Package ‘BiocParallel’

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Author Bioconductor Package Maintainer [cre], Martin Morgan [aut], Valerie Obenchain [aut], Michel Lang [aut], Ryan Thompson [aut]

Maintainer Bioconductor Package Maintainer <maintainer@bioconductor.org>


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**Description**

This package provides modified versions and novel implementation of functions for parallel evaluation, tailored to use with Bioconductor objects.

**Details**

This package uses code from the parallel package.

**Author(s)**

Author: Bioconductor Package Maintainer [cre], Martin Morgan [aut], Valerie Obenchain [aut], Michel Lang [aut], Ryan Thompson [aut]

Maintainer: Bioconductor Package Maintainer <maintainer@bioconductor.org>
BatchJobsParam-class

Enable parallelization on batch systems

Description

This class is used to parameterize scheduler options on managed high-performance computing clusters.

Usage

```r
BatchJobsParam(workers, catch.errors = TRUE, cleanup = TRUE,
work.dir = getwd(), stop.on.error = TRUE, seed = NULL,
resources = NULL, conffile = NULL, cluster.functions = NULL,
progressbar = TRUE, jobname = "BPJOB",
reg.pars=list(seed=seed, work.dir=work.dir),
conf.pars=list(conffile=conffile, cluster.functions=cluster.functions),
submit.pars=list(resources=resources),
...)
```

Arguments

- **workers**: integer(1) Number of workers to divide tasks (e.g., elements in the first argument of `bplapply`) between. On Multicore and SSH backends, this defaults to all available nodes. On managed (e.g., slurm, SGE) clusters workers defaults to NA, meaning that the number of workers equals the number of tasks. See argument `n.chunks` in `chunk` and `submitJobs` for more information.

- **catch.errors**: logical(1) Flag to determine in apply-like functions (see e.g. `bplapply`) whether to quit with an error as soon as one application fails or encapsulation of function calls in `try` blocks which triggers a resume mechanism (see `bpresume`). Defaults to TRUE.

- **cleanup**: logical(1) BatchJobs creates temporary directories in the `work.dir`. If `cleanup` is set to TRUE (default), the directories are removed from the file systems automatically. Set this to FALSE whenever it might become necessary to utilize any special functionality provided by BatchJobs. To retrieve the registry, call `loadRegistry` on the temporary directory.

- **work.dir**: character(1) Directory to store temporary files. Note that this must be shared across computational nodes if you use a distributed computing backend. Default ist the current working directory of R, see `getwd`. Ignored when `reg.pars` is provided.

- **stop.on.error**: logical(1) Stop all jobs as soon as one job fails (`stop.on.error == TRUE`) or wait for all jobs to terminate. Default is TRUE.

- **seed**: integer(1) Set an initial seed for the RNG. See `makeRegistry` for more information. Default is NULL where a random seed is chosen upon initialization. Ignored when `reg.pars` is provided.

- **resources**: list() List of job specific resources passed to `submitJobs`. Default is NULL where the resources defined in the configuration are used. Ignored when `submit.pars` is provided.

- **conffile**: character(1) URI to a custom BatchJobs configuration file used for execution. Default is NULL which relies on BatchJobs to handle configuration files. Ignored when `conf.pars` is provided.
BatchJobsParam-class

cluster.functions
ClusterFunctionsSpecify a specific cluster backend using one of the constructors provided by BatchJobs, see ClusterFunctions. Default is NULL where the default cluster functions defined in the configuration are used. Ignored when conf.pars is provided.

progressbar
logical(1) Suppress the progress bar used in BatchJobs and be less verbose. Default is FALSE.

jobname
character(1) Job name that is prepended to the output log and result files. Default is "BPJOB".

reg.pars
list() List of parameters passed to BatchJobs::makeRegistry(). When present, user-supplied arguments seed and work.dir to BatchJobsParam are ignored.

cnf.pars
list() List of parameters passed to BatchJobs::setConfig(). When present, user-supplied arguments conffile, cluster.functions to BatchJobsParam are ignored.

submit.pars
list() List of parameters passed to BatchJobs::submitJobs. When present, user-supplied argument resources to BatchJobsParam is ignored. submitJobs parameters reg, id cannot be set.

... Addition arguments, currently not handled.

BatchJobsParam constructor
Return an object with specified values. The object may be saved to disk or reused within a session.

Methods
The following generics are implemented and perform as documented on the corresponding help page: bpworkers, bpnworkers, bpstart, bpstop, bpisup, bpbackend, bpbackend<-

Author(s)
Michel Lang,mailto:micellang@gmail.com

See Also
getClass("BiocParallelParam") for additional parameter classes.
register for registering parameter classes for use in parallel evaluation.

Examples
p <- BatchJobsParam(progressbar=FALSE)
bplapply(1:10, sqrt, BPPARAM=p)

## Not run:
## see vignette for additional explanation
funs <- makeClusterFunctionsSLURM("~/slurm.tmpl")
param <- BatchJobsParam(4, cluster.functions=funs)
register(param)
bplapply(1:10, function(i) sqrt)

## End(Not run)
Description

The BiocParallelParam virtual class stores configuration parameters for parallel execution. Concrete subclasses include SnowParam, MulticoreParam, BatchJobsParam, and DoparParam and SerialParam.

Details

BiocParallelParam is the virtual base class on which other parameter objects build. There are 5 concrete subclasses:

- SnowParam: distributed memory computing
- MulticoreParam: shared memory computing
- BatchJobsParam: scheduled cluster computing
- DoparParam: foreach computing
- SerialParam: non-parallel execution

The parameter objects hold configuration parameters related to the method of parallel execution such as shared memory, independent memory or computing with a cluster scheduler.

Construction

The BiocParallelParam class is virtual and has no constructor.Instances of the subclasses can be created with the following:

- SnowParam()
- MulticoreParam()
- BatchJobsParam()
- DoparParam()
- SerialParam()

Accessors

Back-end control: In the code below BPPARAM is a BiocParallelParam object.

bpworkers(x), bpworkers(x, ...): integer(1) or character(). Gets the number or names of the back-end workers. The setter is supported for SnowParam and MulticoreParam only.

bpworkers(x): integer(1). Gets the number of the back-end workers.

bptasks(x), bptasks(x) <- value: integer(1). Get or set the number of tasks for a job.

value must be a scalar integer >= 0L. This argument applies to SnowParam and MulticoreParam only; DoparParam and BatchJobsParam have their own approach to dividing a job among workers.

We define a job as a single call to a function such as bplapply, bpmapply etc. A task is the division of the X argument into chunks. When tasks == 0 (default), X is divided by the number of workers. This approach distributes X in (approximately) equal chunks.
BiocParallelParam-class

A tasks value of > 0 dictates the total number of tasks. Values can range from 1 (all of X to
a single worker) to the length of X (each element of X to a different worker).
When the length of X is less than the number of workers each element of X is sent to a worker
and tasks is ignored. Another case where the tasks value is ignored is when using the
briterate function; the number of tasks are defined by the number of data chunks returned
by the ITER function.

bpstart(x): logical(1). Starts the back-end, if necessary.
bpstop(x): logical(1). Stops the back-end, if necessary and possible.
bpisup(x): logical(1). Tests whether the back-end is available for processing, returning a
scalar logical value. bp* functions such as bplapply automatically start the back-end if
necessary.

bpbackend(x), bpbackend(x) <- value: Gets or sets the parallel bpbackend. Not all back-
ends can be retrieved; see showMethods("backend").
bplog(x), bplog(x) <- value: Get or enable logging, if available. value must be a logical(1).
bpthreshold(x), bpthreshold(x) <- value: Get or set the logging threshold. value must
be a character(1) string of one of the levels defined in the futile.logger package:
"TRACE", "DEBUG", "INFO", "WARN", "ERROR", or "FATAL".
bptimeout(x), bptimeout(x) <- value: numeric(1) Time (in seconds) allowed for worker
to complete a task. This value is passed to base::setTimeLimit() as both the cpu and elapsed
arguments. If the computation exceeds timeout an error is thrown with message 'reached
elapsed time limit'.

bpprogressbar(x), bpprogressbar(x) <- value: Get or set the value to enable text progress
bar. value must be a logical(1).
bpjobname(x), bpjobname(x) <- value: Get or set the job name.

Error Handling: In the code below BPPARAM is a BiocParallelParam object.

bpcatchErrors(x), bpcatchErrors(x) <- value: logical(). DEPRECATED Controls if
errors are caught and returned with completed results.
catch.errors determines whether errors are caught and returned with other results. When
TRUE, all computations are attempted and output contains both errors and successfully com-
pleted results. When FALSE, the job is terminated as soon as the first error is hit and only the
error message is returned (no results); this is the default behavior of the parent packages, e.g.,
parallel, snow, foreach.

bpstopOnError(x), bpstopOnError(x) <- value: logical(). Controls if the job stops when
an error is hit.
stop.on.error controls whether the job stops after an error is thrown. When TRUE, the
output contains all successfully completed results up to and including the error. When
stop.on.error == TRUE all computations stop once the error is hit. When FALSE, the
job runs to completion and successful results are returned along with any error messages.

