ModelDB: a system for managing ML models

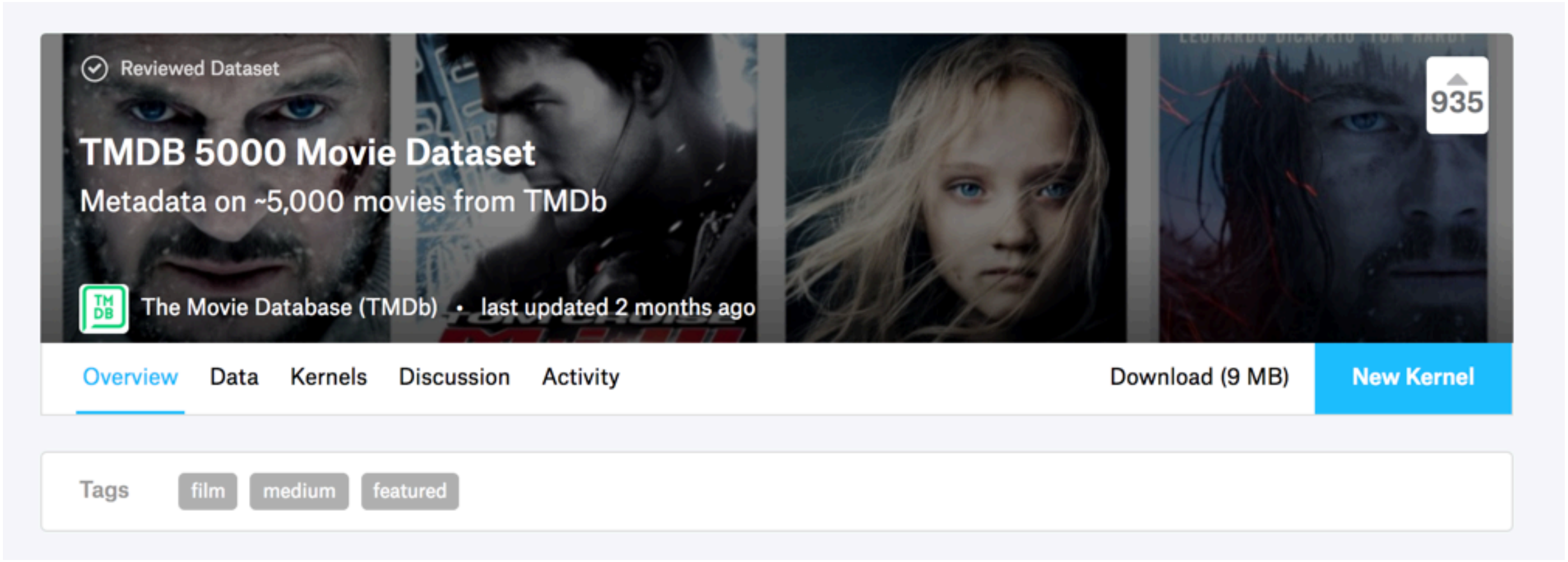
Manasi Vartak, *PhD Candidate*
MIT Database Group

mvartak@csail.mit.edu | @DataCereal

Database Group
MIT Computer Science and Artificial Intelligence Lab

Why Model Management?

IMDB Prediction Task



- Given data about movies (e.g. year made, studio, genres, actors)

- Predict IMDB_score

Model 1

```scala
// process data in
val (preprocessedData, featureVectorNames, _) =
 process(
  "color", "content_rating",
  "country", "first_genre", "second_genre",
  "num_critic_for_reviews", "gross",
  "num_user_for_reviews", "title_year",
  "num_voted_users"
  )
```

```scala
// Train a Linear Regression model.
val labelCol = "imdb_score"
val featuresCol = "features"
val predictionCol = "prediction"
val lr = new LinearRegression()
  .setMaxIter(10)
  .setLabelCol(labelCol)
  .setPredictionCol(predictionCol)
  .setFeaturesCol(featuresCol)
  .setRegParam(0.3)
  .setElasticNetParam(0.1)
val lrModel = lr.fit(train)
lrModel.save("imdb_simple_lr")

// Evaluate the model.
val eval = new RegressionEvaluator()
  .setMetricName("rmse")
  .setLabelCol(labelCol)
  .setPredictionCol(predictionCol)

val predictions = lrModel.transform(test)
val score = eval.evaluate(predictions, lrModel)
```

