Coordinates and Geometries

HES 505 Fall 2023: Session 7

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Map
OF THE MINING SECTIONS OF
IDAHO & OREGON
embracing the GOLD and SILVER mines of
BOISE & OWYHEE
BY GEO. WOODMAN
compiled chiefly from notes of his travels and Surveys
during the last 18 months
PUBLISHED BY A. GENSOUL
511 Montgomery St. San Francisco
REFERENCE.
Sage Desert
Humboldt Mines
Salt Lake City

Today's Plan

Objectives

- Understand the linkage between location, coordinates, coordinate reference systems, and geometry
- Access and manipulate geometries in `R` with `sf` (and `terra`)
- Define `geometry` in the context of vector objects and troubleshoot common problems
- Change the CRS for vectors and rasters (and understand the implications)

But first…

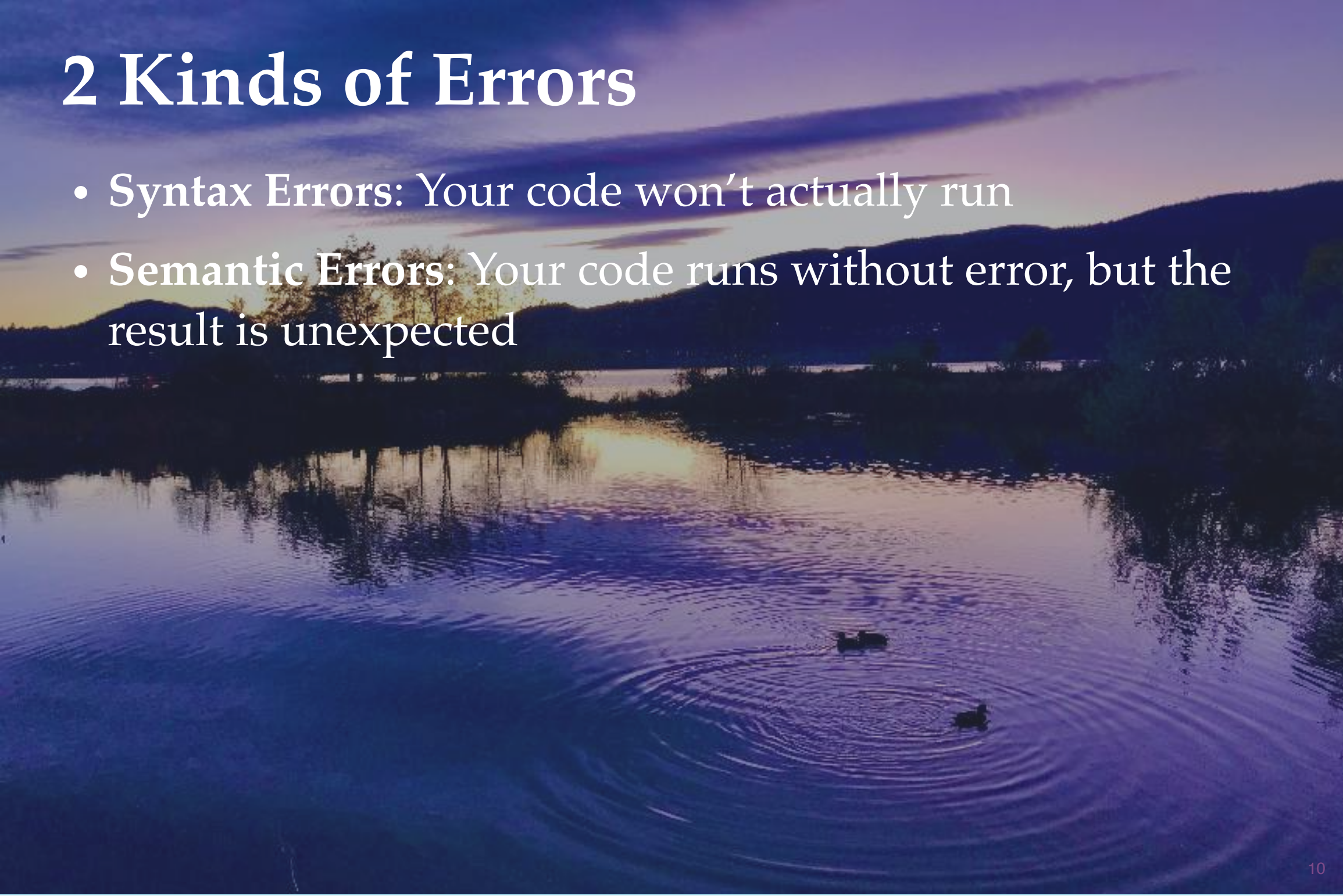
Getting more acquainted with R

- Objects, classes, functions, oh my…
- Intuition for the `tidyverse`
- Getting used to pipes (`%>%` or `|>`)
- Learning to prototype

