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Mpar-Cluster: Applied Algorithm of Geo-Selection for Optimization of the Credit Recovery of Electricity Supply

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Abstract: This paper presents a study of optimization of operational recovery credit default with geoprocessing use through geoprocessing tools, developed in the Receivables Management Companhia de Eletricidade do Estado da Bahia-COELBA sector. The work was initially based on the application of Data Mining Tools for Software KNIME 2.9 and later use of the tool of GIS-ArcGIS 10.X/ESRI .Were evaluated and applied analytical processing algorithms, to improve the process of spatial selection and define the best sets logistical credit recovery. The focus study, based on geoprocessing use in cutting action is due to the fact that this process has the largest collection efficiency. It is understood that the efficiency of the cutting action, should the great importance that electricity has on modern life. The research was guided its evolution from analysis of algorithms agglutination and georeferenced database, whose focus was and is acting in the cutting action due to the fact that this process has the largest collection efficiency. For the implementation of the study, through some geoprocessing techniques, the Mpar-cluster, this optimization model was developed from a custom algorithm for spatial selection, that had with subsidy: information stored in geographic databases, database information alphanumeric, images (aerial photographs and satellite images), text files, and digital tables.

Key words: Geoprocessing, recovery credit, mpar-cluster.

1. Introduction

This article presents a study of operational and financial optimization of the supply of electricity cutting action from analysis of agglutination algorithms and basic georeferenced data. For the application of optimization modeling proposals were used data mining platforms and Geography Information System (GIS) or Geographic Information Systems (GIS).

The focus of this study, based on geotechnology[1] [5, 6] use in the cutting action is due to the fact that this process has the highest collection efficiency. It is understood that the cutting action of efficiency, it should be the great importance that the electricity has in modern life, with the electricity directly related to physiological items of the base of Maslow's needs pyramid [2].

However, the traditional model of disconnection of the power supply is carried out by a specialized workforce, the more expansive significantly the action.

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[1] Geprocessing/Geotechnology is a GIS operation used to manipulate spatial data. A typical geoprocessing operation takes an inputdataset, performs an operation on that dataset, and returns the result of the operation as an output dataset. Common geoprocessing operations include geographic feature overlay, feature selection and analysis, topologyprocessing, rasterprocessing, and data conversion. Geoprocessing allows for definition, management, and analysis of information used to form decisions.

Geoprocessing is a framework and set of tools for processing geographic and related data. The large suite of geoprocessing tools can be used to perform spatial analysis or manage GIS data in an automated way. A typical geoprocessing tool performs an operation on a dataset (such as a feature class, raster, or table) and creates a resulting output dataset. For example, the Buffer tool takes a map layer as input, creates areas around the layer's features to a specified distance, and writes those areas to a new output layer.

In addition to the suite of tools, geoprocessing also has a powerful framework that supports control of the processing environment and allows you to build custom tools that can further automate your work. You can use the geoprocessing tools included in ArcGIS as building blocks to create an infinite number of custom tools that automate repetitive tasks or solve complex problems.

Thus, It has been the cutting action a great setting for an optimization study, where an efficient and high operating costs action, provides scalable gains.

For the development the study optimization algorithms were applied in Data Mining as: K-means and *Equa k-means*[3]. Posteriorly, a second optimization model from a customized geographic selection algorithm was developed. This algorithm has been "baptized" as map-cluster or maximum pick amount per radius-cluster (*aglomerado de valor máximo de seleçãoporraio*)[2]. For the application of map-cluster were used some geotechnology techniques in a GIS environment (Fig. 1), with subsidy information stored in geographical databases, database of alphanumeric information, images (aerial photographs and satellite images) texts, tables and digital files.

Thus, this study demonstrated the possibility of better earnings by reviewing the collection of operational processes in the organization studied through the use of geographical knowledge, based on the geo-referenced location of the clients in the Bahia of state. The work was initially based on the application of tools for Data Mining Software KNIME 2.9 and later

Fig. 1 Estrutura de um SIG. Fonte Medeiros 2012.

[2] Algorithm developed by the authors to receivables management. The sea-cluster is used for geospatial selection of collection cutoff scores. The algorithm can also be applied to identification customers susceptible to new debts, negated and problems in power distribution.

the use of GIS tools — ArcGIS 10.x/ESRI. Were evaluated and applied analytical processing algorithms to improve the spatial selection process and define the best logistics sets of credit recovery. The study analysis focuses on demonstrate the results of operations more efficient strategic and financial charges on portfolios [4].

2. Materials and Methods

2.1 Structure

In Companhia de Eletricidade do Estado da Bahia (COELBA)[3], the operational process of default loan recovery is planned by the Management Unit of the Receivables — CRGR that uses different non-payment combat activities, the expected date of electric energy, planning actions such as warning notices, Short Message Service (SMS), Response Unit audible (URA), negativity, power cut, cut tracking, low administrative, billing advisory and judicial collection. The management of flow collection of default is managed through the Customer Success Story tool — Company CCS SAP, with "rules" specific collection. These rules are parameterized for different clients profiles and following the regulatory guidelines of Resolution No. 414/2010 of ANEEL [1].

The focus of this study was directed to supply cutting action of electric energy. The regulatory control of susceptibility to activity is managed by SAP CSS, the unit being provided a daily list of customers susceptible to power supply suspension action (cut). Currently the list of susceptible is handled in a proprietary system called Information Control and Collection (ICC). This system treats the list provided by SAP CCS, complementing financial information

[3] The Companhia de Eletricidade do Estado da Bahia is the third largest electricity distributor in the country in number of customers and the sixth in power supplied volume. These same terms, ranks first among the North dealers — Northeast. Controlled by Neoenergia Group, one of the largest investors in the Brazilian electricity sector, Coelba is present in 415 of 417 municipalities in Bahia, serving more than 14 million inhabitants in a concession area of 563,000 km^2. Today the company has over 5.6 million customers, 88% of these residential customers.

and automatically applies the logistical limitations of availability of Providers Outsourced Business Services — EPS.

For the implementation of the concept of limitation contractual logistics of EPS, the concession area COELBA is divided into 43 centers of work. ICC system (Fig. 2), these 43 work centers are divided into target zones, these zones represent sets of neighborhoods in the municipal seat or group of municipalities — in the least populated areas. The zones are further subdivided into cluster, which represents sets of neighborhoods neighbors. These definitions of zones and clusters are parameterized empirically, based on the field knowledge of operational coordinators of the respective work centers.

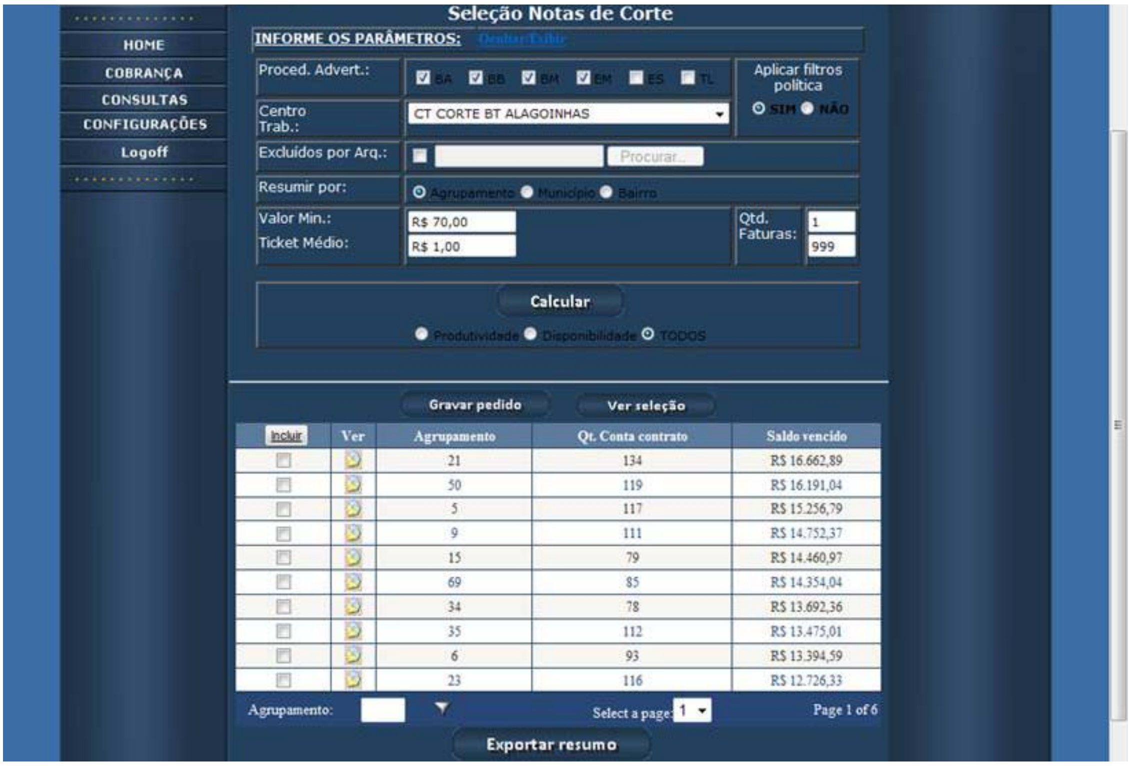

Fig. 2 ICC. Source: COELBA, 2014.

The algorithm used by the ICC for selecting serial succinctly defined by the following steps:

(1) Select a particular zone Work Center — CT to set the selection;

(2) It makes up the summarization of the number of clients per group;

(3) Sort up zones of decreasing order by the charged total;

(4) Select first zones between the amount of service, depending on the logistical limitation;

(5) Repeats 1 through 4 the process to be performed to check banknotes for all areas of all TCs limited to daily target set for each zone;

The selected amount is increased by a percentage of 15% compared to the target area in order to facilitate the composition of sets of notes from classes by EPS. In addition, it adds up over 10% from the percentage of notes identified as paid during field service.

As an example, stands out in Table 1 the selection of the groups 22, 23, 1 and 2 of the sample under study referring to the day 05/20/2014. In Table 1, were summarized customers likely to cut according to the groups being classified the clusters in descending order of sum of debt collect. In this example are highlighted 1007 client where the program selected 1,000 customers, representing: 800 customers regarding the cutting target this area of the work center, plus the 10% paid account and 15% of routing.

This selection of the ICC is directed SAP CCS, that generates the service and provides the following day the cutoff score for its EPS. In EPS, a staff with field experience brings together the notes by class and dispatches to their field technicians. The notes not dispatched by EPS are handled by SAP CCS and subsequently made available to a new selection of ICC.

In Fig. 3, there is an example of the spatial distribution of the notes being displayed on the Google Earth software, relative the generation and dispatch the classes on 05/20/2014. The icons (balloons) in shades of blue show the orders per group, coming from the susceptible portfolio selection process. In addition, perceives in the sameFig. 3 some stains yellow to red, representing, respectively, the smaller the higher concentrations of debts.

In a closer view of the EPS of routing, there is an overlap of activities of the groups, as well as an error of dispatch note orders that impact on an increase displacement in group 2, see Fig. 4.

Analyzing the current model selection, occur improvement points from a selection: more in line with the debt stains with smaller radius of action, with greater concentration and better order per group. From this universe of study, were evaluated two proposals for optimization and debt assemblage, one for analysis of statistical tools for Data mining using clustering algorithms, and another by the mpar-cluster own algorithm, implemented in ArcGIS/ESRI 10.

Table 1 The first lines of the zone groupings 1 do CT of Praça da Sé.

Grouping	Debt	Average	QTD
22	R$ 47'314.43	R$ 142.51	332
23	R$ 42'042.14	R$ 178.90	235
1	R$ 39'326.92	R$ 185.50	212
2	R$ 32'577.55	R$ 142.88	228
16	R$ 29'218.35	R$ 210.20	139
13	R$ 28'277.90	R$ 235.65	120
12	R$ 27'669.40	R$ 172.93	160
7	R$ 25'705.06	R$ 163.73	157

Fig. 3 Satellite image containing the selection of notes and debt stain. Prepared by the authors, 2014.

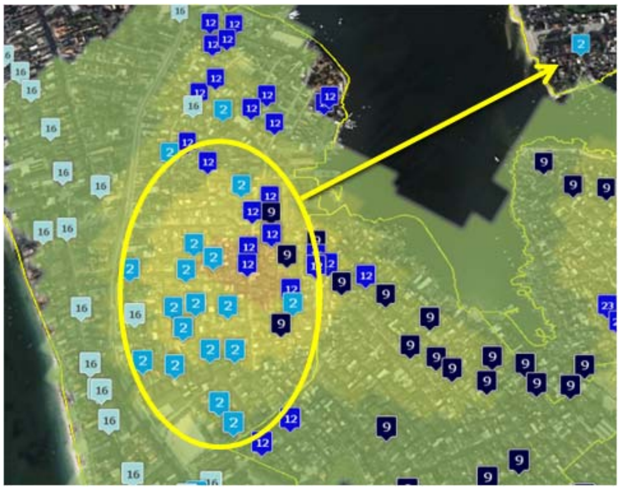

Fig. 4 Overlapping classes and error in the distribution of cutoff scores for group 2. Prepared by the authors, 2014.

2.2 Analysis of Selection of Optimization Proposals

2.2.1 Optimization in Data Mining

The term data mining (mining and mining data) is a part of Knowledge Discovery in Databases (KDD) (knowledge discovery in databases) that deals with knowledge discovery of methods in large amounts of data (Fayyad, Piatetsky-Shapiro, Smyth & Uthurusamy, 1996).

For the study in question was used KNIME software in the free version No 2.9 of the open source type (open source). The choice of the software in question is due to ease of use, with an extensive pre-installed library blocks drag and drop type. Among the available algorithms, there is the K-means. An agglutination or clustering algorithm that aims to break "n" observations "k" sets where each observation belongs to the closest cluster average, see Fig. 5. This results in a division of the data space on a Voronoi diagram, a type of spatial decomposition where the sample segments from distance of relational analysis. In Fig. 5 it can be noted "n" points being divided into three colors, where for defining the color of each point was performed one distance calculation between the other points are assigned a color according to the proximity between individuals.

The geographic coordinates used in KNIME were previously treated in regional geodetic system for South America — South American Datum — SAD 1969 in decimal degrees. Was made necessary normalize latitude dimensions longitude and debt due to the large variation in the data of the latter compared the draft decimal variation of latitude and longitude coordinates, when converted to decimal degrees. This action was taken to mitigate agglutination trend of distance calculation for the dimension debt.

Even with the normalization of the values of debt shaft, it can be seen in the studies a grouping tendency by the distance of debt, getting more clusters grouped by this value due.

In a second stage of the study, it was removed from the size debt and applied the K-means the algorithm for dimensions latitude and longitude. During the study it

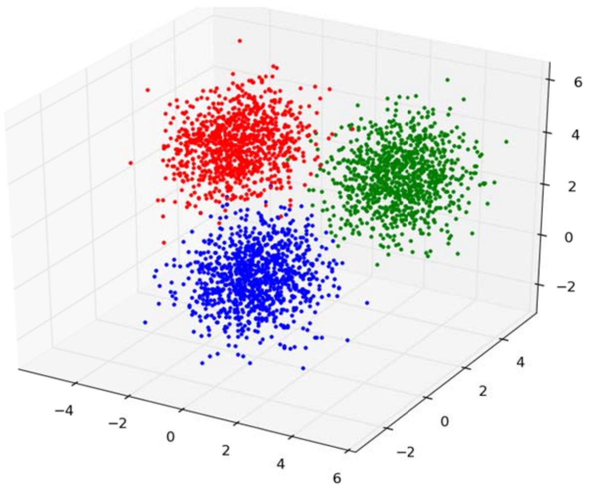

Fig. 5 Graphical representation of the result of a clustering. Source: dartmouth.edu, 2012.

was ratified a limitation of the k-means algorithm linked to the development of the same functionality; it is not possible to create clustering with predefined limits on the number of subjects per group.

From that point, we tried to search clustering algorithms that allow to define the amount of individuals by himself. Thus, it was identified and implemented a new mining algorithm developed by Pierre-David, titled EKmeans. This tool developed oriented programming language object — Java, which uses the concepts implemented in heuristics expression K-means, calculated according to the Euclidean distance, but limiting the number of individuals algorithm for clustering. This Java application was limited to two dimensions, which was already studied in line with the idea of using only the latitude and longitude dimensions for agglutination. By applying the algorithm EKmeans found interesting results which will be shown in the comparative topic between models

2.2.2 Geotechnology Optimization

In addition to the challenging modeling developed in Data Mining, we sought to develop and implement a solution focusing on geotechnology tool. The proposed algorithm developed and has had a focus: identify the client more limited debt amount to a maximum radius of a group action and enhance the clustering with higher note values to the limit of notes per group.

The use of GIS through ArcGIS/ESRI software was necessary due the search of geographical positioning of each customer or the proximity of this with the adjacent post. The location of the customers and the relationship of susceptible to charging by zone or neighborhoods of CT's were fundamental to define the best route to follow and efficiency in the collection, especially with regard to higher values.

The implementation of the designed algorithm was made with the partnership between an Electrical Engineer, postgraduate in Business Management (RODRIGUES, M.) and Geographer, specialist in GIS (COPQUE, A.). Thus, the use of GIS tools enabled the application of mpar-cluster algorithm in the

Company's business model, this application can be exemplified, succinctly, according to the sequence below:

(1) For each Work Center — CT (of the 43 existing) and zone list is georeferenced form all customers susceptible to cutting action;

(2) Among the list of susceptible, you select the highest debt value;

(3) Considering the previous study of a radius by zone if list to all customers around this greater debt to its maximum radius of action;

(4) Selects the highest debts in the action radius to form the amount of notes, the group will act;

(5) Repeat step 2-4 to form all zone groups concerned;

(6) Repeat step 2-4 to all classes of all the work centers by area;

In Fig. 6, there is the application of the algorithm mpar-cluster with the selection of two (2) clusters being displayed on the Google Earth software, referring to customers susceptible to cutting action on 05.20.2014 for CT Praça da Sé. The icons (points) in dark blue represent all customers susceptible to cutting action. The icons (points) in red represent the largest debts to be collected. The red circle represents the radius of action of group, defined from the best results of the field action history. Os ícones (pontos) azul claro representam os clientes suscetíveis e dentro do raio de proximidade da maior dívida. The orange icons (items) representing the likely customers, with larger values

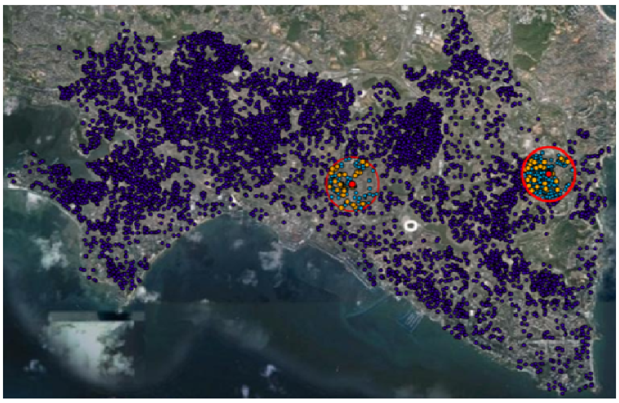

Fig. 6 Application of the algorithm mpar-cluster. Prepared by the authors, 2014.

and debt within the proximity distance higher debt to complete the total customer triggered by a group.

With the application of mpar-cluster were found algorithm further significant results and that will be as follows concerning the comparison between models.

3. Results and Discussions

3.1 Comparison between Models: Current, Mining, GIS

For the comparative evaluation of results of models were developed geographic representations of selection using the gadget ARCGIS 10.x/ESRI and displaying the software Google Earth. Furthermore, it was made a comparative Chart summarizing the information for a global day of action group.

Selecting the view of the ICC cutting portfolio it was presented in "2.1 The structure" through Fig. 3. In that image was observed optimization opportunities, ratified by divergent selection in relation to debt stain concentrations.

On the optimization in Data Mining, it was found in a study that the EKmeans algorithm had a better result than the study of application of K-means. Thus, it was made to Fig. 7, which depicts the application of EKmeans algorithm, referring to customers susceptible to cutting action on day 05.20.2014 for CT of Praça da Sé. The icons (balloons) in shades of blue show the orders per class, resulting from the application of EKmeans algorithm in the database of customers susceptible to cutting action. Furthermore, it appears the same spot due detailed in Fig. 3.

In a visual comparison between Fig. 7 and Fig. 3 it can be seen graphically EKmeans better performance compared to model the ICC. The clustering algorithm generated by EKmeans have a greater alignment between classes and the debt stains. However, it was still possible to see the application of the model EKmeans earning opportunities tied to debt stains not triggered and the dispersion of the class action radius. In this case, it was found for the cluster number 15 one distance greater than Km 3, and a light scattering cluster number 13.

Fig. 8 was made for a graphic display of the application of Geotechnology optimization model. This image depicts the application of mpar-cluster algorithm in customer base susceptible to cutting action, on day 05.20.2014 for CT of Praça da Sé. The icons (points) in reds show orders per group, resulting from the application of mpar-cluster algorithm in the database of customers susceptible to cutting action. Moreover, a similar stain detailed debt is shown in Fig. 3.

Fig. 7 Application of the algorithm *EKmeans*. Prepared by the authors, 2014.

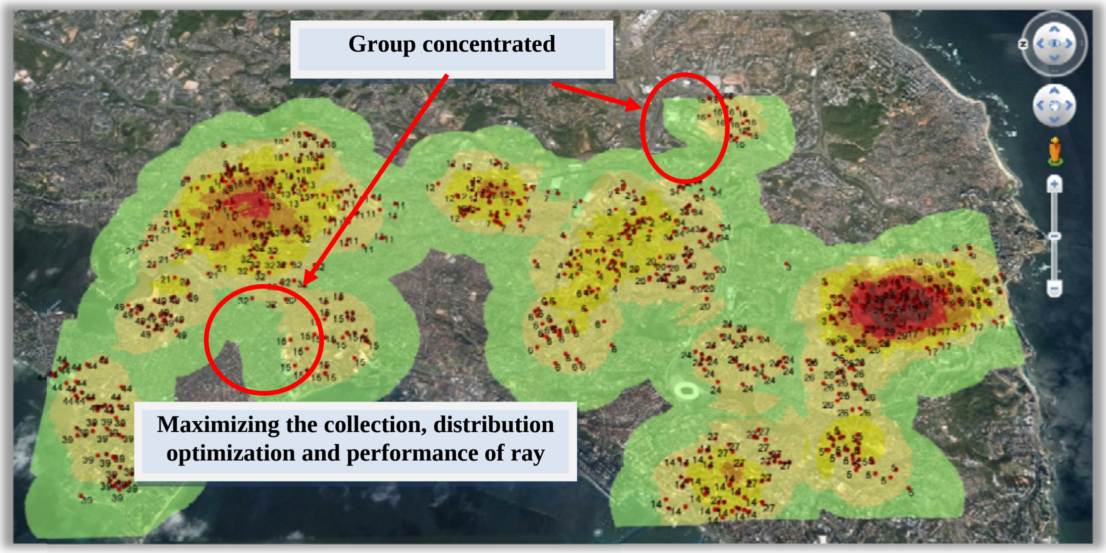

Fig. 8 Application of the algorithm mpar-cluster. Prepared by the authors, 2014.