Methods

Evaluation: In the code below BPPARAM is a BiocParallelParam object. Full documentation
for these functions are on separate man pages: see ?bpmapply, ?bplapply, ?bpvec, ?bpiterate
and ?bpaggregate.

bpmapply(FUN, ..., MoreArgs=NULL, SIMPLIFY=TRUE, USE.NAMES=TRUE, USE.NAMES=TRUE,

bplapply(X, FUN, ..., BPPARAM=bpparam())
bpvec(X, FUN, ..., AGGREGATE=c, BPPARAM=bpparam())
bpiterate(ITER, FUN, ..., BPPARAM=bpparam())
bpaggregate(x, data, FUN, ..., BPPARAM=bpparam())
Other: In the code below BPPARAM is a BiocParallelParam object.

Author(s)

Martin Morgan and Valerie Obenchain.

See Also

- SnowParam for computing in distributed memory
- MulticoreParam for computing in shared memory
- BatchJobsParam for computing with cluster schedulers
- DoparParam for computing with foreach
- SerialParam for non-parallel execution

Examples

getClass("BiocParallelParam")

## For examples see ?SnowParam, ?MulticoreParam, ?BatchJobsParam
## and ?SerialParam.

bpaggregate

Apply a function on subsets of data frames

Description

This is a parallel version of aggregate.

Usage

## S4 method for signature 'formula,BiocParallelParam'
bpaggregate(x, data, FUN, ..., 
  BPREDO=list(), BPPARAM=bpparam())

## S4 method for signature 'data.frame,BiocParallelParam'
bpaggregate(x, by, FUN, ..., 
  simplify=TRUE, BPREDO=list(), BPPARAM=bpparam())

## S4 method for signature 'matrix,BiocParallelParam'
bpaggregate(x, by, FUN, ..., 
  simplify=TRUE, BPREDO=list(), BPPARAM=bpparam())

## S4 method for signature 'ANY,missing'
bpaggregate(x, ..., BPREDO=list(), BPPARAM=bpparam())
bpaggregate

Arguments

x A data.frame, matrix or a formula.
by A list of factors by which x is split; applicable when x is data.frame or matrix.
data A data.frame; applicable when x is a formula.
FUN Function to apply.
... Additional arguments for FUN.
simplify If set to TRUE, the return values of FUN will be simplified using simplify2array.
BPPARAM An optional BiocParallelParam instance determining the parallel back-end to be used during evaluation.
BPREDO A list of output from bpaggregate with one or more failed elements. When a list is given in BPREDO, bpok is used to identify errors, tasks are rerun and inserted into the original results.

Details

bpaggregate is a generic with methods for data.frame matrix and formula objects. x is divided into subsets according to factors in by. Data chunks are sent to the workers, FUN is applied and results are returned as a data.frame.

The function is similar in spirit to aggregate from the stats package but aggregate is not explicitly called. The bpaggregate formula method reformulates the call and dispatches to the data.frame method which in turn distributes data chunks to workers with bplapply.

Value

See aggregate.

Author(s)

Martin Morgan mailto:mtmorgan@fhcrc.org

Examples

if (require(Rsamtools) && require(GenomicAlignments)) {

fl <- system.file("extdata", "ex1.bam", package="Rsamtools")
param <- ScanBamParam(what = c("flag", "mapq"))
gal <- readGAlignments(fl, param=param)

## Report the mean map quality by range cutoff:
cutoff <- rep(0, length(gal))
cutoff[start(gal) > 1000 & start(gal) < 1500] <- 1
cutoff[start(gal) > 1500] <- 2
bpaggregate(as.data.frame(mcols(gal)$mapq), list(cutoff = cutoff), mean)
}

**bpiterate**

Parallel iteration over an indeterminate number of data chunks

### Description

bpiterate iterates over an indeterminate number of data chunks (e.g., records in a file). Each chunk is processed by parallel workers in an asynchronous fashion; as each worker finishes it receives a new chunk. Data are traversed a single time.

### Usage

\[
\text{bpiterate}(\text{ITER, FUN, ...}, \text{BPPARAM}=\text{bpparam})
\]

#### S4 method for signature 'ANY,ANY,missing'

\[
\text{bpiterate}(\text{ITER, FUN, ...}, \text{BPPARAM}=\text{bpparam})
\]

#### S4 method for signature 'ANY,ANY,BiocParallelParam'

\[
\text{bpiterate}(\text{ITER, FUN, ...}, \text{BPPARAM}=\text{bpparam})
\]

### Arguments

- **ITER**
  A function with no arguments that returns an object to process, generally a chunk of data from a file. When no objects are left (i.e., end of file) it should return NULL and continue to return NULL regardless of the number of times it is invoked after reaching the end of file. This function is run on the master.

- **FUN**
  A function to process the object returned by ITER; run on parallel workers separate from the master. When BPPARAM is a MulticoreParam, FUN is ‘decorated’ with additional arguments and therefore must have ... in the signature.

- **BPPARAM**
  An optional BiocParallelParam instance determining the parallel back-end to be used during evaluation, or a list of BiocParallelParam instances, to be applied in sequence for nested calls to bpiterate.

- **...**
  Arguments to other methods, specifically named arguments for FUN, or REDUCE or init.

  - **REDUCE**: Optional function that combines (reduces) output from FUN. As each worker returns, the data are combined with the REDUCE function. REDUCE takes 2 arguments; one is the current result and the other is the output of FUN from a worker that just finished.

  - **init**: Optional initial value for REDUCE; must be of the same type as the object returned from FUN. When supplied, reduce.in.order is set to TRUE.

- **reduce.in.order**: Logical. When TRUE, REDUCE is applied to the results from the workers in the same order the tasks were sent out.

### Details

Supported for SnowParam and MulticorParam.

bpiterate iterates through an unknown number of data chunks, dispatching chunks to parallel workers as they become available. In contrast, other bp*apply functions such as bplapply or bpmapplyly require the number of data chunks to be specified ahead of time. This quality makes bpiterate useful for iterating through files of unknown length.
ITER serves up chunks of data until the end of the file is reached at which point it returns NULL. Note that ITER should continue to return NULL regardless of the number of times it is invoked after reaching the end of the file. FUN is applied to each object (data chunk) returned by ITER.

**Value**

By default, a list the same length as the number of chunks in ITER(). When REDUCE is used, the return is consistent with application of the reduction.

**Author(s)**

Valerie Obenchain mailto:vobencha@fhcrc.org.

**See Also**

- `bpvec` for parallel, vectorized calculations.
- `bplapply` for parallel, lapply-like calculations.
- `BiocParallelParam` for details of BPPARAM.

**Examples**

```r
## Not run:
if (require(Rsamtools) && require(RNAseqData.HNRNPC.bam.chr14) &&
    require(GenomicAlignments) && require(ShortRead)) {
    ## ----------------------------------------------------------------------
    ## Iterate through a BAM file
    ## ----------------------------------------------------------------------
    ## Select a single file and set 'yieldSize' in the BamFile object.
    fl <- RNAseqData.HNRNPC.bam.chr14_BAMFILES[[1]]
    bf <- BamFile(fl, yieldSize = 300000)
    ## bamIterator() is initialized with a BAM file and returns a function.
    ## The return function requires no arguments and iterates through the
    ## file returning data chunks the size of yieldSize.
    bamIterator <- function(bf) {
        done <- FALSE
        if (!isOpen(bf))
            open(bf)
        function() {
            if (done)
                return(NULL)
            yld <- readGAlignments(bf)
            if (length(yld) == 0L) {
                close(bf)
                done <<- TRUE
                NULL
            } else yld
        }
    }
    ## FUN counts reads in a region of interest.
    roi <- GRanges("chr14", IRanges(seq(19e6, 107e6, by = 10e6), by = 10e6), width = 10e6))
    counter <- function(reads, roi, ...) {
        # ...
    }
    ## ...
```
countOverlaps(query = roi, subject = reads)
)

## Initialize the iterator.
ITER <- bamIterator(bf)

## The number of chunks returned by ITER() determines the result length.
bpparam <- MulticoreParam(workers = 3)
bpiterate(ITER, counter, roi = roi, BPPARAM = bpparam)

## Re-initialize the iterator and combine on the fly with REDUCE:
ITER <- bamIterator(bf)
bpparam <- MulticoreParam(workers = 3)
bpiterate(ITER, counter, REDUCE = sum, roi = roi, BPPARAM = bpparam)

