VISIBILITY SIMULATION TECHNIQUE FOR SUPPORT OF VISUAL RECOGNITION OF THE LANDFORM FEATURES

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Abstract

Novel technique for enhanced visual recognition of the landform features developed by spatial analysis on the digital terrain model (DTM) is proposed. The approach called "visibility simulation technique" is consisted form the following steps: (1) visibility calculation, (2) altering an azimuth and zenith angle (following the proposed algorithm), (3) generating continuous surfaces that indicate upper/lower views and relative relief, (4) visual recognition of morphological features by thematic and general cartography, as possible input for further modelling and phenomena detection. Modelling parameters are highly independent on the landform morphology where only the parameter of zenith angle needs some minor adjustments. An interesting application is generation of a comprehensive relative relief. An important auxiliary result considers improving of the DTM quality. The proposed technique was tested on the morphologically various terrains of Mars and demonstrated using a DTM produced from HRSC images of the Mars Express mission.
Keywords: visibility simulation, relative relief, topography, digital terrain model, spatial analysis, visual recognition

1 Introduction

Selected areas on the Earth and especially on the Mars have been studied using DTMs produced from HRSC orthoimages (High Resolution Stereo Camera) on board of the European orbiter "Mars Express" mission of the ESA's research programme "HRSC on Mars Express". The HRSC data were in this case used from the orbit 266 with the central coordinates of 43°S, 95°W. The DTMs were derived in the course of a DTM test (Heipke et al., 2007). The resolution is 50 meters per pixel (the same as for orthoimages) covering the area of 45 km × 80 km (Figure 1). In the course of the Mars project the focus is on areomorphologic analysis and visualisation (i.e. relating to the morphology of Mars) by employing DTM data.

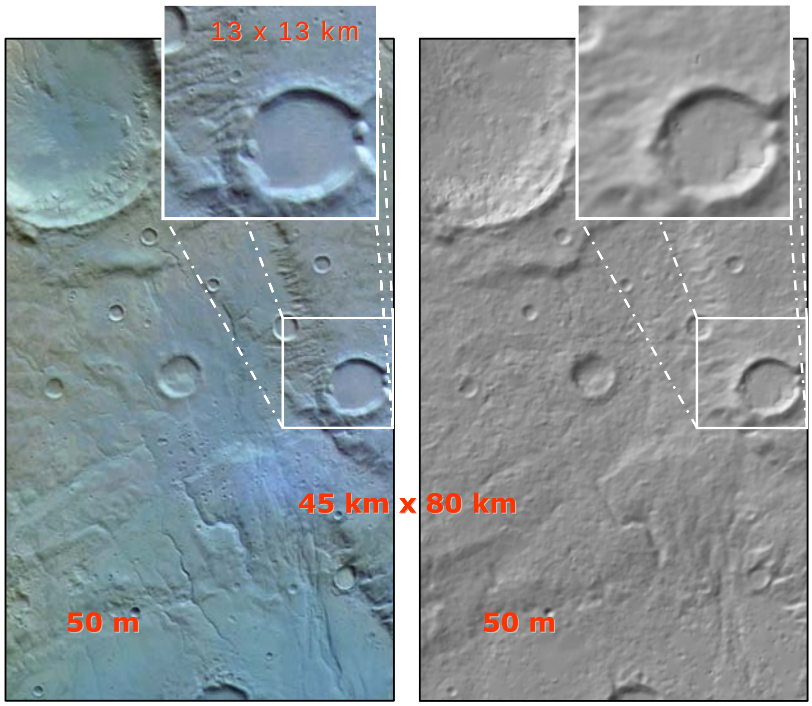

Figure 1: Left is a HRSC orthoimage (iRGB channels), and right analytically shaded HRSC DTM (azimuth φ: 315°, zenith angle θ: 45°) in resolution of 50 m.

