PROPOSAL FOR A LANDSCAPE EVALUATION SYSTEM

P. Midulla

Department of Architecture, University of Palermo, Italy - patrizia.midulla@unipa.it

KEY WORDS: landscape assessment, GIS, Mobile Mapping Technology, view, aesthetic judgement, fMRI.

ABSTRACT:

This paper describes a system, currently being designed, for both perceptual analysis and aesthetic evaluation of a landscape. The choice of this topic is motivated by the fact that systems related to landscape visibility (e.g. Geographical Information Systems (GIS) for visual impact assessment) are not fully satisfactory when it comes to assessing the aesthetic appearance. They mainly analyse geometric aspects, such as the width of visual basins or the interference of visual trajectories, which can be expressed by objective and comparable parameters. Instead, for effective landscape knowledge and protection, it is important to consider other factors that cannot be easily measured, namely the quality of human perception, i.e. the aesthetic judgements that people can express about a landscape.

Based on these considerations, a system has been designed in order to analyse the elements that can influence the aesthetic judgement of a landscape and therefore simulate the more probable aesthetic judgement. Unlike GIS generally works, this system does not use maps, but perspective views obtained by means of vehicle-mounted cameras, as in mobile mapping technology (MMT).

Research into the system described below consisted of two parts: firstly how to form the database on which the system is based and secondly how to use the system. The database contains a large number of views analysed in terms of geometric, qualitative, thematic, topological and gestalt aspects; the results of these analyses are recorded in tables and improved through a parameter expressing an aesthetic judgement. This aesthetic judgement is obtained by processing the responses of a group of participants to a sociological and/or neurological survey (i.e. Functional Magnetic Resonance Imaging). In the operational phase, a new view will be evaluated by comparison with the views stored in the database The new view will be given a judgment, obtained by processing the judgments of the most similar views.

The idea of this system applies both to the assessment of a single view and to the evaluation of territorial contexts.

Once this system has been defined, it will have to be tested through practical application.

1. INTRODUCTION

According to the European Convention, *Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors* (Council of Europe Landscape Convention, 2000). Therefore, landscape is the result of the relationships between land, environment and organisms (scientific-ecological dimension), but it really takes shape when one or more subjects look at it (aesthetic-perceptual dimension). We can also say that landscape is man's perception (Berque, 1999) of the physical-phenomenal environment, produced by multiple complex factors (Turri, 2002; Zagari, 2006) such as economy, culture, human activities, nature, anthropic elements (Council of Europe Landscape Convention, 2000). This means that human perception transforms a land into a landscape (LCA, 2002) and, since perception is conditioned by previous cultural experiences, a common denominator can be found in the aesthetic judgement of viewers who have the same cultural background, age, geographical origin, etc. (Jacobsen, 2010). Each community therefore lives and enjoys its own landscape.

Because of its complexity, the study of landscape requires equally complex methods of investigation at different scales and the contribution of several disciplines. Geography, economics, ecology, architecture, urban planning, biology, human sciences, history, art, psychology, semiology, aesthetics, law, to name but a few.

In the present research, we have chosen to focus on the perceptual aspect of landscape and, more specifically, on the aesthetic judgement a view can evoke in viewers. The aim is to go beyond the visibility analyses generally carried out using GIS, which verify what is visible from a given point of view (Marine, 2022). Nor is it considered exhaustive to confine oneself to the proposal of linking the perceived size of an object and its effect on the observer in a direct proportionality relationship, taking as variables only the position of the observer in relation to the object and the distance between them (Melis and Frongia, 2013).

As a result of these considerations, this paper describes a design for a landscape assessment system that goes beyond the simple analysis of the geometric characteristics of a view. This could provide a deeper understanding of the landscape and tools to choose appropriate solutions to protect and improve sites.

2. MOBILE MAPPING TECHNOLOGY

In mobile mapping technology (MMT), data are collected by means of cameras, video cameras, laser scanners or other types of sensors mounted on a mobile vehicle. Sensor devices are equipped with a positioning system (Global Navigation Satellite System) and an inertial attitude control platform (Inertial Measurement Unit or Inertial Navigation System) so that the captured images are geo-referenced (Schwarz, 2004; Puente et al. 2013; Elhashash et al., 2022).

