POINT OBJECT EXTRACTION FROM SCANNED TOPOGRAPHIC MAPS FOR THE DIGITAL TOPOGRAPHIC MAPS PRODUCTION

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Abstract:

Topographic maps published by the Military Geographical Institute are an important cartographic source in the process of creating a digital topographic map in the scale of 1:25 000. Existing topographic maps are scanned and georeferenced, but vectorization of the required content from these maps is done manually, which requires a lot of time. The homogeneity of cartographic content gives the potential for the application of algorithms for automatic vectorization of geospatial data. This paper presents a tool programmed in the Python programming language that extracts point symbol - well objects (as a hydrographic object) from a georeferenced map, by identifying objects based on assigned samples and generating vector point spatial data. Recognition is performed on a processed input raster containing only shades of blue. The output data are the geographical coordinates of the identified objects and the initial raster with markings at the places where the objects are recognized. 1074 wells on 24 map sheets in the wider area of Novi Sad and Zrenjanin were generated. Proposed Points from Corner method showed satisfactory positional accuracy results.

Keywords:

Object Detection, Automatic Vectorization, Template Matching, Scanned Maps Processing, Computer Vision.

INTRODUCTION

Topographic maps are very important and extensive sources of data. Topographic maps from the period of the second half of the 20th century published by the Military Geographical Institute in Belgrade (hereinafter MGI) represent a very recognizable project of this institution. By switching to the digital system of work, all existing maps in the MGI edition were scanned and georeferenced in order to be used as a cartographic source when performing works on the production of digital geotopographic materials. Manual digitization, which is still mostly done in such and similar examples, requires a lot of effort as well as a lot of time. Therefore, the development of tools for automatic recognition of spatial objects, i.e. information and vectorization of cartographic content is very necessary [1]. Processing of rasters obtained by scanning analog

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topographic contents would be very important because the obtained results would be reflected in more optimal and faster production of digital topographic map in the scale of 1:25 000 (hereinafter DTM25) which is currently the main MGI project. In addition, spatial data on older editions of topographic maps could be searched in much more useful ways [2] therefore in the context of map elements that can be related to today's similar elements (political and administrative borders, river flows, etc.) and elements in the same geographical locations. On the other hand, as stated in [3] raster data is "unintelligent" and any information is only pixel-related. Also, according to [3] objects, contours, lines and symbols are heavily fragmented by the raster, the information of geometric and topological features is mainly lost, reduced or summarized to the raster-compatible information, and between the pixels there is no other geometric and topological relation than the neighborhood from one pixel to the other in certain discrete directions of the raster table. In raster data we cannot recognize objects directly, and we must compare pixels which are standing together, and similar information among these pixels provides segments that may be interpreted as one object [3].

The idea of this paper is to present the possibility of automatic recognition and vectorization of wells as a hydrographic object from the second updated edition of the topographic map in the scale of 1:25 000 (hereinafter TM25) which represents condition from the year of 1968. Map sheets from the wider regions of the cities of Novi Sad and Zrenjanin were processed, from which 1074 wells were detected and generated in the vector point data. The *Points from Corner* method for determining the geographical coordinates of identified objects has been proposed, which has shown potential for other different applications, such as e.g. the process of automatic georeferencing of a scanned topographic map. The possibility has been shown that the created tool is additionally autonomously developed and improved in the direction of further needs of the Institution. Existing software for similar purposes was a model for the development of this tool.

2. TM25 AS A SECONDARY CARTOGRAPHIC SOURCE IN THE PROCESS OF MAKING DTM25

The main activity of MGI is the production of digital topographic map in the scale of 1:25 000. After the Second World War, the map has gone through three editions, while the fourth edition is currently in making, which differs from the previous ones in that the new technological environment is designed so that the entire production process takes place in a central database environment.The condition for making each map is the possession of cartographic sources that allow obtaining the necessary geographical data on the territory of mapping [4]. The main source of the data acquisition in the central database are data obtained by the digital technological process for aero photogrammetric imaging in the MGI [5]. In addition, earlier releases of TM25 have found their application as secondary data sources for content creation on DTM25. In the period from 2002 to 2004, the TM25 was digitized by scanning map sheets. After scanning, georeferencing was performed in the national coordinate system within the seventh zone of the Gauss-Krieger projection (creation of * .tif and * .tfw files), and later in the UTM coordinate system [6]. Geographical elements are the most important part of a topographic map. They make up the basic - geographical content of the map. In cartography, hydrography is a collective term for all waters and objects that have water as an integral part. As a very important element of the content of each topographic map, it influences the development of other geographical elements, reliefs, plants, settlements, communications, etc. It is a kind of basis for displaying other elements of content. In the process of making DTM25, it is applied first and the accuracy of application is taken into account [4].

