USED THE GEODETIC MEASURING INSTRUMENTS: THE CREATION OF ROMAN CIVILIZATION

Ramazan Gürsel HOŞBAŞ, Atinc PIRTI, Ercenk ATA, Turkey

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SUMMARY

Throughout history there have been many civilizations from east to west. Chinese, Indian, Mesopotamian, Egyptian, Greek, Islamic (Arabian, Iranian and Turkish) and Roman civilizations have been found since ancient times. Of course we rank these civilizations as civilizations in the Old World (Asia, Europa and Africa). The Roman Empire, which was ruled after the ancient Greek civilization in the western part of the Old World, became the second principal element of Western civilization. Today, they have introduced Roman numerals in this process continue to be influenced by Julian calendar, Roman law, monumental structures and roads. Cartography/Survey is a respected profession in Rome, a warlike empire. In the construction of large engineering structures, various measuring instruments are used in angle, length and height measurements. In this study, it is aimed to present a brief overview of these instruments and to open a new horizon on the development of measuring instruments to the professionals who deal with cartography/survey discipline today. The Aztec, Inca and Maya civilizations of the New World (America) must be added to the civilizations counted here.

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1. INTRODUCTION

The Romans could not keep up with the developments that the Greeks had started with the reason that they were warriors. Geometry was developed only for war. The determination of the wall height of a castle; they attacked was important for the size of the towers and stairs to be built. It was also important to know the width of the river where the enemy was on the other beach. It was important to know how many days the settlements were located and where they could be built. In order to meet these needs, they made typical road maps with all this information, (Şerbetçi M. 1996, Hoşbaş R.G. 2017).

Roman civilization was centralist, militarist, utilitarian and patriarchal. Education was based solely on pragmatic purposes. The Roman engineers were famous for the monumental works that reflected the dominance of the empire. However, in these works theoretical knowledge played a very minor role. They gave importance to practicality in their research. Construction of roads, bridges, aqueducts, organization of people and public relations, establishment of army, state administration and law. There was not much effect in the field of creative thinking. The Greeks did not have access to the ability to establish theoretical thinking and observation links (Gallo I.M. 2004, Grewe K. 1991, Riffenburg B. 2012).

2. GEODETIC INSTRUMENTS

The Roman Groma (The Roman Surveyor's Workhorse): In Rome, surveyors were always using right-angled systems when they wanted to divide land for military, political, tax collecting, antirational, and temple-making purposes. They were choosing two directions perpendicular to each other.

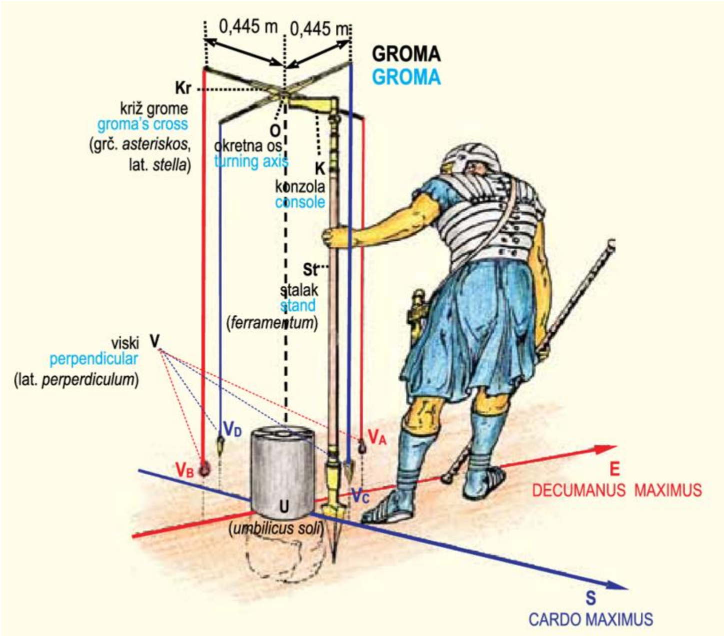

Figure 1. Groma for pegging out a right angle in the field (according to Milić 1994, p. 209), (Miljenko S. and Nikola S., 2009)

In the Etruscans, where they learned cartography/survey, they took the direction of important buildings such as temples from objects in the sky. Generally, north-south (cardo maximus) and east-west (decumanus maximus) directions were used. This direction system is similar to the current perpendicular coordinate system (Figure 1). They used two grommets attached vertically to each other for the application of upright angles or sides, and a grommet consisting of four grommets hanging to their ends (Figure 3). An example of this tool was found in excavations in Pompei in 1912. Cartography/Survey in Rome is a dignified and loved profession. Some cartographers/surveyors were digging the measuring instruments even to the tombstones, (Figure 4) (Grewe K., 2009, Şerbetçi M. 1996).

