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Consistently perturbing tables

Introducing R package cellKey

What (in a nutshell)

- Presenting `R` package `cellKey` (`github.com/sdcTools/cellKey`)
- Developed within project "Open Source tools for perturbative confidentiality methods"
  - Thx to all colleagues from Germany, Netherlands, France, Finland, Slovenia, Finland and Hungary
- The tool implements the (enhanced) cell-key method
  - originally proposed by `ABS`
  - post-tabular method to protect statistical tables
  - enhanced/modified within this project

Features:

- Starting point: microdata
  - important: assignment of record keys (`rkeys`)
  - allows to easily define (complex) tables
  - allows to perturb count- and magnitude tables using cell keys (`ckeys`) derived from `rkeys`
- (Sampling)weights are supported
- Allows for different perturbation parameters by variable
- many auxiliary functions (e.g key generation) available

The method: Starting from micro data

- **Idea**: describing the general idea of the method (easy)
- Post-tabular method when other methods (e.g suppression) are not viable
- starting from a micro data set `md` (nrows: 4580)

```
print(head(md))
```

```
##        sex age high_inc  w savings       rkey
## 1:    male ag3        0 70      12 0.8027299
## 2: female ag3        0 99      28 0.6282568
## 3:    male ag1        0 58     550 0.3713780
## 4:    male ag1        0 23     870 0.2507976
## 5:    male ag4        1 38      20 0.9165093
## 6: female ag3        0 93     102 0.8307836
```

The method: Deriving a cell key

- Identify contributors for a specific cell:

```
##      sex  age high_inc  w savings       rkey
## 1:  male  ag6        0 29     771 0.11134575
## 2:  male  ag6        0 90     767 0.75515496
## 3:  male  ag6        0 38     821 0.56953559
## 4:  male  ag6        0 26      41 0.45790072
## 5:  male  ag6        0 59     281 0.16707917
## 6:  male  ag6        0 39     558 0.05877474
## 7:  male  ag6        0 81     371 0.06648822
```

- `ckey`: Sum of all contributing record keys and taking the fractal part
  - $\rightarrow$ the cell keys are $\sim\in [0, 1)$

```
## [1] 0.1862791
```

- **Consistency**: the same set of units returns the same `ckey`
- **Perturbation**: find a perturbation value based on the `ckey`

The method: Perturbing the cell

- **Trivial**: using the ckey as seed when sampling a perturbation value

```
pval <- function(ckey) { set.seed(ckey); sample(-10:10, 1) }
```

- **Perturbation**: we use the noise value to perturb the cell count

```
result <- sum(contributors$w) + pval(ckey); result
```

```
## [1] 365
```

- **Task:** Finding perturbation values → make use of a perturbation table

The ptable package (1)

- The `CKM` (and thus also `cellKey`) depends on perturbation tables
- These so-called `ptables` encompass noise values and the corresponding probabilities
- There are `ptables` for both: fequency and magnitude tables
- The `ptables` need to be designed such that
  - no bias is introduced
  - the variance of the noise is fixed
  - in case of frequency tables:
    - no negative counts will appear
    - zero counts remain zeroes

The ptable package (2)

- ptables can be computed with R package ptable (github.com/sdcTools/ptable)
- The ptable reults from the solution of non-linear equation systems that are defined by contraints and boundary conditions relying on a maximum entropy optimization
- **Installation** and **Loading** as easy as:

```
remotes::install_github(
  repo = "sdcTools/ptable",
  dependencies = TRUE)

library(ptable)
```

The ptable package (3)

- The package allows for a couple of arguments - used for the constraints of the optimization instance - when designing the `ptable`:
  - **D** maximum noise
  - **V** variance
  - **pstay** probability that a frequency count remains unchanged/unperturbed
  - **js** small counts can be blocked (i.e. they will not appear in the protected table)
  - ... and many more ...
- **Vignette** gives an introduction with examples: call `pt_vignette()`

The ptable package (4)

Example: Design the `ptable` for a frequency table with maximum noise `D=2`, a fixed variance `V=1.05`, counts of `1` shall not appear in the protected tables and the probability that a frequency count is set to 50%.

```
ptab <- ptable::create_cnt_ptable(
  D = 2,
  V = 1.05,
  js = 1,
  pstay = 0.5,
  mono = c(T, T, F, T))
```

The ptable package (5)

