



Univerzitet u Beogradu – Građevinski
fakultet www.grf.bg.ac.rs

Studijski program:

GRAĐEVINARSTVO

Modul:

MASTER STUDIJE

Godina/Semestar:

1 godina / 1 semestar

Naziv predmeta (šifra):

**Geoinformacioni sistemi u
saobraćajnicama (M2S1GI)**

Nastavnik:

Aleksandar Sekulić

Naslov predavanja:

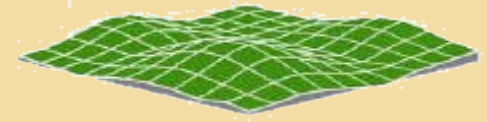
DMT

Datum :

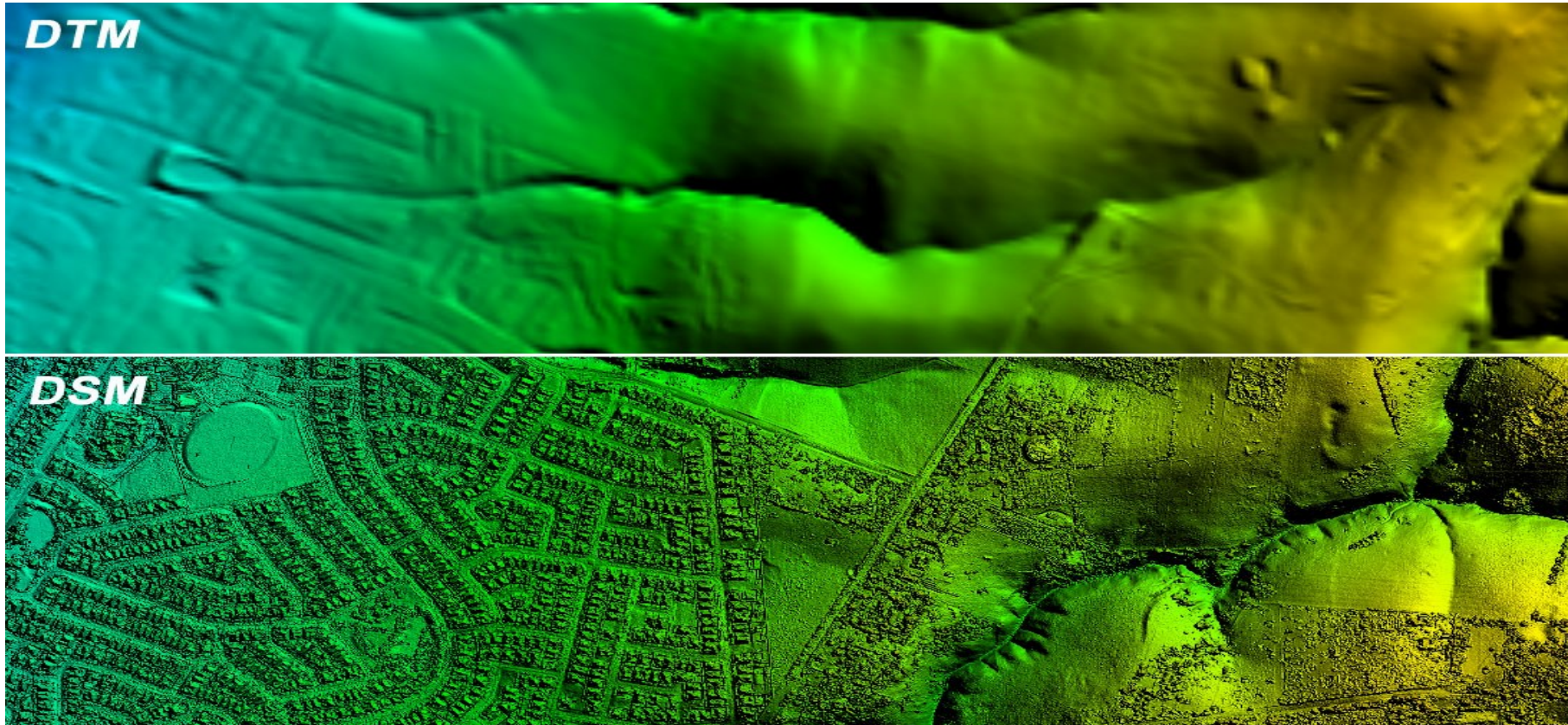
24.11.2021.

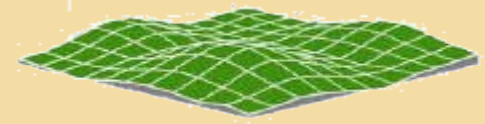
Beograd, 2021.

Sva autorska prava autora prezentacije i/ili video snimaka su zaštićena. Snimak ili prezentacija se mogu koristiti samo za nastavu na daljinu studenta Građevinskog fakulteta Univerziteta u Beogradu u školskoj 2021/2022. i ne mogu se koristiti za druge svrhe bez pismene saglasnosti autora materijala.



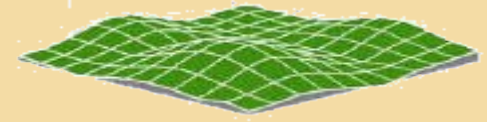
- Digitalni model terena (digital terrain model) – DTM (DMT)
- Digitalni model površi (digital surface model) - DSM



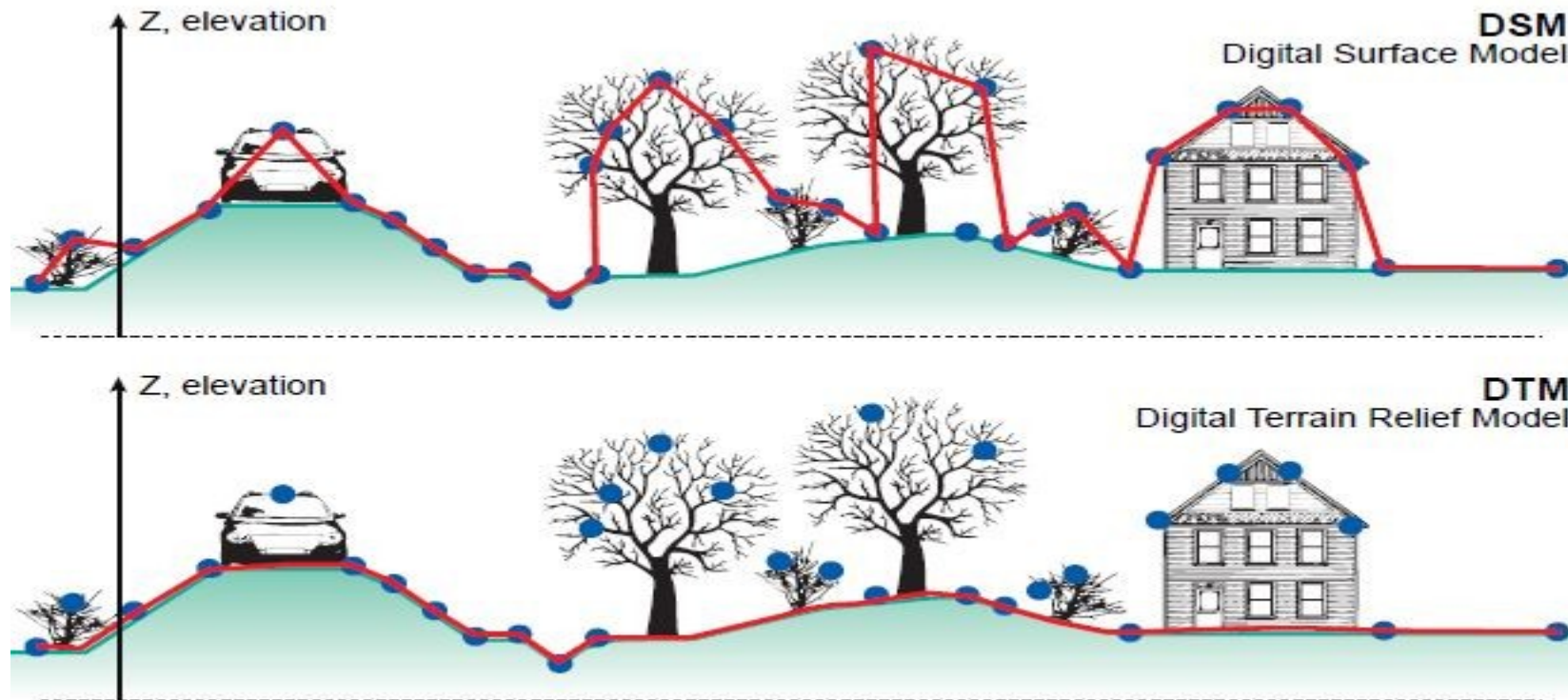


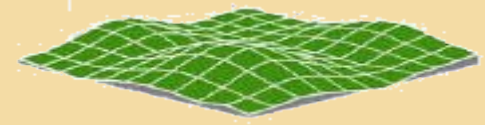
- "DMT je numerička i matematička predstava terena dobijena korišćenjem odgovarajućih visinskih i položajnih merenja, kompatibilnih u gustini i rasporedu sa terenom, tako da visina bilo koje tačke na obuhvaćenom terenu može automatski da se dobije interpolacijom uz odgovarajuću tačnost."

Digitalni model površi

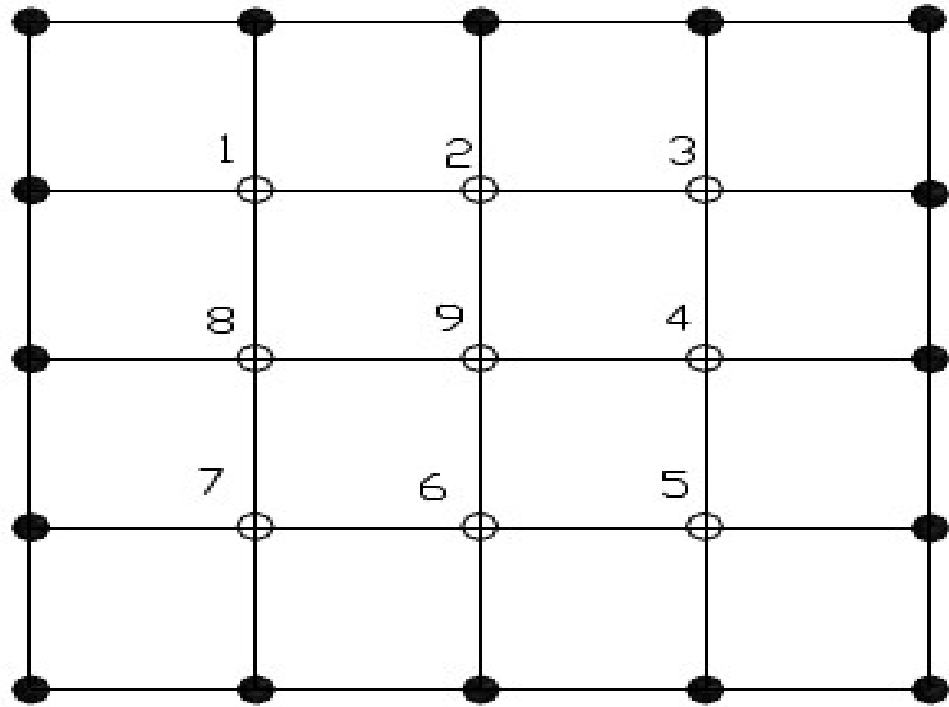
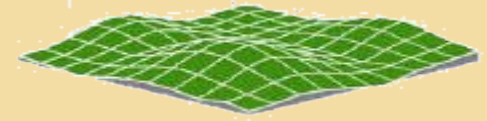


- Visinski model koji obuhvata krovove objekata, rastinje, dalekovode i druge veštačke objekte. U principu on obuhvata gornje površi objekata i površ zemlje koja nije pokrivena objektima.



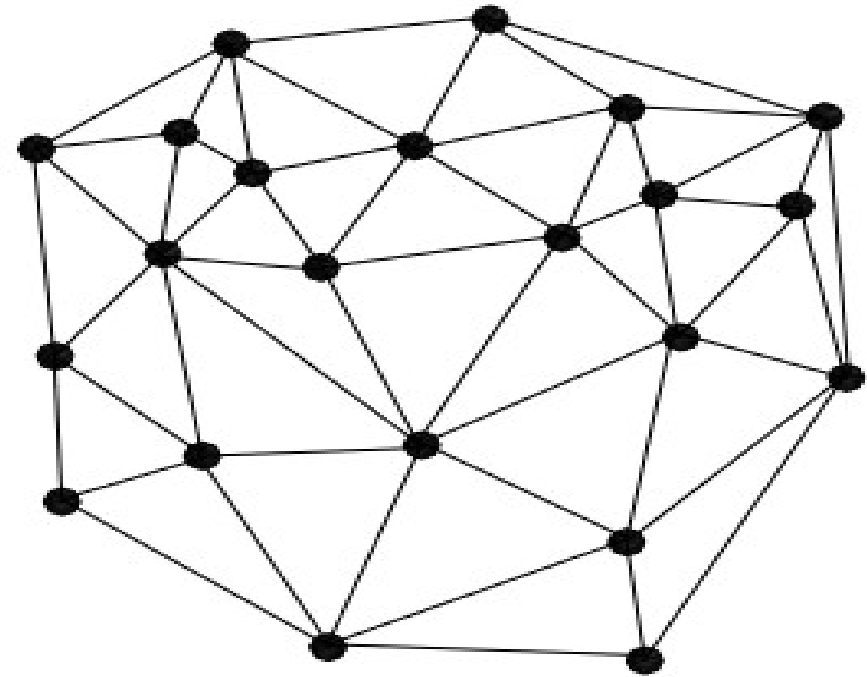


- Pod terminom *Digital Terrain Model* (DTM) podrazumevaju se baze sa TIN (*Triangulated Irregular Network*) strukturom podataka, koju čine nepravilno raspoređene, najčešće originalno merene tačke na terenu, koje predstavljaju temena mreže nepravilnih nepreklapajućih trouglova.
- Pojam *Digital Elevation Models* (DEM) podrazumeva podatke o terenu u obliku matrice visina terena. Ona se često naziva gridnom (rešetkastom) strukturom podataka. Gridne ćelije su obično u obliku kvadrata čija temena predstavljaju visinske tačke, a stranice su paralelne sa osama koordinatnog sistema.



(a)

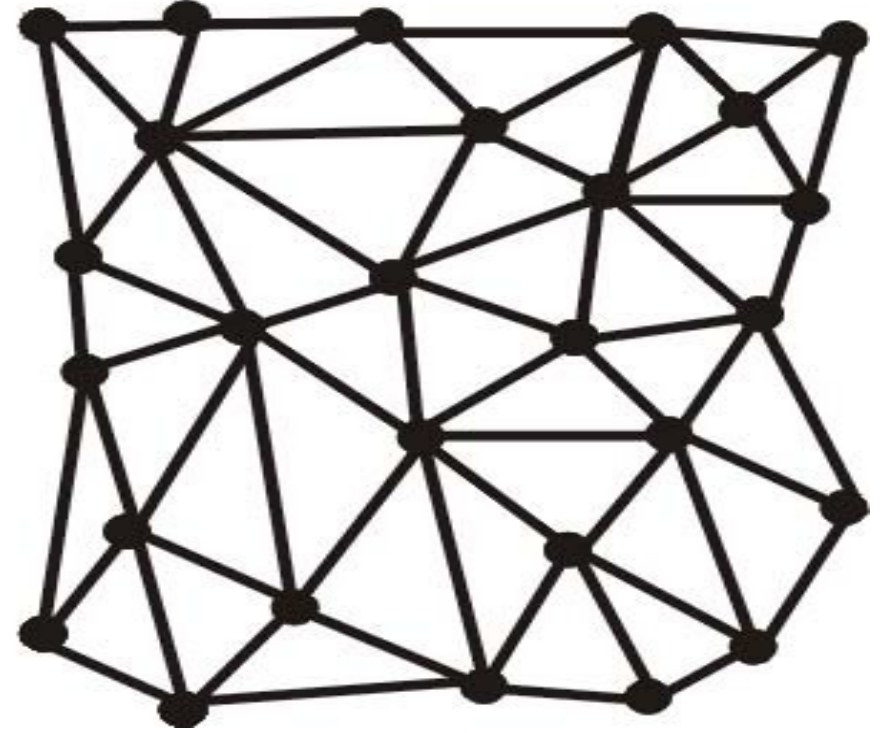
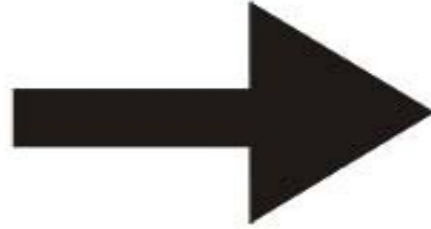
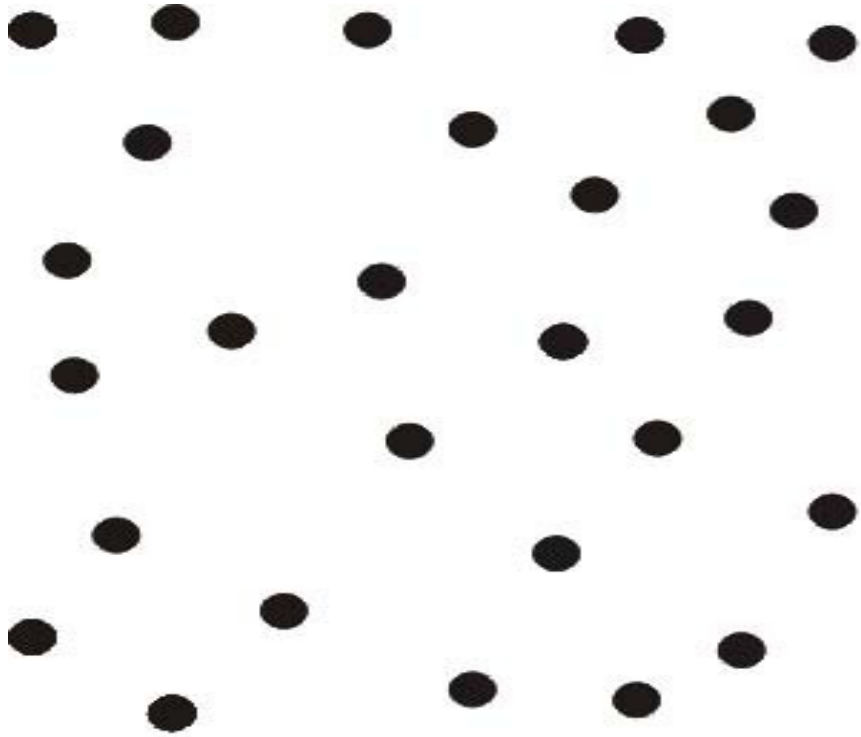
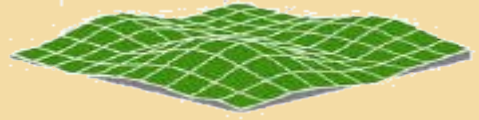
DEM-GRID



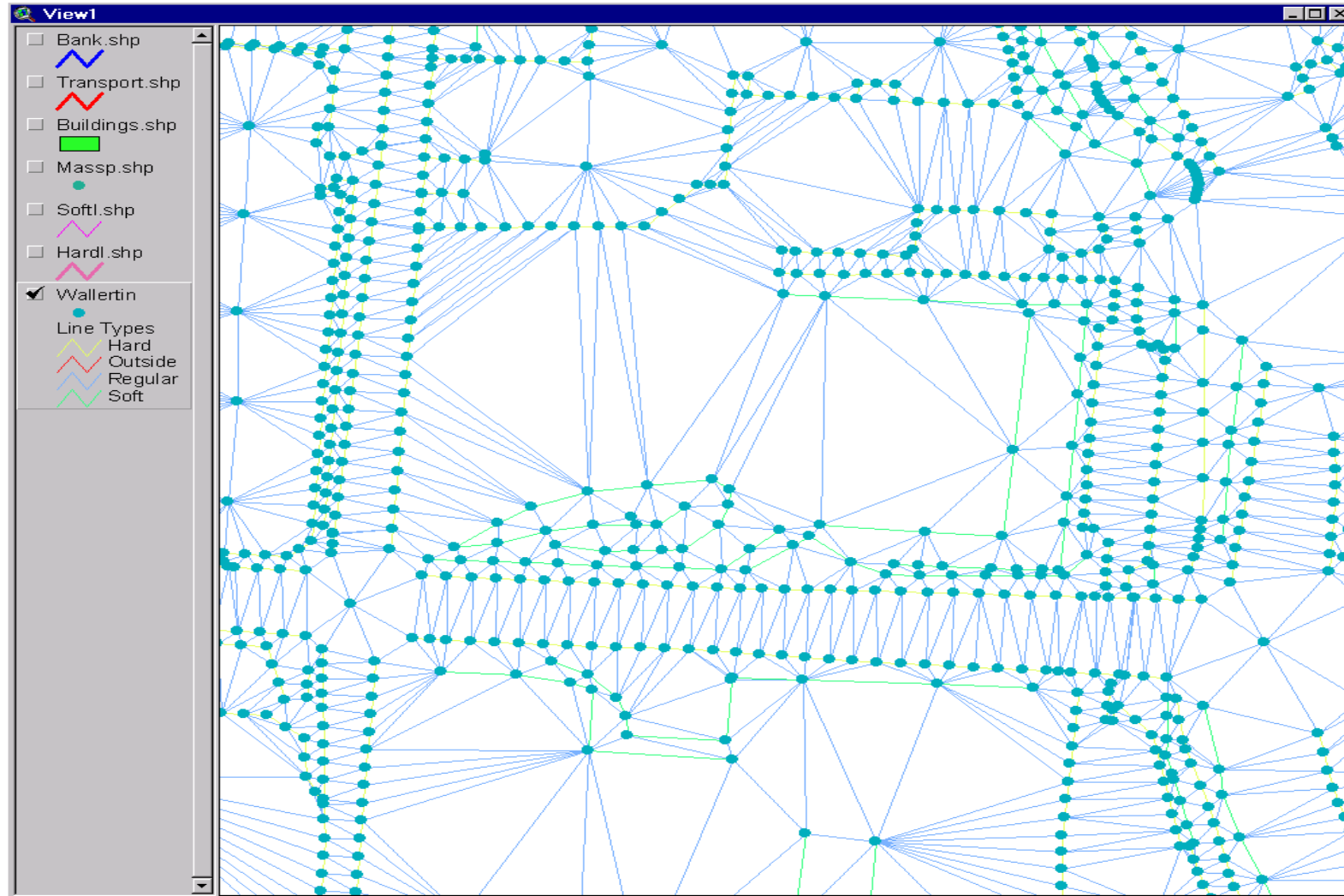
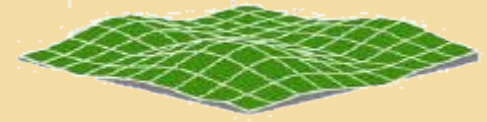
(b)

