Archives of
Transport System
Telematics

Volume 11

Issue 1

February 2018

The Use of Open Geo-Information Bases for Defining Road Nets in a Given Programming Environment

Z. ŁUKASIK, M. GÓRSKA
UNIVERSITY OF TECHNOLOGY AND HUMANITIES, Faculty of Transport and Electrical Engineering,
Malczewskiego 29, 26-600 Radom, Poland
EMAIL: z.lukasik@uthrad.pl

ABSTRACT

The article concerns the application of data, collected by mobile devices, in models road maps needed in virtual environments. Recently, a system has been developed at UTH Radom, with the aim of tracking wanted vehicles. The simulation of such vehicles, understood as units with driver or passenger(s), the acquisition and transfer of related data as well as the processing of information obtained from observation cameras, are subject of ongoing research. A key component for an effective analysis of trajectories, are detailed digital road maps. Given the lack of access to commercial geo-information systems, the compilation of customized digital maps for the territory of interest, using open data collections of geographical data, is essential for research in the public sector. In the present paper, the adaptation of chosen Openstreetmap data structures to the described purposes is presented.

KEYWORDS: systems, telematics, transport, road vehicle, localization

1. Introduction

The RETINA system, extensively described in articles i.a. [3-9], contains three main components: observation centre, observation points (sensors) and telecommunication network. It's main purpose is to observe, approximate and then to predict the wanted vehicle's route. Thus a very important element is the possibility to simulate vehicle's on a real network of roads.

The subject of observation are mobile objects – road vehicles. The aim of this article is to describe the area on which these vehicles can move and which is under the observation.

It is obvious that this domain of interest has to be limited in practice as well as in theory.

A natural choice may be, for example the area of the state, a voivodeship or an-urban conglomeration.

At first, considerations may concern some selected experimental route, i.e. a one-dimentional approach is taken. Next any geometric area, for example a rectangular map section, may be subject to analysis. In any case, at the beginning the borders of the area of interest should be determined. In the case of an administrative district, the contour is defined by a sequence of corners of a polygonal domain. Finally, this domain is given internal structure in the form of a graph, comprising data on vertices (points of interest) and edges (roads connecting the vertices).

2. Modelling the Area of Interest

The projected usage of the Road Vehicle Tracking System Based on Given Identification Features – RETINA, concerns the areas with determined borders, for example specific administration units such as e.g. Mazovia. So we assume for this article that the considered objects move and are observed on a flat area of interest Ω.

Assuming that the dimension is the number of coordinates necessary to describe the location of a given point [2], in case of one-dimension the area could be set as an interval – a section of a route, with length in meters [m], for example:

$$\Omega=[0,400000] \quad (1)$$

while in case of two-dimensional movement the area could be a rectangle, so it is necessary to define two coordinates:

$$\Omega=[0,400000] \times [-100000, 150000] \quad (2)$$

Fig. 1. Exemplary area in one dimension – Polish highway A2 (Swiecko – Konin) [18]

In the first case we can analize the vehicle's movement on the highway with a length of about 270 km, rejecting the option of leaving from the established road, shown on Fig. 1. In the second case the movement and also the observation will consider a rectangle of size 400km by 250km from the map section. The searched object's position is represented as a pair of numbers *(x,y)*, where the first number is the distance from the left boarder, and the second number is the position relative to the horizontal axis, as on Fig. 2. The same method was recently applied in [4].

Fig. 2. Exemplary area Ω in two dimensions (Masovian Voivodeship) [own study]

SI units are accepted – length is measured in meters, time in seconds. The assumption that the observed object moves freely in two or three-dimensional area in usage relevant to road transport is not adequate. It corresponds to the situation for example in aviation, oceanic shipping or during the biological research – migration of birds or fish. In the road transport the extreme inhomogeneity of the area must be taken under consideration [15]. In railway transport, like [1, 13], case is simpler. But in road transport we can distinguish roads, roadways, national roads, highways as also the forest paths. The territory must be classified, distinguished, for example population density or the nature reserves.

In the description of traffic it is reasonable to limit the position to the permitted area, which will be the network of roads located in the previously selected area.

Fig. 3. Exemplary area Ω with rectangular grid (from the left: Manhattan, Lodz, cartesian coordinate system) [own study]

In theoretical considerations it is convenient to adopt the ideal rectangular road grid. Sample layout is presented on Fig. 3.

