xgboost Data-Rate Prediction

```
library(tidyverse)
library(ggplot2)

library(mlr3)
library(mlr3learners)
library(mlr3pipelines)
library(mlr3tuning)
library(paradox)
```

Upload-Rate Prediction

Reading the Data

```
data_dir = "../datasets/"

dataset_ul = read_csv(
  str_c(data_dir, "dataset_ul.csv"),
  col_types = cols(
    drive_id = col_integer(),
    scenario = col_factor(),
    provider = col_factor(),
    ci = col_factor(),
    enodeb = col_factor()
  )
) %>% select(
  drive_id,
  timestamp,
  scenario,
  provider,
  velocity_mps,
  acceleration_mpss,
  rsrp_dbm,
  rsrq_db,
  rssnr_db,
  cqi,
  ta,
  enodeb,
  f_mhz,
  payload_mb,
  throughput_mbits
) %>% drop_na() %>% rowid_to_column(var="row_id_original")
```

```
dataset_ul_o2 = filter(dataset_ul, provider=="o2")
glimpse(dataset_ul_o2)
```

```
## Rows: 2,039
```

```
## Columns: 16
## $ row_id_original   <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15...
## $ drive_id          <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1...
## $ timestamp         <dttm> 2018-12-10 09:08:57, 2018-12-10 09:09:08, 2018-1...
## $ scenario          <fct> campus, campus, campus, campus, campus, campus, c...
## $ provider          <fct> o2, o2, o2, o2, o2, o2, o2, o2, o2, o2, o2, o2, o...
## $ velocity_mps      <dbl> 11.80, 11.49, 7.93, 10.44, 10.92, 12.02, 10.28, 0...
## $ acceleration_mpss <dbl> 0.13, -0.26, 0.23, 0.06, 0.56, 0.09, -1.25, 0.00,...
## $ rsrp_dbm          <dbl> -99, -97, -96, -82, -101, -106, -112, -99, -98, -...
## $ rsrq_db           <dbl> -9, -12, -12, -11, -14, -13, -18, -15, -15, -14, ...
## $ rssnr_db          <dbl> -1, -2, 5, 11, -3, -3, -6, -4, -6, -4, -6, -3, -2...
## $ cqi               <dbl> 8, 9, 5, 15, 6, 6, 3, 4, 7, 4, 4, 5, 6, 5, 1, 4, ...
## $ ta                <dbl> 9, 7, 7, 7, 7, 7, 7, 12, 13, 13, 13, 13, 11, 13, ...
## $ enodeb            <fct> 54016, 52410, 52410, 52410, 52410, 52410, 52410, ...
## $ f_mhz             <dbl> 1750, 1750, 1750, 1750, 1750, 1750, 1750, 880, 88...
## $ payload_mb        <dbl> 1.0, 6.0, 5.0, 7.0, 5.0, 8.0, 9.0, 7.0, 10.0, 2.0...
## $ throughput_mbits  <dbl> 4.66, 3.97, 6.52, 1.37, 0.80, 1.04, 2.34, 4.09, 2...
```

```
dataset_ul_tmobile = filter(dataset_ul, provider=="tmobile")
glimpse(dataset_ul_tmobile)
```

```
## Rows: 2,301
## Columns: 16
## $ row_id_original   <int> 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2...
## $ drive_id          <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1...
## $ timestamp         <dttm> 2018-12-10 09:08:57, 2018-12-10 09:09:07, 2018-1...
## $ scenario          <fct> campus, campus, campus, campus, campus, campus, c...
## $ provider          <fct> tmobile, tmobile, tmobile, tmobile, tmobile, tmob...
## $ velocity_mps      <dbl> 11.83, 11.45, 8.15, 9.42, 10.61, 11.84, 9.75, 0.0...
## $ acceleration_mpss <dbl> 0.03, -0.32, 0.24, 0.43, 0.38, -0.37, -2.15, 0.00...
## $ rsrp_dbm          <dbl> -85, -84, -74, -92, -90, -101, -93, -94, -94, -94...
## $ rsrq_db           <dbl> -5, -6, -5, -6, -6, -10, -8, -11, -11, -10, -9, -...
## $ rssnr_db          <dbl> 22, 11, 29, 13, 16, 13, 7, 0, 8, 2, 24, 10, 22, 1...
## $ cqi               <dbl> 10, 13, 15, 12, 9, 15, 10, 9, 9, 7, 10, 9, 12, 15...
## $ ta                <dbl> 7, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 3, 3...
## $ enodeb            <fct> 103068, 114809, 114809, 114809, 114809, 114809, 1...
## $ f_mhz             <dbl> 1720, 1720, 1720, 1720, 1720, 1720, 1720, 1720, 1...
## $ payload_mb        <dbl> 4.0, 2.0, 4.0, 9.0, 8.0, 6.0, 5.0, 4.0, 3.0, 2.0,...
## $ throughput_mbits  <dbl> 24.52, 14.86, 16.27, 12.68, 14.59, 13.13, 16.37, ...
```

```
dataset_ul_vodafone = filter(dataset_ul, provider=="vodafone")
glimpse(dataset_ul_vodafone)
```

```
## Rows: 1,828
## Columns: 16
## $ row_id_original   <int> 4341, 4342, 4343, 4344, 4345, 4346, 4347, 4348, 4...
## $ drive_id          <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1...
## $ timestamp         <dttm> 2018-12-10 09:09:03, 2018-12-10 09:09:21, 2018-1...
## $ scenario          <fct> campus, campus, campus, campus, campus, campus, c...
## $ provider          <fct> vodafone, vodafone, vodafone, vodafone, vodafone,...
## $ velocity_mps      <dbl> 11.70, 8.22, 8.00, 10.30, 12.28, 0.00, 0.00, 0.00...
## $ acceleration_mpss <dbl> 0.06, 0.32, 0.53, 0.36, 0.12, 0.00, 0.00, 0.00, -...
## $ rsrp_dbm          <dbl> -121, -108, -111, -106, -110, -94, -95, -92, -98,...
## $ rsrq_db           <dbl> -15, -9, -13, -8, -9, -7, -7, -8, -6, -10, -7, -8...
## $ rssnr_db          <dbl> -8, 2, 6, 5, 9, 23, 23, 24, 14, 1, 14, 12, 14, 7,...
```

```
## $ cqi               <dbl> 4, 2, 6, 11, 10, 15, 12, 15, 12, 6, 15, 10, 11, 7...
## $ ta                <dbl> 63, 21, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 1...
## $ enodeb            <fct> 51044, 52316, 50026, 50026, 50026, 50026, 50026, ...
## $ f_mhz             <dbl> 1770, 1770, 1770, 1770, 1770, 1770, 1770, 1770, 1...
## $ payload_mb        <dbl> 6.0, 10.0, 0.1, 2.0, 6.0, 0.1, 0.1, 0.5, 7.0, 0.1...
## $ throughput_mbits  <dbl> 1.29, 3.18, 0.05, 2.93, 8.79, 5.16, 4.73, 10.13, ...
```