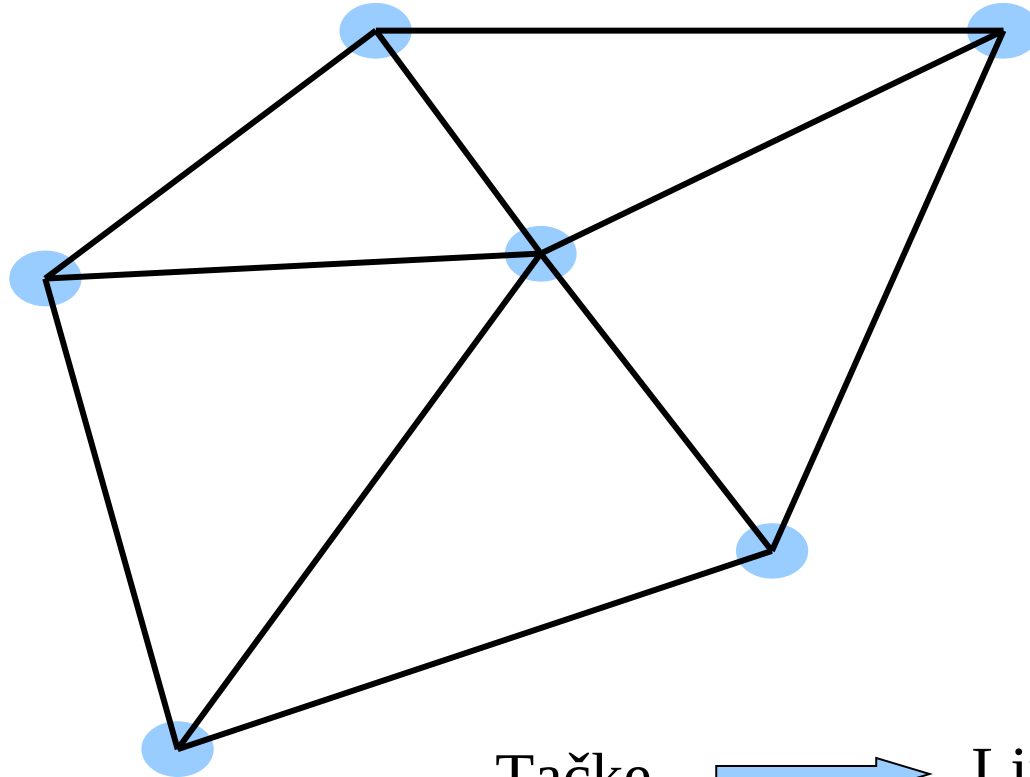
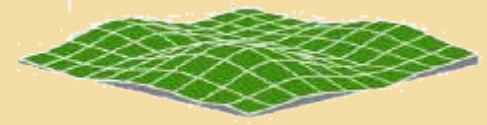
DTM-TIN

Triangular Irregular Network (TIN)



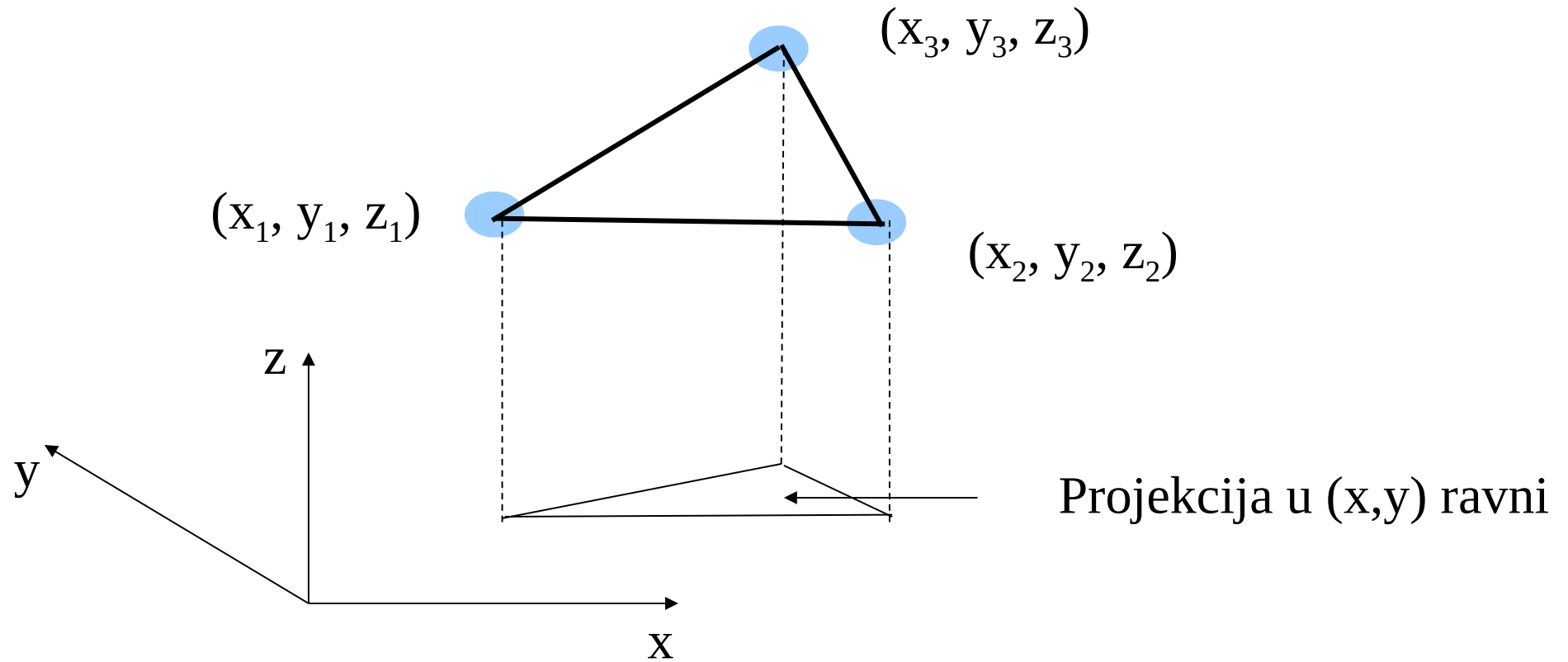
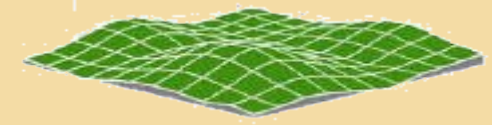
Triangulated Irregular Network (TIN)



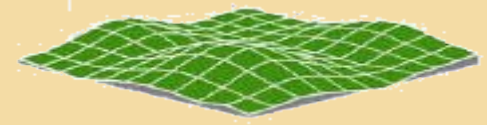


Trouglovi su samo poligoni koji su uvek **ravni** u 3-D prostoru

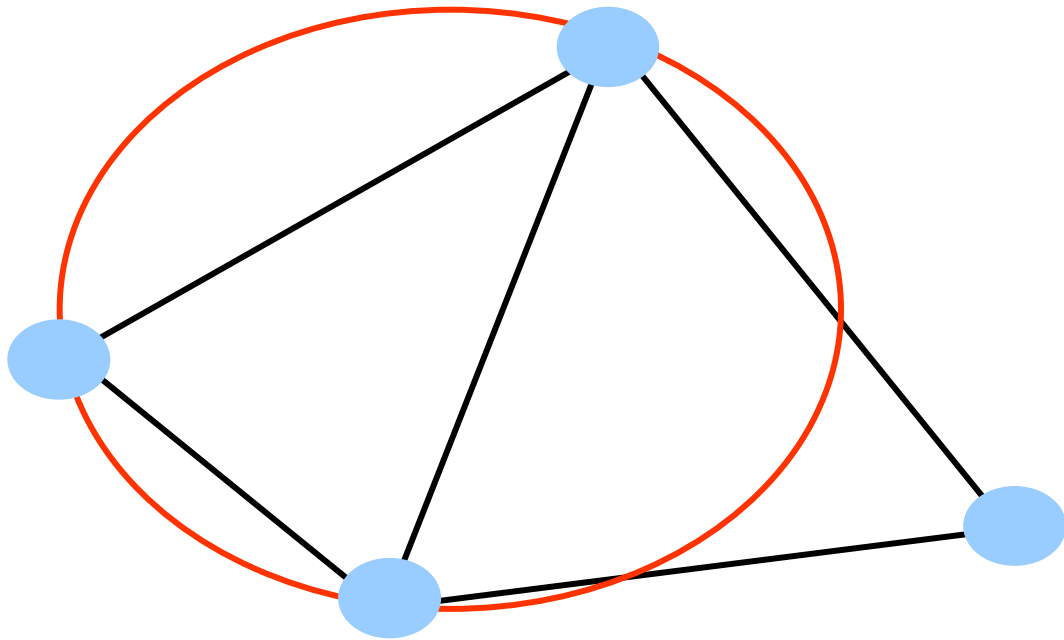
Tačke → Linije → Površī



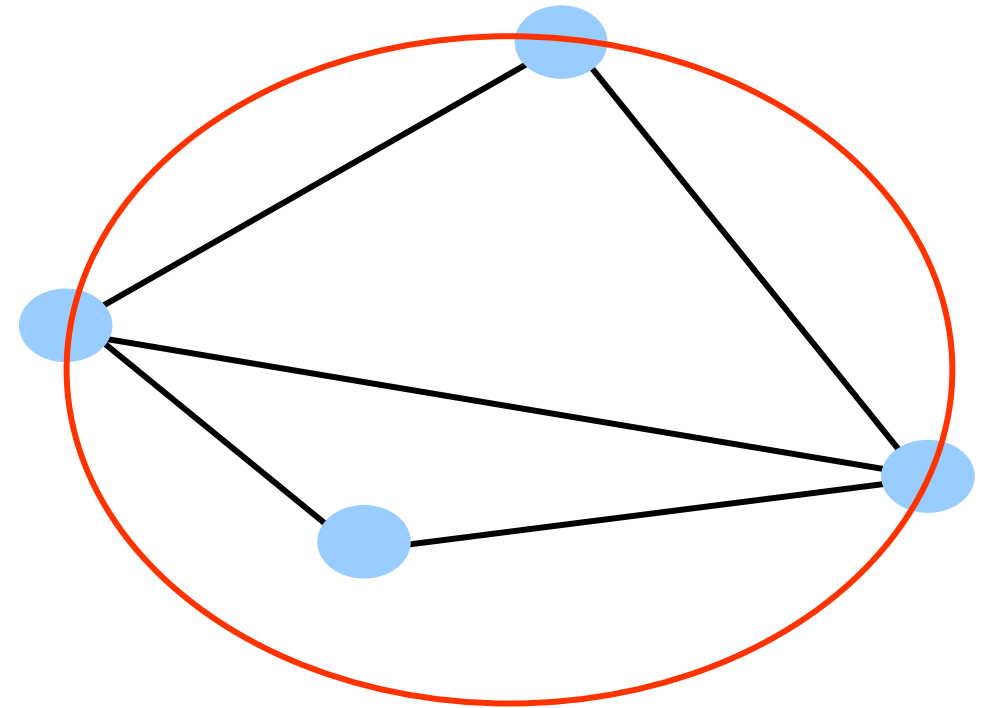
Delanijeva (Delaunay) Triangulacija



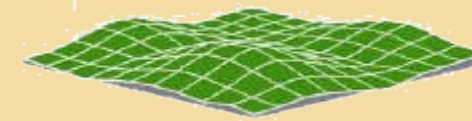
Da



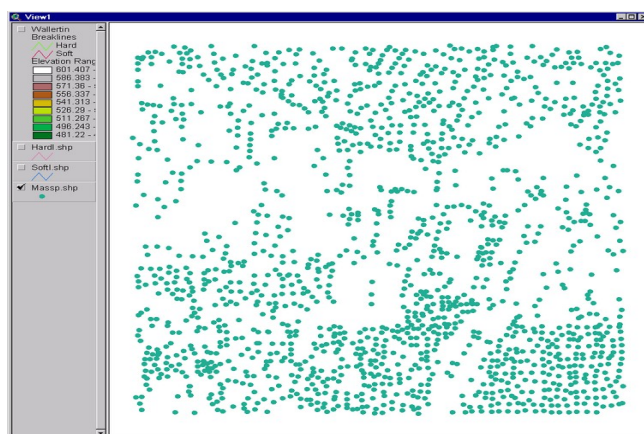
Ne



Ulazni podaci za kreiranje TIN-a



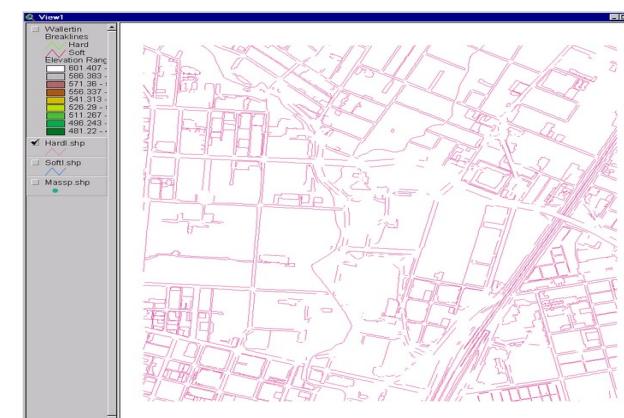
Tačke (*Mass Points*)



‘Meke’ strukturne linije
(*Soft Breaklines*)

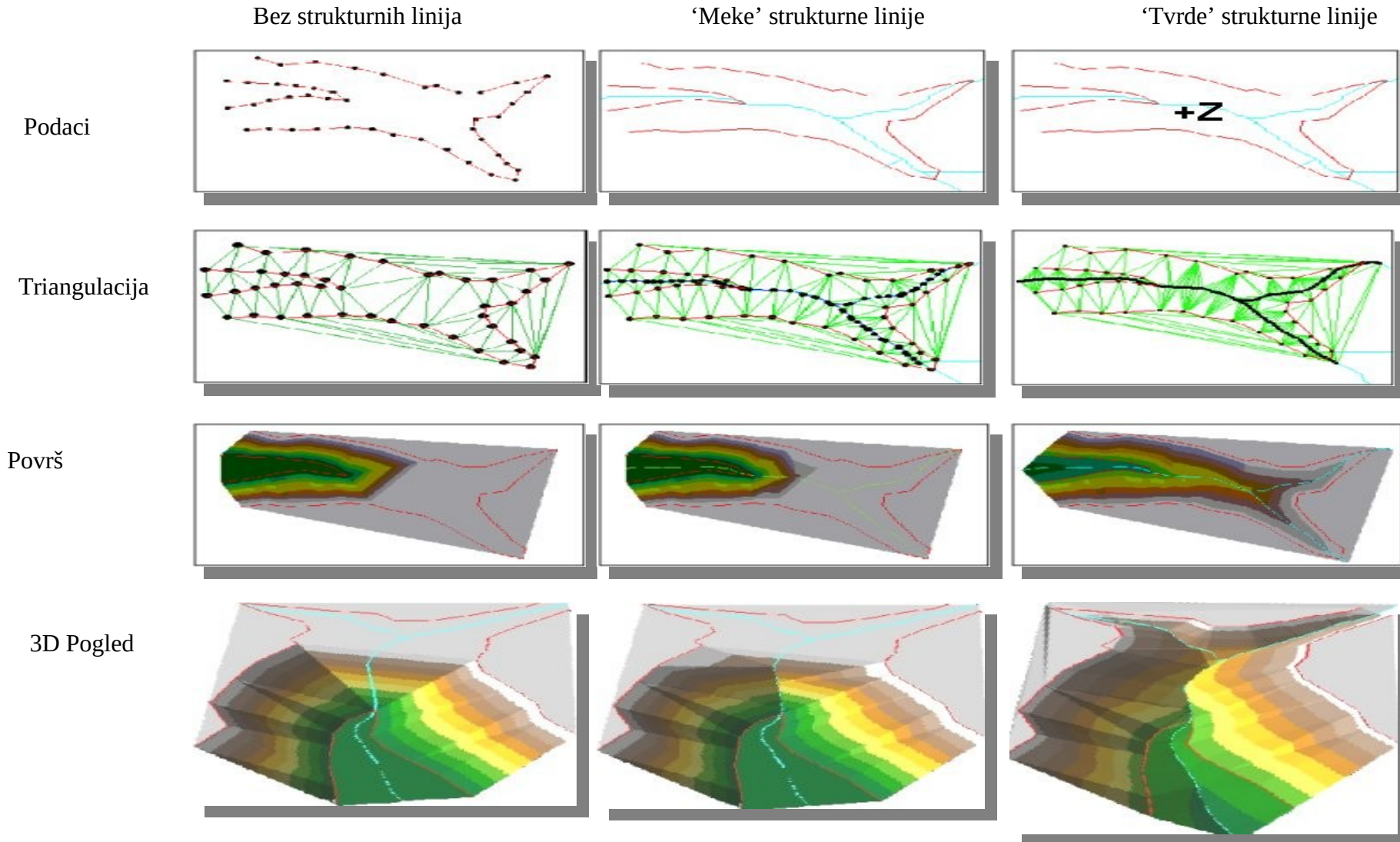
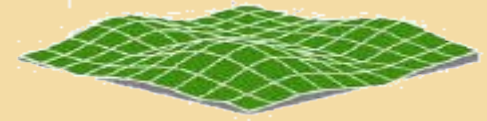


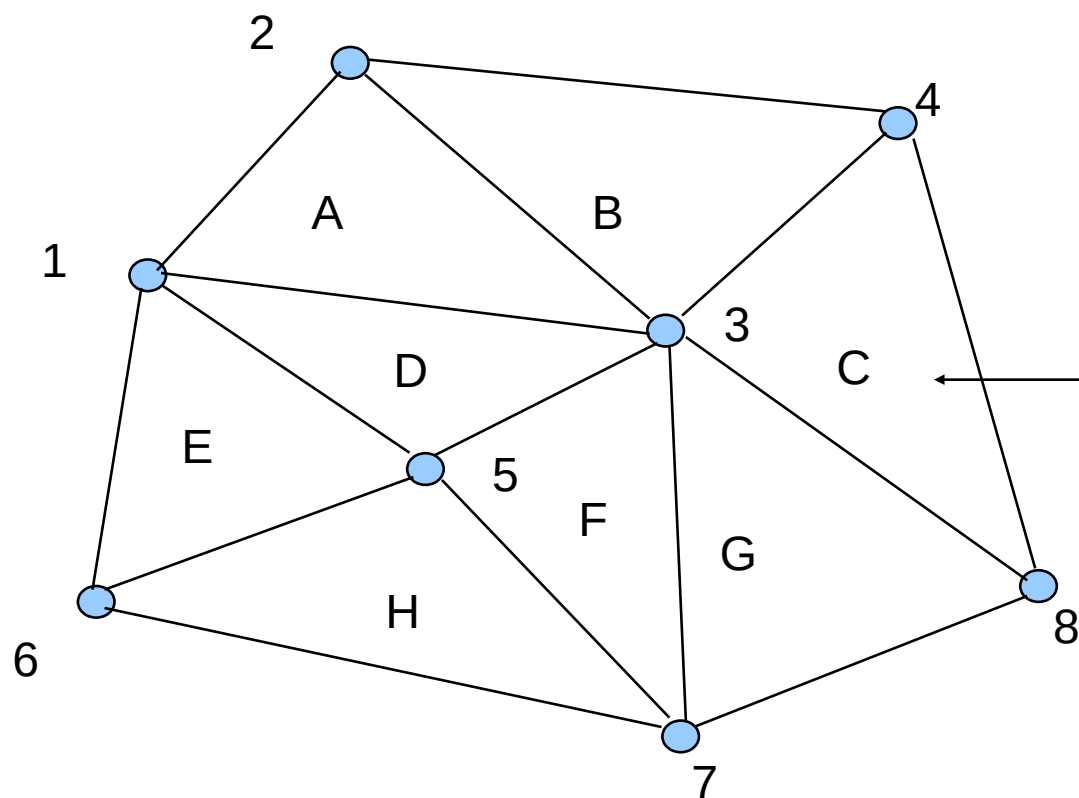
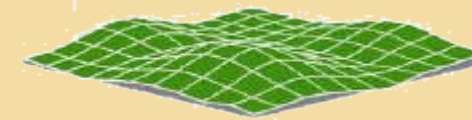
‘Tvrde’ strukturne linije
(*Hard Breaklines*)



- *Hard breaklines* - definišu lokacije naglih promena površi (npr. vododerine, vododelnice, putni nasipi, osnove zgrada, brane)
- *Soft breaklines* - obezbeđuju da tačke duž linearnih prostornih pojava budu strane trouglova u TIN-u.

