Data Cleaning Tutorial: Data Validation

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https://github.com/markvanderloo/UFPEL2019


Try the code

`03valid/check_validity.R`

Data validation

Verify that data satisfy technical restrictions and does not contradict expert knowledge.

Examples of technical demands

- Number of records must equal 60
- Financial variables are numeric
- Records have a unique `id`
- Zipcode consists of 4 numbers followed by 2 letters

Examples of domain knowledge demands

- turnover is nonnegative
- turnover $-$ costs $=$ profit
- profit not larger then 60% of turnover
- average profit is larger than 0
- average profit differs less than 10% from last year's average

Data validation rules

A domain specific language to express demands.

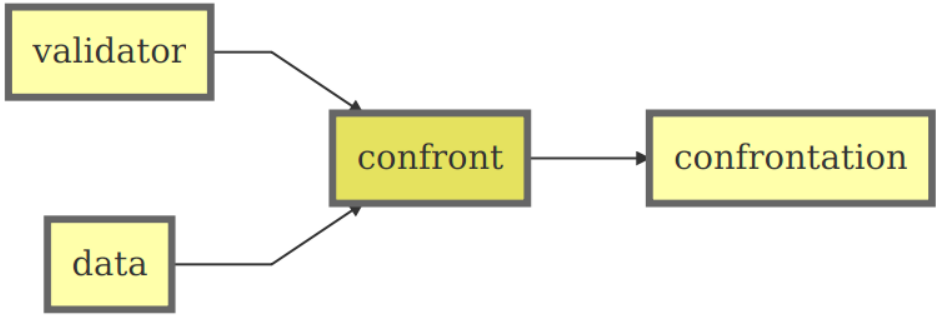
Why?

- Communicate data quality without ambiguities
- Make knowledge explicit and organize it
- Create custom data quality reports
- Reuse ruleset for data cleaning purposes

How?

```
library(validate)
companies <- read.csv("02input/input.csv",stringsAsFactors = FALSE)
rules     <- validator(.file="02input/rules.R")
result    <- confront(companies, rules)
```

Core concepts of the `validate` package



Comparing numbers

```
rules <- validator(turnover + costs == profit)
summary( confront(companies, rules) )
```

```
##   name items passes fails nNA error warning
## 1   V1     0      0     0   0  TRUE   FALSE
##                              expression
## 1 abs(turnover + costs - profit) < 1e-08
```

Data validation: informal definitions

Data validation

Check if a value, or combination of values is in a certain set of valid values or valid value combinations.

Data validation language in `validate`

Any R expression that results in a `logical`.

Expressions that are validation rules

Basic syntax

- Any type check: `is.numeric`, `is.character`,...
- Any comparison: `<`, `<=`, `==`, `identical` `!=`, `%in%`, `>=`, `>`
- Logical operators `|`, `&`, `if`, `!`, `all`, `any`
- Pattern match: `grepl`

Sugar

Dot "`.`" stands for the whole data set:

```
nrow(.) >= 50        # at least 40 rows
"id" %in% names(.)   # 'id' must be present
```

More, see `?syntax` or `vignette("introduction", package="validate")`

Challenges

1. Express the following restrictions on `companies`. Then `confront` and `summary`
   - profit does not exceed 60% of turnover
   - turnover minus costs equals profit
   - Average profit is larger than zero
   - correlation (`corr`) between total cost and staff exceeds 0.5
   - zipcode is 4 numbers followed by two upper case letters (you need to know regex)
2. Read the rules in `rules.R`. Then, `confront`, and `summary`.

More on validation

- Precise definition
- Classification of validation rules

Data Validation

Some examples from a survey amongst the ESS member states

- If a respondents has *income from other activities*, fields under *other activities* must be filled.
- *Yield per area* must be between 40 and 60 metric tons
- A person of *age* under 15 cannot *take part in an economic activity*
- The field *type of ownership* (of a building) may not be empty
- The *regional code* must be in the code list.
- The *current average price* divided by *last period's average price* must lie between 0.9 and 1.1.