3. Hierarchy of Road Models

With a one-dimensional model, it is sufficient to provide one number [2], a coordinate, to determine the position of the object or place of the event. In civil engineering we use marker posts. They represents the definition of the place on the road by giving the distance from its beginning. This distance is usually given with an accuracy of 1 meter in the format (km) xx + yyy or xx, yyy (km), where: xx - total number of kilometers from the beginning of the road or railway line, yyy - total number of meters counted from the last full kilometer. Currently, marker posts are usually placed every 100 meters, as in Fig. 4.

Fig. 4. Typical Polish marker post (situated near Radom – national road no. 7) [own study]

In the developed system, in subsequent articles devoted to vehicle traffic modeling, the marker post will be used to describe the movement along a real, non-straight path using only one parameter, i.e. as given in the example below and also in Fig. 1.

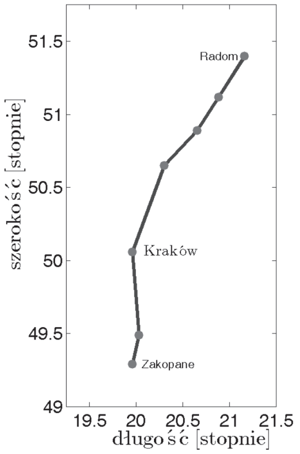


Fig. 5. Example route from Radom to Zakopane [8]

With realistic modeling in two-dimensional areas instead of the definition of two coordinates, for example GPS data, the use of the road identifier is often used along with the marker posts for the conventional beginning of the road, example – Fig. 5. In theoretical considerations and computer simulations, the roads can be numbered and identified with their index.

Fig. 6. shows an example of using this method to study road traffic.

Opis odcinka				Opis punktu pomiarowego			Pomiar dodatkowy poj. ciężarowych	Nazwa Rejonu GDDKIA
Pikietaż Pocz.	Pikietaż Końc.	Długość (km)	Nazwa	Typ	Pikietaż	Miejscowość		
4	5	6	7	8	9	10	11	12
430,0	431,5	1,5	KAMIENNA GÓRA/PRZEJŚCIE 1/	H	430,7	KAMIENNA GÓRA		WAŁBRZYCH
0,0	1,6	1,6	KAMIENNA GÓRA/PRZEJŚCIE 2/	G	0,2	KAMIENNA GÓRA		WAŁBRZYCH
431,5	436,2	4,8	KAMIENNA GÓRA/PRZEJŚCIE 3/	H	432,3	KAMIENNA GÓRA		WAŁBRZYCH
1,6	4,6	3,0	KAMIENNA GÓRA /OBWODNICA/	G	1,8	KAMIENNA GÓRA		WAŁBRZYCH
436,2	444,0	7,8	KAMIENNA GÓRA-GR.PAŃSTWA	G	440,7	LUBAWKA		WAŁBRZYCH

382,4	384,2	1,8	RASZYN-JANKI	H	382,9	RASZYN		OŻARÓW MAZOWIECKI
384,2	388,3	4,1	JANKI-MAGDALENKA	H	386,9	JANKI		OŻARÓW MAZOWIECKI
388,3	402,6	14,4	MAGDALENKA-TARCZYN	F	389,7	ŁAZY		OŻARÓW MAZOWIECKI
402,6	415,0	12,3	TARCZYN-GRÓJEC	H	406,9	PAMIĄTKA		GRÓJEC
415,0	420,2	5,3	GRÓJEC /OBWODNICA 1/	H	L-419.5 P-419.9	SKURÓW		GRÓJEC
420.2 0.0	436.1 1.8	17,6	GRÓJEC-FALĘCICE	F	L-429.4 P-429.5	DŁUGOWOLA /MOPY/		GRÓJEC
1,8	5,2	3,4	FALĘCICE-BIAŁOBRZEGI/DR.48/	H	5,1	BIAŁOBRZEGI		[illegible]
5.2 444.1	8.2 451.3	10,1	BIAŁOBRZEGI/DR.48/-ST.GÓZD	H	444,5	KOLONIA SUCHA		RADOM
451,3	459,2	7,9	ST.GÓZD-JEDLIŃSK	H	455,4	ŻDŻARY		[illegible]
459,2	466,8	7,7	JEDLIŃSK-RADOM	H	462,6	WSOLA		RADOM
478,9	482,1	3,2	RADOM-MŁODOCIN	H	480,3	KOSÓW		RADOM
482,1	499,8	17,7	MŁODOCIN-SZYDŁOWIEC	H	497,6	ŚWIERCZEK		RADOM
499,8	504,1	4,2	SZYDŁOWIEC-BARAK	H	501,6	SZYDŁOWIEC		RADOM
504.1 0.0	513.2 1.1	10,2	BARAK-SKARZYSKO KAM.	H	0,1	SKARŻYSKO-KAM.		STARACHOWICE

