2. Reading, Writing and Converting Simple Features

This vignetted describes how simple features can be read in R from files or databases, and how they can be converted to other formats (text, sp (https://cran.r-project.org/package=sp))

Reading and writing through GDAL

The Geospatial Data Abstraction Library (GDAL (http://www.gdal.org/)) is the swiss army knife for spatial data: it reads and writes vector and raster data from and to practically every file format, or database, of significance. Package `sf` reads and writes using GDAL by the functions `st_read` and `st_write`.

The data model GDAL uses needs

- a data source, which may be a file, directory, or database
- a layer, which is a single geospatial dataset inside a file or directory or e.g. a table in a database.
- the specification of a driver (i.e., which format)
- driver-specific reading or writing data sources, or layers

This may sound complex, but it is needed to map to over 200 data formats! Package `sf` tries hard to simplify this where possible (e.g. a file contains a single layer), but this vignette will try to point you to the options.

Using st_read

As an example, we read the North Carolina counties SIDS dataset, which comes shipped with the `sf` package by:

```
library(sf)
fname <- system.file("shape/nc.shp", package="sf")
fname
## [1] "/tmp/Rtmpaq4C0b/Rinst79437936646a/sf/shape/nc.shp"
nc <- st_read(fname)
## Reading layer `nc' from data source `/tmp/Rtmpaq4C0b/Rinst79437936646a/sf/shape/nc.shp' us
ing driver `ESRI Shapefile'
## Simple feature collection with 100 features and 14 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
```

Typical users will use a file name with path for `fname`, or first set R's working directory with `setwd()` and use file name without path.

We see here that a single argument is used to find both the datasource and the layer. This works when the datasource contains a single layer. In case the number of layers is zero (e.g. a database with no tables), an error message is given. In case there are more layers than one, the first layer is returned, but a message and a warning are given:

```
> st_read("PG:dbname=postgis")
Multiple layers are present in data source PG:dbname=postgis, reading layer `meuse'.
Use `st_layers' to list all layer names and their type in a data source.
Set the `layer' argument in `st_read' to read a particular layer.
Reading layer `meuse' from data source `PG:dbname=postgis' using driver `PostgreSQL'
Simple feature collection with 155 features and 12 fields
geometry type:  POINT
dimension:      XY
bbox:           xmin: 178605 ymin: 329714 xmax: 181390 ymax: 333611
epsg (SRID):    28992
proj4string:    +proj=sterea +lat_0=52.15616055555555 ...
Warning message:
In eval(substitute(expr), envir, enclos) :
  automatically selected the first layer in a data source containing more than one.
```

The message points to the `st_layers` command, which lists the driver and layers in a datasource, e.g.

```
> st_layers("PG:dbname=postgis")
Driver: PostgreSQL
Available layers:
  layer_name geometry_type features fields
1      meuse         Point      155     12
2   meuse_sf         Point      155     12
3       sids Multi Polygon      100     14
4  meuse_tbl         Point      155     13
5 meuse_tbl2         Point      155     13
>
```

A particular layer can now be read by e.g.

```
st_read("PG:dbname=postgis", "sids")
```

`st_layers` has the option to count the number of features in case these are missing: some datasources (e.g. OSM xml files) do not report the number of features, but need to be completely read for this. GDAL allows for more than one geometry column for a feature layer; these are reported by `st_layers`.

In case a layer contains only geometries but no attributes (fields), `st_read` still returns an `sf` object, with a geometry column only.

We see that GDAL automatically detects the driver (file format) of the datasource, by trying them all in turn.

