

# Package StQT

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## Introduction

The StQT package is an attempt to standardize the representation of data transformations, in the same sense that StQ standardizes the representation of data. In fact, it stands for StQ Transformation. But, what do we understand by data transformation? In this context, it means a process that calculates a new data set from an old data set. For example, an imputation, a summary or even a forecast are transformations. But a data merge **is not** a transformation since we are using a second data set (except for a self data merge which will be explained later). If we would happen to need a transformation that uses information from two data sets, we would have to join them into a single data set before.

The main goals of this package are:

- To make clear the steps of a transformation, fixing a few simple rules, which we can use to express any transformation as a sequence of simple steps. We should think that each rule is a function with some instructions about how you use it on the data.
- To add an abstraction layer, which allow us to work with transformations without knowing how they work in the inside. With this package, once we have built a library of transformations (more or less basic), we should be able to combine them into new more complicated transformations.

It is important to focus in the first objective when you write the rules of a transformation. The rules should be flexible enough to represent any transformation in a understandable way, but as usual there is nothing that prevents an unclear codification.

To achieve the second main goal, we are going to implement several tools.

## The representation

It is strongly inspired in the syntax of operator `:=` from `data.table` package. The main idea is to apply a set of rules according to the sentence `data[<domain>,<output>:=<fun>(<input>),by=<by>]` where each `<>` surrounded item is an element of the rule. As long as function definition is included in the object, it is obvious that we can represent this way almost everything. Almost, because the number of rows of `data.table` data, would not be changed. The consequence was to allow a direct assignation in `<output>` field which when present, will create new rows. For a more detailed view of the syntax of the rules read next section.

Note that if we remove `<domain>` and `<by>` and put `<fun>` and `<input>` as the only elements of the rule we still can get any transformation (even with one rule). But this rules representation would be useless in that case, since you have a function (an R function) that does all the work. And anyone who wants to know what the rule does, would have to examine carefully the function. So, generally speaking: keep the functions as simple as possible and try to use the other fields of the rule to achieve that. And be conscious that a lower number of rules **is not** necessarily better.

So, a transformation object has two slots: a `data.frame` with the rules and a list of the functions called by the rules. The functions are inside the object because that way the object has all the information needed to make the transformation. You don't need to load the functions into the workspace or check dependencies, you just load the transformation and apply it.

## Detailed syntax

There are three types of rules in StQT:

- Horizontal: These are by far the more common rules and they are applied as we had said with a command like `data[<domain>,<output>:=<fun>(<input>),by=<by>]`. This creates new or override `<output>` columns with one element per row applying the usual recycling. Next, an elementary example.

```
require(data.table)
require(StQT)
dt <- data.table(Stratum = c("1","2","3"), SD = c(1.54,1.12,1.88))
dt
```

```
##      Stratum   SD
## 1:         1 1.54
## 2:         2 1.12
## 3:         3 1.88
```

```
T1 <- NewStQT(data.frame(
  output = "VAR",
  fun = "*",
  input = "SD,SD",
  stringsAsFactors = FALSE))
TApply(dt,T1)[]
```

```
##      Stratum   SD   VAR
## 1:         1 1.54 2.3716
## 2:         2 1.12 1.2544
## 3:         3 1.88 3.5344
```

We had a table with strata identified and its standard deviation. The transformation binds a new column with the variance of the correspondent strata. We could have defined a function returning the square of its argument. But we don't need to do that, because we can use R primitive function `*` calculating  $VAR$  as  $SD \times SD$ .

- Vertical: Similar to horizontal rules, but output includes some assignments (one or more). For each `<by>` group an additional row is created which copies the variables in `<by>`, sets the assigned variables and calculates the unassigned in a similar way to an horizontal rule. Let's see an easy example.

```
require(data.table)
require(StQT)
dt <- data.table(Region = c("1","2","3"), GDP = c(1.38,0.94,1.23))
dt
```

```
##      Region  GDP
## 1:        1 1.38
## 2:        2 0.94
## 3:        3 1.23
```

```
T1 <- NewStQT(data.frame(
  output = "Region='Total',GDP",
  fun = "sum",
  input = "GDP",
  stringsAsFactors = FALSE))
TApply(dt,T1)
```

```
##      Region  GDP
## 1:         1 1.38
## 2:         2 0.94
## 3:         3 1.23
## 4:      Total 3.55
```

In this case `<by>` is empty, so we have only one group (the whole table) and in consequence we only bind one new row.