Specification of allowed (valid) data

By extension

Marital status must be in
$\{\texttt{never married}, \texttt{married}, \texttt{divorced}, \texttt{widowed}\}$

By intension

- *Age* is a *number* which is not negative and less than or equal to 120.
- (*Age*,*Has_Job*) is a pair from $\mathbb{R} \times \{\texttt{yes}, \texttt{no}\}$, satisfying the implication $\mathit{Age} < 15 \Rightarrow \mathit{Has\_Job} = \texttt{no}$.

Questions

- Can we properly *define* the concept of data validation?
- If so, is it possible to *classify* validation activities?

Definition (European Statistical System)

Definition

Data Validation is an activity verifying whether or not a combination of values is a member of a set of acceptable combinations.

Methodology of Data Validation (ESS Handbook, 2016)

Combinations of values

Single variable; multiple variables

$Age \geq 0$; $Age < 15 \Rightarrow Has\_Job = \texttt{no}$

Multiple entities

$\text{mean}(Profit) \geq 10$

Multiple times or domains

$0.9 < \text{mean}(Profit_{2018})/\text{mean}(Profit_{2017}) < 1.1$

Conclusion

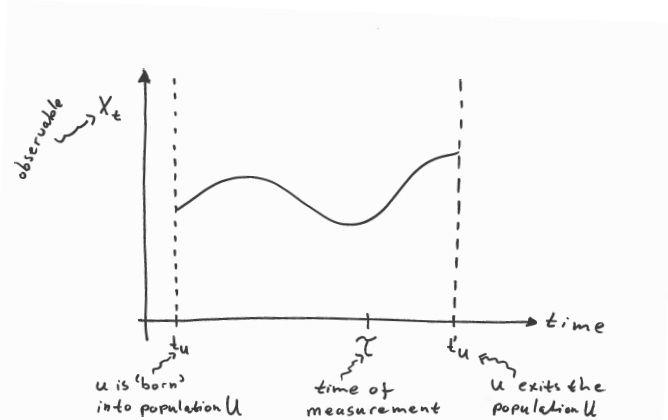
Intuitively:

'Data validation is a function that accepts (some set of) value(s) and returns `TRUE` (valid) or `FALSE` (invalid).'

The catch

To make this precise we must define 'some set of values'.

What characterizes a data point?



What is a data point?

Definition

A *data point* consists of a pair (k, x) where

- x is a *value* (number, text, category, date/time, NA)
- k is a *key* (or list of keys) identifying at least:
  - population U
  - time of measurement τ (or: the measurement event)
  - element of the population u
  - property being measured X
- For formal reasons, we demand that there are only a finite number of possible keys k, coming from a set K.
- We say that x comes from a domain D.

What is a data set?

Definition

A *data set* S is a finite set of key-value pairs

$$S = \{(k_1, x_1), (k_2, x_2), \ldots, (k_{|K|}, x_{|K|})\}$$

where all k_i are different.

Note

- The k_i are often referred to as *metadata*
- The x_i may be of different type
- Given a set of keys K and a domain D. The set of all data sets is denoted D^K.

Example

In 2017 we asked the Dutch company 'Piet's Bakery' for its turnover and whether it owns the building it works in.

Domain D

Numbers or yes/no: $D = \mathbb{R} \cup \{\texttt{yes}, \texttt{no}\}$

Example data points $(k = [U, \tau, u, X], x)$

- $([\text{Dutch Companies}, 2017, \text{Piet's Bakery}, \textit{turnover}], 50.000)$
- $([\text{Dutch Companies}, 2017, \text{Piet's Bakery}, \textit{owns\_building}], \texttt{no})$

Quizz

In September 2018 we ask the two Dutch citizens **A**lice and **B**ob:

1. X: Do you have a job? (`yes`, `no`)
2. Y: What is your age? (`under-aged`, `adult`, `retired`)

Questions

1. Describe D
2. Give all values of k (this constitutes K)
3. How many data sets are possible?

Answers (1)

Each data point is either in $\{\texttt{yes}, \texttt{no}\}$ or in $\{\texttt{under-aged}, \texttt{adult}, \texttt{retired}\}$, so

$$\begin{aligned} D &= \{\texttt{yes}, \texttt{no}\} \cup \{\texttt{under-aged}, \texttt{adult}, \texttt{retired}\} \\ &= \{\texttt{yes}, \texttt{no}, \texttt{under-aged}, \texttt{adult}, \texttt{retired}\} \end{aligned}$$

Answers (2)

- U: Dutch citizens (same for all data points)
- τ: 2017 (same for all data points)
- Values for k:
  - $[U, \tau, \text{Alice}, \text{job}]$
  - $[U, \tau, \text{Alice}, \text{age}]$
  - $[U, \tau, \text{Bob}, \text{job}]$
  - $[U, \tau, \text{Bob}, \text{age}]$

Number of data sets: unrestricted

- There are 4 unique keys in K
- For each key in K there are 5 options.
- Number of data sets: $5^4 = 625$.