Interpretation and presentation of geographical elements on topographic maps is a required and narrowly specialized procedure. Aerial photogrammetric images are used as the primary data source in the process of making DTM25. Data processing is mainly carried out through the phases of 3D and 2D restitution. Through the 3D restitution phase, content is created and stored in a central database. Thereafter, DTM25 goes through a 2D restitution phase. The 2D restitution introduces the cartographic modeling of the content obtained by 3D restitution method and the additional content which was not treated in the 3D restitution process [5]. At this stage of processing, previous releases of TM25 are often used as a secondary data source. The main reason for this is the dilemmas in the process of interpreting aerial photogrammetric images as a cartographic source. There may be a dilemma as to what an object or phenomenon represents in the field. One of the cases, as practice shows, is that, due to the vegetation cover, certain objects and phenomena on the aerial photo cannot be identified and classified with certainty. These can be rivers that do not have a large width, occasional watercourses that, during the summer months, usually do not have water, paths and roads through the forest, certain objects, especially lower altitudes, including wells. Also, the large number of facilities and supporting infrastructure in densely populated areas can make it difficult to spot facilities of public importance and other phenomena that have priority on the map. In such cases, and in order to resolve existing dilemmas, the interpretation of content from previous editions of TM25 can be used to solve the problem.

2.1. TOPOGRAPHIC SIGN OF WELLS ON TM25 AND DTM25

Topographic signs are conditioned and most often established graphic signs (symbols) for displaying, recognizing and determining the qualitative and quantitative characteristics of objects, phenomena and other facts on topographic maps and related geographical maps. The shape or some detail of the internal structure of a drawing usually resemblesthe objects it depicts [7]. Due to its relatively small dimensions, the well cannot be represented on the scale of the map. Therefore, it is given a dotted topographic symbol, which does not show the dimensions of objects in nature, but only their position. As the well is a topographic sign in the shape of a circle ( ), the exact position of the displayed object is determined by the main point of the sign which is located in the middle of the respective image. The topographic symbol of the well created for the logical data model for DTM25, remained unchanged compared to the previous version of the topographic key analog TM25 so that when displaying the well on DTM25 the vector center coincides with the center of the well symbol.

2.2. VECTORIZATION OF WELLS

Wells are classified as drinking water facilities. In addition to the general importance, when they are outside the settlement, they are important means of orientation. The well is shown if it is arranged and has visible aboveground features. In places where the population grows vegetables, so there are more wells, only a few signs are displayed to convey the character of the phenomenon [8]. Where the land is rich in water, wells are mostly shown outside the settlement, while on arid land, on a large map, every well is shown. On multicolor maps, they are shown in blue [4]. Due to the size of the well and the fact that they are often surrounded by other objects in the farm or vegetation, their observation on aerial photographs often challenges even the most experienced performers and requires them to greatly enlarge the image when inspecting the terrain, unnecessary for most content. It takes time, because due to the increase in view, a smaller part of the space is viewed. Therefore, in practice, they are first found on TM25, after which, on the aerial photogrammetric image, special attention is paid to the space where the sign is located on TM25. In this way, the executors are directed to expect the appearance of wells in that area. Finding a well on the TM25 can also be a problem, especially on maps that show a part of the terrain that is loaded withcartographic content. The symbol of the well is small, so here again the executor must enlarge the raster map while working in GIS, again seeing less space and spending more time. TM25 sheets can contain hundreds of wells.

3. METHODOLOGY OF WORK

Our method for generating spatial data of interest - well symbols on the map (Well Generator Tool) is implemented in the Python programming language, using the openCV library. The method works by having a scanned and georeferenced topographic map 1:25 000 as input and raster samples of well signs extracted from the map, and as output the initial raster of the scanned map is generated which contains markers where wells are located and a file in * .csv format in the form of a table with the geographical coordinates of the located wells which are later used to create vector data (Figure 1).

