

Assessing the Performance of Quest Algorithms in Visual Experiments for Blur Discrimination Thresholds

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ABSTRACT

In this paper, Quest algorithms were employed to research the blur discrimination thresholds of human eyes on digital images. The threshold experiment was carried out with 2 images from McGill database that were blurred into 131 images with specific blurriness using a Gaussian filter. 15 observers with normal vision participated in the study. To verify the reliability of the Quest method and to make a contrast, each observer conducted threshold experiments in two different ways: one, using the general bi-directional approach (blurriness continuously changing), and two, using the Quest method (blurriness changes according to previous judgment). Data were collected on each observer and a vertical comparison of the results of the two methods was made. In 60 experiments, 52% showed that the results from the Quest method are approximately consistent with those from bi-directional approach method. Horizontal comparisons between the results of 15 observers showed that the blurriness threshold of human eyes is highly correlated to subjects, but beyond that, it is varied substantially with image contents, especially image texture. Quest method shows its efficiency and potential in dealing with accurate sensation problems in the visual threshold experiments.

KEYWORDS: blurriness, Quest algorithms, blur discrimination thresholds

INTRODUCTION

Visual perception to the blurriness of digital image is a basic subject of cognitive science, and is an important visual faculty that has been intensively researched in application fields like information and communication. High-efficiency compression methods can be developed according to human-eye blur discrimination thresholds to save resources consumed in digital image storage, display and transmission. Rony Ferzli et al. proposed a “just noticeable difference” model^[1] to establish the relations between image data and human perception, and they also presented a perceptual no-reference image sharpness metric by measuring the spread of edges^[2,3].

In this paper, a full-reference visual experiment based on Quest algorithm is introduced, observation samples are blurred images generated from standard images by using a Gaussian low-pass filter. Two images (a standard image and a blur sample) are shown on screen simultaneously. Observers judge whether the images look same/different and ultimately get a just noticeable blurriness as the observer’s discrimination threshold. To assess the performance of the Quest method, bi-directional experiments based on adjustment method are conducted.

PRINCIPLES OF METHOD

1. Quest method

Quest is a Bayesian adaptive psychometric method^[4] and it is widely used for its effectiveness in threshold estimation. The basic idea of Quest is to place each trial at the current most probable Bayesian estimate of threshold. The procedure is implemented in three steps:

(1) Specification of initial probability density function.

$$\tau) \quad \tau) \quad (1)$$

where T is the threshold in log units, A determines the amplitude of the fitted curve, B and C determine the slopes of the fall-off at high and low thresholds respectively, τ corresponds the most probable log threshold value. A, B, C in this paper are 6.29, 1.22, 5.07 respectively.

(2) A method for choosing the stimulus intensity of any trial.

A psychometric function describes the relation between some physical measure of a stimulus and the probability of a particular psychophysical response. Ours is a “2 alternative force choice” (2AFC) experiment, the psychometric function is expressed as $p(r, x, T)^{[5]}$, which represents the probability of a response, r (1 or 0), for a subject with log threshold, T , to a stimulus of log intensity, x . The psychometric function is given by

$$(2)$$

where α is the false positive rate, δ is the false negative rate, β determines the slope of the psychometric function and γ determines the threshold criterion, in this paper they are 0.5, 0.01, 3.5 and 1.5 respectively. Then the probability density function after n th response is given by

$$(3)$$

The next log stimulus intensity x_{n+1} is chosen as the one corresponding to the maximum probability.

(3) A method for choosing a final threshold estimate.

The minimum variance method is been used. The standard deviation of n th response is

$$= \sqrt{\int (T - m_n)^2 q_n(T) dT / \int q} \quad (4)$$

where m is the mean of the probability density function q). When x reaches the termination condition, in this paper is 0.055 times sample size 131, i.e. 7.205, current T is the final threshold result.

