Research Article

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Seamless geospatial data methodology for topographic map: A case study on Baghdad

https://doi.org/10.1515/eng-2022-0358
received March 06, 2022; accepted July 15, 2022

Abstract: Researchers have been focused on evaluating topographic maps in order to identify property and infrastructure and address issues relating to property disputes and its ramifications for a given country. However, over time, the requirements for map production have changed and evolved, and there is a need for an increased level of quality and standard in the map making process. Several cities in Iraq, including Baghdad (capital), do not comply with the existing standards set by the Department of Survey Mapping in Iraq (DSMI). One of the main concerns and issues is with the quality of mapping which is mainly due to inaccurate digitizing procedures. Therefore, the aim of this study is to produce seamless topographic maps using vector data to overcome the problem of no-overlapping that often occurs in producing maps. However, there is another issue regarding edge matching and the lack of standards being met according to the MS1759 procedure. To address this issue, ArcGIS 10.3 software is used as a tool to process data, analyze the index maps, and to produce seamless geospatial data using seamless methods. The database is set up using the characteristics and code properties from the MS1759 standard. The orthophoto image is used as the base map in which the series of maps used is MY Series and its area is of Baghdad. The results indicated that seamless topology is far easier to handle than the base cartography. It also demonstrated that using this method aids in analyzing the data in a far more detailed manner than existing techniques. Overall, the study concludes that seamless topographic map has a better GIS ready quality and the produced map is far more qualitative than the existing map of the Baghdad.

Keywords: geospatial data, topographic map, Baghdad geosurvey, orthophoto, survey mapping

1 Introduction

1.1 Problem background

Geographic information system (GIS) has long been developed and adopted especially in developed countries such as the United States [1–3]. It is a tool that has helped a lot in planning and development. In Iraq, as a developing country, the use of GIS is increasingly being exploited by its advantages [4–6]. Recognizing its extensive use of technology, it has been adopted by certain parties to further institutionalize management and planning for a particular organization as a career field that can be applied [7].

Other than being used to generate maps, GIS is also utilized for managing spatial datasets [8]. The process of linking the attribute data with spatial coordinates of a given map is called Geocoding. Geographic database is generated by creating the field in the attribute database for longitude and latitude of each address. Then, all the attributes are independently combined on the map and form the attribute dataset.

Another great benefit relating to the use of GIS is that it provides spatial criteria based on quick queries such as, “how many schools or hospitals are there within a 2 km radius? [9]” or “what is the temperature index in a given sector in the given city map?” [3]. There are several research papers that focus on understanding and using GIS as a tool in order to enhance the mapping experience in a given city. For instance, there are several research groups that focus on performing impact analysis using complex source area, water pollution [10], build environment, land susceptibility [11–13], and air quality [14] as their research areas. Other researchers use route calculation in tandem with other attributes such as oil pipeline routing [15],

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making a bicycle network, or understanding travel behavior through mapping and GIS.

However, GIS can be used for more than just that, it can be used for infrastructure analysis and prediction patterns as well. For instance, creation of irrigation systems, or providing a vulnerability analysis can be done through a properly set up GIS. Other benefits also include environmental studies [1,2] with identification of environmental emissions, or locating sources of air pollution. These are some of the main benefits of using GIS in cartography. Overall, they will provide a better long-lasting map that is accurate and complete for future use for other researchers. The accuracy of the maps generated can ultimately lead to be used by other researchers on topics that can change different vital aspects of the urban life. All these has been mentioned and studied extensively in the cited research works listed in this section.

Redundancy of data cause the decision making process to be difficult until the effort of combining a lot of data through a computer system is developed by creating a geospatial database to facilitate the operation of data overlays [16]. The data that are merged also need to be of high quality where a good map shows the information of each area such as coordinate exactly as it is on the ground [17].

1.2 Objective of study

Various processes have been done to get the best quality of map [18,19]. Hence this study is to highlight the process of producing the map seamlessly without the need for a lot of layers [20]. Among the methods used in this process is the edge matching method where the process is much the same as the process of identifying other image geometry but this is more focused on data vectors [21]. A new application was developed for joining and storing data seamlessly to allow this vector data to be created automatically [22].

