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Boosting tf.data pipeline

- Rise of accelerators and parallelism
- High-performant tf.data input pipelines
- Adopt pipelines to different scenarios
- Learn better ways of using tf.data operations

ETL Revisited

Extract → Transform → Load

Local (HDD/SSD)

Remote (GCS/HDFS)

Shuffling & Batching
Decompression
Augmentation
Vectorization
. . .

Load transformed data
to an accelerator

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Load transformed data to an accelerator

What happens when you train a model?

Preprocessing + Training → Model training

CPU Utilization

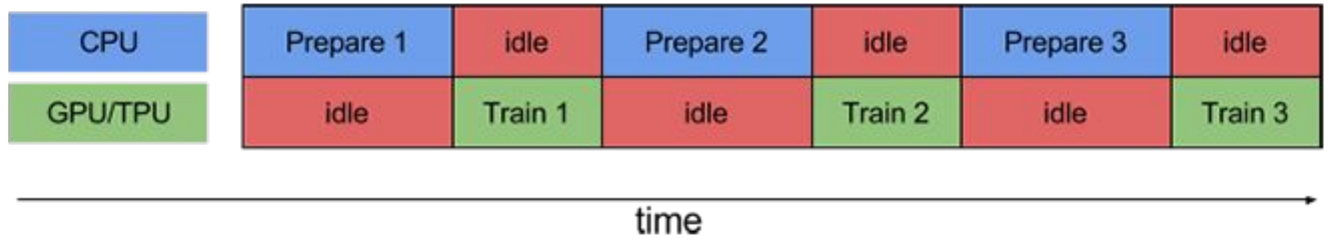
GPU/TPU Utilization

Maximize

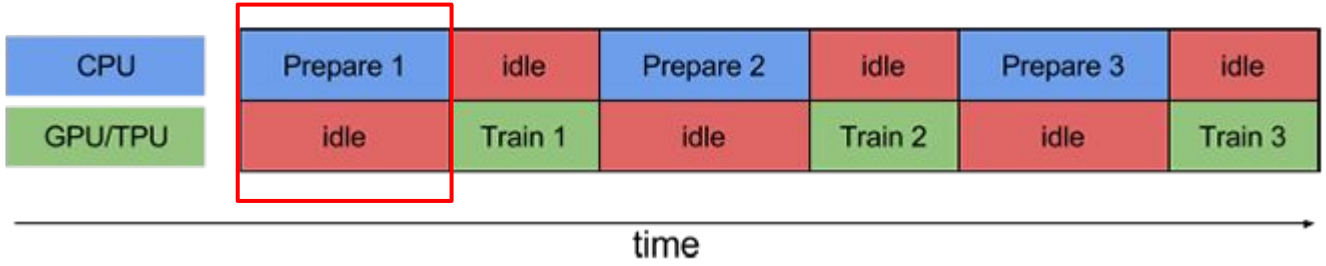
Data and its problems

- Bound to come across fitting input data locally
- When **distributed training** expects **distributed data**
- Avoid having the same data on every machine

