Research Paper Engineering

Using of Fuzzy Set Theory to Assess Natural Parks's Beauty: the Case of Sierra De Grazalema Natural Parks

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ABSTRACT

The Sierra de Grazalema natural parks located at the South of Andalusia (Spain), is one of the most important in the provinces of Cádiz and Málaga. In the last decades, as a consequence of climatic factors, besides the increase of leisure activities, scenic quality assessment methods have been taken into consideration as a key to promote tourism activities. Hitherto, current assessment methods focus on quantitative evaluations that provide digital information to the users, although people prefer more explicit information than detailed quantitative data on scenic quality assessment. In this paper, an expert system tool is used for evaluating scenic quality through fuzzy reasoning. Results showed that physical features of Sierra de Grazalema natural parks, along with landscape design, are very important to evaluate scenic quality. This research developed a methodology of building an expert system in natural parks area.

KEYWORDS Grazalema, expert system, natural parks, fuzzy logic

INTRODUCTION

Although systematic analysis and study of scenic value began in the 1960s (Liao and Nogami, 2000), according to Bin Mao et al. (2015), scenic parks are evaluated trough several indices, which provide an assessment method to identify what types of parks are more attractive for most people. Likewise, natural parks scenic beauty might be considered a characteristic of the product "recreation opportunities", which refer to any on-site, non-profit activity meant to relax, amuse or divert the participant (Liao and Nogami, 2000). It is important for natural park managers to better understand the interactions between scenic beauty and other natural park attributes and be able to predict the expected change in scenic beauty with contemplated natural park management alternatives. Hence, before natural parks managers can make sustainable decisions, an accurate determination and evaluation of scenic beauty by human observers is needed. In this regard, Scenic Beauty Estimation (SBE), as one of the most widely and effectively used methods, was popularized over the last several decades (Daniel and Boster, 1976).

In a typical application of the SBE model, landscape areas are represented by a systematic photographic survey. These photos are presented to observers who independently rate each scene using a numeric scale from 1 to 10 (Bin Mao et al., 2015;Liao and Nogami, 2000). People's evaluation of scenic beauty is subjective, which is difficult to express with a linear relationship (Zhang et al., 2008;Liao and Nogami, 1999). For this reason, observers' perception is adjusted by the scaling procedures so that the resulting SBEs provide an unbiased measure of differences in perceived scenic beauty (Brown and Daniel, 1984). SBEs present evaluative judgments as a combined product of the observer perceptions of scenic beauty in the landscape. This characteristic, and according to Liao and Nogami (2000), makes scenic beauty one of the most difficult natural park resources to measure in an objective and scientific manner. Furthermore, a human observer's perception of a scene is actually a fuzzy set. In other words, a beautiful scene may be judged as high or low quality in fuzzy terms, which means it does not jump abruptly from 0 to 1 when this evaluation is plotted as coordinates on a graph. Furthermore, scenic beauty evaluation may also be non-linear, as shown with the nonlinear methods that attempted to achieve human-like performance in the forest SBE prediction (Bin Mao et al., 2015). The non-linear methods include genetic algorithms and neural networks in which problems are unlikely to be solved efficiently by using conventional methods (Bin Mao et al., 2015;Costa et al., 2006;Pleninger et al., 2003;Pulido et al., 2001;Liao and Nogami, 1999). From this point of view, it is obvious that the widely used SBE method has two drawbacks. The first drawback is that different SBE values are assigned when the same scene is evaluated by different observers. Furthermore, it is usually not necessary to present such detailed values to observers or natural park managers. The second drawback is the time-consuming nature of data collection, which means SBE relies heavily upon field data collection (Flynn, 1997).

Existent studies have documented improvement of the perceived scenic beauty of forest landscapes through many thinning regimes (Ribe, 2005;Tyrvainen et al., 2003;Paquet and Belanger, 1997;Hull et al., 1987;Vodak et al., 1985). However, there is no reference available for logging when the construction of landscape beauty is considered in Quercusfaginea stand. For this reason, the aim of this paper is to employ fuzzy logic theory to convert physical features in natural parks from quantities to categories, and then present the scenic beauty in fuzzy terminology. Besides, it will investigate the possibility of developing an expert system based on fuzzy reasoning to evaluate near-view scenic beauty in Sierra de Grazalema natural parks.

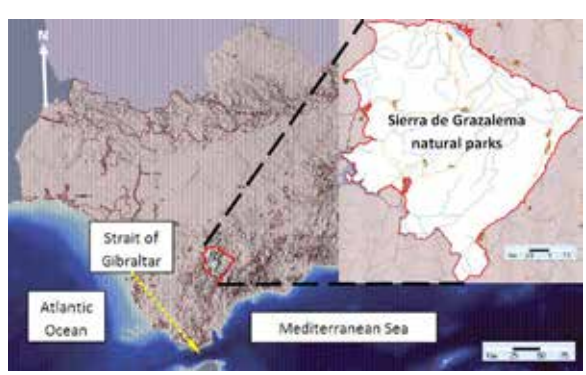

Figure 1:Location of study area.

