Border reconstruction of the Sutorina exit of Bosnia and Herzegovina to the Adriatic Sea by using old maps

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Summary: *The paper presents the results of scientific research of the former Bosnian southernmost border by analyzing historical maps. On the maps (created from the mid-17th until the mid-20th century) of the mentioned area, state and administrative boundary lines are clearly presented. They provide indisputable proof of the centuries-long affiliation of the Sutorina area to the Bosnia and Herzegovina and its entrance to the Adriatic Sea. Showed maps followed the course of the historical changes in this area, which was shaping its boundaries. Propagation of a narrow Sutorina corridor was perceived on the basis of connectivity data on its boundary lines obtained by using historical maps, with the current state of this area. Based on the principles of artificial intelligence, the technique of georeferencing of the old maps was developed for this purpose.*

Keywords: *Historical maps, georeferencing, genetic algorithm, Sutorina, Bosnia and Herzegovina.*

1. Introduction

The general public knows little about the recent exit of Bosnia and Herzegovina to the Adriatic Sea close to Sutorina within the Boka kotorska. The question of return of this territory, which now belongs to the Republic of Montenegro, to Bosnia and Herzegovina, once again was opened during 2006. Since then began extensive talks on this matter, where in the public were often cited conflicting and confusing statements about the corridor, which connected the south of Herzegovina with the Adriatic Sea. Everything was often illustrated with inadequate "handy" maps, with misleading views of the boundary lines (Figure 1).

The aim is to determine the actual shape of a narrow passage that B&H was stretched to the coast of Boka kotorska. Conducted scientific research was based on the original historical cartographic materials.

In the part of various published works could be found reproductions and descriptions of old maps depicting Sutorina (Marković, 1993; Marković, 1999; Šehić i Tepić, 2002; Kozličić, 2010; etc.). Particularly valuable contribution to the study of borders in the area of the Boka kotorska and their views on historical maps was given by Obad S. et al. (1999) and Kozličić M. (2003).

This paper describes the evolution of maps showing the Sutorina and the borders of B&H in this area. Set of maps, of which some were little known, were chronologically exposed.

On detailed maps, created from the mid-19th until the mid-20th century, mapped boundaries of Sutorina corridor faithfully reflect the actual situation on the ground. On the basis of them, it is possible to reconstruct quite properly an image of the former demarcation of the southernmost part of Bosnia and Herzegovina.

Figure 1. Map of B&H exit to Boka kotorska, published in the daily newspaper "Oslobođenje"14th of July 2008.

2. Brief historical review of administrative affiliation of the Sutorina

For a better understanding of the cartographic representations that are described in the next chapter, here is a brief overview of the historical events that preceded the creation of these maps. Sutorina is the area along the homonymous small river that flows into Topaljski Bay on the west side of the entrance to the Boka kotorska (Figure 2). It is mentioned in ancient times as *Subtarre Subturrem* (Lučić, 2000).

Figure 2 Panoramic view of the entrance to the Boka kotorska and areas of Sutorina (Photo by Dušan Stevović, 2007).

In the Middle Ages belonged to the Parish Dračevica (Vego, 1957). In the 1377 Dračevica was merged with the medieval Bosnian state (Komar, 1997; Foretić, 1980). In 1382 Bosnian king Tvrtko I. Kotromanić established the city of Novi (Hrabak, 1978), today's Herceg-Novi, near Sutorina.

After the Bosnian nobles sold Parish Konavle to Dubrovnik, Sutorina becomes a frontier area toward the Republic of Dubrovnik. Identification and marking of boundaries on the ground continued until 1428, when disputes were resolved. Boundary line began at the coast (Cape Kobila) and leads to the northwest ridge mountains that divide the spaces Vitaljina and Sutorina (Lučić, Obad, 1994). In 1482 fortress Novi came under Ottoman rule, which ended their conquest of today's Bosnia and Herzegovina territory. Dračevica is organized as nahiya in Herzegovina's sanjak, which becomes part of the Bosnian ayalet in 1580 (Šabanović, 1982).

Taking the Novi and Sutorina in 1687, the Venetian Republic completes its possessions in the Boka kotorska (Komar, 1997). Venetian-Ottoman War ended after the Karlovac peace treaty in 1699. During the negotiations, which preceded the signing of the peace agreement, it was defined that the Dubrovnik Republic remains separate from the Venetian possessions in Dalmatia and the Boka kotorska by the Ottoman territory (Foretić, 1980). Based on this stipulation, the 1700 demarcation began in Dračevica area (Komar, 1997). Border Commission determined and marked the narrow belt of land in the field (the corridor, the enclave), i.e. boundary line, with the boundary stones and cairns, which the Venetians returned to the Bosnian ayalet. In the northern part, corridor included the mountainous area of Kruševice, and in the south included the Sutorina field, and it exited to the entrance area near Boka kotorska (near the delta of Sutorina). Boundary line began at the coast of today's Igalo, from where it followed relief elevations above the valley of Sutorina and then passed through the area of mountain villages of Dračevica (Marković, 1998; Komar, 1997). Demarcation conducted after the peace treaty signed in Požarevac (1718), does not correct the boundary line in any way (Komar, 1997). Moreover, the borders of the Republic of Dubrovnik were not determined by Treaty of Karlovac and Požarevac (Šljivo, 2001). That boundary line was determined only to the rest of the Boka kotorska that was under Venetian rule.

As part of the Dračevica nahiya, Sutorina becomes a part of Trebinje kadiluk area in 1835. After the establishment of the Bosnian vilayet in 1865, Sutorina and Kruševica received the status of nahiyas within the Kadiluk of Trebinje (Aličić, 1983).

During the Austro-Hungarian occupation and subsequent annexation of Bosnia and Herzegovina (1878 - 1918), Sutorina area was not separated from that province (Šljivo, 2001); it was in the Trebinje county.

Even after the creation of the Mostar district within the Kingdom of Serbs, Croats and Slovenes in 1921, Sutorina belonged to the Trebinje county (Šehić i Tepić, 2002). After the partition of the Kingdom of Yugoslavia to banates in 1929 (Šehić and Tepic, 2002), the Municipality Primorska was formed and it included Sutorina and Kruševice (Aranđelović, 1935). This municipality was located in the Trebinje county, within the Zeta banate (Aranđelović, 1935). Municipality Primorska was separated from the Trebinje county in 1936 and it was annexed to the Boka kotorska county. This was done by the Regulation of the Minister of Internal Affairs, on the basis of the Finance Law for 1936/1937 ("Official Gazette of the Kingdom of Yugoslavia", No. 222/1936).