2 Morphologic phenomena visualisation principles

The visual recognition of morphologic features in the study is going to operate with the following topographic visualisations: (principally) thematic cartography and general cartography. The main aim of topographic thematic cartography is spatial exposal of the studied morphologic features and structures (Podobnikar, 2006; 2008a). As the result is the recognised features, the outputs can be delivered for the further numerical evaluation within spatial modelling. Characteristics of the proposed thematic cartography are:

- morphologic features, structures and patterns are enhanced and recognised
- visualisations are dependant on the particular studied feature (which features are in our interest?)
- visualisations that need more explanation to the other users (with legends and descriptively)
- visual recognition of particular errors allows improving of the DTM quality (e.g. Podobnikar, 2005)

- possible applications educational, for increasing public awareness on environmental studies, etc.

General cartographic visualisation is more conservative with requiring standard topographical rules for the relief presentation as part of an appropriate abstraction of reality (Robinson et al., 1995; Lanius, 1999; Imhof, 2007). The appearances of landform visualisations are more naturalistic than by the thematic cartography. This makes possibility for combination with other cartographic visual resources as the complex topographical maps are combination of science and art. The cartographer selects only the information that is essential to fulfil the purpose of the map, and that is suitable for the selected scale. The map's interpretation depends on a cognitive and semantic perception of the World, by cartographers on one side and users on the other side. Characteristics of the general cartographic visualisations are:

- recognition of the morphologic features is not in a first plan
- terrain presentation should fulfil the cartographic standards
- image of topography should be instantly understandable for everyone
- the developed techniques may be useful for improving of the topographic maps.

3 Visibility simulation technique

Visibility simulation technique can be used in number of applications for visual and possible automated recognition (e.g. Podobnikar 2008b). The following three parameters should be defined for the visibility analysis (see also Figure 2). The azimuth (φ) is defined within the value range of 0 and 360º with 0º indicating the northern direction. The zenith angle (θ) may be defined between 0° and 180°, where 0º is pointing to zenith, 90º to horizon, and 180º to nadir. The catchment radius is important parameter as well. The extension of the study areas for any visibility analysis should be carefully chosen, especially when the chosen parameter of zenith angle is around 90º (horizon). In this case the results may be affected by missing part of morphology around the edges (edge effect) of the study area.

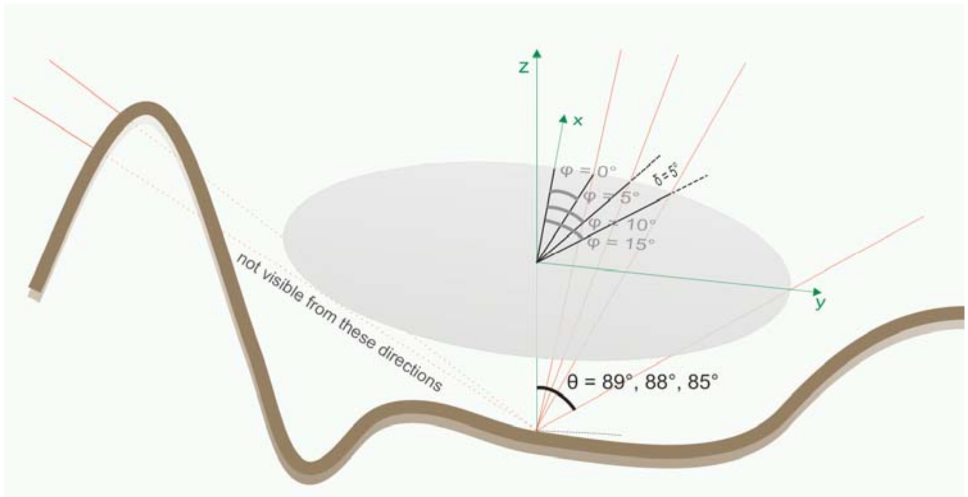

Figure 2: Visibility simulation technique where φ = azimuths, δ = azimuth interval, and θ = zenith angles

The procedure for the visibility simulation technique (Figure 2) uses a DTM in a form of matrix or grid (as a digital elevation model) with a certain resolution (denotes the dimension of cell-grid) is:

1. Calculate visibility from a central point of the particular grid cell in the DTM and assign the binary attributes:
   - 0, if the grid cell is not visible
   - 1, if the grid cell is visible

The parameters and their ranges for visibility calculation are primary the following:

- φ … azimuth [0°, 360°]
- δ … azimuth interval (360°/*n*, where *n* is an integer value)
- θ … zenith (vertical) angle [0°, 180°]
- *r* … radius (∞)

2. Repeat the visibility calculation for every grid-point of the DTM to produce a derivative binary grid B_φ {0, 1} applying certain parameters.

