運用深度學習預測機場能見度-以嘉義機場為例

Application of Deep Learning for Airport Visibility Prediction: A Case Study of Chiayi Airport

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摘　要

嘉義水上機場位於嘉南平原，秋末至隔年初春因東北季風背風效應及強烈輻射冷卻，為輻射霧好發區域，能見度驟降嚴重威脅飛航安全。

本研究以空軍氣象聯隊提供之 2012 年 1 月至 2025 年 1 月機場觀測資料為基礎，建立循環神經網路(RNN)、長短期記憶網路(LSTM)及閘控循環單元(GRU)三種深度學習模型，進行能見度(起霧/不起霧)之二元分類預測。

研究方法包含資料前處理(整點篩選、極端值剔除、缺失值插補)、以三角函數週期化編碼月份與小時等時間特徵，並針對起霧樣本稀少所致之資料極度不平衡問題，於損失函數中加入類別權重，同時採用 Macro F1 作為輔助評估指標，並使用 Optuna 調適最佳超參數組合。

實驗進一步比較不同氣象因子組合與三種學習率策略(固定、階梯式衰退、階梯式熱身)之影響。結果顯示，GRU 模型搭配露點溫度、海平面氣壓與降雨量組合表現最佳，準確率達 97.72%。各模型之最佳氣象組合均包含氣溫與露點溫度，符合輻射霧形成之物理機制。惟受限於資料不平衡，各模型 F1-Score 普遍偏低，顯示模型多傾向學習「不起霧」之多數類別，對實際起霧事件之辨識能力仍有限，其中 RNN 雖整體準確率最低，卻在少數類別偵測上相對表現較佳。

本研究證實深度學習應用於機場能見度預測具備發展潛力，亦指出資料不平衡為後續研究亟待克服之關鍵課題。

關鍵字：輻射霧, 深度學習, 時間序列模型

Abstract

Chiayi Shui-shang Airport, on Taiwan's Chia-nan Plain, is prone to radiation fog in autumn, winter, and spring due to the northeasterly monsoon's lee-side effect and strong nocturnal radiative cooling. Sudden visibility loss threatens flight safety, yet forecasting research for this regional airport remains scarce.

Using Meteorological Aerodrome Report from the Air Force Weather Wing (2012/1/1-2025/1/31), this study built three deep learning time-series models, RNN, LSTM, and GRU, for binary classification of visibility (fog vs no-fog).

Preprocessing removed outliers, imputed missing values, and encoded cyclical time features via sine-cosine transformation. To address the severe class imbalance of fog events, a weighted loss function and Macro F1-score were used alongside accuracy, with hyperparameters tuned via Optuna.

Experiments compared meteorological factor combinations and learning-rate schedules. GRU with dew point, sea-level pressure, and rainfall gave the best result (97.72% accuracy), and every model's optimal features included temperature and dew point, matching radiation fog's physical mechanism. However, F1-scores stayed low across all models, showing accuracy mainly reflects prediction of the majority no-fog class rather than genuine fog-detection skill; RNN, despite lowest accuracy, showed better minority-class detection.

These findings confirm the feasibility of deep-learning-based visibility forecasting while highlighting data imbalance as a key future challenge.

Key words : radiation fog, deep learning, time-series models