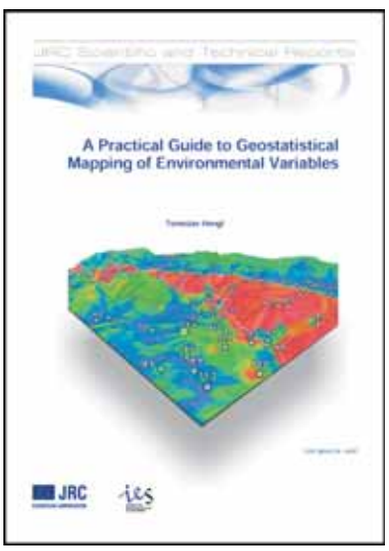
A Practical Guide to Geostatistical Mapping of Environmental Variables

By Tomislav Hengl



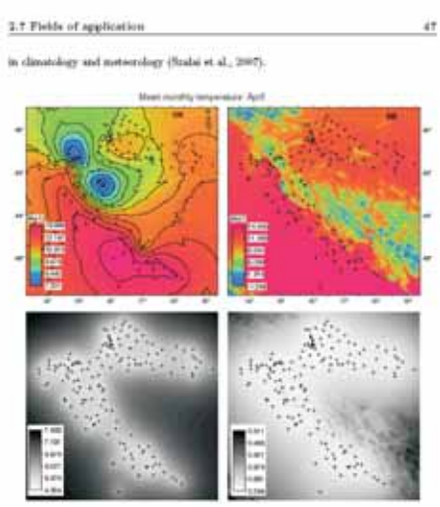
The book *A Practical Guide to Geostatistical Mapping of Environmental Variables* written by Dr. Tomislav Hengl is an extensive and valuable work published in English. A set of methods for analysis and mapping of different environmental variables are presented.

The book is divided into just four clear chapters, but the comprehensive matter is presented through 26 subchapters. Each chapter ends with additional references recommended to reader for extending the knowledge obtained from the chapter.

The first chapter *Theoretical backgrounds* describes terms like environmental variable, spatial dependence and spatial model. It is followed by theories of several interpolation methods, starting with mathematically simpler (*Mechanical spatial prediction models*) like inverse distance, regression and polynomial interpolation (*splines*). The next subchapter includes descriptions of geostatistical tools like variogram and kriging as the most appropriate tools for spatial prediction of regionalized variables. Basic variogram terms are also described (sill, range, nugget), as well as experimental and theoretical approximation models and relations between variogram and covariance. The influence between variogram model and control points distribution on the prediction is described. Finally, the so-called mixed or hybrid geostatistical methods (like cokriging and regression kriging) are explained.

The second chapter, *Regression-kriging*, is dedicated to, as the author mentioned, the main hybrid geostatistical deterministical method of Regression Kriging. It is pointed out that this geostatistical technique can be described with the acronym BLUP (*Best Linear Unbiased Prediction*), i.e. as the first-among-equal geostatistical techniques generally described with the acronym BLUE (*Best Linear Unbiased Estimators*). All other mentioned interpolation techniques (Ordinary Kriging, Polygonal Estimation, Inverse Distance) are considered a special case of Regression Kriging. Moreover, techniques of Universal Kriging, Kriging with External Drift and Regression Kriging can be considered as a unique technique with small differences. These subchapters also contain descriptions of sampling techniques and field of application for Regression Kriging, e.g. in the mapping of soil data, climate and meteorological measurements, representation of plant and animal species, etc. Finally, limitations and alternatives for Regression Kriging (like Collocated Cokriging) are mentioned.