2. Bi-directional approach method

The basic idea of bi-directional approach is the same as adjustment method: observers are able to control the intensity of stimuli directly and adjust it to “just noticeable difference”. The bi-directional experiment in this paper consists of a forward adjustment experiment and a backward adjustment experiment. Observers are required to adjust the image from clear to fuzzy (forward) and then from fuzzy to clear (backward) to find out the perceptual critical image respectively as higher/lower limit of the final threshold range. Observers are allowed to adjust the stimulus intensity within a reasonable range repeatedly.

EXPERIMENT

Two experimental images are selected from the flower and the animal category of McGill database respectively, as shown in Fig.1. Original images are transferred from the RGB space via the LMS space to the DKL color space^[6], and the luminance channel images are extracted as standard images. Two standard images are blurred with the Gaussian filter. According to the Quest algorithm, 131 blurred images suitable for the visual experiment are selected as the experimental samples, and 15 observers participated using both Quest and bi-directional methods.

Gaussian low-pass filter is been used to blur the luminance channel image, it is given by

$$(5)$$

where (u, v) represents a spatial point in the frequency domain, $D(u, v)$ is the distance from the origin, σ is the standard deviation and the image sharpness increase with it. The range and interval of the σ of sample set will affect the experiment results. According to preliminary visual evaluation experiment, the appropriate sample number range is $n = [1, 131]$, corresponding to $\sigma = [385, 60]$, the interval median is $[n, \sigma] = [66, 230]$, the correspondence between the image number n and σ is as follows

$$170/66 \quad n=1, 2, 3, \dots, 131 \quad (6)$$

In our experiment, observers are required to compare two images on screen (one is the standard image and the other is a blurred sample) and find out a critical image as threshold result, it is necessary to define a parameter, B , contrary to image sharpness to describe blurriness of images when we interpret the experiment results, and the blurriness of critical image denoted as B_0 . The smaller the B_0 , the more sensitive the observer is, or the better discriminability the observer has. Blurriness is given by

$$170/66 \quad n=1, 2, 3, \dots, 131 \quad (7)$$

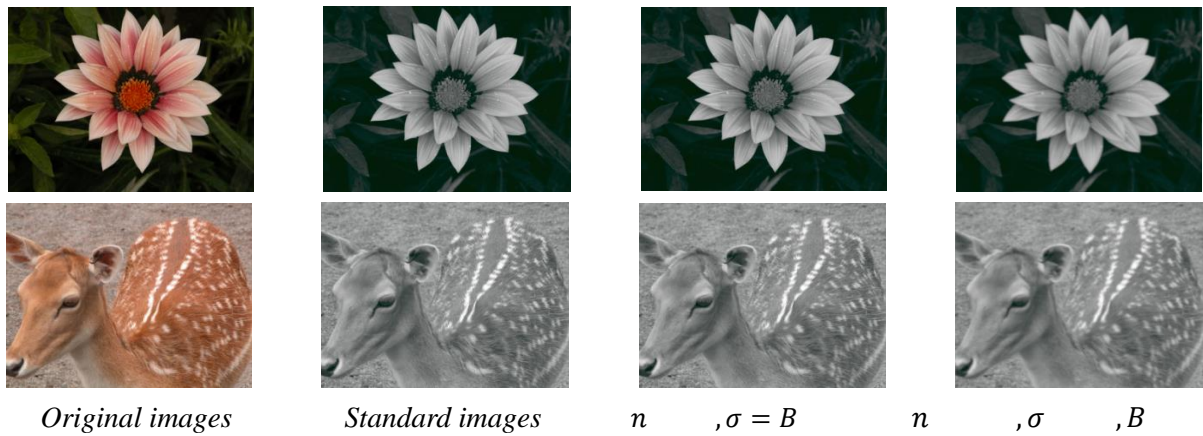


Figure 1: Experimental images.

The display used in our experiment is EIZO ColorEdge CS230(23.1 in.) with a 1928×1080 resolution, which had been color calibrated ($\Delta E = 1.0461$). The experiment was carried out in a dark, soundproof room with suitable temperature. The ambient light is created by two fluorescent lamps on the ceiling behind the screen, preventing reflected light or stray light on the screen. The experiment based on Quest algorithm and bi-directional adjustment method is programmed. The standard image and a blur sample are displayed on the screen at the same time, and all images are 768 × 576 pixels, which is consistent with the original.

