

Handling shapefiles in the `spatstat` package

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This vignette explains how to read data into the `spatstat` package from files in the popular ‘shapefile’ format.

This vignette is part of the documentation included in `spatstat` version 3.0-5. The information applies to `spatstat` versions 1.36-0 and above.

1 Shapefiles

A shapefile represents a list of spatial objects — a list of points, a list of lines, or a list of polygonal regions — and each object in the list may have additional variables attached to it.

A dataset stored in shapefile format is actually stored in a collection of text files, for example

```
mydata.shp
mydata.prj
mydata.sbn
mydata.dbf
```

which all have the same base name `mydata` but different file extensions. To refer to this collection you will always use the filename with the extension `shp`, for example `mydata.shp`.

2 Helper packages

We’ll use two other packages to handle shapefile data.

The `mapprools` package is designed specifically for handling file formats for spatial data. It contains facilities for reading and writing files in shapefile format.¹

The `sp` package supports a standard set of spatial data types in R. These standard data types can be handled by many other packages, so it is useful to convert your spatial data into one of the data types supported by `sp`.

3 Caveat about longitude-latitude coordinates

The shapefile format supports geographical coordinates, usually longitude-latitude coordinates, which specify locations on the curved surface of the Earth. However, `spatstat` deals only with spatial data on a flat two-dimensional plane.

¹Some code in `mapprools` is no longer maintained, and may give you a message recommending that you use the packages `rgdal` and `sf`. However these packages are more difficult to install than `mapprools` because of their software requirements. So we recommend that you try `mapprools` first.

When shapefile data are converted into `spatstat` objects, longitude and latitude coordinates are (currently) treated as x and y coordinates, so that the Earth's surface is effectively mapped to a rectangle. This mapping distorts distances and areas.

If your study region is a *small* region of the Earth's surface (about 3 degrees, 180 nautical miles, 200 statute miles, 320 km across) then a reasonable approach is to use the latitude and longitude as x and y coordinates, after multiplying the longitude coordinates by the cosine of the latitude of the centre of the region. This will approximately preserve areas and distances. This calculation is a simple example of a *geographical projection* and there are some much better projections available. It may be wise to use another package to perform the appropriate projection for you, and then to convert the projected data into `spatstat` objects.

If your study region is a large part of the sphere, then your data may not be amenable to the techniques provided by `spatstat` because the geometry is fundamentally different. Please consider the extension package `spatstat.sphere`.

4 How to read shapefiles into spatstat

To read shapefile data into `spatstat`, you follow two steps:

1. using the facilities of `mapproj`, read the shapefiles and store the data in one of the standard formats supported by `sp`.
2. convert the `sp` data type into one of the data types supported by `spatstat`.

4.1 Read shapefiles using mapproj

Here's how to read shapefile data.

1. ensure that the package `mapproj` is installed. You will need version 0.7-16 or later.
2. start R and load the package:

```
> library(mapproj)
```

3. read the shapefile into an object in the `sp` package using `readShapeSpatial`, for example

```
> x <- readShapeSpatial("mydata.shp")
```

In recent versions of `mapproj` you may get a warning, saying that this code is no longer supported, and recommending the packages `rgdal` and `sf`. As far as we know, this warning is premature, as the code still works fine!

4. To find out what kind of spatial objects are represented by the dataset, inspect its class:

```
> class(x)
```

The class may be either `SpatialPoints` indicating a point pattern, `SpatialLines` indicating a list of polygonal lines, or `SpatialPolygons` indicating a list of polygons. It may also be `SpatialPointsDataFrame`, `SpatialLinesDataFrame` or `SpatialPolygonsDataFrame` indicating that, in addition to the spatial objects, there is a data frame of additional variables. The classes `SpatialPixelsDataFrame` and `SpatialGridDataFrame` represent pixel image data.

