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LAST BUT NOT LEAST

A case of quasi-infinite visual acuity and illusory size

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Abstract. In certain real-life situations, moiré patterns can enhance the observer's ability to resolve fine spatial detail of solid structures, theoretically to unlimited degrees. An example of such a situation can be seen in traffic signs on the M25 motorway around London. Moreover, owing to the interferential nature of the moiré pattern, its angular physical size is independent of observer distance, and thus creates an apparent size discrepancy: the closer you get, the smaller the size of the pattern appears to be—an illusory situation resembling Michael Ende's tale of the pseudo-giant Mr Tur Tur.

Interference patterns of two identical superposed periodic objects can result from either the two being oriented at an angle, or presented at different distances (figure 1). In the latter case, the spatial frequency of the resulting moiré pattern is equal to the difference between the individual spatial frequencies of the two objects. If the difference is small in relation to the original frequencies, the resulting moiré pattern can be regarded as a magnification of the original object. Thus, objects that are too small to be resolved can be made visible by observing the moiré pattern produced by superposition of the object of interest with a fine periodic structure of known size. This technique has been found to have methodological relevance for, eg, high-resolution microscopy, and many perceptual characteristics of moiré patterns have been detailed under experimental conditions (see Spillmann 1993 for a review).

Here, a real-life situation is described, in which the presence of a moiré pattern provides 'super-resolution' to the unaided eye of a normal observer. Suppose you are driving along the M25, a very busy ring-like motorway around London. Approximately every 1000 m large traffic sign panels appear, spanning the entire width of the road.

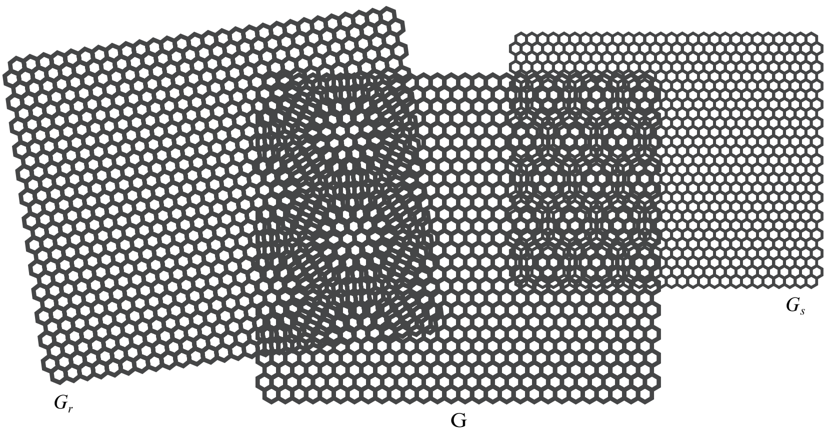

Figure 1. The origin of moiré patterns. A honeycomb-like grid G produces a tilted moiré version of itself when superposed on the tilted grid G_r. The size of the pattern depends on the angle of rotation. A smaller version of G, G_s, has a higher spatial frequency than G, and likewise produces a moiré, the size of which is equal to the difference between the spatial frequencies of G and G_s.

A gantry runs along the panel, flanked by honeycomb-like grid railings on both long sides of the gantry, oriented at a right angle to the traffic (see figure 2a). Under different circumstances, the fine structure of the grid would remain unseen from one's point of view, partly because of the speed of travelling and motion blur, but more importantly because of the small size of the grid parts. In the case of a traffic jam, for example, you cannot see the grid parts even if you are stationary and viewing them from the closest possible distance (say 5 m). Thus, given an observer with normal visual acuity (30 cycles $\deg^{-1}$ grating acuity), the size of the single elements of the grid must be smaller than about 1 cm.

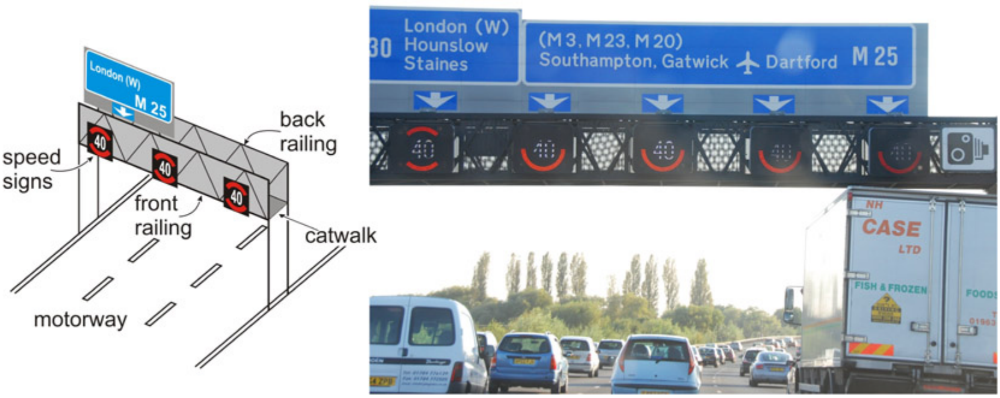

Figure 2. [In colour online, see http://dx.doi.org/10.1068/p6398] (a) A sketch of the street-sign panel setup typically to be observed on the M25 motorway around London. (b) A photograph of the panel from the viewpoint of traffic. A honeycomb-like moiré pattern is visible between speed signs. Note on safety: if you plan to see this yourself, be sure to drive carefully enough to avoid rear-end collisions.

