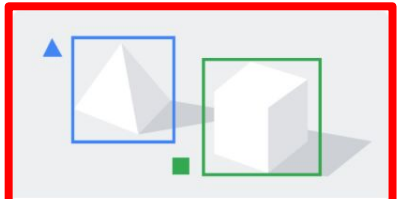

Image object detection

Predict all the locations of objects that you're interested in.

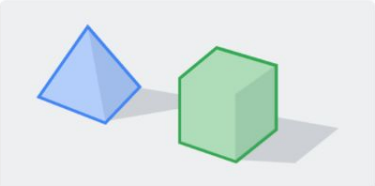

Image segmentation

Predict per-pixel areas of an image with a label.

Region

us-central1 (Iowa)

ADVANCED OPTIONS

You can use this dataset for other image-based objectives later by creating an annotation set. Learn more

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d6_dice_1662878099415

d6_dice_1662878099415...

IMPORT | BROWSE | ANALYZE

All	250
Labeled	0
Unlabeled	250

Filter Filter labels +

Images

ADD NEW LABEL

Filter Filter items

Select all

No bounding boxes

No bounding boxes

No bounding boxes

No bounding boxes

Items per page: 10 1 – 10 of many

Training jobs and models

Use this dataset and annotation set to train a new machine learning model with AutoML or custom code

TRAIN NEW MODEL

Labeling tasks

If your data still needs to be labeled, create a labeling task to have others label it for you

CREATE LABELING TASK

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Vertex AI

Item 5 of many

Data split
Default

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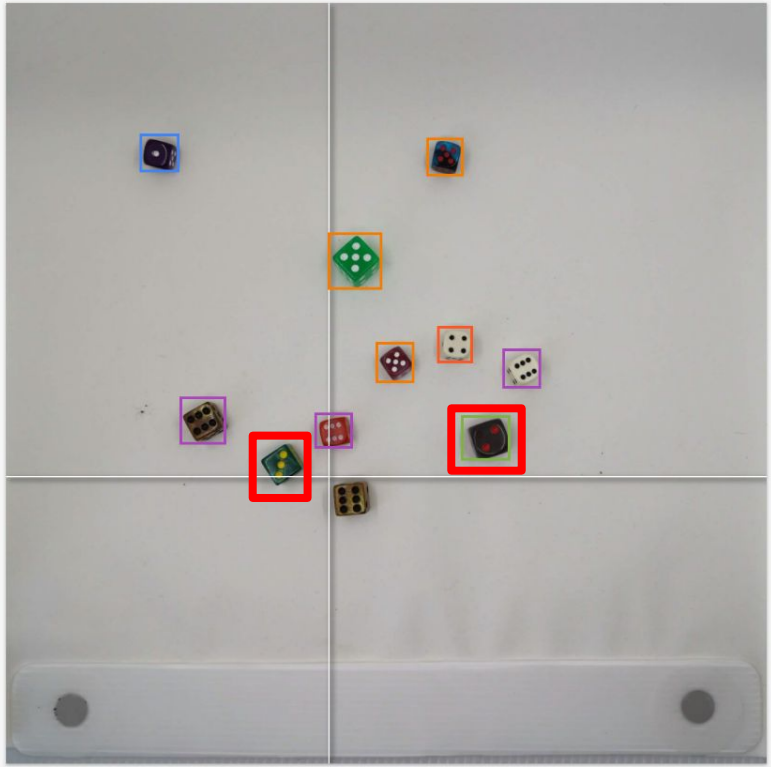
OBJECTS DETAILS

Filter Filter labels

- 1 (1)
  - 1 1
- 4 (1)
  - 4 1
- 2 (1)
  - 2 1
- 6 (3)
  - 6 1
  - 6 2
  - 6 3
- 5 (3)
  - 5 1
  - 5 2