By visually comparing Figs. 8, 7, 3 and Table 2, it validates graphically the best performance of the mpar-cluster algorithm (Fig. 8) compared to EKmeans (Fig. 7) and the ICC (Fig. 3). The clustering generated by mpar-cluster algorithm have a strong alignment between group and the debt stains. Besides having more control over the radius of action of classes, thus avoiding cluster dispersion.

In Table 2 it is possible to identify the measured methods, the total charged by the mpar-cluster algorithm was 61% higher than the current model selection. This gain was recorded even though the amount of notes 1.47% lower than that generated by the ICC selection. Regarding the performance of radius, it can be seen graphically that the mpar-cluster algorithm provides a reduction of the radius of action of group and may even increase the amount of notes executed a day ahead to earnings by reducing shifts.

3.2 Ratification of Geotechnologica Optimization Gains

Aiming to verify the gains from the application of mpar-cluster algorithm was made a new model of the application of simulation in Ilhéus work center in Canavieiras area. He was noticed in Fig. 9 and Table 3, a gain of over 60% compared to the average decrease of the group action radius. Moreover, with the same effective seven (7) classes it was possible to trigger the collection of R$ 187,900.56, representing a gain of 440% over the proposal generated by the ICC algorithm.

The tabulation of the geostatistical analysis used for CT Ilhéus, demonstrates the validity of the study in question and that this tends to bring organizational and financial gains for the sector and thus for the Company.

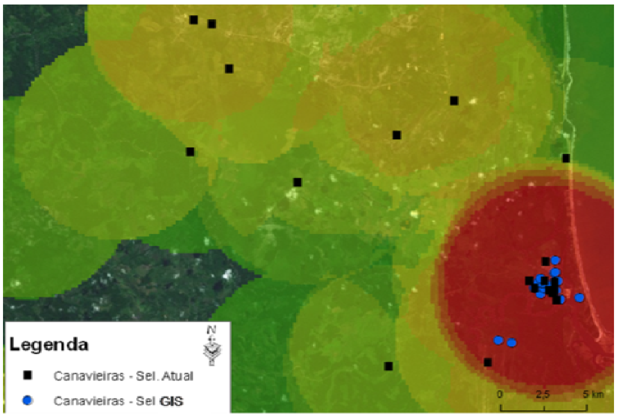

Fig. 10 Comparison between the current selection and GIS for CT Ilheus zone Canavieiras. Prepared by the authors, 2014.

Table 2 Comparative summary of the court of selection models.

Modelagem	QTD Turmas	QTD Notas	Total Cobrado	% Cobrado
Atual	23	747	R$135.095,03	100%
Ekmeans	23	732	R$164.590,76	122%
Algoritmo GIS	23	736	R$217.704,03	161%

Table 3 Comparing the Court of model selection in CT Ilheus.

Metodo	Turmas	Notas	Raio	Valor	%
SelecaoAtual	07	122	15 km	R$42.665,84	100%
Selecao GIS	07	126	5 km	R$187.900,56	440%

The implementation of the geographical concept (see Table 3 — Selection GIS) research was identified in substantial gains, as the amount of notes, action radius and percentage susceptible to collection.

Regarding the reduction of the radius of action, for example, there is a significant logistical gain when compared with the present situation and this selection leads geospatial/entail smaller displacements. In parallel with this it is also possible to have the exact location of the client maps (Digital Printing) from a structured base map.

4. Conclusions

The developed research sought to guide the potential of this study and the main geographical nature of returns, organizational and financial, to the detriment of the use of GIS. To this end, we have been tested and simulated clumping algorithms, focusing on optimizing logistics selecting customers susceptible to energy supply suspension action. All this study was also informed by concepts of GIS anld use of an organized base map.

During development of the research we were tested the applying various clustering algorithms, especially when the results achieved in implementing the mpar-cluster algorithm. The possible gains presented triggered increased value for the charge, which enables a proportional increase of the total amount recovered. In addition, the focus on defining the action radius, provides an increase in the amount of notes made by the forward group displacement economy circumvented by reducing the dispersion of notes.

After this study, it was hired by this company a Geographer/GIS Analyst, which collaborated with the implementation of a pilot project to use this optimization logistics. During deployment, already practical gains of mpar-cluster algorithm has been validated, and other gains related to: basic treatment georeferenced customers; Studies of best access routes; Redefinition of areas of workplaces, based on customer sensitivity, secondary mesh network of energy and support roads;

The optimization pilot project selection via GIS was fully deploying in September 2014.

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Communicative Names of Cities and Streets

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Abstract: This paper presents the different categories of communicative names of cities and streets with some examples all over the world. The commemorative role is playing also by the names of some continents, like America, from the Amerigo Vespucci's name. But many countries and states particularly in the Americas remember the Columbus' name. Many city names remember political leaders of great significance, like Washington after Georg Washington, Monrovia after James Monroe, Leningrad (today Saint Petersburg, which remembered the tsar Peter I). Two soviet leaders, Lenin and Stalin were remembered by two Russian cities, Leningrad and Stalingrad, nowadays Saint Petersburg and Volgograd. The name Ho Chi Minh, after the North Vietnamese leader. The names of other regions and cities have been considered, like many cities and islands named Georgia after some kings. Also Louisiana, The Carolinas, Léopoldville, Elisabethville were named after other kings and queens. Some cities and islands' names remember explorers, like Cook, Stanley, Lourenço Marques (today Maputo, after the name of a river), Brazzaville after, Pietro Paolo Savorgnan di Brazzà etc. Rio de Janeiro is named after the date of its discovery. Many place names were named after Alexander the Great, outer than the Italian Alesssandria, named after the Pope Alexander III. Many place names remember Saints, particularly in Latin America, but also in North America, like St. Francisco. The streets' names are many all over the world. In Rome we have streets names to politicians, like Camill Benso di Cavour, Giuseppe Mazzini and Palmiro Togliatti; writers like Alessandro Manzoni and Torquato Tasso. A name like Giuseppe Garibaldi is extremely diffused in all Italy and also in other countries.

Key words: Continents' names, cities' and islands' names, streets' names, explorers' names, saints' manes, kings' and queens' names, politicians' names.

1. Introduction

The aim of this paper is to present the different categories of communicative names of cities and streets with some examples all over the world. A major function of the communication is the commemoration. But also the names of some continents and countries play a commemorative function. For instance the name of the new continent America appears perhaps for the first time on the Martin Waldseemüller' world map of 1507, entitled *Universalis cosmographia secundumPtholomaei traditionem et AmericiVespucii aliorumque lustrationes*. Waldseemüller used the name of Americus Vespucii like a base for the new name, taking the feminine form *America*, according to the names of other continents: Europa, Asia, Africa, Australia and Oceania. On the JagellonianGlobe of 1511 the inscription "*America noviter reperta*" appears for the first time on a continent America not linked with Asia.

For the communicative names of countries we can mention Columbia. The name "Colombia" is derived from the last name of Christopher Columbus (Italian: *Cristoforo Colombo*, Spanish *Cristóbal Colón*). It was conceived by the Venezuelan revolutionary Francisco de Miranda like a reference to all the New World, but especially to those under the Spanish and Portuguese rule. The name was later adopted by the Republic of Colombia of 1819, formed out of the territories of the old Viceroyalty of New Granada (modern-day Colombia, Panama, Venezuela, Ecuador, and northwest Brazil). Many states, cities and streets refer to the same sailor Columbus:

District of Columbia, the federal district in which the capital of the United States is located; *Columbia*, Alabama, a city; *Columbia*, California, a census-designated place and former boomtown; *Columbia*, San Diego, California, a neighborhood;

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Columbia, Connecticut, a city; *Columbia*, Illinois, a city; *Columbia Fayette County*, Indiana, an unincorporated city; *Columbia*, Kentucky, a city; *Columbia*, Louisiana, a city; *Columbia*, Maine, a city; *Columbia*, Mississippi, a city; *Columbia*, Missouri, a city; *Columbia*, Missouri Metropolitan Area; *Columbia*, New Hampshire, a city; *Columbia*, New York, a city; *Columbia*, North Carolina, a city; *Columbia*, Pennsylvania, a borough; *Columbia*, South Carolina, the capital of South Carolina; *Columbia*, South Carolina Metropolitan Area; *Columbia*, South Dakota, a city; *Columbia*, Tennessee, a city; *Columbia*, Virginia, a city; *Columbia*, West Virginia, an unincorporated community in Fayette Country; *Columbia*, former name of West Columbia, Texas, a city; *Columbia* (electoral district), a former provincial electoral district in British Columbia, Canada, 1903-1928; *Columbia Island* (New York); *Columbia Island* (District of Columbia); *Columbia Street*, New Westminster, the main downtown street of that city, in British Columbia, Canada.

2. Names of Political Leaders of Great Significance

Many city names remember political leaders of great significance:

We can name, e.g., Georg Washington (February 22nd, 1732-December 14st, 1799), who was the first President of the United States (1789-1797), the Commander-in-Chief of the Continental Army during the American Revolutionary War, and one of the Founding Fathers of the United States. He presided over the convention that drafted the United States Constitution, which replaced the Articles of Confederation and remains the supreme law of the land.

His name is remembered both by the current capital of the United States and a state of the United States.

Two soviet leaders, Lenin and Stalin were remembered by two Russian cities: Leningrad and Stalingrad. In 1914 the name of Leningrad was changed from *Saint Petersburg* to Petrograd, in 1924 to Leningrad, and in 1991, back to *Saint Petersburg*. Vladimir Ilyich Lenin; born Vladimir Ilyich Ulyanov (22 April, 1870–21 January, 1924) was a Russian communist revolutionary, politician and political theorist. Under his administration, the Russian Empire disintegrated and was replaced by the Soviet Union. Saint Petersburg was founded by Tzar Peter the Great on May 27, 1703. Between 1713–1728 and 1732–1918, Saint Petersburg was the imperial capital of Russia.

There is another St. Petersburg: a city in Pinellas County Florida, United States. It was named after Saint Petersburg, Russia, where Peter Demens, one of its founders with John Williams, had spent half of his youth.

To Iosif Vissarionovič Džugašvili (1878-1953) known like Joseph Stalin is due one of the names of Volgograd, formerly Tsaritsyn 1589-1925, and Stalingrad (1925-1961).

Lenin and Stalin, like George Washington, were also military commandants.

Togliatti was founded in 1737 like a fortress called Stavropol (Ста́врополь) by the Russian statesman Vasily Tatishchev. Informally it was often referred like Stavropol-on-Volga (Ста́врополь-на-Во́лге, *Stavropol-na-Volge*) to distinguish from Stavropol, a large city in southwest Russia.

The construction of the Kuybishev Dam and Hydroelectric Station on the Volga River in the 1950s created the Kuybishev Reservoir, which covered the existing location of the city, and it was completely rebuilt on a new site. In 1964, the city was renamed Тольятти (Tolyatti, after Palmiro Togliatti, the longest-serving secretary of the Italian Communist Party).

The name of Giuseppe Garibaldi (1807-1882), known also like the hero of two worlds, is remembered in a town in Rio Grande do Soul, southern Brazil. It was settled by Italian immigrants, predominantly Venetians in the late 19th century.

The name of Garibaldi is remembered also in Plaza Garibaldi which is located in historic downtown Mexico City, on Eje central (Lázaro Cárdenas) between historic CalleRepública de Honduras and CalleRepública de Peru, a few blocks north of the Palacio de BellasArtes.

An Italian Club Garibaldi was established in 1882 in Wellington by the first inhabitants of the region.

Of course, most Italian cities have streets and squares named after Garibaldi.

Louisiana was named after Louis 14^{th}, King of France from 1643 to 1715. When René Robert Cavelier, Sieur de la Salle claimed the territory drained by the Misissippi River for France, he named it *La Louisiane*, meaning "Land of Louis".Once part of the French Colonial Empire, the Louisiana Territory stretched from present-day Mobile Bay to just north of the present-day Canadian border, and included a small part of what is now southwestern Canada.

There are two cities named Vladimir: Volodymyr-Volyskyr in Ukraine and Vladimir in Russia named after Valdimir Monomakh.

2.1 Monrovia

James Monroe (Monroe Hall, April 28, 1758 - New York, July 4, 1831) was an American politician. It was the 5^{th} (1817-1825) President of the United States. He is credited with the development of the *Monroe Doctrine*, which focused its ideology in the phrase "America for the Americans". This doctrine will be taken up by Theodore Roosevelt regarding the famous Roosevelt Corollary. Monrovia, capital of Liberia, founded in 1822 during his presidency, was named after him.

Monrovia is another city located in the foothills of the San Gabriel Mountains in the San Gabriel Valley of Los Angeles County, United States

2.2 Georgia

The name Georgia of many states, cities and islands along all the world is eponymous for the first four British Monarchs of the House of Hannover: George I and George II of the Great Britain, George III and George IV, of the United Kingdom who reigned in continuous succession from August 1714 to June 1830. In honor of these monarchs the Georgian architecture was born in most English speaking between 1720 and 1820. The style was revived in the late 19^{th} century in the United States like Colonial Revival Architecture, and in the early 20^{th} century in the Great Britain, referred to the Neo-Georgian architecture.

Many other cities are named Georgetown, but this name derives from different kings, politicians etc.

The name of the British Colony in North America derives from George II of Great Britain: This colony was founded by James Edward Oglethorpe in 1732.

There is another state named Georgia in Caucasus, but its derivation is not from a king: the endonym of this country is Sakartvelo. The inhabitants Kartelebi speak the kartuli language. The esonym Georgia derives from the Persian Gurji that in turn derives from the Arabian جورجيا. This esonym was affected from the Greek γεοργ-, that refers to agriculture.

2.3 Louisiana, The Carolinas

The US state of Louisiana was named after Louis XIV, King of France from 1643 to 1715.

The Carolinas (North and South) were explored by Giovanni da Verrazzano in 1524 and then was colonized by Walter Raleigh, from which he took the name of the capital city. Became a British colony (the Province of Carolina), was so named by King Charles II of England in memory and honor of his father Charles I, beheaded January 30, 1649 at the end of the English Civil War. The division between North and South Carolina became complete in 1712.

2.4 Leopoldville, Elisabethville, Stanleyville, Brazzaville, Kinshasa

The two Republics of Congo show a splendid example of a naming after the changes of power and after explorers.

The explorer Henry Morton Stanley 1881 Leopoldville in honor of the king Leopold II. In 1966 the name was changed in Kinshasa, after the name of a village close to the city.

Henry Morton Stanley also founded Stanley Falls Station in 1883, after Stanleyville. Now Stanleyville is named Kisangani.

In 880 the explorer Pietro Savorgnan de Brazzà had founded Brazzaville.

Elisabethville was founded by Belgian colonizers in 1910 in honor of the Queen Elisabeth, wife of the King Albert I. Elisabetville is now named Lumumbashi after the politician Patrice Lumumba assassinated in 1961.

2.5 Ho Chi Minh

Ho Chi Minh City has gone by several different names during its history, reflecting settlement by different ethnic, cultural and political groups. In the 1860s the occupying force adopted the name *Saigon* for the city, a westernized form of the traditional name.

The name commemorates Ho Chi Min, the pre-eminent North Vietnamese leader. This name, though not his given name, was one he favored throughout his later years. The name means “bringer of light”. Ho Chi Minh was a Communist revolutionary who led the Việt Minh independence movement which established the communist-ruled Democratic Republic of Vietnam in 1945. He was the prime minister from 1945 to 1955 and the president of the Democratic Republic of Vietnam from 1945 to 1969.

2.6 Rio de Janeiro

The most known example of a city named after the date of its discovery is Rio de Janeiro.

Europeans first encountered Guanabara Bay on January 1st, 1502 (hence Rio de Janeiro, “January River”), by a Portuguese expedition under explorer Gaspar de Lemos captain of a ship in Pedro Álvares Cabral's fleet, or under Gonçalo Coelho. Allegedly the Florentine explorer Amerigo Vespucci participated like observer at the invitation of King Manuel I in the same expedition. The region of Rio was inhabited by the Tupi, Puri, Botocudo and Maxacalí peoples.

Since initially Europeans believed that the Guanabara Bay was the mouth of a river, they called in fact “Rio de Janeiro” (or “River of January” in Portuguese). The Tupi Indians who inhabited the Guanabara Bay called newcomers carioca (kara 'iwa = white man and oka = house, where the house of the carioca = white).

3. Explorers

After Columbus and Vespucci the most known explorer is of course James Cook.

The Cook Islands were first settled in the 6th century CE by Polynesian people who migrated from Tahiti, an island 1154 km to the north of Cook Islands.

Spanish ships visited the islands in the 16th century; the first written record of contact with the islands came with the sighting of Pukapuka by Spanish sailor Álvaro de Mendaña de Neira in 1595 who called it *San Bernardo* (Saint Bernard). Pedro Fernandes de Queirós, a Portuguese captain working for the Spanish crown, made the first recorded European landing in the islands when he set foot on Rakahanga in 1606, calling it *Gente Hermosa* (Beautiful People).

British navigator Captain James Cook arrived in 1773 and 1777 and named the islands the *Hervey Islands*; the name “Cook Islands”, in honor of Cook, appeared on a Russian naval chart published in the 1820s.

3.1 Lourenço Marques

On the northern bank of Espírito Santo Estuary of Delagoa Bay, an inlet of the Indian Ocean, Lourenço Marques was named after the Portuguese navigator who, with António Caldeira, was sent in 1544 by the governor of Mozambique on a voyage of exploration. They explored the lower courses of the rivers emptying their waters into Delagoa Bay, notably the Espírito Santo. The forts and trading stations that the Portuguese established, abandoned and reoccupied on the north bank of the river, were all called Lourenço Marques. The existing town dates from about 1850, the previous settlement having been entirely destroyed by the natives. The town developed around a Portuguese fortress completed in 1787.

The Peple's Republic of Mozambique was proclaimed on 25 June 1975 in accordance with the Lusaka accord signed in September 1974. A parade and a state banquet completed the independence festivities in the capital, which was expected to be renamed Can Phumo, or "Place of Phumo", after a Shangaan chief who lived in the area before the Portuguese navigator Lourenço Marques first visited the site in 1545 and gave his name to it.

However, after independence, the city's name was changed (in February 1976) to Maputo. Maputo's name reputedly has its origin in the Maputo River.

Most of the streets of the city, originally named with the names of the Portuguese heroes or important dates in Portuguese history, had their names changed in African languages, revolutionary figures, or pre-colonial historical names.

3.2 Tasmania

The state is named after Dutch explorer Abel Tasman, who made the first reported European sighting of the island on 24 November 1642. Tasman named the island "Anthony van Diemen's Land" after his sponsor Anthony van Die, the Governor of the Dutch East Indies. The name was later shortened to Van Diemen's Land by the British. It was officially renamed Tasmania in honor of its first European discoverer on 1st January 1856.

Abel Janszoon Tasman (1603-1659) was a Dutch seafarer, explorer and merchant, best known for his voyages of 1642 and 1644 in the service of the VOC (Vereenigde Geoctroyeerde Oostindische Compagnie) (United East Company). He was the first known European explorer to reach the islands of Van Diemen's Land (now Tasmania) and New Zealand, and to sight the Fiji islands. His navigator François Visscher, and his merchant Isaak Gilsemans, mapped substantial portions of Australia, New Zealand and some Pacific Islands.

3.3 Alexandria and Alessandria

Alexandria (اسكندرية) is a city in Egypt. There are many cities named Alexandria in the Old and New World, which refer to Alexander the Great, except any of them. I offer a complete list of them:

Places founded or renamed Alexandria by Alexander the GreatAlexandria Aracosia, Afghanistan; now called Kandahar (a contraction of *Iskandahar*); Alexandria Ariana, Afghanistan; Alexandria Bucephalous, Pakistan, on the Jhelum; Alexandria in Orietai, Balochistan, Pakistan; Alexandria Carmania, unknown site in Kerman Province, Iran; Alexandria Eschate, "the Farthest", Tajikistan; Ghazni, formerly Alexandria in Opiania; Alexandria on Caucasus, Afghanistan; Alexandria on the Indus, Pakistan; Alexandria on the Oxus, Afghanistan; Alexandria Susiana, Iran; Alexandria Troas, Turkey;Alinda (Alexandria on the Latmos), Turkey; Cebrene (formerly Alexandria), Turkey; Iskandarya Alexandria), Iraq; İskendurun (Alexandria near Issos), Turkey; Merv, Turkmenistan, sometimes also called Alexandria Margiana.

3.3.1 Other Places Named Alexandria

Australia: Alexandria, Northern Territory; Alexandria, New South Wales; Alexandria, Victoria; Alexandria Station

Canada: Alexandria, British Columbia; Alexandria, Ontario

Ukraine: Oleksandriia, Kirovohrad, a city in central Ukraine; OlexandriaRivne Oblast, a village in northwestern Ukraine

United States: Alexandria, Alabama; Alexandria, California; Alexandria, Indiana; Alexandria Kentucky; Alexandria, Louisiana; Alexandria, Louisina Metropolitan area, a metropolitan area in central Louisiana; Alexandria, Missouri; Alexandria, Minnesota; Alexandria Nebraska; Alexandria, New

Hampshire; Alexandria, New York; Alexandria Bay, New York; Alexandria Ohio; Alexandria, Pennsylvania; Alexandria, South Dakota; Alexandria, Tennessee; Alexandria, Virginia; Alexandria County, formerly in the District of Columbia and later in Virginia; Alexandria Township, Douglas County; Alexandria Township, New Jersey; West Alexandria, Ohio.

Other countries: Aleksandronopol, Armenia; Alexandria, Brazil; Alexandreia, Greece Alexandrium, ancient site in Israel; Alessandria del Carretto, Italy; Alessandria, Italy; Alessandria dellaRocca; Alexandria, Giamaica; Alexandria, Romania; Alexandria, West Dunbartonshire, Scotland; Alexandria Eastern Cape, South Africa.

3.3.2 Some cities named Alexandria, that do not refer to Alexander the Great

Alessandria del Carretto, Italy.

Its official foundation, commissioned by the Marchese Alessandro Pinion lord of the Wheelbarrow, dates back to the 7th century by farmers from the nearby Orion. Subsequently, the population increased in number, thanks to people from neighboring towns like Albidona, Cerchiara and San Lorenzo Bellizzi.

Alessandria della Rocca

Alessandria della Rocca was the name given to the country by royal decree of November 7, 1862: Previously, in fact, the City had other names. The first was Alessandria della Pietra, due to the ancient name of the estate owner, Alessandro Presti, and close to Castello della Pietra D'Amico, dating back to the Saracen. In 1713, appointed Victor Amadeus II, King of Sicily, the municipalities were established: the town took the name of Agrigento in Sicily Alexandria, to be distinguished from common homonyms in the various states of Italy. Finally, in 1862, assumed the name that still holds: Alessandria della Rocca, in honor of Our Lady of the Rock, the patron saint of the country.

