International Cartographic Association
Association Cartographique Internationale

Analyzing colour use in urban point cloud visualizations

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Keywords: point clouds; LiDAR; CIEDE2000; Mobile Mapping Systems; colour scheme; colour palette

Abstract:

This study evaluates the importance of colour in the visualization of complex 3D data, focusing on the representation of urban point clouds in the most recently published and highly cited publications. The aim is to identify consistent colour choices already present in the body of literature as well as to analyse the hues' differences of selected categories with use of perceptual colour difference of CIEDE2000. Based on the conducted analysis, the future goal is to propose a new colour palette for urban point clouds categories that contains discriminable and widely known hues.

Introduction

Colour is a commonly used visual variable applied to present quantitative and qualitative data. With the use of properly designed colour schemes, the input data can be easily read, interpreted, and understood. However, the design of effective colour scheme is a challenging task and require following guidelines developed based on colour perception theory as well as empirical evidence. A categorical colour scheme is required to contain discriminable colours with different hues and of similar lightness. A use of associations regarding the assigned phenomenon is also advised (Lin et al. 2013).

However, in point clouds there are no colour palettes for predefined use, like in GIS or colour advise online tools (Gołębiowska and Çöltekin 2022) that are mainly designed for 2D visualizations. While visualizing point clouds with colour, authors use the colours hues that consider appropriate and, often, this does not allow for an optimal visualization of 3D environments. In addition to point clouds limitations in visualization, such as occlusions, point density variations, and visualization through surfaces, urban environments have many overlapping objects (Barros-Ribademar et al. 2022), so the scene is more difficult to interpret.

Methods

Search criteria and sample selection

To assess the colour palettes used by authors recently in urban point clouds, SCOPUS was used as reference database, as it is one of the largest scientific abstract and citation databases that covers a wide range of publications. The search words were "(classification OR semantic OR segmentation) AND (point-cloud OR lidar OR mobile-laser-scanning OR mobile-mapping-system)" and covered the last 10 years, which coincides with the rise of Artificial Intelligence applied to point clouds in semantic segmentation and automatic object detection, and the publication of several urban point cloud datasets. For each year, the three most cited articles/proceedings were selected considering this metric as a reflect of impact on subsequent research. From 2022, given that the number of recent citations was very similar, it was considered to use the order of relevance provided by the search engine. In addition, among the papers resulting from the search, we filtered and selected those papers that showed legends, or at least a figure where the objects could be clearly identified.

CIEDE2000 and perceptual colour difference

Colour perception is a complex process that is affected by multiple factors, e.g. lightning conditions, individual and group differences. Similarly, determining perceptual colour difference in a numerical way has been a challenge and resulted with several, evolving formulas. The CIEDE2000 developed by CIE Technical Committee is based on CIE Lab colour space and has become industry standard (Sharma et al. 2005). It allows to quantify the difference between two selected colours is a perceptually uniform way. The higher the CIEDE2000 value, the larger the perceptual difference between the two hues, with the 0 value reflecting the no difference between the compared colours. The formula refers to the *just noticeable difference* metric, assuming value *1* as a threshold of colour difference visible for a human eye.

Results

In total, 30 publications have been selected, see (Balado, 2024) for the complete list. The selected publications fall into the fields of autonomous driving and High Definition (HD) map generation from point clouds of urban environments.

https://doi.org/10.5194/ica-abs-8-5-2024 |

The most recurrent classes have been distinguished in the selected papers. Due to different labelling of categories, the semantic appropriateness has been verified in the content of each paper.

The collected data indicate there is little consistency in the choice of colour hues for the *road*, *building*, and *car* classes, nor any discernible evolution over the years. Notably, most of the works utilize data from only three datasets (iQmulus/TerraMobilita, Semantic3D, and SemanticKITTI) or from the same authors, yet the colours employed differ. In contrast, for the *tree* class, there is a greater similarity primarily due to a selection of semantically resonant colours (Lin et al. 2013). However, although green is associated with vegetation, a similar situation does not occur with the road that is predominantly dark. Fig. 1 presents differences of colour choices (expressed in CIEDE2000) for the four categories calculated between each pair of analysed papers. The closer the density graph to 0 value, the more consistent colour choices are in the analysed papers. Therefore, colour differences between each pair of papers show variation in each category, with the largest variation for *car* category, and the smallest for *tree* category.

Moreover, there is also large variation of CIEDE2000 values within a colour scheme applied in each analysed paper. The optimal solution would be similar and as large as possible differences between categories. Unfortunately, it was not applied in the analysed papers. Figure 2 illustrates the large variety of differences between colours applied in an exemplary paper (Yang et al. 2015): narrow ribbons (e.g. between *tree* and *pole* of CIEDE2000=16.38) depict similar colours between categories, whereas wide ribbons represent large colour differences (e.g. between *tree* and *road* of 90.88 CIEDE2000).

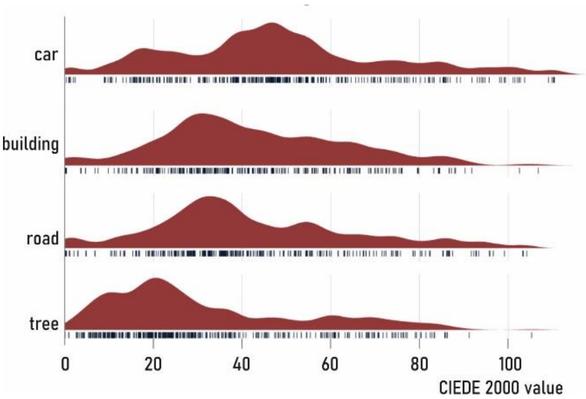

Fig. 1. Density graph of colour differences in four categories between analysed papers. The larger CIEDE2000 value, the larger difference in colour choices between papers. The black dashes below horizontal axes indicate a particular value calculated between each pair of papers.

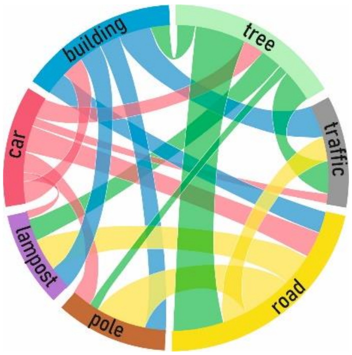

Fig 2. Large variation of CIEDE2000 in one exemplary paper depicted with large variation of ribbons' width connecting particular categories. The wider the ribbon, the more different are colors of the linked categories.

Conclusions

In conclusion, no predominant colour palette has been identified across the publications in point cloud urban environment reviewed in this study, beyond many authors using green for the tree class. Future work will focus on evaluating all mentioned classes across these publications, as well as proposing colour palettes to enhance object visualization.

Acknowledgements

This research was supported by grant RYC2022-038100-I funded by MCIN/AEI/10.13039/501100011033 and FSE+.

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https://doi.org/10.5194/ica-abs-8-5-2024 |