Detection of Speed of Moving Objects from Digital Aerial Camera and QuickBird Sensors

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Abstract

This paper highlights the method to detect moving objects and measure their speeds from high-resolution satellite images and airborne images. First using the images from Google Earth, "ghosts" of moving objects seen in pansharpened QuickBird images are demonstrated. The slight time lag (0.2 seconds) between panchromatic and multispectral sensors of QuickBird is responsible for the ghosts and they can be used to measure the speeds of moving objects using only one scene of QuickBird's "bundle product". However, due to limitation of the short time lag and the resolution (2.4 m for multispectral bands), high accuracy is expected only for high-speed large objects, e.g. airplanes. A method to detect the speed of vehicles is also proposed using a pair of aerial images. An object-oriented approach is employed to detect cars on an expressway automatically and the accuracy is examined comparing with visual extraction results.

Introduction

Satellite remote sensing and aerial photography have been used to capture still (snapshot) images of the earth surface. But if two images with a small time interval are taken, they can be utilized to detect moving objects, e.g. cars, and even to measure their speeds. If such data are available, many new applications can be considered such as observing highway traffic conditions.

From the images taken by high resolution satellites, e.g. QuickBird, we can observe small objects, like cars. It is known that panchromatic and multi-spectral sensors of QuickBird have a slight time lag, about 0.2 seconds, depending on the scanning mode of the instrument. Using this time lag between two sensors of one scene, the speed of moving objects can be detected (Etaya et al., 2004; Xiong and Zhang, 2006). In this study, using the pansharpened images of airports, trains, and expressways from Google Earth, the effect of the small time lag is demonstrated. Then the speed of running cars on a road is evaluated using a QuickBird scene (a bundle product of panchromatic and multi-spectral bands) of Bangkok, Thailand, as an example.

Another method to detect car speed is proposed using aerial photographs. Aerial photographs are often taken along a flight line with an overlap among adjacent scenes. If a moving object captured in a scene is also captured in an adjacent image, the speed of the object can be detected. A new object-based method is developed to extract the moving vehicles and subsequently detect their speeds from two consecutive aerial images automatically. Using a pair of digital aerial images of central Tokyo, the proposed automated extraction method is applied and the accuracy is examined comparing with visual extraction results.

Images of Moving Objects in Google Earth

Google Earth (http://earth.google.com/) recently provides high resolution optical images of urban areas, either from aerial photographs or pansharpened QuickBird (QB) images. For one scene, a pansharpened image can be produced by co-registering a panchromatic (PAN) image and a multispectral (MS) image. But due to the slight time lag (about 0.2 seconds) between a pair of PAN and MS images, the locations of moving objects displace after the short time interval. Even if the PAN and MS bands have been co-registered for still objects like roads and buildings, they cannot be co-registered for moving objects.

Figure 1 shows a part of Ninoy Aquino International Airport, Metro Manila, Philippines, from Google Earth. Two airplanes are seen on the runway. The right plane is just at the moment of landing and the left one is standing still and waiting for take-off. A "ghost" is only seen in front of the moving airplane. Similar ghosts were observed in several airports in the world such as Narita/Tokyo International (Japan), Bangkok International (Thailand), and Hong Kong International. These ghosts were produced due to the time lag between PAN and MS sensors of QB. The speed of the airplane in Fig. 1 is evaluated as 326 km/h assuming the time lag as 0.2 seconds.

