

Illusions of Infinity: Feedback for Infinite Worlds

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ABSTRACT

Sensory feedback for user actions in arbitrarily large information worlds can exhaust the limited dynamic range of human sensation. Two well-known illusions, one optical and one auditory, can be used to give arbitrarily large ranges of feedback.

KEYWORDS: Zoom views, multiscale interfaces, interface feedback, ZUI, sensory illusions

INTRODUCTION.

Graphical user interface design typically tries to give users direct feedback about the consequences of their actions. Newer *Zooming User Interfaces* (ZUIs), like Pad[1] and Pad++[2], however, allow access to virtually infinite information spaces, presenting new feedback challenges. For example, a user can zoom in by more than a factor of 10^{12} dwarfing the dynamic ranges of both physical output media and human senses. Consider a rising tone as auditory feedback use for zooming out and a falling tone for zooming in.: one would require tones too high or too low to be audible.

To render such infinite interaction ranges with finite perceptual media, we use two known perceptual illusions of infinite sequences in finite sensory space. These are analogs of the famous M. C. Escher's famous woodcut of the paradoxical circular staircase where walkers seem to go endlessly up or down but never get anywhere.

AUDITORY EXAMPLE – TONE CUES FOR ZOOMING

The first example uses Shepard tones [3] to indicate zooming direction. Shepard tones paradoxically seem to rise (or descend) endlessly yet never get higher in pitch. They are created by synthesizing many octaves of the same note (say C), with amplitudes given by a bell-shaped envelope (Figure 1). Each sounds like a single note on a rich church organ, with a dominant pitch in the mid-range, but overtones fading away high and low. Successive tones

are generated by moving the individual octave pitches up slightly, while the envelope stays the same. This sounds like the organ note is sliding upward. However, when the components have moved up a whole octave, the signal is exactly as it started. If we tie zooming-in to descending Shepard tones and zooming-out to ascending ones, zoom direction and magnitude can be auditorially distinguished, yet pitches never get too high or too low to be heard.

VISUAL EXAMPLE – NESTED BOXES

A common visualization technique used in ZUI's involves showing hierarchical structure (e.g., file system hierarchies) with nested boxes. If the boxes appear only in outline, partial views in a window can be quite ambiguous and disorienting (Figure 2a). The visual ambiguity is easily resolved by shading the boxes, say coloring inner boxes successively more darkly (Figure 2b). Unfortunately, after a few nestings the boxes are all indistinguishably black.

Using the Cornsweet illusion[4], one can make a series of steps that seem to move from darker to lighter, at each step, yet the overall brightness does not change. This is done by removing the gradual regional changes in brightness and just leaving the edge effects (Figure 3a b). (You can do this in Photoshop® by subtracting, from a black and white image, a very blurred version of itself.) The eye is fooled by the edge effects into seeing gentle level differences. By drawing the boxes with just these edge transients, we get seemingly darker boxes inside brighter ones (Figure 4a), but the nesting can go on forever. Even partial views are unambiguous (Figure 4b). In zooming these boxes, the edge effects must be kept a constant pixel width (not scaling geometrically) to work best. This has the useful side effect that, when the box is small, its center is in fact darker than when it gets larger. Since, by another optical illusion, the eye is insensitive to slow brightness changes, and so object constancy is nicely preserved in slow zoom, despite the average brightness change.

REFINEMENT

Both these techniques provide good feedback for local scale changes without using up dynamic range: a small zoom is easily heard, one box nested within another is unambiguously distinguished. However, we have lost the capability to use the overall tone height, or the overall

