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Slike na naslovnici:

Levo: Kern DKM2-AE, sekundni teodolit z mikrometrskim odčitavanjem smeri na diametralnih položajih kroga. Teodoliti z oznako DKM (nem. Doppelkreis Mikrometer) so prišli na trg leta 1938. Konstruktor instrumentov je bil Heinrich Wild. Teodolit z oznako DKM2 je prišel na trg 1950. Daljnogled daje pokončno sliko, optično grezilo in kompenzator višinskega indeksa. Pripravljen je za dograditev z razdaljemeri tipa Kern DM 500, DM 502 in DM 503. Optični razdaljemer Kern DM500 je prišel na trg leta 1973 in je sestavljen iz dveh objektivov (enega za pošiljanje in drugega za sprejem signala).

Desno: Izsek iz katastrskega načrta Ljubljana mesto, ki je bil ponatisnjen leta 1916, z rdečo barvo pa so dodane številne spremembe. Spodaj je dodan izsek tahimetričnega zapiska geodetske izmere.

AMPAK ...

Anka Lisec

glavna in odgovorna urednica Geodetskega vestnika

V deževno jesen smo zajadrali na krilih uspehov naših športnikov, raziskovalcev, podjetnikov ... Kako lepo je ob jutranji kavi poklepetati o dobrih in navdihujočih novicah! Tako lepo, da nas niti sivi deževni dnevi skoraj ne motijo več. Zdi se, da so celo najbolj zadržani in nergavi posamezniki dovolili nasmehu priti na obraz. In to je dobro ...

Glede na to, da so dobili veliko več medijske pozornosti uspehi športnikov, tudi uspehi podjetij, naj v teh vrsticah povzamem nekaj odmevnejših dosežkov naših raziskovalcev. Že vnaprej se opravičujem, ker sem pri pregledu znanstvenih dosežkov nekoliko pristranska in se osredotočam bolj na področje tehnike in naravoslovja, a so to področja, ki so nekako najbolj povezana z našo stroko, dodatno pa so nova spoznanja zagotovo navdihujoča za splošno javnost.

Skupina slovenskih znanstvenikov, v kateri je z raziskovalci Instituta Jožef Stefan in Fakultete za matematiko in fiziko sodeloval kolega s Fakultete za gradbeništvo in geodezijo Univerze v Ljubljani, je tako objavila znanstveni članek v prestižni reviji *Nature Physics* o odkritju kvantne spinske tekočine; s tem so razrešili štirideset let odprto vprašanje v fiziki, spoznanje pa je pomembno predvsem za nadaljnji razvoj kvantnih tehnologij. V mednarodni raziskovalni skupini na Institutu Jožef Stefan so poleg tega potrdili obstoj mreže vrtincev v tekočih kristalih – dokazana vrtinčasta struktura snovi je izredno zanimiva, saj povezuje fiziko realnega sveta s topologijo, posebno vejo matematike. Veseli dejstvo, da so slovenski raziskovalci in raziskovalne institucije vse uspešnejši pri raziskovalnem programu Obzorje 2020 (Horizon 2020) ter drugih mednarodnih raziskovalnih pobudah.

Odmevni dosežki naših znanstvenikov in raziskovalcev prihajajo tudi iz tujine, med drugim imamo vse več doktorjev znanosti na področju geodezije in geoinformatike, ki po študiju na Univerzi v Ljubljani doktorski akademski naslov pridobijo z odličnimi raziskovalnimi rezultati na priznanih tujih univerzah. Upam samo, da jih bomo lahko privabili nazaj v Slovenijo s prijaznim delovnim okoljem, ki bo precej bolj podpiralo znanstveno-raziskovalno delo in inovacije. Danes je namreč v Sloveniji pomen znanstvenega in razvojnega dela za državo in njeno gospodarstvo zaskrbljujoče prezrt. Ustvariti moramo okolje, da bodo lahko ti »dragulji« s svojim znanjem in izkušnjami prispevali k razvoju naše države.

Pa ste se morda vprašali, kaj je bilo treba storiti posameznikom in skupinam, da žanjejo take uspehe? Če ste prisluhnili kakšnemu intervjuju s posamezniki ali posameznicami, ki so se v preteklih mesecih posebej izkazali z izjemnimi dosežki – pa naj bodo športniki, podjetniki ali raziskovalci, ste zagotovo ugotovili, da so vsi ti uspešni posamezniki, skupine, institucije imeli dobro zastavljene cilje. Vsem je bilo tudi jasno, da je treba biti vztrajen in da je treba za uspeh vložiti veliko truda.

Ko potem na drugi strani pogledam takšne in drugačne težave, s katerimi se vsakodnevno srečujemo, tudi v naši stroki, ne morem mimo dejstva, da se očitno marsikdaj ne ve, kaj je cilj, kaj bi radi … Če se že ve, kaj bi radi dosegli, se najde ovira, ki je bojda »nepremagljiva«. Prepričana pa sem, da če bi res želeli doseči cilje, če bi res želeli kaj spremeniti, bi zagotovo našli pot … **Ampak** na področjih, kjer se ne premaknemo nikamor, se to ne zgodi.

V naši stroki prepogosto slišimo prislov »ampak« v protivnem priredju: »*To bi lahko storili, ampak ne moremo* …«, »*S tem bi lahko uspeli, ampak to ni mogoče* …« itn. – se sliši poznano? Toda prislov ampak lahko uporabimo tudi v zvezi »ne samo, ne le«: »*Ne le da bi to storili, ampak lahko naredimo še več* …«, »*Ne samo, da bi s tem uspeli, ampak uspeli bomo tudi z* …« Zveni bolje, mar ne?

Nihče ne bo opravil dela namesto nas in težave se bodo začele reševati, ko jih bomo začeli reševati sami. Zato, dragi bralec ali bralka teh vrstic, ne izgubljajmo časa za delo v negotovosti, jasno oblikujmo cilje in stopimo odločno korak dalje – sledili nam bodo! Saj ste videli, da sta optimizem in zmagovalni duh nalezljiva ...

Upam, da bo kanček k dobri volji in optimizmu prispevalo tudi prebiranje jesenske številke Geodetskega vestnika – zanimiv in pester je nabor strokovnih člankov, mnogo se je dogajalo tudi na Geodetski upravi RS, na fakulteti, v društvih. Novo je vodstvo na Inženirski zbornici Slovenije, v Matični sekciji geodetov. Imamo pa tudi novega-starega predsednika ZGS, mag. Blaža Mozetiča, ki mu iskreno čestitam ob ponovni izvolitvi in želim uspešno vodenje zveze!

SPOŠTOVANJE

Blaž Mozetič

predsednik Zveze geodetov Slovenije

Z večanjem časovne oddaljenosti od dogodka ostaja z vsakim dnem v spominu več lepih in pozitivnih trenutkov, tisti nekoliko neprijetni pa počasi tonejo v najbolj oddaljene sobane spomina. Najbrž se še spomnite tistih študentskih dni, ko ste v predavalnicah poslušali o modrostih in radostih geodetskih skrivnosti, s katerimi se boste ukvarjali v vsakdanjem življenju. Morda se nekje med vsemi temi modrostmi in radostmi udobno počuti tudi tista o nadštevilčnosti meritev, dolgočasnem iskanju »slabih« meritev in večnem spraševanju o zanesljivosti končnega rezultata. V teoriji vse lepo in prav, vendar se v poslovnem svetu v to geodetsko enačbo hitro vključijo še konstantne neznanke, kot so čas, finančna sredstva, kadri, oprema itd., ki imajo lahko pozitiven ali negativen predznak. Morda bo zvenelo malo filozofsko, ampak sem prepričan, da se boste strinjali z mano, da se samo časa ne da nadomestiti. Saj poznate tisto: »Kaj bi …, če bi …, ko bi…!?« s pogledom, uprtim nazaj na prehojeno pot.

In tako je tudi ob razmišljanju ter pisanju uvodnikov za Geodetski vestnik minil moj mandat na položaju predsednika Zveze geodetov Slovenije. Ko sem pred štirimi leti gledal naprej, se je to zdelo izjemno dolgo obdobje, ko gledam nazaj, pa so minila kot utrinek. Priznati moram, da mi besedna zveza »moj mandat« ni preveč všeč, ker vključuje ednino in ne množine, kajti trdno sem prepričan, da brez vas, odličnih sodelavk in sodelavcev, posebna zahvala Erni in Anki, vsega tega dela ni bi opravili. To je ekipno delo.

Organizirali smo nekaj dogodkov, izdali malo več kot ducat številk Geodetskega vestnika, se nekajkrat srečali, postali bogatejši za nekaj modrosti in izkušenj, pa je čas minil. Ko štiri leta strneš v en stavek, se upravičeno vprašaš o zanesljivosti končnega rezultata. Kakor koli že, vožnja je bila nadvse razburljiva in prijetna. Iskrena hvala vsem, da smo lahko bili vaši sopotniki na tej poti.

No, ja, ker pravijo, da se na lastnih napakah največ naučiš in da se vedno najdeta čas ter prostor za izboljšave, sem kandidiral za nov mandat na mestu predsednika Zveze geodetov Slovenije. Hvala za ponovno izraženo zaupanje in podporo ter zaupano odgovornost, da bom skupaj z ekipo krmaril Zvezo geodetov Slovenije naslednja štiri leta.

Spoštovane geodetke in geodeti, Zveza geodetov Slovenije so ljudje, je ideja, je stroka, je stanovsko združenje, ki živi in deluje, zato ker jo vi napajate z energijo in zavedanjem, da je poslanstvo, ki ga opravljate, že stoletja nerazdružljivo povezano z družbo, pa čeprav tega zunanji opazovalci morda ne želijo priznati. Se mi sami tega dovolj močno zavedamo?

Srečno!

VREDNOTENJE POSTOPKOV ZA OCENJEVANJE TOČNOSTI GEOREFERENCIRANJA GEODETSKIH NAČRTOV

VALIDATION OF GEOREFERENCING ACCURACY ESTIMATION TECHNIQUES FOR GEODETIC PLANS

Nedim Tuno, Admir Mulahusić, Jusuf Topoljak, Dušan Kogoj

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IZVLEČEK

V raziskavi so kritično obravnavane tri tehnike za vrednotenje ocene položajne točnosti georeferenciranja, s čimer smo želeli oceniti možnosti ugotavljanja in odpravljanja geometrijskih deformacij rastrskih slik. Postopki vrednotenja, zasnovani na popravkih veznih točk, metodi testnega vzorca in navzkrižnem preverjanju, so izvedeni v programskem paketu PlanTra. Cenilke točnosti, pridobljene z navedenimi postopki ob uporabi različnih funkcionalnih modelov, so natančno raziskane na značilnem testnem območju. Dokazano je, da daje tehnika navzkrižnega preverjanja veliko zanesljivejše ocene točnosti kot standardni pristop, ki temelji na popravkih veznih točk.

ABSTRACT

Three validation techniques for performing positional accuracy assessments in georeferencing were critically reviewed in this study, with an aim of estimating the possibilities of identifying and removing the geometric deformations of raster images. A validation technique based on the residuals of tie points, Hold-Out and the Cross-Validation technique was implemented within PlanTra software. Accuracy indicators, obtained through these techniques, using different functional transformation models, were thoroughly tested on a typical area. It has been proven that the Cross-Validation technique produces a much more reliable estimation of accuracy in comparison to the standard approach based on the residuals of tie points.

KLJUČNE BESEDE

ocena položajne točnosti, georeferenciranje, navzkrižno preverjanje, RMSE

KEY WORDS

positional accuracy assessment, georeferencing, Cross-Validation, RMSE

1 UVOD

Osnovna zahteva uporabnikov vsakega proizvoda je poznavanje njegove sestave in kakovosti, s čimer se pravzaprav določa njegova uporabna vrednost. Od leta 1980 vse bolj raste zanimanje za prepoznavanje realne kakovosti prostorskih podatkov. K temu je najbolj pripomogel razvoj tehnologije GIS in daljinskega zaznavanja (Manzano-Agugliaro in sod., 2014). Po standardu ISO 19157 (2013) *Geographic information – Data quality* (Geografske informacije – kakovost podatkov) se kakovost prostorskih podatkov opisuje s šestimi elementi: popolnost, logična doslednost, položajna točnost, časovna točnost, tematska točnost in uporabnost. Med temi elementi največjo pozornost v znanstvenih krogih in širši skupnosti proizvajalcev in uporabnikov GIS-a vzbuja položajna točnost. Opredeljena je kot razlika med položajem izbranega objekta v modelu prostora in pravim položajem tega objekta na terenu, oziroma položajem, ki je določen iz drugega vira večje točnosti (Tucci in Giordano, 2011). Številne uradne institucije so objavile standarde in smernice za oceno kakovosti prostorskih podatkov (npr. STANAG 2215, 2002; Guidelines for Best …, 2008), v katerih so opisani postopki preizkušanja, razporeditev in število kontrolnih točk, način opisovanja in prikazovanja položajne točnosti in podobno.

Podatki, ki se nanašajo na pozicioniranje objekta v okviru geoinformacijskih sistemov, so najpogosteje pridobljeni iz zračnih posnetkov (satelitskih ali aerofotogrametričnih – letalskih) in razpoložljive kartografske dokumentacije. Upoštevanje geometrijskih popravkov in georeferenciranje rastrskih digitalnih slik (zračni posnetki ali skenirano karografsko gradivo) sta osnovna pogoja, ki zagotavljata pridobitev kakovostnih geometrijskih podatkov o prostoru. Kakovost prostorskih podatkov je torej odvisna od upoštevanja geometrijskih popravkov in kakovosti georeferenciranja rastrskih slik (Cuartero in sod., 2010; Manzano-Agugliaro in sod., 2014).

Oceno položajne točnosti zračnih posnetkov, načrtov in kart na podlagi neodvisnih kontrolnih točk so v svojih raziskavah uporabili Božić in Radojčić (2011), Govedarica in Borisov (2011), Kosmatin Fras in sod. (2014), Mesas-Carrascosa in sod. (2014) ter mnogi drugi avtorji. V teh delih je kakovost rastrskih podatkov ocenjena po izvedenem postopku georeferenciranja. Analizo položajne točnosti pa je nujno izvesti že v fazi priprave na georeferenciranje. Z izbiro ustreznega modela transformacije, ki bo zagotovil odstranitev lokalnih geometrijskih distorzij, bo dosežen najugodnejši rezultat. Za ta namen je najbolje uporabiti postopke vrednotenja kakovosti transformacijskih modelov, zasnovanih na kontrolnih točkah. Čeprav dajejo taki postopki najboljše rezultate, je v primerih, ko pogosto ni na voljo dovolj veliko število točk, njihova uporaba otežena.

Za geometrijsko korekcijo in georeferenciranje rastrskih prikazov kartografskih prikazov, pridobljenih s skeniranjem, ter zračnih posnetkov se uporabljajo vezne točke. Z veznimi točkami vzpostavimo zvezo med izvornim in ciljnim koordinatnim sistemom. Vezne točke morajo biti enakomerno razporejene po celotnem območju transformacije. Priporoča se, da jih je vsaj dvakrat več od minimalnega števila točk za izračun izbranega transformacijskega modela (Brovelli in Zamboni, 2006). Za uspešno transformacijo običajno potrebujemo veliko veznih točk. Pogosto uporabimo vse razpoložljive točke z znanimi koordinatami v izvornem in ciljnem koordinatnem sistemu. Iz niza vezanih točk ni mogoče izločiti kontrolnih točk, ki bi jih uporabili za oceno položajne točnosti georeferenciranja. Zaradi tega se položajna točnost georeferenciranih posnetkov ali kart oceni samo na podlagi preostalih odstopanj oziroma popravkov globalne transformacije na vseh veznih točkah. McGwire (1996) opozarja, da ima ta postopek niz pomanjkljivosti in da je tako pridobljena ocena položajne točnosti nerealna. Zato je predlagal, da se ocena točnosti satelitskih posnetkov, georeferenciranih s polinomsko transformacijo, opravi s postopkom navzkrižnega preverjanja. Navzkrižno preverjanje je svojevrsten hibrid postopkov, zasnovanih samo na kontrolnih in samo na veznih točkah. Ta postopek so kasneje pri obdelavi satelitskih posnetkov uporabili Giannone (2006), Brovelli in sod. (2008), Jeong in Bethel (2010) itd. Raziskavo kakovosti transformacije skenogramov starih katastrskih načrtov grafične izmere z navzkrižnim preverjanjem so izvedli Herrault in sod. (2013) ter Follin in sod. (2016).

Z raziskavo smo želeli preveriti sposobnost izbranih postopkov za vrednotenje ocene 2D- (horizontalne) točnosti georeferenciranja skeniranih geodetskih načrtov Bosne in Hercegovine (BiH), ki so nastali v novejšem času s terestrično numerično izmero in fotogrametrično izmero. Po vedenju avtorjev celovite raziskave, ki bi obravnavale to problematiko, še niso bile objavljene. Poseben poudarek v raziskavi je preveriti, s kolikšno zanesljivostjo dobljene cenilke točnosti diagnosticirajo odpravo distorzij, ki so posledica deformacije nosilca načrta in nepravilnosti skeniranja glede na uporabljeni model transformacije. Pri tem so obravnavani transformacijski algoritmi, ki so vgrajeni v danes najbolj uporabne programske rešitve CAD in GIS za geometrijsko obdelavo rastrskih digitalnih slik, ki jih ponujajo Autodesk (2009), ESRI (2016) in drugi. Z analizo dobljenih cenilk točnosti skušamo poiskati način, s katerim bomo za potrebe izgradnje geoinformacijskih sistemov na podlagi obstoječega analognega kartografskega gradiva zagotovili zanesljivo diagnostiko položajne kakovosti prostorskih podatkov. Raziskava izhaja iz potrebe po spremembi sedanje geometrijske obdelave skeniranih načrtov, saj se v BiH intenzivno izvaja georeferenciranje obstoječih geodetskih načrtov (Federalna uprava za …, 2016).

2 METODE IN RAZISKOVALNO GRADIVO

2.1 Postopki ocene položajne točnosti

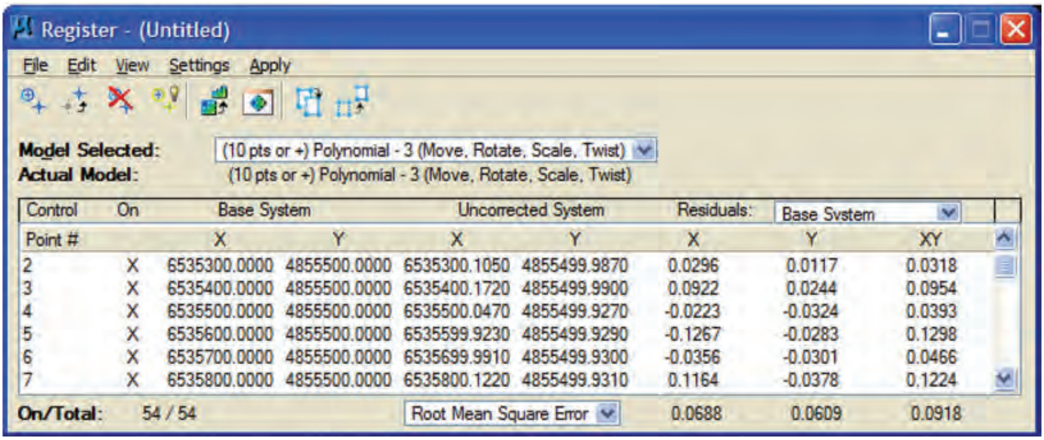
Za oceno položajne točnosti se uporabljajo različni statistični kazalniki, kot so standardni pogrešek (angl. *standard error – SE*), standardna deviacija (angl. *standard deviation – SD*), povprečni pogrešek (angl. *mean error – ME*), srednji standardizirani pogrešek (angl. *mean standardized error – MSE*), koren srednjega kvadratnega standardiziranega pogreška (angl. *root mean square standardized error – RMSS*) itd. (Soycan, 2013). Najpogosteje uporabljena cenilka položajne točnosti je koren srednjega kvadratnega pogreška (angl. *root mean squared error – RMSE*) (Congalton in Green, 2008). *RMSE* je kvadratni koren srednje vrednosti vsote kvadratov razlik transformiranih koordinat točk, izmerjenih v skupini, katere točnost se ocenjuje, in odgovarjajočih pravih vrednosti koordinat. Če obravnavamo 2D-podatke, dobimo na podlagi vrednosti razlik koordinat v smeri koordinatnih osi y in x horizontalni *RMSE* celotnega obravnavanega vzorca (Tuno in sod., 2017). Vrednost *RMSE* se določi na več načinov, ki so predstavljeni v nadaljevanju.

2.1.1 *RMSE* popravkov veznih točk

Standardni postopek ocene kakovosti zmanjšanja geometrijskih distorzij rastrskih kartografskih grafičnih prikazov zahteva določitev *RMSE* na podlagi popravkov (preostalih odstopanj transformacije) veznih točk, ki so uporabljene za transformacijo (McGwire, 1996). Popravki v smeri koordinatnih osi (r_y in r_x) so rezultat izravnave po metodi najmanjših kvadratov, katere cilj je določitev parametrov transformacije na podlagi nadštevilnih veznih točk. *RMSE* je tu mera za odstopanje vrednosti transformiranih koordinat veznih točk od njihovih teoretičnih vrednosti:

$$RMSE_{\text{res}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} r_{xy_i}^2}\ ;\ r_{xy} = \sqrt{r_x^2 + r_y^2} \tag{1}$$

Postopek ocene je enostaven, programske rešitve za georeferenciranje običajno omogočajo prikaz vrednosti $RMSE_{res}$, njegovih komponent po koordinatnih oseh in popravke na posameznih točkah takoj po vnosu koordinat vseh veznih točk itd. (slika 1). V nekaterih državah uradni tehnični normativi za georeferenciranje katastrskih načrtov predpisujejo merila točnosti transformacije (Mađarac, 2017), ki temeljijo na popravkih veznih točk. Predpisi in programska oprema za georeferenciranje običajno spodbujajo k izločanju točk, pri katerih so vrednosti popravkov nesprejemljivo velike, iz transformacijskega modela. Na prvi pogled se to lahko zdi razumna rešitev, vendar z njo velikokrat dosežemo nasprotni učinek. Z izločanjem točk se namreč pogosto zmanjša kakovost prileganja transformacijske ravnine v okolici izločene točke (Mather, 2004). Pomanjkljivost tega postopka je tudi, da vezne točke niso neodvisne od koeficientov transformacije (McGwire, 1996), še bolj problematično pa je, da postopka ni mogoče uporabiti za oceno točnosti globalnih lokalno občutljivih transformacij in lokalnih transformacij (McGwire, 1998).



Slika 1: Programsko okolje orodja za georeferenciranje s prikazanimi vrednostmi *RMSE* in preostalim odstopanjem na veznih točkah po transformaciji.

2.1.2 *RMSE* odstopanj koordinat kontrolnih točk

Položajno točnost najzanesljiveje ocenimo na podlagi kontrolnih točk. Koordinate teh točk določimo s terensko izmero ali pa jih prevzamemo iz drugih neodvisnih baz podatkov. Določene so z večjo točnostjo kot podatki, ki jih testiramo; obravnavamo jih kot referenčne, pogojno točne. Velikost vzorca kontrolnih točk mora zagotavljati statistično zanesljiv rezultat, ob večjem vzorcu bo zanesljivost ocene večja. Običajno se zahteva 20 enakomerno razporejenih kontrolnih točk na enem listu karte ali posnetka (Congalton in Green, 2008).

V statistiki je ta postopek ocene poznan kot metoda testnega vzorca (angl. *hold-out validation* – HOV). Skupino razpoložljivih točk z znanimi koordinatami v izvornem in ciljnem koordinatnem sistemu razdelimo na dve med seboj neodvisni podskupini z naključno razdelitvijo točk: podskupino točk za učenje modela (vezne točke) in podskupino točk za testiranje modela (kontrolne točke). Pri tem v posamezni skupini poskušamo zagotoviti enakomerno razporejenost točk po celotnem območju. Skupino veznih točk uporabimo za določitev parametrov transformacijskega modela, njegovo točnost pa ocenimo z nizom kontrolnih točk. Vrednost *RMSE* dobimo na podlagi razlik vrednosti transformiranih in referenčnih koordinat kontrolnih točk d_y in d_x:

$$RMSE_{\mathrm{HOV}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} d_{xy_i}^2}\,;\; d_{xy} = \sqrt{d_x^2 + d_y^2} \tag{2}$$

Ocena HOV je zelo enostavna in preprosta za računanje, vendar daje slabe rezultate, če je elementov v skupini podatkov za testiranje (kontrolnih točk) malo (Giannone, 2006).

2.1.3 *RMSE* na podlagi navzkrižnega preverjanja

Postopek *k*-kratnega navzkrižnega preverjanja (angl. *k-fold cross validation* – CV) zahteva, da *n* primerov v skupini podatkov *S* razdelimo na *k* podskupin enake velikosti. Algoritem za učenje učimo na *k* – 1 podskupinah, testiramo pa na eni preostali. To se ponovi *k*-krat, vsakič s testiranjem na drugi podskupini. S tem pridobimo *k* ocen, njihovo povprečje pa predstavlja končno vrednost cenilke položajne točnosti (Brovelli in sod., 2008). Po Japkowitzu in Shahu (2011) je psevdokoda navzkrižnega preverjanja videti takole:

```
Razdeli razpoložljivo skupino podatkov S velikosti n na k podskupin Si, i = 1, 2, ... , k
velikosti približno n/k i brez prekrivanja;
Inicializiraj i = 1;
Ponavljaj, dokler je i <= k;
        Označi i-to podskupino Si kot testno skupino;
        Za testno skupino Si generiraj komplement trening skupine Si, ki vsebuje vse
        primere iz S razen tistih v Si;
        Treniraj algoritem učenja na Si in testiraj na Si;
        Izračunaj empirično tveganje Remp(fi) klasifikatorja fi;
        Povečaj za 1;
Izračunaj povprečni Remp(fi) za vse i, tako da dobiš Remp(f), povprečno empirično tveganje
k-kratnega CV;
Prikaži Remp(fi);
```

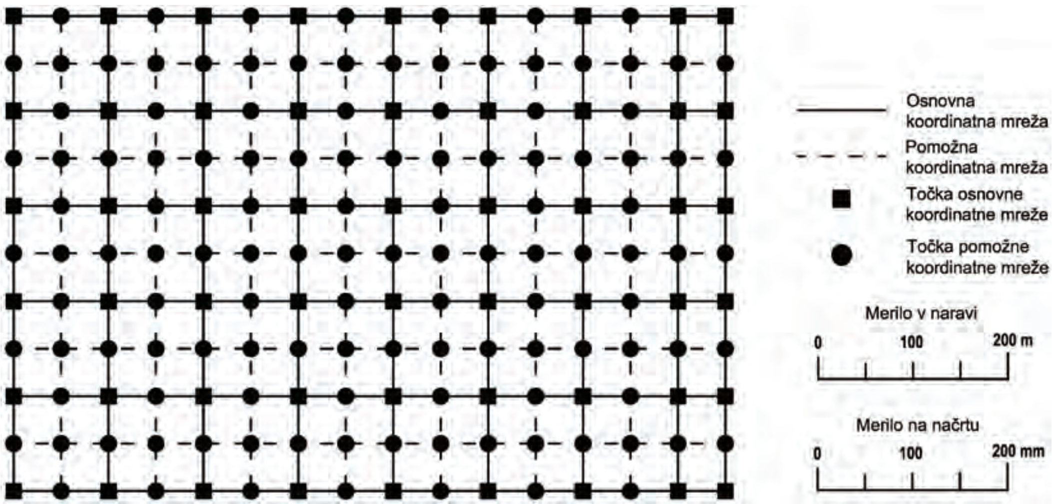
Mejni primer CV za *k* = *n* je posamezno navzkrižno preverjanje (angl. *leave-one-out-cross-validation* – LOOCV). Pri tej oceni se model generira z uporabo *n* – 1 elementov skupine *S*, testira pa se na enem preostalem elementu. Postopek se ponavlja *n*-krat, tako da se vsak element originalnega vzorca uporabi enkrat kot element za testiranje (Giannone, 2006). Vrednost *RMSE* za oceno točnosti georeferenciranja se določi iterativno. Postopek se prične z izločitvijo prve vezne točke iz transformacijskega modela in računanjem parametrov transformacije na podlagi vseh preostalih točk. Na podlagi dobljenih parametrov se izračunajo transformirane koordinate prve točke in njihova odstopanja od teoretičnih vrednosti. Prva točka, ki je bila uporabljena kot psevdokontrolna točka v prvi iteraciji, se vrača v model in opisani postopek se ponovi za vse preostale vezne točke (McGwire, 1996). Skupna točnost georeferenciranja na podlagi ocene LOOCV znaša:

$$RMSE_{\mathrm{LOOCV}} = \sqrt{\frac{\sum_{i=1}^{n}\left(f\left(\hat{x}_i\right) - x_i\right)^2}{n}} \tag{3}$$

kjer je referenčna vrednost *i*-te točke in $f\left(\hat{x}_i\right)$ transformirana vrednost *i*-te točke na podlagi transformacijske funkcije, izračunane ob izločitvi *i*-te točke (Chuvieco, 2016). Postopek navzkrižnega preverjanja LOOCV je robusten in zanesljiv, ni odvisen od izbire skupin točk in omogoča, da je vsaka vezna točka hkrati kontrolna točka (Brovelli in sod., 2008).

2.2 Testno gradivo – geodetski načrti

V raziskavi so obdelani skenirani listi geodetskih načrtov merila 1 : 1000, na katerih je prikazan del ožjega mestnega območja Sarajeva, BiH. Načrti so izdelani s fotogrametrično (aerofotogrametrija) in numerično ortogonalno metodo. Izmero je leta 1968 izvedel tedanji Geodetski zavod Sarajevo. Podroben opis načrtov mesta Sarajeva so predstavili Tuno in sod. (2015). Za analizo položajne točnosti je izbranih 14 listov načrtov, ki poleg mreže s kvadrati dimenzij 100 mm × 100 mm in pravokotniki dimenzij 50 mm × 100 mm vsebujejo pomožno koordinatno mrežo s kvadrati dimenzij 50 mm × 50 mm (slika 2). Točke koordinatne mreže imajo znane koordinate v izvornem koordinatnem sistemu skeniranega načrta in teoretične koordinate v državnem koordinatnem sistemu. Na podlagi teh točk se v uradnih projektih digitalizacije georeferencirajo bosansko -hercegovski katastrski načrti (Tuno in sod., 2017). Ravno zato sta formiranje transformacijskih modelov in raziskava položajne točnosti v naši raziskavi izvedena prav na podlagi točk koordinatne mreže. V izračune je vključeno skupaj 4172 točk (1708 točk osnovne koordinatne mreže in 2464 točk pomožne koordinatne mreže).

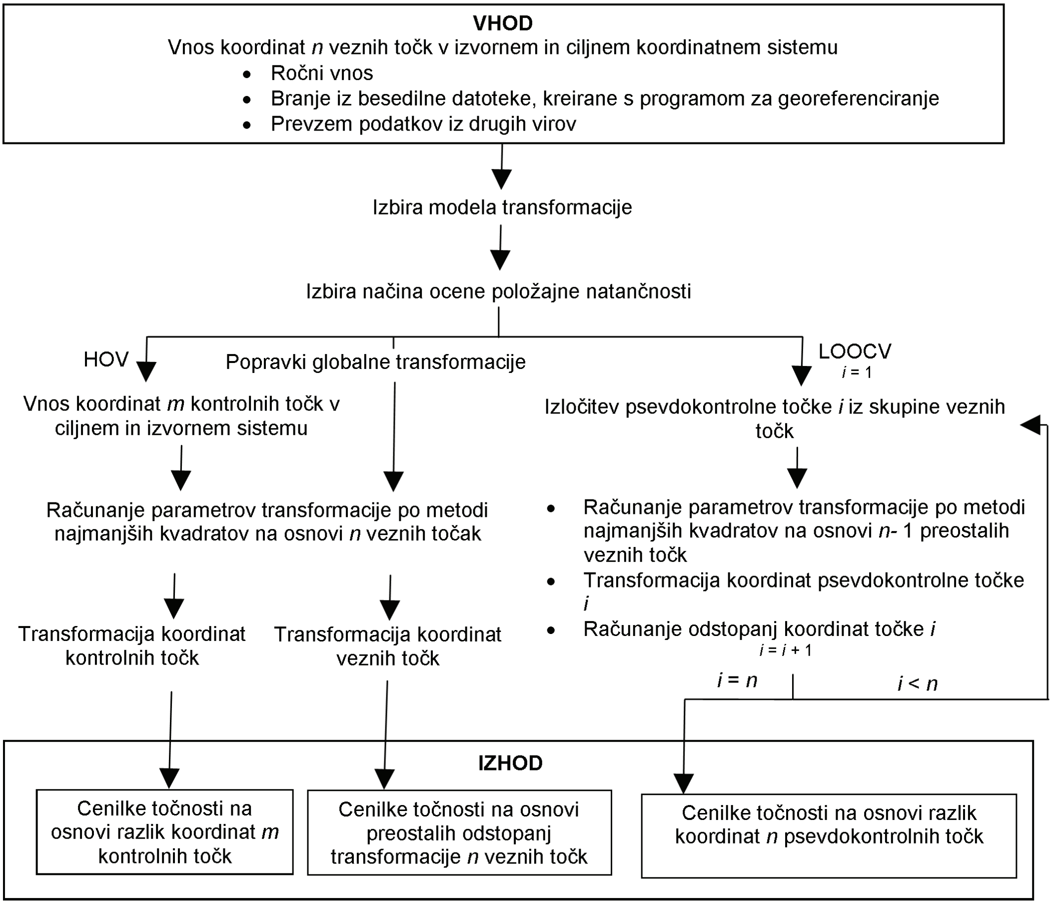


Slika 2: Osnovna in pomožna koordinatna mreža na listu načrta v merilu 1 : 1000.

2.3 Programska rešitev v PlanTra

Danes obstaja veliko posebnih programskih rešitev, ki omogočajo oceno točnosti georeferenciranja rastrskih podatkov s HOV in LOOCV, na primer programski paket SISAR, razvit v Italiji (Brovelli in sod., 2008). Ker avtorji za namen te raziskave niso imeli dostopa do teh programskih paketov, je bilo treba nadgraditi obstoječi programski paket PlanTra, ki je bil razvit na Gradbeni fakulteti Univerze v Sarajevu (Tuno in sod., 2015 in 2017). PlanTra je namenjen podpori za georeferenciranje s standardnimi programskimi paketi (Autodesk Raster Design, Bentley Descartes, Esri ArcGIS in podobno). Nadgrajeni PlanTra omogoča oceno točnosti uporabljenih transformacijskih modelov s postopkoma HOV in LOOCV.

Programi za georeferenciranje omogočajo, da se po določitvi identičnih točk rastra v izvornem koordinatnem sistemu njihove koordinate zapišejo v posebno tekstovno datoteko. To datoteko prebere program PlanTra, ki izračuna vse ustrezne cenilke položajne točnosti georeferenciranja (slika 3).



Slika 3: Diagram poteka programske rešitve ocene HOV in LOOCV v PlanTra.

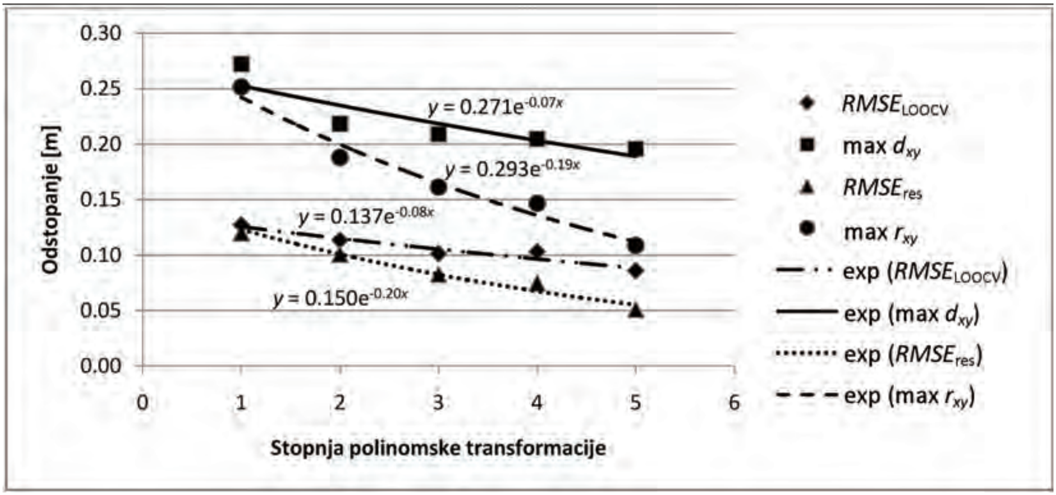
3 REZULTATI IN RAZPRAVA

V obravnavani raziskavi so uporabljeni modeli Helmertove, afine in projektivne transformacije, polinomskih transformacij višjih stopenj ter transformacije po načelih tankoslojnega zlepka (angl. *thin plate spline* – TPS). Navedene transformacije so uporabljene na vsakem izmed 14 listov izbranih načrtov. Pri tem so transformacijski parametri opredeljeni na podlagi veznih točk osnovne koordinatne mreže (54 točk na vsakem listu načrta). Točke osnovne koordinatne mreže so bile uporabljene za oceno točnosti georeferenciranja po postopku preostalega odstopanja transformacije (popravkov) in postopku LOOCV. Ocena točnosti postopka HOV je izvedena z uporabo kontrolnih točk pomožne koordinatne mreže (122 točk na vsakem listu načrta). To je smiselno, saj sta pri izdelavi načrta glavna in pomožna koordinatna mreža kartirani hkrati in z enako točnostjo. Obseg tega članka ne dopušča prikaza in razlage vseh dobljenih cenilk točnosti, zato v prispevku analiziramo le vrednosti $RMSE_{res}$, $RMSE_{LOOCV}$ in $RMSE_{HOV}$, popravke veznih točk ter razlike koordinat psevdokontrolnih in kontrolnih točk.

3.1 Cenilke položajne točnosti georeferenciranja načrtov z uporabo globalnih transformacij

Pri globalnih transformacijah eliminacija ali zmanjševanje geometrijskih distorzij vsebine načrta poteka po istih pravilih, to je z uporabo istih parametrov transformacije za celotno površino lista. Uporabljene so bile enostavne transformacije (Helmertova, projektivna in afina), pa tudi polinomske transformacije 2., 3., 4. in 5. stopnje. Teorija uporabljenih transformacijskih modelov je opisana v strokovni literaturi, na primer v P. Yadav in A. Yadav (2009).

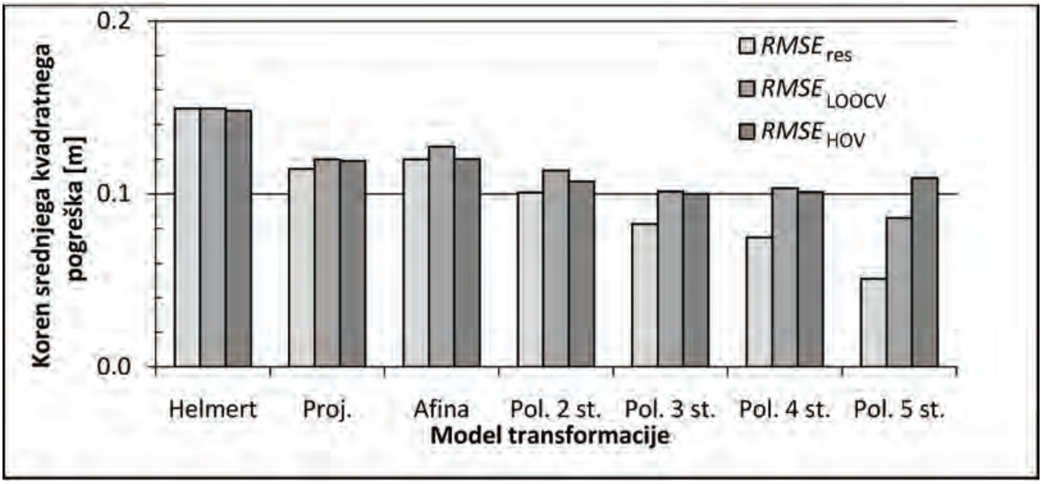
Teoretične vrednosti koordinat točk koordinatne mreže so prave vrednosti, razlike s transformiranimi vrednostmi koordinat lahko zato obravnavamo kot prave pogreške. To je temelj za oceno točnosti. Primerjava cenilk točnosti georeferenciranja, pridobljenih na podlagi popravkov in postopka LOOCV, je za polinomske modele transformacij prikazana na sliki 4.



Slika 4: Trendi povprečnih vrednosti ***RMSE*** in največjih položajnih odstopanj, pridobljenih iz ocene točnosti na podlagi popravkov in s postopkom LOOCV, za izbrane stopnje polinomskih transformacij.

S slike 4 je razvidno, da je mogoče trend sprememb povprečnih vrednosti *RMSE* in največjega odstopanja dobro modelirati z eksponentnimi funkcijami. Kadar so cenilke točnosti dobljene na podlagi popravkov veznih točk, se s povečanjem stopnje polinoma izrazito zmanjšajo vrednosti obravnavanih cenilk. To je najbolj opazno pri največjih popravkih. Pri vseh obravnavanih listih načrtov so zato doseženi najboljši rezultati z uporabo polinomske transformacije 5. stopnje.

V nasprotju z oceno točnosti transformacije na podlagi popravkov, kjer se zaradi povečanja stopnje polinoma vrednost $RMSE_{res}$ zmanjša za približno 2,5-krat, pri oceni LOOCV očitno ni tako. Povprečne vrednosti $RMSE_{LOOCV}$ so mnogo bolj izenačene in se gibljejo v intervalu od 86 mm do 127 mm. Podoben trend opisujejo vrednosti največjih popravkov. V tem primeru se povečanje stopnje polinoma odrazi v minimalnem izboljšanju točnosti transformacije. Večanje stopnje polinoma povzroči vse večje neskladje vrednosti $RMSE_{res}$ in $RMSE_{LOOCV}$. Tako so vrednosti $RMSE_{res}$ afine transformacije (polinomska transformacija 1. stopnje) v povprečju manjše od ustreznih vrednosti $RMSE_{LOOCV}$ za 5 %, pri polinomski transformaciji 5. stopnje pa ta razlika znaša kar 40 %.



Slika 5: Povprečne vrednosti ***RMSE***, dobljene z različnimi načini vrednotenja za različne modele globalnih transformacij.

Slika 5 prikazuje povprečne vrednosti cenilk točnosti vseh uporabljenih transformacijskih modelov in vseh izvedenih načinov ocene točnosti. Razvidno je, da dajejo vsi uporabljeni postopki ocene pri enostavnih transformacijah zelo podobne rezultate. Izrazite razlike se pojavijo pri polinomskih transformacijah višjih stopenj, največje neskladje pa je očitno pri transformacijskem modelu, zasnovanem na polinomu 5. stopnje. Ob upoštevanju razporeditve, števila in točnosti kontrolnih točk lahko trdimo, da so najobjektivnejše cenilke točnosti georeferenciranja v raziskavi dosežene s postopkom HOV.

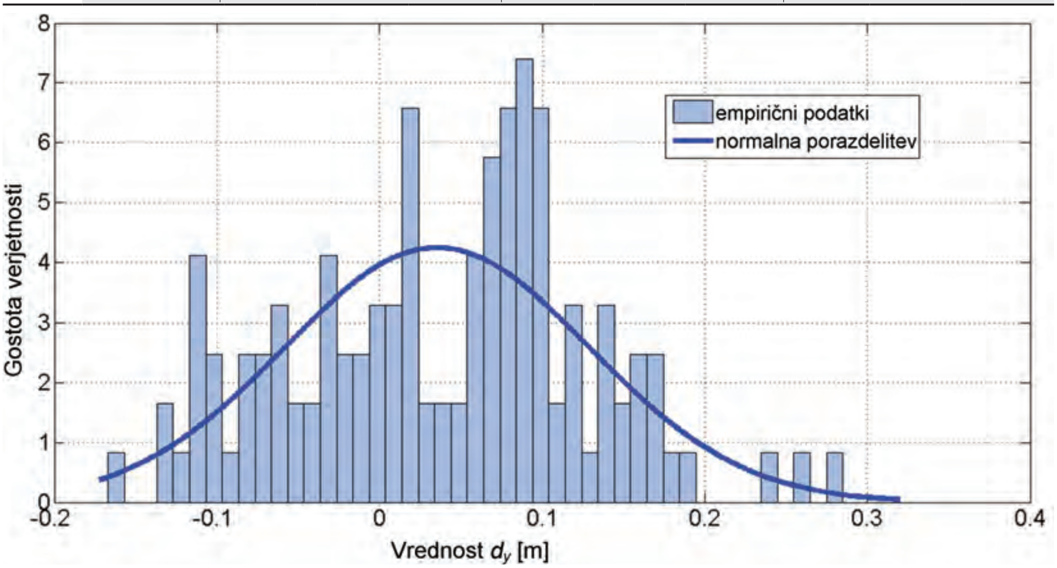
Iz primerjave povprečnih vrednosti cenilk točnosti polinomske transformacije 5. stopnje je razvidno, da je vrednost $RMSE_{res}$ za 53 %, vrednost $RMSE_{LOOCV}$ pa za 21 % manjša od vrednosti $RMSE_{HOV}$. Pri polinomskih transformacijah 3. in 4. stopnje je $RMSE_{res}$ prav tako manjša od $RMSE_{HOV}$, so pa vrednosti $RMSE_{LOOCV}$ in $RMSE_{HOV}$ skoraj enake. To kaže, da je mogoče s postopkom LOOCV pri teh transformacijskih modelih pridobiti zelo realne cenilke točnosti georeferenciranja, kar pa ne velja za polinomsko transformacijo 5. stopnje.

Primerjava točnosti globalnih transformacij, ocenjenih s postopkom HOV, vseh listov načrtov kaže, da so pri načrtih z izrazitejšimi deformacijami najboljši rezultati doseženi s polinomsko transformacijo 4. stopnje, pri načrtih z manjšimi deformacijami pa najboljše rezultate daje afina transformacija. Niti v enem primeru ni polinomska transformacija 5. stopnje zagotovila najboljših rezultatov, prav ta transformacijski model pa je uporabljen za georeferenciranje obravnavanih listov načrtov v okviru uradnega državnega projekta digitalizacije (Angermeier Sarajevo, 2006).

Z georeferenciranjem načrtov v uradnih državnih projektih poskušamo izpolniti predpisano merilo, ki velja za katastrske načrte v postopku georeferenciranja. Vrednost $RMSE_{res}$ mora biti manjša od 0,10 mm × M, kjer je M modul merila kartiranja načrta (Tuno in sod., 2017). Ker polinomska transformacija 5. stopnje najbolje izpolnjuje zahtevano merilo, je bil za georeferenciranje načrtov sprejet ta model. Z natančnejšim vpogledom v rezultate te transformacije pa ugotovimo, da z njeno uporabo na posameznih listih načrta izzovemo velika položajna odstopanja, kar se pri drugih modelih transformacije ne zgodi. Veliko boljše rezultate lahko dosežemo z uporabo drugih transformacijskih modelov. Tako na primer statistične cenilke točnosti za list načrta SA170 (preglednica 1), pridobljene s postopkoma LOOCV in HOV, jasno kažejo, da je po izvedeni transformaciji po polinomskem modelu 5. stopnje opazno prisotna nehomogena točnost vsebine georeferenciranega načrta. Distorzije sistematičnega izvora niso odpravljene. To potrjuje tudi histogram preostalih distorzij v smeri osi *y*, kot tudi ustrezna krivulja normalne porazdelitve, ki ustrezajo empiričnim podatkom, pridobljenim z oceno HOV (slika 6). Na sliki se jasno vidi zamik krivulje normalne porazdelitve zaradi preostalih sistematičnih pogreškov, ki jih glede na točnost izdelave koordinatne mreže ni mogoče zanemariti. Cenilke točnosti, dobljene z oceno točnosti na podlagi popravkov (preglednica 1), več kot očitno kažejo zelo popačeno sliko o dejanski točnosti transformiranega načrta.

