Automated Building Exterior Wall Crack Inspection System Using UAVs and AI-Driven Image Analysis: A Case Study from Zambia

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SUMMARY

Building exterior inspections are critical for maintaining structural integrity and ensuring safety. Traditional manual inspection methods are labor-intensive, risky, and expensive, particularly for high-rise buildings. This paper presents the development and implementation of an Automated Building Exterior Wall Crack Inspection System (ABEWCIS) using a DJI Tello Unmanned Aerial Vehicle integrated with Convolutional Neural Networks for real-time crack detection. The developed ABEWCIS was tested on a dataset comprising high resolution images of cracks on exterior walls of buildings at the Copperbelt University, Zambia collected using smartphones and the DJI Tello UAV with a 14 minutes endurance. Additional images were downloaded from public databases to increase dataset diversity. To improve model discrimination, images of non-wall features like trees, cars, and furniture were also added to the dataset. The dataset was split into 80% training set and 20% validation set. To test its robustness, the ABEWCIS was run under different lighting, surface variation, and complex environmental conditions. The six-layer CNN model was compiled with the Adam optimizer and the binary crossentropy as the loss function. The model parameters were set to 30 epochs maximum with early stopping, batch size of 64 images per batch., and optimized using EarlyStopping and ReduceLROnPlateau callbacks. The ABEWCIS's performance in crack detection reached 85% true positive detection rates while reducing false positives to 10% demonstrating its employability and offering improvements in inspection accuracy, safety, and efficiency compared to traditional methods. Under the different conditions, the ABEWCIS's performance ranged from 80% to 95 % in true positive crack detection rates representing a substantial advancement over traditional manual inspection methods. The successful implementation of ABEWCIS in Zambia provides a model for similar developing countries to adopt advanced inspection technologies, potentially leading to improved infrastructure safety and longevity across the developing world. This study establishes a foundation for continued development in automated structural inspection systems, contributing to safer, more efficient, and

more sustainable infrastructure management practices globally. Furthermore, the study contributes to the advancement of automated structural inspection technologies, particularly relevant for developing countries where cost-effective solutions are essential.