Lesson 2: Wrangling Geospatial Data in R

sf approach and methods

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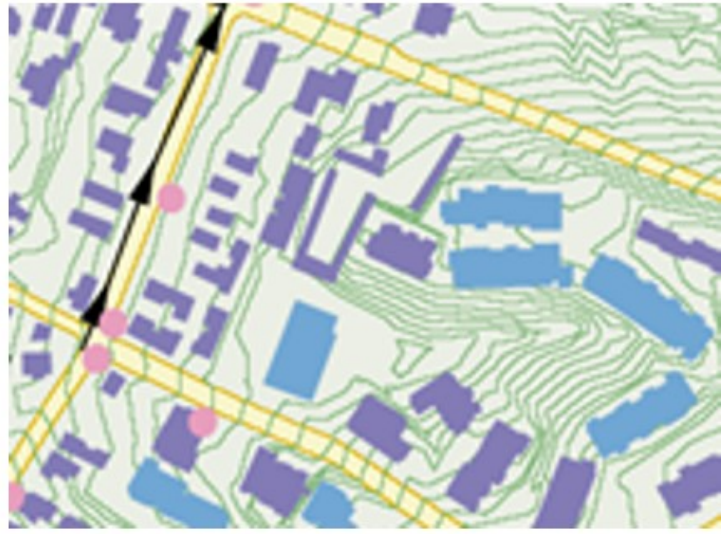
Content

- An overview of Geospatial Data Models
  - Vector and raster data model
  - Coordinate systems and map projection
- Handling Geospatial Data in R: An Overview
- Simple features approach
  - **sf** package

Geospatial Data Models

Why should we worry about?

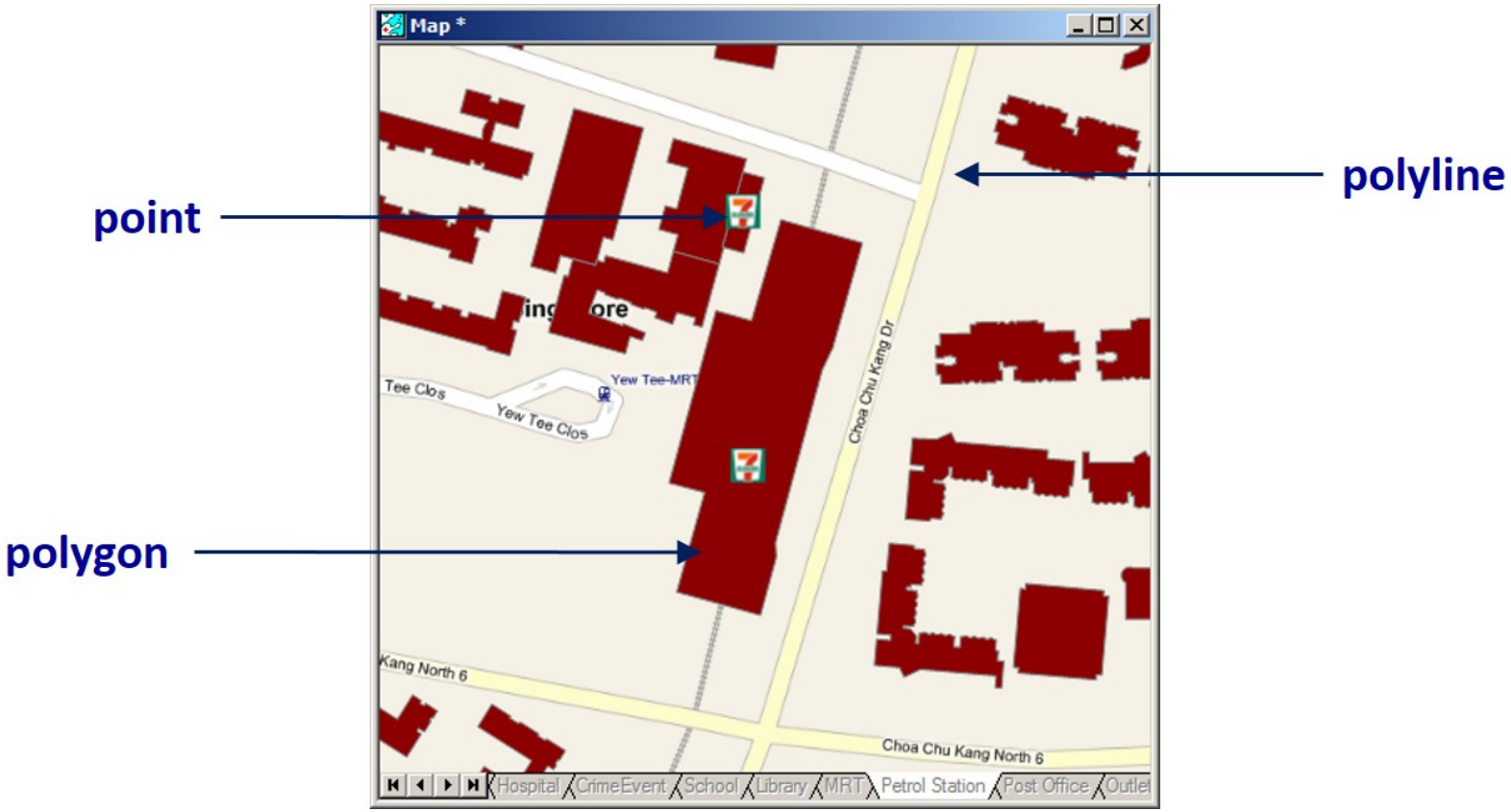


Basic Spatial Data Models

- Vector - implementation of discrete object conceptual model
  - Point, line and polygon representations.
  - Widely used in cartography, and network analysis.
- Raster – implementation of field conceptual model
  - Array of cells used to represent objects.
  - Useful as background maps and for spatial analysis.

