VERY HIGH RESOLUTION REMOTE SENSING DATA: PROCESSING CAPABILITIES AND LIMITATIONS IN URBAN AREA

Jie Shan and   Ejaz Hussain

School of Civil Engineering, Purdue University, West Lafayette, IN 47907, USA
{jshan, ehussain}@purdue.edu

1.   INTRODUCTION

With the recent developments of very high resolution (better than 1 meter in spatial resolution) space borne, airborne sensors, the quality and details of the inherent information in the imagery has increased immensely. This challenges our data processing capabilities and exposes certain limitations that we are facing. These capabilities and limitations are discussed in the subsequent paragraphs, followed by a brief review of such very high resolution remote sensing data.

2.   HIGH RESOLUTION DATA

During the last decade, a lot of new space borne sensors became available to acquire very high resolution digital images. These systems have an improved spatial resolution from 4m to 1.65m for multispectral bands and from 1m to sub meters (0.41m) for panchromatic band. In the meantime, airborne sensors are now capable of providing simultaneously color and infrared images at a resolution of up to 2cm. At this improved spatial resolution level, four (4) bands is the most common spectral resolution, with the recently launched WorldView-2 having 8 bands that provide additional information for agricultural, coastal and biomass studies. Besides, several space borne systems also provide synthetic aperture radar images, such as TerraSAR and ALOS PALSAR, Radarsat 2, at a resolution of several meters. With off nadir pointing capability in both along and across tracks, the satellites can have a revisit time as frequent as almost 1 day. Besides, multi lens and oblique aerial photography is turned out to be very useful for complete data collection and 3D model generation in urban areas. As a relatively new development, airborne laser ranging (lidar) technology is becoming popular and well accepted in the past few years for rapid, direct 3D urban landscape model generation at a resolution of up to a few centimeters.

3.   PROCESSING CAPABILITIES

One of the primary data sources in many urban applications is precision 3D landscape models. This is required by urban runoff analysis, infrastructure and property inventory, development planning, and tele-communication. It is shown [1] that with a biased-corrected sensor model and minimum ground control the geo-referencing accuracy can reach an unprecedented level of 0.1m (0.2 pixels) in planimetry and 0.25m (0.5 pixels) in height for GeoEye-

1 imagery. Despite non-perfect condition of the test area, 0.71m (~1 pixel) height accuracy is achieved from WorldView-1 stereo images for an open area with separated houses and single trees. Certain levels of details can also be identified and reconstructed for single house roof structures [2]. Besides, dense lidar point clouds can be used to reconstruct urban building models with fine details and an accuracy of 0.2-0.5m (~ 0.2-0.5 point spacing) [3].

Our capability in identifying objects and determining their spectral properties is also improving. Most of the previously developed pixel-based image analysis methods have limitations in processing high resolution data acquired over complex, heterogeneous and highly variable urban environments because of the large number of heterogeneous urban features with very similar spectral characteristics among different land cover types and high spectral variation within the same land cover type. On the contrary, object-based processing methods allow the combined use of spatial and contextual features in addition to spectral information, and can produce higher classification accuracy and better thematic maps. Figure 1 left and middle respectively show an aerial image at 15 cm resolution and its derived urban features, including single buildings, water bodies, roads, lawns, and tress. With careful training, over 90% overall classification accuracy can be achieved for complex urban images [4].
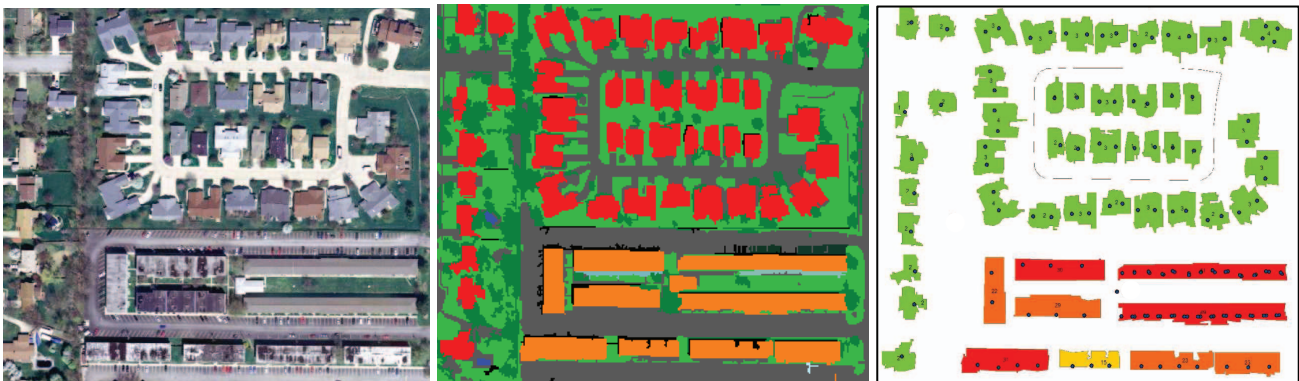