At the session of the Presidency of the AVNOJ (24th of February 1945), internal demarcation of the new Yugoslavia is mentioned. The attitude of the Secretary of the Presidency was that the criterion for the borders of Bosnia and Herzegovina is determined by the Berlin congress from 1878 (Banac, 1988). Therefore, Sutorina was supposed to stay in Bosnia and Herzegovina, but still it went to Montenegro (Banac, 1988), probably thanks to the agreement of the high communist party executives (Šehić and Tepić, 2002). Indirect recognition of such established borders was made by the Decree on determining the areas of people's committees and the establishment of the seats of the local People's Committees, issued by the Presidency of the

National Assembly of Bosnia and Herzegovina ("Official Gazette of Federation B&H", number 13, from 29th of August 1945). On the basis of that Regulation, the area of Trebinje county does not include places Sutorina and Kruševica. The first official data of the Sutorina within Montenegro borders are from 1947 (Šljivo, 2001).
Demarcation of Bosnia and Herzegovina and Montenegro after the Second World War still has not been historically completely investigated. Anyway, within second Yugoslavia, Bosnia and Herzegovina has lost its second exit on the Adriatic, what is confirmed through the history with a set of many maps (Kozličić, 2010).

3. Borders in Sutorina on historical cartographic materials

A large number of maps, created from the late 16th until the mid-20th of century, are valuable historical evidences of the B&H space on the coastline, in the period of Ottoman, Austro-Hungarian and Yugoslav domination over the mentioned area. Some of the many (with borders in the area of the northwestern part of Boka kotorska) will be mentioned. Something more will be discussed about the maps that once represented great progress in the cartographic representation of the area of Boka kotorska.
The demarcation in the Boka kotorska during the medieval Bosnian state has no testimonial maps. Figure 3 gives the reconstruction of the former Bosnian parishes borders in that area.

Figure 3 Southern parishes of medieval Bosnia on the map created by Marko Vego, 1957. (Historical Map of medieval Bosnian state, National and University Library of Bosnia and Herzegovina in Sarajevo – NUBBiH, Map Collection, sign. S-kg-318).

The first detailed maps showing the Boka kotorska appeared during the 16th century. The most significant views from that period came from the workshop of Venetian cartographer Giovanni Francesco Camoci in isolar of the Adriatic-Ionian-Aegean coast, printed in 1572 (Radivović, 1991; Marković, 1993). In the maps showing the Boka kotorska (*URL 1*) differently are marked settlements under Christian and Ottoman rule and the boundary lines are not entered. Herceg-Novi (*Castel Novo*) is presented by a crescent moon, which means that it was the Ottoman settlement.

3.1 Ottoman rule - a period of domination of Western cartographers

Boundary lines of the Boka kotoroska on the geographical maps first appeared in the 17th Century (Kozličić, 2003).

Figure 4. Boka kotorska on the map created by Ivan Lučić, 1669 (Illyricvm Hodiernum, quod Scriptores communiter Sclavonia ..., URL 2, National and University Library in Zagreb - NSK, Map Collection, Sign. S-SW-XVII-46).

Frenchman Pierre Du Val on the map of the Christian-Turkish borders in Europe from 1663 (Kozličić, 2003) and Italian Andrea P. Buffalini on the map of Illyricum from the same year (Marković, 1993), were showing the boundaries of the state entities. Ottoman territory in the Boka on the map of Du Val was presented as the part of Turkish Dalmatia (*DALMATIE AV TVRC*) and extends from Molunat in the west to the Risan on the east. Ivan Lučić (Trogiranin) on the map of modern Illyricum (Marković, 1993; Kozličić, 2003), created on the basis of Buffalini map, correctly placed the western boundary at the entrance of Boka kotorska. In the east of Boka kotorska, Herzegovinian sanjak (*Sanzacatus Herzegowina*) extends to the area between Risan and Perast (Figure 4).
Borders in the Boka kotorska are visible on the map created by the French cartographer Nicolas Sanson. Map was called *Hongrie, Transilvania, Esclavonie, Croacie, Bosnie, Dalmacie* and it was published in 1665 (NSK, Map Collection, sign. S-SW-XVII-15). Figure 5. shows a map segment created by his son Guillaume Sanson (*Il Regno d'Ungaria, Transilvania, Schiavonia, Bosnia, Croatia*, 1683, NSK, Map Collection, sign. S-SW-XVII-17).

Figure 5. Demarcation in the Boka kotorska on the map created by Guillaume Sanson in 1683 (URL 2).

3.2 Ottoman rule - the period dominated by the Venetian cartographers

More accurate representations of borders in the Boka kotorska, are on the maps created by the Venetian cartographers, who began to show greater interest in Dalmatia in the late 17th of century.

Giamoco da Vignola Cantelli is the author of the map of Dalmatia, Istria, Bosnia ... published in 1684 (Marković, 1993). It shows the borders of the Republic of Dubrovnik and the Albania Veneta, while the Herceg Novi (*Castel Nouo*) is shown as the Ottoman fortress.

Vincenzo Maria Coronelli makes a detailed topographic map of the Boka kotorska in 1685 (Radivović, 1991; Marković, 1998). This is the first map that brings toponym Sutorina. It shows the lower river Sutorina next to the highlighted name *Suturina T*. (Figure 6). On its right bank are presented Ottoman salt-pans (*Saline de Turchi*), and Žvinje (*Xuigne V*.) is mapped in the east. The borderline between the Republic of Dubrovnik and the Ottoman's Herzegovina starts on the coast near Cape Kobila (*Chobilia P*.) and runs westward over the mountains that divide Sutorina and Vitaljina (Marković, 1998). The map presented the Venetian-Ottoman borders at the entrance of the inner Boka kotorska. On the issue of this map from the 1688 (Radivović, 1991), beside the town of Herceg-Novi (*Castel Nuouo*) stands the note on its conquest by the Venetian army in 1687. In 1691 Coronelli's map of basin Bojana - Drin (Kozličić, 2003) provided a demarcation of the area of Boka kotorska, after it entirely fell under the Venetian rule.

Figure 6. First map of Sutorina on the Coronelli map from 1685 (Biblioteca Nazionale Marciana, 387.D2, Coronelli, V., Memorie istoriografiche delli regni della Morea e ... Negroponte, Tav. Ddd, fra ff. 72-73: Disegno topografico del canale di Cattaro). This map is not permitted to copy.

