extRatum package example: Built Environment

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Built environment statistical indicators

This notebook demonstrates the use of `extRatum` package drawing on *OpenStreetMap* data. `extRatum` provides summary statistics of local geospatial features within a given geographic area. It does so by calculating the area covered by a target geospatial feature (i.e. buildings, parks, lakes, etc.). The geospatial features can be of any geospatial data type, including point, polygon or line data.

In this example, we focus on built environment characteristics.

We make use of OpenStreetMap data and calculate point-, polygon- and line-based data features. The reference layer is the Lower Layer Super Output Area (LSOA) boundaries for the city of Liverpool in the United Kingdom.

```r
library(extRatum)
library(sf)
```

```
## Warning: package 'sf' was built under R version 4.0.3
```

```
## Linking to GEOS 3.8.0, GDAL 3.0.4, PROJ 6.3.1
```

```r
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```r
library(tmap)
library(osmdata)
```

```
## Data (c) OpenStreetMap contributors, ODbL 1.0. https://www.openstreetmap.org/copyright
```

Read boundaries

First, we read in the LSOA boundaries for Liverpool. The data downloaded from CDRC website: https://data.cdrc.ac.uk/

```
# 1. Read in the FUA grids
LSOAs <- st_read("layers/E08000012.shp")
```

```
## Reading layer `E08000012' from data source `C:\Users\User\Desktop\extRatum_examples\code\layers\E080
## Simple feature collection with 298 features and 1 field
## geometry type:  MULTIPOLYGON
## dimension:      XY
## bbox:           xmin: 333086.1 ymin: 381426.3 xmax: 345636 ymax: 397980.1
## projected CRS:  Transverse_Mercator
```

Because the area of interest is in the UK, we select the British National Grid as a planar coordinate system of reference.

```
BNG = "epsg:27700"
```

Point data metrics

Here, we illustrate the use of `extRatum` with point data.

We create a simple query to download point data representing shops in Liverpool.

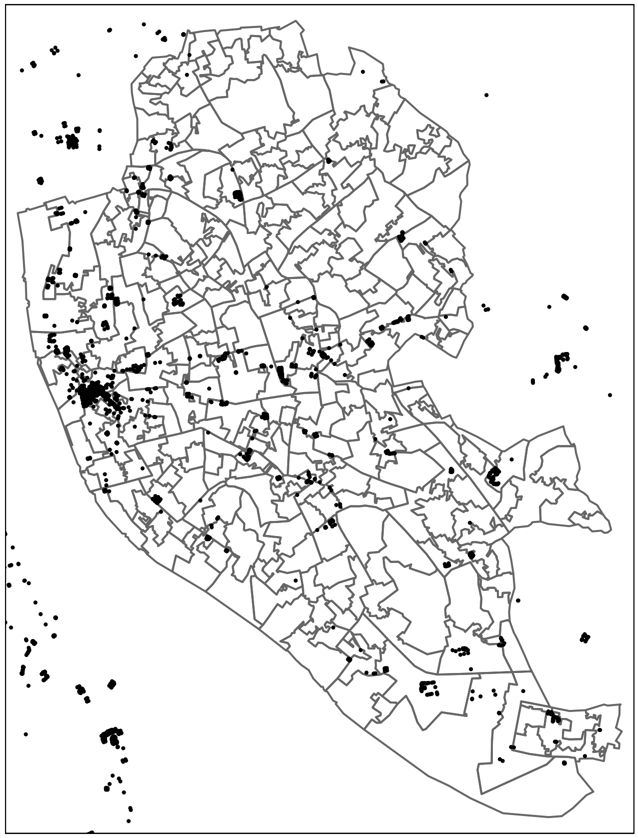
```
q <- getbb("Liverpool") %>%
  opq() %>%
  add_osm_feature(key = "shop")

shops <- osmdata_sf(q)
```

