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ESTIMATION OF MODULATION TRANSFER FUNCTION OF LANDSAT-4 SENSORS FROM MEASURED IMAGERY

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ABSTRACT

Satellite-based multispectral imaging systems have been in operation since 1972 and the latest in the Landsat series of sensors was launched in July 1982. In order to verify that the Landsat-4 Thematic Mapper (TM) and Multispectral Scanner Systems (MSS) sensors are operating within specifications, it is necessary to estimate the system parameters by analysis of the measured data. One parameter of interest is the sensor modulation transfer function (MTF) or the point spread function (PSF) which determines the spatial resolution of the system.

This paper discusses two methods to determine the actual overall resolutions after launch. The problem is formulated as a two-dimensional linear system. The measured data can be expressed in the frequency domain as the product of the overall optical transfer function and the spectrum of the earth scene:

$$G(u,v) = H(u,v)\ F(u,v)$$

where $F(u,v)$ is the spectrum of the earth scene, $H(u,v)$ is the optical transfer function and $G(u,v)$ is the spectrum of the measured data.

Given the measured data, we wish to determine the modulation transfer function. Some knowledge of the earth scene must be known or assumed in order to accomplish this. In our experiments, we use the film scanned data of the aerial photograph of the same coverage as the underlying earth scene.

Our measured inagery is divided into subimages which may overlap. Taking the Fourier transform of each block we obtain:

$$G_i(u,v) = H(u,v)\ F_i(u,v)$$

Taking the logarithm of the magnitude of the spectrum we obtain:

$$\log |G_i(u,v)| = \log |H(u,v)| + \log |F_i(u,v)|$$

A reasonable estimate for the logarithm of the MTF is given as following by averaging over the N subimages.

$$\log |H(u,v)| = \frac{1}{N}\sum_{i=1}^{N} \log |G_i(u,v)| - \frac{1}{N}\sum_{i=1}^{N} \log |F_i(u,v)|$$

The log spectrum of the measured data and the film scanned data can be evaluated easily. Interpolation procedures are carried out to accomodate the different sampling rates of the output and input spectrum.

In the second method, we assume stationarity and use the stochastic linear system relationship:

$$S_{gg}(u,v) = |H(u,v)|^2\ S_{ff}(u,v)$$

where $S_{gg}(u,v)$ and $S_{ff}(u,v)$ are the spectral densities of the measured data and the underlying earth scene respectively.

Thus the estimate of the MTF is given

$$|H(u,v)| = \left| \frac{S_{gg}(u,v)}{S_{ff}(u,v)} \right|^{\frac{1}{2}}$$

A variety of methods, e.g. periodograms, smooth spectrum and maximum entropy

methods are used to estimate the spectral densities. Interpolation procedures are again required to accomodate the different sampling rates of the input and output spectral densities.

In interpreting the results of the MTF estimates, it is convenient to use bandwidth which characterizes the spatial resolution of the sensor. The methods described above were applied to Landsat-4 MSS and TM images from the Webster County, Iowa area and the Chicago, Illinois area. The aerial photograph filmed scanned data was used as the underlying scene. Experimental details and results will be presented at the conference.

AUTHOR BIOGRAPHICAL DATA

CLARE D. McGILLEM is professor of Electrical Engineering at Purdue University and a member of the technical staff of the University's Laboratory for Applications of Remote Sensing (LARS). He received the B.S.E.E. degree from the University of Michigan in 1947 and the M.S.E. and Ph.D. degrees from Purdue University in 1949 and 1955, respectively. After a number of years in government and industry working in the area of aerospace electronics, he joined the faculty of Purdue University in 1963. From 1968-72 he served as Associate Dean of Engineering and Director of the Engineering Experiment Station at Purdue. Dr. McGillem is active in research and teaching in communication theory, radar, and signal processing.

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