This survey system has many purposes, including the generation of GIS data, digital maps, outdoor and indoor 3D modelling (Niu, 2020), digital twins (Hakdaoui, 2020), road sign recognition (Balado, 2020). It has been widely applied in various fields, such as infrastructure management, intelligent transport systems and smart cities (Qui et al., 2022).

Or, more simply, it can be used to capture georeferenced images, even as a series of photographs taken from different points of view, the number and location of which depend on the morphology of the terrain and the possibility/probability of an observer to reach them. Series of images are useful for assessing

the perception of wide environments. Indeed, a complete evaluation could be obtained as an average of the evaluations of single views captured along accessible, meaningful paths.
For these reasons, in the research described below, the acquisition from a mobile vehicle was considered to be the preferred method of collecting images to be used in a landscape assessment system, as it reflects one of the main peculiarities of a landscape, namely its change along a path. It also makes it easier to acquire a large number of images, and the more images that are collected, the more reliable the described system will be. Such images can be a single snapshot or frames extracted from a video recording (Tao, 2000). If the camera is equipped with a spherical lens, panoramic photographs can also be taken. Low resolution images are not a problem as the system does not require collimation functions.

3. VISUAL PERCEPTION

Visual perception generally involves three components: the viewer, the object being observed and the environmental context (Bishop and Karadaglis, 1996).
People perceive images through a process that begins in the eyes and is completed in the brain, where meaning is assigned. Several theories attempt to explain how this happens, i.e. how images are interpreted. Among these are cognitive and Gestalt theories.
According to cognitive theory, people interpret images by drawing on past experiences, stored in memory as simplified mental models. Context is fundamental in this process, confirming or contradicting the meaning initially assigned to the object. In some ways, landscape perception is related to cognitive theory; indeed, it is possible to speak of a cognitive landscape, i.e. a landscape experienced through mental processes (Farina et al., 2005; Bubalo, 2019).
Gestalt psychology is a school of thought founded in the early 1900s. It regards the perception of a image as an organised set of signs to be interpreted as a whole, the parts of which are not connected by simple juxtaposition or accidental proximity, but as elements linked by a relationship, such that the perception of the whole is primary to that of the parts (Wertheimer, 1945). This theory can be summarised in the following laws of perceptual organisation: a) a perceptual field is a dynamic system of individually organised shapes that tend to structure themselves; b) relationships between shapes create meaning that is immediately perceptible; c) in a perceptual field there are formal relationships between elements, such as similarity, proximity, continuity, common fate, symmetry, figure-ground, closure, past experience and *prägnanz*. Modern image segmentation software applies these gestalt principles; e) figures can be more or less complex, good and strong; good figures persist and are pregnant, i.e. they have meaning. The strength of shapes, on the other hand, depends on how easy they are to analyse, while the meaning attributed to them depends on an innate filing system of the mind. That is, the mind has laws of perceptual organisation that are common to all individuals, regardless of culture and past experience. (Geymonat, 2017).
As a result of these claims, it may be legitimate to base an assessing system on previous judgments made by a sample of viewers.
However, since Gestaltists themselves acknowledge that past experience can influence perception (see point c), and according to cognitivist theory, we believe that the evaluation of a landscape should also take into account the cultural background, age and geographical origin of the viewer.

3.1 Categories in perceptual analysis of a landscape

Due to the complexity of the landscape, it is appropriate to analyse a view according to the following categories: geometric, qualitative, thematic, topological and gestalt. Each of these has its own peculiarities and requires specific analysis.

3.1.1 Geometric categories: Geometric categories involved in the analysis of a landscape are shape, size, pattern, visual azimuth and zenith angles.
Shape and size create a hierarchy between the elements of a landscape and give the context a sense of dynamism or, alternatively, static appearance.
Pattern is a more or less regular geometric configuration created by the contours of elements. In landscape it is spatially correlated and scale dependent (Wu, 2004). Words that deal with texture are regular or irregular.
Visual angles and object sizes contribute to knowledge of visual magnitude (Iverson, 1985; Chamberlain and Meitner, 2013; Shang & Bishop, 2000), a parameter developed to estimate the sensitivity of visual perception as an interaction between distance, relative exposure to the observer and the number of potentially visible objects (Melis and Frongia, 2013).
When used in conjunction with a viewshed analysis, visual magnitude calculates the amount of space that a visible area on the landscape occupies within an observer's view (Chamberlain and Meitner, 2013). This is the visual basin, which is the part of the landscape that is visible from a given point of view. Viewshed analysis is a simplified method compared to visual magnitude, as it only provides a binary metric representing visible or non-visible (Fox, 2022). Whereas visual magnitude is calculated using the topographic characteristics of slope and angle, as well as distance relative to the observer, a standard viewshed analysis typically uses only slope and distance relative to the viewer (Chamberlain and Meitner, 2013) to calculate the area visible from a given location. This is achieved using digital terrain models or digital surface models; this capability is included in most GIS software as a common part of terrain analysis tools.
In the research described below, knowledge of the visual basins can be used at an early stage to select the points of view from which to take photographs, but it is not essential to achieve the evaluation. For this reason, only the geometric categories of shape and size will be considered below.

