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Eye tracking for screening design parameters in adjective-based design of yacht hull

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ABSTRACT

Adjective-based design is a method that translates human perception into design parameters quantitatively in order to achieve better understanding between designers and clients. In this approach, adjectives are used to describe product designs, which are generated via design parameters in terms of geometry. As a requirement of the concept, relations between hull adjectives (e.g., comfortable and aesthetic) and design parameters (e.g., length and width) are learned via a machine-learning algorithm. Nevertheless, the relations cannot be represented by some of the design parameters, although they are in the learning process. This issue shows that the parameters do not impact the adjective choices but add noises to the learning process. Therefore, in this study, visual evaluations are made using eye tracking technology for screening the parameters based on their attractiveness and establishing relations between the attractive ones and the adjectives to enhance quality of the relation representations. Eye tracking is used in perceptual research, which proves the existence of correlations between gaze data and human preferences. The main advantage of eye tracking is that reliable human perception data can more likely be collected compared to the user tests, since the evaluation is based on subjects' attention rather than applying solely questionnaires that are limited by the question content. In light of the benefits and finding, an eye tracking device is used to collect gaze data, and then, eye tracking tools such as Area of Interest (AOI), scan path, and heat map are used to evaluate attractiveness of the design parameters. Finally, regression analysis is used to represent relations between gaze data of design parameters and the adjectives.

1. Introduction

1.1. Adjective-based design

Product performance and qualities are not solely good enough criteria for clients as the market competition has already made them compulsory. For products with high quality and good performance, design is highly important for clients to make the final decision (Creusen and Schoormans, 2005) (Yamamoto and Lambert, 1994). However, this criterion is not a clear target to be reached and is measured through client satisfaction, which is highly related to human feelings; therefore, it is difficult to forecast this criterion beforehand. Dogan and Gunpinar (2017) proposed the adjective-based design method, which quantizes human feelings and represents them as relations between adjectives (e.g., charismatic and modern) and design parameters that are geometrically defined on products (e.g., lengths and widths). Such approach aims to provide better communication between designers and clients (Blijlevens et al., 2009). In this method, feelings about designs can be easily expressed using adjectives and their relations with design parameters are used as a guide by designers. Thus, understanding clients and appealing them can be successfully achieved in relatively short times. Dogan and Gunpinar (2017) applied the adjective-based method to yacht hulls. They first learned 10 hull adjectives using a survey method and defined design parameters on hull covering common hull features. A second survey was then applied to eliminate irrelevant parameters searching whether the modifications of these parameters affect any of the adjective choices made by the subjects. After the eliminations, the remaining design parameters were used to generate hull designs via a novel parametric design framework, which is also similar to the method proposed by Khan et al. (2017). Then, another survey was conducted, where the designed hulls were matched with the hull adjectives to create a dataset that included corresponding parameter values and the matched adjectives for each hull. Finally, a machine-learning algorithm that used neural network was fed with the dataset to represent relations between the adjectives and the design parameters as

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mathematical models. However, some design parameters' relations with the adjectives could not be established; thus, it was concluded that the design parameters did not affect the subjects' adjective choices. Such noises are caused by unrelated parameters and need to be removed to raise the quality of relation representations. In this study, it is assumed that if an appearance feature of a product does not attract subjects, the related design parameter with the feature is unattractive and irrelevant to the adjectives as well. An eye tracking device is used to evaluate the degree of attractiveness of design parameters, observing where the subjects' attention is focused.

1.2. Eye tracking system

Eye tracking, where eye movements of subjects are recorded as gaze points on given stimuli, is a commonly used method in neuroscience, psychology, computer science, industrial engineering, and marketing (Duchowski, 2002). In the eye tracking system, illuminators are used to generate near-infrared lights and images of their reflections from eyes are captured by cameras. In addition, an external processor is used to process the images to analyze the reflection patterns and generate a 3D model of the eye with its position in space. The 3D eye model is then used to calculate locations of the gaze points on relevant stimuli. Eye movements are illustrated on stimuli via fixations, which are a batch of gaze points accumulated within a predefined span in shape of circles, and saccades are displayed via straight lines that show eye movements from one fixation to another (Fig. 1 (a)). In this study, the attractiveness of target areas is analyzed through fixation locations and durations at the locations, as well as scan paths (Noton and Stark, 1971), which are combinations of fixations and saccades. Fixations are widely analyzed using the Area of Interest (AOI) tool and heat maps (Blascheck et al., 2014). Using the AOI tool, targets are surrounded with diverse shapes (Fig. 1(b)) to perform quantitative analysis with various metrics such as fixation duration and visit count. The heat map (Fig. 1(c)) represents fixation-accumulated areas based on a color scale where red indicates more attractive areas than the rest of the image. One method to examine the scan path is defining AOIs (see Fig. 1(d) for yellow rectangular shapes) on the path that needs to be searched and the transitions between the AOIs will indicate how often (frequency) the path is used.