Military cartographer Giustino Emilio Alberghetti compiled the map of the Boka kotorska area, which was very rich in content (year: 1700). It was based on the work of the Venetian-Ottoman border commission, which determined the borders on the ground agreed on peace talks in Srijemski Karlovci, (Marković, 1998). Thanks to the large scale (1:35 000), map very clearly show the borders at the area of Boka. Boundary stones, that Venetian-Ottoman border was demarcated in the field, in the map are recorded by serial numbers, where beside the top of each border peak is its name (Marković, 1998). This is the first map that provides a plenty of topographic data for a narrow area of Herzegovina, who divided the territory of the Republic of Dubrovnik from the Venetian possessions in the Boka kotorska. There are numerous villages mapped (*Svigne, Spruglie, Chienizza, Sdoci, Prievor*, etc.), with given position, size and the direction of extension. Relief has perspective-landscape elements (Marković, 1998). Winding line represented a whole river Sutorina (*Suttorin*a), and there have been six of its smaller tributaries. The coastline is quite properly mapped and at the location of the village Njivice is shown a sign for a dock. This is the best cartographic representation of Sutorina by that time. Details in content, clarity, visibility and accuracy, are not exceeded for a very long time. It is very interesting that the map gives a picture of a complexity of the Venetian-Ottoman demarcation in the Boka kotorska before the 1684, and the one of the possible variants of the border, which is offered during the negotiations in 1699 (Obad et al, 1999). On the map at the scale of 1:280 000, which is created by Alberghetti (year: 1701) (Gašparović, 1970), the old borders from 1671 and a new ones from 1701 are marked. The same author creates a new map at the scale of 1:350 000 in 1718 (Marković, 1998), which shows the borders under the regulations of Karlovac peace agreement and an alternative boundary line of Požarevac peace agreement proposed by the Venetians. Border lines drawn on these maps are quite idealized, i.e. with the flat strokes, without

taking into account the facts on the field (Marković, 1993).
Engineer Melchior created a map in 1729 at the scale of 1:350 000, which clearly presented exits of the Ottoman Herzegovina on the coast and marked the Herzegovinian land which the Venetians had to leave after Požarevac peace agreement (Marković, 1998).

Figure 7. Sutorina corridor on the map created by Faustino Brascuglie in 1745 (Biblioteca Nazionale Marciana, It.VI, 195 (= 10 054), Brascuglia, F. Descrizione corografica, topografica & iconografica della provinzia e stati confinanti di Dalmazia, c. 59v: Descrizione del sito, stato, e forza presente del territorio di Cattaro). This map is not permitted to copy.

During this period, smaller scale maps appeared, showing the Bosnian eyalet and its exit at the coast. An example is a Melchiori map from 1738 (Šehić and Tepić, 2002), which provides a late, unsuccessful and stagnant cartographic vision of the Bosnian eyalet (*Passalagio Bosna*).
On Venetian topographic maps of Boka kotorska, created by the late 18th century, there is not a noticeable progress in view of the borders, in spite of cadastral survey from 1704 (Komar, 1997). Examples include maps from 1745 (Figure 7), 1753 (Marković, 1993; Marković, 1998), 1785 (Marković, 1998; Radivović, 1991; Kozličić, 2003) and 1787 (Obad et al, 1999; Kozličić, 2010), where the borders are practically identical to what has been mapped by Alberghetti in 1700.

3.3 Ottoman rule - a period of domination of Austrian cartographers

During the late 18th century the Austrian authors had a leading role in mapping the areas of southern Herzegovina and Dalmatia. At that time maps of the area of Sutorina are worse than the earlier maps by the Venetian cartographers. Examples are the map of Herzegovina created by B. Vukasović in 1788 (Figure 8), a map of Dalmatia created around 1800 (Radivović, 1991) and a map of Dalmatia and Dubrovnik created by Max de Traux in 1810 (Lučić, 2005). Better presentations of that area are given in the work of French cartographers, appeared during the short French rule in Dalmatia. Examples are the Segment 5E of the Napoleon map of Dalmatia from 1807 (Novak, 2005) and a IV. map sheet of Illyrian provinces created by Gaetano Palma in 1812 (Gašparović, 1970; Obad et al, 1999).

Figure 8. Southern border of Herzegovina on the map cretaed by B. Vukasović, in 1788 (Plan von einem Theil der Grafschatf Herzegovina sonsten Ducatus, taken from: Šehić and Tepić, 2002).

In the first half of the 19th century a set of small scale maps of European Turkey was created, which gives a picture of Bosnian eyalet with exits to the coast (Šehić and Tepić, 2002; Gašparević, 1970). First Austrian detailed map presentation of Sutorina corridor is provided in the maps of sanitary cordons created by Taborović in 1821 (Obad et al, 1999). Corridor boundaries are clearly marked, indicating a large number of the border toponyms. Within Sutorina corridor, presented is the area from the coast to the entrance of Sutorina field. Settlements (*Chenics, Spulie, Xwinije*, etc.) positions are well mapped, and a numerous roads that connect them contribute to the orientation. The emphasis is on the so-called Dalmatian postal road, whose portion over the Sutorina is built by French in the period of 1811-1812. Along the river Sutorina are shown (with their names) a number of small tributaries and presented is the Ottoman fortress above the Cape Kobila, etc. Relief is shown by hatched contour bands, which clearly separated some hills and mountains in the border areas.
The first map that brings the depth of the sea with anchors along the coast of Sutorina corridor was a special map made in the period 1822-1824 (Obad et al, 1999; Kozličić, 2010).
Austrian Colonel Count Berhnard Kaboga was in Sutorina in 1832, in order to collect data necessary to assess the value of the enclave (Šljivo, 2001). During his mission Kaboga made a drawing - sketch at scale of 1:4 000 (Šehić and Tepić, 2002), where he marked the Austrian-Ottoman border (Figure 9). Within the Ottoman territory all important places are entered (*Cenich, Spuglie, Svigne, Gnivizze, Prievor, Sceposchevich, Sdozi*) and given are many other

toponyms. The novelties are the signs for the bridges, where a postal road was crossing over the river Sutorina. Relief was partially presented, with hatching.

Figure 9. Detailed view of Sutorina in the work of Berhnard Kaboga, from 1832 (Croquis der türkischen Landzunge Sutorina, taken from: Šehić and Tepić, 2002).