LinearRegression

Accuracy: 62%

Model 2

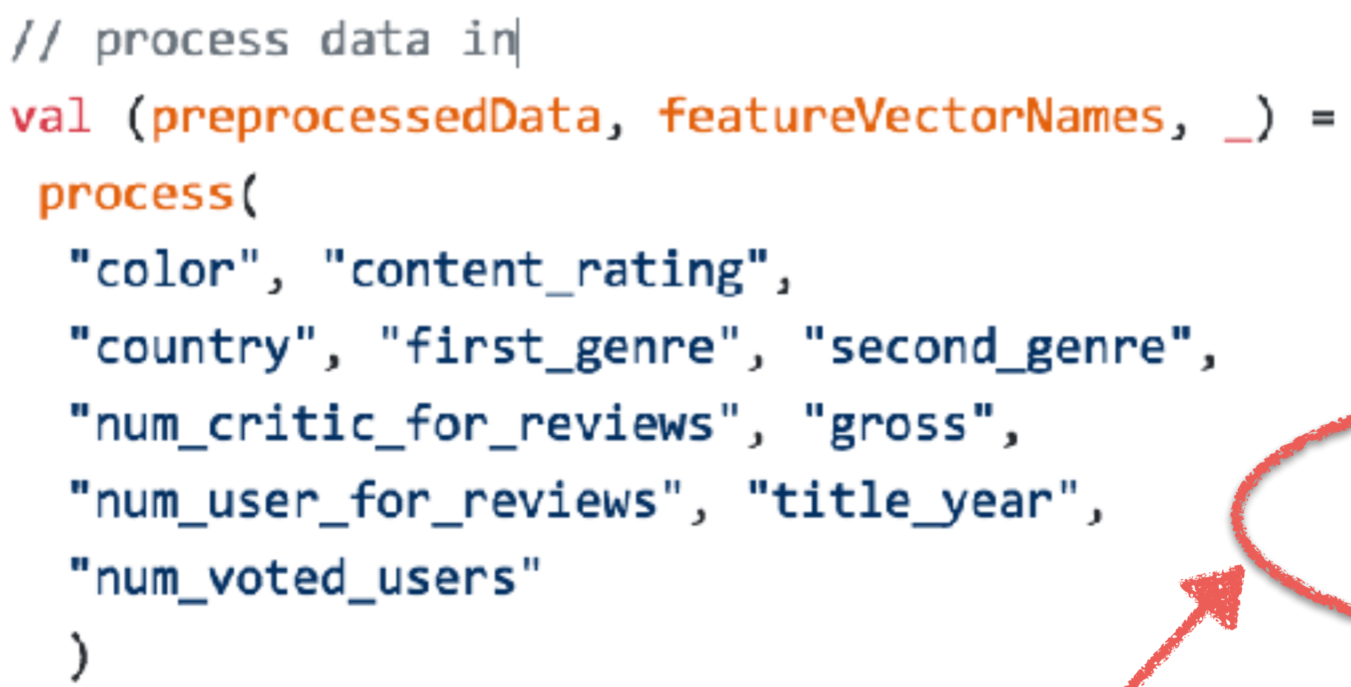
```
// process data in
val (preprocessedData, featureVectorNames, _) =
 process(
  "color", "content_rating",
  "country", "first_genre", "second_genre",
  "num_critic_for_reviews", "gross",
  "num_user_for_reviews", "title_year",
  "num_voted_users"
  )
```