Preglednica 1: Statistike odstopanj za list načrta SA170, pridobljene s polinomsko transformacijo 5. stopnje

Cenilka		Popravki			LOOCV			HOV		
		r_y	r_x	r_{xy}	d_y	d_x	d_{xy}	d_y	d_x	d_{xy}
Minimum [m]		–0,183	–0,052	0,002	–0,293	–0,088	0,004	–0,320	–0,131	0,012
Sredina [m]		0,000	0,000	0,073	–0,009	0,002	0,121	–0,035	0,014	0,107
Maksimum [m]		0,169	0,068	0,184	0,281	0,112	0,300	0,172	0,175	0,321
Razpon [m]		0,352	0,120	0,181	0,574	0,201	0,296	0,492	0,306	0,310
***RMSE* [m]**		0,085	0,024	0,089	0,139	0,039	0,144	0,100	0,066	0,120
Porazdelitev odstopanj %	**|0–5| cm**	44,4	94,4	40,7	22,2	75,9	22,2	28,7	54,1	12,3
	|5–10| cm	31,5	5,6	33,3	31,5	22,2	27,8	40,2	31,1	36,9
	|10–15| cm	13,0	0,0	14,8	18,5	1,9	18,5	20,5	13,9	32,8
	|15–20| cm	11,1	0,0	11,1	7,4	0,0	9,3	7,4	0,8	12,3
	|20–25| cm	0,0	0,0	0,0	13,0	0,0	14,8	0,8	0,0	3,3
	>|25| cm	0,0	0,0	0,0	7,4	0,0	7,4	2,5	0,0	2,5



Slika 6: Histogram in krivulja normalne porazdelitve razlik teoretičnih in transformiranih *y*-koordinat točk pomožne koordinatne mreže lista načrta SA 170.

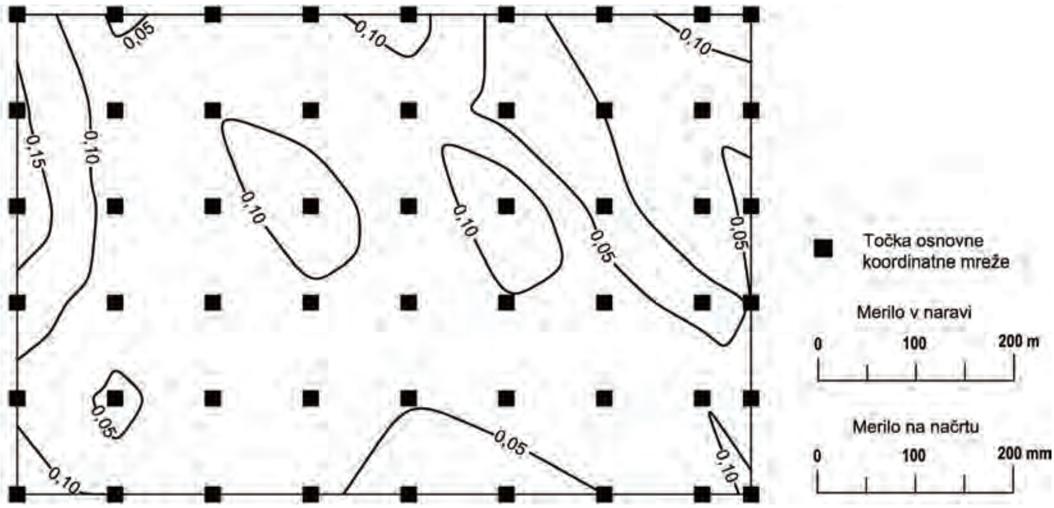
3.2 Položajna točnost georeferenciranja načrtov z lokalno občutljivo transformacijo

Pri lokalno občutljivih transformacijah vezne točke po transformaciji ohranijo svoje teoretične vrednosti koordinat, zato za oceno položajne točnosti ni mogoče uporabiti ocene na podlagi popravkov. Tako sta v tej raziskavi za oceno točnosti lokalnih transformacij uporabljena postopka LOOCV in HOV, raziskan pa je transformacijski model TPS. Podrobneje so ga predstavili Tuno in sod. (2017). Rezultati ocene točnosti transformacije TPS s pomočjo psevdokontrolnih in kontrolnih točk koordinatne mreže so prikazani v preglednici 2. Rezultati ocene HOV kažejo, da daje transformacija TPS v povprečju boljše rezultate kot globalne transformacije. Če obravnavamo kakovost transformacij v okviru posameznih listov načrtov, ugotovimo, da dosežemo z uporabo transformacije TPS najboljšo točnost za 86 % načrtov, za preostale liste pa daje boljše rezultate afina transformacija. S postopkom navzkrižnega preverjanja v primerjavi z uporabo kontrolnih točk pridobimo bolj optimistično oceno položajne točnosti. Povprečna vrednost $RMSE_{LOOCV}$ je za 8 % manjša od povprečne vrednosti $RMSE_{HOV}$, največje položajno odstopanje pa je pri oceni LOOCV manjše za 22 %. Z navzkrižnim preverjanjem je torej mogoče dovolj zanesljivo napovedati točnost georeferenciranja načrtov z modelom TPS.

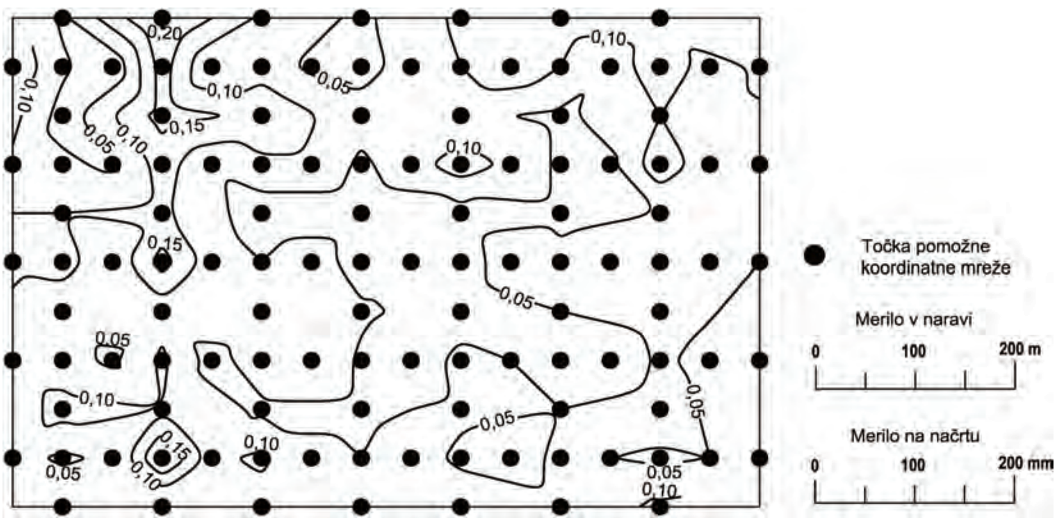
Preglednica 2: Cenilke točnosti georeferenciranja načrtov z uporabo transformacijskega modela TPS.

Oznaka lista načrta	LOOCV						HOV					
	$RMSE_r$	max d_{xy}	Porazdelitev d_{xy} [%]				$RMSE_r$	max d_{xy}	Porazdelitev d_{xy} [%]			
	[cm]		|0 - 10| cm	|10 – 20| cm	|20 – 30| cm	|> 30| cm	[cm]		|0 - 10| cm	|10 – 20| cm	|20 – 30| cm	|> 30| cm
SA 111	9,8	17,8	59,3	40,7	0,0	0,0	9,4	21,5	75,4	23,0	1,6	0,0
SA 112	6,7	13,1	87,0	13,0	0,0	0,0	7,7	19,5	82,0	18,0	0,0	0,0
SA130	7,2	14,4	87,0	13,0	0,0	0,0	8,5	20,8	77,9	21,3	0,8	0,0
SA 131	9,0	19,3	77,8	22,2	0,0	0,0	8,0	22,2	82,0	16,4	1,6	0,0
SA 132	8,7	19,4	75,9	24,1	0,0	0,0	8,1	17,2	77,0	23,0	0,0	0,0
SA 149	6,6	18,9	92,6	7,4	0,0	0,0	8,6	21,7	73,0	25,4	1,6	0,0
SA 150	8,0	14,7	77,8	22,2	0,0	0,0	8,9	25,5	79,5	18,0	2,5	0,0
SA 168	9,4	18,5	64,8	35,2	0,0	0,0	8,8	33,8	77,9	21,3	0,0	0,8
SA 169	9,7	18,3	68,5	31,5	0,0	0,0	11,5	29,7	58,2	32,8	9,0	0,0
SA 170	11,0	26,7	64,8	29,6	5,6	0,0	9,4	19,4	63,1	36,9	0,0	0,0
SA 189	8,9	18,6	79,6	20,4	0,0	0,0	8,4	21,2	78,7	19,7	1,6	0,0
SA 190	9,2	18,2	74,1	25,9	0,0	0,0	8,2	22,9	84,4	13,1	2,5	0,0
SA 211	7,7	14,8	81,5	18,5	0,0	0,0	12,5	25,5	46,7	45,1	8,2	0,0
SA 212	6,8	17,6	83,3	16,7	0,0	0,0	10,8	20,7	60,7	38,5	0,8	0,0
Povprečje	**8,5**	**17,9**	**76,7**	**22,9**	**0,4**	**0,0**	**9,2**	**23,0**	**72,6**	**25,2**	**2,2**	**0,1**

Grafična predstavitev kakovosti transformacije TPS (sliki 7 in 8) z izolinijami enakih preostalih odstopanj d_{xy} daje možnost za oceno ravninske porazdelitve geometrijske točnosti georeferenciranja, določene s postopkoma LOOCV in HOV.



Slika 7: Preostale deformacije d_{yx} na listu SA189, ocenjene s postopkom LOOCV (izolinije z ekvidistanco 0,05 m).



Slika 8: Preostale deformacije d_{yx} na listu SA189, ocenjene s postopkom HOV (izolinije z ekvidistanco 0,05 m).

Porazdelitev preostalih odstopanj d_{xy}-točk kontrolne mreže kaže, da so po transformaciji na načrtu prisotne neenakomerne in neenakomerno porazdeljene lokalne distorzije, katerih velikost je v mejah pričakovanih vrednosti. V predstavljenem primeru ponuja ocena HOV boljše možnosti za opis realnih lokalnih geometrijskih lastnosti transformiranega načrta kot ocena LOOCV. Prikaz lokalnih distorzij je pri oceni HOV podrobnejši. Razlog za to je večje število identičnih točk, vključenih v oceno (LOOCV 54 točk, HOV 122 točk).

4 SKLEP

Zelo pomemben segment georeferenciranja skeniranih geodetskih načrtov je ocena položajne točnosti transformirane vsebine načrta. Kakovost transformacije se običajno opisuje z vrednostjo $RMSE_{res}$, izračunano iz popravkov veznih točk v okviru postopka georeferenciranja. Predstavljena raziskava je pokazala, da daje ta način ocene v nekaterih primerih neobjektivne rezultate. To se zgodi predvsem, če so uporabljene polinomske transformacije višjih stopenj ali če so na skeniranem načrtu prisotne lokalno hitro spreminjajoče se distorzije. Z globalnim transformacijskim modelom v tem primeru ne moremo zajeti kompleksne porazdelitve sistematičnih vplivov.

Rezultati raziskave nedvoumno kažejo, da je mogoče s postopkom LOOCV zagotoviti veliko realnejšo oceno položajne točnosti. Postopek LOOCV ponudi kakovostnejši vpogled v učinke različnih stopenj polinomskih transformacij, kjer je mogoče slediti spremembam vrednosti popravkov na psevdokontrolnih točkah v odvisnosti od uporabljene stopnje polinoma. Zelo pomembno je, da lahko s postopkom LOOCV ocenjujemo položajno točnost tudi ob uporabi lokalnih transformacij.

Algoritem za računanje $RMSE_{\mathrm{LOOCV}}$ in odstopanj koordinat psevdokontrolnih točk običajno ni vključen v standardno programsko opremo za obdelavo rastrskih slik. Najzanesljivejši način za ocenjevanje kakovosti georeferenciranja načrtov je zasnovan na postopku HOV, če obstaja dovolj kontrolnih točk. Zaradi obsega dela in dodatnih materialnih stroškov se ta način ocene v praski uporablja redkeje. Zato se kot sprejemljivejši postopek vrednotenja horizontalne točnosti georeferenciranja načrtov ponuja ocena LOOCV. Z njo pridobimo cenilke točnosti za vsak list načrta. S tem je omogočeno dovolj zanesljivo sprejemanje odločitev o izbiri funkcionalnega modela transformacije, izločanju grobo pogrešenih veznih točk in podobno.

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ALTERNATIVNA METODA TESTIRANJA PREMIKOV V GEODETSKI MREŽI

AN ALTERNATIVE APPROACH TO TESTING DISPLACEMENTS IN A GEODETIC NETWORK

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V geodeziji s postopki statističnega testiranja hipotez z ocenjevanjem in testiranjem značilnih parametrov ugotavljamo izpolnjevanje nekaterih kriterijev in zahtev pri merskih in računskih postopkih. V praksi so se za presojo značilnih premikov uveljavili nekateri kriteriji, ki testno statistiko primerjajo s konstantama $T_{crit} = 3$ ali $T_{crit} = 5$. V članku predlagamo alternativni postopek za določitev empirične porazdelitvene funkcije s simulacijami v 2D- in 3D-geodetski mreži, saj se testna statistika $T = d/\sigma_d$ ne porazdeljuje po nobeni od znanih porazdelitvenih funkcij. Kritična vrednost je spremenljivka, ki pri različni dimenziji mreže ob enakem tveganju ni enaka. Na več testnih primerih pokažemo, da je kritično vrednost T_{crit} mogoče izračunati natančneje, kar zagotavlja zanesljivo ugotavljanje značilnih premikov glede na izbrano stopnjo značilnosti testa. V vseh testnih primerih T_{crit} doseže vrednost 3 pri tveganju, ki je manjše od 1 % za poljubno dimenzijo mreže. Če ocenimo, da je sprejemljivo tveganje 5 %, je kritična vrednost bistveno manjša od 3 ali 5. Značilne premike je torej smiselno obravnavati glede na sprejemljivo tveganje in ne glede na približno ocenjeno kritično vrednost.

ABSTRACT

In geodesy, statistical testing aids in determining the extent to which the criteria and requirements needed in the measurement and calculation proceedings have been fulfilled. A "rule of thumb" method that compares test statistics to constants $T_{crit} = 3$ or $T_{crit} = 5$ has been established. The test statistic T is the ratio between the displacement and its precision. Since it is not distributed through any of the known distribution functions, (statistical) simulations are used to assess the empirical distribution in 2D and 3D geodetic networks. The proposed alternative procedure leads to a more precise detection of significant displacements at a given test significance level α. Regardless of the network's dimensionality, T_{crit} obtains the value of 3 at a risk level below 1%. When 5% is considered to be an acceptable risk level, the critical value can be lower than 3 or 5. Thus, significant displacements should be considered with regard to the acceptable risk level and not according to the usual "rule of thumb".

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statistično testiranje hipotez, stopnja značilnosti, simulirana porazdelitvena funkcija, kritična vrednost, dejansko tveganje, premiki točk

KEY WORDS

statistical hypothesis testing, significance level, simulated distribution function, critical value, actual risk, point displacement

1 INTRODUCTION

In their research, professionals working in the field of geosciences (civil engineers, geologists, miners and others) define the expected displacements. Surveyors can determine the actual displacements based on field measurements such as Marjetič et al. (2012), Kregar et al. (2015), and asses their accuracy using the statistical methodology such as Kregar et al. (2012), Urbančič et al. (2016). This task can also be reversed. We can define the threshold that determines whether the displacement is significant or not with respect to the displacement determination accuracy, which is obtained through measurements and calculations. Some of the approaches can be found in literature. In the literature overview the same symbols as used by the original authors were used.

The classical approach for determining whether the displacement is statistically significant or not is used and described in numerous articles (Caspary, 1987; Dognan et al., 2013; Heck et al., 1977; Koch, 1999; Kuang, 1996; Niemer, 1985, Pelzer, 1971; Savšek-Safić et al., 2003; Sütti and Török, 1996). The critical value at a selected risk level α is compared to the quotient of the quadratic form calculated as the product of the displacement vector and the corresponding cofactor matrix $T = \mathbf{d}^T \Sigma_{\mathbf{dd}}^{-1} \mathbf{d}$, which is distributed by χ_α^2 distribution (Koch, 1999).

Statistical significance of displacement can be tested with conventional deformation analysis (CDA methods) or robust methods (IWST methods). The choice of the method usually depends on the kind of the deformation that is investigated and the type of a control network that is designed for the certain object of study. CDA methods are based on the least squares estimation (LSE) such as Hannover and Karlsruhe method where global congruency test of two epoch adjustment results is used (Pelzer, 1971; Niemeier, 1981). IWST method (Iterative Weighted Similarity Transformation) is a good estimator of the single-point displacement vector in the process of robust S-transformation (Chen et al. 1990). An alternative method M-estimation has been proposed to determine the displacement vector directly from differences in "raw" unadjusted observations (Nowel, 2015; Nowel, 2016). An alternative method is even more efficacious when law values of displacements that slightly exceed measurement errors are expected. A very good empirical measure of the efficacy of outlier tests and robust estimation methods are proposed by Hekimoglu and Koch (2000). The measure is called the mean success rate (MSR) and is computed based on many thousands of different simulated observation sets by the Monte Carlo method as the ratio of the number of sets for which outliers were correctly detected to the number of all sets. The proposed measure of efficiency MSR can be good alternative to statistical measures such as global and local measures of internal reliability in traditional deformation analysis methods.

Rueger (1999) treats the required accuracy of displacement determination similarly to Welsch et al. (2000) and Pelzer et al (1987). If d_y is the estimated value of minimal displacement, then the required accuracy s_y can be assessed with a „rule of thumb" design equation $s_y \leq d/5$. Other authors claim that displacements are significant when the ratio between the displacement and its accuracy is greater than 3 (Klein and Heunecke, 2006).

The U.S. Army Corps of Engineers (USACE Army, 2002) recommends that the standard deviation of measurements for displacement detection should be 9 times lower than the greatest expected displacement. If one uses 95 % confidence level to describe the measurement accuracy, then it should be 4 times lower than the greatest expected displacement.

Hekimoglu et al. (2010) calculate the radius of the corresponding displacement circle r from the elements of the respective sub-matrix of the cofactor matrix $\mathbf{Q_{dd}}$ and α-fractile of the χ^2_2-distribution for 2 degrees of freedom $\chi^2_{2,\alpha}$. They observed what percentage of points has moved in the interval between r and $2r$ or between r and $3r$ for a chosen value of error probability α.

Ramos et al. (2012) developed software for 3D movements of olive trees due to erosion of the terrain. 3D movements were analyzed in two parts: as planimetric and altimetric movements. They decided that the planimetric displacements were significant if the 99 % error ellipses of individual points from each campaign do not intersect. To determine the altimetric movements, they have taken a similar decision: displacement is significant, if the altimetric displacement vector for each point from each campaign is higher than the error interval as calculated by $\sqrt{Error\_C1^2_{99\,\%} + Error\_C2^2_{99\,\%}}$.

So far the literature overview dealt predominantly with displacements in a 2D plane. Berber (2006) and Berber et al. (2009) calculates the threshold value in a 3D space which is an approximation of the 3D confidence ellipsoid using the following equation $\delta_i = \sqrt{\sigma^2_{a_{95_i}} + \sigma^2_{b_{95_i}} + \sigma^2_{h_{95_i}}}$, in which the semi-axes of the 95 % confidence ellipsoid and the vertical interval are obtained as $\sigma_{a,b,h95_i} = 2.795\sigma_{a,b,h_i}$. The standard 3D ellipsoid at $\chi^2_{3;1-\alpha} = 1$ has a confidence level (1-α) of about 20 %. In order to achieve a 95 % confidence level, a multiplication factor 2.795 must be used (Staudinger, 1999).

Displacements and deformations appear on artificial objects such as dams, embankments, bridges, their surroundings (e.g. in reservoir valleys, on the banks of accumulation lakes) as well as in organic areas such as landslides, tectonic faults and marshes. The reasons for displacements can be attributed to external forces (temperature changes, wind, tectonic or seismic effects), mechanical properties of the construction materials and elements, inadequate knowledge of the ground's geomorphologic composition, mechanic properties and hydrological conditions at the time of projecting the object. Establishing the displacements and deformations of artificial and natural objects is one of the most complex tasks in surveying.

Indirectly obtained quantities such as the shift and the corresponding standard deviation (statistically tested with the test statistic $T = d/\sigma_d$) are usually used when assessing the statistical significance of displacements. Since the test statistic T is compared to the critical value T_{crit} – which is determined on the basis of the appropriate distribution function and the chosen significance level – it is important to determine the distribution function correctly. The statistical test determines the subset of a sample space known as the critical value approach or the null hypothesis rejection interval. In practice the criterion of $T > 3$ or $T > 5$, also known as the „rule of thumb" is often used in the assessment of significant displacements. However, as simulation procedures allow us to determine the critical value T_{crit} much more accurately this criterion is not precise enough.

In this article we will deal with the specialities used in the calculation of displacements with corresponding standard deviations in 1D, 2D and 3D geodetic networks. The procedures used to determine the distribution function for the test statistic $T = d/\sigma_d$ are proposed according to the dimensionality of the network. For a 2D and 3D geodetic network the test statistic in not distributed through an analytical distribution function, which is why the appropriate distribution function is determined empirically, through simulations. Since the simulations allow us to determine the critical value T_{crit} for each individual point within a network, the proposed alternative procedure leads to higher quality of the detection of significant displacements at a given test significance level α.

2 DISPLACEMENT AND DISPLACEMENT ACCURACY ESTIMATION

In order to calculate the displacement and its standard deviation, the positions of identical points need to be determined in two time periods. If we have a sufficient number of stable points within a geodetic network, geodetic datum of the network is ensured well. If the calculated displacement values are significantly higher than the corresponding precision, a decision can be reached without any statistical testing. It is often hard to determine the sufficient number of stable points and detect significant displacements in geotechnical studies, for their value can often be found in the rang of their standard deviation. Statistical testing procedures are used in order to reduce the risk of credible detection of significant displacements.

Consider the position of a point P in time t and $t+\Delta t$. The displacement is calculated as follows:

in 1D network: $d_{1D} = \Delta H = H_{t+\Delta t} - H_t$, (1)

in 2D network: $d_{2D} = \sqrt{\Delta y^2 + \Delta x^2} = \sqrt{(y_{t+\Delta t} - y_t)^2 + (x_{t+\Delta t} - x_t)^2}$ in (2)

in 3D network: $d_{3D} = \sqrt{(\Delta y^2 + \Delta x^2 + \Delta H^2)} = \sqrt{(y_{t+\Delta t} - y_t)^2 + (x_{t+\Delta t} - x_t)^2 + (H_{t+\Delta t} - H_t)^2}$, (3)

in which y_t, x_t, H_t and $y_{t+\Delta t}$, $x_{t+\Delta t}$, $H_{t+\Delta t}$ are adjusted coordinates of the same point in different time periods.

In order to calculate the displacement precision, we not only need to know the point coordinates, but also their variance-covariance matrix. Let's assign point P_t in the first time period with the variance-covariance matrix Σ_{P_t} and the same point $P_{t+\Delta t}$ in the second time period with the variance-covariance matrix $\Sigma_{P_{t+\Delta t}}$.

Let's assume that the coordinates of points P in time t are not correlated with the coordinates in time $t+\Delta t$. The variance-covariance matrix of the point in both time periods can be written as follows:

$$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \Sigma_{P_t} & 0 \\ 0 & \Sigma_{P_{t+\Delta t}} \end{bmatrix}, \quad (4)$$

in 1D network: $$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \sigma^2_{H_t} & 0 \\ 0 & \sigma^2_{H_{t+\Delta t}} \end{bmatrix}, \quad (5)$$

in 2D network: $$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \sigma^2_{y_t} & \sigma_{y_t x_t} & 0 & 0 \\ \sigma_{y_t x_t} & \sigma^2_{x_t} & 0 & 0 \\ 0 & 0 & \sigma^2_{y_{t+\Delta t}} & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} \\ 0 & 0 & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} & \sigma^2_{x_{t+\Delta t}} \end{bmatrix} \text{ in} \quad (6)$$

in 3D network: $$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \sigma^2_{y_t} & \sigma_{y_t x_t} & \sigma_{y_t H_t} & 0 & 0 & 0 \\ \sigma_{y_t x_t} & \sigma^2_{x_t} & \sigma_{x_t H_t} & 0 & 0 & 0 \\ \sigma_{y_t H_t} & \sigma_{x_t H_t} & \sigma^2_{H_t} & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma^2_{y_{t+\Delta t}} & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} & \sigma_{y_{t+\Delta t} H_{t+\Delta t}} \\ 0 & 0 & 0 & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} & \sigma^2_{x_{t+\Delta t}} & \sigma_{x_{t+\Delta t} H_{t+\Delta t}} \\ 0 & 0 & 0 & \sigma_{y_{t+\Delta t} H_{t+\Delta t}} & \sigma_{x_{t+\Delta t} H_{t+\Delta t}} & \sigma^2_{H_{t+\Delta t}} \end{bmatrix}. \quad (7)$$

Taking into account the error propagation law, the variance of point P displacement is

$$\sigma_{d_D}^2 = \mathbf{J}_{d_D} \Sigma_{P_t P_{t+\Delta t}} \mathbf{J}_{d_D}^T, \tag{8}$$

in which the Jacobi matrix $\mathbf{J}_{d_D}$ equals:

$$\text{in 1D: } \mathbf{J}_{d_{1D}} = \begin{bmatrix} \frac{\partial d_{1D}}{\partial H_t} & \frac{\partial d_{1D}}{\partial H_{t+\Delta t}} \end{bmatrix} = \begin{bmatrix} -1 & 1 \end{bmatrix}, \tag{9}$$

$$\text{in 2D: } \mathbf{J}_{d_{2D}} = \begin{bmatrix} \frac{\partial d_{2D}}{\partial y_t} & \frac{\partial d_{2D}}{\partial x_t} & \frac{\partial d_{2D}}{\partial y_{t+\Delta t}} & \frac{\partial d_{2D}}{\partial x_{t+\Delta t}} \end{bmatrix} = \begin{bmatrix} -\frac{\Delta y}{d_{2D}} & -\frac{\Delta x}{d_{2D}} & \frac{\Delta y}{d_{2D}} & \frac{\Delta x}{d_{2D}} \end{bmatrix} \text{ in} \tag{10}$$

$$\text{in 3D: } \mathbf{J}_{d_{3D}} = \begin{bmatrix} \frac{\partial d_{3D}}{\partial y_t} & \frac{\partial d_{3D}}{\partial x_t} & \frac{\partial d_{3D}}{\partial H_t} & \frac{\partial d_{3D}}{\partial y_{t+\Delta t}} & \frac{\partial d_{3D}}{\partial x_{t+\Delta t}} & \frac{\partial d_{3D}}{\partial H_{t+\Delta t}} \end{bmatrix} = \begin{bmatrix} -\frac{\Delta y}{d_{3D}} & -\frac{\Delta x}{d_{3D}} & -\frac{\Delta H}{d_{3D}} & \frac{\Delta y}{d_{3D}} & \frac{\Delta x}{d_{3D}} & \frac{\Delta H}{d_{3D}} \end{bmatrix} \tag{11}$$

When we put eqs. (9), (10) and (11) into (8) the variance of point *P*'s displacement is written as follows:

$$\text{in 1D: } \sigma_{d_{1D}}^2 = \sigma_{H_t}^2 + \sigma_{H_{t+\Delta t}}^2, \tag{12}$$

$$\text{in 2D: } \sigma_{d_{2D}}^2 = \left(\frac{\Delta y}{d_{2D}}\right)^2 \left(\sigma_{y_t}^2 + \sigma_{y_{t+\Delta t}}^2\right) + \left(\frac{\Delta x}{d_{2D}}\right)^2 \left(\sigma_{x_t}^2 + \sigma_{x_{t+\Delta t}}^2\right) + 2\frac{\Delta y}{d_{2D}}\frac{\Delta x}{d_{2D}}\left(\sigma_{y_t x_t} + \sigma_{y_{t+\Delta t} x_{t+\Delta t}}\right) \text{ in} \tag{13}$$

$$\text{in 3D: } \begin{aligned} \sigma_{d_{3D}}^2 &= \frac{\Delta y^2}{d_{3D}^2}\left(\sigma_{y_t}^2 + \sigma_{y_{t+\Delta t}}^2\right) + \frac{\Delta x^2}{d_{3D}^2}\left(\sigma_{x_t}^2 + \sigma_{x_{t+\Delta t}}^2\right) + \frac{\Delta H^2}{d_{3D}^2}\left(\sigma_{H_t}^2 + \sigma_{H_{t+\Delta t}}^2\right) + 2\frac{\Delta y \Delta x}{d_{3D}^2}\left(\sigma_{y_t x_t} + \sigma_{y_{t+\Delta t} x_{t+\Delta t}}\right) + \\ &+ 2\frac{\Delta y \Delta H}{d_{3D}^2}\left(\sigma_{y_t H_t} + \sigma_{y_{t+\Delta t} H_{t+\Delta t}}\right) + 2\frac{\Delta x \Delta H}{d_{3D}^2}\left(\sigma_{x_t H_t} + \sigma_{x_{t+\Delta t} H_{t+\Delta t}}\right) \end{aligned} \tag{14}$$

The variance is used for testing the statistical significance of displacements.

3 DETERMINING THE DISTRIBUTION FUNCTION OF THE TEST STATISTICS WITH SIMULATIONS

Following the adjustment of the measurements for both time periods, the displacement of points d and their accuracies σ_d are determined. The test statistic for the detection of significant displacements is written as

$$T = \frac{d}{\sigma_d}. \tag{15}$$

The test statistic can be distributed through known distribution functions (normal, student, Fischer etc.) or the distribution function can be empirically determined through simulations. It is important to accurately determine the distribution function, since the critical value T_{crit} depends on it. The critical value also depends on the significance level α and how the null hypothesis H_0 is set.

The null hypothesis has to be set for statistical testing. This determines the subset of the sample space known as the critical value approach or the null hypothesis rejection interval. An alternative hypothesis needs to be set in case the null hypothesis is rejected. The alternative hypothesis is the opposite of the null hypothesis. The test statistic is tested in relation to the null and alternative hypothesis:

H_0 : d = 0; point has not moved between the two time periods,

H_a : d ≠ 0; point has moved between the two time periods.

The test statistic T is compared to the critical value T_{crit} which is determined on the basis of the distribution function. If the test statistic is lower than the critical value at a chosen significance level α, the risk for rejecting the null hypothesis becomes too high. In this case it can be concluded that the displacement is not statistically significant. On the other hand, when the test statistic is higher than the critical value, it can be concluded that the risk for rejecting the null hypothesis is lower than the chosen significance level α. In this case the null hypothesis is rejected and followed by the conclusion that the tested displacement is statistically significant. Two cases are considered:

$T \leq T_{crit}$: null hypothesis cannot be rejected; point displacement is not statistically significant,

$T > T_{crit}$: null hypothesis must be rejected; point displacement is statistically significant.

3.1 Calculation of the critical value in a 1D network

We assume that the random measurement errors are normally distributed $\varepsilon \sim N(0, \sigma^2)$. If this is the case, then it can be safely assumed that the quantities that are linear combinations of these measurements are also normally distributed $\hat{\mathbf{x}} \sim N(\mu_{\hat{\mathbf{x}}}, \sigma_{\hat{\mathbf{x}}}^2)$. Since d_{1D} is calculated as the difference of two normally distributed variables, the height difference of the same point between two time periods is also normally distributed.

3.2 Calculation of the critical value in a 2D network

Since the displacement d in 2D networks is a non-linear function of two normally distributed variables Δy and Δx it is not distributed through the normal distribution function. The displacement distribution is empirically determined through simulations (Savšek-Safić, 2002). To come up with an accurate distribution function we suggest the use of simulations with dependent random variable samples obtained through linear transformation. The procedure allows for a precise determination of the critical value at a chosen risk level (for null hypothesis rejection).

In order to generate a sample of dependent normally distributed random variables we need to generate a sample of independent normally distributed random variables upon which a linear transformation can be applied. The Box and Müller method (Box et al., 1958; Press et al., 1992) is used to generate independent normally distributed random variables. Let u_{1i} and u_{2i}, $i = 1,\ldots,n$ be two samples of independent random variables U_1 and U_2 evenly distributed on interval (0,1). A sample of two independent normally distributed random variables Z_1 and Z_2 is calculated as:

$$\mathbf{z}_i = \begin{bmatrix} z_{1i} \\ z_{2i} \end{bmatrix} = \begin{bmatrix} \sqrt{-2\ln u_{1i}}\,\sin\left(2\pi u_{2i}\right) \\ \sqrt{-2\ln u_{1i}}\,\cos\left(2\pi u_{2i}\right) \end{bmatrix},\ i = 1 \ldots n \cdot \tag{16}$$

The linear transformation is used to convert the sample of independent normally distributed random variables into a sample of dependent normally distributed random variables

$$\mathbf{y}_i = \mathbf{U}^T \mathbf{z}_i,\ i = 1,\ \ldots,\ n \tag{17}$$

in which matrix $\mathbf{U}$ is obtained through Cholesky's decomposition of the variance covariance matrix Σ, $\Sigma = \mathbf{U}^T\mathbf{U}$

$$\mathbf{U}=\begin{bmatrix} \sigma_{\Delta y} & \dfrac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}} \\ 0 & \sigma_{\Delta x}\sqrt{1-\left(\dfrac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2} \end{bmatrix}. \tag{18}$$

When we want to generate a sample of normally distributed coordinate differences Δy_i and Δx_i we use eq. (17) and assume that the mean values $\mu_{\Delta y}$ and $\mu_{\Delta x}$ equal 0, which gives us:

$$\begin{aligned} \Delta y_i &= z_{1i}\sigma_{\Delta y} \\ \Delta x_i &= z_{1i}\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}}+z_{2i}\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}. \end{aligned} \tag{19}$$

Variances and covariances are:

$$\begin{aligned} \sigma_{\Delta y} &= \sqrt{\sigma_{y_t}^2+\sigma_{y_{t+\Delta t}}^2} \\ \sigma_{\Delta x} &= \sqrt{\sigma_{x_t}^2+\sigma_{x_{t+\Delta t}}^2} \\ \sigma_{\Delta y\Delta x} &= \sigma_{y_t x_t}+\sigma_{y_{t+\Delta t}x_{t+\Delta t}} \end{aligned} \tag{20}$$

in which $\sigma_{y_t}^2$, $\sigma_{x_t}^2$, $\sigma_{y_t x_t}$, $\sigma_{y_{t+\Delta t}}^2$, $\sigma_{x_{t+\Delta t}}^2$, $\sigma_{y_{t+\Delta t}x_{t+\Delta t}}$ are variances and the covariances of coordinates y_t, x_t, $y_{t+\Delta t}$, $x_{t+\Delta t}$.

Since the displacement and standard deviations of point coordinates differ in each time period, the distribution function of the test statistic T is different for each point. Displacement d and its standard deviation σ_d can be calculated with the use of simulated normally distributed variables. The simulation is used for generating a sample of independent normally distributed random variables and through linear transformation we obtain dependent normally distributed random variables. In n simulations the procedure allows us to determine the empirical cumulative probability distribution of the test statistic and corresponding critical value according to the chosen significance level α for each point (Savšek-Safić et al., 2006).

3.3 Calculation of the critical value in a 3D network

Since the displacement d in 3D networks is a non-linear function of three normally distributed variables Δy, Δx and ΔH it is not distributed through the normal distribution function. The displacement distribution is empirically determined through simulations.

The distribution function is determined similarly as in 2D networks. We start off by generating a sample of independent normally distributed random variables. Let u_{1i}, u_{2i}, $i = 1,\ldots,n$ and u_{3i}, u_{4i}, $i = 1,\ldots,n$ be two pairs of samples of independent random variables U_1, U_2 and U_3, U_4 evenly distributed on the interval (0,1). A sample of three independent normally distributed random variables Z_1, Z_2 and Z_3 is calculated as follows:

$$\mathbf{z}_i=\begin{bmatrix} z_{1i} \\ z_{2i} \\ z_{3i} \end{bmatrix}=\begin{bmatrix} \sqrt{-2\ln u_{1i}}\,\sin(2\pi u_{2i}) \\ \sqrt{-2\ln u_{1i}}\,\cos(2\pi u_{2i}) \\ \sqrt{-2\ln u_{3i}}\,\sin(2\pi u_{4i}) \end{bmatrix},\quad i=1\ldots n \tag{21}$$

The linear transformation (17) is used to transform the sample of independent normally distributed variables into a sample of dependent normally distributed variables, for which we use the decomposed matrix **U**:

$$\mathbf{U}=\begin{bmatrix} \sigma_{\Delta y} & \dfrac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}} & \dfrac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}} \\ 0 & \sigma_{\Delta x}\sqrt{1-\left(\dfrac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2} & \dfrac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2-\sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\dfrac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}} \\ 0 & 0 & \sqrt{\sigma_{\Delta H}^2-\left(\dfrac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}}\right)^2-\left(\dfrac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2-\sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\dfrac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}}\right)^2} \end{bmatrix}. \tag{22}$$

The sample of dependent normally distributed variables Δy_i, Δx_i and ΔH_i is generated as follows:

$$\begin{aligned} \Delta y_i &= z_{1i}\sigma_{\Delta y} \\ \Delta x_i &= z_{1i}\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}}+z_{2i}\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2} \\ \Delta H_i &= z_{1i}\frac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}}+z_{2i}\frac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2-\sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}}+z_{3i}\sqrt{\sigma_{\Delta H}^2-\left(\frac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}}\right)^2-\left(\frac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2-\sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}}\right)^2}. \end{aligned} \tag{23}$$

The variances and covariances of the difference between the coordinates of a specific point in two time periods are calculated as follows: for Δy and Δx through eq. (20) while for ΔH eq. (24) is used:

$$\begin{aligned} \sigma_{\Delta H} &= \sqrt{\sigma_{H_t}^2+\sigma_{H_{t+\Delta t}}^2} \\ \sigma_{\Delta y\Delta H} &= \sigma_{y_tH_t}+\sigma_{y_{t+\Delta t}H_{t+\Delta t}}, \\ \sigma_{\Delta x\Delta H} &= \sigma_{x_tH_t}+\sigma_{x_{t+\Delta t}H_{t+\Delta t}} \end{aligned} \tag{24}$$

in which $\sigma_{y_t}^2$, $\sigma_{x_t}^2$, $\sigma_{H_t}^2$, $\sigma_{y_tx_t}$, $\sigma_{y_tH_t}$, $\sigma_{x_tH_t}$, $\sigma_{y_{t+\Delta t}}^2$, $\sigma_{x_{t+\Delta t}}^2$, $\sigma_{H_{t+\Delta t}}^2$, $\sigma_{y_{t+\Delta t}x_{t+\Delta t}}$, $\sigma_{y_{t+\Delta t}H_{t+\Delta t}}$, $\sigma_{x_{t+\Delta t}H_{t+\Delta t}}$ are variances and covariances of the spatial coordinates of a point y_t, x_t, H_t, $y_{t+\Delta t}$, $x_{t+\Delta t}$, $H_{t+\Delta t}$.

In 3D and 2D networks the distribution of the test statistic T varies for each individual point.

4 RESULTS

Several control geodetic networks of different dimensions, shapes, number of reference and control points established for the purpose of deformation monitoring of dams and geological faults in the Slovene area are analyzed in the article. Stability monitoring networks typically have specific geometry (see Appendix). All observations were made using precise total station (*Leica Geosystems* TS30 R1000: $\sigma_{\text{ISO-THEO HZ,Z}} = 0.5''$ and $\sigma_{\text{ISO-EDM}} = 0.6$ mm; 1ppm) in 7 sets of angels. Observations for height determination with geometric levelling are made using precise digital level *Leica Geosystems* DNA03: $\sigma_{\text{ISO-LEV}} = 0.3$ mm/km.

The critical value T_{crit} for a normal distribution function is calculated at a selected significance level α. In practice the most common values are $\alpha = 0.10$, $\alpha = 0.05$, $\alpha = 0.01$ and $\alpha = 0.001$. Besides these values in Table 1 also shows significance levels α that provide critical values T_{crit} 3 and more.

Table 1: Critical value T_{crit} with respect to significance level α.

α	1D	2D			3D		
	T_{crit}	T_{crit}^{min}	T_{crit}^{max}	T_{crit}^{mean}	T_{crit}^{min}	T_{crit}^{max}	T_{crit}^{mean}
0.10	1.64	1.94	2.13	2.07	1.67	1.81	1.71
0.05	**1.96**	2.22	2.43	**2.36**	1.98	2.11	**2.02**
0.01	2.58	2.79	3.01	2.93	2.59	2.69	2.62
0.0027	**3.00**						
0.0081		2.86	3.08	**3.00**			
0.0084					2.97	3.07	**3.00**
0.001	3.29	3.43	3.68	3.59	3.24	3.35	3.28
0.00001	4.42	4.47	4.93	4.76	4.06	4.21	4.08

Table 1 shows that in a 1D network the critical value T_{crit} of the normal distribution function is uniquely defined at a given significance level α. When the significance value decreasing (i. e. the risk of an unjustified rejection of the null hypothesis – error type I. is reduced) the critical value rises accordingly. We can observe that for critical value $T_{crit} = 3.29$ the risk is only 0.1 %. In practice a 95 % probability is usually acceptable when deciding whether the displacement is significant or not. In this case we have to compare the test statistic T with the critical value $T_{crit} = 1.96$ and not with constants 3 or 5. If the client considers that a 5 % risk is acceptable, the given displacement can be identified as significant much sooner. This is crucial for testing as the aim is to detect significant displacement with the greatest possible probability.

In order to obtain the most probable critical value at a chosen significance level we tested several 2D and 3D geodetic networks in Slovenia with different geometries (see Tables in Appendix). Table 1 lists the minimum, maximum and average critical values T_{crit}^{mean} for test networks based on a simulated empirical distribution function for chosen significance level α=0.10; α=0.05; α=0.01 and α=0.001. Table 1 shows a significance level α, that provide an average critical values $T_{crit}^{mean} = 3$, which often occurs in practice for testing significant displacement. Level α for the critical value of 5 is not listed since its value is lower than 0.00001 and can be treated as a non-risk decision.

Table 1 indicates that when the significance value decreasing (i. e. the risk of an unjustified rejection of the null hypothesis – error type I. is reduced) the critical value rises. This can be clearly seen when we compare the test statistic T with the critical value $T_{crit}^{mean} = 3.59$ for 2D geodetic networks and $T_{crit}^{mean} = 3.28$ for 3D geodetic networks where the risk is only 0.1 %. In practice a 95 % probability is usually acceptable when deciding whether the displacement is significant or not. In such an event we have to compare the test statistic T with the critical value $T_{crit}^{mean} = 2.36$ for 2D geodetic networks and $T_{crit}^{mean} = 2.02$ for 3D geodetic networks and not with constants 3 or 5. If the client considers a 5 % risk to be acceptable, then the given displacement can be identified to be significant much sooner. This is crucial for testing as the aim is to detect significant displacement with the greatest possible probability. The client determines the acceptable risk in accordance to the consequences brought forth by a wrong decision. The aim of statistical testing is to detect significant displacement as reliably as possible. Simulation procedures can be of great help since a properly determined distribution function is of utmost importance for a critical value determination.

5 CONCLUSION

A reliable estimate of measurements, coordinates and displacements is of great importance since the deformation analysis deals with large amounts of observations in multiple time periods. Statistical testing represents an indispensable tool for evaluating parameters, identifying the adequacy of observations and mathematical models, detecting gross errors in observations, identifying the compliance of supposedly stable points during a time period and detecting statistically significant displacements of unstable points. Statistical testing procedures help us eliminate the possibility of a specific point displacement being wrongly treated as significant due to inadequate observations, a wrongly selected mathematical model or the non-compliance between the measurements in two time periods. In order to ensure reliable displacement detection it is important to select a representative test statistic when the homogeneous precision of two periods is ensured. This article discusses the common test statistic $T = d/\sigma_d$. In 2D and 3D geodetic networks the displacement is a non-linear function of variables Δy, Δx and ΔH and therefore it is not distributed through any of the analytical distribution functions.

The proposed procedure was tested on multiple geodetic networks varying in size, dimensionality (1D, 2D, 3D), geometry, number of probable stable points and number of repeated measurements (periods). In all cases the empirical distribution function was simulated and critical values were calculated for commonly used significance levels $\alpha = 0.10$, $\alpha = 0.05$, $\alpha = 0.01$ and $\alpha = 0.001$. Special attention was paid to criteria $T > 3$ and $T > 5$, known as the „rule of thumb". In the same way as the distribution function differs for each point, it also does for the critical value. In addition, the critical values that correspond to the same risk level differ for a 1D, 2D or 3D geodetic network.

The critical value is a variable so it should not be treated as a constant (3 or 5). All test cases have shown that the critical value 3 corresponds to an extremely low risk level (less than 1 %). Risk level of 1% is used when statistical tests are applied for research, risk management or in case of deformation measurement on critical infrastructure (nuclear power plants, etc.). For most geotechnical objects (bridges, dams etc.) a risk level of 5 % is sufficient. The client has greater benefits if the empirical distribution function and accurate critical values are determined according to the chosen significance/risk level. The constant risk in all network dimensions is important for the displacement evaluation as this ensures the comparability between periods.

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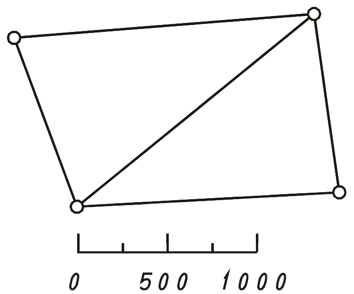
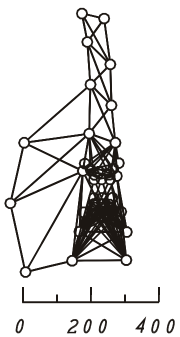
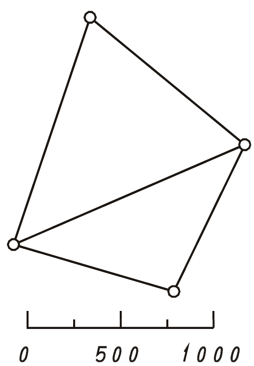
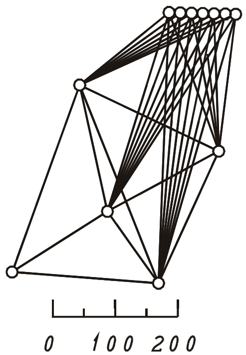
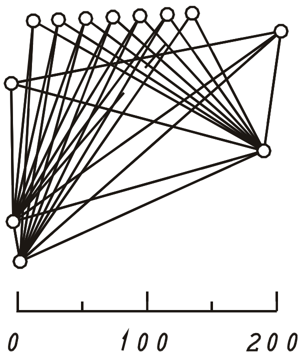
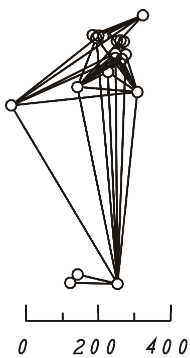
Appendix







Network shape		Number of directions	Number of distances	Num. of zenith distances	Number of unknowns	Number of points	Average σ_p (mm)	α	T^{min}_{crit}	T^{max}_{crit}	T^{mean}_{crit}
Network 1 (image 1)	2D	10	5		12	4	0.2	0.10	2.01	2.12	2.07
								0.05	2.30	2.42	2.63
								0.01	2.86	3.00	2.93
								0.008	2.92	3.08	3.00
								0.001	3.49	3.68	3.59
								0.00001	4.60	4.95	4.75
	3D	10	5	10	16	4	44.8	0.10	1.64	1.64	1.64
								0.05	1.96	1.96	1.96
								0.01	2.57	2.57	2.57
								0.0034	3.00	3.00	3.00
								0.001	3.23	3.23	3.23
								0.00001	4.06	4.06	4.06
Network 2 (image 2)	2D	93	121		99	41	0.3	0.10	1.77	2.14	2.04
								0.05	2.06	2.44	2.33
								0.01	2.65	3.02	2.91
								0.0075	2.75	3.12	3.00
								0.001	3.33	3.69	3.56
								0.00001	4.47	4.97	4.80
	3D	93	121	162	140	41	2.1	0.10	1.70	2.18	1.81
								0.05	2.01	2.46	2.10
								0.0171	2.61	3.01	2.69
								0.01	2.93	3.31	3.00
								0.001	3.27	3.64	3.34
								0.00001	4.06	4.75	4.14
Network 3 (image 3)	2D	10	5		12	4	0.5	0.10	2.06	2.14	2.10
								0.05	2.35	2.43	2.39
								0.01	2.93	3.02	2.98
								0.0093	2.95	3.05	3.00
								0.001	3.58	3.70	3.64
								0.00001	4.55	4.85	4.70
	3D	10	5	10	16	4	30.7	0.10	1.64	1.64	1.64
								0.05	1.96	1.96	1.96
								0.01	2.57	2.57	2.57
								0.0027	3.00	3.00	3.00
								0.001	3.23	3.23	3.23
								0.00001	4.06	4.06	4.06

Network shape		Number of directions	Number of distances	Num. of zenith distances	Number of unknowns	Number of points	Average σ_p (mm)	α	T_{crit}^{min}	T_{crit}^{max}	T_{crit}^{mean}
	2D	44	34		29	12	0.2	0.10	1.89	2.11	2.00
								0.05	2.18	2.41	2.29
								0.01	2.74	2.99	2.85
								0.0062	2.88	3.15	3.00
								0.001	3.37	3.64	3.50
								0.00001	4.51	4.90	4.67
	3D	44	34	44	41	12	3.1	0.10	1.66	1.67	1.66
								0.05	1.97	1.99	1.98
								0.01	2.58	2.59	2.58
								0.0063	3.00	3.01	3.00
								0.001	3.23	3.25	3.24
								0.00001	4.06	4.07	4.06
	2D	39	29		29	12	0.2	0.10	2.02	2.13	2.10
								0.05	2.30	2.43	2.39
								0.01	2.86	3.01	2.97
								0.0090	2.90	3.04	3.00
								0.001	3.50	3.68	3.62
								0.00001	4.45	4.95	4.82
	3D	39	28	36	41	12	1.5	0.10	1.71	1.94	1.79
								0.05	2.02	2.22	2.09
								0.01	2.62	2.77	2.67
								0.0023	2.94	3.08	3.00
								0.001	3.27	3.41	3.33
								0.00001	4.07	4.21	4.09
	2D	76	45		51	19	0.2	0.10	1.87	2.14	2.08
								0.05	2.16	2.44	2.37
								0.01	2.71	3.03	2.95
								0.0085	2.76	3.08	3.00
								0.001	3.34	3.70	3.61
								0.00001	4.25	4.97	4.80
	3D	76	45	76	70	19	2.4	0.10	1.66	1.76	1.72
								0.05	1.97	2.06	2.02
								0.0188	2.58	2.65	2.62
								0.01	2.96	3.04	3.00
								0.001	3.23	3.31	3.29
								0.00001	4.03	4.10	4.07

ALTERNATIVNA METODA TESTIRANJA PREMIKOV V GEODETSKI MREŽI

OSNOVNE INFORMACIJE O ČLANKU:

GLEJ STRAN 387

1 UVOD

Strokovnjaki, ki delujejo na področju geoznanosti (gradbeniki, geologi, rudarji in drugi), v svojih raziskavah opredelijo pričakovane premike. Geodeti na podlagi terenskih meritev določimo dejanske premike kot na primer Marjetič et al. (2012), Kregar et al. (2015), in natančnost določitve premikov z uporabo statističnih metod kot na primer Kregar et al. (2012), Urbančič et al. (2016). Nalogo lahko tudi obrnemo. Glede na natančnost določitve premikov, ki je posledica merjenja in izračunov, lahko izračunamo mejo, do katere lahko trdimo, da točka miruje ali se je značilno premaknila. V literaturi je opisanih nekaj pristopov. V pregledu literature ohranjamo oznake tako, kot jih zapisujejo posamezni avtorji.