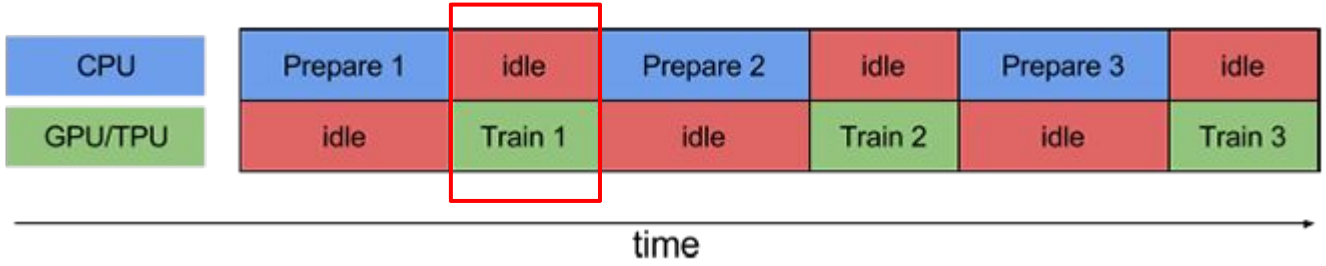
Data and models



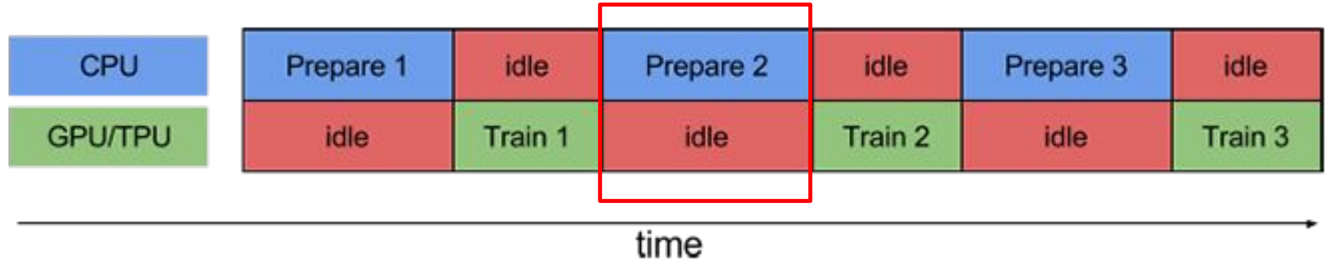
Data and models



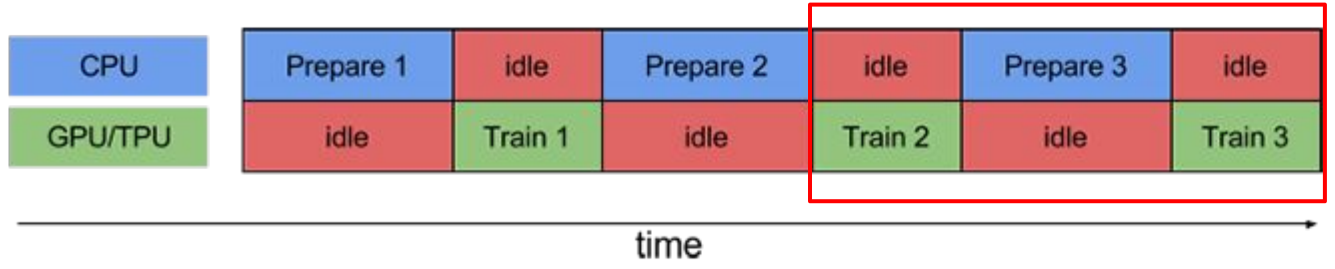
Data and models



Data and models

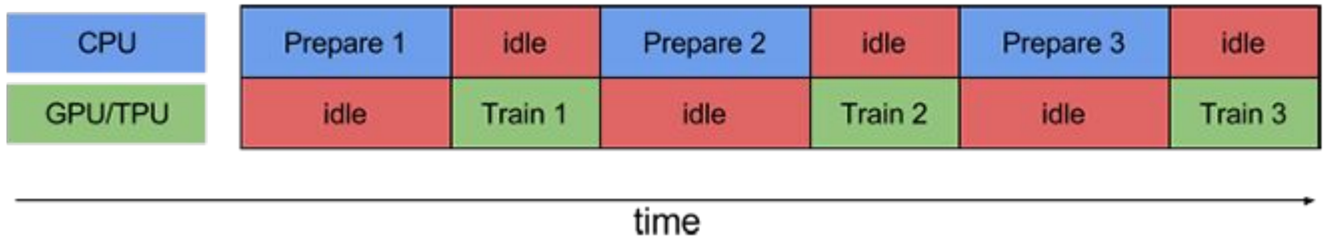


Data and models

