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Paper:

Lovelace, R (2014) *Harnessing open street map data with R and QGIS*. EloGeo

Harnessing Open Street Map Data with R and QGIS

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February 1, 2014

This tutorial shows how open source tools can be used to harness a huge and rapidly growing open source geodatabase: Open Street Map. It is targeted at people new to Open Street Map, but who already have an understanding of basic GIS concepts. Previous experience with the programs QGIS and R would be beneficial, but not essential, for completing the exercises. There are also a number of resources available on-line for more advanced functions, as described below.

Introduction

Open Street Map (OSM) is a crowd-sourced map of the world, the archetype of ‘volunteered geographical information’ (Goodchild 2007). The aim is simple: “to create a set of map data that’s free to use, editable, and licensed under new copyright schemes”, as described in an excellent review article on the subject (Haklay and Weber 2008). Putting the public in charge of editing the world’s surface may seem like a risky business, given that cartographers have specialist skills developed over centuries. This issue is described in *Mapping the Void*, an excellent BBC Radio 4 Documentary on the subject (Salisbury and Jenkins 2014). Yet the emergence of high resolution aerial photography covering the entirety of the Earth’s surface and the explosion in GPS ownership via smartphones has enabled citizens to become accurate sensors of the world. Neis et al. (2012) believe this phenomenon is more than merely technological. In OSM, they see a “revolutionary paradigm shift on how map data is being collected”. Citizen mappers have the added advantage that they may know their local area far better than any professional cartographer.

This tutorial adds a small nugget of information to the growing literature on OSM, by demonstrating how the data can be accessed for teaching or research materials. It’s a completely free and open dataset, so we may as well use it! There is already some good on-line material about OSM data, including:

- a [paper](#) comparing the quality and coverage of OSM map data in different parts of the world (Neis et al. 2013)
- an [overview](#) of handling OSM data in ArcMap
- a [tutorial](#) illustrating its potential use for GIS education and store location planning (Lovelace 2013).

Yet nothing has focussed on simply loading the data using different tools. In this paper we use QGIS and R because these are (arguably) the most popular open source programmes used by geographers, the discipline with most to gain from OSM data. Before delving into the method (which is actually quite straightforward), let’s put OSM data in context.

Why (and why not) use OSM data?

Of course there are teething issues with any large-scale open source database, including variable data quality, patchy and incomplete coverage and inconsistencies from place to place (Haklay 2010). Yet all of these issues are gradually being ironed out. The advantages of Open Street Map outweigh these downsides for many applications *already*. These include:

- Rapid updates of new projects
- Greater range of attributes (e.g. shop names)

- Ability to share data with anyone without breaching license

In additions there are a number of ethical benefits of using OSM: it's community a map for the greater good ([Wroclawski 2014](#)).

There is a strong community of OSM volunteers who use the service for humanitarian purposes (Salisbury and Jenkins 2014). Two excellent examples of this help underline the ethical side of OSM data. [Tindale](#), a settlement in Tanzania that has been mapped rapidly thanks to a single academic project, in collaboration with the authorities, enabling better policy making in the area (see [video](#)). Second, the rapid response of the OSM community to the Typhoon Haiyan disaster. In a matter of days, an army of volunteers had helped to map out the affected zone, aiding relief efforts (e.g. see [MapBox's blog posts on the subject](#)).

An overview of the tutorial

All of the code and data used to create this tutorial is available on [GitHub](#). Feel free to download the project as a `.zip` file from the [project's repository](#) entitled `osm-tutorial` from `github.com/Robinlovelace`. This zip file contains all of the code and data used to generate the tutorial, which is entirely reproducible. If you would like to modify or improve it in any way, please fork a version for you own use, citing the original where appropriate.

The focus is mainly on the technical challenge of extracting the data from servers 'in the cloud' and onto your desktop. We also cover some basic tasks in handling, subsetting and visualising the data, first in the graphical user interface (GUI) of QGIS, and then in the command line with R. The next stage talks about editing raw OSM data, essential if you would like to take subsets of very large OSM datasets, such as `planet.osm` which takes up more than 30 GB of memory. The next stage is to talk about OSM data in PostGIS, a geodatabase program ideal for querying very large spatial datasets. Finally, there is a brief section on further resources. None of the sections require any of the previous ones although the level of difficulty generally increases as you progress.