This kind of ghosts are also seen in front of other moving objects, like trains, automobiles, ships, but due to limitation of the image resolution and short time lag, ghosts are not so clear as those for airplanes. We simulated a higher resolution pansharpened image of an expressway with 0.25 m resolution from an aerial photograph. By this resolution, the ghosts resulting from the time lag between PAN and MS sensors were clearly seen in front of moving vehicles.
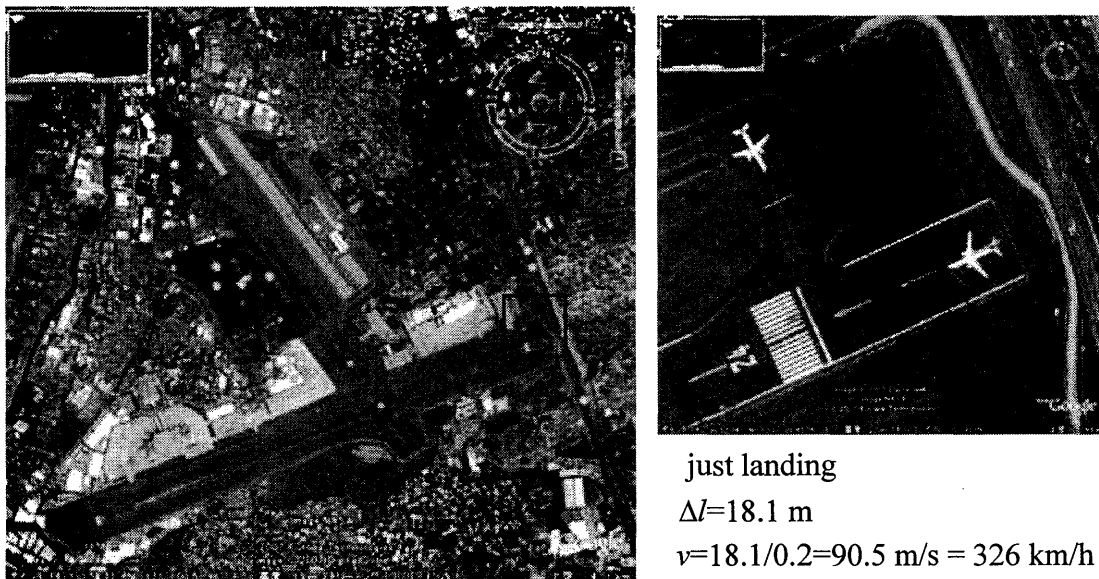

just landing
Δl=18.1 m
v=18.1/0.2=90.5 m/s = 326 km/h

Figure 1 Pansharpened QuickBird Image of Ninoy Aquino International Airport, Manila, Philippines, from Google Earth. A ghost is generated in front of the just landing airplane.

Detection of Car Speed from QuickBird Image

The time lag between PAN and MS sensors of QB was investigated using bundle products of QB. Figure 2 shows the time lag for 36 scenes which we have at hand. These images were taken for various parts of the world, e.g. Japan, USA, Peru, Thailand, Indonesia, Morocco, Iran, Turkey, Algeria, from March 2002 to July 2006. The time lag is either about 0.20 seconds or about 0.23 seconds, but we cannot find any rule to determine this time lag, as also stated by Etaya et al. (2004).
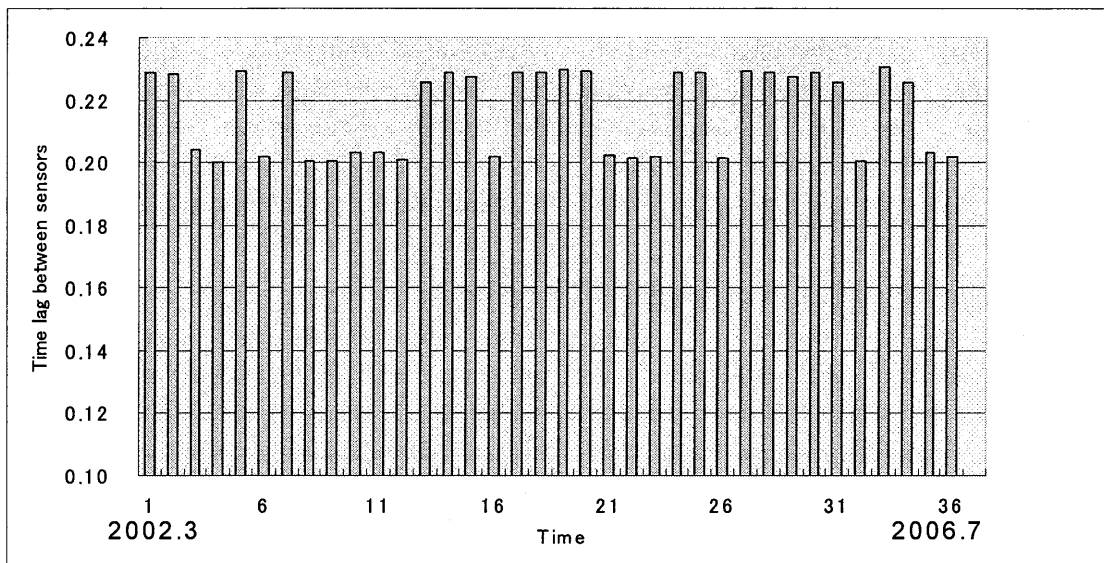
Figure 2 Time lag between PAN and MS sensors of QuickBird for 36 scenes in the world