During the Austrian Geodetic Survey in Konavli and Boka kotorska in 1837 (Obad, 1993; Obad et al, 1999), surveying of the borders towards the Bosnian eyalet have been made. The maps based on the results of this survey, the shape and position of the boundary lines accurately reflects the actual situation on the ground. It is visible on the map of Montenegro, made by the Austrian Colonel Fedor Karachay in 1838 (*Carte du pays de Montenegro*, NUBBiH, Map Collection, sign. S-kg-1) and the tax municipality map of Dalmatia, by A. Floder from 1840 (Obad et al, 1999). Borders are accurately given on the map of the Austrian empire countries from1856 in scale 1:576 000, whose author is Major General, geographer and cartographer Joseph Ritter Scheda (Gašparović, 1970). Map sheet XVIII (Figure 10), shows well generalized topographic features with clear highlight of the whole space of Sutorina corridor, from Zubci to the coast. Relief of the whole area is given (derived by contour bands), and the news are registered altitudes of Orjen and Bjelotina mountain tops.
Austrian Orientalist Otto Blau (since 1870 he was a Consul General) announces the map of Herzegovina in 1861, which is one of the first separate maps of that province (Gašparović, 1970; Šehić and Tepić, 2002). On that map are the limits of Herzegovina clearly highlighted and included Sutorina. Successful mapping of that area gives the map of Bosnia, Herzegovina and Novi Pazar, provided by the Austrian Major Johann Rośkiewicz in 1865 in his work "Studien über Bosnien und Herzegovina" (Šehić and Tepić, 2002).

Figure 10. Corridor Sutorina on the map of Joseph Scheda, from 1856 (Karte Des Oesterreichischen Kaiserstaates, Sheet XVIII, URL 3, Image No: 0879023).

Special topographical maps of Dalmatia at the scale of 1:144 000 from 1869, at the map sheets XIX and XX are extremely accurate and bring in details the vastness of the Boka kotorska area with its borders (Kozličić, 2003).
In the second half of the 19th century, many cartographers produced small scale maps, which include Bosanski eyalet and its exits to the sea. The best of them is the map of Bosnia, Herzegovina, Serbia and Montenegro, the work of Captain (Hauptmann kk) J. Schlacher from 1876. (Šehić and Tepić, 2002). General map of Bosnia, Herzegovina, Serbia and Montenegro in scale 1:300 000, issued by the Military Geographic Institute in Vienna in 1876. (Šehić and Tepić, 2002), at the map sheet *K12 Ragusa* shows Sutorina and its borders, with minor improvements compared to Scheda map. This map has played an important role at the Berlin congress in 1878, when the precise demarcation has been done (Šehić and Tepić, 2002).

3.4 Administration of the Austro-Hungarian monarchy – maps of the Military Geographical Institute in Vienna

Complete picture of the far south Herzegovina was formed in the late 19th century on the special, general and other maps of the Military Geographical Institute in Vienna (Wien: kuk Militärgeographischen Institute). These maps are based on the results of the cadastral survey of Bosnia and Herzegovina conducted in the period 1880-1884.
The first accurate, detailed and comprehensive review of the Sutorina corridor brings General map of Bosnia and Herzegovina at the scale of 1:150 000, from 1884 (Šehić and Tepić, 2002, Gašparović, 1970) (Figure 11). Borders of Bosnia and Herzegovina are given with the bold red line. Within those are presented the boundaries of the municipalities of Sutorina and Kruševice. Map shows

the plenty of high-quality topographic details of the area. Given are the 13 villages that were marked with circles, relief is given with hatching, forest with green color, rivers, streams and coast of sea with blue color, while the communications are classified into the roads and paths. Specific signs presented five churches, huts, trigonometric points, etc. Together with trigonometric points were recorded their heights above the sea level. Names of places, mountains, etc. were properly written in our native pronunciation and with the letters of our alphabet. The presentation of the coast failed to a certain extent, which is especially obvious near village Njivice and Cape Kobila.

Figure 11. South end of Bosnia and Herzegovina on a topographic map from 1884 (XIX - Trebinje, Generalkarte von Bosnien und der Hercegovina, 1:150 000, Archives of the Republic Administration for Geodetic and Property Affairs of B&H in Sarajevo).

Very accurate presentation of forest complexes, major and minor roads, and other cadastral features of the Sutorina area is given on the forest map of Bosnia and Herzegovina from 1885 (Gašparović, 1970). Thanks to its large scale, all details of the boundary lines towards Dalmatia are clearly shown (Figure 12).

Sheets of the General map of Central Europe (*Cattaro 36-42, General Karte von Central-Europa,* 1:200 000, 1894 and *Ragusa 36-43, General karte von Central-Europa*, 1:200 000, 1895, Archives of the Republic Administration for Geodetic and Property Affairs of B&H in Sarajevo), provide plenty of accurate topographical features of Sutorina, with its convenient and clear expression. Although smaller in scale compared to the General map of Bosnia and Herzegovina, this map gives more topographic details. The settlements are differentiated to individual buildings and sets of buildings, shown are all the churches, forts, mills, roads, horse and hiking trails, etc. Selected color tones of relief contributed to the good visibility of the map. In addition to trigonometric points, elevations are given for significant elevation points. On the revised editions of these map sheets from 1901 and 1902, the narrow-gauge railroad Gabela – Zelenika is visible. It was passing within Bosnia and Herzegovina through the valley of Sutorina, at a distance of around 7.5 km.

Exceptionally high-quality presentation of Sutorina Corridor is given in the Special map of the Austro-Hungarian Monarchy (*XIX.36 Cattaro* and *XIX.35 Trebinje und Risano, Specialkarte der Österreichisch-Ungarischen Monarchie*, 1:75 000, 1912, Archives of the Republic Administration for Geodetic and Property Affairs of B&H in Sarajevo), resulted from the reambulation of same maps from the penultimate decade of the 19th century. Used topographical signs, registered names and mapped general situation are made very well and they are slightly different from modern maps that are showing the same area. For the first time terrain heights are presented with contour lines in conjunction with the hatching. Borders of Bosnia and Herzegovina are clearly visible (the boundary lines of Boka kotorska are described in details in Kozličić, 2003).

Figure 12. Exit of Sutorina corridor to the seacoast at the forest map of Bosnia and Herzegovina, 1885. (Forstkarte von Bosnien und der Hercegovina, the map does not contain a label sheet, 1:50.000; Archives of the Republic Administration for Geodetic and Property Affairs of B&H in Sarajevo).

