Scanpath-Based Analysis of Objects Conspicuity in Context of Human Vision Physiology

Piotr Augustyniak, *Member, IEEE*

Abstract—**This paper discusses principal aspects of objects conspicuity investigated with use of an eyetracker and interpreted on the background of human vision physiology. Proper management of objects conspicuity is fundamental in several leading edge applications in the information society like advertisement, web design, man-machine interfacing and ergonomics. Although some common rules of human perception are applied since centuries in the art, the interest of human perception process is motivated today by the need of gather and maintain the recipient attention by putting selected messages in front of the others. Our research uses the visual tasks methodology and series of progressively modified natural images. The modifying details were attributed by their size, color and position while the scanpath-derived gaze points confirmed or not the act of perception. The statistical analysis yielded the probability of detail perception and correlations with the attributes. This probability conforms to the knowledge about the retina anatomy and perception physiology, although we use noninvasive methods only.**

I. Introduction

THE visual information plays currently principal role in many aspects of life. The concurrence of the sources and the information hierarchy build by the recipient is usually based on the conspicuity [1-2]. Therefore proper management of objects conspicuity has considerable impact in many applications including advertisement, web design, man-machine interfacing and ergonomics. The information managers need to gather and maintain the recipient visual attention by putting selected messages in front of the others. Monitors and virtual displays provide flexible arrangement of the contents making the knowledge about the perception useful in many applications [3-5]. An interesting example of perception-based visual information management is motion and still picture compression.

Our research on objects conspicuity was aimed at experimental derivation of the perception probability as a function of objects' size, color and position. Visual tasks used here are far less accurate than typical visual field mapping performed in ophthalmologist office and also inferior to the analysis of activation potentials gathered with microelectrodes from the isolated retina. Nevertheless, the visual tasks are based on natural objects, visual context and the observer curiosity manifested by spontaneous pursuit for the visual information. Thanks to this advantage, the perception is not reduced to the retina activity but it is considered in a wider aspect as a cognitive process involving parallel actions of image capture and interpretation [6-8]. Such approach is particularly interesting for advertisers, web designers and man-machine interfacing or visually impaired support, because it allows to estimate the conspicuity of a particular real object in the scene in a particular human or group without using invasive tools.

Taking into account the subjective factor of perception manifesting itself in course of visual tasks, we correlate as much as possible our results with the knowledge about perception psychophysiology [9-10].

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Author is the head of Multidisciplinary School of engineering In Biomedicine (MSIB), AGH University of Science and Technology; 30, Mickiewicza Ave., 30-059 Krakow Poland, august@agh.edu.pl

II. Materials And Methods

The visual experiment methodology assumes that the observer has the standardized initial knowledge and is motivated for the visual pursuit of completing information in restricted time. Using the analogy from automatics, the observer is the tested object, which features are represented in the response to a visual surrounding (stimulus) being the input. Therefore main part of the experiment include:

- scene preparation and stimulus attributes control,
- response acquisition and interpretation

To suppress the human factor influencing the decision of detail perception, we used the eyetracker to capture the observer response. It provides the information whether a gaze point occurred at coordinates corresponding to the displayed detail within specified time interval typical to visual reactions.

A. Scene generation and analysis procedures

The stimulus was presented to the observer as a series of 10 progressively modified images of the total duration of 8 seconds. Consecutive pictures differ by a single natural detail of increased amount of selected feature: size, distance to the display center, brightness and color in both RGB and HSL spaces. The observer was asked to detect this object.

Natural images edition was performed by the operator using a computer and graphic software and consisted in reverse-order removal of details. Natural images allow the measurement, but not the control of all image attributes. The images were not disclosed to the observer prior to the test. A challenge was repeating the visual experiment conditions in different observers without displaying sequences more than once. It was achieved by precise composition of added details attributes, consequently in different sequences very similar attributes change were measured.