The third chapter, *Hands-on software*, give the reader insight into application of described interpolation methods, i.e. software packages where user can analyse his or her own data. The author's selection included an interesting set of programs (4 packages), some of which are well known in the field of spatial analysis, and other for cartographic needs. These are ILWIS, SAGA, R+gstat and Google Earth. All the programs are open source codes, freeware, i.e. license-free programs. ILWIS (*Integrated Land and Water Information System*) is a stand-alone, integrated GIS package developed at the *International Institute of Geoinformation Science and Earth Observation*) in Enschede, the Netherlands. The program offers possibilities for processing images, vector graphics, raster, database organization, statistical and geostatistical calculations, etc. SAGA (*System for Automated Geoscientific Analyses*) was created at the University in Göttingen, Germany. It was developed with the purpose of simplified application of new algorithms for spatial data analysis. R is the freeware version of the program language S, intended for statistical calculation. It is capable of a wide range of statistical methods (linear and non-linear modelling, classical statistical tests, time-series analyses, classifications, clustering …) and graphical techniques. Gstat is a famous program package for geostatistical analysis developed by Edzer Pebesma from the University of Utrecht, the Netherlands, in 1997. The program Google Earth is a very interesting selection, because it is a geographical browser very popular in the academic community. It was developed by *Keyhole, Inc.*, which was taken over by *Google* in 2004. The usage of geostatistical modules for each of mentioned packages is described. Map visualization is



2.7 Fields of application 47

in climatology and meteorology (Szalai et al., 2007).

Fig. 2.11: The long-term mean monthly temperature for April interpolated using OK (left) and RK (right) at 1 km grid. Predictions (above) and prediction variances (below) in this case differ significantly. In this case, auxiliary predictors (elevation, latitude, direct annual solar insolation, distance from the coast line) explain 95.2% of variation in the original data (182 meteorological stations), hence the mapping precision is considerably higher for RK.

Interpolation of climatic and meteorological data is also interesting because the auxiliary (meteorological images) data are today increasingly collected in shorter time intervals so that time-series of images are available and can be used to develop spatio-temporal regression kriging models. Note also that many meteorological prediction models can generate maps of forecasted conditions in the close future time, which could then again be calibrated using the actual measurements and RK framework (Fig. 2.1).

2.7.3 Mapping plant and animal species

As mentioned previously in §1.1.1, geostatistical modelling of plant and animal data is somewhat more complicated because we commonly deal with dynamic and discrete

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Knjiga *A Practical Guide to Geostatistical Mapping of Environmental Variables* (Praktični vodič kroz geostatističko kartiranje prostornih varijabli) autora dr. sc. Tomislava Hengla obimno je i vrijedno djelo na engleskom jeziku koje obrađuje niz metoda za obradbu i prikaz različitih prostornih varijabli, odnosno mjerenja iz različitih vrsta prirodnih okoliša.

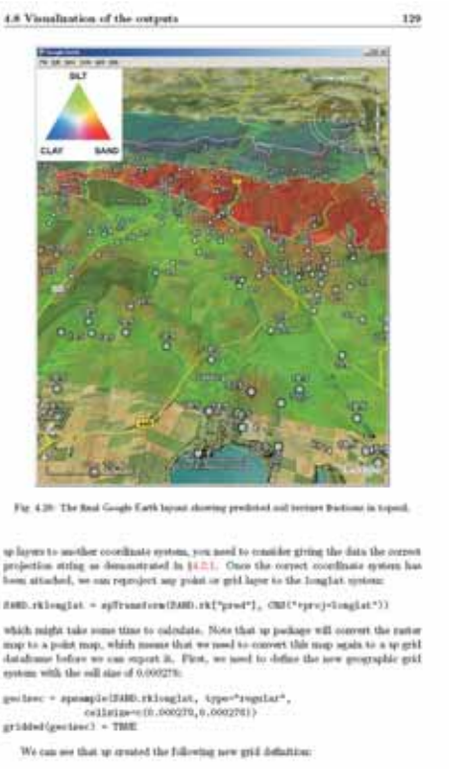
Knjiga je podijeljenja na svega četiri poglavlja, što povećava njezinu preglednost, no opširna materija obrađena je kroz čak 26 potpoglavlja. Na kraju svakoga poglavlja dan je popis literature koji čitatelj može upotrijebiti za proširivanje znanja stečenoga čitanjem pojedinačnih poglavlja.

