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LandRate toolbox: an adaptable tool for eye movement analysis and landscape rating

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Abstract. The paper presents a new software tool called LandRate toolbox. The toolbox constitutes an extension of EyeMMV toolbox and supports the generation of a full analysis report based on experimental data collected through eye tracking methods. Additionally, a new aggregated index (LRI), appropriate for the performance of landscape rating procedures, is introduced. The index combines both quantitative eye tracking metrics and experts' opinions while it can be easily adapted in similar fields.

Keywords. Landscape perception, Eye movement analysis software, Landscape rating

1. Introduction and related work

Understanding how landscape is perceived constitutes a complicated process. Making evaluative judgments about the landscape is an even more challenging endeavor, yet crucial for land use policy and landscape planning. Eye movement analysis has been implemented to gain a deeper understanding of how different landscapes (i.e. landscape photographs) affect observers' gaze patterns (Dupont et al. 2014). Further experimental work has been carried out to investigate the differential visual behaviors and responses to landscapes characterized by different urbanization degrees (Dupont et al. 2017). Besides, Dupont et al. (2016) emphasize the potential use of eye movement analysis in landscape's visual impact assessment.

Eye tracking experimentation provides the important privilege of objectively recording and measuring the way human observation process occurs (Dupont et al. 2014) compared to other methods that are purely qualitative and subjective. More specifically, such experimentation can be of significant use at the perceptual/ descriptive level – that is to accurately approach the observers' visual exploration patterns. A vital step forward is to move from this descriptive towards the evaluative level. Several eye movement metrics are used to analyze the viewing behaviors and patterns and to gain more useful information about the influence of different landscapes on these patterns. Such metrics are revealed by recent literature in the research field (e.g. fixation duration, saccade amplitude etc.) (Dupont et al. 2014). Furthermore, Kiefer et al. (2017) mention that the need for more sophisticated measures is important towards the understanding of visual behavior patterns. Hence, the development of advanced metrics could serve in rating landscapes rather than merely describing or analyzing them.

Recent research work on the development of scientific tools for eye movement analysis has promoted the automated extraction and adaptation of eye tracking metrics. The majority of these tools refers to cross-platform software, which has been designed to work with several eye tracking systems. At the same time, eye tracking tools are freely distributed in the scientific community as open source projects. Such tools have been designed in order to support either well-established eye tracking metrics and visualization techniques or more specific analysis methods. Nevertheless, eye tracking analysis always constitutes a time consuming procedure, which has to be adapted to the special needs of the performed research studies. Undoubtedly, existing eye tracking tools are important platforms which support this process and provide objective measures and visualizations that are used towards the study of visual behavior patterns. Despite this fact, the interpretation of experimental results of eye tracking landscape studies requires the development of integrated methodological approaches, which combine objective measures with expert judgment procedures.

The present paper aims to deliver a new software tool, LandRate toolbox, appropriate for the analysis of eye tracking experimental results. The LandRate toolbox has been designed to export a full eye tracking analysis report based on the computation of well-established metrics and relative visualizations. Additionally, the toolbox supports the computation of a new aggregated index for landscape rating which combines metrics derived from the observation of landscape photographs and expert judgment procedures.

2. LandRate toolbox development

2.1. Toolbox function and capabilities

LandRate toolbox has been designed to support the automatic production of a full analysis report based on experimental data collected through eye tracking methods. More specifically, the presented toolbox has been developed using the scripting language of MATLAB from MathWorks® and constitutes an extension of EyeMMY toolbox (Krassanakis et al. 2014). It is worth mentioning that the development of the toolbox in MATLAB environment allows the execution of LandRate in different operating systems (Windows, MacOS, and Linux). The execution of the toolbox is completed just in one simple step that requires from user to import the experimental raw data and the related parameters. These parameters include the list of visual stimuli, the list of areas of interest (AOIs), the selected parameters for the fixation detection algorithm and for the generation of heatmap visualizations, the parameters of the eye tracker coordinate system (LandRate toolbox can be adapted to every coordinate system, and hence it is compatible with every eye tracker), the weights for the computation of LRI (see section 2.2), and a file name where the final report of the toolbox can be stored. The detection of fixation events is performed through the implementation of EyeMMV's algorithm, which is based on a two-step spatial dispersion threshold and minimum fixation duration (see Krassanakis et al. 2014).

The delivered report of the toolbox involves a full analysis of eye tracking metrics per subject, stimulus, and AOI. For each combination of subjects and stimuli several metrics pertaining to: fixations (total number, minimum, maximum, average and total number of duration, complete list with spatiotemporal coordinates), saccades (total number, minimum, maximum, average and total number of duration, minimum, maximum, and average saccade amplitude and direction angle, and complete saccade list) and scanpaths (length, total duration, saccades and fixations durations ratio) are computed. Additionally, the scanpath on each experimental stimulus for each subject, as well as heatmap visualizations for all stimuli (based on the data of all subjects) are produced (*Figure 1*). Moreover, since the delineation of AOIs constitutes an important process in landscape perception research based on eye tracking techniques (see e.g. Dupont et al. 2014), LandRate toolbox has been designed to compute specific (fixation-based) metric combinations of subject, stimulus, and AOI (*Figure 1*) including the total number, the minimum, maximum, average, the total duration, and the complete list of fixations inside or on the edge of each AOI. These metrics may constitute the basis for further indices/metrics development which can be adapted to each specific study (e.g. time to first fixation metric could be of critical importance for the examination of visual behavior during the observation of landscape photographs).