Getting help

2 Kinds of Errors

- **Syntax Errors**: Your code won't actually run
- **Semantic Errors**: Your code runs without error, but the result is unexpected



Asking better questions, getting better answers

- Places to get help (Google, Slack, Stack Overflow, Github Issue pages)
- What are you trying to do? (the outcome you want/expect)
- What isn't working? (the code and steps you've tried so far)
- Why aren't common solutions working? (proof that you've done your due diligence)

Reproducible examples

- Don’t require someone to have your data or your computer
- Minimal amount of information and code to reproduce your error
- Includes both code and your operating environment info
- More info
- An example with spatial data

Coordinates and Geometries

Reference Systems

- To locate an object or quantity, we need:
  - A fixed *origin* (or **datum**) to measure distances to/from
  - A *measurement unit* (or **scale**) that defines the units of distance
  - **Datum + scale = reference system**

Coordinate Reference Systems

- Map the location on an object to earth (geodetic) or flat (projected) surfaces
- **Coordinate System** - the mathematical rules that specify how coordinates are assigned to points
- **Datum** - the parameter or set of parameters that define the position of the origin, the scale, and the orientation of a coordinate system
- **Coordinate Reference Systems** - a coordinate system that is related to an object by a datum

Accessing CRS with R

- `sf::st_crs()` for vector data
- `terra::crs()` for raster data
- stored in WKT, epsg, or proj4string (deprecated)
- The EPSG website is a great reference for getting projection info

Accessing CRS with R

```
dir.for.files <- "/Users/mattwilliamson/Library/CloudStorage/GoogleDrive-ma
vector.data <- sf::st_read(dsn = paste0(dir.for.files, "cejst_nw.shp"), qui
sf::st_crs(x = vector.data)$input
```

```
[1] "WGS 84"
```

```
sf::st_crs(x = vector.data)$proj4string
```

```
[1] "+proj=longlat +datum=WGS84 +no_defs"
```

```
sf::st_crs(x = vector.data)$wkt
```

```
[1] "GEOGCRS[\"WGS 84\",\n    DATUM[\"World Geodetic System 1984\",\n
ELLIPSOID[\"WGS 84\",6378137,298.257223563,\n
LENGTHUNIT[\"metre\",1]]],\n    PRIMEM[\"Greenwich\",0,\n
ANGLEUNIT[\"degree\",0.0174532925199433]],\n    CS[ellipsoidal,2],\n
AXIS[\"latitude\",north,\n            ORDER[1],\n
ANGLEUNIT[\"degree\",0.0174532925199433]],\n        AXIS[\"longitude\",east,\n
ORDER[2],\n            ANGLEUNIT[\"degree\",0.0174532925199433]],\n
ID[\"EPSG\",4326]]"
```