Accuracy: 68%

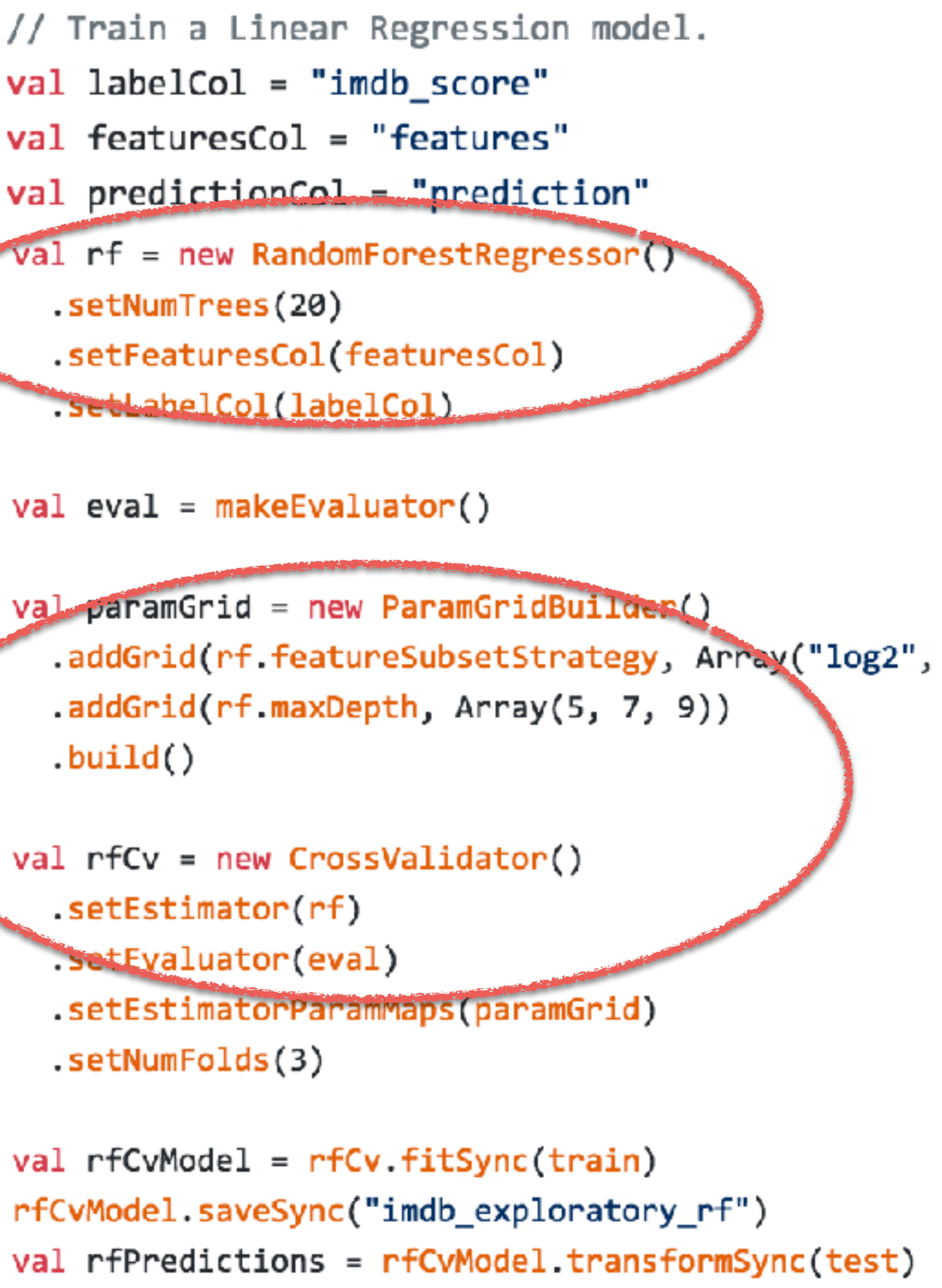
```
// Train a Linear Regression model.
val labelCol = "imdb_score"
val featuresCol = "features"
val predictionCol = "prediction"
val lr = new LinearRegression()
  .setMaxIter(10)
  .setLabelCol(labelCol)
  .setPredictionCol(predictionCol)
  .setFeaturesCol(featuresCol)
val paramGrid = new ParamGridBuilder()
  .addGrid(lr.regParam, Array(0.1, 0.3, 0.5))
  .addGrid(lr.elasticNetParam, Array(0.1, 0.3, 0.8))
  .build()

val lrCv = new CrossValidator()
  .setEstimator(lr)
  .setEvaluator(eval)
  .setEstimatorParamMaps(paramGrid)
  .setNumFolds(3)

val lrCvModel = lrCv.fitSync(train)
lrCvModel.saveSync("imdb_exploratory_lr")
val lrPredictions = lrCvModel.transformSync(test)
```

CrossValidation

Model 3



```
// process data in
val (preprocessedData, featureVectorNames, _) =
 process(
  "color", "content_rating",
  "country", "first_genre", "second_genre",
  "num_critic_for_reviews", "gross",
  "num_user_for_reviews", "title_year",
  "num_voted_users"
  )
```



```
// Train a Linear Regression model.
val labelCol = "imdb_score"
val featuresCol = "features"
val predictionCol = "prediction"
val rf = new RandomForestRegressor()
  .setNumTrees(20)
  .setFeaturesCol(featuresCol)
  .setLabelCol(labelCol)

val eval = makeEvaluator()

val paramGrid = new ParamGridBuilder()
  .addGrid(rf.featureSubsetStrategy, Array("log2",
  .addGrid(rf.maxDepth, Array(5, 7, 9))
  .build()

val rfCv = new CrossValidator()
  .setEstimator(rf)
  .setEvaluator(eval)
  .setEstimatorParamMaps(paramGrid)
  .setNumFolds(3)

val rfCvModel = rfCv.fitSync(train)
rfCvModel.saveSync("imdb_exploratory_rf")
val rfPredictions = rfCvModel.transformSync(test)
```