Klasični pristop ocenjevanja, ali je premik statistično značilen ali ne, je uporabljen in opisan v številnih člankih (Caspary, 1987; Dognan et al., 2013; Heck et al., 1977; Koch, 1999; Kuang, 1996; Niemer, 1985; Pelzer, 1971; Savšek-Safić et al., 2003; Sütti in Török, 1996). Kritična vrednost pri izbrani stopnji značilnosti α se primerja s kvocientom kvadratne forme, ki se izračuna kot produkt vektorja premika točk s pripadajočo matriko kofaktorjev $T = \mathbf{d}^T \Sigma^{-1}_{\mathbf{dd}} \mathbf{d}$, ta se porazdeljuje po porazdelitvi χ^2_α (Koch, 1999).

Statistično značilne premike lahko testiramo s klasičnimi postopki deformacijske analize (angl. *CDA – conventional deformation analysis*) ali z robustnimi metodami (angl. *IWST – iterative weighted similarity transformation*). Izbira metode je običajno odvisna od vrste deformacij, ki jih raziskujemo, in od vrste kontrolne mreže, ki jo vzpostavimo za obravnavani objekt. CDA-metode temeljijo na oceni najmanjših kvadratov (LSE), kot sta Hannover in Karlsruhe, kjer uporabimo globalni kongruenčni test med dvema terminskima izmerama (Pelzer, 1971; Niemeier, 1981). IWST-metode zagotavljajo dobro oceno vektorja premikov za posamezno točko v postopku robustne S-transformacije (Chen et al., 1990). V literaturi je predstavljena alternativna M-ocena za določitev vektorja premikov neposredno iz razlik »surovih« neizravnanih meritev (Nowel, 2015; Nowel, 2016). Metoda je še posebej učinkovita, kadar se pričakujejo mali premiki, ki le malo presežejo merske pogreške. Hekimoglu in Koch (2000) predlagata zelo dobro empirično mero za učinkovito testiranje grobih pogreškov in oceno robustnih metod, imenovano povprečna ocena uspešnosti (angl. *MSR – mean success rate*). Izračunamo jo na podlagi velikega števila simuliranih meritev po metodi Monte Carlo kot razmerje med številom meritev, pri katerih odkrijemo grobe pogreške, in številom vseh meritev. Predlagana mera MSR je lahko dobra alternativa statističnim meram, kot so globalne in lokalne mere notranje zanesljivosti v tradicionalnih pristopih deformacijske analize.

Rueger (1999) obravnava zahtevano natančnost določitve premikov podobno kot Welsch et al. (2000) in Pelzer et al. (1987). Če je ocenjena velikost minimalnega premika d_y, potem lahko zahtevano natančnost meritev s_y ocenimo s približno enačbo $s_y \leq d/5$. V drugih člankih avtorji predpostavijo, da je premik značilen, če je kvocient med premikom in standardno deviacijo premika večji kot 3 (Klein in Heunecke, 2006).

V ameriški agenciji za vojno inženirstvo USACE (USACE Army, 2002) priporočajo, naj bo standardna deviacija meritev ($\sigma_{39\%}$) za določitev deformacij devetkrat manjša od največje pričakovane vrednosti deformacij. Če uporabimo 95 % stopnjo zaupanja, pa mora biti standardna deviacija meritev ($\sigma_{95\%}$) štirikrat manjša od največje pričakovane vrednosti deformacij.

Hekimoglu et al. (2010) izračuna radij pripadajočega kroga premikov *r* iz elementov pripadajoče podmatrike matrike kofaktorjev $\mathbf{Q_{dd}}$ in izbrane stopnje značilnosti α porazdelitve χ^2_2 za 2 prostostni stopnji $\chi^2_{2,\alpha}$. Ob izbrani stopnji značilnosti α ugotavlja, koliko odstotkov točk se je premaknilo v intervalu med *r* in 2*r* oziroma med *r* in 3*r*.

Ramos et al. (2012) so razvili program za 3D-premike oljk, ki jih povzroča erozija terena. Premike so analizirali ločeno za horizontalno in vertikalno komponento. Premike v ravnini so obravnavali kot značilne, kadar se 99 % elipsi pogreškov iz dveh zaporednih izmer ne prekrivata. V višinskem smislu so premik označili kot značilen, kadar je večji od intervala natančnosti $\sqrt{Error\_C1^2_{99\ \%} + Error\_C2^2_{99\ \%}}$.

Do sedaj opravljen pregled literature obravnava premike pretežno v 2D-ravnini. Berber (2006) in Berber et al. (2009) izračunajo mejno vrednost 3D-elipsoida zaupanja z enačbo $\delta_i = \sqrt{\sigma^2_{a_{95_i}} + \sigma^2_{b_{95_i}} + \sigma^2_{h_{95_i}}}$, kjer so posamezne polosi 95 % elipsoida zaupanja in vertikalnega intervala izračunane kot $\sigma_{a,b,h95_i} = 2{,}795\sigma_{a,b,h_i}$. Standardni 3D-elipsoid ima pri $\chi^2_{3;1-\alpha}$ stopnjo zaupanja (1-α) približno 20 %. Da dosežemo 95 % verjetnost, je treba osnovno enačbo standardnega 3D-elipsoida pomnožiti s faktorjem 2,795 (Staudinger, 1999).

Premiki in deformacije nastanejo tako na umetnih objektih, kot so jezovi, nasipi, mostovi, kot tudi v njihovi okolici, na primer v dolinah jezov, na obrežjih umetnih akumulacij, pa tudi na naravnih območjih, kot so plazovi, ob tektonskih prelomnicah, na barjanskih tleh. V splošnem lahko vzroke za nastanek premikov in deformacij pripisujemo delovanju zunanjih vplivov (spremembi temperature, vetru, tektonskim in seizmičnim vplivom), mehaničnim lastnostim gradbenega materiala in konstrukcijskih elementov ter nezadostnemu upoštevanju geološke sestave, mehanskih lastnosti ter hidroloških pogojev tal pri projektiranju objekta. Določitev premikov in deformacij naravnih in umetnih objektov je ena zahtevnejših nalog geodetske stroke.

Pri presoji statistično značilnih premikov navadno uporabimo indirektno določene količine, na primer premik in pripadajočo standardno deviacijo, ki jih z zapisom testne statistike $T = d/\sigma_d$ testiramo s postopki statističnega testiranja hipotez. Ker testno statistiko *T* primerjamo s kritično vrednostjo T_{crit}, ki jo določimo na podlagi ustrezne porazdelitvene funkcije in izbrane stopnje značilnosti testa α, je zelo pomembno, da pravilno določimo porazdelitveno funkcijo, po kateri se testna statistika porazdeljuje. Statistični test predpisuje pravilo za določitev neke podmnožice prostora vzorcev, ki jo imenujemo *kritično območje preizkusa* ali *območje zavrnitve* ničelne hipoteze. V praksi se pri presoji o značilnih premikih pogosto uporabi približni kriterij $T > 3$ ali $T > 5$, ki pa je pogosto preohlapen, saj je s postopki simulacij mogoče natančneje izračunati kritično vrednost T_{crit} porazdelitvene funkcije.

V članku obravnavamo posebnosti pri izračunu premika in pripadajoče standardne deviacije v 1D-, 2D- in 3D-geodetskih mrežah. Zapišemo postopek za določitev porazdelitvene funkcije za testno statistiko $T = d/\sigma_d$ glede na dimenzijo mreže. V ravninski in prostorski mreži se izračunana testna statistika ne porazdeljuje po nobeni od znanih porazdelitvenih funkcij, zato pripadajočo porazdelitveno funkcijo določimo empirično s simulacijami. S simulacijami lahko določimo kritično vrednost T_{crit} porazdelitvene funkcije za vsako točko v mreži, zato lahko predlagani alternativni postopek zagotovi večjo občutljivost pri ugotavljanju značilnih premikov pri izbrani stopnji zaupanja α.

2 OCENA PREMIKOV IN NJIHOVE NATANČNOSTI

Pogoj za izračun premika in pripadajoče standardne deviacije premika je, da so identične točke izmerjene najmanj v dveh terminskih izmerah. Če obstaja dovolj stabilnih točk, ki zagotavljajo kakovosten geodetski datum v obeh izmerah, izračunani premiki pa so značilno večji od standardne deviacije, se za premik lahko opredelijo iz razlike koordinat v dveh terminskih izmerah in dodatno statistično testiranje ni potrebno. V geotehničnih raziskavah je pogosto težavno določiti dovolj stabilnih točk, kakor tudi značilne premike, ki so pogosto le malo večji od standardne deviacije premika. Da bi zmanjšali tveganje pri verodostojni obravnavi značilnih premikov, uporabimo postopke statističnega testiranja, ki nam olajšajo odločitve.

Predpostavimo, da obravnavamo položaj točke P v času t in $t + \Delta t$. Premik točke izračunamo:

v 1D-mreži: $d_{1\mathrm{D}} = \Delta \mathrm{H} = H_{t+\Delta t} - H_t$, (1)

v 2D-mreži: $d_{2\mathrm{D}} = \sqrt{\Delta y^2 + \Delta x^2} = \sqrt{\left(y_{t+\Delta t} - y_t\right)^2 + \left(x_{t+\Delta t} - x_t\right)^2}$ in (2)

v 3D-mreži: $d_{3\mathrm{D}} = \sqrt{\left(\Delta y^2 + \Delta x^2 + \Delta H^2\right)} = \sqrt{\left(y_{t+\Delta t} - y_t\right)^2 + \left(x_{t+\Delta t} - x_t\right)^2 + \left(H_{t+\Delta t} - H_t\right)^2}$, (3)

kjer so y_t, x_t, H_t in $y_{t+\Delta t}$, $x_{t+\Delta t}$, $H_{t+\Delta t}$ izravnane koordinate ene točke v dveh terminskih izmerah.

Da bi lahko izračunali natančnost premika točke, moramo poleg koordinat točke poznati tudi kovariančno matriko koordinat točke za posamezno terminsko izmero. Naj ima točka P_t v prvi izmeri pripadajočo variančno-kovariančno matriko Σ_{P_t} in identična točka $P_{t+\Delta t}$ v drugi izmeri pripadajočo variančno-kovariančno matriko $\Sigma_{P_{t+\Delta t}}$. Predpostavimo, da so koordinate točke P v času t nekorelirane s koordinatami v času $t+\Delta t$. Variančno-kovariančno matriko identične točke v dveh časovno neodvisnih izmerah lahko zapišemo:

$$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \Sigma_{P_t} & 0 \\ 0 & \Sigma_{P_{t+\Delta t}} \end{bmatrix}, \quad (4)$$

v 1D-mreži: $$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \sigma^2_{H_t} & 0 \\ 0 & \sigma^2_{H_{t+\Delta t}} \end{bmatrix}, \quad (5)$$

v 2D-mreži: $$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \sigma^2_{y_t} & \sigma_{y_t x_t} & 0 & 0 \\ \sigma_{y_t x_t} & \sigma^2_{x_t} & 0 & 0 \\ 0 & 0 & \sigma^2_{y_{t+\Delta t}} & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} \\ 0 & 0 & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} & \sigma^2_{x_{t+\Delta t}} \end{bmatrix} \text{ in} \quad (6)$$

v 3D-mreži: $$\Sigma_{P_t P_{t+\Delta t}} = \begin{bmatrix} \sigma^2_{y_t} & \sigma_{y_t x_t} & \sigma_{y_t H_t} & 0 & 0 & 0 \\ \sigma_{y_t x_t} & \sigma^2_{x_t} & \sigma_{x_t H_t} & 0 & 0 & 0 \\ \sigma_{y_t H_t} & \sigma_{x_t H_t} & \sigma^2_{H_t} & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma^2_{y_{t+\Delta t}} & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} & \sigma_{y_{t+\Delta t} H_{t+\Delta t}} \\ 0 & 0 & 0 & \sigma_{y_{t+\Delta t} x_{t+\Delta t}} & \sigma^2_{x_{t+\Delta t}} & \sigma_{x_{t+\Delta t} H_{t+\Delta t}} \\ 0 & 0 & 0 & \sigma_{y_{t+\Delta t} H_{t+\Delta t}} & \sigma_{x_{t+\Delta t} H_{t+\Delta t}} & \sigma^2_{H_{t+\Delta t}} \end{bmatrix}. \quad (7)$$

Po zakonu o prenosu varianc in kovarianc določimo natančnost premika

$$\sigma_{d_D}^2 = \mathbf{J}_{d_D} \Sigma_{P_t P_{t+\Delta t}} \mathbf{J}_{d_D}^T , \tag{8}$$

kjer je Jacobijeva matrika $\mathbf{J}_{d_D}$ enaka

$$\text{v 1D: } \mathbf{J}_{d_{1D}} = \begin{bmatrix} \frac{\partial d_{1D}}{\partial H_t} & \frac{\partial d_{1D}}{\partial H_{t+\Delta t}} \end{bmatrix} = \begin{bmatrix} -1 & 1 \end{bmatrix}, \tag{9}$$

$$\text{v 2D: } \mathbf{J}_{d_{2D}} = \begin{bmatrix} \frac{\partial d_{2D}}{\partial y_t} & \frac{\partial d_{2D}}{\partial x_t} & \frac{\partial d_{2D}}{\partial y_{t+\Delta t}} & \frac{\partial d_{2D}}{\partial x_{t+\Delta t}} \end{bmatrix} = \begin{bmatrix} -\frac{\Delta y}{d_{2D}} & -\frac{\Delta x}{d_{2D}} & \frac{\Delta y}{d_{2D}} & \frac{\Delta x}{d_{2D}} \end{bmatrix} \text{ in} \tag{10}$$

$$\text{v 3D: } \mathbf{J}_{d_{3D}} = \begin{bmatrix} \frac{\partial d_{3D}}{\partial y_t} & \frac{\partial d_{3D}}{\partial x_t} & \frac{\partial d_{3D}}{\partial H_t} & \frac{\partial d_{3D}}{\partial y_{t+\Delta t}} & \frac{\partial d_{3D}}{\partial x_{t+\Delta t}} & \frac{\partial d_{3D}}{\partial H_{t+\Delta t}} \end{bmatrix} = \begin{bmatrix} -\frac{\Delta y}{d_{3D}} & -\frac{\Delta x}{d_{3D}} & -\frac{\Delta H}{d_{3D}} & \frac{\Delta y}{d_{3D}} & \frac{\Delta x}{d_{3D}} & \frac{\Delta H}{d_{3D}} \end{bmatrix} \tag{11}$$

Če vstavimo enačbe (9), (10) in (11) v enačbo (8), varianco premika točke P lahko zapišemo

$$\text{v 1D: } \sigma_{d_{1D}}^2 = \sigma_{H_t}^2 + \sigma_{H_{t+\Delta t}}^2, \tag{12}$$

$$\text{v 2D: } \sigma_{d_{2D}}^2 = \left(\frac{\Delta y}{d_{2D}}\right)^2 \left(\sigma_{y_t}^2 + \sigma_{y_{t+\Delta t}}^2\right) + \left(\frac{\Delta x}{d_{2D}}\right)^2 \left(\sigma_{x_t}^2 + \sigma_{x_{t+\Delta t}}^2\right) + 2\frac{\Delta y}{d_{2D}}\frac{\Delta x}{d_{2D}}\left(\sigma_{y_t x_t} + \sigma_{y_{t+\Delta t} x_{t+\Delta t}}\right) \text{ in} \tag{13}$$

$$\text{v 3D: } \begin{aligned} \sigma_{d_{3D}}^2 = {} & \frac{\Delta y^2}{d_{3D}^2}\left(\sigma_{y_t}^2 + \sigma_{y_{t+\Delta t}}^2\right) + \frac{\Delta x^2}{d_{3D}^2}\left(\sigma_{x_t}^2 + \sigma_{x_{t+\Delta t}}^2\right) + \frac{\Delta H^2}{d_{3D}^2}\left(\sigma_{H_t}^2 + \sigma_{H_{t+\Delta t}}^2\right) + 2\frac{\Delta y \Delta x}{d_{3D}^2}\left(\sigma_{y_t x_t} + \sigma_{y_{t+\Delta t} x_{t+\Delta t}}\right) + \\ & + 2\frac{\Delta y \Delta H}{d_{3D}^2}\left(\sigma_{y_t H_t} + \sigma_{y_{t+\Delta t} H_{t+\Delta t}}\right) + 2\frac{\Delta x \Delta H}{d_{3D}^2}\left(\sigma_{x_t H_t} + \sigma_{x_{t+\Delta t} H_{t+\Delta t}}\right) \end{aligned} \tag{14}$$

Varianco premika uporabimo za testiranje statistično značilnih premikov.

3 DOLOČITEV PORAZDELITVENE FUNKCIJE S SIMULACIJAMI

Po izravnavi najmanj dveh terminskih izmer je mogoče določiti premik točke d in standardno deviacijo premika σ_d. Zapišimo ustrezno testno statistiko, s katero skušamo zaznati značilne spremembe točk v mreži, ki nas zanimajo:

$$T = \frac{d}{\sigma_d}. \tag{15}$$

Testna statistika se lahko porazdeljuje po znanih porazdelitvenih funkcijah (normalna, Studentova, Fisherjeva idr.) ali pa je porazdelitveno funkcijo treba določiti analitično ali empirično s simulacijami. Natančna določitev porazdelitvene funkcije, po kateri se porazdeljuje testna statistika T, je zelo pomembna, saj se glede na porazdelitveno funkcijo izračuna kritična vrednost T_{crit}. Za izračun kritične vrednosti T_{crit} je pomembno tudi, kakšno vrednost stopnje značilnosti testa α izberemo in kako postavimo ničelno hipotezo H_0.

V postopku testiranja hipotez je treba postaviti ničelno hipotezo, s katero se predpisuje pravilo za določitev podmnožice prostora vzorcev, ki jo imenujemo kritično območje preizkusa ali območje zavrnitve ničelne hipoteze. V primeru zavrnitve ničelne hipoteze zapišemo ustrezno alternativno hipotezo. Testno statistiko testiramo glede na postavljeno ničelno H_0 in alternativno hipotezo H_a:

H_0 : d = 0; točka v obdobju dveh terminskih izmer miruje,

H_a : d ≠ 0; točka se je v obdobju dveh terminskih izmer značilno premaknila.

Testno statistiko T primerjamo glede na kritično vrednost T_{crit}, ki jo izračunamo na podlagi porazdelitvene funkcije. Ko je testna statistika manjša od kritične vrednosti ob izbrani stopnji značilnosti testa α, je tveganje za zavrnitev ničelne hipoteze preveliko. V tem primeru ugotovimo, da premik ni statistično značilen. Če je vrednost testne statistike večja od kritične vrednosti porazdelitvene funkcije, pa ugotovimo, da je tveganje za zavrnitev ničelne hipoteze manjše od izbrane stopnje značilnosti testa α. Zato upravičeno zavrnemo ničelno hipotezo in tako potrdimo, da je obravnavani premik statistično značilen. Obravnavamo torej dva primera:

$T \leq T_{crit}$: ne zavrnemo ničelne hipoteze; premik točke ni statistično značilen,

$T > T_{crit}$: zavrnemo ničelno hipotezo; premik točke je statistično značilen.

3.1 Izračun kritične vrednosti v 1D-mreži

Če predpostavimo, da so pogreški opazovanj normalno porazdeljeni $\varepsilon \sim N(0, \sigma^2)$, se enako porazdeljujejo tudi količine, ki so linearne funkcije opazovanj $\hat{\mathbf{x}} \sim N(\mu_{\hat{\mathbf{x}}}, \sigma^2_{\hat{\mathbf{x}}})$. Ker d_{1D} izračunamo kot razliko dveh normalno porazdeljenih slučajnih spremenljivk (glej poglavje 2), je tudi razlika višin identične točke med dvema terminskima izmerama normalno porazdeljena količina.

3.2 Izračun kritične vrednosti v 2D-mreži

Premik d je v 2D-mrežah nelinearna funkcija normalno porazdeljenih spremenljivk Δy in Δx, zato se ne porazdeljuje po normalni porazdelitveni funkciji. Empirično porazdelitveno funkcijo določimo s simulacijami (Savšek-Safić, 2002). Za določitev natančne porazdelitvene funkcije predlagamo uporabo simulacij za pridobitev vzorca odvisnih normalno porazdeljenih slučajnih spremenljivk s pomočjo linearne transformacije. Postopek omogoča natančno določitev kritične vrednosti pri izbrani stopnji tveganja (za zavrnitev ničelne hipoteze).

Osnovna ideja za generiranje vzorca *odvisnih* normalno porazdeljenih slučajnih spremenljivk je, da najprej generiramo vzorec neodvisnih normalno porazdeljenih spremenljivk, potem pa uporabimo linearno transformacijo za pridobitev vzorca odvisnih slučajnih spremenljivk. Za generiranje vzorca normalno porazdeljene slučajne spremenljivke uporabimo metodo Box in Müller (Box et al., 1958; Press et al., 1992). Naj bosta u_{1i} in u_{2i}, $i = 1, \ldots, n$ dva vzorca slučajnih spremenljivk U_1 in U_2, ki sta neodvisni in porazdeljeni enakomerno na intervalu (0,1). Vzorec dveh neodvisnih standardizirano normalno porazdeljenih slučajnih spremenljivk Z_1 in Z_2 izračunamo

$$\mathbf{z}_i = \begin{bmatrix} z_{1i} \\ z_{2i} \end{bmatrix} = \begin{bmatrix} \sqrt{-2\ln u_{1i}}\,\sin\left(2\pi u_{2i}\right) \\ \sqrt{-2\ln u_{1i}}\,\cos\left(2\pi u_{2i}\right) \end{bmatrix},\ i = 1 \ldots n\,. \tag{16}$$

Za pretvorbo vzorca neodvisnih normalno porazdeljenih spremenljivk v vzorec odvisnih normalno porazdeljenih slučajnih spremenljivk uporabimo linearno transformacijo

$$\mathbf{y}_i = \mathbf{U}^T \mathbf{z}_i,\ i = 1, \ldots, n, \tag{17}$$

kjer matriko **U** dobimo s Cholesky razcepom variančno-kovariančne matrike Σ, $\Sigma = \mathbf{U}^T\mathbf{U}$

$$\mathbf{U} = \begin{bmatrix} \sigma_{\Delta y} & \dfrac{\sigma_{\Delta y \Delta x}}{\sigma_{\Delta y}} \\ 0 & \sigma_{\Delta x}\sqrt{1-\left(\dfrac{\sigma_{\Delta y \Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2} \end{bmatrix}. \tag{18}$$

Če želimo generirati vzorec normalno porazdeljenih koordinatnih razlik Δy_i in Δx_i, izračunamo po (17) in predpostavimo, da sta srednji vrednosti $\mu_{\Delta y}$ in $\mu_{\Delta x}$ enaki 0, dobimo:

$$\begin{aligned} \Delta y_i &= z_{1i}\sigma_{\Delta y} \\ \Delta x_i &= z_{1i}\frac{\sigma_{\Delta y \Delta x}}{\sigma_{\Delta y}} + z_{2i}\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y \Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}. \end{aligned} \tag{19}$$

Variance in kovariance izračunamo

$$\begin{aligned} \sigma_{\Delta y} &= \sqrt{\sigma_{y_t}^2 + \sigma_{y_{t+\Delta t}}^2} \\ \sigma_{\Delta x} &= \sqrt{\sigma_{x_t}^2 + \sigma_{x_{t+\Delta t}}^2} \\ \sigma_{\Delta y \Delta x} &= \sigma_{y_t x_t} + \sigma_{y_{t+\Delta t} x_{t+\Delta t}} \end{aligned} , \tag{20}$$

kjer so $\sigma_{y_t}^2$, $\sigma_{x_t}^2$, $\sigma_{y_t x_t}$, $\sigma_{y_{t+\Delta t}}^2$, $\sigma_{x_{t+\Delta t}}^2$, $\sigma_{y_{t+\Delta t} x_{t+\Delta t}}$ variance in kovariance ravninskih koordinat točke y_t, x_t, $y_{t+\Delta t}$, $x_{t+\Delta t}$.

Porazdelitvena funkcija testne statistike T je za vsako točko drugačne oblike, saj sta premik in standardna deviacija koordinat točk v posamezni terminski izmeri za različne točke različna. Z uporabo simuliranih normalno porazdeljenih spremenljivk izračunamo premik d in standardno deviacijo premika σ_d. Simulacije uporabimo za generiranje vzorca neodvisnih normalno porazdeljenih slučajnih spremenljivk in z linearno transformacijo pridobimo odvisne normalno porazdeljene slučajne spremenljivke. V n simulacijah nam postopek omogoča določitev empirične kumulativne verjetnostne porazdelitvene funkcije testne statistike in izračun pripadajoče kritične vrednosti glede na izbrano stopnjo značilnosti testa α za vsako posamezno točko (Savšek-Safić et al., 2006).

3.3 Izračun kritične vrednosti v 3D-mreži

Premik d je tudi v 3D-mrežah nelinearna funkcija normalno porazdeljenih spremenljivk Δy, Δx_i in ΔH, zato se ne porazdeljuje po normalni porazdelitveni funkciji in moramo empirično porazdelitveno funkcijo določiti s simulacijami.

Porazdelitveno funkcijo določimo podobno kot v 2D-mrežah, tako da najprej generiramo vzorca neodvisnih normalno porazdeljenih slučajnih spremenljivk. Naj bosta u_{1i}, u_{2i}, $i = 1,\ldots,n$ in u_{3i}, u_{4i}, $i = 1,\ldots,n$ dva para vzorcev slučajnih spremenljivk U_1, U_2 in U_3, U_4, ki sta neodvisna in porazdeljena enakomerno na intervalu (0,1). Vzorec treh neodvisnih standardizirano normalno porazdeljenih slučajnih spremenljivk Z_1, Z_2 in Z_3 izračunamo po enačbi:

$$\mathbf{z}_i = \begin{bmatrix} z_{1i} \\ z_{2i} \\ z_{3i} \end{bmatrix} = \begin{bmatrix} \sqrt{-2\ln u_{1i}}\sin(2\pi u_{2i}) \\ \sqrt{-2\ln u_{1i}}\cos(2\pi u_{2i}) \\ \sqrt{-2\ln u_{3i}}\sin(2\pi u_{4i}) \end{bmatrix}, \quad i = 1 \ldots n. \tag{21}$$

Nato uporabimo linearno transformacijo (17) za pretvorbo vzorca neodvisnih normalno porazdeljenih spremenljivk v vzorec odvisnih normalno porazdeljenih slučajnih spremenljivk, kjer se matrika **U** izračunana kot:

$$\mathbf{U} = \begin{bmatrix} \sigma_{\Delta y} & \frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}} & \frac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}} \\ 0 & \sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2} & \frac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2 - \sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}} \\ 0 & 0 & \sqrt{\sigma_{\Delta H}^2 - \left(\frac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}}\right)^2 - \left(\frac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2 - \sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}}\right)^2} \end{bmatrix}. \tag{22}$$

Generiranje vzorca odvisnih normalno porazdeljenih Δy_i, Δx_i in ΔH_i izračunamo po naslednjih enačbah:

$$\begin{aligned} \Delta y_i &= z_{1i}\sigma_{\Delta y} \\ \Delta x_i &= z_{1i}\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}} + z_{2i}\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2} \\ \Delta H_i &= z_{1i}\frac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}} + z_{2i}\frac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2 - \sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}} + z_{3i}\sqrt{\sigma_{\Delta H}^2 - \left(\frac{\sigma_{\Delta y\Delta H}}{\sigma_{\Delta y}}\right)^2 - \left(\frac{\sigma_{\Delta x\Delta H}\sigma_{\Delta y}^2 - \sigma_{\Delta y\Delta H}\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}^2\sigma_{\Delta x}\sqrt{1-\left(\frac{\sigma_{\Delta y\Delta x}}{\sigma_{\Delta y}\sigma_{\Delta x}}\right)^2}}\right)^2} \end{aligned} \tag{23}$$

Variance in kovariance razlik koordinat točke v dveh terminskih izmerah Δy in Δx izračunamo po enačbi (20), variance in kovariance v 3D-mreži pa po naslednjih enačbah:

$$\begin{aligned} \sigma_{\Delta H} &= \sqrt{\sigma_{H_t}^2 + \sigma_{H_{t+\Delta t}}^2} \\ \sigma_{\Delta y\Delta H} &= \sigma_{y_t H_t} + \sigma_{y_{t+\Delta t}H_{t+\Delta t}}, \\ \sigma_{\Delta x\Delta H} &= \sigma_{x_t H_t} + \sigma_{x_{t+\Delta t}H_{t+\Delta t}} \end{aligned} \tag{24}$$

kjer so $\sigma^2_{y_t}$, $\sigma^2_{x_t}$, $\sigma^2_{H_t}$, $\sigma_{y_t x_t}$, $\sigma_{y_t H_t}$, $\sigma_{x_t H_t}$, $\sigma^2_{y_{t+\Delta t}}$, $\sigma^2_{x_{t+\Delta t}}$, $\sigma^2_{H_{t+\Delta t}}$, $\sigma_{y_{t+\Delta t} x_{t+\Delta t}}$, $\sigma_{y_{t+\Delta t} H_{t+\Delta t}}$, $\sigma_{x_{t+\Delta t} H_{t+\Delta t}}$ variance in kovariance prostorskih koordinat točke y_t, x_t, H_t, $y_{t+\Delta t}$, $x_{t+\Delta t}$, $H_{t+\Delta t}$.

V 3D- in 2D-mrežah je porazdelitvena funkcija testne statistike T različna za vsako točko.

4 REZULTATI

Na območju Slovenije so vzpostavljene številne geodetske kontrolne mreže za spremljanje premikov pregradnih objektov in geoloških prelomov. V članku analiziramo nekatere kontrolne mreže različnih dimenzij, geometrije in različnega števila referenčnih in kontrolnih točk (glej prilogo). Meritve so bile izvedene s preciznim elektronskim tahimetrom (*Leica Geosystems* TS30 R1000: $\sigma_{\text{ISO-THEO HZ,Z}}$ = 0,5” in $\sigma_{\text{ISO-EDM}}$ = 0,6 mm; 1ppm) v 7 girusih. Za določitev višin z geometričnim nivelmanom smo uporabili precizni digitalni nivelir *Leica Geosystems* DNA03: $\sigma_{\text{ISO-LEV}}$ = 0,3 mm/km.

Za normalno porazdelitev določimo kritično vrednost T_{crit} glede na izbrano stopnjo značilnosti testa α. V praksi najpogosteje uporabljamo vrednosti α = 0,10; α = 0,05; α = 0,01 in α = 0,001. Poleg kritičnih vrednosti za te α v preglednici 1 podajamo še vednosti α za T_{crit} 3 in več.

Preglednica 1: Kritična vrednost T_{crit} glede na izbrano stopnjo zaupanja α.

α	1D	2D			3D		
	T_{crit}	T^{min}_{crit}	T^{max}_{crit}	T^{mean}_{crit}	T^{min}_{crit}	T^{max}_{crit}	T^{mean}_{crit}
0,10	1,64	1,94	2,13	2,07	1,67	1,81	1,71
0,05	**1,96**	2,22	2,43	**2,36**	1,98	2,11	**2,02**
0,01	2,58	2,79	3,01	2,93	2,59	2,69	2,62
0,0027	**3,00**						
0,0081		2,86	3,08	**3,00**			
0,0084					2,97	3,07	**3,00**
0,001	3,29	3,43	3,68	3,59	3,24	3,35	3,28
0,00001	4,42	4,47	4,93	4,76	4,06	4,21	4,08

Kot vidimo iz preglednice 1, je v 1D-mreži pri izbrani stopnji značilnosti testa α kritična vrednost normalne porazdelitvene funkcije T_{crit} enolično določena. Z zmanjševanjem stopnje značilnosti testa oziroma tveganja za neupravičeno zavrnitev ničelne hipoteze (napaka I. vrste) se kritična vrednost ustrezno povečuje. Iz preglednice 1 je razvidno, da je pri kritični vrednosti T_{crit} = 3,29 tveganje minimalno in znaša 0,1 %. V praksi pogosto navajajo 95-odstotno verjetnost kot sprejemljivo verjetnost pri odločitvi, ali neki premik obravnavamo kot statistično značilen ali ne. V tem primeru testno statistiko T primerjamo s konstantno vrednostjo T_{crit} = 1,96 in ne s faktorjema 3 ali 5, kar je v praksi pogosto. Če je za naročnika 5 % tveganje sprejemljivo, to v praksi pomeni, da lahko veliko prej premik neke točke obravnavamo kot statistično značilen. Pri testiranju značilnih premikov je to dejstvo izrednega pomena, saj je cilj odkrivanje značilnih premikov s čim večjo verjetnostjo.

Da bi izračunali najverjetnejšo kritično vrednost pri izbranih stopnjah značilnosti testa, smo testirali različne geometrije mrež na objektih v Sloveniji (glej tabele v prilogi). V preglednici 1 navajamo minimalne in maksimalne kritične vrednosti ter srednjo vrednost T^{mean}_{crit} v testnih mrežah na podlagi simulirane empirične porazdelitvene funkcije za izbrane stopnje značilnosti testa α = 0,10; α = 0,05; α = 0,01 in

α = 0,001. V preglednici 1 navajamo še stopnjo značilnosti α, ki izpolnjuje kriterij mejne vrednosti 3, ki se pri obravnavi značilnih premikov pogosto pojavlja v praksi. Mejne vrednosti 5 ne navajamo, saj je tveganje manjše od 0,001, kar lahko obravnavamo kot odločitev brez tveganja.

Kot vidimo iz preglednice 1, se z zmanjševanjem stopnje značilnosti testa oziroma tveganja za neupravičeno zavrnitev ničelne hipoteze (napaka I. vrste) kritična vrednost ustrezno povečuje. Iz preglednice 1 je razvidno, da je pri primerjavi testne statistike T s kritično vrednostjo T^{mean}_{crit} = 3,59 za 2D-mreže in T^{mean}_{crit} = 3,28 za 3D-mreže tveganje minimalno in znaša 0,1 %. V praksi pogosto navajajo 95 % verjetnost kot sprejemljivo verjetnost pri odločitvi, ali neki premik obravnavamo kot statistično značilen ali ne. V tem primeru testno statistiko T, ki se porazdeljuje po simulirani porazdelitveni funkciji, primerjamo z vrednostjo T^{mean}_{crit} = 2,36 za 2D-mreže in T^{mean}_{crit} = 2,02 za 3D-mreže, in ne s faktorjema 3 ali 5, kar je v praksi pogosto. Če je za naročnika 5 % tveganje sprejemljivo, to v praksi pomeni, da lahko premik neke točke veliko prej obravnavamo kot statistično značilen. Pri testiranju značilnih premikov je to dejstvo izrednega pomena, saj je cilj odkrivanje značilnih premikov s čim večjo verjetnostjo. Glede na posledice nepravilne odločitve se naročnik odloči za sprejemljivo tveganje. V postopku ugotavljanja premikov je cilj statističnega testiranja čim bolj zanesljivo odkrivanje značilnih premikov. Kot vidimo, so nam postopki simulacije v veliko pomoč, saj je pravilno določena porazdelitvena funkcija odločilna pri izračunu natančne kritične vrednosti, na podlagi katere neko točko obravnavamo kos stabilno ali ne.

5 SKLEP

Zanesljivo ocenjevanje opazovanj, neznank in premikov je zelo pomembno, saj imamo v deformacijski analizi opravka z večjim številom opazovanj v več terminskih izmerah. S statističnimi testi ocenjujemo parametre, ugotavljamo skladnost opazovanj in matematičnega modela, odkrivamo grobe pogreške v opazovanjih ter ugotavljamo skladnost domnevno stabilnih točk med terminskimi izmerami in določamo statistično značilne premike nestabilnih točk. Pomembno je, da s postopki statističnega testiranja izločimo možnost, da bi premik neke točke neupravičeno obravnavali kot premik zaradi neskladja med opazovanji in matematičnim modelom ali zaradi neskladja med dvema terminskima izmerama. V tem pogledu je statistično testiranje zelo uporabno orodje, ki nam pomaga pri odločitvah. Ko zagotovimo homogeno natančnost med obravnavanimi terminskimi izmerami, je pomembno, da pri nadaljnji obravnavi premikov uporabimo reprezentativno testno statistiko, s katero bo mogoče premike določiti kar se da zanesljivo. V članku smo podrobneje obravnavali pogosto uporabljeno testno statistiko $T = d/\sigma_d$. V 2D- in 3D-geodetski mreži je premik nelinearna funkcija spremenljivk Δy, Δx in ΔH, zato se ne porazdeljuje po nobeni od znanih porazdelitvenih funkcij.

Uporabnost predlaganega postopka smo testirali na več testnih geodetskih mrežah, ki so se med seboj razlikovale po velikosti in razsežnosti mreže (1D, 2D, 3D), geometriji, številu domnevno stabilnih točk in številu terminskih izmer. V vseh primerih smo simulirali empirično porazdelitveno funkcijo in izračunali kritične vrednosti pri najpogosteje uporabljenih stopnjah značilnosti testa α = 0,10; α = 0,05; α = 0,01 in α = 0,001. Še posebej nas je zanimal v praksi pogosto uporabljen približni kriterij $T > 3$ ali $T > 5$. Ker je empirična porazdelitvena funkcija za vsako točko različna, je različna tudi kritična vrednost. Dodatno so kritične vrednosti ob enakem tveganju različne za 1D-, 2D- ali 3D-geodetsko mrežo.

Ker je kritična vrednost spremenljivka, ni smiselno, da jo obravnavamo kot konstantno vrednost 3 ali

5. V vseh testnih primerih smo ugotovili, da kritična vrednost v vseh dimenzijah mreže doseže vrednost 3 pri izjemno majhnem tveganju, manjšem od 1 %. Stopnjo tveganja 1 % uporabimo pri statističnem testiranju v raziskavah, pri oceni tveganja in pri ugotavljanju premikov kritične infrastrukture (nuklearne elektrarne ipd.). Za večino geotehničnih objektov (mostovi, pregrade idr.) zadošča 95-odstotna zanesljivost ugotavljanja premikov, kar pomeni, da značilen premik lahko odkrijemo že prej. Za naročnika je veliko bolj uporabno, da, glede na ocenjeno tveganje, določimo empirično porazdelitveno funkcijo in s tem tudi natančno kritično vrednost, ki jo primerjamo z izračunano testno statistiko. Pri oceni premikov je konstantno tveganje v vseh dimenzijah geodetske mreže še posebej pomembno, saj tako zagotovimo primerljivost med terminskimi izmerami.

Literatura in viri:

Glej literaturo na strani 397.

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Savšek S. (2017). An alternative approach to testing displacements in a geodetic network. Alternativna metoda testiranja premikov v geodetski mreži. Geodetski vestnik, 61 (3), 387-411. DOI: 10.15292/geodetski-vestnik.2017.03.387-411

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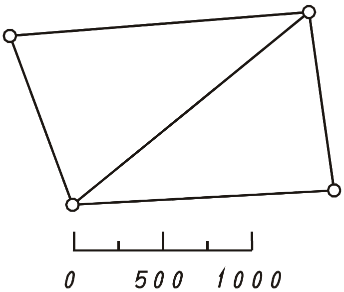
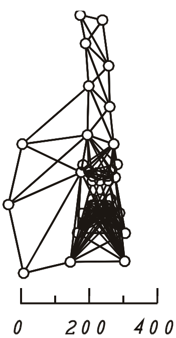
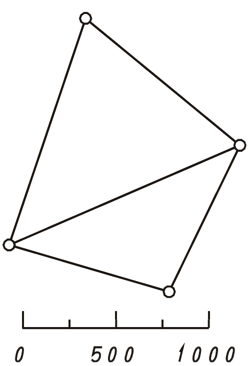
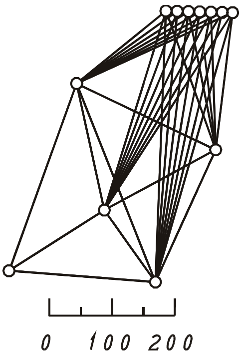
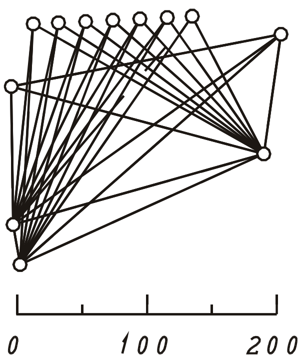
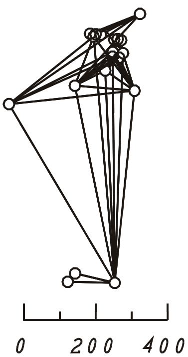
Priloga

Oblika geodetske mreže		Število smeri	Število dolžin	Število zenitnih razdalj	Število neznank	Število točk	Srednja vrednost σ_p (mm)	α	T^{min}_{crit}	T^{max}_{crit}	T^{mean}_{crit}
	2D	10	5		12	4	0,2	0,10	2,01	2,12	2,07
								0,05	2,30	2,42	2,63
								0,01	2,86	3,00	2,93
								0,008	2,92	3,08	3,00
								0,001	3,49	3,68	3,59
								0,00001	4,60	4,95	4,75
	3D	10	5	10	16	4	44,8	0,10	1,64	1,64	1,64
								0,05	1,96	1,96	1,96
								0,01	2,57	2,57	2,57
								0,0034	3,00	3,00	3,00
								0,001	3,23	3,23	3,23
								0,00001	4,06	4,06	4,06
	2D	93	121		99	41	0,3	0,10	1,77	2,14	2,04
								0,05	2,06	2,44	2,33
								0,01	2,65	3,02	2,91
								0,0075	2,75	3,12	3,00
								0,001	3,33	3,69	3,56
								0,00001	4,47	4,97	4,80
	3D	93	121	162	140	41	2,1	0,10	1,70	2,18	1,81
								0,05	2,01	2,46	2,10
								0,0171	2,61	3,01	2,69
								0,01	2,93	3,31	3,00
								0,001	3,27	3,64	3,34
								0,00001	4,06	4,75	4,14
	2D	10	5		12	4	0,5	0,10	2,06	2,14	2,10
								0,05	2,35	2,43	2,39
								0,01	2,93	3,02	2,98
								0,0093	2,95	3,05	3,00
								0,001	3,58	3,70	3,64
								0,00001	4,55	4,85	4,70
	3D	10	5	10	16	4	30,7	0,10	1,64	1,64	1,64
								0,05	1,96	1,96	1,96
								0,01	2,57	2,57	2,57
								0,0027	3,00	3,00	3,00
								0,001	3,23	3,23	3,23
								0,00001	4,06	4,06	4,06

Oblika geodetske mreže		Število smeri	Število dolžin	Število zenitnih razdalj	Število neznank	Število točk	Srednja vrednost σ_p (mm)	α	T_{crit}^{min}	T_{crit}^{max}	T_{crit}^{mean}
	2D	44	34		29	12	0,2	0,10	1,89	2,11	2,00
								0,05	2,18	2,41	2,29
								0,01	2,74	2,99	2,85
								0,0062	2,88	3,15	3,00
								0,001	3,37	3,64	3,50
								0,00001	4,51	4,90	4,67
	3D	44	34	44	41	12	3,1	0,10	1,66	1,67	1,66
								0,05	1,97	1,99	1,98
								0,01	2,58	2,59	2,58
								0,0063	3,00	3,01	3,00
								0,001	3,23	3,25	3,24
								0,00001	4,06	4,07	4,06
	2D	39	29		29	12	0,2	0,10	2,02	2,13	2,10
								0,05	2,30	2,43	2,39
								0,01	2,86	3,01	2,97
								0,0090	2,90	3,04	3,00
								0,001	3,50	3,68	3,62
								0,00001	4,45	4,95	4,82
	3D	39	28	36	41	12	1,5	0,10	1,71	1,94	1,79
								0,05	2,02	2,22	2,09
								0,01	2,62	2,77	2,67
								0,0023	2,94	3,08	3,00
								0,001	3,27	3,41	3,33
								0,00001	4,07	4,21	4,09
	2D	76	45		51	19	0,2	0,10	1,87	2,14	2,08
								0,05	2,16	2,44	2,37
								0,01	2,71	3,03	2,95
								0,0085	2,76	3,08	3,00
								0,001	3,34	3,70	3,61
								0,00001	4,25	4,97	4,80
	3D	76	45	76	70	19	2,4	0,10	1,66	1,76	1,72
								0,05	1,97	2,06	2,02
								0,0188	2,58	2,65	2,62
								0,01	2,96	3,04	3,00
								0,001	3,23	3,31	3,29
								0,00001	4,03	4,10	4,07

UPORABA PODATKOVNE BAZE NOSQL NA PODROČJU 3D-KATASTRA

USING NOSQL DATABASES IN THE 3D CADASTRE DOMAIN

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IZVLEČEK

3D-kataster zahteva podatkovne modele, ki so kompleksnejši od podatkovnih modelov za katastre dveh razsežnosti in ki omogočajo vzpostavitev obsežnejših podatkovnih zbirk. Podatki 3D-katastra bi morali biti organizirani v okviru sistema za upravljanje podatkovnih zbirk, ki bi omogočal popolnost in doslednost pri shranjevanju in vzdrževanju katastrskih podatkov. Sistem za upravljanje relacijskih podatkovnih zbirk temelji na tabelarični strukturi, podatki so shranjeni v predhodno določenih kolonah, s prav tako predhodno določenimi vrstami podatkov, kar je nekoliko neugodno za prostorske podatkovne zbirke v 3D razsežnostih. Študija je namenjena preučitvi možnosti uporabe podatkovnih zbirk NoSQL na področju 3D-katastra. Podatkovne zbirke NoSQL omogočajo shranjevanje nestrukturiranih podatkov, brez predhodne določitve vrste ali razreda podatka, kar smo preizkusili kot možnost za vzpostavitev 3D-katastra. Uporabili smo MongoDB in 3D-katastrski podatkovni model. Pripravili smo 3D-katastrske podatke, tako alfa-numerične kot grafične, ki so bili namenjeni uvozu, shranjevanju, upravljanju, poizvedovanju in posodabljanju v podatkovni bazi NoSQL. Shranjene podatke v podatkovni zbirki MongoDB smo grafično predstavili in po podatkih poizvedovali s spletnim brskalnikom, pri čemer smo uporabili Cesium knjižnico.