ADD LABEL

SAVE



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Item 5 of many

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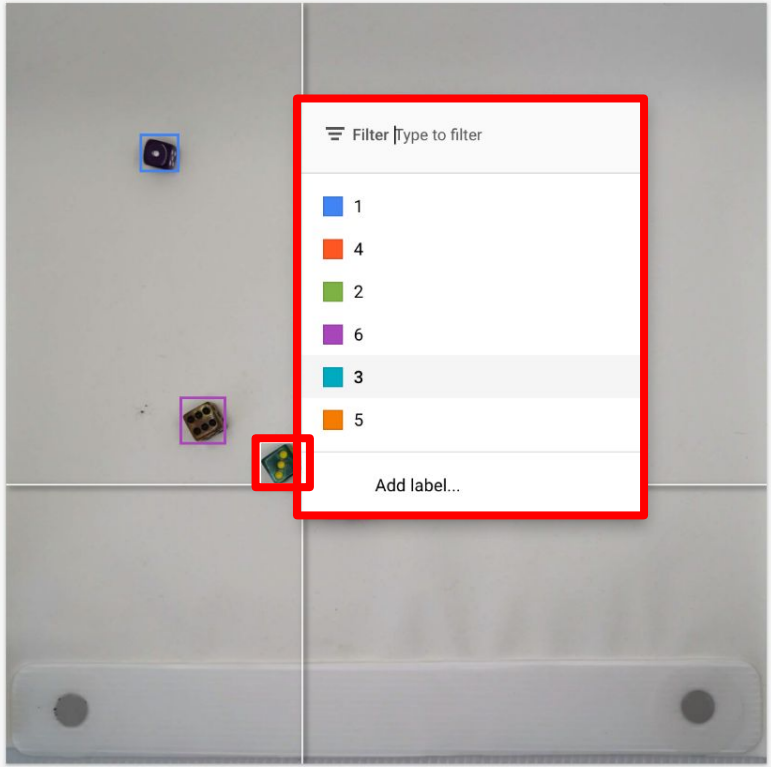
OBJECTS DETAILS

Filter Filter labels

- 1 (1)
  - 1 1
- 4 (1)
  - 4 1
- 2 (1)
  - 2 1
- 6 (4)
  - 6 1
  - 6 2
  - 6 3
  - 6 4
- 5 (3)
  - 5 1

ADD LABEL

SAVE



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MODEL DEVELOPMENT

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d6_dice_1662878099415...

IMPORT | BROWSE | ANALYZE

You're ready to train

Your dataset meets the recommendation of 100 images assigned to each label. Learn more

Labels	Images
1	258
2	272
3	274
4	253
5	280
6	241

Custom data split

You currently don't have any items assigned to Training, Validation, or Test sets. Don't worry, when you train a model, your items will be randomly divided into these sets, using recommended machine learning practices. Learn more

Training jobs and models

Use this dataset and annotation set to train a new machine learning model with AutoML or custom code

TRAIN NEW MODEL

Labeling tasks

If your data still needs to be labeled, create a labeling task to have others label it for you

CREATE LABELING TASK

https://console.cloud.google.com/vertex-ai/locations/us-central1/datasets/3493634425583828992;annotationSetId=8849938305643446272/analyze?project=histogramo-94271

Training a Model

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All

Label

Unlab

Imag

1

2

3

4

5

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ADI

Train new model

1. Training method
2. Model details
3. Training options
4. Compute and pricing

START TRAINING CANCEL

Dataset
d6_dice_1662878099415

Annotation set
d6_dice_1662878099415_iod

Objective
Image object detection

Please refer to the pricing guide for more details (and available deployment options) for each method.

Model training method

- ○ AutoML
  Train high-quality models with minimal effort and machine learning expertise. Just specify how long you want to train. Learn more
- ◉ AutoML Edge
  Train a model that can be exported for on-prem/on-device use. Typically has lower accuracy. Learn more
- ○ Custom training (advanced)
  Run your TensorFlow, scikit-learn, and XGBoost training applications in the cloud. Train with one of Google Cloud's pre-built containers or use your own. Learn more

CONTINUE

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START TRAINING CANCEL

- (●) Train new model
  Creates a new model group and assigns the trained model as version 1
- ( ) Train new version
  Trains model as a version of an existing model

Name *
d6_dice_edge

Description
D6 Dice Model for Edge Devices

Data split

- (●) Randomly assigned
- ( ) Manual (Advanced)

Your dataset will be automatically randomized and split into training, validation, and test sets using the following ratios. Learn more

Training	Validation	Test
80 %	10 %	10 %

- Training: 80%
- Validation: 10%
- Test: 10%
- Default: 0%

Encryption

- (●) Google-managed encryption key
  No configuration required
- ( ) Customer-managed encryption key (CMEK)
  Manage via Google Cloud Key Management Service

SHOW LESS

CONTINUE

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START TRAINING CANCEL

	Goal	Package size	Accuracy	Latency on iPhone X
○	Higher accuracy	5.6 MB	Higher	34ms
◉	Best trade-off	3.1 MB	Medium	23ms
○	Faster predictions	557 KB	Lower	8ms

Please note that prediction latency estimates are for guidance only. Actual latency depends on your network connectivity. Edge TPU predictions typically will have lower latency.

CONTINUE

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START TRAINING CANCEL

Enter the **maximum** number of node hours you want to spend training your model.

