Converting OpenStreetMap (OSM) Data to Functional Road Networks for Downstream Applications

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Abstract

In this work, we study the OpenStreetMap (OSM) data that contains Extensible Markup Language (XML) formatted data. OpenStreetMap data has many different formats. OSM XML format is one of them. OSM data has information in the form of nodes (points), ways (lines and boundaries), and relations (relationships between two or more nodes or ways). Here, we preprocess OSM XML data to extract the ways and nodes information using python to get the whole map of the streets for the Memphis area. We parse the OSM data in such a way that gives us the whole map of the Memphis area. We can further use this map for different Neural Networks (NN) and Machine learning (ML) applications. The steps that are included in this work downloading the Memphis area OSM data, understanding and parsing the OSM XML file, converting the nodes and ways information into the Pandas DataFrame, and visualizing these data into the whole map by using python’s available data visualization libraries.

1 Introduction

OpenStreetMap (OSM) is referred to as the Wikipedia of the mapping of the whole world. People from all over the world work to build it. OSM can describe the ideal concept of every location we want to visit and represent the visual representation of the world. In this work, we detail how to convert OSM data to functional road networks. This is an essential step for various Intelligent Transportation Systems (ITS) applications at all scales, including city-scale traffic simulation, reconstruction, and estimation [1–8], and individual robot/autonomous vehicles’ perception and control [9–14]. This step will also enable the study of mobility informatics [15–17] and network science [18].

OpenStreetMap data can be found in a structured XML format. OSM data is the collection of nodes, ways, and relations. Nodes contain the location in the WGS84 (World Geodetic Coordinate System 1984) coordinate system. A node is the pair of latitude and longitude. A way is a collection of at least two node references. Each node reference

\footnote{https://wiki.openstreetmap.org/wiki/Converting_to_WGS84}
contains latitude and longitude. If a way has ten reference nodes and collects the latitude and longitude of those nodes references and plots those latitudes and longitudes considering the latitude as the X axis and longitude as the Y axis a line will be created. This line considers as one way in the OpenStreetMap. If the first and the last node of the way are the same this way consider a closed way. An element is an ordered list of one or more nodes and ways. It indicates the link between a lake and its island or a couple of roads for a bus route. An infinite of attributes can be assigned to each node, path, and relation. The attributes are usually called tags in OSM. Each tag is composed of a key and a value.

```xml
<?xml version='1.0' encoding='UTF-8'?>
<osm version='0.6' generator='osmconvert 0.8.11' timestamp='2022-09-05T00:00:00Z'>
<bounds minlat='34.91' minlon='90.3599999' maxlat='35.32' maxlon='89.6499999'/>
<node id='116829085' lat='35.2192446' lon='90.1938287' version='1'/>
<node id='116829087' lat='35.2189378' lon='90.1938126' version='1'/>
<node id='116829088' lat='35.2186398' lon='90.1937854' version='1'/>
<node id='116829089' lat='35.2186408' lon='90.1937787' version='1'/>
<node id='116829092' lat='35.2186748' lon='90.1921765' version='1'/>
<node id='116829095' lat='35.2149453' lon='90.190417' version='1'/>
<node id='116829092' lat='35.2141169' lon='90.1894246' version='1'/>
<node id='116829087' lat='35.2134113' lon='90.1882873' version='1'/>
<node id='116829081' lat='35.2120873' lon='90.1877753' version='1'/>
<node id='116829033' lat='35.2126443' lon='90.185192' version='1'/>
<node id='116829048' lat='35.2126258' lon='90.183454' version='1'/>
<node id='116829045' lat='35.2125917' lon='90.1813618' version='1'/>
<node id='116829058' lat='35.2126136' lon='90.1810507' version='1'/>
<node id='116829053' lat='35.2127657' lon='90.1807986' version='1'/>
<node id='116829066' lat='35.2128021' lon='90.1805035' version='1'/>
<node id='116829061' lat='35.2133236' lon='90.1789491' version='1'/>
<node id='116829067' lat='35.2136129' lon='90.1794199' version='1'/>
<node id='116829069' lat='35.2139416' lon='90.1785631' version='1'/>
<node id='116829070' lat='35.2140874' lon='90.1781539' version='1'/>
<node id='116829071' lat='35.2139679' lon='90.1757131' version='1'/>
<node id='116829075' lat='35.2139555' lon='90.1732013' version='1'/>
<node id='116829078' lat='35.2139416' lon='90.1723389' version='1'/>
<node id='116829094' lat='35.0021756' lon='90.3573766' version='1'/>
<node id='116829090' lat='35.0023974' lon='90.3581163' version='1'/>
<node id='116829130' lat='35.002092' lon='90.35643' version='1'/>
<node id='116829135' lat='35.0019162' lon='90.3381656' version='1'/>
<node id='116829137' lat='35.0016877' lon='90.3284523' version='1'/>
<node id='116829198' lat='35.191397' lon='90.1869641' version='1'/>
<node id='116829192' lat='35.1921446' lon='90.1870767' version='1'/>
<node id='116829197' lat='35.1915177' lon='90.1870874' version='1'/>
</osm>
```