The aim of this study is to enhance the mapping process for the seamless geospatial data topographic map in vector data. In this research, the scope has been set as Baghdad. This will be the area of study, alongside ArcGIS 10.3 used as the software for urban map production (1:5 K scale). To achieve this goal, seamless rules alongside vector databases are used in order to analyze the edge matching in every sub-index of the map. There are studies of similar type that have been performed using a different scope such as one that was performed in Ukraine [23]; however, this work is different as the tools that are used to tackle the problem need to adapt to the desert like environment of Baghdad.

This research starts with the introduction which provides a literature background as well as explains the benefits of using GIS. This section also elaborates on the objectives of the research. Section 2 focuses on the methodology of the research and the different tools and elements that are used to conduct the experiment. This section has all the figures and terminology needed in order to identify how each step interacts with one another. In Section 3, the results are illustrated and discussed. Finally, Section 4 gives the conclusion which closes the research by reflecting the objectives of the research and how they were achieved throughout the research.

2 Methodology

In this section the methodology used to conduct the research as well as the location of the study are illustrated and explained.

2.1 Scope of the area

The chosen area of study is set as Baghdad due to its complex metropolitan and dense development area. This area has been chosen for further development which consists several structures and vegetation. There are buildings that are both residential and industrial, as well as some green vegetation that is common for the area of the study [24]. The selection of the study site as well as the production of the topographic maps of Baghdad are extremely important and vital to the cartographical needs of the region. The production of topographical maps for this particular area would aid in resolving real estate disputes as well as implementing a planning and executing work for strategic projects and infrastructure. It also aids in allowing sustainable development across all sectors in the state. Additionally, providing these digital images and models, alongside their topographic elevation with corrected high accuracy coordinates can aid in security, or military aspects. Updating the GIS for Iraq can also mitigate possible issues that can arise from natural or artificial events on the buildings or surrounding structures.

In developing the map from the database, a few scopes have been identified. With the aid of a topography software known as ArcGIS 10.3, map based on the orthophoto taken in 2017 [25] is produced. Seamless rules (auto script) are applied at every point, line, and polygon in topology editing. Data from map series MY SIRI with a scale of 1:5,000 has been used as a guide to locate all features that exist in that area. Both the scales are used to ensure that every single point must be analyzed in order to get a complete map. The location of the specific area in Baghdad city has been marked and shown in Figure 1.

2.2 Data source

The source of the data is produced from the Department of Survey Mapping in Iraq (DSMI), tile-by-tile [26]. The scale of every tile is 1:250. The data collected are also in conjunction with the measurements performed in the field. Conventional data collection methods were used, such as triangulation network to establish the coordination position accurately at that point. However, a digital measurement was also used through photo measurement [27]. These were collected and taken by cameras that are specially installed and fitted on the airplane.

Most map resources or plans are provided by DSMI [28,29]. A clear source is required in order for the orthophoto to be collected. This would then be used based on the exact location of the selected area.

This process is done by DSMI and the data involved for this search is taken from the topographic mapping section. The maps are also obtained in hardcopy (raster data) and softcopy (vector data). The map image data may span large geographic areas and may be displayed in several discrete zoom levels. The map image data may further include various additional services, such as street names, addresses, and businesses for display with or overlaying the map image.

Figure 1: The study area – aerial view of Baghdad.

2.3 Method

Methodology is a set of systematic and orderly procedure in a planning system for obtaining the objectives. In this research, it will discussed more regarding phases in implementing this research [30]. In order to develop the database system, the research methodology stated in Figure 2 are based on the stages in acquiring data acquisition, data processing, and analysis.

This study was conducted to produce a seamless geospatial data method that focused on areas in Baghdad as study area. The data produced ID vector data obtained from the tile-by-tile image where the data are a completed orthophoto image georeferenced. The method for conducting this study is to use the ArcGIS 10.3 software by

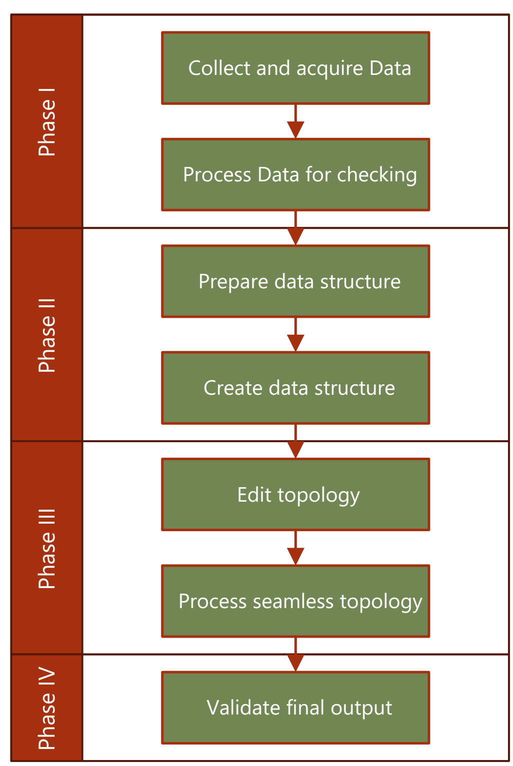

Figure 2: Research methodology.