Applications of similar algorithms on historical maps whose appearance varies from drawing style are much more complex because it is much more difficult to apply one type of algorithm for different types of maps [2]. However, the mentioned topographic maps are homogeneous in their structure, and the process of their production is characterized as standardized. This allows the application of the described methodology on numerous map sheets of this edition with very little user effort. As stated in [9], for homogeneous and large cartographic content (which TM25 is) it is possible to achieve excellent results with algorithms for computer vision, but their application is very specific because it is based on detailed knowledge of the content and construction of the map which implies the potential of such a model. The model is assigned raster samples of well symbols, without its wider environment, taken from the map in the original resolution (Figure 2).

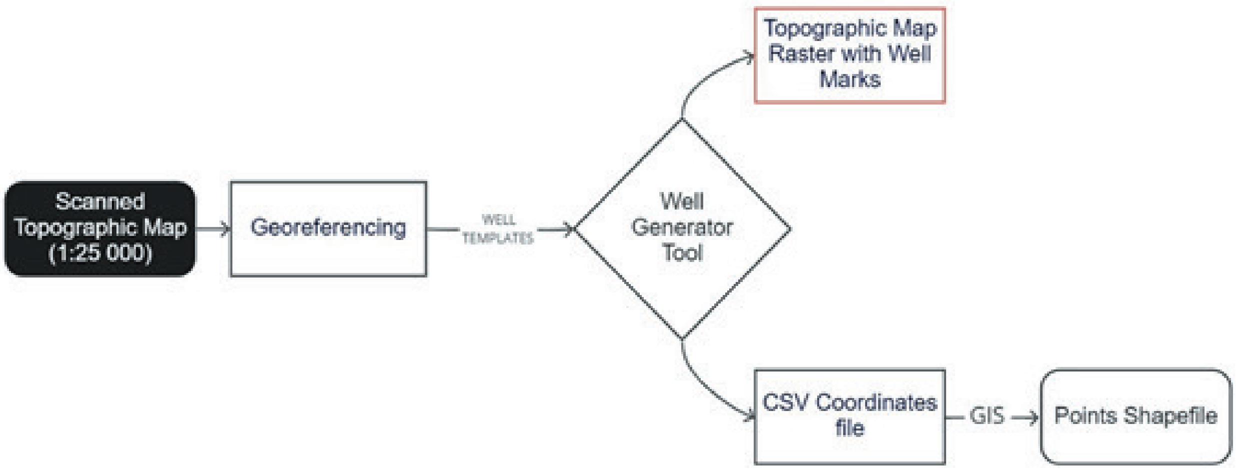

Figure 1 – Workflow.

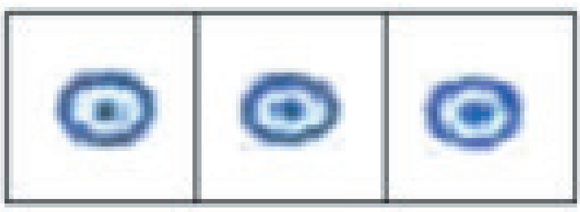

Figure 2 – Well templates.

The output raster represents an existing scanned map with added labels showing the detected object of interest, as shown in Figure 3. Detection of the object of interest is enabled using image processing techniques, the most important of which is the *imageTemplate* function from the openCV library. Detection is performed over a raster version that contains only cartographic content in blue. As the raster of the same resolution is processed, the obtained information on the location of the identified object is only applied to the input raster. The knowledge base of the template matching strategies is the template itself, which is given as pre-information. During the matching process, the template is matched with raster image samples [3]. In its simple form, a given pattern is sought in an image, typically by scanning the image and evaluating a similarity measure between the pattern and every image window [10].

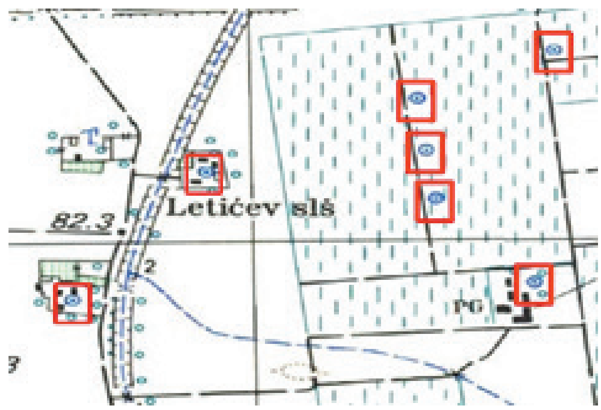

Figure 3 – Raster output with well marks.

A threshold value was introduced as the recognition limit, which defines how much the minimum match of the part of the input raster with the sample is enough for the object to become identified. Unlike the approach in [9] and in accordance with the nature of the input data, the selection of empirically determined unique threshold values with respect to map homogeneity shows good results in practice, but high accuracy results could be achieved by applying techniques to form an adequate individual threshold value.

