Spatiotemporal discrimination thresholds for dynamic random fractal (1/f) textures

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1 Introduction

Fractals are mathematical entities that are self-similar over many spatial or temporal scales.

The 1/f spectra of fractal textures simulate the spectra of natural images without being confounded by phase information.

Similarly, temporal sequences of natural images have 1/f temporal spectra.

So, a reasonable model for spatiotemporal texture sequences is:

\[ A(f) = Kf^{-\alpha} \]

where f is the spatial and temporal frequencies, respectively.

Thus, data on sensitivity to perturbations in a dynamic fractal’s coordinates should provide useful insights into the perception of natural scenes.

2 Methods

2a Participants

Four experienced psychophysical observers. SF was naive to the purpose of the experiment.

2b Apparatus

All stimuli were generated and displayed on a Silicon Graphics U2 at 50 Hz.

Viewing distance was 40 cm.

2c Procedure

Just Noticeable Differences (JNDS) were measured separately for spatial and temporal exponents using an adaptive staircase.

A reference and a comparison image sequence were presented side by side (1.1 mm apart) for 2.133 seconds or until the observer responded, whichever came first.

80 spatiotemporal, grey-scale, random-phase fractals: 10 spatial exponents (0.4 to 2.2 in steps of 0.2) and 8 temporal exponents (static, and 0.2 to 1.4 in steps of 0.2).

The average luminance was constant at 8.57 cd/m².

The Mean Square Contrast was constrained to be 10.98%.

Each fractal was limited to 64x64 pixels (18×18 mm) in size, and 64 frames long (2.133 s).

Spatial JND’s did not vary much with changes in the temporal exponent (Figure 4).

3 Results

3a Spatial JND’s

The reference and comparison image sequences had identical spatial JND’s.

The temporal exponent was held constant while the spatial exponent was adaptively varied.

The observers were asked to identify the reference image: Above JND’s: Find the faster and “more jittery” sequence Below JND’s: Find the slower and “less jittery” sequence

A(f) = Kfs \* ft where fs and ft are the spatial and temporal frequencies, respectively.

The reference and comparison image sequences had identical temporal exponents.

Similarly, temporal sequences of natural images have 1/f temporal spectra.

The observers were asked to identify the reference image: Above JND’s: Find the faster and “more jittery” sequence Below JND’s: Find the slower and “less jittery” sequence

A(f) = Kfs \* ft where fs and ft are the spatial and temporal frequencies, respectively.

The data for both above and below JND’s are remarkably similar across 3 of the 4 subjects. The 4th subject, VB, showed above JND’s of 0.8 which is extreme given the slower persistence of motion.

Discriminations were easiest when the temporal exponent was between 0.8 and 1.0, which is the range of exponents for natural stimuli.

The Mean Square Contrast was constrained to be 10.98%.

Each fractal was limited to 64x64 pixels (18×18 mm) in size, and 64 frames long (2.133 s).

Figure 3: Spatial JND’s collapsed across temporal exponents. Here the spatial discriminations are plotted as a function of spatial exponent.

4 Conclusions

4a Temporal JND’s

The reference and comparison image sequences had identical temporal exponents.

The temporal exponent was held constant while the spatial exponent was adaptively varied.

The observers were asked to identify the reference image: Above JND’s: Find the faster and “more jittery” sequence Below JND’s: Find the slower and “less jittery” sequence

The data for both above and below JND’s are remarkably similar across 3 of the 4 subjects. The 4th subject, VB, showed above JND’s of 0.8 which is extreme given the slower persistence of motion.

The Mean Square Contrast was constrained to be 10.98%.

Each fractal was limited to 64x64 pixels (18×18 mm) in size, and 64 frames long (2.133 s).

Figure 4: Spatial JND’s collapsed across spatial exponents. Here the spatial discriminations are plotted as a function of temporal exponent.

Temporal discriminations became more difficult as the texture became coarser.

5 Spatial Exponent

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Figure 5: Temporal JND’s collapsed across spatial exponents. Here the temporal discriminations are plotted as a function of temporal exponent.

Figure 6: Temporal JND’s collapsed across temporal exponents. Here the temporal discriminations are plotted as a function of spatial exponent.

Discriminations were easiest when the spatial exponent was between 1.4 and 1.8, which is consistent with previous research (1-3).

The data for both above and below JND’s are remarkably similar across 3 of the 4 subjects.

The 4th subject, VB, has higher thresholds and variances. This might be due to sampling problems induced by a mild, congenital paucity of retinal ganglion cells (optic nerve hypoplasia).

Figure 7: MacAdam Ellipses Here the Above and Below JND’s are plotted together.

Figure 8: Temporal JND’s collapsed across temporal exponents. Here the temporal discriminations are plotted as a function of spatial exponent.

Spatial discriminations appear to be independent of the speed or persistence of motion.

Temporal discriminations are dependent on the coherence of the stimuli. This makes intuitive sense, as it would be easier to see a 1 mm object move 2 mm (200% of its size) than it would be to see a 100 mm object move the same distance (0.002% of its size).

The use of a common mathematical framework for characterizing both dynamic noise and dynamic images may facilitate the study of masking of images by noise.

References


ECVP 2000