應用深度學習模型提升 LSPIV 觀測河川流場之準確性

Enhancing River Flow Observations with Deep Learning-Based LSPIV Accuracy Correction

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摘　要

準確量測河川表面流速對水文研究至關重要，然而傳統方法如聲學多普勒流速儀(Acoustic Doppler Current Profiler, ADCP)在成本、覆蓋範圍與設置上皆存在限制。大尺度顆粒影像速度法(Large Scale Particle Image Velocimetry, LSPIV)雖為低成本替代方案，卻容易受感興趣區域(Region of Interest, ROI)的範圍及入侵物而影響 LSPIV 的量測流速的結果。本研究將深度學習整合進 LSPIV 架構中，以克服上述挑戰。其中運用語義分割模型 SegNet 用於影像分割，以及物件偵測模型 YOLO v8 用於物體偵測。

本研究以實際淡水河之台北橋數據進行測試，結果顯示深度學習為基礎的 LSPIV 在準確性上優於傳統方法。其均方根誤差(RMSE)值介於 0.048 至 0.126 m/s，優於傳統 LSPIV；而決定係數(R^2)介於 0.985 至 0.999，顯示與 ADCP 資料高度吻合。SegNet 根據水位變化定義動態 ROI，YOLO v8 則排除船隻影響區域，兩者皆有助於提升 LSPIV 在流速估算的準確度。研究結果顯示結合深度學習與 LSPIV 在複雜環境中實現準確的河川監測之潛力。

關鍵詞：深度學習，SegNet，YOLO v8，LSPIV，河川表面流速

Abstract

Accurate measurement of river surface velocity is vital for hydrological research. However, traditional methods such as the Acoustic Doppler Current Profiler (ADCP) are limited by high costs, restricted spatial coverage, and deployment difficulties. Large-Scale Particle Image Velocimetry (LSPIV), a low-cost alternative, is susceptible to inaccuracies caused by the Region of Interest (ROI) range and the intrusion of external objects. This study integrates deep learning into the LSPIV framework to address these challenges, utilizing the semantic segmentation model SegNet for image segmentation and the object detection model YOLO v8 for identifying interfering objects.

The system was tested using real-world data from the Tamsui River around Taipei Bridge. Results show that the deep learning-based LSPIV outperforms traditional methods in accuracy. The Root Mean Square Error (RMSE) ranged from 0.048 to 0.126 m/s, surpassing traditional LSPIV performance. The Coefficient of Determination (R^2) ranged from 0.985 to 0.999, indicating strong agreement with ADCP measurement data. SegNet was used to define a dynamic ROI based on water level variations, while YOLO v8 identified and excluded vessel-influenced areas. Both models contributed to improved surface velocity estimation. The findings highlight the potential of combining deep learning with LSPIV to achieve accurate river monitoring in complex environments.

Keywords: Deep Learning, SegNet, YOLO v8, LSPIV, River Surface Velocity.