## Iterate through a FASTA file

### Set data chunk size with 'n' in the FastqStreamer object.
sp <- SolexaPath(system.file("extdata", package = "ShortRead"))
fl <- file.path(analysisPath(sp), "s_1_sequence.txt")

### Create an iterator that returns data chunks the size of 'n'.
fastqIterator <- function(fqs) {
  done <- FALSE
  if (!isOpen(fqs))
    open(fqs)
  function() {
    if (done)
      return(NULL)
    yld <- yield(fqs)
    if (length(yld) == 0L) {
      close(fqs)
      done <<- TRUE
      NULL
    } else yld
  }
}

### The process function summarizes the number of times each sequence occurs.
summary <- function(reads, ...) {
  ShortRead::tables(reads, n = 0)$distribution
}

## Create a param.
bpparam <- SnowParam(workers = 2)

## Initialize the streamer and iterator.
fqs <- FastqStreamer(fl, n = 100)
ITER <- fastqIterator(fqs)
bpiterate(ITER, summary, BPPARAM = bpparam)

## Results from the workers are combined on the fly when REDUCE is used.
## Collapsing the data in this way can substantially reduce memory
## requirements.
fqs <- FastqStreamer(fl, n = 100)
ITER <- fastqIterator(fqs)
bpiterate(ITER, summary, REDUCE = merge, all = TRUE, BPPARAM = bpparam)
}

## End(Not run)

### bplapply

**Parallel lapply-like functionality**

**Description**

`bplapply` applies `FUN` to each element of `X`. Any type of object `X` is allowed, provided `length`, `[]`, and `[[` methods are available. The return value is a list of length equal to `X`, as with `lapply`.

**Usage**

```r
bplapply(X, FUN, ..., BPREDO = list(), BPPARAM=bpparam())
```

**Arguments**

- **X**
  - Any object for which methods `length`, `[]`, and `[[` are implemented.
- **FUN**
  - The function to be applied to each element of `X`.
- **...**
  - Additional arguments for `FUN`, as in `lapply`.
- **BPPARAM**
  - An optional `BiocParallelParam` instance determining the parallel back-end to be used during evaluation, or a list of `BiocParallelParam` instances, to be applied in sequence for nested calls to `BiocParallel` functions.
- **BPREDO**
  - A list of output from `bplapply` with one or more failed elements. When a list is given in `BPREDO`, `bpok` is used to identify errors, tasks are rerun and inserted into the original results.

**Details**

See `showMethods(bplapply)` for additional methods, e.g., `method?bplapply("MulticoreParam")`.

**Value**

See `lapply`.

**Author(s)**

Martin Morgan `mailto:mtmorgan@fhcrc.org`. Original code as attributed in `mclapply`.

**See Also**

- `bpvec` for parallel, vectorized calculations.
- `BiocParallelParam` for possible values of `BPPARAM`. 
Examples

```r
showMethods("bplapply")
```

```r
## ten tasks (1:10) so ten calls to FUN default registered parallel
## back-end. Compare with bpvec.
fun <- function(v) {
  message("working")  ## 10 tasks
  sqrt(v)
}
```

```r
bplapply(1:10, fun)
```

---

**bploop**

*Internal Functions for SNOW-style Parallel Evaluation*

**Description**

The functions documented on this page are primarily for use within `BiocParallel` to enable SNOW-style parallel evaluation, using communication between manager and worker nodes through sockets.

**Usage**

```r
## S3 method for class 'SOCKnode'
bploop(manager, ...)  
## S3 method for class 'SOCK0node'
bploop(manager, ...)  
## S3 method for class 'MPInode'
bploop(manager, ...)  
## S3 method for class 'lapply'
bploop(manager, X, FUN, ARGFUN, BPPARAM, ...)  
## S3 method for class 'iterate'
bploop(manager, ITER, FUN, ARGFUN, BPPARAM, REDUCE, init, reduce.in.order, ...)
```

**Arguments**

- `manager`: An object representing the manager node. For workers, this is the node to which the worker will communicate. For managers, this is the form of iteration – `lapply` or `iterate`.
- `X`: A vector of jobs to be performed.
- `FUN`: A function to apply to each job.
- `ARGFUN`: A function accepting an integer value indicating the job number, and returning the job-specific arguments to `FUN`.
- `BPPARAM`: An instance of a `BiocParallelParam` class.
- `ITER`: A function used to generate jobs. No more jobs are available when `ITER()` returns `NULL`.
- `REDUCE`: (Optional) A function combining two values returned by `FUN` into a single value.
**bpmapply**

init  (Optional) Initial value for reduction.
reduce.in.order  (Optional) logical(1) indicating that reduction must occur in the order jobs are dispatched (TRUE) or that reduction can occur in the order jobs are completed (FALSE).

...  Additional arguments, ignored in all cases.

**Details**

Workers enter a loop. They wait to receive a message (R list) from the manager. The message contains a type element, with evaluation as follows:

“EXEC”  Execute the R code in the message, returning the result to the manager.

“DONE”  Signal termination to the manager, terminate the worker.

Managers under lapply dispatch pre-determined jobs, X, to workers, collecting the results from and dispatching new jobs to the first available worker. The manager returns a list of results, in a one-to-one correspondence with the order of jobs supplied, when all jobs have been evaluated.

Managers under iterate dispatch an undetermined number of jobs to workers, collecting previous jobs from and dispatching new jobs to the first available worker. Dispatch continues until available jobs are exhausted. The return value is by default a list of results in a one-to-one correspondence with the order of jobs supplied. The return value is influenced by REDUCE, init, and reduce.in.order.

**Author(s)**

Valerie Obenchain, Martin Morgan. Derived from similar functionality in the snow and parallel packages.

**Examples**

```r
## These functions are not meant to be called by the end user.
```

---

**Description**

bpmapply applies FUN to first elements of ..., the second elements and so on. Any type of object in ... is allowed, provided length, [, and [[ methods are available. The return value is a list of length equal to the length of all objects provided, as with mapply.

**Usage**

```r
bpmapply(FUN, ..., MoreArgs=NULL, SIMPLIFY=TRUE, USE.NAMES=TRUE,
BPREDO=list(), BPPARAM=bpparam())
```

```r
# S4 method for signature 'ANY,missing'

bpmapply(FUN, ..., MoreArgs=NULL, SIMPLIFY=TRUE,
USE.NAMES=TRUE, BPREDO=list(), BPPARAM=bpparam())
```
bpmapply

## S4 method for signature 'ANY,BiocParallelParam'

```r
bpmapply(FUN, ..., MoreArgs=NULL,
         SIMPLIFY=TRUE, USE.NAMES=TRUE, BPREDO=list(), BPPARAM=bpparam())
```

### Arguments

- **FUN**
  - The function to be applied to each element passed via `...`.
- **...**
  - Objects for which methods `length`, `[]`, and `[[]` are implemented. All objects must have the same length or shorter objects will be replicated to have length equal to the longest.
- **MoreArgs**
  - List of additional arguments to `FUN`.
- **SIMPLIFY**
  - If `TRUE` the result will be simplified using `simplify2array`.
- **USE.NAMES**
  - If `TRUE` the result will be named.
- **BPPARAM**
  - An optional `BiocParallelParam` instance defining the parallel back-end to be used during evaluation.
- **BPREDO**
  - A list of output from `bpmapply` with one or more failed elements. When a list is given in `BPREDO`, `bpok` is used to identify errors, tasks are rerun and inserted into the original results.

### Details

See `showMethods(bpmapply)` for additional methods, e.g., `method?bpmapply("MulticoreParam")`.

### Value

See `mapply`.

### Author(s)

Michel Lang. Original code as attributed in `mclapply`.

### See Also

- `bpvec` for parallel, vectorized calculations.
- `BiocParallelParam` for possible values of `BPPARAM`.

### Examples

```r
showMethods("bpmapply")

fun <- function(greet, who) {
  paste(Sys.getpid(), greet, who)
}
greet <- c("morning", "night")
who <- c("sun", "moon")

param <- bpparam()
original <- bpworkers(param)
bpworkers(param) <- 2
result <- bpmapply(fun, greet, who, BPPARAM = param)
cat(paste(result, collapse="\n"), "\n")
bpworkers(param) <- original
```
bpok  

Resume computation with partial results

Description

Identifies unsuccessful results returned from bplapply, bpmapply, bpvec, bpaggregate or bpvectorize. bpresume and bplaterror have been deprecated.

Usage

bpok(x)

## Deprecated:  
bpresume(expr)  
bplaterror()

Arguments

x  Results returned from a call to bp*lapply.

expr  A expression to be re-evaluated. If the original error was due to input error,  
X should be modified. If hardware limitations or failure caused the error this  
expression may be the same as the original.