Figure 1: An Example of Partial Raw OSM XML Data for Memphis Area.

Fig.1 is an example of the OSM XML file. We can further parse the XML file by using Python for getting the actual region of interest.

## 2 Working with Nodes and Ways in OSM Data

A node represents a particular location on the surface of the earth that is identified by its latitude and longitude. At a minimum, each node has an ID number and a pair of coordinates. The shape of a path can also be defined using nodes. The majority of nodes do not have tags when they are used as stops along paths, while some may. Traffic signs are denoted, for instance, by highway=traffic signals. A way is an ordered list of two to two thousand nodes that together define a polyline. The representation of linear features
like rivers and highways is done using ways. For representing the total task, the flowchart in figure 2 helps us to understand.

![Flowchart](image)

**Figure 2: A Flowchart for getting the Map for All Streets in the Whole Memphis Area.**

### 2.1 Downloading the OSM Data for Memphis Area

We have downloaded the data from a website called [https://extract.bbbike.org/](https://extract.bbbike.org/). There are some blanks to fill out for downloading the data on this website. For example, the format of the data, which is the area want to extract, and the email address need to be put on those fields in the website to download the data. Once the blanks are filled in, the authority of this website will send a mail with the link to the data set for the desired area. After downloading the data anyone can use the data for working on different applications.

### 2.2 Extracting the Information from the Nodes

For extracting the information from the nodes, we have used XML formatted data parsing using xml.etree.cElementTree package. This is one of the most popular python packages for parsing XML formatted data. We know that the nodes consist of node id, latitude, and longitude. With the help of xml.etree.cElementTree package we parse the node’s information and convert it into the pandas DataFrame. After converting the node’s information into the pandas DataFrame we got three columns of the DataFrame. The name of the columns is node id, latitude, and longitude. Fig.3 depicts the information of the first four nodes of OSM data for the Memphis area in pandas DataFrame.
2.3 Extracting the Ways Information

For extracting the ways information we have used the same xml.etree.cElementTree python package. In an OSM XML file, a single way can contain way id, the nodes references in the range of two to two thousand, and single or multiple numbers of tags. Each tag has keys and values. For our case, we need only the highway keys to plot the ways for the Memphis area. That’s why we just extract the highway keys and the values of highways named by residential, service, tertiary, track, secondary, primary, tertiary link, secondary link, motorway link, primary link, motorway, trunk link, trunk, footway, construction, pedestrian, proposed, path, raceway, cycleway, living street, steps, abandoned, rest area, corridor, and platform. And we put those pieces of information into pandas DataFrame for user convenience. The pandas DataFrame for the information of ways of OSM data for the Memphis area describe in Fig.4. The columns for the ways in pandas DataFrame are ways id, nodes references, and the values of the tag highways.