Figure 1. 15cm aerial image (left), class map (middle) and micro population map with labeled addresses (right).

4. PROCESSING LIMITATIONS

Although post geo-referencing potential is approaching its limit and receives stable performance, the average 3m accuracy of direct geo-referencing for satellite imagery still has room to improve. For time critical applications and precision change analysis, better and faster solutions are still demanding [5]. In addition, the precision co-registration of heterogeneous data, such as lidar and images, optical and SAR images is of a challenge for generating a unified urban landscape model.

We are lack of operational algorithms for centimeter or sub-meter object detection and recognition for various engineering applications. Figure 2 shows a 7.5cm high resolution airborne digital images, from which we seek to effectively locate individual fire hydrants (red), electric poles (blue), storm water inlets (black), trees, and other similar features. These are necessary for routine maintenance and emergency response. It also provides a rapid, frequent and cost effective means for urban infrastructure inventory and appears as an increasingly promising alternative to the traditional field visit and ground surveying.

Figure 2. 7.5cm aerial image showing storm water inlets (black), electric pole (blue) and fire hydrant (red).

Spectral mixture is more critical in very high resolution images for urban areas [6,7]. Two different objects with similar spectral characteristics, such as building roofs, roads or parking lots, make their separation and classification more complicated as shown in Figure 3. Moreover, dense trees and their shadow overlapping the nearby urban features make the mapping more difficult. Presently, we do not have effective and reliable solution to this problem without using additional data.

Figure 3. QuickBird image (upper, Houston) and its class map. Misclassification is circled. Image courtesy the International Charter and DigitalGlobe.

Different spectral data need to be combined to derive temporal change information which otherwise is not possible with any of the single data source alone. Roads, trees and water have very similar response in ALOS PALSAR data collected during a flood period. To determine the flood extent, optical images at a different time are needed to obtain normal land covers. A combination of these two images produces the actual flood distribution. Figure 4 is such an example of ALOS PALSAR and Landsat images for the Georgia flood in September 2009. Such a need challenges for timely, multiple, complementary data collection and effective integration.

Figure 4. ALOS PALSAR image (left), Landsat image (right), and merged flood distribution (right) for the Georgia floods of September 2009 (ALOS image courtesy the International Charter and JAXA).

Finally, despite the ever higher resolution data, either spatial or spectral, such remote sensing data alone cannot resolve the semantics of complex urban features, such as identifying the usage of the detected buildings. For this purpose, data fusion is needed between spectral and semantic data. Figure 1c shows such an example where residential buildings are separated from other buildings by using zoning map and a micro population map for each building is produced by redistributing the census block data. This example demonstrates the need for integration between remote sensing and geographic information system.

5. CONCLUSION

The availability of very high resolution remote sensing images, either spatially or spectrally, makes it possible to map urban area at sub meter or centimeter levels. We are moving from mapping geographic or cartographic features to engineering features. All of this challenges for precision co-referencing between data sources, novel feature detection and extraction methods, and integration of multi-temporal, heterogeneous data sources for reliable, semantic information extraction, and change analysis.

6. REFERENCES

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