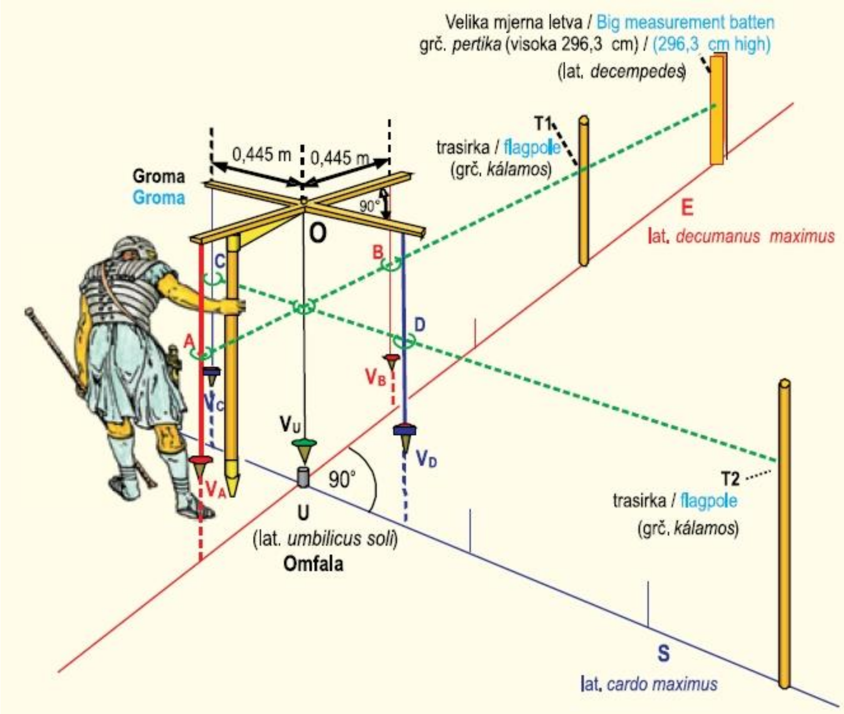

Figure 2. Stake out the right angle and line by using Groma device
(Miljenko S. and Nikola S., 2009)

The gnomon tool was used to measure the shadow if the stake-out distance was too long. They could apply a straight line (limes) like a line 100 km long with a precision of ± 1 m (Figure 2).

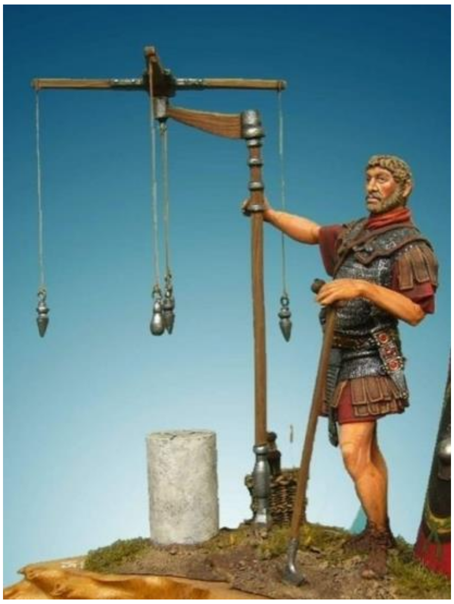

Figure 3. The Roman surveyor using Groma device (Illustration)

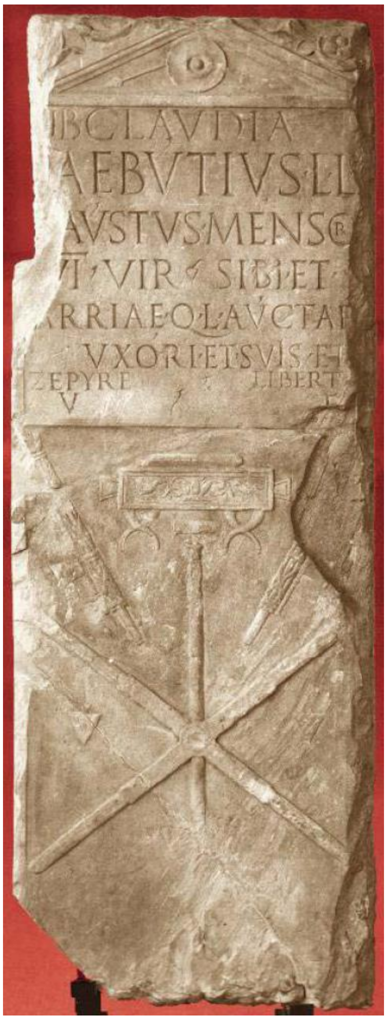

Figure 4. The Groma device, Roman surveyor Lucius Aebutius Faustus's on the tombstone.