2.4 Merging Nodes and Ways Information

Then, we need to merge the node’s information and ways information together for getting the final DataFrame. We know that single ways have multiple node references and we want to extract the latitude and longitude for those node’s references. Once we are able to do that we can plot the latitude and longitude according to the ways for getting the whole map of the Memphis area. Overall, the purpose is to merge the nodes and ways information to collect the information together for our working ease. Fig.5 is the final DataFrame for putting the ways and nodes information together.
2.5 Converting the Latitude and Longitude to X and Y Coordinates

The method for identifying the position on the earth is called the coordinate system. We can use for this case latitude/longitude, easting /northing, and X/Y for detecting the position on the earth. The coordinate systems are classified into two categories. The name of the coordinate systems are geographic and projected. A spherical surface is used for the geographic coordinate system and latitude and longitude are used for detecting the position of the earth. Our main goal is to plot the whole map for the Memphis area. Somehow we need to convert the sphere shape earth into a flat surface. For doing that we have to use the projected coordinate systems. That means the latitude and longitude are converted to X and Y coordinates. For this task, we have used the pyproj python library. And we are successfully able to extract the X and Y coordinates for the latitude and longitude from OSM data for the Memphis area.

3 Results

We conduct a number of experiments for plotting the streets for the whole Memphis area. First of all, we just plot the motorway streets for the Memphis area and use UTM (Universal
Figure 5: The Final DataFrame for Combining the Nodes and Ways Information together for OSM Data in Memphis Area.

| ways_id | node_id | lat         | lon         | tag_highway |
|---------|---------|-------------|-------------|-------------|
| 0       | 12772799| 116829005   | 35.2192446  | -90.1938287 | residential |
| 1       | 12772799| 116829007   | 35.2189378  | -90.1938126 | residential |
| 2       | 12772799| 116829008   | 35.2186398  | -90.1937054 | residential |
| 3       | 12772799| 116829012   | 35.2164748  | -90.1921765 | residential |
| 4       | 12772799| 7221804127  | 35.2163893  | -90.1921167 | residential |

... ... ... ... ... ...

4804508 109191504 10000283288 35.209778 -89.7450093 service
4804509 109191503 10000283290 35.2092545 -89.7470149 service
4804510 109191503 10000283291 35.2092807 -89.7468724 service
4804511 109191504 10000283292 35.2095367 -89.7471001 service
4804512 109191504 10000283293 35.2095649 -89.7469563 service

4804513 rows x 6 columns

Transverse Mercator) zone 15 for the Memphis. For getting information about the UTM zone for the Memphis area the website \(^2\) helps us a lot. The website is about knowing the UTM zone. The map for only the motorway for the Memphis area looks like Fig.6.

Then, we plot the map for the motorway, trunk, primary, and secondary streets. The map for the motorway, trunk, primary, and secondary for the Memphis area is mentioned in Fig.7.

At last, we plot all the streets for OSM data in the Memphis area. The runtime for getting the plot for all the streets is enormous because we had huge amounts of X and Y coordinates for all the streets of OSM data. The map for the whole Memphis area is dictated in Fig.8. The Map is slightly tilted towards the left-hand side.

We are able to plot the whole map for the Memphis area from OpenStreetMap data although the map is slightly tilted left-hand side by using the UTM zone 15 which is the UTM zone for the Memphis area. The observation is that if we are able to plot the map then in the next steps we can apply different Machine Learning (ML) and Nural Networks (NN) for various kinds of applications.

\(^2\)https://www.arcgis.com/apps/View/index.html?appid=7fa64a25efd0420896c3336dc2238475
Figure 6: The Map for only the Motorway Streets for OSM Data in Memphis Area.
Figure 7: The Map for the Motorway, Trunk, Primary, and Secondary Streets for OSM Data in Memphis Area.

Figure 8: The Map for All the Streets for OSM Data in Memphis Area.
4 Conclusion and Future Work

In this task, we have reported on an analysis of nodes and ways in OSM for getting all the streets for the Memphis area. Then we plotted all the streets for visualizing the maps for all the streets in Memphis city. Nodes and ways are two core elements in the OSM data model. In sections 2 and 3, we have discussed in detail how we can process the nodes and ways information to get a DataFrame. Then we can easily plot all the streets by grabbing the coordinates from the DataFrame. For more exploration, we will apply different applications for Machine Learning (ML) and Neural Networks (NN). It will give us a huge opportunity to find new dimensions to go and help in different aspects of developing the target city.

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