

# **The Production and Applications of Digital Orthophoto of Hong Kong Special Administrative Region, China**

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**Key words:** digital orthophoto, orthophoto production, orthophoto application

## **SUMMARY**

Survey and Mapping Office, Lands Department of the Government of Hong Kong Special Administrative Region (HKSAR) is responsible for the provision of maps and aerial photographs of the HKSAR. Digital orthophoto is derived from aerial photographs in which image displacement caused by relief and camera tilts has been rectified. Digital orthophoto maintains the pictorial information of the original aerial photographs and has uniform scale. The first territory-wide Digital Orthophoto DOP10000 series with 1-m Ground Sample Distance (GSD), derived from 20,000 feet flying height aerial photographs, was launched to serve the public and private sectors in 2002. Digital Orthophoto DOP5000 series of 0.5m GSD, derived from 8,000 feet flying height aerial photographs was released in 2003 as an improved version for replacing the DOP10000 series. It has further improved both in image quality and extent of product applications. Digital Orthophoto DOP5000 series is being widely utilized by more than 20 bureau/departments of the Government of HKSAR. At present, it has also been incorporated into the web-based Geo-spatial Information Hub (GIH) of Lands Department of the Government of HKSAR for use of the government users. The DOP5000 series is being well employed for 3D Visualization of major public development projects, in enhancing mapping products like the Hong Kong Guide, Orthophoto Maps, and backdrops for Cadastral Plans and etc. It has also served as an image layer of geographic information system. It is anticipated that the use of digital orthophoto would be further increased for land administration work, engineering development, environmental monitoring and record keeping. Local constraints and environmental factors impose challenges to the production of the digital orthophoto series. Arrangement of appropriate production processes has to be made to overcome the difficulties.

## **1. INTRODUCTION**

The Survey and Mapping Office (SMO) of Lands Department is the survey and mapping authority of the Hong Kong Special Administrative Region (HKSAR) and is committed to the provision of accurate and up-to-date maps to support the rapid and intensive development of Hong Kong. The Photogrammetric and Air Survey Section (PASS) of SMO was established with analogue photogrammetric survey equipment in 1976 for providing aerial photography and photogrammetric survey services to support large scale mapping of Hong Kong. Since the acquisition of the first set of digital photogrammetric workstation by the SMO in 1998, production of orthophoto has become one of our major activities.

Orthophoto images are computer generated images of aerial photograph in which the image displacement of ground features caused by relief and camera tilts has been rectified. Same as line maps, orthophoto has uniform scale. Map readers are required to have a certain level of map reading training before they could understand map features presented in the form of points, lines, polygons and symbols with the help of map legends. Orthophoto provides pictorial information of ground features, users usually do not have difficulty to interpret what have been recorded in the orthophoto.

## **2. DIGITAL ORTHOPHOTO SERIES**

In 2002, a territory-wide Digital Orthophoto DOP10000 series of 1 metre Ground Sample Distance (GSD) was launched to serve the public and private sectors. DOP10000 was produced from colour wide-angle aerial photographs taken at 20,000 feet flying height. Shortly after the launch of this product, appreciation and positive comments from users were received which demonstrated the right decision of creating this new product. In addition to their comments, they also made request for higher resolution orthophoto series to extend their applications.

### **2.1 DOP5000 Series**

In response to the request of the users, a territory-wide Digital Orthophoto DOP5000 series of 0.5 metre GSD derived from about 800 numbers of colour wide-angle aerial photographs

taken at 8,000 feet flying height was released in 2003 as an improved version for replacing the DOP10000 series. It has further improved both in image quality and extent of product applications. At present, DOP5000 has become a standard digital map product of Lands Department. The latest version of DOP5000 was derived from a set of higher percentage of over-lap and side-lap aerial photographs to further improve the quality of orthophoto image and a total of 1,740 aerial photographs were employed for this project.

