Demonstration of Mach Bands and Area Fill-in Contrast

Jan Henrik Wold
Department of Physics, University of Oslo, Norway

Due to the spatial extent of the sun, shadows cast in sunshine do not have sharp edges. What we see is a spatially *graded shadow* mediating between the dark full shadow and the bright outer surround. Under certain conditions one also notices that within the graded shadows there are contours which appear as either significantly brighter or significantly darker than the nearby surround. This latter enhanced contour contrast is often referred to as *Mach bands* after the German scientist and philosopher Ernst Mach, who was the first to perform a systematic investigation of the phenomenon. In his study he concludes that the brighter and darker contours are physiologically provoked, and that they arise along curves across which the spatial brightness profile changes abruptly.

The *area fill-in contrast*, which in some sense may be regarded as complementary to the Mach band phenomenon, has been treated systematically by Craik, O'Brian and Cornsweet. The phenomenon arises when the spatial brightness profile along some curve on a surface has an abrupt, step-like change followed by a smooth fadeout.

At the National College of Art and Design in Oslo a special light source for educational and research purposes has been designed. This source effectively resembles a homogenous, isotropic surface (Lambert surface) of high luminance. Used with appropriate apertures the lamp can be used to project light/shadow distributions that provoke either Mach bands or area fill-in contrast.

Figure 1a shows an arrangement for projection of shadows whose brightness distributions provoke strong Mach Bands. Light from a homogenous and isotropic, triangular aperture (the aperture of the source) is projected through a second aperture of the same shape and orientation.

Figure 1b is a photograph of the image projected onto the screen in an arrangement as sketched in Figure 1a. On gazing steadily on one of the Mach bands, one notices that the band vanishes. Measurements of the spatial transmittance of the photographic film show that it has not been exposed to more light along the lines of the Mach bands than along the nearby surrounds. These observations indicate that the origin of the Mach bands is found in spatial, integrative functions of the eye.

Figure 2a shows an arrangement for projection of shadows whose brightness distributions provoke rather impressive area fill-in contrasts. Here, the shadow casting object corresponds to a pair of crossing rectilinear wires, oriented in such a way that each wire is parallel to one side of the triangular aperture of the source.

Figure 2b is a photograph of the image projected onto the screen in an arrangement as sketched in Figure 2a. When viewed at short distance the photograph gives an impression of the whole surface splitting into regions of three different, almost uniform brightness levels. Furthermore, the way these levels are interconnected make the fill-in effect look like an addition of shadows. At long distances the effect disappears, and the brightness distribution now perceived corresponds closely to the spatial transmittance profile of the photographic film as determined by photometric means. This indicates that, as for Mach bands, the area fill-in contrast has its origin in the spatial, integrative functions of the eye.

Figure 2c is the same photograph as in Figure 2b, except that the regions close to the contrast borders have been masked. The brightness distribution perceived here closely resembles the photometrically determined transmittance profile of the photographic film.

Using two strips of paper, the reader should, as a check, mask the contrast borders of Figure 2b in the same way as shown in Figure 2c. To accent the impression of shadows adding, the reader should also mask each contrast border separately.