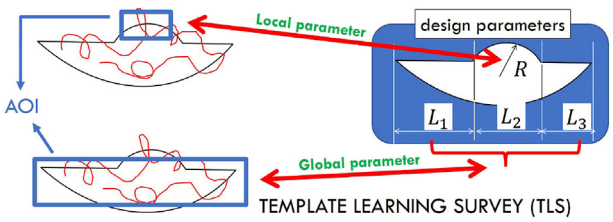


Fig. 2. Two cases to decide whether AOI will be defined on the relevant parameter or TLS will be applied to learn what the best strategy is.

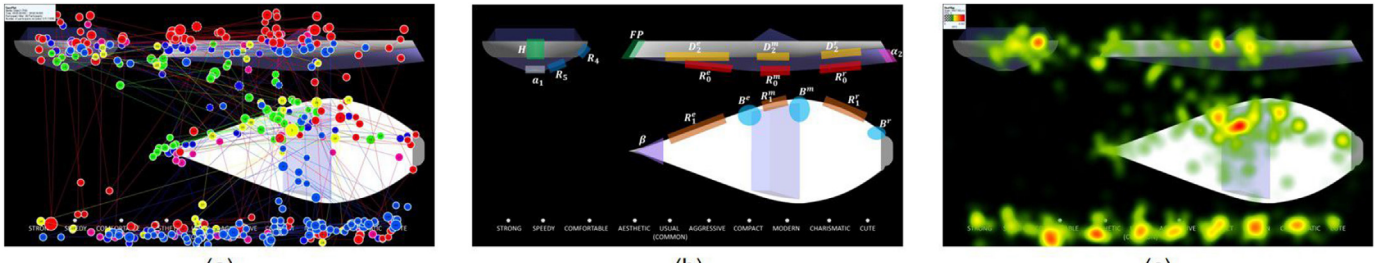
A transition matrix is also used to summarize the transitions in matrix form, as illustrated in Fig. 1(e).

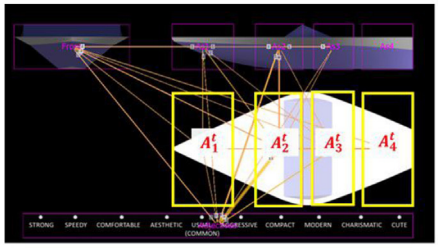
1.3. Template learning survey (TLS)

Design parameters can be classified as local and global parameters (Fig. 2) according to their impact on hull appearance. Local parameters are the ones that have full control on the target shape such as radii of feature curves. On the other hand, global design parameters affect large areas (e.g., lengths and widths) and the recorded gaze data on these areas can be found in any shape related to the search behavior of subjects. Thus, gaze points for global parameters first need to be identified according to the search behavior of subjects in order to analyze them with an appropriate strategy. To do this, a survey is used, called TLS, where all the learned identifier information for the relevant parameter is named as *template*.

1.4. Proposed approach

According to the flow of the proposed approach displayed in Fig. 3, the Eye Tracking Aided Survey (ETAS) is first applied, where participants select appropriate adjectives from a given list for the hull images and gaze points of participants are recorded. The local parameters are analyzed by defining AOIs, while the global parameters are first applied TLS to learn their templates to determine a suitable analysis method. If a template of a global parameter shows the gaze points in the shape of accumulation in a particular area, the parameter is also treated as the local parameter since it is searched locally. On the other hand, if the





AOI Group	nowhere	A_1^t	A_2^t	A_3^t	A_4^t
nowhere	120	5	19	9	5
A_1^t	0	0	10	0	0
A_2^t	0	0	22	7	0
A_3^t	0	0	0	4	3
A_4^t	0	0	0	0	0

(e)

Fig. 1. (a) Fixations are represented via circles and saccades are straight lines that connect consecutive fixations. (b) AOIs are defined via various shapes on target areas for further statistical analysis. (c) Heat map illustrates gaze point accumulations based on a color scale where red areas depict areas that receive maximum attention. (d) Scan path analysis via AOI transitions. (e) Transition matrix for scan path analysis. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)