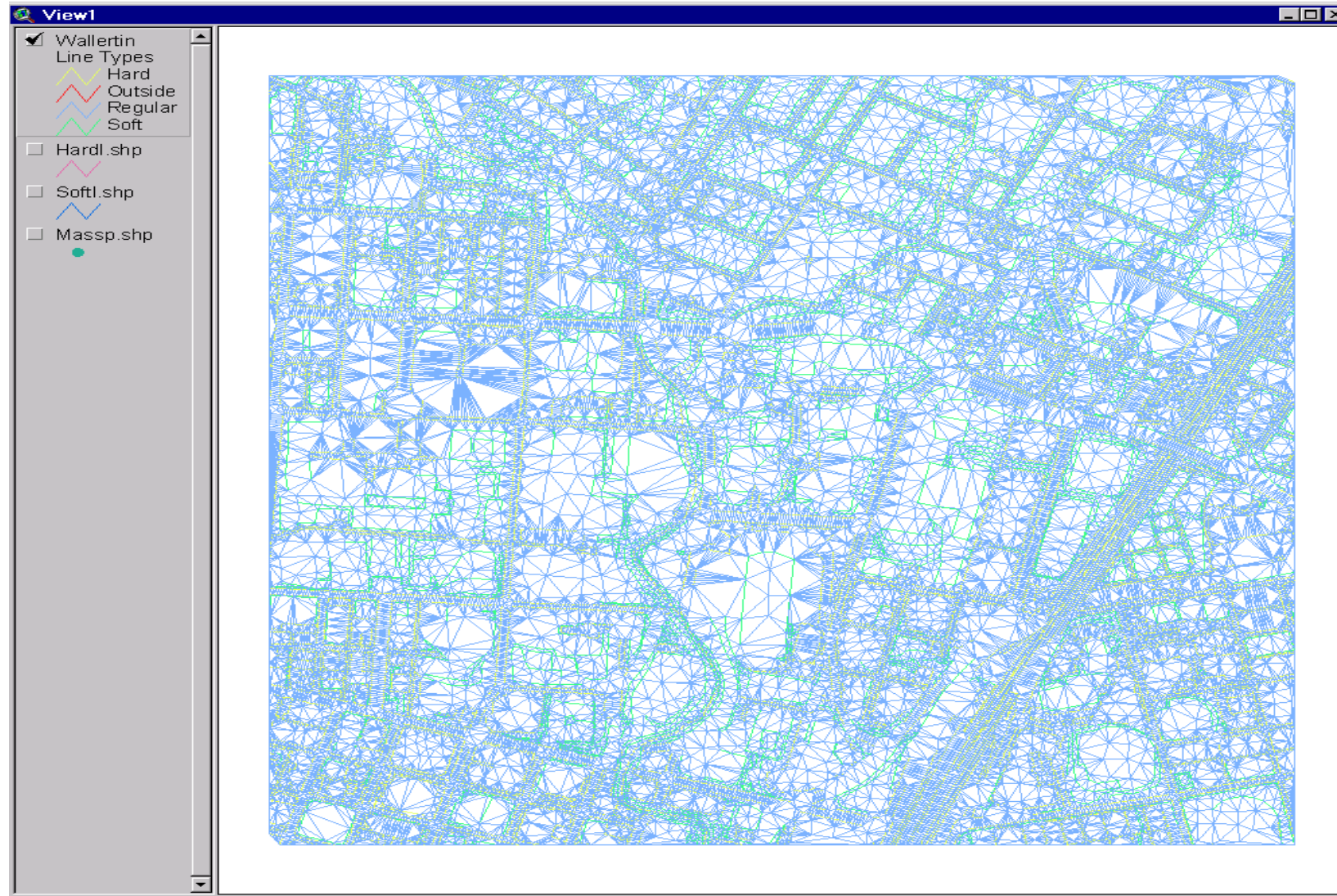
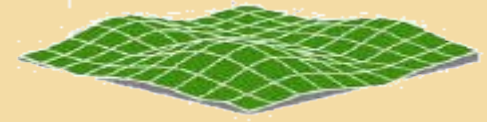
TIN sa strukturnim linijama



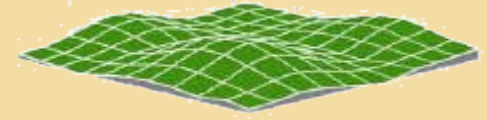


Trougao	Čvorovi	Susedi
A	1, 2, 3	-, B, D
B	2, 4, 3	-, C, A
C	4, 8, 3	-, G, B
D	1, 3, 5	A, F, E
E	1, 5, 6	D, H, -
F	3, 7, 5	G, H, D
G	3, 8, 7	C, -, F
H	5, 7, 6	F, -, E

Primer TIN-a

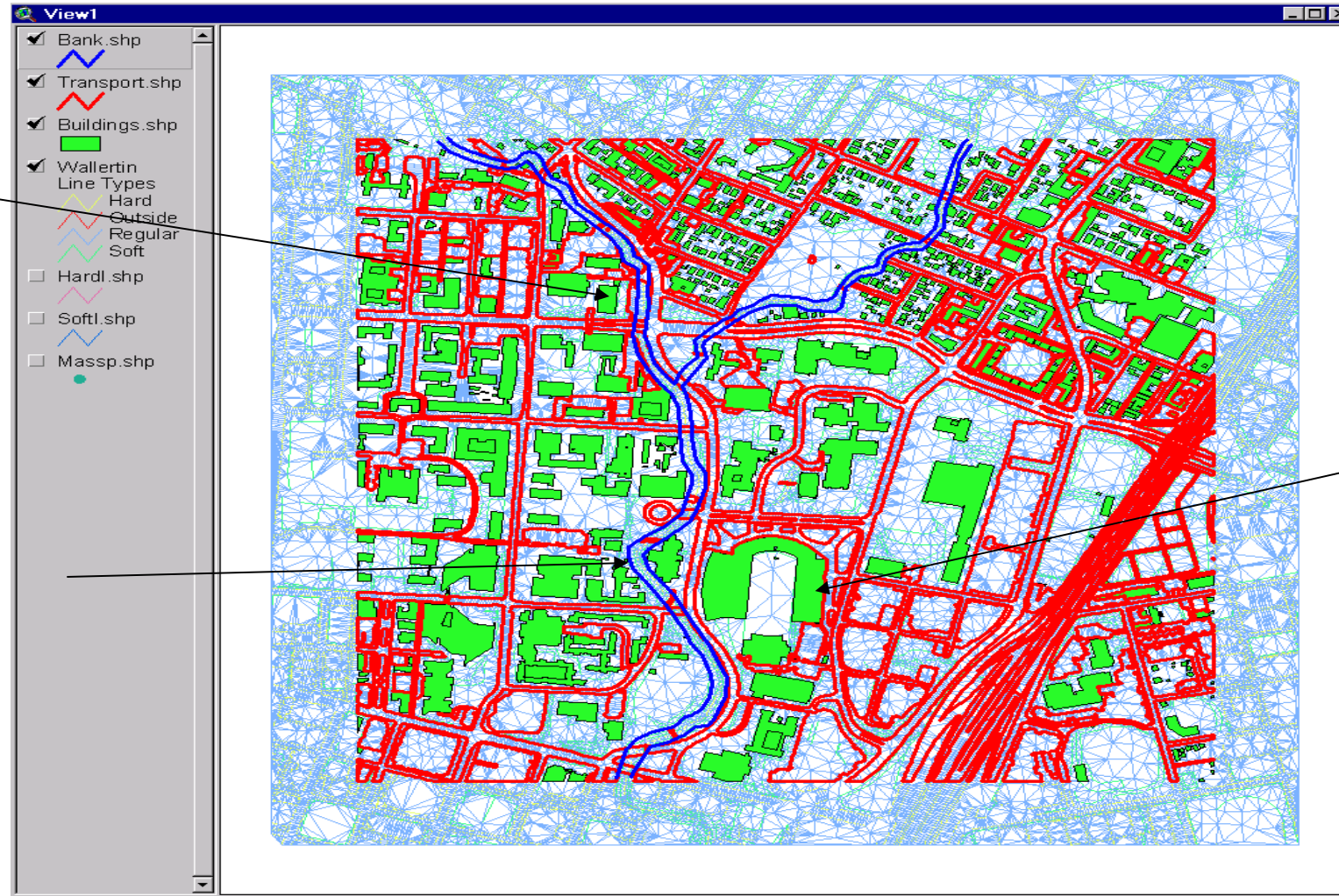


TIN sa površinskim entitetima



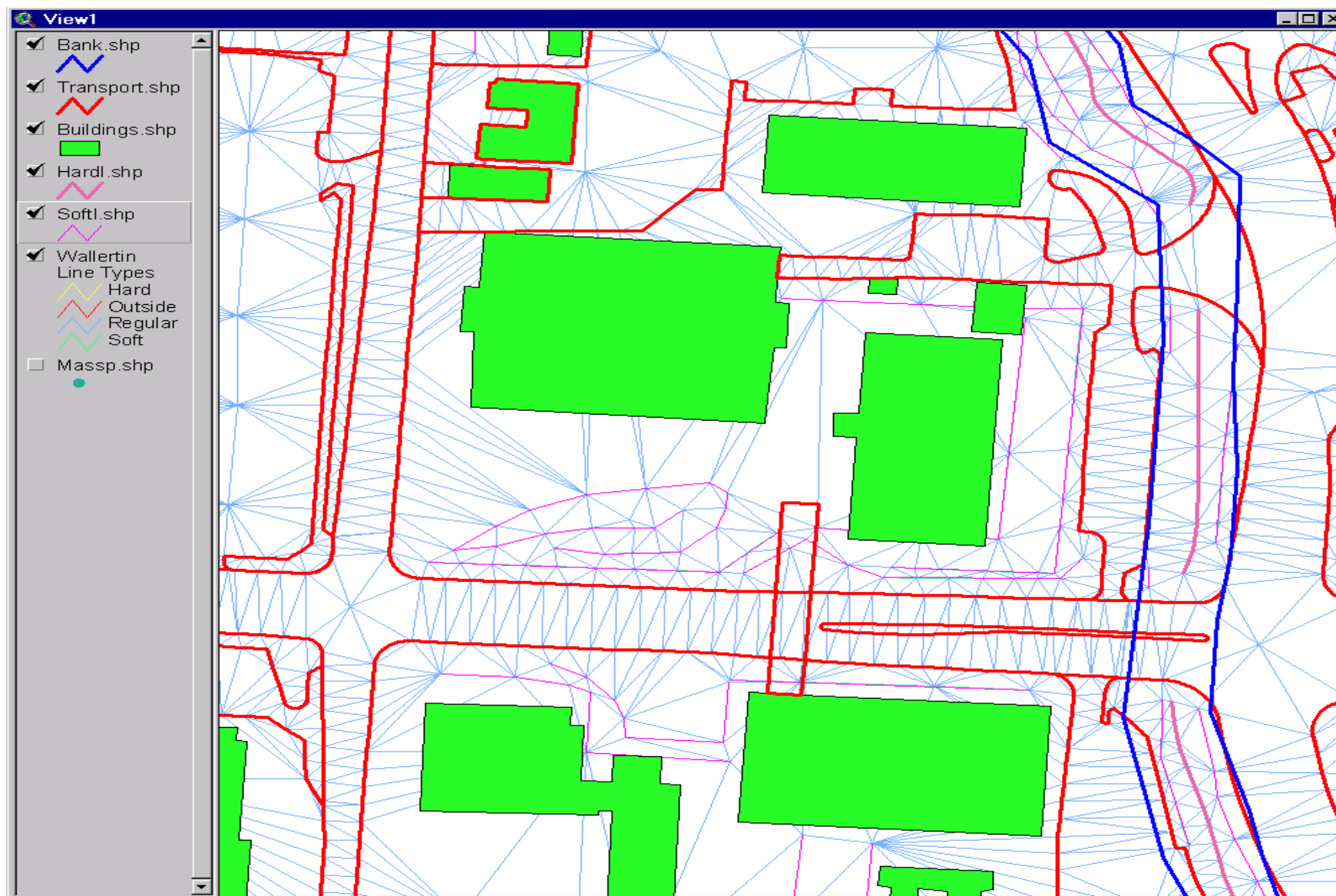
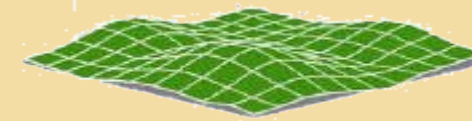
Zgrada

Reka

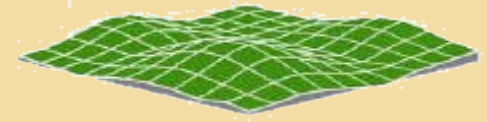


Stadion

Prikaz dela TIN-a



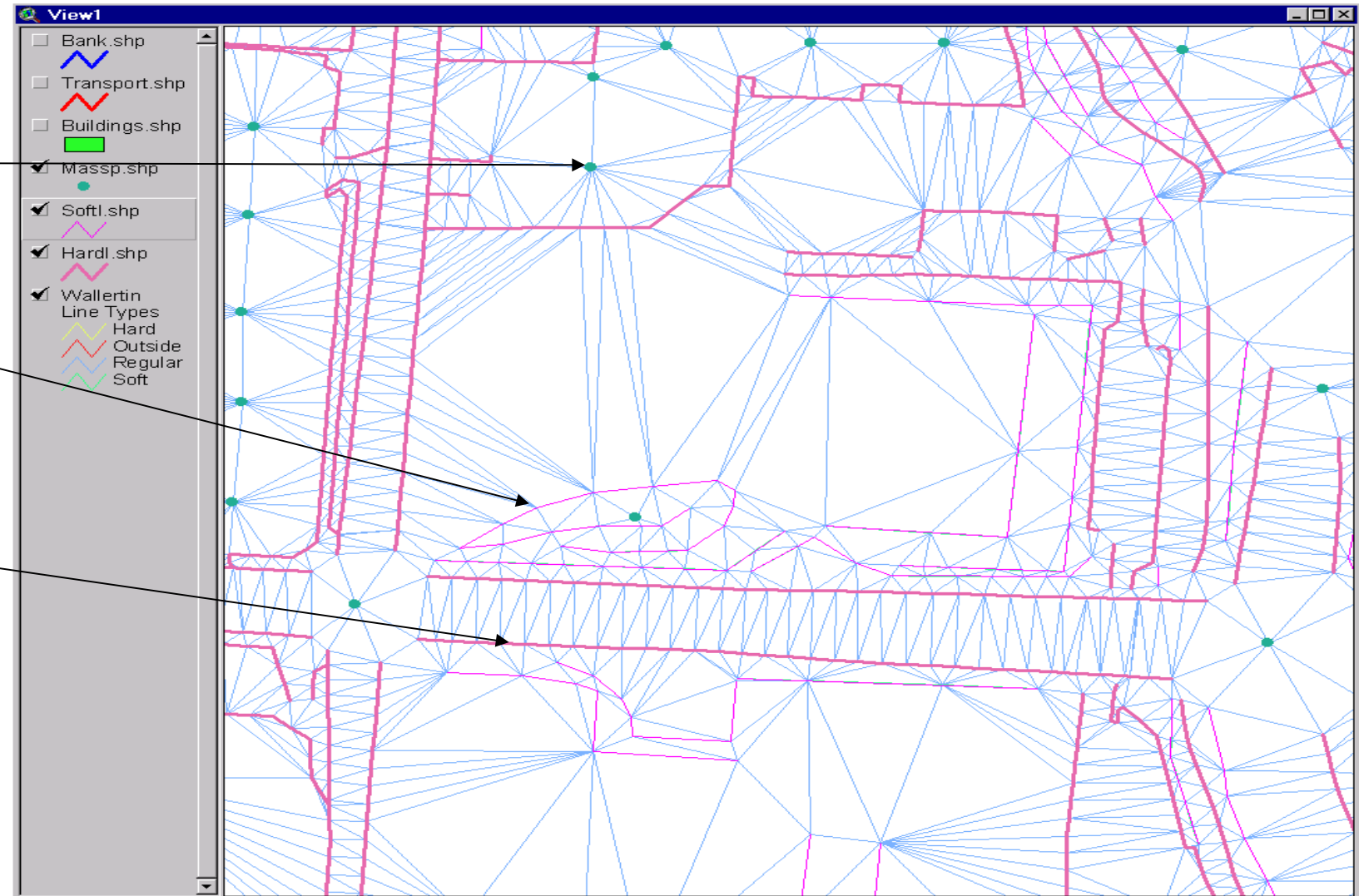
Ulazni podaci za prikazani deo



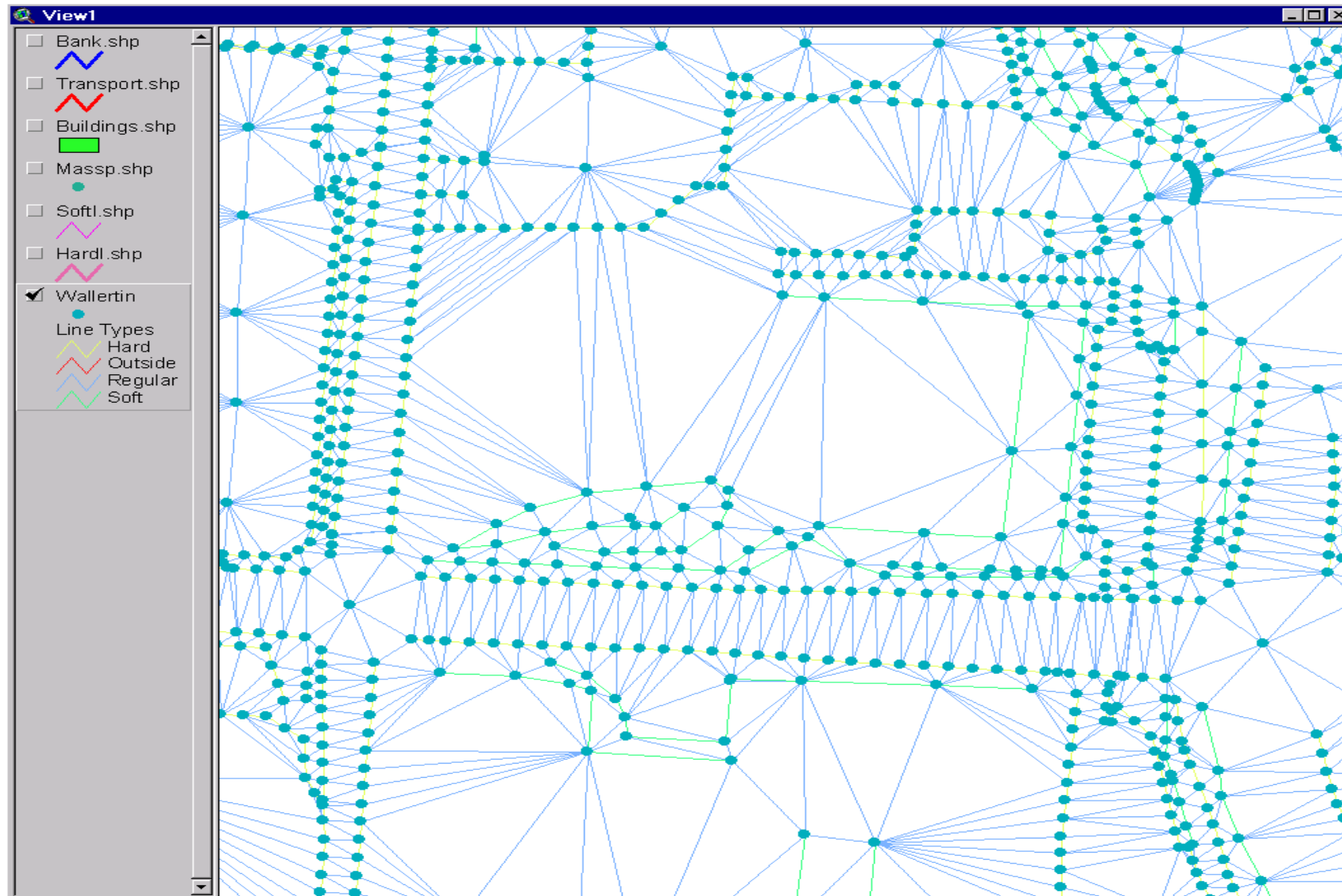
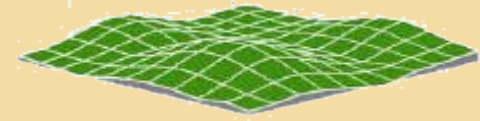
Tačke

