Just tired of endless loops!

or `parallel`: Stata module for parallel computing

George G. Vega Yon[1] Brian Quistorff[2]

[1]University of Southern California
vegayon@usc.edu

[2]Microsoft AI and Research
Brian.Quistorff@microsoft.com

Stata Conference Baltimore
July 27–28, 2017

Thanks to Stata users worldwide for their valuable contributions. The usual disclaimers applies.

Agenda

Motivation

What is it and how does it work

Benchmarks

Syntax and Usage

Concluding Remarks

Motivation

- Both computation power and size of data are ever increasing

Motivation

- Both computation power and size of data are ever increasing
- Often our work is easily broken down into independent chunks

Motivation

- Both computation power and size of data are ever increasing
- Often our work is easily broken down into independent chunks
- Implementing parallel computing, even for these “embarrassingly parallel” problems, however, is not easy.

Motivation

- Both computation power and size of data are ever increasing
- Often our work is easily broken down into independent chunks
- Implementing parallel computing, even for these "embarrassingly parallel" problems, however, is not easy.
- Stata/MP exists, but only parallelizes a limited set of internal commands, not user commands.

Motivation

- Both computation power and size of data are ever increasing
- Often our work is easily broken down into independent chunks
- Implementing parallel computing, even for these "embarrassingly parallel" problems, however, is not easy.
- Stata/MP exists, but only parallelizes a limited set of internal commands, not user commands.
- `parallel` aims to make this more convenient.

What is it and how does it work

What is it?

- Inspired by the R package "snow" (several other examples exists: HTCondor, Matlab's Parallel Toolbox, etc.)

What is it and how does it work

What is it?

- Inspired by the R package "snow" (several other examples exists: HTCondor, Matlab's Parallel Toolbox, etc.)
- Launches "child" batch-mode Stata processes across multiple processors (e.g. simultaneous multi-threading, multiple cores, sockets, cluster nodes).

What is it and how does it work

What is it?

- Inspired by the R package "snow" (several other examples exists: HTCondor, Matlab's Parallel Toolbox, etc.)
- Launches "child" batch-mode Stata processes across multiple processors (e.g. simultaneous multi-threading, multiple cores, sockets, cluster nodes).
- Depending on the task, can reach near linear speedups proportional to the number of processors.

What is it and how does it work

What is it?

- Inspired by the R package "snow" (several other examples exists: HTCondor, Matlab's Parallel Toolbox, etc.)
- Launches "child" batch-mode Stata processes across multiple processors (e.g. simultaneous multi-threading, multiple cores, sockets, cluster nodes).
- Depending on the task, can reach near linear speedups proportional to the number of processors.
  - Thus having a quad-core computer can lead to a 400% speedup.

Simple usage

`Serial:`

- gen v2 = v*v
- do byobs_calc.do
- bs, reps(5000): reg price foreign rep

Simple usage

`Serial:`

- gen v2 = v*v
- do byobs_calc.do
- bs, reps(5000): reg price foreign rep

`Parallel:`

- parallel: gen v2 = v*v
- parallel do byobs_calc.do
- parallel bs, reps(5000): reg price foreign rep

