Visualisations of lidar data in an educational setting

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Abstract:

The ubiquity of digital technologies has profoundly changed several aspects of life: the way of working, communicating, collecting knowledge and information. However, this means that younger people are missing an overall spatial awareness because as today's generation, they have grown up with easy access to GNSS-based tools (Gould, 2021). As the teaching professions face rapidly changing demands due to the exploitation of digital technologies to encourage innovation in education (Redecker, 2017), this study investigated which visualisation method(s) of lidar data is better understood in an educational framework. Lidar (Light Detection and Ranging) is an increasingly widespread technology that determines the distance to an object using laser light. It is an active remote sensing technique that provides three-dimensional terrain data in the form of a point cloud, having an advantage over photogrammetry since there can be several returns for each pulse in wooded areas (Werbrouck *et al.*, 2011). The pulses find their way between the small open spaces of a dense canopy, allowing ground surface points to be collected (Drosos & Farmakis, 2006). By visualising the ground level points of lidar data, many characteristics of the selected area can be revealed. Developing competences for dealing with this type of information in a geographic information system (GIS) environment can thus be seen as a form of geography education, which is indispensable when training young people to be active citizens with a sense of responsibility in the present and future world.

Due to the increasing importance of spatial awareness in today's society and the even wider implementation of lidar in different industries, this study focused on the following research objective: "Which visualisation method(s) can be used best to implement lidar in an educational setting?". The focus is on education in the countries Belgium and Mexico, as a result of an already existing cooperation between the Department of Geography (Ghent University), the Mexican heritage authority (INAH) and indigenous Maya communities. In order to answer this question, an online survey was set up in two different languages: Dutch and Spanish. This was done because the involved target group consisted of pupils (third grade - science) and students (first year students - geography) from both countries. In this way, a minimum age of sixteen years old was achieved, as many of the cognitive skills of spatial thinking are acquired later in life (Perdue & Lobben, 2013).

Different spatial representations for digital terrain models are available, but to compare them all in one test is too difficult and would take too much time. Therefore, a selection of some of these methods was made, keeping in mind that the intention is to select a visualisation that is easy to understand so that lidar images can be read and used in a classroom environment (Zwartjes *et al*., 2016). The final choice of the implemented representations relies on the study by Štular *et al*. (2012) that investigates visualisation methods for lidar-derived relief models to detect archaeological features. In their survey, users with a medium to high level of expertise in lidar-related projects were asked for their preference in visualisation methods. On the one hand, it appeared that both hillshading and slope gradient were commonly used methods, on the other hand, many participants were willing to try the sky view factor in the future (Štular *et al*., 2012). Because of these results and the numerous studies in which these visualisation methods can be found, there was continued with these three methods. First of all, hillshading is the most commonly used visualisation method to represent relief. It is a description of how the relief surface reflects the incoming illumination based on the physical laws (Zakšek *et al*., 2011). Secondly, slope gradient is a visualisation method which, as the name suggests, calculates the average slope or steepness between a cell and those of its neighbours (Kokalj & Hesse, 2017). Finally, sky view factor is a technique that uses uniform, diffuse lighting. This methodology measures the proportion of the sky that is visible from a given point, but only if the elevation data are not manipulated with a vertical exaggeration (ZRC SAZU, 2019). The three visualisations were generated with a resolution of 0.50 m for two study areas: Bellewaerde Ridge (Belgium) and Yucatan South GLASS s399 (Mexico) (Figure 1). By selecting an area from each country, the test could be started with the more familiar area of the respective target group. For the evaluation of the efficiency of the images, the main focus was set on the performance of map reading. Without any prior knowledge, a number of simple, representative map-reading tasks were set up (e.g. select highest/lowest point, link relief section, ...), which all participants had to complete for each method. These data were processed together with the personal information of the participants in the next phase of the research, the statistical analysis.

