Mode of Disparities Error Correction of Eye Tracking Data

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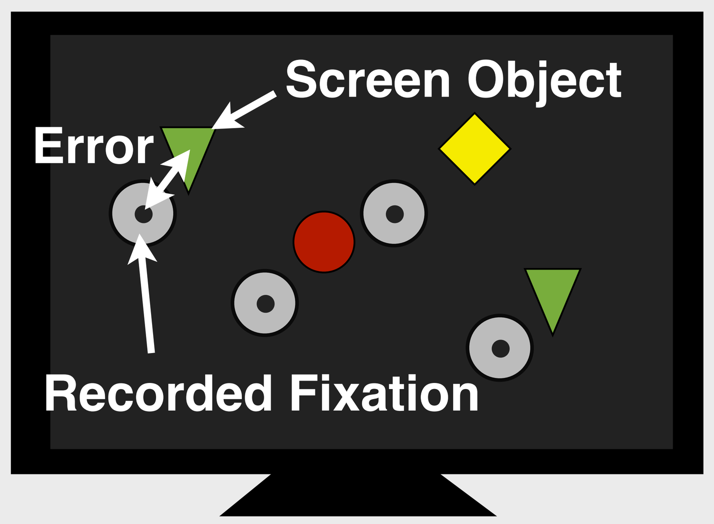
1. Introduction

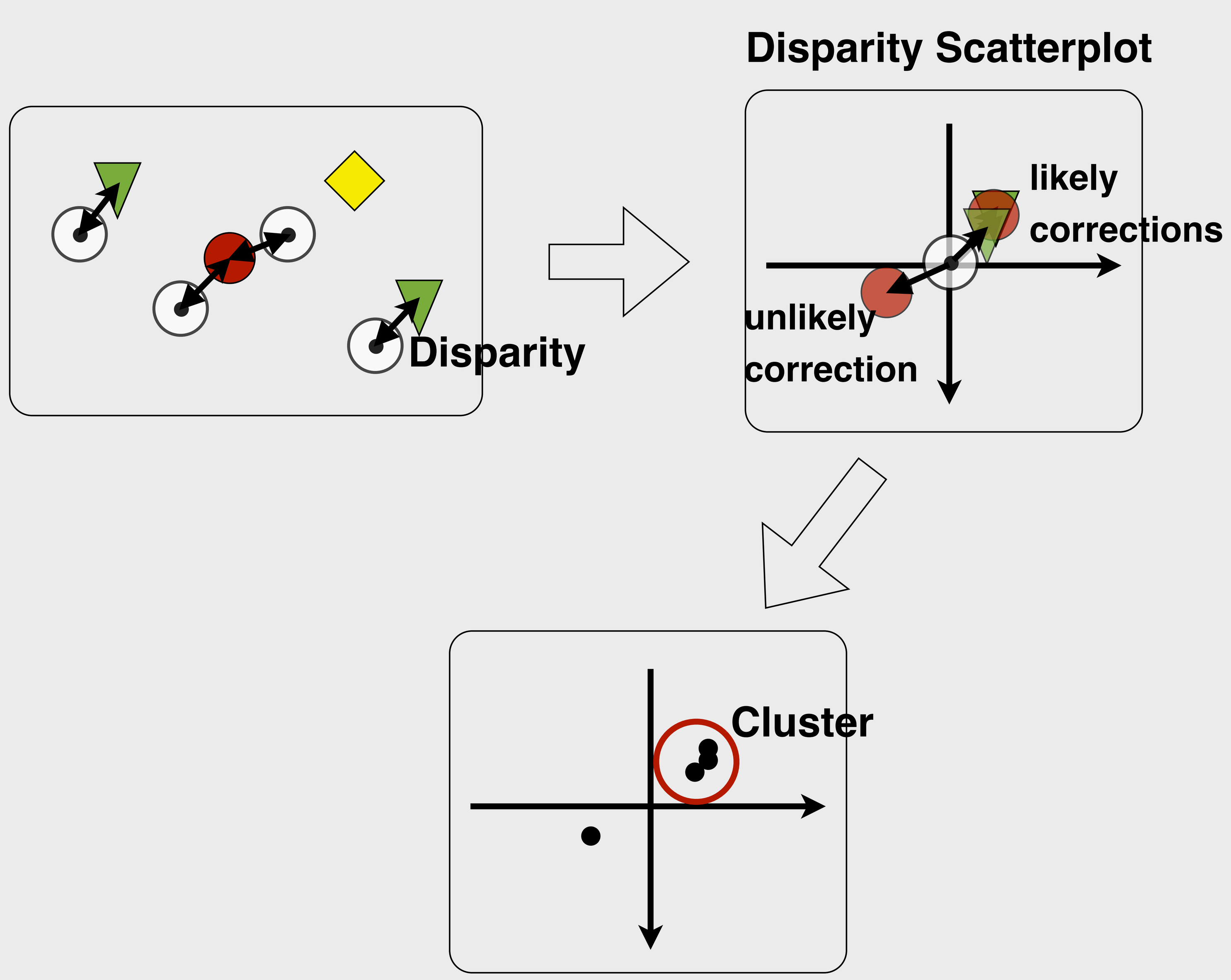
Systematic instrumentation error occurs quite often in eye tracking studies. Systematic error is the relatively constant deviation between the locations recorded by the eye tracker and the locations where people were actually looking. The error may be caused by imperfect calibration, head movement, astigmatism, and other sources. There are only a few methods available for dealing with systematic error and yet the error can have a negative impact on eye movement data analysis.