Accessing CRS with R

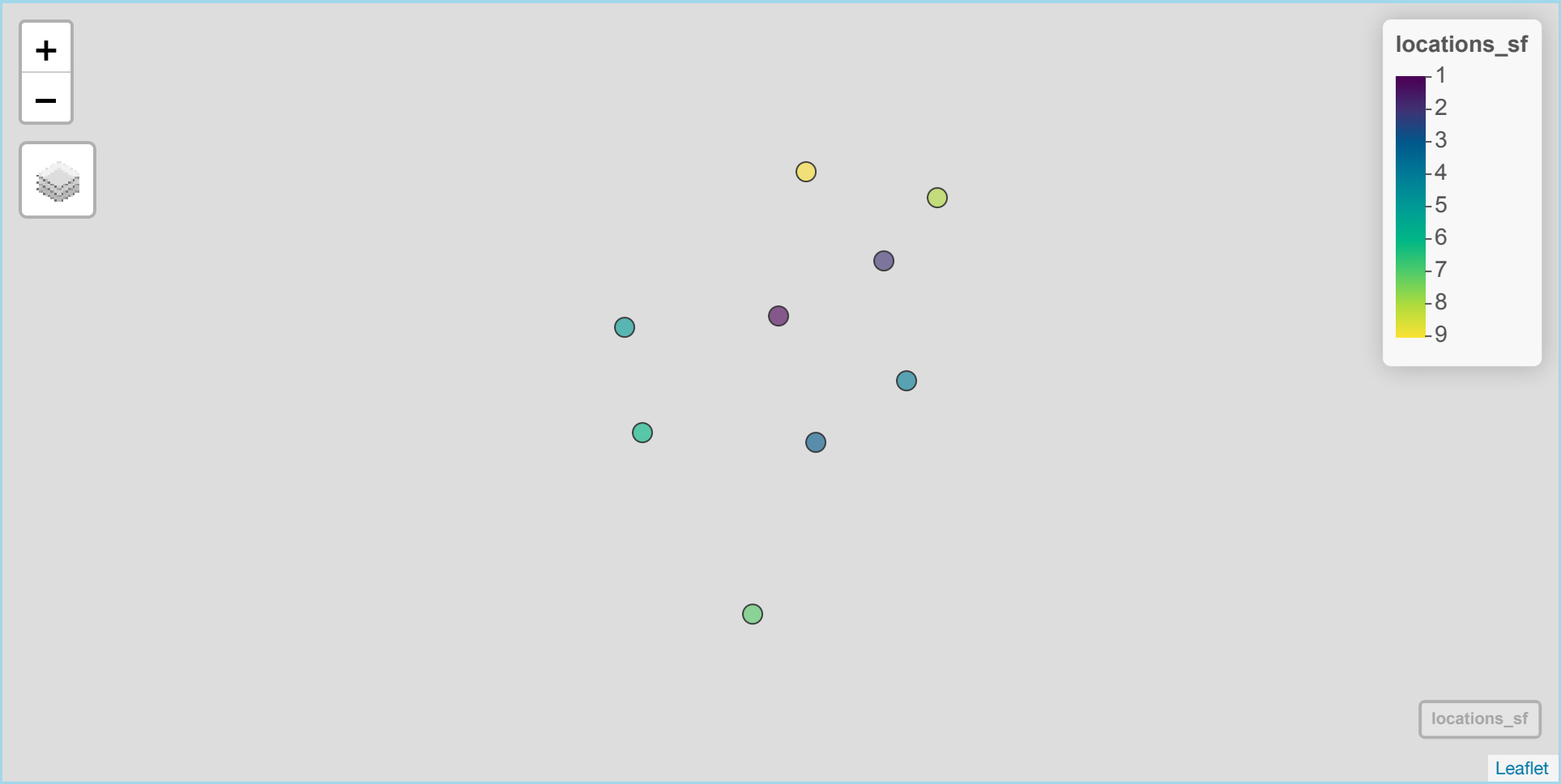
```
raster.data <- terra::rast(x = paste0(dir.for.files, "wildfire_hazard_agg.t
terra::crs(raster.data, describe=TRUE, proj=TRUE)
```

```
     name authority code area          extent
1 unnamed      <NA> <NA> <NA> NA, NA, NA, NA

proj
1 +proj=aea +lat_0=23 +lon_0=-96 +lat_1=29.5 +lat_2=45.5 +x_0=0 +y_0=0
+datum=NAD83 +units=m +no_defs
```

What if you don't know the CRS?

- Sometimes you receive data that is missing the projection
- You can assign it (**with caution**)
- You can guess it using `crsuggest::guess_crs()`

```
library(sf)
library(mapview)
locations <- data.frame(
  X = c(1200822.97857801, 1205015.51644983, 1202297.44383987, 1205877.68696
        1194763.21511923, 1195463.42403192, 1199836.01037452, 1207081.96500
        1201924.15986897),
  Y = c(1246476.31475063, 1248612.72571423, 1241479.45996392, 1243898.58428
        1246033.7550009, 1241827.7730307, 1234691.50899912, 1251125.6780848
        1252188.4333016),
  id = 1:9
)

locations_sf <- st_as_sf(locations, coords = c("X", "Y"))
```

