

数字航摄相机实验室检定研究

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摘要: 主要阐述了航摄相机镜头校准的目的、意义, 回顾了航摄相机校准的发展过程; 分析了数字相机计量校准的发展状况和应用前景, 论述实验室校准的方法和目的; 提出了数字相机检定仪研制初步设想和需要解决的关键技术。

关键词: 航摄相机; 航空摄影测量; 数字相机; 实验室检定

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航空摄影是获取摄影测量所需地理空间信息的重要数据源之一, 航摄相机镜头的最佳对称主点坐标和主距组成的内方位元素和镜头畸变, 是航空摄影相机的重要技术指标和内业测图的重要技术参数, 直接关系到成像质量和测量精度。由于多种因素的影响, 航摄相机在使用过程中内方位元素和畸变会发生变化并带来了测量误差。必须定期校准相机镜头的内方位元素和畸变, 这对于保证摄影测量精度, 具有重要作用和意义。

1 胶片航摄相机的校准

自航空摄影测量发展之初, 航摄相机的检定就作为其理论与实际工作的重要组成部分得到重视, 其检定方法一般为室内利用多筒准直光管或经纬仪进行的精密测角法。由于相机检定有较高的技术与装备要求, 所以一直有相应的专业设置与人员配备, 并不断研制检定设备。

80年代研制了以经纬仪为测角基础的型航摄相机检定仪, 它可以检定所有不同外形、焦距、相幅的航空摄影相机, 包括前苏联的AΦA系列、卡尔蔡司的LMK系列、徕卡的RC系列、国产的HS系列以及其他侦查、勘探用途的相机。进入90年代为适应徕卡RC30相机的要求和数字测图技术的发展, 在国内弹道相机科研成果基础上联合研制了DQCY-120型航摄相机检定仪。该检定仪采用专业角度度盘, 被测镜头接近摄影状态垂直放置, 牢固稳定的仪器主体和防震地基, 提高了测量准确性和重复性, 满足当时的精度要求。

随着数字摄影测量技术与装备的发展, 加强航摄相机检定的标准化、科学化, 建立完善的计量体系, 为数字摄影测量提供更高精度、更加规范的相机内方位元素和畸变差十分必要与迫切。为此我们开展了“航摄相机畸变测量仪标准装置”的研制(见图1)。该装

置以光电编码器测量转臂角度, 精度达到0.33角秒; 采用CCD相机探测技术和亚像素细分算法使瞄准精度达0.29角秒; 综合精密加工与自动化技术优化运动方式, 实现了航摄相机镜头的非接触自动化控制测量; 精确测量格网板刻线误差并带入畸变算法, 提高了数据处理的精度; 采用米字型LED高效冷光源, 既满足照明需要又保证了长度基准对温度变化的要求。多项技术的综合应用, 使装置达到了1角秒的测角精度, 并且缩短了测量周期, 消除或减少了因人眼观测、震动、温度变化等因素引起的误差。

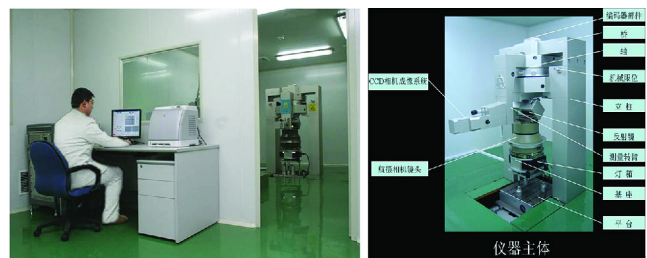


图1 AMA航摄相机畸变测量仪标准装置的控制系统与仪器主体

以“航摄相机畸变测量仪标准装置”为依托建立了航空摄影相机计量校准实验室, 2007年通过了标准与机构考核, “测绘装备内业计量中心”正式获批成立。随后2008年元月该装置通过了由中国计量科学研究院等单位光学计量专家实施的计量标准考核, 2009年通过了军用实验室认可。