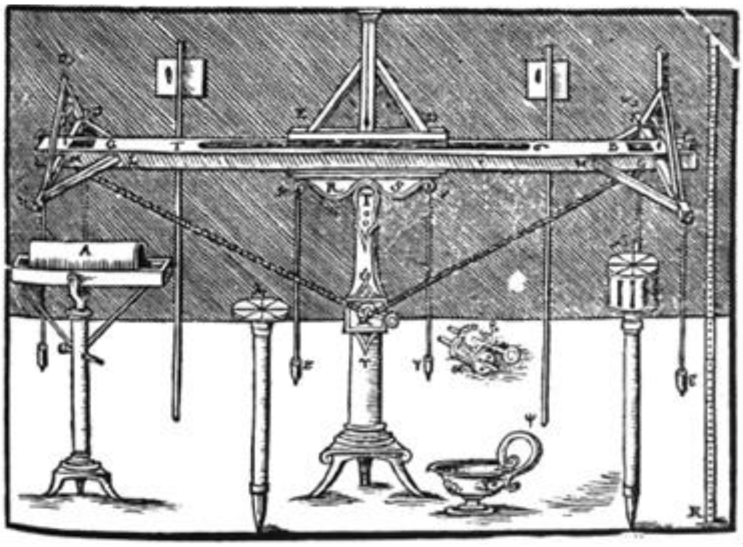

Figure 5. Chorobate device
(Quoted from Marcus Vitrivius Pollio, reconstruction of Gualtherus H. Rivius, Nurnberg 1548)

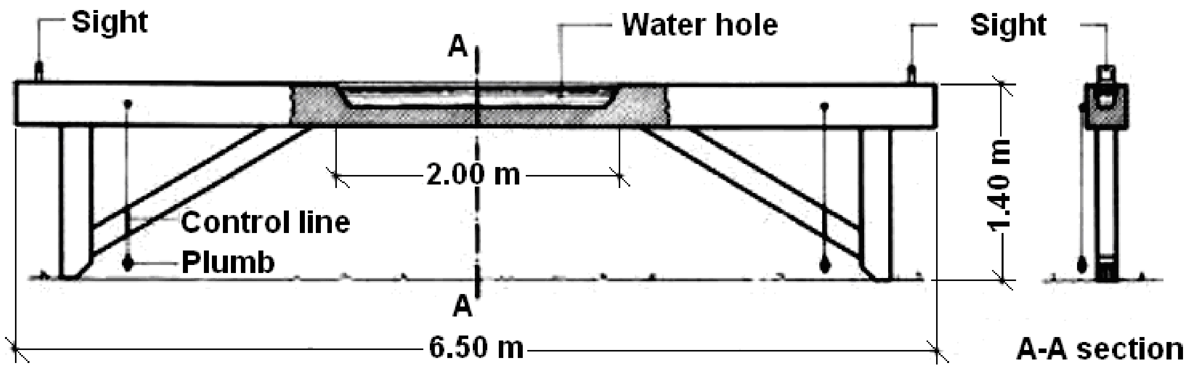

Figure 6. The dimensions of Chorobate device
(Reconstruction of Giovanni Poleni and Simone Stratico, 1825-1830)

The Chorobates (The Roman Spirit Level): The instrument known as the chorobate was described by Marcus Vitruvius Pollio (born c. 80-70 BCE, died c. 15 BCE) as the way that the Roman surveyors checked levels. They were using the chorobate instrument, which was used to build water channels and roads (Figures 5 and 6). The instrument was a 6.5 m long table with a trough of 2 m in length. The table was horizontally plumbed first and then the water level in the ooze (water puddle) was checked. The horizontal direction was observed with the diopter (Figure 7), (Grewe K. 2009, 2010, Şerbetçi M. 1996).

