LAML: Linear Algebra and Machine Learning

- A stand-alone Java library for linear algebra and machine learning

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May 6th, 2015

Features

- Standalone, pure Java, and cross-platform
- Built-in Linear Algebra (LA) library
- Fast implementations for commonly-used machine learning methods and optimization algorithms
- Well documented source code
- Friendly API, **very** easy to use
- Complete separation between feature engineering and model training

SourceForge: http://sourceforge.net/projects/lamal/ since 12072013
Statstics: 1000+ downloads from 56 countries (regions)

LAML V.S. Liblinear

- heart_scale with C = 1.0 and eps = 1e-2
- LAML: 0.04s
- Liblinear: 0.06s
- Intel(R) Core(TM) i7 CPU M620 @ 2.67GHz with 4.00GB memory and 64-bit Windows 7

LAML V.S. JML

- LAML is much faster than JML (more than 3 times faster).
- JML relies on third party linear algebra library, i.e. Apache Commons-math. Sparse matrices and vectors have been deprecated in Commons-math 3.0+, and will be ultimately eliminated. Whereas LAML has its own built-in linear algebra library.
- LAML also provides a lot of commonly used matrix functions in the same signature to Matlab, thus can also be used to manually convert MATLAB code to Java code.
- In short, JML has been replaced by LAML.

LAML V.S. LibLAML

- libLAML is a stand-alone pure C++ static library for linear algebra and machine learning
- libLAML is at least 4 times faster than LAML
- libLAML is not cross-platform

Built-in Linear Algebra Packages

- la.decomposition
  - EVD, LU, QR, and SVD
- la.io
  - IO functions
- la.matrix
  - DenseMatrix and SparseMatrix
- la.vector
  - DenseVector and SparseVector

Built-in Machine Learning Packages

- ml.clustering
- ml.regression
- ml.classification
- ml.topics
- ml.optimization
- ml.sequence
- ml.subspace
- ml.recommendation
- ...

Data Interface

- la.io: IO for dense or sparse matrices
- Load a matrix from a txt file
- Save a matrix to a txt file
- JMatIO can also be used to load and save MATLAB MAT files in Java
- docTermCountArray2Matrix
  - TextProcessor can transform a corpus to a docTermCountArray
- readProblemFromStringArray + features2Matrix

Decomposition

```
Matrix A = hilb(m, n);
Matrix[] VD = EigenValueDecomposition.decompose(A);
Matrix[] LUP = LUDecomposition.decompose(A);
Matrix[] QRP = QRDecomposition.decompose(A);
Matrix[] USV = SingularValueDecomposition.decompose(A);
```

Matrix

- Matrix interface:
  - mtimes, times, plus, minus, transpose, operate, getEntry, setEntry, clear, copy, ...
- DenseMatrix implements Matrix, Serializable
- SparseMatrix implements Matrix, Serializable
  - Standard compressed sparse column (CSC) and compressed sparse row (CSR)
  - full control of the interior arrays in sparse matrices

Vector

- Vector interface:
  - times, plus, minus, operate, get, set, getDim, clear, and copy
- DenseVector implements Vector, Serializable
- SparseVector implements Vector, Serializable
  - full control of the interior arrays in sparse vectors

Matlab

- ml.utils.Matlab: Commonly used Matlab matrix functions with almost the same function input signature
  - ones, zeros, eye, diag, rand, size, sparse, full
  - sort, sum, max, min, vec, cat, vertcat, horzcat, repmat, reshape, kron, find, colon, display
  - svd, eigs, ldivide, rdivide, mldivide, mrdivide, mtimes, times, plus, minus, power, norm, subplus, inv, rank
  - not, and, or, eq, le, ge, lt, gt, isinf, isnan
  - ...