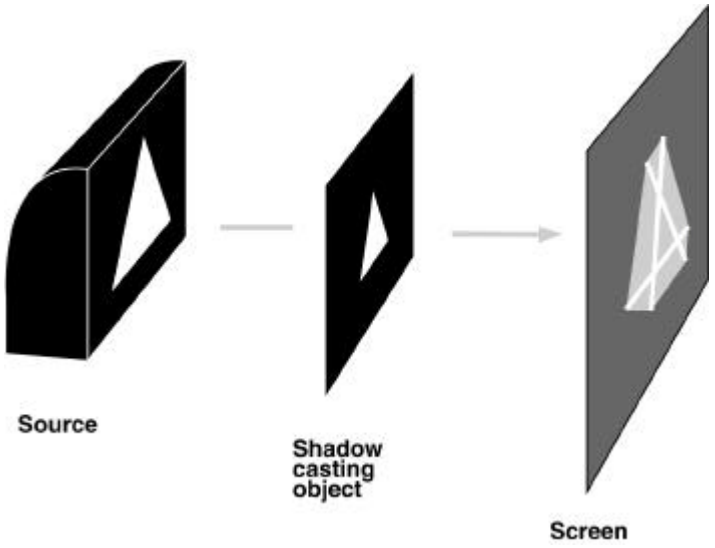

Figure 1a

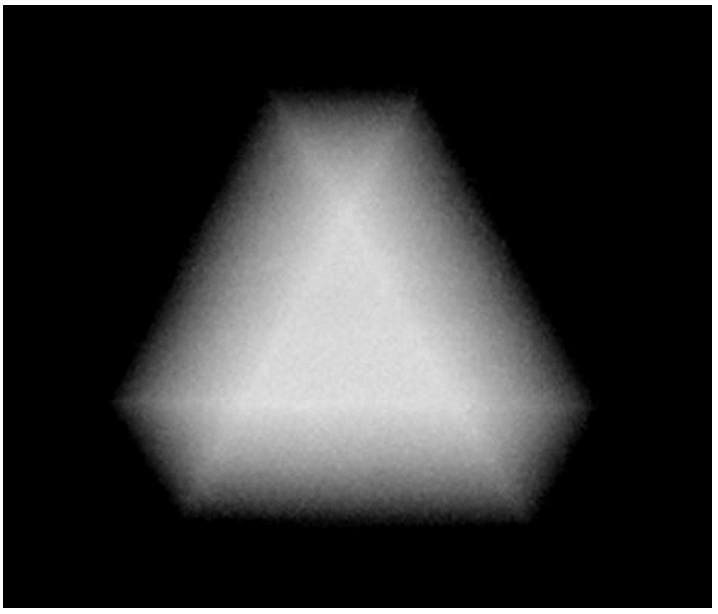

Figure 1b

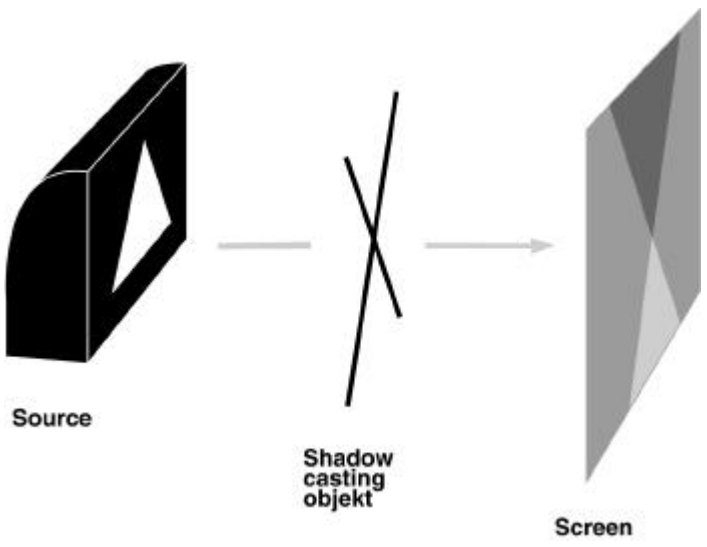

