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Is Human Visual Activity in Simple Human-Computer Interaction Search Tasks a Lévy Flight?

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Abstract: The paper tries to answer the question regarding the nature of the statistical distribution of data gathered by eye tracking software. The experimental data regarding typical search tasks performed while using web sites were formally analysed and discussed. Results show some resemblance of the obtained experimental distributions of distance travelled to heavy tailed power-law type distributions characteristic of Lévy flights. However, the similarity is not as strong as it has been suggested by previous studies. The results of this paper may be used in further attempts of modelling human visual processing in the context of simple human-computer interfaces.

1 INTRODUCTION

Measuring and modelling human behaviour is very interesting for researchers from various fields and has been subject to intense scientific investigations. Since most data that the human being gets from the environment comes from our visual system, it is not surprising that many studies are focused on this aspect.

There has been plenty of research taking advantage of various modern technologies that allow for gathering information about how people see and how visual information is processed by our brains.

Among techniques that are relatively simple on one hand side and provides significant amount of interesting objective data are the eye tracking systems. The gathered data may be used for various types of analyses both qualitative as well as quantitative. In this paper we take advantage of the eye tracking data to examine some statistical properties of the human visual behaviour registered during search tasks performed in the context of simple human-computer interactions.

Some of the previous general studies show that the human visual activity seems to be similar to the so-called Lévy Flights. Recall that a Lévy flight is a random walk in which the step-lengths have a probability distribution that is heavy-tailed. A heavy-tailed distribution is a probability law that has tails at least heavier than exponential. Some authors require more – that the tails are at least of power-law type (see e.g. Janczura and Weron, 2012).

This idea was put forward by Brockmann and Geisel (1999) in their conference paper. Their model was experimentally verified for free scans of natural scenes presented on a computer screen.

A different model automatically generating human scanpaths in a nondeterministic way deriving from that work was proposed by Boccignone and Ferraro (2004). They combined the algorithms of providing the saliency maps with gaze shifts determined by a stochastic process with non-local transition probabilities. A random walk steps were generated according to a Lévy process distribution. The artificially obtained scanpaths were qualitatively very similar to the real eye tracking data. Also here the validation involved free visual screening tasks.

The suggestion that the human visual activity may be successfully modelled by Lévy flights or some combinations of Lévy flights and other processes appeared also in a number of other papers e.g. Stephen et al. 2009, Shinde et al. (2011), Boccignone and Ferraro (2013), Liu et al. (2013) or lately Clavelli et al. (2014).

However, it seems that the presented model might not be applicable in all situations. Stephen and Mirman (2010) focused their study on the nature of

gaze shifts statistical distribution both in single-feature search and visual world paradigm tasks. They analyzed the data individually for six participants and came to the conclusion that the visual behaviour is not purely the result of generic oculomotor dynamics but is also strongly influenced by the task being performed.

In light of these studies, the main objective of this research is to examine the visual search properties in the form of statistical empirical distributions for two types of target objects in the context of the human-computer interaction.

Two experiments were conducted for this purpose. In both, the visual activity was registered by the eye tracking system. In the first experiment participants searched for a target object in a toolbar like graphical panel. In the second study the subjects were to find a hyperlink in the web page or specified information in tabulated data.

Next sections of this work describe and discuss in detail the aforementioned eye tracking experiments.

2 METHOD

2.1 Participants

Thirty students aged between 23 and 25 years took part in the studies. They were volunteers and did not receive any gratification. None of the subjects wore eye glasses or contact lenses.

2.2 Apparatus

Examinations were conducted in a dim-lit laboratory using the Pan/Tilt version of the ASL 6000 eye tracker (Applied Science Laboratories, 2005). The system records eye position with the frequency of 60 Hz and the precision of one visual angle. Visual stimuli were presented by GazeTracker™ software as still images. The same application gathered eye tracking data sent by the ASL 6000 control unit.

2.3 Independent Variables

The study consisted of two visual search experiments concerning toolbar like panels and typical web pages.