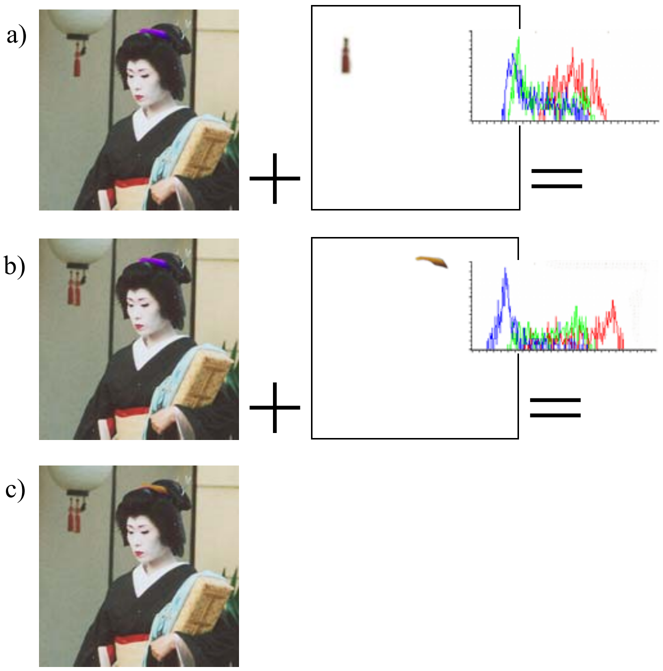

Fig. 1 Example of image sequence analysis (a to c); aiming at the estimation of color influence on details conspicuity, natural details are successively added to presented scene and the detail attributes are measured in RGB color space (only histograms are presented).

B. *Metrological principle of the eyetracker*

For detection of gaze points and confirmation of their possible dependence on the details added to the display, we used the infrared reflection-based eyetracker OBER-2 [11]. Head-mounted goggles illuminate each eyeball with four adjacent spots of total power of 5 mW/cm^2 in 80μs infrared pulses (wavelength 940nm) repeated at the sampling frequency (fig. 2). Four IR sensors per eye work in a pair wise space-differential configuration and capture two-dimensional trace of each eye at the speed up to 2000 samples per second during the presentation limited by the 32k samples data buffer. Time-differential twin sampling is used for discrimination of visible-spectrum sidelight. This technique relates the actual infrared reflection readout to the sidelight background captured ca. 80 ms before the LEDs become active. In consequence the influence of all common light sources is reduced and the device achieves the angular resolution of 0.02 deg.

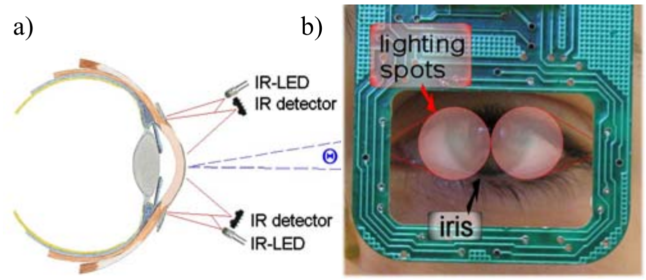

Fig. 2 Details on the Ober-2 eyetracker (a) physical principle and (b) general overview of goggles.

C. *Scanpath signal processing*

The eyetracker calibrated at the beginning of the visual task yields a continuous two-dimensional signal of two eyes position corresponding to the display coordinates. The detection of gaze points is performed automatically [12] with use of specific criteria:

- the 10 ms average eyeglobe velocity does not exceed 6 deg/s,
- the variation of the eye position is within 2,8 deg for at least 30 ms

If these criteria are not met in the first 2 s of the record, threshold values of velocity and spotting area are raised assuming that at least one gaze point occurs in the initial observation. The detection criteria are adapted independently for each eye and are expected to be simultaneously met for a successful gaze point detection (fig. 3).

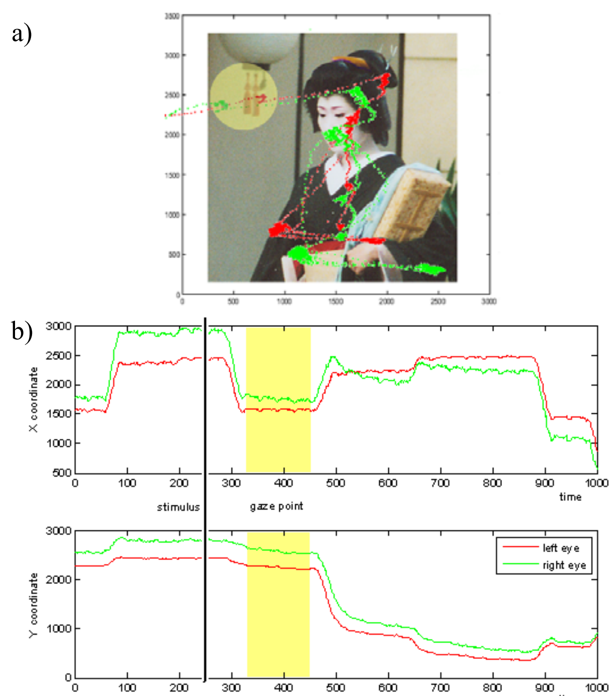

Fig. 3 Scanpath signal and gaze point detection (yellow area); (a) two dimensional plot for both eyes, (b) temporal plot for both eyes.