3. To certify the isotropic processing continue calculation of the derivative binary grids B_φ by a sequence of azimuths φ (applying an appropriate azimuth interval δ), sum up B_φ to produce continuous grids according to:
   - upper views U_θ, and lower views L_θ as $\Sigma(B_\varphi)$, where φ = {0º, δ, 2δ, 3δ, …, 360º - δ}, *n* = 360º/δ times (where the chosen δ = 5º, *n* = 72-times) and according to the chosen zenith angles
   - for U_θ: θ = {89º, 88º, 85º}, in interval [0, 72], and with corresponding values below the horizon
   - for L_θ: θ = {91º, 92º, 95º}, in interval [0, 72]

4. Calculate enhanced continuous surfaces for every θ, what results to:

- upper view: $\Sigma_\theta(U_\theta)$, in interval [0, 288]
- lower view: $\Sigma_\theta(L_\theta)$, in interval [0, 288]
- relative relief: $\Sigma_\theta(RR_\theta)$, in interval [–288, 288]

The described procedure parameters are optimised considering shorten of the processing time and optimise the quality of outputs. Generally the increment interval δ for azimuths φ may be arbitrary changed, where larger increment intervals may cause less smoothed output. Also the vertical angles θ may altered where too many and to dense intervals my cause increasing uncertainty of the outputs.

Presentation of the all visualisations is in grey casts for all of the basic descriptions of the visibility simulation technique (Figures 3 to 5). This kind of presentation is between the most objective when different parameters (related to θ and arithmetical operations between derived surfaces) are tested and applied.

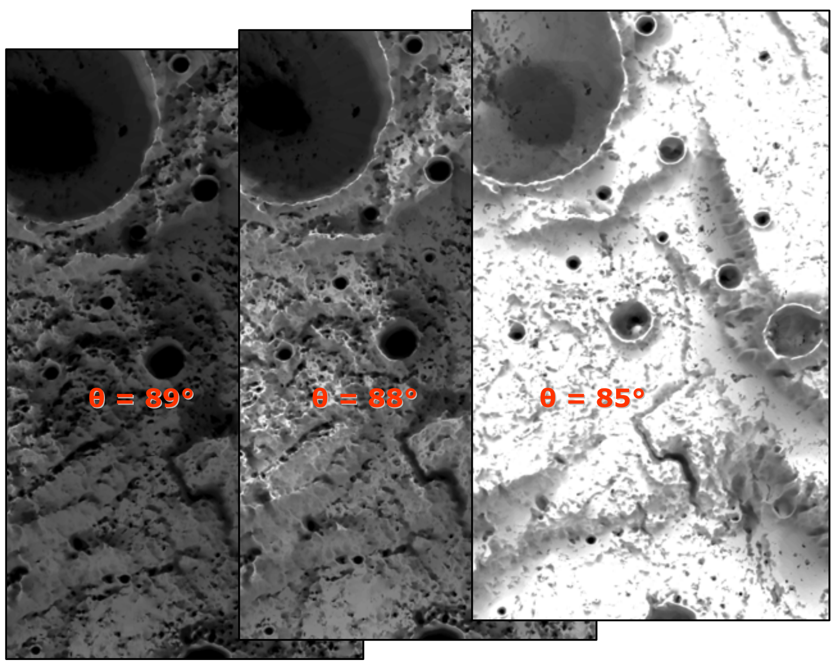

Figure 3: Upper views U_θ, where θ = {89º, 88º, 85º}, on interval [0, 72]. Value 0 denotes never visible areas, presented in black; value 72 denotes always visible areas, presented in white.

