Program for Heat-map Entropy Evaluation of Eye-tracking Data

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1. Introduction

An eye-tracker is useful equipment to record what human looks at in real time. Since the eye tracker collects x,y-coordinated data in a very short time interval, experimenters have abundant eye-tracking data from an experiment which require much time to reach an analysis result. The heat-map entropy is a measure of gaze point dispersion and requires much time to evaluate. To reduce time-consuming data processing and get faster heat-map entropy analysis, a computer software program was developed and this paper shows the development process and an used case.

2. Methods and Results

In this section Heat-map entropy is introduced and the process for the program development is described.

2.1 Heat-map and Heat-map Entropy

Eye-tracker equipment is used to record what human look at in a time and many measures, such as fixation time, gaze plot, visit sequence and so on, are automatically evaluated from collected data. Primitive data is a pair of x- and y-coordinate point on a plain. To visualize their analysis results, the heat-map which shows colored areas overlapped over the background picture (refer to Fig. 1.) is often used. Colored areas are depicted according to the visit frequency and red color means higher frequency than green.

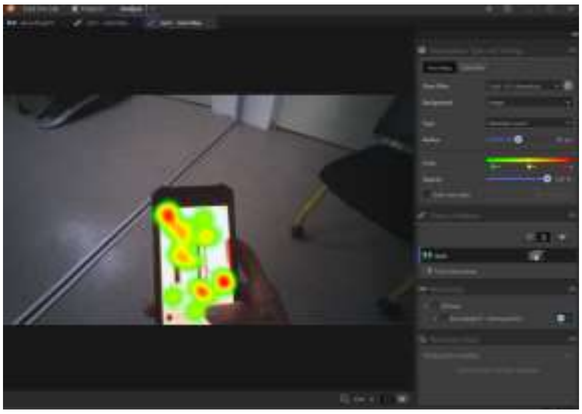

Fig. 1. An example of heat-map from eye-tracker.

The entropy obtained from eye-tracking data gives quantitative unidimensional value which is very comfortable to compare or evaluate human performance. There are two popular entropies that can be obtained from eye-tracking data: Markov entropy and Heat-map entropy. Markov entropy considers eye movements as a sequence of eye fixations so transition paths among AOIs (Area of Interest) are addressed. Heat-map entropy does not consider information about the order of eye fixations and focus on the number of visit and duration in AOIs [1].

The calculation of Heat-map entropy is based on the Gaussian mixture model (GMM) assumption on a rectangle plain space such as a computer screen. Considering a two-dimensional random variable X, Y which represent a position of fixation on a rectangle plain, the joint probability distribution of a fixation (x_f, y_f) is [2]:

$$f_{XY}(x,y) = \frac{1}{2\pi\sigma^2} exp\left(\frac{(x-x_f)^2+(y-y_f)^2}{2\sigma^2}\right) \quad (1)$$

The distribution of the total fixation map can be then represented using the GMM as

$$\tilde{f}_{XY}(x,y) = \sum_{f=1}^{f_n} \alpha_f \frac{1}{2\pi\sigma^2} exp\left(\frac{(x-x_f)^2+(y-y_f)^2}{2\sigma^2}\right) \quad (2)$$

where f_n is the number of fixations and α_f is the weight of each fixation distribution.

$$\sum_{f=1}^{f_n} \alpha_f = 1 \quad (3)$$

Finally, Heat-map entropy can be evaluated on the basis of Shannon entropy [1, 2]:

$$H = -\sum_{xy} \widetilde{f_{XY}}(x,y) log \widetilde{f_{XY}}(x,y) \quad (4)$$

2.2 Program Development

A computer software program for Heat-map entropy evaluation from eye-tracking data was developed according to a process shown as Fig. 2. Programming language is Python for windows platform and Anaconda and Jupiter are supportive tools.

The whole development process consists of two phases: data pre-processing and main analysis. Data pre-processing phase is to refine raw eye-tracking data then to verify no outliners in the data set for the further processing. At first, columns that used for entropy analysis are selected from the raw data set which has many columns such as recording duration, recording date, gaze point x, gaze point y, gaze direction toward, pupil position and diameter. Eye movement type. AOI hit, etc. For the Heat-map entropy, gaze x and y position are selected from the eye-tracking data set. Sometimes a data set can have several broken data, for instance, a missing data in a data row. In such a case the broken data rows must be eliminated to avoid wrong analysis. For the data integrity verification, all pre-processed data is plotted on a rectangle space which is same as data collection environment (refer to Fig. 3.).