2 数字航测相机实验室检定的优点

数字航测相机的校准方法, 可以分为实验室检定和飞行检校两种。

实验室检定范围广, 可以涵盖几何、光度、色度三个方面。几何校准是为了消除镜头的光学畸变误差、像素排列的机械误差、光电信号转化的电学误差而进行的。校准内容包括内方位元素即主点、主距、单个像素的二维几何坐标、光学传递函数(OTF)和调制

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传递函数 (MTF)。光度学辐射校准的目标是消除像素响应非均匀性,校准内容包括缺陷像素、单个像素的感光灵敏度、渐晕效应和光圈的影响。色度学校准目的是测量单个像素光谱敏感度。飞行检校仅可以完成相机几何量的测量。

实验室检定是基础,是最原始的物理参数检定,检定数据是要随机安置在相机固件。而飞行检校最初是为了验证最后测量精度而设置的,随着技术的发展,不断完善,但其检校文件仍是用于测图时脱机校正,其影响小于实验室检定。

实验室检定的不确定度是可控的,精度更高。因为实验室的环境可控,检定标准可溯源,可以用计量的体系要求全面控制。而飞行检校诸多因素都不易控制,精度不好把握,成本高,不易进行计量认可。

以上是我们积极开展数字相机实验室检定研究的原因所在。当然对于非测量型镜头的航摄相机也有试验场摄影检校的方法,篇幅有限不再区分叙述。在此需要说明,计量学中检定比校准有更为严格的要求,比如必需有明确的标准给出被测件合格与否,而校准只需给出测量数据,不必做出结论。完成相机检定是最终目标,但现阶段只能称之为校准。而飞行检校无论从测量仪器、依据规范、参数溯源都无计量学特征,只能称为检校,也只有数字航测相机有此需要。当然国外都以 calibration 表达,不加区分。

3 数字相机实验室检定的方法与目的

数字相机检定的目的除了确定相机的内方位元素,还要解算像素排列模型的未知参数,最终拟合出每个 CCD 像素的位置,以便对畸变造成的影像失真进行纠正。其中后者是数字相机区别于胶片相机新的检定内容,并且无论从难度、意义都超过内方位元素,线阵相机甚至已经不再需要主点概念,所以像素位置的校准是需要研究攻克的主要矛盾。以 ADS40 相机为例,如图 2 所示的是由畸变造成的影像失真;图 3 所示的是单波段的 12 000 个 CCD 像元理论位置、实际位置和检校位置的偏差。

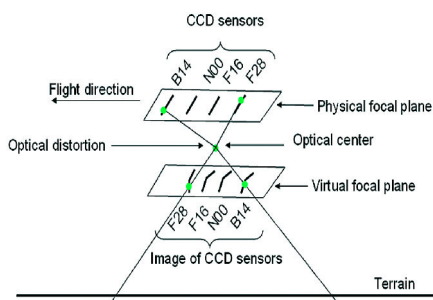


图 2 由畸变造成的影像失真

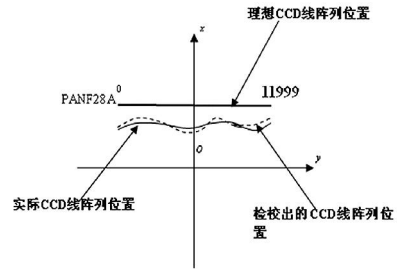


图 3 像元理论位置、实际位置和检校位置的偏差

数字航测相机的实验室几何量校准一般采用精密测角法实现,即用平行光管模拟无穷远目标,成像于数字相机的 CCD 焦平面,并扫描;从相机输出数据中提取目标像的位置坐标,以角度测量系统测量平行光管的转动角度,得到一个如图 4 所示数据集合:

$$\{f, \bar{x}_i, \bar{y}_i, \bar{r}, \Delta r_i, \Delta t_i, \Delta x_i, \Delta y_i\}$$