Here are some examples, using the example shapefiles supplied in the `mapproj` package itself.

```

> setwd(system.file("shapes", package="maptools"))
> baltim  <- readShapeSpatial("baltim.shp")
> columbus <- readShapeSpatial("columbus.shp")
> fylk    <- readShapeSpatial("fylk-val.shp")

> class(baltim)

[1] "SpatialPointsDataFrame"

> class(columbus)

[1] "SpatialPolygonsDataFrame"

> class(fylk)

[1] "SpatialLinesDataFrame"

```

4.2 Convert data to spatstat format

To convert the dataset to an object in the `spatstat` package, the procedure depends on the type of data, as explained below.

Both packages `maptools` and `spatstat` must be **loaded** in order to convert the data.

4.2.1 Objects of class `SpatialPoints`

An object `x` of class `SpatialPoints` represents a spatial point pattern. Use `as(x, "ppp")` or `as.ppp(x)` to convert it to a spatial point pattern in `spatstat`.

(The conversion is performed by `as.ppp.SpatialPoints`, a function in `maptools`.)

The window for the point pattern will be taken from the bounding box of the points. You will probably wish to change this window, usually by taking another dataset to provide the window information. Use `[.ppp` to change the window: if `X` is a point pattern object of class `"ppp"` and `W` is a window object of class `"owin"`, type

```
> X <- X[W]
```

4.2.2 Objects of class `SpatialPointsDataFrame`

An object `x` of class `SpatialPointsDataFrame` represents a pattern of points with additional variables ('marks') attached to each point. It includes an object of class `SpatialPoints` giving the point locations, and a data frame containing the additional variables attached to the points.

Use `as(x, "ppp")` or `as.ppp(x)` to convert an object `x` of class `SpatialPointsDataFrame` to a spatial point pattern in `spatstat`. In this conversion, the data frame of additional variables in `x` will become the `marks` of the point pattern `z`.

```
> y <- as(x, "ppp")
```

(The conversion is performed by `as.ppp.SpatialPointsDataFrame`, a function in `maptools`. So the `maptools` and `spatstat` packages must be loaded in order for this to work.)

Before the conversion you can extract the data frame of auxiliary data by `df <- x@data` or `df <- slot(x, "data")`. After the conversion you can extract these data by `df <- marks(y)`.

For example:

```

> balt <- as(baltim, "ppp")
> bdata <- slot(baltim, "data")

```

4.2.3 Objects of class `SpatialLines`

A “line segment” is the straight line between two points in the plane.

In the `spatstat` package, an object of class `psp` (“planar segment pattern”) represents a pattern of line segments, which may or may not be connected to each other (like matches which have fallen at random on the ground).

In the `sp` package, an object of class `SpatialLines` represents a **list of lists of connected curves**, each curve consisting of a sequence of straight line segments that are joined together (like several pieces of a broken bicycle chain.)

So these two data types do not correspond exactly.

The list-of-lists hierarchy in a `SpatialLines` object is useful when representing internal divisions in a country. For example, if `USA` is an object of class `SpatialLines` representing the borders of the United States of America, then `USA@lines` might be a list of length 52, with `USA@lines[[i]]` representing the borders of the *i*-th State. The borders of each State consist of several different curved lines. Thus `USA@lines[[i]]@Lines[[j]]` would represent the *j*th piece of the boundary of the *i*-th State.

If `x` is an object of class `SpatialLines`, there are several things that you might want to do:

1. collect together all the line segments (all the segments that make up all the connected curves) and store them as a single object of class `psp`.

To do this, use `as(x, "psp")` or `as.psp(x)` to convert it to a spatial line segment pattern.

2. convert each connected curve to an object of class `psp`, keeping different connected curves separate.

To do this, type something like the following:

```
> out <- lapply(x@lines, function(z) { lapply(z@Lines, as.psp) })
```

(The conversion is performed by `as.psp.SpatialLines`, a function in `maptools`. So the `maptools` and `spatstat` packages must be loaded in order for this to work.)

The result will be a **list of lists** of objects of class `psp`. Each one of these objects represents a connected curve, although the `spatstat` package does not know that. The list structure will reflect the list structure of the original `SpatialLines` object `x`. If that’s not what you want, then use `curvelist <- do.call("c", out)` or

```
> curvegroup <- lapply(out, function(z) { do.call("superimpose", z)})
```

to collapse the list-of-lists-of-`psp`’s into a list-of-`psp`’s. In the first case, `curvelist[[i]]` is a `psp` object representing the *i*-th connected curve. In the second case, `curvegroup[[i]]` is a `psp` object containing all the line segments in the *i*-th group of connected curves (for example the *i*-th State in the USA example).