RandomForest

Accuracy: 75%

CrossValidation

Model 4

```scala
val (preprocessedData, featureVectorNames, _) =
 process(
  "color", "content_rating",
  "country", "first_genre", "second_genre",
  "num_critic_for_reviews", "gross",
  "num_users_for_reviews", "title_year",
  "num_voted_users"
  )
val embed_genres: (Array[String] => Int) = ...
preprocessedData.withColumn("embedded_genres",
                            embed_genres)
```

FeatureEngg

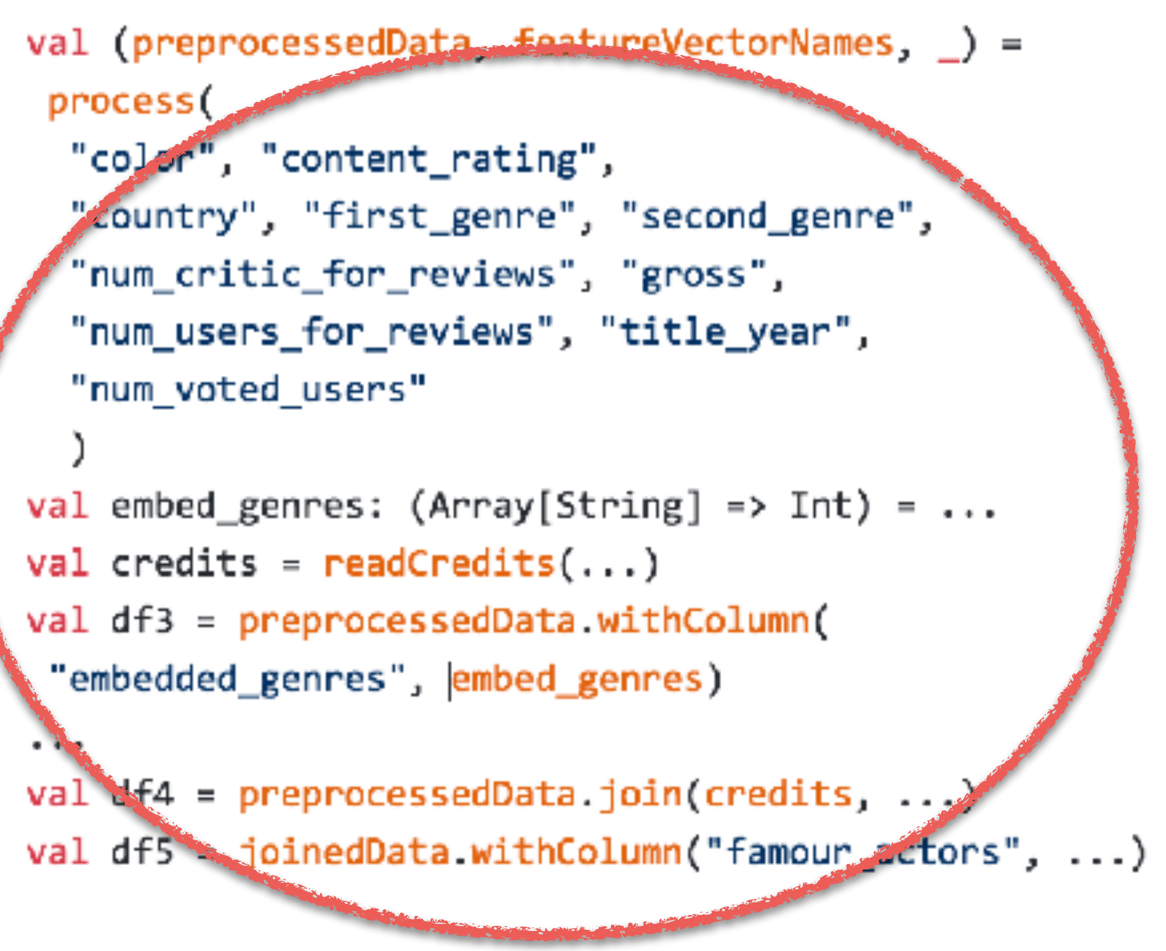
Accuracy: 80%

```scala
// Train a Linear Regression model.
val labelCol = "imdb_score"
val featuresCol = "features"
val predictionCol = "prediction"
val rf = new RandomForestRegressor()
  .setNumTrees(20)
  .setFeaturesCol(featuresCol)
  .setLabelCol(labelCol)

val eval = makeEvaluator()

val paramGrid = new ParamGridBuilder()
  .addGrid(rf.featureSubsetStrategy, Array("log2",
  .addGrid(rf.maxDepth, Array(5, 7, 9))
  .build()

val rfCv = new CrossValidator()
  .setEstimator(rf)
  .setEvaluator(eval)
  .setEstimatorParamMaps(paramGrid)
  .setNumFolds(3)

val rfCvModel = rfCv.fitSync(train)
rfCvModel.saveSync("imdb_exploratory_rf")
val rfPredictions = rfCvModel.transformSync(test)
```