Alessandria, Piedmont, Italy

The city was born in the second half of the 12th century with the name of *Civitas Nova* on an existing urban core consists of the ancient town of Rovereto. The city was officially founded in 1168 and in that year took its current name in honor of Pope Alexander III, who promulgated at the time the action against the Holy Roman Empire and had excommunicated Frederick Barbarossa.

Alexandria, Romania

The city was officially founded in 1834, on the initiative of some residents of the nearby town of Mavrodin and Zimnicea and took the name of Alexandria in honor of the Prince of Romania Alexandru Dimitrie Ghica (ruled 1834-1842), whose imposing cenotaph is housed in the Cathedral of St. Alexander, at the center of the city. The urban structure of the city was designed by Otto von Moritz, already known to be true at the time supervised the renovation of Giurgiu and Brăila, which imposed a number of long straight roads and perpendicular to each other, with the main axis parallel to the river Vedea

4. The Devotion to the Virgin Mary

4.1 Buenos Aires

When the Aragonese conquered Caglairi, Sardinia from the Pisans in 1324, they established their headquarters on top of a hill that overlooked the city. The hill was known to them like *BuenAyre* (or "Bonaria" Local linguage), like it was free of the foul smell prevalent in the old city (the cattle area), which is adjacent to swampland. During the siege of Cagliari, the Aragonese built a sanctuary to the Virgin Mary on top of the hill. In 1335, King Alfonso the Gentle donated the church to the Mercedarians, who built an abbey that stands to this day. In the years after that, a story circulated, claiming that a statue of the Virgin Mary was retrieved from the sea after it miraculously helped to calm a storm in the Mediterranean Sea. The statue was placed in the abbey. Spanish sailors, especially Andalusians, venerated this image and frequently invoked the "Fair Winds" to aid them in their navigation and prevent shipwrecks. A sanctuary to the Virgin of Buen Ayre would be later erected in Seville.

In the first foundation of Buenos Aires, Pedro de Menoza called the city "Holy Mary of the Fair Winds", a name chosen by the chaplain of Mendoza's expedition, a devotee of the Virgin of BuenAyre. Mendoza's settlement soon came under attack by indigenous people, and was abandoned in 1541.

For many years, the name was attributed to Sancho del Campo, who is said to have exclaimed: *How fair are the winds of this land!*, like he arrived. But Eduardo Madero, in 1882, after conducting extensive research in Spanish archives would ultimately conclude that the name was closely linked with the devotion of the sailors to Our Lady of Buen Ayre.

4.2 Los Angeles

The Los Angeles coastal area was first settled by the Tongva (or Gabrieleños) and Chumash Native American tribes thousands of years ago. A Gabrielino settlement in the area was called *iyáangà* (written Yang-na by the Spanish), meaning "poison oak place". Juan Rodríguez Cabrilo, a Portuguese-born explorer, claimed the area of southern California for the Spanish Empire in 1542. Gaspar de Portolà and Franciscan missionary Juan Crespí, reached the present site of Los Angeles on August 2, 1769. In 1771, Franciscan friar Junípero Serra directed the building of the Mission San Gabriel Arcángel, the first mission in the area. On September 4, 1781, a group of forty-four settlers known as "Los Pobladores" founded the pueblo called "El Pueblo de Nuestra Señora la Reina de los Ángeles del Río de Porciúncula"; in English it is "The Town of Our Lady the Queen of Angels of the Porciúncula River". The Queen of Angels is an honorific of the Virgin Mary. Two-thirds of the settlers were mestizo or mulatto with a mixture of African, indigenous and European ancestry. The settlement remained a small ranch town for decades, but by 1820, the population had increased to about 650 residents. Today, the pueblo is commemorated in the historic district of Los Angeles Pueblo Plaza and Olvera Street, the oldest part of Los Angeles.

5. The Commemoration of Battles

After the reclamation of the PontinePlainmanyvillages were founded to commemorate some of the battles of the First World War: Borgo Sabotino, Borgo Carso, Borgo Vodice, Borgo Grappa, Borgo Piave, Borgo Hermada, Borgo Montello, Borgo Bainsizza, Borgo Pasubio, Borgo Podgora, Borgo Faiti, Borgo Isonzo, Borgo. San Michele, Borgo Montenero.

In the city of Rome, a Square is named Piazza dei Caduti del 19 luglio 1943.

On July 19, 1943, during the Second World War, this place was struck by the Allied bombing of Rome, with the aim of attacking the freight still active today, along with the district Tiburtinus to Prenestino at Casilino to Labicano and Tuscolano. Six days later, the Grand Council of Fascism removed the confidence to Mussolini and Fascism ended. At 11:03, 662 U.S. bombers reeled bombs 4000 (about 1060 tons) on the district, resulting in about 3000 deaths, of which 1377 identified and 11000 injured.

In Rome other battles are remembered: Piazza dei Cinquecento commemorates the 500 Italian soldiers massacred in Dogali (Abyssinia) in 1887; Via dell'Amba Aradam recalls the battle of 1936 in Abyssinia; Piazza delle Cinque Giornate remembers the five days of 1848, when the Milanese rose up against the Austrian soldiers.

6. Business Cities

Some cities' names have a commercial meaning, as: San Marzano sul Sannio

The San Marzano tomato of the Agro Nocerino-Sarnese is a variety of tomato recognized as a fruit or vegetable in Italian Protected Designation of Origin.

6.1 San Pellegrino

At the end of the 18^{th} century San Pellegrino is developed as a Joint-Stock Company town, thanks to the sulphate-alkaline-earthy waters that flow at a constant temperature of 26 degrees, known since the Middle Ages. In the 20th century the town is transformed into an elegant Spa. Is created, the Joint-Stock Company (now belonging to the San Pellegrino Joint-Stock Company, known industry that produces water and carbonated soft drinks which belongs to the Swiss Nestlé). The fame of the town increases with the construction of the Municipal Casino in 1904 and the Grand Hotel in 1905.

6.2 Fiuggi

Fiuggi, originally called Anticoli di Campagna, gained fame as early as the 14th century, when Pope Boniface VIII claimed his kidney stones had been healed by the mineral waters from the nearby Fiuggi spring. Two centuries later Michelangelo also extolled the virtues of the water that cured him of what he called “the only kind of stone I couldn’t love”. Soon *Acqua di Fiuggi* was being sent in bottles to all of Europe’s royalty. Not until the turn of the 20th century did it become fashionable to make pilgrimages to spa towns (bathing-places) and it was around this time that the King of Italy renamed Anticoli in honor of its most celebrated attraction — The Fiuggi Water.

6.3 Evian

Evian is a brand of luxury mineral water coming from several sources near Évian-les-Bains, on the south shore of Lake Geneva.

Today, Evian is owned by Danone Group, a French multinational company. In addition to the mineral water, Danone Group uses the Evian name for a line of organic skin care products as well as a luxury resort in France

In popular culture, Evian is portrayed as a luxury and expensive bottled water. It was named in Agatha Christie’s Murder on the Orient Express.

6.4 Dalmine

The town of Dalmine lies 8 km south-west of Bergamo, on the east bank of the river Brembo. The Hon Count Walter Danieli in 1907 persuaded the German steel industry to settle Mannesmann in Dalmine. In 1920 the company became Italian during the first world war, he changed his name to “Dalmine Joint-Stock Company”, taking its name from the area in which it was placed. In 1927 it was the deliberate creation of new and unique town of Dalmine (Royal Decree of July 7, 1927). With the economic crisis of the thirties the property of “Dalmine” became public, with the passage of the shares of the company to Finsider (Financial steel IRI).

7. The Veneration of Saints

7.1 San Francisco

The city was founded by the Spanish in 1776 under the name of La Misión de Nuestro Padre San Francisco de Asís (Mission of Our Father Saint Francis of Assisi). Following independence from Spain, the area became part of Mexico. In 1835 the Englishman William Richardson led a first significant urban expansion outside of the immediate vicinity of the Mission: thus it was that the city, then called Yerba Buena, began to attract a significant immigration of American settlers.

7.2 Santa Barbara

The city was founded by the Spanish explorer Sebastian Vizcaino who, during his voyage of exploration of the Pacific coast, landed here on the day of St. Barbara in 1602, dedicating the site. However, urban development began only in the 19th century. In 1850 the city was annexed to the United States.

7.3 Santa Catarina

Santa Catarina is a state in Southern Brazil. Its capital is Florianópolis, which mostly lies on the Santa Catarina Island. Neighbouring states are Rio Grande do Sul to the south and Paraná to the north. It is bounded on the east by the Atlantic Ocean, and to the west it borders the province of Misiones, Argentina. Most of its inhabitants are descendants of Portuguese, Danish, Dutch, German, Italian and Norwegian immigrants.

7.4 Saint Lucia

Saint Lucia is a sovereign island country in the eastern Caribbean Sea on the boundary with the Atlantic Ocean. Part of the Lesser Antilles, it is located north/northeast of the island of Saint Vincent, northwest of Barbados and south of Martinique. Its capital is Castries.

7.5 Saint Elena

Saint Helena, named after Saint Helena of Costantinople, is a tropical island of volcanic origin in the South Atlantic Ocean. It is part of the British Overseas Territory of St. Helena, Ascension, and Tristan da Cunha, which also includes Ascension Island and the islands of Tristan da Cunha.

7.6 Saint Louis

The city of St. Louis was founded in 1764 by Pièrre Laclede and Auguste Chouteau, and named for Louis 9^{th} of France, canonized by Bonifacius 8^{th} in 1297.

San Diego, California was named after the flagship of Sebastián Vizcaino.

Many cities are named *Santiago*, particularly in Latin America.

8. The Commemorative Street Names

Most of the commemorative cities names is connected with a variety of derivations: from the names of poets, like Victor Hugo in Paris, politicians, like Palmiro Togliatti in Rome, Marquês de Pombal[1] in Lisbon and Eisenhower in New York, philosophers, like Voltaire (François-Marie Arouet) in Paris, and Immanuel Kant in Rome, musicians, like Wolfgang Amadeus Mozart, in Vienna and Rome, explorers like Cristoforo Colombo in Rome, chemists and physicians, like François-Vincent Raspail in Paris and Pierre and Marie Curie in Rome, actors like Alberto Sordi and Anna Magnani in Rome, popes like Leone XIII, Pio XI and Anastasio II in Rome, kings like Carlo III di Borbone (Charles of Bourbon (1716-1788), King of Spain, Naples, and Sicily) in Caserta, Vittorio Emanuele II, in Rome, battles, like Lepanto in Rome, writers like Alessandro Manzoni in Rome, miniaturists like Oderisi da Gubbio (1240?–1299), in Rome, scientists like Guglielmo Marconi, in Rome.

Of course Viale Giulio Cesare could not miss in Rome, as well as references to Augustus, who gave his name to some European ancient cities: *Julia Augusta Taurinorum*, *Augusta Treverorum*, *Augusta Prætoria Salassorum* etc.

But Augusta in Sicily was founded by Frederick II of Swabia in 1232.

The names of the streets and squares affect by a lower vitality, except in the cases of great characters. In addition the names of streets are determined by the municipal commission on place names, and the name of the city is fixed by central government.

9. Concluding Remarks

From this presentation very fast, which has collected examples from space and time, we can infer that the names of the city are imposed by the various powers:

(1) the political and economic power, which gives the names of heads of state. The explorers are always a derivation of this power, because they were sent by the powerful to discover new lands and with the money of it. When Tsar Alexander I sent Bellingshausen to the southern lands thought he could take possession of the lands discovered;

(2) the power of the church, which imposed the names of the saints; but also Islamabad, the capital of Pakistan, can be included in this religious power;

(3) the power of the military commanders, who impose to cities names of battles won and lost. Mussolini was forced by military commanders to give the names of the battles of World War II to the villages founded in the Pontine Plain. At first he was not convinced.

[1] Sebastião José de Carvalho e Mello, marquês de Pombal, also called (1759-1769) conde de Oeiras (1699, 1782), Portuguese reformer and virtual ruler of his country from 1750 to 1777.

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GIS-Practical Experience in the Boundaries Definition of the Platform Deep Crustal Blocks on the Studying of the Earth's Surface Fractal Divisibility: Example of the White Sea-Kuloi Plateau

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Abstract: This study examines the use of the geographic information systems (GIS) in structural geomorphology to build the model of the crust based on fractal analysis of relief. Fractal theory, developed by B. Mandelbrot, used to determination morpho-bloc divisibility of the Earth's surface. There is the traceable statistically recurring relief structure indicate the appropriate tiered hierarchy of crustal blocks forming the tectonic and kinematic layers. This hypothesis tested on a digital elevation model (DEM) of the White Sea-Kuloi Plateau — an area of tectonic and magmatic activity of the Paleozoic era. Found the correlation of position the kimberlite magmatic bodies with the tectonic blocks certain depth according to a fractal analysis.

Key words: Structural relief, tectonic blocs, geographic information systems, digital elevation model, fractal dimension.

1. Introduction

At present days structural geomorphology defines surface earth objects, "not daring" to look into the depths of the earth. Geomorphology "given" this opportunity to geophysical sciences. To the XXI century, this "imbalance" in the study of deep structures began to "straighten out" due to tectonic and geodynamics research [1, 7, 9, 11]. It is known fact for any geomorphologist that the Earth's surface is the direct (!) sign of the crustal structures. Geomety of one face of tectonic blocks peculiar mosaic manifested in relief that allows you directly to read information about the properties of tectonic blocks. Nevertheless, still in geology it prevalent of distorted understanding of the systemic connections in the lithosphere — there is strong opinion about the isolation and independence of the existence of tectonic faults as the geological bodies. This study based on the following position: tectonic fault is the boundary between certain moving volumes of the lithosphere, and, like in any boundary zone in spatial development, it is the tectonic movement of the aggregate volumes of rocks or its geometry; tectonic faults, in most cases, expression on the Earth surface as a drainage network. These suppositions were decided to examine for the White Sea-Kuloi plateau. This region is found at the north-east of the East-European plain. Study area is about 24 000 km^2 — Fig. 1. From the most geomorphological positions the area is a structural denudational plateau, low hill plains. There are V-forms of the river valleys and high drainage density. The well marked river terrace is covered with low thickness of quarternary deposits. All this indicates about ascending tectonic of the territory.

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Fig. 1 Studied area — White Sea-Kuloy plateau (red rectangle).

2. Theoretical Principles

About connections of discrete surface areas with tectonic structure wrote geomorphologist V. P. Philosofov. On the basis of this objective relation, he has developed a superior method for the studying neotectonic structures [6]. However, this method is based on the contour models without automated computational processes and inherently very laborious. It gives a qualitative description of tectonic processes, this method does not provide the quantitative aspect of tectonic events (depth of faulting). Whereas quantitative tectonic movement is determined at the present by the geometry of the moving objects. It means stochastic ties of the block forms with the depth of the contour tectonic boundaries (surface area to volume units).

We are encouraged of one V. P. Filosofov's conclusion that exist direct relations surfaces of the watersheds (or their aggregations) with the tectonic crustal blocks. That helps to study the hierarchical rank-block structure of the crust and its quantitative characteristics.

In the defining of the fractal measure boundaries of the morfo-block are used the relationship between perimeter and area of a fractal object proposed by the mathematician B. Mandelbrot [10]:

$$P^{1/d} = k_1 S^{1/2} \qquad (1)$$

where *P, S* – perimeter and area of the object respectively, *d* – fractal dimension, *k1* – coupling coefficient.

The transition from the square to the depth of the penetration tectonic border (to volume *V*) is based on empirical observations of the Earth layers (characteristic coefficient k_2) [3] and the concept of auto-model geodynamic processes [1, 13] or the fractal divisibility Earth crust [8, 10]:

$$k_1 S^{1/2} = k_2 V^{1/3} \qquad (2)$$

3. Results

In the research processing it was allocated multilevel blocks. We used modern methods for the geoprocessing DEM [4, 5, 14, 15] of the large watershed — between the rivers of the Northern Dvina and Mezen. As mentioned, the energy measure of the tectonic forces or destruction in the boundary zones is associated with penetration depth of tectonic boundaries adopted from fractal geometry [10]. Nonlinearity boundaries of the tectonic blocks appeared from the watershed surfaces and its aggregations — morpho-blocks. This is done through DEM with standard hydrology GIS-module [4]. In this way revealed three levels of hierarchy (truncated volumes) of the respective blocks — Fig. 2. On the basis of the values of fractal measures (f.1) we received block boundaries to calculate of the earth crust model of the White Sea-Kuloi plateau to a depth of 1.2-6.8 km (f.2) – Fig. 3. Spatial correlation was done up for the known magma signs and reducing depth of tectonic blocs and fracturing zones on the territory from calculated data — Fig. 4. The process of the study revealed the following: the fractal dimension of the blocks surface of the White Sea-Kuloi plateau is 1.09-1.16.

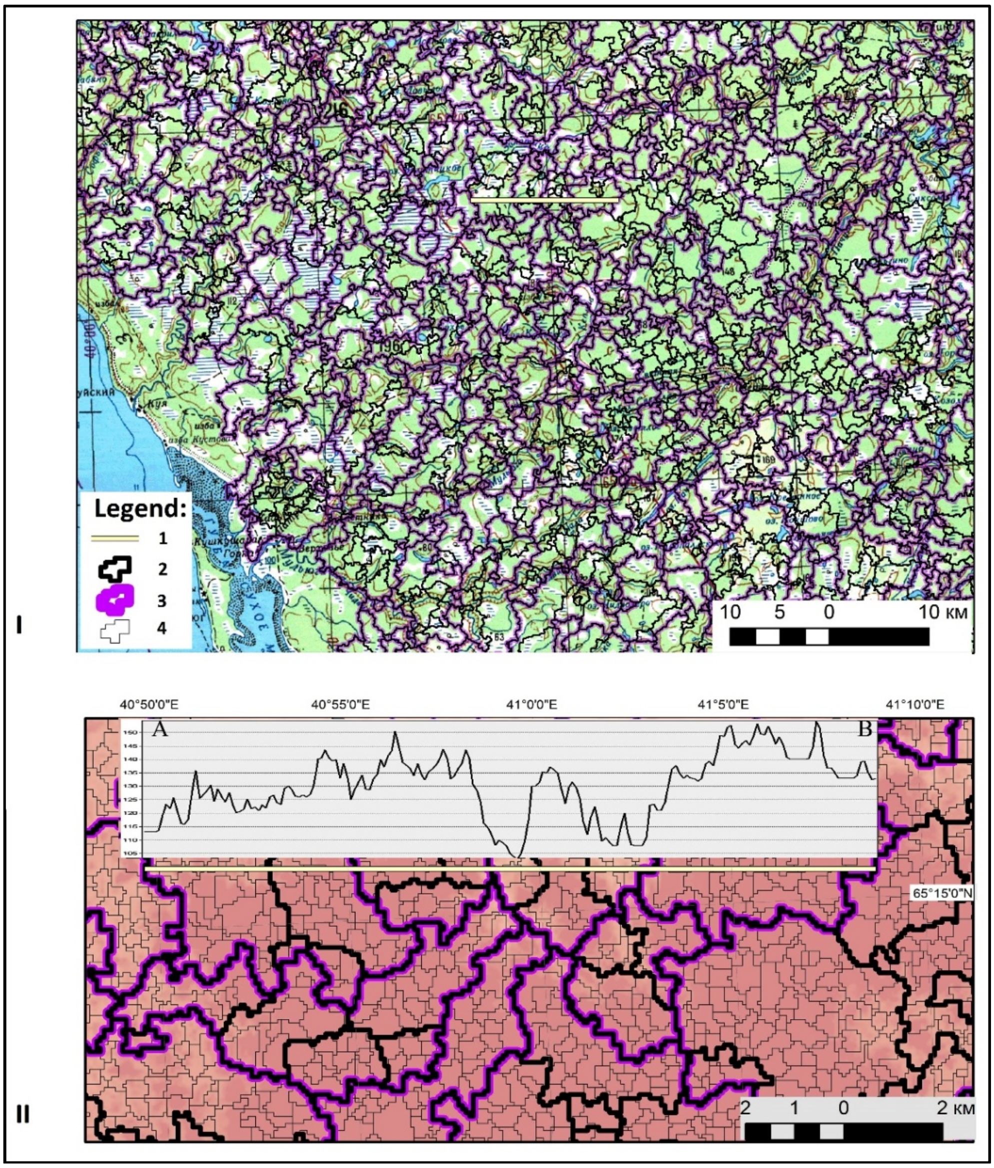

Fig. 2 The blocs allocation of the White Sea-Kuloi plateau and the principle of its receipt as shown in the example of the profile of the earth's surface A-B (in the lower part of the figure - increased). Numbers in legend part I: 1 – profile AB, 2 –

morpho-blocs of the second aggregation, 3 - morpho-blocs of the third aggregation, 4 - morpho-blocs of the first aggregation; part II: AB profile and intersect them morpho-blocs (increased).

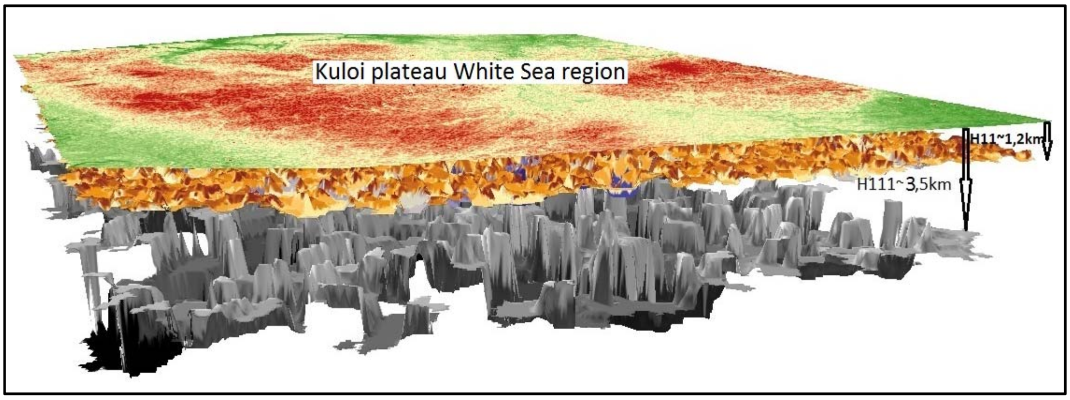

Fig. 3 Two level blocks divisibility of the crustal – H11 and H111, according to fractal analysis of the study areas (a perspective view, the arrows show the average power of the tectonic blocks).