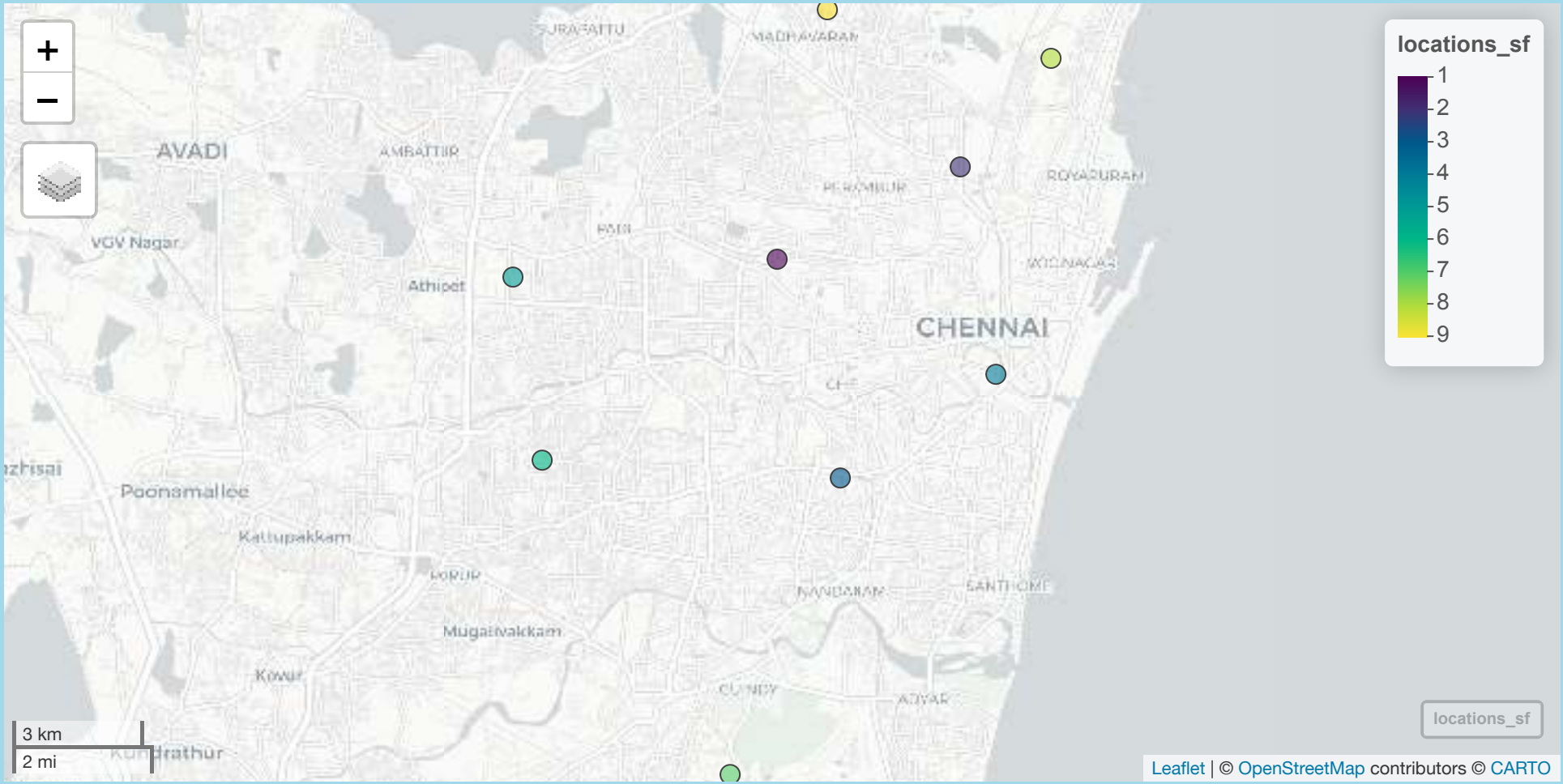

locations_sf
1
2
3
4
5
6
7
8
9
locations_sf
Leaflet

Guessing CRS

```r
library(crsuggest)
guess_crs(locations_sf, "Chennai, India", n_return = 5)
```

```
# A tibble: 5 × 2
  crs_code dist_km
  <chr>      <dbl>
1 7785        4.07
2 24344     806.
3 32644     806.
4 32244     806.
5 32444     806.
```

```r
st_crs(locations_sf) <- 7785
```


locations_sf
1
2
3
4
5
6
7
8
9
AVADI
AMBATTUR
VGV Nagar
Athipet
CHENNAI
Poonamallee
Kattupakkam
Mugaiyakkam
Kovur
ADYAR
3 km
2 mi
locations_sf
Leaflet | © OpenStreetMap contributors © CARTO

All spatial analysis and mapping requires that your data is aligned correctly.