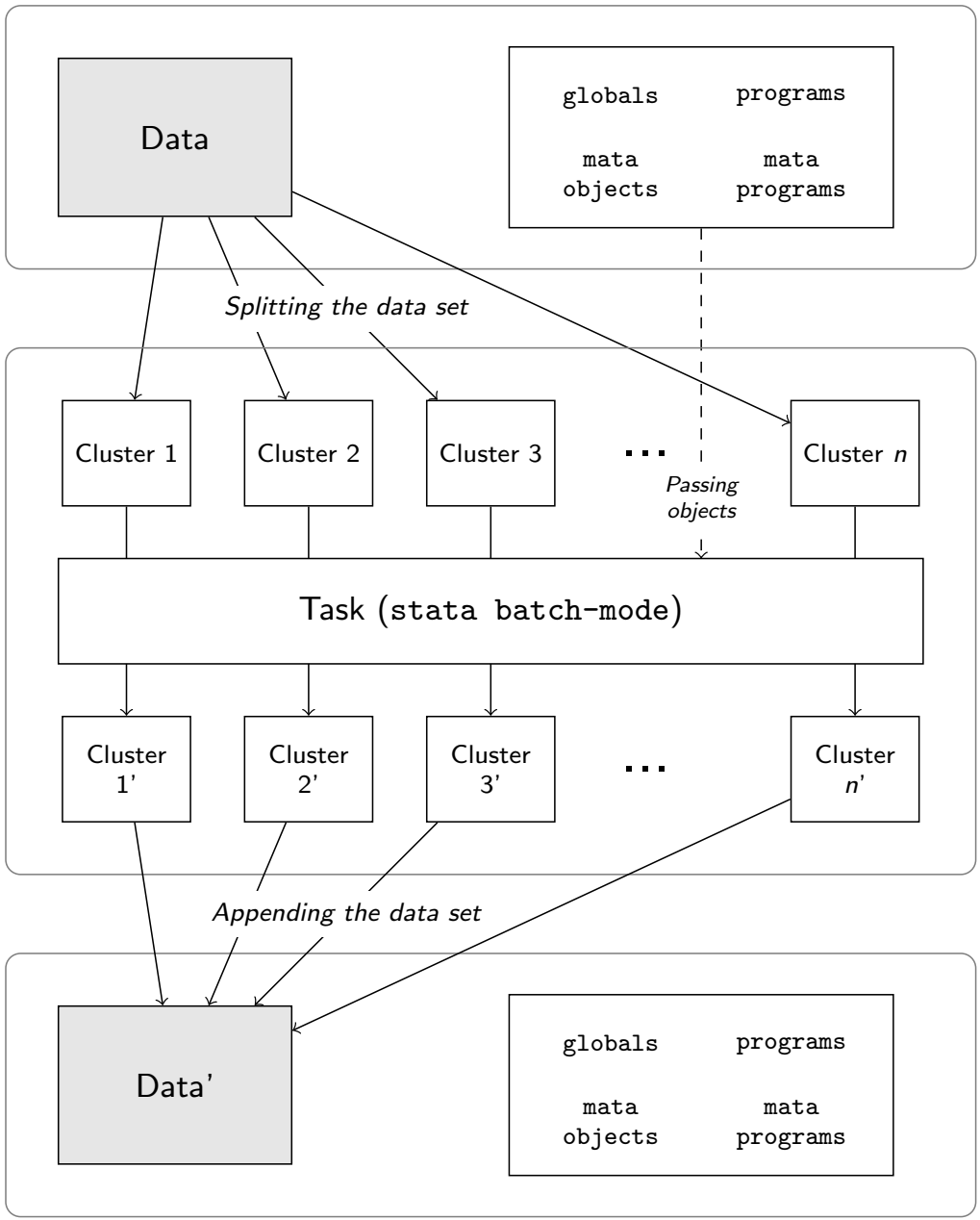
What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce.

What is it and how does it work

How does it work?



Starting (current) `stata` instance loaded with data plus user defined `globals`, `programs`, `mata objects` and `mata programs`

A new `stata` instance (batch-mode) for every data-clusters. Programs, globals and mata objects/programs are passed to them.

The same algorithm (task) is simultaneously applied over the data-clusters.

After every instance stops, the data-clusters are appended into one.

Ending (resulting) `stata` instance loaded with the new data.

User defined `globals`, `programs`, `mata objects` and `mata programs` remind unchanged.

What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce. Very flexible!

What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce. Very flexible!
- Straightforward usage when there is observation- or group-level work

What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce. Very flexible!
- Straightforward usage when there is observation- or group-level work
- If each iteration needs the entire dataset, then use procedure to split the tasks and load the data separately. Examples:

What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce. Very flexible!
- Straightforward usage when there is observation- or group-level work
- If each iteration needs the entire dataset, then use procedure to split the tasks and load the data separately. Examples:
  - Table of seeds for each bootstrap resampling

What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce. Very flexible!
- Straightforward usage when there is observation- or group-level work
- If each iteration needs the entire dataset, then use procedure to split the tasks and load the data separately. Examples:
  - Table of seeds for each bootstrap resampling
  - Table of parameter values for simulations

What is it and how does it work

How does it work?