Fig. 6. Study of traffic intensity using marker post locations [19] - *excerpt*

Instead of global assembly, related to the contractual beginning of the road, in the discussed system it is more convenient to adopt local marker post, which on each section of the route gives the distance to its beginning, that is the nearest node in the direction set.

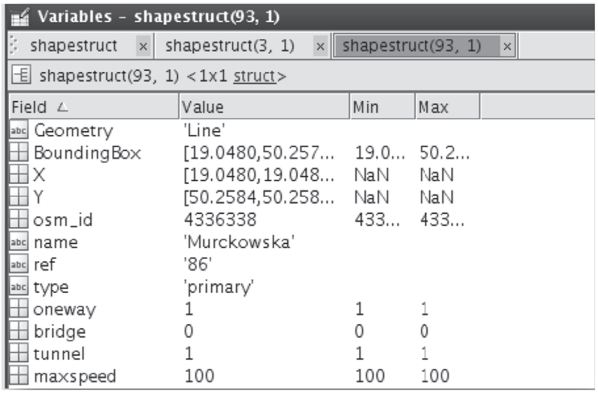
In Fig. 3 the map (right side) contains 16 horizontal and 19 vertical roads. They can be renumbered sequentially, starting from horizontal. In this case, the position definition may be in the form (12,137.563), where the first parameter is the road counter (natural number) and the second parameter is identical to the x-axis coordinate in the Euclidean system.

In order to describe non-trivial road networks it is necessary to introduce selected concepts from the graph theory, which will be presented below.

4. Geographic Data Structures

It should be noted that in practical applications, sometimes the pure graph structure or the oriented graph is insufficient, Extended data structures are introduced, mainly to increase the efficiency of calculations. For example, instead of the edge of a graph, it is possible to assign it to lengths, and vertices to be the coordinates of the corresponding intersections.

In this way, you can immediately create road elements with a wider palette of features. Fig. 7 shows the details of the path from the selected shapefile (*.shp) extracted from the OpenStreetMap.



Field	Value	Min	Max
Geometry	'Line'		
BoundingBox	[19.0480,50.257...	19.0...	50.2...
X	[19.0480,19.048...	NaN	NaN
Y	[50.2584,50.258...	NaN	NaN
osm_id	4336338	433...	433...
name	'Murckowska'		
ref	'86'		
type	'primary'		
oneway	1	1	1
bridge	0	0	0
tunnel	1	1	1
maxspeed	100	100	100

Fig. 7. Sample record from the database [own study]

The fields of this type of elements include the name of the road, category, orientation and the table of items of points marking its course in the area Ω.

Similar supplements work well for intersections. The authors of the work [14] propose, among others, coding of turning rules in the form of a zero-one matrix.

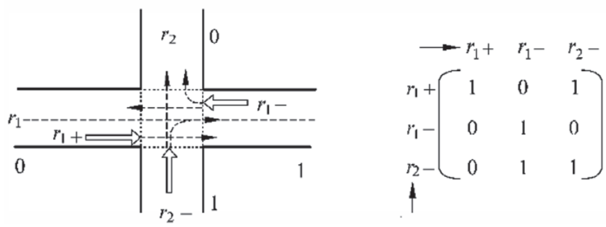


Fig. 8. Communication matrix (example) [14]

An example of such a matrix is presented in Fig. 8, where the intersection can be reached on three sides and the same number of trips. Legal options are marked with ones, for example

$$C_{13} = 1 \tag{3}$$

means that you can turn off at exit 3 when entering road 1.

On the other hand, the entry

$$C_{23} = 0 \tag{4}$$

it is forbidden from taking road no. 2 to road 3.

5. Digital Road Maps

Graph theory is one of the basic tools in traffic modeling, so elementary terms necessary to describe the road network are vertices and edges. The tops correspond to points on the map, such as cities, intersections, entries and trips to / from motorways, petrol stations or car parks.