And plot them.

```
#tmap_mode("view") #use this code for creating an interactive map
tmap_mode("plot")
```

```
## tmap mode set to plotting
```

```
# show the points and grids
tm_shape(LSOAs) +
  tm_borders() +
  tm_shape(shops$osm_points) +
  tm_dots()
```



Then we calculate the number of points in each polygon using the `point_calc()` function. Note that we have to pass a planar coordinate system in all our functions. Here we are using the British National Grid. The output of this function will be a dataframe containing:

- LSOA code;
- total area in sqm of each LSOA;
- number of points (i.e. shops) in each LSOA; and
- ratio of points to the total LSOA area (or in other words the number of points by sqm). In this way, we have a relative measure that can be compared across all LSOAs and is independent of their geographical area.

Note that we have used the argument `total_points = TRUE` which returns the total number of points without differentiating between different shop types.

```
Shops_total <- point_calc(
  point_data = shops$osm_points,
  higher_geo_lay = LSOAs,
  unique_id_code = 'lsoa11cd',
  crs = BNG,
  total_points = TRUE
  )

# inspect the results
head(Shops_total)
```

```
## # A tibble: 6 x 4
```

```
##   lsoa11cd  TotalArea NoPoints      Ratio
##   <chr>         <dbl>    <int>      <dbl>
## 1 E01006513   555037.       29 0.0000522
## 2 E01006514   262031.        2 0.00000763
## 3 E01006515   366500.       16 0.0000437
## 4 E01006518   235181.        1 0.00000425
## 5 E01006520   259435.        1 0.00000385
## 6 E01006522   473782.        3 0.00000633
```

In some cases, we want to know the split between different types of points. To that end, we can change the `total_points = FALSE` and specify the column name that includes the classification (see `class_col`).

```
Shops_class <- point_calc(
  point_data = shops$osm_points,
  higher_geo_lay = LSOAs,
  unique_id_code = 'lsoa11cd',
  class_col = 'shop',
  crs = BNG,
  total_points = FALSE
  )
```

The output of this function will be a list of three dataframes.

1. A dataframe in long format reporting:

- LSOA codes;
- total area in sqm of each LSOA;
- classification of the points within each LSOA;
- number of points in each class (i.e. bakery, beauty) in each LSOA; and
- ratio of points in each class to the total LSOA area (or in other words the number of points by sqm).

```
head(Shops_class$PointsLong)
```

```
## # A tibble: 6 x 5
##   lsoa11cd  TotalArea shop        NoPoints      Ratio
##   <chr>         <dbl> <chr>          <int>      <dbl>
## 1 E01006513   555037. bakery             2 0.00000360
## 2 E01006513   555037. beauty             1 0.00000180
## 3 E01006513   555037. bookmaker          2 0.00000360
## 4 E01006513   555037. books              2 0.00000360
## 5 E01006513   555037. clothes            1 0.00000180
## 6 E01006513   555037. convenience        8 0.0000144
```