Getting the data

OSM data of a specific area can be downloaded directly from the [main map page](#), from the [Overpass API](#) or, for the entire planet, from the huge (currently 32 GB) [planet.osm file](#). A number of third parties also provide more manageable chunks of this dataset, such as the single country datasets provided by [GEOFABIK](#). Command line programs [Osmosis](#) and [Osm2pgsql](#) can be used to process raw OSM data in either `.osm` or `.osm.pbf` file formats. The former is essentially a `.xml` (Extensible Markup Language) text file (encoded with the popular UTF-8 character set); the latter is a compressed version of the former. How we transfer these datasets into a useful form depends on the program you are using. In this tutorial we will explain how to do it in QGIS and R, as well describing the basics of getting it into a [PostGIS](#) database.

OSM data in QGIS

A `.osm` file can be downloaded from the [openstreetmap.org](#) with the bounding box selected by default depending on the current view, or via a manual selection, as shown below.

To load this file into QGIS, you can simply use the **Add Vector Layer** button on the left of the screen. However this does not generate satisfactory results. The *recommended* way to import the data is via the the OSM plugin. When this is installed in QGIS 2.0, use the menu **Vector > OpenStreetMap** to import the xml file and convert it into a SpatiaLite database. Then you can import it into the QGIS workspace.

After this step the file has been saved as a `.osm.db` file. Use the **Export Topology to SpatiaLite** element of the same menu to load the file. Choose the type of spatial data you would like to load - Points, Lines or Polygons. At this stage one can also select which variables ("Tags") you would like to add to the attribute data.

The data is now loaded into QGIS allowing standard methods of analysis. You will notice that the data are not styled at all, leading to very bland maps. To counter this, there have been custom styles developed for visualising OSM data in QGIS, e.g. [those by Anita Grazer](#). Unfortunately these files do not seem to be working with the current version of QGIS so alternative ready-made styles must be created, as suggested by a [stackexchange question](#).

