空中三角测量中 WuCAPS 的应用

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摘　要：通过 WuCAPSGPS 加密方案与传统方案的比较，阐明了 WuCAPSGPS 加密方案在减少野外工作量，缩短成图周期方面的重要意义。

关键词：空中三角测量；WuCAPSGPS；平差
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1　概　述

传统的空中三角测量作业模式总是采用航空摄影、相片控制点野外测量、内业立体量测像点坐标并以地面控制点为基准进行最小二乘平差，以确定地球表面目标的空间位置。该传统模式生产周期长，自动化程度较低，尤其是野外像控测量环境差，在跋山涉水时，作业员要背负仪器和脚架等较重设备进行作业，采集坐标，劳动强度之大不言而喻。

近年来，全球卫星定位系统（GPS）的发展速度非常快，静态定位利用载波相位观测值已经能够达到 1cm ± 1 × 10^{-6}，甚至 1mm ± 1 × 10^{-6} 的相对定位精度，而基于载波相位测量发展起来的高精度 GPS 动态相位差分定位技术，其定位精度已经达到厘米级，这为空中三角测量技术的发展提供了较好的支持，为 WuCAPSGPS 的推广应用奠定了良好的基础。现以我院随州测区空中三角测量为例，介绍基于 WuCAPSGPS 的空中三角测量方法，并相对于传统方案而言，说明其优点。

随州地处长江流域和淮河流域的交汇地带，国家实施西部大开发战略由东向西的重要接力站和中转站，属丘陵地带。本测区总面积 400 km^2，在测区中部架设 2 个 GPS 基准站，采用机载 GPS 的运 5-B8003 飞机搭载 UCD 数码相机拍摄了 3 860 张彩色数码航片，分辨率 9μ，包括 33 条常规航线（东西向飞行）和 6 条构架航线（南北向飞行），并记录每张航片的绝对坐标和角元素，如图 1 所示。基于生产设备运转速度的考虑，把全区共分为 11 个加密区，并把东南角约 23 km^2 的 A 区作为实验区。

2　传统空三加密方案

实验 A 区包括 10 条南北飞行常规航线和 2 条东西

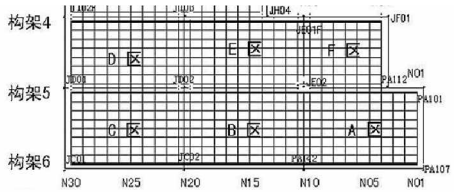

图 1　部分测区分区图（带构架航线）

飞行构架航线，总共 431 张航片，相片控制测量采用全野外布点，共布设相片控制点 124 个，其中包括 4 个构架航线与常规航线共用的平高控制点，如图 2 所示。野外像控点测量采用南方公司 GPS-RTK，内业用 AAT 量测控制点和加密点，并用 PATB 平差解算，成果可靠，精度高。

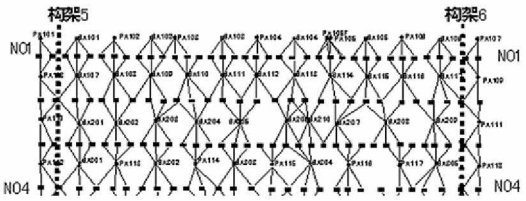

图 2　A 区常规布点图（部分）

3　WuCAPSGPS 平差方案

3.1　WuCAPSGPS 原理

WuCAPSGPS 是 Wuhan Combined Adjustment Program System for GPS Navigation Data and Photogrammetric Observations 的缩写词。它是一个可利用 GPS 导航数据进行摄影测量与遥感高精度点位测定的软件包，它以共线条件方程为核心，融当代基于统计理论的误差随机模型和理论最严密的带附加参数的自检校区域网平差函数模型于一体，利用武汉大学袁修孝教授提出的一整套算法予以实现的程序系统。通过机载动态 GPS 系统主要精确测定在航空摄影曝光瞬间投影中心的三维坐标，同时确定每张相片的外方位元素值

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和时间，作为辅助数据参加摄影测量与非摄影测量的观测值的联合平差，以达到用 GPS 摄站作为空中控制来取代地面控制点的目的，使区域网平差所需的地面控制点大大地减少，使之少到只要解决数据基准和消除 GPS 数据系统误差的程度。目前，国际上一般公认，只要在区域的四角布设 4 个平高地面控制点，再在区域两端布设两排高程地面控制点或是加摄 2 条垂直构架航线就足够了。一旦找到这些点的国家大地控制坐标，就相当于取消了航测外业中艰苦的像片野外控制联测工作。