Note

This includes cases where values are swapped (e.g. $age = \texttt{no}$ and $job = \texttt{under-aged}$)

Number of data sets: with restrictions

Restrictions

- $job \in \{\texttt{yes}, \texttt{no}\}$
- $age \in \{\texttt{under-aged}, \texttt{adult}, \texttt{retired}\}$
- $job = \texttt{yes} \Rightarrow age = \texttt{adult}$

Number of ways for (job, age) pairs to be valid equals 4:

	under-aged	**adult**	**retired**
yes	invalid	valid	invalid
no	valid	valid	valid

There are two such pairs in a data set so there are $4^2 = 16$ valid data sets.

What is data validation?

Definition

A *data validation function* is a surjective function v that accepts a data set in D^K and returns a value in $\{\texttt{FALSE}, \texttt{TRUE}\}$.

- If $v(S) = \texttt{FALSE}$ then S *violates* v
- If $v(S) = \texttt{TRUE}$ then S *satisfies* v
- Surjective means that if we compute v for every possible dataset S, both `FALSE` and `TRUE` have to occur at least once.

Note

Such a function is (almost) always stated as a *rule* stating a condition that data must satisfy.

Validation rule complexity

Observation

Depending on the rule, we may need to compare data points against

- A constant,
- Other data points, coming from other
  - variables,
  - measurement times,
  - statistical units,
  - populations.

Idea

Use the ‘amount of extra information necessary’ to classify the complexity of validation rules.

Classifying validation rules

- Recall the $U\tau uX$ notation
- A rule is labeled with a sequence of four characters *cccc*, where each character is either *s* (single) or *m* (multi).

Example

IF $age < 15$ **THEN** $job = \texttt{FALSE}$

- We see that
  - single population U
  - single measurement time τ
  - single statistical unit u
  - multiple (2) variables X
- Hence, the complexity class is *sssm*

Possible classes

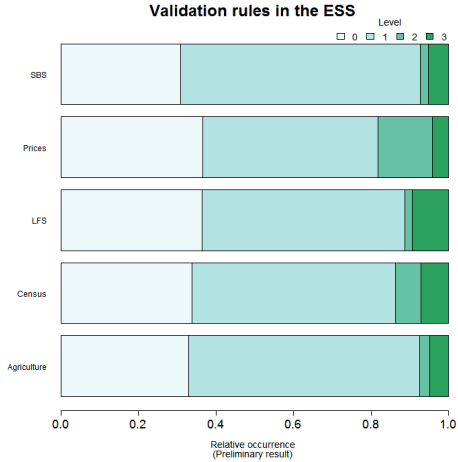
- In principle there are $2^4 = 16$ classes
- However,
  - Given U, the possible u are known
  - Given U, the possible X are known
- This limits the classification to 10 possible options

ssss	*sssm*	*ssms*	*ssmm*	*smss*
smsm	*smms*	*smmm*	*msmm*	*mmmm*.