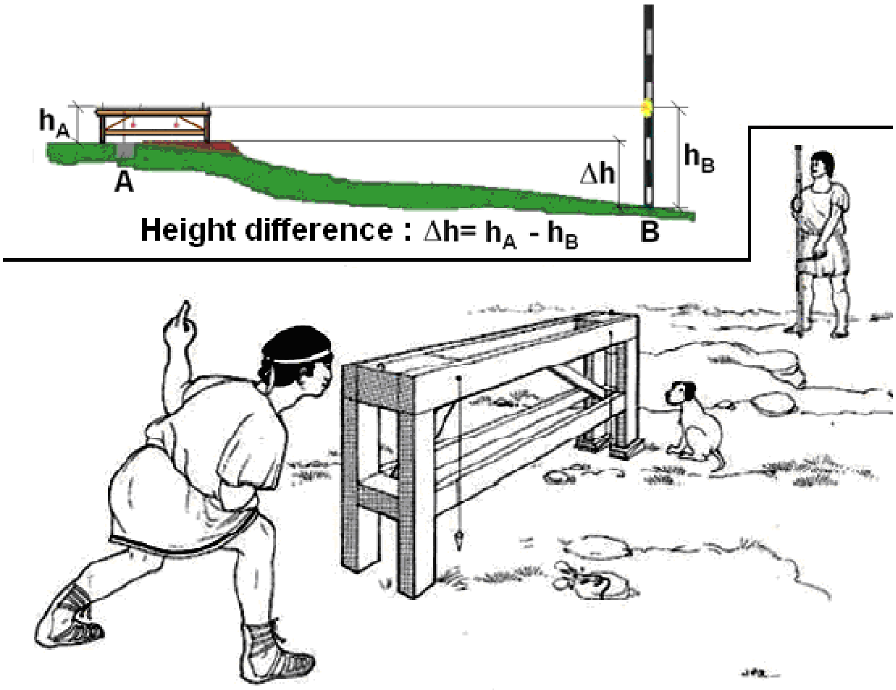

Figure 7. Measurement of height differences using chorobate device

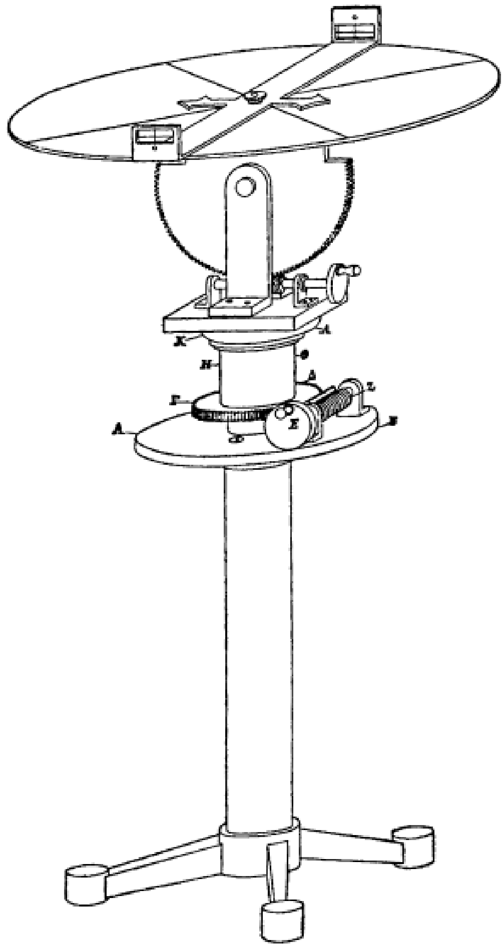

Figure 8. Heron’s dioptra in horizontal mode. Reconstruction reproduced from H. Schöne, “Die Dioptra des Heron,” Jahrbuch des deutschen archäologischen Instituts 14 (1899): fig. 1.

The Dioptra: Because the whole subject cries out for practical experiment, a reconstruction of a standard dioptra was made, the disk being of wood and 60 cm in diameter (Figure 8). The sources are full enough to inspire confidence that this reconstruction is quite close to the truth. It works in either of two planes. When mounted horizontally on a tripod by means of a swivelling joint, it is used to project straight lines, in either direction or in both, for marking on the ground, and if necessary to lay out further lines at right angles to them by means of right-angled diameter lines inscribed on the disk. A quarter of the rim is also graduated in degrees, a facility used (as far as we know) for celestial observations but not for terrestrial surveying.