You can train for as little as 1 node hour. You may also be eligible to train with free node hours. Pricing guide

Budget *
2 Maximum node hours

Estimated completion date: Sep 18, 2022 4 PM GMT-7

Enable early stopping

Ends model training when no more improvements can be made and refunds leftover training budget. If early stopping is disabled, training continues until the budget is exhausted.

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CREATE REFRESH LEARN

TRAINING PIPELINES CUSTOM JOBS HYPERPARAMETER TUNING JOBS

Training pipelines are the primary model training workflow in Vertex AI. You can use training pipelines to create an AutoML-trained model or a custom-trained model. For custom-trained models, training pipelines orchestrate custom training jobs and hyperparameter tuning with additional steps like adding a dataset or uploading the model to Vertex AI for prediction serving. Learn More

Region
us-central1 (Iowa)

Filter Enter a property name

Name	ID	Status	Job type	Model type	Created	Elapsed time	Labels
d6_dice_edge	3563755504767336448	Training	Training pipeline	Image object detection	Sep 18, 2022, 1:38:12 PM	28 min 34 sec	—

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Region
us-central1 (Iowa)

Filter Enter a property name

Name	ID	Status	Job type	Model type	Created	Elapsed time	Labels
d6_dice_edge	3563755504767336448	Finished	Training pipeline	Image object detection	Sep 18, 2022, 1:38:12 PM	2 hr 18 min	–

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d6_dice_edge > Version 1 | VIEW DATASET | EXPORT

EVALUATE | DEPLOY & TEST | BATCH PREDICT | VERSION DETAILS

untitled_4497850143629901824 | COMPARE | CREATE EVALUATION

Filter | Filter labels

All labels	0
6	0.773
1	0.765
3	0.746
2	0.693
5	0.677
4	0.623

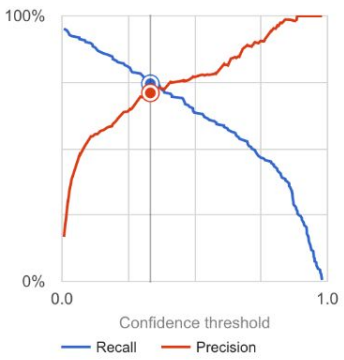
Confidence threshold 0.34 | IoU threshold 0.44

Test images	26

To evaluate your model, set the **confidence threshold** to see how precision and recall are affected. The best confidence threshold depends on your use case. Read some example scenarios to learn how evaluation metrics can be used.

Precision-recall curve

Precision-recall by threshold



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d6_dice_edge > Version 1 | VIEW DATASET | EXPORT | LEARN

EVALUATE | DEPLOY & TEST | BATCH PREDICT | VERSION DETAILS

Use your edge-optimized model

TF Lite
Export your model as a TF Lite package to run your model on edge or mobile devices.

Container
Export your model as a TF Saved Model to run on a Docker container.

TensorFlow.js
Export your model as a TensorFlow.js package to run your model in the browser and in Node.js.

Deploy your model

Endpoints are machine learning models made available for online prediction requests. Endpoints are useful for timely predictions from many users (for example, in response to an application request). You can also request batch predictions if you don't need immediate results.

DEPLOY TO ENDPOINT

Name	ID	Status	Models	Region	Monitoring	Most recent monitoring job	Most recent alerts	Last updated	API	Notification	Labels
No active endpoints containing this model											

Test your model PREVIEW

https://console.cloud.google.com/vertex-ai/locations/us-central1/models/528922267564900352/versions/1/deploy?project=histogramo-94271

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d6_dice_edge > Version 1 | VIEW DATASET

EVALUATE | DEPLOY & TEST | BATCH PREDICT | VERSIO

TF Lite

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Container

Export your model as a TF S
Model to run on a Docker co

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DEPLOY TO ENDPOINT

Name	ID	Status	Models	Region	Monitoring
No active endpoints containing this model					

Test your model PREVIEW

In order to test your model, you will need to deploy it first. Pricing

Export model

LEARN

The **TensorFlow Lite (.tflite)** format allows you to run your model on mobile and embedded devices.