Since the spatial resolution of QuickBird multi-spectral image is 2.4 m, rather coarse to figure out small cars, measuring the speed for smaller and slower objects is not so accurate. Figure 3 shows a QB image of central Bangkok, Thailand. Comparing the location of cars on the road in PAN and MS images with 0.20s time lag, the speed and moving direction of the cars can be evaluated as arrows in the figure. In this investigation, we encountered some difficulty to locate cars in MS images with 2.4 m resolution. Improvement of spatial resolution of satellite sensors is desired to detect the speed and moving direction of cars more accurately.
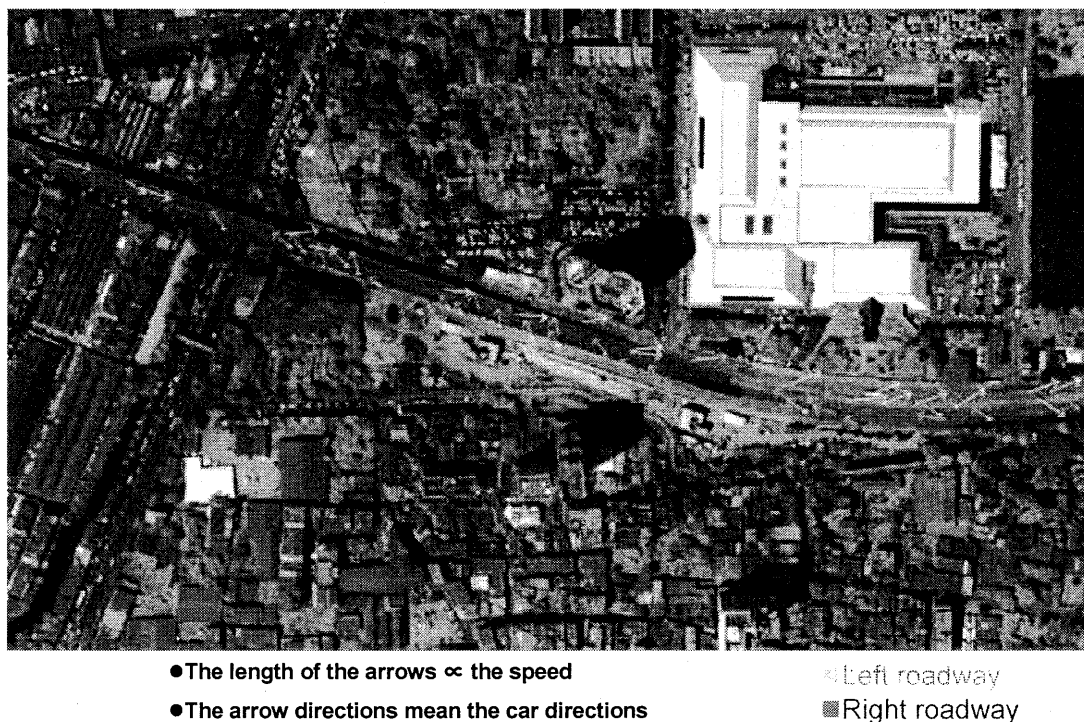

●The length of the arrows ∝ the speed

●The arrow directions mean the car directions

Left roadway

■Right roadway

Figure 3 Result of visual detection of car speed from QB bundle product for central Bangkok, Thailand

Detection of Car Speed from Digital Aerial Images

Aerial images are often taken along a flight line with an overlap among adjacent images. If a moving object is captured in adjacent images, the speed of the object can be detected. Although conventional aerial photography with film has enough high spatial resolution to detect cars, recent digital aerial cameras can provide much higher radiometric resolution even though the spatial resolution is almost the same level. Hence to extract vehicles from an image visually or automatically becomes much easier.

