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Automated registration of hyperspectral images for precision agriculture

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Abstract

Hyperspectral imagery of the Earth's surface is increasingly being acquired from aerial platforms. The dozens or hundreds of bands acquired by a typical hyperspectral sensor are collected either through a scanning process or by acquiring a sequence of images at different wavelengths. This latter method has the advantage of acquiring coherent images of a scene that are more easily interpretable than a given waveband from a scanning system. However, it takes time to collect these images and some form of image-to-image co-registration is required to match the band-to-band pixel locations and build coherent image cubes. In this paper, we present a Phase Correlation (PC) method to register many bands acquired sequentially at different wavelengths. This method was implemented to recover scaling, rotation, and translation from an airborne hyperspectral imaging system, dubbed the Portable Hyperspectral Tunable Imaging System (PHyTIS). The PC approach is well suited for remotely sensed images acquired from a moving platform, which induces image registration errors due to along- and across-track movement. We were able to register images to within ±1 pixel across entire image cubes obtained from the PHyTIS, which was developed for precision farming applications.

Keywords: Hyperspectral; Image registration; Phase correlation; PHyTIS; Precision agriculture; Remote sensing

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1. Introduction

Hyperspectral imagery consists of dozens to hundreds of contiguous wavebands, each representing a narrow width of energy, generally in the visible and near- or mid-infrared portions of the spectrum. Hyperspectral imagery provides complete spectra at each pixel location in a scene delivering more information than is possible with a multispectral imaging system having discrete and usually non-contiguous bands. Imagery can be acquired using two hardware methods. One, a scanning system, where the incoming light is split into many wavebands of discrete widths and directed onto a Charge-Coupled Device (CCD) such that each line of pixels in the sensor records a different waveband of a single line image acquired of the ground scene. Thus, a two-dimensional CCD would represent one line on the ground at many wavelengths. As the aircraft moves forward, the CCD integration time ('frame rate' in traditional videography) is timed so that the image is acquired and saved by the time the aircraft moves far enough to acquire the next line of pixels on the ground. In this way, an image is built up. This has the advantage that all the pixels within each line are spectrally co-registered but spatially each line of pixels will be shifted with respect to the previous line because of aircraft movement (Fig. 1a). Another method acquires imagery similar to that of a standard photographic camera in that each image is of an entire scene. Multiple images, however, can be acquired at different wavelengths. Filters in front of the camera change, allowing an image cube to be built-up where the *X*- and *Y*-axes represent ground directions and the *Z* direction is the stack of images at different wavelengths. The advantage to this is that a scene is spatially coherent within a given waveband but due to aircraft movement and the time required to collect images, the images require co-registration between the wavebands (Fig. 1b).

For hyperspectral imagery to be useful for analysis, the images must be co-registered. Typically, most commercial image registration software allows the user to manually co-register two images. The user chooses ground control points (GCPs), the degree of warping, and resampling method (nearest neighbor, bilinear, etc.). The software uses the GCPs from both images to compute the coefficients of the warping polynomial by minimizing the root mean square (RMS) error of all the points. The advantage of this approach is that the user can exclude GCPs that contribute to large RMS thereby improving the registration of the images. The disadvantage is that the task becomes tedious and time-consuming if there are many images to be registered, such as for hyperspectral imagery.

Many methods have been employed to register spectral multi-temporal remotely sensed images either from space or airborne platforms. Several registration approaches are found in the literature that addresses the registration of monochromatic and spectral images. The most popular registration methods can be placed into two groups: one that uses pixel-based registration and the other that transforms the image to another domain to estimate registration parameters. Most of the approaches correct rotation, translation, and scaling. However, depending on the configuration of the sensor, other effects may be introduced into the imagery. These effects and some of the terminology used in image registration are described in Table 1.

Gradient methods are a type of pixel-based registration and have proven to be effective at finding transformations between images when rotation and translation are very small. Averbuch and Keller (2002) describe the use of a gradient-based motion estimation tech-