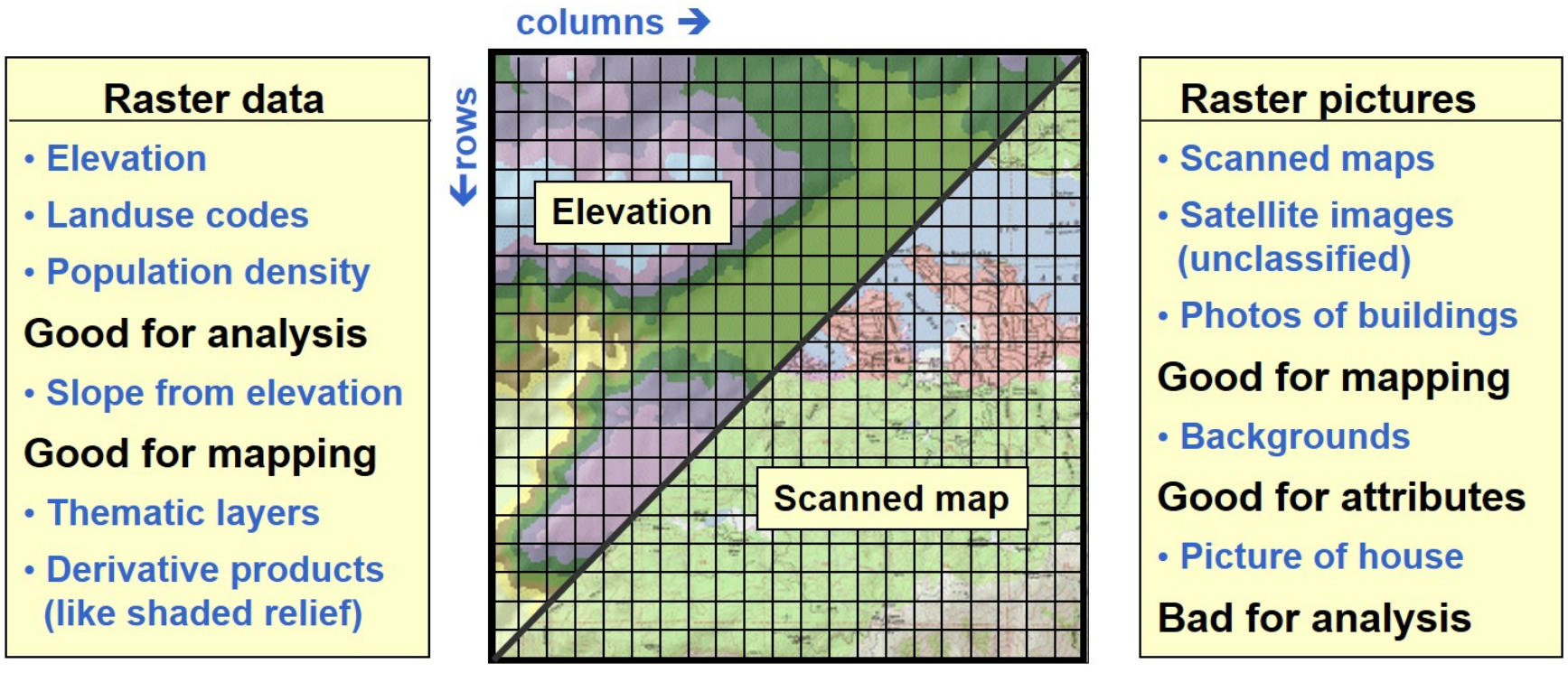
Vector Data Models

- There are three basic geometric primitives, namely: **points**, **lines (or polylines)** and **polygons**.



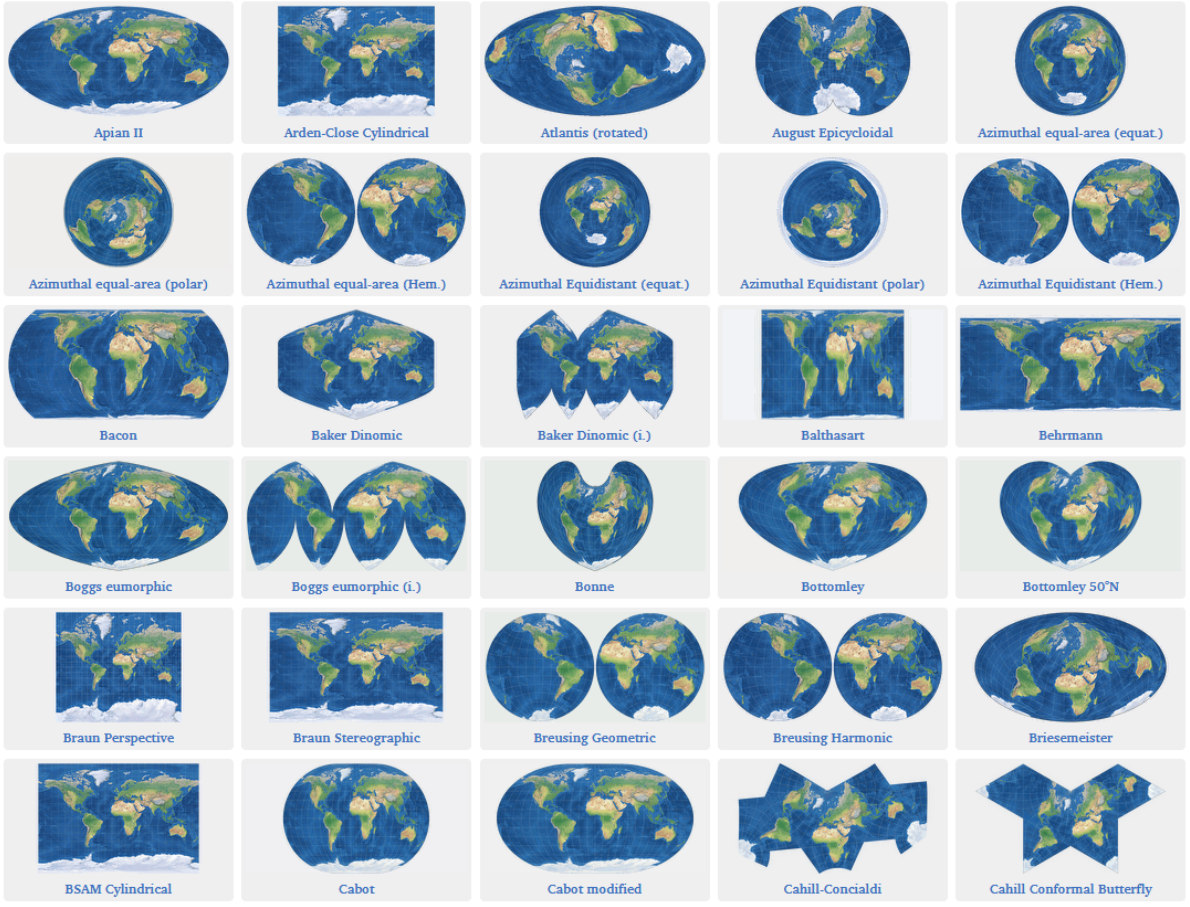
Raster Data Models

- All raster formats are basically the same
  - Cells organized in a matrix of rows and columns.
  - Content is more important than format: data or picture?