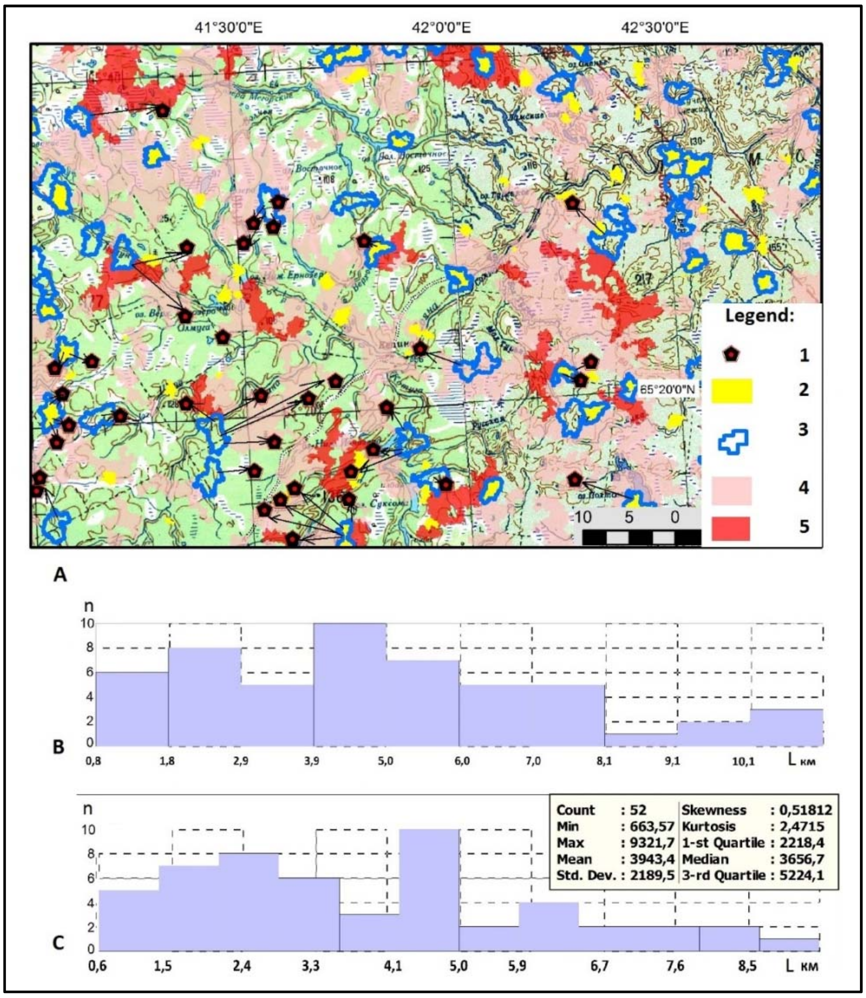

Fig. 4 Zones of the convergence of the calculated depth of the layers and zones of high permeability (fractures) of Earth's crust according to fractal analysis. The position of magma chambers (low depth of the blocks) and known closely to surface kimberlite bodies for the study area. The arrows indicate the relationship with kimberlite formations and magmatic columns at depths 1.6-2.6km interpreted according to the fractal analysis. The length of the arrow is about 0-4km. Numbers in legend are – part A: 1 – known magmatic formations, 2 - zones of the convergence level H11 and H111, 3 – blocs level H111 of low thickness, 4 – zones of medium crustal permeability, 5 – zones of high crustal permeability; part B: the histogram of distant of

the low thickness blocs (1.6-2.6 km) to the numbers of the surface magmatic formations; part C: the histogram of distant of the zones of the convergence level H11 and H111 to the numbers of the surface magmatic formations.

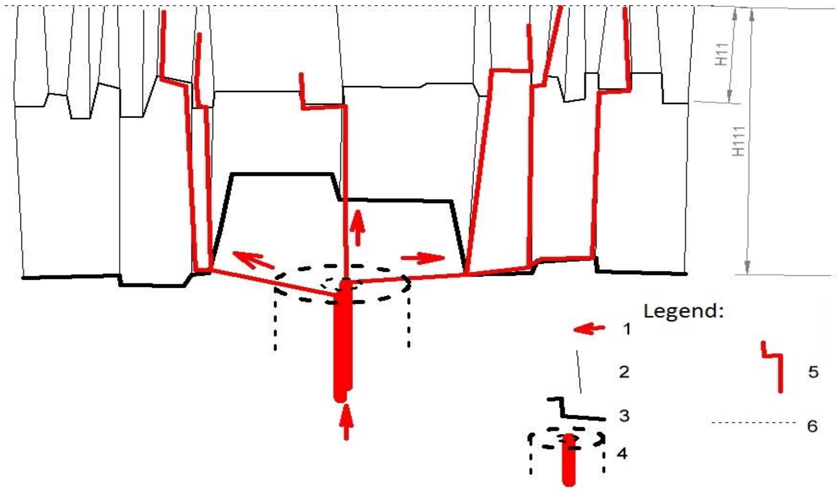

Fig. 5 Diagram of the vertical kimberlite field and block structure in the crust according to fractal analysis. Numbers: 1 – direction of movement of magma in the geological past; 2 – subvertical weakened zones - border of blocks; 3 – the tectonic block soles, corresponding to the depth of the 2-nd and 3-rd bloc levels; 4 – magma columns and its area of influence; 5 – dikes; 6 – day surface.

This corresponds to a geometric divisibility blocks 3.2-3.8, identified in the late 80-ies XX by M.A. Sadovsky, based on observations and laboratory experiments — the coefficient of the rocks and lithospheric blocs divisibility equal to an average of 3.5 [13]. On this data and calculating depth model it has been proposed about the possible penetration of magmatic melts on the interblock zones in the Paleozoic era. On the Fig. 5, it proposed scheme of the structure and position of the magma-fluid columns field on the basis of the done calculations of the penetration depth of tectonic block boundaries. In general, it corresponds to models derived from geophysical data. For example, the N. A. Prusakova determined [12, p. 22]: "At the top of the density section trans-crustal integrated density in homogeneities are spatially associated with the White Sea shore kimberlite fields, are isolated objects with elevated by density and magnetic characteristics and displaying complex anomalies of the gravitational and magnetic fields. The latter are characterized by a combination of local maximums Δg and ΔT that apparently allows to link them to the nature of buried (at a depth of 2-4 km) units mafic-ultramafic magmatism. Most of the manifestations of magmatism the White Sea shore kimberlite fields localized (in groups) within and on the periphery of the contours of the magmatic areas" (emphasis in bold and translate by I. S. Sergeev). The diagram of the structure of kimberlite magmatism manifestations areas to a depth of 3.5 km obtained according to the fractal analysis presented in Fig. 5. As one can see in this figure the scheme is confirmed by cited above N. A. Prusakova's conclusions of obtained in the analysis of geological and geophysical data on the study area.

4. Conclusions

The developed method of the fractal analysis of the Earth's surface divisibility allows to trace the depth development of the interblock tectonic boundaries. The method bases on the following important principles:

(1) Acting "participants" are manifestations of endogenous forces are blocks — this is local volumes of the lithosphere are contacting with each other through the perimeter boundary which are quasi-vertical faults at the surface manifested as parts surfaces watersheds (or their aggregates, so-called morpho-blocks);

(2) The ratio of the volume and surface area of tectonic block (to a first approximation) connect with fractal measure — the degree of expression of tectonic energy of crushing blocks on the boundaries (similar to the coefficient of the lithospheric auto-model divisibility investigated by M. A. Sadovsky).

These provisions applied to the digital elevation model using mathematical apparatus of GIS allows to consider the tectonic structure of the platform regions in the practical aspect of identifying the spatial position of magmatic formation in Paleozoic strata.

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Space and Memory in Children's Constitution: Approaches to School Cartography

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Abstract: In a globalized world, it is increasingly necessary to study the regional and local identities in order to promote their recovery and educating citizens active in all spatial scales. This study conducts a discussion where approaches to memory with spatial representations made by elementary school students in the city of Jaguariaíva, Paraná, Brazil. Cultural identities are treated as meaning production instance about the living spaces. The relations between formal education, especially the curriculum selected by school geography, and the knowledge of lived experience, can contribute to the study of the references and spatial horizons of residents of urban and rural regions. This perspective is proposed as discussion that aims to contribute to the advancement of reflections on the relationship between school mapping and the production of sense of belonging to different locations.

Key words: Space, memory, school mapping.

1. Introduction

This research work is the result of the master's ongoing research in the Graduate Program in Geography from the State University Paulista "Julio de Mesquita Filho", Campus of Rio Claro-SP. Researchers working in UNESP-RC, as Livia de Oliveira and Rosângela Doin de Almeida, together with researchers from other Brazilian universities as Janine Le Sann, Tomoko Ilda Paganelli, Maria Helena Simielli, Marcelo Martinelli, Elza Yakuzo Passini, mostly marked by approaching psychogenic theory of Jean Piaget with the contributions of Jacques Bertin in the field of Graphic Semiology, helped consolidate research on School Cartography in Brazil.

Despite the great theoretical and methodological advances in this field of research, there is a discussion of the language predominantly used by Western map. According to some authors, the maps show an apparent neutrality in its making, because they work with view of the notion of generalization, horizontal and abstract to represent the space that is social, as pointed out by Massey (2008) [1].

In this context, there has been a diversification in the search field for School Mapping in Brazil. With works related to other forms of mapping and understanding the impact of western map in our society, Brazilian researchers relied on other theoretical lines such as phenomenology, post-structuralism, among other perspectives that discuss the history of cartography on an optical critical.

Therefore, we propose a discussion between spatial representation of students from public schools of Jaguariaíva, Paraná, Brazil, with studies of memory, inferring some points of how the subject can contribute to building a sense of belonging to the place, so necessary in a world increasingly globalized.

For this, we rely on historical studies conducted by Harley (2005), studies conducted by the memory Halbwachs (1990), Ricouer (2003), Pollak (1989) and (1992) and other authors [2-6]. In the research, qualitative methodology on the prospect of Bogdan and Binklen (1994) was used [7], relating the analysis of materials with the "evidential paradigm" of Morelli

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(1989), the documentary analysis of Andrew and Ludke (1986) [8] and studies of Zarycky (2000) and (2001) [9, 10], which make relations between studies of pragmatic and cartographic representations.

2. Identity and Mapping Critical

Within the school environment and cultural studies, the sense of consciousness and national identity that geography imposes, throughout history, is on the exaltations of the country's characteristics, the selected elements for the construction of a "imagination community", of a "sense community" [11], for example, here highlights the discourse of the privileged climate and abundance of mineral resources, among others. The training of national consciousness has benefited the interests of the bourgeoisie and the state, which, in turn, supports the institutionalization of geography as an academic science, gaining political importance. Thus, the content taught in school have guided the knowledge produced in the academy. Historically, this process has involved the organization of geographers and teachers training [12].

In school geography, cultural identity formation is linked to the territory, culture and language, cognitive or affective represented to the individual [13]. The speech in favor of a desired culture and proposed by school subject makes students build superficial identities or a reworking of their identity. However, cultural identity is not given once and forever, and, yes, a process in training that builds and rebuilds the course of life of individuals and groups, and is done in different aspects and circumstance [13].

In the context of the history of the approach of school subjects, the school geography considers, above all, the country generalizations and virtually ignores the contrasts and regional peculiarities. Such an approach is justified by the conservative discourse of centralism, the indefinite progress of meaning and power of the unitary state. The changes in contemporary society, such as globalization, migration and decentralization, contributed to the problems involving the national identity [13].

The critical cartography born questioning about the use made of the hegemonic language used by modern cartography. So the map is understood as a cultural product that employs a specific language that conveys information across the board. It presents with apparent horizontal and supposed neutrality. The maps of academic cartography, through the technique and method, have been used by the state to monitor and control information of the territory.

Addressing power relations of Michel Foucault, Crampton and Krygier (2008) [14, 15], an analysis of academic cartography in recent decades. For the authors, use of software and mapping technologies come from the recently held technological transition, and not widespread among cartographers. This fact resulted in a democratization of map information whose developments mobilized other fields of knowledge, such as arising from social theory. Thus, the mapping has been recognized as a political tool and State defense.

> Can be expected that a critical mapping policy weakens the power of the map and work against the transition that put the maps in the hands of a greater number of people. But the exact opposite has occurred. If the map is a specific set of assertions of power and knowledge, then not only the state could do as other competitors and also powerful affirmations. (2008, p. 85)

In this critical context to a hegemonic perspective of Western cartography, Harley (2005) proposes a cartographic epistemology from the social theory, seeking foundations in discourse analysis, with bases the contributions of Michel Foucault and textualisation and deconstruction of Jacques Derrida. The maps would be forms of power and knowledge about a certain period analyzed from the context in which they were produced.

For Massey [1], we represent the space as follows: the representation of space is influenced by intellectual thought; the representation tries to include both space and time; the space must be both constitutive as mimetic.

However, Massey says that the "intellectual activity should not, however, be conceived as a producer of space, or its extended features to shape our imaginations implied into space", in the sense that the space influenced in this way would deprive of its characteristics of freedom, disarticulation and surprise that are essential to the political [1].

Thus, maps as a means of representation of space are influenced on the way to interpret them and join them. Western maps are an example. They suffer political and ideological influences, known as "power of technology" and give the impression of a continuous horizontal on the space [1].

This way, if we consider the current space as multiple interpretations and imaginations, maps as representation of space are no longer seen as a coherent space and all single order, which Massey [1] calls "cartography situationists". This cartographic perspective contrasts the Eurocentric sync the map and values the imagination and the multiplicity of space.

Thus, the map in the social theory interface has become a form of world expression by individuals and groups. The maps as a way of expression, are test instruments for micro-power relations and political space [14].

In this sense, Pearce [16], uses the narrative as a language for developing a sense of belonging in the concept of place. For the author, the graphic semiology used in academic cartography realizes just represent space, but not to represent the place (as a geographical concept). Considering that understand the concept of "place" from Massey [1], the place in which develops in the relation of space with the culture.

With the deconstruction of the map proposed by Harley [2], mapping researchers see using new strategies as ancient artifacts, sounds, photographs and images to represent the place. Pearce [16] states that:

> Increasingly, however, geographers are discussing the need for cartographic languages expanded able to recreate the multiplicity of experiences, web narratives, ontological and epistemological and diversity of historical and cultural geographies. These new digital strategies include the use of color dimensions to encode the emotion, the publication of the news directly on the map, adjust the viewing angle to remove the "view from nowhere" orthogonal perspective, and the expansion of variable sound.

The graphic semiology of Jacques Bertin is based on signs, colors, scales and conventions, with a "grammar" of writing and map reading. Addressing the reflections of Olson (1997) [17] (Chapter 5), the alphabet can make a relationship between what is said and what is written. However, fails to describe in full the intonation in respect of what is said, and write and how you think. Much of feeling housed in what is thought may go unnoticed, especially in writing. Thus, the graphic semiology can make a written map of the world, but cannot effectively represent the stories, memories and feelings in the world, especially in place.

In this sense, much of the local context is lost on the graphic semiology. The signs used them for the representation of the world control our interpretation of space. Olson [17], comments on the representation: "Create representations is not only record speeches or elaborate mnemonic devices: is to build visible artifacts, endowed with autonomy in relation to the authors and with special properties to control its interpretation."

In the text, we use signs to represent our speech. Therefore to interpret whatever be passed through the text, we have to consider: the limitations of alphabetic symbols, the intention of the rhetoric and the intent and interpretation of the reader. Thus Olson shows the different levels of readings [17].

> The act of reading has a purpose: the reader concerned about the substantive issues does not have the same criteria for reading the reader concerned about the literary form. What the reader sees the text depends on their level of competence. A more extensive knowledge allows the reader to find the text rather than find an inexperienced player.

Reading maps depends on the context, the interest and the level of experience that player is. Adding only the reading of graphic symbols in the text does not say exactly what the text is saying, since the intentions and meanings recognized by the author, should be those compatible to the graphic evidence [17].

Whereas the concern of cartographic initiation in primary education is guided by theoretical and methodological aspects that aims to map reading about the look of the graphic semiology, is necessary for the use of the contributions of different languages and cartographic representations in order to create meaning belonging to the living space.

3. Methodology

The qualitative research methodology was done with a view indicated by Bogdan and Binklen (1994) [7]. For the authors, qualitative research presents five features, which are: the qualitative research the source of direct research data is the natural environment; constituting the researcher as the main instrument; qualitative research is descriptive; qualitative researchers are interested in more than just the process the results or products; qualitative researchers tend to analyze your data inductively; the meaning is of vital importance in a qualitative approach. However, this research does not value these characteristics of the same intensity. The qualitative research of the characteristics indicated by Bogdan and Binklen (1994) [7] may be related to the research procedures.

The research assumes that students will report on the production of texts and drawings their experiences, their memories and their views of the city where they live. To read the students' productions, we will adopt a semiotic paradigm [18].

The evidentiary paradigm or "morelliano method" was used by the Italian doctor and art expert Giovanni Morelli between 1874 and 1876, appearing for the first time in Zeitschri/t für bildende Kunst, a series of articles on Italian painting. At that time the method was intended to distinguish false from true works of art. For this, Morelli watched the small painting details as earlobes, nails, forms of the fingers and toes, rather than the most striking general characteristics. The Morelli method for identifying false paintings true was based on evidence imperceptible to most.

To Ginzburg [18], "the story remained as a sui generis science, hopelessly attached to concrete." Even if the historian cannot fail to refer, explicitly or implicitly, the comparable phenomena series, their cognitive strategy and its expressive codes, remain individualized. Thus, the historian, is compared to the doctor working on symptoms "nosographic frames", analyzing the evil of each patient, based on an indirect knowledge, evidentiary and conjectural [18].

The author discusses relation of human subjects and as a guided method for clues and small details can be of great use for constitution of reality. Ginzburg argues:

> If the claims of systematic knowledge show up more and more like lust, or so the whole idea should be abandoned. On the contrary, the existence of a deep connection that explains the surface phenomena is reinforced in time which states that a direct knowledge of such a connection is not possible. If reality is opaque, there are privileged zones — signs, signs — which can decipher it. [18]

This idea penetrated as the essential point of the evidentiary paradigm between various cognitive areas, profoundly shaping the humanities. This perspective has gained prominence from the systematic thinking crisis and the advent of Aforismática literature, which is by definition an attempt to form judgments of society and from symptoms and evidence from a strict evidentiary paradigm.

The production of the students are documents-monuments, that is, buildings resulting from an assembly, composed of "memory materials" that are the monuments, or "legacy of the past", and who keep socially dated and localized meanings. As the author points out, in view of his philological origins of the term, the monument is all that can evoke the past, perpetuate the memory, for example, the "acts registered" [19].

The documentary analysis is justified, since the productions of the students were understood as a vehicle of communication and representations of the locality. As pointed Ludke and Menga [8], one of the basic conditions for using the document analysis is "when the researcher's interest is to study the problem from the very expression of individuals". Within the methodology, search for similarities is essential to organize and search inferences to higher standards [8].

The analysis will be made from the studies of [9, 10]. The author makes the relationship between linguistic theory of pragmatics and the cartographic theory. However, it is clear that our analyzes are "subversive" in the design of Manguel [20], in the sense that our interpretation express our thoughts, with something personal and identity. In this case, reveal our views as teachers and researchers from the School Geography in the context of the School Cartography.

Pragmatics is a semiotic research field, which includes two research fields: the semantic and syntactic. Zarycki, based in Morris, presents the three semiotic study areas and a short description of them:

> "Let me remind you that Morris has divided semiotics into three basic branches: semantic, syntactic and pragmatic. Originally semantics was defined as the study of the signs of meanings (or relations between linguistic forms and world entities), syntactic as the study of relationships between signs (linguistic forms) as pragmatic as the study of indications of relations to their interpreters (or relationship between linguistic forms and their users)." [10]

To approximate the "relationship between the forms of language and its users" is necessary to reconstruct the context for the analysis of the text (in our case the map). Zarycki (2001) [10] addresses the context of ways: the author's perspective and the other the interpreter. For the interpreter, the context is understood as knowledge of history widely understood at different levels of social interaction. This finding can be addressed both to the producer and to the interpreter. On the one hand the story is a starting point for analysis and inferences to interpret. Second, the understanding of history was constituted image that the producer has in the world.

The context can be divided into three categories of analysis from the focus on an event. The first is the co-text or co-map, which would be a cut of a text or a map; the second would be the situational context, which is the analysis of the starting point of the third, which is the cultural context in multiple interfaces (local group, regional, national or global). Regarding the maps, you need to be aware of the context in which the map was produced and what context the map was produced. Considering the research, the spatial representations were produced in different contexts, about the phenomena represented by students who, in general, presents different contexts.

In this sense, pragmatic is very close to the discourse analysis and text linguistics. The textual linguistic analyzes texts in a broad and integrated sense, see the phrases from the point of view of its functions in the texts in which they are immersed. Thus, the linguistic text can be seen in the analysis of the co-text, being part of the context. Similarly, we could approach to the study of maps in the cartographic signs would be analyzed in a broader context map.

Discourse analysis is worked mainly on the map in the deconstruction of the theory of Harley map and has an approach to map the role as ideology propagator of social action and political views. In pragmatic field, the author proposes the analysis of speech acts, seen as studies of social action texts, from the theory of macro-structures, developed by Van Dijk. This theory allows to compare the text and structure of the map, creating ground for further exchange of theoretical tools between the two camps from the coherence and cohesion notions. Cohesion can be considered as a shallow concept, since it relates to the syntactic structure of sentences. Consistency would be at a deeper level, as it would be related to the functional relationships between the text elements. Thus, the consistency can be considered as a pragmatic notion from the relationship with the context. The lack of coherence can be defined as the lack of a common framework (benchmark) for all of the text or map or all of your users. Without the understanding of linguistic points of the text is not possible to make further interpretation without knowledge of any other. The same happens with dependency mapping, where the understanding of maps is often impossible without knowledge of other maps.

The approach presented here are for the interpreter of the map (in our case the researcher). Whereas the research is to analyze and discuss the spatial representations of the students, which in turn, are understood as cartographic representation is necessary to reflect on the context of students as producers of these materials.

4. Analysis of the Results

In the first activity, had the support of the historian Rafael Pomim. He studies the city for several years and works at city hall, developing his work with the department of tourism and culture.

Rafael visited the three schools, and each of them followed the following schedule: first told the story of the city as a whole, dividing between tropeirismo, the railroad and the economics of wood. Then told students the history of formation of each part of the city, considering most emphatically where the college was inserted. Thus, it was told stories involving the schools, squares, early housing, installation of public utility facilities such as hospitals, cemeteries, police station, among others.

In this activity, in general, students show interest in the activity. Some held questions about the past and the present municipality. This made Rafael remembered matters not programmed, bypassing the initial planning, giving other directions in the (re)construction of the city's last image. The performance of activities was evidenced in the production of students, interest in registering cited dates and names and the concern to narrate the facts very similar way to what Rafael had told.

Another factor is that, in the production of the students, there was a concern to tell stories in common. For this, they talked and asked each other questions relating to the theme. Many activities showed similar texts and drawings. These facts bring to light the trading concepts and points of contact of an affective community, as points Halwasch (1990) [3], and as points Pollak (1989) [5], a production selectivity of collective memory (Fig. 1).