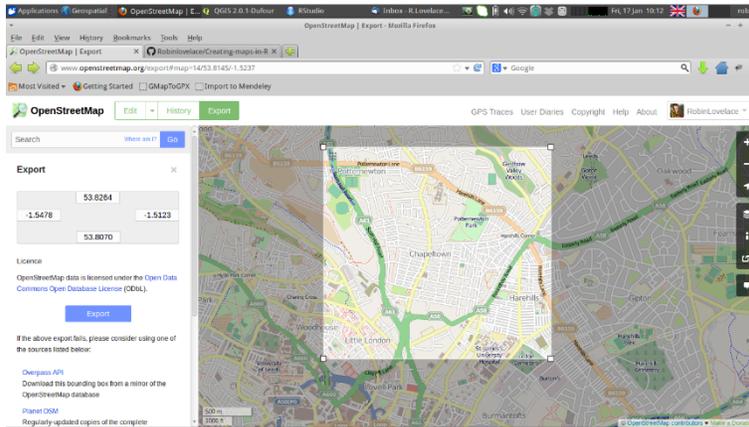


Figure 1: Manual selection of bounding box

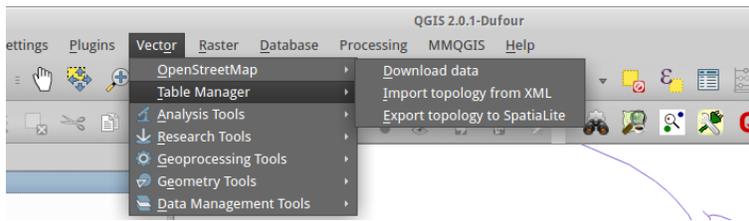


Figure 2: Import the osm data to SpatiaLite

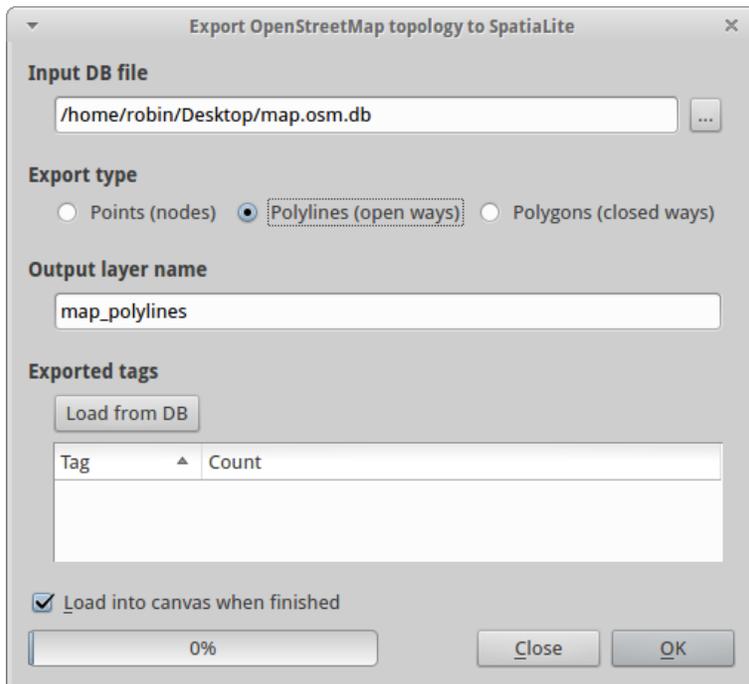


Figure 3: Select Polylines

Once the data is loaded into QGIS, it can be used as with any other spatial data. Next, let's see how R can handle OSM data, via the `osmar` package.

Using `osmar`

`osmar` is an R package for downloading and interrogating OSM data that accesses the data directly from the internet via the R command line. There is an excellent [online tutorial](#) which provides a detailed account of the package (Eugster & Schlesinger, 2012). Here we will focus on loading some basic data on bicycle paths in Leeds. First the package must be loaded:

```
library(osmar) # if the package is not already installed, use install.packages('osmar')

## Loading required package: XML
## Loading required package: RCurl
## Loading required package: bitops
## Loading required package: gtools
## Loading required package: geosphere
## Loading required package: sp
##
## Attaching package: 'osmar'
##
## The following object is masked from 'package:utils':
##
##   find
```

To download data directly, one first sets the source and a bounding box, and then use the `get_osm` function to download it. Selecting Chapeltown as the centrepoint of the map, we can download all the data in the square km surrounding it.

```
src <- osmsource_api()
bb <- center_bbox(-1.53492, 53.81934, 1000, 1000)
ctown <- get_osm(bb, source = src)
plot(ctown)
points(-1.53492, 53.81934, col = "red", lwd = 5)
```

This shows that the data has successfully been loaded and saved as an object called `ctown`. Let's try analysing this object further. In fact, `ctown` is technically a list, composed of 3 objects: nodes (points), ways (lines) and relations (polygons composed of many lines). Such OSM data is thus provided a class of its own, and each sub-object can be called separately using the `$` symbol:

```
names(ctown)

## [1] "nodes"      "ways"       "relations"

class(ctown)

## [1] "osmar" "list"

summary(ctown$ways)
```