- Method is *split-apply-combine* like MapReduce. Very flexible!
- Straightforward usage when there is observation- or group-level work
- If each iteration needs the entire dataset, then use procedure to split the tasks and load the data separately. Examples:
  - Table of seeds for each bootstrap resampling
  - Table of parameter values for simulations
- If the list of tasks is data-dependent then the "nodata" alternative mechanism allows for more flexibility.

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode
  - Seamless user experience by launching the child programs in a hidden desktop (otherwise GUI for each steals focus)

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode
  - Seamless user experience by launching the child programs in a hidden desktop (otherwise GUI for each steals focus)
- For a Linux/MacOS cluster with a shared filesystem (e.g. NFS) and ssh-like commands, can distribute across nodes.

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode
  - Seamless user experience by launching the child programs in a hidden desktop (otherwise GUI for each steals focus)
- For a Linux/MacOS cluster with a shared filesystem (e.g. NFS) and ssh-like commands, can distribute across nodes.
  - New feature so we'd appreciate help from the community to extend to other cluster settings (e.g. PBS)

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode
  - Seamless user experience by launching the child programs in a hidden desktop (otherwise GUI for each steals focus)
- For a Linux/MacOS cluster with a shared filesystem (e.g. NFS) and ssh-like commands, can distribute across nodes.
  - New feature so we'd appreciate help from the community to extend to other cluster settings (e.g. PBS)
- Make sure that child tempnames or tempvars don't clash with those coming from parent.

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode
  - Seamless user experience by launching the child programs in a hidden desktop (otherwise GUI for each steals focus)
- For a Linux/MacOS cluster with a shared filesystem (e.g. NFS) and ssh-like commands, can distribute across nodes.
  - New feature so we'd appreciate help from the community to extend to other cluster settings (e.g. PBS)
- Make sure that child tempnames or tempvars don't clash with those coming from parent.
- Passes through programs, macros and mata objects, but NOT Stata matrices or scalars. No state but datasets are returned to parent.

Implementation

Some details

- Uses shell on Linux/MacOS. On Windows we have a compiled plugging allowing:
  - Functionality when the parent Stata is in batch-mode
  - Seamless user experience by launching the child programs in a hidden desktop (otherwise GUI for each steals focus)
- For a Linux/MacOS cluster with a shared filesystem (e.g. NFS) and ssh-like commands, can distribute across nodes.
  - New feature so we'd appreciate help from the community to extend to other cluster settings (e.g. PBS)
- Make sure that child tempnames or tempvars don't clash with those coming from parent.
- Passes through programs, macros and mata objects, but NOT Stata matrices or scalars. No state but datasets are returned to parent.
- Recover gracefully from child failures. Currently no re-try support.

Benchmarks

Bootstrap with `parallel bs`

```
sysuse auto, clear expand 10

// Serial fashion
bs, rep($size) nodots: regress mpg weight gear foreign

// Parallel fashion
parallel setclusters $number_of_clusters
parallel bs, rep($size) nodots: regress mpg weight gear foreign
```

Benchmarks

Bootstrap with `parallel bs`

```
sysuse auto, clear expand 10

// Serial fashion
bs, rep($size) nodots: regress mpg weight gear foreign

// Parallel fashion
parallel setclusters $number_of_clusters
parallel bs, rep($size) nodots: regress mpg weight gear foreign
```

Problem size	Serial	2 Clusters	4 Clusters
1,000	2.93s	1.62s	1.09s
	×2.69	×1.48	×1.00
2,000	5.80s	3.13s	2.03s
	×2.85	×1.54	×1.00
4,000	11.59s	6.27s	3.86s
	×3.01	×1.62	×1.00

Table: Absolute and relative computing times for each run of a basic bootstrap problem. For each given problem size, the first row shows the time in seconds, and the second row shows the relative time each method took to complete the task relative to using parallel with four clusters. Each cell represents a 1,000 runs.