Create the Prediction Tasks for Each Provider

```
make_task = function(dataset, task_id) {
  task = TaskRegr$new(
    id = task_id,
    backend = dataset %>% select(-drive_id, -timestamp, -provider, -scenario),
    target = "throughput_mbits"
  )

  task$col_roles$name = "row_id_original"
  task$col_roles$feature = setdiff(task$col_roles$feature, "row_id_original")

  return(task)
}

task_ul_o2 = make_task(dataset_ul_o2, "task_ul_o2")
task_ul_o2
```

```
## <TaskRegr:task_ul_o2> (2039 x 11)
## * Target: throughput_mbits
## * Properties: -
## * Features (10):
##   - dbl (9): acceleration_mpss, cqi, f_mhz, payload_mb, rsrp_dbm,
##     rsrq_db, rssnr_db, ta, velocity_mps
##   - fct (1): enodeb
```

```
task_ul_tmobile = make_task(dataset_ul_tmobile, "task_ul_tmobile")
task_ul_tmobile
```

```
## <TaskRegr:task_ul_tmobile> (2301 x 11)
## * Target: throughput_mbits
## * Properties: -
## * Features (10):
##   - dbl (9): acceleration_mpss, cqi, f_mhz, payload_mb, rsrp_dbm,
##     rsrq_db, rssnr_db, ta, velocity_mps
##   - fct (1): enodeb
```

```
task_ul_vodafone = make_task(dataset_ul_vodafone, "task_ul_vodafone")
task_ul_vodafone
```

```
## <TaskRegr:task_ul_vodafone> (1828 x 11)
## * Target: throughput_mbits
## * Properties: -
## * Features (10):
##   - dbl (9): acceleration_mpss, cqi, f_mhz, payload_mb, rsrp_dbm,
##     rsrq_db, rssnr_db, ta, velocity_mps
##   - fct (1): enodeb
```