In the example from Fig. 3 vertices are all points from the area Ω defined as a rectangle, which have coordinate values in this case divisible by 15 (vertical) or 20 (horizontally). It was assumed that the roads (parallel to the axis) were built regularly at intervals of 20 km, relatively 15 km - similar roads were built, eg Manhattan [20]. However, the edges are segments connecting two vertices, so the road is not the same as the edge - it is a series of alternating vertices and edges. Formally, therefore, the G graph is defined as an ordered pair of two sets [10]:

$$G=(V,E) \tag{5}$$

where *V* is the set of all vertices $V=\{v1, v2, \ldots, vm\}$ and *E* is the collection of edges.

Writing $(v1, v2) \in E$ is expressed by the fact that the tops v1 and v2 are connected by a stretch of road. Alternatively, the incident matrix I is used:

$$I\{ij\}=1 \Leftrightarrow (v1, v2) \in E \tag{6}$$

One of the basic theoretical works in the field of car traffic simulation is the article by Nagel and Schreckenberg, [15]. As part of the approach of the authors of this work, sets of data were created describing road networks, such as the United States, where an impressive number of 23,947,347 nodes and 58.333.334 road sections were included. For example, the city of New York has 264,345 points and 733,846 sections, and the above-mentioned Manhattan district has about 12,000 nodes [20].

Fig. 9. A graph representing the Mazovian roads [own study]

The road network developed for research purposes in the Matlab environment, presented in Fig. 9, contains less than 1,500 sections and the same number - the number of nodes. However, to the purpose of the system being designed - this is to verify the ability to track vehicles based on visual data obtained from road cameras - this order of magnitude is appropriate. In this case, the incident matrix has over 2 million entries, which on the one hand is comprehensive enough for academic research, and on the other hand, larger examples are difficult to process on conventional computer equipment.

The graph in Fig. 9 it contains only sections of the motorway, national and provincial roads. All roads of this type are passable in both directions. More advanced modeling requires a distinction between the way, for example, from the node to, and the way from to, because with a higher resolution of the map, for example at the level of the city plan - as in Fig. 10 - one-way streets should also be included. The following figure was created by extracting only the necessary information (geographic coordinates) from data obtained from the OpenStreetMap (OSM) project using the Quantum GIS geoinformation software (QGIS) [21]. However, this solution is not optimal - it is very time-consuming and unfortunately the generated map may contain a large number of errors, types of unfinished roads / streets or incomplete intersections (which may be visible with a high resolution of the city plan). Therefore, for the purpose of further research, the map is used as in Fig. 9.

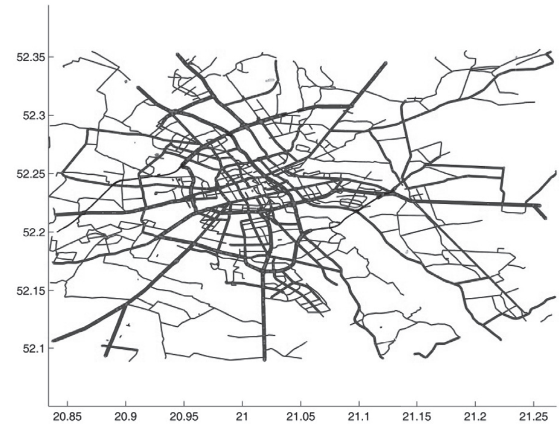


Fig. 10. Map of Warsaw roads selected from the OSM project with the help of QGIS [own study]

This means that there may be a stretch of road from v_1 to v_2, but there is no connection in the other direction, i.e. way from v_2 to v_1.

An appropriate tool for describing such a state of affairs is then an oriented graph with directed edges [14]. The collection *E* is then a set of ordered pairs (v_1, v_2). At the same time pairs of vectors (v_1, v_2) and (v_2, v_1) are different from each other, while the sets $\{v_1, v_2\} = \{v_2, v_1\}$. So an oriented graph is called a pair:

$$\vec{G}=\left(V,\vec{E}\right) \tag{7}$$

where *V* is the set of all vertices $V = \{v_1, v_2, \ldots, v_m\}$ and is a collection of oriented edges.

It should be noted that in the oriented graph, there may even be edges of the type (v_1, v_1), i.e. such sections in the network of roads that connect a given point with itself. One speaks of a loop then, and such a concept may be useful for describing roundabouts. Hence, the notion of the apex order is necessary to define.

