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Research Note

Validation of isovist variables as predictors of perceived landscape openness

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HIGHLIGHTS

- 2D-isovist radials correlate with perceived landscape openness.
- The average radial explains 90% of the variation of perceived openness.
- 2D-isovist values are credible for assessing perceived openness in landscape studies.

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ABSTRACT

This paper tests the quality of calculated 2D isovist variables as predictors of perceived landscape openness. An isovist is the calculated field of view from a given viewpoint in space. Three isovist variables were selected to estimate openness: the minimum radial, the maximum radial and the average radial. An experiment with 32 participants was conducted to compare values of these calculated variables with perceived openness. The comparison showed that two variables, the maximum radial and average radial, explained most of the variation of perceived openness for groups and individuals. The three calculated isovist variables were strongly correlated to their measured equivalents in the field, which were obtained with a binocular with a rangefinder. The isovist variables also showed strong correlations with their perceived equivalents obtained by the perception of the 32 participants, except at very long distances. This research shows that the selected isovist variables are good indicators for perceived landscape openness.

1. Introduction

Landscape openness, described by Kaplan, Kaplan, & Brown (1989) as the amount of space perceivable to the viewer, has been estimated by measuring the visible space from various viewpoints within the landscape (Bishop, 2003; Felleman, 1986; Smardon, Palmer, & Felleman, 1986). In order to measure the visible space, Tandy (1967) introduced the concept of isovists, which was further developed by Benedikt (1979), who defines a 2-D isovist as the set of all points visible from a given viewpoint in space with respect to an environment.

Only a few studies are known that actually validate such numerical and spatially explicit information to assess openness. Palmer and Lankhorst (1998) validated a model of perceived openness for a non-urban area based on landscape elements, whereas Stamps (2005a,b) validated a model of openness for an urban area based on isovists. It is, however, not clear how visible space, calculated by isovists using specific geodata, exactly relates to perceived openness in non-urban areas. Questions regarding the accuracy of calculated isovist values for long-distance views with spaces that are delimited by vegetation, and other features that influence the perception of openness need to be addressed. This research validates the effectives of using isovist variables for a quantitative description of perceived landscape openness in non-urban areas. This paper builds upon research of Weitkamp, Bregt, & Van Lammeren (2011) in which a procedure is proposed for measuring visible space to assess landscape openness.

2. Isovist calculation

Calculation of isovists in this study is based on 2-D Isovist Analyst, a GIS software program as introduced by Rana (Rana, 2002). The program calculates isovists from two input datasets: an obstacles layer, which represents the vertical landscape elements, and

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a point layer that simulates observers by observer locations. The obstacle layer is based on a Dutch topographic dataset Top10Vector, a high-resolution 1:10,000 map scale dataset (Kadaster, 2013) commonly used by institutional policy makers and planners. The obstacle layer is created by selecting the landscape elements from the dataset that are +1.6 m above ground plane level, modeling human eye level.

The point layer represents observer points. Parameters for these points are the maximum viewing distance, which corresponds to the maximum radial of the isovist, and the viewing angle, which corresponds to the radial angle of the isovist. The visible area is calculated by connecting the farthest points of each radial from the observer location into the outline of an isovist polygon per observer point. The number of radials for each observer point is determined by the increment angle in degrees between each radial.

3. Materials and methods

The experiment is conducted in an area with minimal elevation differences, and covers a wide range of degrees of openness related to configurations of vertical landscape elements and view locations. The design of the research consists of three parts. First, a selection of calculated isovist variables are compared with perceived field variables and openness. Second, the equivalent of the isovist variables are measured in the field with a binocular with a rangefinder, and compared with the perceived field variables and openness. Third, the equivalent of the isovist variables that are measured in the field are compared with the isovist variables.

3.1. Variables

We selected three variables based on previous findings on openness in scientific literature (Stamps, 2005a,b; Tveit, 2009; Van der Ham & Iding, 1971; De Veer & Burrough, 1978). Moreover, the variables should be easy detected in the field, which has been tested by three university staff members in the field. The three variables are the minimum line of sight, the maximum line of sight, and the average line of sight. The latest is strongly related to the size of the field of view, while the minimum and maximum line of sight should distinguish shapes and maximum viewing distance for each field of view. The minimum line of sight, maximum line of sight and average line of sight are the perceived field variables. Their isovist-calculated and field-measured equivalents are minimum radial, maximum radial and average radial respectively.

