Three-Dimensional Natural Scene Statistics: Dependencies between Luminance and Range Contrasts

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Computing relative or absolute range (egocentric distance) is difficult because, of course, neither is specified in any direct way by the 2D retinal image. If, however, there was a relationship between range and luminance or color, perhaps it could be exploited to yield fast, initial estimates of range from the retinal image *per se*. We studied the statistical dependence between range (and disparity) contrast and luminance contrast across random point-pairs in natural scenes, and found that changes in range and luminance are highly dependent.

We collected high resolution range maps of natural scenes co-registered with luminance (RGB) images using a Riegl terrestrial scanner, co-mounted camera, and in-house software. Various alternative preprocessing stages were used to simulate the early stages of visual processing (e.g. foveation). Our basic approach was to randomly sample pairs of points in the scenes to determine if the change in range or luminance or both exceeded some criterion. We then 1) compared the conditional density of range edges given luminance edges to the (unconditioned) density of range edges and 2) compared the joint distribution of range and luminance contrast to the product of their marginal distributions.

We found a robust statistical dependence between range and luminance. Additionally, we computed difference surface maps (between the joint distributions and product-of-marginals predicted by independence). These difference surfaces reveal which regions of luminance and range change exhibit the strongest statistical dependencies.The statistical dependence between luminance and range allows the construction of models where one can assign a probability of occurrence of a range edge given a luminance edge at a particular point in a scene. In principle, such a mechanism could also be used by biological visual system to serve as priors when reconstructing the 3D environment from 2D image data.

References

[1] Geisler, W.S., Perry, J.S., Najemnik, J. (2006) Visual search: The role of peripheral information measured using gaze-contingent displays. *Journal of Vision,* 6, 858-873.

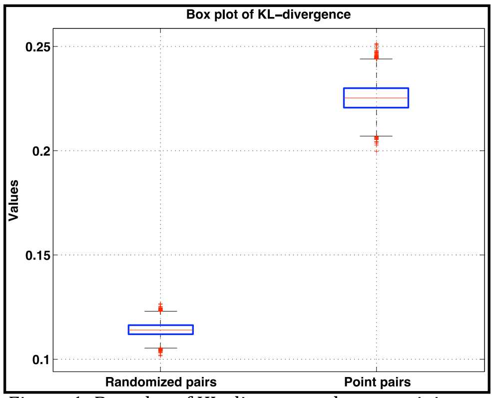

Figure 1: Box plot of KL-divergence between joint distribution and product of marginals for natural scene points and randomized point pairs for benchmarking. A lerger KL-divergence indicates a dependence between the variables. The plot shows that range and luminance contrast at the same point in natural scenes are dependent (have higher KL-divergence than the randomized point-pairs benchmark.)

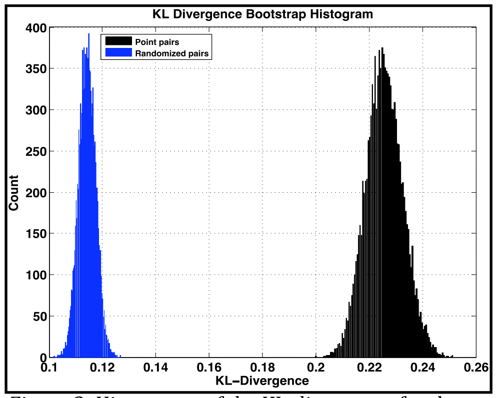

Figure 2: Histograms of the KL-divergence for the point pairs and the benchmark. The clear separation in the histograms is an indication of the statistical significance of the result (range and luminance contrast dependence.)

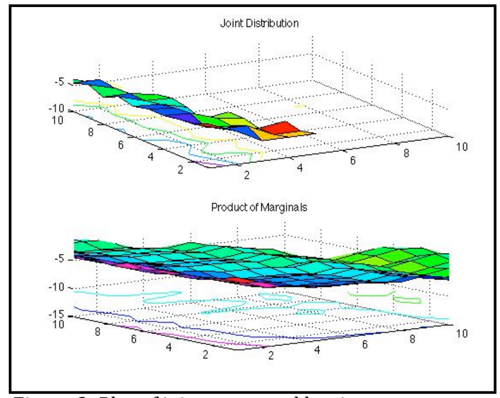

Figure 3: Plot of joint range and luminance contrast density, and plot of the product of marginal's density. This visualizes the difference in the two densities further indicating the dependence of the random variables.

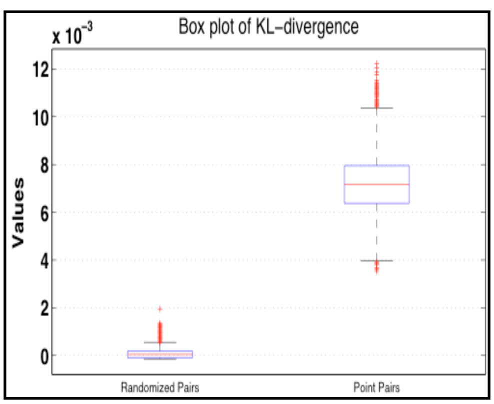

Figure 4: Box plot of KL-divergence between joint distribution and product of marginals for natural scene points and randomized point pairs for benchmarking. A lerger KL-divergence indicates a dependence between the variables. The plot shows that range and luminance contrast at the same point in natural scenes are dependent (have higher KL-divergence than the randomized point-pairs benchmark.) NO FOVEATION, NO POINT LOGARITHM TRANSFORM AT FRONT-END.

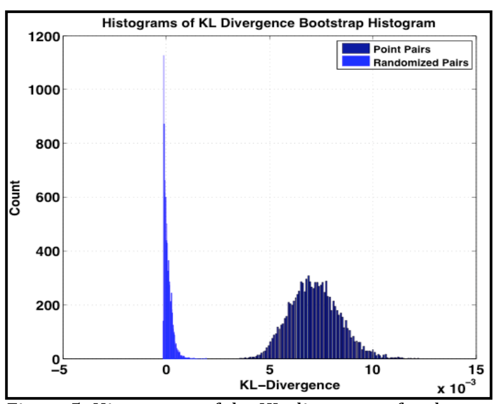

Figure 5: Histograms of the KL-divergence for the point pairs and the benchmark. The clear separation in the histograms is an indication of the statistical significance of the result (range and luminance contrast dependence.) NO FOVEATION, NO POINT LOGARITHM TRANSFORM AT FRONT-END.

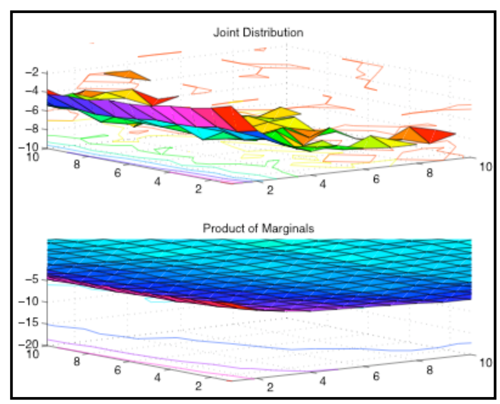

Figure 6: Plot of joint range and luminance contrast density, and plot of the product of marginal's density. This visualizes the difference in the two densities further indicating the dependence of the random variables. NO FOVEATION, NO POINT LOGARITHM TRANSFORM AT FRONT-END.