Classification

- ml.classification
  - MCSVM, Regularized Logistic Regression, MaxEnt, AdaBoost

```
Classifier linearMCSVM = new LinearMCSVM(C, eps);
linearMCSVM.feedData(trainData);    // double[][] or Matrix
linearMCSVM.feedLabels(labels);       // double[][], int[], or Matrix
linearMCSVM.train();
linearMCSVM.predict(testData);          // Predicted labels (int[])

Classifier logReg = new LogisticRegression(regularizationType, lambda);
logReg.feedData(data);
logReg.feedLabels(labels);
logReg.train();
logReg.predict(testData);
```

Regression

- ml.regression
  - LASSO and Linear Regression

```
Regression LASSO = new LASSO(options);
LASSO.feedData(data);
LASSO.feedDependentVariables(depVars);
LASSO.train();
Matrix Yt = LASSO.predict(testData);

Regression LR = new LinearRegression(options);
LR.feedData(data);
LR.feedDependentVariables(depVars);
LR.train();
Matrix Yt = LR.predict(testData);
```

Clustering

- ml.clustering
  - KMeans, NMFs, Spectral Clustering

```
Clustering spectralClustering = new SpectralClustering(options);
spectralClustering.feedData(data);                    // double[][] or Matrix
spectralClustering.clustering();

display(spectralClustering.getIndicatorMatrix());
```

Topic Modeling

- ml.topics
  - LDA // PLSA <=> NMF
  - Read corpora with multiple format:
    - int[][], DocTermCountArray, Matrix, LDAInput

```
int[][] documents = { {1, 4, 3, 2, 3, 1, 4, 3, 2, 3, 1, 4, 3, 2, 3, 6},
                      {2, 2, 4, 2, 4, 2, 2, 2, 2, 4, 2, 2},
                      {1, 6, 5, 6, 0, 1, 6, 5, 6, 0, 1, 6, 5, 6, 0, 0} };

LDA LDA = new LDA(LDAOptions);
LDA.readCorpus(documents);        // Multiple corpus input format
LDA.train();

display(LDA.topicMatrix);
display(LDA.indicatorMatrix);
```

Sequence Labeling

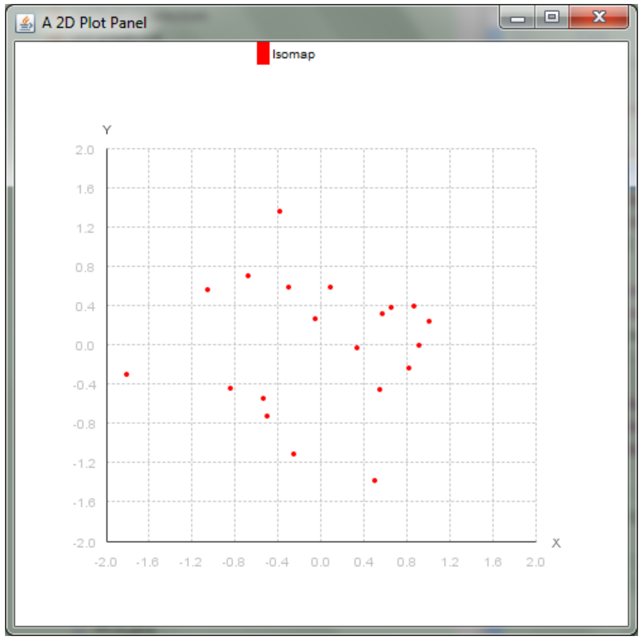
- ml.sequence
  - Conditional Random Field Using L-BFGS
  - Hidden Markov Models

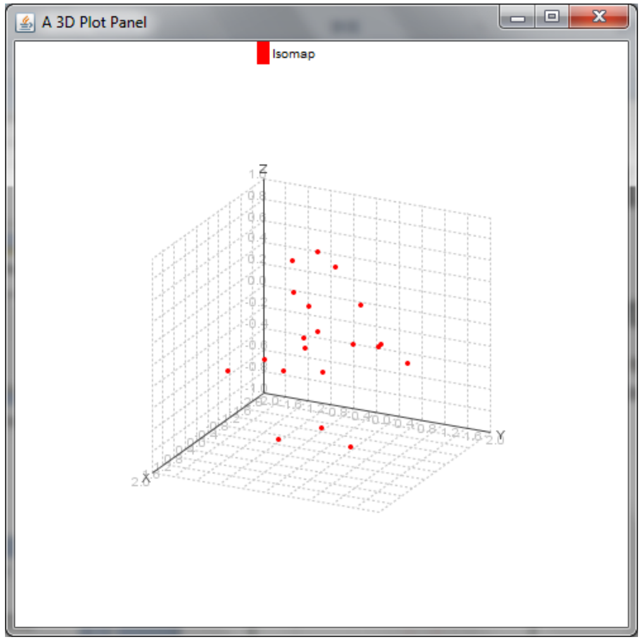
```
HMM HMM = new HMM(numStates, numObservations, epsilon, maxIter);
HMM.feedData(Os);
HMM.feedLabels(Qs); // If not given, random initialization will be used
HMM.train();
HMM.evaluate(O);
HMM.predict(O);

CRF CRF = new CRF(epsilon);
CRF.feedData(Fs);
CRF.feedLabels(Ys);
CRF.train();
CRF.predict(F); // Also compute the probability via Viterbi algorithm
```