3.1. CALCULATION OF GEOGRAPHICAL COORDINATES OF IDENTIFIED OBJECTS

The calculation of geographical coordinates was performed according to the cartographic projection of the map that uses Greenwich as the initial meridian on the Bessel ellipsoid.

The generating of geographical coordinates was done by first identifying the top left cartographic content point, i.e. point with known geographical coordinates. By identifying the point, its pictorial coordinates were also obtained. It was identified in relation to the nearest corner of the outer frame of the map, which was sampled in the same way as the symbol of the well (Figure 4, marked with 1), so the empirical approach led to the mentioned point (Figure 4, marked with 2). How the outer frame of the map sheet was created according to the sample from the map program when creating the topographic map 1:25 000 [4], each of the sheets has an external frame created in the same way, so the assumption was that the starting point empirically determined on one map sheet can be applied to all input map sheets, which proved to be relevant. This method *Points from Corner* was also used to calculate other parameters.

Another important component in the mathematical model for calculating the geographical coordinates of wells concerns the determination of the values of longitude and latitude according to the value of one pixel. As the territory is shown on the map in the format of 7°30' latitude difference and 7°30'of longitude difference, the pictorial distances of the map sheet frame were determined, and the mentioned values were obtained based on the proportion. The image distances of the map sheet frame are different for each sheet by longitude, so this component was calculated separately based on the differences between the pixel coordinates of the starting (Figure 3, marked with 3) and ending points of the scale (Figure 3, marked with 4) located by *Points fromCorner*. After that, local pixel coordinates were obtained by subtracting the image coordinates of the top left point from the image coordinates of the identified object (equations 1 and 2). Multiplying local pixel coordinates with a value of one pixel in longitude and latitude yielded local geographical coordinates (equations 3 and 4), which were added together with the geographical coordinates of the starting point of the map content to give the total values of latitude and longitude coordinates (equations 5 and 6). The equations are shown below.

As multiple well samples were used for identification, the total score would represent the union of the results obtained with each sample. This would lead to the well symbol appearing multiple times in the results. Such a phenomenon is neutralized by processing a set of results and throwing out close and the same pairs of values of geographical coordinates.

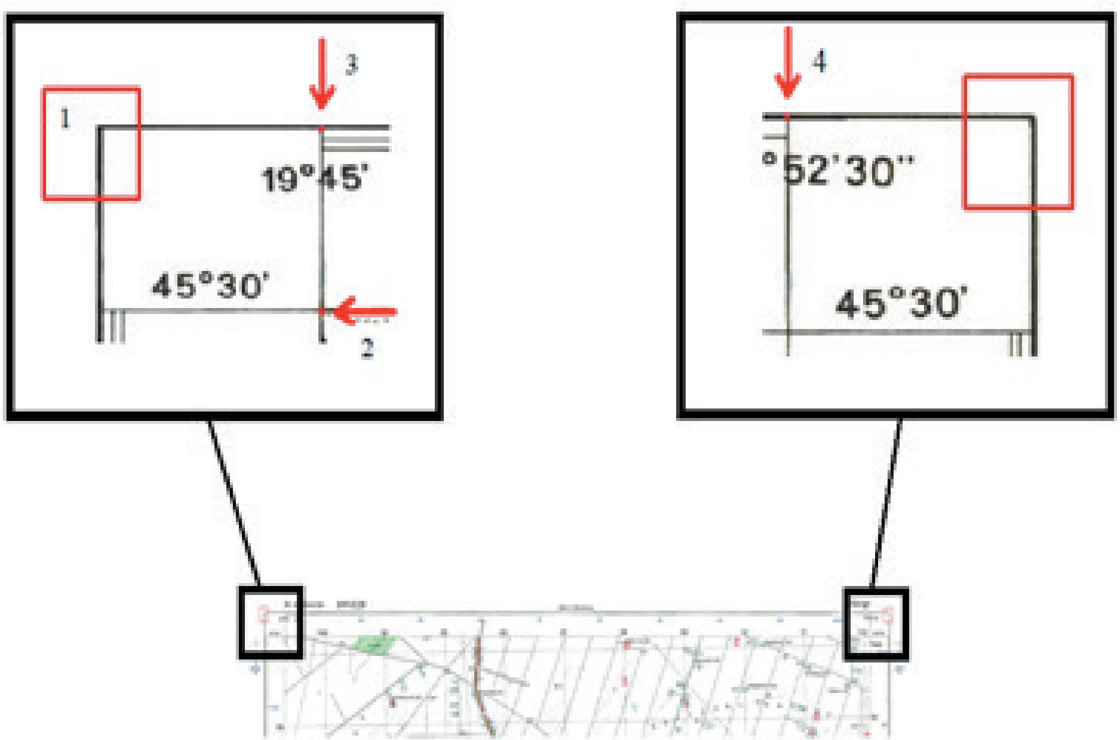

Figure 4 – Map corner with key elements.