MATERIALS AND METHOD

- **Study area**

This study was performed in the Sierra de Grazalema natural parks (Fig. 1) in Andalusia, Spain. Declared a Biosphere Reserve by Unesco, Sierra de Grazalema natural parks is located in the north east of the province of Cadiz and in the north

west of Malaga, at an altitude ranging from 250 to 1654 m above sea level.

Sierra de Grazalema natural parks covers 53411 hectares and it is among the areas of greatest ecological importance in the south of the peninsula, and therefore of great significance in Spain as a whole. It's a special protection area for birds.

It has the highest rainfall in the Iberian Peninsula, with an annual average of over 2000 liters per square meters, and is the most important western massif of the Subbetica range. Its heavy rainfall and limestone terrain have created a limestone landscape rich in slopes, grottoes, caves and winding gorges.

At present, the Sierra de Grazalema natural park is visited by residents from diverse locations with an age ranged from 38 to 42 years. It is important to evaluate their scenic beauty because the visitor numbers is very high (more than 75000 in 2014). Near-view scenic beauty evaluation is considered the most suitable approach in this case due to the geographic factors and physical features in this natural park. In this regard, Brown (1983) specifies that many studies dealing with near-view scenic beauty have focused on timber stands.

- **Data preparation**

Twenty sampling points were selected in this park. The point locations were selected to represent a wide range of physical conditions and stand types (Bo et al., 2009;Assenna et al., 2004; Terry and Michael, 2001). According to Liao and Nogami (2000), a plot center was established at each selected location. Three photographs oriented perpendicularly were taken from the center of the point. Three more photographs were taken from the road outside the stand because observers view the scene while walking along the road. Photographs were taken from the view angle of observers with 35 mm Kodak GOLD color film roll (ISO200) and a NIKON F5 camera with a 50 mm lens. Six additional pictures were taken at the same place with a digital camera (NIKON D3), although its use in the elaboration of this paper didn't contribute any significant effect because each scene was scanned and presented in tablet computer.

Physical features around each point were inventoried using point sampling techniques (Åsa Ode et al., 2010). These features include: average Diameter at Breast Height (DBH), average height of trees, number of trees/ha, basal area/ha, total volume/ha, coverage rate of shrubs, coverage rate of herbage, shade density and visibility in Sierra de Grazalema natural parks. Other geographical features such as the azimuth and the inclination of the ground were also recorded. These features were divided into three classes (low, moderate and high) based on fuzzy logic theoretical considerations of the brain's image when a scene is unusual evaluated by observers, be they experts or tourists.

In this research, a shell called ESGRANAPA is applied to develop the Expert System in Sierra de GRAzalemaNAturalPArks. This expert system was developed in the following steps (Liao and Nogami, 2000): (1) Define the goal (scenic quality evaluation); (2) Define the domain (near-view scenic beauty in natural parks); (3) Define the objects and facts about these objects; and (4) Specify the rule and their relationships.

RESULTS DISCUSSION

- **Near-view scenic beauty evaluation**

From the physical features that were inventoried in the natural parks, it was found relationships among some features. Under normal conditions, there is a positive correlation between average diameter and stand age, as well as between average height and stand age. Also, the average diameter, height and number of trees/ha contribute to increasing the basal area/ha and total volume/ha. Coverage rates of shrubs and herbage correlate to shade density and visibility in natural parks. Therefore, and according to Liao and Nogami (2000), it is not necessary to use all of those physical features to develop the expert system, reducing the huge amount of work in building a knowledge base. The knowledge of natural park scenic beauty evaluation was acquired from the judgment of experts in observing photographs. Based on the analysis results, four of those physical features, *i.e.*, stand age, coverage rate of shrubs, coverage rate of herbage and basal area/ha, which had exceedingly high influences on scenic beauty (the observer's judgment), were selected to make this evaluation.

Each photograph was presented to engineering students, 150 in total, on screen in our computer science laboratory who had participated in this natural parks investigation and scenic beauty evaluation research for years. A score between one (low scenic quality) and ten (high scenic quality) was assigned to each photograph while the combination of physical features changed. A rule base with 143 rules was built based on this questionnaire.

However the question of how to define high, medium and low remained. These linguistic values can be used as fuzzy numbers for the variable (physical feature) attributes. Fuzzy numbers are taken from Zadeh's theory of possibility (an extension of probability theory) and his idea of fuzzy sets (Schmoldt, 1991).