## **2.2 Product Description**

Digital Orthophoto DOP5000 series consists of 189 tiles covering all the land area of Hong Kong. Each tile of orthophoto covered an area of 1,125 Hectares (3.75 km x 3 km). DOP5000 images are provided in Tiff format including a world file with geo-referencing data in Hong Kong 1980 Grid and the data file size of each tile is 128MB. On the request of some users, seamless territory-wide mosaics in MrSID and ECW format are also compiled to meet their requirements and facilitate their applications. As the usefulness of geospatial information data depends on how updated the data could be, DOP5000 has been scheduled to be revised annually.

## **2.3 Processes of Orthophoto Production**

All the production processes of DOP5000 are manipulated in-house by PASS of SMO, from the acquisition of aerial photographs to packaging the orthophoto products. The major processes involved in the production of DOP5000 are as follows:-

- Flight planning and conducting aerial photography
- Develop and processing of aerial film
- Scanning of aerial film to produce digital aerial photographs
- Perform aerial triangulation
- Production of digital terrain model and collection of feature data
- Ortho-rectification of digital aerial photographs (true ortho-rectification will only apply to elevated roads and bridges)
- Overall colour balancing of rectified digital aerial photographs
- Generation of seam polygons and editing of seam lines
- Mosaicking of orthophoto images
- Colour balancing of the orthophoto mosaic

- Partitioning orthophoto images into standard tiles and appends geo-referencing data
- Quality check, packaging, back-up and delivery of the product

### **3. CONSTRAINTS OF AERIAL PHOTOGRAPHY**

The quality of aerial photography would directly affect the effectiveness of the subsequent photogrammetric survey operations and the quality of the products. In Hong Kong, good quality aerial photographs could not always be feasible to acquire due to various local constraints and environment factors.

#### **3.1 Topography and Local Environment**

Hong Kong is situated at the outlet of the Pearl River on the south coast of China. The total area of Hong Kong is about 1,104 square kilometers, which comprises of urban area covered with dense high-rise building, rural area of hilly topography, and more than 200 isolated islands. The variation of terrain height in Hong Kong is large, from sea level to 3,140 feet above Principal Datum Hong Kong. High-rise buildings of height more than 350 feet with narrow spacing between the buildings are very common in the urban area along the Victoria Harbour.



**Figure 1** The extent of Hong Kong Special Administrative Region, China





**Figure 2** Oblique view of urban area



**Figure 3** Vertical view of urban area

### 3.2 Availability of Fine Weather

Fine weather and good visibility conditions are the essential elements of aerial photography. In Hong Kong, fine weather day with high cloud base level and good visibility that are suitable for 8,000 feet flying height aerial photography is only about 20 days every year.

### 3.3 Survey Aircraft and Busy Air Traffic

At present, we are using the Jetstream J-41 aircrafts of the Government Flying Service of the Government of HKSAR for aerial photography mission. These aircrafts are not exclusively for aerial photography activities, higher priority would be given for search and rescue operations. The slowest speed of the Jetstream J-41 aircraft for aerial photography is around 140 knots per hour.

The Hong Kong International Airport is located in Chek Lap Kok at the south-western area of the territory of Hong Kong and is one of the busiest airports in the world. As reported in Hong Kong 2005 that at the end of 2005, there were 79 scheduled airlines together operated about 5,200 weekly scheduled flights between Hong Kong and some 156 cities worldwide. Within 140 kilometers from Hong Kong, there are other four airports located in the Pearl River Delta. Most of the flight paths of our aerial survey projects are overlapped or crossed over with the

landing and take-off flight paths of the commercial flights. At present, it is very difficult to obtain permission to fly over the project area for aerial photography according to our planned schedules. Aerial photography activities in Hong Kong is not always feasible to conduct during the desirable time slot between 10:30 a.m. and 2:30 p.m., and cancellation or suspension of scheduled activities are very often due to various reasons, such as busy air traffic, aircraft urgently deployed for search and rescue operations and sudden change of weather and visibility condition.