Let it $G = (V,E)$ be a graph describing the road network and the top. The number of edges E in the outgoing v is called the row of the top v.

If G it is a graph with orientation (then written in some publications the output and input rows of vertices are defined analogically [16, 17].

It should be emphasized that the definition of a graph is a very abstract tool that examines the structure of a road map, such as properties such as its coherence. On the other hand, in a pure graph description, vertices do not have, for example, positions in space, coordinates, and edges have no course or length. Therefore, in the context of further specification, so-called weights are assigned to both the tops and edges. These can be, for example, the length or volume of traffic on a given section. For this reason, in the work [14] some extensions of the road section and node are introduced, the use of which in the modeling of the road network as part of the project of the Road Vehicle Tracking System Based on Given Identification Features. will be presented in the nearest publications.

6. Selected Computer Experiments

In order to perform specific simulation calculations, maps should be established, i.e. specify areas and road networks, after which the searched vehicles can virtually move and where they can be observed.

On the one hand, it is very demonstrative when one chooses the real: the area and network of roads existing in reality, on the other hand there is a danger that the selection (and determination) of one specific area will lead to results that can not be generalized to any situation. For example, research carried out in the Pomeranian Voivodeship could be inadequate in the case of Lesser Poland Voivodeship.

To avoid premature narrowing of the research plane, the method of generating realistic road grids was introduced. In order to verify the results, the possibility of generating any number of random areas and grids has been introduced. An example of a pseudo-realistic network of roads on a given area is shown in Fig. 11.

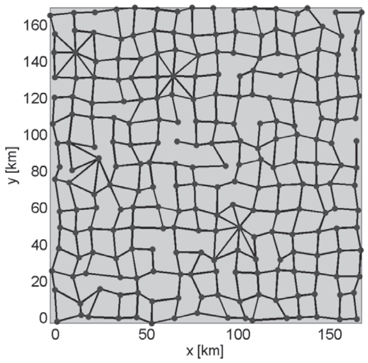


Fig. 11. A synthetic area with a road network [own study]

However, the methodology developed within the framework of this dissertation is to be applicable within specific territories, eg voivodships. The general scheme for creating the data structures necessary to carry out the simulation tests provided for in is also presented above.

The starting point is a map of the selected area, on the example of Mazovia, as in Fig. 12.

Fig. 12.Sector of Mazovia from Google Maps [20]

In the next step, the contour of the area of interest and the considered road sections are marked. An exemplary result of this process is presented in Fig. 13.

Fig. 13. Area with road network [own study]

It should be emphasized that the described procedure, in addition to determining the structure of the grid, will also define the weights of vertices and edges such as:

- coordinates;
- length of sections.

It should be noted that the creation of more detailed maps requires the use of open source numeric databases provided for example by the OpenStreetMap (OSM) project.

The selected example developed in the Matlab environment during the deliberations under this dissertation is shown in Fig. 14.

Additionally, databases of this type allow you to extract, among others, information about:

- traffic restrictions (road signs);
- city positions;
- population density;
- land development

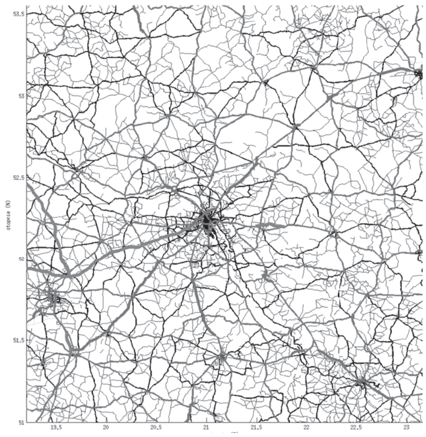


Fig. 14. Selected Mazovian roads generated in the Matlab environment [own study]

The OSM project is a very convenient source of data, because it is primarily non-commercial, and at the same time very accurate and up to date.

Unfortunately, it also has disadvantages. A certain obstacle in separating only the above-mentioned information, for example, is the volume of data contained in it (collected by users / creators of this project).

It is quite easy to get maps in the form of graphic files, while the selection of vector data describing the route or position of objects is tedious and multi-stage and hence the objective of clearly presenting the model in further considerations is the model from Fig. 13.