2.3.1 Toolbar Search

In the first part of the research users searched for a target object within a set of distractors arranged in a panel similar to computer toolbars. Toolbars included 36 identical objects with letters and numbers randomly situated within the panel. We also employed a variety of target background colours to make the experimental results more diverse.

2.3.2 Web Site Search

The second part of the study was focused on searching various targets in web sites. We used popular in our country web sites in one domain namely V, X, Y and Z. These web sites had different design and layout. Similarly as in the first part of the examination also here to make the gathered data be more ecologically valid two types of typical search tasks were involved. The first one was a simple search for a given link on the typical multimedia page, and the second one dealt with finding specific information presented in a tabular way.

2.4 Dependent Measures

Temporal and spatial parameters of the visual activity gathered by the GazeTracker™ computer program, integrated with the eye tracking equipment were used as dependent measures. In this work we specifically analysed saccade lengths gaze points' shifts.

2.5 Experimental Design and Procedure

Before the experiment, participants were informed about the goal and the scope of the examination. Next, eye tracking system calibration took place. Then, subjects performed first the toolbar search tasks and after a short break, the web sites searches took place.

2.5.1 Toolbar Search

Six various colourful toolbars were examined. The within subjects design was applied, thus, the given participant tested all the graphical variants. There were two trials per condition so the participants searched the graphical panels 12 times. The toolbars were displayed in the left upper corner of the screen, and they were visible only during the visual search. The subjects were to click on the target item displayed in the instructive slide, then the appropriate panel appeared and their task was to find and select the desired object. This procedure is illustrated in Figure 1.

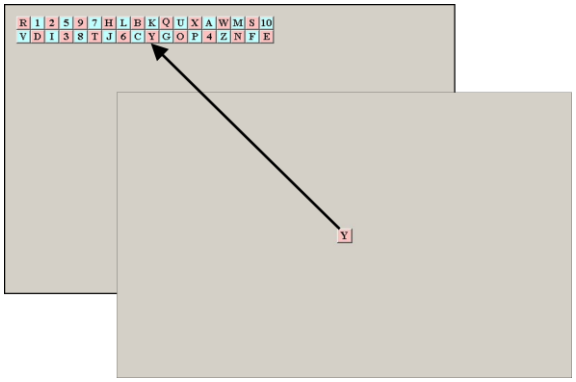

Figure 1. Toolbar visual search task.

2.5.2 Web Site Search

The web site search was repeated ten times for each participant. There were six simple visual searches and four trials of complex table searches. The tasks were presented randomly. Each participant performed all ten search tasks. Every time the instruction appeared in the middle of a screen and then, after mouse click, the tested screen was exposed. The subject was to find the target object as fast as possible and click it. Then, the next instruction was presented. The exemplary task is presented in Figure 2.

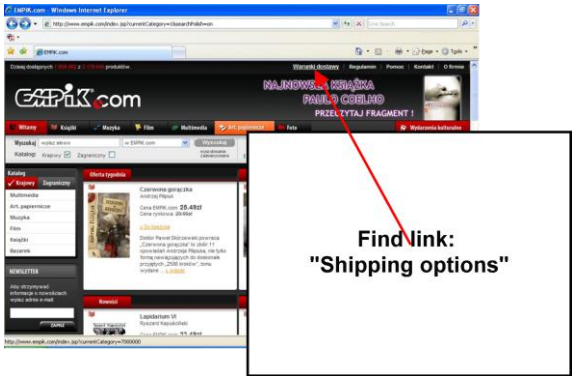

Figure 2: Web site visual search task.

3 RESULTS AND DISCUSSION

Since the main goal of this paper was to verify if eye tracking data gathered for the typical human-computer interaction search tasks come from the process akin to Lévy flights, we prepared empirical probability distributions (PDF) and cumulative probability distributions (CDF). The resulting data are illustrated in Figures 3-8.