KLJUČNE BESEDE

3D-kataster, podatkovna zbirka NoSQL, MongoDB, RDBMS, 3D-vizualizacija, Cesium

ABSTRACT

The 3D cadastre concept brings data models, which are more complex than traditional 2D cadastral data models and could be followed by a large amount of data. The 3D cadastral data should be stored in database management systems, since the cadastral data integrity and consistency have to be satisfied. Relational database management system requires a tabular structure where data are stored within predefined columns and data types, and this could be uncomfortable for 3D cadastre until relational provides full 3D support. This study examines the possibility of using NoSQL databases in the 3D cadastre domain. NoSQL database stores unstructured data, which means that it is not required to define in advance what data types and categories will be used. From the 3D cadastre point of view, the NoSQL approach provides flexibility in data types and allows easier implementation of the 3D cadastral models. The implementation is conducted by using MongoDB and 3D Cadastral Data Model, where 3D cadastral data, including both alphanumerical and geometry part of data, are prepared for importing and then stored, managed, queried, and updated within NoSQL database. Furthermore, data stored in MongoDB are visualized and queried inside a web browser by using Cesium library.

KEY WORDS

3D Cadastre, NoSQL database, MongoDB, RDBMS, 3D visualization, Cesium

1 INTRODUCTION

During the last century, rapid urbanization created significant environmental changes that are mostly reflected by increases in densely populated urban areas. As a result, a space below and above the ground level is occupied and used by complex constructions. These changes have caused a greater importance for representation of the ownership. Traditional cadastral registration systems face many difficulties in representing complex and multilevel property situations on 2D maps (Stoter & Salzmann, 2003). Study by Marcin (2012) illustrated the difficulties in representing 3D properties on 2D maps. Additionally, Navratil (2011) stated that in 2D managed cadastre system, it is not possible to model horizontally divided situations, like in the case with the floors shared by different owners. As a result, these maps cannot be used as a base for registration of complex situations and interlocked rights in urban areas. Therefore, a system which allows easy recording and representing of all possible property situations is necessitated and such a system is called "3D cadastre". A 3D cadastre contains data of land, buildings, building parts, other construction objects, and data of the owners of such objects - including rights, restrictions, and responsibilities (RRR).

There are many reasons why the idea of the 3D cadastre is becoming increasingly widely recognized. Nowadays, more than half of the world's population lives in urban areas (www.un.org, 2014), which has resulted in an increased number of interlocked properties, complex constructions, buildings above roads, tunnels, pipelines, etc. As a consequence, current cadastral registration systems have difficulties in handling the visualization and registration of all property situations in urban areas, both methodologically and technologically (Drobež et al., 2017). Additionally, a rapid development of new technologies, especially 3D technologies, brought new possibilities of storing, manipulating, and visualizing 3D data. This initiated and enabled the development of the 3D cadastre technical approaches as well. Finally, property values increased; for example, the property values in some of the developed countries have experienced large increases of more than 200 percent from 1985 to 2006 (Goodhart & Hofmann, 2008), and all these high-valued properties, including complex structures, are represented by 2D drawings despite the fact that from the juridical point of view cadastral registration has always been 3D. Therefore, higher costs of 3D cadastre implementation can be justified by higher property values. 3D Cadastre, together with 3D city models, can improve land tax estimation and the land market by using visibility analysis (Navratil & Fogliaroni, 2014)

The 3D cadastre can be viewed from two aspects, technological and legal one. From the legal point of view, the 3D cadaster, or a system which will enable to unequivocally register rights on 3D properties, is very important. Paasch, et al. (2016) discussed the legal aspects of 3D real property, while another study, by van Oosterom (2013), describes the current research and development in 3D cadastre area altogether. In our study, we consider only the technical and technological aspects of the 3D cadastre.

According to Stoter & van Oosterom (2002), geo-database management systems (DBMS) should be the starting point for storing and maintaining data on 3D cadastre. DBMS guarantee the consistency of the data (both geometric and alphanumeric), which provides that data are modified only in allowed ways. This is very important for the cadastral data, especially for the legal part of data.

Three possible conceptual data models for the 3D cadastre were described by Stoter & Salzmann (2003). Based on the hybrid and full 3D cadastre models, it could be concluded that 3D cadastral models are much more complex than the traditional 2D cadastral models and could result in large and complex datasets. 3D data manipulation, such as storing, processing and analyzing, presents challenges to relational database management system (RDBMS) due to the lack of full 3D support. Handling large datasets became a very big issue for RDBMS and the solution for this problem was found in scalability and data distribution where data are distributed over several servers. All this makes the whole system more complex and hence affects the operation's performance (Mohamed, et al., 2014). The 3D cadastral datasets have to be divided based on administrative units, and have to wait for further development of RDBMS to fully support the 3D cadastre requirements.

The objective of this study is to explore an alternative way of storing 3D cadastral data, with no intention to substitute the use of relational databases. Starting from the notion that 3D cadastral data should be stored in a DBMS and due to the limited 3D support in RDBMS including issues with large datasets, we analyze the use of alternative database systems called NoSQL in 3D cadastre domain. NoSQL databases are database management softwares that can handle massive data storage and they follow the BASE (Basically Available, Soft State, Eventual consistency) rules.

Section 2 summarizes the complexity of the current 3D cadastral models and the capability of relational DBMS to store 3D cadastral data. Section 3 provides a short analysis of the NoSQL databases based on comparison with the relational databases. In Section 4, we present implementation of the case study based on MongoDB and 3D Cadastral Data Model (3DCDM). Moreover, this section considers the conversion of 3DCDM GML data to JSON documents, their storage in NoSQL database, and querying, selecting and updating data within the database. In addition, 3D cadastral data stored in MongoDB are visualized and queried inside a web browser by using the Cesium library. The conclusions and directions for future work are given in Section 5.

2 3D CADASTRE AND RDBMS

The 3D cadastre could be implemented in different ways; from a full 3D cadastre, which includes 3D volumes, to the current 2D Cadastre models with tags leading to the external 3D models. The hybrid and full 3D cadastre models, together with 3DCDM proposed by Aien et al. (2013) show that operative 3D cadastral models will be much more complex than traditional 2D Cadastre models. Consequently, 3D cadastre models will store much more data.

DBMSs play a central role when it comes to storing 3D cadastral data. Within the RDBMS architecture, the spatial and non-spatial data are maintained and protected by strongly following the ACID (Atomicity, Consistency, Isolation, and Durability) rules that provide a reliable system and data consistency. Certain standards, such as CityGML (Gröger & Plümer, 2012), are very useful for the visualization and exchange of 3D models including topological relationships between different geometric aggregates (*see* Li, et al., 2016). However, they are still only XML schemas that can be easily corrupted or modified and this is not acceptable from the data consistency point of view. Therefore, the 3D cadastral data should be stored in a DBMS (Stoter & Salzmann, 2003; Lemmen & van Oosterom, 2013).

Mainstream DBMS softwares, such as Postgres/PostGIS, Microsoft SQL Server, and Oracle, have provided spatial data types and spatial operators that offer support for cadastral data. However, until recently, they have not provided support for 3D data managing (*see* Schön, et al., 2009). With the Oracle Database Release 11.1, three-dimensional spatial data that include 3D points, 3D lines, 3D polygons, 3D surfaces, and solids can be stored with built-in datatypes. Also, PostGIS supports 3D data types such as points, lines, surfaces, TIN and solids. When it comes to topological relations, no geo-DBMS can provide support in maintaining 3D topological models (Breunig & Zlatanova, 2011). This means that the 3D spatial functionality, regarding complex 3D spatial data types, must be further defined. These advances should be developed (or extended), in order to maintain 3D objects in the database. The authors have also proposed that as soon as 3D geometry and topological models are supported, a DBMS should support functions and operations for analysis, conversion, and validity. According to these statements, there is currently no RDBMS which fully supports all 3D cadastre requirements.

Furthermore, relational databases were created for business data processing needs during the time when interfaces and hardware were different. Despite some changes, no RDBMS has been completely redesigned since that time (Stonebraker, et al., 2007). Therefore, if 3D cadastre models result in large amounts of data, this could potentially influence the handling of these data within RDBMS. Moreover, relational databases could be beaten in almost any area outside of business data processing market, if it is worth to invest in a specialized engine.

3 NOSQL DATABASES

NoSQL databases represent an alternative to the traditional relational databases. They represent the database management systems that respect three BASE principles: 1) Basically Available, 2) Soft State, and 3) Eventual consistency (Nayak, et al., 2013; Chandra, 2015). They are not based on the strict schema, and generally do not support SQL query language for data manipulation. The NoSQL databases were initially developed for the needs of companies that deal with big data and real-time application, such as Google, Yahoo, Facebook, (Mohan, 2013) but now they are used in other domains.

As Chandra (2015) has described, NoSQL database are classified into 2 categories:

- Aggregate Oriented
- Non-aggregate Oriented

Aggregate Oriented NoSQLs collect information from various nodes in the network cluster. Non-aggregate Oriented NoSQLs are the superset of Aggregate Oriented NoSQL, which heavily use relations. Hence, the difference between these two categories is that Aggregate Oriented databases divide relations.

Also, NoSQL databases use different data storage, and based on this criterion they can be categorized into 5 different types (Nayak, et al., 2013; Chandra, 2015; Moniruzzaman & Hossain, 2013):

1. *Key-value store* databases represent the most basic type of NoSQL database where data items are stored as keys. Data items are converted into keys by using a formula and when the data are queried, the key is converted back to the location of the stored data (Chandra, 2015). These databases are very similar to hash tables, and they provide fast querying of a big data storage (Nayak, et al., 2013).

2. *Column-Oriented* databases provide a multi-dimensional sorted map for storing data where each record can be stored in a different number of fields. Fields can be grouped in a way to create a column set. Data

is retrieved by a key which is associated with one column or column set. These databases are good for data mining and analytic applications (Nayak, et al., 2013).

3. *Document* databases store data as documents, which means that all the data are stored in formats such as JSON or XML. These databases can store same, similar, or dissimilar data. Each stored document gets a unique key which is used for retrieving the document (Nayak, et al., 2013). Documents can also be retrieved by any attribute within the document, including the ability to query and update values inside the document. Some databases, such as MongoDB, provide the index options, including text indexes, geospatial indexes, unique indexes, and others (website-mongoDB).

4. *Graph* databases, store data as a graph where nodes, edges and properties represent data. As Chandra (2015) has concluded, graph databases are suitable for the Location-based services and other complex network-based applications.

5. *Object-Oriented* databases store data as an object and they can be treated as a combination of database principles and object-oriented programming (Nayak, et al., 2013).

There are several studies that have compared NoSQL databases to the relational databases (Mohamed, et al., 2014; Nance, et al., 2013; Nayak, et al., 2013; Tauro, S, & A.B., 2012). Based on these publications, it can be concluded that NoSQL databases have advantages and disadvantages when compared to the relational databases—RDBMS.

Main advantages of NoSQL databases are flexibility and not strict data models which enables easy storage of different data types and allows the system to change and evolve. NoSQL databases have capabilities to store structured, semi-structured, and even unstructured data, unlike RDBMS where data have to fit into the predefined table structure. It means that it is possible to store data based on two or more data models within the NoSQL database, and this is very suitable for hybrid models. NoSQL databases are primary designed to handle big data, compared to RDBMS, where large amount of data may slow down their performance. NoSQL databases have implemented methods that improve the performance of storing and retrieving data (Mohamed, et al., 2014).

However, NoSQL databases are still immature systems, and this is the reason why many large institutions will not transfer their systems from relational databases to NoSQL databases (Nance, et al., 2013). Furthermore, they do not use standard query language. Most of the NoSQL database providers have offered different query language and the introduction of standard query language for NoSQL systems will be a big step forward (Nayak, et al., 2013). There is no unique standard user interface offered by different providers, and there is also a lack of database design tools for NoSQL databases with complex data models (Mohan, 2013). Moreover, a big disadvantage is that some of the NoSQL systems do not follow the ACID rules, and BASE rules provide less strict assurance than ACID. This is important for 3D cadastre, in the case that transactions are related to legal aspect of 3D cadastre, when high data consistency is required. Also, NoSQL databases depend on backup files when it comes to crash recovery, while some of them, such as MangoDB, provide Journal file as crash recovery (Mohamed, et al., 2014).

With regards to spatial data, a few NoSQL databases such as MongoDB, Neo4j, Bigtable, Cassandra, etc. provide basic spatial operators and spatial indexes, but there are still no 3D operators. This might be a disadvantage when compared to RDBMS due to the fact that it provides some of the 3D operators.

Nance et al., (2013) concluded that many areas can benefit from using NoSQL databases since they could be used and involved in many different platforms. Relational databases will be used in the future because NoSQL databases and relational databases do not tend to solve the same problems. In other words, there is room for the development of both approaches. For the purpose of this research, 3DCDM data are stored, queried, and updated within a NoSQL document database called MongoDB.

4 3D CADASTRE DATA IN NOSQL DATABASE

In this study, some elements of 3DCDM described formerly by Aien, et al. (2014) were used. Data are stored, managed, and processed within MongoDB, which is free and is an open-source NoSQL database. MongoDB is the most popular NoSQL database and the fourth most popular DBMS system (db-engines.com, 2016). The NoSQL Viewer application was used as a user interface.

The described physical data model of the 3DCDM has been developed as a schema of the GML language (Geography Markup Language). The GML is the XML grammar developed for geographical features by the Open Geospatial Consortium (OGC). According to this, the described 3DCDM physical data model is an XML-based schema. MongoDB stores JSON-like documents, hence for the purpose of this research the 3DCDM physical data model is converted from the XML-based schema to JavaScript Object Notation (JSON). This can be easily performed by many applications and online converters; for example, the conversion in this study was performed using codebeautify.org.

Aien, et al. (2014) defined eleven XML namespaces where each 3DCDM module has a namespace and each namespace is connected to an URI and has a suggested prefix. As a case study, we used three 3DCDM modules including: Building, Terrain and Utility modules. To elaborate, we used eight building units (including two underground units), TIN terrain model and data on two utility networks (water supply and hot water network). An example of a physical model (XML document) for two TIN triangles is as follows:


```
<physicalModel>
<UrbanModel>
<physicalObjectMember>
<trn:Terrain gml:id="TIN_1">
<trn:terrainSource>
<trn:TIN gml:id="TIN-1">
<trn:tinSource>
<gml:TriangulatedSurface gml:id="DCDM_tinSurface_1">
<gml:trianglePatches>
<gml:Triangle>
<gml:exterior>
<gml:LinearRing>
<gml:posList srsDimension="3" count="5">998.417 1018 0 1000.04 1033 3.29259 1000.75
1045.08 6.15357 998.417 1018 0</gml:posList>
</gml:LinearRing>
</gml:exterior>
</gml:Triangle>
<gml:Triangle>
<gml:exterior>
<gml:LinearRing>
```

```
<gml:posList srsDimension="3" count="5">1070.83 1039.07 6.57358 1076.54 1038.65
7.28319 1073.98 1046.35 7.9522 1070.83 1039.07 6.57358</gml:posList>
</gml:LinearRing>
</gml:exterior>
</gml:Triangle>
</gml:trianglePatches>
</gml:TriangulatedSurface>
</trn:tinSource>
</trn:TIN>
</trn:terrainSource>
</trn:Terrain>
</physicalObjectMember>
</UrbanModel>
</physicalModel>
```


The first step was converting the case study data from XML schema to JSON. The conversion was performed for all case study data: the terrain model and eight building units including two basements and two utility networks. An example of converted data (two TIN triangles) is as follows:


```
{"physicalModel": {
"UrbanModel": {
"physicalObjectMember": {
"trn:Terrain": {
"-gml:id": "TIN_1",
"trn:terrainSource": {
"trn:TIN": {
 "-gml:id": "TIN-1",
  "trn:tinSource": {
   "gml:TriangulatedSurface": {
    "-gml:id": "DCDM_tinSurface_1",
     "gml:trianglePatches": {
      "gml:Triangle": [
       {
         "gml:exterior": {
          "gml:LinearRing": {
           "gml:posList": {
            "-srsDimension": "3",
            "-count": "5",
            "#text": "998.417 1018 0 1000.04 1033 3.29259 1000.75 1045.08 6.15357
            998.417 1018 0"
            }}}},
       {
         "gml:exterior": {
          "gml:LinearRing": {
           "gml:posList": {
            "-srsDimension": "3",
             "-count": "5",
              "#text": "1070.83 1039.07 6.57358 1076.54 1038.65 7.28319 1073.98
              1046.35 7.9522 1070.83 1039.07 6.57358"
              }}}}
                      ]
         }}}}}}}}}}
```

Hereafter, as the input data, we used data from the terrain model, building units and utilities converted to JSON documents. Figure 1 shows the terrain model which has a small valley prepared for building infrastructure and which is built from the 237 triangles.

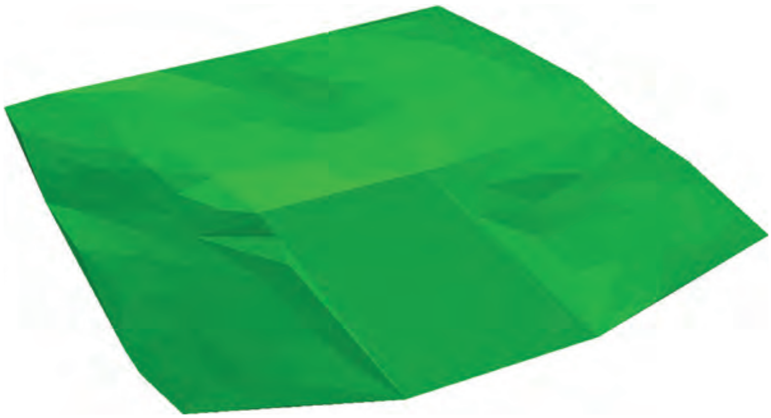

Figure 1: Visualization of the terrain model.

Figure 2 shows the terrain model and the building units. Figure 2a portrays six building units of six owners above ground whereby every building unit is colored to represent a different property holder. Figure 2b shows two underground building units — basements, and they are also colored according to property holder. Additionally, the water supply network (blue) and hot water network (red) are represented in Figure 2b. Both of them contain the main pipe and connecting pipe between the building and the main pipe.

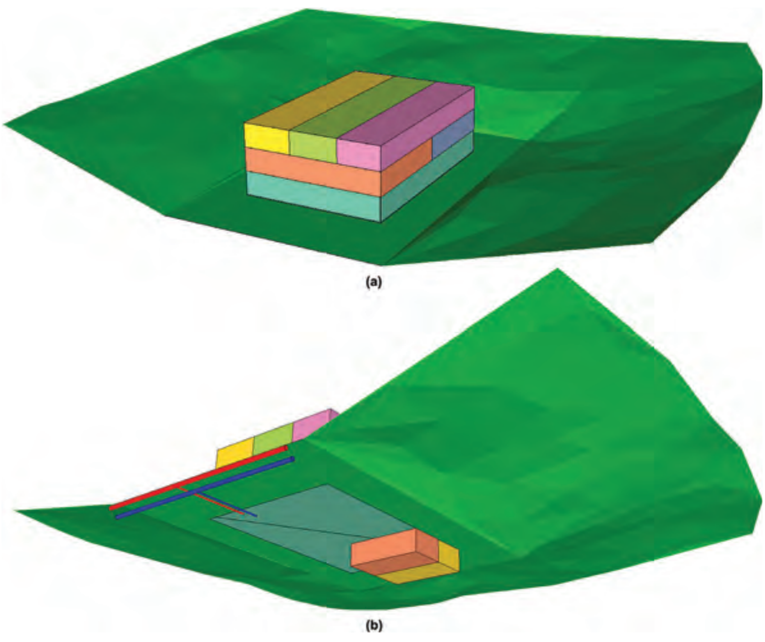

Figure 2: The terrain model and the building units. a) Six building units. b) Two underground units —basements and utilities.

The second step was to import data (JSON documents) to the MongoDB database. Imported documents are stored in the database called "3DCadastre" and within collections called "Terrain", "BuildingUnits" and "Utilities". Collections in MongoDB represent the set of documents grouped together. A collection may store documents that are not the same in structure and it can be seen as an analogy to a table of an RDBMS. The syntax for creating the database and the "Terrain" collections, as well as for importing the terrain model is as follows:

```
mongoimport --db 3DCadastre --collection Terrain --type json --file D:\3DCadastre\
Terrain\TIN.json
```

Note that a new database and collection can be created on the fly as a part of an import function without the previous definition. The syntax for importing other JSON documents related to Building Units is the same, but it can be modified to import all documents at once.

```
FOR %i IN (D:\3DCadastre\BuildingUnits\*.json) DO mongoimport --db 3DCadastre --col-
lection BuildingUnits --type json --file %i
```

By using just this simple syntax, many documents and 3D cadastral data can be easily imported and stored within the MongoDB database. Once imported, it is ready for querying, managing, and processing. Similar to RDBMS, data can be queried to define the conditions that need to be satisfied by returning documents. Additionally, it is possible to indicate the fields that should be returned including all or just the specified ones. Furthermore, it allows sorting options to be defined using extra logic. An example of returning the whole document that stores data on "Unit1" is as follows:


```
use 3DCadastre
db.BuildingUnits.find({ "UrabnCadastralModel.name.__text": "Unit1" })
```

Querying only specified fields (such as owner of the "Unit2") can be done by the following syntax:

```
use 3DCadastre
db.BuildingUnits.find(  { "UrabnCadastralModel.name.__text": "Unit2" },
{_id:0,"UrabnCadastralModel.physicalModel.UrbanModel.physicalObjectMember.Build-
ing.consistsOfBuildingPart.Unit.lpo.LegalPropertyObject.proprietor.InterestHold-
er._pName":1})
```

The query returns the following JSON document:

```
{
  "UrabnCadastralModel":{
    "physicalModel":{
      "UrbanModel":{
        "physicalObjectMember":{
          "Building":{
            "consistsOfBuildingPart":{
              "Unit":{
                "lpo":{
                  "LegalPropertyObject":{
                    "proprietor":{
                      "InterestHolder":{
                        "_pName":"Petar Markovic"
                      }}}}}}}}}}}}
```

The query can be modified to return only the value, with additional options, including logic operators and sorting options. The following query returns owners of all units in ascending order by the owner's name:

```
use 3DCadastre
var myQuery = db.BuildingUnits.find( { }, {_id: 0, "UrabnCadastralModel.name.__text":
1,"UrabnCadastralModel.physicalModel.UrbanModel.physicalObjectMember.Building.
consistsOfBuildingPart.Unit.lpo.LegalPropertyObject.proprietor.InterestHolder._
pName":1}).sort( { "UrabnCadastralModel.physicalModel.UrbanModel.physicalObject-
Member.Building.consistsOfBuildingPart.Unit.lpo.LegalPropertyObject.proprietor.
InterestHolder._pName": 1 } )

myQuery.forEach(
function(myDoc) { print( "Owner of the " + myDoc.UrabnCadastralModel.name.__text +
" is " + myDoc.UrabnCadastralModel.physicalModel.UrbanModel.physicalObjectMember.
Building.consistsOfBuildingPart.Unit.lpo.LegalPropertyObject.proprietor.Interest-
Holder._pName ); }
);
```

The query returns the following results:

```
Owner of the Unit4 is Aleksa Pavlovic
Owner of the Unit5 is Jovana Petrovic
Owner of the Unit1 is Marko Jovanovic
.
.
.
```

From the cadastral point of view, the data update is very important. Data stored within MongoDB can be updated by using *db.collection.update()* function. The query that updates the owner name of Unit1 to "Janko Jankovic" is as follows:

```
use 3DCadastre
db.BuildingUnits.update({ "UrabnCadastralModel.name.__text": "Unit1"},
{$set: {"UrabnCadastralModel.physicalModel.UrbanModel.physicalObjectMember.Build-
ing.consistsOfBuildingPart.Unit.lpo.LegalPropertyObject.proprietor.InterestHolder._
pName": "Janko Jankovic" } } )
```

All these queries are connected to alphanumeric data without any spatial queries. Regarding spatial queries, MongoDB supports the following GeoJSON objects:

- Point
- LineString
- Polygon
- MultiPoint
- MultiLineString
- MultiPolygon
- GeometryCollection

Additionally, it supports inclusion queries that allow the selection of documents with geospatial data within a specified shape. Intersection queries are also supported and the $near operator is very useful for returning documents from "nearest to farthest" with regards to a specified point. MongoDB supports 2D geospatial indexes for both 2D plane data and geometries on a sphere. MongoDB does not currently support 3D geospatial indexing and 3D geospatial querying. However, some applications, such as 3DRepo (3drepo.org, 2017), use the MongoDB database for storing their 3D models.

The 3D geometry data can still be updated as coordinate pairs. The next query updates the terrain model by extending the existing TIN with inserting two additional triangles.

```
use 3DCadastre

var AdditionalTriangle1 =  {
                          "exterior":{
                            "LinearRing":{
                              "posList":{
                                "__prefix":"gml",
                                 "__text":" 978 990 0 978 1018 0 998.417 990 0 978
990 0"},
                              "__prefix":"gml"},
                            "__prefix":"gml"},
                          "__prefix":"gml" }
var AdditionalTriangle2 =  {
                          "exterior":{
                            "LinearRing":{
                              "posList":{
                                "__prefix":"gml",
                                 "__text":"998.417 990 0 978 1018 0 998.417 1018 0
998.417 990 0"},
                              "__prefix":"gml"},
                            "__prefix":"gml" },
                          "__prefix":"gml"}

db.Terrain.update({
    "UrabnCadastralModel.name.__text": "TERRAIN"},
    {
   $push : {    "UrabnCadastralModel.physicalModel.UrbanModel.physicalObjectMember.
Terrain.terrainSource.TIN.tinSource.TriangulatedSurface.trianglePatches.Triangle" :
{ $each: [AdditionalTriangle1, AdditionalTriangle2]}
    }})
```

The "valley" of the terrain model is extended by inserting these two additional triangles. Figure 3 shows the modified terrain model and the edges of the inserted triangles are represented in red.

Since MongoDB stores data as JSON documents, it can be easily integrated with Java Script libraries for 3D visualization or even for 3D operations. In this study, 3D Cadastral data stored in MongoDB are visualized and queried inside a web browser by using Cesium Java Script library. MongoDB provides REST (Representational State Transfer) API, and together with JSONP enables returning JSON objects from the database (server) based on client query. An example of returning a JSON object from the Mongo database can be found on the following link (osgl.grf.bg.ac.rs/mongo_rest, 2017). The received JSON object represents TIN data used in the case study.

Furthermore, received data are provided to Cesium library which visualizes interactive 3D primitives. Figure 4 shows a representation of an interface of a web application based on Cesium, for which query and read data are from MongoDB.

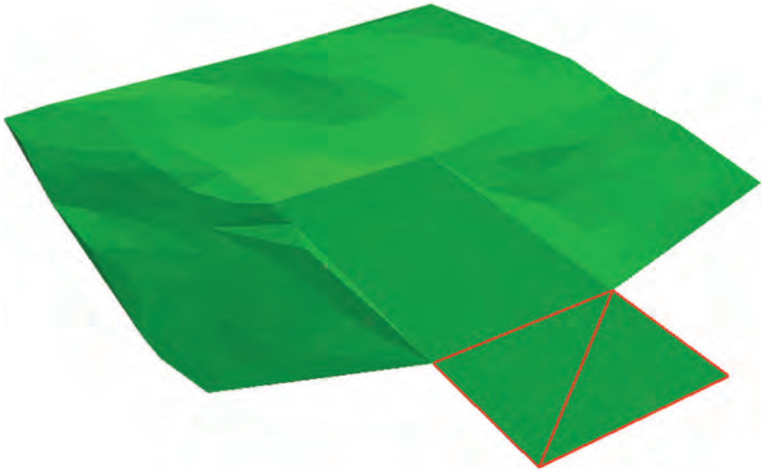

Figure 3: Visualization of the modified terrain model.

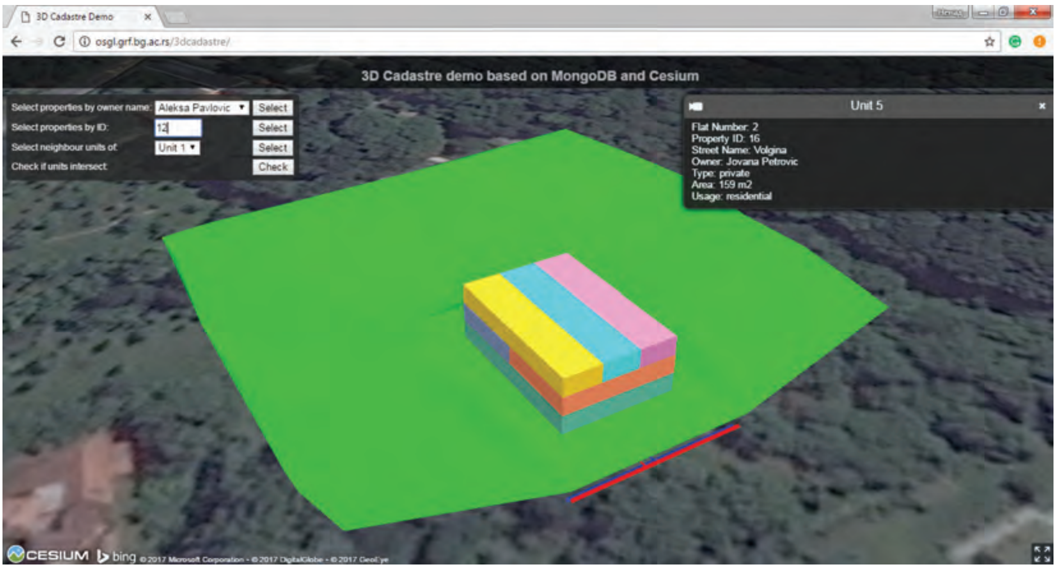

Figure 4: 3D cadastre demo based on MongoDB and Cesium.

The demo of the discussed 3D cadastre application is available at the web page URL: http://osgl.grf.bg.ac.rs/3dcadastre/ and it is optimized for the Google Chrome browser. Besides the visualization of 3D spatial data, the application provides interactive support and returns alphanumeric data stored in the database when the user clicks on a primitive. It also enables the selection and retrieval of property information based on owner name or property ID.

Regarding 3D operations, the CSG JavaScript library (github.com, 2017) was integrated into a demo application and it is used to support spatial queries. CSG (Constructive Solid Geometry) is a technique for solid modeling that uses Boolean operations to combine 3D solids. Two options are developed that offer selecting neighbor units (touching primitives with 0.01 m tolerance) and checking if building units intersect. These operations can be used as an example of topology rules. Furthermore, topology rules can be used to check topological relationships of data in the database until DBMS extends support for 3D topological models. Checking similar topology rules on a large dataset by using external libraries should be performed on the server side; for example, node.js (JavaScript runtime environment) modules can be used rather than using JavaScript libraries on the client side. This will help to avoid sending large data sets over the network and calculations on the client side, and hence clients will get only the part of the dataset they want to see checked based on topology rules. The presented 3D cadastre demo is feasible for adaptation to use data stored in RDBMS such as Postgres/PostGIS.

MongoDB, as one of the most popular NoSQL databases, can be used for storing 3D cadastral data. Due to the schema that allows varying sets of fields, with different types selected for each field, MongoDB easily store 3D models in many different formats such as CityGML or 3DCDM model presented in this study. Merging those models with 2D cadastral data, it is possible to implement hybrid 3D cadastral models.

MongoDB supports only 2D GeoJSON data types, 2D indexing, and 2D spatial queries. This is the main disadvantage for managing 3D cadastral data, although some of the basic 3D queries could be performed based on the geometry represented as a coordinate list. MongoDB can become a promising alternative to RDBMS if further development of NoSQL databases would include the support of 3D queries and 3D indexing, especially as an architecture that supports the storage of large amounts of data.

5 CONCLUSIONS

The transition from traditional cadastral systems to 3D cadastre brings new issues on the management of spatial data and it could result in very large datasets. On one hand, some of the relational database management systems support storing 3D objects and 3D operations. Whereas, on the other hand, they still do not fully support all 3D cadastre requirements.

Considering their flexibility to support non-strict data models, the NoSQL databases can be easily used for storing 3D cadastral data in different formats such as CityGML or XML formats. This option eliminates the disadvantages of these schemes with regards to simplified modification of text documents, efficient data protection and export within NoSQL database. As a result of the free-schema approach, NoSQL databases represent a good choice when it comes to hybrid models; i.e., mixed models of the current traditional 2D cadastral registration systems and 3D cadastre elements. This is due to the fact that these models can be easily stored within a NoSQL database (unlike relational databases, where the 2D cadastre model needs to be extended with new predefined tables for the 3D elements). Their capability to handle large datasets is also interesting for subsequent investigation of using NoSQL databases as DBMS in 3D cadastre.

Analogous to RDBMS, the NoSQL database requires long-term development to fully support all 3D cadastre requirements such as 3D spatial indexing, 3D queries, and 3D topology. In the last several years, progress in developing NoSQL database has been made and it can be encouraging and promising for the development of 3D features, as well.

NoSQL databases are immature (resulting in no standard query language and user interface) and some NoSQL systems do not follow the ACID properties which might be a drawback for 3D cadastre requirements. Non-standard query languages and user interfaces of NoSQL are also disadvantageous when compared to relational databases.

Future work should include research on developing 3D features within NoSQL databases, accompanied with investigation that will compare capabilities of RDBMS and NoSQL database to handle large 3D cadastral datasets. Furthermore, future research should include the development of 3D cadastral models that will be adjusted to NoSQL databases. In that way, it will be possible to use all the capacity of NoSQL databases for storage and manipulation of 3D cadastral datasets.

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DOLOČEVANJE REGIONALNEGA MODELA IONOSFERE TER PRIMERJAVA Z GLOBALNIM MODELOM

DETERMINING REGIONAL IONOSPHERIC MODEL AND COMPARING WITH GLOBAL MODELS

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IZVLEČEK

Signal GNSS (globalni navigacijski satelitski sistem) potuje do sprejemnika na Zemlji skozi različne sloje atmosfere. Eden izmed teh je ionosfera in se nahaja med približno 70 in 1000 kilometri nad površjem Zemlje. Razmere v ionosferi so odvisne od dnevnega in letnega časa, geografske lokacije in Sončeve aktivnosti. Vpliv ionosfere na signal GNSS je sorazmeren s količino prostih elektronov (TEC, angl. Total Electron Content). Za modeliranje ionosfere je ključno določevanje spremenljive vrednosti TEC. V našo raziskavo vrednosti TEC smo vključili opazovanja 26 postaj GNSS, 14 postaj omrežja TUSAGA-ACTIVE (CORS-TR) in 12 postaj omrežja IGS, ki smo jih obdelali s programskim paketom Bernese v5.2. Vrednosti TEC smo izračunali za dvourne intervale, za en dan v mesecu v obdobju med letoma 2009 in 2015. Vrednosti TEC, ki smo jih določili na podlagi opazovanj GNSS z uporabo modela enega sloja ionosfere (angl. Single Layer Model), smo primerjali z globalnimi kartami ionosfere (GIM-TEC), ki jih izdelujejo center CODE (Center for Orbit Determination in Europe), Evropska vesoljska agencija ESA, laboratorij JPL (Jet Propulsion Laboratory), ter z vrednostmi TEC (IRI-2012 TEC), pridobljenimi v okviru mednarodnega ionosferskega referenčnega programa. Za najboljša regionalna modela ionosfere sta se izkazala tista, ki ju zagotavljata CODE in ESA. Izdelali smo tudi karto regionalnih in globalnih vrednosti TEC za obravnavano območje.

ABSTRACT

GNSS (Global Navigation Satellite System) signals pass through various layers of the atmosphere until reaching the receiver on the Earth. The ionosphere, one of these layers, is about 70 km to 1000 km above the Earth surface and constantly changes with the time of day, seasons, geographical location and solar explosions. The GNSS signals affected by the variable structure of the ionosphere are proportional to the total electron content (TEC). Determination of the TEC change is important for modelling of the ionosphere. In this study, totally 26 stations, including 14 TUSAGA-ACTIVE (CORS-TR) stations in Turkey and 12 IGS stations, were selected and evaluated. Bernese v5.2 GNSS software was used for evaluation. TEC values were calculated at intervals of two hours, one day per each month, from 2009 to 2015. TEC values, obtained from GNSS measurements using Single Layer Model, were compared with global ionosphere maps (GIM-TEC) issued by the Center for Orbit Determination in Europe (CODE), the European Space Agency (ESA), the Jet Propulsion Laboratory (JPL), and TEC (IRI-2012 TEC) values obtained from international ionosphere reference program. The best approach to regional ionosphere model obtained as result of comparison was shown by CODE and ESA. Additionally TEC map was produced for the selected area as utilizing regional and global TEC values.

KLJUČNE BESEDE

GNSS, ionosfera, skupna vsebnost elektronov (TEC), globalna karta ionosfere (GIM)

KEY WORDS

GNSS, ionosphere, total electron content (TEC), global ionosphere maps (GIM)

1 INTRODUCTION

The atmosphere can be divided into different layers according to ionization and distribution. Due to the vertical change of temperature, the atmosphere is generally defined by four layers consisting of the troposphere (up to 10 km), stratosphere (10 km to about 50 km), mesosphere (50 km to about 70 km), and thermosphere (70 km to about 400 km) (Memarzadeh, 2009) (Figure 1). The exosphere is the outermost layer of the atmosphere. According to the signal propagation, the atmosphere is divided into two regions, the troposphere and the ionosphere. The troposphere usually covers a region being up to 40 km from the sea surface, and the ionosphere covers about 70 km to 1000 km and even more (Başpınar, 2012).

With respect to the signal propagation, the atmosphere is subdivided into two main layers of the troposphere (also referred to as neutral atmosphere) and ionosphere (Memarzadeh, 2009). The troposphere has refraction effect and causes similar effects on both code and phase modulation and results in a delay of up to 30 meters for a horizontal path. Therefore, the effect of the troposphere is considered one of the major sources of errors imposed on the satellite signals. On the other hand, the ionosphere having a dispersing effect among ionized atmosphere layer(s) affects the signal code and phase modulation in an opposing way (Başpınar, 2012).

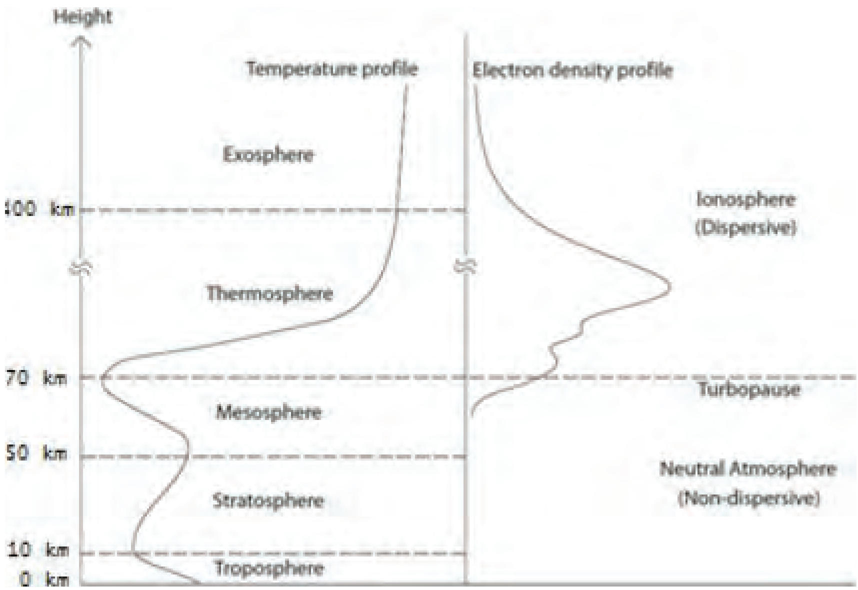

Figure 1: Atmosphere layers (Memarzadeh, 2009).

The ionosphere is an atmosphere layer, that is a region being from about 70 km to 1000 km from the Earth, and consists of gases surrounding the Earth and ionized by solar radiation. The most part of the ionosphere composes of neutral gases. Ionized gases are mostly formed by the short wave radiation (ultraviolet and X radiation). The amount of free electrons in the ionosphere depends on many factors such as time, location, geomagnetic mobility (Aysezen, 2008). The electron density in the ionosphere is changed by all effects like day/night, seasonal, geographic location, and magnetic storms occurred at Sun. The electrons that gets free as getting independent from their electrons by solar radiation reach at their high density at between 12:00–14:00 during the local day time. At night, the ionization gets less since electrons unites with ions. Seasonal electron density changes in the ionosphere are caused by the angle and distance changes between the Earth and the Sun. However, the 11-year solar cycle has also an effect on the electron density in the ionosphere (Komjathy, 1997). One of the parameters used to define the status of the ionosphere is Total Electron Content (TEC). The TEC represents the total number of free electrons contained in a column with cross-sectional area of 1-square meter and its unit is TECU, where 1 TECU is 10^{16} el/m^2 (Schaer, 1999; Dach et. al., 2015).

Changes of the TEC in the ionosphere may be determined by GNSS observations before, during and after earthquakes (Ulukavak and Yalçınkaya, 2014). Electrical and magnetic field changes may be occurred in the earthquake area and its vicinity due to earthquakes. As these changes proceed to the atmosphere, the electron density of ionosphere changes due to the uniting of neutral atmosphere and ionized plasma (coupling) (Calais et al., 1998). Before big volcanic eruptions, the rate of occurrence of TEC anomalies are related to volcanic type and geographical location (Li et al., 2016). Thus, the effects of earthquakes and volcanic eruptions may be monitored.

2 THE STRUCTURE OF THE INOSPHERE

2.1 The regions of the ionosphere

The ionosphere is divided into three major regions, geographically, the high latitude region, the middle latitude region and the equatorial region, and scientific studies are based on these regions (Figure 2).

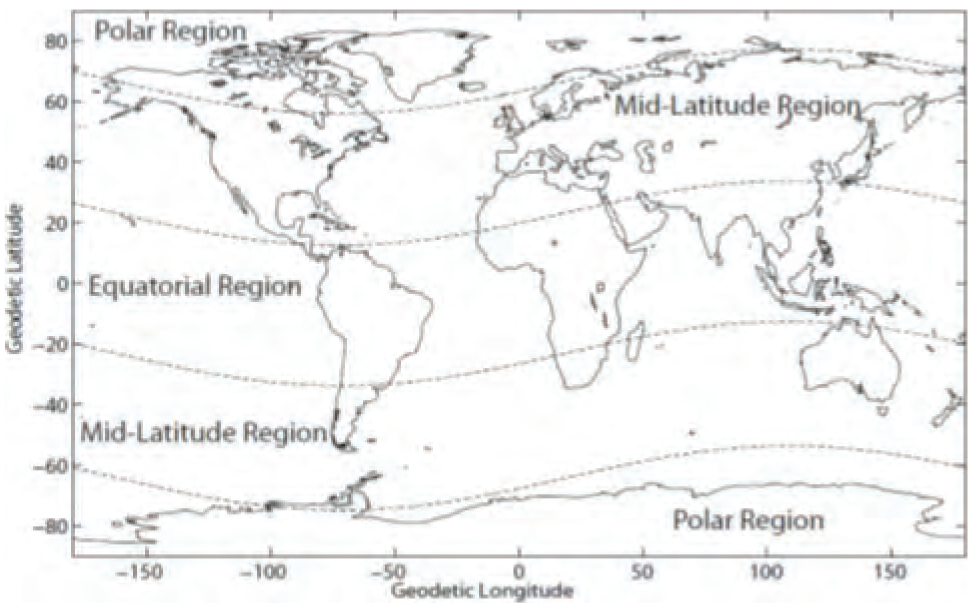

Figure 2: The regions of Ionosphere (Memarzadeh, 2009).

The high latitude region consists of auroral and polar regions. The electron density values are lower in this region than equatorial region. However, the short cyclic ionospheric variations are greater than in the equatorial region (Skone and Cannon, 1999; Danilov and Lastovicka, 2001).

The middle latitude region, in which Turkey is also located, is the best-known region, since a large part of research refers to this region. The region in which the ionosphere is calm and has little change is the middle latitude region. For this reason, the majority of the ionosphere survey stations and ionospheric studies are conducted in the countries in the middle latitude region (Schaer, 1999). The ionization that occurs in this region is usually produced by solar X-ray emission and energy-loaded ultraviolet radiation. Ionization ends up with chemical processes involving ionized moieties as well as neutral atmosphere (Arslan, 2004).

The equatorial region is the region that has the highest electron density, and the amplitude and phase of the signal are frequently changed. The reason of that is strong solar radiation and intense ionization. The ionospheric activity occurred in the equatorial region is called as equatorial anomaly. The equatorial anomaly is defined as the decrease in electron density due to magnetic storms. This anomaly changes with the dynamo of the E layer, which causes the regional electric field in equator and is controlled by global tide winds. The daily equatorial anomaly starts at 9:00–10:00 local time and reaches its highest value at 14:00–15:00 (Gizawy, 2003).

2.2 Ionosphere Layers

The ionosphere consists of different layers. Each of these layers which are caused by the severity of ionization level behaves differently during the day and these layers are generally classified as D, E, F1, F2 (Figure 3).

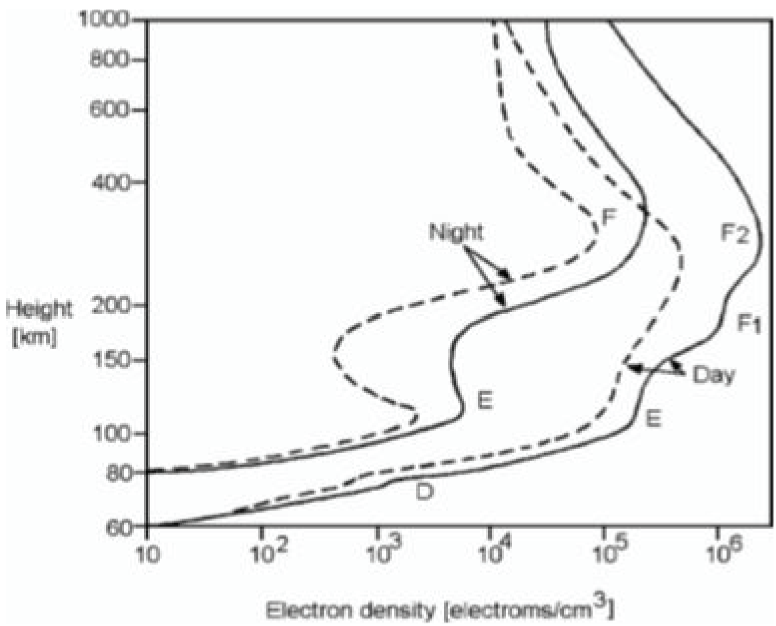

Figure 3: Ionosphere Layers (Hargreaves, 1992).

The D layer is the least ionized layer and is 60–90 km high from the Earth's crust (Wild, 1994). It is not thought that this layer has strong effects on GNSS measurements (Petrie et al., 2011). The E layer, which is formed by the influence of weak X-ray, is 90–140 km above the Earth's crust. This layer where the partial ionization, called as irregular Es, occurs has a little effect on GNSS measurements. The ionization is not thought to be related to the E layer during daylight hours, the anomaly formed by solar particles cause sparkles in polar region (Arslan, 2004).

The F layer, which is investigated in two parts, F1 and F2, is located 150 km over the Earth's crust and is formed by ultraviolet rays of the sun. Approximately 10% of the delay of the GNSS signal in the ionosphere is due to the F1 layer (Parkinson and Spilker, 1999). The structure of this layer is regular and controlled by changes in the Sun, 140–200 km above sea level. The F2 layer, which has the most impact on GNSS measurements, has an irregular structure and is 200–1000 km above the Earth's surface (Parkinson and Spilker, 1999). The electron density of the F2 layer, which shows different changes in polar regions, irregularly decreases at night. This layer is very irregular in the equatorial region, and the electron density at night time may be higher than at noon (Wild, 1994, Poole, 1999). The ionosphere layers and their specifications are presented in Table 1.