3.1.2 Qualitative categories: Texture and colour are qualitative categories of interest when analysing a landscape.
Image texture is a micro-distribution of tones, i.e. the local variability in digital number value (Purinton,2023) It plays an important role in computer vision applications such as object recognition, surface defect detection, pattern recognition, medical image analysis (Armi and Fekri-Ershad, 2019). As with pattern, it depends on the scale of observation, as some surfaces may have a coarse texture when viewed at a large scale, but appear smooth when viewed at a small scale. Words that deal with texture include: coarse, fine, grainy, mottled, repetitive, rough, woven, wrinkled (Bhushan et al., 1997).
Colours are how humans perceive electromagnetic radiation reflected from surfaces in the visible light spectrum. They are an essential part of a landscape; in other words, tone, contrast, brilliance and saturation can all influence how a view is perceived. As they can change under different environmental conditions, the images submitted for evaluation should preferably have been taken under the same weather conditions, at the same time of day and in the same season as the image of the database.

3.1.3 Thematic categories: Thematic categories are multidisciplinary and include data on history, population, economy, environment, toponyms, artistic and natural heritage, etc. We can say that geometric and qualitative categories are semiotic categories, while cultural categories are semantic categories. The proposed system will take into account the following thematic categories: historical, artistic and natural heritage; natural or anthropic objects.
Although the knowledge of the historical, artistic and natural heritage might not seem to be directly involved in the process of aesthetic perception, it can in fact condition the judgement of an observer.

3.1.4 Topological categories: Topological relations are used to describe the mutual spatial relationships between elements. It can be thought of as a geometric category, but whereas geometry is mainly quantitative, topology provides a formal language for qualitative mathematics. In topology, therefore, we study the relations of proximity or closeness without using distances (Snášel et al. 2017). Topology includes: connection, adjacency, separation, containment, overlap. In the system described, adjacency is taken into account. Each region contains data on adjacent regions, so that their mutual influences are taken into account. This consideration is also supported by Gestalt theory (see paragraph 3). In particular, influences between colours of adjacent regions, and categories of adjacent regions will be considered. Indeed, depending on how they are combined, they can evoke different sensations.

3.1.5 Gestalt categories: Gestalt categories, such as figure-ground and adjacency will be taken into account in the proposed system.

4. NEUROLOGICAL SURVEY

For several decades now, neurology has been studying the relationship between the perception of images and the brain, trying to understand from a physiological point of view what has always been considered an emotional response and/or an aesthetic pleasure.
In particular, studies have focused on how the brain perceives the topography of places (Aguirre et al. 1996; Aguirre et al. 1998) and reacts to the sight of a landscape, going so far as to analyse the neural mechanisms underlying aesthetic judgements. (Kawabata and Zeki, 2004; Jacobsen, 2010). For this purpose, functional Magnetic Resonance Imaging (fMRI) is often used as a valid tool. It is a neuroradiological examination that can be used to monitor which areas of the brain are activated during the performance of a particular activity (Epstein. and Kanwisher, 1998; Aguirre. et al. 1998; Kimberg et al. 2000; Zhao et al. 2020; Isik and Vessel, 2021). Research using magnetic resonance imaging has shown that the hippocampus and the medial orbitofrontal cortex are involved in aesthetic judgement. Compared to other stimuli, intense activity in these brain areas was only found when participants viewed their favourite works of art (Nadal and Pearce, 2011). In short, these brain areas are activated for images that the observers themselves judge to be beautiful, but not for images that are judged to be ugly (Kawabata and Zeki, 2004; Yue et al. 2007; Ishizu and Zeki, 2011).
For these reasons, we believe that the fMRI could be used to provide data on aesthetic judgement within the proposed system.
Neurological research differentiates between static and dynamic vision (Zhao et al. 2020; Isik and Vessel, 2021). In the following, we only refer to static vision. That is, the perception of single images.