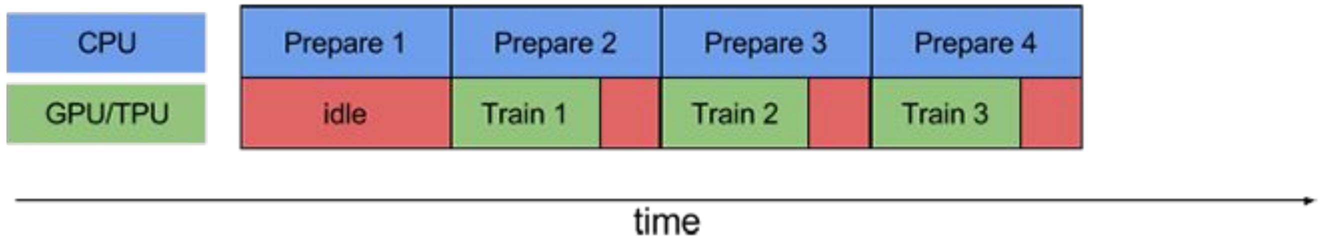


Pipelining

Without pipelining



With pipelining



Improve training time with caching

- In-memory

```
tf.data.Dataset.cache()
```

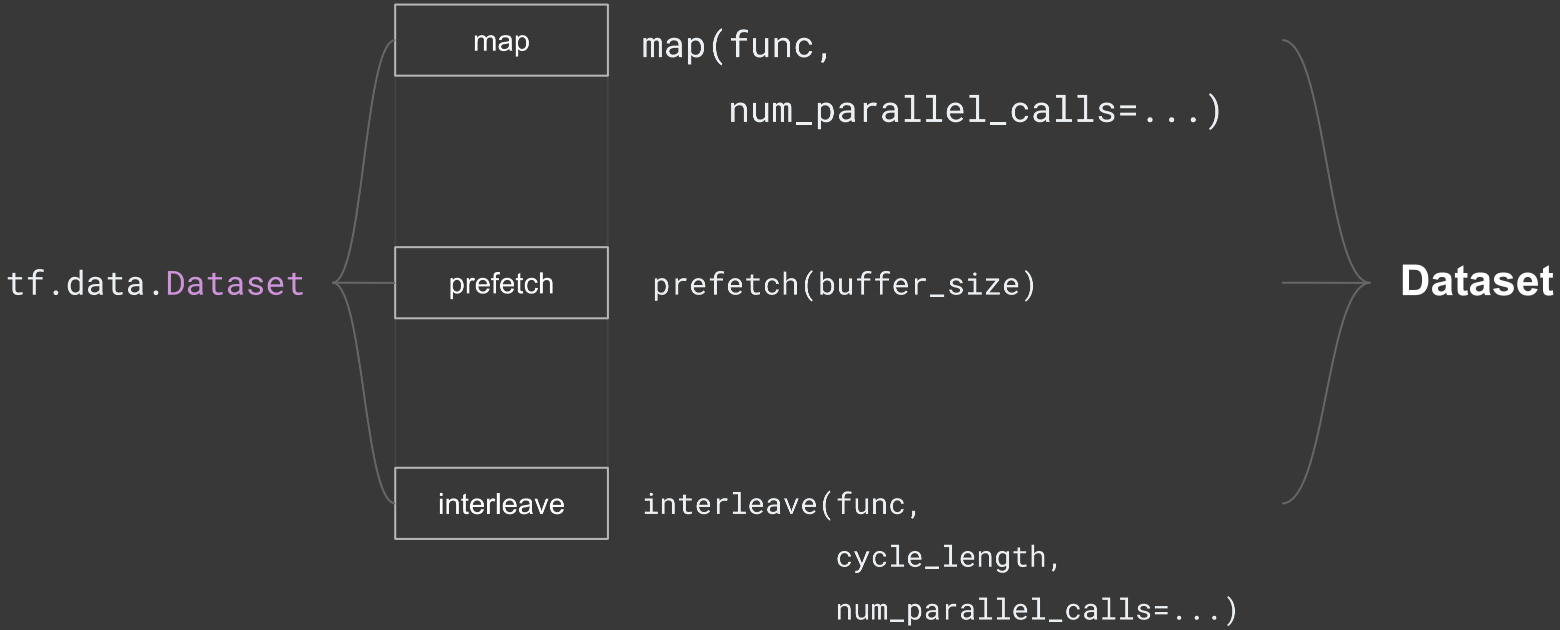
- Disk

```
tf.data.Dataset.cache(filename=...)
```

