Supplementary Materials: Analytical Model of Hausdorff Distance with Swarical

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ABSTRACT

This supplementary document provides an analytical model that describes the relationship between the camera error and Hausdorff distance described in a manuscript submitted to the ACM MM 2024. Based on this model, we present the estimated Hausdorff distance (HD) and compare it with the observed HD. Obtained results show the model is highly accurate, providing estimates within a few percentage points of the observed HD.

1 ANALYTICAL MODEL

Figure 14 shows a camera error of [0.9-1.2] cm resulting in an HD that is 20x higher. It is possible to model the relationship between the camera error and the observed HD. Given a shape, these analytical models enable a user to estimate the HD for a tracking device. Below, we describe the analytical models.

The camera error adds a positive percentage error to the distances measured by FLSs. Let D denote the average distance between FLSs, say D=7 cm. Moreover, let the average percentage error attributed to the camera be ϵ%, say ϵ=1.15%. When FLSs localize erroneously using distances that are ϵ percentage (1.15%) larger than the ground truth, the point cloud shrinks ϵ%. This is because a localizing FLS overestimates its distance to an anchor FLS, causing it to adjust its distance to be shorter than the ground truth.

To estimate the observed error, one may shrink a point cloud ϵ% and compare it with the original point cloud. The intuition here is that the localization error depends on how the distance between the matching points between the two point clouds changes as we scale one of the point clouds and align their center. The results will approximate the HD expected with a camera that provides ϵ% error in its measurements.

Table 1 shows the estimated and observed HD with the different shapes. The estimated HD is not identical to the observed HD because it is computed based on the average distance between the localizing and anchor FLSs, 7 cm. In contrast, Figure 11 shows the observed distribution of distance varies between 6 and 8 cm with G=50.

Table 1: Estimated and observed HD (mm) for different shapes, G=50.

Shape	# FLSs	Estimated HD	Observed HD	% Difference
Chess piece	100	8.58	8.38	2.39
Chess piece	408	9.05	8.84	2.38
Palm tree	725	24.73	24.14	2.44
Dragon	1147	23.66	23.10	2.42
Skateboard	1372	19.32	18.86	2.44