Changing the CRS

- Requires recomputing coordinates
- Coordinate Conversion - No change to the datum; lossless
- Coordinate Transformation - New datum; relies on models; some error involved

Changing the CRS in R

- `sf::st_transform` for vectors
- `terra::project` for rasters
- **Projecting Rasters Causes Distortion**

Changing the CRS in R

```
vector.data.proj <- vector.data %>%
  sf::st_transform(., crs = 3083)
st_crs(vector.data.proj)$input
```

```
[1] "EPSG:3083"
```

```
vector.data.proj.rast <- vector.data %>%
  sf::st_transform(., crs = crs(raster.data))
st_crs(vector.data.proj.rast)$proj4string
```

```
[1] "+proj=aea +lat_0=23 +lon_0=-96 +lat_1=29.5 +lat_2=45.5 +x_0=0 +y_0=0
+datum=NAD83 +units=m +no_defs"
```

Changing the CRS in R

```
raster.data.proj <- project(x = raster.data, y = "EPSG:3083")
crs(raster.data.proj, describe=TRUE, proj=TRUE)
```

```
                                    name authority code
1 NAD83 / Texas Centric Albers Equal Area      EPSG 3083
                          area                          extent
1 United States (USA) - Texas -106.66, -93.50, 36.50, 25.83

proj
1 +proj=aea +lat_0=18 +lon_0=-100 +lat_1=27.5 +lat_2=35 +x_0=1500000
+y_0=6000000 +datum=NAD83 +units=m +no_defs
```

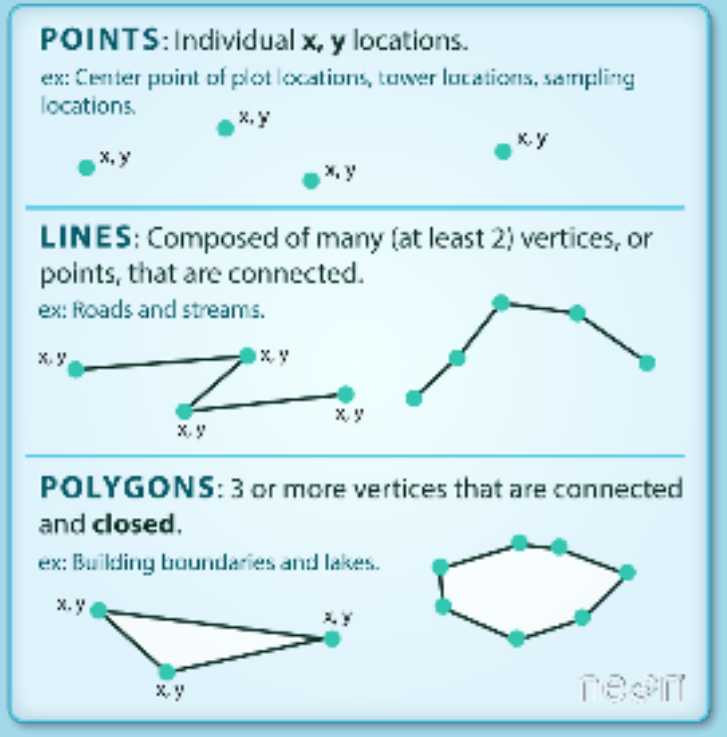
```
raster.data.proj.vect <- project(x = raster.data, y = vect(vector.data))
crs(raster.data.proj.vect, describe=TRUE, proj=TRUE)
```

```
    name authority code area         extent
proj
1 WGS 84       EPSG 4326 <NA> NA, NA, NA, NA +proj=longlat +datum=WGS84
+no_defs
```