`st_read` follows the conventions of base R, similar to how it reads tabular data into `data.frame` s. This means that character data are read, by default as `factor` s. For those who insist on retrieving character data as character vectors, the argument `stringsAsFactors` can be set to `FALSE`:

```
st_read(fname, stringsAsFactors = FALSE)
```

Alternatively, a user can set the global option `stringsAsFactors`, and this will have the same effect:

```
options(stringsAsFactors = FALSE)
st_read(fname)
## Reading layer `nc' from data source `/tmp/Rtmpaq4C0b/Rinst79437936646a/sf/shape/nc.shp' us
ing driver `ESRI Shapefile'
## Simple feature collection with 100 features and 14 fields
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: -84.32385 ymin: 33.88199 xmax: -75.45698 ymax: 36.58965
## epsg (SRID):    4267
## proj4string:    +proj=longlat +datum=NAD27 +no_defs
```

Using st_write

To write a simple features object to a file, we need at least two arguments, the object and a filename:

```
st_write(nc, "nc1.shp")
```

The file name is taken as the data source name. The default for the layer name is the basename (filename without path) of the the data source name. For this, `st_write` needs to guess the driver. The above command is, for instance, equivalent to:

```
st_write(nc, dsn = "nc1.shp", layer = "nc.shp", driver = "ESRI Shapefile")
## Writing layer `nc' to data source `nc1.shp' using driver `ESRI Shapefile'
## features:       100
## fields:         14
## geometry type:  Multi Polygon
```

How the guessing of drivers works is explained in the next section.

Guessing a driver for output

The output driver is guessed from the datasource name, either from its extension (`.shp` : `ESRI Shapefile`), or its prefix (`PG:` : `PostgreSQL`). The list of extensions with corresponding driver (short driver name) is:

extension	driver short name
bna	BNA
csv	CSV
e00	AVCE00
gdb	FileGDB
geojson	GeoJSON
gml	GML
gmt	GMT
gpkg	GPKG
gps	GPSBabel
gtm	GPSTrackMaker
gxt	Geoconcept

extension	driver short name
`jml`	`JML`
`map`	`WAsP`
`mdb`	`Geomedia`
`nc`	`netCDF`
`ods`	`ODS`
`osm`	`OSM`
`pbf`	`OSM`
`shp`	`ESRI Shapefile`
`sqlite`	`SQLite`
`vdv`	`VDV`
`xls`	`xls`
`xlsx`	`XLSX`

The list with prefixes is:

prefix	driver short name
`couchdb:`	`CouchDB`
`DB2ODBC:`	`DB2ODBC`
`DODS:`	`DODS`
`GFT:`	`GFT`
`MSSQL:`	`MSSQLSpatial`
`MySQL:`	`MySQL`
`OCI:`	`OCI`
`ODBC:`	`ODBC`
`PG:`	`PostgreSQL`
`SDE:`	`SDE`

Dataset and layer reading or creation options

Various GDAL drivers have options that influences the reading or writing process, for example what the driver should do when a table already exists in a database: append records to the table or overwrite it:

```
st_write(st_as_sf(meuse), "PG:dbname=postgis", "meuse",
    layer_options = "OVERWRITE=true")
```

In case the table exists and the option is not specified, the driver will give an error. Driver-specific options are documented in the driver manual of gdal (http://www.gdal.org/ogr_formats.html). Multiple options can be given by multiple strings in `options` .

For `st_read`, there is only `options`; for `st_write`, one needs to distinguish between `dataset_options` and `layer_options`, the first related to opening a dataset, the second to creating layers in the dataset.

Reading and writing directly to and from spatial databases

Package `sf` supports reading and writing from and to spatial databases using the `DBI` interface. So far, testing has mainly be done with `PostGIS`, other databases might work but may also need more work. An example of reading is:

```
library(RPostgreSQL)
conn = dbConnect(PostgreSQL(), dbname = "postgis")
meuse = st_read(conn, "meuse")
meuse_1_3 = st_read(conn, query = "select * from meuse limit 3;")
dbDisconnect(conn)
```

We see here that in the second example a query is given. This query may contain spatial predicates, which could be a way to work through massive spatial datasets in R without having to read them completely in memory.

Similarly, tables can be written:

```
conn = dbConnect(PostgreSQL(), dbname = "postgis")
st_write(conn, meuse, drop = TRUE)
dbDisconnect(conn)
```

Here, the default table (layer) name is taken from the object name (`meuse`). Argument `drop` informs to drop (remove) the table before writing; logical argument `binary` determines whether to use well-known binary or well-known text when writing the geometry (where well-known binary is faster and lossless).