2. A dataframe in wide format reporting:

- LSOA codes;
- number of points in each class (i.e. bakery, beauty) in each LSOA.

```
head(Shops_class$PointsCountWide)
```

```
## # A tibble: 6 x 92
##   lsoa11cd alcohol  Baby baby_goods   bag bakery beauty   bed beverages bicycle
##   <chr>      <int> <int>      <int> <int>  <int>  <int> <int>     <int>   <int>
## 1 E010065~      NA    NA         NA    NA      2      1    NA        NA      NA
## 2 E010065~      NA    NA         NA    NA     NA     NA    NA        NA      NA
## 3 E010065~      NA    NA         NA    NA     NA     NA    NA        NA       1
## 4 E010065~      NA    NA         NA    NA     NA     NA    NA        NA      NA
## 5 E010065~      NA    NA         NA    NA     NA     NA    NA        NA      NA
## 6 E010065~      NA    NA         NA    NA     NA     NA    NA        NA      NA
## # ... with 82 more variables: bookmaker <int>, books <int>, `Business
## #   Service` <int>, butcher <int>, cakes <int>, car <int>, car_parts <int>,
## #   car_repair <int>, carpet <int>, catalogue <int>, charity <int>,
## #   chemist <int>, clothes <int>, coffee <int>, computer <int>,
## #   confectionery <int>, convenience <int>, cosmetics <int>, craft <int>,
## #   deli <int>, department_store <int>, Discount <int>, doityourself <int>,
## #   dry_cleaning <int>, electrical <int>, electronics <int>, erotic <int>,
## #   estate_agent <int>, florist <int>, food <int>, frozen_food <int>,
## #   funeral_directors <int>, furniture <int>, games <int>, garden_centre <int>,
## #   gift <int>, greeting_card <int>, `greetings cards` <int>,
## #   hairdresser <int>, hardware <int>, health_food <int>, hifi <int>,
## #   houseware <int>, jewelry <int>, kiosk <int>, laundry <int>, leather <int>,
## #   mall <int>, mobile_phone <int>, music <int>, musical_instrument <int>,
## #   newsagent <int>, optician <int>, outdoor <int>, pawnbroker <int>,
## #   perfumery <int>, pet <int>, photo <int>, religion <int>, salon <int>,
## #   second_hand <int>, shoes <int>, sports <int>, stationery <int>,
## #   storage_rental <int>, supermarket <int>, tailor <int>, tea <int>,
## #   ticket <int>, `ticket;convenience` <int>, toys <int>, trade <int>,
## #   travel_agency <int>, vacant <int>, variety_store <int>, video_games <int>,
## #   Vintage_Boutique <int>, watches <int>, window_blind <int>, wine <int>,
## #   yes <int>, `<NA>` <int>
```

3. A dataframe in wide format reporting:

- LSOA codes;
- ratio of points in each class to the total LSOA area (or in other words the number of points by sqm).