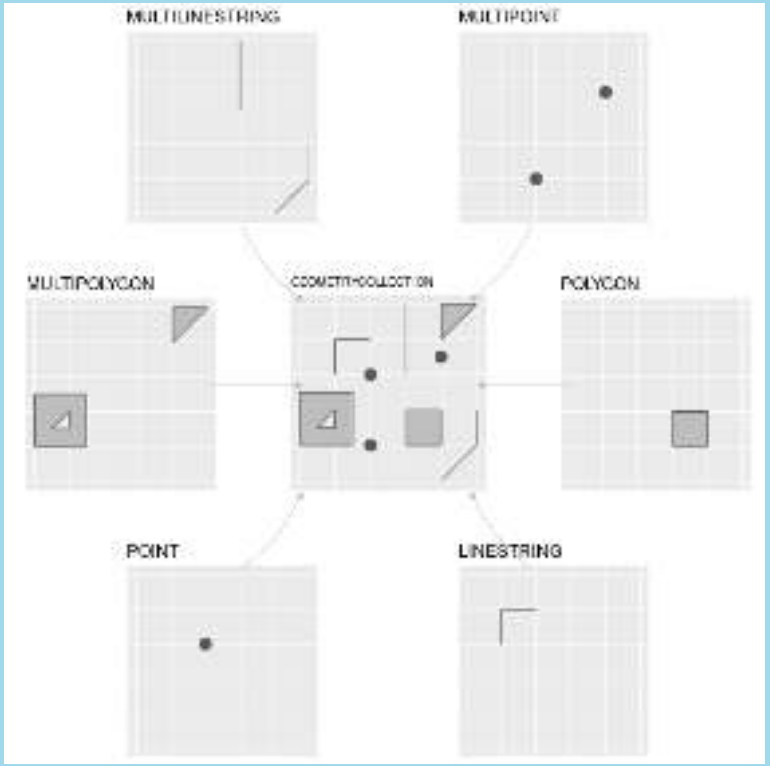
Geometries

The Vector Data Model

- Coordinates define the **Vertices** (i.e., discrete x-y locations) that comprise the geometry
- The organization of those vertices define the *shape* of the vector
- General types: points, lines, polygons



Representing vector data in R



From Lovelace et al.

- `sf` hierarchy reflects increasing complexity of geometry
  - `st_point`, `st_linestring`, `st_polygon` for single features
  - `st_multi*` for multiple features of the same type
  - `st_geometrycollection` for multiple feature types
  - `st_as_sfc` creates the geometry list column for many `sf` operations

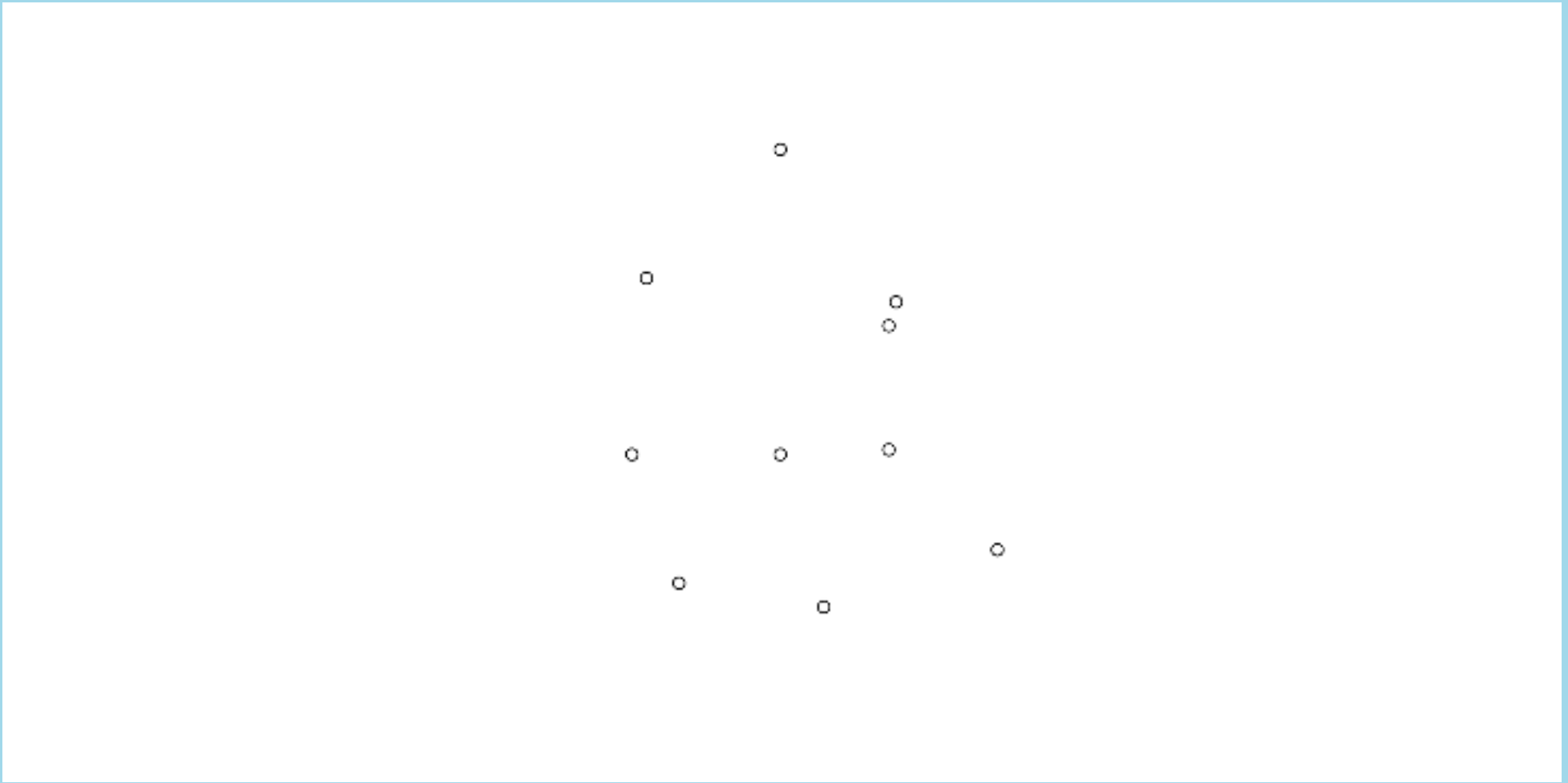
Points

```
1  library(sf)
2  proj <- st_crs('+proj=longlat +datum=WGS84')
3  long <- c(-116.7, -120.4, -116.7, -113.5, -115.5, -120.8, -119.5, -113.7, -
4  lat <- c(45.3, 42.6, 38.9, 42.1, 35.7, 38.9, 36.2, 39, 41.6, 36.9)
5  st_multipoint(cbind(long, lat)) %>% st_sfc(., crs = proj)
```

```
Geometry set for 1 feature
Geometry type: MULTIPOINT
Dimension:     XY
Bounding box:  xmin: -120.8 ymin: 35.7 xmax: -110.7 ymax: 45.3
Geodetic CRS:  +proj=longlat +datum=WGS84
```

