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# Effects of Background Imagery On Coordinate Measurement

## Heterogeneous detail around a sharp, circular, high-contrast point should not affect the pointing results.

Abstract: *This investigation was concerned with the centering by the human visual system of a black circular measuring mark in sharp circular targets simulating artificially marked points in a photographic emulsion. Special instrumentation was used. The targets were viewed against an infinite density surrounding with white annular rings serving as heterogeneous background configurations, both symmetric and asymmetric configurations being used. Both monocular and binocular vision was used and the results indicate that heterogeneity should not cause a loss in precision. Asymmetry was found to cause a small systematic error in accuracy of centering but it would not be a factor in using the present-day one-micrometer comparators. An interesting statistical approach was used to analyze the more than 25,000 pointings.*

With increasing sophistication of photogrammetric instruments and computational procedures, image quality is becoming of more interest to the photogrammetrist. This paper summarizes a research project which was concerned with one specific image quality factor, namely the effect of adjacent image detail on the accuracy and precision of coordinate measurement. Surveyors, photogrammetrists, and geodesists alike know the fundamental importance of target symmetry. But given a symmetric target, how much and what kind of effect will the target surroundings have on the pointing to that target? To answer this question, two situations need to be considered: (1) when the surrounding detail is symmetric but not homogeneous in appearance; and (2) when the surrounding detail is asymmetric.

The scope of this investigation was limited to the photogrammetric problem of centering a black circular measuring mark in a sharp circular target. This is not an uncommon task, and the elements involved are considered basic to most pointing tasks. The approach used was functional, seeking relationships on the basis of correlations between measured responses and controlled changes in the visual stimuli. Research of this type is difficult because the measurements are subjective in nature, the result of a psychophysiological process which itself cannot be the subject of experimentation.

### Experimental Design

The main instrument was designed for the purpose of measuring the precision with which an operator can center a black circular measuring mark in white circular targets of varying diameters. The standard clinical viewing distance of 6 meters was used. The centering mechanism was placed in front of the observer, and the 5 meter viewing distance was obtained by reflection from a mirror 3 meters distant. In this way the operator had direct control of the movements of the centering mechanism.

The $X$ and $Y$ axes were constructed so as to be independent from each other, with one driving the target and the other driving the measuring mark. A lead-screw drive was used,

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with the axes encoded with magnetic reading heads. The coordinates were recorded on punch cards by depressing a foot switch, and the least-count of the system was 0.02 seconds of arc at 6 meters. The measuring mark was 3.41 minutes of arc in diameter.

The main background around the circular targets was black. Light background configurations of variable intensity were superimposed upon this by means of an optical beamsplitter. The configurations used were annular rings and quadrant segments of rings with centers of radius at the centers of the targets, and with variable diameters and widths.

The main objective of the experiment was to determine whether or not surrounding detail would affect the precision and accuracy of centering a black circular measuring mark in circular targets of various diameters. Because each observer measures with a different precision, all observers were required to perform the pointing tasks both with and without the background configurations present, and a comparison of the estimates of the variance obtained in these two cases was the basis for decision regarding precision.

To determine if a change in accuracy occurred between a symmetric and an asymmetric background configuration, each asymmetric case was observed just before or just after its corresponding symmetric case without disturbing the target or reindexing the measuring mark. Differences between the coordinate means of these two cases provided an indication of an accuracy effect.

In any psychophysiological experiment of this type the results may be variable over time and, to reduce this effect, the experiment was repeated three separate times over a period of approximately three months. During each repetition the obse-ving order of the various backgrounds and targets was randomized.

The factors involved in the analysis were repetitions, coordinate axis, target diameter, monocular or binocular vision, background configuration, and observer. Because of the number and type of factors involved it was considered that an analysis of variance technique would be appropriate. This would enable one to determine whether differences exist and, if so, which factors are causing the variation. In this way the effects of several of the factors could be analyzed at the same time, and the danger of ascribing variation to one factor where it was partially or wholly caused by another is lessened if all or most of the factors are contained in the same model. The relative magnitudes of the individual variations can also be analyzed. As all of the levels of the above factors, with the exception of repetitions, were selected a priori with the objective of finding whether or not specific differences exist and the inferences were to pertain only to those levels, they were considered as fixed. The repetitions were considered as random. and the models where thus mixed models. Several models were used due to the fact that all of the observations were not made under the same arrangement of factors and levels.

Although the analysis of variance technique is normally used in conjunction with means, it can be applied to variances if the data is first transformed. In this experiment all of the variances were transformed with the input to the analysis of variance being the $log\ _{10}S^2$, where $S^2$ is the sample variance computed from the observations of either the $X$ or $Y$ coordinate. For each model the expected mean squares were developed, and the appropriate $F$-tests were then performed on the calculated mean squares from the analysis of variance. The level of significance used in all tests was selected as 5 percent.