Details

• bpok Returns a logical() vector: FALSE for any jobs that resulted in an error. x is the result  
list output by bplapply, bpmapply, bpvec, bpaggregate or bpvectorize.

• bpresume THIS FUNCTION IS DEPRECATED. The resume mechanism allows computa-

tions with errors to be re-attempted and is triggered when the argument catch.errors is  
TRUE.

Unsuccessful results returned from bp*lapply can be identified with bpok. Failure may have  
been due to faulty input or hardware error. Incomplete portions of the job can be reattempted  
with bpresume. New results are merged with the previous and returned to the user.

• bplaterror THIS FUNCTION IS DEPRECATED. Use attr on the output of bp*apply to see  
traceback. See examples.

Author(s)

Michel Lang, Martin Morgan and Valerie Obenchain

Examples

## Catch errors:
## By default 'stop.on.error' is TRUE in BiocParallelParam objects.
SnowParam(workers = 2)
# Schedule back-end Params

## Description

Use functions on this page to influence scheduling of parallel processing.

## Usage

```r
bpschedule(x)
```
Arguments

- **x**: An instance of a `BiocParallelParam` class, e.g., `MulticoreParam`, `SnowParam`, `DoparParam`. `x` can be missing, in which case the default back-end (see `register`) is used.

Details

`bpschedule` returns a logical(1) indicating whether the parallel evaluation should occur at this point.

Value

`bpschedule` returns a scalar logical.

Author(s)

Martin Morgan `mailto:mtmorgan@fhcrc.org`.

See Also

`BiocParallelParam` for possible values of `x`.

Examples

```r
bpschedule(SnowParam())  # TRUE
bpschedule(MulticoreParam(2))  # FALSE on windows

p <- MulticoreParam()
bpschedule(p)
blapply(1:2, function(i, p) {
  bpschedule(p)    # TRUE
}, p = p, BPPARAM=p)
```

bptry

Try expression evaluation, recovering from `berror` signals

Description

This function is meant to be used as a wrapper around `blapply()` and friends, returning the evaluated expression rather than signalling an error.

Usage

`bptry(expr, ..., bplist_error, berror)`
Arguments

expr An R expression; see tryCatch.

bplist_error A 'handler' function of a single argument, used to catch bplist_error conditions signalled by expr. A bplist_error condition is signalled when an element of bplapply and other iterations contain a evaluation that failed. When missing, the default retrieves the ‘result’ attribute from the error, containing the partially evaluated results.
Setting bplist_error=identity returns the evaluated condition.
Setting bplist_error=stop passes the condition to other handlers, notably the handler provided by b perror.

bperror A 'handler' function of a single argument, use to catch bperror conditions signalled by expr. A bperror is a base class to all errors signaled by BiocParallel code. When missing, the default returns the condition without signalling an error.

Additional named handlers passed to tryCatch(). These user-provided handlers are evaluated before default handlers bplist_error, bperror.

Value

The partially evaluated list of results.

Author(s)

Martin Morgan <martin.morgan@roswellpark.org>

See Also

tryCatch, bplapply.

Examples

param = registered()[[1]]
param
X = list(1, "2", 3)
bptry(bplapply(X, sqrt)) # bplist_error handler
bptry(bplapply(X, sqrt), bplist_error=identity) # bperror handler

bpvalidate Tools for developing functions for parallel execution in distributed memory

Description

bpvalidate interrogates the function environment and search path to locate undefined symbols.

Usage

bpvalidate(fun)
Arguments

fun    The function to be checked.

Details

bpvalidate tests if a function can be run in a distributed memory environment (e.g., SOCK clusters, Windows machines). bpvalidate looks in the environment of fun, in the NAMESPACE exports of libraries loaded in fun, and along the search path to identify any symbols outside the scope of fun. bpvalidate can be used to check functions passed to the bp* family of functions in BiocParallel or other packages that support parallel evaluation on clusters such as snow, BatchJobs, Rmpi, etc.

testing package functions  The environment of a function defined inside a package is the NAMESPACE of the package. It is important to test these functions as they will be called from within the package, with the appropriate environment. Specifically, do not copy/paste the function into the workspace; once this is done the GlobalEnv becomes the function environment.

To test a package function, load the package then call the function by name (myfun) or explicitly (mypkg:::myfun) if not exported.

testing workspace functions  The environment of a function defined in the workspace is the GlobalEnv. Because these functions do not have an associated package NAMESPACE, the functions and variables used in the body must be explicitly passed or defined. See examples.

Defining functions in the workspace is often done during development or testing. If the function is later moved inside a package, it can be rewritten in a more lightweight form by taking advantage of imported symbols in the package NAMESPACE.

NOTE: bpvalidate does not currently work on Generics.

Value

A list of length 2 with named elements ‘inPath’ and ‘unknown’.

• inPath A named list of symbols and where they were found. These symbols were found on the search path instead of the function environment and should probably be imported in the NAMESPACE or otherwise defined in the package.

• unknown A vector of symbols not found in the function environment or the search path.

Author(s)

Martin Morgan mailto:mtmorgan@fhcrc.org and Valerie Obenchain mailto:vobencha@fhcrc.org.

Examples

```r
## Not run:
library(myPkg)

## Test exported functions by name or the double colon:
bpvalidate(myExportedFun)
bpvalidate(myPkg:::myExportedFun)
```
## Non-exported functions are called with the triple colon:
bpvalidate(myPkg:::myInternalFun)

## End(Not run)

---

## Testing workspace functions
---

## Functions defined in the workspace have the .GlobalEnv as their
## environment. Often the symbols used inside the function body
## are not defined in .GlobalEnv and must be passed explicitly.

## Loading libraries:
## In 'fun1' countBam() is flagged as unknown:
fun1 <- function(fl, ...)  
  countBam(fl)  
bpvalidate(fun1)

## countBam() is not defined in .GlobalEnv and must be passed as
## an argument or made available by loading the library.
fun2 <- function(fl, ...) {  
  library(Rsamtools)  
  countBam(fl)  
}
bpvalidate(fun2)

## Passing arguments:
## 'param' is defined in the workspace but not passed to 'fun3'.
## bpvalidate() flags 'param' as being found 'inPath' which means
## it is not defined in the function environment or inside the function.
library(Rsamtools)
param <- ScanBamParam(flag=scanBamFlag(isMinusStrand=FALSE))

fun3 <- function(fl, ...) {  
  library(Rsamtools)  
  countBam(fl, param=param)  
}
bpvalidate(fun3)

## 'param' is explicitly passed by adding it as a formal argument.
fun4 <- function(fl, ..., param) {  
  library(Rsamtools)  
  countBam(fl, param=param)  
}
bpvalidate(fun4)

## The corresponding call to a bp* function includes 'param':
## Not run: bplapply(files, fun4, param=param, BPPARAM=SnowParam(2))

---

bpvec  
Parallel, vectorized evaluation
**Description**

`bpvec` applies `FUN` to subsets of `X`. Any type of object `X` is allowed, provided `length` and `[` are defined on `X`. `FUN` is a function such that `length(FUN(X)) == length(X)`. The objects returned by `FUN` are concatenated by `AGGREGATE` (`c()` by default). The return value is `FUN(X)`.

**Usage**

```r
bpvec(X, FUN, ..., AGGREGATE=c, BPREDO=list(), BPPARAM=bpparam())
```

**Arguments**

- **X**
  Any object for which methods `length` and `[` are implemented.

- **FUN**
  A function to be applied to subsets of `X`. The relationship between `X` and `FUN(X)` is 1:1, so that `length(FUN(X, ...)) == length(X)`. The return value of separate calls to `FUN` are concatenated with `AGGREGATE`.

- **...**
  Additional arguments for `FUN`.

- **AGGREGATE**
  A function taking any number of arguments `...` called to reduce results (elements of the `...` argument of `AGGREGATE` from parallel jobs. The default, `c`, concatenates objects and is appropriate for vectors; `rbind` might be appropriate for data frames.

- **BPPARAM**
  An optional `BiocParallelParam` instance determining the parallel back-end to be used during evaluation, or a list of `BiocParallelParam` instances, to be applied in sequence for nested calls to `BiocParallel` functions.

- **BPREDO**
  A list of output from `bpvec` with one or more failed elements. When a list is given in `BPREDO`, `bpok` is used to identify errors, tasks are rerun and inserted into the original results.

**Details**

This method creates a vector of indices for `X` that divide the elements as evenly as possible given the number of `bpworkers()` and `bptasks()` of `BPPARAM`. Indices and data are passed to `bplapply` for parallel evaluation.