Table 1: Ionosphere layers and features (Wild, 1994; Arslan, 2004).

Layers	Height (km)	Electron Content (1/cm^3)		Neutral gas content (1/cm^3)
		Night	Day	
D	60–90	10^2–10^4	---	10^{15}
E	90–140	10^5	$2 \cdot 10^3$	$2 \cdot 10^{12}$
F_1	140–200	$3 \cdot 10^5$	10^3	10^{10}
F_2	200–1000	$5 \cdot 10^5$	$3 \cdot 10^3$	10^6–10^{10}

3 THE EFFECT OF THE IONOSPHERE ON GNSS SIGNALS

The ionospheric data can be available in detail based on a large number of GNSS observation stations and GNSS satellites scattered all around the Earth. TEC values may be determined by the help of L1 and L2 carrier phases sent from GNSS satellites since the ionosphere is a scattering medium. TEC values contain data about the global or regional ionosphere structure (Davies and Hartmann, 1997; Fedrizzi et al., 2001). The local (regional) TEC map is obtained by applying the Taylor expansion to the *L4* linear combination, which is equal to the difference of *L1* and *L2* phase measurements.

$$L_4 = L1 - L2 \qquad (1)$$

For modelling of global ionosphere effects, spherical harmonic expansion is used since the Taylor expansion being regional is insufficient (Arslan, 2004).

3.1 Obtaining TEC values with GNSS measurements

Determining TEC values with GNSS measurements is a fast and low-cost method used to understand the structure of the ionosphere. The graphical representation of the total electron content in the ionosphere is given in the Figure 4. TEC is a value with plus sign; if there is a negative value this is the cause of receiver and satellite errors.

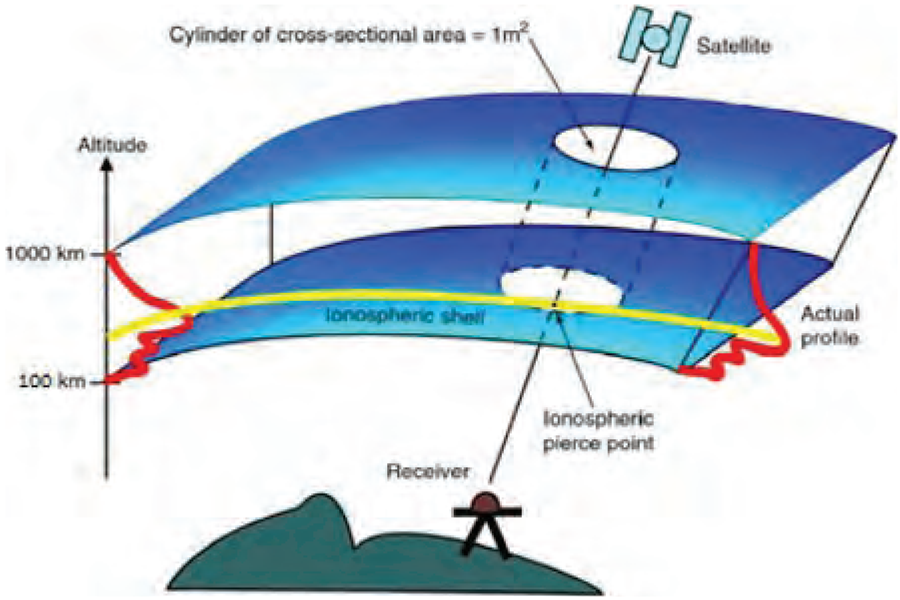

Figure 4: The graphical representation of the total electron content (Langley, 2002).

The height of the ionosphere is generally accepted as 450 km by softwares and it is assumed that TEC being at this height is at its highest value (Komjathy and Langley, 1996).

3.2 Single Layer Model

Ionosphere has a wide band. For defining this band, the single layer model, where free electrons with the maximum density are considered to be in an infinitely thin area is utilized (Hugentobler et al., 2001). The model assumes that all electrons in the ionosphere gather in an infinitely thin layer, which is between 300 and 450 km over the Earth surface (Inyurt, 2015). In the figure 5 the single layer model is shown.

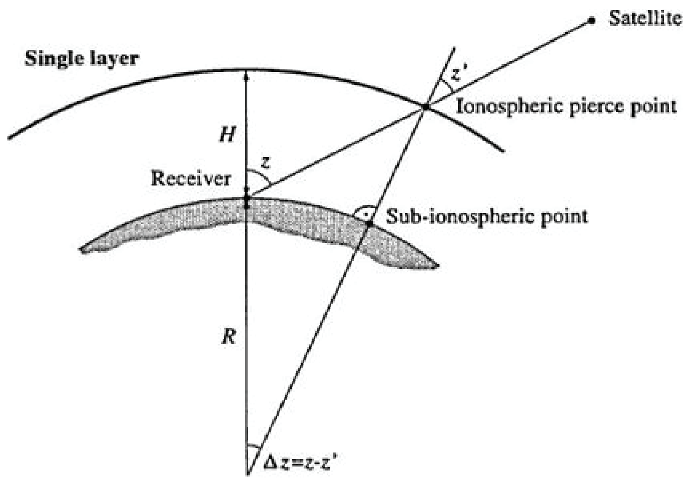

Figure 5: The Single Layer Model (Schaer, 1999).

The Single Layer Projection Function F_I,

$$F_I(z) = \frac{E}{E_V} = \frac{1}{\cos Z'} \qquad (2)$$

$$\sin Z' = \frac{R}{R+H} \sin Z \qquad (3)$$

is obtained by these equations. In the equations (2) and (3), E is electron content along the signal way, E_v is vertical electron content, z and z' are zenith angles, R is the mean Earth radius, Δz is difference between z and z' zenith angles, H is the height of the single layer.

3.3 Local TEC Model

If $E_v(\beta, s)$ is expanded as to two-dimensional Taylor series to present total vertical electron content:

$$E_v(\beta, s) = \sum_{n=0}^{n_{\max}} \sum_{m=0}^{m_{\max}} E_{nm} (\beta - \beta_0)^n \cdot (s - s_0)^m \qquad (4)$$

In this equation; n_{max} and m_{max} are the maximum orders of the two-dimensional Taylor series expansion in latitude and longitude, E_{nm} is the unknown coefficients of the Taylor series expansion, (β, s) are the solar-geographic coordinates of the ionospheric pierce point, (β_0, s_0) are the coordinates of the origin of Taylor series expansions. The unknown parameters for each satellite and receiver E_{nm}, are estimated by applying the least squares method. The angle of Taylor series depends on the behaviour of the ionosphere. If the angle is too high, the reliability of the estimated ionosphere parameters decreases (Wild, 1994). Zero angle defined as E_{00} informs about TEC on the reference station which TEC parameters are expanded by series. GNSS measurements and TEC values can be derived directly from the station-related data, as well as from GNSS-based models generated. GIM (Global Ionosphere Maps) can be an example for that. In addition, at our present time the International Reference Ionosphere (IRI) model provides ionospheric parameters such as electron density, ion and electron temperature as well as TEC information.

3.4 Global TEC Model

The Taylor expansion used for local models is insufficient for a global TEC model. The spherical harmonic expansion is accepted as an ideal approach to determine a global TEC (Schaer et al., 1995). The spherical harmonic expansion is as

$$E_v(\beta, s) = \sum_{n=0}^{n_{\max}} \sum_{m=0}^{m_{\max}} P_{nm}(\sin\beta)\big(C_{nm}\cos(ms) + S_{nm}\sin(ms)\big) \qquad (5)$$

In this equation, $E_v(\beta, s)$ is the vertical total electron content, $P_{nm}(\sin\beta)$ is the normalized Legendre Function, C_{nm} and S_{nm} are the unknown spherical harmonic coefficients and global ionosphere map parameters, respectively, n_{max} and m_{max} are the maximum degree of the spherical harmonic expansion, $\beta$is the latitude, s is the sun-fixed longitude (Arslan, 2004).

There are a lot of institutions which produces Global Ionosphere TEC maps all over the world. These are the CODE (Center for Orbit Determination in Europe), DLR (Fernerkundungstation Neustrelitz, Germany), ESA/ESOC (the European Space Agency, Germany), JPL (Jet Propulsion Laboratory, USA), NOAA (National Oceanic and Atmospheric Administration, USA), NRCan (Natural Resources, Canada), ROB (Royal Observatory of Belgium, Belgium), UNB (New Brunswick University, Canada), UPC (Polytechnic University of Catalonia, Spain), WUT (Warsaw University of Technology, Poland) (Schaer, 1999). The Global ionosphere map (GIM) is issued in the format of IONEX (IONosphere map EXchange). IONEX formatted TEC values are lined up as involving all over the world. The TEC value at required point may be obtained from this line. If the latitude and longitude of a point are known, the relevant TEC value is obtained with the help of the 4 nearest TEC values covering two variable interpolation points (Schaer et al., 1998). When the value calculated to determine the TEC in the TECU unit is multiplied by 0.1, the TEC value of the relevant point is determined in the TECU unit. IONEX formatted global ionosphere maps are produced at intervals of 2 hours. For TEC values, the increase in the longitude is 5° and the increase in the latitude is 2.5° (Arslan, 2004). The accuracy of TEC values published in IONEX format varies between 2–8 TECU.

The solutions to GIM maps can be downloaded from the IGS data center (URL 1). Up to the present, there have been no discrepancy between the solutions issued by different analytic centers. The IRI model was produced by the cooperation of the International Union of Radio Science (URSI) and COmittee on SPAce Research (COSPAR) and is still regularly developed and improved. The last version of the model that you may get online is IRI-2012 (Bilitza et.al., 2014). IRI can present a number of parameters related to the ionosphere, including the TEC value for ionospheric heights between 60 km and 2000 km, as to required location, date and time (Leong et. al., 2015). TEC values can be calculated with international ionosphere reference model (IRI-2012) via internet address (URL 2).

4 APPLICATION

In this study, 14 of TUSAGA-ACTIVE (CORS-TR) stations located between 36–40 latitudes and 27–35 longitudes in Turkey was used to set a regional ionosphere model. Totally 26 stations were used – the others were IGS stations. RINEX data related to designated stations from 2009 till the end of 2015 was obtained. Regional TEC values for the selected region from 2009 until 2015 were determined through the evaluation made by Bernese v5.2 GNSS software. The GIM values produced by CODE, ESA and JPL and the IRI-2012 (International Reference Ionosphere) model developed by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI) were used to compare the produced TEC values.

The TUSAGA-ACTIVE (CORS-TR) and IGS (International GNSS Service) stations used are geographically presented in the Figure 6. The data belonged to TUSAGA-ACTIVE stations was obtained from (URL 3) website and the data from the IGS stations was obtained from (URL 4) website. Regional TEC values from 2009 to 2015 were obtained as a result of the conducted research. In order to compare the regional TEC values obtained from the GNSS measurements with the Bernese v5.2 GNSS software, the GIM-TEC values published by the CODE, ESA and JPL were downloaded from the web (URL 1) and TEC values obtained from IRI were calculated using the provided online solution (URL 2). The minimum (Table 2) and maximum (Table 3) results achieved in the study are presented in the Table 2 and Table 3.

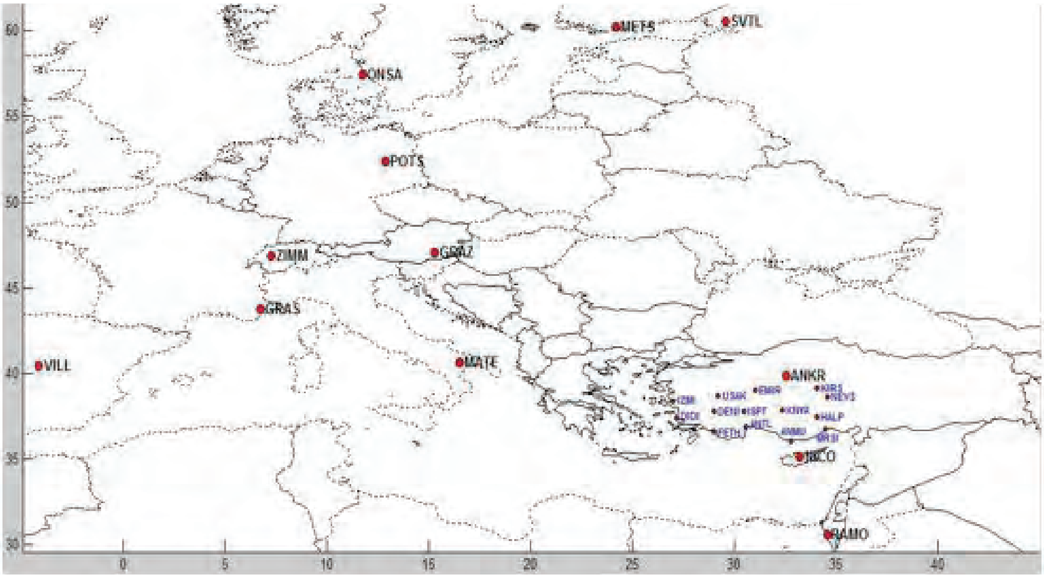

Figure 6: The general structure of the network.

Table 2: Minimum observed TEC values.

Years	Minimum Observed Values									
	RIM		CODE		ESA		JPL		IRI	
	TEC	UTC Time	TEC	UTC Time	TEC	UTC Time	TEC	UTC Time	TEC	UTC Time
2009	5.50	02:00	7.08	02:00	5.05	02:00	8.25	02:00	1.74	02:00
2010	7.03	02:00	9.00	02:00	5.92	02:00	9.59	02:00	2.25	02:00
2011	9.55	02:00	9.91	02:00	7.95	02:00	11.35	02:00	3.39	02:00
2012	10.65	02:00	11.30	02:00	9.23	02:00	12.32	02:00	4.04	02:00
2013	11.06	02:00	12.01	02:00	10.53	02:00	13.03	02:00	4.18	02:00
2014	12.48	02:00	12.97	02:00	12.43	02:00	13.78	02:00	4.71	02:00
2015	11.15	02:00	11.50	02:00	10.99	02:00	12.45	02:00	4.19	02:00

The graphical representations of obtained TEC values were prepared by **MATLAB** software. As a result of evaluations, the mean of TEC values from 2009 to 2015 was calculated and compared with IRI and GIM (JPL, ESA, CODE) mean TEC values. The results belonged to FETH, IZMI, KIRS and MRSI stations are graphically represented. When Table 2–3 are examined, it is seen that 2009 and 2014 have minimum and maximum TEC values, respectively. The minimum TEC values for 2009 and the maximum TEC values for 2014 are shown in Figures 7–8, respectively and the TEC maps for these years are shown in Figures 9–12.

Table 3: Maximum observed TEC values.

Years	Maximum Observed Values									
	RIM		CODE		ESA		JPL		IRI	
	TEC	UTC Time	TEC	UTC Time	TEC	UTC Time	TEC	UTC Time	TEC	UTC Time
2009	13.40	10:00	14.23	10:00	12.94	10:00	16.62	10:00	10.33	10:00
2010	18.63	10:00	19.54	10:00	17.21	10:00	21.37	10:00	12.96	10:00
2011	29.67	12:00	29.49	12:00	29.27	12:00	31.59	12:00	18.43	10:00
2012	35.22	10:00	34.83	10:00	33.28	10:00	37.12	10:00	22.09	10:00
2013	34.71	12:00	34.28	10:00	35.09	12:00	36.84	12:00	23.92	10:00
2014	41.07	10:00	40.96	10:00	44.71	12:00	43.27	10:00	25.98	10:00
2015	34.24	12:00	34.46	12:00	37.76	12:00	36.33	12:00	22.72	10:00

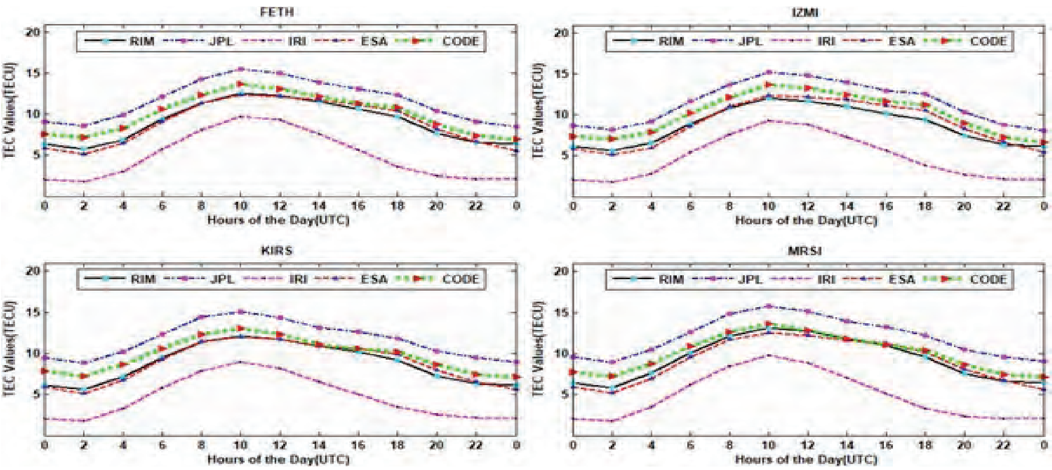

Figure 7: Comparison of mean TEC values (RIM-Result) obtained at FETH, IZMI, KIRS, MRSI points with CODE, ESA, JPL, IRI values for 2009.

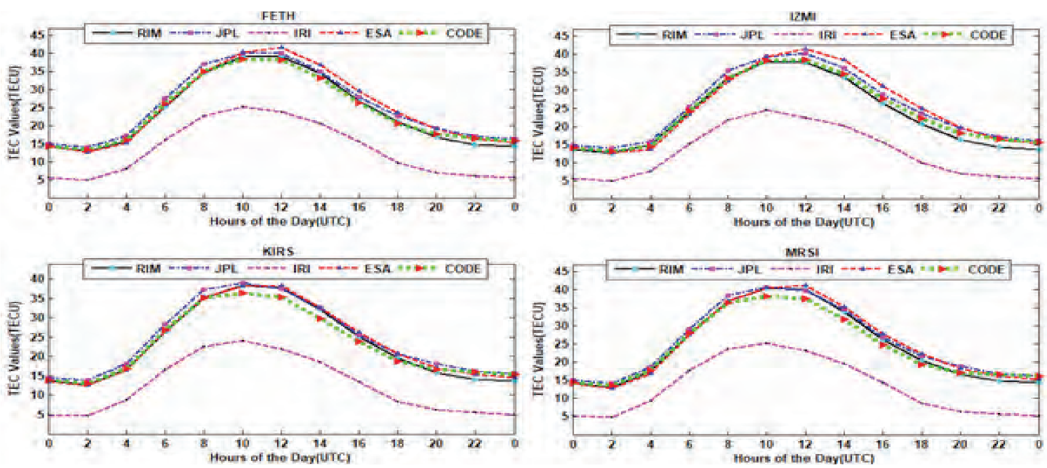

Figure 8: Comparison of mean TEC values (RIM-Result) obtained at FETH, IZMI, KIRS, MRSI points with CODE, ESA, JPL, IRI values for 2014.

The mean TEC values, which were produced at intervals of two hours for the selected days by using the TEC values obtained from the evaluation, were compared with the mean TEC values of GIM and IRI. In the graphs, the horizontal axis represents the universal time in hours, and the vertical axis represents TEC in TECU units.

The TEC values obtained from the global ionosphere model (CODE, ESA, JPL) began to increase at 02:00 am and reached to its maximum value at 12:00. In general, the global TEC values are of the lowest value at 2:00 am and the highest value between 10:00 am and 12:00 pm. The TEC values obtained online in the IRI model are of the lowest value at 02:00 am and the highest value at 10:00 am. In the regional ionosphere model (RIM), the TEC values obtained from the result of the evaluation began to increase at 02:00 am and rise to 12:00 pm, as in the global ionospheric models. In general, it is seen that the RIM-TEC values are at the lowest value at 02:00 am, similar to the global TEC values, and at the highest value between 10:00 am and 12:00 pm (Figure 7–8, Table 2, 3).

As utilizing the regional TEC values obtained from the evaluation and the global TEC values, and writing a command called as *TECmap* via **MATLAB**, and TEC map was produced by using mean TEC (RIM-TEC) values obtained from analysis for selected region and GIM (CODE) mean TEC values. The obtained TEC maps involve 24-hour time period starting from 00:00 hours at 2 hours intervals (Figure 9–12).

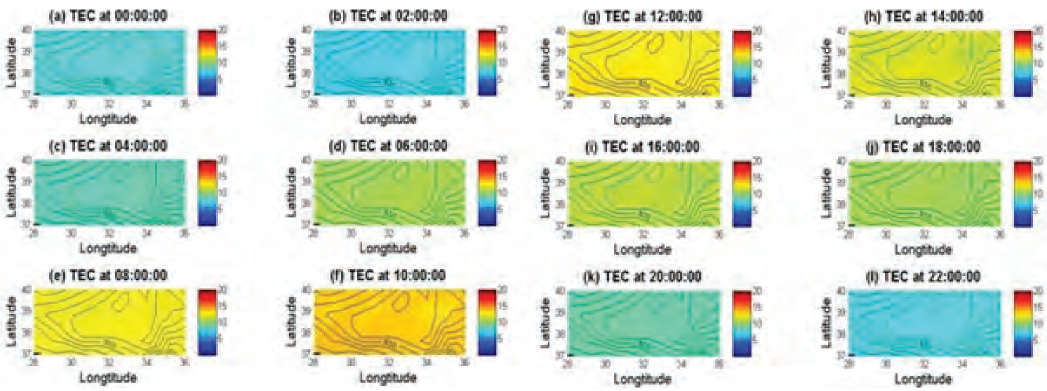

Figure 9: Global CODE TEC maps produced at 2 hour intervals for 2009

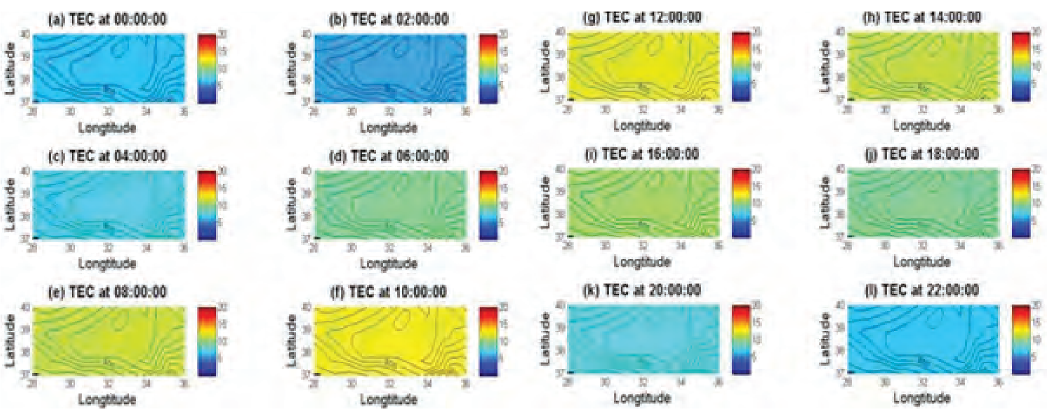

Figure 10: Regional RIM TEC maps produced at 2 hours intervals for 2009

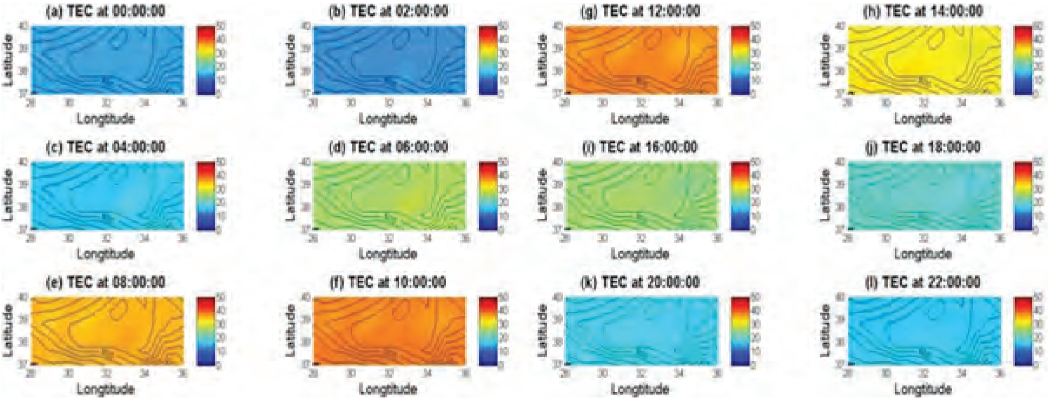

Figure 11: Global CODE TEC maps produced at 2 hour intervals for 2014

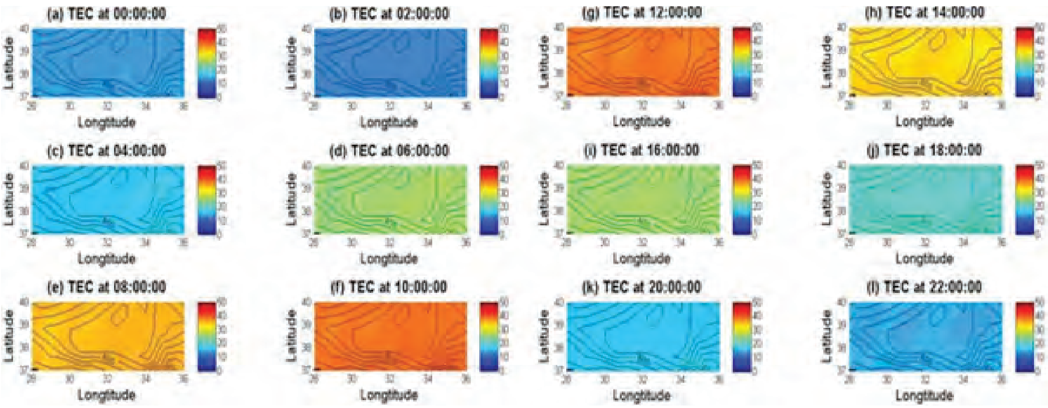

Figure 12: Regional RIM TEC maps produced at 2 hour intervals for 2014.

TEC maps were produced as calculating the mean of TEC values belonged to 14 TUSAGA-ACTIVE (CORS-TR) stations used for evaluation at various times of day. When examined all the maps produced from 2009 to 2015, it is seen that all TEC values increased until noon times and after that they decrease (Figure 9–12).

5 CONCLUSION

In this study, the regional ionosphere model was set by utilizing totally 26 GNSS stations as 14 of these were TUSAGA-ACTIVE (CORS-TR) stations located between 36–40 latitudes and 27–35 longitudes in Turkey. The regional ionosphere model that had been set was compared with global ionosphere model (CODE, ESA and JPL) issued by IGS and the IRI-2012 and the ionosphere maps covering the selected region were produced. Hence, Bernese v5.2 GNSS software was used to determine regional TEC values.

TEC values obtained from the regional ionosphere model (RIM), global ionosphere model (CODE, ESA, JPL) and IRI model generally began to increase at 02:00 am and reached at their maximum values at 12:00 pm. They began to decrease after 12:00 pm. Additionally, the density is at minimum values at 02:00 am and maximum values between 10:00–12:00.

When examining the Figure 7–8, it is seen that there is a substantially similarity between obtained regional (RIM) TEC values and global (CODE, ESA, JPL) TEC values, and TEC values obtained from IRI-2012 are lower in comparison to those four values. The most important reason why the IRI-2012 TEC estimate is low is that the TEC estimate obtained is kept low due to the absence of the ionosonde station in Turkey. On the other hand, it has been shown that five different TEC values obtained had similar behaviour during the day. It is generally seen that the five TEC values obtained increased until noon, and then the TEC values decreased due to the recombination of the ions in a free state. One of the most important reasons for that is thought to be the sun rays. At noon, when the sun rays are most forceful, the molecules in the air are separated by the effect of this radiation, and that causes increasing number of electrons in free state.

TEC maps that shows TEC changes as to latitude and time were produced for the selected region covering the 24-hour time period at 2 hours intervals by utilizing the regional TEC values obtained from the evaluation made from 2009 till the end of 2015 and the global TEC and IRI TEC values. When examined figure 9-12, it is seen that the produced TEC maps and TEC values belonged to points at Figure 7-8 shows similar results.

Establishing a system which will continuously monitor the change of TEC values as the most important function of the ionosphere, especially at the TUSAGA-ACTIVE (CORS-TR), will make a great contribution to studies about earthquake, volcanic eruptions, and determining the location of the missiles and for both improving accuracy of location and examining the relationship with ionosphere.

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SODOBNI SISTEM KLASIFIKACIJE TRGA NEPREMIČNIN

MODERN CLASSIFICATION SYSTEM OF REAL ESTATE MARKETS

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IZVLEČEK

Tema študije je klasifikacija stanovanjskega trga nepremičnin v urbanem okolju, kjer je kot osnovno orodje za določevanje objektivnih primerjalnih kriterijev izbrano razvrščanje. Glavni cilj raziskave je bil razviti postopek za točkovanje stanovanjskega trga nepremičnin, katerega rezultati bil bile kakovostne informacije oziroma znanje o trgu nepremičnin, kar bi pomembno prispevalo k sprejemanju zanesljivih odločitev na trgu. Klasifikacija je bila izvedena ločeno za povpraševanje in ponudbo. V ta namen je bilo uporabljenih več razredov informacij, ki se nanašajo na stanovanjske, gospodarske, družbene, prostorske in lokacijske dejavnike ter lahko pomembno vplivajo na odločitve na nepremičninskem trgu. Ključna pri predlagani metodologiji je določitev točke primerjave ali tudi točke benchmarking. *Ta se določi za namene izračuna točk za razvrščanje, ki temeljijo na predpostavki najvišje stopnje podobnosti glede na druge objekte in se določijo na podlagi teorije grobih množic. Točka primerjave lahko predstavlja stopnjo podobnosti (nerazločnosti, kot je poznano v teoriji grobih množic) pojava v množici. Rezultati raziskave so pokazali povezavo med kakovostjo urbanega prostora in stanovanjskim trgom, predvsem pri načrtovanem razvoju območja in izboljšavi kakovosti življenja, manj pa za primere gospodarske blaginje območja.*

ABSTRACT

In this study, rating is proposed as a modern tool providing objective comparability criteria to classify the residential market within the urban space. The main aim of this study was the development of the rating score procedure for residential market as a specific knowledge platform to help in the making of reliable decisions. The classification was conducted for demand and supply separately with the use of categories of information relating to residential, economic and political, social, spatial and location factors that can have the most important influence on market decision-making. The crucial stage in this methodology was establishing the benchmark point (BB) to calculate the rating score that was determined on the assumptions of the highest value of the similarity in relation to other objects with the use of a rough set theory. This point might represent the level of similarities (indiscernalities, as in rough set theory) of the features in the set. The results demonstrate that there is a link between the condition of urban space and the residential market but in the case of the expectation of further area development and quality of life rather than the economic prosperity of a region.

KLJUČNE BESEDE

trg nepremičnin, klasifikacija, sistem razvrščanja, urbani razvoj

KEY WORDS

real estate market, classification, system-rating, development of urban area

1 INTRODUCTION

Cities and regions wishing to achieve a dominant position in the network via their policy try to attract as many entities and types of activity as possible. When examining the structure and the character of the surrounding space, it is possible to determine whether there are attractive prospects, and whether there is growth potential in the analyzed area. The link between real estate markets and potential of urban growth was revealed a long time ago (e.g. D'Arcy and Keogh, 1999; Leung, 2004). Real estate markets play an increasingly important role in the global economy and attract a growing number of international investors, which is why the demand for reliable classification and scoring systems will continue to grow and become an essential tool in the process of investment planning. The positions of particular cities that will be developed according to established criteria can be crucial when choosing an investment location, and can affect the range of influence of the central site for the entire region.

Making optimum decisions should rely on reliable data describing reality, in line with the decision-maker's preferences (Saaty, 2008). However, it should be highlighted that necessary parameters for decision making are: availability of information (uncertainties – risks) and rationality of decision making (bounded rationality implies human shortcuts). However, access to reliable data or information is difficult nowadays, not so much because of lack of access to them, but due to excessive amounts of such data (so-called information noise) and difficulties in the proper selection of the right type of data. Classification of the real property market's potential based on the conditions and specific character of the analysed urban space allows for its evaluation and, on the other hand, for inspiring its development and adjustment to current and future needs.

The *main problem* in the field involves the development of a comprehensive classification of the real estate market relevant to the specific character of real estate market operations, which involves complex procedures and decisions, as well as the unique character of real estate data. These factors prevent the smooth flow of information, which is required for the implementation of rational decisions and actions in business, investment, financial and promotional projects. Providing access to the knowledge of the real estate market, developed in the form of a simple message, is the only way to solve this problem. The author assumed that this can be achieved by developing a rating measure of the real estate markets providing general and clear information classifying the object of analysis.

The *main aim* of this study was the development of a rating score procedure for real estate markets. Proposed by author classification can be used as a tool providing objective comparability criteria in the adopted reference perspective. The prepared results allow for the identification of economic and social processes in the spatial aspect, which leads to a better and more efficient self-organization of space. This study analyzes the assumption that there is a direct interaction between the conditions of human existence and, generally speaking, the quality of life and the structure of the urban areas determined by the macro and micro location conditionals and the development and growth potential of residential real estate markets. Data used in the rating process characterize the location area in detail, along with real property entities, introduce objective comparison criteria for real property markets, and help in making rational decisions with respect to the location of investments.

Object. The object of the analysis was the residential real estate markets represented by residential apartments, taking into account the commonality of their use. The study was conducted on the basis of 16 provincial markets within the time period 2012-2014 that constitute the most important space of impact onto other regions and the best point of reference – representation of their region, also on account of more complete access to data. The study contains 122 attributes that were used for the rating classification of real property markets (see Appendix 1).

Research method. The author proposed the methodology of the rating score in the form of a multivariate procedure. In the analytical part of the procedure to determine the rating for real estate markets the valued tolerance relation formula, existing mainly as an extension model of the classical rough set theory, was applied. The development of a benchmarking level was the most significant point in this analysis because it has an influence on the classification of the further ratings levels of specific variables. Due to the small number of observations (cases), there are limited possibilities of using statistical methods, which are generally based on the assumption of a larger number of cases compared to the data describing them. Therefore, the rough set theory was applied as a method that takes into account the small size of the data.

2 RELEVANT LITERATURE – THE NEED FOR PROPERTY MARKET RATING

"Rating" is an economic term with a variety of meanings. In the discussed context, a rating was defined as the process and the results of the evaluation and classification of a given phenomenon. Ratings might be applied on different markets – categorization based on nature of goods: (1) capital, (2) labor and service, (3) commodity markets. Originally, the rating was created to the classification of the capitals (1) and it is called credit rating. Based on the original assumptions the author try to develop methodology of this kind of classification such rating, particularly devoted to the real estate market.

Generally, ratings are performed by credit rating agencies (CRA), as well various institutions, which use ratings for their own needs, mostly banks, investment funds and insurance companies. Basically, we can define credit ratings as a system for evaluating and classifying investment risk. In the last few years we have noticed that credit ratings enjoy growing popularity as a source of information about the risk of bankruptcy, and the financial condition of the analysed entity. Despite delayed and inaccurate predictions, credit ratings are a highly effective analytical tool. The independent and objective nature of CRAs has been recognized and emphasized by EU law (Regulation (EC) No. 1060/2009 of the European Parliament and of the Council of 16 September 2009 on credit rating agencies and Commission Delegated Regulation (EU) No. 447/2012 of 21 March 2012 supplementing Regulation (EC) No. 1060/2009 of the European Parliament and of the Council on credit rating agencies by laying down regulatory technical standards for the assessment of compliance of credit rating methodologies). However, the credit rating methodologies (Lynch, p. 24.) cannot simply be copied to the real estate market in the view of the specificity of the real estate market. We need the methodology to adjust to this domain because of the specific nature of the real estate data and market. The methods and procedures that may be developed and implemented should account for the following defects in real estate data: significant variations in the quantity of available information, absence of data, small number of transactions, significant variations in attribute coding, non-linear correlations between the analyzed data and the type of the underlying market, etc. The solutions should support market analysis at the potential (theoretical) and actual (applied) levels.

Markets are generally classified in view of the type of traded estate (land plots, buildings, apartments), parties to the transaction (local government, central authorities, individuals), type of real estate (residential, commercial, industrial, recreational, agricultural) and geographic reach (local, regional, national, international). Taxonomy and segmentation imply detailed classification of real estate markets, based on the preferences of specific buyer groups or condition of buildings. These classifications use basic criteria, which may not be enough regarding current increased access to knowledge and requirements of market participants. A more sufficient market classification was presented, among others, by Goodman and Thibodeau (1998, 2003), in which residential property was classified based on criteria such as spatial variation, neighborhood and physical attributes. Keener Hughen and Dustin (2014) developed models to classify the market within parameters determining the evolution of the demand on the basis of developers' activities concerning inclusionary housing policy. The analyses explored the relationship between real estate development decisions and inclusionary housing policies in different types of economic environments. Another interesting analysis was conducted by Sato and Xiaob (2015), who analysed the interactions between labour and housing (and land) markets in a city. They proved that labour market conditions affect the land price, land development, housing price, housing consumption, and city configuration. On the other hand, Liu et al. (2006) indicated that interaction effects and non-linear relationships between market prices and hedonic variables complicate the direct interpretation of market classification and fluctuation.

The necessity of determining the structural and spatial classification of real property markets results from various needs. D'Arcy and Keogh (1999) argued that the role of the property market in determining urban competitiveness is significant. They proved that the real estate market has a direct influence on high and sustainable urban economic growth. Moreover, the significant link between the real estate market and urban space was proved by The Torto Wheaton Research (2002). They showed that real estate prices in Amsterdam over 300 years displayed no trends, although it had deep volatility, and they indicated that there might be a high probability that some features connected with the social, political and economic condition of the city may have an impact on this phenomenon. Moreover, Leung (2004) raise the issue that conjecture between the growth and decline of cities and housing markets should be irrefutably and scientifically established.

Analysis of the relationship between urban areas and real estate markets is a current issue for several reasons. Firstly, the development of cities is strongly determined by the development of real property markets as an important element attracting people to a given location. On the other hand, a real property market is shaped not only by real properties, but also by certain features of its environment: the immediate one (e.g. prices, vacancy), and, more and more frequently, the more distant one, related to the macro-economic determinants, e.g. inflation, the prosperity of the area, global crisis, the condition of the banking sector, etc. (Jud and Winkler, 2002; Leung, 2004; Źróbek and Grzesik, 2013; Biłozor and Renigier-Biłozor, 2014). The development of cities depends on their attractiveness, expressed by the number of attracted people, and in particular inhabitants and capital. On the other hand, Kotler (2011) claims that nations and urban areas position themselves on their ability to attract certain groups of human and physical capital and at the same time discourage other groups (e.g. low-income families, the homeless, or criminal types). Secondly, housing market fluctuation may result from fluctuation in urban areas (Dobkins and Ioannies, 2001; Leung, 2004). Urban city variability may help us understand the relationship between the macroeconomy and the real estate market, and how the real estate market will change in the frame of globalization and financial integration. Nowadays, at a time of an exceptionally fast downward demographic tendency of developing countries and developed countries, the attractiveness of residential markets is a very important competitive element of cities and regions. There is a strong feedback loop between the residential property market and a city, because the development and attractiveness of residential property markets are conditioned by economic, political, social, spatial and location factors offered by urbanized space. On the other hand, the development of cities depends on the attractiveness of real property markets as an effect of conducting efficient territorial marketing by cities, which is taken into account by potential city dwellers as a very important element of the "migrant decision" (Kotler et al., 1993; Dinis, 2006; Bernat et al., 2014). Furthermore, the attractiveness of the real estate market is a very important element in the procedure of city branding construction, which constitutes a fundamental part of forming and meeting residents' satisfaction (Dinnie et al., 2010).

An accurate prediction of the real estate market potential is essential to prospective homeowners, developers, investors, appraisers, tax assessors, and other real estate market participants, such as, mortgage lenders and insurers (Case, 2000; Frew and Jud, 2003; McCue and Belsky, 2007; Foryś, 2011; Global Real Estate Transparency Index, 2014). Kan et al. (2004) conducted a more comprehensive analysis the real estate markets to increase mortgage-based securities. Moreover, learning lessons from the last outbreak the Global Financial Crisis (2007-2008), primarily initiated by the insolvency of mortgage borrowers, it can be assumed that current and objective monitoring of the real estate market is an absolute requirement to maintain balance, increase security and minimize the risk of crisis in many aspects of human existence in urban space. Although recent year have witnessed the growing popularity of various support systems, comprehensive and effective information systems that facilitate the real estate market continue to be in short supply. The scarcity of relevant information and objective knowledge results from the shortcomings of market effectiveness analyses (Case and Shiller, 1989; Fama, 1990; Kaklauskas et al., 2011; Renigier-Biłozor and Wiśniewski 2012, Bilozor, 2014; Stec et. al. 2014).

The potential and power of classifying real estate market in the rating form was indicated by TEGOVA (2003) and Kalberer (2012). They defined "Property and Market Rating" as a versatile instrument for assessing the quality of property. However, these authors recommended the use of a developed procedure to assess individual properties' risks for securitization purposes rather than for markets in general. Others authors find real estate market ratings a useful tools for a variety of practical purposes. They are used to developing portfolio investment strategies (Anglin and Yanmin, 2011, Collett et al, 2003) and formulating long-short portfolio strategies on housing indices for more risky and less risky assets characterized by low liquidity (Berach and Skiba, 2011).

Rating has the potential to increase market effectiveness analyses as a source of objective knowledge. In the light of the research the author proposed the development of a "ratings of real estate market" as a modern tool that can be used in analyses and predictions of real estate market potential.

3 METHODS OF RESEARCH

The main aim of this study was the development of a rating score procedure. Because the general assumption of the rating is to provide quick, objective, reliable and updated information, a dataset has to be developed as a specific knowledge platform for dedicated analyses. Every rating is developed for a broad group of recipients who have varied levels of knowledge about the analyzed real estate market. A rating scale for classifying real estate markets is proposed in Table 1.

Table 1: Rating scale for classifying real estate markets.

Group	Description of market characteristics
Investment level (A category)	**"High"** High return on investments; Positive market outlook; High market growth potential; High potential for economic and spatial growth; Self-regulatory capacity, flexible response to economic changes; The situation on the real estate market fosters positive social change; Satisfactory price-cost relationship; Stable behavior of real estate market actors; Low threats to the growth of the real estate market; The situation on real estate market fosters positive social change.
Development level (B category)	"Moderate" Moderate return on investments; Moderate market outlook; Certain threats to market growth potential; Moderate potential for economic and spatial growth; Lower self-regulatory capacity, less flexible response to economic changes; The situation on the real estate market fosters moderately positive social change; Greater discrepancies between the cost and prices of real estate; Less predictable behavior of real estate market actors; Moderate threats to the growth of the real estate market; The situation on the real estate market fosters moderately positive social change.
Stagnant level (C category)	**"Low"** **Low return on investments; Negative market outlook; High threats to market growth potential (supply and demand on the real estate market); Low potential for economic and spatial growth; Low self-regulatory capacity, significantly less flexible response to economic changes; The situation on the real estate market does not foster positive social change; High discrepancies between the cost and prices of real estate; The behavior of real estate market actors is likely to be unpredictable; High threats to the growth of the real estate market; The situation the real estate market does not foster positive social change.**
Crisis level (D category)	"Lack"/"deficit" No returns on investments; The market is stagnant with no prospects for growth; No potential for economic or spatial growth; The market is undergoing reorganization. The price-cost relationship cannot be determined; The behavior of market participants cannot be predicted; Very high threats to the growth of the real estate market; The situation on the real estate market drives negative social change.

Source: own study basis on Renigier-Biłozor et al. (2014).

The real estate markets were scored on a 10-point rating scale and were divided into four rating level groups: investment, development, stagnant and crisis. Except for the crisis level group, which has a single score – D, there are three scores per group: AAA/BBB/CCC, AA/BB/CC and A/B/C. Scores AAA/BBB/CCC represent the highest rating, AA/BB/CC – a medium rating, and A/B/C – the lowest rating in a given group.

The determination of the rating score for the real estate markets was prepared in the form of a procedure aimed at obtaining a significant element supporting decision making in the market (Fig. 1). The author proposed the methodology of the rating score in the form of a multivariate procedure. The procedure consisted of the several stages that are methodological opened.

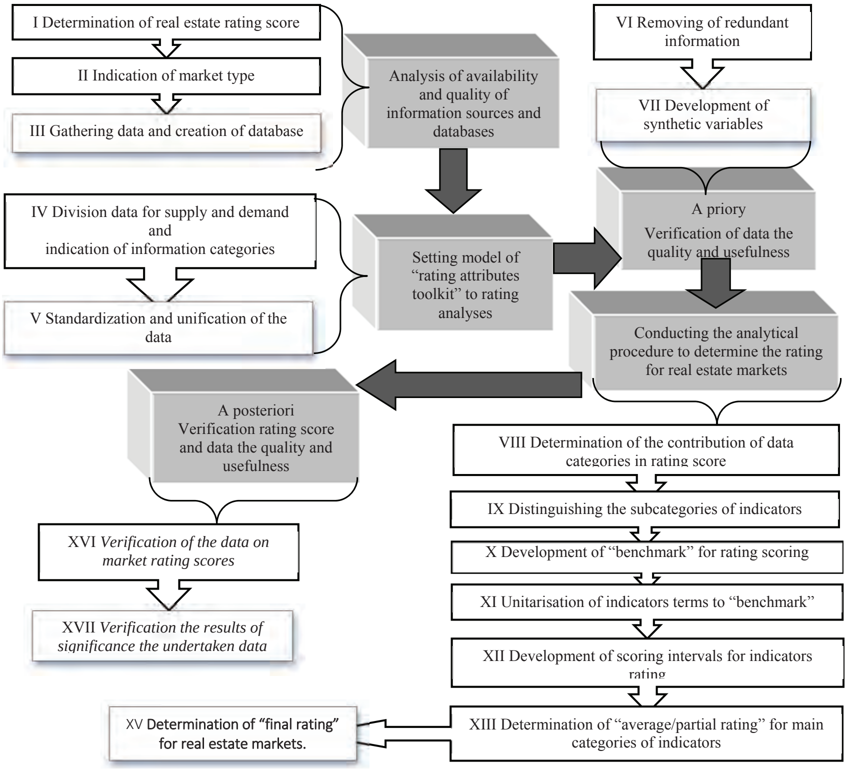

Figure 1: Procedure of the rating score for the real estate markets. Source: Author's elaboration.

The proposed rating score procedure assumed a few main stages leading to the development of a reliable rating for real estate markets. One of the stages is related to the analysis of availability and quality of information sources and databases. In the initial phase, it is necessary to define the purpose and the scope of the study within the determination of the overall rating score. A precise description of the type and the segment of the real estate market, and the utility function of the real estate is necessary to develop reliable results. The next step assumed the review and analyses of the sources of information from available databases. The following stage assumed the setting model of a "rating attributes toolkit" for rating analyses. In this context, the division of data for information categories (i.e. social, economic, etc.) within the supply and demand side of indicators should be prepared. In order to obtain comparable data for different subjects of the field, analysis of the standardization and unification of the data has to be conducted. A priory verification of data on the quality and usefulness is the subsequent stage in the procedure. In this stage, the procedure assumed the removal of redundant information that enables the elimination of dispensable, unnecessary data with the use of correlation analyses. In order not to lose important information, the development of synthetic variables was assumed. The next stage expected a conducting of the analytical procedure to determine the rating for real estate markets. The procedure assumed a few main steps connected with distinguishing the subcategories, unitarisation data and development scoring results. The above stages were presented and descripted more precisely in the paper Renigier-Biłozor et al. (2017).

The analytical procedure assumed the determination of the benchmarking (reference point) that constitutes the main (basis) platform for the analytical ranking of rating levels. For the analysis, the valued tolerance relation formula, existing mainly as an extension model of the classical rough set theory, was applied. The development of a benchmarking level is the most significant point in this analysis because it has an influence on the classification of the further ratings levels of specific variables. The author assumed that it is some point that represents the level of similarities (indiscernalities) of the features in the set. It is known from theory and practice that two identical real properties or two real property markets do not exist. The problem that appears here consists in finding the manner of comparing similarities of real property markets.