其中:实际像点的向径 $\bar{r} = \sqrt{\bar{x}^2 + \bar{y}^2}$

理想像点的向径 $r = f \cdot \tan W$

径向畸变即为 $\Delta r = \bar{r} - r$

需要建立像差数学模型,要求模型可以尽量逼近实际测量的结果,比如式(1)各项参数具有实际物理意义的 Australis 模型。

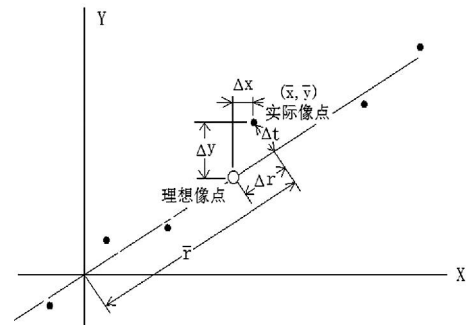


图 4 理想/实际像点示意

$$\begin{cases} \Delta x = \bar{x}(r^2 K_1 + r^4 K_2 + r^6 K_3) + (r^2 + 2\bar{x}^2)P_1 + 2\bar{x}\bar{y}P_2 + \bar{x}B_1 + \bar{y}B_2 \\ \Delta y = \bar{y}(r^2 K_1 + r^4 K_2 + r^6 K_3) + 2\bar{x}\bar{y}P_1 + (r^2 + 2\bar{y}^2)P_2 \end{cases} \quad (1)$$

式中, K_1 、 K_2 、 K_3 所在的项为径向畸变; P_1 、 P_2 所在的项为镜头的偏心畸变; B_1 是像素的非正方形比例因子, B_2 是 CCD 阵列排列非正交性的畸变系数。

几何校准的目的就是求取式(1)中的各项参数,这是一个优化计算的过程。优化的目标和规则是使畸变的测量值与模型推导值偏差的平方和最小,即式(2)。

$$\sigma^2 = \sum [(\Delta x_i - \Delta'x_i)^2 + (\Delta y_i - \Delta'y_i)^2] \quad (2)$$

在图像处理时,再利用经几何校准确定参数的像差模型,重新计算修正每个像素的坐标,以提高图像的几何定位精度。

4 数字相机检定制研制设想与关键技术

检定制研制的初步思路是:将被检测的航摄相机

固定在一个可以绕相机的光轴旋转的转台之上。用相机的下方的目标平行光管模拟无穷远的目标成像于 CCD 焦平面。

通过转臂旋转,使目标像点在 CCD 探测平面上以像主点为圆心沿直径方向作径向移动。转台和转臂的旋转就能使像点在 CCD 像面上产生米字形分布。

采集目标图像数据和光电编码器测量出的转臂角度。结合相关算法,便能够解算出需要的相机模型参数,实现对相机的几何检定。图 5 所示的为数字相机检定仪结构设计示意图。关键技术如下:

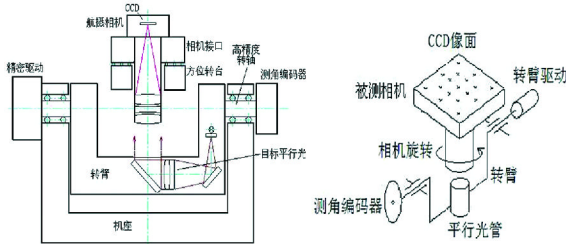


图 5 数字相机检定仪结构设计示意图

1) 高精度目标像的定位。目标图像测量精度要求达到 1/20 到 1/25 像素,需要将传统十字形目标改进为圆形。CCD 光斑定位算法常用的有质心法、边缘检测法等。考虑提高定位精度,适应目标图像光强变化,我们提出基于插值的非线性加权质心算法。另外,转臂内的平行光管要满足模拟不同参数相机对无穷远目标清晰成像的要求,要尽可能的实现长焦距大口径,并且本身畸变要可忽略不计。

2) 高精度的回转轴系和光电轴角编码器。转臂转动的精度要求很高,当光管沿 CCD 像面的径向方向转动时,它在切向的晃动应限定为 0.5 角秒。同时还要求轴系摩擦力矩小,无爬行,操控方便。

3) 几何校准的算法与软件。几何校准的算法与计算软件是整个系统的理论核心,需要对现有的数学模

型和算法仔细研究、突破创新。

4) 多镜头拼接面阵相机当前研发迅速,此类相机的校准,除对单个镜头进行几何校准外还要校准不同镜头光轴之间的空间角度。目标平行光管的口径要起码能够包含两个被测镜头,需要有第二个目标像要落在相邻两个相机的视场的重叠区域之内,就可以校准出这两个相机的光轴之间俯仰角、偏航角和相邻相机 CCD 平面之间的滚转角。