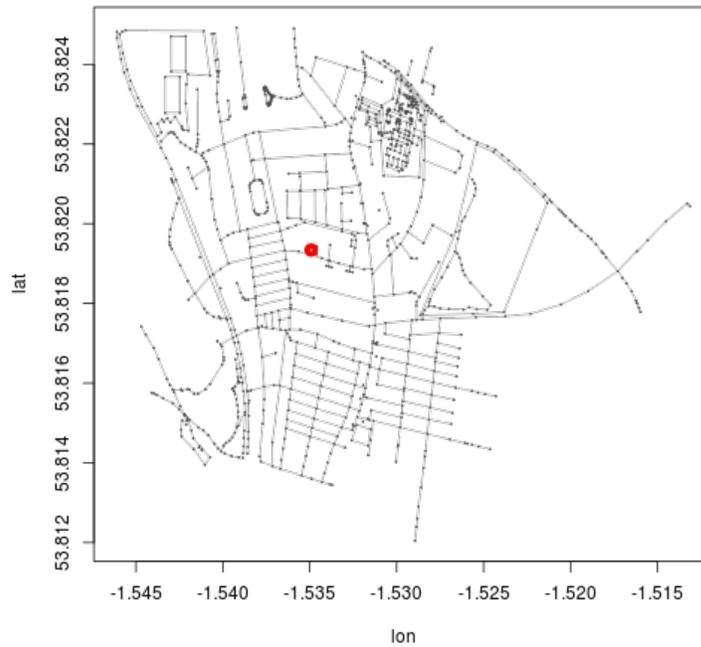


Figure 4: Preliminary plot of Chapletown with osmar

```
## osmar$ways object
## 179 ways, 505 tags, 1270 refs
##
## ..$attrs data.frame:
##   id, changeset, timestamp, version, visible, user, uid
## ..$tags data.frame:
##   id, k, v
## ..$refs data.frame:
##   id, ref
##
## Key-Value contingency table:
##      Key                Value Freq
## 1 highway      residential    71
## 2 source:name OS_OpenData_Locator 49
## 3 highway      service       41
## 4 created_by      JOSM        25
## 5 source          Bing        23
## 6 highway      unclassified   17
## 7 highway      footway       15
## 8 building      yes         11
## 9 lit           yes         11
## 10 source       npe         10
```

Let's use the dataset we have loaded to investigate the cycle paths in the vicinity of my house. First we need to understand the data contained in the object. Let's look at the tags and the attributes of the `ways` object:

```
summary(ctown$ways$tags) # summary of the tag data

##      id                k                v
## Min.   :5.09e+06 highway :155 residential : 71
```

```
## 1st Qu.:7.73e+06  name      :128  OS_OpenData_Locator: 49
## Median :8.46e+07  source   : 56  service             : 41
## Mean   :8.71e+07  source:name: 54  yes                 : 32
## 3rd Qu.:1.50e+08  created_by : 25  JOSM                : 25
## Max.   :2.45e+08  building : 12  Bing                 : 23
##                                     (Other)  : 75  (Other)             :264
```

```
ctown$ways$attrs[1:8, 1:6] # attributes of first 8 ways - see I'm in there!
```

```
##      id changeset      timestamp version visible      user
## 1  5088536  15128484 2013-02-22 22:08:24     13   true CompactDstrxion
## 2  22818969 13039300 2012-09-08 23:06:53     20   true  LeedsTracker
## 3   6273628   483846 2007-09-21 17:25:37      1   true    SteveC
## 4   6273619 14114856 2012-12-01 17:57:45      2   true      sc71
## 5   6273721   444107 2007-09-16 17:23:14      1   true     noii
## 6   6273722   444107 2007-09-16 17:23:16      1   true     noii
## 7   6273726   444107 2007-09-16 17:23:20      1   true     noii
## 8   6273736  18672988 2013-11-02 10:56:24      5   true RobinLovelace
```

From looking at the [OSM tagging system](#), we can deduce that `id` is the element's id, `k` refers to the OSM key (the variables for which the element has values) and that `v` is the value assigned for each id - key combination. Because OSM data is not a simple data frame, we cannot use the usual R notation for subsetting. Instead we use the `find` function. Let us take a subset of bicycle paths in the area and plot them.

```
bikePaths <- find(ctown, way(tags(k == "bicycle" & v == "yes")))
bikePaths <- find_down(ctown, way(bikePaths))
bikePaths <- subset(ctown, ids = bikePaths)
plot(ctown)
plot_ways(bikePaths, add = T, col = "red", lwd = 3)
```

The above code block is used to identify all ways in which cycling is permitted, “overriding default access”, according OSM’s excellent [wiki page on bicycle paths](#).