Conversion to other formats: WKT, WKB, sp

Conversion to and from well-known text

The usual form in which we see simple features printed is well-known text:

```
st_point(c(0,1))
## POINT (0 1)
st_linestring(matrix(0:9,ncol=2,byrow=TRUE))
## LINESTRING (0 1, 2 3, 4 5, 6 7, 8 9)
```

We can create these well-known text strings explicitly using `st_as_wkt`:

```
x = st_linestring(matrix(0:9,ncol=2,byrow=TRUE))
str = st_as_text(x)
x
## LINESTRING (0 1, 2 3, 4 5, 6 7, 8 9)
```

We can convert back from WKT by using `st_as_sfc`:

```
st_as_sfc(str)
## Geometry set for 1 feature
## geometry type:  LINESTRING
## dimension:      XY
## bbox:           xmin: 0 ymin: 1 xmax: 8 ymax: 9
## epsg (SRID):    NA
## proj4string:    NA
## LINESTRING (0 1, 2 3, 4 5, 6 7, 8 9)
```

Conversion to and from well-known binary

Well-known binary is created from simple features by `st_as_binary`:

```
x = st_linestring(matrix(0:9,ncol=2,byrow=TRUE))
(x = st_as_binary(x))
##  [1] 01 02 00 00 00 05 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
## [24] f0 3f 00 00 00 00 00 00 00 40 00 00 00 00 00 00 08 40 00 00 00 00 00
## [47] 00 10 40 00 00 00 00 00 00 14 40 00 00 00 00 00 00 18 40 00 00 00 00
## [70] 00 00 1c 40 00 00 00 00 00 00 20 40 00 00 00 00 00 00 22 40
class(x)
## [1] "raw"
```

The object returned by `st_as_binary` is of class `WKB` and is either a list with raw vectors, or a single raw vector. These can be converted into a hexadecimal character vector using `rawToHex`:

```
rawToHex(x)
## [1] "0102000000050000000000000000000000000000000000000000000000f03f000000000000004000000000000000840000
000000001040000000000000144000000000000018400000000000001c4000000000000020400000000000000224
0"
```

Converting back to `sf` uses `st_as_sfc`:

```
x = st_as_binary(st_sfc(st_point(0:1), st_point(5:6)))
st_as_sfc(x)
## Geometry set for 2 features
## geometry type:  POINT
## dimension:      XY
## bbox:           xmin: 0 ymin: 1 xmax: 5 ymax: 6
## epsg (SRID):    NA
## proj4string:    NA
## POINT (0 1)
## POINT (5 6)
```