Create Data Splitting Strategies for Testing and Validation

The outer resampling is used for the train/validation split.

```
get_row_ids_by_drive_ids = function(task, drive_ids) {
  result = (tibble(task$row_names) %>%
    inner_join(dataset_ul, by=c("row_name"="row_id_original")) %>%
    filter(drive_id %in% drive_ids))$row_id
  return(result)
}

make_outer_resampling = function(task, drive_ids_train, drive_ids_test) {
  row_ids_train = get_row_ids_by_drive_ids(task, drive_ids_train)
  row_ids_test = get_row_ids_by_drive_ids(task, drive_ids_test)

  result = rsmp("custom")
  result$instantiate(task, train_sets=list(row_ids_train), test_sets=list(row_ids_test))

  return(result)
}
```

The inner resampling is used for the parameter tuning on the training set.

```
make_inner_resampling = function(task, last_drive_id) {
  train_sets = list()
  test_sets = list()

  for (cur_last_drive_id_train in 2:(last_drive_id-1)) {
    drive_ids_train = 1:cur_last_drive_id_train
    drive_ids_test = cur_last_drive_id_train + 1

    row_ids_train = get_row_ids_by_drive_ids(task, drive_ids_train)
    row_ids_test = get_row_ids_by_drive_ids(task, drive_ids_test)

    train_sets[[length(train_sets)+1]] = row_ids_train
    test_sets[[length(test_sets)+1]] = row_ids_test
  }

  result = rsmp("custom")
  result$instantiate(task, train_sets=train_sets, test_sets=test_sets)

  return(result)
}
```

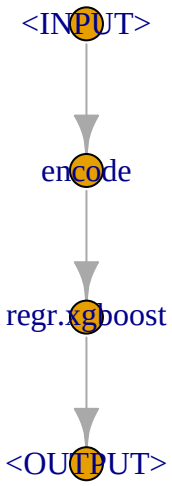
Create the Prediction Pipeline for Each Provider

```
make_learner = function(nrounds=100, eta=NULL, gamma=NULL, lambda=NULL) {
  factor_encoding = po(
    "encode",
    method = "one-hot",
    affect_columns = selector_type("factor")
  )
  xgboost = lrn("regr.xgboost")

  if (!is.null(nrounds)) {
```

```
    xgboost$param_set$values = mlr3misc::insert_named(
      xgboost$param_set$values,
      list(nrounds=nrounds)
    )
  }
  if (!is.null(eta)) {
    xgboost$param_set$values = mlr3misc::insert_named(
      xgboost$param_set$values,
      list(eta=eta)
    )
  }
  if (!is.null(gamma)) {
    xgboost$param_set$values = mlr3misc::insert_named(
      xgboost$param_set$values,
      list(gamma=gamma)
    )
  }
  if (!is.null(lambda)) {
    xgboost$param_set$values = mlr3misc::insert_named(
      xgboost$param_set$values,
      list(lambda=lambda)
    )
  }

  pipe = factor_encoding %>>% PipeOpLearner$new(xgboost)
  learner = GraphLearner$new(pipe)
  return(learner)
}
```