$$\text{Object pixel coordinate}_X\text{-Starting point pixel coordinate}_X\text{=Local object pixel coordinate}_X \quad (1)$$

$$\text{Object pixel coordinate}_Y\text{-Starting point pixel coordinate}_Y\text{=Local object pixel coordinate}_Y \quad (2)$$

$$\text{Longitude pixel increment}\cdot\text{Local object pixel coordinate}_X=\Delta\lambda \quad (3)$$

$$\text{Latitude pixel increment}\cdot\text{Local object pixel coordinate }_Y=\Delta\varphi \quad (4)$$

$$\lambda_0+\Delta\lambda=\lambda \quad (5)$$

$$\varphi_0+\Delta\varphi=\varphi \quad (6)$$

4. RESULTS AND DISCUSSION

4.1. DATA USED

The demonstrated methodology was applied on a sample of 24 map sheets of topographic map in the scale of 1:25 000. The sheets refer to the territories of South Bačkacounty in the wider region of Novi Sad (8 sheets) and Central Banatcounty in the wider region of Zrenjanin (16 sheets) and together form a whole of 6 neighboring map sheets in 4 rows. The scanned maps image's resolution is about 6700x6600 pixels and 96 dpi.

4.2. SAMPLE RECOGNITION RESULTS

All experiments presented in this paper were performed on a desktop computer. The entire process and data generation takes about 20 seconds per map sheet. The results are shown in Table 1. The results are shown as the percentage of wells detected in relation to the total number of wells on the map, the percentage of false-positive detections representing false results in relation to the number of identified objects and the percentage of undetected wells in the map number of wells. The part of the table above the dashed line represents the map sheets that refer to the wider region of Novi Sad, while the part below the dashed line refers to the wider region of Zrenjanin. The percentage of detected wells varies from sheet to sheet, but when you look at the results shown, you can see that 83.91% of the total number of wells was recognized. Attention should also be paid to the appearance of false positive results, i.e. results that are recognized as a well, and on the map actually represent another phenomenon or object. As color preprocessing resulted in cartographic content that is only blue, objects resembling a well or represented by a symbol having the same geometry, but a different color were not detected as false-positive results.

Some of such examples are a symbol for a lighthouse ( ), leveling point ( ), church as a trigonometer ( ) and sinkholes ( ). However, even after the contents of the blue color were separated, certain symbols remained, which were noticed to appear more often than others as false results. These are symbols for a source of less bounty ( ) and fountain symbol ( ) which, in addition to being the same color as the symbol of the well, geometrically resemble it. The table also shows that the number of false results also varies from sheet to sheet, and that there are sheets on which they do not appear. Such results can be obtained for each sheet individually, but this would mean that before releasing each sheet for processing, the threshold value that would give the best result for a particular sheet should be redefined. However, as the goal here was primarily to speed up DTM25 production by processing many sheets in a short time, a unique value was taken for the recognition limit, which proved to be very good on some map sheets, and excellent on some.

In addition to symbols that are the same or similar to the well symbol, the results are corrupted by cases in which there is an overlap between a symbol and a well symbol. The number of such cases is not small, and those in which wells and isohypses overlap, wells and edges of a polygon, wells and road symbols, wells and fence symbols, etc. can be singled out as frequent. Many of these situations are resolved by color preprocessing. Also, there are other situations in which the well coincides with other hydrographic content, but their number is insignificant.

