`ftools`: a faster Stata for large datasets

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https://github.com/sergiocorreia/ftools

Outline

1. Motivation: `bysort` is slow with large datasets
2. Solution: replace it with hash tables
3. Implementation: new Mata object
4. Implementation: new Stata commands
5. Going forward: faster internals and more commands

1. Motivation

Motivation (1/3)

- Stata is fast for small and medium datasets, but gets *increasingly slower* as we add more observations
- Writing and debugging do-files is very hard if `collapse`, `merge`, etc. take hours to run
- Example:

```
set obs `N'
gen int id = ceil(runiform() * 100)
gen double x = runiform()
collapse (sum) x, by(id) fast
```

Motivation (2/3)

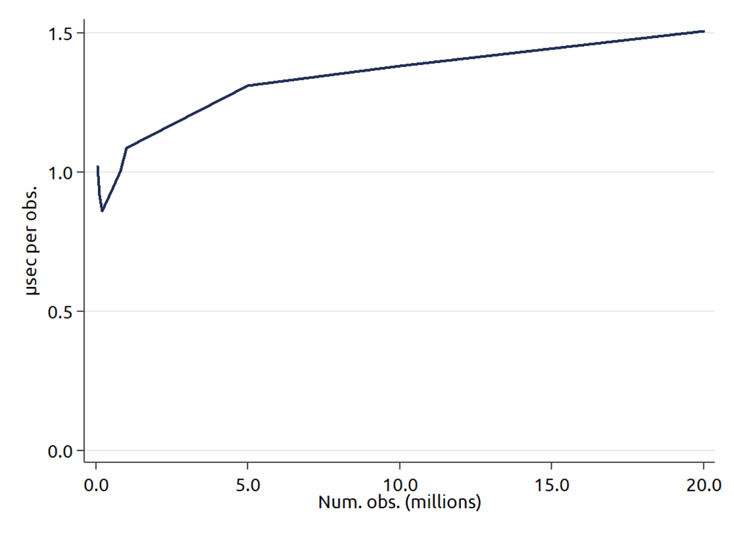


Figure 1: Speed of `collapse` per observation, by number of obs.

Motivation (3/3)

- `collapse` gets slower because underneath it lies a `sort` command such as:

  ```
  bysort id: replace x = sum(x)
  by id: keep if _n == _N
  ```

  - Sorting in Stata is probably implemented through quicksort, which is an $O(\mathrm{n} \log \mathrm{n})$ algorithm.
  - Thus, `collapse` is also $O(\mathrm{n} \log \mathrm{n})$
- This goes beyond `collapse`, as many Stata commands rely on `bysort` (`egen`, `merge`, `reshape`, `isid`, `contract`, etc.)
- See *"Speaking Stata: How to move step by: step"* (Cox, SJ 2002)

2. Solution

Solution

- When appropiate, replace `bysort` with a hash table
  - Already implemented by Pandas, Julia, Apache Spark, R, etc.
  - Also, internally by some Stata users
- A hash function is “any function that can be used to map data of arbitrary size to data of fixed size”
- Implemented in Stata:

```
. mata: hash1(”John”, 100)
  52
```

- How does this work? Let’s implement `collapse` with a hash table!

Solution: collapse with a hash table

```
// Alternative to: collapse (sum) price, by(turn)
sysuse auto
mata:
  id = st_data(., ”turn”)
  val = st_data(., ”price”)
  index = J(1000, 2, 0) // Create hash table of size 1000
  for (i=1; i<=rows(id); i++) {
    h = hash1(id[i], 1000) // Compute hash
    index[h, 1] = id[i] // Store value of turn
    index[h, 2] = index[h, 2] + val[i] // Construct sum
  }
  index = select(index, index[.,1]) // Select nonempty rows
  sort(index, 1) // View results
end
```

Solution: collision resolution (advanced)

- Sometimes two different values can return the same hash:

```
. mata: hash1(”William”, 100)
  43

. mata: hash1(”Ava”, 100)
  43
```

- To solve this, Mata’s `asarray()` stores lists of all colliding values
- Instead , `ftools` uses linear probing

3. Implementation

Implementation: `ftools`

`ftools` is two things:

1. A `Mata` class that deals with **factors** or categories (`ftools` = factor tools)
2. Several Stata commands based on this class (`fcollapse`, `fmerge`, `fegen`, etc.)