With little evidence other than Marcus Vitruvius Pollio' writing, historians are not sure how effective the chorobates was and how often it was used by Roman surveyors and builders. Tests have shown that it may not have been accurate enough for the gentle gradient required for building aqueducts, but it would have found use for levelling the ground prior to road building and ensuring that road followed a constant gradient. For higher accuracy work, the Romans probably used a device based upon a Greek design, known as the Dioptra. This device, described by the inventor Heron of Alexandria (10-70 ACE), could be used to find the angle of a gradient, through simple geometry. When complex angles and vertical angles were needed, or the terrain was too steep for the Groma and Chorobates, the Dioptra came into its own. This instrument was the forerunner of modern surveying instruments and the complexity of the Dioptra is where the skill of the Roman surveyors came to the fore. The Dioptra consisted of a circular table affixed to a tripod or monopod, and this was calibrated with angles. Using four screws, the user levelled the table, using two small water levels set at 90 degrees to each other and, once level, he could measure the angle between two distant objects. Using a rotating bar with sights, pivoted around the centre of the table, the surveyor could look at a distant object and then, by rotating the circular table, calculate the angle to a second object (Şerbetçi M. 1996, Hoşbaş R.G. 2017)

The Hodometer: Since the Late Hellenistic period and during the Romans, a tool called a hodometer (Figure 9) was used, which works with a pendulum tool attached to the length measurement. Originally invented by Archimedeus for the first time during the war with the Cartagians, the tool was introduced by writer, architect and engineer Marcus Vitrivius Pollio around 27-23 BC. At device, a metal ball from each milliarum (Roman shaft) through a carefully crafted wheel assembly, fell through the pipe. The two-wheeled car had wheels of 4 pes (4 foot approx. 1,185 m) and a circumference of 12.5 pes (approx. 3.7 m). The wheel made 400 turns and 1 milliarum.

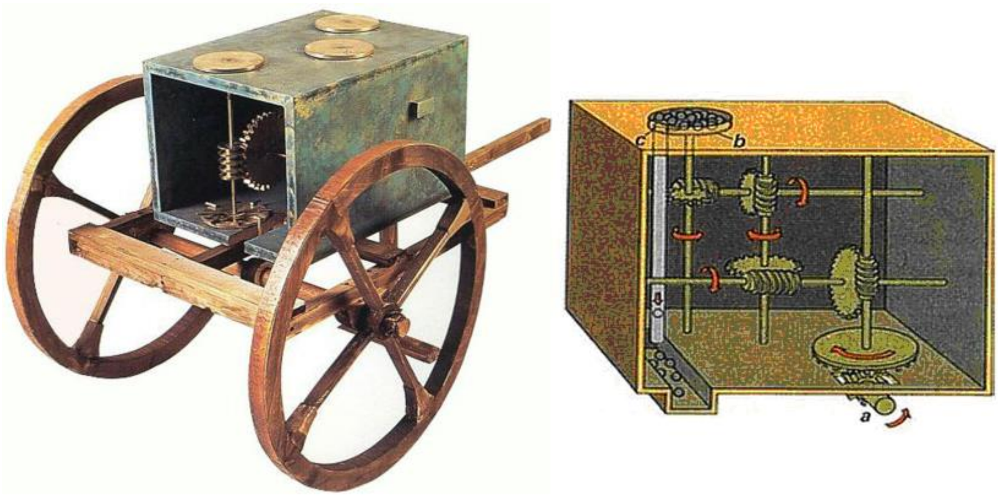

Figure 9. The Rome hodometer (reconstruction, Pinterest)

The Roman hodometer was a very advanced surveying tool for measuring distance, consisting of a small cart that the surveyor or his assistant could push along. A one-toothed gear attached to the wheel of the cart engaged another gear with 399 short teeth and one long tooth. After a distance of one Roman Mile, this long tooth would push a pebble into a bowl, and the surveyor could count the distance travelled at the end of the day. The Romans liked to set up milestones along major highways, letting the military and other travellers see how far they were from cities (Hoşbaş R.G. 2017).

The names of the cartographers/surveyors are like mensor, grommet, agrimensor, bematist, finitores, mensores aedificiorum, castramensores in the ancient times.