### **3.4 Problems Encountered**

Due to the above constraints, our territory-wide aerial photography projects could only be completed under several photography missions conducted on different dates of various photography conditions. High speed aerial films have to be used for the aerial photography. The image quality of the aerial photographs acquired has been affected as follows:-

- long shadows effect due to low sun angle at exposure time
- inconsistent image quality, contrast and colour variation occurred in the photographs covering the entire project area due to the photography are conducted under different time slots and different weather conditions
- hot spots effect appeared on water surface.

Though dodging and dividing the aerial film into sectors according to the recorded ground feature types (such as images of natural ground, build-up area and water area) for establishing appropriate individual scanning parameters in the scanning process for producing digital images, the quality of the produced digital images still could not meet the standard we expected for the production of orthophoto. Additional efforts are required for reducing the hot spots effect, obtaining consistent image contrast and colour tone of photographs, and conducting further colour balancing of the produced orthophoto mosaic.

Labour intensive procedures of editing the seam lines are also imposed for image smoothing of the dense high-rise buildings and water surface features along the seam lines of the ortho-rectified photographs for achieving an acceptable result.

To overcome the problems generated from the high variation of topography and high-rise building in respect to the flying height of photography, 80 percents over-lap and 40 percents

side-lap aerial photography are adopted to guarantee full coverage of the project area. Additional flight paths are inserted between the planned flight paths over the urban area to further improve the side-lap percentage of aerial photographs for reducing the extent of dead area created from the high-rise buildings.

#### **4. APPLICATIONS OF DIGITAL ORTHOPHOTO DOP5000**

Digital Orthophoto DOP5000 series are being widely utilized by more than 20 bureaus/departments of the Government of HKSAR and the public for various applications including city planning, feasibility study of engineering projects, environment study, land management, planning and briefing of operation, deriving orthophoto maps and plans, monitoring of land use and change detection.

##### **4.1 Paper-based Orthophoto Maps and Plans**

The availability of advanced high quality plotter/printer and photographic printing equipment has made the effective provision of good quality paper based orthophoto plan feasible. The image quality of paper print products has been improved and became consistent since the introduction of colour management system to our printing facilities in 2004. Orthophoto maps and plans are being generally adopted by the users and the demand for this service is increasing. Since 2004, the DOP5000 orthophoto images have been employed in enhancing and deriving several paper-based map products. The Orthophoto Maps OPM50 and OPM100 of scale 1:50,000 and 1:100,000 respectively are the first set of orthophoto map series of Hong Kong and they will be updated annually. The Hong Kong Guide 2005 is another successful application of DOP5000. This is the first photomap edition since its first publication in 1988 and has been one of the best selling map products.

Using the DOP5000 orthophoto images data as backdrops with enhancement of relevant information of applications, orthophoto plans of specific purposes would be produced to meet the requirement of individual user. Since the first publication of DOP5000, several types of orthophoto plan of various activities have been produced. Their applications are mainly for environmental study, planning and briefing of operation, operational chart of activities, land management and cadastral applications.



## **4.2 Geographic Information System**

With the advanced high speed and large capacity storage computing facilities, powerful and sophisticated Geographic Information System (GIS) software and freeware are available for various applications. Digital orthophoto has become one of the important GIS information for analysis. Many government departments are making use of the digital orthophoto for reconnaissance and measurement purposes simply with a freeware browser on their computer. Some departments have incorporated the digital orthophoto DOP5000 into their GIS for more comprehensive analysis with other geospatial information data.

## **4.3 3D Visualization Model**

Orthophoto image is one of the essential elements for producing 3D visualization models. The advancement of computing technology has made 3D visualization models widely employed for visualization study and presentation of projects. At present, nearly all the 3D visualization models of the public projects produced by the government departments are using DOP5000 orthophoto images as the image base for building up models.

## **4.4 Web-based Distribution of the DOP5000**

The HKSAR Geospatial Information Hub (GIH) is the geospatial information service provided by the SMO of Lands Department. It was successfully rolled-out within the Lands Department in 2005 and has been further extended to about 40 other government departments/bureaus. The GIH is a web-based information hub integrated with maps, aerial photographs, and vast amount of land and geographical information. Digital orthophoto DOP5000 is one of the major geospatial information integrated into the GIH. Through the government internal network, the GIH is capable of providing a quick and convenient reference of integrated geospatial information and offering spatial analysis function to the government users.