Prvo poglavlje *Theoretical backgrounds* (Osnovna teorija) opisuje pojmove poput varijable iz okoliša, prostorne zavisnosti te prostornoga modela. Zatim je čitatelj postupno uveden u teoriju nekoliko interpolacijskih metoda počevši s matematematički jednostavnijima (*Mechanical spatial prediction models*) poput inverzne udaljenosti, regresije i polinomne interpolacije (*splines*). U sljedećem potpoglavlju objašnjeni su geostatistički alati poput variograma i kriginga, kao najčešće primjenjivani za prostornu procjenu regionaliziranih varijabli. Prikazani su variogramski pojmovi (prag, doseg, odstupanje), eksperimentalni i teorijski aproksimacijski modeli te odnos između variograma i kovarijance. Opisan je utjecaj variogramskog modela i rasporeda kontrolnih točaka na vrijednosti procjene dobivene kriginganjem te na kraju složene ili hibridne geostatističke metode koje obuhvaćaju kokrigiranje i regresijsko krigiranje.

Drugo poglavlje *Regression-kriging* (Regresijsko krigiranje) autor je posvetio, kako je napisao, glavnoj hibridnoj geostatističkoj deterministčkoj metodi regresijskoga krigiranja. Istaknuto je kako je upravo tu geostatističku tehniku moguće označiti akronimom BLUP *(Best Linear Unbiased Prediction)*, odnosno kao prvu među jednakim geostatističkim tehnikama koje su opisane akronimom BLUE *(Best Linear Unbiased Estimators)*. Istaknuto je i kako su sve druge spomenute interpolacijske tehnike (obično krigiranje, poligonalna procjena, inverzna udaljenost, …) promatrane kao poseban slučaj regresijskog krigiranja. Nadalje, tehnike univerzalnog krigiranja, krigiranja s vanjskim driftom te regresijskoga krigiranja mogu se smatrati jedinstvenom tehnikom s tek vrlo malim razlikama. Kroz potpoglavlja su istaknuti načini uzorkovanja podataka te područja primjene regresijskoga krigiranja, npr. u kartiranju podataka iz tla, klimatskih i meteoroloških mjerenja, prikazivanje vrsta biljnoga i životinjskoga svijeta i tome sl. Na kraju su spomenuta ograničenja i alternative regresijskom krigiranju (poput kolokacijskoga kokrigiranja).

Treće poglavlje *Hands-on software* (Priručni programski paketi) uvodi čitatelja u praktičnu primjenu opisanih interpolacijskih metoda, odnosno programske pakete u kojima može samostalno analizirati svoje vlastite podatke. Autor je odabrao zanimljiv skup programa, njih 4 od kojih su neki vrlo poznati u području prostorne analize, a drugi za kartografske prikaze. To su ILWIS, SAGA, R+gstat i Google Earth. Svi programi su otvorenoga koda (*open sources*) ili slobodno dostupni (*freeware*) za koje nije potrebna licenca. ILWIS (*Integrated Land and Water Information System*) je samostalni, integrirani GIS paket razvijen na Međunarodnom institutu za geoinformatičke znanosti i opažanje Zemlje (*International Institute of Geoinformation Science and Earth Observation*) u Enschedeu u Nizozemskoj. Program nudi mogućnost obrade slika, vektorskih grafika, rastera, organizaciju baze, statističkih i geostatističkih računanja i tome sl. SAGA (*System for Automated Geoscientific Analyses*) potječe sa Sveučilišta u Göttingenu u Njemačkoj, a razvijen je s ciljem pojednostavnjenja primjene novih algoritama za prostornu analizu podataka. R je slobodna inačica programskoga jezika S namijenjenog za statističke proračune. Omogućava upotrebu širokog raspona statističkih metoda (linearnih i nelinearnih modeliranja, klasičnih statističkih testova, analize vremenskih serija, klasifikacija, klasteriranja…) te grafičkih tehnika. Gstat je poznati programski paket za geostatističku analizu što ga je razvio Edzer Pebesma na Sveučilištu u Utrechtu u Nizozemskoj 1997. Zanimljiv odabir je paket Google Earth kao geografski pretraživač vrlo popularan u istraživačkoj zajednici. Razvila ga je tvrtka *Keyhole, Inc*., što ju je preuzeo *Google* 2004. Za svaki od navedenih programskih paketa opisana je upotreba geostatističkih alata. Kod programa Google Earth opisan je način vizualizacije karata, što je glavna namjena programa, a poglavlje završava kratkim opisom još nekih programa koji se mogu upotrebljavati za geostatističke ili geografske i kartografske (GIS) analize, poput paketa Isatis, GRASS i Idrisi.