The goal of this research is to provide a general solution to correct systematic error in eye tracking data. The main challenge here is to identify the truly fixated object for some set of fixations so that the systematic error can be measured.

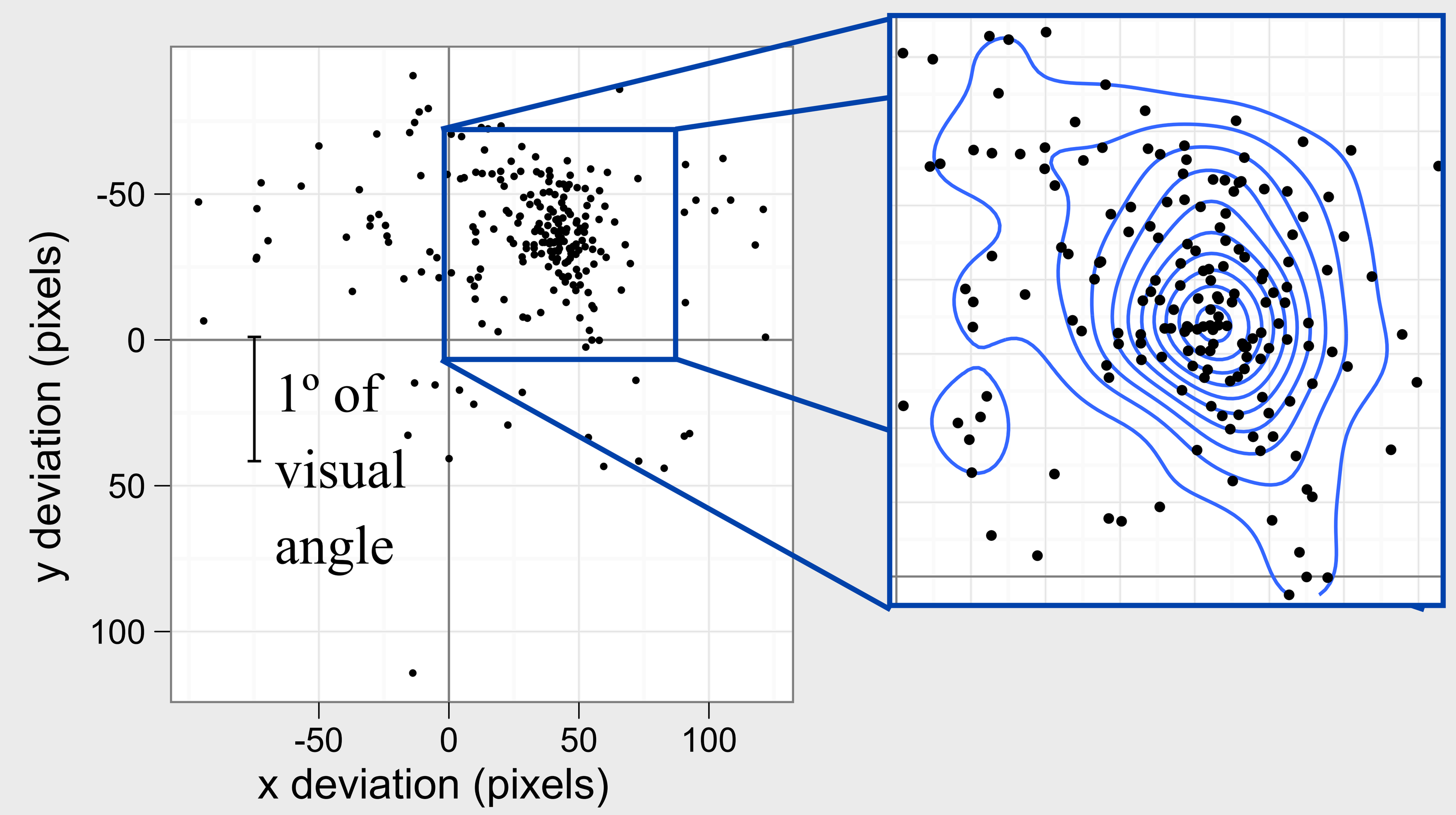
2. Transform Data

The key idea of the proposed method is to exploit a pattern in the scatterplots of the disparities between fixations and their nearest objects. These disparity scatterplots are drawn by first repositioning every fixation to (0, 0) on a common graph, and then plotting each fixation's nearest object on the same graph, at the *relative* position to its fixation. A cluster of disparities often appears on the scatterplots near but not directly at (0, 0). This cluster is likely formed by the disparity between the location reported by the eye tracker, and where the person was truly looking.



3. Estimate Systematic Error

The center of the cluster on the disparity scatterplot is a good estimate of the systematic error. Since the cluster often has the highest density, the mode of disparities would correctly locate the center of the cluster.