To install:

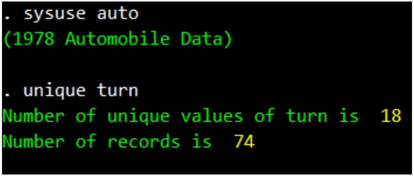
- `ssc install ftools`
- `ssc install moremata` (used in “collapse (median) ...”)
- `ssc install boottest` (for Stata 11 and 12)
- `ftools, compile` (if we want to use the Mata functions directly)

Implementation: `Factor` class

```
sysuse auto
mata: F = factor(”turn␣foreign”) // New object
mata: F.num_levels // Number of distinct values
mata: F.keys, F.counts // View values and counts
```

- `help ftools` describes in detail the methods and properties of this class
- These will remain stable, so you can implement your own commands based on it
- Please do so!

Creating new commands: example 1 - `unique`

- `unique` (from SSC) counts the number of unique values but is very slow on large datasets:
- 

```
. sysuse auto
(1978 Automobile Data)

. unique turn
Number of unique values of turn is  18
Number of records is  74
```

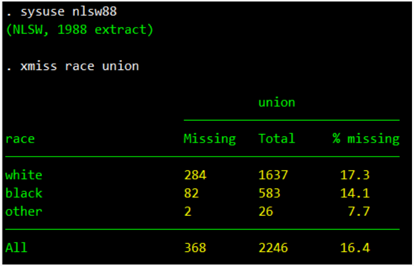
- Alternative:

```
mata: F = factor(”turn”)
mata: F.num_levels, F.num_obs
```

- 10x faster with 10mm obs.

Creating new commands: example 2 - xmiss

- `xmiss` (from SSC) counts missing values per variable



```
. sysuse nlsw88
(NLSW, 1988 extract)

. xmiss race union

                                   union
                         ----------------------------
race                     Missing    Total    % missing
----------------------------------------------------
white                    284        1637        17.3
black                    82         583         14.1
other                    2          26           7.7
----------------------------------------------------
All                      368        2246        16.4
```

- Alternative (12x faster with 10mm obs.)

```
mata: F = factor(”race”)
mata: F.panelsetup()
mata: mask = rowmissing(st_data(., ”union”))
mata: missings = panelsum(F.sort(mask), F.info)
mata: missings, F.counts
```

4. Stata commands included with `ftools`

Commands included with `ftools`

- `fcollapse` (replaces `collapse`, `contract`, and most of `egen`)
- `fegen group`
- `fisid`
- `fmerge` and `join`
- `flevelsof`
- Also see: `reghdfe`

`fcollapse`

- To use it: add `f` before your existing `collapse` calls
- Supports all standard functions (mean, median, count, etc.), all weights, etc.
- Can be extended through Mata functions (see `help fcollapse` for an example)
- `fcollapse ... , merge` merges the collapsed data back into the original dataset, making it equivalent to `egen`.
- `fcollapse ... , freq` is the equivalent to `contract`
- `fcollapse ... , smart` checks if the data is already sorted, in which case it just calls `collapse`

Performance (back to collapse)

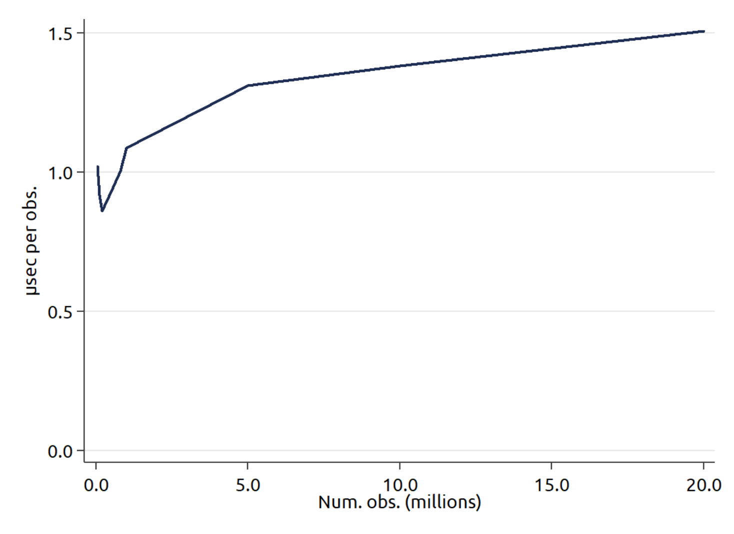


Figure 2: Speed of `collapse` per observation, by number of obs.