Apart from Euclidean distances between gazepoints the graphs also contain standardized distances computed by dividing the gaze shift by the time between two gazepoints and multiplied by the average shift time for all saccades. For the comparison purposes, the figures present also the theoretical power-law and exponential curve fits. The CDFs/PDFs were elaborated separately for the graphical panel and web site search tasks and are given in Figures 3 and 4 respectively.

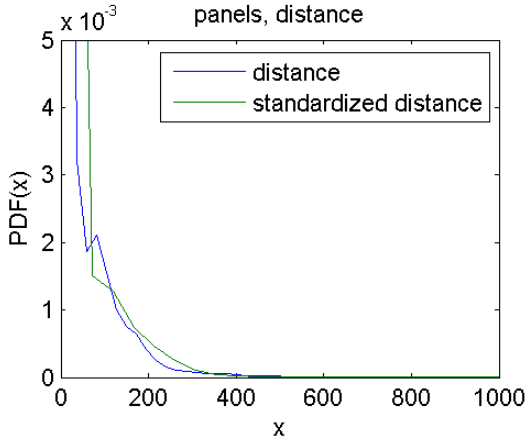

Figure 3. Empirical probability distribution of Euclidean distances between gazepoints (in pixels) for the experiment with toolbar-like panels.

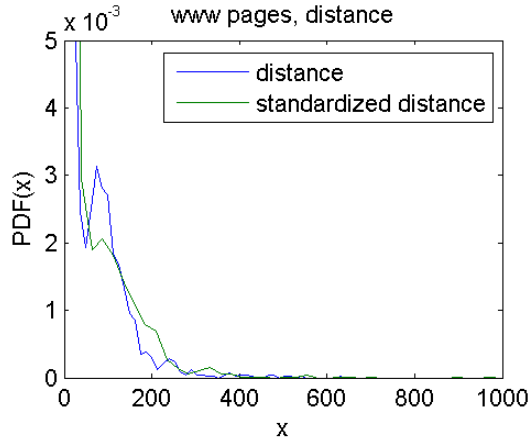

Figure 4. Empirical probability distribution of Euclidean distances between gazepoints (in pixels) for the experiment with web pages.

While analysing an empirical distribution that could exhibit heavy tails, it is convenient to plot the (right) tail of the distribution, i.e. *1 – CDF*, on a double logarithmic or a semi-logarithmic scale. If the data points constitute a straight line on the double logarithmic scale then the tail of the distribution is approximately of power-law type. On the other hand, if the data points constitute a straight line on the semi-logarithmic scale then the tail of the distribution is approximately exponential. Therefore, Figures 5 and 6 demonstrate *1 – CDFs* for both experiments and in Figures 7 and 8 the Euclidean distances between gazepoints are additionally presented on a logarithmic scale.

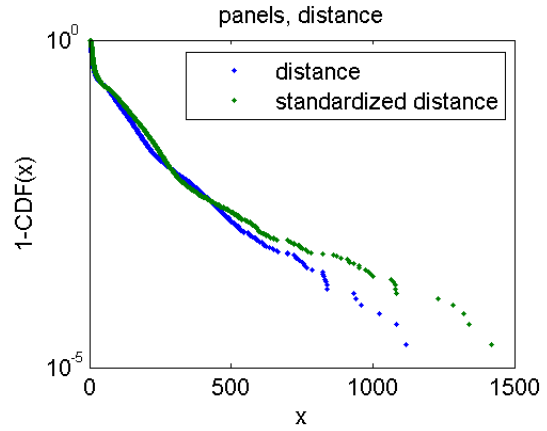

Figure 5. Right tail of the empirical cumulative distribution of Euclidean distances between gazepoints (in pixels) for the experiment with toolbar-like panels on a semi-logarithmic scale.