Each detected gaze point is validated in context of the sequence displayed as stimulus. The gaze points represent the perception of particular added detail only if both criteria of correspondence are fulfilled:

– the gaze point starts within 50 to 250 ms after the detail has been displayed,
– the gaze point position corresponds to the detail position within the tolerance margin of 2,8 deg guaranteeing the detail image is projected at the central area of the retina at least in one eye,

The use of eyetracker and automatic scanpath signal processing standardizes the detection of the perception act among the population of observers and significantly eliminates subjective errors caused by observers emotions.

D. Observer population and statistical summary

Forty-two healthy volunteers (24 males + 18 females, age 23 ± 3) were recruited for the visual tasks among of our students. Although prepared for different captivity in the subject's population, we had to reject 10 records with no successful perception. These records were manually inspected for the gaze points, but the lack of foveation caused by added details was confirmed. Other four records were rejected due to the poor cooperation of the observers (e.g. moving of the head, speaking etc.). Consequently, 28 records containing up to 5 qualified perception acts were correlated with three details attributes: size, color and position in order to reveal their contribution to the detail conspicuity.

III. Results

Two initial assumptions about the sequences of progressively modified images were first verified from the data:

1. each sequence contained 10 details, however in best case only 5 of them were spotted (average 2,2 ± 0,9), visual tasks were thus too difficult for the average observer,
2. the intended increasing conspicuity of added details was achieved and is manifested by high correlation (r–Pearson) of the detection with the image number: $r_{RGB} = 0,924$, $r_{(HS)L} = 0,922$ and $r_{size} = 0,932$.

These facts prove that although natural images were used, a nearly linear growth of conspicuity was achieved in each of the image attribute domain.

A. Conspicuity versus attributes in RGB color space

The correlation of the conspicuity with RGB color space differences was investigated first. Its components correspond to three wavelengths characteristic to photoreceptors in human retina. The regression plots are displayed in figure 4.