3.2 WuCAPSGPS 平差计算方案

为了充分验证 WuCAPSGPS 软件的加密平差成果可靠性，对实验 A 区采用与常规方案相同的像点网参与平差解算，相片控制点选择 4 个角上的平高控制点，其他野外相片控制点全部用作检查点，包括 56 个平高点和 64 个高程点。平差解算时，导入每张相片的投影中心的三维坐标 (Xs，Ys，Zs)、外方位元素值 (φ、ω、κ) 和时间 (T)。大地定向点坐标残差平差结果如表 1 所示，定向点残差符合设计书要求。检查点坐标不符值如表 2 所示。

表 1 大地定向点坐标残差

序号	点名	Dx	Dy	Dxy	Dh
1	7302	-0.005	-0.005	0.007	0.000
2	5011	0.008	-0.007	0.011	-0.002
3	5033	0.002	-0.002	0.002	0.000
4	6101	-0.005	0.014	0.014	0.002

表 2 检查点坐标不符值

点名	Ds	Dh	点名	Ds	Dh	点名	Dh	点名	Dh
6109	0.072	0.011	6122	0.032	0.139	8203	0.129	8503	0.029
6113	0.130	0.086	6123	0.084	-0.030	8204	-0.012	8605	-0.012
6115	0.154	0.223	6125	0.251	-0.152	8207	0.016	8903	-0.056
6126	0.068	-0.140	6128	0.300	-0.024	8209	0.141	61031	0.035
…			…			…		…	
8404	0.070	0.115	6102	0.366	-0.064	8506	0.217	8110	0.051
			平面中误差 Ms = 0.214 m			高程中误差 Mh = 0.185 m			

分析表 1 和表 2，可以看出：

1) 采用 WuCAPSGPS 平差解算需要的外业像控点比较少，且平差精度较好；

2) 采用 WuCAPSGPS 平差解算后，检查点与外业实测像控点成果相比较，平面误差 Ds ＜ 0.3 m 的点数超过 85 %，高程误差 Dh ＜ 0.3 m 的点数超过 80 %，如图 3 所示，这种精度能够满足设计书要求；

3) 在表 2 中，有几个点位的平面误差或高程误差较大，经过分析，认为这是由于检查点在田角位置选择不明确，或测量时间与摄影时间间隔较长引起的。

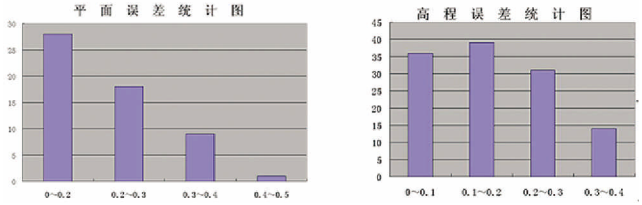

图 3 检查点精度统计

4 结 语

本文介绍了随州西南角实验区的 2 种不同空三加密方案，该加密实验区由构架航线和常规航线组成，并具体说明了采用 WuCAPSGPS 平差解算的精度。对比传统 PATB-AAT 加密方案而言，可以得出以下结论：

1) 利用 PATB-AAT 平差解算和利用 WuCAPSGPS 平差解算的精度都能达到设计书要求，均满足实际成图要求。

2) 采用带 GPS 信息的航片并结合 WuCAPSGPS 平差解算时，仅需要 4 个相片控制点，相对于需布设大量野外像控点的传统方案而言，可以节省大量人力物力，减少或免除在困难地区或人员不可能到达地区的航测外业工作，这对于缩短航测成图周期，提高生产效率具有极为重要的意义。

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HBCORS Lightning Protection System Designing Procedures
by YANG Huaxian

Abstract Lightning is an atmospheric discharge of electricity accompanied by thunder, lightning strike are electrical discharges caused by lightning, direct lightning strike can cause severe damage to ground structure and electrical device. For protection of ground structure and electrical equipment from lightning strike, different method may have to employed. For ground structure (observation pillar), lightning rod will installed 3m away from observation pillar, high voltage current will channel away by grounding adapter. For protection of electrical device, protection device will install on signal cable, ethernet cable and electricity outlet to channel overcurrent to grounding adapter. In addition, device for electromagnetic pulses (EMP) protection is installed for each reference stations.