For Halbwachs, memory reflects feelings, images and ideas about a place, an event or people. Each individual brings with it feelings and pre-established images, and from this, with new interactions between people, places, are constructed and reconstructed new ideas, images and feelings that make individual memories. However, for the formation of a collective memory, there must be contact points between the images and feelings of the same group. In this type of interaction, individuals, images, and memories are tensioned and socialized with the group. Thus, the collective memory is "negotiated".

However, studies of Pollak (1989) [5], point to the concept of "collective memory" of Maurice Halbwasch, as a form of domination of official memory state over other forms of memory and power. Bosi draws attention to the context in which Halbwasch, developed his understanding of memory.

> To understand Halbwasch of concern universe we must place it in the French sociology tradition, he is an admirable heir. Halbwasch extends the studies of Emile Durkheim that led to hypotheses of field research Auguste Comte on the precedence of "social fact" and "social system" on the phenomena of psychological, individual.
>
> With Durkheim, the axis of the investigations into the "psyche" and the "spirit" moves to the functions that the representations of men's ideas carries on within your group and society in general. This pre-existence and that social dominance over the individual should, under substantially changing the focus of psychological phenomena said as perception, awareness of memory (2004, p. 53).

For Pollak [5], the "negotiation" of memory in an attempt to reconcile the apparently individual memories and the group's memory to the formation of an "affective community", is the point where begins the segregation between the official memory and underground memories. This fact causes a hierarchical classification and memory, inducing a symbolic violence in the group's individuals. Thus, the collective memory takes a uniform character, oppressor and violator. In the author's words:

Fig. 1 Similar productions.

In Durkheim's methodological tradition of treating social facts as things, it becomes possible to take these different points of reference as empirical indicators of the collective memory of a particular group, a structured memory with their hierarchies and classifications, a memory also that, define what is common to a group and that differentiates it from the others, establishes and reinforces feelings of belonging and socio-cultural boundaries.

In Durkheim's approach, the emphasis is on almost institutional strength of this collective memory, the duration, the continuity and stability. So Halbwachs, far from seeing this collective memory a levy, a specific form of domination or symbolic violence, accentuates the positive functions of the common memory, namely, to strengthen social cohesion, not by coercion but by affective group membership, hence the term uses of "affective community". In the European tradition of the nineteenth century in Halbwachs, including the nation is the most complete form of a group, and national memory, the most complete form of a collective memory [5].

Some narratives developed by the students showed a similarity in structure. For example, in State College Rodrigues Alves students shared their texts discussing the following issues: The farm of Colonel Luciano Carneiro (farm that gave rise to the municipality), the Francisco Matarazzo industries, the arrival of the railroad and link the jaguaraivense and former Governor Paraná state Moyses Lupion with the history of the College.

However some subjects were judged more interesting than others by the students, which they did comment on some more, some less. For example, the College Nile, the most talked about subject was the history of the city's mayor, Sillas Gerson Ayres, put a television in color in the neighborhood square for all to watch, especially the World Cup Football in 1970 (Fig. 2).

Fig. 2 The TV in the square in front of the College Nilo Peçanha in the 1970 World Cup.

The narrative of a student says, "[...] how people were paying their homes, had no money to buy a TV. So Sillas Gerson Ayres put a TV in the square, which today is called Sillas Gerson Ayres, for all to see. The TV was turned on only at night."

Rafael, recounting the stories, brings an interpretation of previously built last. When reporting stories related to areas frequented by students, has a power in the construction of identity on students, as from Pollak (1992) [6], we construct our identity in a process acceptability, credibility and admissibility.

Complementing to Braga and Smolka (2005), we construct our identity through the image others have of us. From the moment Rafael talks about the spaces, makes his account from the image that has these spaces. In turn, students become part of this relationship and find themselves in these spaces.

For Pollak (1992) [6], building our identity when we move our image to others, and then the others speak to/for us, and, how we interpret the past speech. In this sense, identity is an individual mental and collective construction.

> That is, the image that a person acquires lifelong referring to itself, the image she builds and presents to others and herself, to believe in their own behalf, but also to be perceived the way wants to be perceived for others [6].

For Pollak [6], the construction of identity inserts the three essential elements. The first is to have physical boundaries (examples are: the space belonging to the group, the person's body), the moral and psychological sense (examples are: values, speech and thought), and, finally, the sense of coherence "of that the different elements that make up an individual are effectively unified". For Pollak [6], no one is able to make a self-image of themselves, and the "Other" that plays a fundamental role in the construction of identity.

> The construction of identity is a phenomenon that occurs in reference to others, in reference to the eligibility criteria of admissibility, credibility, and that is done through direct negotiation with others [6].

Braga and Smolka (2005, p. 23) using a Backtiniano reference, explain this phenomenon. According to the authors, the image we have of us is in the relationship of the image that others have of us. Thus, the image memory and the other enable the "aesthetic finish of the subject". The images and eigenimages are formed by a memory historically constructed. The images and eigenimages are based on the group's position and social practices.

The second activity was to make students reflect on your neighborhood, on your city, telling their impressions, their fears, their customs, their beliefs, their activities, their experiences, everything they thought necessary to express your images on your space experience.

In this activity we highlight two productions of the students who express views many are distinct from each other on the same neighborhood.

João Vitor said of the neighborhood where you live: "I live in a really nice neighborhood. The day I go out is to play football and to play various things. The name neighborhood is Santa Cecilia. I know many nice people in it. To me, he is a very humble neighborhood. It has no problem." (Fig. 3)

In a completely different picture about the same neighborhood, Felipe says, "It's fun to live there. There is the favela invasion. It has pretty girl, women and police. The police are full of want to beat magazine worldwide. It is the slum of fear [...] there they put fear in people, they steal who gets there, there has drunk pub, they are taking cachaça..." (Fig. 4).

The visions of Felipe and João Vitor are distinct because they lived or inherited concretely many stories. The analysis of the images indicate that the social frameworks [3] in which they are embedded are also very distant, although spatially are nearby. Although they fall into their narratives as neighborhood residents, most peculiar social frames inserted in the neighborhood, permeate your memories, creating many different images.

To Halbawacsh (1990) [3], we remind us of the past as a member of the social group, and when we interpret our memories, we consider our position in the current frame. Thus, confronted testimonials and agreeing in essence, building a set of memories that makes us sense.

Fig. 3 The João Vitor neighborhood.

Fig. 4 The Philip neighborhood.

However, other people can spend their memories as we "inherit". This occurs through mediation instruments. But likewise, are passed within social frameworks, and interpreted on our way.

The forms they narrated the neighborhood makes you think about the "narrative and forgetting" of Ricoeur (2003) [4]. Forgetting through the mediating role of narrative moves in extremes of passivity and activity of memory, to the point of crossing between memory and identity due to its ideological bias. However, in transit between passivity and activity, we cannot consider the individuals involved in this phenomenon as "buckets" empty of history, memory, experience and ideology. In front of the situation, especially of passivity, there are conflicts in memory for acceptability, admissibility, credibility and meeting points between what is said and the memories that are already in. What "keeps" this phenomenon, is then incorporated into the speech.

At first, it is considered that the narrative has, in addition to an ideological dimension, a selective dimension. "Just as it is impossible to remember everything, it is impossible to tell everything." [4]. Here is the link between declarative memory, narrative, witness and figurative representation of the past. It is in these types of working approaches with the narrative that we tell the story otherwise changing scenarios, rearranging times, restructuring characters, deleting and exalting what is of interest. As this plot we build our personal and collective identity that structure our membership link.

However, to Felipe and João Vitor narrate their neighborhoods thus went through a process of negotiation and selection in the groups to which they belong. They incorporated to his speech which was the conflict enters its memory with your experiences and memories, especially past through narratives.

The different views of students on district is what Foucault (1984) [21] calls heterotopia. For the author, the company consists of spaces that exert power over the individual, permeating our conduct, then our imagination. The way that the neighborhood is in Philip's view, makes us behave differently in relation to João Vitor neighborhood tells us.

In this context, Felipe e Joao Vitor should develop their "organized setting" Middleton and Brown (2006) [22]. The images produced here are the "organized setting" of students, where new experiences will be compared images of the past. This concept will serve so they understand the world more stable.

Middleton and Brown [22] "organized scheme" integrates the individual mind with the environment, shows the relationship between cognition, affect and cultural symbols. Enables the world to be designed by us in a more stable way, not forcing us to fit the particular characteristics of so drastically environment. In this sense, we have built several "organized scenarios", enabling the reflection on the relationship between them.

The "scenarios" are not immutable, or deterministic about our way of thinking. But serve as starting points for interpretation of new experiences. They nurture the work, enable transforming everyday behavior, occurring through the construction of a synthesis between sensory and symbolic issues included in the various "scenarios" built by the individual.

Middleton and Brown (2006) [22], emphasize the exchange of experience through conversation in the construction and reconstruction of "organized settings". During our conversations we add symbolic meanings that were not present in the "scenario", as reinterpreted exclude others. We put our prints to the test on the other agree or not, trade prints without concern ourselves with accuracy.

For Massey [1], the various agreements and disagreements that occur in space-time part of the place. This process she calls "contingencies of space-time".

> One way to see "places" is through the map surface: Samarkand is there, the United States of America (the finger indicating a limit) here. But escapes from a space imagination as surface is leaving, too, this place of vision. If space is undoubtedly a simultaneity of stories until then, places are therefore collections of these stories, joints within the broader "power geometry" of space. His character is a product of these intentions within that big picture, and that made of them. But also of not dating, disconnections, relationships are not established, the exclusions. All this contributes to the specificity of the place [1].

For the author, the place is in the movement of life and the contingencies in respect of "essences" lives provided with space. The "essences" derive from stories, cultures and "power geometry" formed here. In this sense, the place is a result of space and time together here so far. Massey says "here":

> "Here" is where the spatial narratives are or form settings, cyclical trajectories that have their own temporality (so "now" is as problematic as "here"). But where the succession of meetings, the accumulations of the plots and meetings form a story. Are the returns (my, the birds) and the very differentiation of temporality that provide continuity. But the returns are always to a place that has become, or layers of our meeting intercepting and affecting each other, the fabric of a process of space-time. Layers as adding meetings. So something could be called the "there" and thus is implying here and now. "Here" is imbricate stories in which the spatiality of these stories (her then as much as your here), is inescapably intertwined. Even the interconnections are part of the construction of identity ... [1]

Paul Ricoeur, the basis of the work of Henri Bergson called "Matery and Memory", makes a distinction between memory and image. The memory is connected to the virtual state of the representation of the past, something pure, and that is conserved in some corner of memory. On the other hand, the image is formed when we bring to the fore the pure memory and to adjust and update through the reunion and recognition, turning our attention to the situation and object, in which the author calls the image-memory.

In the update process between pure memory for an image-memory is where the forgetting occurs. At the time of setting, there is an insertion of gift items and a "disposal" of other elements present in pure memory that represents the past. In this sense, forgetfulness is the image and the memory is forgotten. Thus, both the wayside as the images (derived from memories) are not related to the past, but with this, building a historical consciousness, allowing anticipate and return through an expectation of experience regarding future events or objects [4].

The setting is linked to a refresh our memory through “social frameworks” [3]. In this context, reinterpret our memory in accordance with our position in the group at any given time, making a synthesis and subsequently an image. The synthesis it is a question of metacognition or object, resulting in an image, which in turn is a representation of this one last thing.

5. Conclusion

The place, as the “here” and “now” in space-time, undergoes changes caused by the attribution of meaning. In this sense, the place as a result of the update image is the result, and the negotiation and selection of collectively constructed plots to a given time, lifelong. This leads to the fact that the “place” is not something romantic, apolitical, synchronous and coherent. For Massey, if we treat the place as something coherent and synchronous, would open the door to the uniqueness and the depoliticized.

Individuals and groups go through the process of construction and reconstruction of the image through memory and forgetting, however, their interests and goals are different, being a meeting place of those stories. These meetings may or may not result in frames if result once again will be selected and traded, generating new images that reconfigure and reterritorialization space time, giving new meaning to the place. So the place is always open and unfinished, understood in different possibilities and imaginations.

Thus, it is necessary to highlight the importance of spatial analysis to establish relationships with memory, with the stories of live that the mapped locations. It is in relation to time and space that are built, shaped and transformed the notions of identity mediated by memory. It is this relationship that we build our “places” and therefore studies in this field can be of great relevance to members sciences and the languages of school cartography.

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Recovery of the Spatial State of the Ionosphere Using Regular Definitions of the TEC Identifier at the Network of Continuously Operating GNSS Stations of Ukraine

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Abstract: We developed a system for monitoring the ionosphere, which uses the GNSS network located in the western part of Ukraine. The system is based on determining the ionosphere parameters from GNSS observations performed at an individual station. We are proposed algorithm for restoring the spatial position of the ionospheric state or its ionization field according to the regular definitions of the TEC parameter. The description below shows one of the possible solutions that are based on the application of the regularized approximation of functions with numerous variables. To experimentally determine the changes in the ionization field in time, we took measurements from 272 days in 2013 that were determined during the GNSS observations at 17 continuously operating stations of the ZAKPOS network. The resulting error indicators show that the developed algorithm gives consistent results for ionization field restoration that do not depend on the ionosphere state, satellites positions and changes in number of stations in the network used for computations.

Key words: Ionosphere, ionospheric parameters, GNSS-measurements, interpolation, regularized approximation, Spline approximation.

1. Introduction

Due to the wide application of global navigation satellite systems (GNSS), the development of the modern GNSS infrastructure moved the monitoring of the Earth's ionosphere to a new methodological and technological level. The peculiarity of such monitoring is that it allows conducting different experimental studies including the study of the ionosphere directly while using the existing networks of reference GNSS stations intended for solving other problems.

The application of the modern GNSS infrastructure is another innovative step in the ionospheric studies as such networks allow to conduct measurements continuously over time in any place. This is used during the monitoring of the ionosphere and allows studying the global and regional phenomena in the ionosphere in real time.

Application of a network of continuously operating reference stations to determine numerical characteristics of the Earth's ionosphere allows creating an effective technology to monitor the ionosphere regionally. This technology is intended to solve both scientific problems concerning the space weather, and practical tasks such as providing coordinates of the geodetic level accuracy.

Thus, for the calculated numerical characteristics of the ionosphere that reflects the determined functional dependencies from the time [1, 2] of the individual system parameters and processes of different nature, a universal algorithm of regularized identification of mathematical macromodels was developed.

The practical implementation of this algorithm improves the processing of the measured data,

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monitoring tools, recovery of missed measured data and its prediction.

2. Formulation of the Problem

For continuously operating reference GNSS stations, the results of the determined ionization identifier *TEC* (Total Electron Content) that describes the number of ions in the atmosphere on the line between the ground station and the moving satellite accumulate. On the one hand, this data reflects the state of the ionosphere during the observation; on the other hand, it is a substantial tool for accuracy improvement and reliable determination of coordinates of the observation place.

Thus, it was decided to solve a problem of restoring the spatial position of the ionospheric state or its ionization field according to the regular definitions of the *TEC* identifier, i.e., *STEC* (Slant *TEC*). The description below shows one of the possible solutions that is based on the application of the regularized approximation of functions with numerous variables.

Initial data to restore the ionization field:

- coordinates of reference stations:

$$X_i^{st}(t_k), Y_i^{st}(t_k), Z_i^{st}(t_k) \quad (i=\overline{1,n_k};\ k=\overline{1,K}), \quad (1a)$$

- coordinates of GNSS satellites:

$$X_j^{sp}(t_k), Y_j^{sp}(t_k), Z_j^{sp}(t_k) \quad (j=\overline{1,m_k};\ k=\overline{1,K}), \quad (1b)$$

- *STEC* values between the station *i* and satellite *j*:

$$s_{ij}(t_k) \quad (i=\overline{1,n_k};\ j=\overline{1,m_k};\ k=\overline{1,K}), \quad (1c)$$

where: t_k – time of the *STEC* measurement; K – number of measurements; i – station number; j – satellite number; n_k, m_k, – number of stations and satellites during the measurement k, respectively. Further, we used data from 19 reference stations in the Western Ukraine.

The solution to this problem is to define the ionization field

$$v = v(x, y, z, t)$$

for the area where the stations are located (x, y, z) during the time $t \in [t_1, t_K]$.

3. Restrictions and Assumptions for Use of the GNSS Measurements to Restore the Ionization Field

The coordinates of an individual station (1a) and available satellite *j* (1b) define the line segment that connects the point on the Earth's surface with the satellite. This line segment comes through the Earth's ionosphere as well. One of the assumptions in this case is that the ionosphere layer has an effective thickness that is defined by the sub-ionospheric point *H*. According to this assumption, all ionized atoms are located on the surface of some sphere with the radius defined by the sub-ionospheric point.

Let's divide the part of the specified line segment into *N-1* equal segments, thus, getting *N* equally located nodes that lie on a beam from the station to the satellite below the sub-ionospheric point (Fig. 1):

$$\overline{x}_{ijl}^k = \overline{x}_{ijl}(t_k), \quad \overline{y}_{ijl}^k = \overline{y}_{ijl}(t_k), \quad \overline{z}_{ijl}^k = \overline{z}_{ijl}(t_k), \quad (2)$$

where: $\overline{x}_{ijl}^k$, $\overline{y}_{ijl}^k$, $\overline{z}_{ijl}^k$ are spatial coordinates of a point l on a beam between station i and satellite j ($i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $l=\overline{1,N}$; $k=\overline{1,K}$).

Supposing that the state of the ionosphere changes evenly along the beam between the station and the satellite, the ionization field indicator in each node can be described as:

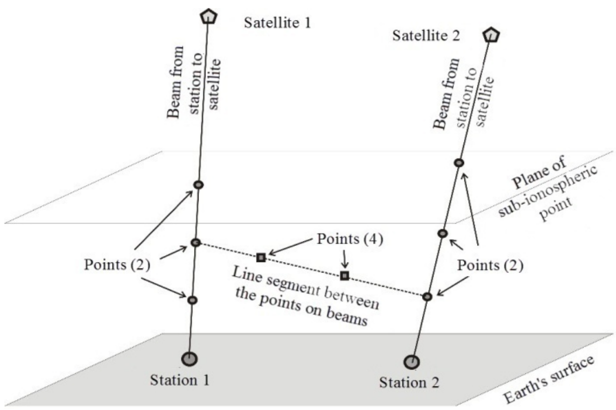


Fig. 1 Spatial location of the nodes.

$$\bar{v}_{ijl}^{k} = s_{ij}(t_k)/N \, (i=\overline{1,n_k};\ j=\overline{1,m_k};\ l=\overline{1,N};\ k=\overline{1,K}), \quad (3)$$

where $\bar{v}_{ijl}^{k}$ – ionization parameter in point *l* on a beam between station *i* and satellite *j*.

Expression 3 describes the ionization values determined experimentally. GNSS observations show that the beams from satellites to stations at one point in time lie mostly in certain directions only, while there are few of them that lie in other directions or none at all (Fig. 2).

This fact makes the conditions of the interpolation problem worse. For their improvement, we connected all the points (2) on the beams between the stations and satellites and on the formed line segments we defined internal equally located nodes that do not lie on the boundaries of the line segments (see Fig. 3):

$$\breve{x}_{ijpq}^{kr},\ \breve{y}_{ijpq}^{kr},\ \breve{z}_{ijpq}^{kr}, \quad (4)$$

where: $\breve{x}_{ijpq}^{kr}$, $\breve{y}_{ijpq}^{kr}$, $\breve{z}_{ijpq}^{kr}$ — spatial coordinates of the point *r* ($r=\overline{1,M}$) on the line segment between the nodes ($\bar{x}_{ijp}^{k}$, $\bar{y}_{ijp}^{k}$, $\bar{z}_{ijp}^{k}$), ($\bar{x}_{ijq}^{k}$, $\bar{y}_{ijq}^{k}$, $\bar{z}_{ijq}^{k}$); $p,q \in [1,N]$; $i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $k=\overline{1,K}$; M – number of internal nodes on a line segment between the points on the beam.

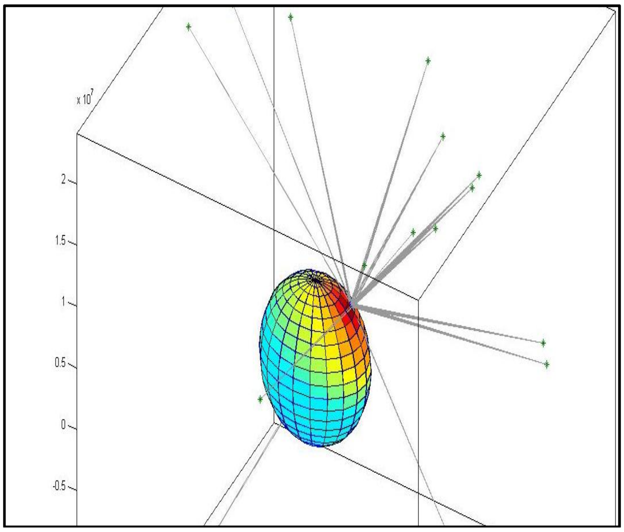


Fig. 2 Common view of beams from the station to the satellites according to (1a) and (1b).

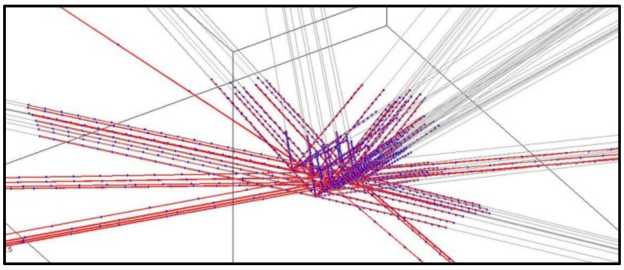


Fig. 3 Beams from stations to satellites (in grey), their sub-ionospheric line segments (in red) and points (2) on them (in blue).

Ionization parameters in the nodes (4) are defined using linear interpolation value of this indicator on a line segment between the points ($\bar{x}_{ijp}^{k}$, $\bar{y}_{ijp}^{k}$, $\bar{z}_{ijp}^{k}$), ($\bar{x}_{ijq}^{k}$, $\bar{y}_{ijq}^{k}$, $\bar{z}_{ijq}^{k}$); $p,q \in [1,N]$; $i=\overline{1,n_k}$; $j=\overline{1,m_k}$. It is described as:

$$\breve{v}_{ijpq}^{kr} \, (i=\overline{1,n_k};\ j=\overline{1,m_k};\ p,q \in [1,N];\ r=\overline{1,M};\ k=\overline{1,K}) \quad (5)$$

Expression 3 describes ionization in the nodes (2) located along the beams between the stations and satellites. Expression 5 describes ionization in the nodes (4) that lie between such different beams. It was found that data from expressions 2-5 is not enough to restore the ionization field as approximating functions deviate greatly from the observational ionization values beyond the nodes (2), (5).