1. Export your model as a TF Lite package.

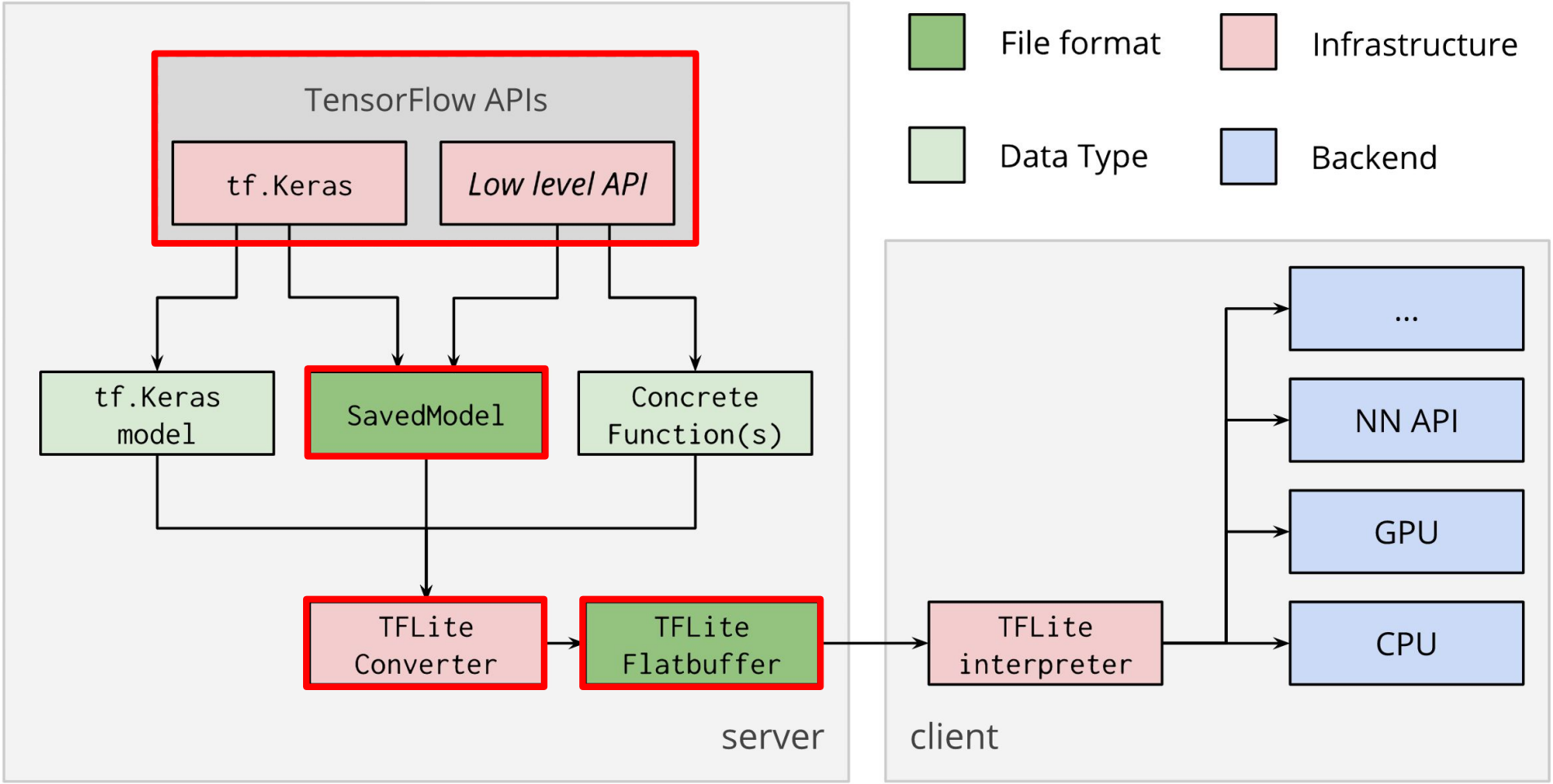
Destination folder on Cloud Storage *
gs:// d6_dice_edge BROWSE

EXPORT VIEW FOLDER

2. Model export takes a couple of minutes. After exporting is finished, copy the package to your computer using the following command:

```
$ gsutil cp -r gs://d6_dice_edge ./download_dir
```

CLOSE


File format
Infrastructure
Data Type
Backend
TensorFlow APIs
tf.Keras
Low level API
tf.Keras model
SavedModel
Concrete Function(s)
TFLite Converter
TFLite Flatbuffer
server
TFLite interpreter
...
NN API
GPU
CPU
client