RandomForest

CrossValidation

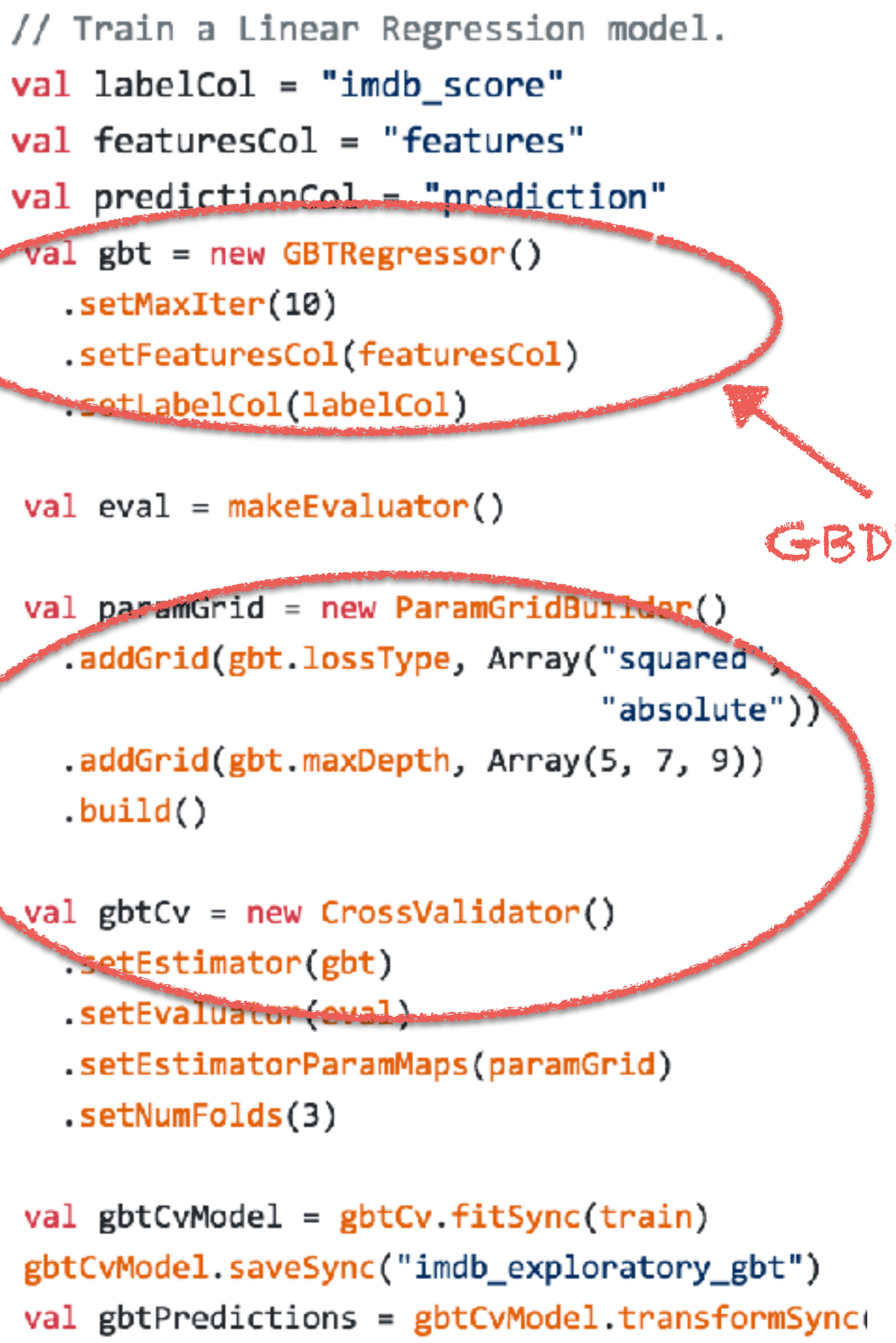
Model 50



```
val (preprocessedData, featureVectorNames, _) =
 process(
  "color", "content_rating",
  "country", "first_genre", "second_genre",
  "num_critic_for_reviews", "gross",
  "num_users_for_reviews", "title_year",
  "num_voted_users"
  )
val embed_genres: (Array[String] => Int) = ...
val credits = readCredits(...)
val df3 = preprocessedData.withColumn(
 "embedded_genres", embed_genres)
..
val df4 = preprocessedData.join(credits, ...)
val df5 = joinedData.withColumn("famour_actors", ...)
```

