Massively parallel analytics for large datasets in R with *nza* package

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useR! 2010

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Main assumptions

- **Data stored in Netezza Performance Server database**
  - > Provides data parallelism in cluster environment
  - > Provides what R lacks: performance & out-of-memory storage
- **Processing should be close to the (large) data**
  - > Limit a data transfer between the cluster nodes
- **Symmetrical processing**
  - > Single Instruction Multiple Data
  - > Lack of deadlocks due to smart representation

Tradeoff between Flexibility and Performance

- R language (high flexibility, low performance)
- In-database processing
- C++ language (low flexibility, high performance)

Approaches to data processing in *nza*

- **Direct data processing in R**
  - Execution of R functions passed to **data operators**
  - Abstraction over SQL
  - Parallel execution over the data chunks
  - High flexibility, medium performance
- **Construction of statistical models using in-database processing**
  - Efficient, parallel algorithms for model construction
  - High performance, medium flexibility
- **High performance&flexibility**
  - Fast in-database calculation of data aggregates
  - Flexibility of aggregate manipulation in R

Direct parallel data processing in R

- R code is executed in database, close to data and in parallel.
- *Data operator* is responsible for
  - > Propagation of given task and data stream to R
  - > Selecting optimal model of execution
  - > Propagation of the results to DB
- Data operators

	nzApply	nzTApply	nzGroupedApply
Data abstraction	row	group	row in group
State machine?	SL	SL	SF, merged
Type of transformation	1 row -> 1 row	1 group -> 1 row	(1+) row -> 1 row reduction

Direct parallel data processing in R

```
library(nza)
nzConnectDSN("NSQL")
nzadults <- nz.data.frame("database..table")

FUN1 <- function(x) {sqrt(x[[1]])}
FUN2 <- function(x) {mean(x)}

nzApply(nzadults[,1:2], FUN1, output.table="ttable1")
nzTApply(nzadults[,1:3], nzadults[,4], FUN2, output.table="ttable2")
```

In-database processing

- **Efficient, specialized parallel algorithms (SQL+native processing)**
  - Decision trees (classification and regression)
  - K – means
  - Naive Bayes
  - One- and two-way ANOVA
  - Simple statistics and support for hypothesis testing
- **Output compatible with native R objects**
- **Model creation and application**

In-database processing
Decision trees [regression]

- **Tree building**
  - > *tree.model* = nzDecTree (form, data,
    outtable = uniqueTableName(), minsplit = 1000, maxdepth = 62,
    id = "id", qmeasure = "wAcc")
- **Prediction**
  - > predict.nzDecTree (*tree.model*, newdata, id = "id")
- **Generic**
  - > print (*tree.model*), plot (*tree.model*)

In-database processing
Decision trees [regression]

- **Tree building**
  - *tree.model* = nzRegTree (form, data,
    outtable = uniqueTableName(), minimprove = 0.1,
    maxdepth = 62, minsplit = 2, id = "id'')
- **Prediction**
  - predict.nzRegTree (*tree.model*, newdata, id = "id")
- **Generic**
  - print (*tree.model*), plot (*tree.model*)

In-database processing
K – means

- **Model building**
  - *model* = nzKMeans (data, k = 2, maxiter = 10, distance = "euclidean", outtable = uniqueTableName(), id = "id", getLabels = F, randseed = 1234)
- **Prediction**
  - predict.nzKMeans (*model*, newdata, id = "id")
- **Generic**
  - print (*model*)

In-database processing
Naive Bayes

- **Model building**
  - *model* = nzNaiveBayes (form, data, outtable = uniqueTableName(), id = "id")
- **Prediction**
  - predict.nzNaiveBayes (*model*, newdata, id = "id")
- **Generic**
  - print (*model*)

In-database processing
ANOVA

- **Testing hypothesis about means**
  - > *model.av* = nzAnova (form, data, outtable = uniqueTableName())
- **Generic**
  - > print (*model.av*)