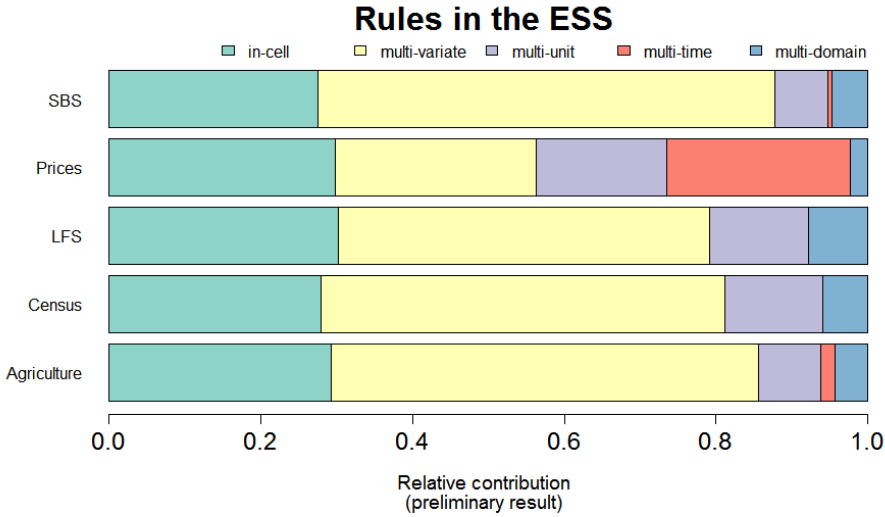
Validation rule classification

Validation level				
0	1	2	3	4
ssss	sssm	ssmm	smmm	mmmm
	ssms	smsm	msmm	
	smss	smms		

Validation rules in the ESS (1/3)



Validation rules in the ESS (2/3)



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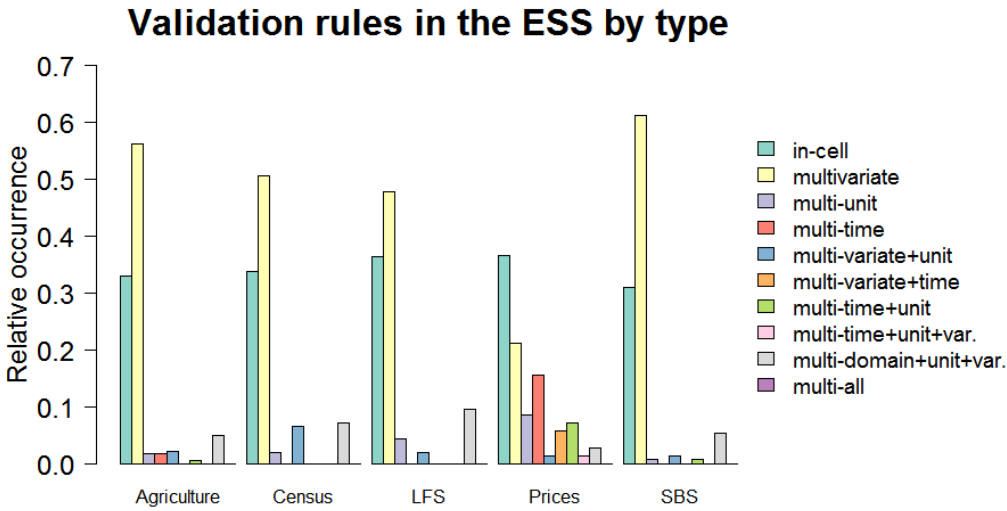
Validation rules in the ESS (3/3)



Quizz (1)

What is the *UτuX* *s*ingle/*m*ulti classification of the following rule?

$$\mathrm{mean}(\mathit{price}) \geq 1$$

Quizz (2)

What is the *UτuX* *s*ingle/*m*ulti classification of the following rule?

$$\frac{\text{mean}(\textit{price}_{2018})}{\text{mean}(\textit{price}_{2017})} \leq 1.1$$

Quizz (3)

What is the $U\tau uX$ *s*ingle/*m*ulti classification of the following rule?

$$\max\left(\frac{x}{\text{median}(X)}, \frac{\text{median}(X)}{x}\right) < 10$$

Quizz (4)

What is the $U\tau uX$ *s*ingle/*m*ulti classification of the following rule?

$$\underbrace{COE + GOS + GMI + T_{P\&M} - S_{P\&M}}_{\text{GDP, Income approach}} = \underbrace{C + G + I + (X - M)}_{\text{GDP, expenditure approach}}$$

- COE: Compensation of employees
- GOS: Gross operating surplus
- GMI: Gross mixed income
- $T_{P\&M} - S_{P\&M}$: Taxes minus subsidies on production and import
- C: Consumption by households
- G: Government consumption & investment
- I: Gross private domestic investment
- $X - M$: Export minus Imports of goods and services