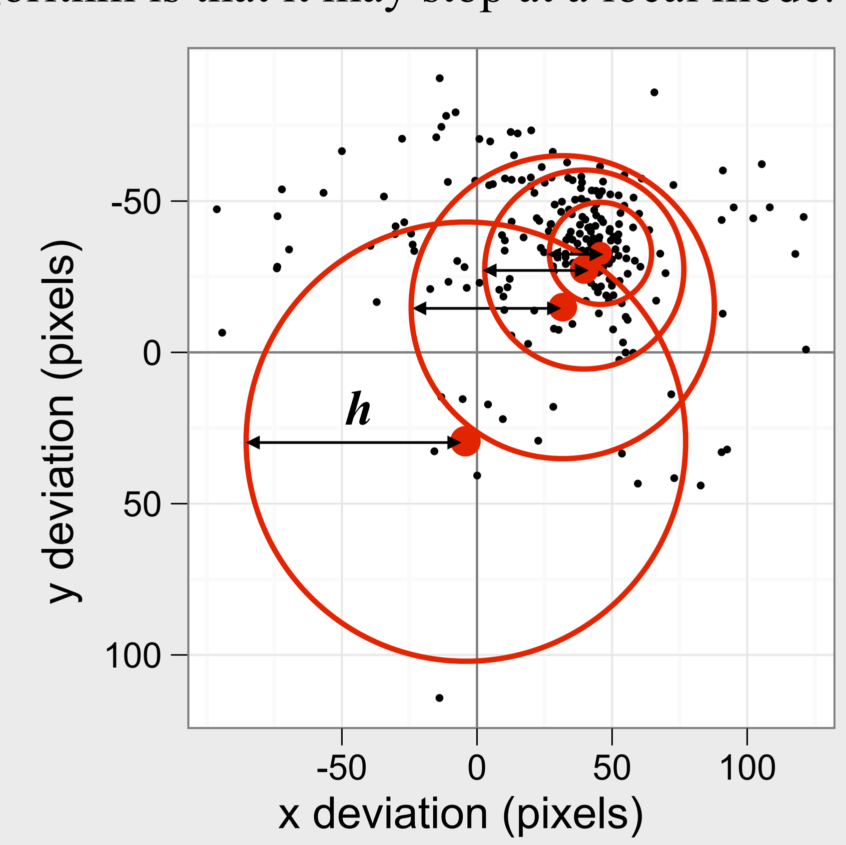
4. Locate The Mode of Disparities

The mean shift algorithm, which was developed for solving computer vision problems [1], is adapted to find the mode of disparities. The algorithm can be summarized as follows:

1. Randomly pick a starting point *x* on the disparity scatterplot.
2. Calculate the weighted average of all disparities. The weights here are determined by a two-dimensional Gaussian distribution whose center is set to *x* and whose standard deviation is controlled by the bandwidth parameter *h*,
3. Set *x* to the result of Step 2, and repeat Steps 2 and 3 until *x* does not change.

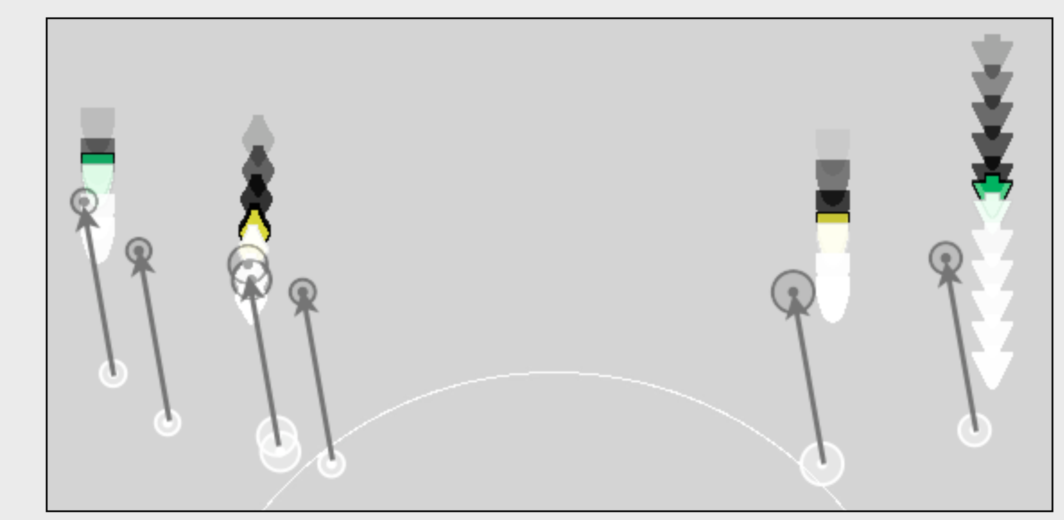
One drawback of the mean shift algorithm is that it may stop at a local mode. To reliably find the global mode of the disparities, we use its adapted version, the annealed mean shift algorithm [2].

The annealed mean shift algorithm finds the global mode by applying multiple passes of the standard mean shift process with a sequence of decreasing bandwidths.