	Goal	Package size	Accuracy	Latency on iPhone X
○	Higher accuracy	5.6 MB	Higher	34ms
◉	Best trade-off	3.1 MB	Medium	23ms
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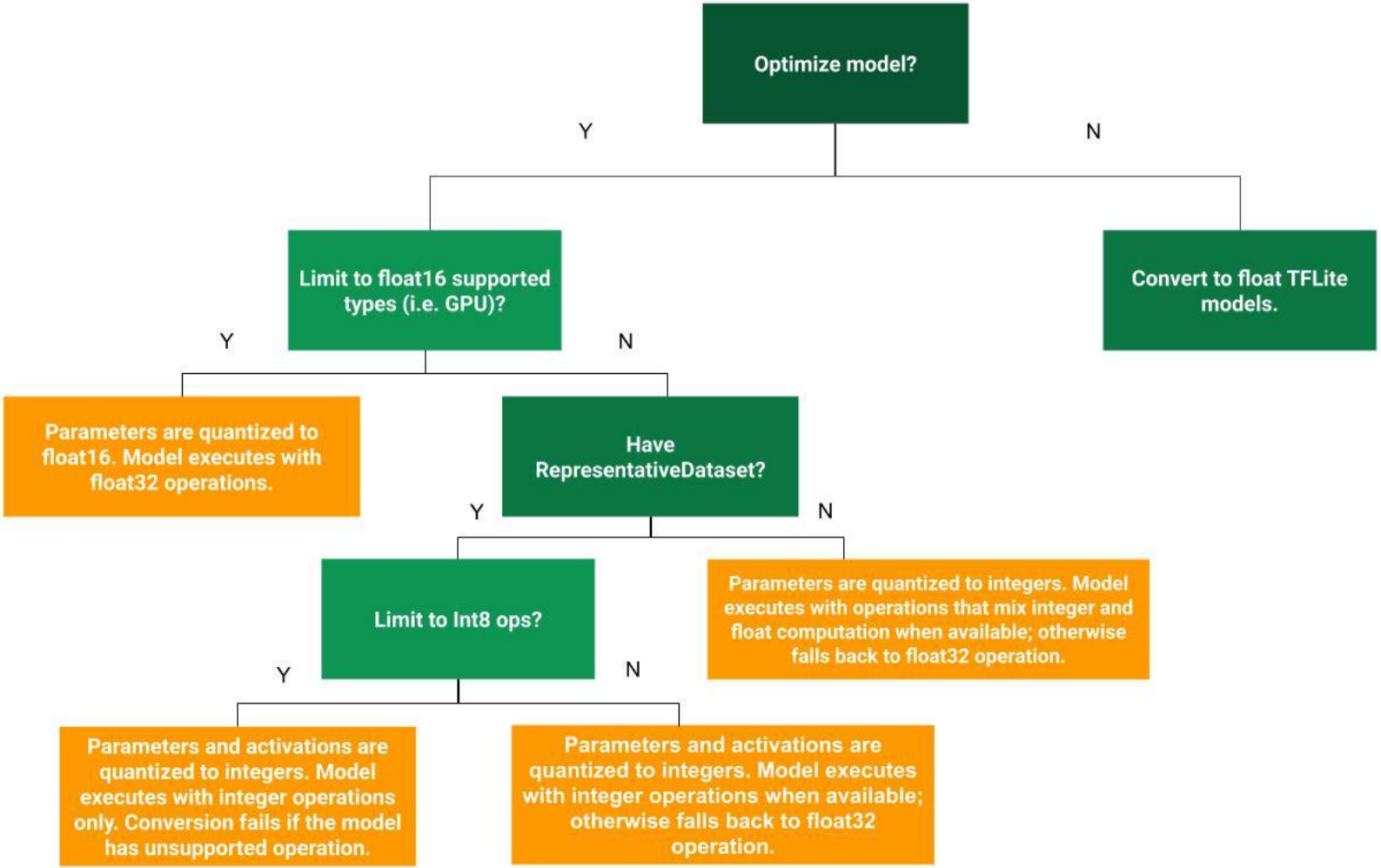
Please note that prediction latency estimates are for guidance only. Actual latency depends on your network connectivity. Edge TPU predictions typically will have lower latency.

Post-Training Quantization Options

TF Lite Option	Technique Used	Benefits	Hardware
OPTIMIZE_FOR_SIZE	“Hybrid operations”	4x smaller, 2-3x speedup, accuracy	CPU
DEFAULT	Integer Quantization	4x smaller, More speedup	CPU, Edge TPU, etc.

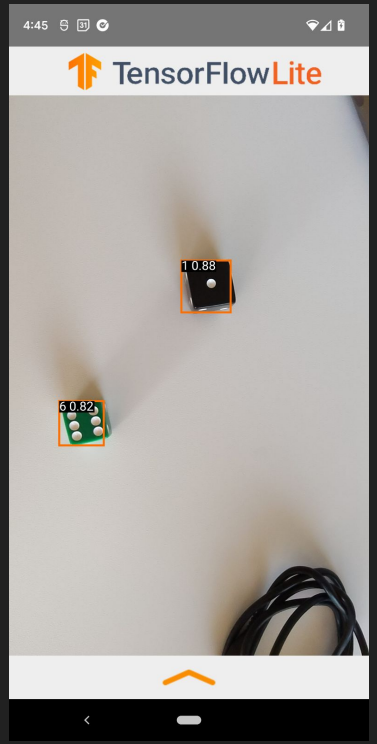

Optimize model?
Y
N
Limit to float16 supported types (i.e. GPU)?
Convert to float TFLite models.
Y
N
Parameters are quantized to float16. Model executes with float32 operations.
Have RepresentativeDataset?
Y
N
Limit to Int8 ops?
Parameters are quantized to integers. Model executes with operations that mix integer and float computation when available; otherwise falls back to float32 operation.
Y
N
Parameters and activations are quantized to integers. Model executes with integer operations only. Conversion fails if the model has unsupported operation.
Parameters and activations are quantized to integers. Model executes with integer operations when available; otherwise falls back to float32 operation.