‘Meke’ strukturne linije

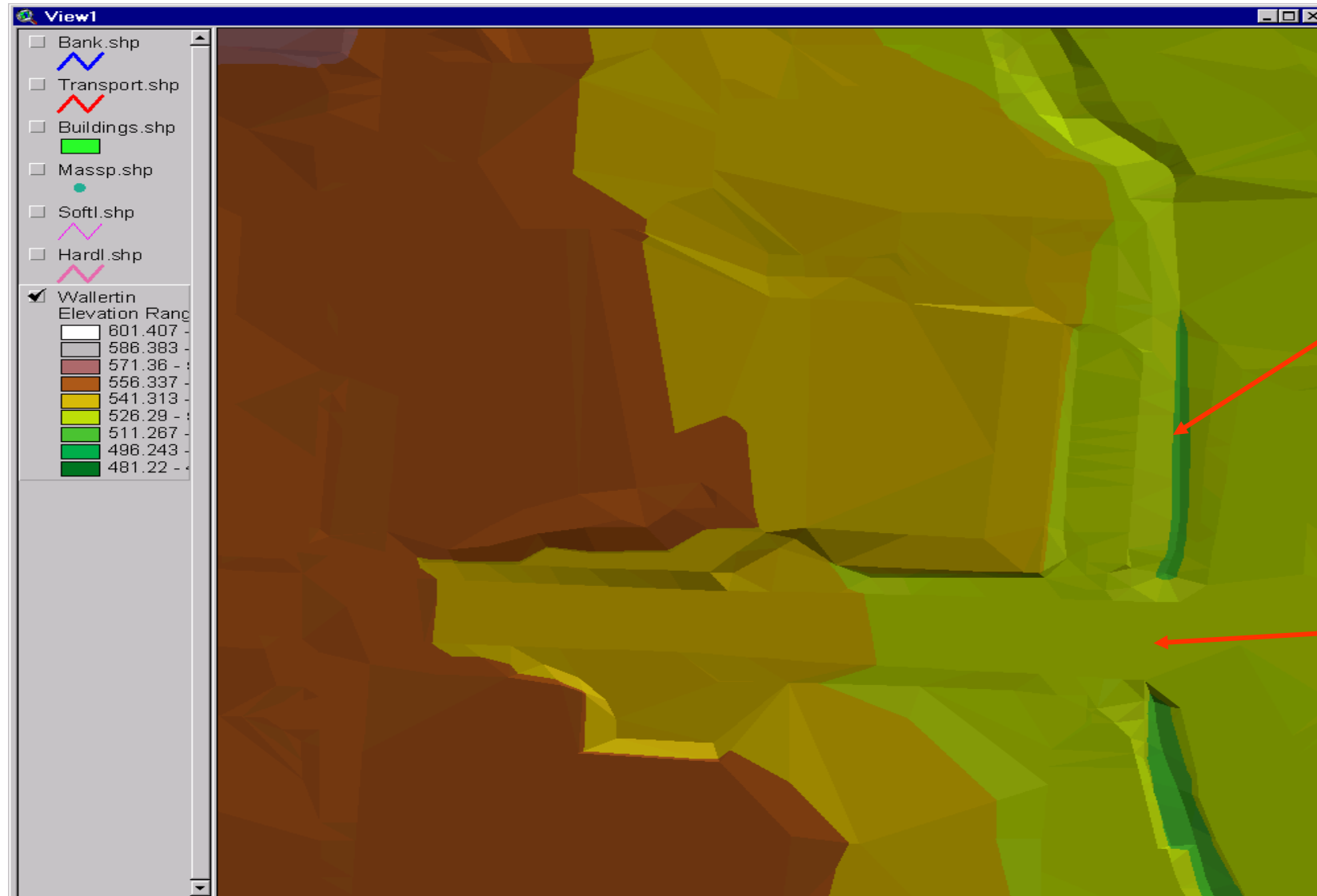
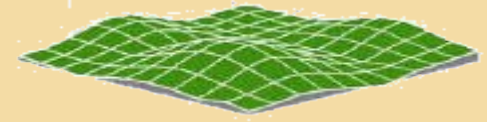
‘Tvrde’ strukturne linije



TIN čvorovi i trouglovi



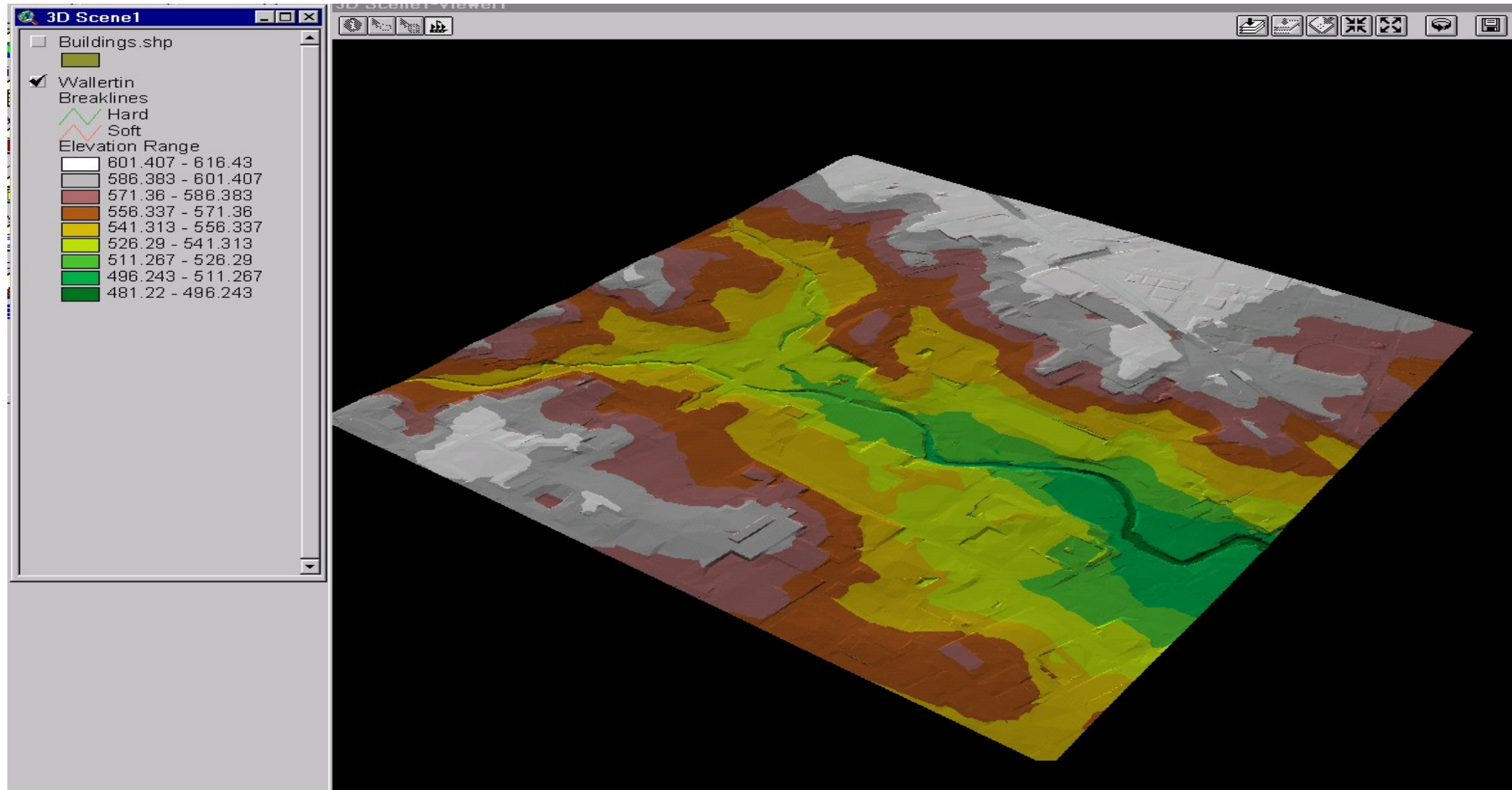
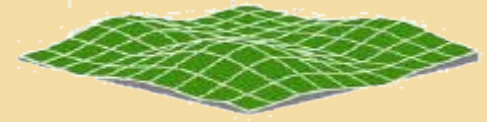
TIN model površi



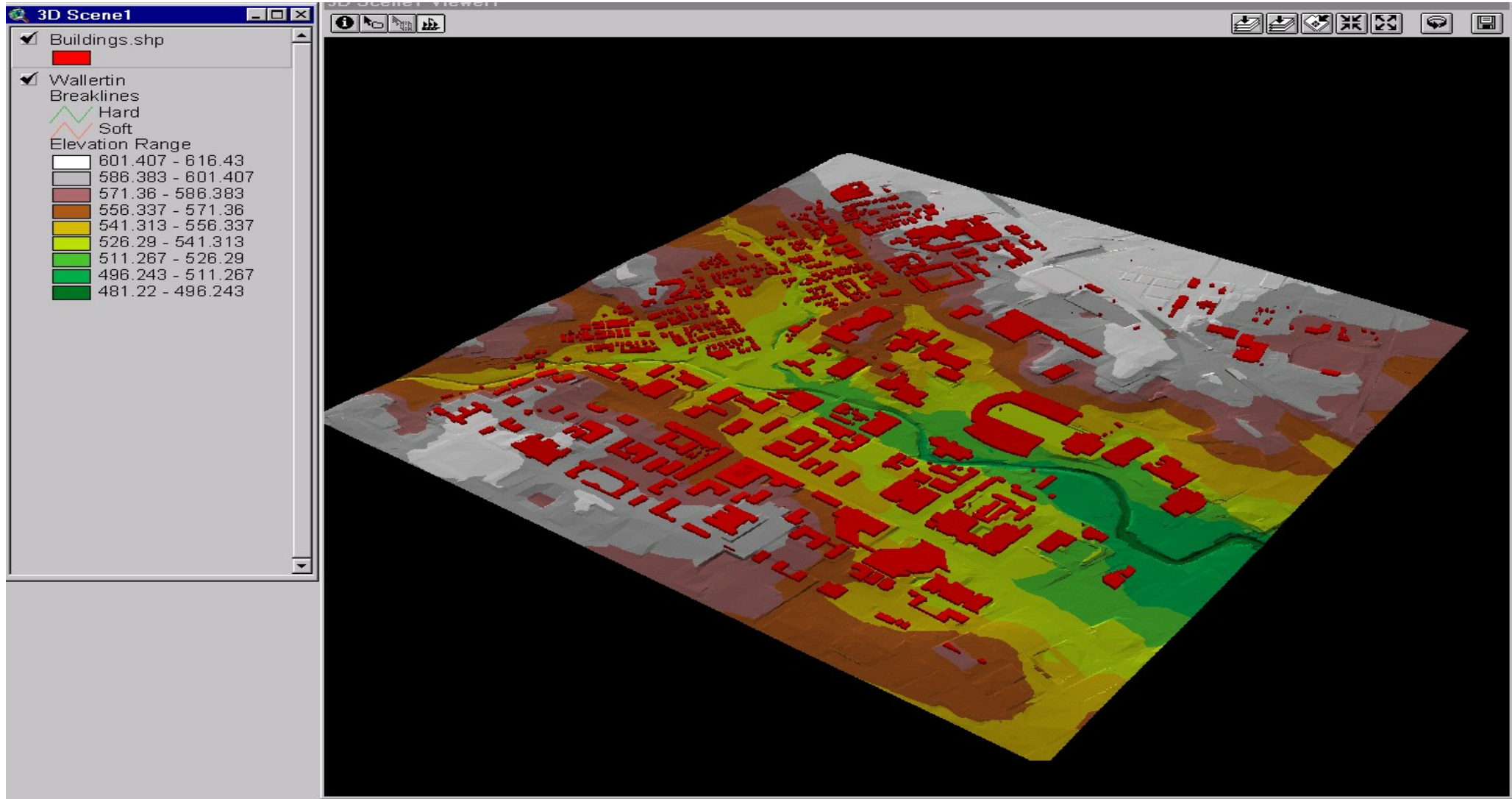
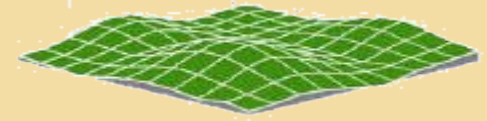
Rečno
korito

Ulica i most

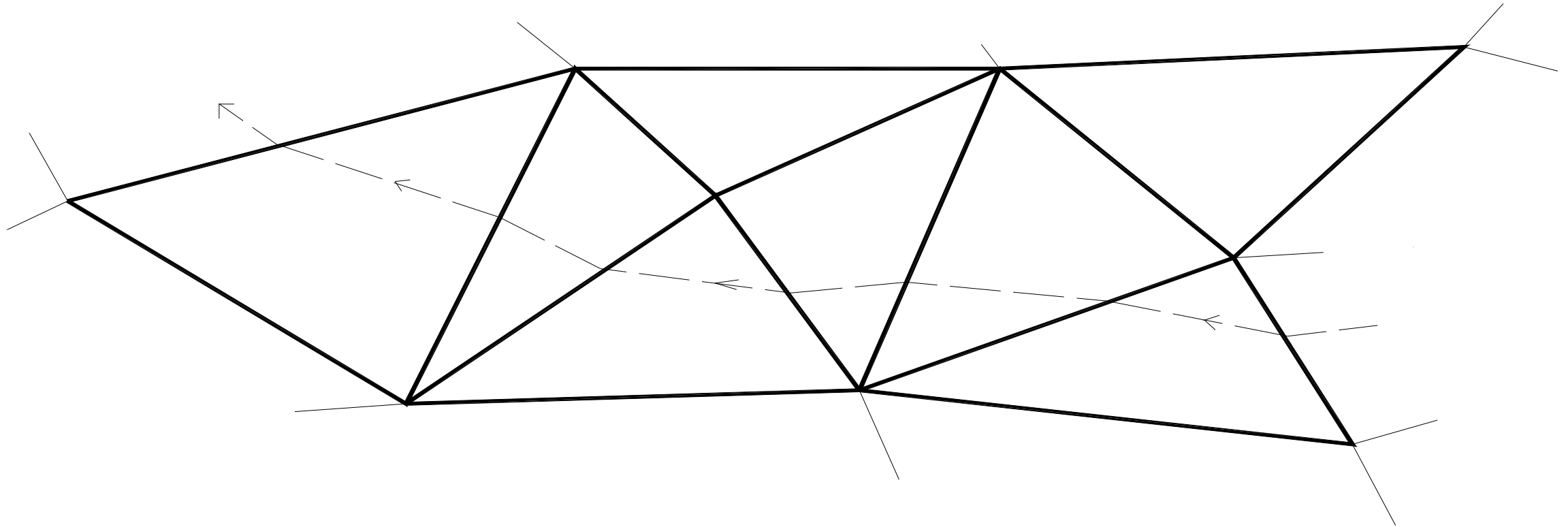
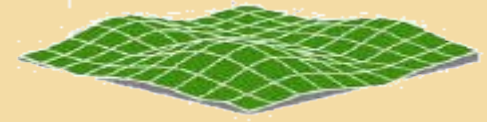
3-D Scena

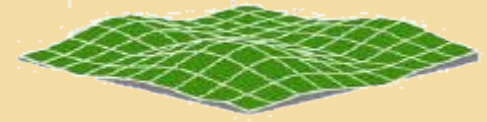


3-D Scena sa zgradama

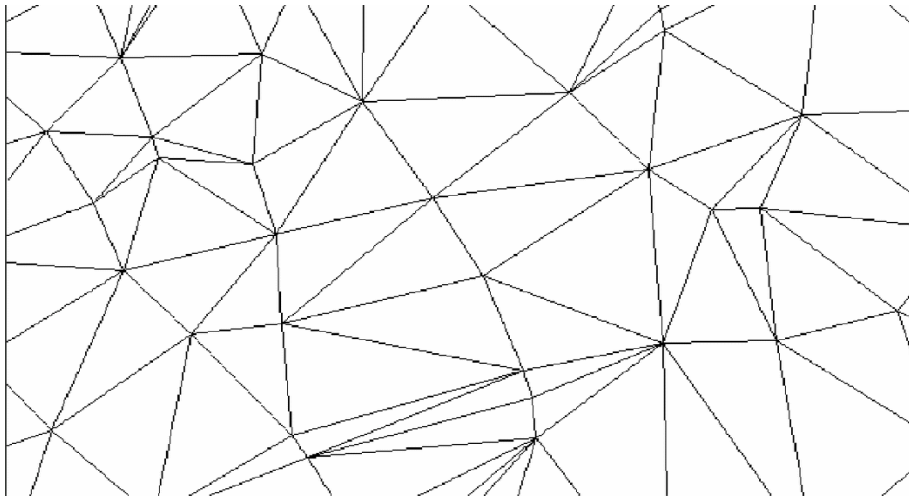


Interpolacija izohipsi u TIN-u



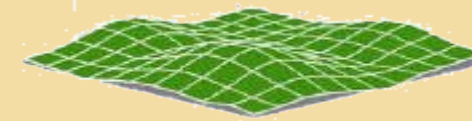


Skup susednih nepreklapajućih trouglova dobijenih iz slučajno raspoređenih tačaka.

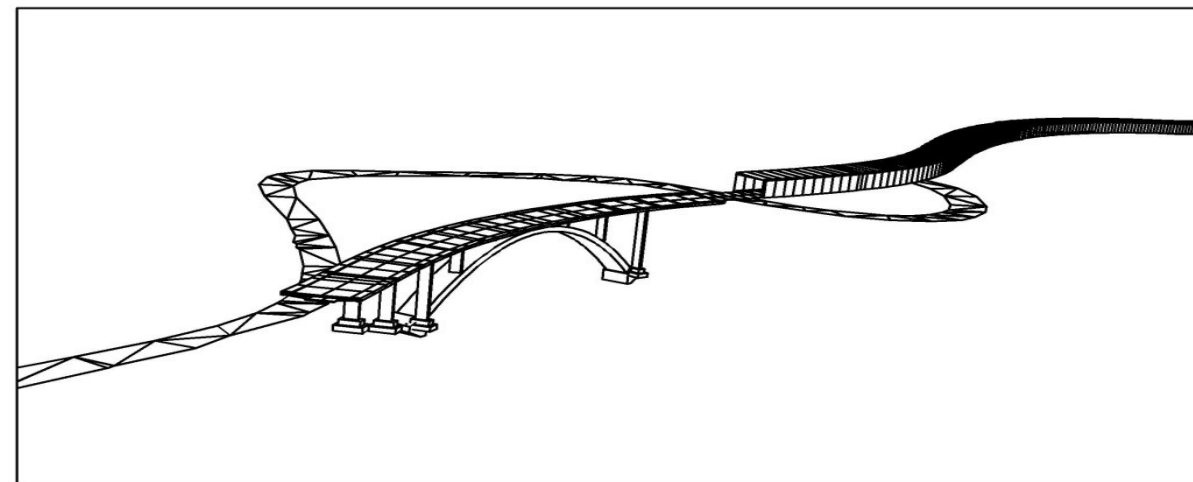
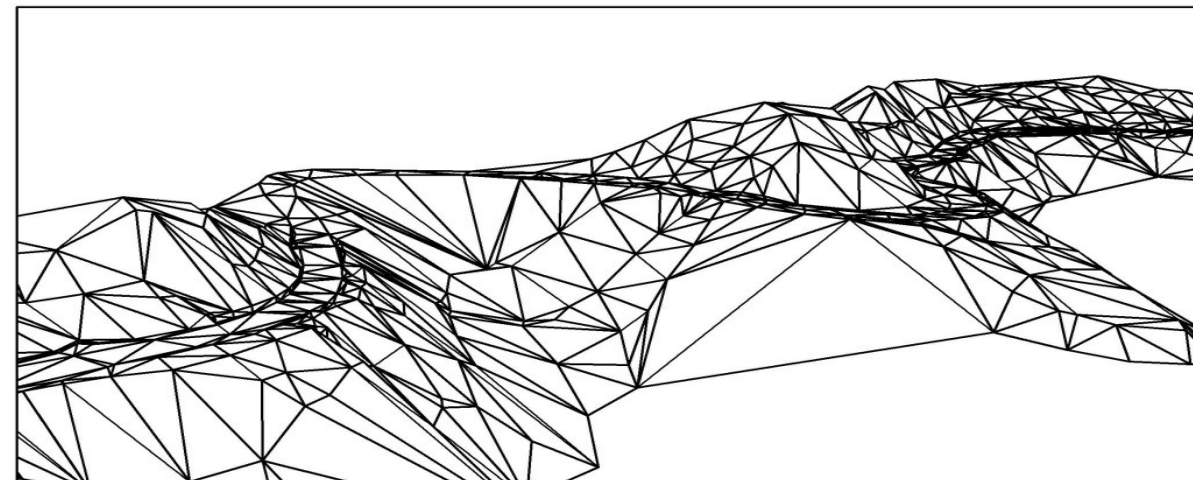


- *Prednosti*
 - Obuhvata istaknute geomorfološke oblike (vododelnice, jaruge, vrhove, itd.)
 - U ravnim terenima potrebno je samo nekoliko trouglova
 - Relativno laki za određene analize: nagibi, aspekti, zapremine
- *Nedostaci*
 - Teško se upoređuju i kombinuju sa drugim lejerima podatka.