During the administration of the Austro-Hungarian monarchy a large number of small scale maps of Bosnia and Herzegovina were created. They properly reflected borders of Bosnia and Herzegovina (Šehić and Tepić, 2002). Their authors, beside Austrians, were also cartographers from other countries.

3.5 Administration of the old Yugoslavia

After joining the Kingdom of SHS, a leading role in mapping of Bosnia and Herzegovina territory was under the Military geographical institute in Belgrade. Maps in scale 1:100000 were issued. They were based on the renewal of the Austro-Hungarian maps in scale 1:75 000. The content of the map sheets (*129 Kotor* and *120 Trebinje*, Military Geographic Institute of the Kingdom of Yugoslavia, 1:100 000, 1930) were almost identical to the Austro-Hungarian originals excluding minor details. The biggest differences between these maps are in their coloring, the way of shown relief, and the language in which the toponyms were written. Trebinje district boundaries are very visible and within them, in the far south, is Sutorina. More detailed picture of that area provides a topographic map in scale 1:50 000 (*120/3 Trebinje-3* and *129/1 Kotor-1 (Ercegnovi)*, Military Geographic Institute Belgrade, 1:50 000, 1937). During the 1943 these maps were, based on seized archival originals (under the same labels), reproduced and published by cartographic section of the Headquarters of German Army (Heraugegeben vom OKH / GenStd H; Chef des Kriegskarten-und Vermessungswesens).

Figure 13. The southern part of the Mostar area in the Kingdom of SHS, on the map created by Madžarević P. from 1924. (Map of the Kingdom of Serbs, Croats and Slovenes, NUBBiH, Map Collection, sign. S-kg-54)

During this period there were also other maps that show corridor of Sutorina, as the part of: Bosnia and Herzegovina, area of Mostar and district of Trebinje. Examples are the maps created by Vladimir Marinković in 1920 (Šehić and Tepić, 2002), Peter Madžarević (Figure 13) and Tihomir Aranđelović (*Map of the Kingdom of Yugoslavia - an administrative classification*, NUBBiH, Map Collection, 1930).

3.6 Administration of the new Yugoslavia

Sutorina is presented within the People's Republic of Bosnia and Herzegovina, at different cartographic presentations created after 1945. The first post-war map of Bosnia and Herzegovina appears in 1946 and it is published by the National publishing company Svjetlost Sarajevo (*Map of the People's Republic of Bosnia and Herzegovina - Scale 1:300 000*, Bosniak Institute Sarajevo, Maps B&H E, ID: 89093022). Sutorina is clearly shown as the part of the B&H territory (Figure 14). In this area map is a deficient with topographic data, which could be displayed with respect to its scale. The exit of Bosnia and Herzegovina to the sea in Boka kotorska is evident at the map of People's Republic of Croatia from 1947 (Obad et al, 1999). On a topographic map of the U.S. Army Map Service (*NK 34-4 Titograd*, *Series M501 - Western Europe*, U.S. Army Map Service, The University of Texas at Austin, University Libraries, 1:250 000, 1954) borders of the Yugoslav republics were mapped. Sutorina's area located in the People's Republic of Bosnia and Herzegovina, its border with the People's Republic of Croatia is given approximately (as indicated on the map), while the border with the People's Republic of Montenegro is presented quite correctly (Figure 15).

Figure 14. Sutorina on the first B&H map created after the II. World War, 1946.

Geographical Institute of the Yugoslav Army during the fifties and sixties of the 20th century printed topographic maps based on pre-war editions of originals returned from Germany. Boundary lines of district Trebinje in the area of Kruševice, can be seen on the map sheets at the scale of 1:100 000 (*Trebinje*, 1958) and 1:50 000 (*Trebinje-3*, 1955). In the neighboring southern map sheets, which show Sutorina (*Kotor*, 1:100 000, 1950) and (*Kotor-1*, 1:50.000, 1958) the boundary lines are omitted.

Figure 15. Exit of the People's Republic of Bosnia and Herzegovina in the Boka kotorska on the topographic map of the U.S. Army, 1954.

The first cartographic evidence of Sutorina as an integral part of Montenegro, as a new reality after the Second World War, is the work of P. Mardešić, J. Zoričić and J. Uhlik from 1948 (*People's Republic of Montenegro*, NUBBiH, Map collection, sign. S-kg-5).

4. Transformation of the source maps

From the previous considerations it can be concluded that, as we approach the present time, cartographic presentations were more numerous and more realistic, as expected. Maps created before the mid-19th century were not based on reliable geodetic data, and for this reason they usually give inaccurate and distorted picture of Sutorina corridor. It can be confidently claimed that the earliest fairly accurate information about the borders of Ottoman Bosnia-Herzegovina exit to the sea, provide maps that appeared after a geodetic survey of the adjacent Austrian areas in 1837. The first accurate and full cartographic presentations of Sutorina area, obtained by geodetic surveying, were created after 1884. They have clearly entered the right border of Bosnia and Herzegovina under the decisions of the Berlin Congress. Maps at the scale of 1:75.000 are probably the most credible historical documents for research of Boka kotorska borders (Kozličić, 2003). They were partially complemented during the 1930-ies, resulting in new topographic maps at the scale of 1:50.000, which provide more detailed picture of demarcation in this area.
Scanned segments of maps at the scales of 1:200.000, 1:150.000, 1:75.000 and 1:50.000 were used in this article, in order to obtain data on the former border lines.