The distinction between `bpvec` and `bplapply` is that `bplapply` applies `FUN` to each element of `X` separately whereas `bpvec` assumes the function is vectorized, e.g., `c(FUN(x[1]), FUN(x[2]))` is equivalent to `FUN(x[1:2])`. This approach can be more efficient than `bplapply` but requires the assumption that `FUN` takes a vector input and creates a vector output of the same length as the input which does not depend on partitioning of the vector. This behavior is consistent with `parallel:::pvec` and the `?pvec` man page should be consulted for further details.

**Value**

The result should be identical to `FUN(X, ...)` (assuming that `AGGREGATE` is set appropriately).

When evaluation of individual elements of `X` results in an error, the result is a list with the same geometry (i.e., `lengths(.)`) as the split applied to `X` to create chunks for parallel evaluation; one or more elements of the list contain a `bperror` element, indicating that the vectorized calculation failed for at least one of the index values in that chunk.

An error is also signaled when `FUN(X)` does not return an object of the same length as `X`; this condition is only detected when the number of elements in `X` is greater than the number of workers.
### Description

This transforms a vectorized function into a parallel, vectorized function. Any function `FUN` can be used, provided its parallelized argument (by default, the first argument) has a length and `[` method defined, and the return value of `FUN` can be concatenated with `c`.

### Usage

```r
bpvectorize(FUN, ..., BPREDO=list(), BPPARAM=bpparam())
```

#### S4 method for signature 'ANY,ANY'

```r
bpvectorize(FUN, ..., BPREDO=list(), BPPARAM=bpparam())
```

#### S4 method for signature 'ANY,missing'

```r
bpvectorize(FUN, ..., BPREDO=list(), BPPARAM=bpparam())
```

### Arguments

- **FUN**: A function whose first argument has a length and can be subset `[`, and whose evaluation would benefit by splitting the argument into subsets, each one of which is independently transformed by `FUN`. The return value of `FUN` must support concatenation with `c`. 

---

**Author(s)**

Martin Morgan [mailto:mtmorgan@fhcrc.org](mailto:mtmorgan@fhcrc.org)

**See Also**

- `bplapply` for parallel `lapply`.
- `BiocParallelParam` for possible values of `BPPARAM`.
- `pvec` for background.

**Examples**

```r
showMethods("bpvec")
```

```r
## ten tasks (1:10), called with as many back-end elements are specified
## by BPPARAM. Compare with bplapply
fun <- function(v) {
  message("working")
  sqrt(v)
}
system.time(result <- bpvec(1:10, fun))
result
```

```r
## invalid FUN -- length(class(X)) is not equal to length(X)
bptry(bpvec(1:2, class, BPPARAM=SerialParam()))
```
... Additional arguments to parallization, unused.

BPPARAM An optional BiocParallelParam instance determining the parallel back-end to be used during evaluation.

BPRED0 A list of output from bpvectorize with one or more failed elements. When a list is given in BPRED0, bpok is used to identify errors, tasks are rerun and inserted into the original results.

Details

The result of bpvectorize is a function with signature ...; arguments to the returned function are the original arguments FUN. BPPARAM is used for parallel evaluation. When BPPARAM is a class for which no method is defined (e.g., SerialParam), FUN(X) is used. See showMethods{bpvectorize} for additional methods, if any.

Value

A function taking the same arguments as FUN, but evaluated using bpvec for parallel evaluation across available cores.

Author(s)

Ryan Thompson mailto:rct@thompsonclan.org

See Also

bpvec

Examples

psqrt <- bpvectorize(sqrt) ## default parallelization
psqrt(1:10)

---

DoparParam-class Enable parallel evaluation using registered dopar backend

Description

This class is used to dispatch parallel operations to the dopar backend registered with the foreach package.

Usage

DoparParam(catch.errors = TRUE, stop.on.error=TRUE)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>catch.errors</td>
<td>DEPRECATED 1 logical(1) Flag to determine in apply-like functions (see e.g. bp1apply) whether to quit with an error as soon as one application fails or encapsulation of function calls in try blocks which triggers a resume mechanism (see bpresume). Defaults to TRUE.</td>
</tr>
<tr>
<td>stop.on.error</td>
<td>logical(1) Stop all jobs as soon as one jobs fails (stop.on.error == TRUE) or wait for all jobs to terminate. Default is TRUE.</td>
</tr>
</tbody>
</table>
**Details**

DoparParam can be used for shared or non-shared memory computing depending on what backend is loaded. The doSNOW package supports non-shared memory, doParallel supports both shared and non-shared. When not specified, the default number of workers in DoparParam is determined by getDoParWorkers(). See the foreach package vignette for details using the different backends:

http://cran.r-project.org/web/packages/foreach/vignettes/foreach.pdf

**DoparParam constructor**

Return a proxy object that dispatches parallel evaluation to the registered foreach parallel backend.

There are no options to the constructor. All configuration should be done through the normal interface to the foreach parallel backends.

**Methods**

The following generics are implemented and perform as documented on the corresponding help page (e.g., ?bpisup): bpworkers, bpnworkers, bpstart, bpstop, bpisup, bpbackend, bpbackend<-, bpvec.

**Author(s)**

Martin Morgan mailto:mtmorgan@fhcrc.org

**See Also**

getClass("BiocParallelParam") for additional parameter classes.

register for registering parameter classes for use in parallel evaluation.

foreach-package for the parallel backend infrastructure used by this param class.

**Examples**

```r
## Not run:
# First register a parallel backend with foreach
library(doParallel)
registerDoParallel(2)

p <- DoparParam()
bplapply(1:10, sqrt, BPPARAM=p)
bpvec(1:10, sqrt, BPARAM=p)

register(DoparParam(), default=TRUE)

## End(Not run)
```
MulticoreParam-class

Enable multi-core parallel evaluation

Description

This class is used to parameterize single computer multicore parallel evaluation on non-Windows computers. multicoreWorkers() chooses the number of workers based on operating system (Windows only supports 1 core), global user preference (options(mc.cores=...) or the minimum of 8 and the number of detected cores (detectCores()).

Usage

## constructor
## ------------------------------------
MulticoreParam(workers = multicoreWorkers(), tasks = 0L,
catch.errors = TRUE, stop.on.error = TRUE,
progressbar = FALSE, RNGseed = NULL,
timeout = 30L * 24L * 60L * 60L,
log = FALSE, threshold = "INFO", logdir = NA_character_,
resultdir = NA_character_, jobname = "BPJOB", ...)

## detect workers
## ------------------------------------
multicoreWorkers()

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>workers</td>
<td>integer(1) Number of workers. Defaults to all cores available as determined by detectCores.</td>
</tr>
<tr>
<td>tasks</td>
<td>integer(1). The number of tasks per job. value must be a scalar integer &gt;= 0L. In this documentation a job is defined as a single call to a function, such as bplapply, bpmapply etc. A task is the division of the X argument into chunks. When tasks == 0 (default), X is divided as evenly as possible over the number of workers. A tasks value of &gt; 0 specifies the exact number of tasks. Values can range from 1 (all of X to a single worker) to the length of X (each element of X to a different worker). When the length of X is less than the number of workers each element of X is sent to a worker and tasks is ignored.</td>
</tr>
<tr>
<td>catch.errors</td>
<td>DEPRECATED. logical(1) Enable the catching of errors and warnings.</td>
</tr>
<tr>
<td>stop.on.error</td>
<td>logical(1) Enable stop on error.</td>
</tr>
<tr>
<td>progressbar</td>
<td>logical(1) Enable progress bar (based on plyr:::progress_text).</td>
</tr>
<tr>
<td>RNGseed</td>
<td>integer(1) Seed for random number generation. When not NULL, this value is passed to parallel:::clusterSetRNGStream to generate random number streams on each worker.</td>
</tr>
</tbody>
</table>
timeout    numeric(1) Time (in seconds) allowed for worker to complete a task. This value is passed to base::setTimeLimit() as both the cpu and elapsed arguments. If the computation exceeds timeout an error is thrown with message ‘reached elapsed time limit’.

log        logical(1) Enable logging.
threshold   character(1) Logging threshold as defined in futile.logger.
logdir      character(1) Log files directory. When not provided, log messages are returned to stdout.
resultdir   character(1) Job results directory. When not provided, results are returned as an R object (list) to the workspace.
jobname     character(1) Job name that is prepended to log and result files. Default is "BPJOB".
...          Additional arguments passed to makeCluster

Details

MulticoreParam is used for shared memory computing. Under the hood the cluster is created with makeCluster(..., type = "FORK") from the parallel package. If not specified, the default number of workers is determined by multicoreWorkers(), which is parallel::detectCores() - 2. Machines with 3 or less cores are assigned a single worker.