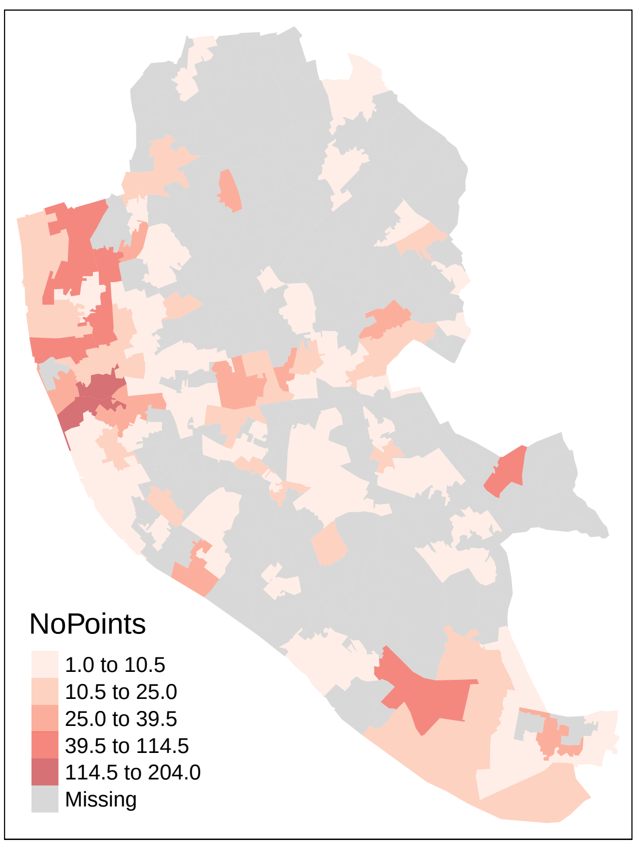
```
head(Shops_class$PointsRatioWide)
```

```
## # A tibble: 6 x 92
##   lsoa11cd alcohol  Baby baby_goods   bag   bakery   beauty   bed beverages
##   <chr>      <dbl> <dbl>      <dbl> <dbl>    <dbl>    <dbl> <dbl>     <dbl>
## 1 E010065~      NA    NA         NA    NA  3.60e-6  1.80e-6    NA        NA
## 2 E010065~      NA    NA         NA    NA NA       NA          NA        NA
## 3 E010065~      NA    NA         NA    NA NA       NA          NA        NA
## 4 E010065~      NA    NA         NA    NA NA       NA          NA        NA
## 5 E010065~      NA    NA         NA    NA NA       NA          NA        NA
## 6 E010065~      NA    NA         NA    NA NA       NA          NA        NA
## # ... with 83 more variables: bicycle <dbl>, bookmaker <dbl>, books <dbl>,
## #   `Business Service` <dbl>, butcher <dbl>, cakes <dbl>, car <dbl>,
## #   car_parts <dbl>, car_repair <dbl>, carpet <dbl>, catalogue <dbl>,
## #   charity <dbl>, chemist <dbl>, clothes <dbl>, coffee <dbl>, computer <dbl>,
## #   confectionery <dbl>, convenience <dbl>, cosmetics <dbl>, craft <dbl>,
## #   deli <dbl>, department_store <dbl>, Discount <dbl>, doityourself <dbl>,
```

```
## #   dry_cleaning <dbl>, electrical <dbl>, electronics <dbl>, erotic <dbl>,
## #   estate_agent <dbl>, florist <dbl>, food <dbl>, frozen_food <dbl>,
## #   funeral_directors <dbl>, furniture <dbl>, games <dbl>, garden_centre <dbl>,
## #   gift <dbl>, greeting_card <dbl>, `greetings cards` <dbl>,
## #   hairdresser <dbl>, hardware <dbl>, health_food <dbl>, hifi <dbl>,
## #   houseware <dbl>, jewelry <dbl>, kiosk <dbl>, laundry <dbl>, leather <dbl>,
## #   mall <dbl>, mobile_phone <dbl>, music <dbl>, musical_instrument <dbl>,
## #   newsagent <dbl>, optician <dbl>, outdoor <dbl>, pawnbroker <dbl>,
## #   perfumery <dbl>, pet <dbl>, photo <dbl>, religion <dbl>, salon <dbl>,
## #   second_hand <dbl>, shoes <dbl>, sports <dbl>, stationery <dbl>,
## #   storage_rental <dbl>, supermarket <dbl>, tailor <dbl>, tea <dbl>,
## #   ticket <dbl>, `ticket;convenience` <dbl>, toys <dbl>, trade <dbl>,
## #   travel_agency <dbl>, vacant <dbl>, variety_store <dbl>, video_games <dbl>,
## #   Vintage_Boutique <dbl>, watches <dbl>, window_blind <dbl>, wine <dbl>,
## #   yes <dbl>, `<NA>` <dbl>
```

Finally we can map the results to show the density of shops in the city of Liverpool at the LSOA level.

```r
# attach the information calculate using extRatum to the LSOA boundaries
Liv_shops_geo <- dplyr::left_join(LSOAs, Shops_total, by = "lsoa11cd")

tm_shape(Liv_shops_geo) +
  tm_fill("NoPoints", style = "fisher", palette = "Reds", alpha = 0.6)
```



Polygon data analysis

Next, we illustrate the use of `extRatum` with polygon data.