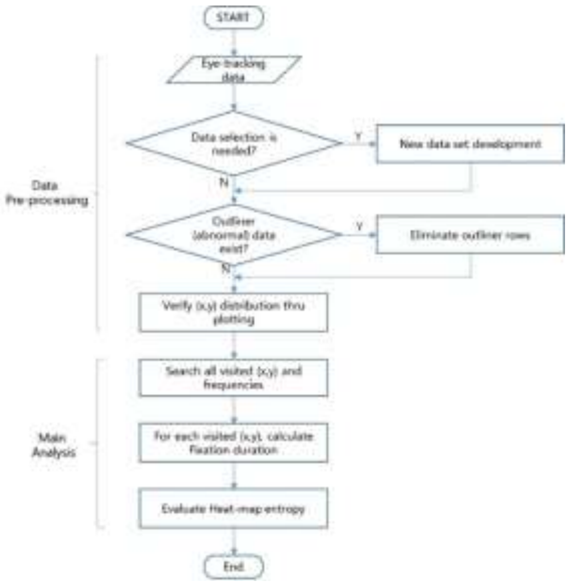

Fig. 2. Flow chart for the heat-map entropy evaluation program

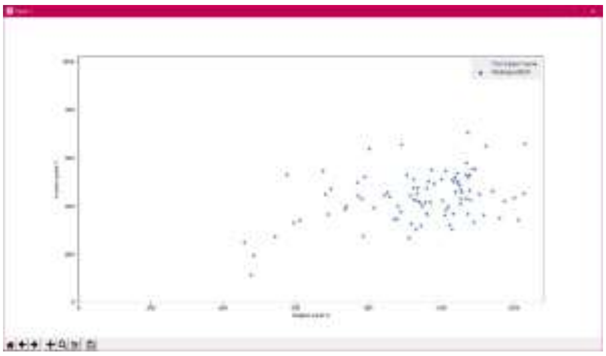

Fig. 3. Screen snapshot of a data plotting for data verification

Main analysis phase is a serial course to calculate Heat-map entropy. The process is composed of (1) counting the number of visit (frequency) for each fixation point (2) calculating fixation duration for each fixation point and then (3) evaluate Heat-map entropy for an eye-tracking data set. The developed program was to applied to evaluate Heat-map entropy from a real eye-tracking data set for a subject (refer to Fig. 4., Fig. 5.).

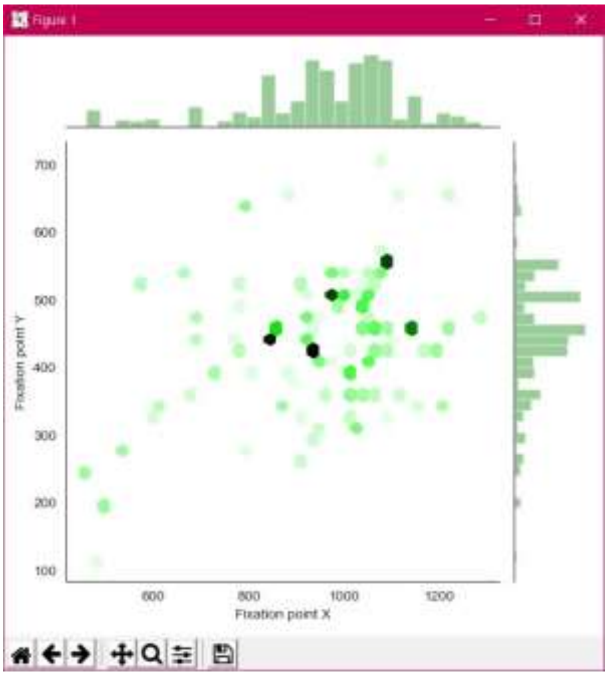

Fig. 4. Visualization for Verification of Real Data Set from a Subject

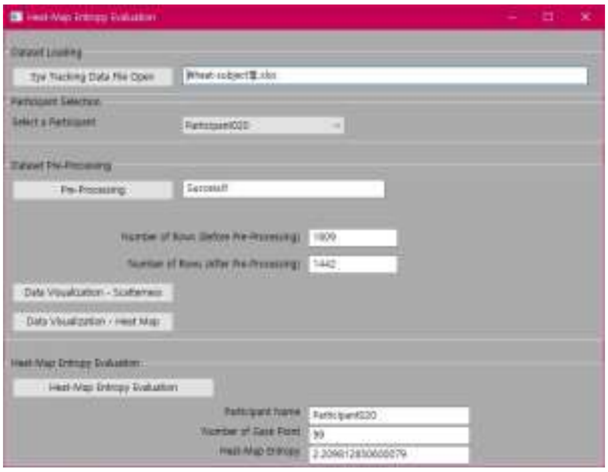

Fig. 5. Calculation of Heat-map entropy for a subject (A snapshot of Python results)

As a result, it is verified that the program produced Heat-map entropy for each subject so quickly and correctly compared with manual processing.

3. Conclusions

Heat-map entropy is a useful measure for analyzing visual attraction and attention level from an information display. Eye-tracker does not provide an automatic calculation function for Heat-map entropy so experimenters have to consume much time and resources to get entropy evaluation results. To reduce resource for analyzing Heat-map entropy and to get pretty fast results, a Python program was developed and applied to analyze real eye-tracking data set. It is verified that the program is used for entropy evaluation from eye-tracking data set.

REFERENCES

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