digitizing the image to make Urban Map. The scale used for the producing Urban Map is 1:5,000.

The objective of this research was the implementation of a seamless geospatial data methodology for topographic map. The first method was data acquisition which is mention above, while the second method is processing done by using software ArcGIS 10.3, where all the processes involved with the map projection and creating layer database have been done by using ArcGIS 10.3. Detecting any edge matching or overlapping layer will also be done in this stage.

2.4 Validation and verification

When vector data are given from an organization, or from a client, the first step is to perform a data identification which is done in a pre-checking phase. Once the data are uploaded to the software, they are then used in the checking process. Data vectors are collected from DSMI in a tile-by-tile fashion. Then, edge matching is checking for all the given images, this is important step, as it ensures there are no overlapping in the final image. Once this step is completed, the image is used as a base map and projection, which is used for the digitalizing process. The map projection for this search is based on the WGS 1984.

In order to adjust the position of the features, the edge matching ensures that the sheet boundaries do not overlap. It also ensures that the collected features are cross adjacent in the map sheet and they all share the same edge locations. There are often issues that arise regarding the acceptable tolerance regarding mismatches in a sheet. However, this mismatch occurs mainly due to the shrinkage or expansion that happens on paper maps. This would lead to errors in scanning and digitization of the image. Errors can also occur if they have happened in a much earlier setting during the geo-referencing process or if the equipment used to measure the site has been faulty and inaccurate. Extrapolation or rounding-off errors also often lead to a mismatch error when added over time.

The orthophoto provided by the city planning department needs to be checked for the projection of the map. This would identify the coordinates and the projection of each of the obtained data points. This cross referencing is done through the ArcGIS software, which adds the detailed information about each of the projections and their related properties.

2.5 Creating data structure for layer

During this stage, the process of preparing the data structure depends in the second phase. The preparation of data structures is to create a layer for each theme as an example of a building, housing. In this step of creating, feature class and feature dataset are also to be set in this process [31].

The type of building is determined based on what is on the orthophoto map as well as the type identification through google street image. Each layer also has a separate database which is referred to as MS1759 [31], for standardization purposes shown as building, vegetation, hydrology, and transportation in Table 1. Once feature extraction after geo-referencing and creating the feature dataset and feature data class based on MS1759 code are completed, then the next process of digitizing can be done in ArcMAP [32].

2.6 Validating completeness and accuracy

After georeferencing and creating the feature dataset and feature data class based on MS1759 code completed, then the next process of digitizing can be done in ArcMAP. The last step which is final checking (validating), which is important, needs to be made to ensure that all the geometries that have been digitized are perfect. This is to ensure that the GIS data produced has a good quality and is suitable for reference maps. For example, data checking can be made in topology editing to ensure digitizing using polygon geometry either overlapping with each other or not. The geometry that uses polygons is the building and vegetation that have majority themes in this map. Geometry in simple language is the shape of a feature. In determining the shape or geometry of a particular item, many other features that may be taken into account in the checking process are to look at the geometric type. Geometry has many kinds such as: (i) point (point or multipoint), (ii) line (multilines), and (iii) polygons (polygon or multipolygons).