We create a query to download building footprints for the city of Liverpool using *OpenStreetMap* data.

```
q2 <- getbb("Liverpool", limit = 100) %>%
  opq() %>%
  add_osm_feature(key = "building")

buildings <- osmdata_sf(q2)
```

We can then subset the buildings that are classified as retail.

```
retail_buildings <- subset(buildings$osm_polygons, building=="retail")
```

Then, we run the function that calculates the area in sqm covered by retail buildings in each LSOA using `areal_calc()` function.

```
Liv_retail <- areal_calc(
  polygon_layer = retail_buildings,
  higher_geo_lay = LSOAs,
  unique_id_code = 'lsoa11cd',
  crs = BNG
  )
```

The output of this function will be a dataframe containing:

- LSOA codes;
- total area in sqm of each LSOA;
- area in sqm covered by the geospatial feature we have selected in each LSOA; and
- ratio of geospatial feature area to the total LSOA area (or in other words the area covered by the geospatial feature by sqm).

Given that everything is measured in sqm, the ratio represents what is the % of area covered by retail buildings by sqm. In this way, we have a relative measure that can be compared across all LSOAs and is independent of their size.

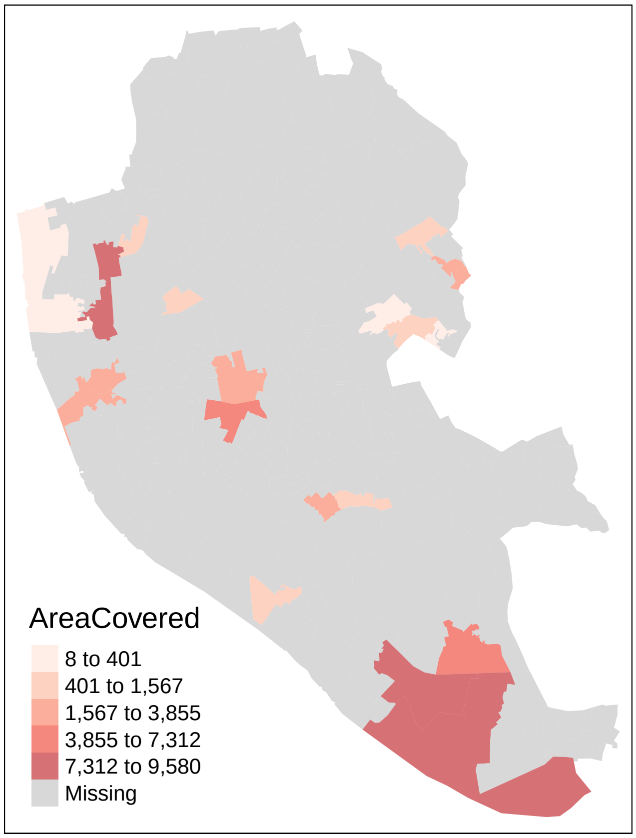
We can also transform the calculated values in sqkm by dividing the value in sqm by 1,000,000. This can be done as follows.

```
Liv_retail$AreaCovered_sqkm <- Liv_retail$AreaCovered /1000000

head(Liv_retail)
```

```
## # A tibble: 6 x 5
##   lsoa11cd  TotalArea AreaCovered     Ratio AreaCovered_sqkm
##   <chr>         <dbl>       <dbl>     <dbl>            <dbl>
## 1 E01006519   505501.       946.   0.00187         0.000946
## 2 E01006537  1077345.      5864.   0.00544         0.00586
## 3 E01006563   287328.      1455.   0.00506         0.00145
## 4 E01006570   443140.         7.59 0.0000171       0.00000759
## 5 E01006571   404631.       830.   0.00205         0.000830
## 6 E01006572   135551.       110.   0.000813        0.000110
```

Finally, we can plot the results, showing the total area covered by retail buildings in each LSOA in Liverpool. Note that OSM data on retail buildings are not complete for the city of Liverpool. Thus, we see too many LSOAs with missing data.

```
Liv_retail_geo <- dplyr::left_join(LSOAs, Liv_retail, by = "lsoa11cd")

tm_shape(Liv_retail_geo) +
  tm_fill("AreaCovered", style = "fisher", palette = "Reds", alpha = 0.6)
```



Line data analysis

Now, we illustrate the use of `extRatum` with line data.