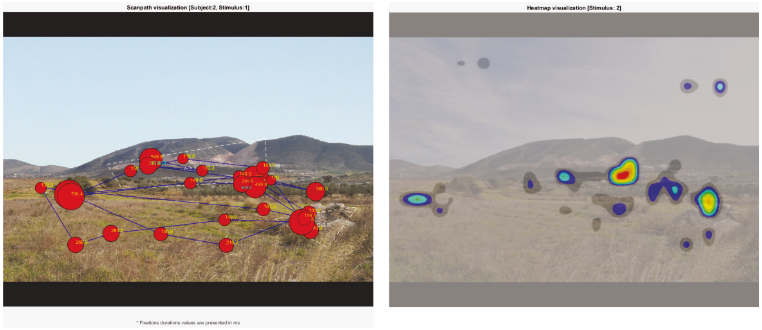

Figure 1. Examples of scanpath (left) and heatmap (right) visualizations supported by LandRate toolbox.

Except for the aforementioned metrics and visualizations, LandRate toolbox supports the computation of LRI which is used for landscape ranking process. The full description of this index is presented in section 2.2. LandRate toolbox is freely distributed to the scientific community under the third version of General Public License (GPL v.3) through github platform (https://github.com/krasvas/LandRate).

2.2. Landscape Rating Index (LRI)

Landscape Rating Index (LRI) constitutes an aggregated indicator which can combine all supported eye tracking metrics referring to a specific visual stimulus and rating weights which can be produced through expert judgment procedures. The computation of LRI is based on the following formula:

$$\mathrm{LRI} = \frac{\sum_{i=1}^{n} w_i \times m_i}{\sum_{i=1}^{n} |w_i|} = \frac{w_1}{\sum_{i=1}^{n} |w_i|} \times m_1 + \frac{w_2}{\sum_{i=1}^{n} |w_i|} \times m_2 + \ldots + \frac{w_n}{\sum_{i=1}^{n} |w_i|} \times m_n$$

where i corresponds to the number of the different metrics (m_i) and w_i to the respective weights produced by experts. Each weight expresses the rank given by an expert (or the *"representative"* rank given by a group of different experts) which indicates the contribution of each metric in the process of rating the stimuli. This means that LRI can be adapted according to the nature of the experimental stimuli and research question by considering only these metrics that are pertinent, resulting to a specific *"LRI model"* for the interpretation of the analysis results. In this way, quantitative results revealed by eye tracking data are combined with the qualitative evaluation of experts towards the computation of an integrated index. A typical example may involve the examination of visual complexity of a landscape photograph. In this example, LRI can be used in order to compare different stimuli used in the same experimental set while its computation can lead to a landscape rating expressed in arithmetic values.

In the current (first) version of LandRate toolbox, 19 metrics referring to the visual scene have been considered for the computation of LRI. The list of metrics includes the total number, the minimum, maximum, average, and total duration of fixation and saccade events, the minimum, maximum, and average saccade amplitude and direction angle, the total scanpath length and duration of scanpath, and the duration ratio of saccades and fixations of the tested stimulus. The m_i parameters correspond to the average values of metrics normalized in the range between 0 and 1 (the normalization is based on the linear model). Additionally, the weights can be expressed in any arithmetic scale while the contribution of each w_i parameter can be either negative or positive. The value of zero indicates that the corresponded metric does not affect the computation of the index. Hence, the values of LRI lie in a range between -1 and 1 and landscape ranking process is based on the comparison of these values. Moreover, it is important to mention that this comparison is reasonable to be executed only in the case of the same *"LRI model"* and experimental setup.

To provide an example of LRI model, a set of three subjects gaze data during the observation of three different mining landscape photographs is used (experimental data, parameters etc. can be downloaded through toolbox link). The model considers three selected metrics: average fixation duration (m_1), average saccade amplitude (m_2) and saccade fixation duration (m_3). It is assumed that the expert judgment hypothetical weights corresponding to the three metrics are: 5, 3 and -1, accordingly (positive/ negative values indicate positive/ negative contribution of the metric regarding the research question). The produced LRI model is: $LRI=0.556 \cdot m_1+0.333 \cdot m_2-0.111 \cdot m_3$, while the results of stimuli ranking are displayed in Table 1.

	AVG m_1	AVG m_2	AVG m_3	LRI
Stimulus 1	294.20 ms	207.67 px	0.12	0.66
Stimulus 2	325.24 ms	215.95 px	0.14	0.70
Stimulus 3	375.96 ms	192.64 px	0.10	0.78

Table 1. Results of LRI computation based on the example values. The values correspond to the average values produced by all subjects.

3. Conclusion and future research work

The development of LandRate toolbox and the implementation of LRI constitute a ground work towards the evaluation of visual behavior during landscape viewing. Additionally, despite that the motivation behind the development of the presented toolbox came from the field of landscape perception, it is also worth mentioning that this toolbox can be also serve as a generic tool for eye tracking analysis while the introduced index can be adapted in similar studies (e.g. maps and graphical user interfaces evaluation etc.).

However, the work described in the present paper is in progress. One of the most challenging issues that have to be addressed refers to the establishment of a robust methodological framework for the computation of metrics' weights. Such framework has to be connected with the research questions of the studied field while it must be based on specific criteria (e.g. negative or positive contribution of a metric in the perception of a specific stimulus). The practical implementation of the required weights computations can be based on simple (i.e. questionnaires) or more sophisticated survey methods, such as Fuzzy Cognitive Mapping (e.g. Misthos et al. 2017), that could include the opinion expressed by experts of the field. Hence, the next step of the present research work involves testing procedures using several groups of experts and data collected during the observation of several landscape stimuli. Another important prospect is the extension of the index for incorporating AOI-based metrics, further serving in landscape visual impact assessment.

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