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Technical note

Modelling the soundscape quality of urban waterfronts by artificial neural networks

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ABSTRACT

The renewal of the urban waterfronts has become a major focus of attention for politicians and decision makers in the city's management programs. The recognition of the patterns that define the waterfronts' identity is essential to select new strategies of intervention for the environmental recovery. In order to create adequate environments for everyday life within a sustainable development, new links between human senses, human perception and design need to be created. Within this wide approach, the landscape and the soundscape play a significant role and can become a key driving force in the implementation of the changes. New techniques have to be tested to identify the sonic and visual parameters capable to explain the specificity of a waterfront. With this purpose, an artificial neural network (ANN) was developed, and the relative importance of the input variables was evaluated. The collected database was also analysed by multiple linear regression (MLR) to compare the outcomes of both models. The urban waterfront of Naples (Italy) was chosen as case study. The results obtained show that the performance of the neural network is better than the one of the linear regression (rANN = 0.949, rMLR = 0.639). The interpretation of the relative importance method is also quite satisfactory in the ANN.

1. Introduction

Waterfront cities have a strong identity derived from the dialectical confrontation between urban and water context. The recognition of the patterns that define the waterfronts' identity is essential in building strategies aimed at the sustainable development of the coastal cities, within a maritime and urban cultures [1,2]. In this search for the sustainability, the reinterpretation of the local specificity and identity of the waterfront may be a valuable tool to establish new links with the existing urban fabric [3]. Finding this new local specificity is the starting point for enhancing the quality of the existing city in pursuit of on-going improvement to attract major events and become more competitive. In addition new standards of quality lead to reconsider the role within the urban fabric of the port facilities disused or neglected, driving the redevelopment of these underused areas by means of the creation of new landscapes [4,5].

The mentioned complexity involves that a "one size fits all" approach to the waterfronts problems is not appropriate and that new strategies are required for the recovery of the environment in a broadest sense [6].

Considering wellness and health fundamental pieces in the population balance, a sustainable development needs to establish new links between human senses, human perception and design in order to create adequate environments for everyday life [7–9].

The sonic environment of the waterfronts carries significant dynamic information of its reference sources, becoming an integrating element that provides constant meaning and coherence to the overall environment. The sounds of the water against the stones, the wind or the sea birds give sense and significance to the landscape and allow citizens to achieve an effective identification of the waterfronts environment. Therefore, the sensorial experience of the waterfronts is not complete without the complete perception of its identifier elements [2,10]. However, the perception of a sonic environment is not only influenced by the sound sources, but also by the visual elements that shape the landscape.

Within this wide context, the evaluation of the soundscape and the visual elements that influence its perception can be a powerful force in the renewal of urban open spaces applying design theories based on the human perception.

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1.1. Assessment of the visual elements shaping the landscape

The landscape ecology has been applied to urbanism only from some decades ago [11]. The landscapes were initially defined by the landscape ecology as dynamic compositions of patches with different features (size, shape, spatial configuration...) linked by means of spatial connections (corridor, stream corridors, networks...) [12]. Since these first steps, many different disciplines have applied the landscape ecology supported by specific sectorial theories to explain different phenomena.

The holistic nature of the perception has been taken forward by some approaches regarding the landscape ecology such as "Holism" and "Thinking system" theories [13,14]. "Holism" theory highlights the importance of the whole in comparison with the sum of their composing parts, and states that single landscape elements regain in significance by its context and the relation with it [14,15]. The "System thinking" theory, born within the context of the "Holism" ideas, defends the importance of the spatial relationship between the different parts that compound the landscape [16]. Within this theoretical framework, the interpretation of the human perception of a landscape can be underpinned by the establishment of links of different nature between its component parts. Thus, residential neighbourhoods, natural elements, pedestrian and road traffic areas are interrelated components able to contribute to the characterization of a place and their social, cultural or economical context [14].

The use of the aerial photograph for analysing landscapes offers the possibility to explore the relations of the parts with the whole, as well as the urban structure, through the study of the spatial relationships between different land uses. The analysis of this complex network of relationships can serve to explain how the landscapes affect the preferences for certain areas based on the holistic nature of perception [11]. On the other hand, the photos of the landscape taken in situ enable to capture not only perdurable but also dynamic situations that cannot be reflected in aerial photographs due to its two-dimensional structure.

