摘要

由於全球氣候變遷與溫室效應的影響，導致極端降雨事件頻傳，民國 98 年莫拉克颱風即為強降雨事件的明顯案例，造成臺灣中南部山區遭受嚴重災情，此一事件亦突顯大規模崩塌所造成之災害，未來恐對臺灣山坡地聚落造成嚴重災害威脅。因此，為預防未來豪大雨或颱風來襲時可能造成之災害，有必要針對山坡地的易崩特性、崩塌風險及警戒機制等課題進行更深入的研析。

而過去本計畫已於相關計畫發展崩塌風險警戒機制模式，透過崩塌風險的三項因子(危害度、易損性以及暴露量)整合於塌風險評估模式，其可有效掌握到個別因子的影響性，即降雨時序特徵對地面環境的影響性(危害度)、地面環境對於降雨的承受能力(易損性)以及保全對象所在的位置(暴露度)；在地面環境對於降雨的承受能力(易損性)之研究中，仍有幾個研究問題有待解決: 1. 本研究主要是基於單一坡面單元之數據組成並透過統計分析模式所建立之分析模型，這可能存在忽略坡面單元間之空間相關性的問題，因此難以探索整個集水區之坡面單元間之整體崩塌變化且對於崩塌變異不明顯之坡面單元亦可能於分析模型過程中被忽略，這可能引起一些潛在之威脅未被預測到或是單一坡面間之數值組成之同質性較高，而產生過多崩塌發生之不合理誤判產生。2. 當不易變動之因子(空間關聯特徵、地文潛勢)資料建立完畢後，對於具有時空變異特性之降雨因子資料庫於模式之角色就相當重要，我們認為崩塌災事件的發生有次序性關係，也就是當降雨發生後，其規模由小到大，當降雨規模達到一定程度後(誘因條件滿足)，再加上不同集水區的環境條件的組合關係(潛因條件滿足)後，就會發生崩塌事件。因此本計畫將導入時序性深度學習以及圖像深度學習以改善模型對於降雨引致的崩塌潛勢於未知的降雨雨場中，萃取出關鍵之降雨誘發牽動關係，增加模型對於雙參數雨量時空因子之敏感性，使模式本身的預測能力可以再提高。

最後，完成了崩塌潛勢評估模型之優化、更新崩塌風險警戒機制以及訂定一套崩塌風險指標警戒門檻後，為了能夠有效地應用於災害應變管理，本計畫將崩塌災害警戒管理落實於自主防災為主要目的，將進行自主防災崩塌警戒發布管理流程設計並嘗試落實坡地崩塌評估模式於社區自主災害警戒應用於高風險潛勢社區，並規劃相關避難路線及崩塌風險地圖等，進而達社區自主避災、防災及減災的目標。

關鍵字: 坡面單元、崩塌、深度學習、警戒管理、自主防災

Abstract

Due to the impact of global climate change and the greenhouse effect, extreme rainfall events are frequent in recent years. Typhoon Morakot in 1998 was an example of heavy rainfall events, which caused severe disasters in the mountain areas of central and southern Taiwan. This event also highlighted the large-scale landslide and its serious impacts. Therefore, to prevent future disasters that may be caused by heavy rains or typhoons, it is necessary to conduct a more in-depth study and analysis on the potential and risk of landslides, and early warning systems.

In the past, the research team has developed a landslide risk evaluation and warning model in related projects. The three factors of landslide risk (hazard, vulnerability, and exposure) are integrated into the landslide risk assessment model, which can effectively understand the individual factors, such as the impact of the temporal characteristics of rainfall on the local environment (hazard), the local environment's ability to withstand rainfalls (vulnerability), and the location of the protected objects (exposure). In the research of vulnerability, there are still several research problems to be solved: 1. The previous research model was mainly based on the data composition of a single slope unit. This may have the problem of ignoring the spatial correlation between slope units, so it is difficult to explore overall variation of the entire catchment area. The variation between slope units may also be ignored in the analysis, which may cause some potential threats to be unpredicted, or the numerical composition of slope units is relatively homogeneous, resulting in unreasonable landslide potential estimation. 2. After the data of stable factors (i.e., spatial correlation characteristics and geological potential) are established, the role of the rainfall database with spatiotemporal variation characteristics in the model is very important. It is assumed that the occurrence of collapse events is in sequential relationship, that is, when the

rainfall occurs and the scale of rainfall reaches a certain level (triggering conditions), with the environmental vulnerability (potential conditions), there will be a landslide. Therefore, this project will introduce time-series and image deep learning methods to improve the model's performance for rainfall-induced landslide in the unknown rainfall field, and to extract the key influence relationship. The improved sensitivity of factors can further improve model's ability of landslide prediction.

Finally, after completing the optimization of the landslide potential assessment model, updating the landslide warning mechanism, and setting landslide risk indicator thresholds, this plan will implement the landslide disaster management and design the warning issuing process for disaster resistant communities. The proposed landslide potential model will be introduced to the communities with high-risk of landslide disasters, and the evacuation maps and landslide potential maps will also be prepared. The goal of disaster avoidance, prevention, and mitigation for a community will be achieved in the end.

Keyword: slope unit, landslide, deep learning, warning system, disaster resistant