5. ABOUT THE SYSTEM

The aim of the system is twofold: a) to assess the aesthetic judgements of a view; b) to identify which characteristics of a landscape prompt a positive response from the viewer and which generate a negative response or indifference. The results can be used to improve the usability of a landscape or to understand how to mitigate the impact of new development.
The system is currently being designed. What is described hereby is an outline of the functionality that can be implemented. Some actions will have to be performed manually, but ways to automate the whole system, including the use of artificial intelligence, are being explored.
In the operational phase, a landscape will be evaluated by comparing a new view with a database containing tables related to a large number of landscape images. The tables describe some image characteristics and are improved through an aesthetic judgement. A suitably structured query will retrieve images with similar characteristics within a given range; their judgments will then be processed to provide the judgment of a new view.
Previous research on the described system consisted of two parts: first, how to create the database; second, how to use the system in the operational phase.

5.1 Database

The implementation of the database consists of the following steps:

1. Image acquisition
2. View analysis
3. Social survey
4. Neurological survey
5. Data storage

5.1.1 Image acquisition: Landscape images used to build the database will be taken from a mobile vehicle, from viewpoints and angles that cover significant parts of the territory. Based on the morphology of the terrain, e.g. by means of a digital terrain model, the position of the viewpoints and the focal length of the camera will be chosen possibly to simulate the field of view of an observer. The images can be single shots in RGB wavelength bands (Figure 1), RGB video recordings or panoramic photographs. A mosaic of images can also be used to obtain 360° views. Deformations, if any, should be considered as having small importance considering the aim of the system. It is best to take all images at the same time of day and season to avoid temporary situations.

Figure 1. Example of a view

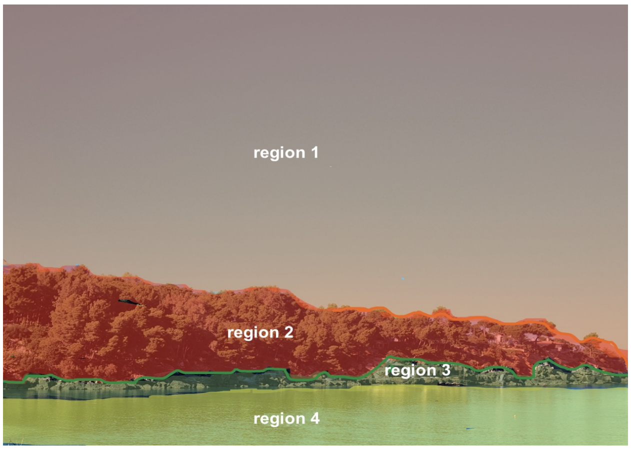

Figure 2. Example of a view segmented into regions

5.1.2 View analysis:

View analysis will be performed as follows:

- Image segmentation into homogeneous regions
- Definition of topological relationships between segmented regions
- Pattern recognition and classification
- Evaluation of the site's relevance

Segmentation divides images into non-overlapping meaningful regions according to human perception (Zhu, 2015). This can be achieved by grouping adjacent pixels with predominantly similar characteristics, such as colour, texture, brightness, etc. (Figure 2)
The evaluation of the site's relevance will be based on historical, artistic and naturalistic studies, the results of which will be converted into a number according to a predetermined scale of values.
The attributes obtained (pattern and relevance of the site) will be recorded in a table where the features are the images. The table will be related to the images.

Each region:

- Identification of categories (vegetation, buildings, sea, river, historical, artistic and natural heritage, etc.)
- Definition of shapes
- Calculation of single areas as a percentage of the whole image
- Colour quantization (RGB)
- Texture classification
- Differentiation figure-ground
- Differentiation natural or anthropic
- Colour quantization of adjacent regions
- Identification of categories of adjacent regions

The attributes obtained will be recorded in tables, where the features will be the regions. These tables will be related to the table of the images.
The knowledge of various attributes will make it possible to carry out statistical processing in order to understand which characteristics influence the aesthetic judgement of a landscape and, in turn, to improve the perception of a place. It also possible to select the attributes to be used when searching for the most similar images.