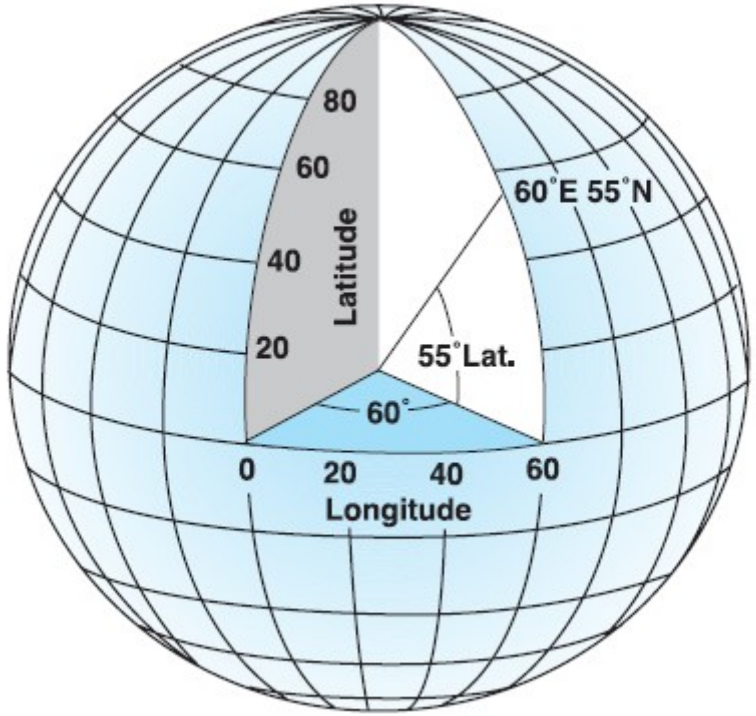


Coordinate Systems and Map Projections

What is a coordinate system?



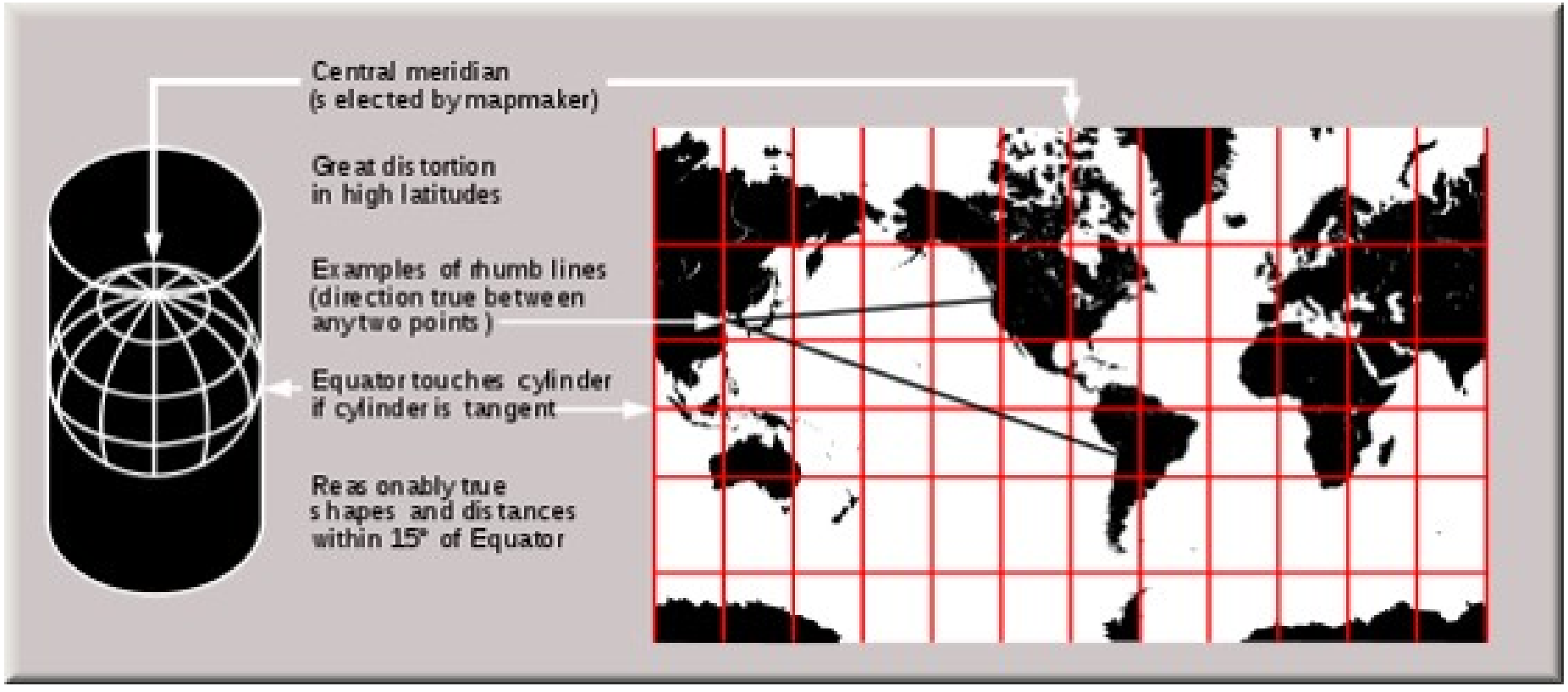
Geographical Coordinate Systems



Reference: http://en.wikipedia.org/wiki/Map_projection

Projected Coordinate Systems

- Based on a map projection such as transverse Mercator, Albers equal area, or Robinson.



Singapore Projected Coordinate System

Old → **New**

Cassini-Soldner	Transverse Mercator
Spheroid: Revised Everest Datum: ASA(Kertau) Projection origin: 103deg 51 min 10.78 sec long 1 deg 17 min 15.08 sec lat	Spheroid: WGS-84 Datum: SVY21 Projection origin: 103 deg 50 min long 1 deg 22 min lat

- epsg.io provides a comprehensive list of country coordinate systems such as svy21.

Coordinates Reference Systems in R

- In R, the notation used to describe the CRS is **proj4string** from the **PROJ.4** library. It looks like this:

> +proj=tmerc +lat_0=1.36666666666667 +lon_0=103.833333333333 +k=1 +x_0=28001.642 +y_0=38744.572 +ellps=WGS84 +units=m +no_defs

- This library is interfaced with R in the **rgdal** package, and the CRS class is defined partly in **sp**, partly in **rgdal**.
- A **CRS** object is defined as a character NA string or a valid PROJ.4 CRS definition.

Standard for Geospatial Data Handling and Analysis

OGC® Making location count.

ABOUT MEMBERSHIP STANDARDS & RESOURCE

Simple Feature Access - Part 1: Common Architecture

1) Overview

Currently, the ISO 19125: Simple Features SWG is working to update the OGC Simple Features standards. The purpose of the ISO 19125 SWG is to update the common standard that is both the OGC Simple Features Implementation Standard and the ISO 19125 Standards (Part 1: Common Architecture, and Part 2 SQL Option) to:

- Maintain and correct the current standard,
- Synchronize with SQL/MM: Part 3 Spatial,
- Introduce new geometry types,
- Support 3D coordinates, and Linear reference systems including segmented attributes.