A FORK transport starts workers with the mcfork function and communicates between master and workers using socket connections. mcfork builds on fork() and thus a Linux cluster is not supported. Because FORK clusters are Posix based they are not supported on Windows. When MulticoreParam is created/used in Windows it defaults to SerialParam which is the equivalent of using a single worker.

error handling: The catch.errors field has been deprecated.

By default all computations are attempted and partial results are returned with any error messages.

- catch.errors (DEPRECATED) determines whether errors are caught and returned with other results. When TRUE, all computations are attempted and output contains both errors and successfully completed results. When FALSE, the job is terminated as soon as the first error is hit and only the error message is returned (no results); this is the default behavior of the parent packages, e.g., parallel, snow, foreach.
- stop.on.error A logical. Stops all jobs as soon as one job fails or wait for all jobs to terminate. When FALSE, the return value is a list of successful results along with error messages as ‘conditions’.
- The bpok(x) function returns a logical() vector that is FALSE for any jobs that threw an error. The input x is a list output from a bp*apply function such as bplapply or bpmapply.

logging: When log = TRUE the futile.logger package is loaded on the workers. All log messages written in the futile.logger format are captured by the logging mechanism and returned real-time (i.e., as each task completes) instead of after all jobs have finished. Messages sent to stdout and stderr are returned to the workspace by default. When log = TRUE these are diverted to the log output. Those familiar with the outfile argument to makeCluster can think of log = FALSE as equivalent to outfile = NULL; providing a logdir is the same as providing a name for outfile except that BiocParallel writes a log file for each task.

The log output includes additional statistics such as memory use and task runtime. Memory use is computed by calling gc(reset=TRUE) before code evaluation and gc() (no reset) after.
The output of the second gc() call is sent to the log file. There are many ways to track memory use - this particular approach was taken because it is consistent with how the BatchJobs package reports memory on the workers.

**log and result files:** Results and logs can be written to a file instead of returned to the workspace. Writing to files is done from the master as each task completes. Options can be set with the logdir and resultdir fields in the constructor or with the accessors, bplogdir and bpresultdir.

**random number generation:** MulticoreParam and SnowParam use the random number generation support from the parallel package. These params are snow-derived clusters so the arguments for multicore-derived functions such as mc.set.seed and mc.reset.stream do not apply.

Random number generation is controlled through the param argument, RNGseed which is passed to parallel::clusterSetRNGStream. clusterSetRNGStream uses the L’Ecuyer-CMRG random number generator and distributes streams to the members of a cluster. If RNGseed is not NULL it serves as the seed to the streams, otherwise the streams are set from the current seed of the master process after selecting the L’Ecuyer generator. See ?clusterSetRNGStream for more details.

**Constructor**

MulticoreParam(workers = multicoreWorkers(), tasks = 0L, catch.errors = TRUE, stop.on.error = FALSE, tasks = 0L, ... = Inf, log = FALSE, threshold = "INFO", logdir = NA_character_, resultdir = NA_character_, jobname = "BPJOB", ...):

Return an object representing a FORK cluster. The cluster is not created until bpstart is called. Named arguments in ... are passed to makeCluster.

**Accessors: Logging and results**

In the following code, x is a MulticoreParam object.

bpprogress(x), bpprogress(x) <- value: Get or set the value to enable text progress bar. value must be a logical(1).

bpjobname(x), bpjobname(x) <- value: Get or set the job name.

bpRNGseed(x), bpRNGseed(x) <- value: Get or set the seed for random number generation. value must be a numeric(1).

bplog(x), bplog(x) <- value: Get or set the value to enable logging. value must be a logical(1).

bpthreshold(x), bpthreshold(x) <- value: Get or set the logging threshold. value must be a character(1) string of one of the levels defined in the futile.logger package: "TRACE", "DEBUG", "INFO", "WARN", "ERROR", or "FATAL".

bplogdir(x), bplogdir(x) <- value: Get or set the directory for the log file. value must be a character(1) path, not a file name. The file is written out as LOGFILE.out. If no logdir is provided and bplog=TRUE log messages are sent to stdout.

bpresultdir(x), bpresultdir(x) <- value: Get or set the directory for the result files. value must be a character(1) path, not a file name. Separate files are written for each job with the prefix JOB (e.g., JOB1, JOB2, etc.). When no resultdir is provided the results are returned to the session as list.

**Accessors: Back-end control**

In the code below x is a MulticoreParam object. See the ?BiocParallelParam man page for details on these accessors.


MulticoreParam-class

bpworkers(x)
bpnworkers(x)
bptasks(x), bptasks(x) <- value
bpstart(x)
bpstop(x)
bpisup(x)
bpbackend(x), bpbackend(x) <- value

Accessors: Error Handling

In the code below x is a MulticoreParam object. See the ?BiocParallelParam man page for details on these accessors.

bpcatchErrors(x), bpcatchErrors(x) <- value
bpstopOnError(x), bpstopOnError(x) <- value

Methods: Evaluation

In the code below BPPARAM is a MulticoreParam object. Full documentation for these functions are on separate man pages: see ?bpmapply, ?bplapply, ?bpvec, ?bpiterate and ?bpaggregate.

bpmapply(FUN, ..., MoreArgs=NULL, SIMPLIFY=TRUE, USE.NAMES=TRUE, BPPARAM=bpparam())
bplapply(X, FUN, ..., BPPARAM=bpparam())
bpvec(X, FUN, ..., AGGREGATE=c, BPPARAM=bpparam())
bpiterate(ITER, FUN, ..., BPPARAM=bpparam())
bpaggregate(x, data, FUN, ..., BPPARAM=bpparam())

Methods: Other

In the code below x is a MulticoreParam object.

show(x): Displays the MulticoreParam object.

Author(s)

Martin Morgan mailto:mtmorgan@fhcrc.org and Valerie Obenchain

See Also

• register for registering parameter classes for use in parallel evaluation.
• SnowParam for computing in distributed memory
• BatchJobsParam for computing with cluster schedulers
• DoparParam for computing with foreach
• SerialParam for non-parallel evaluation
Examples

```r
## Job configuration:
##
## MulticoreParam supports shared memory computing. The object fields
## control the division of tasks, error handling, logging and
## result format.
 bpparam <- MulticoreParam()

## By default the param is created with the maximum available workers
## determined by multicoreWorkers().

multicoreWorkers()

## Fields are modified with accessors of the same name:
 bplog(bpparam) <- TRUE
 bpresultdir(bpparam) <- "/myResults/"

## Logging:
##
## When 'log == TRUE' the workers use a custom script (in BiocParallel)
## that enables logging and access to other job statistics. Log messages
## are returned as each job completes rather than waiting for all to finish.

## In 'fun', a value of 'x = 1' will throw a warning, 'x = 2' is ok
## and 'x = 3' throws an error. Because 'x = 1' sleeps, the warning
## should return after the error.

X <- 1:3
fun <- function(x) {
  if (x == 1) {
    Sys.sleep(2)
    if (TRUE & c(TRUE, TRUE)) ## warning
      x
  } else if (x == 2) {
    x ## ok
  } else if (x == 3) {
    sqrt("FOO") ## error
  }
}

## By default logging is off. Turn it on with the bplog()<- setter
## or by specifying 'log = TRUE' in the constructor.
 bpparam <- MulticoreParam(3, log = TRUE, stop.on.error = FALSE)

res <- tryCatch({
  blapply(X, fun, BPPARAM=bpparam)
}, error=identity)

## When a 'logdir' location is given the messages are redirected to a file:
## Not run:

bplogdir(bpparam) <- tempdir()
```
register

```r
bplapply(X, fun, BPPARAM = bpparam)
list.files(bplogdir(bpparam))

## End(Not run)

## ---------------
## Managing results:
## ---------------

## By default results are returned as a list. When 'resultdir' is given
## files are saved in the directory specified by job, e.g., 'TASK1.Rda',
## 'TASK2.Rda', etc.

## Not run:
bpparam <- MulticoreParam(2, resultdir = tempdir(), stop.on.error = FALSE)
bplapply(X, fun, BPPARAM = bpparam)
list.files(bpresultdir(bpparam))

## End(Not run)

## ---------------
## Error handling:
## ---------------

## When 'stop.on.error' is TRUE the job is terminated as soon as an
## error is hit. When FALSE, all computations are attempted and partial
## results are returned along with errors. In this example the number of
## 'tasks' is set to equal the length of 'X' so each element is run
## separately. (Default behavior is to divide 'X' evenly over workers.)

## All results along with error:
bpparam <- MulticoreParam(2, tasks = 4, stop.on.error = FALSE)
res <- bptry(bplapply(list(1, "two", 3, 4), sqrt, BPPARAM = bpparam))
res

## Calling bpok() on the result list returns TRUE for elements with no error.
bpok(res)

## ---------------
## Random number generation:
## ---------------

## Random number generation is controlled with the 'RNGseed' field.
## This seed is passed to parallel::clusterSetRNGStream
## which uses the L'Ecuyer-CMRG random number generator and distributes
## streams to members of the cluster.

bpparam <- MulticoreParam(3, RNGseed = 7739465)
bplapply(seq_len(bpnworkers(bpparam)), function(i) rnorm(1), BPPARAM = bpparam)
```

---

register

Maintain a global registry of available back-end Params
register

Description
Use functions on this page to add to or query a registry of back-ends, including the default for use when no BPPARAM object is provided to functions.