Due to the small number of observations (cases), there are limited possibilities of using statistical methods, which are generally based on the assumption of a larger number of cases compared to the data describing them. Therefore, the rough set theory was applied as a method that takes into account the small size of the data. Moreover, the assumptions of this theory are relatively simple, clear and repetitive in subsequent rating years without changing. The rough set theory is used to analyse data that is qualitatively and quantitatively ambiguous, imprecise and varied. The classical rough set theory was developed (Pawlak, 1982) to analyse the imprecise and vague data which is commonly found in the real estate market and accompanies decision making (fuzzy decision making) in that market. Moreover, the theory with a valued tolerance relation extension is used in many sciences, and it is often applied as the main support tool in decision-making systems (Polkowski and Semeniuk-Polkowska, 2010; Zavadskas and Turskis, 2011; Renigier-Biłozor, 2011; Renigier-Biłozor and Wiśniewski, 2011; Chung and Tseng, 2012). The rough set theory assumed the development of a decision table – the determination of the domains of different conditional attributes (real estate market attributes) and the decision attribute (rating of the market). The equivalence classes of the indiscernibility relation were determined based on similarity between the analyzed properties markets with the use of Value Tolerance Relation that allow to obtain "fuzzy" similarities.

4 RESULTS – SIMULATION OF RATING PROCEDURE

The prepared results allow for developing a rating measure of the real estate markets providing general and clear information classifying the object of analysis. That classification can then be used in property market rating as a tool providing objective comparability criteria in the adopted reference perspective. Within the range of this study the authors assumed that the rating would be performed for residential real estate markets represented by residential apartments, taking into account the commonality of their use. The study was conducted on the basis of 16 provincial markets within the time period 2012–2014. All the proposed provincial cities constitute the most important space of impact onto other regions and the best point of reference – representation of their region, also on account of more complete access to data. The database, called the "rating toolkit", was developed in the previous work of the author, entitled "Rating attributes toolkit for the residential property market" (Renigier-Biłozor et al., 2017). The determination of databases for real estate market rating was prepared in the form of a procedure aimed at obtaining a reliable a knowledge platform for rating analysis. The study contains 122 attributes that were used for the rating classification of real property markets (see Appendix 1).

The next step of the procedure assumed the development of data categories scope. The existing knowledge was compiled to develop a set of indicators for the overall evaluation of the real estate markets. An attempt was made to develop features that can have the most important influence on market decision-making on the basis of literature analysis (mentioned in the above literature review) and thoughtful observations by participants in the real estate market. These include categories of information strictly relating to the residential, economic and political, social, spatial and location realms. Each of these realms represents a different range of information that more or less affects quality of life. Thus, in the long term, it has an influence on decisions concerning the buying, renting or selling of residential real estate. Variables were classified and labelled during the construction of the database on supply or demand indicators (see App. 1). Such a division was proposed due to the diversity of the target group for these two market phenomena. This division was also dictated by significant differences in the growth potential of the analysed real estate markets. The following stage was an a priori verification of the quality of data in the rating attributes toolkit. The aim of the aforementioned verification was the removal of redundant information. For this purpose, cross-correlation analysis was applied (the Pearson correlation analysis and Kendall's τ). The developed analyses allowed for a decision to be made on the reduction of redundant combinations of variables.

The further stage assumed conducting the analytical procedure to determine the rating score that is the main part of the presented study. In the aforesaid procedure the first step concerned the establishing of the contribution of indicators of each category in rating score. The contribution was developed on the basis of assuming the importance of each category in the real estate rating classification. The percentage contribution of toolkit indicators on the rating score is considered in the following way: I set of residential indicators – 40%, II set of economic and political – 20%, III set of social – 20%, IV set of spatial and location – 20%. Residential indicators constituted the most significant type of data, followed by political and economic, social, spatial and location indicators. The lower contribution of data expressed by economic, social and location indicators was assumed, due to the indirect connection with the current situation in the real estate market. Those factors are still very important, but instead initiated and inspired changes in the longer period, which means that they did not play a foreground role or have an impact on the diagnosis of the real estate market condition. However, it is important to underline that the residential indicators are the evidence of the current situation, the condition in the market that has been created due to social, economic or spatial features. Moreover, in each of the set categories the subcategories of indicators determining (det.) or destimulating (des.) supply or demand were distinguished.

The next issue was the determination of a reference point (basic platform) to calculate the rating level for the database. First of all, the adopted rating levels were assigned to a numerical form: AAA – (1), AA – (2), A – (3), BBB – (4), BB – (5), B – (6), CCC – (7), CC – (8), C – (9) and D – (10). The reference point was BB level – a rating score was designated due to the observation that demand still outpaces supply in Poland's emerging real estate market. Rating scores were determined individually for supply and demand due to various market functions and the supply-demand imbalance.

Designation of the BB level (called the benchmark, reference point, basic platform) was established for each indicator separately with the use of an assumption of the rough set theory and value tolerance relations on the basis of the formula below:

$$R_j(x,y) = \frac{\max\left(0, \min\left(c_j(x), c_j(y)\right) + k - \max\left(c_j(x), c_j(y)\right)\right)}{k} \tag{1}$$

where: $R_j(x, y)$ – relationship between two sets with membership function [0,1]

x, y – number of provincial real estate market (x = 1:16; y = 1:16)

$c_j(x)$, $c_j(y)$ – value of jth indicator of the analyszed real estate market

j – number of indicator

k – coefficient adopted as standard deviation for a given real estate market attribute, allow to consider objects as a indiscernible without having identical values.

The formula, marked as (1), has been developed and discussed by Stefanowski and Tsoukias (2000). It been applied in real estate market analyses by d'Amato (2007), Renigier-Biłozor (2011). The formula is used to compare two data sets and obtained result within the [0, 1] range marks the level of the indiscernibility relation. In the formula output, there is a level of indiscernibility relation between the object and the rule, assuming a **k level** of threshold for the measure of the attribute.

For example in case of indicator 1 (see app. 2) the relationship between the object $c_1(1)$ (x=1 its Gdańsk; $c_1(1)$= 44.0) and object $c_1(2)$ (y=2 its Olsztyn; $c_1(2)$= 36.8) where k=8.966 has a value 0.20. This value is obtained as follows:

$$R_1(1,2) = \frac{\max(0; 36.8 + 8.966 - 44.0)}{8.966} = 0.20$$

In view of the above, the benchmark (BB) was calculated on the basis of the results produced by the valued tolerance relation matrix for every indicator of every market. The formula presented below assumed that BB_j is equal to the maximum sum of R_j for those market (from 1 to 16) that achieved maximum results of R_j(x,y) that indicated the biggest similarity and representation among others markets.

$$BB_j(x) = \sum_{y=1}^{16} R_j(x, y); BB_j = \max_{x=1:16} BB_j(x) \qquad (2)$$

These benchmarks need to be realistic and objectively measurable. In the light of the analysis, the benchmark level is established on the assumption of the highest value of the similarity in relation to other objects. The aim of this analysis was to obtain the objective level of the relative comparison values in a specific set of particular the variables that it was possible to determine in this field of research. An example of the conducted analysis is presented in Table 2. This table consists of the result of the calculation benchmark (BB) level for indicator no. 1.

Table 2: Determination of BB point (benchmark) for indicator No. 1 (*j* = 1) with the use of the value tolerance relation.

Market's number	**1**	**2**	**3**	**4**	**....**	**16**
1	1	0.2	0	0	…	0.63
2	0.2	1	0.68	0	…	0.57
3	0	0.68	1	0	…	0.24
4	0	0	0	1	…	0
....	0.59	0.61	0.29	0	…	0.96
16	0.63	0.57	0.24	0	…	1
BB1(x)	3.54	**5.49**	4.93	1.08	…	5.39

Source: Author's calculation

The table indicates that the benchmark point was established at the level of the second market (x=2) because $BB_1(2)$ was the highest (5.49). The benchmark point for indicator No. 1 was constituted as $c_1(2)$=36.80, which was the ranking of the quality of local government for market No. 2 (that is Olsztyn – see append. 2). The benchmark point was determined for every indicator in the above way.

The following step concerned the unitarisation of indicators of terms to the "benchmark" level. The unitarization of indicators was established based on the formula below:

$$U_j = \frac{c_j(x) - BB_j}{\Delta c_j} \quad (3)$$

where:

$$\Delta c_j = \max_{x=1:16} c_j(x) - \min_{x=1:16} c_j(x)$$

The results of the unitarisation value for the sets were sorted in ascending order. An example of the conducted analysis for indicator No. 1 is presented in Table 3.

Table 3: determination of U_1 value (indicator No. 1).

Market's number	13	4	8	14	6	3	11	2	5	7	10	16	1	12	15	9
BB1 = 36.80 and Δc_1 = 32 U_1	-0.478	-0.422	-0.191	-0.172	-0.116	-0.091	-0.059	0.000	0.109	0.109	0.109	0.122	0.225	0.241	0.509	0.522

Source: Author's calculation

The next issue was the development of scoring intervals for indicator ratings. The scoring intervals were established separately for determinants and destimulants with the assumptions below:

- for determinants: if BB = 0 than AAA = 1 and D = -1
- for destimulants: if BB = 0 than AAA = -1 and D = 1

The determinants positively influence the features that shape the housing real estate market condition, while the destimulants have a negative influence on them.

To account for the aforesaid, the intervals were determined separately for determinants and destimulants (Tab. 4).

Table 4: Scoring intervals for the indicator's rating.

Rating levels for determinants			**Rating levels for destimulants**		
Numerical classification	The range of levels	Rating scale	Numerical classification	The range of levels	Rating scale
-1.00	below -0.910	D	-1.00	below -0.876	AAA
-0.8	-0.710 to -0.900	C	-0.75	-0.626 to -0.875	AA
-0.60	-0.510 to -0.700	CC	-0.50	-0.376 to -0.625	A
-0.40	-0.310 to -0.500	CCC	-0.25	-0.126 to -0.375	BBB
-0.20	-0.110 to -0.300	B	0.00	-0.125 to 0.100	BB
0.00	-0.100 to 0.125	BB	0.20	0.110 to 0.300	B
0.25	0.126 to 0.375	BBB	0.40	0.310 to 0.500	CCC
0.50	0.376 to 0.625	A	0.60	0.510 to 0.700	CC
0.75	0.626 to 0.875	AA	0.80	0.710 to 0.900	C
1.00	higher than 0.876	AAA	1.00	higher than 0.910	D

Source: Author's calculation

On this basis every indicator from the "rating attributes toolkit" was evaluated. An example of the determination of the indicator's rating is shown in Table 5.

Table 5: Results of the rating for indicator No. 1 (determinants) and indictor No. 4 (destimulants).

Market's number	Rating for determinants		Market's number	Rating for destimulants	
	Ui for indicator no. 1	Rating score		Ui for indicator no. 4	Rating score
13	-0.478	CCC	**1**	-0.194	BBB
4	-0.422	CCC	**11**	-0.167	BBB
8	-0.191	B	**13**	-0.083	BB
14	-0.172	B	**15**	-0.028	BB
6	-0.116	B	**10**	0.000	BB
3	-0.091	BB	**4**	0.028	BB
11	-0.059	BB	**9**	0.028	BB
2	0.000	BB	**12**	0.083	BB
5	0.109	BB	**6**	0.194	B
7	0.109	BB	**16**	0.194	B
10	0.109	BB	**14**	0.222	B
16	0.122	BB	**8**	0.250	B
1	0.225	BBB	**3**	0.389	CCC
12	0.241	BBB	**7**	0.444	CCC
15	0.509	A	**5**	0.556	CC
9	0.522	A	**2**	0.806	C

Source: Author's calculation

The next step was the determination of a "partial rating" for subcategories indicated in step IV. The partial rating scores were determined individually for residential, economic, social and location sub-categories within the supply and demand of sets. An arithmetic mean was calculated from indicators belonging to the given subcategory. For example, the following values were determined for Gdańsk in the economic and political set for supply: ind.4 – BBB (score 4); ind. 5 – A (score 3). ind. 6 – BBB (score 4); ind. 7 – A (score 3); mean – 3.50 (A).

Due to the fact that every category has a different contribution in the final rating, it was necessary to prepare more detailed intervals to account for variations within each rating score ("+" and "-" signs). Plus (+) and minus (-) signs must be appended to rating symbols to indicate their relative position within each rating category. The intervals were determined within the main categories to determine final ranking scores. Additionally, those intervals were set to account for the fact that the calculated "partial rating" scores for the main categories (e.g. AAA) would not always equal 1. The final rating scores were determined for the analyzed markets by calculating the mean for partial rating scores, taking into account the percentage of each subcategory in the final result. Final rating scores were designated based on the intervals of rating scores. The results of the final rating score for demand and supply of analysed markets is shown in Table 6.

Final rating scores were determined to minimize the impact of the potential subjective classification of various indicators. The rating score for analysed markets was quite good (the worst was at the B- level) in general. The score resulted from the choice of subjects for experiment and the simulation of the developed rating methodology. There were main markets in the country with the greatest potential for development and the best economic condition within the region (province). Moreover, the rating for supply and demand was not identical for particular markets. This is understandable because the balance between supply and demand does not exist in the real cases in the property markets.

The analysis indicated that Wroclaw received the highest results for supply (an area in the strong stage of recent development and with good future expectations of urban growth), and the lowest was received by Bialystok (the relatively poorest area of the country, and with uncertain future expectations for urban growth). Simultaneously, the rating for demand was different for most markets. Poznań received the highest result (an area with a good quality of life, and in a strong stage of development, and with good future expectations for urban growth), and Łódź received the lowest (an industrial area with a poor quality of life, and with uncertain future expectations for urban growth). However, the following markets received a high evaluation of demand rating: Opole and Rzeszów (BBB), with a relatively high unemployment rate and poor living conditions, especially in comparison to the nearest main neighbouring markets, but with a big potential for growth in comparison (contrast) with the poor development of the urban areas closest to where they are.

For a better interpretation, a visualization of results is presented on the maps (Fig. 2 and 3). It must be stressed that just the real estate markets which were analysed are presented on the maps. All the proposed markets constitute the most important space impact onto other regions and the best point of representation of their region. Analysing the maps, we cannot notice the existence of any obvious space trend. There is no connection between size of the city and rating of the residential markets due to the fact, that the markets' condition doesn't depend from the availability of area, but more from the social, economic and quality of life from overall point of view and future perspective of the city development.

The space of the analysed country was not divided into better (with a higher rating score) or worse (with a lower rating score) part of the area regarding real estate markets. We can just notice that the best markets are mostly surrounded by the worse (Fig. 2, e.g. Warszawa - Bydgoszcz, Kielce, Bialystok; fig.2, e.g. Katowice – Kielce . Łódź). It is possible that the markets with the highest score work as a magnet and aggravate the condition of the main market (town) surrounding them. Therefore, it can be assumed that the analysed (main) property markets works autonomously and strongly compete to attract people by using their own strategy.

Table 6: The final rating score for the residential real estate markets.

Rating of supply			Rating of demand		
Gdańsk	3.47	A-	Gdańsk	4.35	BBB-
Olsztyn	5.40	BB-	Olsztyn	4.60	BB+
Szczecin	4.68	BB+	Szczecin	5.12	BB
Bydgoszcz	5.59	B+	Bydgoszcz	5.41	BB-
Białystok	**6.31**	B-	Białystok	5.64	B+

Rating of supply			**Rating of demand**		
Poznań	5.02	BB	**Poznań**	**3.15**	A
Warsaw	3.46	A-	Warsaw	3.38	A-
Łódź	4.62	BB+	**Łódź**	**5.78**	B
Wrocław	**3.24**	A	Wrocław	4.29	BBB-
Lublin	5.09	BB	Lublin	5.28	BB
Kraków	4.31	BBB-	Kraków	4.32	BBB-
Rzeszów	4.97	BB	Rzeszów	3.54	BBB+
Zielona Góra	5.27	BB-	Zielona Góra	5.06	BB
Kielce	6.05	B	Kielce	5.71	B+
Katowice	3.85	BBB	Katowice	3.42	A-
Opole	4.99	BB	Opole	4.08	BBB

Source: Author's elaboration

Figure 2: Rating of real estate markets for supply.
Source: Author's elaboration.

Figure 3: Rating of real estate markets for demand.
Source: Author's elaboration.

The last stage of the elaborated procedure assumed the verification rating score and data on the quality and usefulness a posteriori. This analysis will be conducted in the next study. The author assumed using the parametrical (e.g. Hellwig's method) and non-parametrical (rough set theory) methods for this analysis.

5 DISCUSSION

Due to the globalization, the implementation of IT solutions and the increasing mobility of people, making decisions in the real property market is no longer limited to the analysis of local and technical factors of real properties. Residential properties constitute not only a common element for securing basic existential needs and capital location, but they are also an important factor determining the conditions and development and investment potential of a given region. The main problem in the field involves the development of a comprehensive classification of the real estate market relevant to the specific character of real estate market operations, which involves complex procedures and decisions, as well as the unique character of real estate data. Providing access to the knowledge of the real estate market, developed in the form of a modern classification system (rating), is the only way to solve this problem.

The main objective of real estate market ratings is to create a universal and standardized classification system for evaluating the real estate market potential and a reduction of speculative information noise. The main aim of this study was the conducting of an analytical procedure to determine the rating for real estate markets concerning condition of urban space. The efficiency of the presented studies depends to a significant degree on the availability and reliability of data, and the methodology of the analysis. The elaborated procedure consists of 5 main stages with 17 steps that are methodologically open and can be moderate due to the frame of analysis. Within the scope of the study the final rating for the main Polish residential markets was established. In this case the methods of Boolean inference, value tolerance relations and scoring analysis were used.

The established rating provided a current, reliable, useful and comparable picture of the situation of individual cities or regions (markets) that can help to improve the decision-making process. The presented analysis indicated that Polish markets are not divided into particular regions. It should be underlined that markets received maximum A and minimum B-. Considering that Poland is generally in quite a good condition, and with good future expectations (EU funds), rating scores below BB might be alarming. The classification indicated that the analyzed markets regarding the provincial capitals have better, worse or alarmingly weak potentials for residential market growth. This should be considered by entities in real estate markets (e.g. buyers, sellers and investors), and on the other hand by the initiators or inspirers of urban space changes (e.g. local government. business society, etc.).

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Appendix 1: Sample of rating attributes toolkit for residential property market

Group I – supply-side indicators:	
a) social set	1 – ranking of quality of life for "quality of local government" (max 100 p.)-det.* 2 – number of deaths of those older than 50 (per 1000 residents) - det. 3 – contribution of individuals in the post-productive age (per cent) - det.
b) economic and political set	4 – fuel prices per litre – des.* 5 – number of new registered businesses industry and construction (per 10000 residents) - det. 6 – local government spending on public utilities and environmental protection (per resident) - det. 7 – local government spending on investments (per resident) - det.
c) residential set	8 – vacancy rate for office properties (per cent) – des. 9 – vacancy rate for retail properties (per cent) – des. 10 – vacancy rate for warehouses properties(per cent) – des. 11 – number of apartments (per 1000 residents) – det. 12 – usable dwelling space(per resident) – det. 13 – average number of rooms in a dwelling– det. 14 – value of new mortgage agreement (per resident) – det. 15 – total number of issued construction permits (per 10000 residents) – det. 16 – number of issued construction permits – individual (per 10000 residents) – det. 17 – number of apartments with started constructions (per 10000 residents) – det. 18 – number of completed apartments (per 10000 residents) – det. 19 – number of completed rooms (per 10000 residents) – det. 20 – the average number of rooms in completed apartments – det. 21 – the average area of a room (per m2) - det. 22 – number of developers on the local market (per 10000 residents) – det. 23 –number of property transactions (per 10000 residents) - det. 24 – value of property transactions (per 1000 residents) - det. 25 – affordability of rental housing (number of square meters that can be financed from an average local salary per month) – det. 26 –difference in the structure of (<=40) supply of usable area per transaction and offers on the primary market (per cent) – des. 27 – difference in the structure of (40; 60) supply of usable area per transaction and offers on the primary market (per cent) – des. 28 – difference in the structure of (60; 80) supply of usable area per transaction and offers on the primary market (per cent) – des. 29 – difference in the structure of (>80) supply of usable area per transaction and offers on the primary market (per cent) – des. 30 – structure of (>80) supply of usable area per transaction on the primary market (per cent) – det. 31 – structure of (>80) usable area supply for offers/quotation on the primary market (per cent) – des. 32 – balance of supply and demand for apartments below or equal to 50m2 on the primary market (per cent) - det. 33 – balance of supply and demand for apartments over to 50m2on the primary market (per cent) - det. 34 – difference in the structure of (<=40) supply of usable area per transaction and offers on the secondary market (per cent) – des. 35 – difference in the structure of (40; 60) supply of usable area per transaction and offers on the secondary market (per cent) – des. 36 – difference in the structure of (60; 80) supply of usable area per transaction and offers on the secondary market (per cent) – des. 37– difference in the structure of (>80) supply of usable area per transaction and offers on the secondary market (per cent) – des. 38 – structure of (>80) supply of usable area per transaction on the secondary market (per cent) – det. 39 – structure of (>80) supply of usable area per transaction per offers on the secondary market (per cent) – des. 40 – local government spending on housing policy (per residents) - det. 41 – number of property offers, average from the most popular websites in Poland (per 1000 residents) - det.
d) spatial and location set	42 – per cent of land covered by zoning plans – det. 43 – level of retail area (m2/1000 residents) – det. 44 – supply of office area (m2/1000 residents – det. 45 – supply of warehouse area (m2/1000 residents) – det.

Group II – demand-side indicators:	
a) social set	46 – forecasting of population number for 2020 (per cent in comparison with 2013)-det. 47 – forecasting of population number for 2035 (per cent in comparison with 2013) –det. 48 – number of private cars (per 10 residents) – det. 49 – ranking of quality of life for health (max 100 p.) – det. 50 - ranking of quality of life for satisfaction with life (max 100 p.) – det. 51 - ranking of quality of life for safety (max 100 p.) – det. 52 – unemployment rate (per cent)- des. 53 – unemployment rate (per cent average from last 5 years) – des. 54 – difference between regional and local unemployment rate (per cent) – det. 55 – population growth (per 1000 residents) – det. 56 – net migration rate (per 1000 residents) – det. 57 – number of marriages (per 1000 residents) - det. 58 – number of students (per 1000 residents) – det. 59 –contribution of individuals in the productive age (per cent) – det. 60 – contribution of individuals in the pre-productive age group(per cent) – det. 61 – contribution of individuals in the post-productive age (per cent) – det. 62 –number of sports clubs (per 10000 residents) – det. 63 – number of cultural centres (per 100000 residents) – det. 64 – number of cinemas (per 100000 residents) – det. 65 – number of hypermarkets (per 100000 residents) – det.
b) economic and political set	66 – average rent in a new shopping centre (affordability per average local salary-m2)–des. 67 – average rent in the office blocks (affordability per average local salary–PLN/m2)-des. 68 – number of science and technology parks - det. 69 – fuel prices (per litre) – des. 70 – number of suspended business activities(per 1000 residents)-des. 71 – number of new businesses (per 1000 residents) – det. 72 – number of self-employed individuals (per 1000 residents) -det. 73 – number of businesses employing 0-9 workers(per 10000 individuals in the productive age) - des. 74 – number of businesses employing 10-49 workers (per 10000 individuals in the productive age) -des. 75 – number of businesses employing 50-249 workers (per 10000 individuals in the productive age) -det. 76 – number of businesses employing 250 and more workers (per 10000 individuals in the productive age) -det. 77 – number of businesses with foreign capital (per 10000 residents)- det. 78 – Gross Domestic Product (Poland=100p.) – det. 79 – local government income (per resident) – det. 80 – local government spending (per resident) – det. 81 – difference between the national average salary and the average salary on the local market (per cent) – det.
c) residential set	82 – the average number of individuals in an apartment – det. 83 –availability of apartments on the primary market in terms of average salary(m2)– det. 84 – availability of apartments on the secondary market in terms of average salary(m2)– det. 85 – offered purchasing power on the local housing market (average salary on the local market / average price per 1 m2 of property on the local market) – det. 86 – transaction purchasing power on the local housing market (average salary on the local market / average price per 1 m2 of property on the local market) – det. 87 – availability of mortgages in terms of m2 (average property price / average credit rating of a family or individual) – det. 88 – availability of mortgages on the secondary market in terms of PLN credit (m2) – det. 89 – availability of mortgages on the primary market in terms of PLN credit (m2)– det. 90 – value of new mortgages (per resident)– det. 91 –– number of real estate agents on the local market (per 10000 residents) – det. 92 – number of real estate appraisers on the local market (per 10000 residents)-des. 93 – number of property transactions (per 10000 residents) - des. 94– value of property transactions (per 1000 residents) - det. 95 – average time on the secondary market (in days) – des. 96 – difference between the average offered and transaction price of m2 the real estate on the primary market (PLN) –des.

	97 – difference between the average offered and transaction price of m2 the real estate on the secondary market (PLN) –des. 98 – changes in local property offered prices (per cent) –det. 99 – changes in local property transaction prices (per cent) – det. 100 – difference between changes in offered and transaction prices on the secondary market (per cent) -des. 101 – difference between changes in offered and transaction prices on the primary market (per cent) -des. 102 – affordability of rental housing on the secondary market (number of square meters that can be financed from an average local salary per month) –det. 103 – difference between the minimum and maximum transaction prices on the primary market (PLN/m2) –det. 104 – balance of supply and demand for apartments below or equal to 50m2 (per cent) 105 –balance of supply and demand for apartments of over to 50m2 (per cent) -det. 106 – difference between the minimum and maximum transaction prices on the secondary market (PLN/m2) –det. 107 – difference between offered and transaction prices for low standard (PLN/m2) –des. 108 – difference between offered and transaction prices for medium standard (PLN/m2) –des. 109 – difference between offered and transaction prices for high standard (PLN/m2) –des. 110 – difference between low and high standard for offered prices (PLN/m2)– det. 111 – difference between low and high standard for transaction prices (PLN/m2) – det. 112 – ratio of replacement value per 1 m2 of property to the transaction price (per cent) – det. 113 – ratio of replacement value per 1 m2 of property to the offered price (per cent) – det.
d) spatial and location set	114 – per cent of green areas (per cent) – det. 115 – cycle path (per 10000. residents) – det. 116 – length of bus-lane (km) – det. 117 – roads with hard surface (km per 10000 residents) – det. 118 – roads with hard surface (km per km2 of city) – det. 119 – number of green parks in the region – det. 120 – population density (per km2)– det. 121 – number of buses (per 1000 residents) – det. 122 – number of high schools (per 100000 residents) – det.

*det. – determinats. des. – destymulants

Appendix 2. Database of the rating attributes toolkit.

		Number of indicator for 2014 year.								
		1	2	3	4	5	6	7	...	122
o.n.	Markets	soc.	soc.	soc.	econ.	econ.	econ.	econ.	**...**	spat. and loc.
1	Gdansk	44.0	9.58	21.30	5.23	26	234.61	1607.42	…	2.82
2	Olsztyn	**36.8**	7.75	18.50	5.59	18	496.34	852.20	…	2.29
3	Szczecin	33.9	9.61	21.10	5.44	32	250.11	733.60	…	3.18
4	Bydgoszcz	23.3	9.76	21.60	5.31	19	197.11	586.89	…	2.50
5	Białystok	40.3	7.45	18.10	5.50	18	174.11	1048.67	…	3.73
6	Poznan	33.1	10.03	21.30	5.37	21	124.77	891.87	…	4.74
7	Warszawa	40.3	10.21	22.40	5.46	20	215.86	1055.70	…	4.58
8	Łodz	30.7	13.24	24.30	5.39	19	334.11	1034.03	…	3.09
9	Wrocław	53.5	9.40	21.50	5.31	22	363.91	822.74	…	3.80
10	Lublin	40.3	8.27	20.40	5.30	16	305.87	1577.41	…	2.62
11	Krakow	34.9	8.94	21.00	5.24	19	286.78	528.65	…	2.77
12	Rzeszów	44.5	7.11	17.80	5.33	17	410.25	1331.75	…	2.73
13	Zielona Gora	21.5	8.42	20.40	5.27	24	150.92	545.78	…	2.53

		Number of indicator for 2014 year.								
		1	2	3	4	5	6	7	...	122
o.n.	Markets	soc.	soc.	soc.	econ.	econ.	econ.	econ.	**...**	spat. and loc.
14	Kielce	31.3	8.92	21.60	5.38	16	220.73	983.01	…	5.00
15	Katowice	53.1	10.70	22.50	5.29	15	322.81	1404.23	…	4.93
16	Opole	40.7	9.49	21.20	5.37	20	327.14	982.64	…	3.33
		No. of indic. for 2012y.								
		1	2	3	4	5	6	7	…	122
	Gdansk	n.d.*	9.11	20.70	5.65	26	191.50	2465.97	…	2.82
	Olsztyn	n.d.	7.43	17.60	5.82	17	236.61	781.83	…	2.29
	Szczecin	…	…	…	…	…	…	…	…	3.67

* n.d.– no data

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ANALITRA.SI – A NE NA LITRE ...

ANALITRA.SI – BUT NOT BY LITRES ...

Joc Triglav

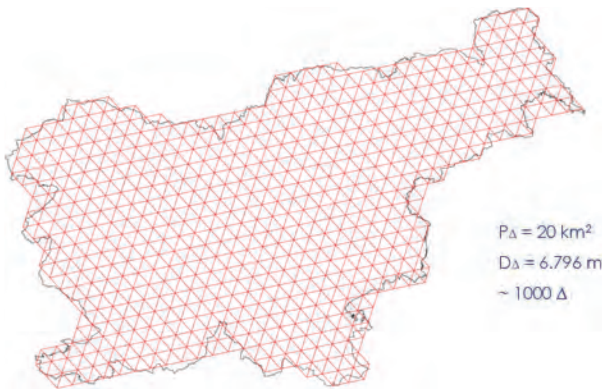
1 UVOD

…, res ne na litre, temveč na centimetre izračunana odstopanja med D96/TM-koordinatami ZK-točk, shranjenimi v evidenci zemljiškega katastra na podlagi meritev v geodetskih elaboratih, in D96/TM-koordinatami ZK-točk, transformiranimi z vsedržavno trikotniško transformacijo V4.0 iz D48/GK-koordinat, shranjenih v taisti evidenci zemljiškega katastra.

Gornji stavek, ki se s … nadaljuje še iz naslova, zveni kar zapleteno, dejansko pa zamisel pod delovnim imenom AnaliTra.SI vključuje matematično enostaven postopek na veliki množici podatkov. Vsi podatki in znanje, potrebni za izvedbo, so zbrani na glavnem uradu GURS. Poglejmo na kratko opis ideje in prve analitično-vizualne rezultate postopka AnaliTra.SI za območje Prekmurja.

2 CILJ

Želimo in v dnevni geodetski praksi nujno potrebujemo (zase in za uporabnike naših podatkov!) nekaj podobnega, kar imajo v švicarski državni geodetski upravi – glej članek v Geodetskem vestniku (Triglav, 2014). Švicarji imajo vizualizacijo po kvadratih, mi bi jo zaradi narave naše vsedržavne trikotniške transformacije GURS lahko imeli po enakostraničnih trikotnikih, kot je razvidno s slike 1.



Slika 1: Mreža enakostraničnih trikotnikov vsedržavne trikotniške transformacije (Berk in Komadina, 2010).

3 DOSEDANJE IZKUŠNJE

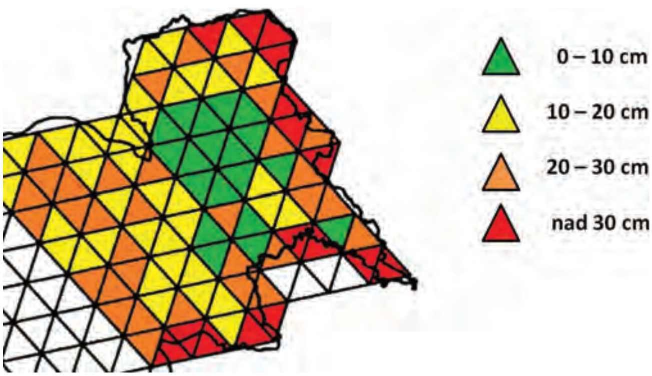
Za območje Pomurja smo v letih 2010–2011 na vzorcu približno 62.000 ZK-točk, ki so imele v zemljiškem katastru določene koordinate v sistemu D48/GK in D96/TM, izvedli analizo odstopanj med v katastru evidentiranimi D96/TM-koordinatami in D96/TM-koordinatami, dobljenimi iz takratne vsedržavne trikotniške transformacije V3.0. Rezultate analize smo avtorji predstavili na Geodetskem dnevu na Ptuju leta 2011 in v članku v Geodetskem vestniku (Berk, Komadina in Triglav, 2011).

Začetne izkušnje so bile v nadaljevanju temeljito kakovostno nadgrajene ter po obsežnem in napornem delu sodelavcev Urada za geodezijo verificirane za območje celotne Slovenije – glej predstavitev z letošnjega Geodetskega dneva na Brdu (Berk in sod., 2017).

4 GROBA IZVEDBENA IDEJA ANALITRA.SI

Vsa »matematika« in vsi ustrezni podatki so v rokah in pristojnosti GURS:

- uporabimo bazo ZK-točk za vso Slovenijo;
- naredimo »razrez« ZK-točk po trikotnikih vsedržavne trikotniške transformacije GURS V4.0;
- pogledamo, koliko izmed ZK-točk ima v bazi pred transformacijo par D48/GK- in D96/TM -koordinat;
- izvedemo vsedržavno trikotniško transformacijo GURS V4.0 za vse te ZK-točke;
- izračunamo razmerje med številom evidentiranih D96/TM-točk /vseh ZK-točk, izraženo kot ulomek in kot odstotek;
- primerjamo transformirane in že evidentirane D96/TM-koordinate ZK-točk po trikotnikih;
- izdelamo sliko povprečnih odstopanj med transformiranimi in že evidentiranimi D96/TM-koordinatami ZK-točk po trikotnikih;
- povprečna odstopanja po trikotnikih po neki dogovorjeni lestvici odstopanj prikažemo v barvah, glej na primer shematski prikaz ideje na sliki 2;



Slika 2: Primer ideje grafičnega prikaza odstopanj po trikotnikih vsedržavne transformacije po neki dogovorjeni lestvici odstopanj (slika je simbolična in ne temelji na dejanskih podatkih).

- statistiko avtomatizirano periodično ponavljamo v rednih časovnih presledkih, na primer vsak mesec, in rezultat z barvnimi trikotniki prikažemo na portalu s podloženo karto Slovenije M = 1 : 1.000.000;

- vse periodične statistike hranimo v arhivu po časovnem zaporedju nastanka, z možnostjo interaktivnega priklica po časovnem traku;
- opomba: V prihodnje bi bilo priporočljivo stranico trikotnikov zmanjšati na primer na četrtine sedanje stranice, s čimer bi dobili gostejši grid enakostraničnih trikotnikov za prikazovanje odstopanj in s tem statistike odstopanj za manjše trikotnike;
- izvajalec naloge: GURS - Urad za geodezijo v sodelovanju z Uradom za nepremičnine;
- vizualizacije izračunov AnaliTra.SI naj bi bile prikazane na spletni strani Preg oziroma na portalu Prostor, v začetnem obdobju samo za geodete in v nadaljevanju za vse uporabnike;
- rok izvedbe naj bo čim krajši, saj je to naloga geodetske službe kot nosilke temeljnih slojev infrastrukture prostorskih podatkov; ukrepati moramo hitro in delovati proaktivno, sicer bo na področja naše izvorne pristojnosti vskočil kakšen drug akter in nam »solil pamet« glede položajne kakovosti naših podatkov.

5 PRVI POSKUSNI IZRAČUN

Urad za geodezijo je v dogovoru z Uradom za nepremičnine z nekaterimi modifikacijami in prilagoditvami osnovne ideje že izvedel prvi poskusni izračun. Na Uradu za nepremičnine je z izvozom iz baze ZK-točk s koordinatami v sistemih D48/GK in D96/TM nastala datoteka s 3.476.512 ZK-točkami. ZK-točk z metodo določitve 94 ali 95 ali 96 v datoteko niso zapisali in torej v prvem poskusnem izračunu niso bile predmet obdelave. V datoteki so na Uradu za geodezijo koordinate ZK-točk v sistemu D48/GK z vsedržavnim modelom trikotniške transformacije GURS V4.0 transformirali v koordinate v sistemu D96/TM. Nato so izračunali koordinatna in položajna odstopanja za vse ZK -točke. Položajna odstopanja so bila podlaga za določitev cenilk skladnosti uporabljenih lokalnih in trikotniške transformacije. Uporabljena osnovna prostorska enota za izračun in prikaz vseh statistik je območje katastrske občine.

Kot primarna cenilka je izbrana mediana položajnih odstopanj. Mediana je v matematiki srednja vrednost nekega zaporedja števil, ki razdeli števila, razvrščena po velikosti, na dve enaki polovici po številu elementov. Prednost mediane pred aritmetično sredino je, da osamelci (podatki, ki ekstremno odstopajo od ostalih podatkov) manj vplivajo na njeno vrednost. Polovica ZK-točk v katastrskih občinah ima torej večje, polovica pa manjše položajno odstopanje od izračunane cenilke. Odstopanja so glede na vrednosti mediane razvrstili v štiri razrede od 1 do 4:

- 1 – mediana položajnih odstopanj, manjša od 5 centimetrov (zelena barva);
- 2 – mediana položajnih odstopanj med 5 in 10 centimetri (rumena barva);
- 3 – mediana položajnih odstopanj med 10 in 20 centimetri (rdeča barva);
- 4 – mediana položajnih odstopanj, večja od 20 centimetrov (vijolična barva).

Izračunali so še nekatere pomembne kategorije vrednosti odstopanj, ki dajejo koristno dopolnilno informacijo o vrednostih odstopanj v vsaki posamezni katastrski občini. Izračunana odstopanja so za posamezno katastrsko občino zapisali v datoteko z naslednjimi stolpci:

- SIFKO: šifra katastrske občine,
- Mediana [m]: mediana položajnih odstopanj, v metrih,
- N_skupno: skupno število ZK-točk s koordinatami v obeh sistemih,

- N_Δ>10 cm: število ZK-točk s položajnimi odstopanji, večjimi od 10 centimetrov,
- %_Δ>10 cm: odstotek ZK-točk s položajnimi odstopanji, večjimi od 10 centimetrov,
- N_Δ>25 cm: število ZK-točk s položajnimi odstopanji, večjimi od 25 centimetrov,
- %_Δ>25 cm: odstotek ZK-točk s položajnimi odstopanji, večjimi od 25 centimetrov,
- N_Δ>50 cm: število ZK-točk s položajnimi odstopanji, večjimi od 50 centimetrov,
- %_Δ>50 cm: odstotek ZK-točk s položajnimi odstopanji, večjimi od 50 centimetrov,
- Razred: šifra razreda in barve za prikaz median odstopanj,

kot je prikazano v spodnji tabeli 1.

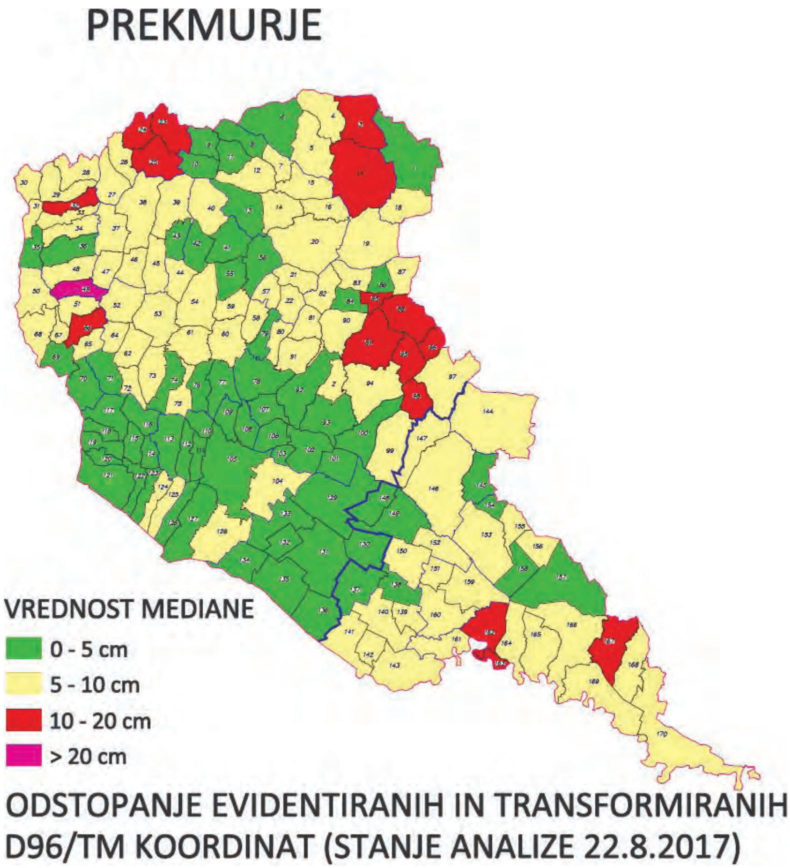
Tabela 1: Videz datoteke z izračunom kategorij odstopanj na vzorcu katastrskih občin z začetnimi šiframi SIFKO od 1 do 18 (Vir podatkov: GURS, Urad za nepremičnine, izračun: GURS, Urad za geodezijo).

SIFKO	Mediana [m]	N_skupno	N_Δ >10 cm	%_Δ >10 cm	N_Δ >25 cm	%_Δ >25 cm	N_Δ >50 cm	%_Δ >50 cm	Razred
1	**0,049**	5868	921	15,7	45	0,8	0	0,0	**1**
2	**0,064**	573	72	12,6	1	0,2	0	0,0	**2**
3	**0,167**	978	530	54,2	1	0,1	0	0,0	**3**
4	**0,083**	726	362	49,9	0	0,0	0	0,0	**2**
5	**0,098**	1114	516	46,3	0	0,0	0	0,0	**2**
6	**0,037**	1288	385	29,9	9	0,7	0	0,0	**1**
7	**0,074**	217	24	11,1	0	0,0	0	0,0	**2**
8	**0,044**	278	62	22,3	0	0,0	0	0,0	**1**
9	**0,036**	114	20	17,5	0	0,0	0	0,0	**1**
10	**0,037**	233	16	6,9	0	0,0	0	0,0	**1**
11	**0,044**	420	46	11,0	3	0,7	0	0,0	**1**
12	**0,063**	496	0	0,0	0	0,0	0	0,0	**2**
13	**0,043**	286	11	3,8	0	0,0	0	0,0	**1**
14	**0,062**	927	39	4,2	0	0,0	0	0,0	**2**
15	**0,067**	92	0	0,0	0	0,0	0	0,0	**2**
16	**0,087**	291	24	8,2	2	0,7	0	0,0	**2**
17	**0,146**	643	414	64,4	0	0,0	0	0,0	**3**
18	**0,077**	334	0	0,0	0	0,0	0	0,0	**2**

…

6 VIZUALIZACIJA REZULTATOV ANALITRA.SI ZA PREKMURJE

Za vizualizacijo rezultatov AnaliTra.SI je iz tabele 1 v splošnem najbolj uporaben atribut mediane oziroma iz nje dobljeni razred odstopanj. Za območje Prekmurja s šiframi katastrskih občin od 1 do 170 je primer vizualizacije prvega poskusnega izračuna odstopanj po zgoraj navedenih razredih prikazan na sliki 3.

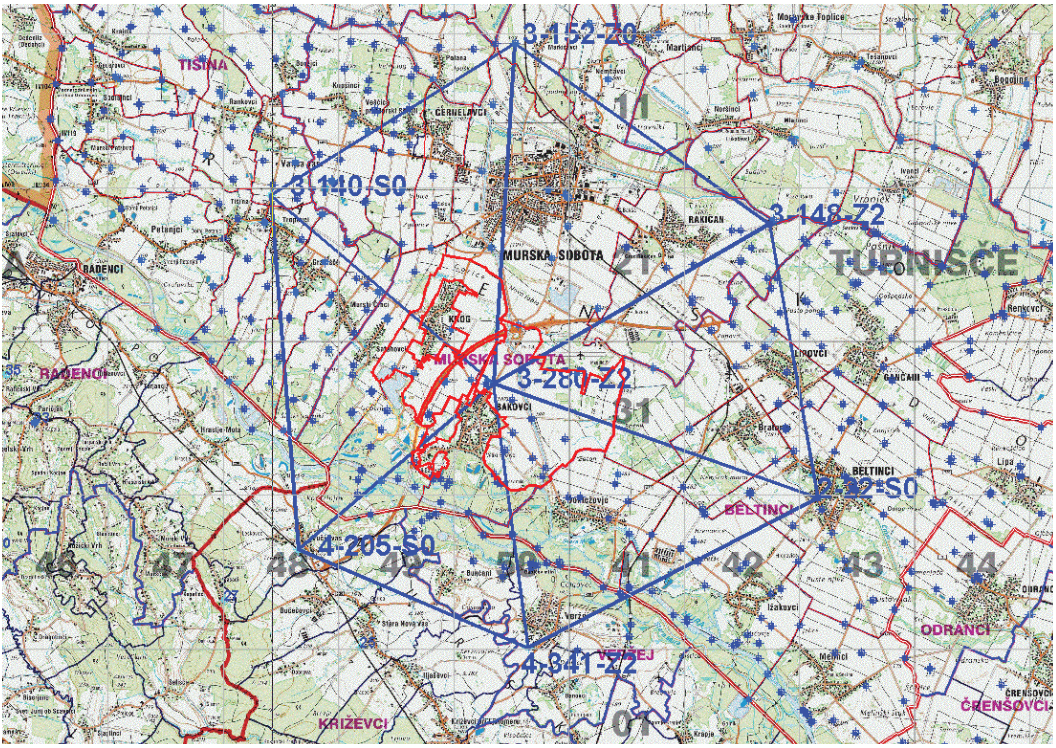


Slika 3: Primer vizualizacije prvega poskusnega izračuna odstopanj po razredih vrednosti mediane za katastrske občine na območju Prekmurja (šifre katastrskih občin od 1 do 170).

7 ZAKLJUČNI KOMENTAR

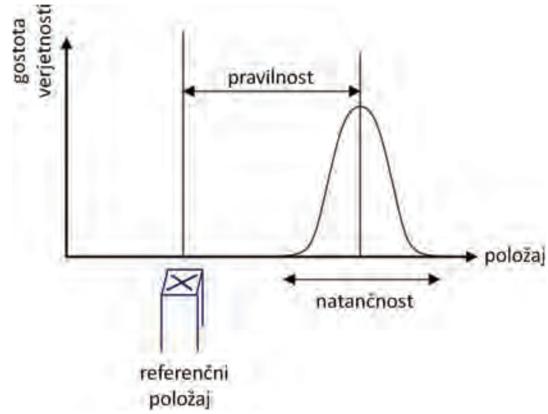
S slike 3 nazorno vidimo lokacijsko razporeditev razredov mediane za območja katastrskih občin. Slika res pove več kot tisoč besed (in številk). Barve na sliki za območje Prekmurja so v okviru pričakovanj na podlagi dosedanjih praktičnih izkušenj in rezultatov geodetskih meritev ter ne prinašajo večjega presenečenja. Hkrati pa nam nazorno pokažejo, kje je treba biti še posebej pozoren pri izvajanju geodetskih del in kje so v prihodnje še potrebni posebni strokovni napori in ciljne meritve za morebitne izboljšave v naslednjih verzijah vsedržavne trikotniške transformacije oziroma za sanacije samih katastrskih izmer. V ta namen bodo še kako uporabne točke obstoječe trigonometrične, navezovalne in poligonske mreže, izmerjene in kakovostno stabilizirane v preteklih desetletjih v koordinatnem sistemu D48/GK. Samo na območju geodetske pisarne Murska Sobota je določenih približno 500 trigonometričnih, približno 500 navezovalnih in približno 34.000 poligonskih točk. Na sliki 4 je prikaz primera uporabe trigonometričnih in navezovalnih točk v transformacijskih trikotnikih za izvedbo pripravljalnih geodetskih meritev na območjih komasacij Krog in Bakovci iz leta 2010.

Za izvedbo komasacij je bila mreža trikotnikov veznih točk za transformacijo v širšem šesterokotniku še zgoščena z izmero in uporabo dodatnih navezovalnih točk. Srednji položajni pogrešek uporabljene transformacije za navedeno komasacijo je bil 5,8 centimetra. Poligonske točke na območju Prekmurja na sliki 4 niso prikazane, ker bi zaradi svoje prostorske gostote povsem »*počrnile*« sliko. To pa seveda ne pomeni, da niso uporabne za terensko geodetsko delo in meritve ter za izračune transformacijskih parametrov med sistemoma D48/GK in D96/TM. Ravno nasprotno je res!