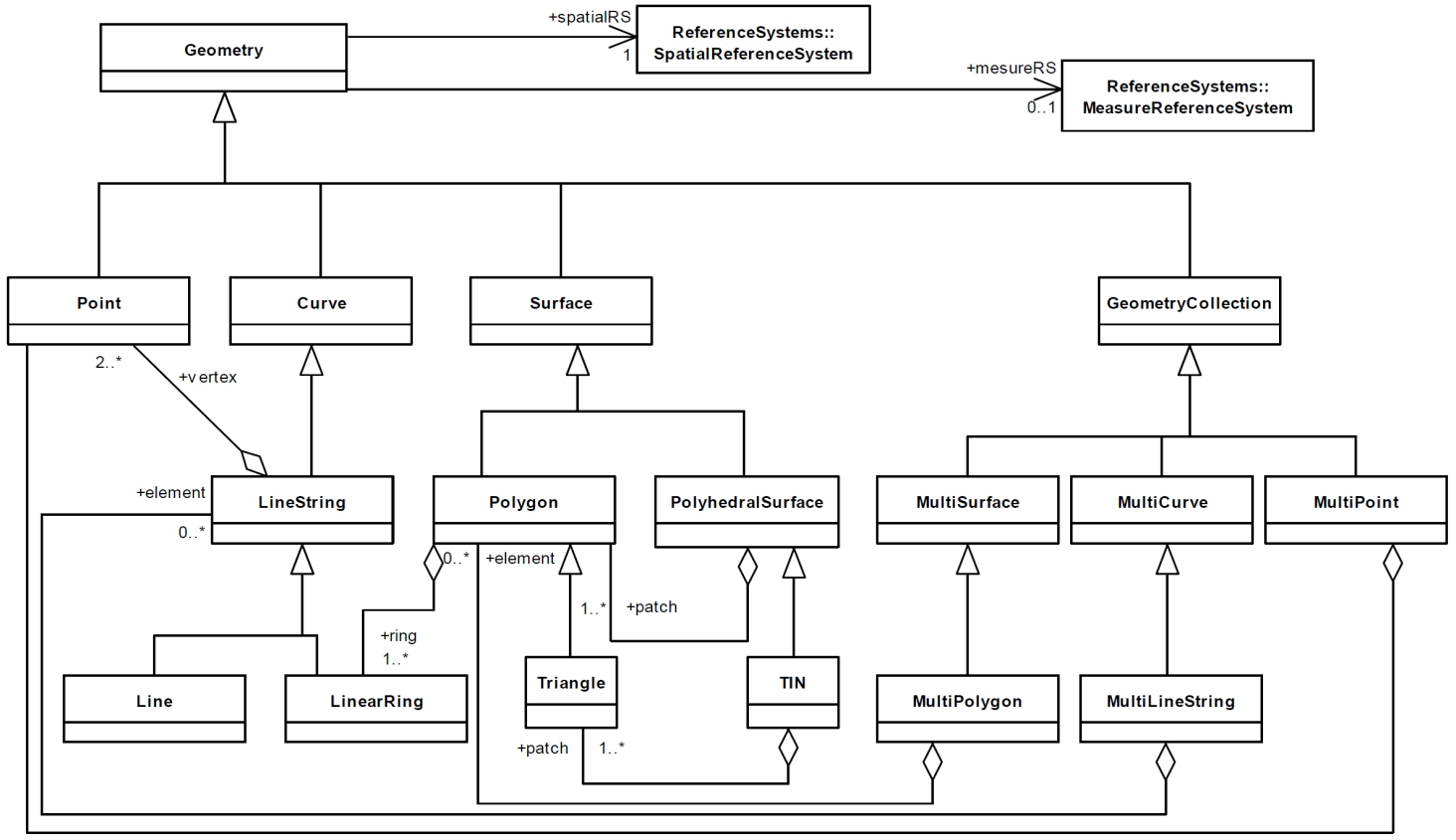
For more information, visit this link.

An introduction to simple features

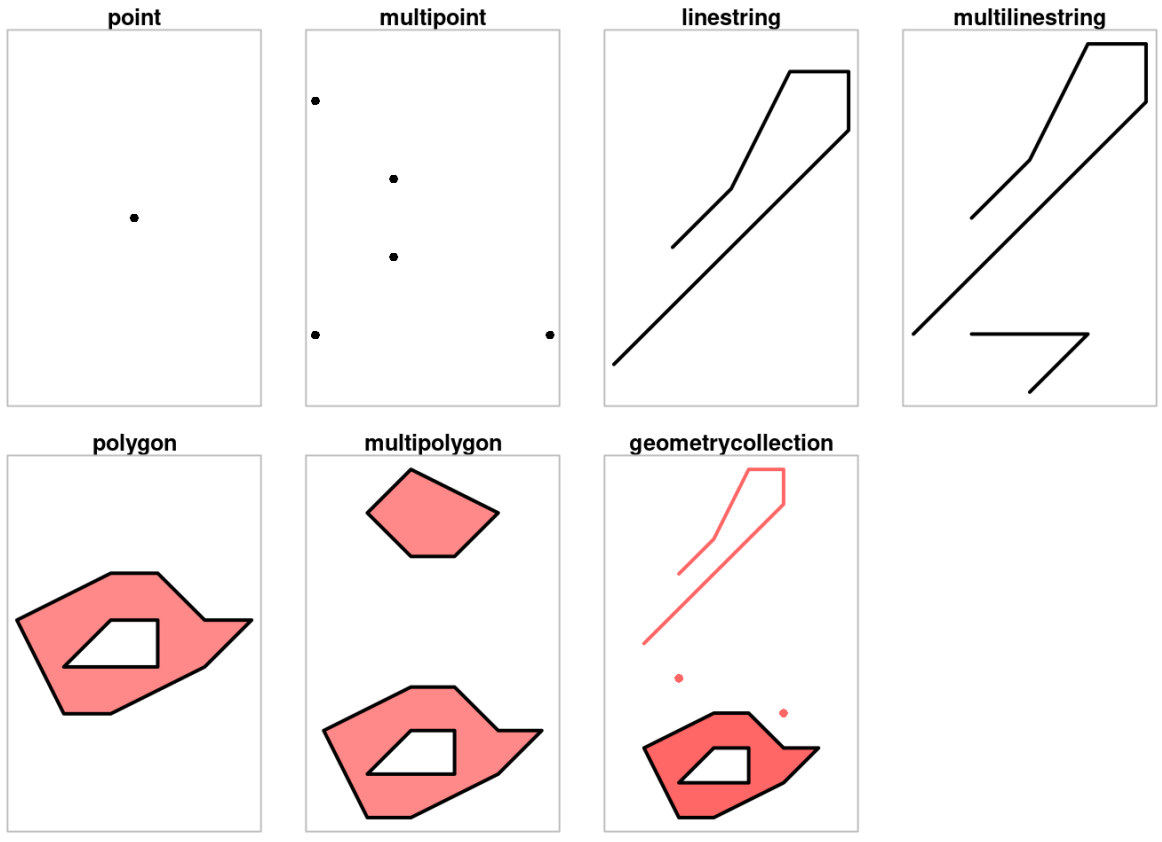
- **feature**: abstraction of real world phenomena (type or instance); has a geometry and other attributes (properties)
- **simple feature**: feature with all geometric attributes described piecewise by straight line or planar interpolation between sets of points (no curves)
- It is a hierarchical data model that simplifies geographic data by condensing a complex range of geographic forms into a single geometry class.