In-database processing
Example R session

RGui

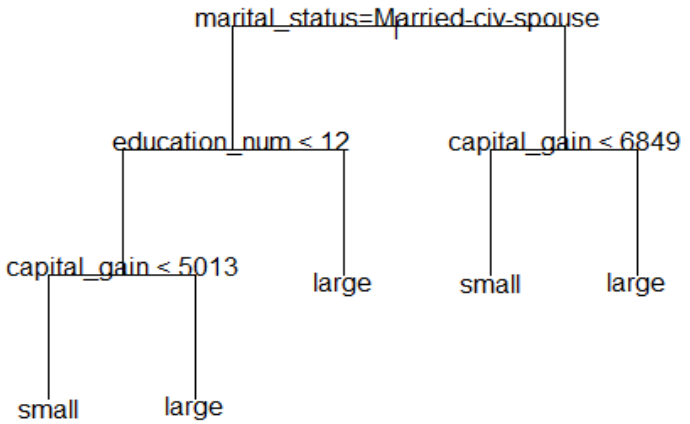
File History Resize Windows

R Console

```
>  library(nza)
>  nzconnect("admin", "password", "TT4-R040", "nza")
>  nzadult = nz.data.frame("adult")
>  adultTree = nzDecTree(income~., data=nzadult, maxdepth=4)
>  plot(adultTree)
>  adultTree
node), split, n, deviance, yval, (yprob)
      * denotes terminal node

1) root 32561 0 small ( 0.24081 0.75919 )
  2) marital_status=Married-civ-spouse 14976 0 small ( 0.44685 0.55315 )
    4) education_num < 12 10507 0 small ( 0.33102 0.66898 )
      8) capital_gain < 5013 9979 0 small ( 0.29672 0.70328 ) *
      9) capital_gain > 5013 528 0 large ( 0.97917 0.02083 ) *
    5) education_num > 12 4469 0 large ( 0.71918 0.28082 ) *
  3) marital_status < >Married-civ-spouse 17585 0 small ( 0.06534 0.93466 )
    6) capital_gain < 6849 17274 0 small ( 0.04915 0.95085 ) *
    7) capital_gain > 6849 311 0 large ( 0.96463 0.03537 ) *
>  head(predict(adultTree, nzadult))
   ID CLASS
1  12 large
2  64 large
3  88 large
4 112 large
5 124 large
6 136 large
>
>  getContTable(~EDUCATION+OCCUPATION, nzadult, T)$mat
             Adm-clerical Armed-Forces Craft-repair Exec-managerial Farming-fishing Handlers-cleaners
12th                   38            0          170              24              44                71
9th                    67            0          175              34              37               123
10th                   38            1           58              13              16                38
7th-8th                 0            0           23               4              18                16
Assoc-acdm              6            0           43               1              36                40
Masters                11            0          116              19              70                46
11th                   14            0           96              13              28                49
1st-4th               193            0          115             145              14                24
```

R Graphics: Device 2 (ACTIVE)



Data aggregates (high performance & flexibility)

- **Decomposition of model creation into:**
  - In-database calculation of Sufficient Statistics for model construction
    - **Dot product matrix (X^TX)**
    - **Multivariate contingency table**
  - Model fitting directly in R environment
- **Data aggregates**
  - Computed „close" to the data in (embarassingly) parallel way
  - Information extraction (reduction of the data being transfered)
  - Does not reduce flexibility of model creation
  - Computed and transmitted once, used multiple times

Dot product (X^TX) matrix

- **Sufficient statistics for linear models**
- **In-database calculation of model matrix with**
  - > support for categorical variables (dummy variables)
  - > support for continuous variables (centering, scaling)
  - > support for bootstrap samples and weighted case
- **Model size depends only on the number of columns (and levels)**

Dot product (X^TX) matrix

- **nza functions using the dot product matrix:**
  - nzLm(formula, nzdf)
  - nzRidge(formula, nzdf, lambda=10)
  - nzPCA(formula, nzdf)
  - *nzANOVA(*formula*, nzdf)*
  - *nzPCR(*formula*, nzdf)*
  - *nzCanonical(*formula*, nzdf)*
- **R package nzMatrix can operate on matrices as large as e.g. 100k x 100k (limited by total RAM of the NPS)**

Multivariate Contingency Table

- 2 or more categorical variables
  (a multimatrix, a hypercube)
- The “dot product” matrix for categorical data
- Analysis of the relations and correspondence between given variables (correlation, CA, MCA)

Multivariate Contingency Table

- **Aggregate creation:**
  - Actual
    model = nzTable (form, nzdf, makeMatrix=T)
  - Read from DB
    model = getContTab(form, nzdf, makeMatrix=F)
- **Example**
  - getContTab(~EDUCATION+OCCUPATION, nzadult, T)

Multivariate Contingency Table

- ***nza* functions that make use of contingency table:**
  - nzca(form, nzdf, ...)
  - nzchisq.test(form, nzdf, ...)
  - nzMantelHenszel.test(form, nzdf, ...)
  - *nzGoodman(form, nzdf, …)*
- **Compute once and reuse**

Summary: *nza*

- **Provides various tools and strategies for parallel, out-of-memory data processing**
  - > Direct use of R code with specialized data operators
  - > R wrappers for specialized in-DB functions for model creation
  - > In-DB intensive calculation of data aggregates (sufficient statistics) and R functions for model creation (from suff. statistics)
- **Uses Netezza Performance Server as a backend**

Thank you

Questions?

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