THE LABELS ARE IN THE MODEL FILE
imgflip.com

TFLite Android Example App

TensorFlow Lite Object Detection Android Demo

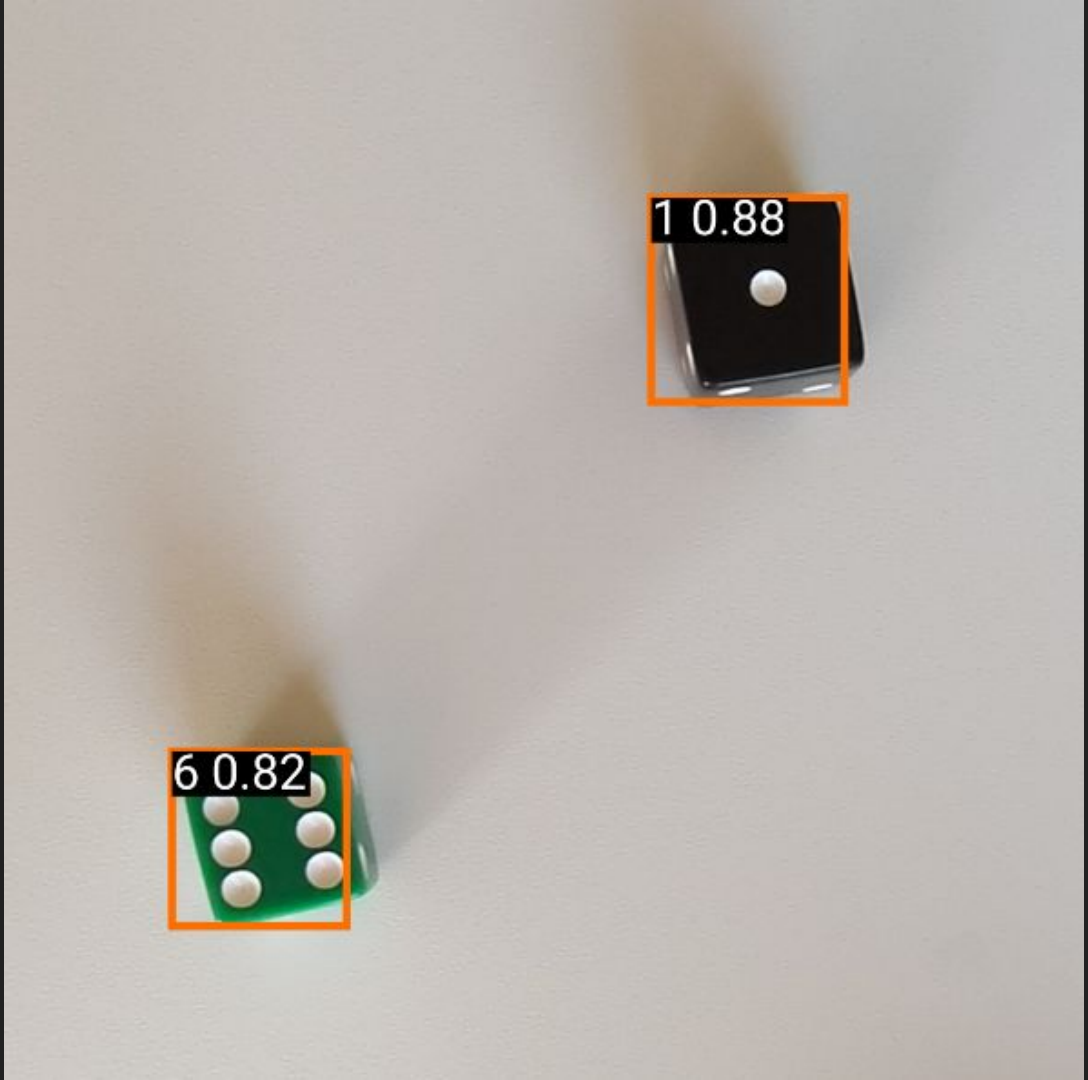
https://github.com/tensorflow/examples/tree/master/lite/examples/object_detection/android