Benchmarks

Simulations with `parallel sim`

```
prog def mysim, rclass
    // Data generating process
    drop _all
    set obs 1000
    gen eps = rnormal()
    gen X = rnormal()
    gen Y = X*2 + eps

    // Estimation
    reg Y X
    mat def ans = e(b)
    return scalar beta = ans[1,1]
end

// Serial fashion
simulate beta=r(beta), reps($size) nodots: mysim

// Parallel fashion
parallel setclusters $number_of_clusters
parallel sim, reps($size) expr(beta=r(beta)) nodots: mysim
```

Benchmarks

Simulations with `parallel sim (cont.)`

Problem size	Serial	2 Clusters	4 Clusters
1000	2.19s	1.18s	0.73s
	×3.01	×1.62	×1.00
2000	4.36s	2.29s	1.33s
	×3.29	×1.73	×1.00
4000	8.69s	4.53s	2.55s
	×3.40	×1.77	×1.00

Table: Absolute and relative computing times for each run of a simple Monte Carlo exercise. For each given problem size, the first row shows the time in seconds, and the second row shows the relative time each method took to complete the task relative to using parallel with four clusters. Each cell represents a 1,000 runs.

Code for replicating this is available at
`https://github.com/gvegayon/parallel`

Syntax and Usage

Setup

parallel setclusters `#|default [, force hostnames(namelist)]`

Syntax and Usage

Setup

parallel setclusters #|default [, force hostnames(namelist)]

Main command types

parallel [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*)
nodata]: *stata_cmd*

Syntax and Usage

Setup

parallel setclusters #|default [, force hostnames(namelist)]

Main command types

parallel [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]: *stata_cmd*

parallel do *filename* [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]

Syntax and Usage

Setup

parallel setclusters #|default [, force hostnames(namelist)]

Main command types

parallel [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*)
nodata]: *stata_cmd*

parallel do *filename* [, by(*varlist*) programs(*namelist*) mata seeds(*string*)
randtype(*random.org*|*datetime*) nodata]

Helper commands

parallel bs [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*)
randtype(*random.org*|*datetime*) *bs_options*]: *stata_cmd*

Syntax and Usage

Setup

parallel setclusters #|default [, force hostnames(namelist)]

Main command types

parallel [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]: *stata_cmd*

parallel do *filename* [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]

Helper commands

parallel bs [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) *bs_options*]: *stata_cmd*

parallel sim [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) *sim_options*)]: *stata_cmd*

Syntax and Usage

Setup

parallel setclusters #|default [, force hostnames(namelist)]

Main command types

parallel [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]: *stata_cmd*

parallel do *filename* [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]

Helper commands

parallel bs [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) *bs_options*]: *stata_cmd*

parallel sim [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) *sim_options*)]: *stata_cmd*

parallel append [*files*], do(*command*|*dofile*) [in(*in*) if(*if*) expression(*expand_exp*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*)]

Syntax and Usage

Setup

parallel setclusters #|default [, force hostnames(namelist)]

Main command types

parallel [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]: *stata_cmd*

parallel do *filename* [, by(*varlist*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) nodata]

Helper commands

parallel bs [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) *bs_options*]: *stata_cmd*

parallel sim [, expression(*exp_list*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*) *sim_options*)]: *stata_cmd*

parallel append [*files*], do(*command*|*dofile*) [in(*in*) if(*if*) expression(*expand_exp*) programs(*namelist*) mata seeds(*string*) randtype(*random.org*|*datetime*)]

Additional Utilities

parallel version/clean/printlog/viewlog/numprocessors

Debugging

- Use **parallel printlog**/**viewlog** to view the log of the child process (includes some setup code as well). Can **set trace** in the child do-file or command to see more.