In Quest experiment, by comparing whether the images automatically given by the program look same/different continually, observers can make judgments corresponding to their perception, and ultimately get a blur discrimination threshold B_0 as result. Quest experiments need to be done twice.

In the forward (or backward) experiment of bi-directional approach method, observers can scroll the mouse wheel up (or down) to increase (or decrease) the blurriness of the next image by themselves until a satisfactory threshold image is found. The final result is a threshold range determined by the blur discrimination thresholds of the forward and backward experiments.

Each observer shall perform visual evaluation experiments on the flower and the animal image, each of which is carried out in this order (with 3-minuts break in-between parts): forward and backward adjustment experiment, twice Quest experiments. After the experiment, a simple survey was performed to know each observer’s experimental experience and their focused area when making judgments on minor differences.

The experiment program recorded the image number, the σ value, corresponding judgment, the time of each judgment and the total length of the experiment automatically. 30 threshold ranges of bi-directional experiments and the 60 threshold results B_0 of Quest experiments are obtained.

RESULTS & DISCUSSION

1. Blur discrimination thresholds

The results gained from the 15 observers were compared individually. Taking observer 6 as an example (as shown in fig.2), to each image respectively, the B_0 values obtained using Quest all fell within the threshold range obtained using bi-directional method which suggests consistent results from two different experimental methods. Also shown in fig.2, the observer spent significantly less amount of time on the flower image.

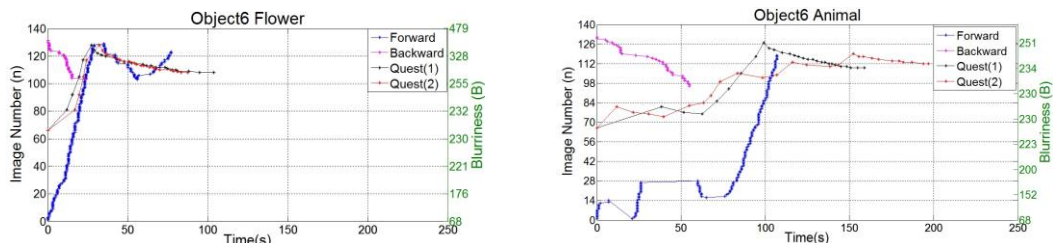


Figure 2: The change in blurriness of the two images as the experiment progresses over time. (Observer no.6)

Figure 3 displays the threshold/ B_0 results from all 15 observers. When the allowable error is 0.0425 ($\Delta\sigma=17$), consistent results are 31 in total, the coincidence rate is 52%. When the coincidence rate is 55%, the error is 0.05 ($\Delta\sigma=20$). In addition, there are 6 B_0 s (10%) significantly smaller than the lower limit of threshold range, these Quest results are stopped near the midpoint of former inflection points (where opposite judgments were made), which means the experiments are terminated reasonably, thus 10% of the Quest experiments obtained better results that are closer to perception limits than the bi-directional experiments.

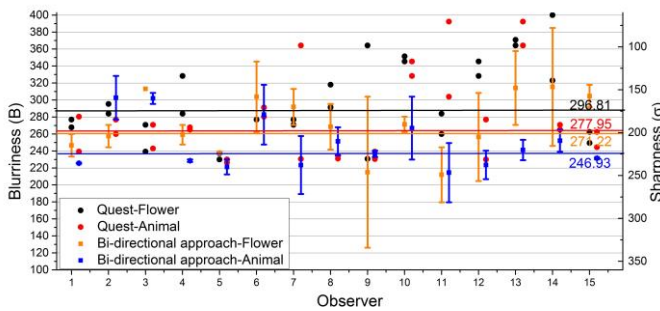


Figure 3: B_0 values of the two images obtained by using Quest and Bi-directional methods.