2.7 Attribute entry

The spatial data that has been collected from DSMI is in ECW format and can be opened by using ArcMap. It needs to be converted to a SHP (.shp) file and this is where the

Table 1: Standard code MS1759 used to create layer

Type	Building			Vegetation		Hydrology	Transportation	
	BA residential	BB commercial	BC industrial					
Feature code	BA0010	BB0010	BC0010	VD0040	VD0060	RA0100	TA0060	TA0090
Feature name	Residential building	Commercial building	Industrial building	Limestone forest	Planted forest	Spot height	Road	Road junction
Definition	Building or property designated for use as premises for dwelling units or home.	Building or property designated for use as premises for business-related activities such as trading and services.	Building or property designated for use as premises for manufacturing and processing-related industry, repairing, servicing activities, foundries, and warehousing/storage.	A forest type, mostly small tree species and shrubs, found on limestone rock, hills, and surroundings.	An area planted with tree species and managed as forest plantation.	Locations where height has been determined with respect to a vertical datum.	An established surface on the right of way in areas meant for exclusive use of vehicles.	A point where two or more roads cross or meet.
Feature class	Point, polygon	Point, polygon	Point, polygon	Polygon	Polygon	Point	Line, polygon	Point

digitizing process is involved in order to build up this vector data. The onscreen digitizing is a manual process that involves digitizing on the computer monitor using a data source as the background and it is an efficient method for editing and updating an existing layer.

Figure 3 illustrates the data that have been given by DSMI which is orthophoto that locate the area of Baghdad, it is in the ECW format. This has been adopted as a background to do the digitizing process. Also, coordinate system is about using map coordinates to assign a spatial location to map features. The elements in a map have a specific geographic location and extent that enables to be located near to the earth's surface. A coordinate system has been set for the base map. The coordinate system used is WGS 1984.

2.8 Advantages of a seamless database for DSMI

The advantages of a seamless database for DSMI users are as follows. They can obtain the desired data regarding the topographic map of study area at DSMI. The maps are also obtained in hardcopy (raster data) and softcopy (vector data). The database provides complete and conclusive cadastral survey information for the purpose of topographic map, manages the cadastral survey, and maps database efficiently in order to allow GIS users to get benefits from the geospatial dataset in the desired location according to the coordinates. Providing the topographic map infrastructure and checking edge matching of all image must be done to avoid overlapping image.

2.9 Topology editing

Many GIS applications provide tools for topological editing. For example, in ArcGIS there are tools for topological editing to improve editing and maintaining common boundaries in polygon layers. A GIS such as ArcGIS "detects" a shared boundary in a polygon map so that only the edge vertex for one polygon boundary has to be moved which will ensure the updating of the other polygon boundaries. Another topological option allows to prevent polygon overlaps during digitizing. In this search, as the methodology to seamless geodatabase, append tools has been introduced.

Appends is a tool that can input multiple datasets into an existing target dataset. Input datasets can be point,

Figure 3: ECW image for both orthophoto of the case study area.

line, or polygon feature classes, tables, raster, raster catalogs, annotation feature classes, or dimensions feature classes. Validation for output identification of information is important once the digitization process is complete.

This is because, detailed information is needed when producing map as it can be used by the public to help them travel and so on. To ensure that every given information is accurate, the surveyor will go to the field to check that what is shown on the map must be exactly what is in the real area.

3 Results and discussion

In seamless database, features are not separated into individual parts but instead they are considered to be continuous by the edge of the sheet maps. Every feature is displayed and treated as a continuous and unique identity managing geographical data.

There are generally two methods used to generate a seamless database [33]. The first method uses the storage of spatial data in different files. Each of the files is indexed in order to speed up the loading process. The second method uses special attributes stored in one database, instead of different files [34]. This research uses the second method in order to generate a seamless database.

3.1 Topology results

The result of this study is a generated map that contains layer covering area of study features and need to be analyzed for the effectiveness and development of the seamless geospatial database system. In this study, GIS data are divided into two general parts which is attributed data and spatial data.

The goal of this test was to generate seamless database and create required tools for joining objects that have same edge location. For analysis, there are few tests that have been applied for checking the geodatabase system which is used topology function.

Topology can check error that occurs while digitizing. So, classes, subclasses, and attributes as well as required threshold for topology construction were defined and created in dataset.

Topology checking has been viewed as a spatial data structure which most fundamentally ensures data quality. In addition, it also allows geodatabase to more realistically represent geographic features.

A database provides a framework whose features can have behaviors such as subtype, validation rules, attribute domains, or other features. Result of topology rules on geodatabase for all tiles is listed in Table 2.

For the analysis, the error for tile 3 is highest compared to tile 1 and tile 2 for the built_environment_P. Based on the observations in Table 3, the value error is 1,125 for tile 3, 875 and 615 for tile 1 and tile 2, respectively. It is due to the compact area which is tile 3 classified as urban area, while for tile 1 and tile 2, it shows the rural area. Second analysis is focused on error transportation_L which shows the highest error on tile 1, which is 1,925, followed by tile 2 and tile 3 with 35 and 855, respectively. It is due to the area in tile 1 which faces more development in urbanization township in terms of road compared to the others.