4. Description of the Method for Determining Ionization Using STEC

For practical purposes, we need to define ionization in the spatial area:

$$x \in [x_{\min}^{k}, x_{\max}^{k}],\ y \in [y_{\min}^{k}, y_{\max}^{k}],\ z \in [z_{\min}^{k}, z_{\max}^{k}] \quad (6)$$

where the area boundaries are defined by the extreme points of the set of nodes (2) that are located on the beams between the stations and satellites:

$$x_{\min}^{k} = \min_{ijl} \bar{x}_{ijl}^{k};\ y_{\min}^{k} = \min_{ijl} \bar{y}_{ijl}^{k};\ z_{\min}^{k} = \min_{ijl} \bar{z}_{ijl}^{k};$$

$$x_{\max}^{k} = \max_{ijl} \bar{x}_{ijl}^{k};\ y_{\max}^{k} = \max_{ijl} \bar{y}_{ijl}^{k};\ z_{\max}^{k} = \max_{ijl} \bar{z}_{ijl}^{k}.$$

Let's divide line segments that describe the rectangular area (6) into *L-1*smaller segments and determine the coordinates of the equally located nodes:

$$\widehat{x}_i^k,\ \widehat{y}_j^k,\ \widehat{z}_l^k \quad (i, j, l = \overline{1, L}). \qquad (7)$$

To restore the ionization field in the area (6) according to the data from the expressions 2-5, a new condition needs to be imposed: ionization derivatives with respect to the coordinates must be minimal in the points (7). Such condition reduces strong deviations of the approximating function beyond the nodes (2), (4). It should be noted that the solution to the problem of the ionization field restoration lies in finding the ionization values in the nodes (7).

Set of the points (2), (4) coordinates is denoted by:

$$x_a^k = \left\{\overline{x}_{ijl}^k, \breve{x}_{ijpq}^{kr}\right\},\ y_a^k = \left\{\overline{y}_{ijl}^k, \breve{y}_{ijpq}^{kr}\right\},\ z_a^k = \left\{\overline{z}_{ijl}^k, \breve{z}_{ijpq}^{kr}\right\}, \quad (8)$$

where: $a = \overline{1, A_k}$; A – number of points in the expressions (2), (4) ($i = \overline{1, n_k}$; $j = \overline{1, m_k}$; $p, q \in [1, N]$; $r = \overline{1, M}$; $k = \overline{1, K}$).

Set of the ionization identifier values (3), (5) is denoted by:

$$v_a^k = \left\{\overline{v}_{ijl}^k, \breve{v}_{ijpq}^{kr}\right\}, \qquad (9)$$

where: $a = \overline{1, A_k}$; $i = \overline{1, n_k}$; $j = \overline{1, m_k}$; $p, q \in [1, N]$; $r = \overline{1, M}$; $k = \overline{1, K}$.

Sets (8), (9) define the discrete dependency of the ionization v_a^k from the values of three spatial coordinates (x_a^k , y_a^k , z_a^k) ($a = \overline{1, A_k}$). This dependency is approximated by the exponential polynomial from numerous arguments:

$$v(x, y, x) = P_k(x, y, x).$$

During the calculations, such polynomials were selected:

$$P_k(x, y, x) = \sum_{i+j+l<R} c_{ijl}^k x^i y^j z^l ;$$

$$P_k(x, y, x) = \sum_{|i+j+l|<R} c_{ijl}^k x^i y^j z^l ;$$

$$P_k(x, y, z) = \sum_{i+j+l<r} c_{ijl}^k x^{\lambda i} y^{\lambda j} z^{\lambda l} ;$$

$$P_k(x, y, z) = \sum_{|i+j+l|<R} c_{ijl}^k x^{\lambda i} y^{\lambda j} z^{\lambda l} ,$$

where: R – exponent of polynomial (R = 1,…,4)); c_I^k – coefficients of this polynomial, I – multi-indexes of these coefficients; λ – number close to R (λ∈[R-0.3;R+0.3]). Polynomial with random exponents was also selected:

$$P_k(x, y, z) = \sum c_{\xi_x \xi_y \xi_z}^k x^{\xi_x} y^{\xi_z} z^{\xi_z} ,$$

where ξ_i (i = x, y, z) equally distributed random numbers. In particular, exponents $\xi_i \in$ [-0.5, +0.5], $\xi_i \in$ [-1, +1] were selected as an initial approximating basis from 50, 100 and 200 polynomial items. The structure of the approximating basis was selected in such a way that the argument exponents are close to 1. It is empirically known that this improves the extrapolation of the simulated values in the nodes (7).

Polynomials, rational functions and generalized polynomials are used for the approximation of functions as well [3]:

$$f(x) = \sum_{j=1}^{L} a_j \varphi_j(x),$$

where: $f(x)$ – approximating function; a_j – approximation coefficients; $\varphi_j(x)$ - functions with special properties, in particular, trigonometric and exponential functions; n – number of functions. If $\varphi_j(x)$ is Legendre polynomial, then during its orthogonalization fractional-rational functions that are identical to polynomials with fractional exponents appear [4].

To find approximation coefficient c_I^k using the data from expressions (8) and (9), we used identification problems regularized by minimizing the stabilizing Tikhonov functional [5] and reduction of the approximating basis [6, 7]. However, such approximation has an acceptable error of approximation only in the identification nodes (2), (4) and beyond them deviates greatly from the approximated value in the points (7).

Thus, to restore the ionization field, additional measures were taken. An artificial argument that depends nonlinearly on x, y, z was added to the arguments of the polynomial:

$$P_k(x,y,z,r) = \sum_{|i+j+l+p|<R} c_{ijlp} x^{\lambda i} y^{\lambda j} z^{\lambda l} r^{\lambda p} \quad (10)$$

in particular:

$$r = \sqrt{(x_c^k - x)^2 + (y_c^k - y)^2 + (y_c^k - y)^2},$$

where r – radius-vector; x_c^k, y_c^k, z_c^k – center coordinates of the parallelepiped (7).

Identification problem intended to determine the polynomial coordinates for a separate calculation $k\in[1,K]$ has two conditions:

- approximation of values (9) in the points (8):

$$\min_{c_I^k} \sum_{a=1}^{A} \left[v_a^k - P_k(x_a, y_a, z_a, r_a) \right]^2 + \alpha \sum_I \left(c_I^k \right)^2 \quad (11)$$

- minimization of the polynomial derivative P_k with respect to its argument in the points (7)

$$\min_{c_I^k} \sum_{i,j,l,p=1}^{L} \left(0 - \sum_{q=x,y,z,r} P_k^q(\hat{x}_i, \hat{y}_j, \hat{z}_l, \hat{r}_p) \right)^2 + \alpha \sum_I \left(c_I^k \right)^2 \quad (12)$$

where: c_I^k – polynomial coefficients P_k; I – their multi-indexes; P_k^q – polynomial derivatives P_k ($q = x, y, z, r$):

$$P_k^x = \frac{\partial}{\partial x} P_k(x,y,z,r);$$

$$P_k^y = \frac{\partial}{\partial y} P_k(x,y,z,r);$$

$$P_k^z = \frac{\partial}{\partial x} P_k(x,y,z,r);$$

$$P_k^r = \frac{\partial}{\partial r} P_k(x,y,z,r) \cdot$$

To solve (11), (12), the reduction of the approximating basis described in [6-8] was used. To reduce the deviations of the approximating polynomial from the measured ionization values, the first-degree (R = 1) polynomial was chosen and minor deviations $\lambda\in[0.7, 1.3]$ were applied [9-11].

Multiple solving of the problems (11) and (12) for all measured data $k = \overline{1,K}$ lead to such interim conclusions:

- if polynomial exponents of numerous arguments are close to 1, then approximation basis found using the reduction of the polynomial exponent while solving the problem (11), (12) for the values of an individual measurement k (1)

$k\in[1, K]$ provides an acceptable approximation for all measurements $k = \overline{1,K}$.

- if the exponent of the approximation polynomial differs greatly from 1 ($\lambda R > 1.5$, or $\lambda R < 0.5$), the reduction of the approximation polynomial exponent for each measurement leads to obtaining different approximation bases. This does not lead to substantial improvement of the approximation accuracy (10) and mostly makes the accuracy of the expression (12) worse.

From the results of these computational experiments, it can be concluded that to restore the ionization field, it is advisable to use the polynomial (10) with the exponent $R = 1$ and multiplier λ that is slightly less than 1. For other conditions, we need substantial costs for computational resources to determine the approximation basis and coefficient c_I^k for each of the measurements ($k = \overline{1,K}$) separately.

5. Results of the Experimental Restoration of the Changes in the Atmosphere Ionization

To experimentally determine the changes in the ionization field in time, we took $k = 46$ measurements from 272 days in 2013, namely STEC values with time interval of 15 sec. during the first 12 minutes from the beginning of the day that were determined during the GNSS observations at 17 continuously operating stations of the ZAKPOS network [12].

For the most measurements ($k = \overline{1,K}$), in case of the reduction of the approximation polynomial exponent, the same approximation basis was found.

The exponents of the polynomial arguments are given in the Table 1. The full set of coefficients of this approximation basis is determined using the parameters R = 1; $\lambda = 1.3^{-1}$; $|i+j+l+p| \leq 1$. Values of the approximation coefficients c_I^1 determined for a measurement at the time $t_1 = 0$ (the time is defined in the seconds of the day) are provided in the table as well.

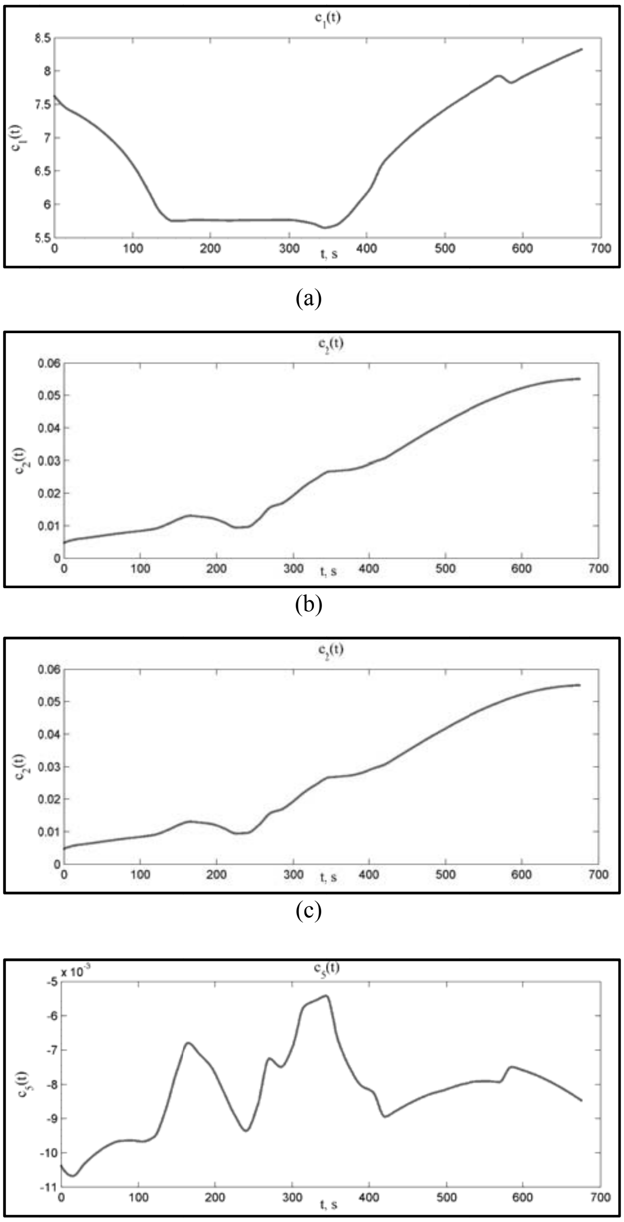
The obtained solutions to the problems (11) and (12) are the coefficient values $c_i(t_k)$ ($i = \overline{1,n}$; $k = \overline{1,K}$) at the time t_k where n = 6 – number of these coefficients.

Using cubic Hermite spline for interpolation (function pchip in Matlab), we obtained the approximation coefficients values for each second. Using the interpolation by the fifth-degree spline, their continuous values $c_i(t)$ ($t \in [t_1, t_k]$ were determined. Fig. 4 shows the common dependencies of these approximation parameters from time.

Fig. 4a-c shows that parameters gradually change over time. This change depends on angle altitude of certain satellites and their ascent and descent, namely changes in number of satellites. Only one parameter $c_5(t)$ changes relatively very quickly (Fig. 4d). This indicates that the problem of restoration of $c_i(t)$ during $t \in [t_1, t_k]$ using data (1) to determine the reduced (regularized) approximation basis common to all observations $k = \overline{1,K}$ is incorrect. However, the above solution shows that the change speed of $c_5(t)$ is limited. This fact confirms a good choice in the approximation basis for all observations $k = \overline{1,K}$ (during all time $t \in [t_1, t_k]$).

Table 1 Exponents of the polynomial arguments determined for the most measurements and the values of the approximation coefficients c_I^1 for a measurement k = 1.

№	Exponent *x*	Exponent *y*	Exponent *z*	Exponent *r*	Coefficient c_I^1
1	0	0	0	0	7.623044
2	0	0	0	0.769231	0.004773
3	0	0	0.769231	0	–0.000469
4	0	0.769231	0	0	–0.003179
5	0.769231	0	0	0	–0.010377
6	0	0	–0.769231	0	–6.092696



(a) (b) (c) (d)

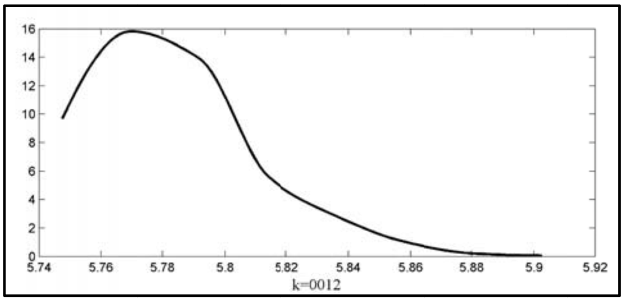
Fig. 4 Time dependencies graph of approximation coefficients $c_1(t)$ (a), $c_2(t)$ (b), $c_3(t)$ (c), $c_5(t)$ (d).

The quality analysis of the graphs $c_i(t)$ ($t \in [t_1, t_k]$) described above is applied to control the adequacy of the solution to the problem (11), (12) for all $k = \overline{1,K}$. In addition, to evaluate this solution, we applied quality analysis of the determined ionization distribution in the points (7). Acceptable solutions to (11) and (12) are distribution (probability density) of the needed ionization in the points (7) that has a central maximum or is close to even or linear distribution. Fig. 5 shows common distribution graphs and functions of the ionization distribution $v(x, y, z, t_{12})$ determined using the polynomial (10) in the points (7).

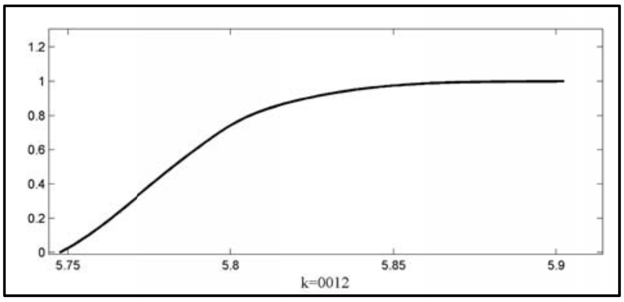
It can be seen that all the restored ionization values are approximately equal to experimentally measured ionization values. Fig. 5 also illustrates a common result of using the approximation basis (see Table 1) determined in one point (k = 2) to restore ionization in another point (k = 12). Such quality analysis of distribution laws for ionization approximation in the points (7) is applied to all measurements $k=\overline{1,K}$.

To restore the change in the ionization field, we need to determine continuous dependencies of the area center coordinates (7) $x_c(t)$, $y_c(t)$, $z_c(t)$ ($t\in[t_1,t_k]$) from time using approximation by spline. Graphs of the coordinate changes are shown on Fig. 6.

Fig. 6 shows the shifts of the center of the rectangular area with irregular fluctuations. This can be explained by the movement of satellites and discrete division of sub-ionospheric line segment of the beam from the station to satellite. This indicates that the ionization field depends on the algorithm parameters.

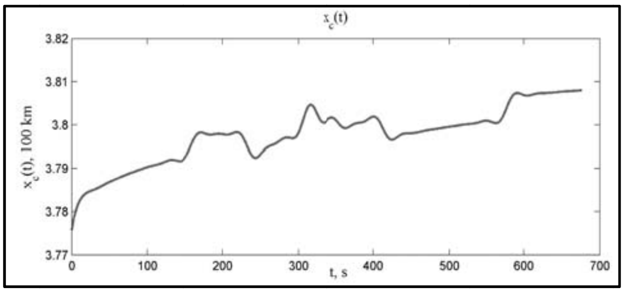


(a)

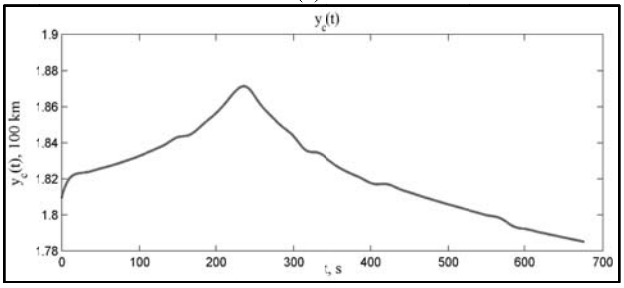


(b)

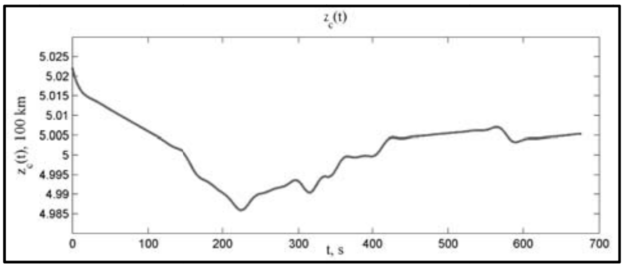
Fig. 5 Common view of graphs for probability density (a) and distribution function (b) of the ionization value $v(x, y, z, t_{12})$ restored in the rectangular area (14).



(a)



(b)



(c)

Fig. 6 Time dependency graphs of the center of the ionization restoration area x_c(t) (a), y_c(t) (b), z_c(t) (c).

It should be noted that the area boundaries (7) change gradually depending on the satellite movements. Common graphs of change $x_{\min}(t_k)=x_{\min}^k$; $y_{\min}(t_k)=y_{\min}^k$; $z_{\min}(t_k)=z_{\min}^k$; $x_{\max}(t_k)=x_{\max}^k$; $y_{\max}(t_k)=y_{\max}^k$; $z_{\max}(t_k)=z_{\max}^k$ ($k=\overline{1,K}$) are shown on Fig. 7.

Extreme values of these boundaries were defined for the ionization field restoration:

$$\overline{x}_{\min}=\max_{k\in[1,K]} x_{\min}^k;\quad \overline{y}_{\min}=\max_{k\in[1,K]} y_{\min}^k;\quad \overline{z}_{\min}=\max_{k\in[1,K]} z_{\min}^k;$$

$$\overline{x}_{\max}=\min_{k\in[1,K]} x_{\max}^k;\quad \overline{y}_{\max}=\min_{k\in[1,R]} y_{\max}^k;\quad \overline{z}_{\max}=\min_{k\in[1,K]} z_{\max}^k.$$

They describe rectangular area

$$x\in[\overline{x}_{\min},\overline{x}_{\max}],\quad y\in[\overline{y}_{\min},\overline{y}_{\max}],\quad z\in[\overline{z}_{\min},\overline{z}_{\max}] \quad (13)$$

for which the ionization values during the whole period of observations $t\in[t_1,t_k]$ are restored.

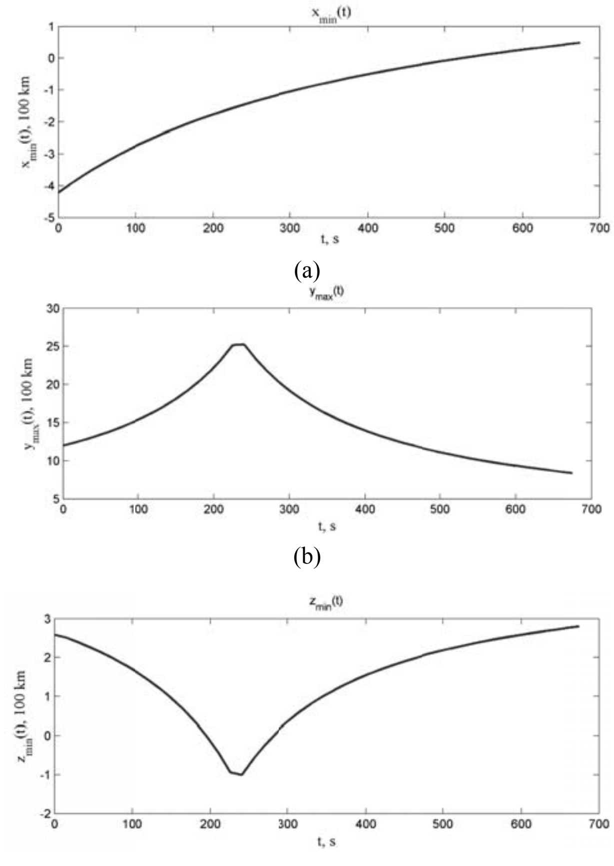


Fig. 7 Common view of time dependency graphs of the changes in boundaries of the ionization restoration area: $x_{min}(t)$ (a), $y_{max}(t)$ (b), $z_{min}(t)$ (c).

Let's divide the line segments (13) into *L-1* segments and determine the coordinate values for equally located nodes:

$$\hat{x}_i, \hat{y}_j, \hat{z}_l \ (i, j, l = \overline{1, L}). \quad (14)$$

Ionization values in the nodes (14) are computed using the polynomial (10) with parameters $c_i(t)$ ($i = \overline{1, n}$), $x_c(t)$, $y_c(t)$, $z_c(t)$, that depend on time:

$$v(x, y, z, r) = \sum_{ijlp} c_{ijlp}(t) x^{\lambda i} y^{\lambda j} z^{\lambda l} r^{\lambda p} \quad (15)$$

where: *i, j, l, p* are the indexes of the polynomial coefficients. The exponents of its arguments are determined beforehand based on computational experiments conducted when solving the problems (11) and (12) (see Table 1). The common view of graph that shows the instantaneous value of the ionization field restored in the nodes (14) is illustrated on Fig. 8. In formula (15), continuous time functions $c_i(t)$ ($i = \overline{1, n}$), $x_c(t)$, $y_c(t)$, $z_c(t)$, are defined using splines. According to formula (15), we determine the ionization at an arbitrary time $t \in [t_1, t_k]$ in the arbitrary point (13). It was found that most often, the ionization increases with an altitude and there is a shift of spherical areas with reduced or increased ionization. Sometimes such areas stop shifting and start moving in the opposite direction and mix. Restoring the spatial dynamics of ionization (15) models complex processes of electric charge movements in the ionized air.

The described method is based on the interpolation of the coefficients of the polynomial from numerous arguments (10). It can be used for data in (8) and (9) that leads to the same reduced approximation basis. This method is described briefly in the algorithm at the end of the article (see chapter 5).

