**The following should be included in your acknowledgements section:**

Map data copyrighted OpenStreetMap contributors and available from [https://www.openstreetmap.org](https://www.openstreetmap.org/)

**Reference:**

OpenStreetMap contributors. (2015) Planet dump [Data file from $date of database dump$]. Retrieved from [https://planet.openstreetmap.org](https://planet.openstreetmap.org/).

**OSM** OpenStreetMap

**OPEN DATA CHAPTER:**

Falar sobre a importancia de open data nas cidades a partir do governo e empresas. Falar sobre medidas colaborativas como o OpenStreetMap.

Development

**A brief word on OpenStreetMap**

OpenStreetMap (OSM) is a collaborative mapping project where volunteers are free to create and edit geographic map information over the world to an open database. This database is also available for free under the Open Database License.

The street data from OSM, that are relevant to this project, are organized in nodes and ways. The node is the smallest point of data in the map, it represents a single point by defining its latitude and longitude. The nodes can also contain more information inside it, called tags, the tags are used to better qualify the node when it make sense, for example if the node represent a pedestrian crossing or bus stops, this information will be refereed in tags. Some nodes has no tags, which is not a problem as they are used to represent a path.

<node id="21433116" visible="true" version="10" changeset="31019058" timestamp="2015-05-11T21:05:16Z" user="ddtuga" uid="1858517" lat="38.7244842" lon="-9.1772710"/>

Node example, user data omitted

Streets in the OSM are represented using ways. Ways are ordered list of nodes, the way direction is defined by the order of the nodes in the way, having that the way starts at the first node and end at the last. Tags are also presented in ways to define things like the street name, the possible directions of the road, among other relevant information. Nodes shared between two or more ways define intersections between streets. Not all nodes are shared, there are nodes that are solely included in one way, for example, a node representing a pedestrian crossing may not also represent a street connection, among other cases.

<way id="233939235" visible="true" version="1" changeset="17392454" timestamp="2013-08-18T08:21:23Z" user="Bernhard W" uid="110838">

<nd ref="2422521543"/>

<nd ref="2422521485"/>

<nd ref="2422521542"/>

<tag k="highway" v="residential"/>

<tag k="lanes" v="1"/>

<tag k="name" v="Rua de Campolide"/>

<tag k="oneway" v="yes"/>

</way>

Way example, user data omitted

OSM is a powerful collaborative project that allow a variety of applications and studies on its data. There are much more about nodes, ways and how they relate to each other than discussed above, but that are not relevant to this project and therefore will not be addressed here.

**Arcs data**

In order to develop this project, data from Campolide streets are required, such as streets directions, length and connections, this information can be obtained using OSM. Data from OSM can be exported directly from the main website, but to this project a package called OSMnx was used. OSMnx is a Python package created by Boeing, G. (2017) that facilitates the download of administrative boundaries streets, and perform a bunch of useful calculations using data from OSM.

Using OSMnx to download the data, a graph structure is retrieved with the nodes and ways representing the nodes and edges of a graph respectively. OSMnx perform data cleansing process automatically on downloads, the nodes that are not used in intersection and are presented in OSM ways are removed by an algorithm. This result in a simplified graph with just the relevant edges and nodes of a certain location.

COMO FALAR QUE PRECISO DAS DISTANCIAS AQUI???

After the download of data from Campolide and Lisbon, both data can be stored in the local machine using the library function *save\_graphml* to reduce the amount of time required to the upcoming runs of the algorithm, the graph is saved as a GraphML file into the disk.

From the

The data from OSM

**Distance matrix calculation**

Having AR the set of required arcs, to this project, a matrix MxM with distances between required edges was computed, being M the total amount of required edges.

First, with the data of the streets from both Campolide, and Lisbon (which also includes Campolide), a matrix

The first step of HGA is to initialize the matrix of distances between required arcs. Let ER be the set of required edges and AR be the set of required arcs, where for each required edge {i, j} ∈ ER there are two corresponding required arcs (i, j), (j, i) ∈ AR. A matrix SP of dimensions |AR| × |AR| is computed such that each entry SP[e, f] is the shortest path cost from the ending node of arc e ∈ AR to the starting node of arc f ∈ AR. For sparse graphs (where |E| is much less than |V| 2) the SP can be computed within O(|V| 3) time and O(|V| 2) space by using the Floyd–Warshall algorithm (Cormen et al., 2001). The SP allows HGA to retrieve the distances between required arcs in O(1) time throughout the optimization process. [Hybrid genetic algorithm for the open capacitated arc routing problem]