Here we can see the prediction pipeline:

```
make_learner()$graph$plot()
```



Parameter Tuning

```
parameter_space = ParamSet$new(list(
  ParamInt$new("regr.xgboost.nrounds", lower=100, upper=1000),
  ParamDbl$new("regr.xgboost.eta", lower=0.01, upper=1),
  ParamDbl$new("regr.xgboost.gamma", lower=0, upper=10),
  ParamDbl$new("regr.xgboost.lambda", lower=0, upper=10)
))
```

```
get_tuning_result = function(task, grid_resolution, n_evals) {
  tuning_instance = TuningInstanceSingleCrit$new(
    task = task,
    learner = make_learner(),
    resampling = make_inner_resampling(task, last_drive_id=7),
    measure = msr("regr.mae"),
    terminator = trm("evals", n_evals=n_evals),
    search_space = parameter_space,
    store_benchmark_result = TRUE,
    check_values = TRUE
  )

  tuner = tnr("grid_search", resolution = grid_resolution)
  tuner$optimize(tuning_instance)

  return(tuning_instance)
}
```

```
tuning_result_o2 = get_tuning_result(task_ul_o2, grid_resolution = 20, n_evals = 10)

tuning_result_tmobile = get_tuning_result(task_ul_tmobile, grid_resolution = 20, n_evals = 10)

tuning_result_vodafone = get_tuning_result(task_ul_vodafone, grid_resolution = 20, n_evals = 10)
```

```
tuning_result_o2$result
```

```
##    regr.xgboost.nrounds regr.xgboost.eta regr.xgboost.gamma regr.xgboost.lambda
## 1:                  479       0.06210526           8.947368            8.421053
##    learner_param_vals  x_domain regr.mae
## 1:          <list[7]> <list[4]> 2.283779
```

```
tuning_result_tmobile$result
```

```
##    regr.xgboost.nrounds regr.xgboost.eta regr.xgboost.gamma regr.xgboost.lambda
## 1:                  716        0.3747368           6.315789            3.157895
##    learner_param_vals  x_domain regr.mae
## 1:          <list[7]> <list[4]> 3.189625
```

```
tuning_result_vodafone$result
```

```
##    regr.xgboost.nrounds regr.xgboost.eta regr.xgboost.gamma regr.xgboost.lambda
## 1:                  716       0.06210526           5.263158            1.052632
##    learner_param_vals  x_domain regr.mae
## 1:          <list[7]> <list[4]> 2.552795
```

Create Learners with Tuned Hyperparameters

```
learner_ul_o2 = make_learner(
  nrounds = tuning_result_o2$result$regr.xgboost.nrounds,
  eta = tuning_result_o2$result$regr.xgboost.eta,
  gamma = tuning_result_o2$result$regr.xgboost.gamma,
  lambda = tuning_result_o2$result$regr.xgboost.lambda
)

learner_ul_tmobile = make_learner(
  nrounds = tuning_result_tmobile$result$regr.xgboost.nrounds,
  eta = tuning_result_tmobile$result$regr.xgboost.eta,
  gamma = tuning_result_tmobile$result$regr.xgboost.gamma,
  lambda = tuning_result_tmobile$result$regr.xgboost.lambda
)

learner_ul_vodafone = make_learner(
  nrounds = tuning_result_vodafone$result$regr.xgboost.nrounds,
  eta = tuning_result_vodafone$result$regr.xgboost.eta,
  gamma = tuning_result_vodafone$result$regr.xgboost.gamma,
  lambda = tuning_result_vodafone$result$regr.xgboost.lambda
)
```

Validation Results

Provider O2

```
validation_result_ul_o2 = resample(
  task = task_ul_o2,
  learner = learner_ul_o2,
  resampling = make_outer_resampling(task_ul_o2, drive_ids_train=1:7, drive_ids_test=8:10),
  store_models = TRUE
)
```