Given that the grid happens to be doubled on the far side of the gantry, approximately 2 m away from the one in front (roughly measured by satellite images[(1)] of the type of traffic panel in question), two versions of the same grid pattern with different spatial frequencies are superposed. As a result, a clear moiré pattern unfolds, revealing the fine structure of the grid railings (figure 2b).

To account for the super-resolution in this situation, consider the following example: your distance from the traffic-sign panel may be such that observer distance, D, (the line of sight) is 200 m, and let us further suppose grid spacing, g, of the railing is 1 cm. The spatial frequency of the near grid is then $1/\alpha = 1/\arctan[(g/2D) \times 2] = 349$ cycles $\deg^{-1}$, which is about 10 times beyond what could be normally resolved. However, the spatial frequency of the distant grid is 352.5 cycles $\deg^{-1}$ (assuming the aforementioned width of the gantry). The difference, 3.5 cycles $\deg^{-1}$, is the spatial frequency of the resulting moiré pattern, and is, of course, easily resolved.

What happens if the panel is viewed from 1000 m? The calculation reveals that the difference between near and distant spatial frequencies (1745.4 cycles $\deg^{-1}$ and 1748.9 cycles $\deg^{-1}$, respectively) is still 3.5 cycles $\deg^{-1}$. This relation implicitly assigns the following feature to the moiré pattern: its angular size is independent of observer distance. By simple transformation of the above equation, it can be generally shown that the spatial frequency of a moiré that is produced by two superimposed grids with relative distance r, is calculated by $1/\alpha = 1/[\arctan(g/2r)]$, and is hence independent of the observer distance. Thus, theoretically speaking, one would be able to resolve a grid spacing of 1 cm from infinity. From a practical viewpoint, this cannot be achieved, because in order to resolve the grid structure, at least one instance of the moiré pattern

(1) http://tinyurl.com/cj6wmn

honeycomb has to 'fit' into the sign panel. With an assumed width of 20 m, the physical dimension of the panel would then limit super-resolution viewing distance to about 7000 m, which is still quite remarkable.

The invariance of spatial frequency of the panel's moiré pattern produces a perceptual size effect worth mentioning. Because it is normally not possible for a stationary object to be seen at a fixed angular size regardless of viewing distance (unless the object is constantly changing its size with viewing distance, which is, of course, unlikely), the apparent size of the pattern changes with distance. If one is driving towards the panel, the moiré pattern appears to get smaller, because more cycles of the pattern are seen on a given area of the panel. The apparently largest pattern is seen from the furthest viewing distance (see figure 3). This illusory size effect resembles the story of the tragical pseudo-giant Mr Tur Tur in Michael Ende's fantasy novel *Jim Knopf und Lukas der Lokomotivführer* (*Jim Button and Luke the Engine Driver*): Mr Tur Tur is a gentle, normal-sized man who appears larger the farther he is away, so that he looks like a scary giant from far away which makes him a very lonely man.

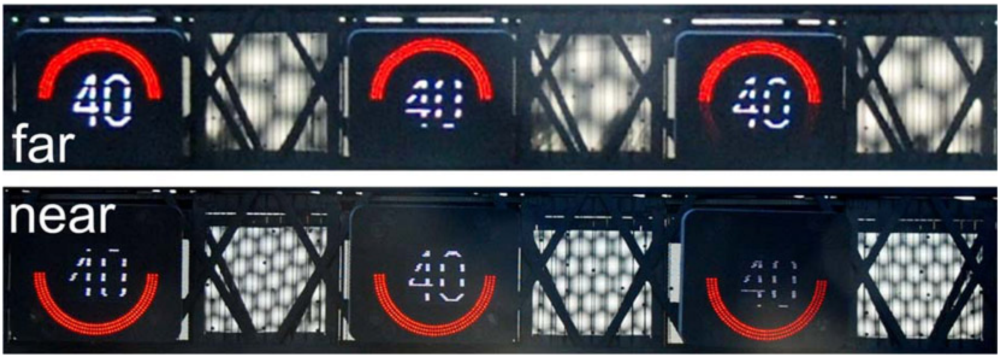

Figure 3. [In colour online.] The 'Tur-Tur effect': the closer you get, the smaller the grid appears to be, although its physical size is constant. The upper photograph is taken from about 2.5 times greater distance than the lower one. Note that the two images are cropped in different places to show a similar scene and thus to demonstrate the perceptual effect.

Reference

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