Table 2: Result of topology rules on geodatabase tiles 1, tiles 2, and tiles 3

Exceptions	Errors 3 Tiles 3	Errors 2 Tiles 2	Errors 1 Tiles 1	Class 1	Rule	Class 2
0	0	0	0	Must be larger than cluster tolerance		
0	1,125	615	875		Must not have gaps	Built_environment_P
0	164	5	322		Must not have gaps	Transportation_P
0	97	1	126		Must not overlap	Hydrography_P
0	215	1	0		Must not overlap	Transportation_P
0	5	1	0		Must not overlap	Hydrography_P
0	6	20	43		Must not overlap	Built_environment_P
0	38	1	293	Transportation_P	Must not overlap with	Built_environment_P
0	1	3	0	Hydrography_P	Must not overlap with	Built_Environment_P
0	9	109	8	Vegetation_P	Must not overlap with	Hydrography_P
0	161	12	296	Transportation_P	Must be inside	Transportation_L
0	663	0	3		Must not overlap	Transportation_L
0	5	0	0		Must not overlap	Hydrography_L
0	5	0	0		Must not intersect	Hydrography_L
0	718	6	6		Must not intersect	Transportation_L
0	855	35	1,925		Must not have dangles	Transportation_L
0	20	10	2		Must have not dangles	Hydrography_L
0	0	0	0		Must be disjoint	Transportation_X
0	0	0	0		Must be disjoint	Built_environment_X
0	0	0	0		Must be disjoint	Hydrography_X

Table 3: Result of topology rules on geodatabase, with appended tiles

Class 1	Rule	Class 2	Errors	Exceptions
Must be larger than cluster tolerance			0	0
Bulit_environment_P	Must not have gaps		0	3,023
Transportation_P	Must not have gaps		4	483
Hydrography_P	Must not overlap		97	0
Transportation_P	Must not overlap		0	214
Hydrography_P	Must not overlap		0	1
Built_environment_P	Must not overlap		0	35
Built_environment_P	Must not overlap	Transportation_P	0	325
Built_environment_P	Must not overlap	Hydrography_P	0	4
Hydrography_P	Must not overlap	Vegetation_P	0	136
Transportation_L	Must be inside	Transportation_P	2	253
Transportation_L	Must not overlap		0	662
Hydrography_L	Must not overlap		2	0
Hydrography_L	Must not intersect		2	0
Transportation_L	Must not intersect		0	710
Transportation_L	Must not have dangles		2	3,077
Hydrography_L	Must not have dangles		0	16
Transportation_X	Must be disjoint		0	0
Built_environment_X	Must be disjoint		0	0
Hydrography_X	Must be disjoint		0	0

Errors are marked as an exception, which is a valid case of a topology rule violation. It can be done by using topology layer properties dialog box to specify symbology and which rules, errors and exceptions can be selected. Below are two types of exceptions that have been detected in this search which is topology single and topology interlayer, respectively. Figures 4 and 5 show that the topology and raster images in the blue circle have error that needs exceptions due to real situation in the ground.

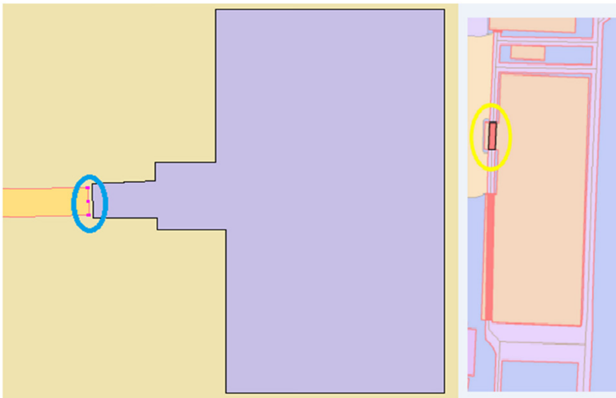

Figure 4: Topology error in rule, building must not have gap.

Figure 5: Raster image in rule, building must not have gap.

Following the above rule, Figure 4 illustrates that building and transportation must be connected but in the real situation there is a gap between the building that separated the house and the paved road, the error is seen inside the blue circle. The figure also shows that topology and raster image in the yellow circle has error that needs exception due to real situation same as above. By following the rule of topology, the error means that there must not be any overlapping between transport and building but the image captures shows that the roof is on the paved road and it must accept this error as an exception.