Simple features specification

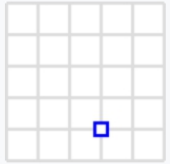
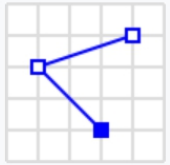
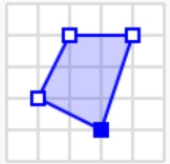
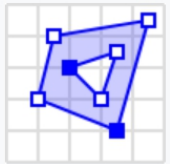
- *Simple features specification* is an open standard developed and endorsed by the Open Geospatial Consortium (OGC) to represent a wide range of geographic information.



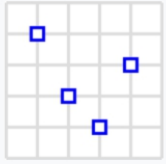
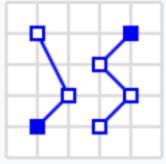
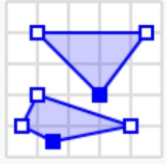
Commonly used simple features



Simple Features: How they look like?

Type	Examples	
Point		`POINT (30 10)`
LineString		`LINESTRING (30 10, 10 30, 40 40)`
Polygon		`POLYGON ((30 10, 40 40, 20 40, 10 20, 30 10))`
		`POLYGON ((35 10, 45 45, 15 40, 10 20, 35 10), (20 30, 35 35, 30 20, 20 30))`

Simple Features: How they look like?

Type	Examples	
MultiPoint		`MULTIPOINT ((10 40), (40 30), (20 20), (30 10))`
		`MULTIPOINT (10 40, 40 30, 20 20, 30 10)`
MultiLineString		`MULTILINESTRING ((10 10, 20 20, 10 40), (40 40, 30 30, 40 20, 30 10))`
MultiPolygon		`MULTIPOLYGON (((30 20, 45 40, 10 40, 30 20)), ((15 5, 40 10, 10 20, 5 10, 15 5)))`
		`MULTIPOLYGON (((40 40, 20 45, 45 30, 40 40)), ((20 35, 10 30, 10 10, 30 5, 45 20, 20 35), (30 20, 20 15, 20 25, 30 20)))`

Geospatial Data Object Framework

- To begin with, all contributed packages for handling spatial data in R had different representations of the data. This made it difficult to exchange data both within R between packages, and between R and external le formats and applications.
- The first general package to provide classes and methods for spatial data types that was developed for R is called **sp**. It was first released on CRAN in 2005.
- In late October 2016, **sf** was first released on CRAN to provide standardised support for vector data in R.

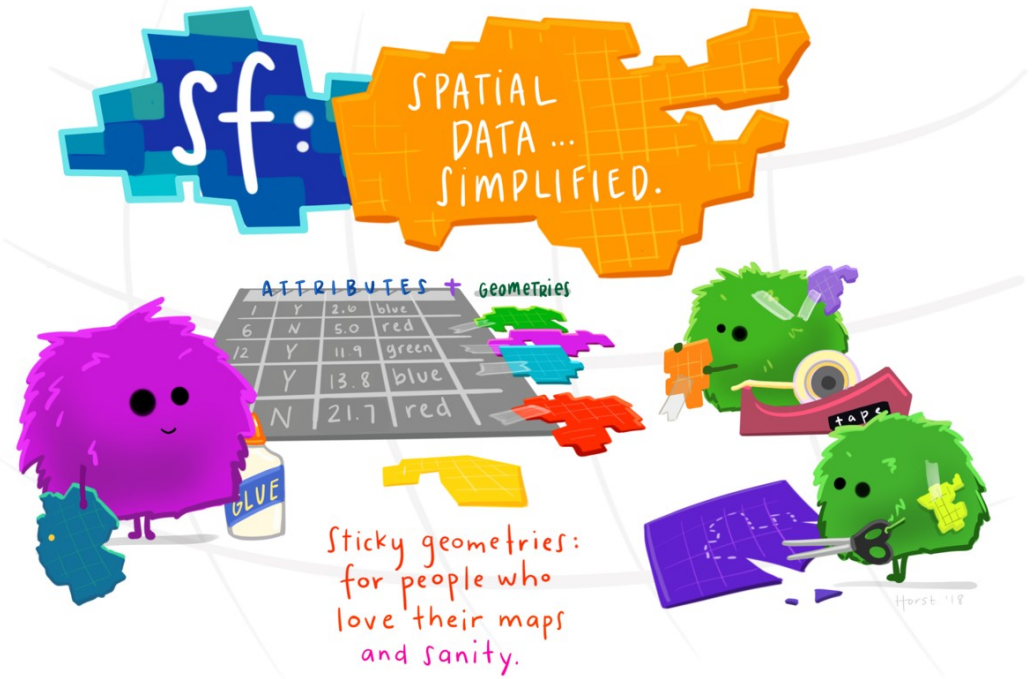
R packages that support spatial classes

In general, three R packages will be used to handle vector-based geospatial data in spatial classes, they are:

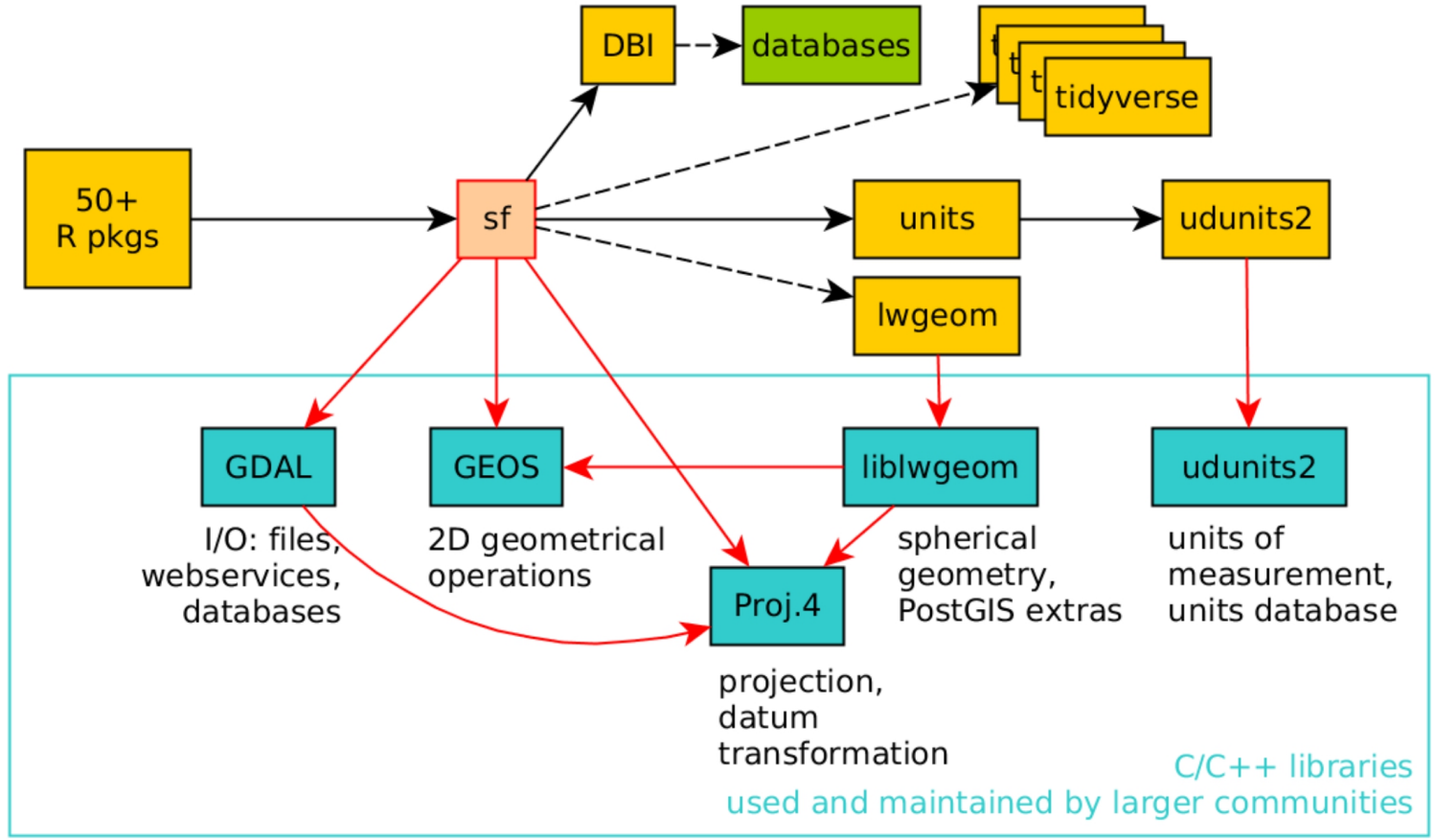
- **sp** provides classes and methods for dealing with spatial data in R.
- **rgdal** allows R to understand the structure of a geospatial data file by providing functions to read and convert geospatial data into easy-to-work-with R dataframes.
- **rgeos** implements the methods of the OGC standard.

Introducing sf Package

- **sf** package provides a syntax and data-structures which are coherent with the tidyverse.
- A quick introduction can be found here.
- For more detail, visit this link.



sf package dependencies



Source: Tidy spatial data analysis

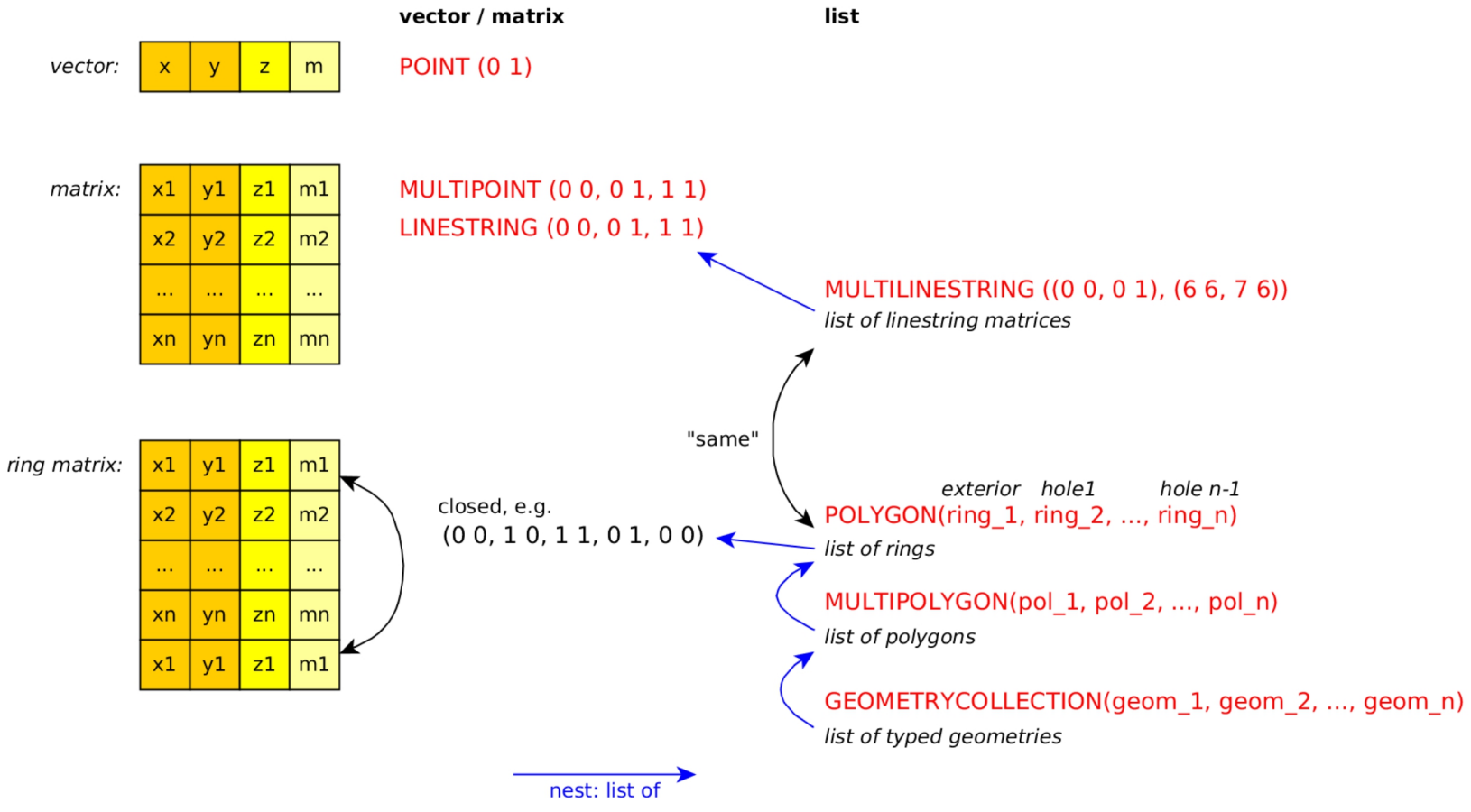
sf & tidyverse

- sf spatial objects are data.frames (or tibbles)
- you can always un-sf, and work with tbl_df or data.frame having an sfc list-column
- sf methods for filter, arrange, distinct, group_by, ungroup, mutate, select have sticky geometry
- *st_join()* joins tables based on a spatial predicate
- summarise unions geometry by group (or altogether)

What is so special about sf?