## **5. HIGHLIGHTS OF ORTHOPHOTO PROJECTS IN HONG KONG**

Since the SMO introduced the first set of digital photogrammetric system in 1998, several orthophoto projects had been conducted for various applications. The following are some highlights of the projects.

### **5.1 Aircraft Crash Emergency Survey**

In 22 August 1999, an aircraft crash occurred at the runway of the Hong Kong International Airport at Chek Lap Kok during its landing stage. An emergency survey consisting of aerial photography was conducted to record the wreckage and aftermath situation. Orthophoto plan had been produced as a kind of image base record to help visualization of the incident and provide a measurable record for accident investigation. A simulated animation of the accident was also produced to facilitate the investigation.

### **5.2 Orthophoto of Oyster Farm**

Orthophoto has the capability to record features that are not feasible to be presented in the line map. In 2002, the 'Hong Kong - Shenzhen Western Corridor' Project of Highways Department had requested orthophoto at 0.1 metre GSD of the oyster farm located within the project area for feasibility study, planning and compensation purposes. Aerial photography at a flying height of 1,000 feet was conducted for this project. A total of 175 aerial photographs were taken to produce the orthophoto plan. In order to ensure the oyster bed has fully exposed for record and measurement purposes, aerial photography had to be performed during the low tide session.



requirement of  $\pm 0.3$  metre in the monitoring of rubble structures (Li and Mo, 2003). Adopting this method for monitoring of rubble structures not only allows easy visualization of the overall condition of the structures, the orthophoto also serves as a valuable source of quantitative information.

## 6. THE WAY FORWARD

At present, the Digital Orthophoto DOP5000 series has been widely adopted and utilized by the users under different aspects of application. Comments have been received for further improve its image resolution to 0.2 m GSD to enrich its visualization power. To improve the image resolution from 0.5 m GSD to 0.2 m GSD will increase the data file size by 6.25 times. The effectiveness of manipulating vast amount of geospatial information data for a convenient and comprehensive analysis is one of the basic requirements of GIS. We anticipate that based on the recent development trend of computing technology, the capability of computing facilities in term of speed and storage capacity to meet the above requirements would no longer be a problem. More precise orthophoto requires digital aerial photographs of higher resolution as well as control points of higher accuracy that involving large amount of additional expenses. Could the problems generated from the local constraints and environment factors be effectively handled in upgrading the digital orthophoto series? Is it affordable and worth to do so? These are the issues we should deal with before a decision has made.

The first set of territory-wide aerial photograph of Hong Kong was taken in 1963 for the production of basic map of Hong Kong at a scale of 1:600 in the urban area and a scale of 1:1,200 in the rural area. It comprises of more than 5,500 numbers of photograph acquired in 10 different flying heights from 2,500 feet to 8,000 feet. For years, aerial photographs of 1963 have been widely employed for extracting evidences in the past for change detection and settle land boundary disputes. Ad hoc projects of orthophoto derived from 1963 aerial photographs for specific cadastral survey and change detection activities were conducted in the recent years. Overlaying the 1963 orthophoto with other cadastral information, such as correlated lot boundary data and old survey record sheets, would help re-establishing the old lot boundary and provide evidence to resolve boundary disputes. The 1963 orthophoto has also been employed for landslip monitoring and natural terrain hazard study. Establishing of sufficient aerial photograph control points for the production of territory-wide 1963

orthophoto is one of the great challenging tasks, as high speed and comprehensive development has been taken place over the territory of Hong Kong in the last forty years. There is no doubt of the usefulness and applications of the 1963 orthophoto, and we are sure that it is one of the major issues we should face in the coming years.

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## BIOGRAPHICAL NOTES

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Strategic Integration of Surveying Services

FIG Working Week 2007

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