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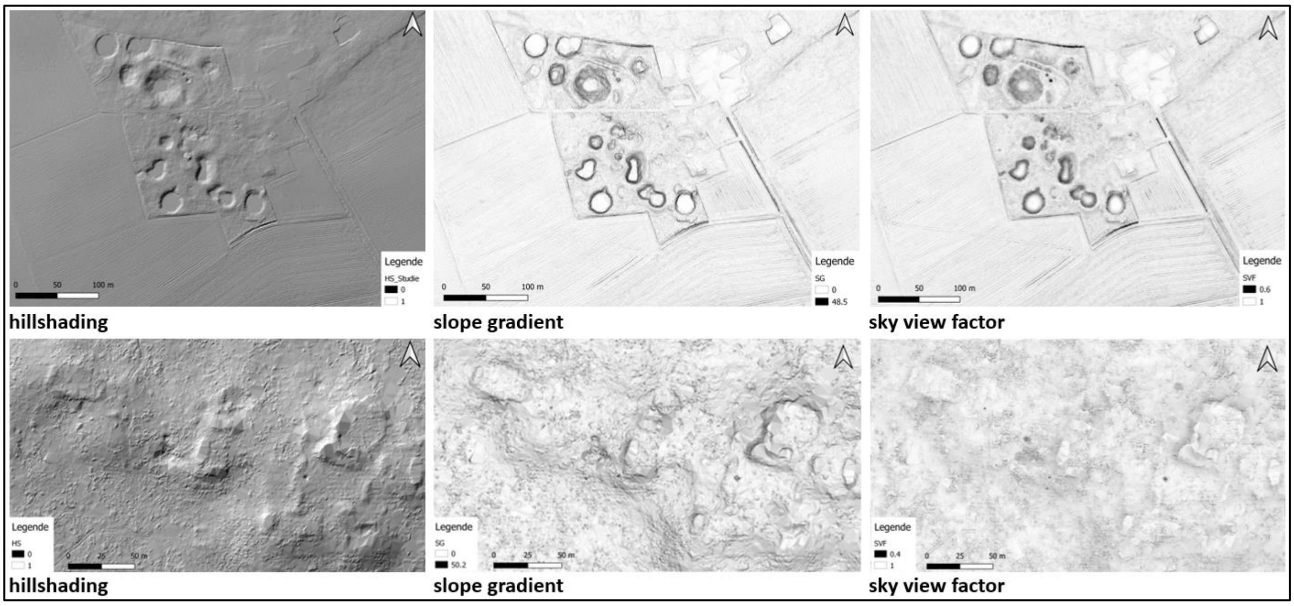

Figure 1. Different visualisation techniques showing Bellewaerde Ridge (Belgium) above and Yucatan South GLAS s399 (Mexico) below. The Bellewaerde site has a rich history as one of the most explosive front sections in Flanders, whereas the area in Mexico is characterised by borrow pits, plazas and structures.

Once the online survey was closed, the data were cleaned in the pre-processing phase before the various statistical tests were performed. This resulted in a total of 88 correctly completed tests, with the group of Mexican students eliminated due to a too small sample size. When the data were ready for further processing, it was statistically examined whether there was a best fit visualisation method for the different target groups, which factors influenced performance, did user preference differ from their performance and was there a difference between the results of the two study areas. Firstly, there could be concluded that both the pupils and the students from Belgium significantly made fewer errors with the hillshade visualisation. Nevertheless, among the Mexican students no significant differences were found. One cause of this result can be seen in the difference in education. According to the International Geographical Union (2016), the level of education can differ between several countries. In other words, some people have less access to high-quality geographical education than others (IGU UGI, 2016). Furthermore, the study by Villagrán *et al.* (2016) found that all students surveyed at the *Instituto Tecnológico Superior de Champotón* used the internet, but 54% reported that they went online for less than three hours a week. Mexico appears to have a disadvantage compared to producing countries, as the resources available online and the newest educational software are mostly of foreign origin (Villagrán *et al.*, 2016). In the end, a look at the approach of the educational crisis during the covid 19 pandemic shows that the Mexican government decided that the best way to provide education was through the use of television, looking at the country's facilities (Rivers *et al.*, 2020). Conversely, Belgium gave a boost to online education (Sleiderink, 2020). For instance, Belgians may have come into contact more quickly with hillshading, which turned out to be the best fit for them. Secondly, the statistical analysis showed that there appeared to be a significant difference in the results of the different countries. This was not the case according to gender and educational institution, which was rather remarkable. The existence of gender differences is a recurring topic of discussion when it comes to spatial skills (Lawton, 1994; Reilly, 2012), which in this case does not seem to affect the results. In addition, the same occurs with the educational institution, whereby the knowledge of students would be rated higher than that of pupils. This was not the case when we look at the average (difference of 3%), with a possible explanation found in the conditions in which the test was taken. Thirdly, hillshading proved to be the preferred method for visualising lidar data in general when the results where compared to the performance. A hillshade is therefore seen as the most natural visual impression of all the techniques according to Kokalj and Hesse (2017). Finally, a significant difference was found between the results of the two study areas. This could be explained by the research of Štular *et al.* (2012) which states that the used visualisation technique largely succeeds or fails due to the scale and form of the archaeological features observed. This is also confirmed by Hanus and Havelková (2019) who conclude that the choice of visualisation depends primarily on the characteristics of the relief sought and the general landscape forms, which are different in the case of Bellewaerde Ridge and Yucatan South GLAS s399.

Despite the fact that a considerable number of studies have attempted to evaluate the usefulness of visualisation methods, the use of lidar imagery in an educational context is still in its initial stages. Therefore, this topic requires more research into its potential and added value for scientific studies in the fight against geographical illiteracy. Subsequent research can go in many directions: what is the most effective method to integrate this in the classroom, do user preferences change in the long run, are there other visualisations than the ones tested here that could also be considered, etc. In this way, lidar data can be used in the future to develop geospatial thinking, which is considered necessary for living and working in the 21st century.

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