Završno, četvrto poglavlje *A geostatistical mapping exercise* (Vježbe iz geostatističkog kartiranja) temelji se na podacima prikupljenima na analiziranom području veličine 10×10 km u blizini grada



presented for the program Google Earth, and this chapter ends with a description of some other programs that could be applied for geostatistical or geographical (GIS) analyses, like Isatis, GRASS and Idrisi packages.

The last, fourth chapter, *A geostatistical mapping exercise*, is based on input data originated from analysed area of 10×10 km size, located near the town of Göttingen in central Germany. This area was explored in detail during several years, mostly with purpose of developing digital techniques for mapping soil variables. This example was analysed at the same time with all four packages – SAGA, ILWIS, R and Google Earth. Generally, the procedure starts with data analysis (descriptive statistics and point geometry analysis); it is followed by determination of secondary variables (*auxiliary predictors*) like DEM *(Digital Elevation Model*) parameters, satellite images of soil samples and geological strata, which are compiled into components useful for prediction of soil characteristics. Finally, predictions and simulations were made in the R package and results exported into ILWIS, where they were modified for final presentation in Google Earth. This chapter also includes a description of regression modelling in the R language using several techniques and concluding if the secondary variables (*predictors*) can explain variation observed in target (primary) variables. Variogram modelling, as well as value prediction and simulation, were represented in the gstat program. Quality of such an estimation was described with two values (1) Mean Prediction Error (abbr. ME) and (2) Root Mean Square Prediction Error (abbr. RMSE). Results obtained with different input, caused by different cell size or sampling pattern are shown. Visualization of outputs was performed by ILWIS, and exported to Google Earth using the KLM format. The book ends with a bibliography consisting of 128 references, and an index of almost 250 English terms.

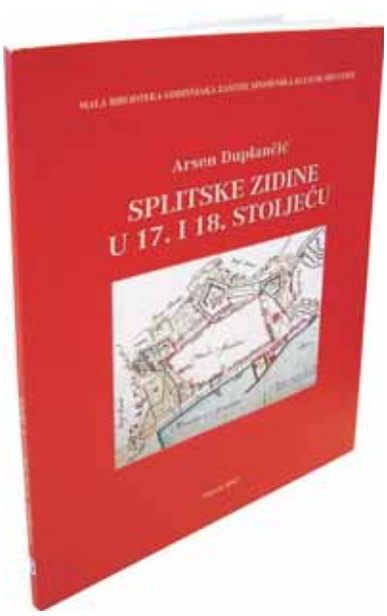
The book was published in 2007 by the *Joint Research Centre of the European Commission*, i.e. *Institute for Environment and Sustainability*. It was catalogued as publication EUR 22904 EN, ISBN 978-92-79-06904-8 and ISSN 1018-5593. It is protected by the author's copyright, but also freely available as a PDF. The full, 146 page text can be downloaded from the following address: http://eusoils.jrc.it/ESDB_Archive/eusoils_docs/other/EUR22904en.pdf .

The author invested much knowledge, experience and effort into this book, which is a high quality scientific work for advanced users. Also, numerous procedures and program packages are described, which is why this book can also be a valuable guide for teams engaged in (geostatistical) mapping of different environmental variables (primarily from soil, but can also be applied to other regionalized variables from human environment, like geological, geographical, meteorological and other variables, …). Such teams include professionals from different fields (data processing, cartography, computer programming), and this book covered each of them.