The results of the analysis will be completed with an aesthetic judgment. The judgements will be the result of a sociological and/or neurological survey carried out on a group of participants.

5.1.3 Social survey: Social survey aims to collect the judgments of a sample of participants, while viewing the images of the database. Participants will be of different ages, geographical origins and cultural backgrounds. The larger the sample of participants, the more reliable the results. Social survey can be replaced or supported by neurological survey in order to provide an objective check of the judgments.
The sociological survey will be carried out according to the following actions:

- Participants will be given time to relax and concentrate.
- While viewing the landscape images, they will be asked to evaluate each image along a set of established aesthetic dimensions.
- Participants' judgments will be processed to produce a single score for each image. It will be possible to disaggregate the results by age, cultural background, etc. as this information will have been collected in advance.

5.1.4 Neurological survey: Neurological examination will be carried out on a group of participants by means of functional magnetic resonance imaging. By observing the responses of certain areas of the brain, it can provide clues to the following classes of judgement: beautiful, ugly or indifferent (see paragraph 4).
The following actions will be carried out:

- Participants will be given time to relax and concentrate.
- Participants will be scanned by magnetic resonance imaging (fMRI) while viewing images of the landscapes. At the same time, their physiological responses, heart rate and breathing are measured.
- The results are then converted into scores and processed to produce a score for each image.

Neurological survey can be used as an objective check on sociological survey, or as a substitute for sociological survey itself. In the first case, the results of the resonance will be compared with the judgments expressed by participants, both referred to the same scale of values; then any conflicting judgments are eliminated and a score is obtained for each view. In the second case, the score of each image will be obtained by processing the results of the fMRI alone

5.1.5 Data storage: The tables related to images will be stored in the database. The database will be used for the perceptual evaluation of new views.

5.2 How to use the system

The aim of the system is to assess any landscape by comparing a new view with the views of the database. This will be achieved by means of the following steps:

- Analysing the new image using the same procedures as in the database, thus obtaining the related tables (see section 5.1.2.).
- Through a suitably structured query, extracting the views from the database whose tables best match in

terms of geometric, qualitative, thematic, topological and gestalt characteristics within a predetermined range.
- Assigning to the new view the same aesthetic score as the most similar view in the database. If several views are retrieved, their scores will be processed to provide a score.

The search can be performed by selecting one or more attributes.
A final aesthetic score will configure the perceptual landscape evaluation.

5.3 System testing.

Once the data structure has been correctly organised, the database created and the database management tools defined, the system will be verified through a field application to check the validity of the results. This could be done by evaluating a sample of new images through two different evaluation procedures: one procedure using the proposed system and one based on a sociological and/or neurological survey carried out on participants other than those involved in creating the database.
This gives two scores for each image, one simulated and one surveyed. The simulated scores are considered more valid the closer they are to the surveyed scores. The difference between the judgement values of the two classes, i.e. the class of simulated judgements and the class of detected judgements, could be processed to give a single value that could indicate the validity of the system.

6. CONCLUSIONS

The research carried out has led to the hypothesis of an aesthetic landscape assessment system. The evaluation is carried out by comparing new views with the most similar views in a database. The views are taken from a mobile vehicle.
This is currently a project. However, the likely advantages and disadvantages can be speculated.
One of the advantages is the possibility of studying which characteristics have the greatest impact on the perception of a landscape, e.g. colours, patterns, historical, artistic or natural heritage, etc. The system is easy to use once the database has been set up, while the acquisition of images from a mobile vehicle reflects one of the main peculiarities of a landscape, namely its changing views along a path. It also allows a large number of images to be taken in the same area, which is useful for assessing territorial contexts.
On the other hand, one of the critical points is the need to analyse a large number of views to create the database (the greater the number, the more reliable the results), although it should be stressed that this drawback is limited to the creation of the database, a one-off operation carried out by technicians implementing the system, without involvement of the end user. Another critical point is that some of the operations described are not currently fully automated. Finally, it should be noted that the system provides a simulated assessment. Also, it should be borne in mind that the evaluation can be affected by the viewer's characteristics and the position of the viewpoint. The first limitation can be mitigated by disaggregating the evaluations according to the age, culture, geographical origin etc. of the observers etc. The latter can be overcome by extending the analysis to whole territorial contexts, i.e. by evaluating several images well distributed over the territory of interest.