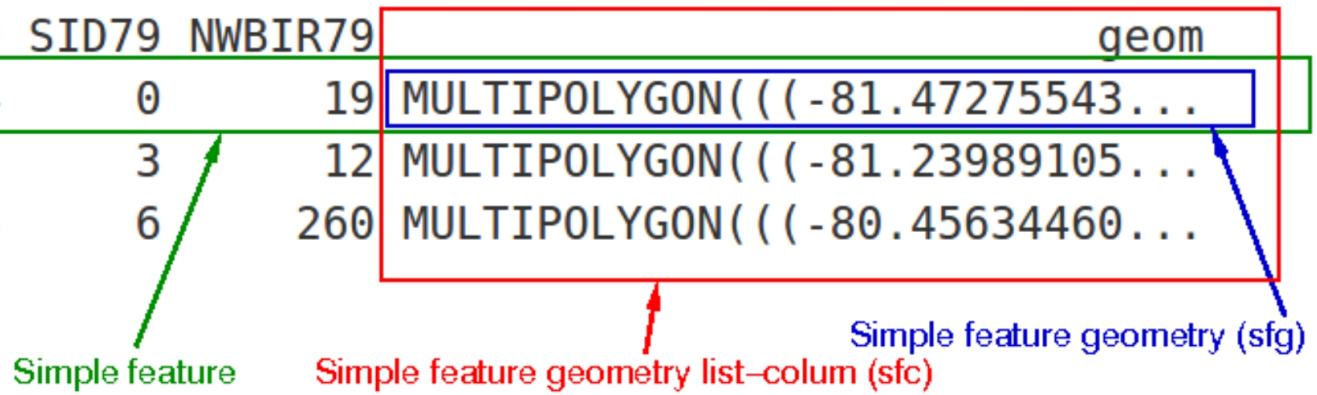
- It builds upon the simple features standard (not R specific!), represents natively in R all 17 simple feature types for all dimensions (XY, XYZ, XYM, XYZM),
- uses S3 classes: simple features are data.frame objects (or tibbles) that have a geometry list-column,
- interfaces to GEOS to support the DE9-IM,
- interfaces to GDAL with driver dependent dataset or layer creation options, Date and DateTime (POSIXct) columns, and coordinate reference system,
- transformations through PROJ.4,
- provides fast I/O with GDAL and GEOS using well-known-binary written in C++/Rcpp, and
- directly reads from and writes to spatial databases such as PostGIS using DBI.

sfg : geometry for one feature



sf: objects with simple features

```
## Simple feature collection with 100 features and 6 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
## precision:      double (default; no precision model)
## First 3 features:
##   BIR74 SID74 NWBIR74 BIR79 SID79 NWBIR79                              geom
## 1  1091     1       10  1364     0       19 MULTIPOLYGON(((-81.47275543...
## 2   487     0       10   542     3       12 MULTIPOLYGON(((-81.23989105...
## 3  3188     5      208  3616     6      260 MULTIPOLYGON(((-80.45634460...
```



sf functions

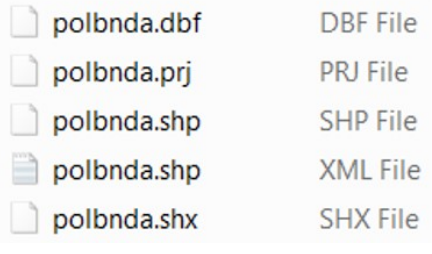
- Geospatial data handling
- Geometric confirmation
- Geometric operations
- Geometry creation
- Geometry operations
- Geometric measurement

Geospatial data handling functions

- *st_read* & *read_sf*: read simple features from file or database, or retrieve layer names and their geometry type(s)
- *st_write* & *write_sf*: write simple features object to file or database
- *st_as_sf*: convert a sf object from a non-geospatial tabular data frame
- *st_as_text*: convert to Well Known Text(WKT)
- *st_as_binary*: convert to Well Known Binary(WKB)
- *st_as_sfc*: convert geometries to sfc (e.g., from WKT, WKB) as(x, "Spatial"): convert to Spatial*
- *st_transform*(x, crs, ...): convert coordinates of x to a different coordinate reference system

Popular geospatial data format supported by *read_st()*: ESRI shapefile

- A shapefile is a simple, non-topological format for storing the geometric location and attribute information of geographic features.
- Geographic features in a shapefile can be represented by points, lines, or polygons (areas).



Sample code chunk:

```
sf_mpsz = st_read(dsn = "data/geospatial",
                  layer = "MP14_SUBZONE")
```

and

```
st_write(st_poly, "data/my_poly.shp")
```

Other vector GIS formats

- MapInfo TAB format - MapInfo's vector data format using TAB, DAT, ID and MAP files.
- Personal Geodatabase - Esri's closed, integrated vector data storage strategy using Microsoft's Access MDB format
- Keyhole Markup Language (KML) - XML based open standard (by OpenGIS) for GIS data exchange.
- Geography Markup Language (GML) - XML based open standard (by OpenGIS) for GIS data exchange.
- GeoJSON - a lightweight format based on JSON, used by many open source GIS packages.
- TopoJSON, an extension of GeoJSON that encodes topology.

Sample code chunk to import kml file:

```
sf_preschool = st_read("data/geospatial/pre-schools-location-kml.kml")
```

Geometric confirmation

- *st_intersects*: touch or overlap
- *st_disjoint*: !intersects
- *st_touches*: touch
- *st_crosses*: cross (don't touch)
- *st_within*: within
- *st_contains*: contains
- *st_overlaps*: overlaps
- *st_covers*: cover
- *st_covered_by*: covered by
- *st_equals*: equals
- *st_equals_exact*: equals, with some fuzz

  returns a sparse (default) or dense logical matrix

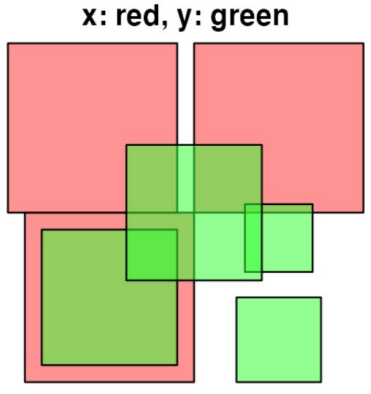
Note: These functions return a logical matrix indicating whether each geometry pair meeting the logical operation.