Tomislav Malvić

Split City Walls in the 17th and 18th Century

Arsen Duplančić



In 2007, the Administration for the Protection of Cultural Heritage of the Ministry of Culture of the Republic of Croatia published *Split City Walls in the 17th and 18th Century* as the 13th volume in the edition *Mala biblioteka Godišnjaka zaštite spomenika kulture Hrvatske* (Small Library of the Annual of Croatian Cultural Monument Protection). The author is Arsen Duplančić, a historian and librarian of the Archaeological Museum in Split. The book has 76 pages, A4 format, it is paperback, and has ISBN 978-953-6240-63-0.

The *Preface* written by Stanko Piplović states that the Split city walls from the 17th century were an extraordinary project comparable to the construction of Diocletian's Palace by work extent, resources invested and number of constructors. Their construction was critical for Split's existence and destiny in the most difficult times of its turbulent history. According to Piplović, this publication is the first significant attempt to comprehensively represent the city walls, with plentiful archive sources and graphical documents. He states there are several plans representing Split's baroque fortresses in various ways. He believes this leads to considerations that some of the representations are incorrect, that some proposals were not realized or about states before the final decision. He adds that newer research offers interesting data about gradual transformation of Split's fortresses and the way its defence was reorganized.

The publication features a detailed chronological representation of Split's city walls construction based on written and pictorial material kept at libraries, archives, museums in Croatia and abroad. Book content is divided into following chapters:

- Situation before the beginning of the Candiot War in 1645
- Candiot War and fortification of Split
- Projects by C. Gonzaga and I. Conti
- City Gate
- Funds, house and church demolishing
- Situation and appearance of city walls after constructions

Göttingena u središnjoj Njemačkoj. To područje je detaljno istraživano niz godina, prvenstveno u cilju razvoja digitalnih tehnika za kartiranja varijabli mjerenih u tlu. Primjer je obrađen usporedno kroz četiri programska paketa – SAGA, ILWIS, R i Google Earth. Načelno postupak započinje analizama podataka (deskriptivnom statistikom i analizom geometrije), zatim su određene pomoćne varijable (*auxiliary predictors*) poput parametra za DEM (*Digital Elevation Model*), satelitskih slika uzoraka u tlu i geoloških slojeva, te su pretvorene u komponente kojima se može predviđati karakteristike tla. Na kraju su pokrenute procjene i simulacije u paketu R, a rezultati preneseni u ILWIS gdje je pripremljen konačni izlaz za prikaz u Google Earthu. Opisano je regresijsko modeliranje unutar jezika R pomoću nekoliko tehnika te zaključivanje mogu li pomoćne varijable (*predictors*) objasniti varijacije opažene u ciljnim (primarnim) varijablama. Prikazano je variogramsko modeliranje programom Gstat, te procjena i simulacija vrijednosti. Kvaliteta takve procjene opisana je kroz dvije vrijednosti (1) srednjom pogrješkom predviđanja (*Mean Prediction Error – abbr. ME*) te (2) korijenom srednje kvadratne pogrješke *(Root Mean Square Prediction Error – abbr. RMSE)*. Prikazani su rezultati predviđanja dobiveni različitim ulaznim vrijednostima, zbog razlike u veličini ćelije ili gustoći uzorkovanja. Vizualizacija izlaznih vrijednosti načinjena je s pomoću ILWIS-a, te kroz format KLM prenijeta u Google Earth. Knjiga završava bibliografijom od 128 referenci, te indeksom pojmova od gotovo 250 engleskih izraza.

Knjiga je priređena 2007. godine u izdanju *Joint Research Centre of the European Commission* (Zajedničkog istraživačkog centra Europske komisije), odnosno njezinoga *Institute for Environment and Sustainability* (Instituta za okoliš i održivost). Katagolizirana je pod oznakama EUR 22904 EN, ISBN 978-92-79-06904-8 te ISSN 1018-5593. Uz poštivanje zaštićenih autorskih prava slobodno je dostupna u PDF-u. Cjeloviti tekst na 146 stranica dostupan je na mrežnoj adresi http://eusoils.jrc.it/ESDB_Archive/eusoils_docs/other/EUR22904en.pdf .

