The Spatial Standard Observer

Degrees of visibility and discriminability of targets in images can be estimated.

Ames Research Center, Moffett Field, California

The spatial standard observer is a computational model that provides a measure of the visibility of a target in a uniform background image or of the visual discriminability of two images. Standard observers have long been used in science and industry to quantify the discriminability of colors. Color standard observers address the spectral characteristics of visual stimuli, while the spatial standard observer (SSO), as its name indicates, addresses spatial characteristics.

The SSO is based on a model of human vision. The SSO was developed in a process that included evaluation of a number of earlier mathematical models that address optical, physiological, and psychophysical aspects of spatial characteristics of human visual perception. Elements of the prior models are incorporated into the SSO, which is formulated as a compromise between accuracy and simplicity. The SSO operates on a digitized monochrome still image or on a pair of such images. The SSO consists of three submodels that operate sequentially on the input image(s):

1. A contrast model, which converts an input monochrome image to a luminance contrast image, wherein luminance values are expressed as excursions from, and normalized to, a mean;
2. A contrast-sensitivity-filter model that includes an oblique-effect filter (which accounts for the decline in contrast sensitivity at oblique viewing angles); and
3. A spatial summation model, in which responses are spatially pooled by raising each pixel to the power beta, adding the results, and raising the sum to the $1/\beta$ power. In this model, β=2.9 was found to be a suitable value.

The **SSO Was Applied to These Two Images** of targets viewed from a UAV. The left image contains a target calculated to have a visibility of 4.25 JND; the right image contains a similar target that has been reduced in contrast to have a visibility of 1 JND.

The net effect of the SSO is to compute a numerical measure of the perceptual strength of the single image, or of the visible difference (denoted the perceptual distance) between two images. The unit of a measure used in the SSO is the just noticeable difference (JND), which is a standard measure of perceptual discriminability. A target that is just visible has a measure of 1 JND.

The SSO was devised to satisfy an increasing need for a rapid, objective means of estimating degrees of visibility and discriminability of visual elements in scenes observed, not only by humans, but also by robotic vision systems, under a variety of circumstances. Examples of potential applications of the SSO include evaluating vision from unpiloted aerial vehicles (UAVs) [see figure]; predicting visibility of UAVs from other aircraft; estimating visibility, from a control tower, of aircraft on runways; measuring visibility, from a distance, of damage on aircraft and on a space shuttle; evaluation of legibility of text, icons, or other symbols; specification of resolution of a camera or a display device; inspection of display devices during manufacturing; estimating the quality of compressed digital video imagery; and predicting the outcomes of corrective laser eye surgery.

This work was done by Andrew B. Watson and Albert J. Ahumada, Jr., of **Ames Research Center**.

This invention is owned by NASA and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-2954.Refer to ARC-14569-1.

Less-Complex Method of Classifying MPSK

Nearly optimal performance can be obtained with less computation.

NASA's Jet Propulsion Laboratory, Pasadena, California

An alternative to an optimal method of automated classification of signals modulated with *M*-ary phase-shift-keying (*M*-ary PSK or MPSK) has been derived. The alternative method is approximate, but it offers nearly optimal performance and entails much less complexity, which translates to much less computation time.

Modulation classification is becoming increasingly important in radio-communication systems that utilize multiple data modulation schemes and include software-defined or software-controlled receivers. Such a receiver may "know" little *a priori* about an incoming signal but may be required to correctly classify its data rate, modulation type, and forward error-correction code before properly configuring itself to acquire and track the symbol timing, carrier frequency, and phase, and ultimately produce decoded bits. Modulation classification has long been an important component of military interception of initially unknown radio signals transmitted by adversaries. Modulation classification may also be useful for enabling cellular telephones to automatically recognize differ-