3.2. Viewpoint locations

The experiment should cover the full range of openness in the Netherlands. This was achieved by creating an openness classification based on isovist values for 4000 randomly selected points within the Netherlands, on average one point each 10 km^2. For each point the maximum radial and average radial were calculated. The maximum value for the maximum radial was set at 1200 m because we expected a minimal effect of landscape openness beyond this distance (De Veer & Burrough, 1978). The dispersion graph shows two main categories, one for isovists with a maximum radial of less than 1200 m ($n = 1574$), and one for isovists with a maximum radial of 1200 m ($n = 2426$). In order to cover the full range of openness in the Netherlands, we defined classes based on a combination of values of both the maximum and average radial. As class boundaries the values 250, 500, 750, 1000, and 1200 m are used. Finally, we excluded three classes containing less than 1% of the 4000 points. Thirteen classes remained, and one view location for each class was selected by the criteria of flatness of the terrain and practical requirements such as traveling time. The 13 view locations were found in the Gelderse Vallei region are shown in Fig. 1B.

3.3. Observers

Thirty-two Dutch students from Wageningen University were selected to participate in the field experiments. A few weeks before the experiments, the observers were asked to fill in an intake form with personal information such as: field of study (results ranged from molecular science to business administration), living environment until the age of 12 (results showed 41% countryside, 22% park-like, and 37% urban), living environment at present (results showed 12% countryside, 19% park-like, 69% urban), age (results: Mean ± SD: 21.5 ± 2.4), and sex (results: 59% male, 41% female).

3.4. The experiment

The experiment aims at validating isovist variables as estimators of perceived landscape openness. The main assumption was that the minimum radial, the maximum radial and the average radial of the calculated isovist are related to perceived openness. Therefore, a questionnaire was created in which we asked participants to rate preference and several indicators of landscape value. Besides openness, we asked them to rate preference, complexity, naturalness, cultural value, spaciousness, and legibility on a Likert scale from 1 (low) to 10 (high). We also asked them to estimate the minimum line of sight, the maximum line of sight and the average line of sight (in meters). The participants were not told what the objective of the experiments was, and could not relate the estimated values to openness specifically, because many other indicators were rated as well. Finally, we asked one question about the direction of the maximum line of sight, and one question about the distribution of landscape elements in foreground and background.

All 32 participants visited the 13 locations shown in Fig. 1 in the same order. Four groups of eight people each were dropped with a minibus at each view point location to fill in the questionnaire and picked up again when ready.

4. Results

We used multiple regression analysis to compute the relationship between perceived openness and the calculated isovist variables: minimum radial, maximum radial and average radial. We treated the dependent variable openness as a continuous (numerical) variable. In this case, categories in the ordinal scale were numbered consecutively and plain least-squares regression was used. This type of analysis (e.g. Hagerhall, 2001; Tveit, 2009) is commonly used when the dependent variable has a large number of categories (five or more) and is therefore treated as ratio data (Lindhagen, 1996; Torra, Domingo-Ferrer, Mateo-Sanz, & Ng, 2006).

The regression analysis resulted in two models: the first [1] with only the isovist average radial and the second [2] with two isovist variables: average radial and maximum radial. The coefficient for minimum radial was not significant, ($p < 0.01$) in both models, and was therefore excluded in both models. The correlation of model [2] ($r = 0.954$) was higher than model [1] ($r = 0.914$). In model [2] the average radial contributed more than maximum radial, according the absolute standardized coefficient 0.691 and 0.354, respectively. The low (1.66) variance inflation factor for model [2] referred to low multi-collinearity.

In general, the minimum radial did not contribute much to the model and the average radial dominates. However for individual locations the perception of openness could change in relation to the value for minimum line of sight. For example, when comparing location 11 and 13 (Fig. 1), location 13 showed a higher