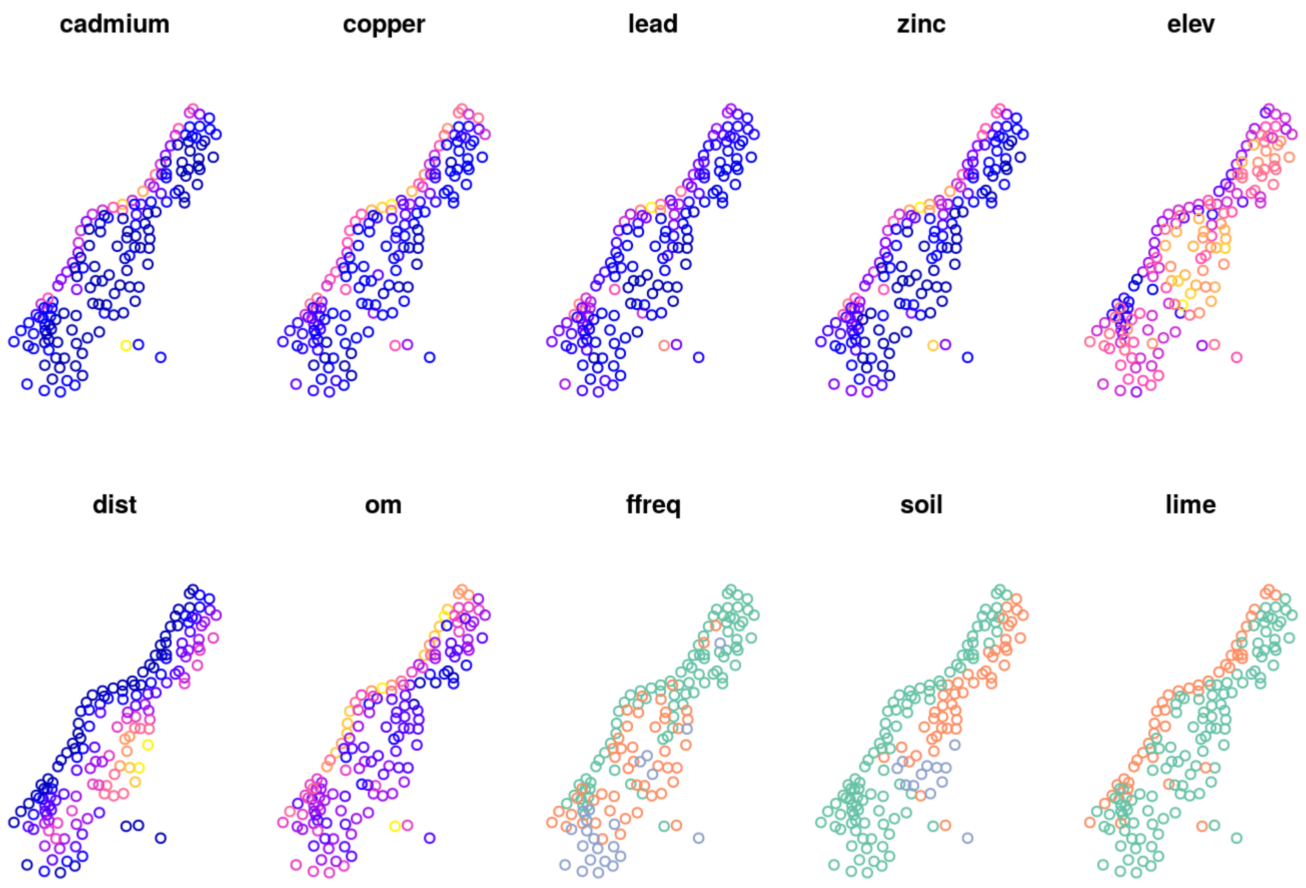
Conversion to and from sp

Spatial objects as maintained by package `sp` can be converted into simple feature objects or geometries by `st_as_sf` and `st_as_sfc`, respectively:

```
methods(st_as_sf)
## [1] st_as_sf.Spatial*    st_as_sf.data.frame* st_as_sf.lpp*
## [4] st_as_sf.map*        st_as_sf.ppp*        st_as_sf.psp*
## [7] st_as_sf.sf*
## see '?methods' for accessing help and source code
methods(st_as_sfc)
##  [1] st_as_sfc.SpatialLines*       st_as_sfc.SpatialMultiPoints*
##  [3] st_as_sfc.SpatialPixels*      st_as_sfc.SpatialPoints*
##  [5] st_as_sfc.SpatialPolygons*    st_as_sfc.TWKB*
##  [7] st_as_sfc.WKB*                st_as_sfc.bbox*
##  [9] st_as_sfc.blob*               st_as_sfc.character*
## [11] st_as_sfc.dimensions*         st_as_sfc.factor*
## [13] st_as_sfc.list*               st_as_sfc.map*
## [15] st_as_sfc.raw*
## see '?methods' for accessing help and source code
```

An example would be:

```
library(sp)
data(meuse)
coordinates(meuse) = ~x+y
m.sf = st_as_sf(meuse)
opar = par(mar=rep(0,4))
plot(m.sf)
## Warning: plotting the first 10 out of 12 attributes; use max.plot = 12 to
## plot all
```



Conversion of simple feature objects of class `sf` or `sfc` into corresponding `Spatial*` objects is done using the `as` method, coercing to `Spatial` :

```
x = st_sfc(st_point(c(5,5)), st_point(c(6,9)), crs = 4326)
as(x, "Spatial")
## SpatialPoints:
##      coords.x1 coords.x2
## [1,]         5         5
## [2,]         6         9
## Coordinate Reference System (CRS) arguments: +proj=longlat
## +datum=WGS84 +no_defs +ellps=WGS84 +towgs84=0,0,0
```