4.1 Principles and problems of georeferencing the old maps

In order to connect the data from the old maps with today's situation, maps should be positioned in the Bosnia and Herzegovina State Geodetic Coordinate System (SCS), which is accomplished by georeferencing. The aim of georeferencing is to establish connection between the coordinate system of digital images and the reference coordinate system, with removal of image distortion by geometric transformation. Georeferencing is based on the control points with known coordinates in both systems. Points of the map coordinate grid are most commonly used for this purpose (Tuno, 2007).
Austro-Hungarian topographic maps have known geographic coordinates (datum and projection) of a certain number of points, which are located on the map neatline. Within this neatline, there is no grid (map at the scale of 1:75.000) or grid is presented by small number of points (e.g. only three points for the map at the scale of 1:200.000). If the transformation is performed using only the coordinate grid, control points would not correctly covered area that needs to be transformed.
For this reason it is not possible to remove the raster image distortion due to deformation of paper on which the original map was printed, scanning errors, etc.
To get a better quality of results, it is necessary to perform the transformation on the basis of content that can be identified on old maps and which has known SCS coordinates.
Trigonometric and elevation points, shown on old maps, can be efficiently used for this purpose. The positions of trigonometric points, which are representing SCS, often correspond to places where points of old Austrian triangulation were located.
Classic visually finding the right pair of points is difficult and time-consuming process. Problems arise because modern triangulation contains larger number of points, and it happens that today's points are not placed at the same places in relation to the old triangulation.
The maps at the scale of 1:50.000, from the period of the Kingdom of Yugoslavia, have a grid with the crowns known in the Gauss-Krüger projection. Comparing these maps with modern topographic maps, at the scale of 1:25.000, there are visible discrepancies of the grid and detail.
Grid of the map at the scale of 1:50.000 has been shifted on average by about 220 m to the southwest, according to real position. Since the deviations have not the same size and direction everywhere, georeferencing has been done on the basis of details that exist on the map 1:25.000. Identification of control points was has been done visually, and the quality of the final results of georeferencing is consistent with the quality of the original maps.

4.2 Determination of transformation parameters using genetic algorithm

In order to solve the problems described in the chapter 4.1., it is necessary to extract the trigonometric points from the old maps. Map segments are represented by corresponding sets of points. Total 18 points on the map at the scale of 1:150.000, 48 points on the maps scale 1:200.000 and 50 points on the maps scale 1:75.000 were identified at the observed area. These sets of points (Ai) were then compared with the reference set (B), which was constituted of database with coordinates of 172 present trigonometric points, distributed in this area. Depending on transformation model, it is necessary to determine certain number of transformation parameters, which means that the appropriate number of corresponding points in both sets has to be found. Since these sets contain a relatively large number of points, the number of possible associations are large, what is manifested in the size of the search space.
Application of genetic algorithm in the search space efficiently finds the optimal solution to this problem (Figure 16). Genetic algorithms (GA) are optimization techniques and search techniques, based on the principles of genetics and natural selection. A GA allows a population composed of many individuals to evolve under specified selection rules to a state that minimizes the cost function (Haupt and Haupt, 2004).

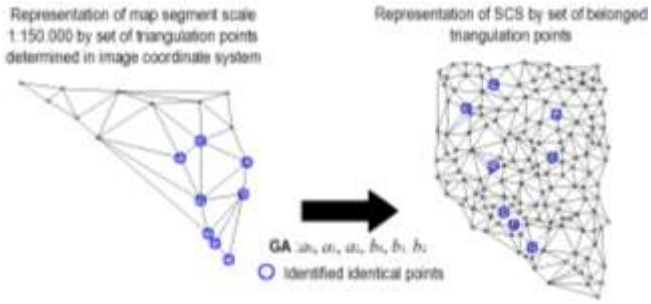

Figure 16. Principle of determination of transformation parameters using GA.

In order to georeference map segment, transformation parameters between the map segment coordinate system and SCS should be determined. According to scale, characteristics and condition of the Austro-Hungarian maps, it is sufficient to determine the 6 parameters of first order polynomial transformation (affine transformation). Polynomial transformations in general are given by following expressions:

$$x = \sum_{p=0}^{n}\sum_{q=0}^{n-p} a_{pq} u^p v^q$$
$$y = \sum_{p=0}^{n}\sum_{q=0}^{n-p} b_{pq} u^p v^q.$$

where u and v are coordinates in the image coordinate system, x and y coordinates in the system where the image should be transformed, n is the polynomial order and a_{pq} and b_{pq} are transformation parameters to be determined (Tuno, 2007).

4.3 Representation of chromosomes

Transformation parameters to be optimized are defined in the form of chromosome, composed of 6 variables:

$$chromosome = [a_0, a_1, a_2, b_0, b_1, b_2].$$

Binary string was used for the chromosome representation, where it is necessary to determine the domain of each variable. Taking into account this domains and the required accuracy of transformation parameters (Haupt and Haupt, 2004), it was determined that each variable should be represented by 16 bits. In this way, the optimization solutions are the chromosomes (96-bit strings), and each gene (16-bit string) represents a single transformation parameter.

4.4 Fitness function

In order to georeference set A to set B, it is necessary to define some similarity measure of these sets. Considering the partial bidirectional Hausdorff distance between two point sets, we can conclude that if the distance is smaller, the degree of sets matching is higher (Huttenlocher et al, 1993). For this reason, partial bidirectional Hausdorff distance is defined as fitness (cost) function:

$$Fitnes = H_{LK}(A,B) = \max\left(h_L(A,B), h_K(B,A)\right).$$

4.5 Genetic operators

The simplest form of genetic algorithm involves three types of genetic operators: selection, mating (single-point crossover) and mutation (Avdagić, 1999).
Selection operator selects chromosomes in the population for reproduction. If chromosome is more capable, it is more likely to be chosen for reproduction.
Crossover operator randomly chooses one location and makes changes of subsequences in front of and behind that location between the chromosomes, in order to create new offspring.
Mutation operator randomly changes a certain percentage of bits in the chromosome list, in order to prevent GA to converge too quickly, before an entire search space is examined (Avdagić, 1999, Haupt and Haupt, 2004).

4.6 Implementation of genetic algorithm

For two sets of points A and B, it is necessary to determine the population size N, the number of

individuals for the elimination X, probability of crossover p_c, probability of mutation p_m, fractions f_L and f_K of partial bidirectional Hausdorff distance and the stopping criteria for GA (the maximum number of generations G_{max}). Simple genetic algorithm works as follows (Avdagić, 1999):

Step 1: Create initial population of N chromosomes, consisting of randomly generated ones and zeros and decoding into real values. Based on the decoded parameters, the transformation of coordinates from the image coordinate system to the reference system is performed.

Step 2: Calculating the fitness of each chromosome and ranking chromosomes according to obtained fitness values. Creating a new population by repeating the next steps:

a) Elimination selection of N-X chromosomes with the best fitness values, to continue the process.

b) Replacement of discarded chromosomes by the new chromosomes, resulting from uniform crossover of survived chromosomes, with the probability p_c.

c) Applying of simple mutation with the probability p_m, with the condition of elitism.

Step 3: After selection, crossover and mutation, a new population was obtained in the previous step, which is re-evaluated.