FeatureEngg

Accuracy: 84%



```
// Train a Linear Regression model.
val labelCol = "imdb_score"
val featuresCol = "features"
val predictionCol = "prediction"
val gbt = new GBTRegressor()
   .setMaxIter(10)
   .setFeaturesCol(featuresCol)
   .setLabelCol(labelCol)

val eval = makeEvaluator()

val paramGrid = new ParamGridBuilder()
   .addGrid(gbt.lossType, Array("squared",
                                "absolute"))
   .addGrid(gbt.maxDepth, Array(5, 7, 9))
   .build()

val gbtCv = new CrossValidator()
   .setEstimator(gbt)
   .setEvaluator(eval)
   .setEstimatorParamMaps(paramGrid)
   .setNumFolds(3)

val gbtCvModel = gbtCv.fitSync(train)
gbtCvModel.saveSync("imdb_exploratory_gbt")
val gbtPredictions = gbtCvModel.transformSync(
```

GBDT

CrossValidation

Why is this a problem?

- No record of experiments — Did my colleague do that already?
- Insights lost along the way — How did normalization affect my ROC?
- Difficult to reproduce results — What params did I use?
- Cannot search for or query models — Where is the prod version of the model for churn?
- Difficult to collaborate — How does someone review your model?

ModelDB: an end-to-end model management system

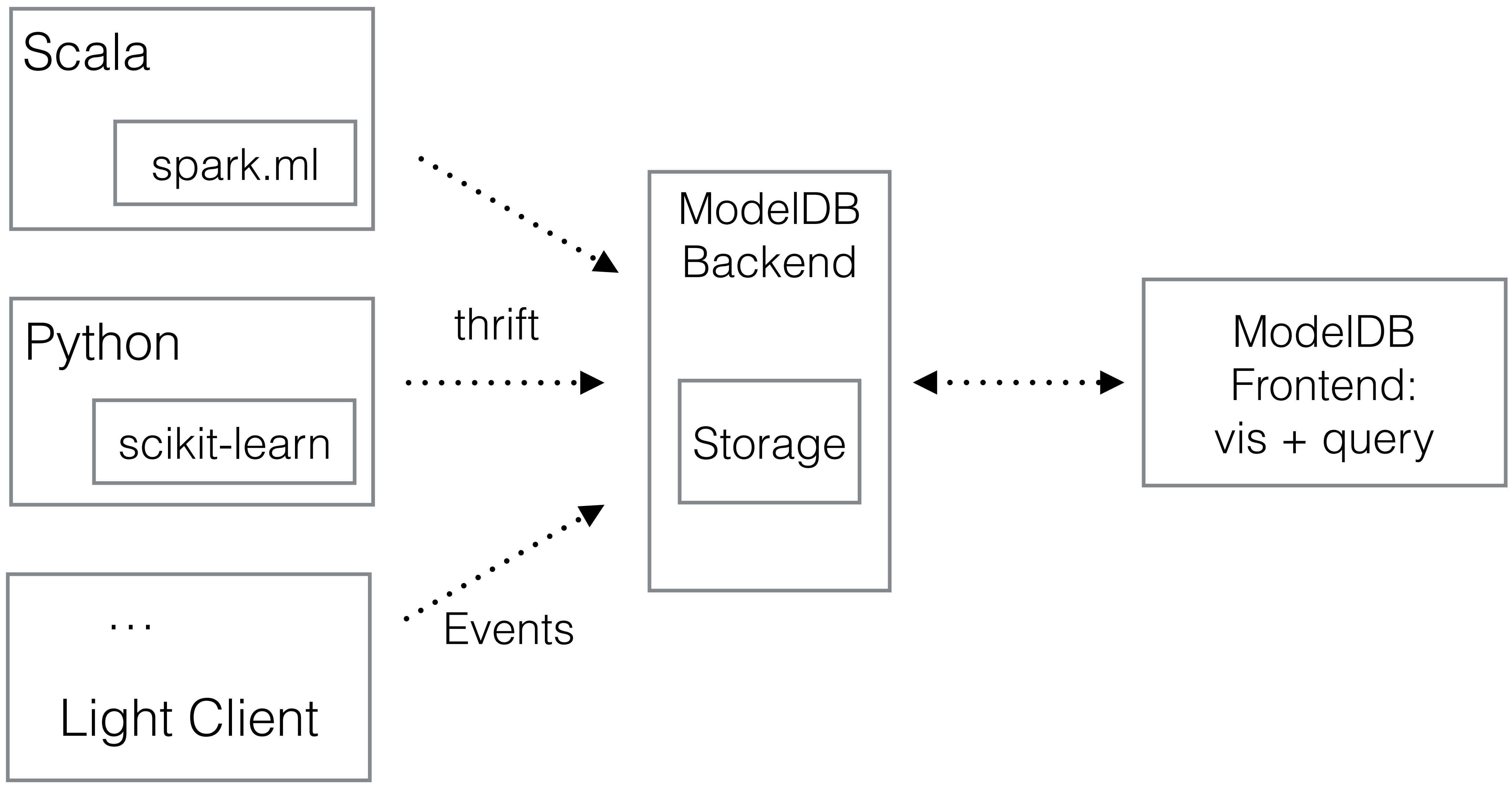
Ingest models, metadata

Store and version modeling artifacts

Query