Caching with tf.data

```
dataset = tfds.load('cats_vs_dogs',split=tfds.Split.TRAIN)


# In-memory caching

train_dataset = dataset.cache()

model.fit(train_dataset, epochs=...)


# Disk caching

train_dataset = dataset.cache(filename='cache')

model.fit(train_dataset, epochs=...)
```

Parallelism with tf.data



```
map(func,
    num_parallel_calls=...)
```

```
prefetch(buffer_size)
```

```
interleave(func,
           cycle_length,
           num_parallel_calls=...)
```

Data transformations

- Transformations can be expensive
- Time-consuming as CPU is not fully utilized

e.g., Resizing, preprocessing, augmentation in images

Consider the following transformation

```
def augment(features):
  X = tf.image.random_flip_left_right(features['image'])
  X = tf.image.random_flip_up_down(X)
  X = tf.image.random_brightness(X, max_delta=0.1)
  X = tf.image.random_saturation(X, lower=0.75, upper=1.5)
  X = tf.image.random_hue(X, max_delta=0.15)
  X = tf.image.random_contrast(X, lower=0.75, upper=1.5)
  X = tf.image.resize(X, (224, 224))
  image = X / 255.0
  return image, features['label']
```

Whats happens when you map that transformation?

```
dataset = tfds.load('cats_vs_dogs',
                    split=tfds.Split.TRAIN)
```

```
augmented_dataset = dataset.map(augment)
```

Parallelizing data transformation

```
map(func, num_parallel_calls=...)
```

```
augmented_dataset = dataset.map(augment, num_parallel_calls=1)
```

Parallelizing data transformation

```
map(func, num_parallel_calls=...)
```

```
augmented_dataset = dataset.map(augment, num_parallel_calls=1)
```

Maximizing the utilization of CPU cores

```
# Get the number of available cpu cores
num_cores = multiprocessing.cpu_count()

# Set num_parallel_calls with 'num_cores'
augmented_dataset = dataset.map(augment, num_parallel_calls=num_cores)
```

Autotuning

- `tf.data.experimental.AUTOTUNE`
- Tunes the value dynamically at runtime
- Decides on the level of parallelism
- Tweaks values of parameters in transformations (tf.data)
  - Buffer size (`map, prefetch, shuffle`, ...)
  - CPU budget (`num_parallel_calls`)
  - I/O (num_parallel_reads)

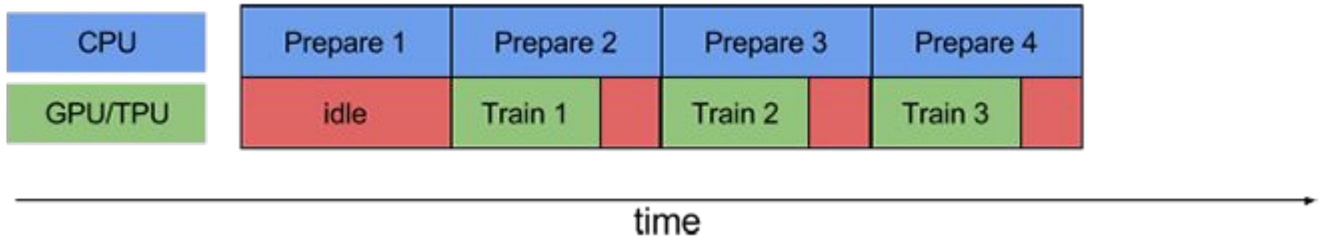
Autotune in practice

```
from tensorflow.data.experimental import AUTOTUNE
```

```
augmented_dataset = dataset.map(
                        augment,
                        num_parallel_calls=AUTOTUNE)
```