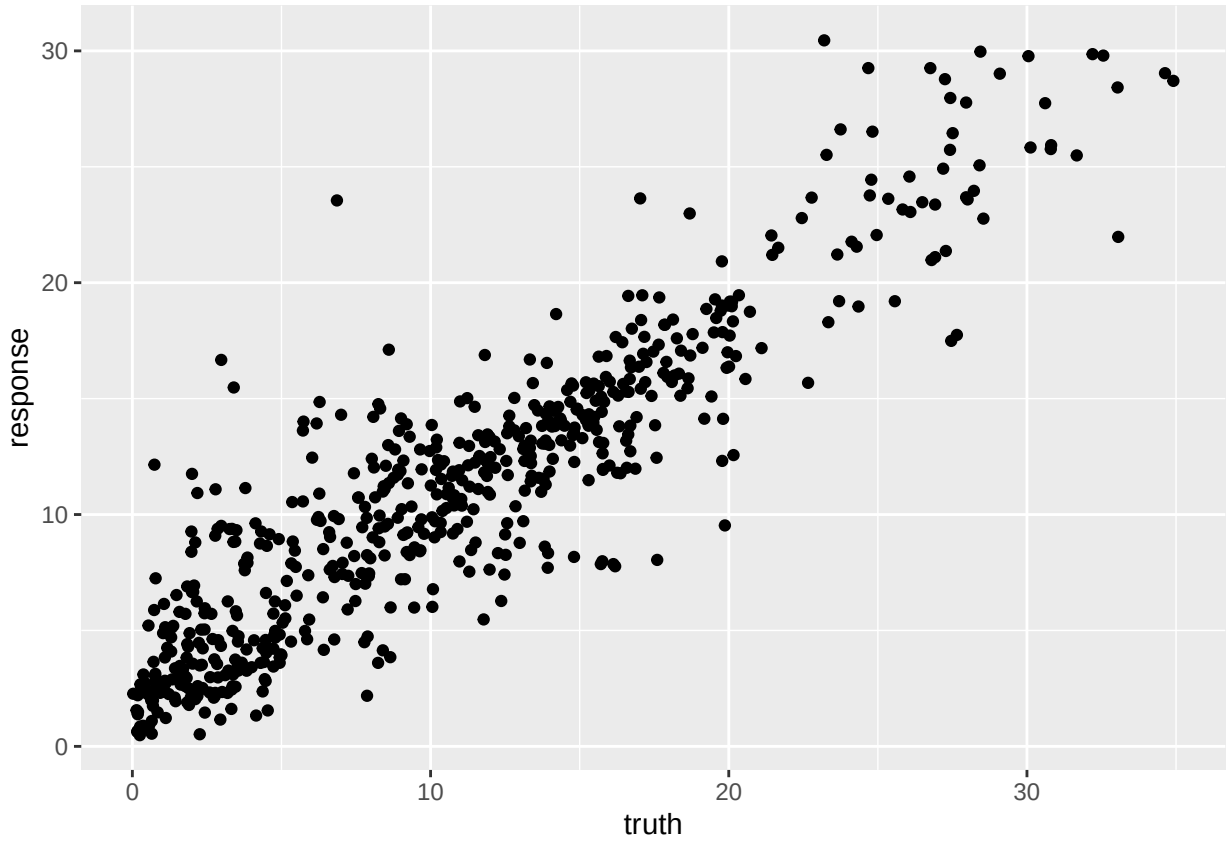
```
validation_result_ul_o2$aggregate(msr("regr.rsq"))
```

```
##  regr.rsq
## 0.8200591
```

```
validation_result_ul_o2$aggregate(msr("regr.mae"))
```

```
## regr.mae
##  2.36251
```

```
predictions_ul_o2 = as.data.table(validation_result_ul_o2$prediction())
ggplot(predictions_ul_o2, aes(x=truth, y=response)) +
  geom_point()
```



Provider T-Mobile

```
validation_result_ul_tmobile = resample(
  task = task_ul_tmobile,
  learner = learner_ul_tmobile,
  resampling = make_outer_resampling(task_ul_tmobile, drive_ids_train=1:7, drive_ids_test=8:10),
  store_models = TRUE
)
```