Example (continued)

```
# Evaluate the result
ptab@empResults
```

```
##      i p_mean  p_var  p_sum  p_stay  iter
##  1:  0      0   0.00      1  1.0000     0
##  2:  1      0   1.05      1  0.0000     1
##  3:  2      0   1.05      1  0.5557     1
##  4:  3      0   1.05      1  0.2881     6
##  5:  4      0   1.05      1  0.5000     1
```

The ptable package (6)

Example (continued)

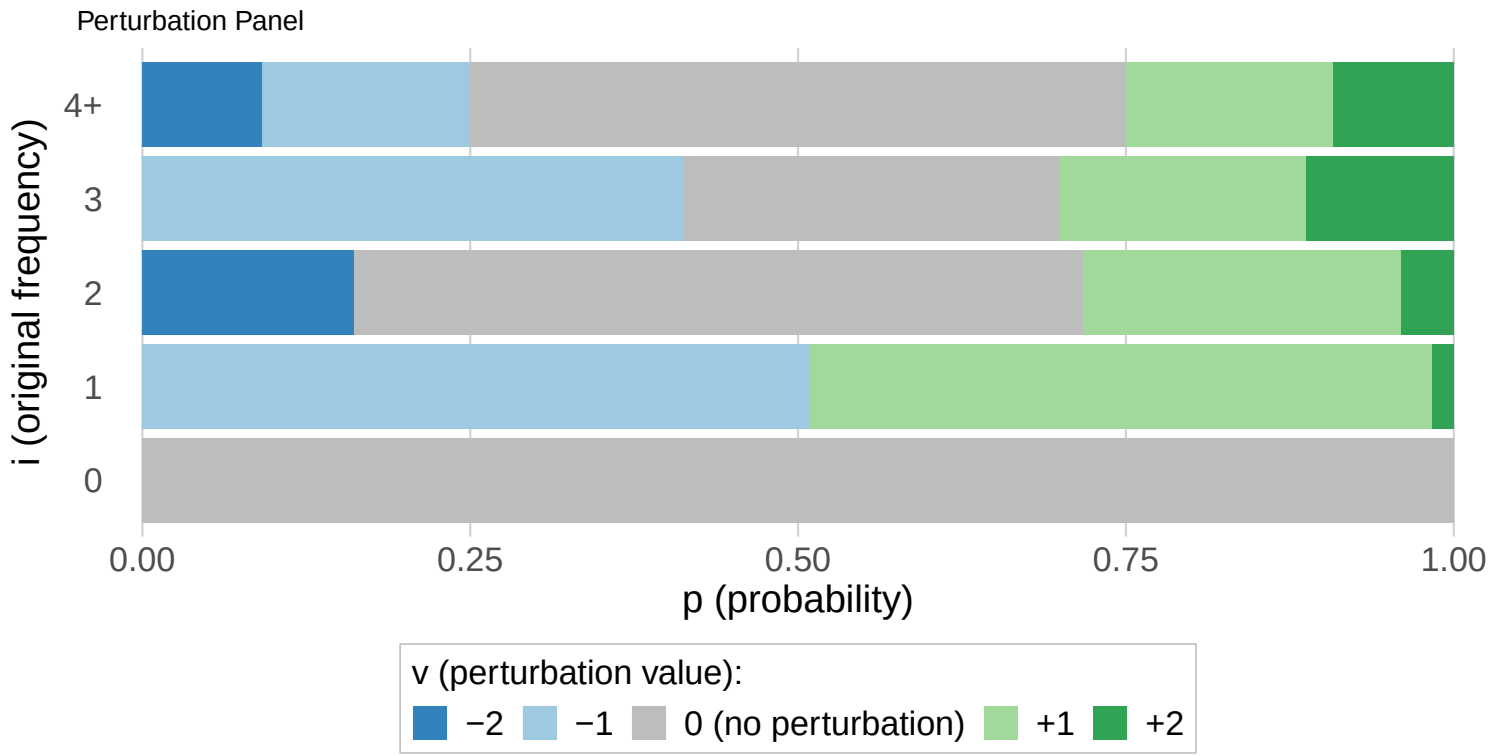
```
# Look at the ptable
head(ptab@pTable)
```

```
##     i j           p  v  p_int_lb  p_int_ub type
## 1:  0 0 1.00000000  0 0.0000000 1.0000000  all
## 2:  1 0 0.50833333 -1 0.0000000 0.5083333  all
## 3:  1 2 0.47500000  1 0.5083333 0.9833333  all
## 4:  1 3 0.01666667  2 0.9833333 1.0000000  all
## 5:  2 0 0.16155827 -2 0.0000000 0.1615583  all
## 6:  2 2 0.55565037  0 0.1615583 0.7172086  all
```