A new object-based method was developed to extract the moving vehicles and subsequently detect their speeds from two consecutive digital aerial images automatically (liu et al., 2007). Several global and local parameters of gray values and sizes are examined to classify the objects in the image. The vehicles and their associated shadows can be discriminated by removing big objects such as the roads. To detect the speed, firstly vehicles and shadows are extracted from two consecutive images (Vu et al., 2005). The corresponding vehicles from these two images are then linked based on similarity in the shape, size and their distance within a threshold. Finally, using the distance between the corresponding vehicles and the time lag of the two images, we can detect the moving speed and moving azimuth angle. Our test shows a promising result of detecting the speed of moving vehicles. In addition, the speed detection process also helps to mitigate the errors generated in the vehicle extraction.

Figure 4 shows two consecutive images of central Tokyo taken by UltraCamD (Vexcel Corporation, 2007). The images are much clearer than those obtained by film cameras. Two other features of digital cameras help to measure the speed and azimuth direction of vehicles. One is very high overlapping ratio (80 % in this example) and another is very accurate acquisition time. These characteristics of digital aerial cameras enable us to calculate the speed and azimuth directions of moving objects very

GPS Time: 438380.2618s

GPS Time: 438383.3394s

-7507.91W
-38375.49S

-7474.55W
-38358.52S
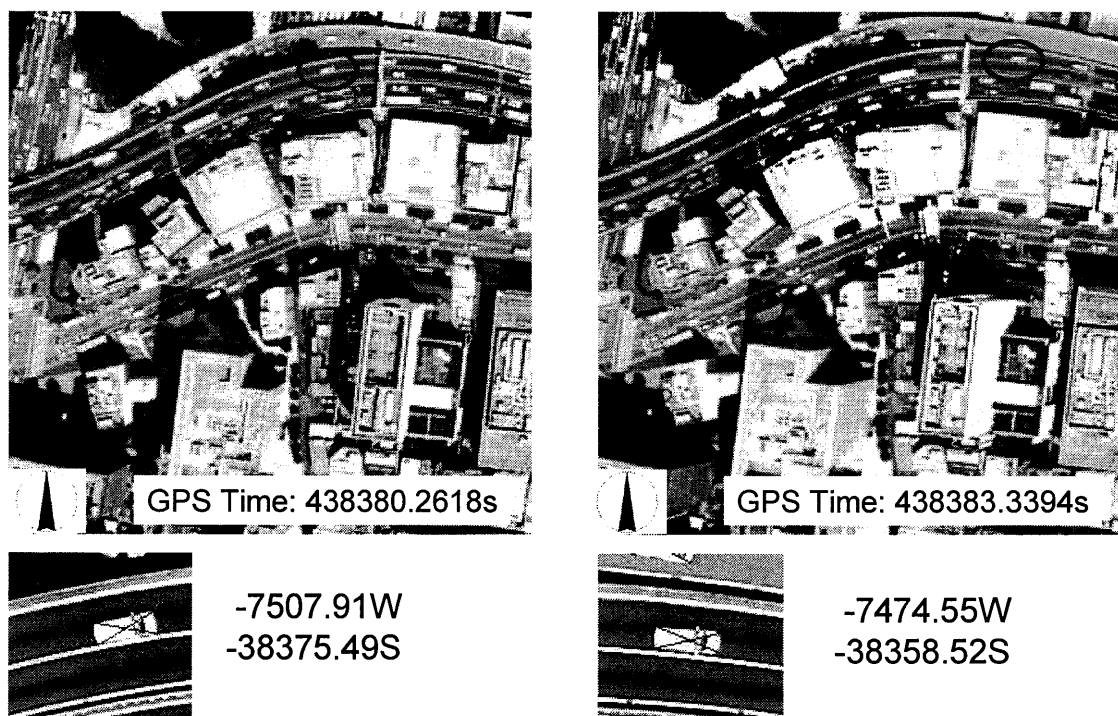
$$\Delta t = 438383.3394 - 438380.2618 = 3.0776s$$

Figure 4 Two consecutive aerial images of central Tokyo having about 3.08 s time lag, taken by digital aerial camera. The images were provided by Geographical Survey Institute of Japan.

accurately.