Debugging

- Use **parallel printlog**/**viewlog** to view the log of the child process (includes some setup code as well). Can **set trace** in the child do-file or command to see more.
- Auxiliary files created during process (harder to use):

Debugging

- Use **parallel printlog**/**viewlog** to view the log of the child process (includes some setup code as well). Can **set trace** in the child do-file or command to see more.
- Auxiliary files created during process (harder to use):
  - (Unix) __pll*ID*_shell.sh
  - __pll*ID*_dataset.dta
  - __pll*ID*_do*NUM*.do
  - __pll*ID*_glob.do
  - __pll*ID*_dta*NUM*.dta
  - __pll*ID*_finito*NUM*

Debugging

- Use **parallel printlog**/**viewlog** to view the log of the child process (includes some setup code as well). Can **set trace** in the child do-file or command to see more.
- Auxiliary files created during process (harder to use):
  - (Unix) __pll*ID*_shell.sh
  - __pll*ID*_dataset.dta
  - __pll*ID*_do*NUM*.do
  - __pll*ID*_glob.do
  - __pll*ID*_dta*NUM*.dta
  - __pll*ID*_finito*NUM*
- Can keep these around by specifying the **keep** or **keeplast** options

`parallel suits ...`

- Repeated simulation

Syntax and Usage

Recommendations on its usage

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)

Syntax and Usage

Recommendations on its usage

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)
- Bootstrapping/Jackknife

Syntax and Usage

Recommendations on its usage

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)
- Bootstrapping/Jackknife
- Multiple MCMC chains to test for convergence (Gelman-Rubin test)

Syntax and Usage

Recommendations on its usage

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)
- Bootstrapping/Jackknife
- Multiple MCMC chains to test for convergence (Gelman-Rubin test)

`parallel doesn't suit ...`

- (already) fast commands

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)
- Bootstrapping/Jackknife
- Multiple MCMC chains to test for convergence (Gelman-Rubin test)

`parallel doesn't suit ...`

- (already) fast commands
- Regressions, ARIMA, etc.

Syntax and Usage

Recommendations on its usage

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)
- Bootstrapping/Jackknife
- Multiple MCMC chains to test for convergence (Gelman-Rubin test)

`parallel doesn't suit ...`

- (already) fast commands
- Regressions, ARIMA, etc.
- Linear Algebra

Syntax and Usage

Recommendations on its usage

`parallel suits ...`

- Repeated simulation
- Extensive nested control flow (loops, while, ifs, etc.)
- Bootstrapping/Jackknife
- Multiple MCMC chains to test for convergence (Gelman-Rubin test)

`parallel doesn't suit ...`

- (already) fast commands
- Regressions, ARIMA, etc.
- Linear Algebra
- Whatever Stata/MP does better (on single machine)

Use in other Stata modules

- EVENTSTUDY2: Perform event studies with complex test statistics
- MIPARALLEL: Perform parallel estimation for multiple imputed datasets
- Synth_Runner: Performs multiple Synthetic Control estimations for permutation testing

Concluding Remarks

- Brings parallel computing to many more commands than Stata/MP

Concluding Remarks

- Brings parallel computing to many more commands than Stata/MP
- Its major strengths/advantages are in simulation models and non-vectorized operations such as control-flow statements.

Concluding Remarks

- Brings parallel computing to many more commands than Stata/MP
- Its major strengths/advantages are in simulation models and non-vectorized operations such as control-flow statements.
- Depending on the proportion of the algorithm that can be parallelized, it is possible to reach near to linear scale speedups.

Concluding Remarks

- Brings parallel computing to many more commands than Stata/MP
- Its major strengths/advantages are in simulation models and non-vectorized operations such as control-flow statements.
- Depending on the proportion of the algorithm that can be parallelized, it is possible to reach near to linear scale speedups.
- We welcome other user commands optionally utilizing `parallel` for increased performance.

Concluding Remarks

- Brings parallel computing to many more commands than Stata/MP
- Its major strengths/advantages are in simulation models and non-vectorized operations such as control-flow statements.
- Depending on the proportion of the algorithm that can be parallelized, it is possible to reach near to linear scale speedups.
- We welcome other user commands optionally utilizing `parallel` for increased performance.
- Install, contribute, find help, and report bugs at `http://github.com/gvegayon/parallel`

Thank you very much!

George G. Vega Yon[1] Brian Quistorff[2]

[1]University of Southern California
vegayon@usc.edu

[2]Microsoft AI and Research
Brian.Quistorff@microsoft.com

Stata Conference Baltimore
July 27–28, 2017