According to this source, the correct way to refer to an on-road cycle path is with the `cycleway` tag. However, none of these have been added to the roads that have on-road cycle lanes in this example dataset (as of January 2014). Perhaps someone will add these soon.

```
which(ctown$ways$tags$k == "cycleway")
```

```
## integer(0)
```

There are, by contrast, a large number of ways classified as “residential”. Let us use the same method to select them and add them to the map.

```
res <- find(ctown, way(tags(k == "highway" & v == "residential")))
res <- find_down(ctown, way(res))
res <- subset(ctown, ids = res)
plot(ctown)
plot_ways(res, add = T, col = "green", lwd = 3)
```

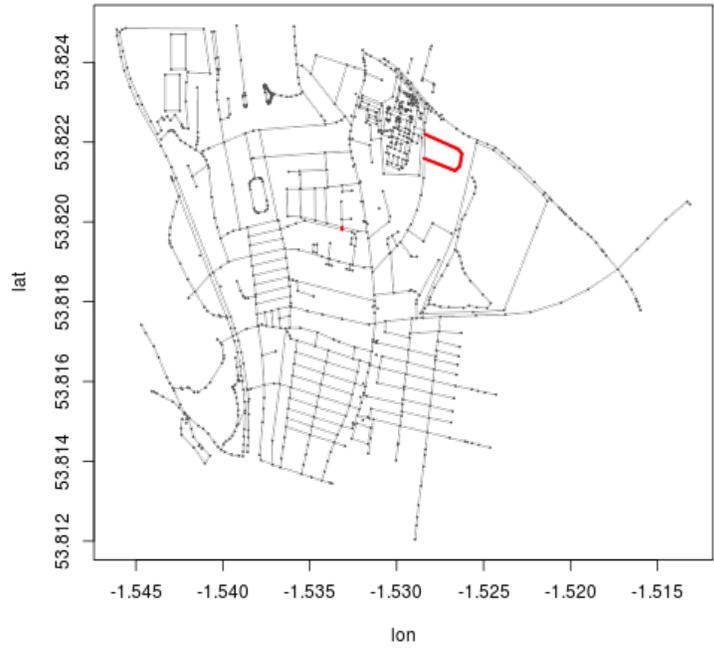


Figure 5: Bike paths of Chapeltown

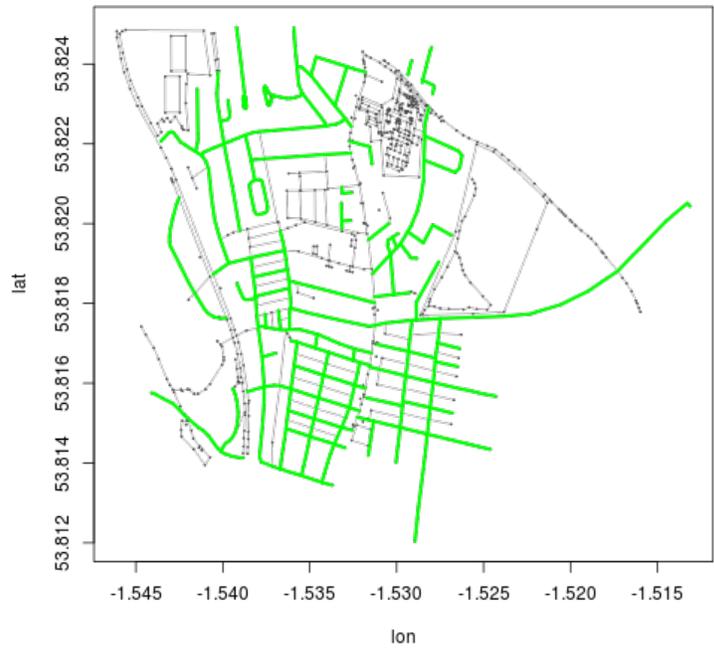


Figure 6: Residential streets in Chapeltown

Handling raw OSM data

Although this section will be of most use for dealing with very large files, a small example is used here to showcase the methods. The file `map.osm` downloaded directly from openstreetmap.org is small, allowing available on-line, from [here](#) (highlighting the advantages of open data for educational purposes - there are few license restrictions).