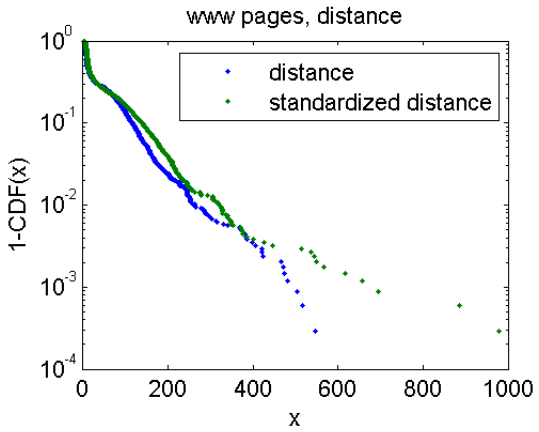

Figure 6. Right tail of the empirical cumulative distribution of Euclidean distances between gazepoints (in pixels) for the experiment with web pages on a semi-logarithmic scale.

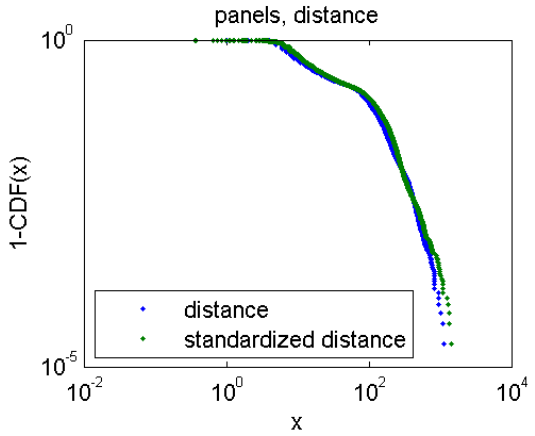

Figure 7. Right tail of the empirical cumulative distribution of Euclidean distances between gazepoints (in pixels) for the experiment with toolbar-like panels on a double logarithmic scale.

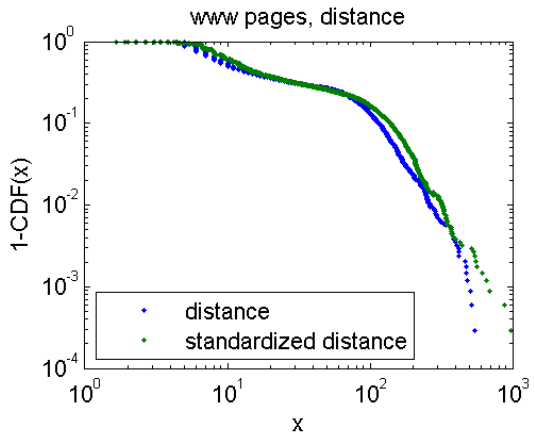

Figure 8. Right tail of the empirical cumulative distribution of Euclidean distances between gazepoints (in pixels) for the experiment with web pages on a double logarithmic scale.

The obtained plots show that the tails are almost linear on a semi-logarithmic scale for the web pages search tasks and only slightly heavier than linear for the toolbar-like panel searches. In general, the obtained empirical distributions have tails that are not heavy enough to come from a power-law type distribution. Thus, these findings rather do not allow for comparing the registered human visual activity to Lévy flights.

4 CONCLUSIONS

In general, the obtained empirical distributions do not fully reflect the distributions characteristic of Lévy flights. On the other hand, results and simulation studies of previous papers (Brockmann & Geisel, 1999; Boccignone and Ferraro, 2004) quite convincingly support the hypothesis that the human visual activity is to some degree similar to Lévy flights. Thus, one may suggest that the people may flexibly adapt their visual activity - intentionally or unconsciously - to the existing needs. Presumably, there does not exist any single process that would be appropriate for modelling eye balls behaviour in all situations.

The obtained results seem to be in concordance with the findings of Stephen & Mirman (2010) where the distributions gathered for various viewing conditions for six individuals were considerably different.

The presented data give some more insight into the nature of human visual behaviour in a specific context. Answering the question whether and in what circumstances the human visual behaviour can be modelled by Lévy flights may be helpful in the further development of models from the Human-Computer Interactions field trying to imitate the human visual activity such as ACT-R (Anderson et al. 1997) or EMMA (Salvucci, 2001).

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