5) 对于三线阵相机,像面上有至少 3 个线列 CCD,要校准出每个像素的两维空间指向角。对线列一维 CCD 数据进行细分定位,可以决定其线列径向的精确座标,但是垂直线列方向的座标不易确定。解决这个问题的方案之一是采用平行光管二维转动扫描的机构,并且要求在法向能够作精密和细微的运动。另一种方案是由平行光管产生特殊的光电编码校准像。这种图像不需要目标在法向的精确定位,依靠目标编码技术即可测定目标图案的垂向精确位置的方法。

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(上接第 5 页) 进一步推动空间信息的社会化进程, 为个人消费者、企业用户和政府部门提供随时随地的基于位置的服务。总之, 空间信息移动服务将成为人们日常生活中一种重要的信息服务, 并成为未来信息服务业的重要组成部分。它所具有的巨大的商业价值, 将在各行业中日益显现出来。我们相信, 在未来 5 ~ 10 年内, 地理空间信息 (Geo- Information) 将实现随时 (anytime)、随地 (anywhere) 为所有的人 (anybody) 和事 (anything) 提供实时服务 (4A 服务)。

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Study of WebGIS in 3G Networks

by Bie Yeren

Abstract This paper introduced geographic information system (GIS) and third generation mobile communication network-related features. The geographic information system was currently applied in the mobile network market situation and related techniques were analyzed, and the future relationship between the two do Outlook study.

Key words 3G, WebGIS, mobile services (Page:1)

Research of Digital Aerial Camera Laboratory Calibration

by Mou Jian

Abstract This paper expatiated the aim of the aerial camera calibration and reviewed the development of aerial camera calibration, analysed the developed status and apply foreground of digital camera calibration, discussed the method and aim of laboratory calibration :gave the assume of the equipment of aerial camera calibration and the key technic.

Key words aerial camera, aerial photogrammetry, digital camera, laboratory calibration (Page:6)

Mosaic Techniques for Batch Data Inbound Based on GeoMedia

by Xue Ping

Abstract This article had introduced and summarized the method for data inbound based on GeoMedia and related existing issues, and mainly studied on mosaic techniques for batch data inbound based on GeoMedia. Two processing methods had been depicted in details, which had produced very good results in practical project production.

Key words GeoMedia, data inbound, Access, SQL code (Page:9)

GOCE Satellite in the Military Applications

by Wang Liupeng

Abstract GOCE gravity satellite described in detail. Analysis of load on the satellite configuration and functionality. GOCE mission's scientific goals combined with a detailed analysis of its prospects in the military applications, and list important application on the direction of the military. We hope that the measurement sector of the GOCE gravity field of satellite applications for more use.

Key words GOCE, military applications, gravity measurement (Page:11)

Geographic Information Service Platform on Urban Architecture

by Xiao Jianping

Abstract The paper focused on the key problems of GIS service platform. We took the production, modeling, management and applications of geographic information as the main stream and flowchart, payed more attentions on techniques of platform to implement the integration of spatial database and the management of thematic information with distributed network. The geographic phenomena can be visualized through web with different networks, whether e-government network or public network. The system included three scenarios that's collection and maintain of geo-information, management of geo-information, share and distribution of geo-information. The system provided a foundational platform for applications of different fields.

Key words geographic information, database, distributed management, service platform, geographic information service (Page:13)

Dynamic Monitoring of the Ecoenvironment Influence of Tunnel Construction Based on Remote Sensing

by Wei Dezhao

Abstract In order to deeply understand the ecoenvironment influence of tunnel construction, using remote sensing technology on the mountain tunnel construction and operation process to monitoring the environmental changes. This paper studied the methods and technical routes using multi-tempora remote sensing images in dynamic inspection of the influence of tunnel construction and operation process.

