

# Extending trackr with custom backends

Gabriel Becker

August 15, 2018

## Contents

<b>1</b>	<b>Creating custom backends</b>	<b>2</b>
<b>2</b>	<b>Customizing metadata extraction</b>	<b>5</b>
2.1	Adding custom tags for a class . . . . .	5
2.2	Defining customized formal metadata for a class . . . . .	5

# 1 Creating custom backends

The `trackr` package supports storing metadata and artifacts in either a JSON file or Solr database. To extend `trackr` to support a new storage backend, it is necessary to define a derivative of `VirtHistoryTracker` and implement methods on six generic functions:

1. `prep_for_backend`, which prepares a `PlotFeatureSet` for insertion into the backend data store;
2. `insert_record`, which inserts the prepared feature set into the database;
3. `remove_record`, which removes a plot from the database;
4. `trackr_write`, which writes the the current state of an in-memory backend to disk;<sup>1</sup>
5. `trackr_lookup`, which looks up a single plot based on its ID or an object representing it; and
6. `trackr_search`, which provides whatever search functionality is supported by the backend.

These functions are called internally by the user-facing `addPlot`, `rmPlot`, and `findPlot` functions.

For the remainder of this section, we will walk through the creation of a toy-example backend based on **R** lists. While this would not suffice in practice because it offers no persistence, it will serve as an illustration of how one would implement a backend more generally — e.g., for MongoDB [?] or your database of choice.

To implement our backend, we first define the S4 class representing an instance of our `list` backend, `ListBackend`, which simply inherits from the base `list` class. We also define a constructor, for convenience.

```
library(trackr)

lb = setRefClass("BasicListBackend", fields = list(dat = "list"))
BasicListBackend = function() lb$new()
```

We then define our methods which will allow `trackr` to interact with our backend. For full customization, we could in principle first write a specific `prep_for_backend` method. When writing custom `prep_for_backend` methods, they must:

- Generate a unique id for the object, typically by calling `uniqueID` on the `ObjectFeatureSet`;
- use `trackr_lookup` to confirm no plot with that id already exists in the datastore;
- write any image-files and serialized objects that need to be created in the file system;
- transform the plot, metadata, and file paths into the form your `insert_record` method will be able to process; and
- return the transformed data

In practice, however, `trackr` provides an "ANY" method which will generally suffice for most backends. It returns a `list` with a generated id and a flattened `list` of the plot's metadata, along with saving out image files based on the options set on your `TrackrDB`. We will use this method by simply not creating a backend-specific one for our `ListBackend` class. With `prep_for_backend` addressed, we move on to methods for inserting plots into and removing them from our `list` data store.

All `insert\_record` and `remove\_record` methods must accept five and four arguments, respectively:

1. `object` - the document to be inserted or deleted within the datastore, or the id of the record to be deleted;
2. `id` - the unique id to associate with the added plot, or the id of the plot to remove (*insert\_record only*);

---

<sup>1</sup>This function can often be a no-op if `insert_record` performs a permanent write operation

3. target - the backend object (of the new class that we have created);
4. opts - a TrackrOptions object
5. verbose - a logical indicating whether the backend should emit informational messages (if supported)

The methods themselves must then update the backend object by performing the desired insertion or removal, assign the updated backend back into the database, and return the database. In our toy list-backend case, we can achieve this like so:

```
setMethod("insert_record", c(target = "BasicListBackend"),
function(object, id, target, opts, verbose = FALSE) {
  target$dat[[id]] = object
  invisible(target)
})

setMethod("remove_record", c(object = "character", target = "BasicListBackend"),
function(object, target, opts, verbose = FALSE) {
  ## object is the id
  target$dat[[object]] = NULL
  invisible(target)
})
```

Note we are only defining a `remove_record` method for when the `object` argument is a `character`, thus our backend only supports removal by id. The `trackr` package uses S4 dispatch to funnel all logic through `character`-based id methods for `remove_record`, so no other methods are required.

Along with our `insert_record` and `remove_record` methods, we must define a `trackr.write` method which finalizes any changes to the `trackr` database our backend uses. The framework requires this in order to allow backends to accumulate changes in memory or immediately write them (within `insert_record` and `remove_record`, in which case `trackr.write` is a simple no-op).

Because our `list` backend has no persistent storage behind it, our `trackr.write` method does nothing:

```
setMethod("trackr_write", c(target = "BasicListBackend"),
function(target, opts, verbose = FALSE) target)
```

Next is a `trackr.lookup` method, which takes the `object`, `db`, `backend` and `exist` parameters. The `object`, put simply, is the query. The `db` and `backend` parameters represent and behave as they have throughout this discussion. Finally, the `exist` parameter specifies whether the lookedup plot entry from the data-store (FALSE — the default) or whether a logical value indicating whether such an entry was found (TRUE) should be returned.

