

Working with **sp** and **aRT**

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1 Introduction

sp (Pebesma & Bivand, 2005) is an important package defining standards and allowing for exchanging information between spatial packages in R. As **aRT** manipulates all spatial data formats, it was designed to follow **sp** standards to represent spatial data, i.e., **aRT** assumes and stores data using the **sp** format. Therefore, when working with **aRT** and spatial data in R it is required that objects containing spatial data are converted, if necessary, to the **sp** format. For further details on **sp** package see <http://r-spatial.sourceforge.net>.

On the other hand, **TerraLib** databases can contain data that cannot be directly converted to **sp** data. For example:

1. **TerraLib** (and therefore **aRT**) requires ID in *all* spatial data, different from **sp**, that requires ID only for lines and polygons.

2. TerraLib layers have support to multigeometry, meaning that each spatial element can have more than one geometry associated. For example, a layer of cities can store both, contours and centroids.
3. geometries and attributes are stored in different objects in a TerraLib database. Geometries are stored directly inside layers, whereas attributes are stored in tables inside layers. The reason why tables cannot be in the same object as geometries is because TerraLib supports different types of table, for example, *static*, *event* and *dynamic* tables.

This document illustrates how to manipulate spatial data in **aRT**, showing how to import to and read from TerraLib databases. The data (and also some sentences!) used in this document are based on Pebesma and Bivand (2005).

We start by loading the package and, for convenience here, setting **aRT** to the silent mode which hides some information messages issued by **aRT** functions; followed by establishing a connection to a DBMS. The database to be used in the examples is called “sp”, which, if exists, is removed from the DBMS and recreated. Notice this is a TerraLib database, i.e., a database created following the TerraLib structure.

```
> require(aRT)

-----
R-TERRALIB API
http://www.leg.ufpr.br/aRT
TerraLib version 3.2.0 is now loaded
aRT version 1.5-1 (2008-04-09) is now loaded
-----

> aRTsilent(TRUE)

[1] TRUE

> con = openConn(name = "root")
> if (any(showDbs(con) == "sp")) deleteDb(con, "sp", force = T)
> db = createDb(con, "sp")
```

Further details on connections to the DBMS are provided by the package vignette *aRTconn*.

2 Spatial points

2.1 Points without attributes

Our first example illustrates how to handle data with a *points geometry*. For instance, consider a set of 10 points randomly generated on the unit square $[0, 1] \times [0, 1]$ and stored in a matrix **xy**. The first step is to use **sp** to convert into a **SpatialPoints** object.

```
> xy = matrix(runif(20), nc = 2)
> xy.sp = SpatialPoints(xy)
> xy.sp
```

SpatialPoints:

```
      coords.x1 coords.x2
[1,] 0.6739453 0.3021973
[2,] 0.9619853 0.6170330
[3,] 0.9228386 0.9050982
[4,] 0.7747456 0.8476483
[5,] 0.7248062 0.4579902
[6,] 0.7413480 0.3863993
[7,] 0.6302933 0.6443511
[8,] 0.1903071 0.7170724
[9,] 0.6977443 0.1980982
[10,] 0.3703263 0.2772779
```

Coordinate Reference System (CRS) arguments: NA

However, an `SpatialPoints` object cannot be used by `aRT` functions because it does not have ID and it is necessary to convert to a `SpatialPointsDataFrame`.

```
> xy.spdf = SpatialPointsDataFrame(xy, data.frame(ID = paste(1:10)))
```

PEDRO AQUI DEVERIA SER xy ou xy.sp ????

The first step in order to store this data in a `TerraLib` database is to create a *layer*. A layer is a container that can store any geometric type and also, optionally, other types of objects. A layer can be created in a database using `createLayer()` and the function call receives as arguments the database object and a string defining the name to be set for the layer.

```
> lpoints = createLayer(db, "points")
> lpoints
```

Object of class `aRTlayer`

```
Layer: "points"
Database: "sp"
Layer is empty
Projection Name: "NoProjection"
Projection Datum: "Spherical"
Tables: (none)
```

Notice that we have two names, `"points"` which is the name of the layer in the database, and `lpoints`, an R object which can access `"points"`. Next the function `addPoints()` is used to store the points into the layer. Notice that after that the layer object acknowledges the points are now stored into the database.

```
> addPoints(lpoints, xy.spdf)
> lpoints
```

Object of class `aRTlayer`

```
Layer: "points"
Database: "sp"
Number of points: 10
Projection Name: "NoProjection"
Projection Datum: "Spherical"
Tables: (none)
```

To conclude storing the points a further step creating adding a table to the layer is still necessary in order to be able to read any data from the layer. This is a TerraLib requirement needed even when the spatial data does not have any attributes. Geometries with no entry in any table cannot be retrieved from the database.

```
> tpoints = createTable(lpoints, "tpoints")
> tpoints
```

Object of class `aRTtable`

```
Table: "tpoints"
Type: static
Layer: "points"
Rows: 10
Attributes:
  id: character[16] (key)
```

```
> lpoints
```