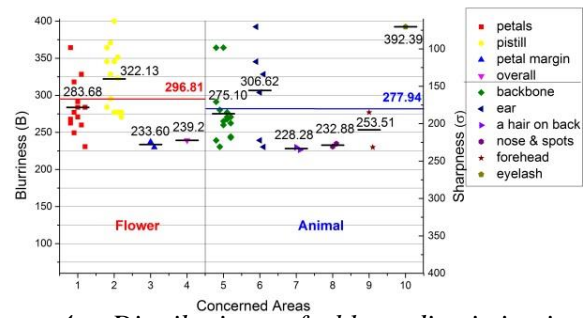


Figure 4: Distribution of blur discrimination threshold (B_0) according to varied focused areas on the two images. (with average B_0 values calculated)

2. The relationship between blur discrimination threshold and image content

As shown in fig.3, the average of the flower image is 296.81, the median of the threshold range is 271.22, the average of the animal image is 277.95, and the threshold interval is 246.93. Observers' visual acuity to the blurriness of the animal image is generally higher. For a single observer, 67% of the flower image is larger than the animal image's, while in the bi-directional experiment, the ratio is 80%. When the ratio of the Quest method reaches 80%, the corresponding error is only 0.03 ($\Delta\sigma=12$).

Through interviews with the observers, we could identify the most focused areas on the images. These are the petals, the pistil, the petals margin on the flower image (fig.4, $x=1$ to 4), and the backbone, the ear, the hair on the back, the nose, the forehead and the eyelash on the animal image (fig.4, $x=5$ to 10). The average B_0 for each area is also shown in fig.4, a larger B_0 is obtained from observers who focused on clearer areas (e.g. upper petals, backbone) while a smaller B_0 is obtained from observers who focused on more detailed areas (e.g. petals margin, a single hair). Although the blur discrimination threshold varies with subjects, the results based on the same concerned area are concentrated at the mean.

CONCLUSION

In this paper, the luminance channel of two images of the McGill database is blurred by using Gaussian filtering. Based on the parameter σ in Gaussian filter, we have defined a parameter B represents the blurriness of images. Visual evaluation experiments based on Quest algorithm and bi-directional approach are programmed and obtained blur discrimination thresholds of 15 observers. The average B_0 of the flower image is 296.81, the animal image's is 277.95, and the results of both methods are shown that the animal image's is mostly smaller than the flower image's. The results are further divided by areas of concern, which also show that human eyes have a better discriminability for images with rich texture and clear details.

Compared with the threshold range obtained by bi-directional approach method, 52% B_0 fall within the corresponding range (± 0.0425 , $\Delta\sigma=17$). Quest is single-threaded and is only 25 attempts (on average) away from determination, consuming nearly half the time of the bi-directional approach experiment.

The experimental results show that Quest is a promising way to deal with the accurate sensation problems in the visual threshold experiments, which paved the way for extensive experiments based on image classification.

REFERENCES

- [1] Ferzli R, Karam L J.2006. *Human visual system based no-reference objective image sharpness metric*, IEEE International Conference on Image Processing 2006:2949-2952.
- [2] Ferzli R, Karam L J.2007. *A no-reference objective image sharpness metric based on just-noticeable blur and probability summation*, IEEE International Conference on Image Processing 445-448
- [3] Ferzli R, Karam L J.2009. *A No-Reference Objective Image Sharpness Metric Based on the Notion of Just Noticeable Blur (JNB)*, IEEE Transactions on Image Processing 18(4) 717-728
- [4] Watson A B, Pelli D G.1983. *QUEST: A Bayesian adaptive psychometric method*, Perception & psychophysics 33(2): 113-120.
- [5] P. EWEN King-Smith, Scott S. Grigsby, Algis J. Vingrys, Susan C. Benes.1994. *Efficient and Unbiased Modifications of the QUEST Threshold Method: Theory, Simulations, Experimental Evaluation and Practical Implementation*. Vision Research 34(7) 885-912
- [6] Brainard D.H. *Cone contrast and opponent modulation color spaces*. Human Color Vision, 2nd edition. Washington DC: Optical Society of America 1996:563-579