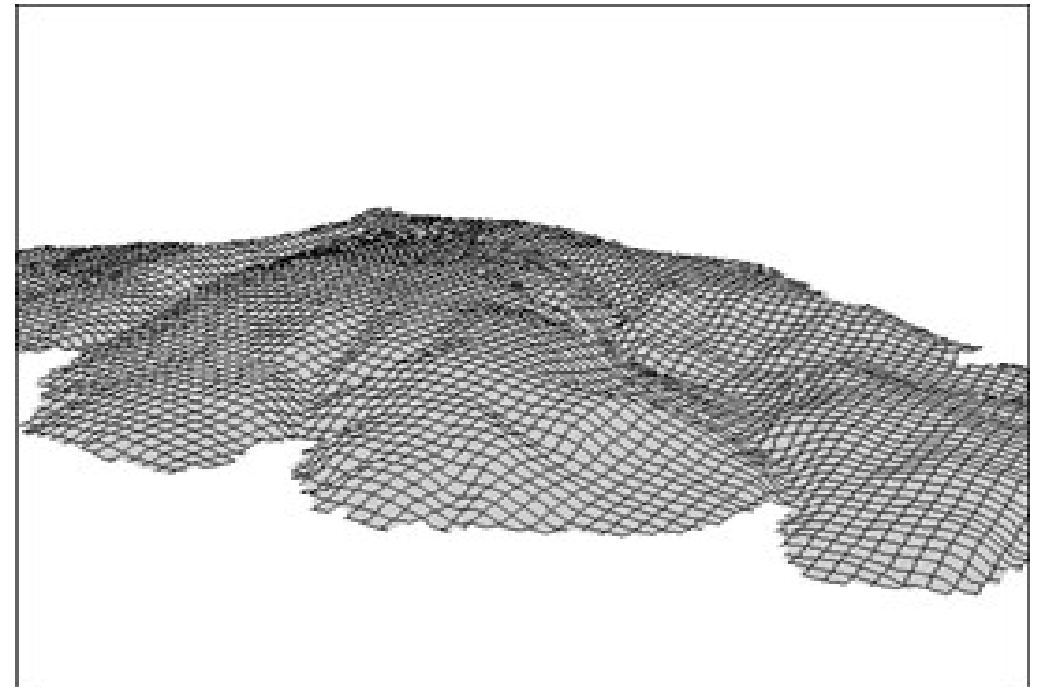
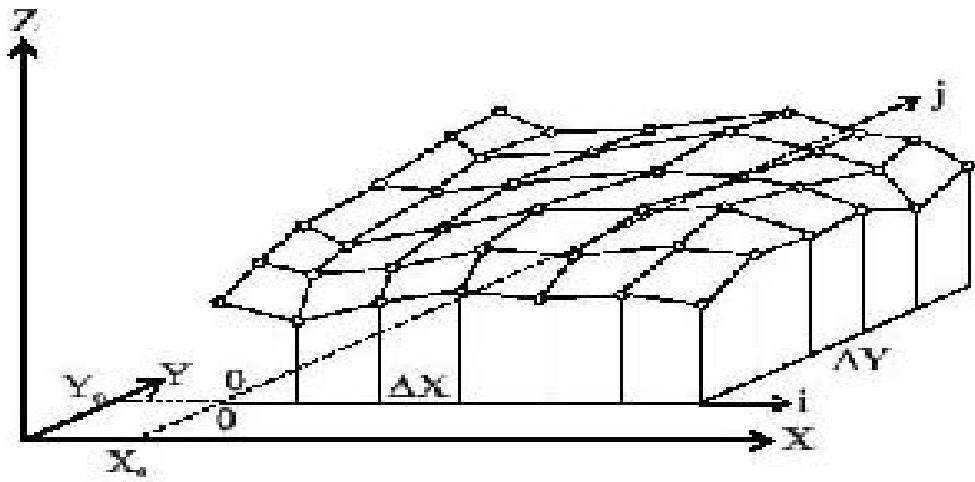
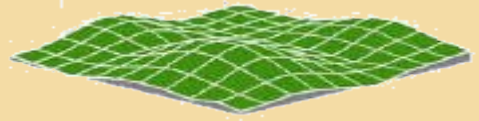
TIN baze podataka

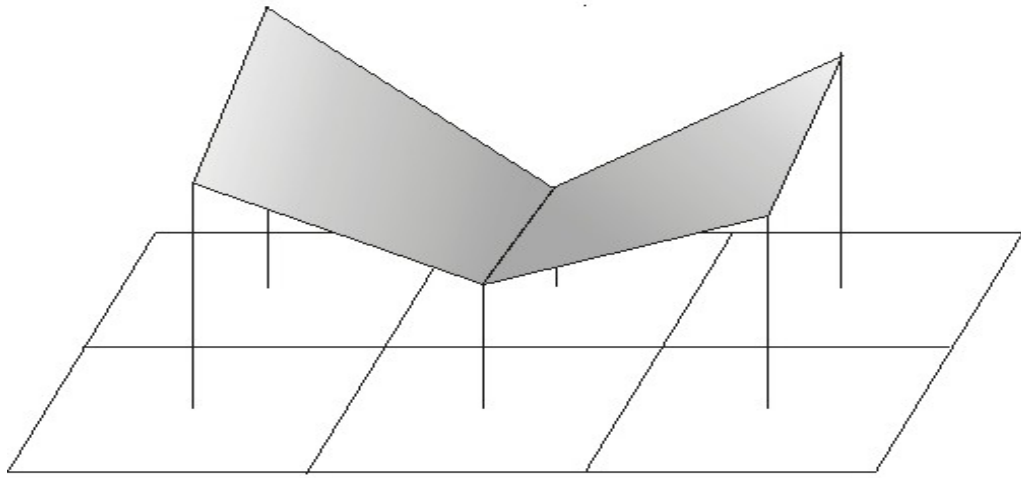
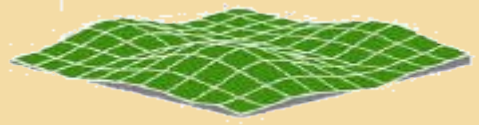


- TIN-ovi
 - Upotrebljivi za prikazivanje površi kod vektorskih GIS-ova.
 - Skupovi podataka sačinjeni od bilo koje kombinacije izohipsi, strukturnih linija i visinskih tačaka (čak i u obliku grida) mogu se kombinovati kod izrade TIN-a.
- TIN-ovi su posebno efikasni za:
 - Modele koji verno prikazuju teren
 - Jednostavno računanje površi i zapremina na terenu

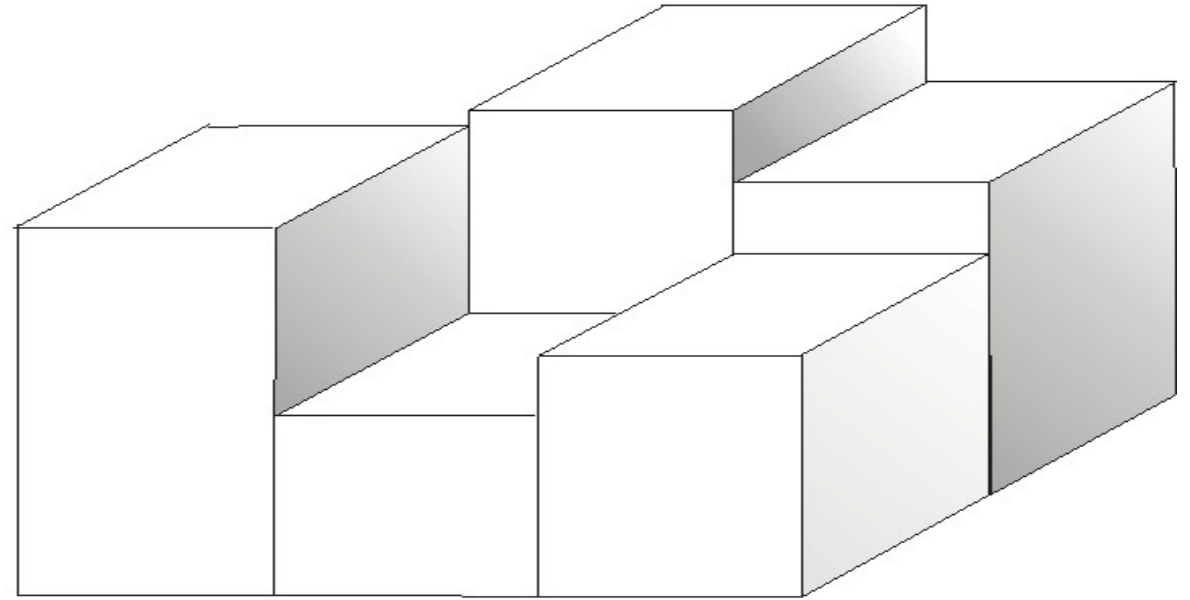


GRID



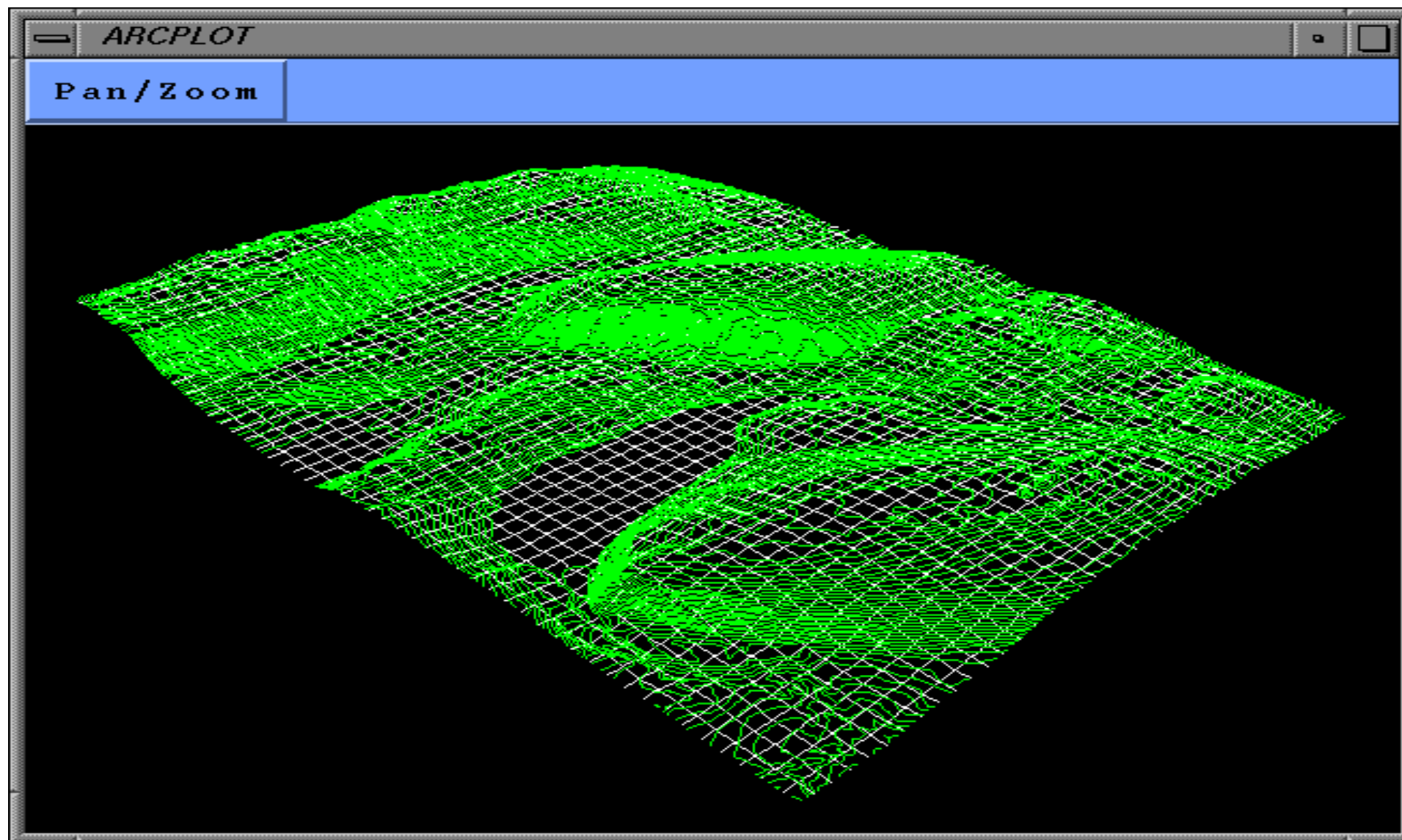
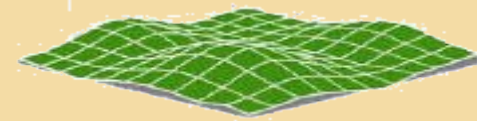


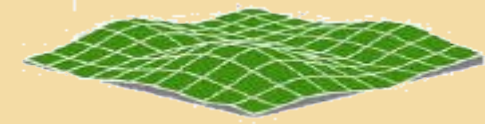
Lattice



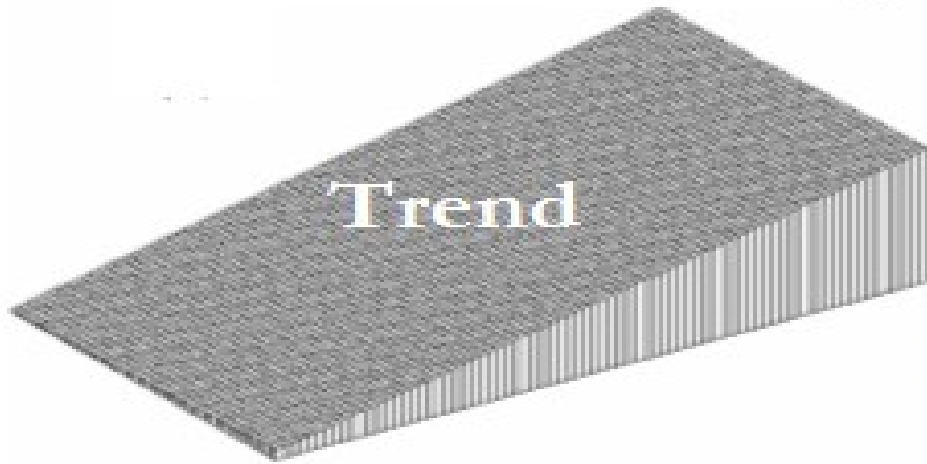
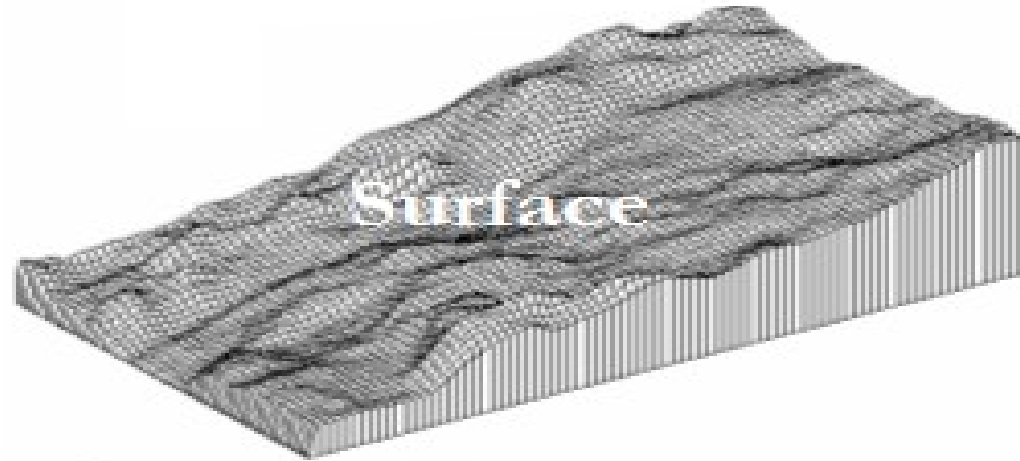
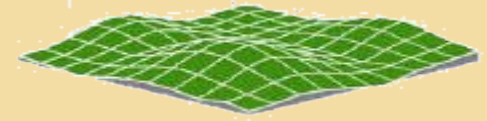
Grid Surface

GRID sa 3D izohipsama





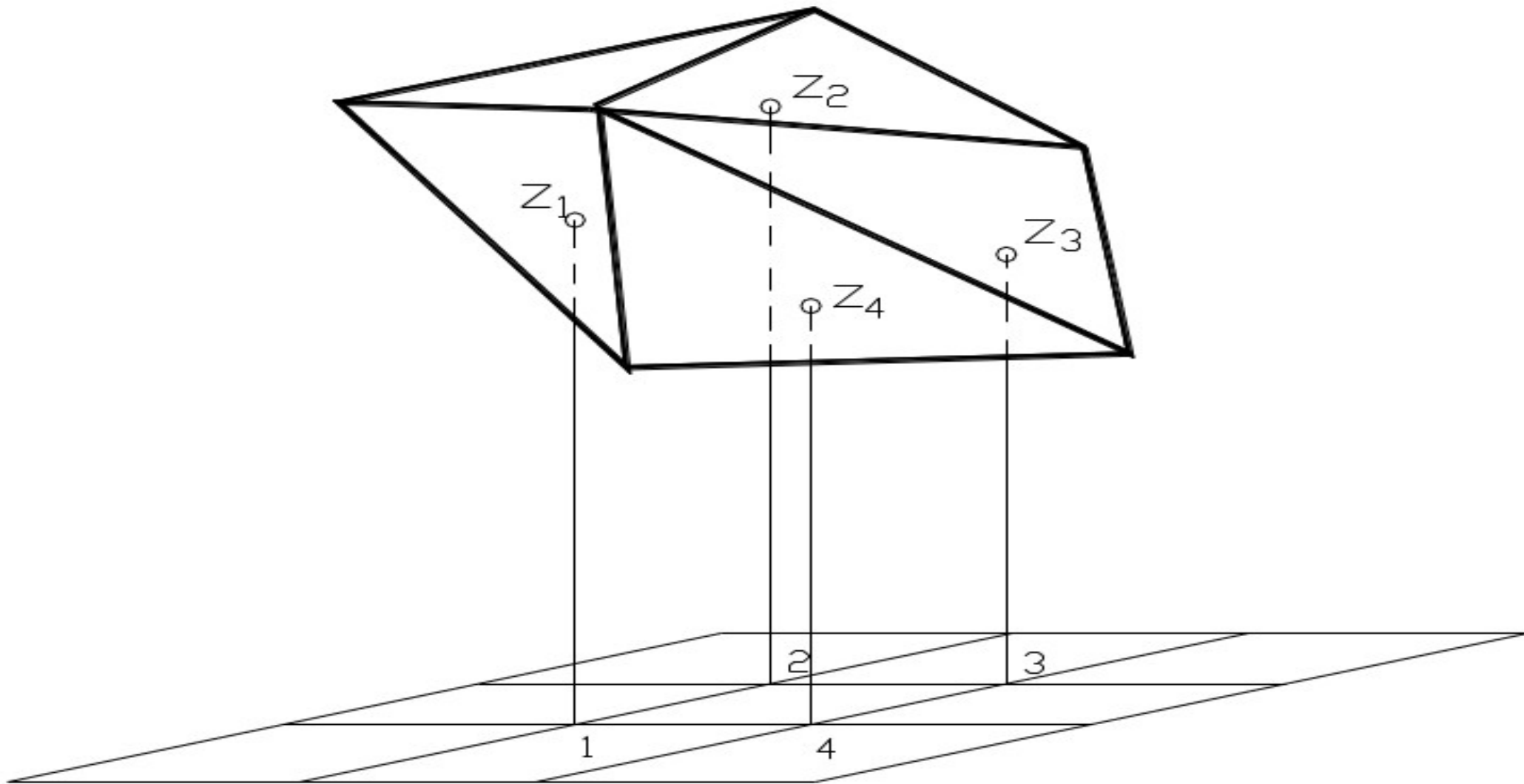
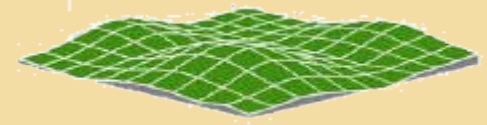
- Globalne metode
- Lokalne metode
 1. Interpolacija iz TIN-a
 2. Interpolacija iz pravilnog ili nepravilnog uzorka
 - a) Pridruživanje vrednosti najbližih susednih tačaka
 - b) Linearna interpolacija
 - c) Bilinearna interpolacija
 - d) Kubna konvolucija
 - e) Inverzna distanca
 - f) Pokretne sredine
 - g) Geostatističke metode (Kriging)

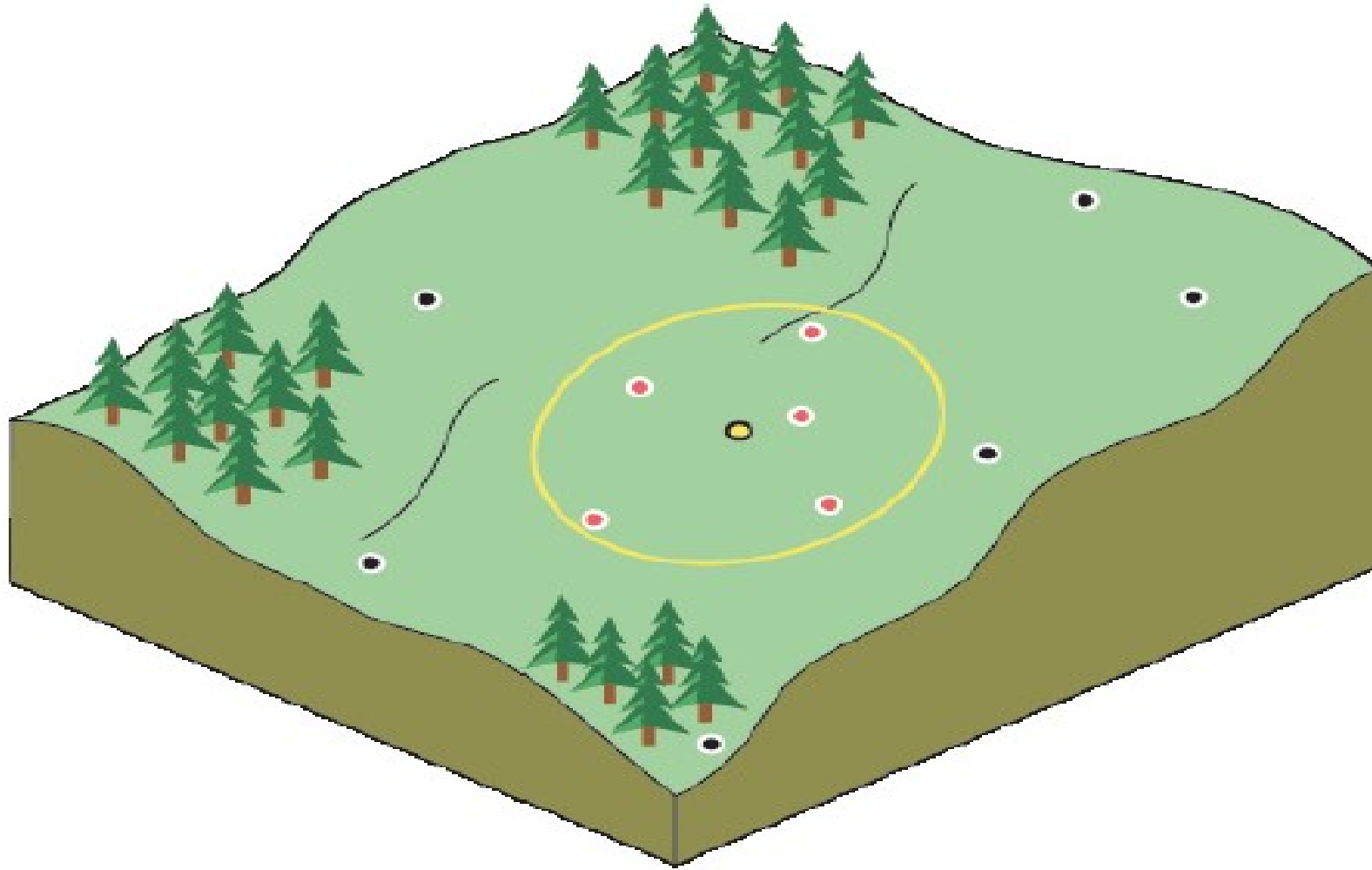
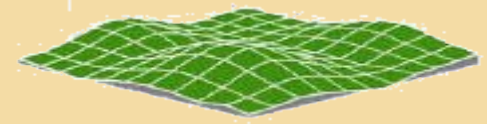