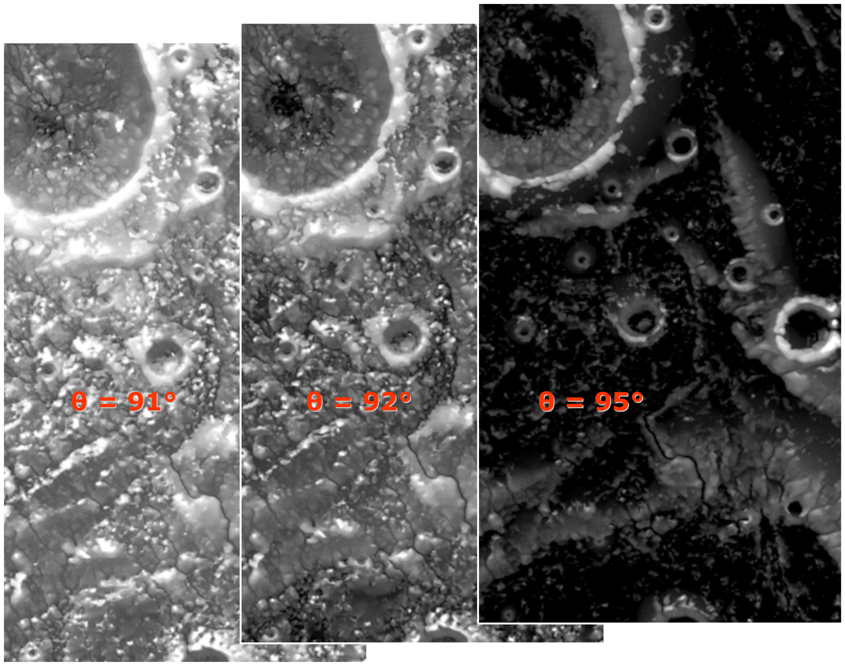

Figure 4: Lower views L_θ where θ = {91º, 92º, 95º}, on interval [0, 72]. Value 0 denotes never visible areas, presented in white; value 72 denotes always visible areas, presented in black.

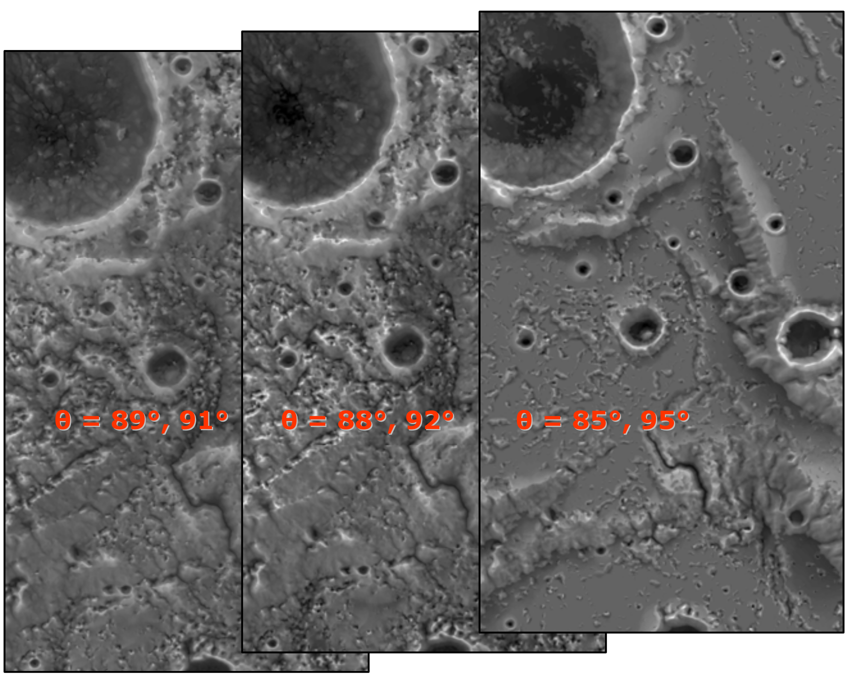

Figure 5: Relative reliefs $RR_\theta = U_\theta - L_\theta$, where θ = {89º/91º, 88º/92º, 85º/95º}, on interval [–72, 72]. Value –72 denotes lowest areas or depressions (always visible areas for L and never for U), presented in black; 0 denotes large flat areas (always visible for U and L) or just transitional areas in U and L, presented in grey; value 72 denotes highest or exposed areas (always visible areas for U and never for L), presented in white. In case where θ = 89º/91º, many details are recognised.

