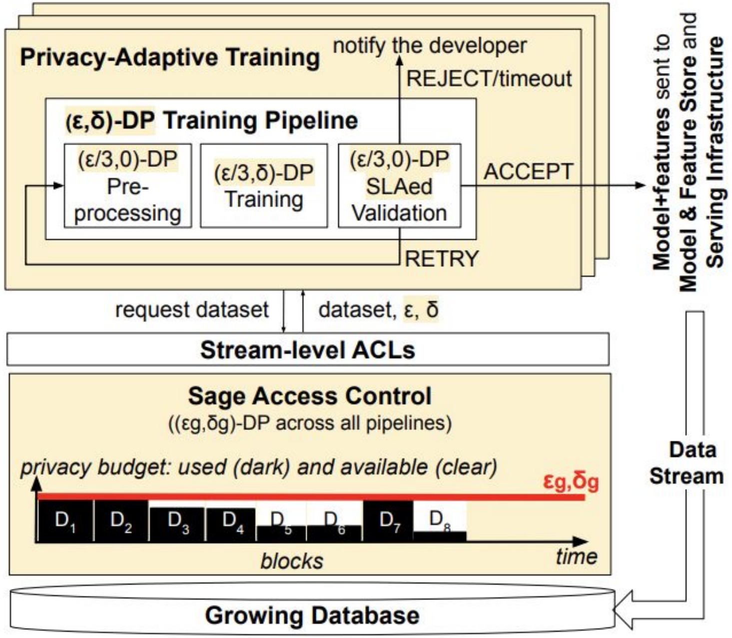
Privacy Accounting and Quality Control in Sage

Whys is DP needed with ML?

- ML datasets could leak specifics about individual entries in their training sets.
- Prevent featurization of dataset
  - Membership inference
  - Reconstruction attacks

Q: Why can't you just train a ML model using PINQ?

Sage Access Control & privacy adaptive training



Leverages the idea that the growing database is not static but growing, keeps training models endlessly on sensitive data stream

Challenges

Privacy Utility trade-off:

- Less accurate results that fail to meet the quality targets more often then w/o DP.
- low -quality models whose validations succeed by chance.

Splitting the data

- User-Level: based on user ID
  - Use incrementing userID's, max stored
  - New blocks are only created when new users join
- Event-level: splitting on time
  - days , months, etc.

Taxi Example

- Preprocessing_fn: makes aggregate features i.e distance of ride, hour of day
  - Dp_group_by_mean:
    - Number of times key appears
    - Sum of values associated w/ key
  - Each data point has one key

```
def preprocessing_fn(inputs, epsilon):
  dist_01 = tft.scale_to_0_1(inputs["distance"],0,100)
  speed_01 = tft.scale_to_0_1(inputs["speed"],0,100)
  hour_of_day_speed = group_by_mean
  sage.dp_group_by_mean(
    inputs["hour_of_day"], speed_01, 24, epsilon, 1.0)
  return {"dist_scaled": dist_01,
    "hour_of_day": inputs["hour_of_day"],
    "hour_of_day_speed": hour_of_day_speed,
    "duration": inputs["duration"]}

def trainer_fn(hparams, schema, epsilon, delta): [...]
  feature_columns = [numeric_column("dist_scaled"),
    numeric_column("hour_of_day_speed"),
    categorical_column("hour_of_day", num_buckets=24)]
  estimator = \
    tf.estimator.DNNRegressorsage.DPDNNRegressor(
      config=run_config,
      feature_columns=feature_columns,
      dnn_hidden_units=hparams.hidden_units,
      privacy_budget=(epsilon, delta))
  return tfx.executors.TrainingSpec(estimator,...)

def validator_fn(epsilon):
  model_validator = \
    tfx.components.ModelValidatorsage.DPModelValidator(
      examples=examples_gen.outputs.output,
      model=trainer.outputs.output,
      metric_fn = _MSE_FN, target = _MSE_TARGET,
      epsilon=epsilon, confidence=0.95, B=1)
  return model_validator

def dp_group_by_mean(key_tensor, value_tensor, nkeys,
  epsilon, value_range):
  key_tensor = tf.dtypes.cast(key_tensor, tf.int64)
  ones = tf.fill(tf.shape(key_tensor), 1.0)
  dp_counts = group_by_sum(key_tensor, ones, nkeys)\
    + laplace(0.0, 2/epsilon, nkeys)
  dp_sums = group_by_sum(
    key_tensor,value_tensor,nkeys)\
    + laplace(0.0, value_range * 2/epsilon, nkeys)
  return tf.gather(dp_sums/dp_counts, key_tensor)
```

Sage Access Control : requirements for composition theory

- R1: Multiple training pipelines w/ differing amounts of data needed for performance
- R2: Adaptivity in choice of queries, DP parameters and data subsets
- R3: Some models are ran periodically w/ new data and others are retired

Failed Methods: which rules do these violate?

1. Query across the entire stream:
    - $\epsilon_{Д} = \epsilon_1 + \epsilon_2 + \epsilon_3$
2. Queries split in to subqueries and each run DP on individual blocks, results aggregated
3. A new data point is allocated to one of the waiting queries, which consumes entire privacy budget.

Block Composition Theory cont.

- Splits data into disjoint blocks adaptively chosen(R1, R2)
- Privacy loss of three queries will be max of $\epsilon 1 + \epsilon 2$, and $\epsilon 2 + \epsilon 3$
- New blocks D5 arrive w/ privacy loss of zero(R3)

System can run endlessly by training new models on new data!

Q: What does it mean for DP parameters to be chosen Adaptively?

Adaptive Parameters

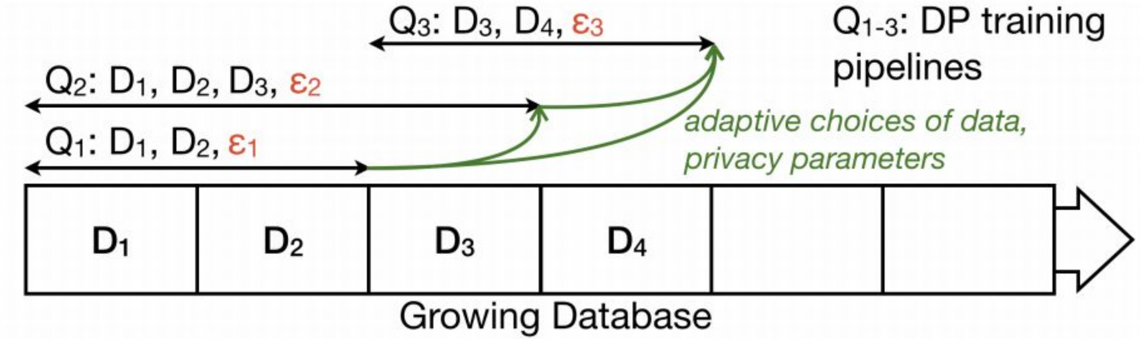


Fig. 3. Characteristics of Data Interaction in ML.

Privacy-Adaptive Training

- To improve DP quality:
  - Increase privacy budget(ϵ, δ) or increase dataset size
- Accept: prediction target reached
- Retry: more data needed for assessment
- Reject: model will never reach target w/ sample size/privacy requirements

Discuss:

Q: What assumptions are made about the data? In what cases could Sage potentially not perform well?