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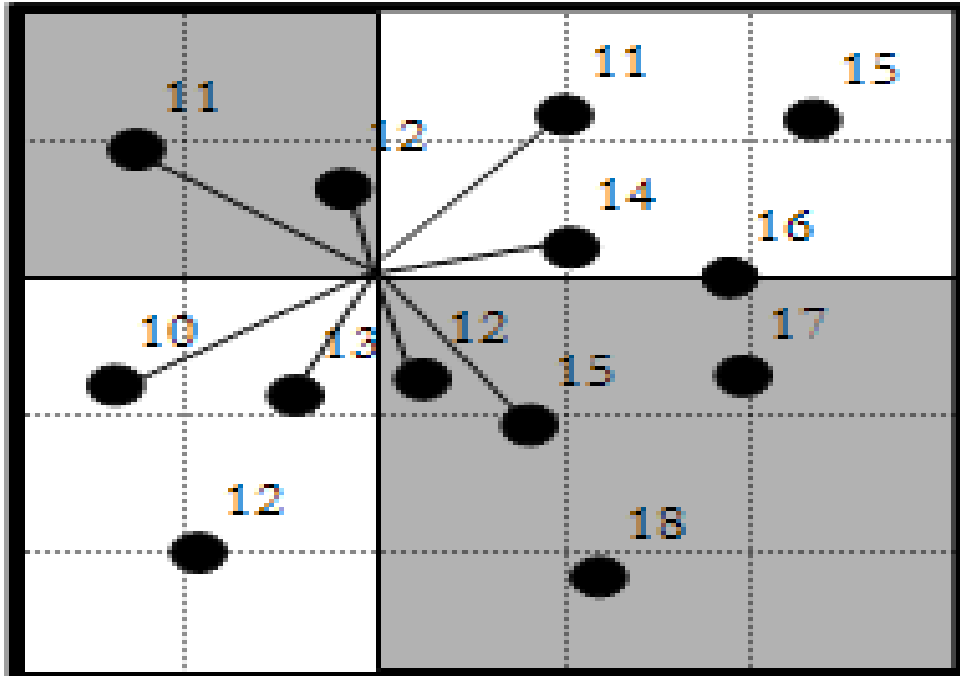
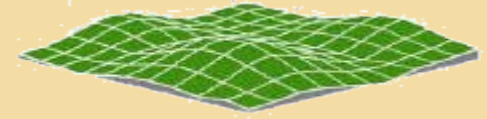


Konverzija visina iz TIN u gridnu strukturu

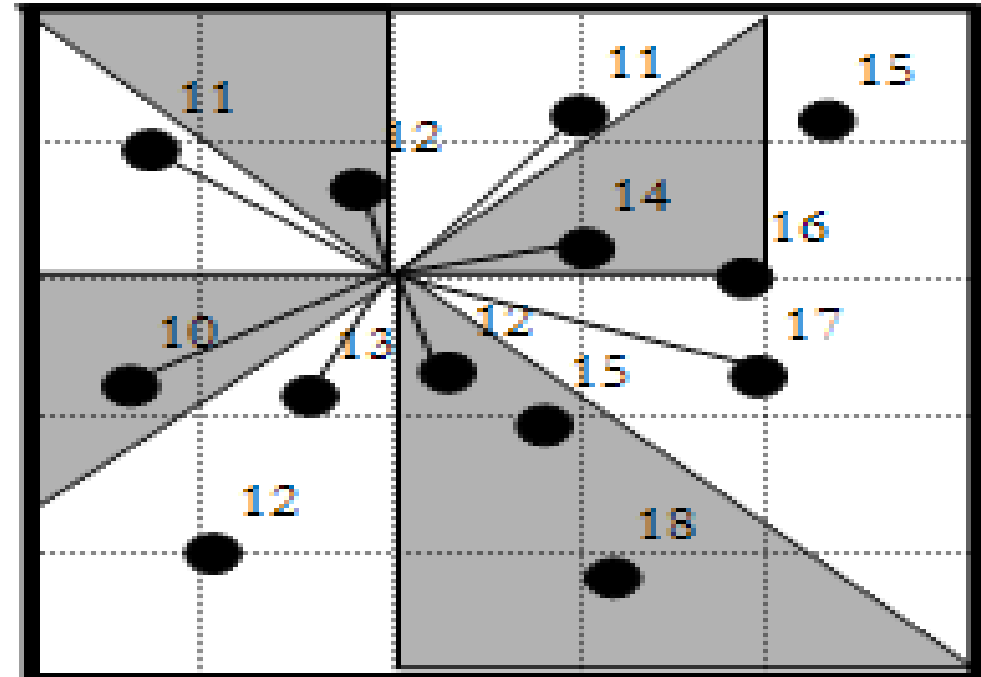




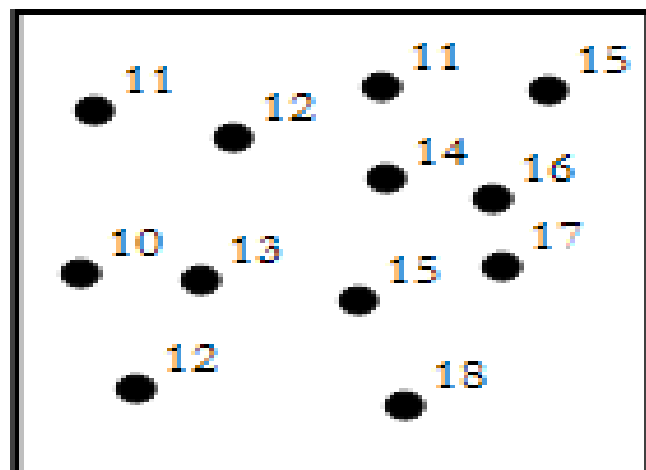
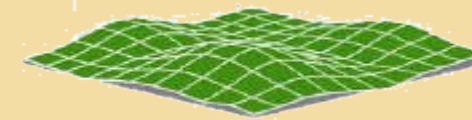
Tenike pretraživanja najbližih tačaka



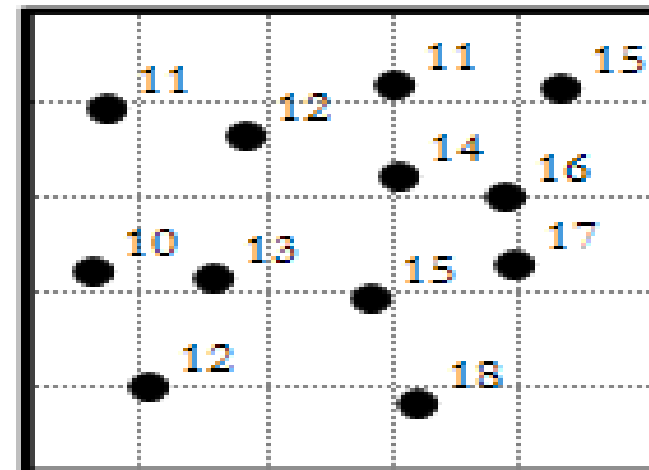
Kvadrantno pretraživanje



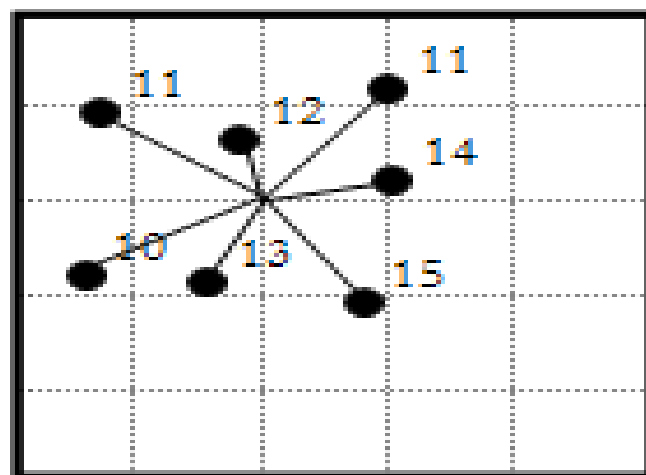
Oktantno pretraživanje



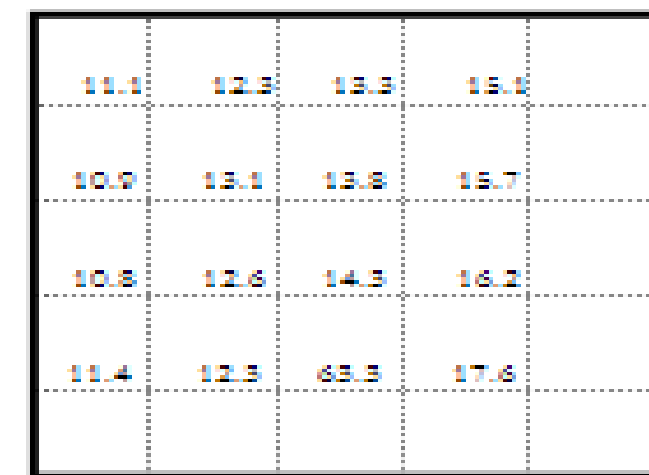
(a)



(b)

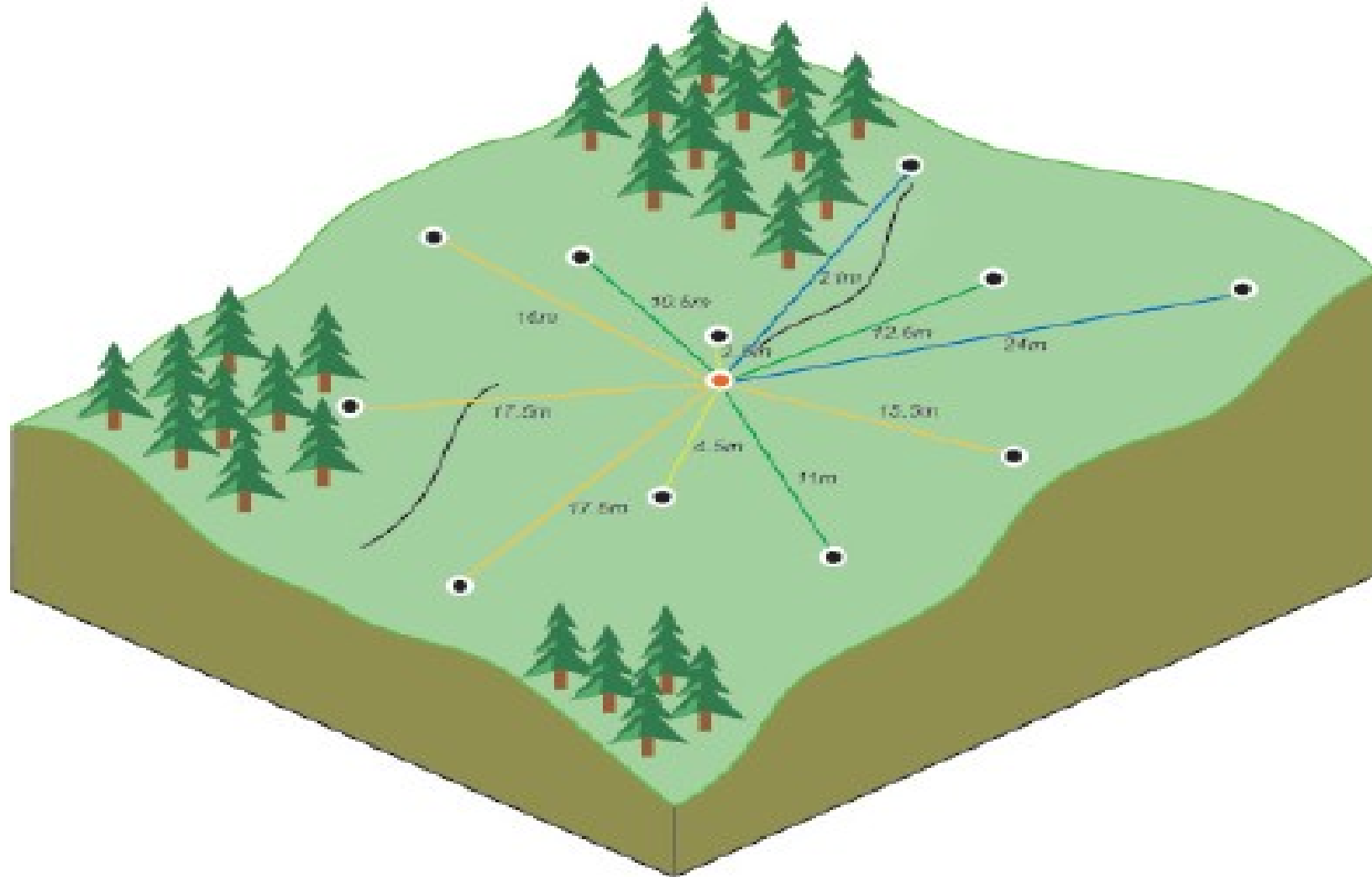
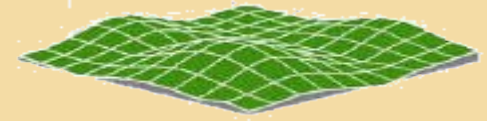


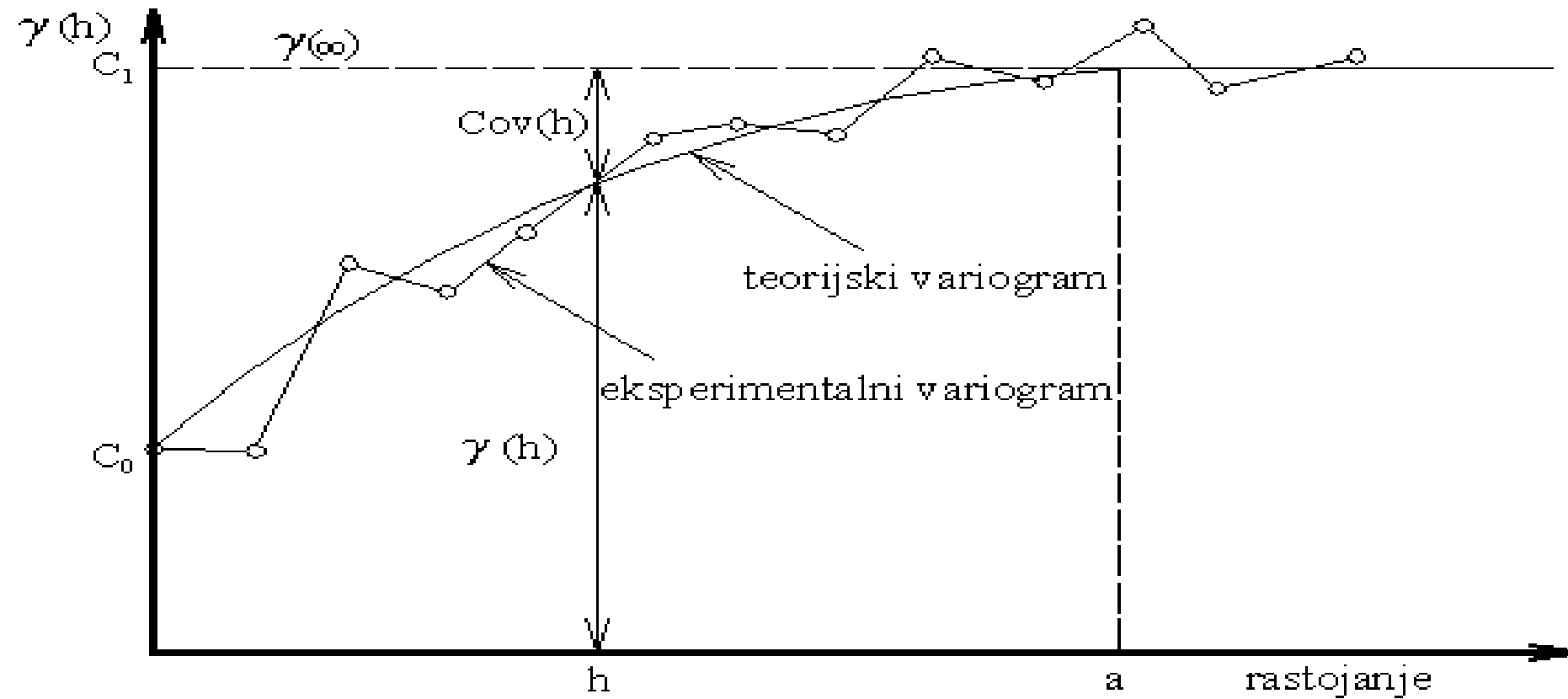
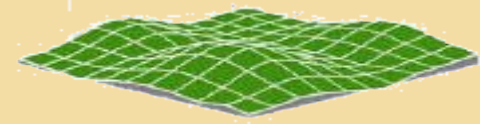
(c)



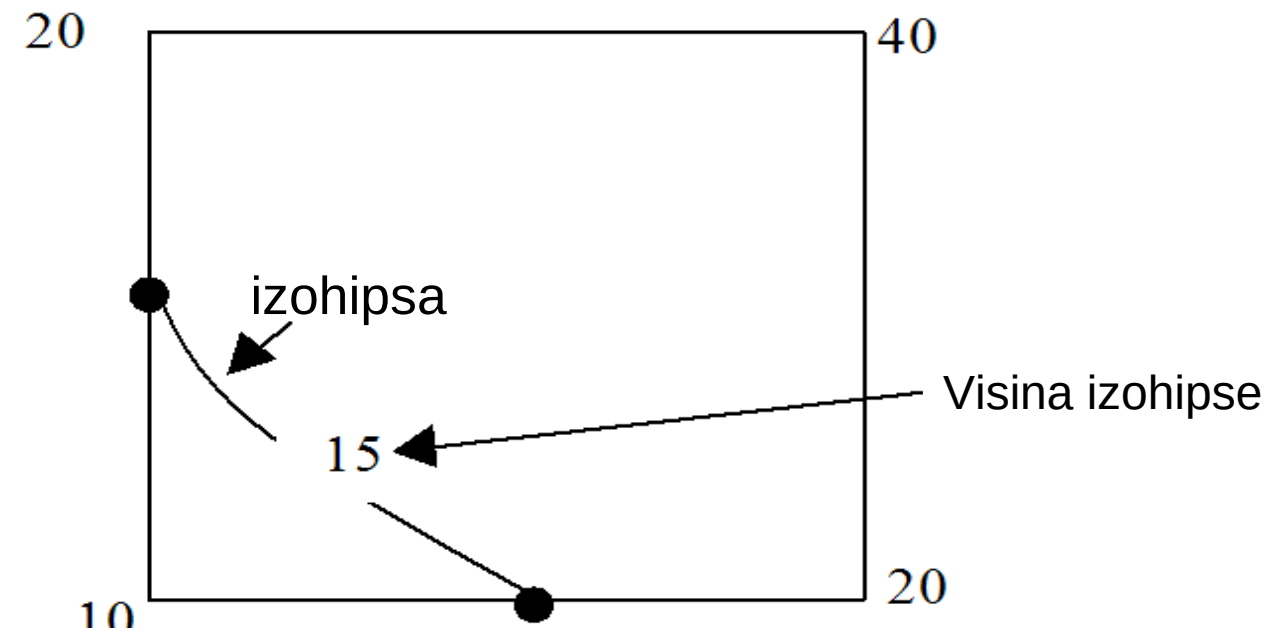
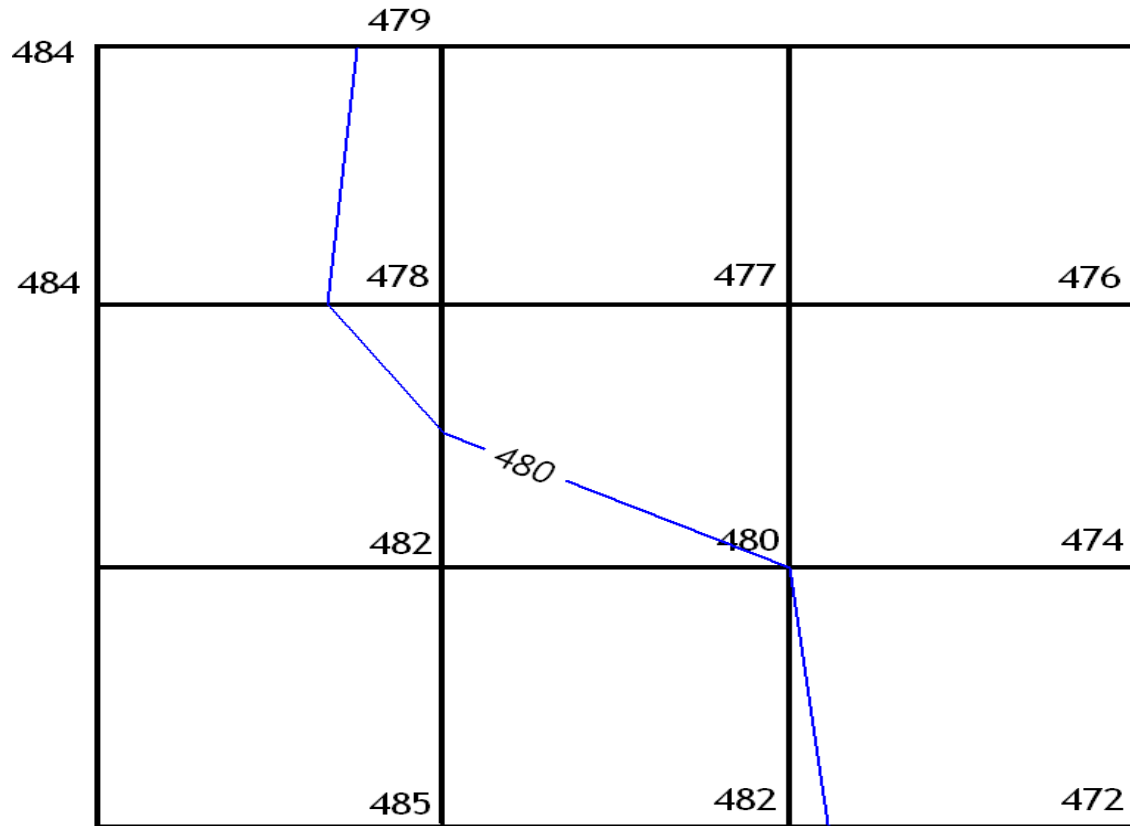
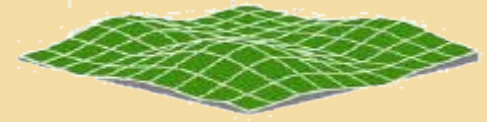
(d)