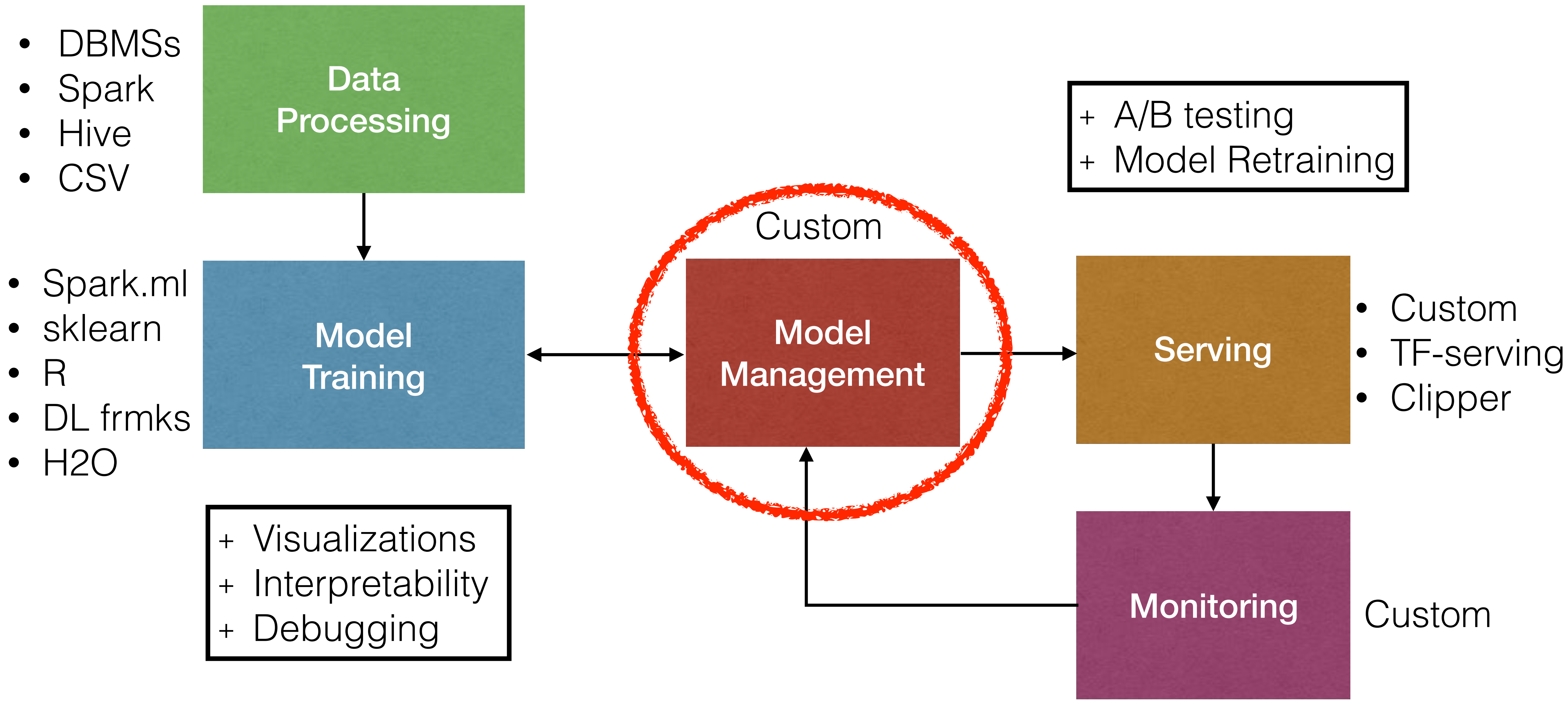
Collaborate, Reproduce results

ModelDB Architecture



Demo

ML Infrastructure



Benefits of model management

Offline

Developer Productivity

+ Provenance
+ Reproducibility
+ Meta-analyses

Increased Transparency

+ What models have been built
+ How well do models work?
+ Auditability

Online

Model Monitoring

+ Model performance over time
+ Anomaly detection
+ Trigger retraining

Fast Failure Analyses

+ How was this model built?
+ What has changed?

At last NIPS

- Initial version of ModelDB with sklearn, spark.ml support
- Early adopters (banks, financial firms), early feedback
- Focus on developer productivity

Since last NIPS!

- Initial release of ModelDB in Feb early 2017
- Adoption/evaluation at Adobe, banks, financial institutions, and tech companies
- Won AIGrant for open-source projects
- See papers at SIGMOD, NIPS workshops

Since last NIPS!

- Easy installation: docker, pip
- Light clients (R, YAML, packages outside of sklearn)
- Flexible metadata storage
- Collecting metrics over time
- Fine-grained visualizations
- In the (research) pipeline
  - Data and intermediate storage
  - Model diagnosis

ModelDB so far

- Incredible inbound interest
  - Banks, finance, insurance, tech