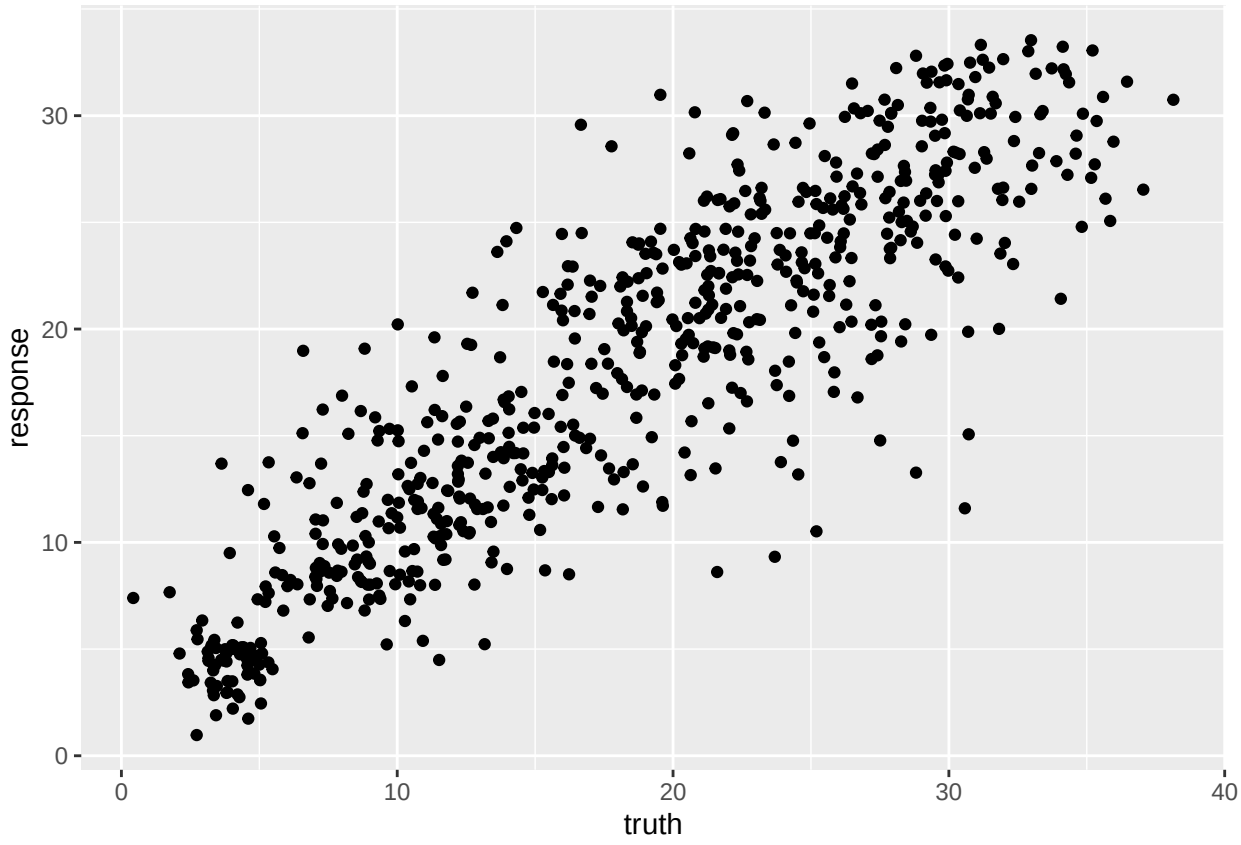
```
validation_result_ul_tmobile$aggregate(msr("regr.rsq"))
```

```
##  regr.rsq
## 0.7761381
```

```
validation_result_ul_tmobile$aggregate(msr("regr.mae"))
```

```
## regr.mae
## 3.158567
```

```
predictions_ul_tmobile = as.data.table(validation_result_ul_tmobile$prediction())
ggplot(predictions_ul_tmobile, aes(x=truth, y=response)) +
  geom_point()
```



Provider Vodafone

```
validation_result_ul_vodafone = resample(
  task = task_ul_vodafone,
  learner = learner_ul_vodafone,
  resampling = make_outer_resampling(task_ul_vodafone, drive_ids_train=1:7, drive_ids_test=8:10),
```

```
  store_models = TRUE
)
```

```
validation_result_ul_vodafone$aggregate(msr("regr.rsq"))
```

```
##  regr.rsq
## 0.7231985
```

```
validation_result_ul_vodafone$aggregate(msr("regr.mae"))
```

```
## regr.mae
## 2.386074
```

```
predictions_ul_vodafone = as.data.table(validation_result_ul_vodafone$prediction())
ggplot(predictions_ul_vodafone, aes(x=truth, y=response)) +
  geom_point()
```