Object of class `aRTlayer`

```
Layer: "points"
Database: "sp"
Number of points: 10
Projection Name: "NoProjection"
Projection Datum: "Spherical"
Tables:
  "tpoints": static
```

Now the layer has 10 points and one table, and we can retrieve the point coordinates using `getPoints()`, which returns a object of the class `???????????`:

```
> points = getPoints(lpoints)
```

Figure 2 illustrates two different ways for visualising the point coordinates, on the left by plotting the points from an R object with `plot(points)`, or directly from the layer, with `plot(lpoints)`, which does not requires the existence of an R object containing the points. CHECAR AQUI A DESCRICAO NO

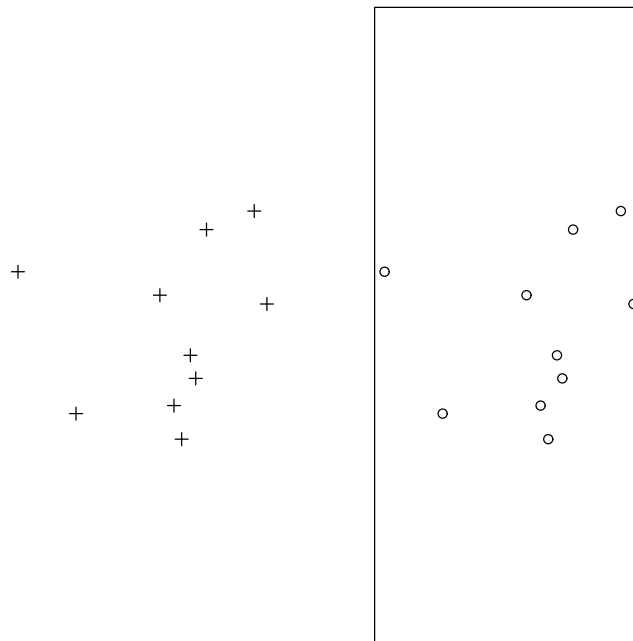


Figure 1: Plot of a layer with points

PARAGRAFO ESTA DIFERENTE DO COMANDO. USAR `plot(lpoints)` ou `aRTplot` ??? As the points do not have an associated geometry, we do not care about their order, and the order is indeed different from the original. If we see the data we can check what is different:

```
> cbind(xy, points)

              points
[1,] 0.6739453 ? NULL
[2,] 0.9619853 ? NULL
[3,] 0.9228386 ? NULL
[4,] 0.7747456 ? NULL
[5,] 0.7248062 ? NULL
[6,] 0.741348  ? NULL
[7,] 0.6302933 ? NULL
[8,] 0.1903071 ? NULL
[9,] 0.6977443 ? NULL
[10,] 0.3703263 ? NULL
```

2.2 Points with attributes

Another possible way of creating a `SpatialPointsDataFrame` object is by building it by combining a `SpatialPoints` object and a data frame containing associated attributes. In the following example we combine the object `xy.sp` with a data frame `df` containing attributes. Notice the `ID` column is required by any `sp` object.

```
> df = data.frame(z1 = round(5 + rnorm(10), 2), z2 = 0:9, ID = paste(1:10))
> xy.spdf = SpatialPointsDataFrame(xy.sp, df)
> xy.spdf
```

	coordinates	z1	z2	ID
1	(0.673945, 0.302197)	3.10	0	1
2	(0.961985, 0.617033)	4.15	1	2
3	(0.922839, 0.905098)	3.68	2	3
4	(0.774746, 0.847648)	4.45	3	4
5	(0.724806, 0.45799)	6.62	4	5
6	(0.741348, 0.386399)	5.57	5	6
7	(0.630293, 0.644351)	3.66	6	7
8	(0.190307, 0.717072)	3.75	7	8
9	(0.697744, 0.198098)	5.19	8	9
10	(0.370326, 0.277278)	5.02	9	10

As before we create a layer and add the points to it. Next, as our object now has attributes, we can import the table data using `importTable()`.

```
> lpointsdf = createLayer(db, "lpointsdf")
> addPoints(lpointsdf, xy.spdf)
> tpointsdf = importTable(lpointsdf, "tpointsdf", id = "ID", xy.spdf)
> tpointsdf
```

Object of class `aRTtable`

```
Table: "tpointsdf"
Type: static
Layer: "lpointsdf"
Rows: 10
Attributes:
  ID: character[16] (key)
  z1: numeric
  z2: integer
```

```
> lpointsdf
```

Object of class `aRTlayer`

```
Layer: "lpointsdf"
```

```

Database: "sp"
Number of points: 10
Projection Name: "NoProjection"
Projection Datum: "Spherical"
Tables:
    "tpointsdf": static

```

When retrieving data from the database to R getting point coordinates and the table at once from the layer we can use a second argument of `getPoints()` with the table to be read.

```

> getPoints(lpointsdf, tpointsdf)

      coordinates ID   z1 z2
1 (0.673945, 0.302197) 1 3.10 0
2 (0.370326, 0.277278) 10 5.02 9
3 (0.961985, 0.617033) 2 4.15 1
4 (0.922839, 0.905098) 3 3.68 2
5 (0.774746, 0.847648) 4 4.45 3
6 (0.724806, 0.45799) 5 6.62 4
7 (0.741348, 0.386399) 6 5.57 5
8 (0.630293, 0.644351) 7 3.66 6
9 (0.190307, 0.717072) 8 3.75 7
10 (0.697744, 0.198098) 9 5.19 8

```

2.3 Doing all at once

All the steps above can be encapsulated using `importSpData()`.