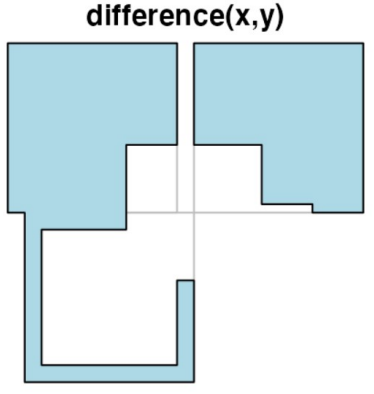
```
> st_intersects(sf_mpsz3414, sf_preschool3414)
Sparse geometry binary predicate list of length 323,
where the predicate was `intersects'
first 10 elements:
 1: (empty)
 2: 84, 85, 620, 660, 661
 3: (empty)
 4: 10, 13
 5: 737
 6: 14, 79, 623, 731, 732, 734, 735, 736, 738, 739
 7: 619, 656, 657, 658
 8: 86, 663, 672, 673
 9: 41, 45, 696
 10: 618
```

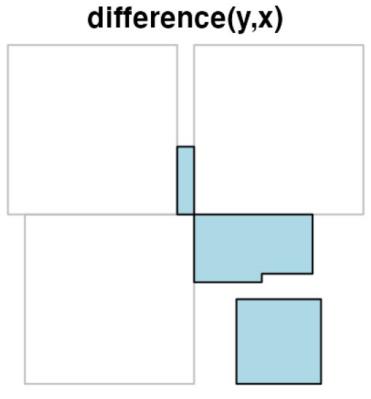
sf Methods

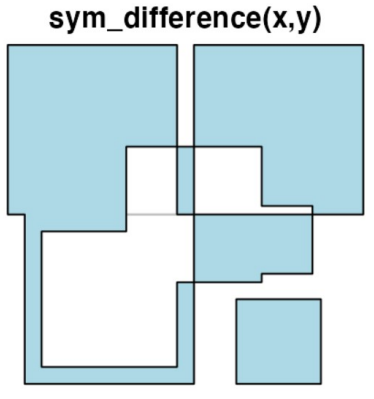
Geometry generating logical operators

- st_union: union of several geometries
- st_intersection: intersection of pairs of geometries
- st_difference: difference between pairs of geometries
- st_sym_difference: symmetric difference (xor)







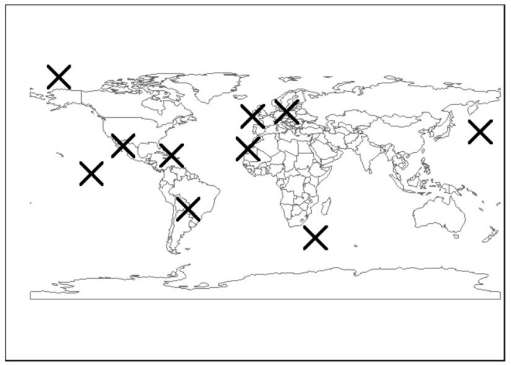


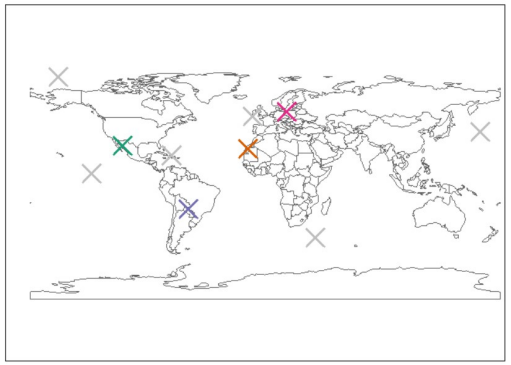
sf Methods

Higher-level operations: summarise, interpolate, aggregate, st_join

- aggregate and summarise use *st_union* (by default) to group feature geometries
- *st_interpolate_aw*: area-weighted interpolation, uses st_intersection to interpolate or redistribute attribute values, based on area of overlap:
- *st_join* uses one of the logical binary geometry predicates (default: st_intersects) to join records in table pairs

```
rd_joined = st_join(random_points, world)
```

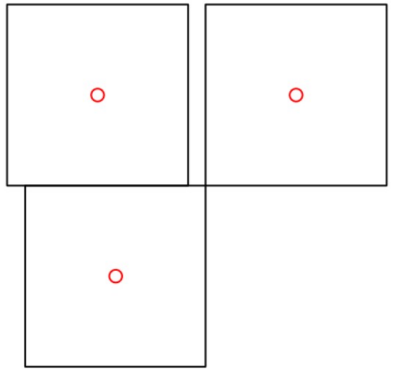




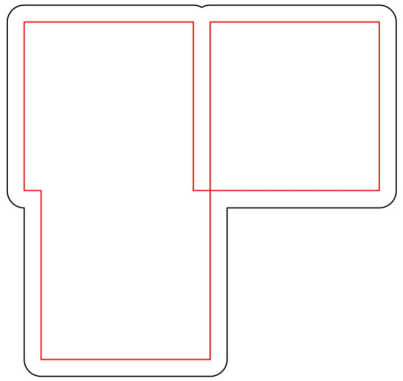
Manipulating geometries

- *st_line_merge*: merges lines
- *st_segmentize*: adds points to straight lines
- *st_voronoi*: creates voronoi tesselation
- *st_centroid*: gives centroid of geometry
- *st_convex_hull*: creates convex hull of set of points
- *st_triangulate*: triangulates set of points (not constrained)
- *st_polygonize*: creates polygon from lines that form a closed ring
- *st_simplify*: simplifies lines by removing vertices
- *st_split*: split a polygon given line geometry
- *st_buffer*: compute a buffer around this geometry/each geometry
- *st_make_valid*: tries to make an invalid geometry valid (requires lwgeom)
- *st_boundary*: return the boundary of a geometry

```
centroid_poly <- st_centroid(poly)
```



```
buf_poly <- st_buffer(poly, 5)
```



Convenience functions

- *st_zm*: sets or removes z and/or m geometry
- *st_coordinates*: retrieve coordinates in a matrix or data.frame
- *st_geometry*: set, or retrieve sfc from an sf object
- *st_is*: check whether geometry is of a particular type

```
> st_geometry(sf_preschool3414)
Geometry set for 1359 features
Geometry type: POINT
Dimension:     XYZ
Bounding box:  xmin: 11203.01 ymin: 25667.6
 xmax: 45404.24 ymax: 49300.88
z_range:       zmin: 0 zmax: 0
Projected CRS: SVY21 / Singapore TM
First 5 geometries:
POINT Z (19997.26 32333.17 0)
POINT Z (19126.75 33114.35 0)
POINT Z (20345.12 31934.56 0)
POINT Z (20400.31 31952.36 0)
POINT Z (19810.78 33140.31 0)
```

References

All About sf package

- Reference manual
- Tidy spatial data analysis

Vignettes:

1. Simple Features for R
2. Reading, Writing and Converting Simple Features
3. Manipulating Simple Feature Geometries
4. Manipulating Simple Features
5. Plotting Simple Features
6. Miscellaneous

Others

1. R spatial follows GDAL and PROJ development