Usage
register(BPPARAM, default=TRUE)
registered(bpparamClass)
bpparam(bpparamClass)

Arguments
- **BPPARAM**: An instance of a BiocParallelParam class, e.g., MulticoreParam, SnowParam, DoparParam.
- **default**: Make this the default BiocParallelParam for subsequent evaluations? If FALSE, the argument is placed at the lowest priority position.
- **bpparamClass**: When present, the text name of the BiocParallelParam class (e.g., “MulticoreParam”) to be retrieved from the registry. When absent, a list of all registered instances is returned.

Details
The registry is a list of back-ends with configuration parameters for parallel evaluation. The first list entry is the default and is used by BiocParallel functions when no BPPARAM argument is supplied.

At load time the registry is populated with default backends. On Windows these are SnowParam and SerialParam and on non-Windows MulticoreParam, SnowParam and SerialParam. When snowWorkers() or multicoreWorkers() returns a single core, only SerialParm is registered.

The BiocParallelParam objects are constructed from global options of the corresponding name, or from the default constructor (e.g., SnowParam()) if no option is specified. The user can set customizations during start-up (e.g., in an .Rprofile file) with, for instance, options(MulticoreParam=quote(MulticoreParam(workers=8))).

The act of “registering” a back-end modifies the existing BiocParallelParam in the list; only one param of each type can be present in the registry. When default=TRUE, the newly registered param is moved to the top of the list thereby making it the default. When default=FALSE, the param is modified ‘in place’ vs being moved to the top.

bpparam(), invoked with no arguments, returns the default BiocParallelParam instance from the registry. When called with the text name of a bpparamClass, the global options are consulted first, e.g., options(MulticoreParam=MulticoreParam()) and then the value of registered(bpparamClass).

Value
register returns, invisibly, a list of registered back-ends.

registered returns the back-end of type bpparamClass or, if bpparamClass is missing, a list of all registered back-ends.

bpparam returns the back-end of type bpparamClass or,

Author(s)
Martin Morgan mailto:mtmorgan@fhcrc.org.
See Also

`BiocParallelParam` for possible values of BPPARAM.

Examples

```r
## The registry
## -----------------------------------------------
## The default registry.
default <- registered()
default

## When default = TRUE the last param registered becomes the new default.
snowparam <- SnowParam(workers = 3, type = "SOCK")
register(snowparam, default = TRUE)
registered()

## Retrieve the default back-end,
bpparam()

## or a specific BiocParallelParam.
bpparam("SnowParam")

## restore original registry -- push the defaults in reverse order
for (param in rev(default))
    register(param)

## Specifying a back-end for evaluation
## -----------------------------------------------
## The back-end of choice is given as the BPPARAM argument to
## the BiocParallel functions. None, one, or multiple back-ends can be
## used.
bplapply(1:6, sqrt, BPPARAM = MulticoreParam(3))

## When not specified, the default from the registry is used.
bplapply(1:6, sqrt)
```

---

### SerialParam-class

**Enable serial evaluation**

**Description**

This class is used to parameterize serial evaluation, primarily to facilitate easy transition from parallel to serial code.

**Usage**

```
SerialParam(catch.errors = TRUE, stop.on.error = TRUE, log = FALSE,
threshold = "INFO", logdir= NA_character_)
```
SnowParam-class

Arguments

- **catch.errors**: DEPRECATED; see SnowParam.
- **stop.on.error**: A logical determining behavior on error; see SnowParam.
- **log**: logical(1) Enable logging; see SnowParam.
- **threshold**: character(1) Logging threshold; see SnowParam.
- **logdir**: character(1) Log files directory. When not provided, log messages are returned to stdout.

Constructor

SerialParam(catch.errors = FALSE, log = FALSE, threshold = "INFO"):
Return an object to be used for serial evaluation of otherwise parallel functions such as bplapply, bpvec.

Methods

The following generics are implemented and perform as documented on the corresponding help page (e.g., ?bpworkers): bpworkers, bpisup, bpstart, bpstop, are implemented, but do not have any side-effects.

Author(s)

Martin Morgan mailto:mtmorgan@fhcrc.org

See Also

getClass("BiocParallelParam") for additional parameter classes.
register for registering parameter classes for use in parallel evaluation.

Examples

```r
p <- SerialParam()
simplify2array(bplapply(1:10, sqrt, BPPARAM=p))
bpvec(1:10, sqrt, BPPARAM=p)
```

## Not run:
register(SerialParam(), default=TRUE)

## End(Not run)

---

SnowParam-class  

Enable simple network of workstations (SNOW)-style parallel evaluation

Description

This class is used to parameterize simple network of workstations (SNOW) parallel evaluation on one or several physical computers. snowWorkers() chooses the number of workers based on global user preference (options(mc.cores=...)), or the minimum of 8 and the number of detected cores (detectCores()).
Usage

```r
## constructor
SnowParam(workers = snowWorkers(), type=c("SOCK", "MPI", "FORK"),
tasks = 0L, catch.errors=TRUE, stop.on.error = TRUE,
progressbar = FALSE, RNGseed = NULL,
timeout = 30L * 24L * 60L * 60L,
log = FALSE, threshold = "INFO", logdir = NA_character_,
resultdir = NA_character_, jobname = "BPJOB", ...)
```

```r
## coercion
## ------------------------------------
## as(SOCKcluster, SnowParam)
## as(spawnedMPIcluster, SnowParam)
## detect workers
## ------------------------------------
snowWorkers()
```

Arguments

- **workers**: integer(1) Number of workers. Defaults to all cores available as determined by `detectCores`. For a SOCK cluster workers can be a character() vector of host names.

- **type**: character(1) Type of cluster to use. Possible values are SOCK (default) and MPI. Instead of type=FORK use MulticoreParam.

- **tasks**: integer(1). The number of tasks per job. Value must be a scalar integer >= 0L.

  In this documentation a job is defined as a single call to a function, such as bplapply, bpmapply etc. A task is the division of the X argument into chunks. When tasks == 0 (default), X is divided as evenly as possible over the number of workers.

  A tasks value of >0 specifies the exact number of tasks. Values can range from 1 (all of X to a single worker) to the length of X (each element of X to a different worker).

  When the length of X is less than the number of workers each element of X is sent to a worker and tasks is ignored.

- **catch.errors**: DEPRECATED. logical(1) Enable the catching of errors and warnings.

- **stop.on.error**: logical(1) Enable stop on error.

- **progressbar**: logical(1) Enable progress bar (based on pplyr:::progress_text).

- **RNGseed**: integer(1) Seed for random number generation. When not NULL, this value is passed to parallel::clusterSetRNGStream to generate random number streams on each worker.

- **timeout**: numeric(1) Time (in seconds) allowed for worker to complete a task. This value is passed to base::setTimeLimit() as both the cpu and elapsed arguments.
If the computation exceeds timeout an error is thrown with message 'reached elapsed time limit'.

**log**
- logical(1) Enable logging.

**threshold**
- character(1) Logging threshold as defined in futile.logger.

**logdir**
- character(1) Log files directory. When not provided, log messages are returned to stdout.

**resultdir**
- character(1) Job results directory. When not provided, results are returned as an R object (list) to the workspace.

**jobname**
- character(1) Job name that is prepended to log and result files. Default is "BPJOB".

... Additional arguments passed to makeCluster

### Details

SnowParam is used for distributed memory computing and supports 2 cluster types: 'SOCK' (default) and 'MPI'. The SnowParam builds on infrastructure in the snow and parallel packages and provides the additional features of error handling, logging and writing out results. When not specified, the default number of workers is determined by snowWorkers() which is parallel::detectCores() - 2. Machines with 3 or less cores are assigned a single worker.

#### error handling:

By default all computations are attempted and partial results are returned with any error messages.

- **catch.errors** (DEPRECATED) determines whether errors are caught and returned with other results. When TRUE, all computations are attempted and output contains both errors and successfully completed results. When FALSE, the job is terminated as soon as the first error is hit and only the error message is returned (no results); this is the default behavior of the parent packages, e.g., parallel, snow, foreach.

- **stop.on.error** A logical. Stops all jobs as soon as one job fails or wait for all jobs to terminate. When FALSE, the return value is a list of successful results along with error messages as 'conditions'.

