SOME EXPERIENCES IN ANALYTICAL RELIEF SHADING

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CROATIA
INTRODUCTION

• Croatia has a number of mountains
• Shaded reliefs in Croatia were done manually until recent days

• Today, cartography in Croatia is in expansion
  – new series of the official topographic maps
  – national strategy towards tourism has encouraged publishers to provide all kinds of map products

• Increasing need for relief shades
CROATIAN RELIEF (SRTM data)

• Geomorphology of Croatian mountains:
  – 95 % sediment
  – 2-4 % metamorphic
  – 1 % vulcanic

• Karst (krš) with it’s irregular shape is difficult to present with shades
MEDVEDNICA MOUNTAIN

- Peek – 1035 m – 10 km from Zagreb’s main square
- The most visited mountain in Croatia
- The largest number of cartographic representations among Croatian mountains

- DEM of Medvednica derived from contours from the topographic map at the scale of 1:25 000 will be used for examples
Perspective view of DEM

The main ridgeline is in SW-NE direction with spurs perpendicular to this direction.
Top of Medvednica (Lovrić, 1993)

Average direction of light

Shades are drawn manually. Adaptive direction of light
Panoramic view

Direction of light

Artistic hand drawing
Bicycle map of Medvednica

Analytical shading of digital relief model.

Direction of light
Photograph of the relief model (source unknown)
Hand drawn shades, by Ante Čala
MOTIVATION

- Absence of people specialized for manual relief shading
- Shades prepared for one map usually cannot be reused for other maps
- Investigate analytical relief shading and modify it to better serve the purpose for topographic and thematic maps
METHODOLOGY


- Modification of the azimuth, height and length of the vector of light

- The goal: Weight of shades on the map: as small as possible while preserving the best perception of the relief
Weight of shades

\[ R_{nm} \]

- raster matrix of shaded relief with values [0,255]

\[
W = \frac{\sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left( 1 - \frac{R_{ij}}{255} \right)}{m \cdot n} \cdot 100 \% 
\]

calculated weight by this equation have relative meaning and does not represent final weight on printed map.
Weight calculated by equation

$$W = \frac{\sum_{x=0}^{255} \sum_{y=0}^{255} \left(1 - \frac{R_y}{255}\right)}{255 \cdot 255} \cdot 100\%$$
DIFFUSE SHADING

\( \vec{r}_{ij} \) - normal vector of relief surface

\( \vec{l}_{ij} \) - vector of light

Cosine of the angle between vectors \( \vec{r}_{ij} \) and \( \vec{l}_{ij} \).

\[
D_{ij} = \frac{\vec{l}_{ij} \cdot \vec{r}_{ij}}{|\vec{l}_{ij}| \cdot |\vec{r}_{ij}|}
\]

\( i = 0,1,\ldots,m \quad j = 0,1,\ldots,n \)

Linear transformation from \([\min(D_{ij}), \max(D_{ij})]\) to \([0, 255]\)

\[
R_{ij} = \frac{255}{\max(D_{ij}) - \min(D_{ij})} \left( D_{ij} - \min(D_{ij}) \right)
\]
Vector of light

\[ \vec{l}_{ij} = x_{ij}\hat{i} + y_{ij}\hat{j} + z_{ij}\hat{k} \]  triple \( x_{ij}, y_{ij}, z_{ij} \) defining the radius vector

\[ H_{ij} = \arctan\left( \frac{z_{ij}}{\sqrt{x_{ij}^2 + y_{ij}^2}} \right) \]  height above horizon

\[ A_{ij} = \arctan\left( \frac{y_{ij}}{x_{ij}} \right) \]  azimuth

\[ I_{ij} = \sqrt{x_{ij}^2 + y_{ij}^2 + z_{ij}^2} \]  length

\[ \vec{l}_{ij} = \{H_{ij}, A_{ij}, I_{ij}\} \]

\[ \vec{l}_{ij} = f(\vec{r}_{ij}) \neq \text{const.} \]
Diffuse shading
A=135°
H=45°
I=1

Direction of light

Weight: 27%
Modification of azimuth

Calculate the aspect \( a_{ij} \)

with starting direction \( A_{ij} = A_{\text{const.}} \ (135^\circ) \)

Transformation to the first quadrant:

\[
a_{ij} = \arcsin\left(\left|\sin(a_{ij})\right|\right)
\]

Final azimuth of the light:

\[
A_{ij} = A_{\text{const.}} \pm a_{ij}
\]
First step: aspect map with 135° as starting direction

\[ a_{ij} \]
Azimuth of the light

\[ A_{ij} = A_{\text{const.}} - a_{ij} \]
Modification of azimuth

\[ A_{ij} = A_{\text{const.}} - a_{ij} \]
Comparison
Modification of height

Calculate the slope of relief \( S_{ij} \)

Let the height be perpendicular to the slope:

\[
H_{ij} = 90^\circ - S_{ij}
\]
Modification of azimuth and height

Direction of light

Height of light

Weight: 14%
Modification of the length of vector

\[ I(\min(R_{mn})) = 1 \] - length of the light vector for minimum elevation

\[ I(\max(R_{mn})) = k \] - length of the light vector for maximum elevation

Linear relationship between the length and elevation

\[ I_{ij} = \frac{k - 1}{\max(R_{mn}) - \min(R_{mn})}(R_{ij} - \min(R_{mn}))+1 \]

Transformation to the grayscale

\[ R_{ij} = \frac{255}{D_{flat} - \min(D_{mn})}(D_{ij} - \min(D_{mn})) \]

- If \( R_{ij} > 255 \) then \( R_{ij} = 255 \)
All three modifications

Direction of light

Height of light

Length of vector

Weight: 9%
CONCLUSION

- Light vector as function of relief model can give different results
- Presented modifications are simple and easy to interpret, and applicable to any relief model
- Modified results can be used for easier creation of final shades
Overlay of the shades on the map

Standard diffuse shading

Modification of the azimuth and height of the light (our approach)
Thank you!