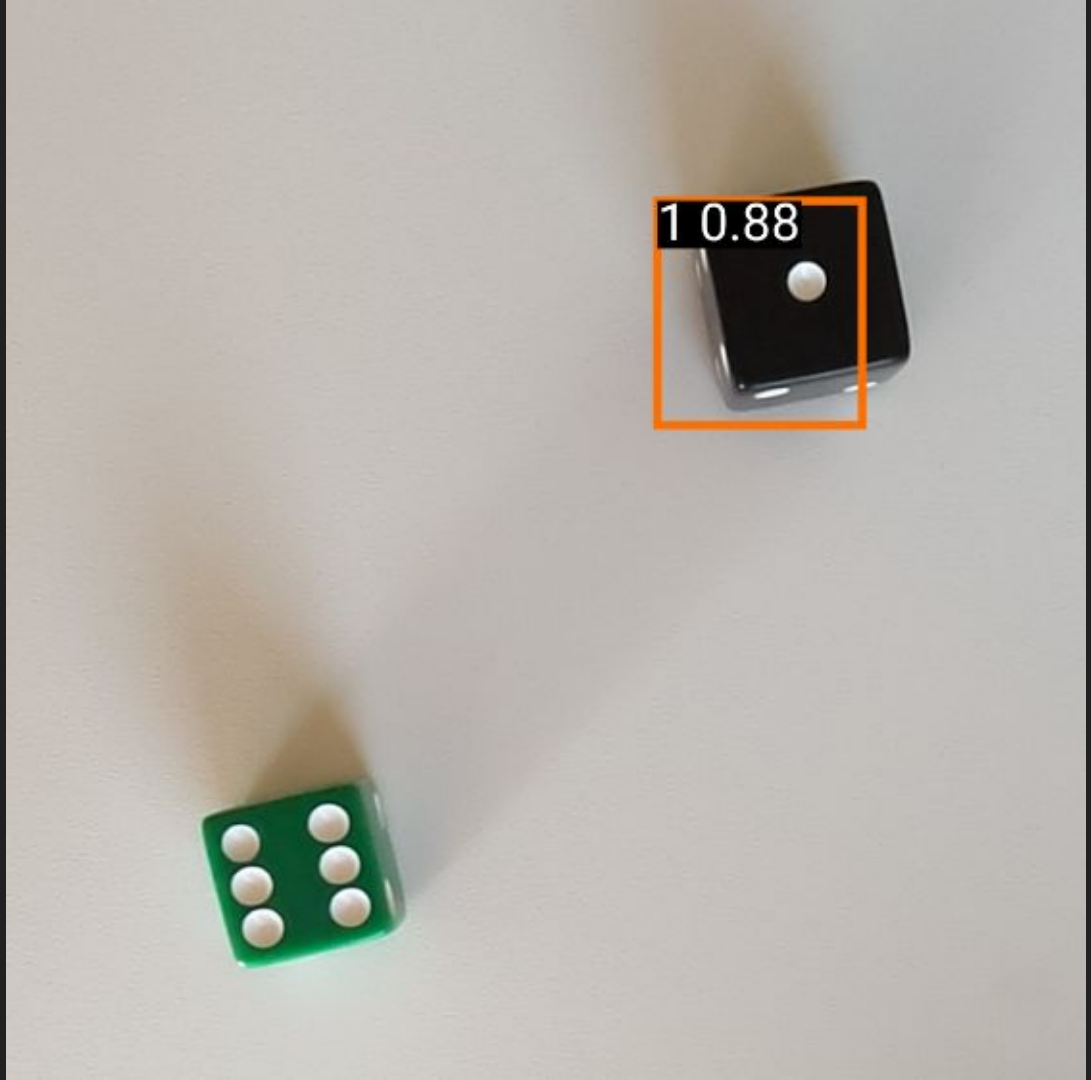


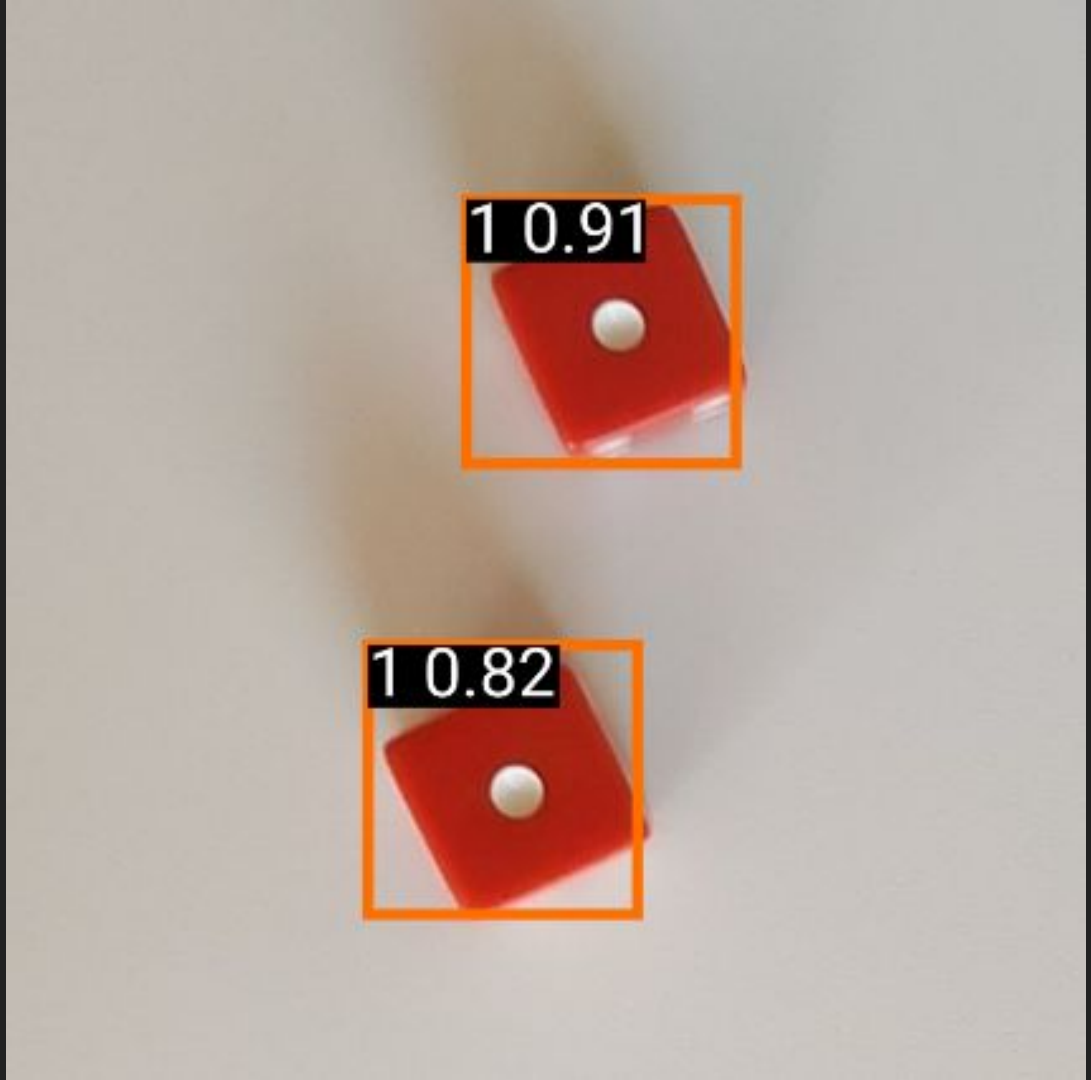
```diff
+++ b/android/app/src/main/java/org/tensorflow/lite/examples/objectdetection/ObjectDetectorHelper.kt
@@ -82,14 +82,7 @@ class ObjectDetectorHelper(

         optionsBuilder.setBaseOptions(baseOptionsBuilder.build())

-        val modelName =
-            when (currentModel) {
-                MODEL_MOBILENETV1 -> "mobilenetv1.tflite"
-                MODEL_EFFICIENTDETV0 -> "efficientdet-lite0.tflite"
-                MODEL_EFFICIENTDETV1 -> "efficientdet-lite1.tflite"
-                MODEL_EFFICIENTDETV2 -> "efficientdet-lite2.tflite"
-                else -> "mobilenetv1.tflite"
-            }
+        val modelName = "model.tflite"
```


1 0.88
6 0.82


1 0.88


1 0.91
1 0.82

Links

- Object Detection
  - Object Detection in 20 Years: A Survey
  - Object Detection using YOLOv5 and OpenCV DNN in C++ and Python
  - YOLO v5
  - YOLO Algorithm and YOLO Object Detection
  - COCO Dataset
- Vertex AI
  - Vertex AI NAS Announcement 11/30/2021
  - AutoML Beginner's Guide
- TensorFlow and TensorFlow Lite
  - TensorFlow Lite Object Detection Android Demo
  - Easier object detection on mobile with TensorFlow Lite
  - TensorFlow post-training quantization
- Dice Detection
  - Six-sided Dice Dataset
  - Real-time dice detection and classification

Thank you!