- The bpok(x) function returns a logical() vector that is FALSE for any jobs that threw an error. The input x is a list output from a bp*apply function such as bplapply or bpmapply.

#### logging:

When log = TRUE the futile.logger package is loaded on the workers. All log messages written in the futile.logger format are captured by the logging mechanism and returned real-time (i.e., as each task completes) instead of after all jobs have finished.

Messages sent to stdout and stderr are returned to the workspace by default. When log = TRUE these are diverted to the log output. Those familiar with the outfile argument to makeCluster can think of log = FALSE as equivalent to outfile = NULL; providing a logdir is the same as providing a name for outfile except that BiocParallel writes a log file for each task.

The log output includes additional statistics such as memory use and task runtime. Memory use is computed by calling gc(reset=TRUE) before code evaluation and gc() (no reset) after. The output of the second gc() call is sent to the log file. There are many ways to track memory use - this particular approach was taken because it is consistent with how the BatchJobs package reports memory on the workers.

#### log and result files:

Results and logs can be written to a file instead of returned to the workspace. Writing to files is done from the master as each task completes. Options can be set with the logdir and resultdir fields in the constructor or with the accessors, bplogdir and bpresultdir.
random number generation: MulticoreParam and SnowParam use the random number generation support from the parallel package. These params are snow-derived clusters so the arguments for multicore-derived functions such as mc.set.seed and mc.reset.stream do not apply.

Random number generation is controlled through the param argument, RNGseed which is passed to parallel::clusterSetRNGStream. clusterSetRNGStream uses the L’Ecuyer-CMRG random number generator and distributes streams to the members of a cluster. If RNGseed is not NULL it serves as the seed to the streams, otherwise the streams are set from the current seed of the master process after selecting the L’Ecuyer generator. See ?clusterSetRNGStream for more details.

NOTE: The PSOCK cluster from the parallel package does not support cluster options scriptdir and useRscript. PSOCK is not supported because these options are needed to re-direct to an alternate worker script located in BiocParallel.

Constructor

SnowParam(workers = snowWorkers(), type=c("SOCK", "MPI"), tasks = 0L, catch.errors = TRUE, stop.on.error = FALSE, ... = Inf, log = FALSE, threshold = "INFO", logdir = NA_character_, resultdir = NA_character_, jobname = "BPJOB", ...):

Return an object representing a SNOW cluster. The cluster is not created until bpstart is called. Named arguments in ... are passed to makeCluster.

Accessors: Logging and results

In the following code, x is a SnowParam object.

bpprogressbar(x), bpprogressbar(x) <- value: Get or set the value to enable text progress bar. value must be a logical(1).

bpjobname(x), bpjobname(x) <- value: Get or set the job name.

bpRNGseed(x), bpRNGseed(x) <- value: Get or set the seed for random number generation. value must be a numeric(1).

bplog(x), bplog(x) <- value: Get or set the value to enable logging. value must be a logical(1).

bpthreshold(x), bpthreshold(x) <- value: Get or set the logging threshold. value must be a character(1) string of one of the levels defined in the futile.logger package: “TRACE”, “DEBUG”, “INFO”, “WARN”, “ERROR”, or “FATAL”.

bplogdir(x), bplogdir(x) <- value: Get or set the directory for the log file. value must be a character(1) path, not a file name. The file is written out as BPLOG.out. If no logdir is provided and bplog=TRUE log messages are sent to stdout.

bresultdir(x), bresultdir(x) <- value: Get or set the directory for the result files. value must be a character(1) path, not a file name. Separate files are written for each job with the prefix TASK (e.g., TASK1, TASK2, etc.). When no resultdir is provided the results are returned to the session as list.

Accessors: Back-end control

In the code below x is a SnowParam object. See the ?BiocParallelParam man page for details on these accessors.

bpworkers(x), bpworkers(x) <- value, bpnworkers(x)

bptasks(x), bptasks(x) <- value

bpstart(x)

bpstop(x)
bpisup(x)
bpbackend(x), bpbackend(x) <- value

Accessors: Error Handling

In the code below x is a SnowParam object. See the ?BiocParallelParam man page for details on these accessors.

bpcatchErrors(x), bpcatchErrors(x) <- value
bpstopOnError(x), bpstopOnError(x) <- value

Methods: Evaluation

In the code below BPPARAM is a SnowParam object. Full documentation for these functions are on separate man pages: see ?bpmapply, ?bplapply, ?bpvec, ?bpiterate and ?bpaggregate.

bpmapply(FUN, ..., MoreArgs=NULL, SIMPLIFY=TRUE,
USE.NAMES=TRUE, BPPARAM=bpparam())
bplapply(X, FUN, ..., BPPARAM=bpparam())
bpvec(X, FUN, ..., AGGREGATE=c, BPPARAM=bpparam())
bpiterate(ITER, FUN, ..., BPPARAM=bpparam())
bpaggregate(x, data, FUN, ..., BPPARAM=bpparam())

Methods: Other

In the code below x is a SnowParam object.

show(x): Displays the SnowParam object.

bpok(x): Returns a logical() vector: FALSE for any jobs that resulted in an error. x is the result list output by a BiocParallel function such as bplapply or bpmapply.

Coercion

as(from, "SnowParam"): Creates a SnowParam object from a SOCKcluster or spawnedMPIcluster object. Instances created in this way cannot be started or stopped.

Author(s)

Martin Morgan and Valerie Obenchain.

See Also

• register for registering parameter classes for use in parallel evaluation.
• MulticoreParam for computing in shared memory
• BatchJobsParam for computing with cluster schedulers
• DoparParam for computing with foreach
• SerialParam for non-parallel evaluation
Examples

```r
## Job configuration:
## SnowParam supports distributed memory computing. The object fields
## control the division of tasks, error handling, logging and result
## format.
bpparam <- SnowParam()
bpparam
## Fields are modified with accessors of the same name:
bplog(bpparam) <- TRUE
bpresultdir(bpparam) <- "/myResults/"
bpparam

## Logging:
## When 'log == TRUE' the workers use a custom script (in BiocParallel)
## that enables logging and access to other job statistics. Log messages
## are returned as each job completes rather than waiting for all to
## finish.

## In 'fun', a value of 'x = 1' will throw a warning, 'x = 2' is ok
## and 'x = 3' throws an error. Because 'x = 1' sleeps, the warning
## should return after the error.
X <- 1:3
fun <- function(x) {
  if (x == 1) {
    Sys.sleep(2)
    if (TRUE & c(TRUE, TRUE)) ## warning
      x
  } else if (x == 2) {
    x ## ok
  } else if (x == 3) {
    sqrt("FOO") ## error
  }
}

## By default logging is off. Turn it on with the bplog()<- setter
## or by specifying 'log = TRUE' in the constructor.
bpparam <- SnowParam(3, log = TRUE, stop.on.error = FALSE)
tryCatch({
  bplapply(X, fun, BPPARAM = bpparam)
}, error=identity)

## When a 'logdir' location is given the messages are redirected to a
## file:
## Not run:
bplogdir(bpparam) <- tempdir()
bplapply(X, fun, BPPARAM = bpparam)
list.files(bplogdir(bpparam))
```
SnowParam-class

## End(Not run)
## -----------------------------------------------------------------------
## Managing results:
## -----------------------------------------------------------------------

## By default results are returned as a list. When 'resultdir' is given
## files are saved in the directory specified by job, e.g., 'TASK1.Rda',
## 'TASK2.Rda', etc.
## Not run:
bpparam <- SnowParam(2, resultdir = tempdir())
bplapply(X, fun, BPPARAM = bpparam)
list.files(bpresultdir(bpparam))

## End(Not run)
## -----------------------------------------------------------------------
## Error handling:
## -----------------------------------------------------------------------

## When 'stop.on.error' is TRUE the process returns as soon as an error
## is thrown.
## When 'stop.on.error' is FALSE all computations are attempted. Partial
## results are returned along with errors. Use bptry() to see the
## partial results
bpparam <- SnowParam(2, stop.on.error = FALSE)
res <- bptry(bplapply(list(1, "two", 3, 4), sqrt, BPPARAM = bpparam))
res

## Calling bpok() on the result list returns TRUE for elements with no
## error.
bpk(res)

## Random number generation:
## -----------------------------------------------------------------------

## Random number generation is controlled with the 'RNGseed' field.
## This seed is passed to parallel::clusterSetRNGStream
## which uses the L’Ecuyer-CMRC random number generator and distributes
## streams to members of the cluster.
bpparam <- SnowParam(3, RNGseed = 7739465)
bplapply(seq_len(bpnworkers(bpparam)), function(i) rnorm(1),
  BPPARAM = bpparam)
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