Using this algorithm, the results of the ionization field restoration were obtained. In particular, this algorithm was applied with the following parameters: number of points on the beam from the station to satellites $N = 3$; number of points between the points on different beams $M = 1$. With such parameters in the expression (11), the number of approximation nodes exceeds 55 thousand. Number of nodes along the area boundary of the ionization restoration is $L = 20$. Using this value, the number of minimization nodes of the

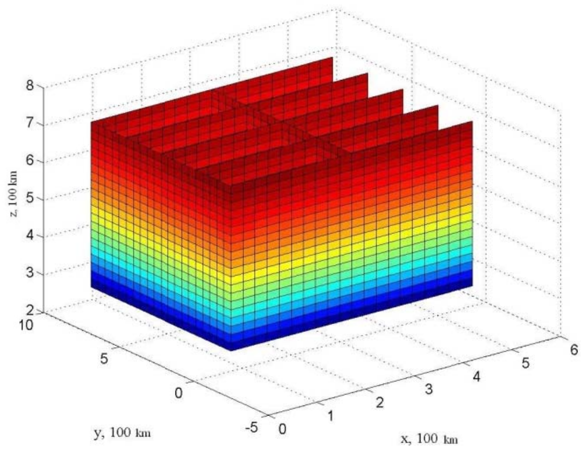


Fig. 8 Graphs of the ionization dependency from the spatial coordinates (in 100 km) in the moment (t_{38} = 555 s).

derivative by the polynomial from numerous arguments in (12) is 9261. An increase in the above-mentioned parameters causes severe computation complications in problems (11) and (12) and does not improve the accuracy of its solution.

Statistical characteristics, that describe 46 results of the solution to the problem (11) and (12), ($k = \overline{1, K}$, $K = 46$), are provided in Table 2.

This table shows such characteristics:

- standard deviation (SD) of the absolute approximation error in 46 results of the problem (11);
- SD of the relative approximation error in 46 results of the problem (11);
- average ionization in the approximation nodes (8) computed for 46 moments in observation from polynomial (10);
- average ionization in the approximation nodes (experimental values from 46 observational moments) (9);
- average relative approximation error by module for 46 solutions to the problem (11).

For these characteristics, such parameters were computed: the smallest, largest and average value, median, distribution mode, standard deviation of the accuracy identifier as a set of its 46 values. The first two rows of the last column show the standard deviation of the SD of 46 approximation problems (11). These parameters describe the accuracy of application of common approximation basis (see Table 1) in order to restore the changes in the ionization field in time.

Table 2 Statistical characteristics for 46 results of the solution to the problem (11) obtained using common approximation basis.

Name of identifier	Parameters					
	The smallest value	The biggest value	Average value	Median	Distribution mode	SD
SD of the absolute approximation error in (11)	1.3892	1.4652	1.4198	1.4226	1.3892	0.016779
SD of the relative approximation error in (11)	0.15017	0.15737	0.15247	0.15230	0.15017	0.001354
Average ionization in the approximation nodes (8) computed from polynomial (10)	5.7050	5.8206	5.7377	5.7354	5.7050	0.021957
Average ionization in the approximation nodes (8), experimental values (9)	5.7049	5.8206	5.7377	5.7352	5.7049	0.021971
Average relative approximation error (11) (by module)	0.21556	0.22512	0.21967	0.22016	0.21556	0.002148

In particular, Table 2 shows that the average values of the experimental and model (obtained from approximation) values are close for all measurements. The relative accuracy of the problem (11) solution for an individual measurement is approximately 21% (with dispersion 0.21% for all measurements). The standard deviation of this error is 15% (with dispersion 0.13% for all measurements). This means that using the common approximation basis, we obtained ionization approximation (11) with relatively low accuracy (21%) but the error of such approximation varies a little for each of the measurements. This proves the efficiency of applying the common approximation basis for regularized approximation of the atmosphere ionization when using the polynomial from numerous arguments with coefficients dependent on time. It should be noted that before we added a new argument to the polynomial (10), the approximation accuracy was worse. Other ways to expand or change the approximation basis (described above) do not influence the accuracy parameters for ionization field restoration.

6. Algorithm of the Ionization Field Change Restoration Using the Approximation of the Change in Time of the Coefficients of the Polynomial from Numerous Arguments

(1) Obtain the coordinates of the stations (1a), satellites (1b) and STEC values (1c).

(2) Determine the altitude of the sub-ionospheric point.

(3) Select a number of points N on the beams from the stations to satellites located lower than the sub-ionospheric point.

(4) Compute (2) the coordinates $\overline{x}_{ijl}^{k}$, $\overline{y}_{ijl}^{k}$, $\overline{z}_{ijl}^{k}$ of the points located on the beams between the stations and satellites lower the sub-ionospheric point ($i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $l=\overline{1,N}$; $k=\overline{1,K}$).

(5) Compute (3) the value $\overline{v}_{ijl}^{k}$ in the points (2) (located on the beams between the stations and satellites lower than the sub-ionospheric point) that are defined in step 4 ($i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $l=\overline{1,N}$; $k=\overline{1,K}$).

(6) Select a number of internal nodes located on the line segments between two points on the beams from stations to satellites.

(7) Compute coordinates of internal nodes $\breve{x}_{ijpq}^{kr}$, $\breve{y}_{ijpq}^{kr}$, $\breve{z}_{ijpq}^{kr}$ (4) that lie on the segments between two points on the beams from stations to satellites ($r=\overline{1,M}$; $p,q\in[1,N]$; $i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $k=\overline{1,K}$).

(8) Using interpolation determine $\breve{v}_{ijpq}^{kr}$ (5) in the points defined in steps 6 and 7 ($i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $p,q\in[1,N]$; $r=\overline{1,M}$; $k=\overline{1,K}$).

(9) Determine boundaries $x_{\min}^{k}$, $y_{\min}^{k}$, $z_{\min}^{k}$, $x_{\max}^{k}$, $y_{\max}^{k}$, $z_{\max}^{k}$ (6) of the rectangular spatial area with the points $\overline{x}_{ijl}^{k}$, $\overline{y}_{ijl}^{k}$, $\overline{z}_{ijl}^{k}$ (2) and defined values $\overline{v}_{ijl}^{k}$ (3) ($i=\overline{1,n_k}$; $j=\overline{1,m_k}$; $l=\overline{1,N}$) for each measurement ($k=\overline{1,K}$).

(10) Select a number of points L where the spatial area is divided and limited by the boundaries (6) set in step 9.

(11) In the rectangular area defined in step 9 determine the coordinates of the equally located points $\hat{x}_{i}^{k}$, $\hat{y}_{j}^{k}$, $\hat{z}_{l}^{k}$ (7) ($i,j,l=\overline{1,L}$).

(12) Join the sets of the nodes coordinates on the beams from stations to satellites (2) and on these beams (4) and sets of the correspondent known values (3), (5) into a combined set x_{a}^{k}, y_{a}^{k}, z_{a}^{k}, v_{a}^{k} (8), (9) ($a=\overline{1,A_k}$) that is experimentally defined discrete functional dependency of the ionization from spatial coordinates for a measurement k ($k=\overline{1,K}$).

(13) Determine the best approximation basis common for all measurements $k=\overline{1,K}$ from the results of the problems (11), (12), exponent reduction of the polynomial from numerous arguments (10) [3, 4].

(14) Solve the problem (11), (12) for all measurements $k=\overline{1,K}$ using approximation basis determined in step 13.

(15) Based on the results from step 14, using the interpolation by spline, define coefficient dependencies $c_i(t)$ ($i=\overline{1,n}$) of the polynomial (10) from time and dependency of the center coordinates $x_c(t)$, $y_c(t)$, $z_c(t)$ of the rectangular area (7) from time ($t\in[t_1,t_k]$).

(16) Make a quality analysis of changes in the polynomial (10) coefficient $c_i(t)$ ($i=\overline{1,n}$) in time ($t\in[t_1,t_k]$).

(17) Define approximation errors in the problem (11) for all measurements.

(18) Make a quality analysis of the probability density (and distribution function) of the restored ionization value $v(x, y, z, t)$ in points (7) in the rectangular area (6). If these distributions have central maximum or are approximately even or linear, and if approximation errors in the problem (11) for all measurements are within acceptable limits then the determined approximation basis (step 13) can be regarded as acceptable. Otherwise, go to step 3.

(19) Define the boundaries $[\overline{x}_{\min}, \overline{x}_{\max}]$, $[\overline{y}_{\min}, \overline{y}_{\max}]$, $[\overline{z}_{\min}, \overline{z}_{\max}]$ (13) of the rectangular area (14) where the approximation value of the ionization for all measurements $k = \overline{1, K}$ is computed.

(20) Determine the coordinates of the equally located points $\hat{x}_i, \hat{y}_j, \hat{z}_l$ in the rectangular area defined in step 18 ($i, j, l = \overline{1, L}$).

(21) Using the coefficients $c_i(t)$ ($i = \overline{1, n}$) in the polynomial (10) and the center coordinates $x_c(t)$, $y_c(t)$, $z_c(t)$ of the rectangular area (13) that depend on time, determine the ionization value $v(x, y, z, t)$ at an arbitrary time $t \in [t_1, t_k]$ in the arbitrary point of the area (13).

(22) To represent the results of the ionization restoration graphically, compute the ionization values in the points (14), i.e., compute $v(\hat{x}_i, \hat{y}_j, \hat{z}_l, t)$ ($i, j, l = \overline{1, L}$; $t \in [t_1, t_k]$).

7. Conclusion

The resulting error indicators show that the developed algorithm gives consistent results for ionization field restoration that do not depend on the ionosphere state, satellites positions and changes in number of stations in the network used for computations. Instant accuracy of the ionization field restoration is acceptable for our problem. To improve the described method, we need to conduct research to explain the structure of the approximating polynomial and search for additional computation tools to increase the approximation accuracy in the observational nodes and prevent rapid change of the approximating polynomial beyond these nodes.

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A Hybrid Model to Predict Cartesian Planimetric Coordinates

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Abstract: Coordinates are basic needs for both geospatial and non-geospatial professionals and as a result, geodesists have the responsibility to develop methods that are applicable and practicable for determining cartesian coordinates either through transformation, conversion or prediction for the geo-scientific community. It is therefore necessary to implement mechanisms and systems that can be employed to predict coordinates in either two dimensional (2D) or three dimensional (3D) spaces. Artificial Intelligence (AI) techniques and conventional methods within the last decade have been proposed as an effective tool for modeling and forecasting in various scientific disciplines for solving majority of problems. The primary objective of this work is to compare the efficiency of artificial intelligence technique (Feed Forward Back propagation Neural Network (FFBPNN)) and conventional methods (Ordinary Least Squares (OLS), General Least Squares (GLS), and Total Least Squares (TLS)) in cartesian planimetric coordinate's prediction. In addition, a hybrid approach of conventional and artificial intelligence method thus, TLS-FFBPNN has been proposed in this study for 2D cartesian coordinates prediction. It was observed from the results obtained that FFBPNN performed significantly better than the conventional methods. However, the TLS-FFBPNN when compared with FFBPNN, OLS, GLS and TLS gave stronger and better performance and superior predictions. To further confirm the superiority of the TLS-FFBPNN the Bayesian Information Criterion was introduced. The BIC selected the TLS-FFBPNN as the optimum model for prediction.

Key words: Artificial intelligence, ordinary least squares, total least squares, general least squares, cartesian coordinates.

1. Introduction

In surveying and mapping, one of the primary tasks for geodesist and surveyors is to determine precise coordinates for accurate positioning on the Earth surface. These coordinates may range from the global to local sphere and are pertinent for a variety of applications in both applied science and geodesy. Over the years, the issues of precise point positioning for geodetic applications have become a real, persistent and serious problem facing the developing countries like Ghana, calling for pragmatic solutions. The increasing use of the Global Navigation Satellite System (GNSS) such as Global Positioning System (GPS) has significantly advanced the expansion of global application of geodetic surveys in all areas of the globe, even though many countries, for example, Ghana are still yet to fully utilize the full potentials of GPS.

Ghana is one such post-colonial countries' where the use of non-geocentric coordinate system established through conventional techniques of surveying for national mapping still persist [1, 2]. Moving along with the disheartened political, economic and socio-cultural trend, there are numerous challenges to incorporating GPS derived coordinates into the Ghana National coordinate system, thus, demanding the determination of transformation parameters by scaling, translation and rotation. To solve this, 3D similarity transformation models of three translations, three rotations and one scale factor [3, 4] are used to estimate the transformation parameters. Several transformation models have been put forth to estimate transformation parameters for geodetic reference network for

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countries [5-8] such as Ghana. The most commonly used among these models in Ghana are the conformal methods of Bursa-Wolf, Molodensky-Badekas and Helmert similarity [8-10]. It is worth noting that the first step in applying any of the above-mentioned conformal similarity transformation models in Ghana is the conversion of the geodetic data of common points into cartesian rectangular coordinates using Bowring's algorithm.

Although Bowring's algorithm [11-15] has established a forward computation for transforming geodetic coordinates to cartesian coordinates, it will take some time before this can be applied directly in Ghana due to the non-geocentric coordinate system. Therefore, for local application to be realized, the iterative Abridged Molodensky transformation model [16, 17] must be applied to the geographic coordinates of common points on the War office ellipsoid [10]. This will then be used to determine the approximate change in ellipsoidal heights which are then used to calculate the ellipsoidal height for the local geodetic network before Bowring's equation can be applied to the data. The reason is because the Ghana geodetic reference network established through classical methods of surveying is referenced on the War Office ellipsoid with data in latitude, longitude and orthometric height without the existence of ellipsoidal height [2, 8, 9, 18].

The above prevailing situation has hampered the use of GPS effectively thereby creating inconsistencies in the transformation parameters derived among researchers in Ghana. As a result, users from all related disciplines adopt different techniques in the post-processing of the GPS observational raw data and these generate a lot of uncertainties in the use of the GPS data from different sources [9, 10]. Also, the lack of geoid model for Ghana War Office datum has also contributed to the inconsistencies in the transformation parameters determined by researchers in Ghana. These have lead to non-existence of standards to regularize GPS usage in its domain, even though it is acknowledged that the use of GPS for geodetic surveys is on the increase in Ghana and around the world.

Efforts have been made by researchers [2, 8-10, 18, 19] in Ghana and foreign agencies to determine a suitable method and transformation parameters for the Ghana Geodetic Reference Network. No decision has been reached as to which of them is the selected technique and no doubt this is an area where deliberations will continue for some time to come. Consequently, an optimum set of transformation parameters between the War Office datum and WGS 84 datum does not exist; this makes it difficult for Ghana to utilize the massive potential of GNSS services. In order to establish compatibility in data obtained from GPS measurements correctly and effectively in Ghana, it is necessary to determine appropriate transformation parameters that relate the coordinates in the War Office system to the WGS 84 system using relevant transformation models. In view of the above development, it can be inferred that the inconsistencies in the parameters determined among researchers is further creating distortions in the local coordinates generated from these parameters. Therefore, there is a need to model out distortions within the local coordinates in our local geodetic system after applying the national transformation parameters.

Conversely, there exist physically based numerical methods that can serve as practical alternative in modelling out these distortions by way of converting geodetic data to cartesian coordinates for a local geodetic network by way of prediction to a tolerable degree of accuracy and precision. For example, Ref. [20] applied linear regression (OLS) to find a relationship between global and cartesian coordinates. They concluded that the proposed linear regression models were suitable for predictions at 95% confidence interval and do not violate any of the statistical assumptions of a linear model. In Ref. [21] linear regression was also applied for two different regions in the Ondo State, Nigeria whereby their respective results were compared. It was established by the authors that distances between random distributions of points can be a factor when developing regression model for local coordinate prediction. Also, Ref. [22] developed regression models for coordinate prediction at Makkah Metropolitan area. The simplicity and accuracy of the regression models were considered. Moreover, the authors' proposed that these regression models could be used for surveying and mapping activities such as GIS, data collection, engineering surveying and topographic mapping based upon their prediction capabilities.

Other numerical methods applicable for predicting local cartesian coordinate is the Total Least Squares (TLS) and General Least Squares (GLS). It is worth mentioning that several studies have been carried out by researchers into TLS in 3D coordinate transformation and in robotics [23-26]. Although extensive applications of linear regression (OLS) and TLS has been carried out, limited literature is available in geodesy technical papers on the application of TLS, GLS for two-dimensional (2D) local cartesian coordinate prediction.

This study also considered the artificial intelligence technique of Feed Forward Back Propagation Neural Network (FFBPNN) as an alternative to predicting local cartesian coordinates from global coordinates within the local geodetic system in Ghana. It must be emphasized that artificial intelligence techniques has been widely used in solving problems in geodesy. For example, researchers like [27-30] applied the back propagation and radial basis function neural network as an alternative to 3D coordinate transformation by comparing with conformal similarity models. Moreover, several research works have been carried out using artificial neural network (ANN) for GPS height conversion. This can be found in [31-34]. Yet, a study on the integration of conventional technique into ANN to improve the efficiency of the model developed has not been comprehensively investigated for planimetric coordinate predictions.

Therefore, this study focused on Ghana as a case for application of the conventional methods (OLS, GLS, and TLS), FFBPNN and a proposed hybrid approach of TLS-FFBPNN for the study area. The hybridized model yielded the most precise coordinate values in good agreement with the measured data.

2. Study Area

Ghana is a country located in the Western part of Africa and is bordered by Cote D'Ivoire to the West, Togo to the East, Burkina Faso to the North and the Gulf of Guinea to the South. The country has a 239,460 km^2 land mass generally consisting of low plains [35] with 2,093 km of international land borders. Lying just above the equator, Ghana has a tropical climate with mean annual temperature ranging between 26 °C and 29 °C but temperature are generally higher in the North than in the South [35]. The country is divided into ten administrative regions as shown in Fig. 1 below.

This study covers the western administrative region in Ghana (Fig. 1). This region have almost all the natural resources such as gold, bauxite, manganese, oil, timber, cocoa and many others found in the country and thus, are of high economic value. It also forms part of the ongoing newly established geodetic reference network referred as the Golden Triangle [19].

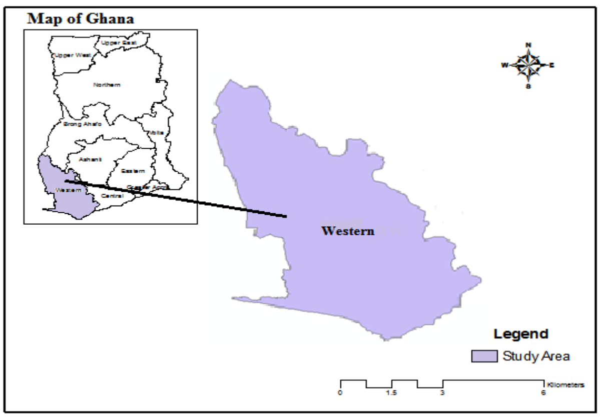

Fig. 1 Map of Ghana showing the study area.

3. Data

Primary control point data of global geodetic coordinates (ϕ, λ) were collected by field work using the Trimble GPS receivers with the static GPS surveying technique adopted. Their corresponding existing cartesian coordinates (E, N) in the Ghana local coordinate system were acquired from a mining company's database in Ghana. A total of 200 above-mentioned datasets were used in this study to develop the prediction models and obtain an approximation of the relationship between (ϕ, λ) and (E, N) respectively. An independent datasets of 26 was then applied to test the model prediction accuracy level.

4. Methods

Normally in applied numerical problems in engineering and in the field of sciences, it is essential to fit a surface or curve to a set of data points with known coordinates. The most commonly used method is the Ordinary Least Squares. Its aim is to minimise the sum of squared errors of only one of the variables but not of the others [36]. However, in surveying and mapping, all observed data (coordinates) may suffer from errors. Fortunately, there exist numerical techniques that incorporate errors in both coordinates in their respective procedures. Two of such methods namely, Total Least Squares and General Least Squares were considered in this study. Artificial intelligence technique namely, Feed Forward Back Propagation Neural Network was also applied. Finally, a hybrid model was proposed.

4.1 Ordinary Least Squares

The Ordinary least Squares (OLS) mathematical model for fitting a straight line to points is of the form $y = mx+c$ where x and y are the coordinates of a point, m is the slope of a line, and b is the y intercept at $x = 0$. The assumption in the OLS is that residuals are applied only to the observation vector (y coordinate) even though both observations (x, y) contain errors. In an ideal situation, all coordinates points must lie on a least squares line if they are truly linear and no observation errors exist. On the other hand, this is seldom the case in that (1) the observations contain errors; (2) the functional model could be a higher-order curve, or both (Ghilani, 2010). If the desirable best-fitting straight line is found for the data, residuals are added to the least square equation. Hence, accounting for the errors in the observation vector (y). Assuming four control points A, B, C, and D, its observation equation in least squares term can be written as

$$mx_A + c = y_A + v_{yA}$$
$$mx_B + c = y_B + v_{yB}$$
$$mx_C + c = y_C + v_{yC}$$
$$mx_D + c = y_D + v_{yD}$$

The above observation equation contains two unknown parameters, m and b, with four observations. Their matrix representation in the least squares form is $AX = L+V$ where

$$A = \begin{bmatrix} x_A & 1 \\ x_B & 1 \\ x_C & 1 \\ x_D & 1 \end{bmatrix}, \quad X = \begin{bmatrix} m \\ b \end{bmatrix}, \quad L = \begin{bmatrix} y_A \\ y_B \\ y_C \\ y_D \end{bmatrix},$$

$$V = \begin{bmatrix} v_{yA} \\ v_{yB} \\ v_{yC} \\ v_{yD} \end{bmatrix}$$

The equation is then solved using the least squares method $X = (A^TA)^{-1}A^TL$ and the observational residuals are calculated using $V = AX-L$.

4.2 General Least Squares

The General Least Squares (GLS) postulates that both observed variables (x and y) contain errors since they are observational data. Yet in the case of the OLS mathematical model, the residuals are applied only to the *y* coordinate. This clearly shows the deficiency in the OLS model by failing to account for the error in the other observed variable (x coordinate). Assuming that four control points A, B, C, and D were surveyed on the field, its observation equation in GLS can be written as [37]

$$F(x, y) = (y + v_y) - m(x + v_x) - b = 0$$

where V_x and V_y are the residuals of the coordinate points (x, y), *m* is the slope of the line and *b* is the intercept. The above equation having the unknown parameters is nonlinear and therefore requires linearization.