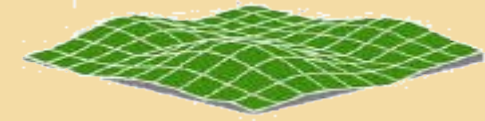
Geostatistične metode interpolacije



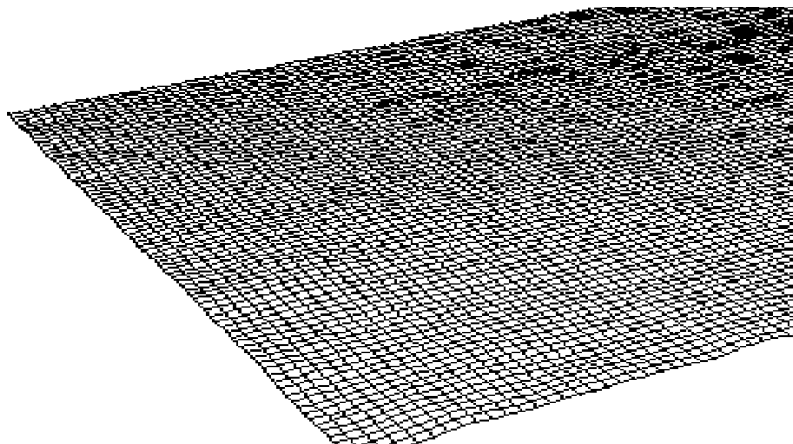


Interpolacija izohipsi u GRID-u





- Niz visina (z) koje su regularno raspoređene u pravcu X i Y ose.
- Generalno postoje dva pristupa u definisanju visina površi u gridu.
 - Rešetkasti (***lattice***), svaka tačka u mreži reprezentuje visinu centra gridne rešetke..
 - Gridna površ (***surface grid***) podrazumeva da površ cele gridne ćelije ima konstantnu vrednost visine (z).

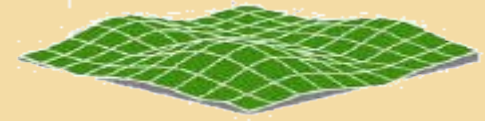


Prednosti

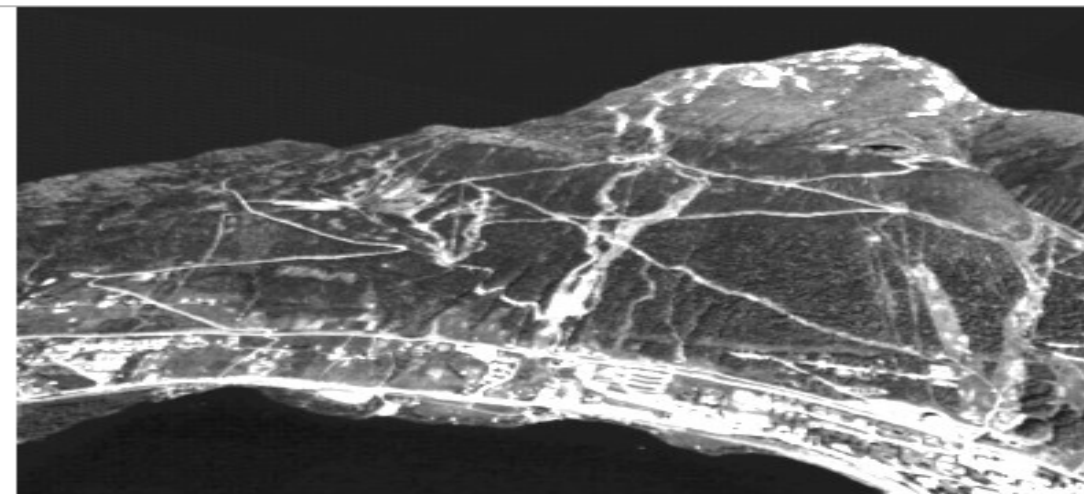
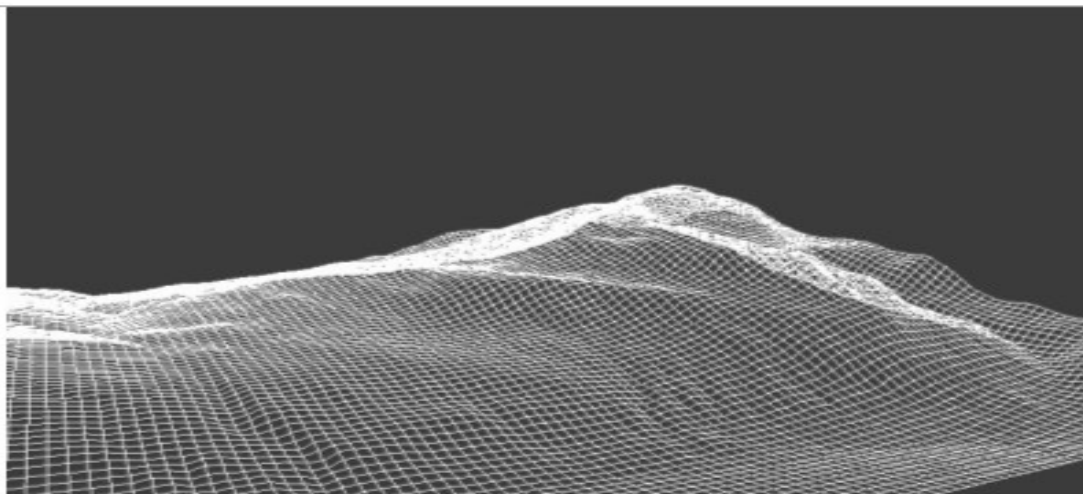
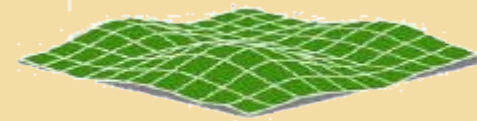
- Jednostavni konceptualni model
- Podaci se lako dobijaju
- Lako se upoređuju sa drugim rasterskim podacima
- Nepravilni skup tačaka se lako konvertuje u GRID

Nedostaci

- Nije pogodan u slučaju promenljivog terena
- Entiteti sa linarnim strukturama nemogu se lako prikazati



- **GRID-ovi su klasični rasterski format**
- **GRID -ovi** memorišu podatke u obliku:
 - **Celeobrojnih vrednosti (Integer):** u tom slučaju postoje pridružene **VAT tabele** (*value attribute table*) koje sadrže jedan zapis za svaku različitu vrednost u rasteru (normalno da imamo mnogo manje zapisa u VAT tabeli nego što imamo rasterskih ćelija).
 - **Pokretni zarez (Floating point):** (broj sa decimalnom tačkom)VAT tabela ne postoji i svaka ćelija ima svoju brojnu vrednost
- Celebrojni GRID-ovi su vrlo pogodni za brzo procesiranje.



F

GRID sa ortofoto snimkom postavljenim preko njega

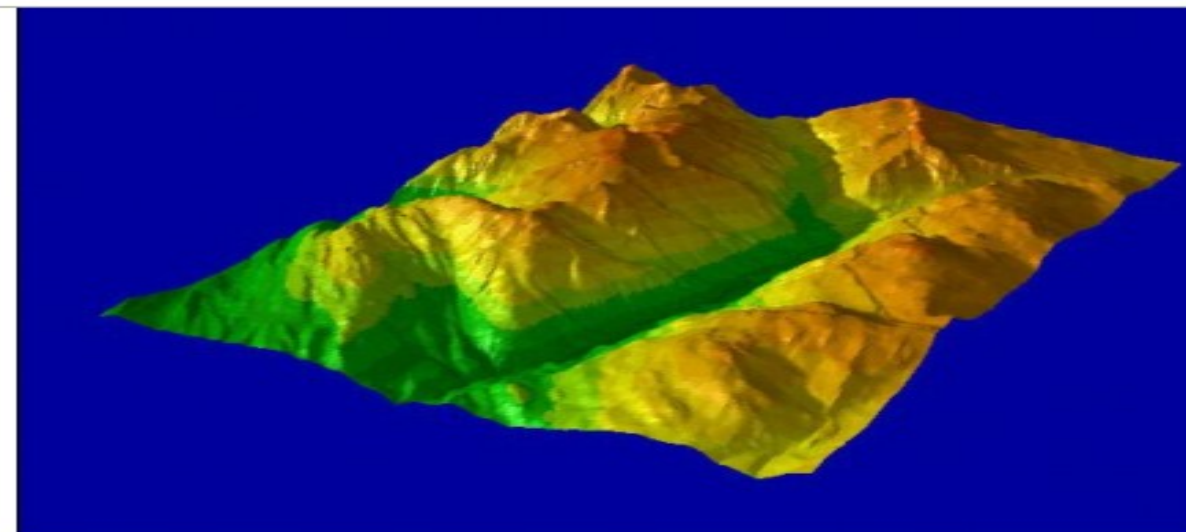
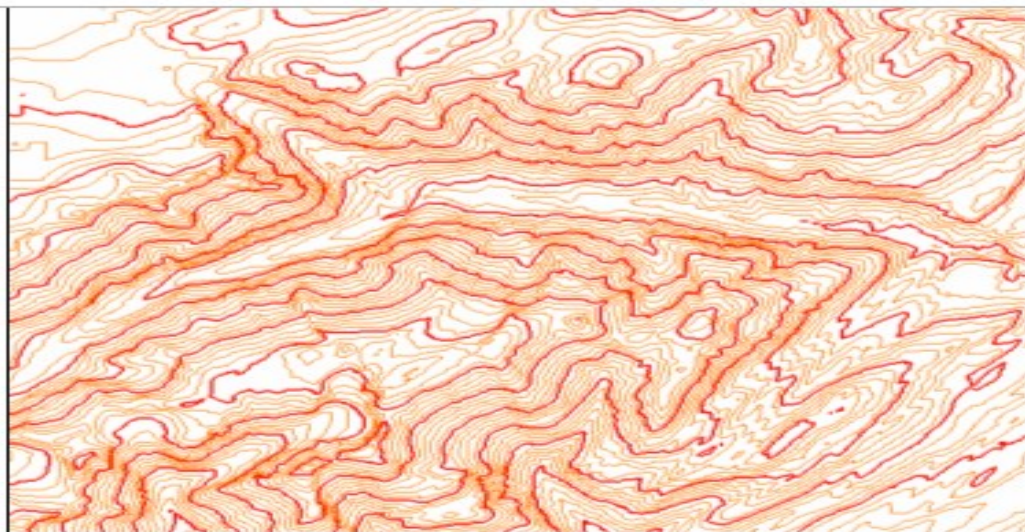
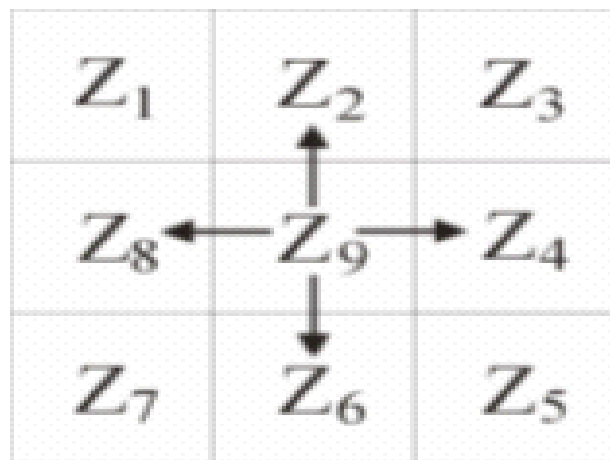
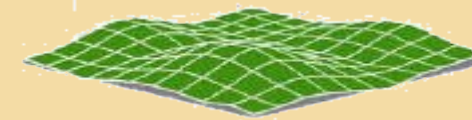


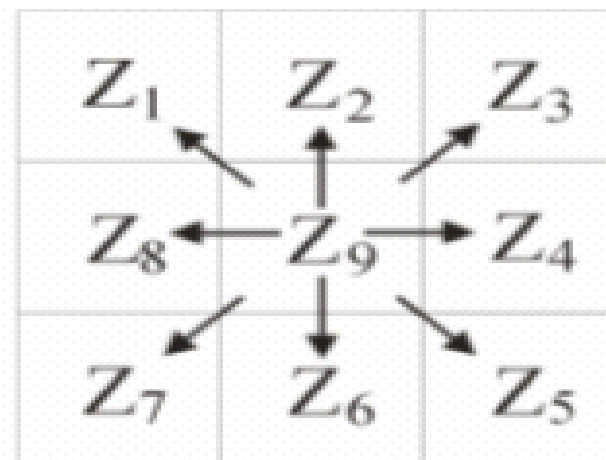
Figure 2: Colour rendering of a Grid model

GRID renderisan bojama

Topografski parametri



Rook's case



Queen's case

- Primarni topografski parametri
- nagib,
- aspekt,
- horizontalna zakrivljenost terena,
- vertikalna profilna zakrivljenost terena,
- tangencijalna zakrivljenost.

$$z_x = \frac{\partial z}{\partial x} = \frac{z_4 - z_8}{2d}$$

$$z_y = \frac{\partial z}{\partial y} = \frac{z_2 - z_6}{2d}$$

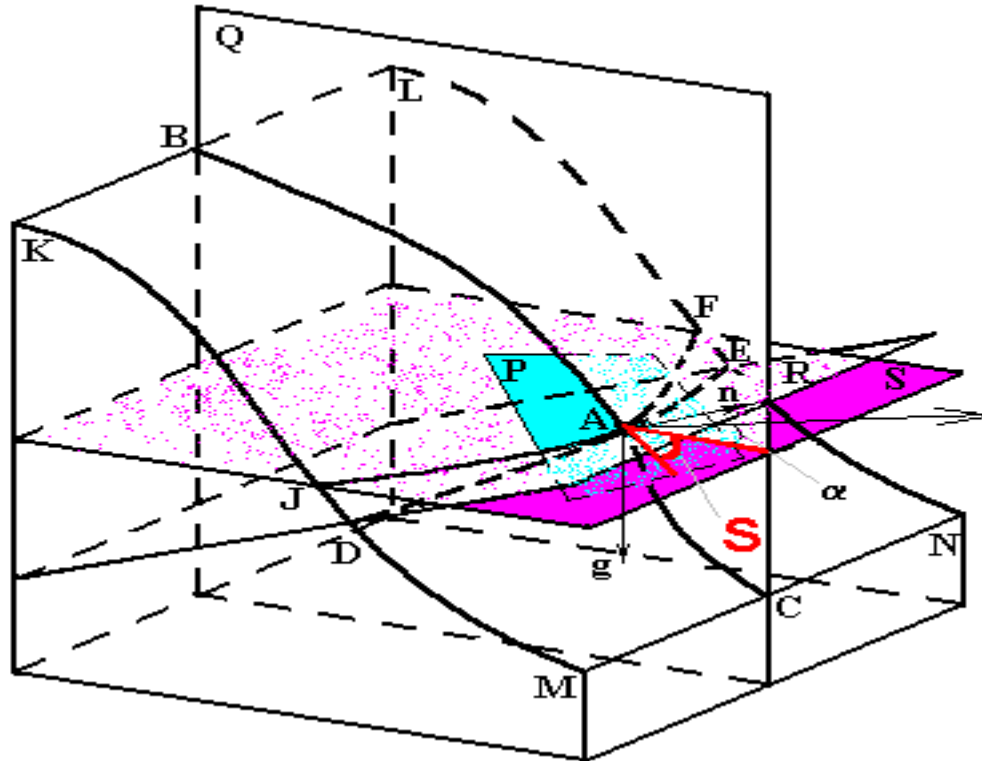
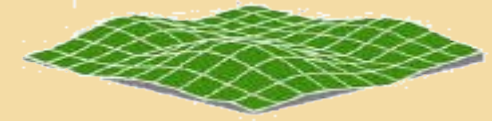
$$z_{xx} = \frac{\partial^2 z}{\partial x^2} \approx \frac{z_4 - 2z_9 + z_8}{d^2}$$

$$z_{yy} = \frac{\partial^2 z}{\partial y^2} \approx \frac{z_2 - 2z_9 + z_6}{d^2}$$

$$z_{xy} = \frac{\partial^2 z}{\partial x \partial y} \approx \frac{-z_1 + z_3 + z_7 - z_5}{4d^2}$$

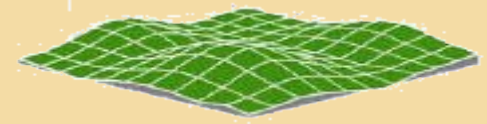
$$P = z_x^2 + z_y^2$$

$$Q = P + 1$$



- Nagib terena u nekoj tački definiše se kao ugao meren u vertikalnoj ravni koji zahvata tangencijalna ravan na površ terena u datoj tački sa horizontalnom ravni u istoj tački.

$$S = \sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2} = \sqrt{z_x^2 + z_y^2}$$