The Java command line tool `Osmosis` is used for this purpose.

To show how Osmosis can subset raw OSM files, let us take a real world example from the dataset we imported with the `osmar` package. Imagine that we want to extract all osm data (nodes, ways and relations) from the area in and around Potternewton Park. We could do this manually by looking up the park on-line and selecting the associated elements in QGIS. But imagine we want to do it from the command line (e.g. for batch processing). First we need a bounding box of all items containing the text string "Potternewton Park". For this we use `osmar`:

```
potter <- find(ctown, way(tags(grepl("Potternewton Park", ctown$ways$tags$v))))
potter <- find_down(ctown, way(potter))
potter <- subset(ctown, ids = potter)
plot_ways(potter) # sanity check
```

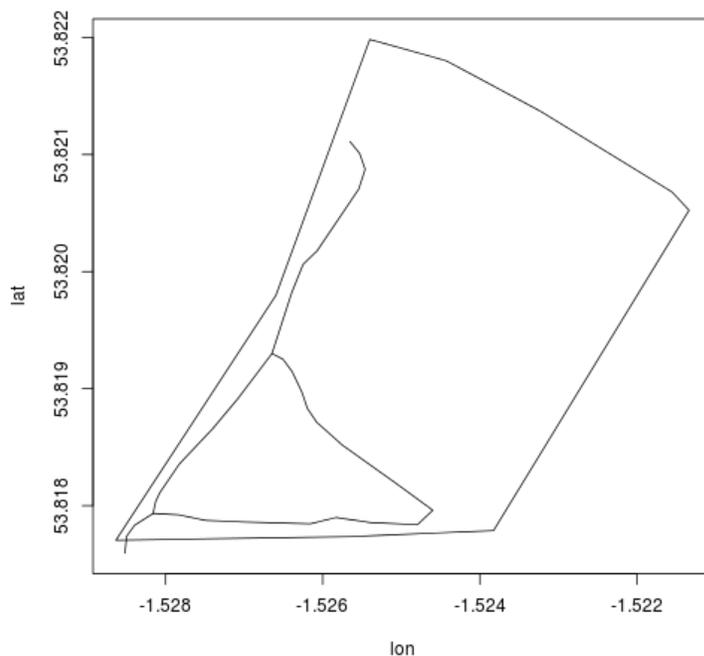


Figure 7: Line data of Potternewton park

```
potter.l <- as_sp(potter, "lines") # convert data to sp class
b <- bbox(potter.l) # save the bounding box
b[1, ] <- (b[1, ] - mean(b[1, ])) * 1.05 + mean(b[1, ])
b[2, ] <- (b[2, ] - mean(b[2, ])) * 1.05 + mean(b[2, ])
# scale longitude and latitude (increase bb by 5% for plot) replace 1.05
# with 1.xx for an xx% increase in the plot size
b

##      min      max
## x -1.529 -1.521
## y 53.817 53.822
```

Now that we know the bounding box, we can transfer to using osmosis from the command line. If the shell is open in the correct working directory (e.g. "osm-tutorial-master", if downloaded from GitHub), the following code will subset the data and output a new, smaller .osm file.

```
osmosis --read-xml data/map.osm --bounding-box top=53.822093 left=-1.528815
        bottom=53.817486 right=-1.521155 --write-xml potter.osm
```

To check whether or not this has worked, and demonstrate osmar's ability to read in .osm files, let us try to load an plot the dataset just exported by osmosis.

```
src <- osmsource_osmosis(file = "data/potter.osm")
bp <- center_bbox(mean(b[1, ]), mean(b[2, ]), 1000, 1000)
potter <- get_osm(bp, src)
plot(potter)
```