The window for the spatial line segment pattern can be specified as an argument `window` to the function `as.psp`.

(The conversion is performed by `as.psp.SpatialLines` or `as.psp.Lines`, which are functions in `maptools`.)

4.2.4 Objects of class `SpatialLinesDataFrame`

An object `x` of class `SpatialLinesDataFrame` is a `SpatialLines` object with additional data. The additional data is stored as a data frame `x@data` with one row for each entry in `x@lines`, that is, one row for each group of connected curves.

In the `spatstat` package, an object of class `psp` (representing a collection of line segments) may have a data frame of marks. Note that each *line segment* in a `psp` object may have different mark values.

If `x` is an object of class `SpatialLinesDataFrame`, there are two things that you might want to do:

1. collect together all the line segments that make up all the connected lines, and store them as a single object of class `psp`.

To do this, use `as(x, "psp")` or `as.psp(x)` to convert it to a marked spatial line segment pattern.

2. keep each connected curve separate, and convert each connected curve to an object of class `psp`. To do this, type something like the following:

```
> out <- lapply(x@lines, function(z) { lapply(z@Lines, as.psp) })
> dat <- x@data
> for(i in seq(nrow(dat)))
+   out[[i]] <- lapply(out[[i]], "marks<-", value=dat[i, , drop=FALSE])
```

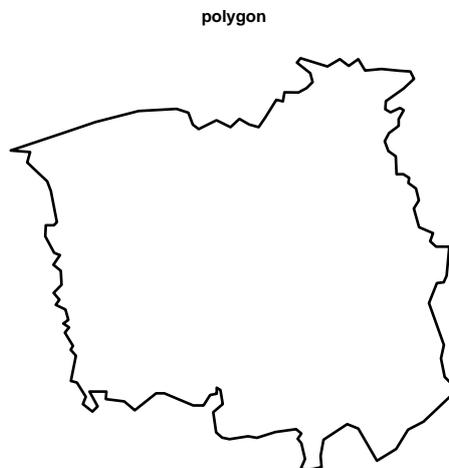
The result is a list-of-lists-of-`psp`'s. See the previous subsection for explanation on how to change this using `c()` or `superimposePSP`.

(The conversion is performed by `as.psp.SpatialLines`, a function in `maptools`. So the `maptools` and `spatstat` packages must be loaded in order for this to work.)

In either case, the mark variables attached to a particular *group of connected lines* in the `SpatialLinesDataFrame` object, will be duplicated and attached to each *line segment* in the resulting `psp` object.

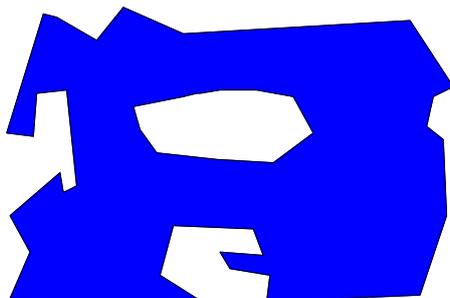
4.2.5 Objects of class `SpatialPolygons`

First, so that we don't go completely crazy, let's introduce some terminology. A *polygon* is a closed curve that is composed of straight line segments. You can draw a polygon without lifting your pen from the paper.



A *polygonal region* is a region in space whose boundary is composed of straight line segments. A polygonal region may consist of several unconnected pieces, and each piece may have holes. The boundary of a polygonal region consists of one or more polygons. To draw the boundary of a polygonal region, you may need to lift and drop the pen several times.

polygonal region



An object of class `owin` in `spatstat` represents a polygonal region. It is a region of space that is delimited by boundaries made of lines.

An object `x` of class `SpatialPolygons` represents a **list of polygonal regions**. For example, a single object of class `SpatialPolygons` could store information about every State in the United States of America (or the United States of Malaysia). Each State would be a separate polygonal region (and it might contain holes such as lakes).