Step 4: The process is cyclically repeated until the algorithm stopping criteria is not fulfilled. The optimal transformation parameters are determined by the best chromosome, resulted from the points of sets A and B, with the best match. If G_{max} is not reached, go to *Step 2*.

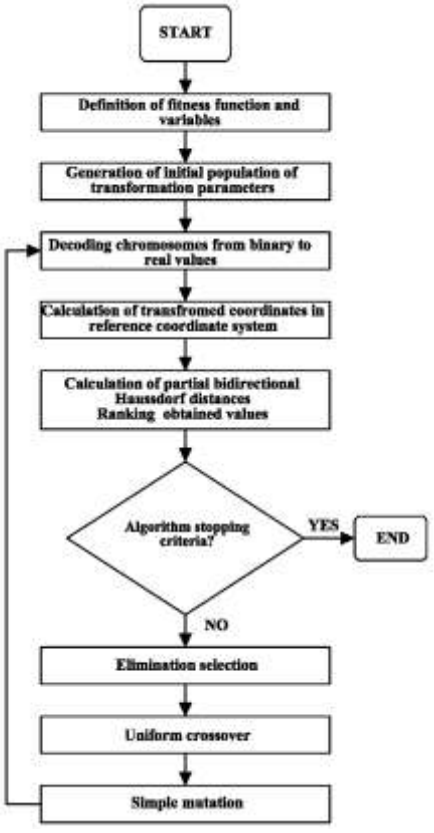

Figure 17. Flowchart of proposed GA.

4.7 Experimental results

After performing a larger number of experiments, the parameters of GA were determined, which are shown in Table 1.

For the realization of this genetic algorithm, own software solution developed in Visual Basic, was used. During the implementation of GA, for each of the old maps, a certain number of identical points were identified (Table 2) and optimal transformation parameters were determined based on them. From Table 2 it is evident that the standard deviations of transformations are below 0.3 mm x M, which is consistent with the quality of the original maps and results of earlier researches (Molnar et al, 2008).

After determining the parameters of transformation, it is possible to rectify map segments and position them in the SCS, using the appropriate GIS application.

Table 1: Parameters of GA

Parameter	Designation	Value
Population size	n_{pop}	100
Probability of mutation	p_m	0.02
Probability of crossover	p_c	0.5
Number of individuals for elimination	X	n_{pop} /2
Number of iterations	G_{max}	500

5. Analysis of the results of georeferencing the original cartographic presentations

In order to control the quality of georeferencing, a comparison of the position of the churches, which were read on transformed map with their positions on modern topographic maps at the scale of 1:25.000, was performed. For example, on the map sheet XIX.36 at the scale of 1:75.000, 20 churches, which are located within the corridor and in the border area, were compared. Based on this, obtained standard positional deviation is 33 m. For the map sheet 36-42 at the scale of 1:200.000 in a similar way is obtained standard deviation of 73 m, based on 14 analyzed churches. After georeferencing the original maps, manual vectorization of boundary lines was performed.

Due to relatively low-resolution of rasters and density of detail, it was not possible to apply semi-automatic or automatic vectorization. Comparing the lines obtained from maps of different scales, it was found that the maximum deviation in some places is up to 220 m. More than 3/4 of boundary lines are located on the mutual distance of less than 100 m (Figure 18).

The most parts of Sutorina corridor had clear natural boundaries that have constituted the hilltops, and mountain ridges, straits, watershed, etc. (Lučić and

Obad 1994, Komar, 1997). Comparing the reconstructed borderline from the map at the scale of 1:50.000 with presentation of terrain in contemporary maps at the scale of 1:25.000, it is evident that the boundary line properly follows these forms of relief.

On the basis of modern topographic map sheets at the scale of 1:25.000 issued by Military Geographical Institute, Belgrade (159-1-1 Herceg Novi, 1979; 147-3-3 Orjen, 1979; Sutorina 158-2-2, 1980 and Dubravka 146-4-4, 1975), a map of the present state of the former Sutorina corridor was created (Figure 19). Data on the western and eastern borders of the corridor were obtained using a georeferenced map at the scale of 1:50.000. Northern border is taken from the map at the scale of 1:150.000. Area of the corridor was approximately 85 km2. Corridor was approximately 10 km wide in its initial northern part (area Vrbanj). Corridor width was gradually decreased, going toward the south.

Corridor was the narrowest in the area of Sutorina field, where its width was only 1.5 km. The southernmost point of Bosnia and Herzegovina was located on the coast in the location of Cape Kobila. Today it is located 15 km northern. In order to obtain data on the former coast, on a topographic map at the scale of 1: 25.000 (159-1-1 Herceg Novi, 1979), coastline was vectorized. In this way it has been determined that the former coastline of the southern exit of BiH to the sea was 5.3 km long.

Table 2: Overview of transformation results

Designation of map sheet	Scale	Number of identified identical points	Lowest positional deviation	Largest positional deviation	Standard deviation of transformation
XIX.36 Cattaro	1:75.000	22	8,8 m	32,9 m	20,2 m
XIX.35 Trebinje und Risano	1:75.000	17	3,5 m	35,8 m	22,2 m
XIX - Trebinje	1:150.000	8	3,9 m	57,8 m	45,2 m
Ragusa 36-43	1:200.000	17	7,1 m	90,9 m	45,9 m
Cattaro 36-42	1:200.000	10	16,0 m	75,7 m	52,3 m