Edge matching features tool can be used to modify input line features by spatially adjusting their shapes, guided by the specified edge match links, so they become connected with the lines in the adjacent dataset.

Figure 6 shows the result on hydrography features that is not connected to each other. To connect the features one tool has been used which is spatial adjustment tool that can adjust edge match of that line.

This tool helps in minimizing time in adjusting edges. The result is as shown on Figure 7. For the analysis, Figure 6 shows the line that is not located at the same edge location with the other map index after the seamless process in done. This is because it has different digitizing of its center line and different value use of buffer compared to the other. The unconnected line can be adjusted by using spatial adjustment tool that has been discussed

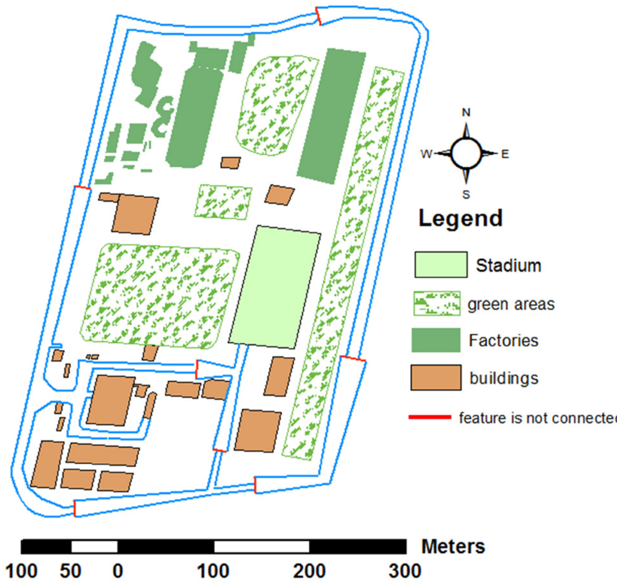

Figure 6: Hydrography feature separated sections.

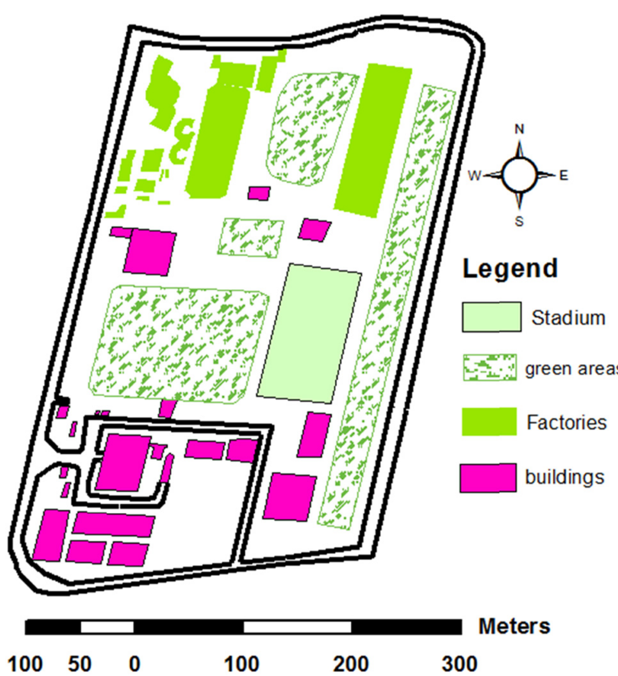

Figure 7: Result of the edge match process.

Figure 8: Illustrates the complete features to run.

above. Figure 6 is the final result after edge match process has been done.

The edge matching process is done via the use of the GIS. In Figure 7, the results indicate that an accurate depiction of topographic maps from where edge matching features are presented and it would allow the map users to specifically identify the issues relating to proper disputes. As mentioned earlier, the use of GIS can provide several benefits; however, in this research the main goal was to prevent property disputes in the given area. The reason why this particular issue was used is because that due to the tribal nature of Iraq, the concept of a property has a great impact on the geopolitical and geosocial aspects of the country.

3.2 Model builder script

By using ArcMap, scripts for joining every features consisted in each different files can be created. Database as well as dataset was created for storing spatial and attribute data. The schema of created dataset was defined according to MS1759 standards, so that classes, subclasses, and attributes as well as required threshold for topology construction were defined and created in dataset. For example; every subtype must be same for joining features and topology must be created for every single file.