4.3. POSITIONAL ACCURACY OF GENERATED POINT VECTOR DATA

The ArcGIS software package is the most common software in the process of creating DTM25 on MGI, so the final result was generated as vector data in Shapefile format. The data loaded into the ArcMap software within the mentioned package over the initially georeferenced

Map sheet nomenclature	Map sheet name	Detected wells on the map sheet (%)	False-positive detections (%)	Undetected wells on the map sheet (%)
378-2-1	Sirig	86.02	5.88	13.98
378-2-2	Temerin	94.74	8.47	5.26
378-2-3	Novi Sad - sever	89.66	11.86	10.34
378-2-4	Kać	69.05	3.33	30.95
378-4-1	Novi Sad - jug	58.00	29.27	42.00
378-4-2	Sremski Karlovci	78.87	29.11	21.13
378-4-3	Ruma	97.22	39.66	2.78
378-4-4	Krušedol	76.19	30.43	23.81
379-1-1	Čurug	89.00	1.11	11.00
379-1-2	Taraš	88.51	15.38	11.49
379-1-3	Đurđevo	73.24	0.00	26.76
379-1-4	Mošorin	94.32	9.78	5.68
379-2-1	Elemir	95.65	8.33	4.35
379-2-2	Zrenjanin - sever	73.68	0.00	26.32
379-2-3	Deonica	93.06	10.67	6.94
379-2-4	Zrenjanin - jug	77.78	36.36	22.22
379-3-1	Kovilj	62.50	35.48	35.70
379-3-2	Krčedin	74.19	13.21	25.81
379-3-3	Inđija	83.05	3.92	16.95
379-3-4	Novi Karlovci	98.11	20.00	1.89
379-4-1	Titel	89.23	18.31	10.77
379-4-2	Perlez	89.13	8.89	10.87
379-4-3	Surduk	60.98	13.76	39.02
379-4-4	Opovo	87.50	33.33	12.50
		83. 91	**14.76**	**16.09**

Table 1 – Detection results.

topographic maps show that the positional accuracy of the obtained results is satisfactory. Table 2 shows a coordinates comparison of manually mapped wells with the wells obtained as a result from the same source.

5. CONCLUSION

The paper focuses on the detection of a certain element of cartographic content from a georeferenced raster, and we have introduced a practical approach to solving this problem. This paved the way for mass extraction of data from scanned maps in MGI as a great cultural-historical and information heritage. Progress has been made in understanding the problem of identifying and extracting objects from a map, both on one sheet and on a larger group of mapsheets. The results showed a kind of instability on the whole group of mapsheets, while the method, applied especially for an individual sheet, proved to be very good. The above, but also the experience gained from this project led to the following concluding theses:

- The application of deep learning algorithms would significantly contribute to the improvement of results on the entire sample of input data, primarily in order to determine the appropriate threshold values for each map sheet individually;

- Preprocessing of the input raster by passing colors of interest significantly contributes to a higher rate of object identification and reducing the occurrence of false-positive results from other thematic units of cartographic content, especially when it comes to symbols similar to the well symbol;
- The *Points from Corner* method proved to be relevant for determining the geographical coordinates of identified objects, which shows the high positional accuracy of the obtained vector data in relation to the georeferenced raster data, but also showed the potential for other different applications and
- Homogeneous cartographic content of input data shows eligibility for usage of automatic vectorization algorithms.

Guidelines for future work would be improving the tools according to the concluding theses, first in order to reduce the number of false-positive results, and then to reduce the number of unidentified objects. Optimizing program code for faster processing is something to look out for in the future. Directly generating geographic coordinates would be one of those steps, although the *Points from Corner* method has shown good results, it is complex. It is necessary to consider the possibility of applying other ways of computer vision to identify objects processed in [11]. Although the proposed method can speed up the vectorization, it is not fully automatic and requires user input, which is reflected in the manual sample selection which may have an impact on the proposed method application.

This would not be practical if we wanted to vectorize all types of point objects [12]. Future work could be focused on the complete automation of the project, as well as on solving the previously mentioned.

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Extracted data (°)		Manual vectorization (°)		Δ(°)		Δ(")	
Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude
19.78221	45.39781	19.78225	45.39782	0.000039	0.000015	0.140	0.054
19.78523	45.40073	19.78525	45.40072	0.000023	-0.000007	0.083	-0.025
19.79002	45.40238	19.79004	45.40239	0.000023	0.000006	0.083	0.022
19.79020	45.40121	19.79024	45.40122	0.000039	0.000010	0.140	0.036
19.79043	45.40013	19.79047	45.40013	0.000039	0.000001	0.140	0.004
19.79269	45.39822	19.79269	45.39824	0.000003	0.000021	0.011	0.076
19.79313	45.40349	19.79314	45.40349	0.000015	0.000001	0.054	0.004

Table 2 – Positional accuracy of extracted point objects (Figure 3 map extent – 7 objects).

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