Autor je u knjigu uložio mnogo znanja, iskustva i truda, koja je sa znanstvene strane vrlo kvalitetno djelo za naprednije korisnike. Također, zbog brojnih postupaka i programskih paketa koji su opisani u knjizi, ona može biti vrijedan vodič timovima koji se bave (geostatističkim) kartiranjem različitih varijabli prikupljenih u čovjekovu okolišu (prvenstveno se to odnosi na tlo, ali se može primijeniti i na druge regionalizirane varijable u čovjekovoj okolini, poput geoloških, geografskih, meteoroloških, …). Takvi timovi uključuju niz stručnjaka za pripremu podataka, kartografsku obradbu te programiranje aplikacija, a knjiga je obradila svako od tih područja.

Tomislav Malvić

Splitske zidine u 17. i 18. stoljeću

Arsen Duplančić

Uprava za zaštitu kulturne baštine Ministarstva kulture objavila je 2007. godine u ediciji *Mala biblioteka Godišnjaka zaštite spomenika kulture Hrvatske* kao 13. svezak publikaciju *Splitske zidine u 17. i 18. stoljeću*. Autor publikacije je Arsen Duplančić, povjesničar i knjižničar u Arheološkom muzeju u Splitu. Publikacija ima 76 stranica formata A4, meko je ukoričena, nosi oznaku ISBN 978-953-6240-63-0.

U *Predgovoru* što ga je napisao Stanko Piplović, navodi se da su splitske zidine iz 17. st. izuzetan graditeljski pothvat koji se po opsegu radova, uloženim sredstvima i broju graditelja može usporediti s izgradnjom Dioklecijanove palače. Njihova je izgradnja bila presudna za opstanak i sudbinu Splita u najtežim vremenima njegove burne povijesti. Prema njegovu mišljenju, tekst ove publikacije je prvi značajni pokušaj cjelovitog prikaza zidina koji je bogato potkrijepljen arhivskim izvorima i slikovnim dokumentima. Piše da je poznato više planova koji prikazuju splitske barokne utvrde na dosta različite načine. Smatra da to navodi na razmišljanje da je u nekim slučajevima riječ o netočnim prikazima, o nekim prijedlozima koji nisu ostvareni ili o stanjima prije nego što se prišlo ostvarenju konačnog rješenja. Dodaje da novija istraživanja pružaju zanimljive podatke o postupnom preobražaju splitskih utvrda i o načinu reorganizacije obrane.

Publikacija donosi detaljni kronološki prikaz izgradnje splitskih zidina na temelju prikupljene pisane i slikovne građe što se čuva u knjižnicama, arhivima, muzejima u Hrvatskoj i inozemstvu. Sadržaj knjige podijeljen je na sljedeća poglavlja:

- Stanje prije početka Kandijskog rata 1645.
- Kandijski rat i utvrđivanje Splita
- Projekti C. Gonzage i I. Contija
- Gradska vrata
- Novčana sredstva, rušenja kuća i crkava
- Stanje i izgled zidina nakon izgradnje
- Zidine i prostor uz njih prelaze u ruke privatnika
- Propadanje zidina i počeci rušenja u 19. stoljeću
- Oporuke i sredstva za uzdržavanje zidina
- Utvrđivanje istočnog zida Dioklecijanove palače
- Zgrade uz istočni zid Dioklecijanove palače

Duplančić navodi da je Split na najstarijoj slici grada iz polovice 16. st. pa do slike s početka 17. st. bio prikazan unutar Dioklecijanove palače i zidina koje su obuhvaćale njegov dio proširen prema Marjanu. Spominje da se u izvješćima mletačkih predstavnika vlasti i inženjera ističe slaba obrambena moć Splita i nužnost da se ona poboljša. To se osjetilo neposredno prije Kandijskog rata započetog u lipnju 1645.

Važno razdoblje za utvrđivanje Splita je od 1656. do 1668. u kojem je ostvarena