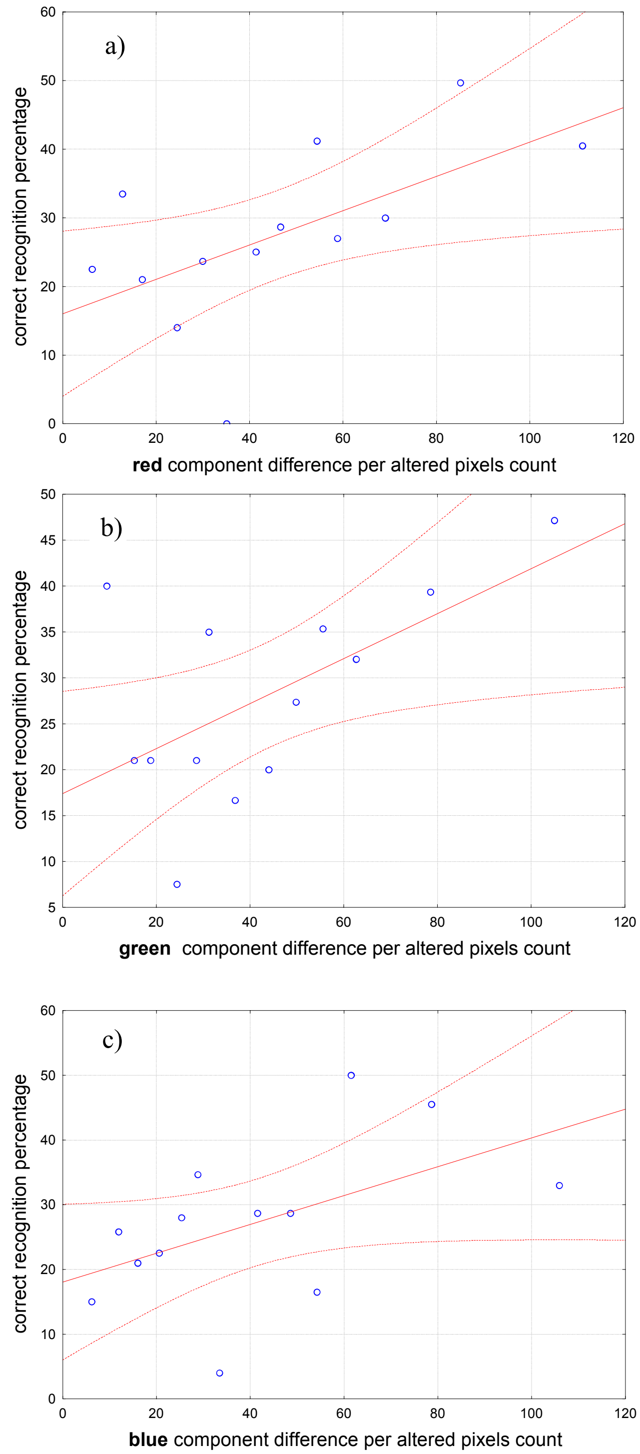

Fig. 4 Added details conspicuity in correlation with components of RGB color space (a) red component r–Pearson = **0,600**, (b) green component r–Pearson = **0,593**, (c) blue component r–Pearson = **0,519**. Dotted lines delimit the 95% confidence level.

B. Conspicuity versus detail size

Second attribute investigated as having impact to the added detail conspicuity was its size. The regression plot is displayed in figure 5.

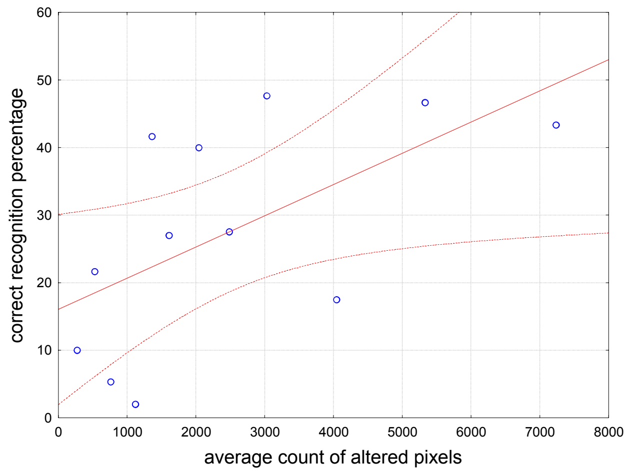

Fig. 5 Added details conspicuity in correlation with the size of the detail, r–Pearson = **0,595**. Dotted lines delimit the 95% confidence level.

C. *Conspicuity versus distance to the center*

Finally, the last investigated detail attribute was the distance from the scene center. The corresponding regression plot is displayed in figure 6.

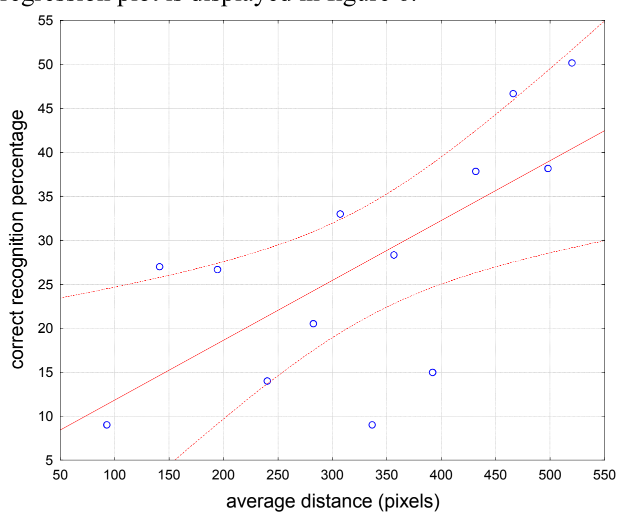

Fig. 6 Added details conspicuity in correlation with the distance to the image center, r–Pearson = **0,678**. Dotted lines delimit the 95% confidence level.

IV. Discussion

A series of visual experiments using sequences of progressively modified natural images revealed the dependence of objects' conspicuity on their attributes. The correlations for red and green components are similar and can be justified by the similar count of long-wave and middle-wave cones in the retina. The blue component does not influence the conspicuity as much as red and green, because of significantly lower count of short-wave cones. The conspicuity also grows with the object size that implies the object is projected to a larger area in the retina. However, we obtained also some unexpected results: the conspicuity growing with the distance to the image center. This could be explained partially by the dependence of the distance and the size r–Pearson = **0,547**, and partially by the dependence of the distance and the luminance r–Pearson = **0,349**. In author's opinion however, this explanation is not complete and further investigations should be made to eventually confirm and explain this relationship.

V. Conclusion

In authors' opinion, interesting results explaining the relationship of natural objects' conspicuity and their measurable attributes were achieved in the presented research. The methodology of visual tasks is relatively cheap, not invasive and can be applied for the investigations of object visibility and human perception in a wide spectrum of domains including advertisement, visual design, man-machine interfacing and ergonomics.

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