Dimensionality Reduction

- ml.subspace
  - PCA, KernelPCA, MDS, Isomap, and LLE

```
int n = 20; int p = 10; Matrix X = rand(p, n);
int K = 6; // number of nearest neighbors
int r = 3; // reduced dim
Matrix R = Isomap.run(X, K, r);
```





Matrix Recovery

- ml.recovery
  - Robust PCA and Matrix Completion

```
Matrix D = ... // Observation matrix
double lambda = 1.0;

RobustPCA robustPCA = new RobustPCA(lambda);
robustPCA.feedData(D);
robustPCA.run();

// Low-rank recovery of D
Matrix A_hat = robustPCA.GetLowRankEstimation();
// Error matrix between D and A
Matrix E_hat = robustPCA.GetErrorMatrix();
```

Recommendation

- ml.recommendation
  - Factorization Machines

```
// Training
int idxStart = 0;
feedTrainingData(trainFilePath, idxStart);
allocateResource(k);
feedParams(maxIter, lambda);
initialize();
train();

// Prediction
DataSet testData = loadData(testFilePath, 0);
double[] Y_pred = predict(testData.X);
```

General-Purpose Optimization

- ml.optimization
  - L-BFGS
  - Proj L-BFGS (Simplex, Box, or Nonnegative)
  - General Quadratic Programming (of course General Linear Programming)
  - Nonlinear Conjugate Gradient
  - Primal-Dual Interior-Point methods
  - Accelerated Proximal Gradient
  - Accelerated Gradient Descent

Utils

- ml.utils
  - ArrayOperator: commonly used double array operations
  - InPlaceOperator: a set of in-place functions without memory allocation
  - Printer: print matrices, vectors, arrays, and formatted strings
  - Times: tic and toc
  - ...

Others

- ml.graph
  - Minimum Spanning Tree and Shortest Path
- ml.kernel
  - 'linear' | 'poly' | 'rbf' | 'cosine'
- ml.manifold: semi-supervised/unsupervised
  - Adjacency graph (directed or undirected)
  - Laplacian regularization
  - Local learning regularization
- ml.random: Probability distributions
  - Multivariate Gaussian Distribution

DataSet and Data

- la.io.DataSet and la.io.Data
  - readDataSet(ArrayList<String> feaArray)
  - readDataSetFromFile(String filePath)
  - writeDataSet(Matrix X, int[] Y, String filePath)

```
// Read a data set from a LIBSVM formatted string array or file
DataSet.IdxStart = 0;
trainDataSet = Data.readDataSetFromFile(featureFilePath);
Matrix X = trainDataSet.X; // n x p
int[] labels = trainDataSet.Y; // Used for classification or recommendation

Data.IdxStart = 0;
trainDataSet = Data.readDataSetFromFile(featureFilePath);
Matrix X = trainDataSet.X; // n x p
double[] labels = trainDataSet.Y; // Used for regression
```

Combine TextProcessor and LAML

- For text mining, our input are text corpora, not sparse matrices.

```
Options options = new Options();
options.workSpacePath = "....";
options.mergedFileName = "";
options.dataDirName = "...";
options.ext = "txt";
TextProcessor textProcessor = new TextProcessor(options);
textProcessor.buildDocStringArray();
textProcessor.processStringArray(textProcessor.docStringArray);
/* Generate the dictionary, DocTermCountArray, GroundTruth, LabelIDMap,
LDA format Input (file or stringArr), LIBSVM format input (file or stringArr) */

Matrix X = IO.docTermCountArray2Matrix(textProcessor.docTermCountArray);
int[] labelIDs = textProcessor.getLabelIDs();
```

Future Work

- Multi-task learning
- Multi-label learning
- Multi-instance learning
- Feature selection
- Deep learning in Java (Parallel)