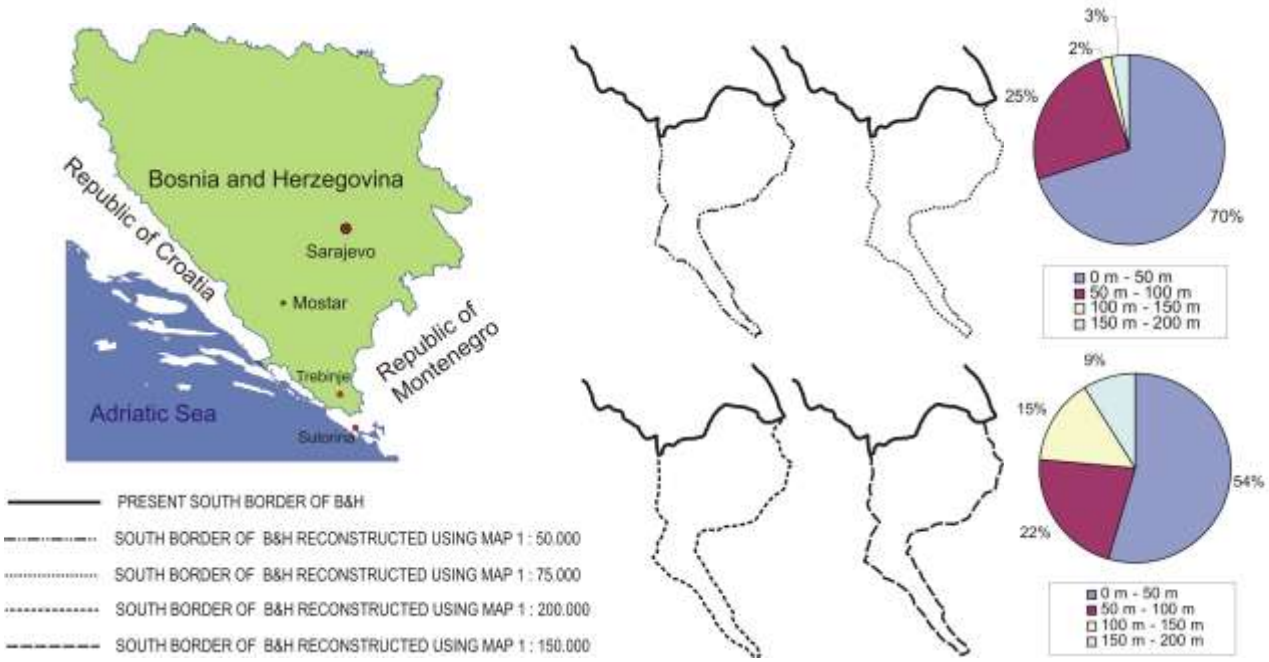

Figure 18. Results of vectorization of boundary lines on a georeferenced maps and matching of obtained boundary lines (above are the maps at the scales of 1:50.000 and 1:75.000, 1:150.000 and 1:200.000 below)

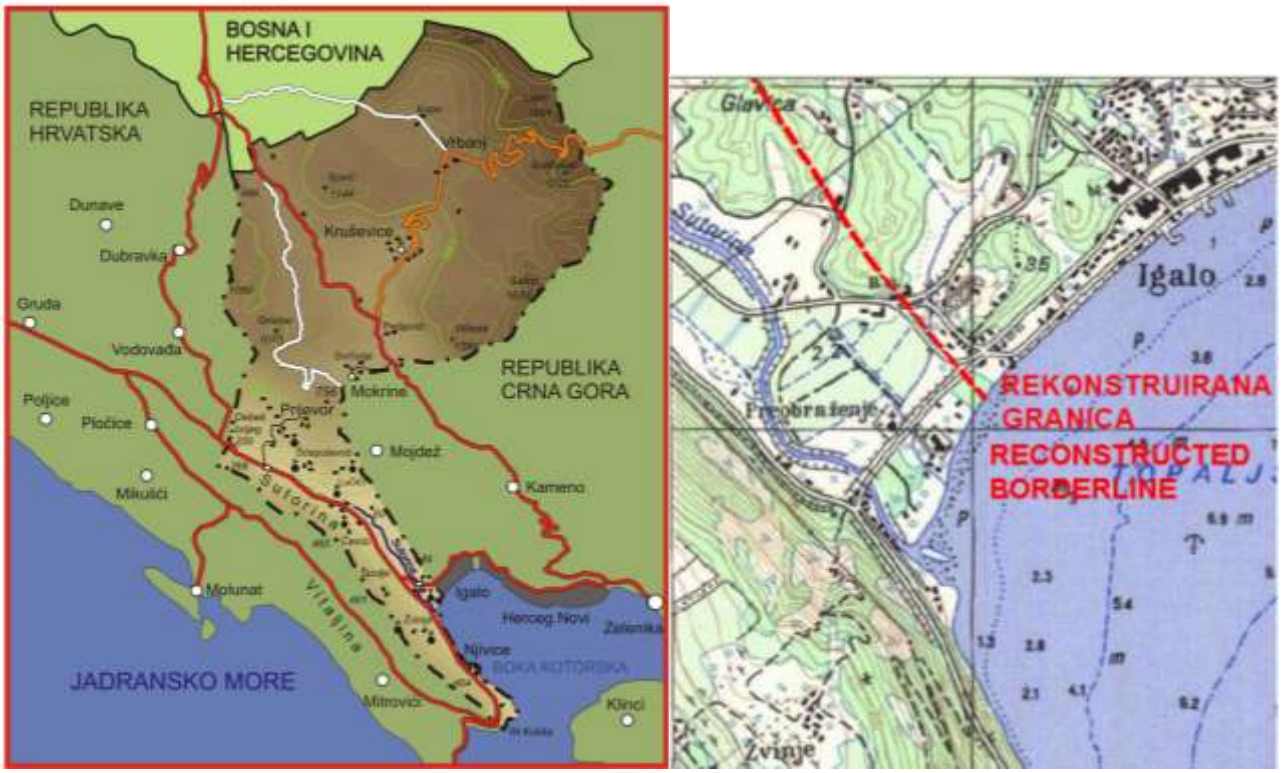

Figure 19. Map of the reconstructed Sutorina corridor (left), a detailed presentation of the beginning of the former border at the coast near Igalo.

6. Conclusion

Cartographers knew demarcation in the Bay of Kotor very well and regularly emphasized the Bosnian-Herzegovinian exit to the sea in Sutorina. This narrow land area was an integral part of many maps, including those with smaller scales, with a high degree of generalization. Old cartographic presentations clearly testify about the areas where Bosnia and Herzegovina, in its recent past, reached the Adriatic at two places. It is quite certainly possible to determine shape of the boundary lines of that exit, based on the content of historical maps.

Georeferencing historical map is usually complicated and hard. To overcome the shortcomings of traditional methods of solving this problem, automated algorithms were developed recently.

These algorithms enable the automatic identification of control points, deleting points with gross errors from the transformation model, as well as the selection of the most suitable model of transformation.

Genetic algorithm can be applied in this manner, as a tool to efficiently search the entire space of possible solutions, in order to find the optimal transformation parameters. It is possible to solve very complex problems, but in order to achieve this, problem must be appropriately adapted to genetic algorithm.

This paper describes the transformation of the old maps in today's geodetic coordinate system. It is performed using a genetic algorithm, by minimizing the distance that represents a measure of similarity of the original and the reference model. Based on data obtained from the transformed historic maps, the image of the recent Bosnian-Herzegovinian south was reconstructed

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