Length measurement units:

1 digitus (finger)		= 1,85 cm
1 palmus (hand's breadth)	= 4 digitus	= 7,40 cm
1 pes (foot) = 4 palmus	= 16 digitus	= 29,6 cm (29,57 cm)
1 cibutus (arm length)	= 1,5 pedes	= 44,4 cm
1 passus (step)	= 5 pedes	= 1,48 m (1,4785 m)
1 decempade (pertica)	= 10 pedes	= 2,96 m
1 actus	= 120 pedes	= 35,5 m
1 stadium	= 625 pedes	= 185 m (184,81 m)
1 milliarum (mil)	= 5.000 pedes	= 1.481 m (1.478,5 m)

Area measurement units:

1 pes quadratus	= 1 pes^2	= 0,0876 m^2
1 decempade kare	= 100 $pedes^2$	= 8,76 m^2
1 actus simplex	= 480 $pedes^2$	= 42,1 m^2
1 uncia	= 2.400 $pedes^2$	= 210 m^2
1 actus quadratus	= 14.400 $pedes^2$	= 1.262 m^2
1 jugerum	= 28.800 $pedes^2$	= 2.523 m^2
1 heredium	= 2 jugera	= 5.047
1 centirua	= 200 jugera	= 50,5 ha
1 saltus	= 800 jugera	= 201,9 ha

3. CONCLUSION

The Roman surveyors were highly skilled professionals, able to use a number of tools, instruments, and techniques to plan the courses for roads and aqueducts, and lay the groundwork for towns, forts and large buildings. We half-jokingly talk about the Romans and their straight roads, but that throwaway statement is not far away from the truth. The Romans preferred to build straight roads wherever possible and relied upon their surveyors to chart the route of their great highways. In most cases, the military would be responsible for plotting the route of new roads, but civil surveyors were used to survey courses for aqueducts, settle boundary disputes, and prepare the groundwork for buildings. To help in their task, they used a number of instruments, most borrowed from earlier culture but refined and improved by the Romans. With these simple tools and a good knowledge of geometry, they managed to plot complex courses for roads and aqueducts, their skill so great that they could design huge aqueducts with a gradient of less than 1 in 400.

REFERENCES

GALLO I.M. (2004), “Roman Surveying”, Proceedings of the European Congress, Roman Public Works, ISBN 84-688-8190, 2pp 25-68.

GREWE K. (1991), “Vermessungsgeraete der Römer”, VPK-Mensuration, Photogrammetrie, Genie Rural, Band 89, Heft 11, pp 606-616.

GREWE K. (2009), “Chorobat und Groma: Neue Gedanken zur Rekonstruktion und Handhabung der beiden wichtigsten Vermessungsgeraete antiker Ingenieure”, Bonner Jahrbücher Band 209, Verlag Philipp von Zabern, Darmstadt, pp 109-128.

GREWE K. (2010), “Die Groma-das genial einfache Winkelkreuz der römischen Landmesser”, Vermessung und Geoinormation VDV, Magazin, 5/2010 Seite 366-370, 42115 Wuppertal.

HOŞBAŞ R.G. (2017), “Haritacılık Bilimi Tarihi”, Lecture Notes, Yıldız Technical University, Faculty of Civil Engineering, İstanbul.

RIFFENBURG B. (Çev. ÇAĞLAR S.) (2012), “Antik Dönemden Günümüze Haritacılar”, Türkiye İŞ Bankası Kültür Yayınları, İstanbul.

MILJENKO SOLARIĆ AND NIKOLA SOLARIĆ (2009). “Laying Out Land Parcels and the Oldest Boundary Stone in Croatiafrom the 4th Century BC.“, Kartografija i geoinformacija, Vol. 8, No. 12, Zagreb, str. 59.-77.

ŞERBETÇİ M. (1996), “Haritacılık Bilimi Tarihi”, Harita Dergisi Özel Sayı, Yıl 63 Özel Sayı: 15, Harita Genel Komutanlığı Matbaası, Ankara.

WHITFIELD P., (Çev. USLU S.), (2008), “Batı Biliminde Dönüm Noktaları”, Küre Yayınları Bilim Tarihi 1 (46. Kitap), Vefa İstanbul.

AUTHORS' ADDRESSES

Ramazan Gürsel HOŞBAŞ, Assistant Prof. Dr.
Yildiz Technical University, Faculty of Civil Engineering
Department of Geomatic Engineering
Davutpasa Campus, 34220, Istanbul-Turkey
ghosbas@yildiz.edu.tr

Atinc PIRTI, Prof.Dr.
Yildiz Technical University, Faculty of Civil Engineering
Department of Geomatic Engineering
Davutpasa Campus, 34220, Istanbul-Turkey
atinc@yildiz.edu.tr

Ercenk ATA, Associated Prof. Dr.
Yildiz Technical University, Faculty of Civil Engineering
Department of Geomatic Engineering
Davutpasa Campus, 34220, Istanbul-Turkey
ata@yildiz.edu.tr