Key words lightning protection, design, HBCORS (Page:1)

Comparative Study of Mixed Pixel Unmixing in Hyperspectral Image
by LIU Tao

Abstract Spectral unmixing of remote sensing imagery as a remote sensing classification and cartographic method has its unique advantages. In this paper, Hyperion remote sensing images of Fukang region was used, in ENVI/IDL software running environment, respectively, utilizing the hourglass algorithm method, SMACC algorithm and volume method for endmember extraction. A comparative analysis of these methods to choose the actual extraction of the end of the hourglass algorithm as the most terminal endmember had been carried out. On this basis, respectively using the fully constrained least square method and OSP algorithm for mixed-pixel decomposition, all unmixing methods had been counted and compared. The results showed that in the area, the endmember extracted from hourglass algorithms had higher accuracy, and the result of all constrained least squares was satisfied to the ground fact.

Key Words mixed pixel, pixel unmixing, endmenber (Page:3)

Measuring and Analysis of Water Apparent Optical properties in Water Subsidence Area by ZHU Jiwen

Abstract Through the actual measurement of the water depth in water subsidence area, understand the water optical properties was that the different water depth could cause the attenuation characteristics change, establishing the expression of water depth and spectrum characteristics response, determined the best spectrum scope to get water depth information. It revealed the relationship between water components of chlorophyll, suspended material, CDOM etc. and water spectrum characteristics change, so it depicted the change rule of water absorption spectra, scattering spectra because of the main component changing.

Key words remote sensing; radiation from water rate; downlink irradiation; uplink irradiation; sensing reflectivity (Page:6)

Construction and Application of Urban Public and Geospatial Information Service Platform Based on SGS by ZHANG Pengcheng

Abstract Using urban basic spatial database of GuangZhou, according to the criterion of urban public participation GIS platform and geomatics framework construction for digital city, the mapping data for E-government informatization is produced after extraction, recombinant and expansion; Based on SGS, the sharing and exchanging platform for government geospatial information of GuangZhou is developed, the users of government department can obtain the data and function service by four methods of on-line browsing, customization, map API and interface transferring.

Key words SGS, E-governmen, SuperMap, public service platform, geographical information, geographical data (Page:9)

Spatial Pattern Analysis of Urban Expansion Based on GIS
by YANG Zhandong

Abstract To urban expansion as the core content of the urban land use / land cover change has become the national land use / land cover change (LUCC) research focus. Based on a place from 2002 to 2007 land use data, the paper extracted urban land use information, used global and local spatial association model to analyze the spatial distribution of the regional characteristics of urban expansion, obtained research results.

Key words urban expansion, spatial association model, spatial pattern (Page:12)

Aerotriangulation Surveying Based on WuCAPS
by WEI Zhong

Abstract Through compared WuCAPSGPS encrypt mehod with traditon mehods, clarified the encrypt mehod's significance in reduce countryside workload and to cut down map-producted period.

Key words aerotriangulation surveying , WuCAPSGPS ,adjustment (Page:15)

Design Philosophy for the Project of Hebei Province Fundamental Surveying and Mapping Production Process by MA Maosheng

Abstract By sort out the ideas of design and development of the project of Hebei Province fundamental surveying and mapping Production Process, described its several core concepts, including: the objective of the fundamental surveying and mapping database,the structure of the GeoDatabase,the realization of the Symbolic,the relationship of the attribute label and annotation,and more.

Key words fundamental surveying and mapping, production process, Geodatabase, topographic, GIS (Page:17)

Study of Monitoring Remote Sensing of Dynamic Change of Land-use
by ZHANG Huijiang

Abstract In this paper, for the County of remote sensing monitoring of land use change on the basis of the special geographical environment of Guizhou Province for the Zhijin County as a test area, TM and CBERS satellite remoted sensing image in different periods through correction, image enhancement and classification had been used to extract information of the County Land Use Change. It indicated that the research method was effective .

Key words land use, remote sensing, geographic information system, remote sensing classification, contrastive analysis (Page:20)

CAD to GIS Data Conversion and Storage by WANG Bo

Abstract This paper analyzed the problems in CAD to GIS data conversion process.With the Geoway data processing,effectively solved the appearance of data loss,at last,developed a data storage module based on ArcGIS Engine compact,achieved batch storage and improved efficiency.

Key words CAD,GIS,Geoway,ArcGIS engine,data conversion (Page:24)

Empirical Study on the Mass Appraisal of Real Estate Taxable Valueby GENG Jijin

Abstract This paper took the example of Shenzhen on the second-hand housing transaction tax base price assessment. Under the application of CAMA, this paper adopted the long-term trend method to assess the tax base prices of the full property rights houses, and the GIS spatial interpolation method was used to assess the tax base prices of non-market houses, and for the private residence of the farmers the cost method was used. Finally, we adopted three different methods to test the tax base prices based on the mass appraisal models.

Key words CAMA, GIS, Long-term trend method, cost method, real estate taxable value (Page:27)

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