Figure 2a

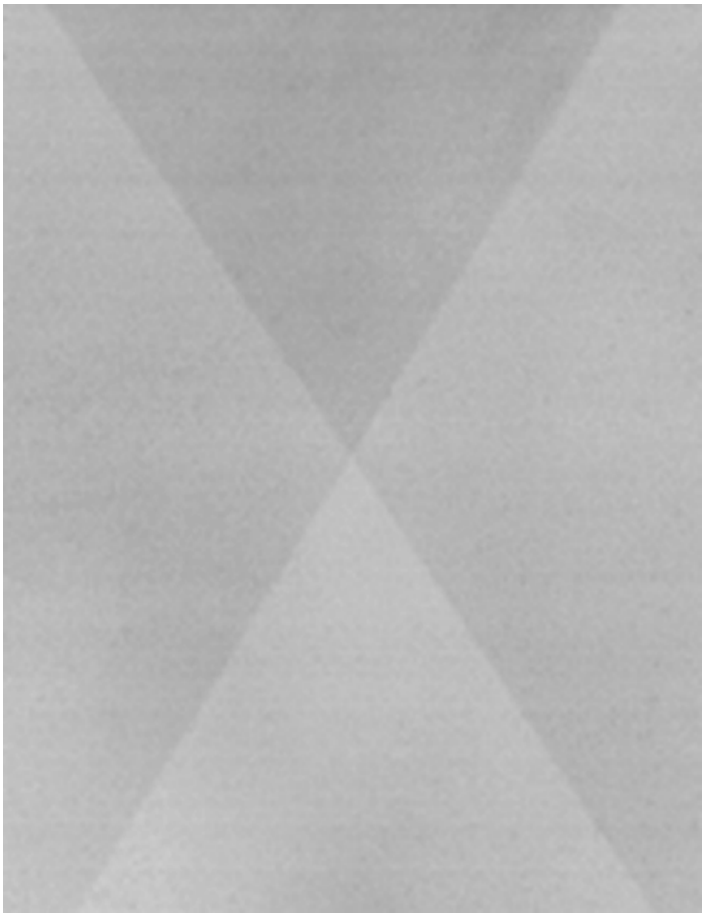

Figure 2b

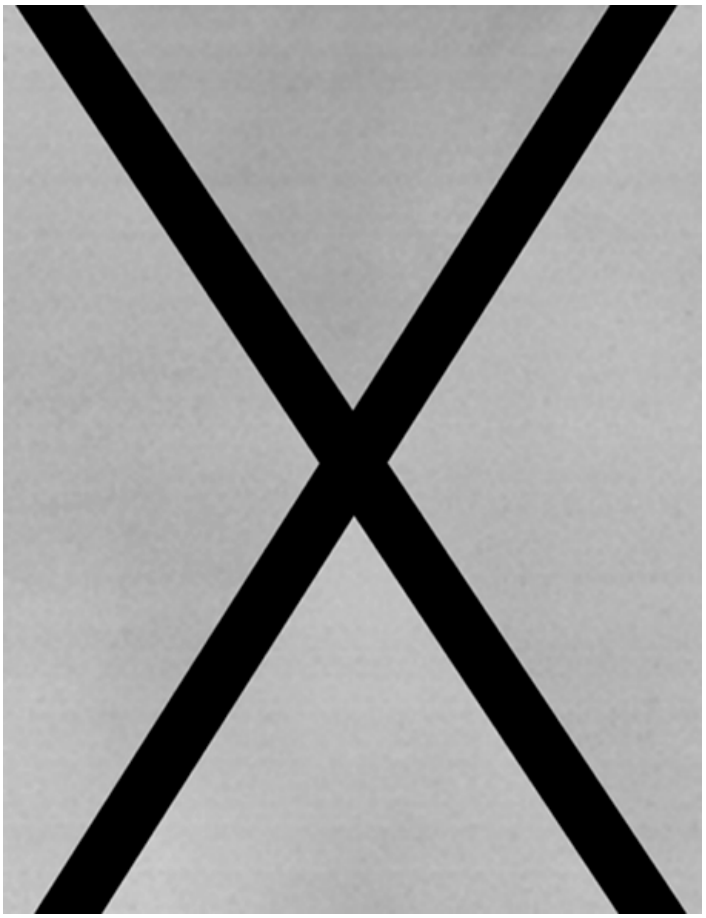

Figure 2c