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Quantifying visual heterogeneity of paper maps using diffuse reflectance spectroscopy

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Abstract:

Over the last decades, the concept of map visual complexity has been extensively investigated in cartographic research. Existing approaches provide specific measures and metrics which can be utilized towards the objective examination of map effectiveness, e.g. Monmonier (1974), MacEachrean (1982), Fairbairn (2006), and Rautenbach et al. (2015). Moreover, recent studies analyze behavioral data, e.g. Cybulski (2020), Tzelepis et al. (2020), using cartographic products distributed in the internet (Schnur et al., 2018). However, map visual complexity could be affected by several factors. Among them, map scale seems to play a significant role, since it is connected to the accuracy and the level of information delivered by a cartographic product (Dumont et al., 2020).

In this work, the concept of map visual complexity is connected to visual heterogeneity. A new method for quantifying visual heterogeneity of paper maps is proposed. The method is based on diffuse reflectance spectroscopy and on a random segmentation and sampling in maps with different scale levels. It is shown that by using certain segmentation size, an indicator based on Shannon entropy of the samples can be efficient in characterizing the visual heterogeneity and the scale of the maps. A low-cost optical spectrometer is utilized in order to record the spectra of 40 random segments of the maps. Reflectance spectroscopy aims at measuring the relative level of reflected light as it is compared with a reference (white surface) to record a percentage value at each wavelength and for each segment of the map. A bifurcated optical fiber has been used to deliver the reference light to the map surface (Halogen light source), while the reflected light is guided to the spectrometer (Figure 1). Segment size is defined by moving the fiber closer to the map surface and it is expected to significantly affect the estimation of the indicator.

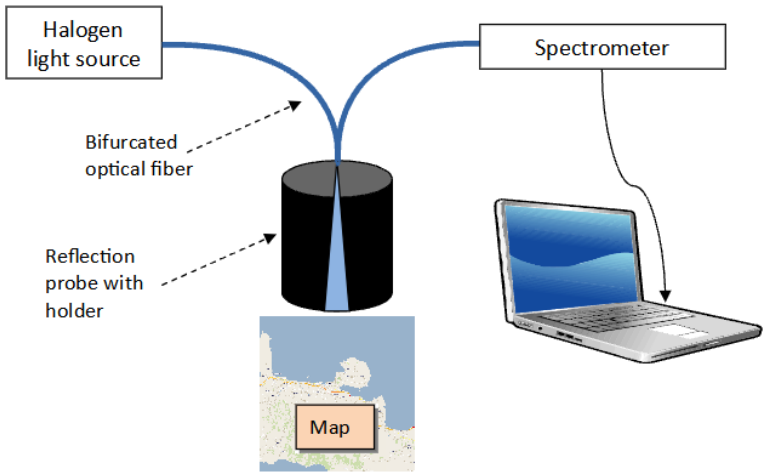

Figure 1. Experimental setup

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In the present experiments, the distance of the fiber from the map surface is such so that the diameter of the randomly selected segments is approximately 3 mm. The spectrometer spectral resolution is approximately 1.5 nm and, consequently, more than 240 spectral channels are recorded for each sample, since only the visible region of the spectrum is required (380 nm - 750 nm). The proposed heterogeneity indicator is the Shannon entropy, as is calculated by the probabilities to record similar reflection spectral values (relative reflected light) in the space defined by the 40 samples of each map. Since the spectral values are continuous variables, they have to be properly quantized (discretization process), before the probabilities and the entropy are calculated. In addition, Principal Component Analysis (PCA) can be also utilized in order to reduce the spectral data dimensions (channels) and to enable faster calculations.

As a means to evaluate the proposed indicator, 60 different paper maps are used. Maps' production is based on the use of the standard layer of OpenStreetMap (OSM) as it is provided by the Web Map Service (WMS) of terrestris GmbH & Co. KG. OSM cartographic backgrounds are utilized in this work because they present adequately high information (content) density and diversity across different scale – or zoom – levels compared to other online map services, e.g. Google Maps, Here WeGo, etc. (Skopeliti and Stamou, 2019). More specifically, for the needs of this research study, twenty regions in Greece and three different map scale levels (1:k, 1:4k, & 1:40k) are examined. The produced maps are printed using the same paper quality. Box plots are applied to show the indicator with respect to the scale. It is shown that the scale of the map strongly affects the information content and the visual heterogeneity of the map.

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