In this study, Taylors Series for linearizing nonlinear equations was applied. The resulting equation for the four assumed control points after linearization can be written as:

$$-m_o V_{x_A} + V_{y_A} - x_A dm - db = -(m_o x_A + b_o - y_A)$$
$$-m_o V_{x_B} + V_{y_B} - x_B dm - db = -(m_o x_B + b_o - y_B)$$
$$-m_o V_{x_C} + V_{y_C} - x_C dm - db = -(m_o x_C + b_o - y_C)$$
$$-m_o V_{x_D} + V_{y_D} - x_D dm - db = -(m_o x_D + b_o - y_D)$$

These equations can be represented in matrix form as:

$$BV + JX = K$$

Where

$$B = \begin{bmatrix} -m_o & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -m_o & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -m_o & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -m_o & 1 \end{bmatrix}$$

$$J = \begin{bmatrix} -x_A & -1 \\ -x_B & -1 \\ -x_C & -1 \\ -x_D & -1 \end{bmatrix}, \quad V = \begin{bmatrix} v_{x_A} \\ v_{y_A} \\ v_{x_B} \\ v_{y_B} \\ v_{x_C} \\ v_{x_D} \\ v_{y_D} \end{bmatrix}, \quad X = \begin{bmatrix} dm \\ db \end{bmatrix},$$

$$K = \begin{bmatrix} -(m_o x_A + b_o - y_A) \\ -(m_o x_B + b_o - y_B) \\ -(m_o x_C + b_o - y_C) \\ -(m_o x_D + b_o - y_D) \end{bmatrix}$$

In solving for the general least squares, the unknown parameters *dm* and *db* is estimated using the relationship; $X = (J^T W_e J)^{-1} J^T W_e J$. Where W_e is the equivalent weight matrix given us; $W_e = (B \Sigma B^T)^{-1}$ and Σ is the covariance matrix of the observations. The observational residuals are estimated using the equation $V = \Sigma B^T W_e V_e$ and $V_e = JX\text{-}K$ is the equivalent residuals. It should be noted that GLS is a nonlinear equation system and therefore requires iteration until convergence is achieved.

4.3 Total Least Squares (TLS)

The Total Least Squares (TLS) is a technique that is appropriate when there is an existence of errors in both the observation vector and in the data matrix [38]. In the plane, the main goal of TLS is to determine a line that minimises the sum of the squared distances from that line to a given data point in the plane. The total least squares method adopt the symmetric form of the equation of a line. Thus, the distance *d* from a point say (p, q) to a straight line will have the equation $rx+sy\text{-c} = 0$ that acknowledges the following formula [36]:

$$d^2 = \frac{(rp + sq - c)^2}{r^2 + s^2}$$

If the line passes through a point $\vec{X}_0 = (x_0, y_0)$, then $c = rx_0 + sy_0$. Therefore the equation becomes $r(x - x_0) + s(y - y_0) = 0$. So, with given data points $\vec{X}_1 = (x_1, y_1), \ldots\ldots, \vec{X}_n = (x_n, y_n)$, the problem of the TLS consists of determining a line, defined by a point (x_0, y_0) on the line and by normal vector (r, s), which minimises the sum D of the squared distances given as

$$D(r, s, \vec{x}_o; \vec{x}_1, .. \vec{x}_n) = \sum_{i=1}^{n} \frac{(r(x_i - x_o) + s(y_i - y_o))^2}{r^2 + s^2}.$$

It must be known that the line of total least squares passes through the centroid of the data points.

4.4 Feed Forward Back Propagation Neural Network (FFBPNN)

Artificial neural networks (ANNs) are computational standards based on mathematical models inspired by the structure, operation and behaviour that imitate the human brain of biological neurons in the nervous system. These networks consist of highly interconnected neurons (Sordo, 2002) via links of variable synaptic weights (Handhel, 2009) that process information through an interaction with the environments. Generally, there are different types of ANN based on their architecture. The most popular network architecture in use today for engineering applications is the Feed Forward Back Propagation Neural network (FFBPNN) (Haykin, 2007). This network consists of three layers; input layer which act as control variables having an influence over the desired output of the neural network and an output layer giving the internal computation results. Between these two layers exist another layer not evident from the outside called the hidden layer liable for executing intermediate calculations (Konaté, 2015). It is pertinent to note that the efficiency of a neural network and its simplicity depends on the appropriate number of neurons applied in the hidden layer.

The number of hidden neurons is determined by trial and error procedure depending on the characteristics of the problem, training samples size and requirement. This is due to some of these factors; the problem under consideration, the choice of neural network structure and proposed theories that are yet to be accepted universally to clarify the number of hidden units needed to approximate a given function. In this study, the optimum number of neurons in the hidden layer was selected by sequential trial and error procedure based on the smallest mean square error (MSE).

The choice for the hidden layer used in this study was 1. This decision was based on [43] which further corroborate that Feed Forward Back Propagation Neural Network (FFBPNN) with one hidden layer together with their hidden and output transfer functions is a universal approximator of any discrete and continuous functions. The hyperbolic tangent was chosen as the hidden neurons activation function while a linear transfer function was used in the output neurons. The hyperbolic tangent can be expressed mathematically as

$$f(t) = \tan sig(t) = \frac{e^t - e^{-t}}{e^t + e^{-t}}$$

where *t* is the sum of the weighted inputs.

For the network training, the objective is to find optimal weight connection w^* in such a way that it will provide estimated outputs that match for each example of the desired outputs value. This is a typical nonlinear optimization problem, where w^* is given as [42]

$$w^* = \arg\min E(w),$$

where ***w*** is the weight matrix and $E(w)$ is an objective function on ***w***, which is to be minimize. The $E(w)$ is evaluated at any point of ***w*** as follows:

$$E(w) = \sum_n E_n(w),$$

where ***n*** is the number of examples in the training set and $E_n(w)$ is the output error for each example ***n*** and is defined as

$$E_n(w) = \frac{1}{2}\sum_j \left(d_{nj} - y_{nj}(w)\right)^2 ,$$

where $y_{nj}(w)$ and d_{nj} are the calculated and desired network outputs of the ***j***-th output neuron for ***n***-th example, respectively. Substituting $E_n(w)$ into $E(w)$ gives

$$E(w) = \frac{1}{2}\sum_n \sum_j \left(d_{nj} - y_{nj}(w)\right)^2$$

In this study, Levenberg-Marquardt algorithm (LMA) was chosen to train the neural network because it is faster and has more stable convergence than the classical gradient descent algorithm. This was proven in the work of [44]. The LMA can be thought of as a combination of steepest descent and the Gauss-Newton method. The algorithm behaves like steepest descent method when the current solution is far from the correct one. Thus, slow but guaranteed to converge. On the other hand, when the algorithm approaches the correct solution, it becomes a Gauss-newton method. Detailed analysis of the LMA is beyond the scope of this study and interested reader is referred to [45] for more comprehensive treatments.

4.5 Concept of the Proposed Method

Three conventional techniques namely OLS, GLS, and TLS were employed in this study. Having considered the strengths and weaknesses as well as the results obtained for each method the TLS was the preferred method to OLS and GLS for the hybridization with FFBPNN. Hence, the proposed hybrid technique of TLS-FFBPNN was developed. The concept is elaborated below.

(1) First the TLS models were determined for Eastings and Northings coordinates respectively. However, like in every survey measurements there exist random errors after any least squares adjustment. This therefore limited the prediction potential of the TLS models developed. Also, jackknifing validation approach being implemented further show that the model is not in good agreement with the measured data.

(2) In order to improve the efficiency of the model, the residuals obtained from the TLS adjustment and it's predicted coordinates values was used as a training sample in conjunction with the global coordinates in the FFBPNN.

(3) The TLS-FFBPNN hybrid model was then used to predict the 2D cartesian coordinates.

5. Performance Criteria

The evaluation of the performance of the implemented methods was focused on the residuals generated from test data by each prediction models developed for predicting (E, N) from (ϕ, λ). In order to check the validity of the solutions obtained from the prediction models, the following statistical estimation accuracy measures were used as a performance criteria index (PCI) namely: Mean Square error (MSE), Root Mean Square error (RMSE), Nash-Sutcliffe Efficiency Index (η), Index of Agreement (D) and Modified Index of Agreement (D). Mathematical representations of the PCIs are given by:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(t_i - o_i)^2 ,$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(t_i - o_i)^2} ,$$

$$\eta = 1 - \frac{\sum_{i=1}^{n}(t_i - o_i)^2}{\sum_{i=1}^{n}\left(t_i - \bar{t}_i\right)^2} , \quad D = 1 - \frac{\sum_{i=1}^{n}(t_i - o_i)^2}{\sum_{i=1}^{n}\left(t_i^{'} + o_i^{'}\right)^2} ,$$

where $t_i^{'} = \left|t_i - \bar{o}_i\right|, o_i^{'} = \left|o_i - \bar{o}_i\right|$,

$$MID = 1 - \frac{\sum_{i=1}^{n} |t_i - o_i|}{\sum_{i=1}^{n} \left(|o_i - \bar{t}| + |t_i - \bar{t}| \right)}.$$

where n is the total number of examples presented to the learning algorithm, t and o are the observed values and predicted values. $\bar{t_i}$ is the mean of the observed values and $\bar{o_i}$ is the mean of the predicted values respectively.

6. Results and Discussion

6.1 Models Developed

Different model equations were determined between geodetic coordinates (latitude, longitude) and cartesian coordinates (Eastings (E), Northings (N)) respectively. A total of 200 data points were used to form the models. Tables 1 and 2 below present the various models developed when OLS, GLS, TLS, FFBPNN and TLS-FFBPNN were applied on the datasets.

From Table 1 above, it can be observed that the OLS, GLS and TLS models for both Eastings-Longitude and Northings-Latitude exhibit a positive linear relationship. This indicates that models for Eastings and Longitude as well as Northings and Latitude all move in the same direction. That is, a unit increase in Longitude increases the Easting component by 110932.46313 having a constant of 1499298.88761for the OLS. In the case of GLS and TLS, there was a unit increasing of 110932.46220 and 110933.24579 with a constant value of 1499298.87783 and 1499307.31603 respectively. The same situation was also observed for the Northings and Latitude models determined (Table 2).

The FFBPNN models accepted for predicting cartesian planimetric coordinates consist of three layers; thus, 1input layer, 1 hidden layer and 1 output layer. With reference to Tables 1 and 2, it could be

Table 1 Models determined for eastings and longitude.

Method	Models developed
OLS	E = 110932.46313 (Longitude) + 1499298.88761
GLS	E = 110932.46220 (Longitude) + 1499298.87783
TLS	E = 110933.24579 (Longitude) + 1499307.31603
FFBPNN	2-16-1
TLS-FFBPNN	4-5-1

Table 2 Models determined for northings and latitude.

Method	Models developed
OLS	N =110325.28210 (Latitude) + 1894.85001
GLS	N = 110325.28213 (Latitude) + 1894.85012
TLS	N = 110325.52889 (Latitude) + 1893.07289
FFBPNN	2-8-1
TLS-FFBPNN	4-4-1

seen that the optimum FFBPNN architecture has 2 input neurons corresponding to 2 selected inputs (longitude, latitude), hidden neurons of 16 and 8 with 1 output neuron of Eastings and Northings respectively. However, the proposed hybrid model (TLS-FFBPNN) consist of 4 inputs namely (latitude, longitude, residuals from TLS, TLS predicted coordinates), hidden neurons of 5 and 4 with 1 output neuron of Eastings and Northings respectively.

6.2 Prediction

A closer look at Tables 3 and 4, it is evident that both the OLS, GLS and TLS produced identical results which were closely related to the existing data. This clearly shows that there is not much difference between the three least square approaches. However, the predictions from the FFBPNN showed significant improvement in the predicted coordinate values compared to the least square methods. Nevertheless, there was substantial improvement in the TLS-FFBPNN model predicted values compared with the other methods.

6.3 Model Performance Evaluation

The validity of the models developed was further accessed based on the performance criteria index (PCI) stipulated in section 5. The MSE and the RMSE values for each method in relation to their respective models were calculated and the results are shown in Tables 5 and 6 below. The MSE and RMSE are useful when comparing different techniques applied to the same dataset. Hence, the MSE and RMSE was used in this study as a criterion to measure the goodness of fit of the various models developed. The closer the MSE is to 0 the better the prediction capabilities of the model. On the basis of the results (Table 5), the MSE values obtained for OLS, GLS, TLS were identical and was in the range of 0.74 m. This means that the models (OLS, GLS, TLS) could predict observations within the accuracy of 0.74 m. In the case of the FFBPNN, the 0.14 m obtained shows that the model predictions could only deviate from the existing observations by not more than 0.14 m. However, the hybrid approach (TLS-FFBPNN) produced values that are in close agreement with the measured data. This was based on the MSE value of 0.000900 m. It could be seen that the TLS-FFBPNN gave better prediction capabilities among all the methods applied. With reference to Table 6, the MSE values obtained by each least square methods were identical with a prediction accuracy of 0.6 m. The FFBPNN MSE of 0.03 m shows the extent to which the model fit the observational data. The

Table 3 Predicted northing coordinate values.

EXISTING NORTHING (m)	PREDICTED NORTHING COORDINATES (m)				
	OLS	GLS	TLS	FFBPNN	TLS-FFBPNN
796594.03	796593.45	796593.45	796593.45	796593.96	796594.02
796970.81	796972.31	796972.31	796972.31	796970.71	796970.69
796147.42	796147.52	796147.52	796147.52	796147.37	796147.43
796502.50	796502.32	796502.32	796502.32	796502.44	796502.49
796393.86	796393.87	796393.87	796393.87	796393.86	796393.86
796213.96	796214.04	796214.04	796214.04	796214.05	796213.98
795818.81	795818.86	795818.86	795818.86	795818.63	795818.80
796881.79	796880.96	796880.96	796880.96	796881.32	796881.79
796963.26	796965.03	796965.03	796965.03	796963.66	796963.13
796906.12	796905.34	796905.34	796905.34	796906.17	796906.12
796685.47	796684.69	796684.69	796684.69	796685.68	796685.47
796100.84	796101.07	796101.07	796101.07	796100.74	796100.86
795822.14	795822.39	795822.39	795822.39	795822.11	795822.14
796510.30	796510.05	796510.05	796510.05	796510.56	796510.29
796823.82	796822.82	796822.82	796822.82	796823.68	796823.81
796991.42	796991.62	796991.62	796991.62	796991.67	796991.33
796967.81	796968.89	796968.89	796968.89	796967.81	796967.65
796685.59	796684.80	796684.80	796684.80	796685.58	796685.56
796980.24	796980.14	796980.14	796980.14	796980.21	796980.16
795996.81	795997.03	795997.03	795997.03	795996.75	795996.81
796666.56	796665.83	796665.83	796665.83	796666.58	796666.56
796968.35	796969.88	796969.88	796969.88	796968.33	796968.23
795846.76	795846.88	795846.88	795846.88	795846.58	795846.76
796375.90	796375.89	796375.89	796375.89	796375.95	796375.90
796450.97	796450.80	796450.80	796450.80	796450.88	796450.96
796963.67	796964.81	796964.81	796964.81	796963.64	796963.58

TLS-FFBPNN MSE value of 0.004 m act as a measure of how well the model explain a given sets of observations.

The RMSEs shown in Tables 5 and 6 above were used in the evaluation process because the RMSEs are sensitive to even small errors and can determine the quality of a model, making it good in comparing small changes between predicted and observed differences in models. It is evident that the RMSE (Tables 5 and 6) obtained for Eastings-Longitude and Northings-

Table 4 Predicted easting coordinate values.

EXISTING EASTING (m)	PREDICTED EASTING COORDINATES (m)				
	OLS	GLS	TLS	FFBPNN	TLS-FFBPNN
304470.199	304470.842	304470.842	304470.840	304470.277	304470.198
304623.270	304622.819	304622.819	304622.819	304623.255	304623.271
304588.533	304587.210	304587.210	304587.209	304587.480	304588.530
304698.670	304697.255	304697.255	304697.255	304698.130	304698.701
304815.158	304814.067	304814.067	304814.068	304815.290	304815.183
305086.147	305085.962	305085.962	305085.965	305086.147	305086.067
305393.409	305394.687	305394.687	305394.692	305393.547	305393.488
304590.688	304589.539	304589.540	304589.539	304590.632	304590.674
304622.893	304621.488	304621.488	304621.488	304622.006	304622.883
304751.579	304750.281	304750.281	304750.281	304751.668	304751.599
304893.491	304892.607	304892.607	304892.609	304893.339	304893.485
305039.514	305039.149	305039.149	305039.151	305039.437	305039.429
305215.634	305216.086	305216.086	305216.090	305215.000	305215.654
305393.275	305394.576	305394.577	305394.581	305393.201	305393.264
304323.571	304324.522	304324.522	304324.519	304323.441	304323.572
304415.356	304416.152	304416.152	304416.150	304415.553	304415.359
304251.031	304251.861	304251.861	304251.858	304250.956	304251.041
304244.736	304245.538	304245.538	304245.535	304244.821	304244.735
304411.266	304412.048	304412.048	304412.046	304411.416	304411.265
304494.100	304494.803	304494.803	304494.802	304494.256	304494.098
304552.457	304552.821	304552.821	304552.820	304553.124	304552.451
304619.673	304619.713	304619.713	304619.713	304620.166	304619.655
304512.787	304513.218	304513.218	304513.217	304512.762	304512.791
304588.770	304588.985	304588.985	304588.984	304588.736	304588.765
304612.633	304612.613	304612.614	304612.613	304612.536	304612.631
304637.892	304637.684	304637.684	304637.684	304638.271	304637.880

Table 5 Statistical indicators for easting-longitude model.

PCI	METHODS				
	OLS (m)	GLS (m)	TLS (m)	FFBPNN (m)	TLS-FFBPNN (m)
MSE	0.746325	0.746322	0.746279	0.139851	0.000900
RMSE	0.863901	0.863900	0.863875	0.373966	0.030002
η	0.999992	0.999992	0.999992	0.999999	1.000000
D	0.999998	0.999998	0.999998	1.000000	1.000000
MID	0.998441	0.998441	0.998442	0.999484	0.999964

Table 6 Statistical indicators for northing-latitude model.

PCI	METHODS				
	OLS (m)	GLS (m)	TLS (m)	FFBPNN (m)	TLS-FFBPNN (m)
MSE	0.575834	0.575885	0.576120	0.026614	0.003570
RMSE	0.758837	0.758871	0.759025	0.163138	0.059749
η	0.999996	0.999996	0.999996	1.000000	1.000000
D	0.999999	0.999999	0.999999	1.000000	1.000000
MID	0.999175	0.999175	0.999176	0.999832	0.999948

Latitude models identified the variations in observed and predicted values. Visual inspection of Tables 5 and 6 shows that the TLS-FFBPNN attained the smallest RMSE value among the methods. This signify that the TLS-FFBPNN gave better model performance than the other methods because the closer the RMSE value is to 0 the better the prediction accuracy of the model.

The Nash-Sutcliffe Efficiency Index (η) is a commonly used reliable statistic for measuring model efficiency by comparing predicted values to its corresponding observed values. The (η) range from $-\infty$ to 1 with improved model performance approaching 1. It can be inferred from Tables 5 and 6 that the TLS-FFBPNN based model attained the optimum value of 1 for both models unlike the FFBPNN where 0.999999 was achieved for the Easting-Longitude and 1 for the Northing-Latitude model. This shows that the TLS-FFBPNN predictions are closest to the existing coordinates hence performing better than other models. Nevertheless, the OLS, GLS, TLS and FFBPNN indicated good model performance as their respective values were approaching 1 (Tables 5 and 6).

The index of agreement (D) takes values from 0 to 1 with higher index values indicating that the modelled values have better agreement with the observations. Observation of Tables 5 and 6 show good model performance for all models. However, the TLS-FFBPNN and FFBPNN further showed their superiority over the least square methods based on their respective D values. Although, the D values obtained are better indications of the efficiency of the respective models, research have shown that relatively high values could be obtained even for a poor model fit. Also, D is sensitive to extreme values due to the square differences in the mean square error in the numerator. In addition, the presence of outliers in the dataset may lead to relatively higher values of D due to the squaring of the difference term [46]. Based on these reasons the authors applied the Modified Index of Agreement (MID) as part of the PCIs. The results for MID in Tables 5 and 6 further corroborate the above mentioned deficiencies in the D. The MID varies from 0 to 1 with higher values indicating a better fit of the model. With this in mind, it can be stated that the TLS-FFBPNN models are better than the other models.

6.4 Model Selection Criteria

In order to further confirm the superiority of the hybrid approach (TLS-FFBPNN) as the optimum model in predicting 2D cartesian coordinates over the FFBPNN and the least square methods (OLS,GLS,TLS) the Bayesian Information criterion (BIC) was applied. Also, BIC tends to favour models with fewer parameters because its penalty term is smaller compared to other criteria. The BIC is represented mathematically as

$$BIC = n * \ln\left(\frac{SS_E}{n}\right) + K * \ln(n)$$

where n denotes the number of observations, SS_E the sum of squares of residuals, and K is the penalty term for the number of parameters.

The results in Table 7 illustrates that the BIC selected both the TLS-FFBPNN models of Northing-Latitude and Easting-Longitude as the optimum model for 2D cartesian coordinates prediction. The reason is that the

Table 7 Model selection results.

METHOD	BIC VALUES	METHOD	BIC VALUES
OLS	-1.091247	OLS	-7.834144
GLS	-1.091342	GLS	-7.831833
TLS	-1.092840	TLS	-7.821243
FFBPNN	-44.630483	FFBPNN	-87.767933
TLS-FFBPNN	-175.820946	TLS-FFBPNN	-139.996336

TLS-FFBPNN model obtained the least value of BIC among the other models.

7. Conclusion

Coordinate prediction is crucial in the surveying and mapping industry especially in developing countries like Ghana where a non-geocentric coordinate system and datum are still used. It is worth knowing that coordinates determined for any geodetic application is used by geospatial and non-geospatial professionals for various purposes. For this reason, in order to facilitate setting a standard in practice for coordinate prediction especially in Ghana, a hybrid approach of Total Least Squares-Feed Forward Back Propagation Neural Network (TLS-FFBPNN) is proposed to be used over conventional techniques (Ordinary Least Squares, Total Least Squares, General Least Squares) particularly within local geodetic networks. Hence, building an effective and accurate prediction model has become a major research area for both academia's and field practitioners in recent times. The proposed hybrid method utilizes the prediction tool capabilities of both the total least squares and artificial neural network architecture of a multilayer perceptron. Using this methodology, researchers and surveyors will be able to predict two-dimensional (2D) coordinates using readily available global geodetic data. This methodology can stir up an intelligent front end and also add a whole new dimension to the usage of artificial neural network in the surveying and mapping industry. It further proves that there is a relationship, no matter how complex in nature, between global geodetic coordinates and 2D cartesian coordinates. It was also shown from the study that a carefully designed artificial neural network is capable to predict 2D coordinates of Eastings and Northings with accuracies comparable to actual measurements than the conventional techniques. The final hybrid prediction models summary in this study have shown that the models gives more than 99% overall accuracy for the prediction of the 2D cartesian coordinates. This has further shown that the computational efficiency of hybridizing artificial neural network and conventional methods cannot be over stated. To conclude, the proposed hybrid model could be used for cadastral surveys, farm compensation surveys, topographic mapping, engineering surveying and other related mapping activities because of the following considerations: the mean-square error and root mean square error is small indicating no significant over fitting occurring; an overall hybrid model prediction error of not more than 15 cm; satisfied the performance criteria evaluations as well as the Bayesian Information Criterion test.

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