Key words tunnel construction, ecoenvironment influence, remote sensing inspection (Page:16)

Accuracy Analysis and Application of CORS System in Nanning

by Zeng Xiangxin

Abstract A brief overview of NNCORS was given in the paper. And the accuracy of the NNCORS and the rove stations was analyzed by the author though the processing data of the RTK reference station. The results show that the system runs well.

Key words CORS, RTK, accuracy (Page:20)

CBERS-02B Image Fusion Technology Research Of Karst Areas

by Hu Juan

Abstract In Karst mountain areas, the high altitudes and relatively elevation differences were large, land fragmentation severely and land cover types di-

versity, there always cloudy and rainy all year round, therefore, the quality of satellite remote sensing data has severely being affected. Self-made satellite CBERS-02B to obtain high-resolution panchromatic images (HR) and multi-spectral Charge-coupled Device (CCD) image can be more efficient and easier to provide remote sensing image of the Karst Mountains. In this paper HIS transform, PCA transform, HPF and other image fusion methods were used for the fusion comparative study of the CBERS-02B satellite HR and CCD image, and for the analysis and evaluation of its mean, standard deviation, entropy, cross entropy, spectral authenticity, deviation index, average gradient indicators, in order to explore the best fusion method of Karst mountains plateau CBERS-02B satellite HR and the CCD data in the background of the Karst mountains plateau.

Key words CBERS-02B, karst mountain area, image fusion (Page:22)

Reserch of Spatial Data Quality Check System for Urban Planning

by Wang Lei

Abstract On the basis of spatial data analysis, this paper introduced special data quality control and evaluation system design principia. Then the method of data check and evaluating each spatial data quality index was described. The research content and method had succeeded in applying to Guangzhou data check system. The application results of special data quality control and evaluation system indicates that the menthod is right.

Key words information mapping, special data, quality testing, data quality evaluation (Page:25)

Design and Realization of Virtual City System Supporting the Urban Conception Design

by Cheng Sichong

Abstract The urban conception design is the guiding ideology of the urban design. The virtual city system facing the urban conception design can preview the configuration character with realistic virtual scene, which can help the urban designer estimate the design ideology. Using the data foundation of Ziyang city, the paper designed the virtual city system supporting the urban conception design and constructed the virtual city landscape model base.

Key words virtual city, landscape model base, conception design, urban design (Page:28)

Design of Urban and Rural Integrative Cadastral Information System Function

by Li Xiaodong

Abstract On the basis of generalized analysis the functions of Urban Cadastral Information System and Land Use Information System, this article studied and designed the functions of Urban and Rural Integrative Cadastral Information System. It has designed management and maintenance, land survey, cadastral changes, land registration, query and analysis, statistical analysis and sharing services and so on seven subsystems from three levels: cadastral data's gathering, updating and using.

Key words urban-rural integrative, Cadastral Information System, Urban and Rural Integrative Cadastral Information System (Page:31)

Typhoon Hazard Assessment System Based on GIS

by Liu shaojun

Abstract Typhoon hazard assessment was a complicatedly multi-source process analysis, ArcGIS has characteristics of powerful functions, simplified operation and visualized interfaces, which was used to develop typhoon hazard assessment system. The system realized the typhoon disaster visualization and can provide the policy-making service for the typhoon disaster prevention and reduction based on GIS function of spatial visualization and analysis.

Key words typhoon, hazard assessment, GIS (Page:34)

Design of the Reuse Component Resources in the GIS Development

by Zhang Heng

Abstract The traditional GIS application is mostly developed by adopting structured design thought, needs repetition of the design, develops related module, the efficiency of development is lower. So this paper introduced the reusable components to the GIS application development practice, summed up the component component reuse thought, component development process, discussed the reuse interface design thoughts of GIS development, including: spatial database interoperation and layer loading interface design, data query and maintenance interface design, spatial analysis interface design. Practice shows that the GIS system development based on reusable components can be highly efficient and rapid developed a more stable system, the development costs can be significant reduced.

Key words COMGIS, Component-Based Development (CBD), reuse (Page:36)

Research of GeoProcessing Modeling Based on Workflow

by Liu Lin

Abstract Through the analysis of the traditional geographic process modeling