Matching between Different Image Domains

Charles Toth, Hui Ju, and Dorota Grejner-Brzezinska

The Center for Mapping, The Ohio State University,
470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210
toth@cfm.ohio-state.edu

Abstract. Most of the image registration/matching methods are applicable to images acquired by either identical or similar sensors from various positions. Simpler techniques assume some object space relationship between sensor reference points, such as near parallel image planes, certain overlap and comparable radiometric characteristics. More robust methods allow for larger variations in image orientation and texture, such as the Scale-Invariant Feature Transformation (SIFT), a highly robust technique widely used in computer vision. The use of SIFT, however, is quite limited in mapping so far, mainly, because most of the imagery are acquired from airborne/spaceborne platforms, and, consequently, the image orientation is better known, presenting a less general case for matching. The motivation for this study is to look at the feasibility of a particular case of matching between different image domains. In this investigation, the co-registration of satellite imagery and LiDAR intensity data is addressed.

Keywords: Image registration/matching, LiDAR, satellite imagery.

1 Introduction

Image registration is a core technique for various applications in digital photogrammetry, computer vision, remote sensing, and vision-aided navigation. The basic idea is to find the correspondences between images and image pairs acquired at different times, perspectives or even from different sensors. With rapid developments in sensor technologies, increasing data volume are acquired from spaceborne, airborne and mobile platforms in various data domains. While the georeferencing of images is improving, which is essential to constrain the search space, the need for methods that can provide robust co-registration between various image domains is sharply growing.

The majority of the image registration/matching methods are applicable to images acquired by either identical or similar sensors from various positions. Simpler techniques assume some object space relationship between sensor reference points, such as near parallel image planes, certain overlap and comparable radiometric characteristics; all are typical in airborne surveying. More robust methods allow for larger variations in image orientation and texture. One of these techniques is the Scale-Invariant Feature Transformation (SIFT), proposed by Lowe in 1999, a highly robust technique that has been widely used in the computer vision community. Though, SIFT is known in mapping circles, its use is quite limited so far, mainly,

U. Stilla et al. (Eds.): PIA 2011, LNCS 6952, pp. 37–47, 2011.

because most of the imagery are acquired either from airborne or spaceborne platforms, and, consequently, the image orientation is better known, presenting a less general case for matching. In addition, the accuracy of SIFT is modest to digital photogrammetric practice. As an increasing number of various image sensors provide multiple image coverage worldwide, the need for co-registering imagery acquired in different domains is growing. Several satellite systems deliver high-resolution imagery in short repeat time, large-format aerial digital cameras provide multispectral imagery, LiDAR systems collect both range and intensity images at local scale, IfSAR data are acquired from spaceborne and airborne platform at global scale, etc., all these data should be accurately co-registered for data fusion to support better geospatial data and information extraction.

The motivation for this study is coming from two applications: terrain-based navigation and improving the georeferencing of satellite imagery by using ground control. Commercial satellite systems have shown remarkable improvements recently; the image resolution of several systems has increased to the maximum allowable 0.5 m GSD, and the georeferencing accuracy is around the few meter level. Given the worldwide availability of satellite imagery and its short repeat time, satellite images represent valuable data for terrain-based navigation.

Identifying conjugate feature points from LiDAR data is practically impossible, as the LiDAR point cloud is sparse and furthermore the intensity associated with the points has different characteristics compared to optical imagery. Therefore, other image primitives such as 3D straight lines and surface patches are generally considered (Habib, Bang, Aldelgawy, Shin, & Kim, 2007; Habib, Ghanma, & Tait, 2004; Habib, M.S.Ghanma, Morgan, & Mitishita, 2004; Kim & Habib, 2009). With increasing laser point density, better LiDAR intensity images are formed, which could be potentially registered to optical imagery. Due to its robust scale- and rotation-invariant properties, SIFT (Lowe, 1999; Brown, Lowe, 2002; Lowe, 2004) is a widely used matching technique in optical image domain (Abedini, Hahn, & Samadzadegan, 2008). Based on earlier experiences, SIFT was successfully applied to satellite and aerial image registration (Toth, Ju, & Grejner-Brzezinska, 2010). However, in our tests, SIFT failed to provide robust registration between optical and LiDAR intensity images. Therefore, an alternative method has been developed in this study.

2 SIFT Matching

The Scale Invariant Feature Transform (SIFT) matching is a technique to extract highly invariant features from images and to perform reliable matching; a thorough description on SIFT can be found in (Lowe, 2004). To achieve robust performance, the features for image matching should be generally invariant to scale, rotation, affine distortion and intensity changes to handle varying imaging conditions. The SIFT algorithm consists of several stages and the computation requirements are quite substantial; in particular, the matching of the extracted features could be a challenge for larger number of features, as it is based on k-D tree structure. There are also some modifications to SIFT to make it more effective: PCA-SIFT (Ke and Sukthankar, 2004), GLOH (Gradient Location-Orientation Histogram) (Mikolajczyk and Schmid,