Applied to the specificity of the historical urban waterfronts, the landscape interpretation can open up new paths to evaluate the relationship between the human perception of the landscape and the interrelation of different land uses (as the sea, the urban fabric, the singular buildings or the pedestrian areas).

1.2. Assessment of the sonic environment

Numerous definitions of soundscape can be found in literature since Schafer coined this term in the seventies [17]. In the latest years, the definition with more repercussion, stated in the ISO/DIS 12913 [18], emerges from an attempt to develop a semantic common frame for the future works of research. The ISO remarks the differences between sonic environment and soundscape. Soundscape is defined as an "acoustic environment as perceived or experienced and/or understood by a person or people, in context" [18]. From this statement, we can reach the following conclusions: on the one hand the inclusion of the perception of sound in the definition involves taking into account the complex cognitive process that intervenes in the interaction between human and its environment. Therefore, the perception of a sound environment is affected not only by the sounds, but also by what the environment evokes in the individual according to her/his set of experiences [19]. On the other hand, the sound environment plays a fundamental role not only in the behaviour of individuals, but also in the social development of groups and cultures over time [20,21].

1.3. Artificial neural networks as a tool to model soundscape perception

The artificial neural networks has been considered in literature as a tool to evaluate the soundscape, and their performance has been qualified as more accurate than the one of other methods [22,23]. However, they have only been used to obtain a good approximation among calculated values of the soundscape perception and measured values, and the contribution of each predictor in the conformation of the model has not been evaluated.

1.4. Objective

The aim of this paper is to evaluate the influence of objective acoustic and visual parameters on the perception of the sonic environment of a specific waterfront in order to define the elements that identify it. The modelling of the sonic environment perception will be made through artificial neural network. A comparison with a linear regression model was made in order to evaluate the performance of the model. The waterfront of Naples has been chosen as case study.

2. Methodology

Naples has the highest population density of Italy, with 8563 pop./km^2 [24]. Its bustling atmosphere reflects the convergence of historical, social and cultural factors that have determined the urban morphology and the singular character of its inhabitants.

The waterfront of Naples is a must-see for tourists and a place of recreation and amusement for residents. It offers a broad range of hotel establishments, restaurants, bars, as well as leisure events. As a result, the waterfront presents a high number of peculiarities that shape the local identity of the place [25].

The selected study area has an approximate length of 3 km, and a medium width of 25 m. The campaign was performed along "Francesco Caracciolo", "Partenope" and "Nazario Sauro" streets, within the districts of "Chiaia" and "S. Ferdinando" (Fig. 1). In this stretch, several sites can be distinguished by their scenic beauty and historical richness ("Castel dell'Ovo,", "Villa Comunale" park and "Fontana del Gigante") [2,26].

2.1. Field survey

Two survey campaigns were performed along the waterfront of Naples; the first one was conducted in January and February 2014, and the second one in July and August of the same year. Both campaigns were carried out in weekends and weekdays, between 10:30 and 17:00 h [26].

Face to face interviews were carried out simultaneously to sound recordings. After each interview, GPS position and panoramic photos were taken to acquire precise visual objective data. In total, 254 interviews were made in the proximities of the 10 selected sites. Among other questions, interviewees were requested to appraise the soundscape quality. The appraisals on quality were given on 7 interval Likert scale, from very poor (1) to excellent (7). Further description of the questionnaire can be found in [26].

The sonic environment in each of the selected sites was recorded binaurally (16 bits/44.1 kHz) in fixed positions through binaural headphones ("Sennheiser HDC 451") worn by the operator and connected to a portable digital audio recorder (M-Audio Microtrack 24/96). The equipment was calibrated by means of the 01-Metravib acoustic calibrator "CAL21".

The photos were taken by a Nikon D80 digital camera equipped with an objective AF-S Nikkor 18–105 mm (1:3.5–5.6G ED), set on a tripod 1.5 m above the ground. They were taken in 10-deg turn around the z axis till the completion of 360 deg, to obtain only the fix elements in the final compound panoramic photo.