If the coordinate factor or vision was found significant, it was inferred that the variance of $X$ coordinates was different from that of $Y$ coordinates, or that monocular vision caused a different variance than binocular vision. An investigation of the magnitudes of the variance estimates in these instances then enabled the experimenter to decide which was larger. The inferences for the targets and background configurations were only over the levels used. All of the above inferences were limited to the three observers used. Any differences between repetitions were inferred to repetitions in general and not to the specific repetitions used.

If a factor contained more than two levels, such as background which in some models had as many as eleven, and if the analysis of variance indicated that the variation ascribed to that factor was significant, it was desired to determine which of the differences between the levels were significant. Several methods are currently in use for making multiple non-independent significance tests on differences among individual means in an analysis of variance. The Newman-Keuls Sequential Range test was selected, and it has the ability to maintain good power although holding the significance level fairly constant. In this test the various differences between the means of the factor levels in question are arranged in a specified order in tabular form and sequentially tested against a special list of ranges for significance. The results of the analyses of variance, and of the Newman-Keuls tests when used, were considered simultaneously with the known subjective feelings of the observers and any appropriate a priori knowledge of the experimental conditions in order to arrive at the experimental results.

As was mentioned previously the major portion of the experiment consisted of three repetitions or groups. A very practical approach or method of testing variances is to split the group of observations into subgroups and to conduct an analysis of variance between and within groups on the logarithms of the sub-group variances. This apapproach was used as it also enables the observer to pause between the sub-group, thus reducing fatigue somewhat. The group of observations for each particular combination of factors was divided into three sub-groups. Thus the final estimate of variance obtained for each combination of factors was based on nine individual estimates (three sub-group estimates per repetition of experiment and three repetitions). Each cell in the analysis of variance therefore contained the logarithms of three variance estimates. Each estimate was computed from 15 observations (this size of sub-group was experimentally determined as the optimum size, considering several factors). Thus the final estimate of variance was computed from 135 observations, or centerings.

## Results

The precision of the visual system in such a pointing task was found to be about 0.5 seconds of arc with the smallest target tested, which was 3.67 minutes of arc in diameter. This was the value sought and is consistent with the findings of O'Connor[1] and others. It indicates that the least count of the instrument was sufficiently small so as not to be a factor. However, most comparators in use today do not approach such a refinement and thus are not able to exploit fully the ability of the visual system (O'Connor found that in a typical stereocomparator under 12-times magnification a subtense of one micrometer at the photo plane corresponds to a visual angle of about 10 seconds of arc).

No significant change in the results occurred in switching from monocular to binocular vision, although all observers expressed the definite feeling that binocular viewing was more comfortable, especially for the smaller targets. No significant correlation existed between the *X* and *Y* coordinates. A significantly higher precision of pointing was found in the horizontal retinal meridian, with respect to the vertical meridian, regardless of whether monocular or binocular vision was used or whether background configurations were present. Although differences existed between the observers, the overall average increase in standard deviation in the vertical meridian with respect to the horizontal was 30 percent.

Perhaps one of the most significant results of this experiment was the finding that a symmetric annular background ring caused no significant change in the precision of pointing if it was far enough from the target so as to be seen indistinctly. If the ring was closer than about 2 arc minutes from the target, however, it caused interference with the viewing and a corresponding decrease in pointing precision.

The introduction of an asymmetric portion of a background ring was found to cause a systematic error in the accuracy of pointing. If the ring segment was close enough to the target so as not to be distinguished as separate, it tended to shift systematically the subjective center towards it. This is logical because the ring then appeared as an extension of the target. Where it was far enough from the target to be seen as separate, it caused a systematic shift away from the target. The magnitude of this effect seemed relatively constant with increasing distance of the ring from the target. An increase in area of the segment did not cause a greater shift, indicating that the existence of an edge was the governing factor. The magnitude of the shift varied with the observer, but 5 seconds of arc seemed to be representative. This effect, then, would not be serious in using a one-micrometer comparator. Because of the excessive contrast and lack of other imagery in the experimental background, the effects found here are probably larger than would be found using regular photography.

As expected, the existence of personal systematic error was found. One interesting aspect of the data was that the personal systematic errors using binocular vision tended to be very similar to those when using the dominant eye alone.

These results are based on some 25,000 pointings to high-contrast targets. There were significant variations between observers, and also within observers over time. It should be realized that many of the above-found effects may not be observable if the instrument is not sufficiently sensitive.

In summary, in using present-day photogrammetric instruments, heterogeneous detail around a sharp, circular, high-contrast point should not affect the pointing results. If the detail is severely asymmetrical and of high contrast, and the target is of low contrast and not easily visible, it may cause a small systematic bias in the centering results.

References 2 and 3 provide a more complete explanation of the psychophysiological and technical aspects of the research and of the ensuing analysis. The author wishes to thank Dr. Desmond O'Connor, Dr. Virgil Anderson, and Dr. Edward Mikhail for their assistance and advice.

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