Points

```
1 plot(st_multipoint(cbind(long, lat)) %>%
2                    st_sfc(., crs = proj))
```



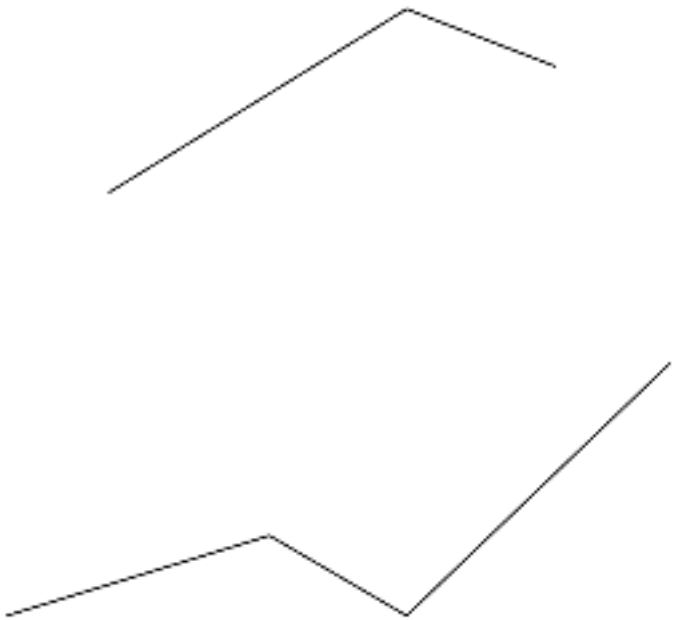
Lines

```
1 lon <- c(-116.8, -114.2, -112.9, -111.9, -114.2, -115.4, -117.7)
2 lat <- c(41.3, 42.9, 42.4, 39.8, 37.6, 38.3, 37.6)
3 lonlat <- cbind(lon, lat)
4 pts <- st_multipoint(lonlat)
5
6 sfline <- st_multilinestring(list(pts[1:3,], pts[4:7,]))
7 str(sfline)
```

```
List of 2
 $ : num [1:3, 1:2] -116.8 -114.2 -112.9 41.3 42.9 ...
  ..- attr(*, "dimnames")=List of 2
  .. ..$ : NULL
  .. ..$ : chr [1:2] "lon" "lat"
 $ : num [1:4, 1:2] -111.9 -114.2 -115.4 -117.7 39.8 ...
  ..- attr(*, "dimnames")=List of 2
  .. ..$ : NULL
  .. ..$ : chr [1:2] "lon" "lat"
 - attr(*, "class")= chr [1:3] "XY" "MULTILINESTRING" "sfg"
```