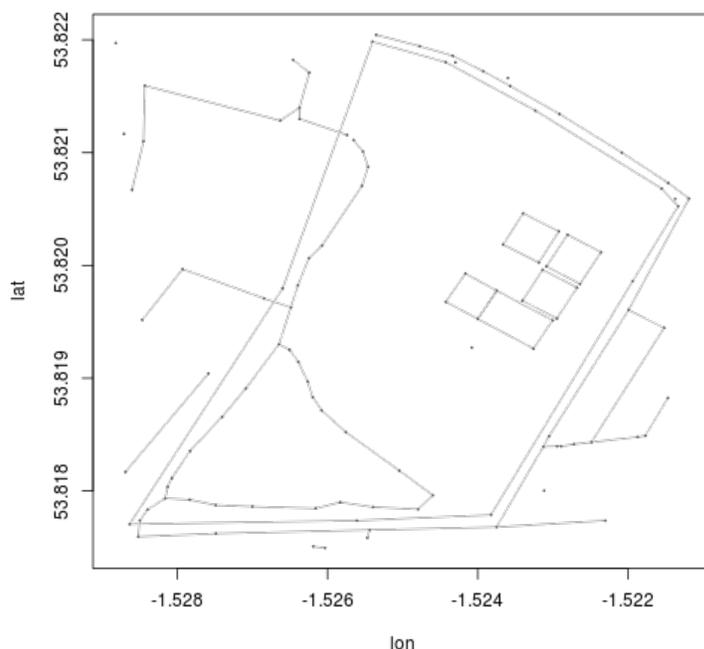


Figure 8: All OSM data in and directly surround Potternewton Park

Local knowledge or a quick look on an online will confirm that this is indeed Potternewton Park, with its rectangular tennis courts, play area and skate park just west of its centre. The file `potter.osm` can equally be loaded into QGIS or any other GIS. The point is to illustrate how Osmosis works.

For further functionality, including clipping to polygons, extracting files from enormous and compressed `planet.osm.bz2` files and ways to extract only elements with certain attributes, please refer to the [osmosis page of the osm wiki](#). The final section discusses (but does not implement) the most advanced method of harnessing OSM data, via a PostGIS database.

Creating a PostGIS database of OSM data

There are a number of advantages of storing large datasets in a database:

- The data can be accessed by a variety of 3rd party programs

- Spatial queries can be made by a variety of clients accessing the db, widening the functionality
- Huge datasets can be stored in a database, as it sits on the hard disk, only being transferred to RAM when a specific query is called

Because of the size and complexity of the planet-wide OSM database, it must be stored in a spatial database to be used. For this use the command line tool `osm2pgsql`. The basics of installation and usage can be found online.

Using a spatial database, it does not take a very large leap to realise that organisations can create a customised version of the OSM database for their own purposes. For example, an organisation interested in store location analysis could keep maintained a version of OSM with everything with elements labelled as shops removed. Alternatively, an organisation interested in woodlands could maintain an up-to-date version of OSM woodlands. Both organisations could supplement these custom databases with their own data, combining the best of crowd-sourced and centralised data collection methods.

The [OSM-GB](#) project, hosted at the University of Nottingham does precisely this, with the aim of quality-checking community contributed data. Here is not the place to describe how to set-up a PostGIS database with OSM data, but is well worth flagging as it has great potential, especially when combined with rapidly evolving open source web mapping technologies such as [GeoServer](#) (part of the [GeoNode](#) stack), [Leaflet](#) and [GeoDjango](#).

Conclusion

With the certainty of peak oil and possibility of effective climate change regulations, transport will become increasing expensive in future years. Thus, the tendency towards geographical homogenisation of economic activity may go into reverse ([Greer 2009](#); [Curtis 2009](#)). This is bad news for many, but it is good news for people with a strong interest in regional diversity, local economies and geographic diversity.

It is also potentially good news for geographers advocating for location-specific solutions. With increased concern over the highly centralised power structures of the internet following the revelations leaked by Edward Snowden about massive online spying and infringement of digital privacy, there is a huge potential for community-based, problem-specific solutions. It is with this wider context in mind that this tutorial ends - think of the potential benefits if citizens were encouraged to be both producers and consumers of the maps on which we all now depend. Happy mapping!

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`source("md2pdf.R") # convert markdown document to LaTeX`