In the other extreme situation we have one new column per row:

```
dt <- data.table(Region = c("1","2","3"), GDP = c(1.38,0.94,1.23))
dt
```

```
##      Region  GDP
## 1:         1 1.38
## 2:         2 0.94
## 3:         3 1.23
```

```
T1 <- NewStQT(data.frame(
  output = "Copy=TRUE,GDP",
  fun = "sum",
  input = "GDP",
  by = "Region",
  stringsAsFactors = FALSE))
TApply(dt,T1)
```

```
##      Region  GDP Copy
## 1:         1 1.38  NA
## 2:         2 0.94  NA
## 3:         3 1.23  NA
## 4:         1 1.38 TRUE
## 5:         2 0.94 TRUE
## 6:         3 1.23 TRUE
```

- Internal: These are not real functions but *special* codes in `<fun>` field that trigger concrete behaviors different to usual horizontal or vertical rules. They are *FunDelVar*, *FunDelRow* and *FunAutoLink* so far. Except for *FunDelRow*, we could write functions to get the same behavior (at least when applied to `data.table` objects), but they are anyways useful because they implement common tasks in a standard way which helps to make understandable the rules.

*FunDelVar* removes the variables specified in `output`, *FunDelRow* removes the rows in `<domain>` and *FunAutoLink* copies the `<input>` variables to the `<output>` variables, linking rows according to the equality specified in `domain`. The equality must be like `a == b & c == d & ...`, and be careful: in this case the

equality is not commutative! When you put `a==b` you are linking each row with other row that has in variable *b* the same value than the original row has in variable *a*. So, if you swap *a* and *b*, you are making a different linkage. Now, let's see some examples:

```
dt <- data.table(Unit = 1:10, Value = rnorm(10), Next = c(2:10,NA))
T1 <- NewStQT(data.frame(
  domain = c("Next==Unit","", "Value < 0"),
  output = c("Value_next", "Value_next", ""),
  fun = c("FunAutoLink", "FunDelVar", "FunDelRow"),
  input = c("Value", "", ""),
  stringsAsFactors = FALSE))
dt
```

```
##      Unit      Value Next
## 1:      1  0.6255609    2
## 2:      2  1.3971012    3
## 3:      3  0.5953114    4
## 4:      4 -0.6352175    5
## 5:      5 -1.5165684    6
## 6:      6 -1.7467945    7
## 7:      7 -1.0459675    8
## 8:      8 -0.8405386    9
## 9:      9 -1.1232984   10
## 10:     10  0.8940803   NA
```

```
TApply(dt, T1[1])
dt
```

```
##      Unit      Value Next Value_next
## 1:     10  0.8940803   NA          NA
## 2:      1  0.6255609    2  1.3971012
## 3:      2  1.3971012    3  0.5953114
## 4:      3  0.5953114    4 -0.6352175
## 5:      4 -0.6352175    5 -1.5165684
## 6:      5 -1.5165684    6 -1.7467945
## 7:      6 -1.7467945    7 -1.0459675
## 8:      7 -1.0459675    8 -0.8405386
## 9:      8 -0.8405386    9 -1.1232984
## 10:     9 -1.1232984   10  0.8940803
```

```
TApply(dt, T1[2])
dt
```

```
##      Unit      Value Next
## 1:     10  0.8940803   NA
## 2:      1  0.6255609    2
## 3:      2  1.3971012    3
## 4:      3  0.5953114    4
## 5:      4 -0.6352175    5
## 6:      5 -1.5165684    6
## 7:      6 -1.7467945    7
## 8:      7 -1.0459675    8
## 9:      8 -0.8405386    9
## 10:     9 -1.1232984   10
```

```
TApply(dt, T1[3])
```

```
##      Unit      Value Next
## 1:    10 0.8940803   NA
## 2:     1 0.6255609     2
## 3:     2 1.3971012     3
## 4:     3 0.5953114     4
```

```
dt
```

```
##      Unit      Value Next
## 1:    10 0.8940803   NA
## 2:     1 0.6255609     2
## 3:     2 1.3971012     3
## 4:     3 0.5953114     4
## 5:     4 -0.6352175     5
## 6:     5 -1.5165684     6
## 7:     6 -1.7467945     7
## 8:     7 -1.0459675     8
## 9:     8 -0.8405386     9
## 10:    9 -1.1232984    10
```

The examples also show how to use the operator `[]`, that applies a subset of the rules. Note that some rules modify the original data, but some others do not. *TApply* uses `data.table` methods by reference when possible, but sometimes they are unavailable (row insertion and deletion). I strongly recommend to assign the old table to the new one `dt <- TApply(dt, T1)` to avoid confusion. If you don't want to lose information just don't remove the data.