Lines

```
1  plot(st_multilinestring(list(pts[1:3,], pts[4:7,])))
```

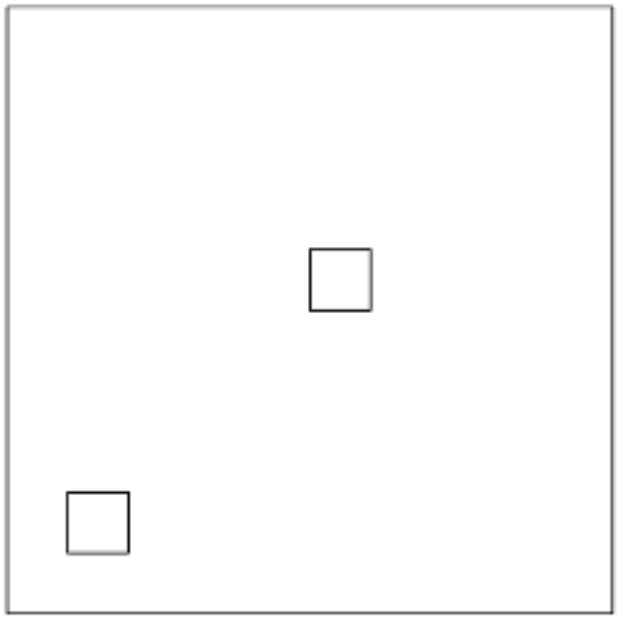


Polygons

```
outer = matrix(c(0,0,10,0,10,10,0,10,0,0),ncol=2, byrow=TRUE)
hole1 = matrix(c(1,1,1,2,2,2,2,1,1,1),ncol=2, byrow=TRUE)
hole2 = matrix(c(5,5,5,6,6,6,6,5,5,5),ncol=2, byrow=TRUE)
coords = list(outer, hole1, hole2)
pl1 = st_polygon(coords)
```

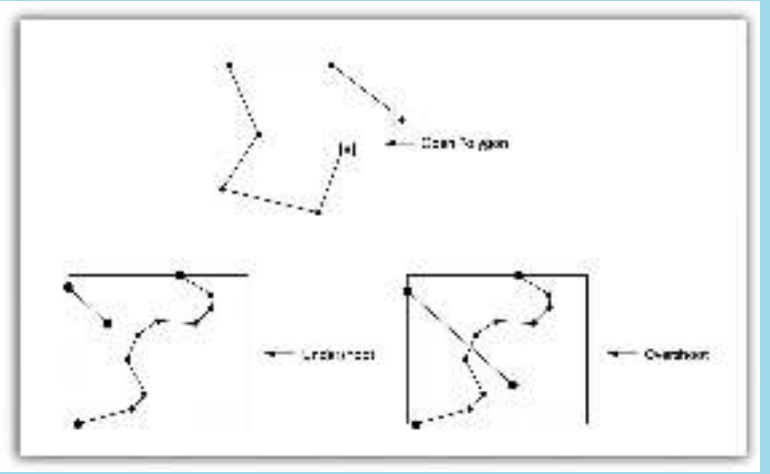
Polygons

```
1  plot(pl1)
```



Common Problems with Vector Data

- Vectors and scale
- Slivers and overlaps
- Undershoots and overshoots
- Self-intersections and rings



Topology Errors - Saylor Acad.

We'll use `st_is_valid()` to check this, but fixing can be tricky

Fixing Problematic Topology

- `st_make_valid()` for simple cases
- `st_buffer` with `dist=0`
- More complex errors need more complex approaches

A Note on Vectors

Moving forward we will rely primarily on the `sf` package for vector manipulation. Some packages require objects to be a different class. `terra`, for example, relies on `SpatVectors`. You can use `as()` to coerce objects from one type to another (assuming a method exists). You can also explore other packages. Many packages provide access to the 'spatial' backbones of `R` (like `geos` and `gdal`), they just differ in how the "verbs" are specified. For `sf` operations the `st_` prefix is typical. For `rgeos` operations, the `g` prefix is common.