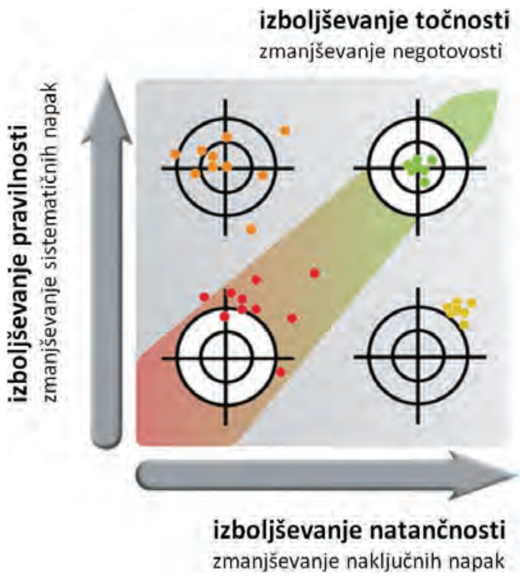
Slika 4: Na kartografski podlagi karte Pomurja prikazana skorajda idealna razporeditev izhodiščnih transformacijskih trikotnikov, uporabljenih leta 2010 v pripravljalnih delih za območje komasacij Krog in Bakovci (obod območja v rdeči barvi, velikost območja približno 1000 ha). Točkovno so prikazane trigonometrične in navezovalne točke na širšem območju okolice komasacij (Vir: OGU Murska Sobota).

Konec komentarja ponazorimo slikovno (sliki 5 in 6) še s pojmi točnosti (angl. *accuracy*), pravilnosti (angl. *trueness*) in natančnosti (angl. *precision*) iz standarda SIST ISO 5725-1:2003 - *Točnost (pravilnost in natančnost) merilnih metod in rezultatov – 1. del : Splošna načela in definicije*. Po tem standardu je točnost opredeljena kot stopnja ujemanja med rezultatom preskusa in sprejeto referenčno vrednostjo, sestavljena iz pravilnosti (stopnja ujemanja med povprečno vrednostjo, dobljeno iz velike serije rezultatov preskusov in sprejeto referenčno vrednostjo) in natančnosti (stopnja ujemanja med neodvisnimi rezultati preskusa, pridobljenimi v dogovorjenih razmerah), pri čemer je natančnost odvisna samo od porazdelitve naključnih napak in se ne nanaša na pravo vrednost ali določeno vrednost.



Slika 5: Po standardu ISO 5725-1 je točnost opredeljena kot stopnja ujemanja med rezultatom preskusa in sprejeto referenčno vrednostjo, sestavljena je iz pravilnosti in natančnosti. Referenčna vrednost v geodeziji je na primer položaj geodetske točke ali mejnika (Slika prirejena po viru: Wikipedia, CC BY-SA 3.0).

Še preprosteje si to lahko predstavljamo s prikazom skupin zadetkov v tarčo, kot je razvidno na sliki 6.



Slika 6: Izboljševanje točnosti rezultatov dosežemo z izboljševanjem natančnosti in pravilnosti. (Slika prirejena po viru: http://www.artel-usa.com/resource-library/defining-accuracy-precision-and-trueness/)

Če gornji sliki pogledamo v geodetskem smislu, se nam hitro zbistri spoznanje, da lahko z najsodobnejšo mersko tehnologijo sicer dosegamo vrhunsko natančnost meritev. Pomemben pa je naslednji kavelj, na katerega v sodobnem času prepogosto »*pozabimo*«. Potrebno in zahtevano točnost rezultatov meritev bomo namreč lahko dosegli le, če bomo upoštevali natančnost in pravilnost rezultatov dela generacij naših geodetskih predhodnikov ter tehnične pogoje in strokovna pravila, na podlagi katerih so bili ti rezultati doseženi.

Saj poznate tisti občutek pri iskanju obstoječih točk geodetske mreže ali mejnikov, ko ob udarcu kovine na beton vaša trasirka zaškrta z značilnim pridušenim škrbinastim kovinskim zvenom?! In ko še malo razbrskate po tleh, pa se vam precej skriti kamen razkrije v vsem svojem zdelanem sijaju? Takrat kar »*pokate*« od zadovoljstva, takrat ste v očeh vaših strank kralj, takrat veste, da obvladate svoje geodetsko delo. Takrat vaše znanje in natančnost pridobita tudi potrditev v pravilnosti in točnosti rezultata vašega dela in dela vašega geodetskega predhodnika, ki je pred leti ali desetletji izvorno postavil in izmeril tisti kamen.

In kaj ima s tem AnaliTra.SI s svojimi ciframi in barvnimi slikicami, porečete? Predvsem bo lahko krasen pripomoček in vodilo pri izvajanju del, da bodo rezultati naših meritev ne samo lepo zgoščeni v čim ožji »*hribček*«, temveč da bodo tudi čim bližje sredini naših vsakokratnih tarč, tj. da bo vrh našega hribčka meritev čim bliže izvornemu referenčnemu položaju, kot je bil določen v predhodni izvorni meritvi. Ko bomo podrobneje razumeli moč izračunov AnaliTra.SI, se nam bodo zagotovo odprle številne nove ideje o možnostih uporabe in nadaljnjega razvoja analitičnih orodij za obravnavo rezultatov transformacij med koordinatnima sistemoma D48/GK in D96/TM.

Po približno četrt stoletja, odkar se geodeti v Sloveniji intenzivneje ukvarjamo z novim koordinatnim sistemom, smo torej mogoče na »*koncu začetka*« tega dela. Za geodete je zdaj strokovno in znanstveno zelo zanimiv čas. Ampak to ni še nič v primerjavi s časom, ki prihaja v naslednjih letih in desetletjih – ta bo šele izredno zanimiv za nas!!

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NOVICE S PODROČJA DELA GEODETSKE UPRAVE RS

Tomaž Petek

Spoštovani bralci Geodetskega vestnika, v nadaljevanju smo pripravili povzetek nekaterih dejavnosti in dogodkov, ki so zaznamovali delovanje Geodetske uprave RS med izidom dveh številk strokovne publikacije. V branje vam tako ponujamo informacije o prenovi portala in objavi gradiva o vzpostavljanju sistema množičnega vrednotenja nepremičnin ter informacije z mednarodnih konferenc, na katerih je geodetska uprava sodelovala s prispevki in referati.

GRAFIČNA IN VSEBINSKA PRENOVA PORTALA PROSTOR

Z namenom približevanja potrebam uporabnikov je geodetska uprava konec maja 2017 grafično in vsebinsko prenovila in nadgradila portal Prostor (http://www.e-prostor.gov.si/), ki je tako postal pestrejši in bolj pregleden. Vse strani so prilagojene za uporabo na mobilnih napravah. Povezave na notranjih straneh portala se sedaj oblikujejo drugače kot na starih straneh, zato preverite in po potrebi osvežite svoje bližnjice!

10. REGIONALNA KONFERENCA O KATASTRU IN INFRASTRUKTURI ZA PROSTORSKE INFORMACIJE V REGIJI ZAHODNEGA BALKANA

Od 8. do 9. junija 2017 je v organizaciji Agencije za kataster nepremičnin Republike Makedonije v Skopju potekala že 10. redna letna konferenca o katastru in infrastrukturi za prostorske informacije v regiji zahodnega Balkana. Na konferenci je sodelovalo več kot sto udeležencev iz dvanajstih držav ter predstavniki mnogih mednarodnih organizacij in združenj. Geodetsko upravo Republike Slovenije sta zastopala generalni direktor Anton Kupic in Tomaž Petek. Udeležence je v uvodu nagovoril minister za promet in zveze v vladi republike Makedonije ter napovedal nove reforme na področju evidentiranja nepremičnin, ki si jih je zadala pred kratkim imenovana vlada. Sledile so predstavitve o delovanju združenja Eurogeographics in UN-GGIM Evropa ter predstavitve regionalnih projektov IMPULS in SPATIAL. V popoldanskem delu konference so svoje delovanje orisali predstavniki geodetskih fakultet in zbornic geodetov iz zahodnobalkanske regije. Opisali so vsebine izobraževalnih programov in predstavili načrte za prihodnost izobraževalnega procesa na področju geodezije.

Drugi dan konference sta se predstavili obe nosilni organizaciji na področju registracije nepremičnin v Turčiji, in sicer Generalna komanda za topografijo in kartografijo, ki deluje v okviru turškega ministrstva za obrambo, ter Direktorat za kataster in register zemljišč, ki je zadolžen za evidentiranje podatkov o zemljiščih in lastnikih zemljišč v Turčiji. Turčija je v zadnjih letih močno izboljšala in posodobila sistem zemljiške administracije.

Udeleženci okrogle mize med razpravo na 10. regionalni konferenci.

Sledila so predavanja o rezultatih geodetskih uprav iz regije v preteklih desetih letih. Federacija BiH je na primer poenotila SW za zemljiški kataster v vseh lokalnih skupščinah občin in v sistem vgradila tudi časovno komponento. Hrvaška geodetska uprava je vzpostavila enoten informacijski sistem skupaj z zemljiško knjigo, morda še največji napredek pa so pri registraciji nepremičnin izvedli ravno v Makedoniji. V večini držav so vzpostavili mreže GNSS-postaj in izdelali ortofoto načrte za ozemlje svojih držav, medtem ko se trenutno izvajajo aktivnosti vzpostavljanja registra naslovov, vrednotenja nepremičnin in katastra podzemnih vodov.

V sklepnem delu konference so o projektih in načrtih za sodelovanje v regiji zahodnega Balkana spregovorili še predstavniki Norveške in Švedske geodetske uprave ter predstavnik CLGE, ki je govoril o pomenu reguliranega poklica in javnih pooblastil na področju geodetske dejavnosti. Udeleženci so sklenili, da bo naslednja konferenca junija 2018 v Sofiji.

SEDMO PLENARNO ZASEDANJE SKUPINE STROKOVNJAKOV PRI OZN ZA GLOBALNO UPRAVLJANJE GEOGRAFSKIH INFORMACIJ – UN-GGIM

Od 1. do 4. avgusta 2017 je na sedežu Organizacije združenih narodov v New Yorku potekalo sedmo plenarno zasedanje skupine strokovnjakov za globalno upravljanje geografskih informacij UN-GGIM. Udeležilo se ga je 268 delegatov iz 87 držav članic OZN ter 82 predstavnikov različnih nevladnih organizacij ter strokovnih mednarodnih združenj in organizacij. Slovenijo je zastopal predstavnik naše geodetske uprave, ki je v tem mandatu član evropskega regionalnega izvršilnega odbora skupine strokovnjakov za upravljanje geografskih informacij v Evropi (UN-GGIM Evropa).

Pred uradnim zasedanjem je bila na sporedu vrsta spremljevalnih dogodkov ter sestanek izvršilnega odbora UN-GGIM Evropa. Na forumu z naslovom *Kje so podatki?* je bila obravnavana Agenda 2030 za doseganje ciljev trajnostnega razvoja. Svoje poglede so predstavili predstavniki različnih organizacij, ki delujejo v okviru OZN, in še drugih organizacij. Predstavitve so podali predstavniki statistične komisije (UNSD), Programa ZN za naselja (UN-HABITAT), Programa ZN za okolje (UNEP), Ekonomske komisije ZN za Afriko (UNECA) ter Svetovne banke in Evropske vesoljske agencije (ESA).

Dvorana med sedmim plenarnim zasedanjem UN-GGIM.

Večina predstavitev se je nanašala na določitev kazalnikov in zagotavljanje ustreznih prostorskih podatkov, potrebnih za spremljanje doseganja ciljev trajnostnega razvoja. Predstavnik agencije ESA je napovedal program EO4SD, v katerem bodo uporabili rezultate daljinskega zaznavanja in opazovanja zemlje za potrebe trajnostnega razvoja. Na enem od spremljevalnih dogodkov je predstavnik Eurogeographicsa Mick Cory predstavniku kartografske enote GIS pri OZN predal podatke o administrativnih mejah na območju geografske Evrope, ki jih enota potrebuje v okviru projekta vzpostavitve baze administrativnih enot na drugi ravni podrobnosti (angl. *second level administrative boundary* – SALB) (http://www3.who.int/whosis/gis/salb/salb_home.htm).

Plenarni del zasedanja se je začel v sredo, 2. 8. 2017, dopoldne in je trajal vse do petka, 4. 8. 2017, popoldne. Odprl ga je g. Liu Zhenmin, namestnik generalnega sekretarja OZN, odgovoren za ekonomske zadeve (USG DESA), ki je povzel ključne dejavnosti OZN na področju zagotavljanja ciljev trajnostnega razvoja v obdobju od zadnjega zasedanja UN-GGIM. Vsa gradiva, obravnavana na plenarnem zasedanju, so dostopna na spletni strani UN-GGIM. Sledili so nastopi predstavnikov regionalnih odborov UN-GGIM, ki delujejo na petih svetovnih celinah. Vsebina predstavitev je povzeta v dokumentu z naslovom Contribution of regional committees and thematic groups to the global geospatial information agenda.

V nadaljevanju plenarnega zasedanja so bili obravnavani posamezni pripravljeni dokumenti, vsaki predstavitvi je sledila izčrpna razprava. V tem poročilu so povzete samo nekatere ključne ugotovitve iz razprave in sprejeti sklepi.

Delovna skupina UN-GGIM za globalni geodetski referenčni sistem je predstavila vsebino poročila o svojem delu v preteklem letu (Global geodetic reference frame). V razpravi, ki je sledila, je bilo predstavljeno tudi stališče UN-GGIM Evropa, v katerem je bila izražena podpora za predlagani petletni program dela delovne skupine in namero, da ob robu naslednjega foruma UN-GGIM na visoki ravni, ki bo v Mexico Cityju novembra 2017, ustanovijo podskupino za geodezijo. UN-GGIM Evropa podpira prizadevanja za odpravo podvajanja dela na tem področju ter vključitev vseh ustreznih deležnikov v pripravo tako imenovanega vzpostavitvenega dokumenta (angl. *position paper*) ter analize GAP.

Poročilo je predstavila tudi delovna skupina UN-GGIM, ki obravnava temeljne podatkovne nize na globalni ravni (Determination of global fundamental geospatial data themes). Sledila je razprava, v kateri je večina razpravljavcev podprla predstavljeni seznam minimalnih temeljnih geoprostorskih nizov podatkov, ki se zahtevajo na globalni ravni, ter se zavzela za dokončanje začetega dela v tej delovni skupini. Naslednji koraki bodo namenjeni predstavitvi rezultatov širši skupnosti strokovnjakov v državah članicah OZN.

Delovna skupina UN-GGIM, ki obravnava trende na področju institucionalne organiziranosti upravljanja prostorskih podatkov na globalni ravni, je predstavila poročilo z naslovom Trends in national institutional arrangements in global geospatial information management in še nekaj spremljevalnih dokumentov s priporočili in opisov primerov dobrih praks (Framework, Principles and Guidelines | Compendium of Good Practices). V razpravi, ki je sledila, se je potrdila ugotovitev, da gre za obsežno in večplastno vprašanje. Pri UN-GGIM Evropa so zastopali stališče, da so lahko primeri dobrih praks zelo koristen pripomoček za izboljšanje institucionalne ureditve na tem področju. Predstavljeni dokumenti omogočajo lažjo izvedbo naslednjih korakov, ki so vključeni v program dela delovne skupine.

Sekretariat je predstavil poročilo o pravnem in političnem okvirju globalnega upravljanja prostorskih podatkov (Legal and policy frameworks, including issues related to authoritative data), v katerem je napovedana ustanovitev delovne skupine, ki bo obravnavala to področje. Večina razpravljavcev je podprla predstavljeno zamisel in spodbudila enakopravno vključenost predstavnikov držav z vseh geografskih območji sveta v njeno delo. Stališče UN-GGIM Evrope je, da mora delo v delovni skupini potekati na podlagi enakopravnega vključevanja stališč vseh deležnikov in ne sme biti pod enostranskim vplivom ene skupine, kot je bilo mogoče razumeti iz konvencije, ki jo je leta 2015 pripravilo mednarodno združenje pravnikov/odvetnikov IBA (*International Bar Association*).

Tri mednarodne standardizacijske organizacije (OGC, ISO in IHO) so pripravile skupno poročilo o uporabi standardov pri globalnem upravljanju prostorskih informacij (Implementation and adoption of standards for the global geospatial information community), v katerem so podane ugotovitve o stanju standardizacije ter priporočila in napotki za izboljšanje tega področja. Predstavnik UN-GGIM Evropa je predstavil skupno stališče članov iz Evrope, ki podpiramo proces standardizacije obravnavanega področja, ter napovedal posebno delavnico v okviru konference evropskih statistikov, ki bo med 6. in 8. novembrom v Stockholmu. V nadaljevanju zasedanja je bil predstavljen tudi dokument o povezovanju prostorskih in statističnih podatkov (Integration of geospatial, statistical and other related information).

Statistična komisija OZN je v dokumentu poudarila potrebo po nadaljevanju prizadevanj za sodelovanje geodetskih in statističnih uprav v državah članicah OZN, pri čemer je mišljeno, da ima skupina strokovnjakov za globalno upravljanje prostorskih podatkov vlogo koordinatorja. Na šestem plenarnem zasedanju UN-GGIM leta 2016 je bila ustanovljena nova delovna skupina na globalni ravni, ki se ukvarja z zemljiško administracijo in upravljanjem zemljišč. Vodi jo predstavnica UN-GGIM Evropa. Čeprav je imela skupina ustanovni sestanek šele maja 2017, je do tokratnega zasedanja že izdelala prvo poročilo z naslovom Application of geospatial information related to land administration and management. V razpravi so države članice OZN izrazile veliko podporo delovnemu programu za leti 2017 in 2018 ter poudarile potrebo po odzivu delovne skupine na obveznosti, ki se v Agendi 2030 nanašajo na upravljanje zemljišč in zemljiško administracijo.

V predstavitvi seznama globalnih kazalnikov za spremljanje ciljev trajnostnega razvoja (Global Indicators Geospatial shortlist) je delovna skupina IAEG-SDGs podala poročilo o svojem delu in predstavila dokument z naslovom Geospatial information for sustainable development. V razpravi je prevladalo mnenje o veliki potrebi po regionalnem povezovanju pri spremljanju ciljev trajnostnega razvoja.

Delovna skupina, ki se ukvarja z opredelitvijo vloge prostorskih podatkov za potrebe preprečevanja naravnih nesreč in ukrepanje ob odpravi njihovih posledic, je predstavila dosedanje rezultate, ki so strnjeni v dokumentu z naslovom Geospatial information and services for disasters. Razpravljavci so menili, da ni treba hiteti s pripravo resolucije OZN na tem področju, dokler niso izčrpane druge možnosti za oblikovanje skupnega stališča ter povezovanje in sodelovanje.

Predstavnik Slovenije med plenarnim zasedanjem UN-GGIM.

UN-GGIM je v sodelovanju s sekretariatom in Svetovno banko pripravil poročilo z naslovom National geospatial data and information systems, v katerem je predstavljena skupna vizija pri podpori in pomoči posameznim državam na področju premagovanja digitalne ločnice in vzpostavljanju nacionalnih informacijskih infrastruktur za prostorske informacije in nacionalnih informacijskih sistemov. V razpravi je bila izražena podpora predstavljeni nameri in sklenjenemu dogovoru med statistično enoto OZN in Svetovno banko o sodelovanju na navedenem področju.

Pregled dejavnosti Organizacije združenih narodov na področju upravljanja prostorskih podatkov je predstavil predstavnik sekretariata OZN, ki je izdelal dokument Review of United Nations activities in geospatial information management. Večina sodelujočih v razpravi je podprla tretjo od predstavljenih možnosti, ki predvideva manj formalno povezovanje vseh organizacijskih enot in skupin, delujočih v okviru OZN na področju upravljanja prostorskih podatkov in storitev v zvezi z njimi. Uresničevali bi ga s sistemsko mrežo tematskih skupin.

Razširjeni biro UN-GGIM je posredoval udeležencem plenarnega zasedanja gradivo z naslovom Strengthening geospatial information management, v katerem so zbrane ugotovitve in priporočila o prihodnjih strateških usmeritvah za aktivnosti, ki jih bo UN-GGIM izvajal naslednjih pet let, do naslednjega poročila za Ekonomski in socialni svet (ECOSOC). Sekretariat UN-GGIM je pripravil tudi informacijo o uporabi prostorskih podatkov na področju pomorstva (Marine geospatial information).

OBJAVLJEN DOKUMENT O UVELJAVITVI IN IZVAJANJU MNOŽIČNEGA VREDNOTENJA NEPREMIČNIN V SLOVENIJI

Geodetska uprava Republike Slovenije je na svoji spletni strani objavila dokument z naslovom *Uveljavitev in izvajanje množičnega vrednotenja nepremičnin v Sloveniji*. Z njim želi informirati in krepiti razumevanje javnosti o vsebini, vlogi in namenu sistema množičnega vrednotenja nepremičnin v Sloveniji. Dokument na kratko opisuje vzpostavljanje podlag za delovanje sistema, postopke priprave prvih modelov vrednotenja v letih 2010–2012 ter vzdrževanje sistema za čim boljše ocene tržnih vrednosti nepremičnin.

Naslovna stran gradiva..

V dokumentu so tudi kritično predstavljene dosedanje izkušnje z vzpostavitvijo in izvajanjem množičnega vrednotenja, predstavitev je dopolnjena s pregledom stroškov vzpostavitve in vzdrževanja sistema množičnega vrednotenja. Dokument odgovarja na vrsto vprašanj in dilem strokovne in laične javnosti ter s svojo sporočilnostjo omogoča učinkovitejšo in bolj usmerjeno razpravo v postopku sprejemanja ZMVN-1.

KONFERENCA INSPIRE 2017

Od 6. do 8. septembra 2017 je v Strasbourgu v Franciji potekala konferenca INSPIRE 2017. V dneh od 4. do 5. septembra pa je bila organizirana še vrsta delavnic v sosednjem mestu Kehl v Nemčiji. Konference se je udeležilo 650 obiskovalcev in predavateljev, ki so v šestih vzporednih sekcijah predstavili 240 referatov v 48 vsebinskih sklopih. Zaradi velikosti šteje konferenca med vodilne dogodke na temo geoinformatike, zagotavljanja in uporabe prostorskih podatkov v skladu z zahtevami evropske direktive INSPIRE.

Letošnja konferenca je potekala pod naslovom *Thinking out of the box*. Poudarek je bil na posodobitvi procesov ePoročanja ter prikazu obstoječih orodij za preverjanje skladnosti rešitev s specifikacijami INSPIRE. Predstavljeni so bili rezultati posameznih poročil, v katerih je evropska komisija popisala izvajanje obveznosti iz direktive INSPIRE v državah članicah (tako imenovanih *country fichev*). Poročila so dostopna na spletni strani INSPIRE. V veliko prispevkih je bilo obravnavano tudi zagotavljanje trajnih enoličnih identifikatorjev, semantične medopravilnosti ter povezave INSPIRE z nalogami eUprave. Ena od osrednjih tem je bilo povezovanje prostorskih in neprostorskih podatkov ter horizontalno povezovanje programov, pobud in iniciativ na ravni EU in mednarodni ravni. V precej prispevkih je bilo obravnavano tudi povezovanje prostorskega načrtovanja in nacionalnih infrastruktur za prostorske podatke.

Udeleženci med plenarnim zasedanjem..

V nadaljevanju je povzetih nekaj prispevkov s konference:

Na otvoritvem plenarnem zasedanju konference je bil podan pregled vseh ključnih programov in aktivnosti, ki jih izvajajo evropska komisija in njeni direktorati na področju okolja (GD ENV) in informacijske družbe (GD INFSO) ter upravljanja prostorskih podatkov. Na plenarnem delu zasedanja so sodelovali generalna direktorja GD ENV Daniel Calleja in GD INFSO Roberto Viola ter Robert Herman, predsednik metropolitanskega območja Strasbourg, ter drugi visoki predstavniki evropske komisije ter držav gostiteljic Francije in Nemčije. Po desetletju izvajanja direktive INSPIRE številne javne uprave vodijo in vzdržujejo veliko prostorskih podatkov in storitev, do katerih tudi omogočajo dostop. Več podatkov je na voljo na spletni strani programa ISA2 (http://ec.europa.eu/isa/).

Sledila je vrsta vzporednih sekcij, razdeljenih na vsebinska področja. V bolj tehnično usmerjenih so bila v ospredju vprašanja o razširitvah standardov INSPIRE, skupnih enoličnih identifikatorjih (URI), rešitvah glede vodenja registrov (Reg3stry, UKGovLD), samodejnem povezovanju podatkov (LinkedData), organizaciji in vodenju portalov INSPIRE itd.

Drugo plenarno zasedanje je bilo usmerjeno na regionalno raven, ki je tudi odgovorna za izvajanje direktive INSPIRE, in zato vir za drugačno, vendar pomembno perspektivo. Regije se tako na primer ukvarjajo s specifičnimi izzivi, ki zahtevajo ustvarjalne rešitve (na primer omejeni viri). Regije so neposredni vmesnik med državljani in administracijo ter raven za izvajanje projektov e-uprave, ki zahtevajo interakcijo med različnimi ravnmi uprave.

Udeleženci konference INSPIRE iz Slovenije.

Tomaž Petek med predstavitvijo slovenskega referata..

V sekciji Alignment with National, EU and International Policies je Tomaž Petek predstavil referat z naslovom *Merging INSPIRE Obligations with eGov and Open Data Initiative in Slovenia*. V isti sekciji so bile predstavljene še izkušnje Slovaške, Nemčije, Nizozemske in Španije v zvezi z povezovanjem IN-

SPIRE in odprtih podatkov, posodobitve ter avtomatizacije ePoročanja. Predstavljeno je bilo orodje v okviru Hale, ki ga je razvil nizozemski Geonovum za preoblikovanje nizov podatkov v obliko GML in XML, kot jo zahteva okoljsko poročanje. Orodje je brezplačno na voljo tudi drugim državam članicam.

Na drugem plenarnem delu zasedanja so predstavniki evropske komisije in posameznih držav in regij predstavljali primere čezmejnega in medregijskega sodelovanja pri uporabi in izmenjavi prostorskih podatkov in zagotavljanju omrežnih storitev. Večkrat je bil izpostavljen program Copernicus in njegovi in situ podatki ter podatki Sentinel, ki so prosto dostopni uporabnikom prek portala CORDA. Več informaciji je na voljo na spletni strani programa Copernicus (http://ec.europa.eu/growth/sectors/space/copernicus_en). V nadaljevanju so v strnjeni obliki predstavljeni še nekateri drugi poudarki s posameznih predavanj oziroma smernic, podanih na predavanjih, celotna predavanja pa bodo uporabnikom na voljo na spletni strani konference.

Na tehnološkem področju oziroma pri razvoju storitev je veliko poskusov, kako povezati infrastrukturo INSPIRE oziroma na ISO/OGC-standardih razvite storitve z usmeritvami in storitvami na podlagi W3C ter s storitvami, ki se razvijajo v okviru stebra e-uprave in ISA, ter s strategijo digitalnega trga. V tem kontekstu so bile predstavljene različne rešitve oziroma prototipi za vzpostavitev enoličnih, dolgoročno nespreminjajočih se identifikatorjev, dostopnih prek URI-povezav (gl. npr. predavanje *Developing a national Persistent Identifier Management System*), poskusi prikaza enostavnejših URI-povezav do uporabnikov z uporabo NGINX reverse proxy (‚GMLID-EU – *data acces point for short URLs. Harmonized access to data using INSPIRE WFS download services*).

Posebno pozornost smo posvetili predstavitvam, povezanim z implementacijo sistema Re3gistry. V povezavi s tem smo se posvetovali s kolegi, ki so sistem že implementirali (v Avstriji imajo na primer veliko pripomb glede trenutne funkcionalnosti sistema), pa tudi z razvijalci sistema, ki so na predavanju z naslovom *Re3gistry version 2 – Manage and share reference codes in a simple way* predstavili sedanji razvoj sistema. Glede na slišano pričakujemo, da bo verzija 2, ki bo predvidoma dostopna konec januarja 2018, vsebovala niz funkcionalnosti in dopolnitev (na primer uporabniški vmesnik, avtentifikacijo in avtoritzacijo, skrbništvo, procesni modul, možnost dodajanja lastnih atributov, servise nad podatki v realnem času ...).

Na področju razvoja programskih orodij je razvidno, da je odprtokodno okolje zelo dinamično. Poleg razvoja in dopolnitev posameznih orodij so se pojavili ponudniki, ki so integrirali posamezne produkte (na primer Geoserver, Geonetwork, Deegree) v povezan skupek orodij – v produkte, ki omogočajo zajem, kontrolo, metapodatke, vizualizacijo in prenos prostorskih podatkov v kontroliranem procesu, podprtem z nadzorom delovnih postopkov in nadzorom kakovosti metapodatkov, storitev in podatkov. Napredek je tudi pri orodjih za transformacijo (FME, HALE), ki omogočajo več integracije, boljše vmesnike in hitrejše delo, prikazani pa so bili tudi primeri poskusov namestitev prostorske infrastrukture v računalniški oblak z uporabo kontejnerjev Docker, razširitev Geonetworka za publiciranje vira Atom (angl. *Atom feed*).

Na splošni ravni so bile prikazane različne izvedbe INSPIRE na regionalni in nacionalni ravni. Tako so na primer v Luxembourgu prešli na odprtokodna orodja (Geoserver, Geonetwork) in se implementacije lotili precej pragmatično – izvedli so le, kar je bilo obvezno (na primer odločili so se, da bodo metapodatkovni opisi le v angleškem jeziku, ker menijo, da je INSPIRE namenjen predvsem strokovno usposobljenim uporabnikom). Sedaj na enem mestu skrbniška organizacija skrbi za 253 podatkovnih nizov 22 državnih organizacij.

Splošna ugotovitev je, da je INSPIRE kot infrastruktura za prostorske podatke na dobri poti, da je odlično opredeljena ter zelo dobro in kakovostno dokumentirana platforma. Dejstvo pa je, da je zasnova stara deset let, razvoj na področju informacijskih tehnologij pa je dinamičen, zato je treba iskati načine, kako bi se prilagodili novim tehnologijam in smernicam. Teh je kar nekaj, kot ene bolj aktualnih naj izpostavimo načine publiciranja, ki bi bili primernejši za semantični WEB (npr. RDF ter povezani podatki – *linked data*). Na tem področju še ne obstajajo ustrezne splošno sprejete metodologije in standardne rešitve za prostorske podatke, se pa izvajajo aktivnosti, tako poizkusi implementacij kot tudi usklajevanja med različnimi ključnimi deležniki JRC/ISO/OGC/W3C. Konkretnih končnih dokumentov še ni veliko, so pa že nastala nekatera priporočila, na primer Usmeritev za preverbo prostorskih podatkov v RDF ali dokument, ki sta ga skupaj pripravili delovni skupini iz OGC in W3C, Prostorski podatki in splet.

Tretje plenarno zasedanje je bilo namenjeno izmenjavi podatkov med javnim in zasebnim sektorjem, s poudarkom na potrebnih spremembah in dopolnitvah specifikacij INSPIRE, da bi izmenjava bolj stekla in bi postala del rednih procesov v gospodarstvu. Podatki, ki jih zbira zasebni sektor in državljani – s senzorji v internetu stvari in podatkovnem gospodarstvu na splošno –, eksponentno rastejo. Komisija v okviru spremljanja vmesnega pregleda strategije za enotni trg trenutno preučuje, kako bi lahko organi javnega sektorja bistveno izboljšali svoje odločanje, če bi lahko uporabljali tudi komercialne informacije, zlasti za namene javne zdravstvene politike, prostorskega urbanističnega načrtovanja, obvladovanja naravnih in tehnoloških tveganj, upravljanja energetskih omrežij ali varovanja okolja. Na plenarnem zasedanju so udeleženci razpravljali, kako se morajo infrastrukture podatkov, kot je INSPIRE, razvijati v smeri, da se zagotovi učinkovita izmenjava informacij med zasebnim in javnim sektorjem ter državljani.

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ZBOR MATIČNE SEKCIJE GEODETOV PRI INŽENIRSKI ZBORNICI SLOVENIJE

Matej Kovačič

Junija je potekal zbor Matične sekcije geodetov (MSGeo) pri Inženirski zbornici Slovenije. Letošnji zbor je bil tudi volilni, saj so med drugim potekale volitve v organe sekcije, in sicer v upravni odbor ter strokovni svet. Skupaj je glasovalo nekaj več kot 70 članov sekcije. Za naslednji mandat so bili izvoljeni naslednji kandidati:

- za predsednika upravnega odbora MSGeo je bil izvoljen Matej Kovačič, univ. dipl. inž. geod.;
- za člane upravnega odbora MSGeo so bili izvoljeni:
  - dr. Aleš Breznikar, univ. dipl. inž. geod.,
  - Simona Čeh, univ. dipl. inž. geod.,
  - Tomaž Farič, univ. dipl. inž. geod.,
  - Matjaž Grilc, univ. dipl. inž. geod.,
  - Tadej Ledinek, inž. geod.,
  - Jana Martinuč Brajnik, univ. dipl. inž. geod.,
  - Matej Plešnar, inž. geod.;
- za predsednika strokovnega sveta MSGeo je bil izvoljen Samo Lenarčič, univ. dipl. inž. geod.;
- za člane strokovnega sveta MSGeo so bili izvoljeni:
  - Miran Brumec, univ. dipl. inž. geod.,
  - mag. Edvard Mivšek, univ. dipl. inž. geod.,
  - Barbara Kremesec, univ. dipl. inž. geod.

Za stare in novo izvoljene člane organov sekcije se pričakuje, da bodo dejavno soustvarjali in se po svojih močeh trudili pri izvajanju nalog in poslanstva zbornice, da bo tako zagotovljena strokovnost in ustrezna kakovost na področju izvajanja geodetske dejavnosti. V zadnjem času je bila večina članov angažirana pri pripravi sprememb gradbene, prostorske zakonodaje, zato je bila ena od točk zbora tudi nov Zakon o arhitekturni in inženirski dejavnosti (ZAID).

Na zboru je predstavnica Ministrstva za okolje in prostor Republike Slovenije mag. Sabina Jereb predstavila predlog zakona, ki je pred kratkim šel v parlamentarni postopek. Zakon bo bistveno vplival na izvajanje geodetske dejavnosti, ukinja namreč regulirana poklica geodet in geodetski strokovnjak ter na novo postavlja pogoje za izvajanje dejavnosti – tako za geodetska kot ostala arhitekturno-inženirska podjetja. V razpravi so se odpirala predvsem vprašanja glede prehodnih določb, novosti pri zavarovanju odgovornosti, obveznih izobraževanjih, disciplinskih prekrških.

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SEZNAM DIPLOM NA ODDELKU ZA GEODEZIJO UL FGG

OD 1. 5. 2017 DO 31. 7. 2017

Teja Japelj

UVOD

Letošnje zelo vroče poletje se počasi končuje, čeprav nas toplo sonce še vedno razvaja in verjetno nas ni malo, ki se bojimo, da bo jesen prišla prekmalu. Pravijo, da imamo ljudje zelo radi letni čas, v katerem smo rojeni, kar zame definitivno velja, zato si vsako leto zaželim, da bi bil vsaj še en mesec poletni. Vedno ostanejo še skrite želje, ki jih čez poletje nismo uresničili.

Pričakovali bi, da se bo delo v počitniških mesecih malce ustavilo, vendar ni tako. Zaključil se je že prvi vpisni rok za študente, ki se vpisujejo prvič na našo fakulteto, nekaj študentov se je vpisalo že v višje letnike, nekateri pa počitnice izkoristijo za to, da dokončajo diplomske naloge. V tej številki so objavljene zaključne naloge, ki so jih študenti zagovarjali v polenih mesecih.

Na visokošolskem strokovnem študijskem programu prve stopnje tehnično upravljanje nepremičnin so svojo nalogo uspešno zagovarjali in študij zaključili tri študenti, na magistrskem študijskem programu druge stopnje geodezija in geoinformatika šest študentov in ena študentka na magistrskem študijskem programu druge stopnje prostorsko načrtovanje.

GEODEZIJA IN GEOINFORMATIKA, 2. STOPNJA

Kaja Hrvacki: Deformacijska analiza s kinematičnim deformacijskim modelom

Mentorica: doc. dr. Simona Savšek

Somentor: izr. prof. dr. Tomaž Ambrožič

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92374

Deformacijska analiza je postopek ugotavljanja stabilnosti točk, kar je pri določanju premikov temeljnega pomena. Dobljene vrednosti premikov in deformacij predstavimo z deformacijskim modelom, le-ta pa opisuje najverjetnejši potek deformacije. V preteklosti so klasični postopki obravnavanja deformacij temeljili na kongruenčnem modelu. Z razvojem računalništva, merskih tehnik in algoritmov vrednotenja pa se je spremenila tudi metoda deformacijske analize, ki poleg osnovne določitve geometrije objekta vključuje še časovni potek premikov, lahko pa tudi vzroke za njihov nastanek. Osredotočili smo se na kinematični deformacijski model, pri katerem predpostavimo, da je obravnavani objekt nenehno v gibanju. S tem v model vpeljemo tudi časovno komponento. Na izbranem objektu, kjer je bilo že opravljenih več terminskih izmer, smo preverili stabilnost referenčnih točk in določili statistično značilne premike kontrolnih točk oziroma določili stabilnost le-teh s kongruenčnim deformacijskim modelom. Obravnavali smo časovni okvir, znotraj katerega so bili na določenih *točkah že v preteklosti zaznani konkretnejši premiki. V sklopu magistrskega dela smo izdelali program za obdelavo kinematičnih meritev s Kalmanovim filtrom za primer diskretnega kinematičnega modela. Testirali smo stabilnost kontrolnih točk ter rezultate prikazali numerično in grafično. Pričakovano je uporabljeni pristop ponudil nekatere dodatne informacije (hitrost in pospešek premikov) o stanju obravnavanega objekta v prostoru in času, kar predstavlja alternativni pristop dosedanjemu kongruenčnemu modelu vrednotenja v deformacijski analizi.*

Jan Kočila: GNSS in klasične meritve na komparatorski bazi Logatec

Mentorica: doc. dr. Polona Pavlovčič Prešeren

Somentor: izr. prof. dr. Tomaž Ambrožič

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92706

V magistrskem delu obravnavamo različne načine meritev na komparatorski bazi Logatec. Preverjamo kakovost določitve dolžin in višinskih razlik na podlagi različnih metod GNSS-izmere, in sicer s statično metodo izmere in pa RTK-metodo izmere. Opisujemo tudi potek in rezultate klasične terestrične metode izmere, saj smo dolžine in višinske razlike, dobljene s tem načinom meritev, vzeli kot referenčne vrednosti za primerjavo z rezultati GNSS-izmere. V nalogi smo ugotavljali, kako različni načini naknadne obdelave podatkov GNSS-izmere vplivajo na kakovost določitve položajev točk. Ugotavljali smo tudi razlike določitve položajev točk v mreži GNSS, kjer smo imeli najprej nadštevilne vektorje, kjer je bila potrebna izravnava, in kasneje tudi situacijo brez izravnave. Ugotavljali smo tudi, kako interval registracije in dolžina trajanja opazovanj vplivata na kakovost obdelave posameznega baznega vektorja, in ugotovili, da daljši intervali registracije niso dali bistveno boljših rezultatov kot krajši intervali. Preverjali smo tudi navezavo baznih vektorjev na različne stalne postaje omrežja SIGNAL Idrija in Ljubljana ter na virtualno referenčno postajo VRS, ki je dala tudi najboljše rezultate. Nadalje smo na istih točkah ocenili kakovost določitve koordinat z RTK-metodo izmere, kjer smo terensko izmero izvedli podobno, kot je opisano v standardu ISO17123-8. Ponovno lahko izpostavimo, da je večkratna določitev položajev točk po preteku daljšega časovnega intervala nujno potrebna, saj se lahko koordinate iz različnih meritev zaradi vplivov na opazovanja razlikujejo.

Tina Pirnat: Izdelava 3D-modela poslovne stavbe za kataster nepremičnin

Mentorica: izr. prof. dr. Anka Lisec

Somentorja: doc. dr. Dušan Petrovič, viš. pred. dr. Miran Ferlan

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=93042

V magistrskem delu je predstavljen 3D-grafični model izbrane poslovne stavbe, na podlagi katerega predstavljamo možnost evidentiranja stavbe v 3D-kataster. Za namen razumevanja problema vzpostavitve 3D-katastra je predstavljena zakonodajo s področja zemljiškega katastra in katastra stavb v Sloveniji. Nadaljnje sta opredeljena koncept 3D-modeliranja in vrste 3D-katastra, predstavljene so prednosti 3D-katastra. 3D-žični model stavbe je izdelan v okolju AutoCAD in modeliran na podlagi podatkov, ki smo jih pridobili iz obstoječih nepremičninskih evidenc, podatkov geodetske terenske izmere in projektne dokumentacije stavbe. Model smo razdelili na več nepremičninskih enot ter razdelitev stavbe grafično predstavili na več načinov. V razpravi in zaključku so podane ugotovitve za lažjo izdelavo 3D-modela in za nadaljnjo vzpostavitev 3D-katastra v Sloveniji.

Klemen Ritlop: Analiza vpliva različnih modelov troposferske refrakcije na kakovost položaja GNSS

Mentor: prof. dr. Bojan Stopar

Somentor: asist. dr. Oskar Sterle

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=93041

Vpliv troposferske refrakcije na opazovanja GNSS je eden izmed glavnih vplivov, ki znižujejo kakovost položaja, določenega z GNSS. Čim kakovostnejše modeliranje troposferske refrakcije je zato ključno za določitev položaja z visoko točnostjo in natančnostjo. Sodobne komercialne programske rešitve za obdelavo opazovanj GNSS imajo praviloma implementiranih več modelov troposferske refrakcije, kar uporabnika postavi pred vprašanje, kateri model izbrati za pridobitev položaja čim višje kakovosti. V okviru magistrskega dela analiziramo vpliv šestih, v program Leica Infinity implementiranih modelov troposferske refrakcije, na kakovost relativno določenega položaja z GNSS. Osnovo za analize predstavljajo nizi baznih vektorjev, ki se med seboj razlikujejo po času trajanja opazovanj in/ali tem, v kakšnih razmerah v troposferi so bila opazovanja pridobljena, bazni vektorji v posameznem nizu opazovanj pa se razlikujejo po dolžini in višinski razliki med krajiščema baznega vektorja. Vpliv modela troposferske refrakcije ter vpliv višinske razlike med krajiščema baznega vektorja in njegove dolžine na kakovost položaja analiziramo ločeno za višinsko in horizontalno komponento položaja. Vse z namenom dobiti odgovor, kateri izmed obravnavanih modelov troposferske refrakcije zagotavlja najvišjo kakovost položaja.

Jasmina Šantl: Analiza vpliva prostorske ločljivosti oblakov točk na izračun prostornin

Mentor: doc. dr. Božo Koler

Somentor: asist. Tilen Urbančič

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92710

Magistrsko delo Analiza vpliva prostorske ločljivosti oblakov točk na izračun prostornin zajema filtriranje oblakov točk bližnjeslikovnega zajema in izračun prostornin deponiranega gradbenega materiala. V delu so predstavljeni fotogrametrični oblaki točk kot izvorni podatki. Opisan je postopek pridobivanja teh oblakov in njihova uporabnost. Opisana so testna območja in uporabljena programska oprema za izvedbo postopkov filtriranja in izračuna prostornin. Predstavljeni so izvedeni postopki izreza testnih območij, filtriranja oblakov točk, interpolacije ploskev ter izračuna prostornin. V zaključku magistrskega dela so predstavljeni in analizirani rezultati. Podane so ugotovitve glede vpliva avtomatskih in ročnih postopkov na izračun prostornin, glede učinkovitosti posamezne programske opreme pri filtriranju oblakov točk in glede vpliva prostorske ločljivosti oblakov točk na izračunano prostornino. Ugotovitve lahko koristijo prihodnjim uporabnikom programske opreme ali fotogrametričnih oblakov točk.

Aleksander Šašo: Pregled in ocena metod zajema geometričnih podatkov zunanjosti stavb za program epiqr® in 3D-prikaz

Mentorica: doc. dr. Mojca Kosmatin Fras

Somentorja: dr. Janja Avbelj, Vincent Peyremale, MSc of Env. Eng

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92709

V magistrskem delu smo naredili pregled in oceno metod zajema geometričnih podatkov zunanjosti stavb za program epiqr® in 3D-prikaz. V prvem, teoretičnem delu smo naredili pregled obstoječih prostorskih *podatkov, ki omogočajo pridobitev geometričnih podatkov zunanjosti obstoječih stavb. Naredili smo pregled obstoječih tehnologij in metod zajema, ki omogočajo določitev geometričnih podatkov in izdelavo 3D-modela zunanjosti stavb. Te tehnologije in metode smo med seboj primerjali ter jih ovrednotili z vidika metodologije epiqr®. Kot rezultat teoretičnega dela smo predlagali pet različnih metod za določitev geometričnih podatkov in izdelave 3D-modela zunanjosti stavb. V drugem, praktičnem delu smo predlagane metode preizkusili na treh testnih stavbah, ki se razlikujejo v velikosti, kompleksnosti geometrije in prisotnosti ovir, ki lahko otežijo zajem podatkov na terenu. Praktični preizkus je v odvisnosti od metode obsegal pridobitev obstoječih podatkov, načrtovanje in izvedbo dela na terenu (meritve in zajem podatkov zunanjosti stavb), obdelavo podatkov, izdelavo 3D-modela in določitev geometričnih podatkov zunanjosti stavb, pri tem pa smo beležili porabljen čas za dokončanje posameznih faz. Predlagane metode smo ovrednotili glede na geometrično natančnost, časovno potratnost in dodano vrednost. Pri tem smo geometrično natančnost predlaganih metod ocenili na osnovi izračunanih odstopanj geometričnih podatkov zunanjosti testnih stavb, pridobljenih v sklopu praktičnih preizkusov predlaganih metod, z referenčnimi vrednostmi geometričnih podatkov zunanjosti testnih stavb, ki smo jih določili s klasično metodo izmere karakterističnih točk stavb. Na osnovi pridobljenih rezultatov smo ocenili primernost predlaganih metod za namen programa epiqr® in 3D-prikaz.*

PROSTORSKO NAČRTOVANJE, 2. STOPNJA

Ana PlavčaK: Zelena infrastruktura – koncept in načrtovalski preizkus na primeru Savinjske statistične regije

Mentorica: doc. dr. Alma Zavodnik Lamovšek

Somentorica: viš. pred. dr. Maja Simoneti

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=93043

Magistrska naloga obravnava koncept zelene infrastrukture v povezavi s prostorskim načrtovanjem. Predstavljena so razlikovanja med navidezno podobnimi pojmi; zelene površine, zeleni sistem in zelena infrastruktura. Opisane so sestavine, elementi in opredeljene so funkcije zelene infrastrukture. Načrtovalski proces je predstavljen v dveh delih. V prvem delu so predstavljena načela in evropska dimenzija načrtovanja zelene infrastrukture. Opisani so različni pristopi k načrtovanju zelene infrastrukture, s poudarkom na regionalni ravni. Drugi del načrtovanja zelene infrastrukture je vezan na primer Savinjske statistične regije. Za umestitev koncepta zelene infrastrukture v proces načrtovanja so predstavljena načrtovalska izhodišča državnih, regionalnih in lokalnih strateških dokumentov. Opisani sta prostorska in razvojna analiza Savinjske statistične regije. Na podlagi analiz različnih strokovnih podlag je izdelan in opisan koncept načrtovanja zelene infrastrukture na primeru Savinjske statistične regije.

TEHNIČNO UPRAVLJANJE NEPREMIČNIN, 1. STOPNJA

Anja Judež Nivelmanska izmera HE Formin in jezovne zgradbe Markovci

Mentor: doc. dr. Božo Koler

Somentor: asist. Tilen Urbančič

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92932

Katja Mestnik Analiza postopkov registriranja novega stanja pri komasaciji po Zakonu o kmetijskih zemljiščih

Mentor: viš. pred. dr. Miran Ferlan

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92933

Matjaž Novak Kolesarske poti in prostorski razvoj na Ptuju

Mentorica: doc. dr. Alma Zavodnik Lamovšek

Somentor: asist. dr. Gašper Mrak

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=92652

GEO & IT NOVICE

Aleš Lazar, Klemen Kregar

Kam gre odprtokodni gis?