Maximizing utilization

With `prefetch`



Parallelizing data loading

`prefetch(buffer_size)`

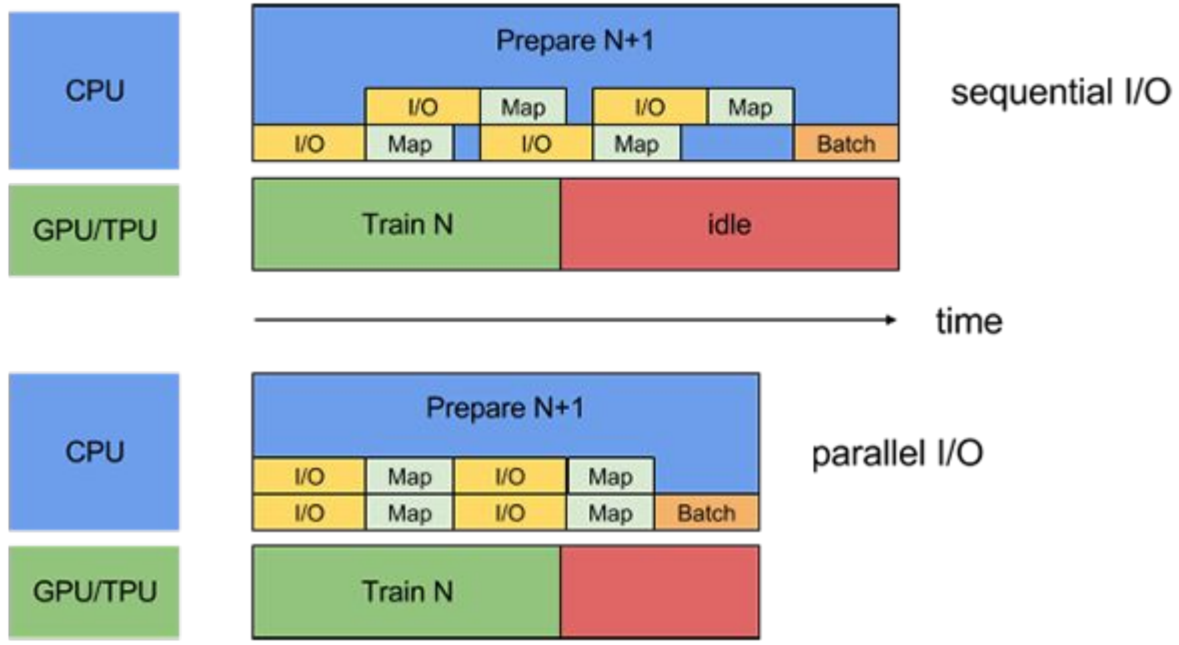
```
dataset = tfds.load('cats_vs_dogs', split=tfds.Split.TRAIN)


# With prefetch
train_dataset = dataset.map(format_image).prefetch(tf.data.experimental.AUTOTUNE)
```