REFERENCES

Aguirre, G. K., Detre, J. A., Alsop, D. C., D'Esposito, M., 1996, The parahippocampus subserves topographical learning in man. *Cerebral Cortex* 6, 823–829. doi: 10.1093/cercor/6.6.823
Aguirre, G. K, Zarahn E, D'Esposito M., 1998. Neural components of topographical representation. *Proc Natl Acad Sci U S A*. 1998 Feb 3;95(3):839-46. doi: 10.1073/pnas.95.3.839.

Ajmar, A., Balbo, S., Boccardo, P., Piras, M., Princic, J., 2013. A Low-Cost Mobile Mapping System (LCMMS) for field data acquisition: a potential use to validate aerial/satellite building damage assessment. *International Journal of Digital Earth* (SUPPL.2), pp. 103-123.

Armi, L, Fekri-Ershad, S., 2019. Texture image analysis and texture classification methods - A review. *International Online Journal of Image Processing and Pattern Recognition* Vol. 2, No.1, pp. 1-29, 2019

Balado, J., González, E., Arias, P., Castro, D., 2020. Novel Approach to Automatic Traffic Sign Inventory Based on Mobile Mapping System Data and Deep Learning. *Remote Sens*. 2020, 12(3), 442; https://doi.org/10.3390/rs12030442

Berque, A., 1999. All'origine del paesaggio, *Lotus international*, n. 101, pag 115.

Bhushan, N, Rao, A.R., Lohse, G. L., 1997. The Texture Lexicon: Understanding the Categorization of Visual Texture Terms and Their Relationship to Texture Images. *Cognitive Science,* Volume 21, Issue 2, April–June 1997, Pages 219-246

Bishop, I. D., Karadaglis C., 1996. Use of interactive immersive visualization techniques for natural resources management. *Electronic Imaging*, 8 March 1996, Environmental Science, https://doi.org/10.1117/12.234662

Chamberlain, B.C, Meitner, M.J., 2013. A route-based visibility analysis for landscape management, *Landscape and Urban Planning*, 111(0), pp. 13-24.

Council of Europe Landscape Convention, 2000. *ETS No. 176*, Florence.

Elhashash M., Albanwan H., Qin., R., 2022. A Review of Mobile Mapping Systems: From Sensors to Applications. *Sensors* 2022, *22*(11), 4262; https://doi.org/10.3390/s22114262

Epstein, R. & Kanwisher, N. A, 1998. ùcortical representation of the local visual environment. *Nature* 392(6676), 598–601. https://doi. Org/10.1038/33402.

Fox, N., Chamberlain, B., Lindquist, M.,Van Berkel D., 2022. Understanding Landscape Aesthetics Using a Novel Viewshed Assessment of Social Media Locations Within the Troodos UNESCO Global Geopark, Cyprus. *Front. Environ. Sci., Sec. Environmental Informatics and Remote Sensing,* Volume 10 - 2022 | https://doi.org/10.3389/fenvs.2022.884115

Geymonat L., 1971. Storia del pensiero filosofico e scientifico, Garzanti.

Hakdaoui S., Emran A.,; Oumghar F., 2020. Mobile Mapping, Machine Learning and Digital Twin for Road Infrastructure Monitoring and Maintenance: Case Study of Mohammed VI Bridge in Morocco. *2020 IEEE International conference of*

Moroccan Geomatics (Morgeo), DOI: 10.1109/Morgeo49228.2020.9121882

Ishizu, T., Zeki, S., 2011. Toward a brain-based theory of beauty, *PLoSOne* 2011;6(7):e21852. Doi: 10.1371/journal.pone.0021852. Epub 2011 Jul 6

Isik A. I., Vessel E. A., 2021. From Visual Perception to Aesthetic Appeal: Brain Responses to Aesthetically Appealing Natural Landscape Movies, *Frontiers in Human Neuroscience*, 21 July 2021 Sec. Cognitive Neuroscience, https://doi.org/10.3389/fnhum.2021.676032

Iverson, W.D., 1985. And that's about the size of it: Visual magnitude as a measurement of the physical landscape. *Landscape Journal*, 4 (1), pp. 14-22.

Jacobsen, T., 2010. Beauty and the brain: culture, history and individual differences in aesthetic appreciation. *Journal of Anatomy*. 2010 Feb; 216(2): 184–191, Published online 2009 Nov 19. doi: 10.1111/j.1469-7580.2009.01164.x.