Na področju GISov obstaja precej odprtokodnih programov, med katerimi trenutno prevladujejo QGIS, GRASS in gvGIS. Največjo prednost si je v zadnjih letih pridobil QGIS zaradi prijaznega uporabniškega vmesnika ter širokega kroga razvijalcev in uporabnikov. Številni vtičniki v QGISu omogočajo integracijo drugih orodij, kot sta R in GoogleMaps.

Težko je napovedati prihodnost odprtokodnih GISov in ali bodo kdaj ogrozili glavne komercialne programe, kot je ESRIjev ArcGIS. Do nedavnega sta bili glavni prednosti ArcGISa prav enostavnost uporabniškega vmesnika ter kompleksnejši algoritmi 3D- in mrežnih analiz. Razvijalci QGISa, ki obstaja od leta 2002, so v zadnjem času veliko pozornosti namenili prvi temi, medtem ko sta tako GRASS kot QGIS postala zelo uporabna za uvoz in obdelavo manj konvencionalnih podatkovnih oblik, ki jih lahko uspešno kombinirata z drugimi podatki.

Najboljša pot razvoja odprtokodnih programov, po kateri bodo morda lahko prehiteli komercialne programe, se zdi povezljivost z drugimi odprtimi orodji. Namesto izdelave novih orodij se raje povezujejo z obstoječimi prek vtičnikov, podobno kot sta se R in MySQL povezala s QGISom.

Zdi se, da odprtokodne GIS-programe čaka svetla prihodnost, saj so se v zadnjih letih res hitro razvijali. Skladno s tem se je povečevala skupnost uporabnikov in razvijalcev teh programov. Tako velika skupnost ne bo zadovoljna z golo funkcionalnostjo geografskih analiz, ampak bo zahtevala/ustvarila tudi vedno večjo integracijo in izboljšano uporabnost uporabniških vmesnikov.

Vir: GIS LOUNGE, avgust 2017 – https://www.gislounge.com

Japonska izstreljuje satelite Michibiki za izboljšanje kakovosti GPS-a

Mitsubishi Heavy Industries Ltd. in japonska agencija za vesoljske raziskave JAXA sta 1. junija uspešno izstrelili drugi navigacijski satelit. Raketa H-IIA številka 34 je iz vesoljskega centra Tanegashima v orbito ponesla drugi satelit Michibiki za navigacijski sistem Quasi-Zenith (QZSS). Izstrelitev je šla kot po maslu in satelit je bil izpuščen v orbito 28 minut in 21 sekund po vzletu.

Prvi satelit Michibiki je bil izstreljen septembra 2010, o čemer smo seveda poročali, v tem letu pa nameravajo izstreliti še dva. S štirimi kvazi geostacionarnimi sateliti v orbiti bo vedno vsaj eden od njih nad Japonsko po 8 ur na dan. Sistem bo v kombinaciji z ameriškim

GPS zagotavljal večjo stabilnost sprejema signalov ter izboljšano položajno natančnost. V urbanih okoljih Japonske je sicer položajna natančnost GPSa približno 10 metrov, s sistemom QZSS pa jo bodo izboljšali na nekaj centimetrov.

Čeprav so bili sprva predvideni le trije sateliti, japonska vlada sedaj načrtuje izstrelitve skupno sedmih satelitov, s čimer bi si Japonska zagotovila lasten navigacijski sistem, ki ne bi bil več odvisen od ameriškega.

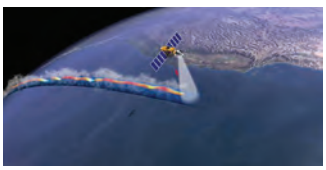
Vir: Reuters, junij 2017 – https://www.reuters.com; GPS world, junij 2017 – http://gpsworld.com

FARO Focus S70

FARO je 1. avgusta 2017 izdal nov terestrični laserski skener Focus S70. Gre za nadgradnjo letošnje januarske izdaje cenejšega skenerja Focus M70. Oba imata podobno zunanjost, merski doseg 70 metrov, IP 54 za uporabo v neugodnih razmerah in HDR-zajem podob. Razlika med njima je v hitrosti in natančnosti zajema podatkov. S70 omogoča skeniranje s hitrostjo 1 milijon točk na sekundo, M70 pa 500.000 točk/sekundo. Natančnost skeniranja pri M70 znaša 3 mm, pri S70 pa +/– 1 mm. Enako natančnost imata še FAROva modela Focus S350 in S150, ki dosega daljše razdalje. Z modelom M70 proizvajalci ciljajo na industrijo AEC (angl. *Architectural, Engineering and Construction*; področje arhitekture, inženirstva in konstrukcije) ter na forenzično industrijo.

Vir: FARO, avgust 2017 – http://www.faro.com/focus

Satelit Jason-2 za kartiranje morskega dna



Satelit Jason-2 je aktiven že devet let, redno spremlja nihanja površine oceanov in beleži druge meritve oceanov. Z leti se satelit postara in poškoduje zaradi različnih dejavnikov, ki nastopajo v orbiti zunaj ozračja. Zaradi varnosti drugih satelitov v njegovi orbiti bodo morali Jason-2 spustiti v nižjo orbito, kjer bo uporaben za druge naloge. Ameriški agenciji Nasa in NOAA, Francoska vesoljska agencija in Evropska organizacija za izkoriščanje meteoroloških satelitov začenjajo skupni projekt, s katerim bodo nadaljevali uporabo satelita Jason-2. Z njim bodo pridobivali nova znanja o morjih ter kartirali morska dna. Čeprav je satelit že presegel predvideno življenjsko dobo v orbiti, znanstveniki pravijo, da bi radi še naprej uporabljali njegove meritve. Z nekaj spremembami se da stari satelit vendarle uporabiti za zbiranje podatkov, ki so dragoceni za raziskovalce svetovnih morij. Nižja orbita bo satelitu omogočila spremljanje morskih tokov, podporo vremenskim napovedim in drugo.

Satelit bo meril morsko dno na vsakih pet milj, s temi podatki pa bodo lahko izdelali visoko ločljive modele površin morskih dnov. Doslej je Jason-2 z radarjem meril višine na 95 % svetovnih oceanov, ki jih ne oklepa led.

Cilj projekta je ustvariti podrobnejše karte morskih dnov, ki bodo namenjene modeliranju vedenja oceanov med cunamiji, podvodnimi potresi in drugimi anomalijami, ki se pojavijo na morskih dneh. Delo Jasona-2 bo tlakovalo pot dodatnim satelitom, ki bodo izstreljeni v prihodnjih letih. Naslednji takšen Nasin satelit izdelujejo skupaj z Veliko Britanijo in Kanado, namenjen pa bo sledenju površinskih vod in izdelavi topografij oceanov.

Vir: GIS LOUNGE, avgust 2017 – https://www.gislounge.com

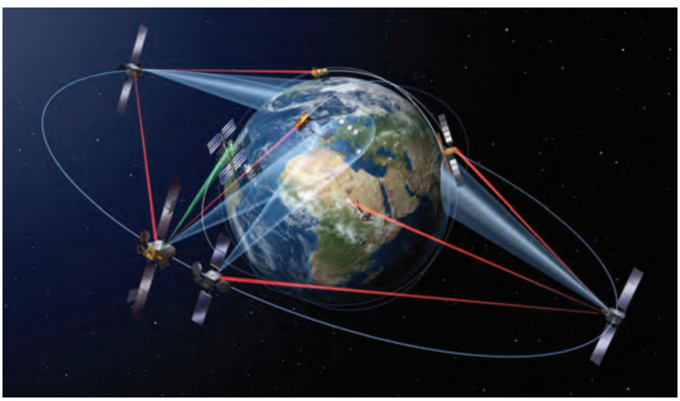
Nenavaden predlog delitve evrope iz leta 1920

Na internetu smo našli nenavaden predlog za razdelitev Evrope, ki bi preprečil nadaljnje konflikte po koncu prve svetovne vojne. Združena Nemčija je hkrati prevelika, da bi bila lahko normalna evropska država, ter premajhna, da bi zavzela celotno celino. Njeno moč bi bilo treba porazdeliti v nadnacionalno strukturo s središčem v Nemčiji. Na karti iz leta 1920 je predstavljena vizija Evrope za trajni mir, ki bi ga dosegli s politično združitvijo srednje Evrope. Predlog predvideva združitev celinske Evrope pod skupno državo, ki bi ji vladali z Dunaja (v tem primeru bi ga preimenovali v Zvezno prestolnico sv. Štefana). V zvezi ne bi imeli več tradicionalnih držav članic, ki izvirajo iz zgodovine ali iz jezikovnih, etničnih ali verskih skupin. Zveza bi bila z ravnimi mejami razdeljena v 24 kantonov v obliki žarkov, ki izvirajo iz prestolnice, in namenoma ne upoštevajo narodnostnih meja.

Kljub absurdnemu predlogu se zdi predlagana razdelitev vsaj malo smiselna. Današnja Slovenija bi večinoma padla v Graški kanton, ki bi poleg slovenskega ozemlja vseboval še avstrijsko Štajersko ter Istro in del Hrvaške.

Vir: Big think, avgust 2017 – http://bigthink.com/strange-maps

Prve z laserjem poslane podobe misije sentinel-2



V prejšnji številki smo pisali o izstrelitvi satelita Sentinel-2B, ki skupaj s satelitom Sentinel-2A vsakih pet dni na Zemljo pošlje posnetek celotne površine planeta. Podatke, ki jih satelita pošiljata na Zemljo, je mogoče uporabljati zlasti za izboljševanje kmetijstva, nadzorovanje gozdov, prepoznavanje onesnaževanja in spremljanje naravnih nesreč. Na mnogih področjih uporabnosti posnetkov pa je pomembno, da posnetke dobimo na Zemljo hitreje kot po petih dneh.

Dne 12. junija je satelit Sentinel prvič z laserjem poslal podatke 36000 kilometrov oddaljenemu geostacionarnemu satelitu Alphasat. Ta je Sentinelove posnetke pasu od Evrope do severne Afrike dostavil na zemljo le šest minut po tem, ko so bili posneti.

Satelita, ki si potujeta nasproti po isti orbiti na višini 800 kilometrov in snemata vsak 290 kilometrov širok pas površja, posnameta celo Zemljo v petih dneh, Evropo pa vsaka dva do tri dni. Podatke na zemljo pošljeta le, kadar letita nad sprejemnimi postajami, ki so v Evropi. Geostacionarni sateliti na višini 36000 kilometrov pa ves čas »lebdijo« nad enim območjem na Zemlji, saj krožijo z enako hitrostjo, kot se vrti Zemlja. Ti sateliti imajo ves čas pogled na svoje sprejemne postaje na Zemlji, zato lahko tja zelo hitro pošiljajo podatke. Satelita Sentinel-2 sta opremljena s terminali za prenos podatkov z laserjem do geostacionarnih satelitov, kot so Alphasat in European Data Relay System (EDRS), ki podatke nato pošljejo na Zemljo.

Vir: ESA, avgust 2017 – http://www.esa.int

Morda niste vedeli:

Nasin Center za Zemlji navaja, da je 1. septembra 2017 Zemljo na varni razdalji obletel največji asteroid, odkar jih vesoljske agencije aktivno spremljajo, tj. od leta 1890. 4,3-kilometrski asteroid Florence se je Zemlji približal na 7 milijonov kilometrov, kar je 18-krat dlje od Lune. Asteroid s svojo velikostjo spada med potencialne prekucnike civilizacij. Pristojne službe ga spremljajo že od leta 1981, dodobra so ga premerili in precej natančno naračunali njegovo orbito. Njegova možnost trčenja z Zemljo je še stoletja praktično nična. Najbližje Zemlji se je pred leti približal kot hiša velik asteroid *2014 RC* na le 40.000 kilometrov, kar ni daleč od geostacionarnih satelitov. (MMC RTV Slovenija, september 2017)

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VOLILNA SKUPŠČINA ZVEZE GEODETOV SLOVENIJE 2017

Jožica Marinko

Predstavniki Zveze geodetov Slovenije in sedmih društev geodetov Slovenije smo se 16. junija 2017 zbrali na prijetni lokaciji v Ljubljani. Razlog je bila redna letna skupščina Zveze geodetov Slovenije. Leto 2017 je za zvezo tudi volilno leto, saj so predstavniki društev volili novo vodstvo.

Predsednik Zveze geodetov Slovenije mag. Blaž Mozetič je v uvodu pozdravil navzoče in preveril sklepčnost skupščine. V nadaljevanju je podal poročilo o delovanju zveze za leto 2016 ter se zahvalil za sodelovanje v preteklih štirih letih, za iskrenost in odprtost članov. Pomembni dogodki so se vrstili na društvenem, strokovnem področju, pa tudi na mednarodni ravni. Ključne dejavnosti so bile:

- slavnostna akademija ZGS v počastitev 5. evropskega dneva geodetov in geoinformatikov v marcu;
- podelitev priznanj Zveze geodetov Slovenije;
- 60 let Geodetskega vestnika ter zaznamovanje pomembnega mejnika s slavnostnim koncertom v septembru v Cankarjevem domu;
- priprava knjige Geodetski instrumenti in oprema na Slovenskem – izdaja v letu 2017;
- mnenje Zveze geodetov Slovenije k osnutku arhitekturne politike Slovenije ter odziv na novo prostorsko in gradbeno zakonodajo;
- priprava koledarja s starimi geodetskimi instrumenti;
- zagotovitev izdajanja Geodetskega vestnika;
- zagotavljanje financiranja Zveze geodetov Slovenije;
- posodabljanje spletnih strani Zveze geodetov Slovenije;
- strokovno delovanje v okviru sekcij in sodelovanje na področju zakonodaje;
- mednarodno sodelovanje.

V nadaljevanju je potekala predstavitev kandidata za novega predsednika Zveze geodetov Slovenije. Za položaj je prispela samo ena kandidatura, in sicer je Ljubljansko geodetsko društvo za predsednika Zveze geodetov Slovenije predlagalo mag. Blaža Mozetiča.

Mag. Mozetič je s svojo predstavitvijo orisal dosedanjo strokovno pot, kjer se je izkazal na strokovnem področju, s samoiniciativnostjo, odločnostjo in prilagodljivostjo. Za ponovno kandidaturo se je odločil zaradi prepričanja, da ponuja veliko možnosti za strokovni in stanovski razvoj geodetske stroke. Poudaril je tudi, da radikalnih sprememb ne bo, so pa vedno možnosti za nadgradnje in izboljšave. Glavni poudarek delovanja Zveze geodetov Slovenije v naslednjem štiriletnem obdobju bo:

- na <u>društvenem področju</u> zlasti obveščanje članstva, organiziranje tematskih delavnic oziroma izobraževanj, povezovanje društev in pridobivanje novih članov;
- v slovenskem <u>strokovnem prostoru</u> zlasti zagotovitev izhajanja Geodetskega vestnika, organizacija vsakoletnega Geodetskega dneva, vzpostavitev sodelovanja z drugimi sorodnimi društvi;
- na <u>mednarodni ravni</u> financiranje mednarodnega delovanja in vzpostavitev sodelovanja s tujimi sorodnimi društvi.

Ključni cilji in dejavnosti Zveze geodetov Slovenije za naslednja štiri leta:

- organiziranje Geodetskega dneva;
- zagotavljanje izdajanja Geodetskega vestnika;
- strokovno delovanje in promocija stroke ter delovanja;
- mednarodno sodelovanje;
- zagotavljanje finančnih sredstev za delovanje Zveze geodetov Slovenije.

Sledile so volitve za predsednika Zveze geodetov Slovenije, ki so na predlog predsednice delovnega predsedstva dr. Anke Lisec potekale javno. Z vsemi glasovi ZA je bil za nov mandat za naslednja štiri leta izvoljen mag. Blaž Mozetič.

Novoizvoljeni predsednik Zveze geodetov Slovenije mag. Blaž Mozetič se je zahvalil za zaupanje in podal predlog za izvolitev nove generalne sekretarke Zveze geodetov Slovenije, predstavnikov v izvršni odbor, nadzorni odbor in častno razsodišče.

Na predlog predsednika so bili izvoljeni:

- <u>generalna sekretarka:</u> Jožica Marinko;
- <u>izvršni odbor:</u> dr. Bojan Stopar, Andrej Mesner, mag. Erna Flogie Dolinar;
- <u>nadzorni odbor:</u> Daca Ferid, mag. Martin Smodiš, mag. Gregor Klemenčič;
- <u>častno razsodišče:</u> dr. Anton Prosen, Milan Brajnik, Simona Čeh.

Petkovo popoldansko srečanje smo sklenili v sproščenem klepetu in prijetni družbi stanovskih kolegov.

Zahvala vsem dosedanjim predstavnikom in iskrene čestitke novo izvoljenim članom vodstva Zveze geodetov Slovenije!

Jožica Marinko, za Zvezo geodetov Slovenije
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Zveza geodetov Slovenije
LJUBLJANSKO GEODETSKO DRUŠTVO

23. TRADICIONALNO SREČANJE NA KRIMU

Miloš Šušteršič

Tretjega junija 2017 je Ljubljansko geodetsko društvo organiziralo 23. tradicionalno srečanje na Krimu. Na dogodek so bili poleg članov društva vabljeni njihovi družinski člani in prijatelji.

Slika 1: Spominsko obeležje trigonometrične točke na Krimu.

Slika 2: Panoramska plošča na razgledni točki na vrhu Krima.

Ljubljansko geodetsko društvo je leta 1994 v sodelovanju z nekaterimi institucijami obnovilo trigonometrično točko prvega reda št. 172 na Krimu in na vrhu pred pohodniškim planinsko kočo postavilo obeležje, ki označuje zgodovinsko izhodišče krimskega koordinatnega sistema. Otvoritev obeležja je bila takrat združena s simbolnim srečanjem, ki je poleg domoljubnega imelo širši, srednjeevropski značaj. Krim je tako že 23 let razpoznaven simbol geodetske dejavnosti v Sloveniji in kraj našega vsakoletnega stanovskega srečanja.

Slika 3: Kolesar, ki je celotno progo prevozil po zadnjem kolesu..

Program srečanja je bil tudi letos takšen kot doslej:

1. POHOD (daljša različica) z izhodiščem pri domu v Iškem vintgarju, ki poteka po gozdni markirani poti, z višinsko razliko Dh = 750 m;

2. POHOD (krajša različica) z izhodiščem na križišču ceste Preserje–Rakitna in ceste na Krim, ki poteka po gozdni cesti, z višinsko razliko Dh = 300m;

3. TEKMOVANJE KOLESARJEV z izhodiščem pri Rakitniškem jezeru, ki poteka približno 2 kilometra po asfaltirani in 8 kilometrov po makadamski cesti, z višinsko razliko Dh = 300m;

4. TEK, z izhodiščem na križišču ceste Preserje–Rakitna in ceste na Krim, ki je dolg približno 8 kilometrov in poteka po gozdni makadamski cesti, z višinsko razliko Dh = 300m.

Slika 4: Gasilska fotografija najboljših tekmovalcev.

Rekreativni in tekmovalni del dogodka se je sklenil s podelitvijo kolajn in pokalov na ploščadi pod vrhom Krima, sledilo je druženje. V nadaljevanju so po kategorijah predstavljeni rezultati tekmovalnega dela:

MESTO	*Startna številka*	*Ime in priimek*	*Letnica rojstva*	*Podjetje*	*Čas*
		KOLESARJI I.			
1	106	TONE KOGOVŠEK	1957	KRIM	30:40
2	101	BOŠTJAN SAVŠEK	1967	MOP	50:15
3	113	MARKO FATUR	1967	LUZ	57:38
		KOLESARJI II.			
1	110	ROK ZUPANČIČ	1974	DČ	32:03
2	109	FERID DACA	1975	GEOGRAD	58:18
		KOLESARJI III.			
1	102	BOŠTJAN KOŽUH	1977	DČ	33:40
2	103	VITO KRIŽMAN	1977	LUZ	40:00
		KOLESARJI IV.			
1	105	MARKO KRIŽMAN	2001	DČ	32:12
2	104	MATJAŽ KRIŽMAN	1999	DČ	53:45
3	112	JAKOB TERŠAN	2000	DČ	54:45
		KOLESARJI V.			
1	111	FILIP ZUPANČIČ	2004	DČ	38:50
2	107	NEJC DACA	2006	DČ	58:05
3	108	MATIC DACA	2008	DČ	65:45
		KOLESARKE I.			
1	114	NATAŠA DACA	1978	DČ	65:48
2	115	MARJANA ČERNE		GEODATA	69:40
		TEKAČI I.			
1		ALJAŽ PEKLAJ	1992	LUZ	34:00

Slika 5: Najstarejši udeleženci srečanja in predsednik društva.

Vsi tekmovalci so prejeli kolajne: zlate, srebrne ali bronaste. Najboljši kolesar je bil TONE KOGOVŠEK, najboljša kolesarka pa NATAŠA DACA, najboljši kolesar med najmlajšimi je bil MATJAŽ KRIŽMAN. Vsi trije so prejeli pokale. Najboljši in edini tekač je bil ALJAŽ PEKLAJ, ki je tudi prejel pokal. Posebna pohvala je bila izrečena najstarejšim udeležencem, ki so bili: VALENKA GOSTIČ, MILAN NAPRUDNIK, MARJAN JENKO, FERENC ČERNE, VERA VOVK in SAŠA BRINŠEK. Posebno pohvalo za opravljeno daljšo različico pohoda so dobili naslednji udeleženci: ANA BARBIČ, NACE PERNE in ELIZABETA TRAMBUŠ. Pohvala je bila izrečena tudi najštevilčnejši družini z aktivnimi kolesarji, to je bila DRUŽINA DACA, in družinama z največ udeleženci, to sta bili DRUŽINI ZUPANČIČ in BRAJNIK, ter najstarejši udeleženki srečanja, to je bila gospa VALENKA GOSTIČ, predstavnica četrte generacije družine, katere člani so bili prisotni na letošnjem srečanju na Krimu.

Slika 6: Druženje na Krimu 2018.

Hvala vsem udeležencem in organizatorjem srečanja. Posebne pohvale gredo vsem, ki so pomagali pri organizaciji, med katerimi naj bodo zaradi izdatnega truda posebej imenovani naslednji: RADO ŠKAFAR, GREGOR MIKLAVC, RENATO ROMIČ, LIJA ŠUŠTERŠIČ, MILAN BRAJNIK in STANE DRENŠEK. Vsi udeleženci in vsi organizatorji so v znak hvaležnosti in v spomin na srečanje na Krimu 2017 prejeli spominske kolajne.

Slika 7: Pozdrav do srečanja na Krimu 2018.

Se vidimo naslednje leto.

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Zveza geodetov Slovenije
LJUBLJANSKO GEODETSKO DRUŠTVO

IZLET STAREJŠIH ČLANOV LGD NA KOROŠKO

Stane Drenšek

Kot vsako leto smo se tudi letos starejši člani Ljubljanskega geodetskega društva odpravili na potep. Tokrat smo za cilj izbrali Koroško in izlet poimenovali: *Koroška od Slovenj Gradca do Mute*.

Iz Ljubljane smo se odpeljali ob sedmih zjutraj. Kot vedno smo se zbrali na parkirišču Dolgi most. Odpeljali smo se proti Štajerski. Naša prva postaja je bilo parkirišče na Lukovici. Tu smo se okrepčali s kavo in koščkom potice, ki je bila zelo okusna in zdrava, saj jo je naša članica Kristina spekla iz korenčka.

Pot smo nadaljevali proti Slovenj Gradcu, kjer je bila naša prva postaja. Tu smo si ogledali Koroški pokrajinski muzej z zbirko nekdanjega domačina Huga Wolfa ter zbirko umetniških slik in drugih eksponatov (slika 1).

Slika 1: V Koroškem pokrajinskem muzeju.

Slika 2: Panoramski vlakec turistične kmetije Klančnik.

Ker nas je priganjal čas, smo se po krajšem sprehodu po središču mesta odpeljali naprej proti Dravogradu. Ustavili smo se na turistični kmetiji Klančnik. Gospodar Marko nam je razložil, kako poteka delo pri njih. Imeli smo še manjšo pokušino domačih dobrot. Med zanimivo razlago o delu na kmetiji nam je natrosil cel kup šal. Pri Klančnikovih imajo tudi manjši muzej o zgodovini kmetije ter zbirko starih glasil in knjig, predvsem versko obarvanih. Nato smo se z njihovim vlakcem (slika 2) odpeljali do njihovega lovišča, kjer imajo v koči urejen lasten lovski muzej (slika 3). Tu najdete razstavljenih večino živali, ki živijo na ozemlju Slovenije, pa tudi nekaj primerkov z drugih celin. Na koncu ogleda smo nakupili nekaj domačih dobrot in spominkov ter končali prijetno druženje na kmetiji Klančnik.

Slika 3: Utrinek iz lovskega muzeja turistične kmetije Klančnik.

Odpravili smo se naprej. Naš naslednji cilj je bila Gortina, kjer domujejo Koroški splavarji. To je bil tudi naš glavni cilj izleta. Splavarji so nam pripravili lep sprejem z nagovorom in harmoniko. Sledilo je skupinsko fotografiranje. Splavarski starešina nam je lepo prikazal splavarjenje na Dravi skozi zgodovino. Seveda med razlago ni manjkalo smešnih zgodbic in šal iz splavarskega življenja. Sledila je dobri dve uri dolga plovba po Dravi (slika 4). Na splavu so nam postregli s splavarskim menijem: to sta golaž in polenta. Ko smo se vračali proti izhodišču, so nam uprizorili še splavarski krst. Krstili so dva naša člana, ki sta tako postala častna člana splavarjev. V spomin na dogodek sta dobila tudi ustrezni pisni priznanji. Po izkrcanju na suho so nas že čakale fotografije, ki so jih naredili ob našem prihodu. Po lepem, a malo hladnem doživetju – po dolini Drave v oblačnem vremenu vedno piha hladen veter – smo se odpravili naprej proti naši zadnji postaji, ki je bila Muta.

Slika 4: Na splavu.

Na Muti smo obiskali gasilsko-kovaški muzej. Tu imajo res lepo zbirko starih pripomočkov teh dveh poklicev. V zbirki se je našlo marsikaj zanimivega. V načrtu smo imeli še vožnjo po Dravski dolini proti Mariboru, vendar smo morali ta del opustiti. Zato smo se odpravili po isti poti nazaj do Velenja, od tam pa mimo Šoštanja, kjer smo si iz avtobusa ogledali novo termoelektrarno. Na poti domov smo naredili kratek postanek na Trojanah, kjer smo si privoščili krofe. Druženje smo nekaj po devetih zvečer končali tam, kjer smo ga začeli – v beli Ljubljani, a bogatejši za flosarsko doživetje.

Flosarska pesem

Hiti le trte vit, sneg se že z'lo tali,
voda s planine nam jaderno dol sverši,
bomo zvezali, urno peljali, bratec le hit'!

Slika 5: »Življenje – to niso dnevi, ki so minili, temveč dnevi, ki smo si jih zapomnili.« (Pjotr A. Pavlenko)

Stane Drenšek, upokojenec
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Foto: Lija in Miloš Šušteršič
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Zveza geodetov Slovenije
LJUBLJANSKO GEODETSKO DRUŠTVO

14. TRADICIONALNI TURNIR V MALEM NOGOMETU IN ODBOJKI V BEVKAH

Miloš Šušteršič

Dne 13. maja 2017 je Ljubljansko geodetsko društvo organiziralo 14. tradicionalni turnir v malem nogometu in odbojki na mivki v Bevkah. Na dogodek so bili poleg geodetskih društev in podjetij vabljeni tudi prijatelji in družinski člani geodetov.

Turnir se igra po naslednjih pravilih: igra se po sistemu vsak z vsakim, vratar in pet soigralcev. Igra traja 2 x 8 minut brez odmora. Zmagovalec tekme dobi tri točke, poraženec pa nič točk. V primeru neodločenega rezultata dobi vsaka ekipa po eno točko. Če dve ali več ekip osvoji enako število točk, se upoštevajo naslednja merila po tem vrstnem redu:

- medsebojno srečanje,
- gol razlika z vseh tekem,
- število danih zadetkov na vseh tekmah.

Če tudi po teh merilih ne bi bilo zmagovalca, ga določi žreb. Ekipe se na koncu razvrstijo po treh kategorijah: vse ekipe skupaj, geodetska društva in geodetska podjetja posebej. Tudi za razvrstitev znotraj kategorij podjetij in društev se upoštevajo zgoraj navedena merila in rezultati celotnega turnirja.

Razpored tekem turnirja v malem nogometu

Krog	Ekipa 1	Ekipa 2	REZULTAT
1. krog	Ljubljanski geodetski biro	Ljubljanski urbanistični zavod	1 : 0
2. krog	Ljubljansko geodetsko društvo	Celjsko geodetsko društvo	0 : 1
3. krog	Ljubljanski geodetski biro	Društvo geodetov Gorenjske	0 : 1
4. krog	Ljubljanski urbanistični zavod	Ljubljansko geodetsko društvo	1 : 0
5. krog	Celjsko geodetsko društvo	Društvo geodetov Gorenjske	2 : 2
6. krog	Ljubljanski geodetski biro	Ljubljansko geodetsko društvo	1 : 1
7. krog	Ljubljanski urbanistični zavod	Društvo geodetov Gorenjske	0 : 3
8. krog	Ljubljanski geodetski biro	Celjsko geodetsko društvo	0 : 3
9. krog	Ljubljansko geodetsko društvo	Društvo geodetov Gorenjske	1 : 1
10. krog	Ljubljanski urbanistični zavod	Celjsko geodetsko društvo	0 : 0

Rezultati turnirja v malem nogometu

	TOČKE	RAZVRSTITVE SKUPNO	RAZVRSTITEV DRUŠTEV	RAZVRSTITEV PODJETIJ
Celjsko geodetsko društvo	**8**	**2**	**2**	
Društvo geodetov Gorenjske	**8**	**1**	**1**	
Ljubljanski geodetski biro	**4**	**3**		**1**
Ljubljansko geodetsko društvo	**2**	**5**	**3**	
Ljubljanski urbanistični zavod	**4**	**4**		**2**

V odbojki na mivki sta se letos pomerili le dve ekipi, in sicer Celjsko geodetsko društvo in Ljubljansko geodetsko društvo. Zmaga je pripadla Celjskemu geodetskemu društvu z rezultatom 3 : 1, tako je bilo Ljubljansko geodetsko društvo drugo. Pokal so poleg ekip dobile tudi navijačice.

Slika 1: Športni utrinek.

Slika 2: Taktika je obrodila sadove.

Hvala vsem udeležencem in organizatorjem turnirja ter lep pozdrav do naslednjega leta.

Miloš Šušteršič
Ljubljansko geodetsko društvo
e-naslov: lija.milos@gmail.com

Foto:
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KOLEDAR STROKOVNIH SIMPOZIJEV

V OBDOBJU OKTOBER–DECEMBER 2017

Aleš Lazar

V SLOVENIJI

16.–17. november 2017	**Slovenski regionalni dnevi 2017** Kranjska Gora, Slovenija Spletna stran: http://rrs.zrc-sazu.si/
1. december 2017	**Konferenca e-prostor in tretji slovenski dan INSPIRE** Ljubljana, Slovenija Spletna stran: http://www.geoportal.gov.si/
1.–3. december 2017	**COMPTECH** Ljubljana, Slovenija Spletna stran: http://www.comptech.si/
3. december 2017	**TEDxLjubljana 2017** Ljubljana, Slovenija Spletna stran: http://tedxljubljana.com/

V TUJINI

1.–3. oktober 2017	**EuroGeographics General Assembly** Dunaj, Avstrija Spletna stran: http://www.eurogeographics.org/
4.–5. oktober 2017	**International Conference on Geomatic and Geospatial Technology 2017** Kuala Lumpur, Malezija Spletna stran: http://www.geoinfo.utm.my/ggt2017
4.–6. oktober 2017	**2nd International Conference on Smart Data and Smart Cities**

	Puebla, Mehika Spletna stran: http://ing.pue.itesm.mx/udms2017/
5.–6. oktober 2017	**International Conference on Geo-Spatial Technologies and Earth Resources** Hanoj, Vietnam Spletna stran: http://ism2017.humg.edu.vn/
5.–6. oktober 2017	**Common Vision Conference 2017** Dunaj, Avstrija Spletna stran: http://www.bev.gv.at/
7.–10. oktober 2017	**GI Research 2017, SMPR 2017, EOEC 2017** Teheran, Iran Spletna stran: http://ing.pue.itesm.mx/udms2017/
9.–10. oktober 2017	**EuroSDR/ISPRS workshop Oblique 2017** Barcelona, Španija Spletna stran: http://www.eurosdr.net/workshops/eurosdrisprs-workshop-oblique-2017
10.–12. oktober 2017	**The Year in Infrastructure 2017** Singapur, Singapur Spletna stran: http://www.bentley.com/en/yii/home
11. oktober 2017	**ISPRS Workshop on Role of Geoinformatics in Citizen Science for Governance** New Delhi, Indija Spletna stran: http://www.isprs.org/
14.–15. oktober 2017	**4th International Workshop on Geoinformation Science: GeoAdvances 2017** Safranbolu, Karabuk, Turčija Spletna stran: http://3dgirg.karabuk.edu.tr/geoadvances2017/
16.–19. oktober 2017	**17th International Scientific and Technical Conference** Hadera, Izrael Spletna stran: http://conf.racurs.ru/conf2017/eng/
18.–20. oktober 2017	**Ingeo 2017** Lizbona, Portugalska Spletna stran: http://ingeo2017.lnec.pt
18.–20. oktober 2017	**QKEN Plenary Meeting** Frankfurt, Nemčija

	Spletna stran: http://www.eurogeographics.org/
18.–21. oktober 2017	**International Symposium on GIS Applications in Geography and Geosciences** Canakkale, Turčija Spletna stran: http://isggg2017.comu.edu.tr/
23.–25. oktober 2017	**GSTIC 2017 conference** Bruselj, Belgija Spletna stran: https://www.gstic.org/
24.–27. oktober 2017	**3D Australia Conference 2017** Melbourne, Avstralija Spletna stran: http://3dgeoinfo2017.com/
25.–27. oktober 2017	**ISPRS WG: Frontiers in Spectral imaging and 3D Technologies for Geospatial Solutions** Jyväskylä, Finska Spletna stran: http://www.mit.jyu.fi/scoma/spec3d/index.html
28. oktober 2017	**IEEE/ISPRS 4th Joint Workshop on Multi-Sensor Fusion for Dynamic Scene Understanding** Benetke, Italija Spletna stran: https://msf-workshop.com/
1.–3. november 2017	**ILUS 2017** Dresden, Nemčija Spletna stran: http://www.ilus2017.ioer.info/
1.–3. november 2017	**XXVII Brazilian Congress of Cartography** Rio de Janeiro, Brazilija Spletna stran: http://www.cartografia.org.br/cbc/
8.–10. november 2017	**The 7th China Surveying, Mapping and Geoinformation Technology Equipment Exhibition** Nanjing, Kitajska Spletna stran: http://www.tleerw.com/en/
14.–16. november 2017	**Pecora20** Sioux Falls, Južna Dakota, ZDA Spletna stran: http://pecora.asprs.org/
15.–18. november 2017	**UCTEA International GIS Congress 2017** Adana, Turčija Spletna stran: http://www.giscongressturkey.org/

20. november 2017	**ISPRS Workshop on Passive and Active Electro-Optical Sensors for Aerial & Space Imaging** Wuhan, Kitajska Spletna stran: https://www2.informatik.hu-berlin.de/cv/psivt2017/
24. november 2017	**Urban Data Modelling and Visualisation** Fribourg, Švica Spletna stran: http://smartlivinglab.ch/index.php/en/home/events/189-udmv2017.html
27.–30. november 2017	**Pacific Islands GIS/RS User Conference 2017** Suva, Fidži Spletna stran: http://gisconference.gsd.spc.int/
28.–29. november 2017	**LowCost 3D-Sensors, Algorithms, Applications** Hamburg, Nemčija Spletna stran: http://www.lc3d.net/
2.–7. december 2017	**International Committee on Global Navigation Satellite Systems** Kjoto, Japonska Spletna stran: http://icg12.jp/
4. december 2017	**ISPRS WG: Geospatial Solutions for Structural Design, Construction and Maintenance in Training Civil Engineers and Architects** Kijev, Ukrajina Spletna stran: http://geospace.net.ua/isprs_eng.html
4.–8. december 2017	**Ocean Teacher Global Academy** Ostende, Belgija Spletna stran: http://www.ioc-unesco.org/
4.–8. december 2017	**Annual Conference and Meeting FIG Commission 7** Cartagena, Kolumbija Spletna stran: http://fig717.net

Sporočila s podatki o nacionalnih in mednarodnih kongresih, simpozijih in srečanjih s področja geodezije, upravljanja zemljišč in na splošno geoinformatike v Sloveniji ali tujini pošiljajte na e-naslov: lazarales@ gmail.com.

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MEJNA ZNAMENJA – UNESCOV-A KULTURNA DEDIŠČINA?

Iz Avstrije, z njihove geodetske uprave in geodetskega društva, smo prejeli zanimivo pobudo. Ideja je, da bi pripravili predlog za razglasitev UNESCO-ve materializirane kulturne dediščine, in sicer za najbolj zanimiva in izstopajoča geodetska znamenja na območju nekdanjega avstrijskega dela Habsburške monarhije – simbolično tudi ob 200-letnici začetka franciscejskega katastra.

Na seznam zavarovane kulturne dediščine bi uvrstili izbor:

- najstarejših ohranjenih geodetskih znamenj (geodetske točke, mejni deželni kamni, mejni kamni med katastrskimi občinami ipd.) in
- z geodezijo ter katastrom povezanih stavb.

Geodetska točka na Dravskem polju (Foto: J. Dajnko, OGU Ptuj)

Na spletnem naslovu goo.gl/6P3xpN je rezervirano mesto za zbiranje predlogov. Na tem mestu boste dostopali do dokumenta »PREDLOG_ZA_UNESCO.doc«, kjer so pripravljene tri tabele za zbiranje predlogov: (1) mejna znamenja, (2) druge geodetske točke in (3) stavbe.

Če imate kakšen predlog, ga enostavno dodajte v pripravljene tabele, tudi če so podatki o »geodetski posebnosti« nepopolni, prednost pa bodo imeli predlogi, ki so že ali bodo v kratkem zavarovani kot kulturna dediščina.

V pripravo končnega predloga boste vključeni vsi, ki boste prispevali predloge, seveda bomo tudi korektno navajali avtorje fotografij, vire gradiv. Ker je rok zelo kratek in nas čaka še veliko dela, prosimo za vaš prvi odziv do 2. 10. 2017.

Za več informacij lahko neposredno kontaktirate Anko Lisec (anka.lisec@fgg.uni-lj.si) ali Jožeta Dajnka (joze.dajnko@gov.si).

Hvala za vse prispevke že v naprej!

Mag. Blaž Mozetič
predsednik ZGS

F. WEILAND, LIEBENWERDA, ZEICHEN- UND MESSGERÄTEFABRIK / 1900* /

F. Weiland, Liebenwerda

Tovarna tehničnih izdelkov, kot so merilni in geodetski instrumenti, poslovna enota Liebenwerda, je bila ustanovljena leta 1882. Arhivski instrument je bil izdelan v začetku 20. stoletja. Vertikalni krog in daljnogled sta nameščena na enostranskem nosilcu. Instrument ima vgrajeno busolo, katere razdelba nadomešča horizontalni krog. Za odčitavanje vertikalnega kroga sta nameščena dva nonija, 360-stopinjska razdelba vertikalnega kroga je vgravirana na kovinski krog, ki je zaščiten z ohišjem instrumenta. Instrument ima za horizontiranje nameščeni dve libeli. Reichenbachov nitni križ, nameščen v okularju daljnogleda, omogoča odčitavanje odsekov na lati, ima multiplikacijsko konstanto 100 in adicijsko konstanto 0,28 metra.

Tovrstni instrument se pojavlja pri vzdrževanju zemljiškega katastra na več lokacijah (npr. Slovenske Konjice, Žalec).

Arhivski primerek hranijo v geodetski pisarni Žalec.

Avtor besedila: mag. Janez Slak *Fotografija: Boštjan Pucelj*

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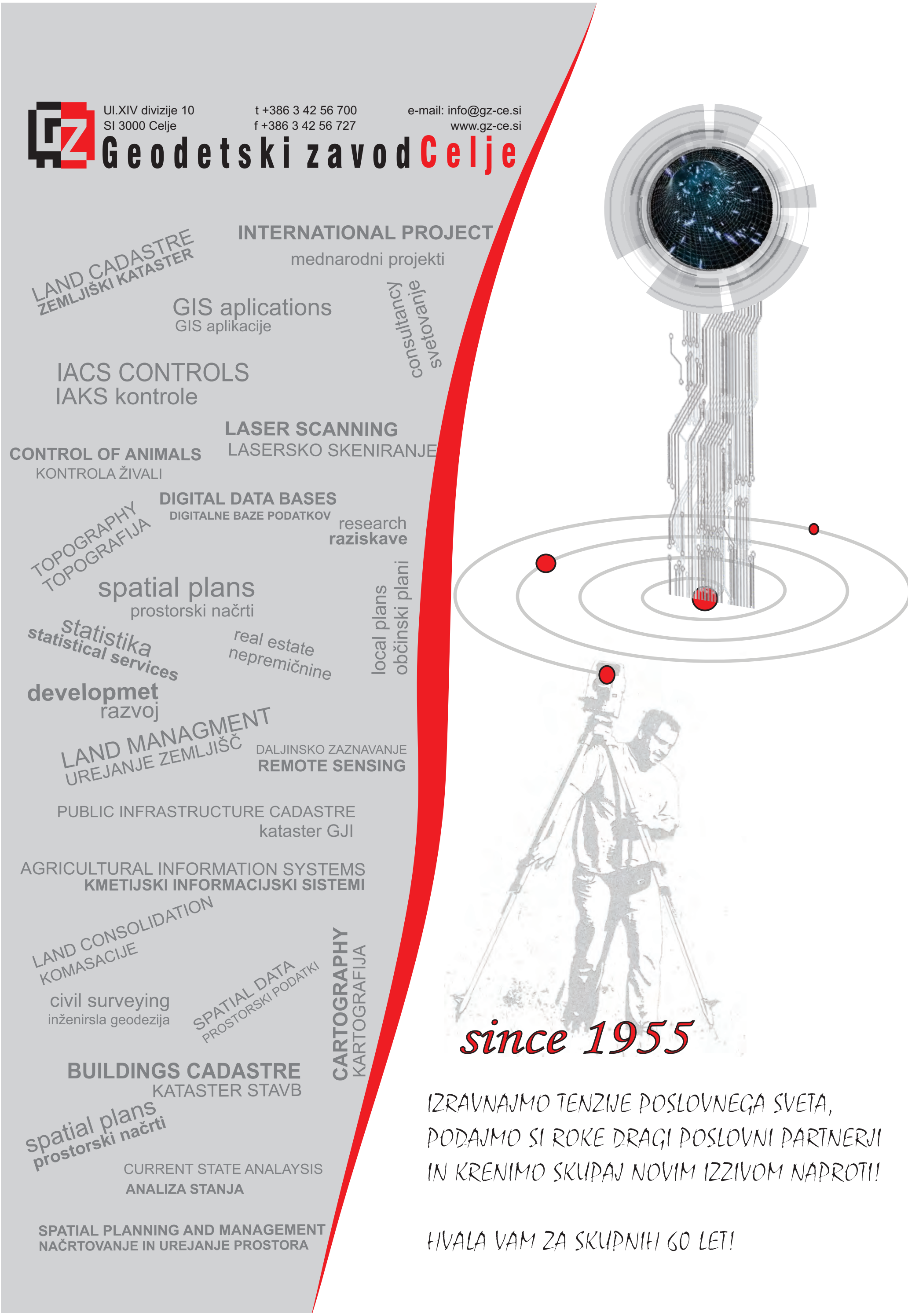
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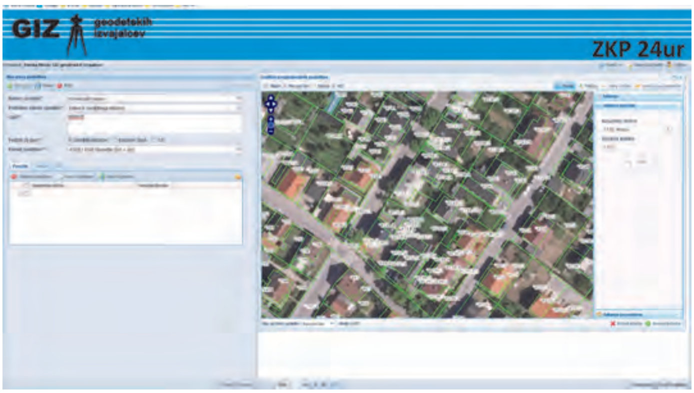

Vse dodatne informacije dobite na
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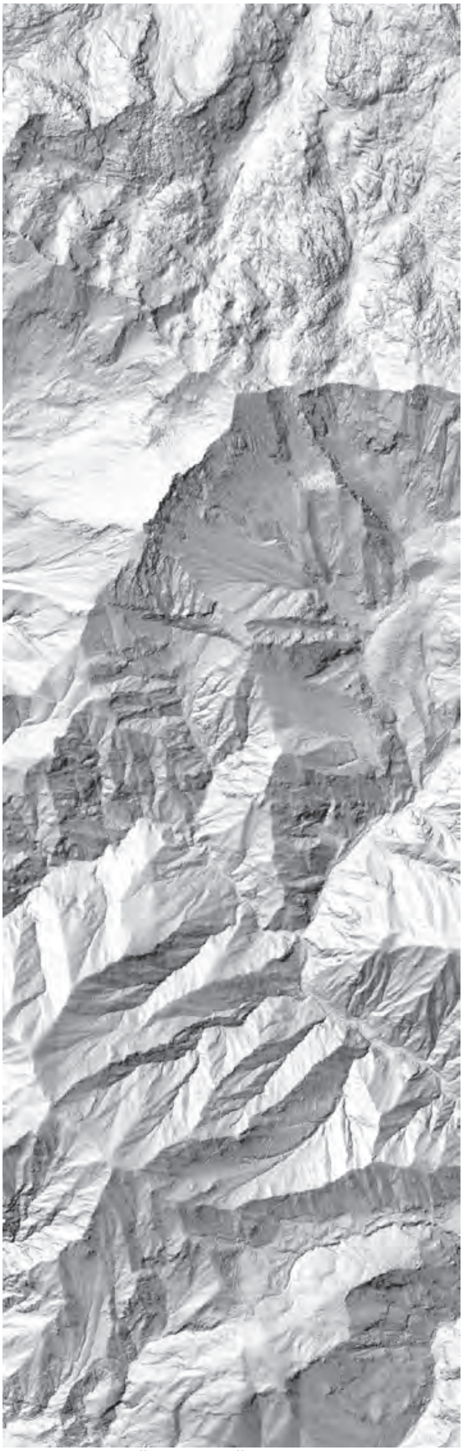

Podoba analitičnega senčenja DMR1
Laserskega skeniranja Slovenije 2014-2015

GEODETSKI INŠTITUT SLOVENIJE

- Geodetski referenčni sistem, SIGNAL
- Prostorski podatki, statistike in analize
- Nepremičninske evidence in upravljanje z nepremičninami
- Daljinsko zaznavanje, fotogrametrija in lasersko skeniranje
- Hidrografija
- Kartografija
- Geografski informacijski sistemi (GIS)
- Lokacijske storitve in navigacija
- Izdelki za orientacijo in mobilnost ranljivih skupin
- Razvoj kazalnikov in večrazsežna vizualizacija
- Priprava in vodenje mednarodnih projektov
- Izobraževanje
- Izdelava prostorskih maket
- Grafične storitve

Geodetski inštitut Slovenije, Jamova cesta 2, 1000 Ljubljana
tel.: 01 200 29 00, faks: 01 425 06 77, e-pošta: info@gis.si
medmrežje: www.gis.si


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PRIHODNOST PRINAŠA TRAJNOSTNE IZZIVE NA ZEMLJI IN NOVE V VESOLJU.
BOŠ ZRAVEN, KO SE BO GRADILA PRIHODNOST?
Vabljeni na Dan odprtih vrat UL FGG,
ki bo potekal v četrtek, 19. 10. 2017,
od 9. do 16. ure
Univerza v Ljubljani
Fakulteta za gradbeništvo in geodezijo