3 Grids

(not supported yet)

4 Lines

4.1 Building line objects from scratch

In many instances, line coordinates will be retrieved from external sources. The following example shows how to build an object of class `SpatialLines` from scratch. As objects from this class already stores ID, they are pushed in the layer directly using `addLines()`.

```

> l1 = cbind(c(1, 2, 3), c(3, 2, 2))
> l1a = cbind(l1[, 1] + 0.05, l1[, 2] + 0.05)
> l2 = cbind(c(1, 2, 3), c(1, 1.5, 1))
> S11 = Line(l1)

```

```

> S11a = Line(l1a)
> S12 = Line(l2)
> S1 = Lines(list(S11), ID = "a")
> S2 = Lines(list(S12), ID = "b")
> S3 = Lines(list(S11a), ID = "c")
> S1 = SpatialLines(list(S1, S2, S3))
> llines = createLayer(db, "llines")
> addLines(llines, S1)
> createTable(llines, "llines")

```

Object of class aRTtable

Table: "llines"

Type: static

Layer: "llines"

Rows: 3

Attributes:

id: character[16] (key)

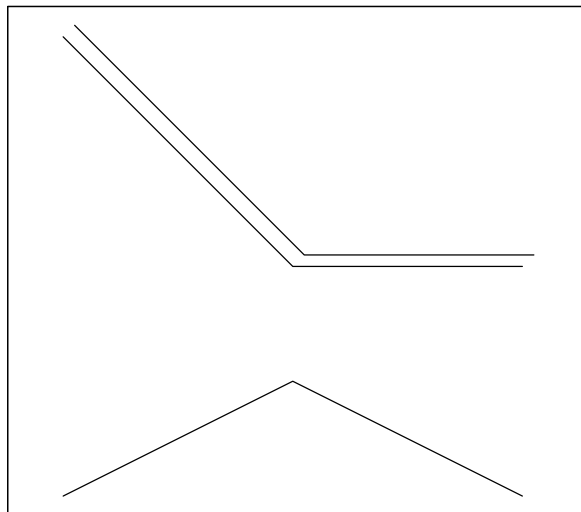


Figure 2: Plot of a layer with lines

4.2 Building line objects with attributes

The same as polygons

5 Polygons

5.1 Building from scratch

The following example shows how a set of polygons are built from scratch. Note that **Sr4** has the opposite direction (right) as the other three; it is meant to represent a hole in the **Sr3** polygon.

```
> Sr1 = Polygon(cbind(c(2, 4, 4, 1, 2), c(2, 3, 5, 4, 2)))
> Sr2 = Polygon(cbind(c(5, 4, 2, 5), c(2, 3, 2, 2)))
> Sr3 = Polygon(cbind(c(4, 4, 5, 10, 4), c(5, 3, 2, 5, 5)))
> Sr4 = Polygon(cbind(c(5, 6, 6, 5, 5), c(4, 4, 3, 3, 4)), hole = TRUE)
> Srs1 = Polygons(list(Sr1), "s1")
> Srs2 = Polygons(list(Sr2), "s2")
> Srs3 = Polygons(list(Sr3, Sr4), "s3/4")
> SR = SpatialPolygons(list(Srs1, Srs2, Srs3), 1:3)
> lrings = createLayer(db, "lrings")
> addPolygons(lrings, SR)
> trings = createTable(lrings, "trings")
> lrings
```

Object of class `aRTlayer`

```
Layer: "lrings"
Database: "sp"
Number of polygons: 4
Projection Name: "NoProjection"
Projection Datum: "Spherical"
Tables:
  "trings": static

> polys = getPolygons(lrings)
```

5.2 Polygons with attributes

Polygons with attributes, objects of class `SpatialPolygonsDataFrame`, are built from the `SpatialPolygons` object (topology) and the attributes (data.frame):

To import the attributes, we need to create a table, but, due to the internal differences of `sp` data storage we need to insert `SrDf` manually, creating both table and the two integer columns before inserting the data:

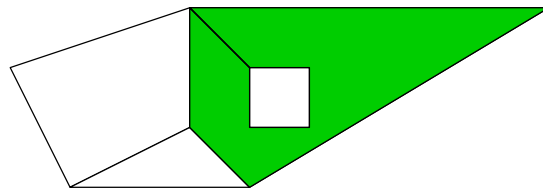


Figure 3: plot of a layer with polygons

References

- Chambers, J.M., 1998, Programming with data, a guide to the S language. Springer, New York.
- Pebesma, E.J. and Bivand, R.S., 2005, Classes and methods for spatial data in R, R-News 5 (2), pp. 9-13.