Kawabata, H., Zeki, S., 2004. Neural correlates of beauty. *Journal of Neurophysiology 91*, 1699–1705. https://doi.org/10.1152/jn.00696.2003.

Kimberg, D.Y:, Aguirre, G. K., D'Esposito, M., 2000, Modulation of task-related neural activity in task-switching: an fMRI study. *Cognitive Brai Research*, Volume 10, Issues 1-2, September 2000, pgg. 189-196.

Landscape Character Assessment – guidance for England and Scotland, (LCA) prepared on behalf of The Countryside Agency and. Scottish Natural Heritage, 2002. *https://usu.infrastructure.com*>files>download. (January 2023)

Marine, N., 2022. Landscape Assessment Methods Derived from the European Landscape Convention: Comparison of Three Spanish Cases. *Earth, 3* (2), 522-536

Melis, G. Frongia, G., 2013. Nuovi approcci per la valutazione dell'impatto visuale alla scala territoriale: dalla *viewshed analysis* all'indice di intensità percettiva potenziale. *Bollettino dell'Associazione Italiana di Cartografia,* pgg 247, 26.

Nadal, M., Pearce, M. T., 2011. The Copenhagen neuroaesthetics conference: prospects and pitfalls for an emerging field. *Brain and Cognition* 76 (1), 172–183. https://doi.org/10.1016/j.bandc.2011.01.009

Niu, X., Liu, T., Kuang J.,, Li Y., 2020. A novel position and orientation system for pedestrian indoor mobile mapping system. *IEEE Sensors Journal* – ieeexplore.ieee.org

Puente, I., González-Jorge H., Martínez-Sánchez, J., Arias, P., 2013. Review of mobile mapping and surveying technologies. *Measurement,* Volume 46, Issue , August, pgg. 2127-2145.

Purinton, B., Mueting, A., Bookhagen, B., 2023. Image Texture as Quality Indicator for Optical DEM Generation: Geomorphic Applications in the Arid Central Andes. *Remote Sensing*, 15(1), 85; https://doi.org/10.3390/rs15010085

Qiu, Z., Martínez-Sánchez, J., Brea, V. M., López P., Arias, P., 2022. Low-cost mobile mapping system solution for traffic sign segmentation using azure kinect. *International Journal of Applied Earth Observation and Geoinformation*, Volume 112, August, 102895.

Schwarz, K.P., El-Sheimy, N., 2004. Mobile mapping systems–state of the art and future trends. *ISPRS Archives*, https://www.isprs.org/proceedings/xxxv/congress/comm5/papers/652.pdf

Shang, H., Bishop, I.D., 2000. Visual thresholds for detection, recognition and visual impact in landscape settings. *Journal of Environmental Psychology*, 20, pp. 125-140.

Snášel, V., Nowaková, J., Xhafa, F., Barolli L., 2017. Geometrical and topological approaches to Big Data. *Future Generation Computer Systems,* Volume 67, February, Pages 286-296

Tao V. C., 2000. Mobile Mapping Technology for Road Network Data Acquisition, *Journal of Geospatial Engineering*, Vol. 2, No.2, pp. 1-13.

Turri, E., 2002. La conoscenza del territorio. Metodologia per un'analisi storico-geografica. Marsilio, Venezia.

Wertheimer, M., 1945. Productive Thinking, ed. V. Sarris 2020.

Wu, J., 2004. Effects of changing scale on landscape pattern analysis: scaling relations. *Landscape Ecology* 19: 125–138.

Yue, X., Vessel, E., Biederman, I., 2007. The neural basis of scene preferences. *NeuroReport* 18, 525–529. doi: 10.1097/WNR.0b013e328091c1f9.

Zagari, F, 2006. Questo è paesaggio, 48 definizioni, ed. Mancosu, Roma.

Zhao, X., Wang J., Li, J., Luo, G., Li, T., Chatterjee, A., Zhang, W., He, X. 2020. The neural mechanism of aesthetic judgments of dynamic landscapes: an fMRI study. *Scientifc Reports* 10:20774, https://doi.org/10.1038/s41598-020-77658-y

Zhu, H., Meng, F., Cai, J., Lu S., 2015. Beyond Pixels: A Comprehensive Survey from Bottom-up to Semantic Image Segmentation and Cosegmentation. *arXiv:1502.00717v1* [cs.CV] 3 Feb.