In the first rule, we are storing the value of the next element according to *Next* field in the new variable *Value\_next*. In the second one, we are removing the new column so we recover the original `data.table`. Finally we remove the rows where *Value* is negative, but as seen *dt* remains unchanged.

There is also an `<order>` field which if not empty, orders the data by the variables specified.

Note that `<key>` field is ignored unless we are transforming an *StQ* object (see next section).

## How does a transformation work on *StQ* objects

We are assuming that the reader is familiarized with *StQ* objects and its internal representation. First of all, we have to ask ourselves what a variable is. When you dcast an *StQ* object, you get a lot of columns with long "\_" separated names. For us, those **are not** variables. For us, a variable is an IDDD-sort element of the data slots from a *DD* object. Moreover it would be useful to think in it as a vector with a component for each qualifiers combination.

But we have to make some concessions to the qualifiers, because they are the "dimensions" of our vector variable. So we have to allow them in the rules, but we should avoid them when possible in `<input>` and `<output>` field, specially `<input>`. In `<by>` and `<domain>` they are perfectly acceptable. Let's say we have a variable by unit and region, and we want the total by unit. Then we only have to sum the variable by unit and that's it. In this example, we have had to use the unit qualifier in the `<by>` field, and the rule seems quite clear. By the way, we have to specify that the resulting variable has unit as only qualifier (and not unit *and* region). This is what `<key>` field is intended for. We know that R sum function returns a single value, and since we are grouping by unit, the `<key>` should be unit. But if we substitute sum by another function,

and we only have its closure and arguments, it would be very difficult to find an automatic way to decide if it returns a single value. So we specify `<key>` as unit.

A second question is what do we do with more than one variable. Let's see. If we have two or more variables whose qualifiers are exactly the same, we only have to put them as columns and we have a `data.table` where to apply the rule as usual. It is natural to associate values of both variables when they have the same key. When their qualifiers are different, we look for a variable whose qualifiers are the union of all the qualifiers of all the variables. We are going to name this variable as main variable, and we are going to use it to link them all. If such variable does not exist, that means that there are more than one maximal variables (in the sense that its qualifiers are not included in the other qualifiers), and there is not an unique way to link them. In this case the rule is considered no valid, and an error is shown. If we need to link this way, we have to use auxiliary variables.

When you call `TApply`, the first step is to extract the data needed for the transformation, the second one to apply the rules in the extracted data, and the final step is to merge the transformed data with the unchanged data.

## Data extraction

Variables used in the rules are looked for in the `StQ`, grouped by set of qualifiers, cast and put in a list of `data.table`. Since each `data.table` contains variables that share qualifiers, the key in each `data.table` is the set of qualifiers. The purpose of this structure is to speed up by avoiding repeating cast operations. Variables not in the rules are kept in a copy of the data slot of the `StQ`.

## Rules application

This is by far the more complex step. We apply the following algorithm for each rule:

- Extract the variables used in the rule from the list.
- Select the main variable.
- Merge the variables on the keys of the main variable.
- Apply the transformation on the `data.table`.
- Set the key of the transformed `data.table` as `<key>`. If `<key>` does not exist it defaults to the key of the main variable.
- The output is made unique by key.
- For new output variables they are merged in the `data.table` list. When the variables were already in the list, only non missing values are copied. *You can't set to NA any value.*
- The DD file is updated with the new variables.

Internal function `FunDelVar`, deletes the variables in any `data.table` of the list, and also removes them from the DD file. To keep referential integrity, it removes any variable qualified by them. Finally, any unneeded qualifier is deleted too.

Internal function `FunDelRow` (\*\* not implemented \*\*) is intended to put NA in the `<domain>` specified.

For the moment `FunAutoLink` is expected to work as is.

## Data merge

We just melt the data and rbind them. We also rbind the data slot with the remaining variables.

## Other methods