We create a query to download highway lines for the city of Liverpool using OpenStreetMap data.

```
q3 <- getbb("Liverpool") %>%
  opq() %>%
  add_osm_feature(key = "highway")

highways <- osmdata_sf(q3)
```

We can then create subsets of the dataset such as pathways for pedestrian use.

```r
pedestrian <- subset(highways$osm_lines, highway == "pedestrian")
```

Then we can calculate the total length of pedestrian pathways routes by LSOA using `line_calc()` function.

```r
Liv_footways <- line_calc(
  line_layer = pedestrian,
  higher_geo_lay = LSOAs,
  unique_id_code = 'lsoa11cd',
  crs = BNG
  )
```

The output of this function will be a dataframe containing:

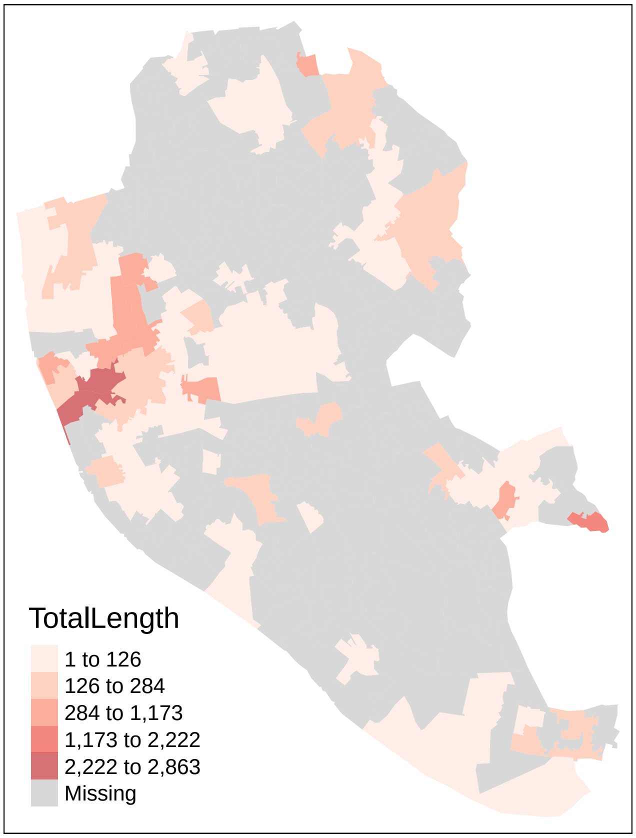
- LSOA codes;
- total area in sqm of each LSOA;
- total line length in metres by the geospatial feature we have selected in each LSOA; and
- ratio of geospatial feature length to the total LSOA area (or in other words the length of the geospatial feature by sqm). In this way, we have a relative measure that can be compared across all LSOAs and is independent of their size.

```r
head(Liv_footways)
```

```
## # A tibble: 6 x 4
##   lsoa11cd  TotalArea TotalLength     Ratio
##   <chr>         <dbl>       <dbl>     <dbl>
## 1 E01006512   283907.       22.7  0.0000799
## 2 E01006513   555037.      190.   0.000342
## 3 E01006514   262031.        9.73 0.0000371
## 4 E01006515   366500.       38.3  0.000104
## 5 E01006518   235181.       29.5  0.000125
## 6 E01006521   603082.       29.2  0.0000484
```

Finally, we can plot the results, showing the total length of pedestrian pathways in each LSOA in Liverpool. Note that the majority is around Liverpool city centre where we see darker colours.

```r
Liv_footways_geo <- left_join(LSOAs, Liv_footways, by = "lsoa11cd")


tm_shape(Liv_footways_geo) +
  tm_fill("TotalLength", style = "fisher", palette = "Reds", alpha = 0.6)
```


TotalLength
1 to 126
126 to 284
284 to 1,173
1,173 to 2,222
2,222 to 2,863
Missing