The `object` argument can be an R object representing, an `ObjectFeatureSet` object, or a `character` id. As with `remove_record`, however, general methods provided by `trackr` funnel all dispatch through `character`-based methods, so we only need to provide a `character` id-based lookup method when defining a backend. We implement this like so:

```
setMethod("trackr_lookup", c("character", target = "BasicListBackend"),
function(object, target, opts, exist = FALSE){
  found = which(object == names(target$dat))
  if(exist)
    return(length(found) > 0)
  else
    return(backend[[found]])
})
```

Finally, the last method we require to define our backend is `trackr_search`. This accepts a regular expression (pattern), the usual db and backend, a vector of fields to search (fields), the form in which to return the results (ret\_type — id, list, or a backend-specific option), and a verbose option. Its exact behavior may be backend-specific, but it is intended to find matches to pattern within the selected fields within the backend's datastore.

In the case of our backend, `trackr_search` will loop through our list and grep for the supplied pattern. We will write a simplified version which always returns the vector of matching ids:

```
setMethod("trackr_search", c(pattern = "character", target = "BasicListBackend"),
  function(pattern, target, opts, fields = NULL, ret_type = c("id", "list", "backend"),
    verbose = TRUE) {
    if(is.null(fields)) {
      fields = TRUE ## grab all of them
    }

    inds = sapply(target$dat, function(y) any(grepl(pattern, paste(y[fields]))))
    names(target$dat)[inds]
  })
```

With this, our backend is complete and ready for use.

```
library(ggplot2)
plt = qplot(x = 1:10, y = rnorm(10))
be = BasicListBackend()
db = TrackrDB(backend = be)
defaultTDB(db)

## An object of class "TrackrDB"
## Slot "opts":
## An object of class "TrackrOptions"
## Slot "insert_delay":
## [1] 0
##
## Slot "img_dir":
## [1] "./images"
##
## Slot "img_ext":
## [1] "png"
##
## Slot "backend_opts":
## list()
##
## Slot "backend":
## Reference class object of class "BasicListBackend"
## Field "dat":
## list()

record(plt)

## Warning in fullData(object): Only plotted data will be returned, which may be
## limited to a summary of the original data. This may be due to use of vectors (rather
## than a data.frame) in the ggplot call.
```

```
## Note: method with signature 'FeatureSet#TrackrDB' chosen for function 'prep_for_backend',
## target signature 'GGplotFeatureSet#TrackrDB'.
## "ObjFeatureSet#ANY" would also be valid
## Creating image directory at ./images

findRecords("rnorm")

## [1] "SpkyV2:49cb100d6dbc9f7ed10b02562d541147"
```

In this section, we provided methods for all low-level generics (other than `prep_for_backend`, which is only required in special cases), for the purposes of illustrating the extension mechanism. In point of fact, however, `trackr` provides default methods for `insert_record`, `remove_record`, and `trackr_lookup` which work for any backend whose class has `[]` and `[[<-` methods defined which allow indexing by character, and where assignment of `NULL` into an existing entry is equivalent to removal. Thus, only `trackr_write` and `trackr_search` methods are actually required in many cases, including the `list`-backend case we presented here.

## 2 Customizing metadata extraction

### 2.1 Adding custom tags for a class

Metadata extraction can be customized in two ways within the `trackr` framework. First, users can define an S4 method for the `generateTags` generic for a class. This is called by `makeFeatureSet` methods `trackr` provides to perform metadata extraction, and is passed the object that `trackr` is extracting metadata from. Any (character) values returned will be added to the tags for the object. This provides an easy way to add non-key-value annotations to objects you are recording.

NOTE: defining an S3 method (simply creating a function called `generateTags.yourclass` will not work. You must create a formal method.

```
y = 5
class(y) = "sillyclass"
setMethod(generateTags, "sillyclass", function(object) "Hi vignette readers!")

## in method for 'generateTags' with signature '"sillyclass"': no definition for
class "sillyclass"

fs = makeFeatureSet(y)
tags(fs)

## [1] "Hi vignette readers!"
```

### 2.2 Defining customized formal metadata for a class

Customizing tag generation only allows us to add tags, however. We can also customize the formal key-value metadata pairs generated for a class of object. This is a two-step process. First we extend the virtual `FeatureSet` class with a subclass that adds slots for the formal pieces of metadata we will extract from objects of a particular class. Often we will actually inherit from `ObjFeatureSet`, which has slots for the object itself and its class. We will create a toy example which customizes the metadata extracted from integer vectors by capturing the set of unique values the vector takes.

```
setClass("AwesomeIntFeatureSet", contains = "ObjFeatureSet",
        slots = c(uniquevals = "integer"))
```

We then define a method for `makeFeatureSet` that takes an integer vector and returns an `AwesomeIntFeatureSet` object. How the internals of the method behave is up to the author, but suggested practice when inheriting from a subclass of `FeatureSet` — as we are here by inheriting from `ObjFeatureSet` — is to use the constructor for the parent class to generate any non-customized information, then use that in construction of the final object, like so.

```
setMethod("makeFeatureSet", "integer", function(object, ...) {
  innerobj = ObjFeatureSet(object, ...)
  new("AwesomeIntFeatureSet", innerobj, uniquevals = unique(object))
})
```

```
x = sample(1:20, 20, replace=TRUE)
makeFeatureSet(x)@uniquevals
```

```
## [1] 19  4 18  3 17 14  1 16 15  6  8 13  2 12
```