Example (continued)

```
plot(ptab, type = "p") # Plot the ptable (perturbation panel)
```

```
## Perturbation Panel
```



- **Installation**
  - directly from the `github.com/sdcTools/cellKey` (not yet on CRAN)
- (online) **Dokumentation**: `sdctools.github.io/cellKey`
  - includes a `package vignette`
- **defining hierarchies**
  - `cellKey` uses functionality from `sdcHierarchies`
  - hierarchies can be created
    - indirectly (from a character vector)
    - directly (by adding nodes to a tree)

cellKey: Setup a table

- **Prerequisites**: micro data, hierarchies, optionally count and continuous variables, weights and record keys
- **Dimensions**

```
dims <- list(
  sex = hier_create("total", nodes = c("male", "female")),
  age = hier_create("total", nodes = paste0("ag", 1:6)))
```

- **Table instance**

```
tab <- ck_setup(x = md, rkey = "rkey", dims = dims,
  w = "w", countvars = c("high_inc"), numvars = "savings")
```

cellKey: working with a table

- objects created with `ck_setup()` have their data and methods bundled together
- methods can be called with the following syntax

```
obj$method(...)
```

- for example (no perturbed results yet):

```
head(tab$freqtab(v = "total"))
```

```
##       sex    age vname   uwc      wc puwc pwc
## 1: total total total  4580 274917   NA  NA
## 2: total   ag1 total  1969 119138   NA  NA
## 3: total   ag2 total  1143  68337   NA  NA
## 4: total   ag3 total   864  51841   NA  NA
## 5: total   ag4 total   423  24759   NA  NA
## 6: total   ag5 total   168  10105   NA  NA
```

cellKey: perturbation parameters (1)

- **Attaching** parameters to variables:
  - for count variables: `ck_params_cnts()`
  - for continuous variables: `ck_params_nums()`
- **Example:** Parameters for a count variable

```
library(ptable)
cnt_params1 <- ck_params_cnts(ptab = create_cnt_ptable(
  D = 8, V = 3, js = 2))

cnt_params2 <- ck_params_cnts(ptab = create_cnt_ptable(
  D = 10, V = 10, js = 5))
```

cellKey: attaching perturbation parameters (2)

- **Attaching** parameters to variable(s)
  - `params_cnts_set()` / `params_nums_set()`

```
tab$params_cnts_set(cnt_params1) # default: all vars
```

```
## --> setting perturbation parameters for variable 'total'
```

```
## --> setting perturbation parameters for variable 'high_inc'
```

- for specific variables (resetting previous parameters)

```
tab$params_cnts_set(v = "high_inc", val = cnt_params2)
```

```
## --> replacing perturbation parameters for variable 'high_inc'
```

cellKey: Perturbing variables and returning results

- **Perturbation**: use the `perturb` method (for both count- and continuous variables)

```
tab$perturb(c("total", "high_inc"))
```

```
## Count variable 'total' was perturbed.
```

```
## Count variable 'high_inc' was perturbed.
```

- **Results**: use the `freqtab()` and `numtab()` methods

```
##       sex    age     vname uwc     wc puwc          pwc
## 1:  total  total high_inc 445  26535  444 26475.3708
## 2:  total    ag1 high_inc 192  11881  190 11757.2396
## 3:  total    ag2 high_inc 123   6833  122  6777.4472
## 4:  total    ag3 high_inc  82   4980   78  4737.0732
## 5:  total    ag4 high_inc  34   1967   33  1909.1471
## 6:  total    ag5 high_inc  14    874   12   749.1429
```

cellKey: additional features

- CKM was extended quite a lot for magnitude tables
  - different "starting values" for perturbation possible
  - apply different ptables for cells with
    - an even/odd number of contributors
    - very small values
  - allow for extra perturbation for sensitive cells
    - `supp_{method}()` namespace for identification
- distance/utlity measures for count-variables (`measures_cnts()`)
- perturbation parameters can be saved for reproducability (`ck_write_yaml()` and `ck_read_yaml()`)

Summary and the Future

- **Future development**:
  - incorporating **feedback** from users
  - add utility statistics and measures for continuous variables
  - achieve full consistency with the implementation from τ-argus
- **Summary**
  - `cellKey` allows to consistently perturb statistical tables
  - it makes use of ptables created from the `ptable` package
- **Important Links**
  - **Documentation**: `sdctools.github.io/cellKey/`
  - **Questions**: `github.com/sdcTools/userSupport`
  - **Bug-Reports**: `github.com/sdcTools/userSupport/issues`

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