There are two things that you might want to do with an object of class `SpatialPolygons`:

1. combine all the polygonal regions together into a single polygonal region, and convert this to a single object of class `owin`.

For example, you could combine all the States of the USA together and obtain a single object that represents the territory of the USA.

To do this, use `as(x, "owin")` or `as.owin(x)`. The result is a single window (object of class "owin") in the `spatstat` package.

2. keep the different polygonal regions separate; convert each one of the polygonal regions to an object of class `owin`.

For example, you could keep the States of the USA separate, and convert each State to an object of class `owin`.

To do this, type the following:

```
> regions <- slot(x, "polygons")
> regions <- lapply(regions, function(x) { SpatialPolygons(list(x)) })
> windows <- lapply(regions, as.owin)
```

The result is a list of objects of class `owin`. Often it would make sense to convert this to a tessellation object, by typing

```
> te <- tess(tiles=windows)
```

(The conversion is performed by `as.owin.SpatialPolygons`, a function in `maptools`. So the `maptools` and `spatstat` packages must be loaded in order for this to work.)

The following is different from what happened in previous versions of `spatstat` (prior to version 1.36-0.)

During the conversion process, the geometry of the polygons will be automatically “repaired” if needed. Polygon data from shapefiles often contain geometrical inconsistencies such as self-intersecting boundaries and overlapping pieces. For example, these can arise from small errors in curve-tracing. Geometrical inconsistencies are tolerated in an object of class `SpatialPolygons` which is a list of lists of polygonal curves. However, they are not tolerated in an object of class `owin`, because an `owin` must specify a well-defined region of space. These data inconsistencies must be repaired to prevent technical problems. `Spatstat` uses polygon-clipping code to automatically convert polygonal lines into valid polygon boundaries. The repair process changes the number of vertices in each polygon, and the number of polygons (if you chose option 1). To disable the repair process, set `spatstat.options(fixpolygons=FALSE)`.

4.2.6 Objects of class `SpatialPolygonsDataFrame`

What a mouthful!

An object `x` of class `SpatialPolygonsDataFrame` represents a list of polygonal regions, with additional variables attached to each region. It includes an object of class `SpatialPolygons` giving the spatial regions, and a data frame containing the additional variables attached to the regions. The regions are extracted by

```
> y <- as(x, "SpatialPolygons")
```

and you then proceed as above to convert the curves to `spatstat` format.

The data frame of auxiliary data is extracted by `df <- x@data` or `df <- slot(x, "data")`.

For example:

```
> cp <- as(columbus, "SpatialPolygons")
> cregions <- slot(cp, "polygons")
> cregions <- lapply(cregions, function(x) { SpatialPolygons(list(x)) })
> cwindows <- lapply(cregions, as.owin)
```

There is currently no facility in `spatstat` for attaching marks to an `owin` object directly.

However, `spatstat` supports objects called **hyperframes**, which are like data frames except that the entries can be any type of object. Thus we can represent the `columbus` data in `spatstat` as follows:

```
> ch <- hyperframe(window=cwindows)
> ch <- cbind.hyperframe(ch, columbus@data)
```

Then `ch` is a hyperframe containing a column of `owin` objects followed by the columns of auxiliary data.

4.2.7 Objects of class `SpatialGridDataFrame` and `SpatialPixelsDataFrame`

An object `x` of class `SpatialGridDataFrame` represents a pixel image on a rectangular grid. It includes a `SpatialGrid` object `slot(x, "grid")` defining the full rectangular grid of pixels, and a data frame `slot(x, "data")` containing the pixel values (which may include NA values).

The command `as(x, "im")` converts `x` to a pixel image of class `"im"`, taking the pixel values from the *first column* of the data frame. If the data frame has multiple columns, these have to be converted to separate pixel images in `spatstat`. For example

```
> y <- as(x, "im")
> ylist <- lapply(slot(x, "data"), function(z, y) { y[,] <- z; y }, y=y)
```

An object `x` of class `SpatialPixelsDataFrame` represents a *subset* of a pixel image. To convert this to a `spatstat` object, it should first be converted to a `SpatialGridDataFrame` by `as(x, "SpatialGridDataFrame")`, then handled as described above.