應用深度學習與三維雷達觀測於複雜地形之定量降雨估計

Combining Deep Learning and radar observations to develop QPE Technique in complex terrain

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摘　　要

台灣之地理位置特殊且地形複雜，故每年因強降雨事件產生之損失不計其數；如何即時提供高時空解析度之降雨資訊供防救災單位使用，一向為台灣防災之重要課題。傳統雷達定量降雨估計法為Z−R關係式，此法僅使用最靠近地面之可用回波值進行雨量推估，因此處理複雜地形降水估計時準確度較低。本研究將嘗試在給予充足的雷達資料的情況下，使用深度學習法提取有效的特徵並進行複雜地形上之降水估計。

本研究應用卷積神經網路（Convolutional neural network, CNN）深度學習法分析CFAD（Contoured Frequency by Altitude Diagram）以提取三維雷達回波資訊並進行定量降雨估計，針對台灣北部及東部區域現有雨量站建立各站之CNN模型。考量到強降雨與弱降雨事件個數差異過大，為提升CNN模型在大雨事件（≧10mm/1hr）之表現，故在計算模型損失函數時針對大雨事件增加權重。以2018年測站觀測分析降雨估計結果顯示，CNN模型之表現較傳統Z−R關係式為佳。此外，為增加預報之實用性，本研究亦提出兩種簡易方法進行面化之降雨估計；校驗結果顯示，尤其是在山區及東部地區離雷達較遠處，CNN模型可達到精確之降水估計並改善傳統Z−R降水估計低估的現象。

最後，選定2018年0613豪雨事件（6/13）及0909熱帶低壓事件（9/9）進行面化成果的視覺化展現，發現CNN模型對小尺度天氣系統有較佳之解析度，並可精確掌握山區雨量分布概況。在氣象與防救災上，此方法能協助民眾及防救災單位即時掌握準確降雨資訊，對複雜地形區域之小尺度汛洪及淹水尤有助益。

關鍵字：深度學習、雷達定量降雨估計、卷積神經網路

Abstract

Due to the special geographical location and complicated topography, there are countless losses caused by heavy rainfall every year in Taiwan. It is thus an important issue to provide high temporal and spatial resolution precipitation information for disaster prevention. The traditional radar quantitative precipitation estimation (QPE) method is based on the Z-R relation. This method only uses the single lowest available echo to estimate the rain rate. Although it is convenient for operation, it has low accuracy in complex terrain. In recent years, a growing number of researches show that deep learning approaches can extract effective features and estimate precipitation in complex terrain using an ample account of radar data.

This research uses convolutional neural networks (CNN) to analyze radar CFAD (contoured frequency by altitude diagram) and conduct QPE. The CNN models were built on existing rain-gauges

in northern and eastern Taiwan. Because the numbers of heavy rainfall and weak rainfall events differ dramatically, we increased the weight of heavy rain events when calculating the model loss function to improve the CNN’ s accuracy for heavy rain events (≧10mm/1hr). Based on the 2018 observation, the results show that the CNN model performs better than the Z-R relation. Moreover, to increase the forecast practicability, this research also proposes two simple methods to develop two dimensions QPE. The data from independent rain-gauges verify these methods and show that the CNN model can improve the underestimation of Z-R relation, especially in mountainous in eastern Taiwan.

This research selected 2018 6/13 and 9/9 for the case analysis to visualize the results. We found that the CNN model generates a better resolution for small-scale weather systems in mountainous areas. This method can assist disaster prevention in obtaining accurate precipitation information, especially helpful for small-scale floods in complex terrain.

Key words: deep learning, radar quantitative precipitation estimation, convolutional neural network