

Multivariate Data Analysis with TMVA 4



TMVA core developer team: A. Höcker, P. Speckmayer, J. Stetzer, H. Voss; arXiv physics/0703039

The toolkit for multivariate analysis, TMVA, provides a large set of advanced multivariate analysis techniques for signal/background classification. In addition, TMVA now also contains regression analysis, all embedded in a framework capable of handling the pre-processing of the data and the evaluation of the output, thus allowing a simple and convenient use of multivariate techniques. The analysis techniques implemented in TMVA can be invoked easily and the direct comparison of their performance allows the user to choose the most appropriate for a particular data analysis.

preprocessing

Apply selection cuts

- Possible independently for each class

Data input

- Combination of function of available variables
- Similar to ROOT's TTree, C++

Define event weights

- Can be defined globally (tree-wide) and class-wise

Transformations

Can be set for each method independently

- TMVA knows:
 - Normalization
 - Decorrelation
 - Principal component analysis
 - Cosine-sine
- Transformations can be chained
- Transformations improve result in case of strong non-linear correlations of variables
- May not improve classification in case of strong non-linear correlations

minimization

Brute force method

- Sample entire solution space, and choose best-fit providing minimum estimator
- Good global minimum finder, but poor accuracy

Default solution in ROOT: Minuit

- Gradient-driven search, using variable metric, can use quadratic Newton-type solution
- Poor global minimum-finder, gets quickly stuck in presence of local minima

Biologically-inspired

- "Genetic" representation of points in the parameter space
- Uses mutation and "crossover"
- Finds approximately global minima

Like heating up metal and slowly cooling it down ("annealing")

Atoms in metal move towards the state of lowest energy while for sudden cooling atoms tend to freeze in intermediate higher energy states → slow "cooling" of system to avoid "freezing" in local solution

Scan over classifier output variable

Scans over classifier output variable (ranges set of $[x_{cut,1}-x_{cut,2}]$ points in ROC-curve)

ROC (Receiver operating characteristic) curve

Curve describes performance of a binary classifier by plotting the false positive vs. the true positive fraction

classification

(C_1, C_2) → S → R^1

cut on the classifier → "condense the information" → to separate into classes → to one classifier output

regression

X_1, X_2, X_3, X_4 → $R = (R^1)$

use their information → to predict the value of one (or more) dependent variable(s) (target)

Approximates the functional dependence of a target from (X_1, X_2)

Example: Target as a function of 2 variables

Estimated value minus true value as a function of the true value

TMVA provides many evaluation means producing plots and numbers which help the user to decide on the best classifier for an analysis

evaluation

TMVA provides many evaluation means producing plots and numbers which help the user to decide on the best classifier for an analysis

summary

- Large number of MVA methods implemented
- One common platform/interface for all MVA methods
- Common data pre-processing capabilities
- Common input and analysis framework (ROOT scripts)
- Train and test all methods on same data sample and evaluate consistently
- Method application w/ and w/o ROOT, through macros, C++ executables or python

Common data pre-processing capabilities

- Feature reduction (project), but challenging for strongly non-linear feature spaces
- ROC Range Search (RRS) from multi-class (linear) to optimal classification
- Functional Description Analysis

Method application

- Minimal overhead: Tree based, fast, not multi-lingual necessary
- Support vector machine: fast global minimum, multi-lingual necessary
- Learning via rule induction

summary

Classifier	Classifier						
	tree	svm	nn	boost	bag	net	rule
Pre-processor	✓	✓	✓	✓	✓	✓	✓
Minimizer	✓	✓	✓	✓	✓	✓	✓
Classifier	✓	✓	✓	✓	✓	✓	✓
Regression	✓	✓	✓	✓	✓	✓	✓
Method application	✓	✓	✓	✓	✓	✓	✓
Common framework	✓	✓	✓	✓	✓	✓	✓

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