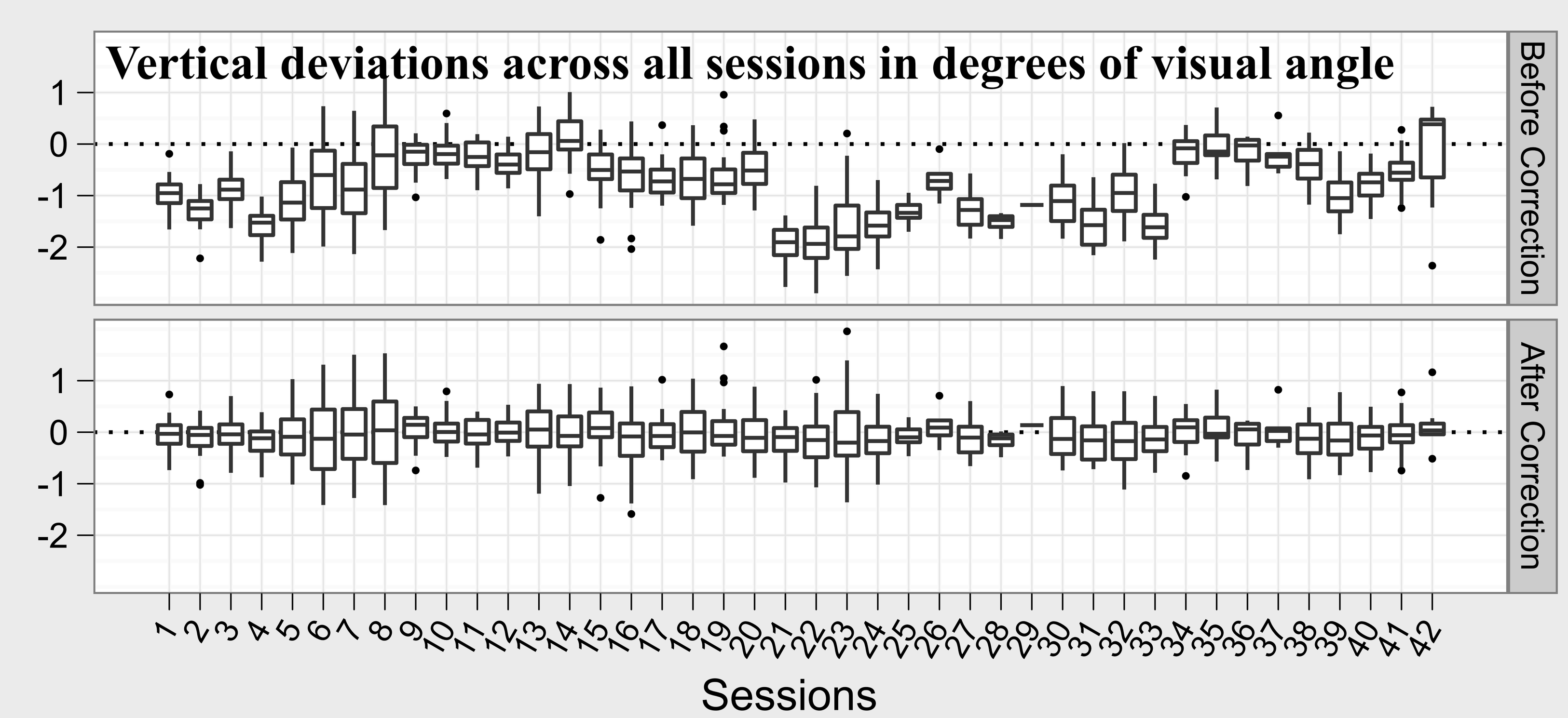


5. Validate The Method

An experiment validated the Mode of Disparities error correction method. We examined the visualizations of the eye movement data and found that the error correction substantially improved the accuracy of the data. The corrected data (gray circles in the example below) are much closer to the stimuli than the uncorrected data (white circles).



A quantitative analysis confirmed the accuracy improvement brought by the error correction. The initial deviations between fixations and their truly fixated objects (as determined through careful data and task analysis) were large, with many of the vertical median deviations reaching -1º to -2º of visual angle (shown below). The deviations in the corrected data, however, all align at 0º.



6. Conclusion

The Mode of Disparities error correction method can reliably estimate and clean up systematic error for eye tracking experiments. The key strength of the method is that it does not need to be adapted to different experimental designs. The only parameters that need to be set are a series of bandwidths used by the annealed mean shift algorithm. The only inputs required are the fixation locations, which are directly available from the eye tracking data, and the visual stimulus locations, which are directly available from the task.

[1] Comaniciu, D. & Meer, P. (2002). *IEEE Transactions on Pattern Analysis and Machine Intelligence, 24*(5), 603-619.
[2] Shen, C., Brooks, M. J., & Van Den Hengel, A. (2007). *IEEE Transactions on Image Processing, 16*(5), 1457–1469.