The two images in Figure 4 were coregistered first by image-to-image matching using eight control points. The result of the automated car extraction and speed detection is shown in **Figure 5**. A total of 37 vehicles were detected in the pair of images and their speeds were evaluated. The average speed on the top lanes (east bound) is obtained as 39.7 km/h while that on the bottom lanes (west bound) as 19.0 km/h. These values well represent a heavy traffic condition of this segment of the urban expressway.

The proposed method does not need to deploy ground-based traffic sensors and can cover wide areas at a time. Hence it is expected to serve as a convenient tool to assess traffic conditions of urban areas.
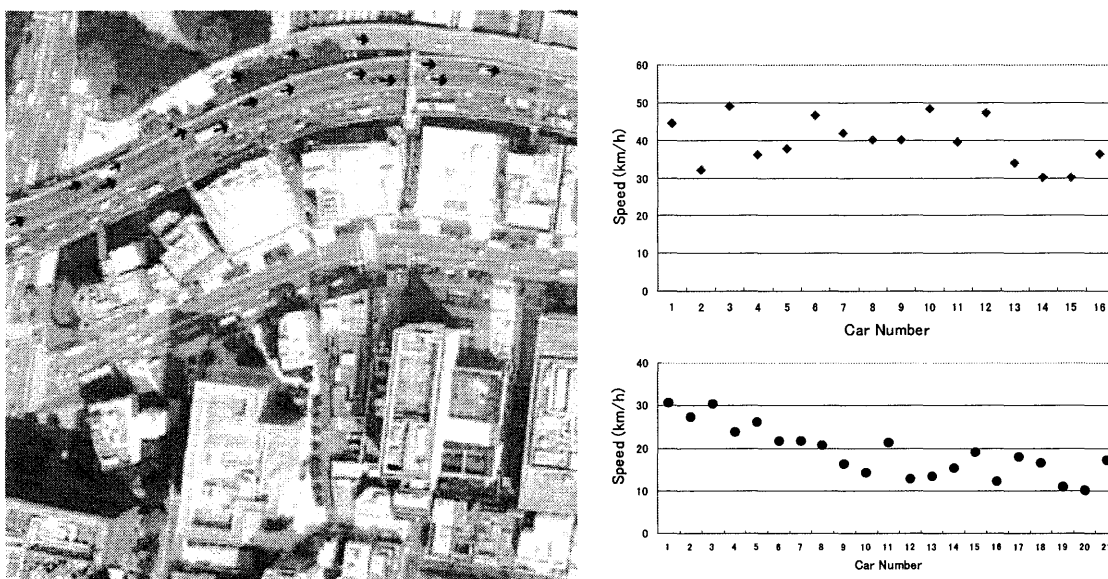

Figure 5 Result of detection of speed and azimuth direction of vehicles. The top graph shows car speed in east bound lanes and the bottom graph shows that in west bound lanes.

Conclusions

Methods to extract moving objects and measure their speeds from high-resolution satellite images and airborne images were highlighted. First using the images from Google Earth, "ghosts" of moving objects in pansharpened QuickBird images were demonstrated. The slight time lag, about 0.2 seconds, between panchromatic and multispectral sensors of QuickBird was shown to be responsible for the ghosts and they can be used to measure the speeds of moving objects using only one scene of QuickBird's "bundle product". Due to limitation of the short time lag and the resolution (2.4 m for multispectral bands), however, high accuracy is expected only for high-speed large objects, e.g. airplanes. An example of visual detection of speed and azimuth direction of cars was provided using a QB image of central Bangkok, Thailand.

A method to detect the speed of vehicles is also proposed using a pair of overlapped aerial images. An object-oriented approach is employed to detect cars on an expressway automatically. The method was applied to two adjacent images of central Tokyo. Comparing the location of extracted corresponding vehicles in the image pair, the speed and azimuth direction of moving vehicles were obtained with high accuracy. The proposed method may be used in assessing traffic conditions of wide urban areas without using ground-based traffic sensors.

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