One natural park might be described as "high" and another one as "low". However, observers would not pay attention, for example, to the exact age. Instead they would describe the natural park stand age with a vague term such as "old" or "young". Zadeh's theory of possibility distribution was widely used to account for this vagueness. This theory uses a membership function μ_A (A represents high, medium and low) to assign a probability (also called confidence) to each measurement reflecting its degree of membership in the fuzzy subset "A". Figure 2 presents the possibility distribution (membership function) of physical features in this research.

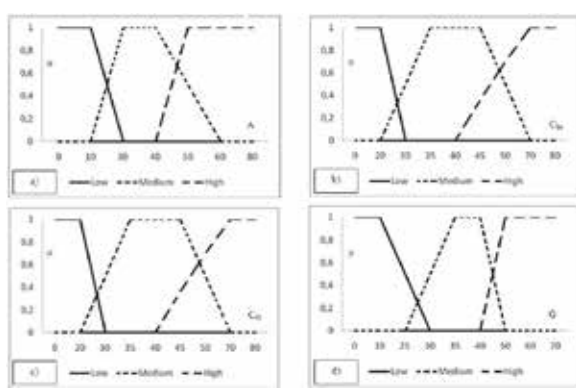

Figure 2:Fuzzy membership functions of the variables: a) A = stand age; b) C_{he} = coverage rate of herbage; c) C_{sh} = coverage of shrubs; d) G = basal area/ha.

- **Verification**

The architecture of this expert system is shown in Figure 3. The input physical features of natural parks were natural park stand age, 60 (mean value); coverage rate of herbage in the natural park, 11% (mean value); coverage rate of shrubs, 22% (mean value); and basal area/ha, 30 m^2 (mean value). In this case, the fuzzy reasoning result of scenic beauty was medium quality with fuzzy confidence of 0.874.

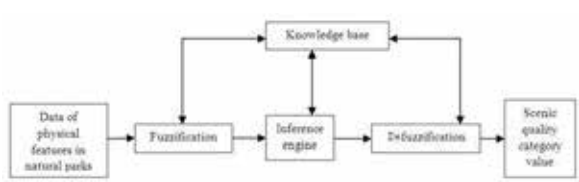

Figure 3:Architecture of ESGRANAPA expert system.

To verify this diagnostic system, it was taken a questionnaire (Rebecca et al., 2009;Ke-Tsung Han, 2003) in a parcel (75 hectares) near of the Sierra de Grazalema natural parks. The objects of questionnaire were divided into two groups-one consisted of tourists (fifty persons), also engineering students selected by random from 150 initial, and another consisted of experts (twenty persons) (Anne R. Kearney et al., 2008). The result is shown in Table 1. Since the dispersion of the data in the system which probes an individual sense like scenic beauty evaluation is large, can be considered that the result in this paper is almost satisfactory while this system is applied in the Sierra de Grazalema natural parks.

DISCUSSION

In this study, all parameters selected were found to decrease with the increasing of SBE grade. These results suggested that when enjoying individual areas in a scenic natural parks, people preferred sceneries with colorful and both very dense and varied vegetation.

This is an attempt to develop a fuzzy-based expert system in natural parks scenic beauty evaluation. As a prototype system, at least 3 significant points can be listed from this work: 1) the object of this system was the Sierra de Grazalema natural parks is extended to leisure activity and environmental protection, a new measure is necessary to judge the value of scenic beauty in natural parks. This system provides an intuitive tool for students who intend to understand the new concept of using those natural parks.; 2) this system makes it easier to evaluate the scenic beauty of these natural parks by view their physical features, and may provide useful data to plan revising.; 3) natural park management plans are generally drawn up by agricultural engineers and managers. It has, however, become increasingly clear, that suggestions of common people should be considered in management plans as multiple-use natural parks have lately become more and more important. The work of this research, using qualitative models labeled with linguistic terms, sheds light into the scenic beauty process.

CONCLUSIONS

Evaluating scenic beauty in natural parks was usually considered hard work due to the field data collection, time consuming calculations, and subjective evaluation. This research shows that it is possible to build a bridge between tourists and natural parks in developing a fuzzy-set theory based expert system. Such a system applies the collected data and the knowledge of domain experts to objectively evaluate the scenic quality in natural parks. The introduction of fuzzy logic to the expert system enables it to perform optimally with uncertain or ambiguous data and knowledge. The output from this qualitative system was a range of values (the probability distribution of some linguistic terms) and contains some explicit measure of uncertainty. It was much better than conventional systems that yielded a single numerical value without any sense for its precision. The system used in this study, can be difficult to apply it to other objects (for example, areas devastated by forest fires as happened in Lújar (Granada, Spain) in July 2015) for evaluating the ecological impact. This will be a good starting point for quantifying both economic losses from natural disasters such as to obtain the actual value of any natural landscape.

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