Performance

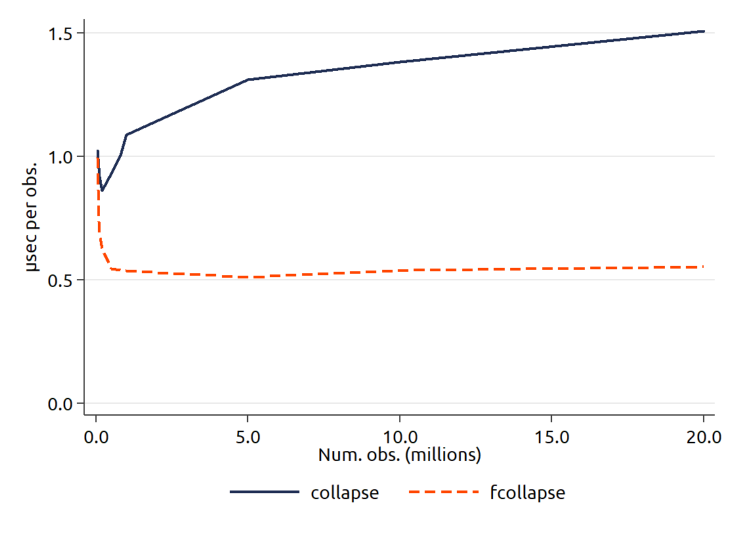


Figure 3: Speed of `collapse` and `fcollapse` by number of observations

Performance

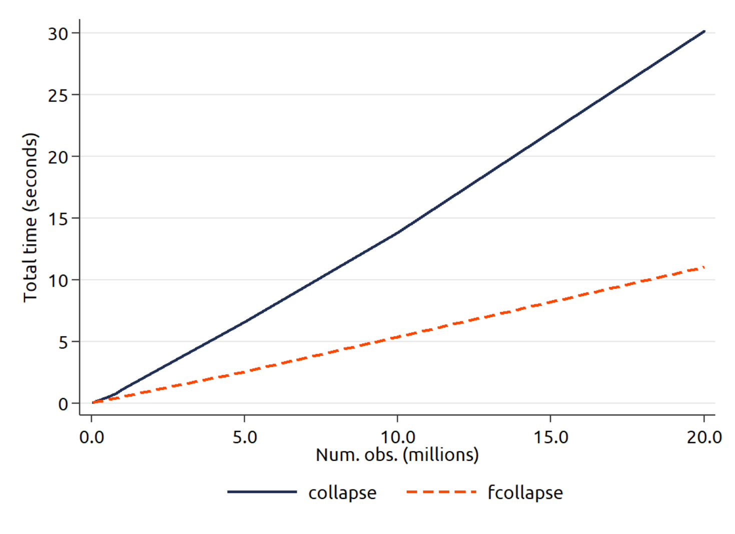


Figure 4: Elapsed time of `collapse` and `fcollapse` by num. obs.

4. Going forward

Going forward

- The principles behind `ftools` allow Stata to work efficiently with large datasets (1mm obs. and higher)
- Still, there is large room for improvement
- `ftools` could be significantly speed up through improvements in Mata (better hash functions, more built-in functions, integer types, etc.)
- `gtools`, a *very new* package by Mauricio Caceres, implements some commands as a C plugin (`gcollapse`, `gegen`):