  - Lots of feature requests (e..g monitoring, diagnosis, DL). *More than research resources can handle :)*
- Validation
  - Every data scientist building > 10 models needs model management and is looking for these tools
  - Vision: Industry standard tool for managing ML models and metadata

Moving to Apache Incubation

- With MIT, Adobe, other partners (*MLSys community)
- Open development to wider community
- Contributions across industry
- Roadmap
    - Multiple storage backends, DL frameworks, R
    - Monitoring capabilities

Call for Contributions!

- Community over code
- Build once, reuse many times
- Why?
  - It will measurably improve your workflow
  - Pay it forward
  - Be part of larger open-source project

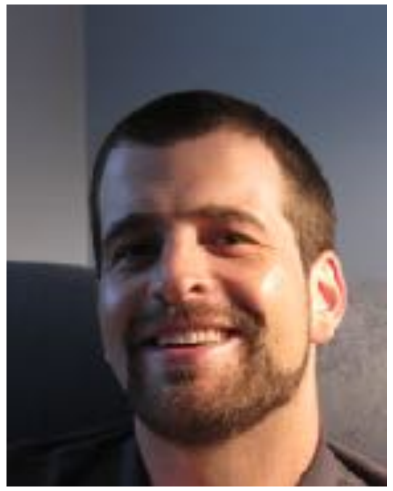
How to Contribute

- Test it out and give feedback
- Share: teams, meetups, data science meetings, blogs
- Documentation
- Code:
  - Lots of issues on GitHub
  - Add support for your favorite ML frameworks

Informal Meeting at MLSys

- Interested in testing/adopting ModelDB?
- Did you build such a system, can you share lessons?
- **Open-source Contributors!**
- How/when
    - Whova app ("Model Management Meetup")
    - mvartak@csail.mit.edu
    - Poster

People



ModelDB

https://github.com/mitdbg/modeldb

http://modeldb.csail.mit.edu

Manasi Vartak | @DataCereal