The schema of the input datasets must match the schema of the target dataset in order for data to be appended. Then, to create seamless database, one script model builder was developed using ArcMap and for joining features which had lied in different map index and had been divided to two objects by the edge of the sheets. Figure 8 shows the illustrated structure of developed script model builder.

4 Conclusion

The aim of this study was to enhance the mapping process for the seamless geospatial data topographic map in vector data. This study was performed on Baghdad, Iraq as the main scope of the location. This location was chosen as it is the vital location in Iraq, as it is the capital of the country, and is one of the cities that has the most issues in regards to property disputes in the country. The focus was to increase the accuracy of the process via GIS and the use of an edge matching process. There are existing studies that have used a GIS in order to increase accuracy in countries like Ukraine for big cities like Kiev. However, the main issue here is to focus on property disputes, while other research works focus on other aspects such as environmental matter, or oil routing as well as many others.

This study highlights on how to use seamless vector on multiple geodatabase for easy viewing on map. The result of this search showed that using a seamless database in big and national organizations that are responsible for map production and selling them to customers is very useful from the perspective of data management and analysis as well as selling map to customers according to their demand point of view.

For practical purposes, it is possible to develop this test to implement a seamless database for DSMI and to provide them with advantages of using a seamless database. Different methods of making a seamless database were tested and evaluated. The characteristics of these methods for managing and analysis of geographical data as well as topologically structuring of data were be evaluated and compared.

References

[1] Adimalla N, Taloor AK. Hydrogeochemical investigation of groundwater quality in the hard rock terrain of South India using Geographic Information System (GIS) and groundwater quality index (GWQI) techniques. Groundw Sustain Dev. 2020;10:100288.
[2] Lu B, Stocks M, Blakers A, Anderson K. Geographic information system algorithms to locate prospective sites for pumped hydro energy storage. Appl Energy. 2018;222:300–12.
[3] Zhu J, Wright G, Wang J, Wang X. A critical review of the integration of geographic information system and building information modelling at the data level. ISPRS Int J Geo-Inform. 2018;7(2):66.
[4] Demeuov A, Tilekova Z, Tokpanov Y, Hanchuk O, Panteleeva N, Varfolomyeyeva. Use of GIS technology in geographical education. E3S Web of Conferences. Second International Conference on Sustainable Futures: Environmental, Technological, Social and Economic Matters; 2021.
[5] Ogrodnik K, Kolendo Ł. Application of gis technology and AHP to determine the areas with fully developed, compact functional and spatial structure: A case study of Bialystok, Poland. Land Use Policy. 2021;109:105616.
[6] Picchio R, Pignatti G, Marchi E, Latterini F, Benanchi M, Foderi C, et al. The application of two approaches using GIS technology implementation in forest road network planning in an Italian mountain setting. Forests. 2018;9(5):277.
[7] Singh A. Remote sensing and GIS applications for municipal waste management. J Environ Manag. 2019;243:22–9.
[8] Chan SW, Abid SK, Sulaiman N, Nazir U, Azam K. A systematic review of the flood vulnerability using geographic information system. Heliyon. 2022;8:e09075.
[9] Cecconi FR, Moretti N, Tagliabue LC. Application of artificial neutral network and geographic information system to evaluate retrofit potential in public school buildings. Renew Sustain Energy Rev. 2019;110:266–77.
[10] Jha MK, Chowdhury A, Chowdary VM, Peiffer S. Groundwater management and development by integrated remote sensing and geographic information systems: prospects and constraints. Water Resour Manag. 2007;21(2):427–67.
[11] Oh H-J, Lee S. Landslide susceptibility mapping on Panaon Island, Philippines using a geographic information system. Environ Earth Sci. 2011;62(5):935–51.
[12] Lee S, Lee S, Lee MJ, Jung HS. Spatial assessment of urban flood susceptibility using data mining and geographic information System (GIS) tools. Sustainability. 2018;10(3):648.
[13] Ali S, Biermanns P, Haider R, Reicherter K. Landslide susceptibility mapping by using a geographic information system (GIS) along the China–Pakistan Economic Corridor (Karakoram Highway), Pakistan. Nat Hazards Earth Syst Sci. 2019;19(5):999–1022.