- Queen's case

$$S = \sqrt{S_{e-w}^2 + S_{n-s}^2} \times 100$$

$$S_{e-w} = \frac{(z_3 + 2z_4 + z_5) - (z_1 + 2z_8 + z_7)}{8 \times d}$$

$$S_{n-s} = \frac{(z_1 + 2z_2 + z_3) - (z_7 + 2z_6 + z_5)}{8 \times d}$$

- Rook's case

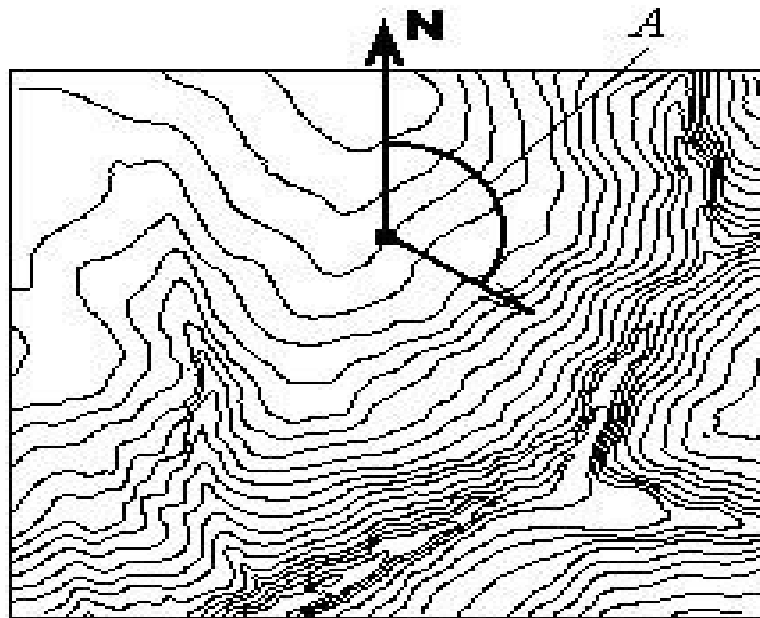
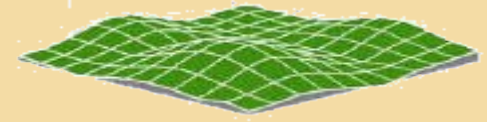
$$S = \sqrt{S_{e-w}^2 + S_{n-s}^2} \times 100$$

$$S_{e-w} = \frac{z_4 - z_8}{2 \times d}$$

$$S_{n-s} = \frac{z_2 - z_6}{2 \times d}$$

- Max. gradijent

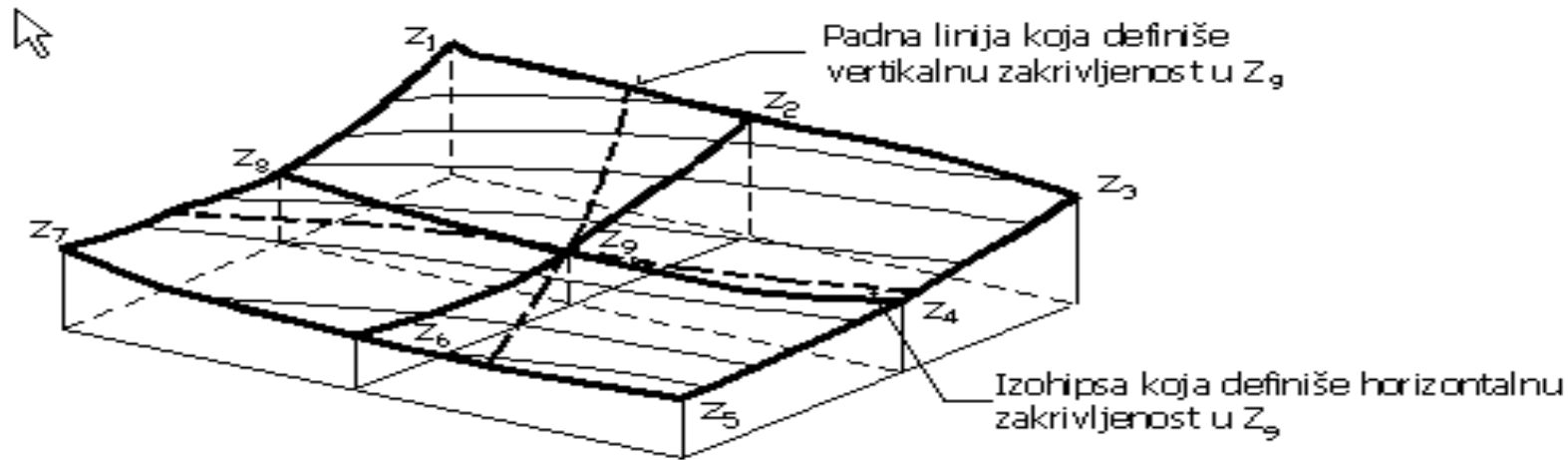
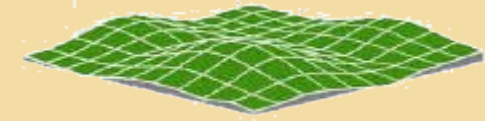
$$S = \max \left(\frac{z_9 - z_i}{d_c} \right) \times 100$$



- Aspekt terena predstavlja orijentaciju linije najvećeg nagiba za posmatranu tačku.

$$A = 180^\circ - \arctan\left(\frac{z_y}{z_x}\right) + 90^\circ \left(\frac{z_x}{|z_x|}\right)$$

Zakrivljenost terena



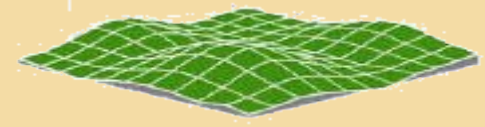
Padna linija koja definiše vertikalnu zakrivljenost u Z_g

Izohipsa koja definiše horizontalnu zakrivljenost u Z_g

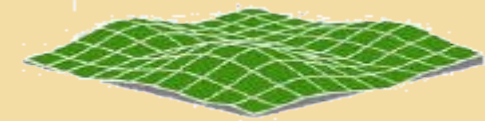
$$K_p = \frac{z_{xx}z_x^2 + 2z_{xy}z_xz_y + z_{yy}z_y^2}{P\sqrt{Q^3}}$$

$$K_c = \frac{z_{xx}z_y^2 - 2z_{xy}z_xz_y + z_{yy}z_x^2}{\sqrt{P^3}}$$

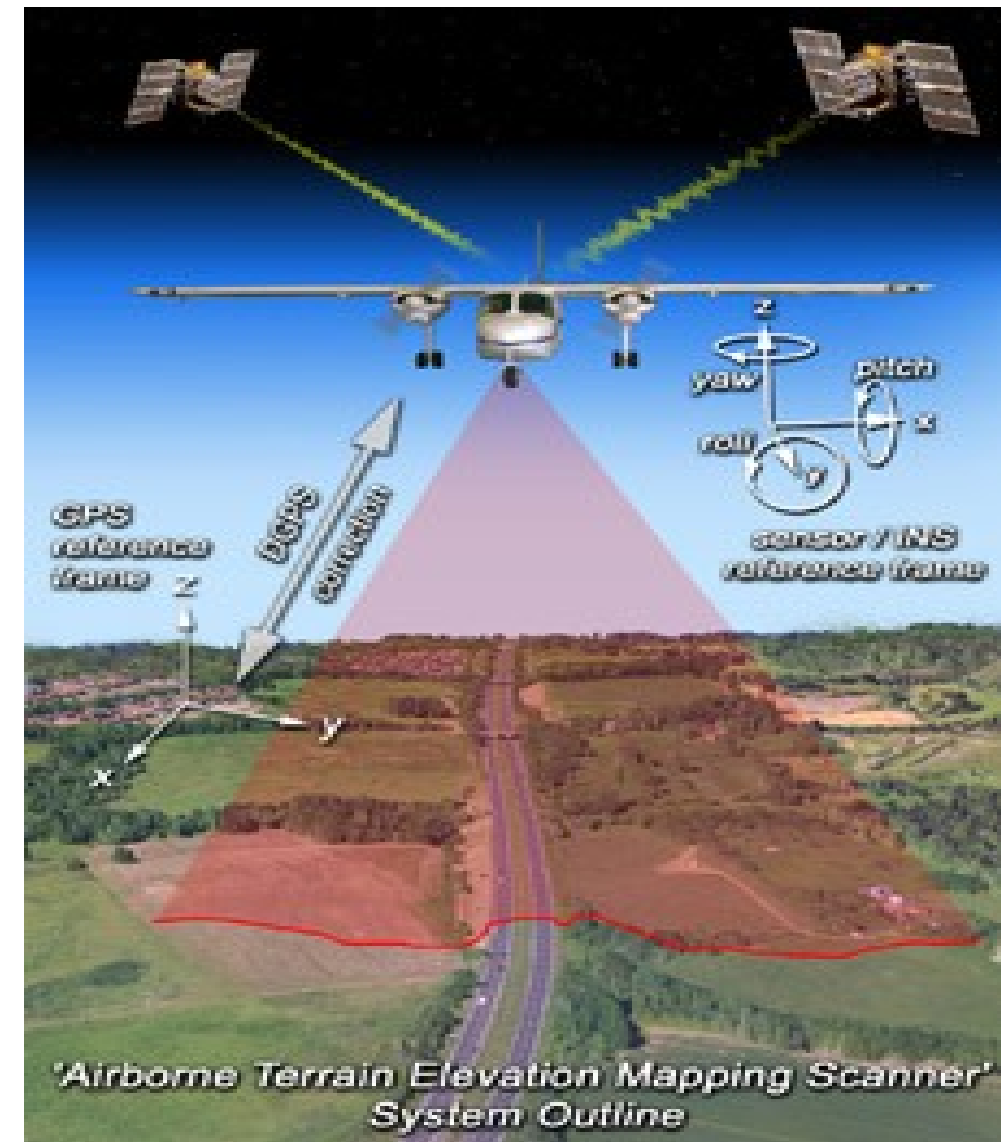
$$K_t = \frac{z_{xx}z_y^2 - 2z_{xy}z_xz_y + z_{yy}z_x^2}{P\sqrt{Q}}$$

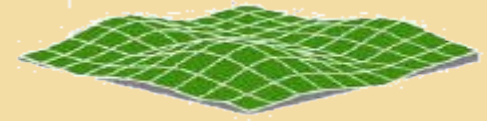


- Digitalizacija postojećih podloga
- Fotogrametrija
- LIDAR
- SAR ili InSAR
- Terestičke metode merenja (tahimetrija, GPS)



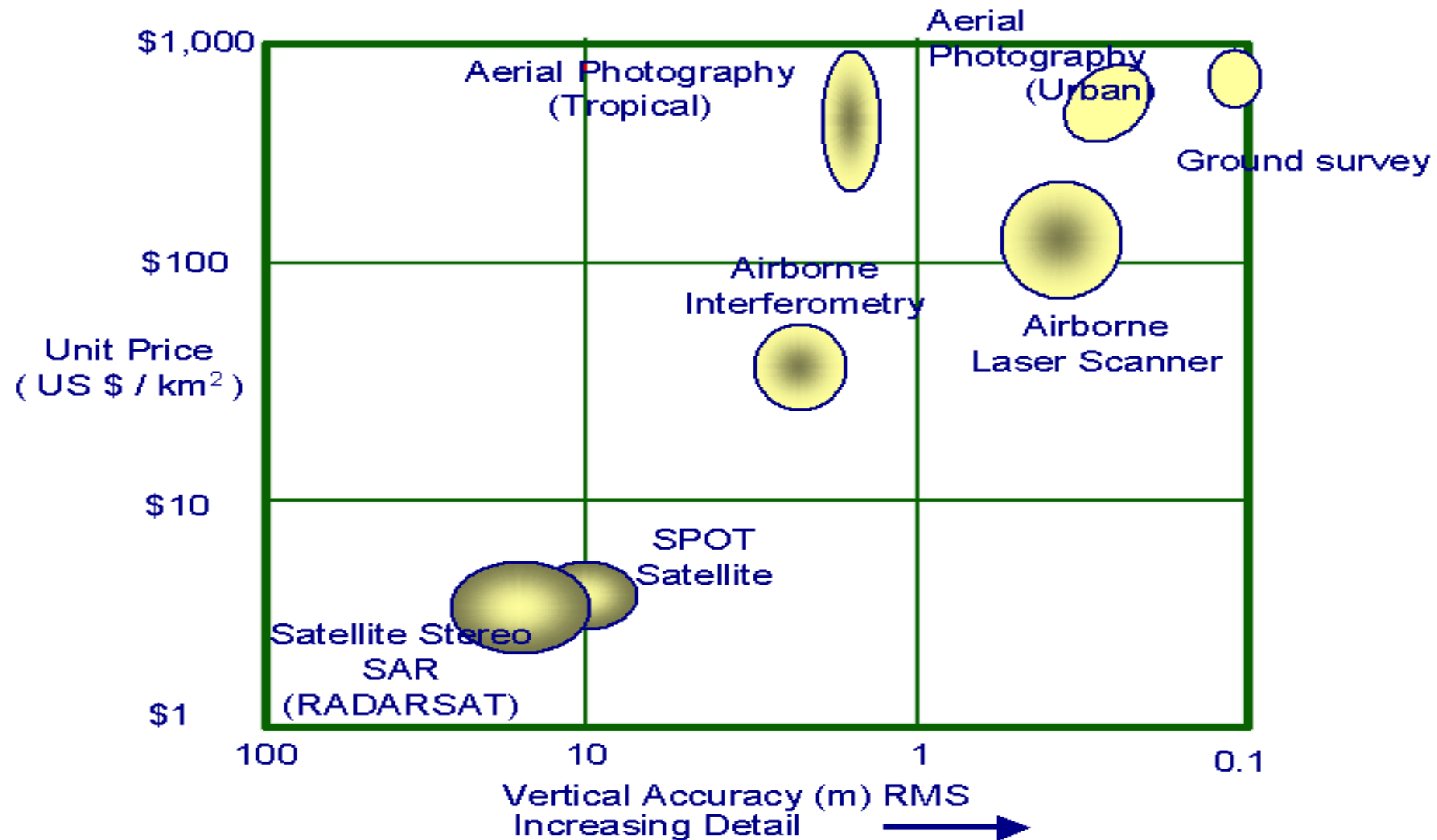
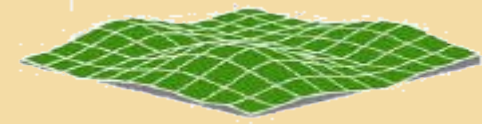
- Fotogrametrija
- LIDAR ili AVL
- SAR i InSAR
- Satelitski snimci visoke rezolucije



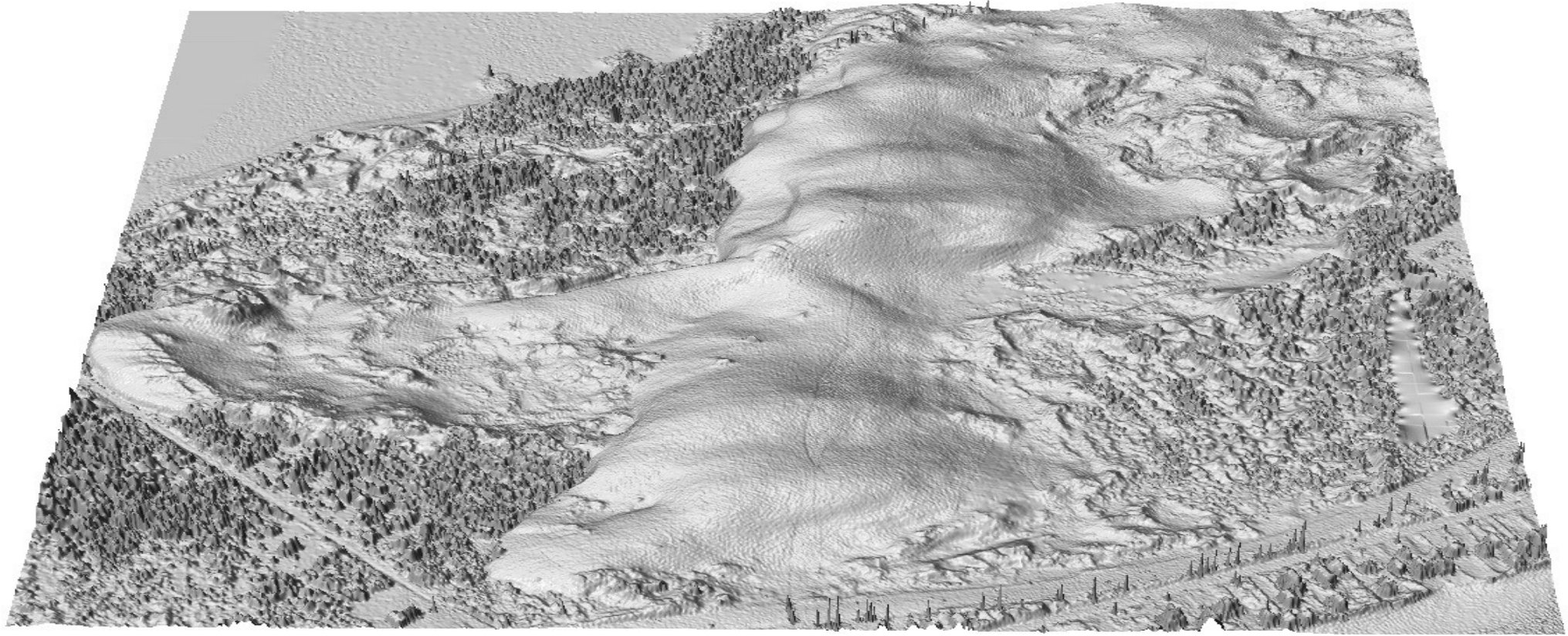
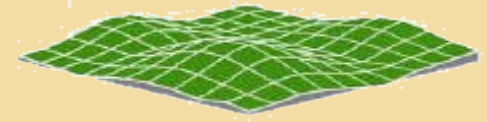


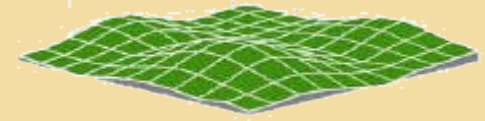
<i>Izvori podataka</i>	
Izvor	Max. vertikalna tačnost
Tahimetrija	mm/cm opseg
GPS	cm opseg
Topografske karte	1/3 ekvidistance
Laser Scanning	15 cm
Fotogrametrija	15 cm
InSAR	0.5m
Satelitski snimci	2m

Odnos tačnosti i ekonomičnosti metoda prikupljanja podataka

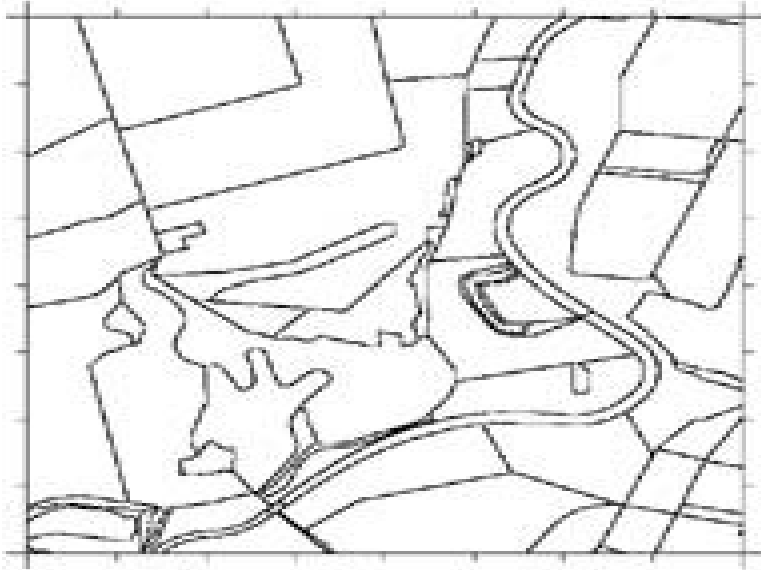
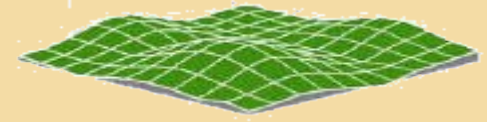


Digitalni model površi

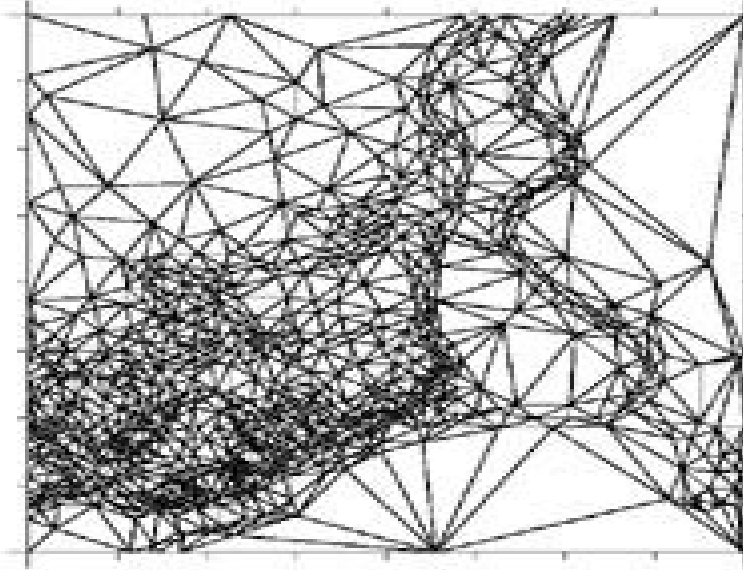




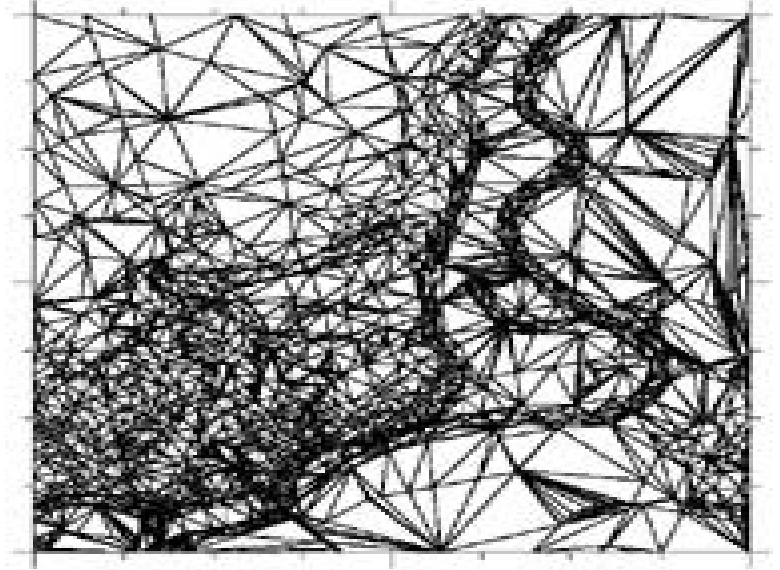
- Memorisanje visinskih podataka za potrebe izrade digitalnih topografskih karata,
- Izrada digitalnih i analognih ortofoto planova i karata,
- Rešavanje problema građevinskih profila kod projektovanja saobraćajnica, i vojno inženjerskih projekta,
- Trodimenzionalni prikazi zemljišnih oblika i simulacije letenja,
- Pejzažna arhitektura i planiranje prostora,
- Analize dogledanja,
- Planiranje komunikacija,
- Određivanje lokacija za brane i mostove,
- Hidrološka i ekološka modeliranja,
- Hidrauličko modeliranje i simulacije,
- Analize geomorfoloških parametara (ekspozicija, nagibi, zakrivljenosti terena),
- Podloga za druge vrste prostornih informacija (satelitske snimke, tematske karte, itd.)



2D GIS



DMT-TIN



2.5D GIS