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1. INTRODUCTION

The knowledge of the resolution of a sensor is an important characteristic which allows the analysis of their performance. The spatial resolution remains an obscure domain and was tried to be many times defined. The resolution is what characterize the capacity of an imaging system to describe how much details are visible in the image, depending on their size. Image quality is often characterized by well-known measures and criteria, usually linked with radiometry, like mean, contrast, brightness, noise variance, radiometric resolution or granularity. Only a few tools are available to characterize the spatial performance of an imaging device. The most often used are Point Spread Function-like functions (**Li** 2000), gradient or high-pass filters in general (**Zhou** 1998), Ground Sampled Distance (GSD) (**Vrabel** 2000, **Wald** 2002), Full Width at Half Maximum (FWHM), or visual analyses (**IRARS** 1996).
The problem encountered with selecting a certain band width by original image numerical filtering is that only the extracted spatial structures are highlighted. The spatial features of other spatial frequency are neglected. The idea would be to use a function or a criteria which characterize the overall geometrical quality of the images delivered by an instrument. The problem of specifying resolution and perceived sharpness was solved with the introduction of the Modulation Transfer Function (MTF), a precise measurement made in frequency domain. By definition, the MTF is the Fourier transform of the instrument answer to a pulse. It subdues the contrast of the image with the frequency, caused by finite detector size, sensor motion, diffraction, aberrations, atmospheric scattering, turbulence, and electronic effects (**Holst** 1995). Only the mean of the image is perfectly conserved, and the MTF tends to gather all numerical accounts around this mean. If the spatial frequency of an object is higher than the cut-off frequency, its image will be characterize by a uniform enlightenment.
In the field of Earth observation, MTF is an information that, in most cases, satellite providers don't deliver easily. Representative of the intrinsic quality of their device products, the shape of the MTF and more particularly the cut-off frequency is not clearly given or even defined. Distortions and limit of sensors are well guarded. For instance, the documentation of SPOT Image (**Anonymous** 1986) remains very vague on the subject of MTF. They give specifications for the cut-off frequency of SPOT P images without informing about the way they calculated it and no information was found about multispectral images. Moreover, some confusions between terms like, MTF, resolving power, cut-off frequency, minimum allowable MTF at the Nyquist frequency, create inconvenient ambiguity. Some are looking for the highest resolution pattern where detail was visible, whereas others define a percentage of attenuation of 10, 5 or even 2% of the original contrast, but no standard threshold is determined.
The objective of this paper is to use the MTF in order to assess the overall image geometrical quality or resolution of an imaging system. As this function is not always clearly described by manufacturers, the MTF should be directly estimated from raw satellite images. By using the MTF, two systems can readily be compared. In this paper, a method for this estimation is presented. An example is provided, dealing with IKONOS imagery. **Ryan et al.** (2003) estimated MTF from real images where constructed targets were settled in order to check the matching of the original IKONOS imagery MTF specifications. We compare our estimation of MTF to their results. Some perspectives on the use of MTF as a quality criteria are proposed.

2. BACKGROUND

Several methods exist to determine the MTF. The MTF is the amplitude spectrum of the system answer to an perfect impulsion, or point spread function PSF. For an optic system, the stain of diffusion which stems from a perfect luminous point (called Dirac impulsion) corresponds to the PSF of the system. The image of this object will be at least one pixel wide. Instead, it will normally consist of a spot of several pixels, brightest in the centre and progressively darker away from the centre, and is deeply related to sampling. It describes how the sharp edge has been spread out by the imaging process. Now, the resolution can be also defined as the width within which the PSF drops to half the maximal value, called full width half maximum FWHM, but give only one single value of the entire image spatial quality. The PSF need not be symmetrical, so there may be different spatial resolutions in different directions.

Drawing a point or even a cloud of points is conceivable for a scanner of a numerical camera. This becomes far more unconceivable for satellite images, even with constructed targets. A solution to since former problem was to simulate the pulse from the available information. The traditional method of calculating the MTF involves taking an edge scan of an image perpendicular to the edge (edge spread function ESF). The edge is not an instantaneous transition and appears to be more gradual, and give some information about how the imaging system treats edges. To create the pulse, the edge is derivated leading to the Line Spread Function or PSF if a profile perpendicular to the edge is plotted. The Fourier transform (FT) of the PSF provides an estimate of the MTF in one orientation.
As an edge will only contain a few points and to locate the inflexion point (and consequently the location of the pulse response) we would need to oversample the edge. This can be done by the use of a long enough tilted slop instead of an horizontal or vertical one. In our natural environment, however, finding a perfect tilted sloped such as long bridges, big roads, large buildings and other large size linear features, is not very common. So **Ryan et al.** (2003) chose to use artificial targets located in large fields, where they controlled the angle of orientation of the tarp to evaluate MTF of IKONOS sensors. Nevertheless, despite the efficiency of the method, logistical difficulties with artificial targets and lack of control of natural ones, make target-free approaches to image-quality evaluation desirable.

3. EXPERIMENT

Following the idea of **Luxen et Förstner** (2002), a systematic method to read MTF is defined from any image. The needed PSF is derived from the sharpness of the edges located in the image. In order to alleviate the lack of perfect contours in nature, a statistical approach of the problem was opted. A number of significant amplitude edges is selected and oversampled in each direction with a bicubic interpolation, and in both direction (vertical and horizontal). This selection is performed using the two corresponding images in the directional multiresolution decomposition of **Mallat** (1989). Then, a numerical derivation is applied to the edges, with the following numerical filter : [-1, 0, 1], and the corresponding transposed for the other direction, in order to get the pulse function. Finally, Fourier transform is applied to the pulse and the MTF for one profile is obtained. For a better estimation, all the maximum edges are processed the same way. The MTF at the Nyquist frequency is expected to be lower in the vertical direction, caused by the scanning system motion.

4. EVALUATION AND PERSPECTIVES

A comparison between our estimation of the MTF from an IKONOS image over the area of Frederiktown (Canada) and those obtained by **Ryan et al.** (2003) is presented. A study of differences existing in the MTF between the two directions in the image is proposed. Based on MTF estimation, some quality criteria are envisaged and discussed. These criteria will add on the process of describing the intrinsic quality of a sensor.

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