[14] Jasim OZ, Hamed NH, Abid MA. Urban air quality assessment using integrated artificial intelligence algorithms and geographic information system modeling in a highly congested area, Iraq. J Southwest Jiaotong Univ. 2020;55(1).
[15] Ma L, Cheng L, Li M. Quantitative risk analysis of urban natural gas pipeline networks using geographical information systems. J Loss Prev Process Ind. 2013;26(6):1183–92.
[16] A. Elubid B, Huang T, H. Ahmed E, Zhao J, M. Elhag K, Abbass W, et al. Geospatial distributions of groundwater quality in Gedaref State using geographic information system (GIS) and drinking water quality index (DWQI). Int J Environ Res Public Health. 2019;16(5):731.
[17] Kearney SP, Coops NC, Sethi S, Stenhouse GB. Maintaining accurate, current, rural road network data: An extraction and updating routine using RapidEye, participatory GIS and deep learning. Int J Appl Earth Observ Geoinf. 2020;87:102031.
[18] Kim H, Jung WK, Park YC, Lee JW, Ahn SH. Broken stitch detection method for sewing operation using CNN feature map and image-processing techniques. Expert Syst Appl. 2022;188:116014.
[19] Li X, Li Z, Feng R, Luo S, Zhang C, Jiang M, et al. Generating high-quality and high-resolution seamless satellite imagery for large-scale urban regions. Remote Sens. 2020;12(1):81.
[20] Di K, Jia M, Xin X, Wang J, Liu B, Li J. High-resolution large-area digital orthophoto map generation using LROC NAC images. Photogram Eng Remote Sens. 2019;85(7):481–91.
[21] Sombatpiboonporn P, Charoenpong T, Supasuteekul A, Chianrabutra C, Pattanaworapan K. Human edge segmentation from 2D images by histogram of oriented gradients and edge matching algorithm. In 2019 First International Symposium on Instrumentation, Control, Artificial Intelligence, and Robotics (ICA-SYMP). IEEE; 2019. p. 29–32.
[22] Karpinskyi Y, Lazorenko-Hevel N. The system model of topographic mapping in the national spatial data infrastructure in Ukraine. Interdepartmental scientific and technical review "Geodesy, Cartography and …; 2020.
[23] Lazorenko-Hevel N, Kin D, Karpinskyi Y. Some aspects of the edge matching method of digital topographic maps in the scale of 1:50,000 for creation the main state topographic map.2020. In International Conference of Young Professionals GeoTerrace. European Association of Geoscientists & Engineers. 2020;2020(1):1–5.
[24] Al-Ansari N. Topography and climate of Iraq. J Earth Sci Geotech Eng. 2021;11(2):1–13.
[25] Karpinskyi, Y. U. R. I. I., & Lazorenko-Hevel, N. A. D. I. I. A. The system model of topographic mapping in the national spatial data infrastructure in Ukraine. Interdepartmental scientific and technical collection Geodesy, cartography and aerial photography; 2020.
[26] Webster T. Laser altimetry: what can be learned about geology and surface processes from detailed topography. Earth Sci. 2012;457.
[27] Ruiz JJ, Ariza FJ, Ureña MA, Blázquez EB. Digital map conflation: a review of the process and a proposal for classification. Int J Geograph Inf Sci. 2011;25(9):1439–66.
[28] Al-Saaidy HJ, Alobaydi D. Studying street centrality and human density in different urban forms in Baghdad, Iraq. Ain Shams Eng J. 2021;12(1):1111–21.
[29] Numan NM, Awda GJ, Thannoon HA. Topographic map revision in northern Iraq using DTMs and orthophotos. ITC J. 1992;3:244.
[30] Brown G, Kyttä M. Key issues and priorities in participatory mapping: Toward integration or increased specialization? Appl Geogr. 2018;95:1–8.
[31] Hamzah NA, Othman AN, Khalid N. Surface and subsurface utility database and mapping: UiTM Shah Alam; p. 012011.
[32] Gorshkov A, Novikova O. Estimating the validity of the recognition results of earthquake-prone areas using the ArcMap. Acta Geophys. 2018;66(5):843–53.
[33] Zuo Z, Zhou S, Hu M. Distributed massive GIS spatial database building method based on multi-level mode. In 2010 18th International Conference on Geoinformatics. Beijing, China: IEEE; 2010. p. 1–6.
[34] Harris N, Goldman ED, Gibbes S. Spatial database of planted trees (SDPT) version 1.0. Technical Note, World Resources Institute; 2019.