密閉空間空載光達之灌溉暗渠隧道巡檢–以新竹坪林圳為例

UAV LiDAR-Based Tunnel Survey for Canal Maintenance: A Case Study of Pinglin Canal

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摘　要

新竹管理處轄下水圳共 61 條，其中坪林圳灌全長約 1.8 公里、溉面積約 542 公頃，沿途經三處清代由人工建造之過山隧道，第三段隧道末端因近代修復工程採用箱涵方式，導致高度較低，僅能以半蹲姿勢勉強通過，其餘隧道皆為堪容一人直立行走之土渠，三條隧道長度分別為 100 公尺、50 公尺及 80 公尺，其間以水覓連接清淤全靠人力維護不易，故三條隧道將進行水利工程改善。近年來隨著密閉空間空載光達技術日益成熟，其於橋梁、室內與煉油廠等等之巡檢應用逐漸普及，成為重要檢修手段，其中因灌溉暗渠隧道狹窄密閉空間無光源適合利用光達進行巡檢及掃描作業，降低人工檢修之人力負擔及作業風險。

本研究以無人飛行載具（UAV）搭載光達系統進行隧道掃描作業，並輔以全站儀進行定位控制。於隧道入口處貼設反光標籤供光達掃描，將全站儀架於隧道外之地面控制點，聯測該等反光標籤，建立相對坐標之平面及高程控制。UAV 搭載光達設備每顆電池最遠可提供 150 公尺長隧道之 1 去回掃描作業，以坪林圳 100 公尺長之隧道為研究場域，作業時間約為 1 小時。光達掃描之點雲資料可建三維模型後保存，作為歷史數據參考，藉由三維點雲模型，可測得隧道之長度、高度及斷面面積，相較於傳統地面掃描，UAV 光達可於前期提供有效資訊協助清淤規劃及隧道工程改善，降低人員進入未知環境之風險，提升整體作業效率。

關鍵詞：密閉空間空載光達，隧道掃描

Abstract

Hsinchu Irrigation Management Office oversees 61 canals, among which the Pinglin Canal irrigates approximately 542 hectares and extends about 1.8 kilometers in length. Along its course, it passes through three tunnels manually constructed during the Qing Dynasty. At the end of the third tunnel, modern restoration works adopted a box culvert design, resulting in a relatively low height that requires a person to crouch to pass through. The other tunnels, however, remain earthen canals tall enough to allow a person to stand upright. The three tunnels are approximately 100 meters, 50 meters, and 80 meters in length, respectively, connected by wooden aqueduct. Silt removal relies entirely on manual labor, making maintenance difficult so water conservancy improvements will be carried out in the three tunnels. In recent years, with the growing maturity of UAV LiDAR technology, its use in the inspection of infrastructure such as bridges, indoor, and oil refinery has become increasingly widespread. LiDAR is especially suitable for scanning in confined, unlit tunnel environments, reducing manpower requirements and operational risks associated with manual inspection and silt removal.

In this study, an unmanned aerial vehicle (UAV) equipped with a LiDAR system was used for tunnel scanning, supported by a total station for positioning control. Reflective targets were placed at the tunnel entrance for the LiDAR to detect, and the total station was set up at ground control points outside the tunnel to survey the targets, thereby establishing planar and elevation control within a relative coordinate system. Each UAV battery allows for a round-trip scan of up to 150 meters of tunnel. Using the 100-meter-long tunnel segment of the Pinglin Canal as the study area, the operation took approximately one hour. Collected point cloud data was used to build a 3D model for historical reference. From the 3D point cloud model, measurements of the tunnel's length, height, and cross-sectional area can be obtained. Compared to traditional ground-based LiDAR scanning, UAV LiDAR can provide effective information in the early stages to assist in desilting planning and tunnel engineering improvements, reduces the risk of unknown tunnel conditions, and enhances overall operational efficiency.

Keywords: UAV LiDAR-Based, Tunnel Survey