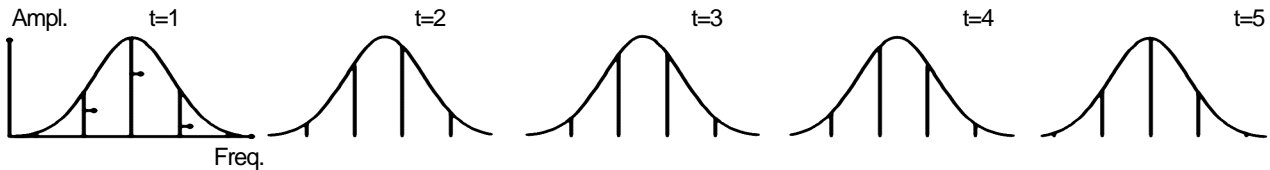


Figure 1: Shepard Tones – individual pitch components move up smoothly in frequency while envelope stays the same. Subjectively, pitch seems to rise but ends up with t=5 identical to t=1.

darkness to signal absolute zoom or nesting level. We can, however, recover this to some extent, by re-introducing an attenuated version of the basic level changes (Figure 6). Thus for example, we can let the bell-shaped envelope of the Shepard tones slowly move upwards at a rate that goes from low to high over the dozen orders of magnitude of the ZUI. For the nested boxes, in addition to the edge transients, we can let the boxes get slowly darker overall as we nest inwards.

SUMMARY

The contribution here is using the perceptual system itself to overcome the limits of the perceptual system, and applying it to design.

ACKNOWLEDGMENTS

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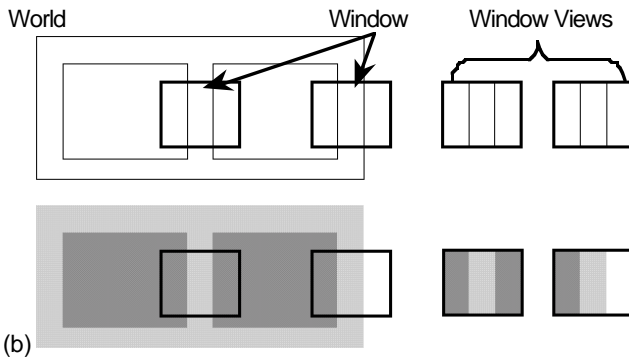


Figure 2: Visual ambiguity of partial views of nested box outlines(a) resolved by shading boxes(b)

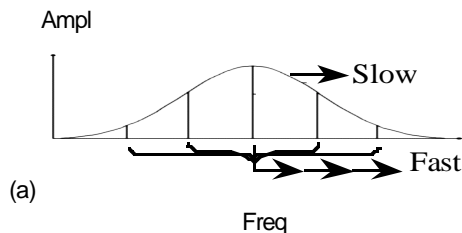


Figure 5: (a) Shepard tones modified so envelop rises slowly as individual pitch components rise quickly. (b) Cornsweet edge transients accompanied by gradual level changes.

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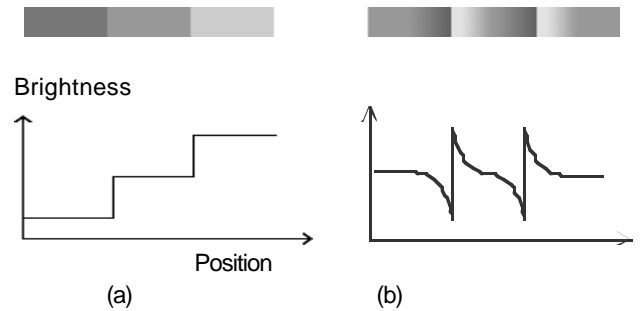


Figure 3: Cornsweet Illusion - Brightness steps (a) suggesed by edge transients in (b).

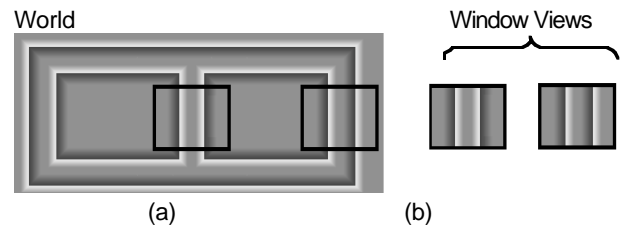


Figure 4: Boxes draw with edge effects (a) show nesting even in partial views(b).