4 Conclusions

The main task of this study was to develop and testing the algorithm that we called "visibility simulation technique". The applied part was detection and recognition of some morphologic features on the Mars planet using a HRSC DTM. The visibility (or shadow) simulation is an unconvential but relatively simple technique that was developed for various visualisation purposes and for the numerical modelling. The basic technique comprises the following steps: (1) visibility calculation, (2) altering an azimuth and zenith angle (following the proposed algorithm), (3) generating continuous surfaces that indicate upper/lower views and relative relief, (4) visual recognition of morphologic features by thematic and general cartography as possible input for further modelling and phenomena detection. The outputs of this technique are various visualisations or maps to be analysed, but in this paper are in a higher detail described relative relief.

The main advantages of the outputs of this proposed technique are: they are not subject matter to particular azimuth, they show a very high level of morphologic detail, the applied parameters are robust for almost any type of terrain, and they simulate a natural impression of the terrain (similarly as analytical shading and height-coding). The most promising results are in combination of the selected techniques that can be applied in many applications. The important role of this study was to develop simple techniques, but as much as possible effective. In the future, more comprehensive combination based on visual simulation technique are planned to introduce some other effects important either for detection of the morphological features in GIS or enhance the cartographic visualisation of Mars, Earth or any other spatial surface.

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References

Heipke, C., Oberst, J., Albertz, J., Attwenger, M., Dorninger, P., Dorrer, E., Ewe, M., Gehrke, S., Gwinner, K., Hirschmüller, H., Kim, J., Kirk, R., Mayer, H., Muller, J., Rengarajan, R., Rentsch, M., Schmidt, R., Scholten, F., Shan, J., Spiegel, M., Wählisch, M. and Neukum, G. (2007), Evaluating planetary digital terrain models – the HRSC DTM test. Planetary and space Science, Elsevier 55 (14), 2173-2191.

Helgason, J. (1999), Formation of Olympus Mons and the aureole-escarpment problem on Mars, Geology, 27 (3), 231-234.

Imhof, E. (2007), Cartographic Relief Presentation. ESRI Press, 388 pp.

Lanius, C. (1999): Mathematics of Cartography. Rice University, Department of Mathematics, http://math.rice.edu/~lanius/pres/map/

Podobnikar, T. (2005), Production of integrated digital terrain model from multiple datasets of different quality. International journal of geographical information science, Taylor & Frances 19 (1), 69–89.

Podobnikar, T. (2006), DEM from various data sources and geomorphic details enhancement. In: Petrovič, D (ed.). Proceedings of 5th Mountain Cartography Workshop, Bohinj, Slovenia, 29 March - 1 April 2006. Zurich: International Cartographic Association, Commission on Mountain Cartography; Ljubljana: Association of Surveyors of Slovenia, Section of Cartography: Faculty of Civil and Geodetic Engineering, pp. 189-199.

Podobnikar, T. (2008a), Enhancing terrain features for improved cartographic visualization. Second international conference on cartography and GIS, Proceedings 1, 21-24 January, ICA, Borovets, Bolgaria.

Podobnikar, T. (2008b), Simulation and representation of the positional errors of boundary and interior regions in maps. In: Moore, A., Drecki, I. (eds.), Geospatial vision: New dimensions in cartography: selected papers from the 4th National Cartographic Conference Geocart'2008, New Zealand, (Lecture notes in geoinformation and cartography). Berlin; Heidelberg: Springer, pp. 141-169.

Robinson, A.H., Morrison, J.L., Muehrcke, P.C., Kimerling, A.J. and Guptil, S.C. (1995. Elements of Cartography. 6th ed., John Wiley & Sons.