7. Conclusion

The work presents the basics of road network modeling, which constitute an essential component of the described in the series of articles i. a. [3-9] Road Vehicle Tracking System Based on Given Identification Features. Systems like this can increase human safety, other cases, where human is the biggest problem of the system are described in [11, 12].

The methodology of creating vector data describing the structure of the graph, whose vertices are intersections and the edges – road sections, is given. The advantage of the created data sets is the possibility of using them directly in vehicle traffic simulations. The scale of the resolution is adapted to the intended use – traffic simulation of road vehicles moving around the size of a typical voivodeship, at a speed level around 100km/h. The covered distances are assumed to be up to 200km, and the observation time is discretized at steps of one minute.

Bibliography

[1] CISZEWSKI T., NOWAKOWSKI W.: Interoperability of IT systems in the international railways, Conference Proceedings 16th International Scientific Conference Globalization and Its Socio-Economic Consequences, University of Zilina, Part I, 2016, pp. 312-320

[2] ENGELKING R.: Teoria wymiaru, Państwowe Wydawnictwo Naukowe, 1977

[3] GÓRSKA M.: Application of dash-cams in road vehicle location systems, Autobusy – Technika, Eksploatacja, Systemy Transportowe no. 12/2017, pp. 122-126

[4] GÓRSKA M., JACKOWSKI S.: Selected aspects of road vehicle localization, Autobusy – Technika, Eksploatacja, Systemy Transportowe no. 12/2016, pp. 122-126

[5] GÓRSKA M., JACKOWSKI S.: Retina – a surveillance tool for road traffic, TTS Technika Transportu Szynowego no. 12/2015, pp. 648-655

[6] GÓRSKA M.: Analiza wybranych cech dystynktywnych pojazdów drogowych w systemie RETINA, Logistyka no. 6/2014, str. 4059-4068

[7] GÓRSKA M.: Podstawy modelowania sieci dróg w Systemie Poszukiwania Pojazdów Drogowych Według Zadanych Cech, Autobusy – Technika, Eksploatacja, Systemy Transportowe no. 3/2013, pp. 2139-2147

[8] GÓRSKA M.: Metody matematyczne ekstrapolacji trajektorii ruchu pojazdów drogowych, artykuł recenzowany, TTS Technika Transportu Szynowego no. 9/2012, str. 4201-4211

[9] GÓRSKA M.: Course prediction for mobile object tracing network, Proceedings of the 4th International Interdisciplinary Technical Conference of Young Scientists, Poznań 2011, pp.148-152

[10] KLIN M.CH., PÖSCHEL R., ROSENBAUM K.: Algebra stosowana dla matematyków i informatyków: grupy, grafy, kombinatoryka, Wydawnictwa Naukowo-Techniczne, 1992

[11] ŁUKASIK Z.: Teoria informacji i sygnałów, Wydawnictwo Uniwersytetu Technologiczno-Humanistycznego w Radomiu, 2012

[12] ŁUKASIK Z., CISZEWSKI T., NOWAKOWSKI W.: The human as the weakest link in ensuring technical safety, Conference Proceedings 17th International Scientific Conference Globalization and Its Socio-Economic Consequences, University of Zilina, 2017, Part IV, pp. 1788-1795

[13] ŁUKASIK Z., USHAKOV A.: Modern container tracking systems on russian railroads: technologies and prospects, Autobusy: technika, eksploatacja, systemy transportowe no. 6/2017, pp. 1613-1615

[14] MENG X., CHEN J.: Moving objects management: models techniques and applications, Wydawnictwa Tsinghua University Press, Beijing oraz Springer-Verlag Berlin Heidelberg, 2010

[15] NAGEL K., SCHRECKENBERG M.: A cellular automaton model for freeway traffic, Journal de Physique I France 2, vol. 2, no. 12, 1992

[16] OLARIU S, WEIGLE M.C.: Vehicular networks – from theory to practice, Chapman & Hall/CRC, 2009
[17] SŁUPECKI J., HAŁKOWSKA K., PIRÓG-RZEPECKA K.: Logika i teoria mnogości, Wydawnictwo Naukowe PWN, 1994
[18] www.conadrogach.pl [date of access: 30.01.2018]
[19] www.gddkia.gov.pl [date of access: 30.01.2018]
[20] www.google.pl/maps [date of access: 30.01.2018]
[21] www.newyorkinplainsight.blogspot.com [date of access: 30.01.2018]
[22] www.openstreetmap.org.pl [date of access: 30.01.2018]