颱風結構分析與深度學習之應用

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摘　要

近年國內之颱風預報雖已能對路徑與主要降雨分佈有相當掌握，但對於颱風結構演變、及非軸對稱之陣風與強降雨特徵之預報能力則仍有進步空間。而缺乏一套系統性的颱風結構分析資料似是進一步了解颱風結構演變的主要障礙。多元的衛星觀測是能用以分析颱風結構的主要資料，但傳統的統計或主觀分析法在分析多頻道、高維度、時空採樣不均質的衛星觀測資料上面臨諸多限制。因此，我們開始應用近年蓬勃發展的資料科學演算法進行颱風結構分析研究。

許多深度學習演算法（包含：捲積類神經網路、生成對抗網路、與循環神經網路）在電腦視覺相關議題取得了重大突破，故極適合用於分析診斷衛星影像或動畫。藉由捲積類神經網路能自動萃取高維度資料中抽象特徵的能力，它能以回歸或分類的方式精準估計颱風的強度及暴風半徑。若再結合循環神經網路分析時間序列資料的能力，我們則開始能利用深度學習法預報颱風強度演變及快速增強發生之機率。而藉由生成對抗網路，我們能加以利用時空不均質的多種衛星資料，進一步增進深度學習網路的學習能力，並改善模式的表現與可應用性。本報告將探討發展此類深度學習統計預報技術時，如何將大氣科學專業知識導入所發展之資料科學演算法中；亦將討論深度學習在研究颱風結構相關科學議題的潛力；並簡短介紹本團隊目前的研究成果。

關鍵字：颱風、颱風結構、衛星遙測、深度學習、類神經網路

Typhoon structure analysis and deep learning

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Abstract

The improvement of tropical cyclone (TC) forecasting in recent years ensures fairly well prediction of TC tracks and primary rainfall distribution. However, there is still room for improvement in the ability to predict TC structure evolution, as well as the asymmetric characteristics of gust wind and heavy rainfall. The lack of a systematic TC structural dataset appears to be the main obstacle to further understanding the evolution of TC structure. Although satellite remote sensing provides various observational data for TC structure analysis, the conventional statistical or subjective methods face limitations in analyzing multi-channel, high-dimensional, and temporal-spatially heterogeneous satellite data. Therefore, we began to apply deep learning algorithms, which have been booming in recent years, to analyze TC structure.

Many deep learning algorithms (including convolutional neural network, generative adversarial network, and recurrent neural network) have made substantial breakthroughs in computer vision-related topics, and thus possess great potential for analyzing/diagnosing satellite images or animations. A convolutional neural network, with the ability to automatically extract abstract features from high-dimensional data, can accurately estimate typhoon intensity and size by regression or classification. If combined with the ability of a recurrent neural network of analyzing time-series data, we can begin to apply such a deep learning neural network to predict TC intensity evolution and the probability of the occurrence of rapid intensification. Furthermore, a generative adversarial network could enable the usage of satellite data that is heterogeneous in time and space, thereby enhancing the learning ability of the deep neural network and improve the model's performance and applicability. This presentation will discuss how to introduce atmospheric science domain knowledge into deep learning algorithms that conduct statistical forecasting; it will also discuss the potential of deep learning in studying scientific topics related to TC structure, and briefly present the current research results in our group.

Keywords: typhoon, tropical cyclone structure, satellite remote sensing, deep learning, neural network