ENHANCEMENT OF SMALL INTENSITY VARIATIONS IN NOISY DIGITAL IMAGES BY USING A LEAST-SQUARES ARTIFICIAL ILLUMINATION METHOD. Ernest Schonfeld, NASA Johnson Space Center, Houston, Texas 77058.

Small intensity variations (such as altitude) are very difficult to detect by the eye. If the image is noisy the problem is even worse. One technique that helps in interpreting altitude maps is called artificial illumination or shaded relief (1). It consists in computing the reflected light as a result of artificially illuminating a surface. It was probably used first by Leonardo da Vinci and has been used successfully in geological applications (2). This technique gives an illusion of relief in 3 dimensions. It is a natural process in the sense that people are used to interpreting shadows in terms of relief. It also increases considerably the contrast of very small intensity variations in an image. This technique has higher contrast than contouring or using pseudo-color levels because it uses about 10 times more intensity levels. The intensity variable can be any characteristic of an image such as altitude, sea level, gravity anomaly, chemical concentration, NMR intensity, etc.

The way to compute the illuminated light or the brightness of an object as seen by the eye depends on what law of reflectance is used. A relatively simple reflectance law is the Lommel-Seelinger law (1,2). This law can further be simplified if one assumes that the light source is parallel to the level surface and the slopes are smaller than 5 to 10 degrees. Then the intensity of the reflected light is simply equal to the partial derivative of the intensity with respect to the distance in the direction of the light source. Because derivatives increase the noise, least-squares versions of the partial derivatives were used to eliminate this effect (3).

The artificial illumination method has some problems, such as: 1) In the direction perpendicular to the illumination, the relief effect is maximum but in the direction of the illumination is minimum. To solve this problem one should obtain several maps with different light directions. 2) Noise is usually amplified due to the differential nature of the artificial illumination method. One way to decrease this noise problem is to use least-squares methods (as in this work).

APPLICATIONS. A) Seasat altimeter data. Shown in fig. 1 is the result of artificially illuminating the Seasat sea altimeter data assuming the light is coming from the North. The mean surface of the sea contains information on the ocean floor topography (4). Fig. 1 shows very long and short distance variations. There is a very large circular depression, NW of Africa, that matches the shape of the NW portion of Africa, probably related to the continental drift. B) Venus topographic data. Figures 2 and 3 show altitude data from Venus (Pioneer-Venus) artificially illuminated. Fig. 2 shows the Aphrodite region and fig 3 the Beta-regio. The geology of these regions has been previously described (5). In the Aphrodite region there are several very long troughs (many thousands of km long). Some of these troughs can be seen well only with a NW illumination of this image. In the Beta-regio there is also a very long trough running from N to S that starts or ends at a circular feature (at the N section). This feature can be seen well because of the western illumination. C) Medical images. The least-squares illumination technique as developed for geological applications was applied to medical images such as NMR or nuclear magnetic resonance (figs 4 and 5) and nuclear medicine (fig. 6). Fig. 4 shows a NMR image of a leg cross section and fig. 5 shows the same image after artificial illumination (from the west) was applied. The illuminated image shows better the boundaries between different tissues such as muscle, bone, and fat. Fig. 6 shows a liver scan produced by nuclear medicine after the illumination technique was applied. The illuminated image shows much better the small variations in the original liver scan (not shown).

Fig. 1. SEASAT altimeter data "illuminated" (North)

Fig. 2 (top). Venus. Aphrodite region. Topographic data illuminated (NW).
Fig. 3 (right). Venus. Beta-regio. Illuminated (W).

Fig. 4. NMR of leg bone and muscle.

Fig. 5. Same as fig. 4 but illuminated (West).

Fig. 6. Liver scan (Tc-99m) illuminated (East).