Parallelizing data loading

`prefetch(buffer_size)`

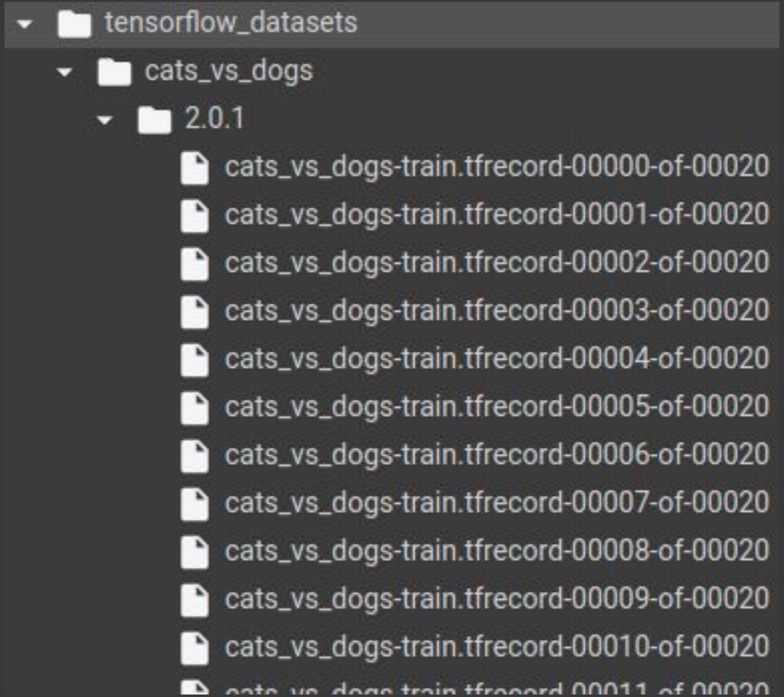
```
dataset = tfds.load('cats_vs_dogs', split=tfds.Split.TRAIN)

# With prefetch
train_dataset = dataset.map(format_image).prefetch(tf.data.experimental.AUTOTUNE)
```

Maximizing I/O utilization



Let’s inspect TFRecords of a TFDS

```
dataset = tfds.load(name='cats_vs_dogs',
                    split=tfds.Split.TRAIN)
```



```
tensorflow_datasets
  cats_vs_dogs
    2.0.1
      cats_vs_dogs-train.tfrecord-00000-of-00020
      cats_vs_dogs-train.tfrecord-00001-of-00020
      cats_vs_dogs-train.tfrecord-00002-of-00020
      cats_vs_dogs-train.tfrecord-00003-of-00020
      cats_vs_dogs-train.tfrecord-00004-of-00020
      cats_vs_dogs-train.tfrecord-00005-of-00020
      cats_vs_dogs-train.tfrecord-00006-of-00020
      cats_vs_dogs-train.tfrecord-00007-of-00020
      cats_vs_dogs-train.tfrecord-00008-of-00020
      cats_vs_dogs-train.tfrecord-00009-of-00020
      cats_vs_dogs-train.tfrecord-00010-of-00020
      cats_vs_dogs-train.tfrecord-00011-of-00020
```

Parallelizing data extraction

```
TFRECORDS_DIR = '/root/tensorflow_datasets/cats_vs_dogs/<dataset-version>/'
files = tf.data.Dataset.list_files(TFRECORDS_DIR +
                                       "cats_vs_dogs-train.tfrecord-*")

num_parallel_reads = 4

dataset = files.interleave(
                tf.data.TFRecordDataset, # map function
                cycle_length=num_parallel_reads, # ...
                num_parallel_calls=tf.data.experimental.AUTOTUNE) # ...
```

Parallelizing data extraction

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TFRECORDS_DIR = '/root/tensorflow_datasets/cats_vs_dogs/<dataset-version>/'
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```

Performance considerations

- The Dataset APIs are designed to be flexible
- Most operations are commutative
- Order transformations accordingly

```
e.g., map, batch, shuffle, repeat, interleave, prefetch, etc.,
```

Map and Batch

The `map` transformation has overhead in terms of

- Scheduling
- Executing the user-defined function

Map and Batch

Solution: Vectorize the user-defined function

```
dataset = dataset.batch(BATCH_SIZE).map(func)
```

or

```
options = tf.data.Options()
options.experimental_optimization.map_vectorization.enabled = True
dataset= dataset.with_options(options)
```

Map and Batch

Solution: Vectorize the user-defined function

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or

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dataset= dataset.with_options(options)
```

Map and Cache

```
# Use map before cache when the transformation is expensive
transformed_dataset = dataset.map(transforms).cache()
```

Shuffle and Repeat

- Shuffling the dataset before applying repeat can cause slow downs
- `shuffle.repeat` for ordering guarantees
- `repeat.shuffle` for better performance

Map and (Interleave / Prefetch / Shuffle)

- All transformations maintain an internal buffer
- Memory footprint is affected if map affects the size of elements
- Generally, have order that affects the memory usage the least