Going forward: `gtools`

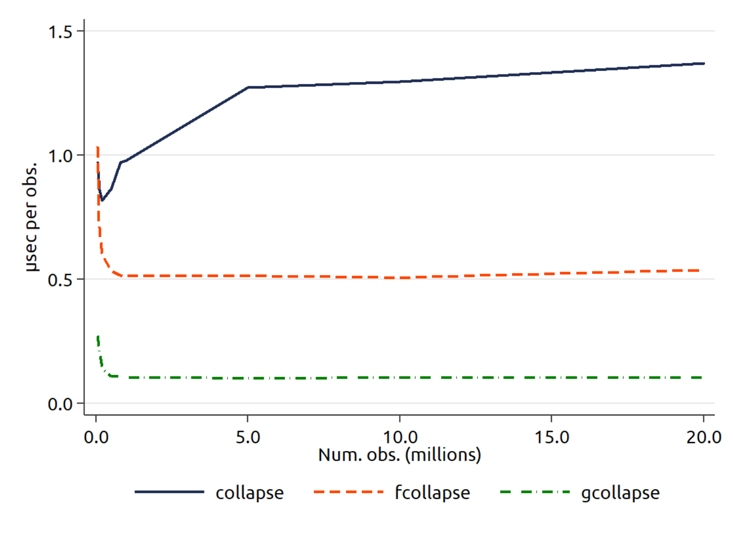


Figure 5: Speed of `collapse`, `fcollapse` and `gcollapse`

Going forward: 28s --> 10s --> 2s

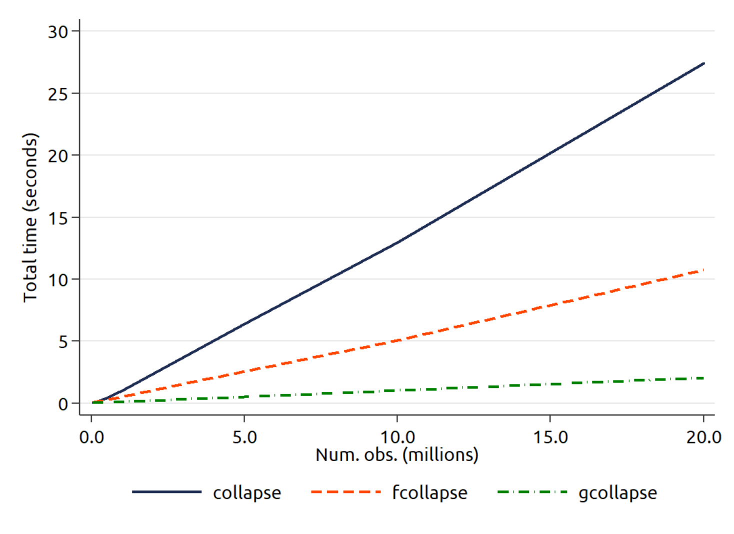


Figure 6: Elapsed time of `collapse`, `fcollapse` and `gcollapse`

Conclusion

- With `ftools`, working with large datasets is no longer painful
- Still, we can
  - Speed it up (builtin functions, `gtools`)
  - Extend it to more commands (reshape, table, distinct, egenmore, binscatter, etc.)

The End

Additional Slides

References and useful links

- Caceres, M. (2017). *gtools*
- Cox, NJ. (2002). *Speaking Stata: How to move step by: step.* Stata Journal 2(1)
- Gomez, M. (2017). *Stata-R benchmark*
- Guimaraes, P. (2015). *Big Data in Stata*
- Maurer, A. (2015). *Big Data in Stata*
- McKinney, W. (2012). *A look inside pandas design and development*
- Stepner, M. (2014). *fastxtile*

Tricks learned while writing `ftools` (advanced)

- If you want to write fast Mata code, see these tips
- If you want to distribute Mata code as libraries, but don't want to deal with the hassle of compiling the code, see this repo
- If you usually declare your Mata variables, consider including this file at the beginning of your `.mata` file

Mata Wishlist

Any of the following would significantly speed up `ftools`:

- Integer types so we can loop faster
- A `rowhash1()` function that computes hashes in parallel for every row
- A faster alternative of `hash1()`, such as SpookyHash, from the same author
- An optimized version of `x[i] = x[i] + 1`
- Radix sort function for integer variables (recall that counting sort is $O(\mathrm{n})$)