# FACADE DEGRADATION ASSESSMENT IN HERITAGE BUILDINGS: A UAV-BASED APPROACH FOR THE CHURCH OF OUR LADY OF MOUNT CARMEL IN OLINDA-PE.

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**ABSTRACT**: This study addressed the preservation of historic architectural heritage by inspecting the facades of the Church of Nossa Senhora do Carmo in Olinda-PE. Using Unmanned Aerial Vehicles (UAVs) for high-resolution image collection, combined with manual mapping and inferential statistical analysis, a comprehensive diagnosis of pathologies was achieved. The results revealed varied degradation among the facades, with paint detachment (34.6%), soiling (25.8%), and cracks (12.2%) as the most prevalent. Correlation analysis identified strong connections: moisture with cracks/biological aggression; paint detachment with vegetation/wood degradation; and soiling with multiple cracks. The methodology proved effective and non-invasive, enhancing diagnostic precision and supporting more assertive conservation plans.
**Keywords:** Historic heritage, Facade inspection, Damage mapping, pathological manifestations.

# AVALIAÇÃO DA DEGRADAÇÃO DE FACHADAS EM EDIFICAÇÕES PATRIMONIAIS: UMA ABORDAGEM BASEADA EM VANT PARA A IGREJA DE NOSSA SENHORA DO CARMO EM OLINDA, PE.

**RESUMO:** Este estudo abordou a preservação do patrimônio arquitetônico histórico, inspecionando as fachadas da Igreja de Nossa Senhora do Carmo em Olinda-PE. Utilizando Veículos Aéreos Não Tripulados (VANTs) para coleta de imagens de alta resolução, combinada com mapeamento manual e análise estatística inferencial, alcançou-se um diagnóstico abrangente de patologias. Os resultados revelaram degradação variada entre as fachadas, com destacamento de pintura (34,6%), sujidade (25,8%) e trincas (12,2%) como as mais prevalentes. A análise de correlação identificou fortes ligações: umidade com trincas/agentes biológica; destacamento de pintura com vegetação/degradação de madeira; e sujidade com trincas múltiplas. A metodologia mostrou-se eficaz e não invasiva, aprimorando a precisão diagnóstica e subsidiando planos de conservação mais assertivos.
Palavras chaves: Patrimônio histórico, Inspeção de fachadas, Mapeamento de danos, manifestações patológicas, Olinda-PE.

## INTRODUCTION

The preservation of historic architectural heritage is paramount for maintaining cultural and historical identity. In Brazil, a country rich in centuries-old constructions, safeguarding buildings of historical and artistic value is particularly urgent (Brazil, 1988; Borba, 2022). Historical preservation guidelines, such as the Athens Charter (1933) and the International Charter for the Conservation and

Restoration of Monuments and Sites (1964), emphasize regular maintenance over extensive restoration (Barbosa et al., 2013).

However, inspecting facades of complex or tall historical buildings, like the Church of Our Lady of Mount Carmel in Olinda, PE, presents significant challenges for conventional methods. These methods often suffer from limitations such as difficult access, high costs, time consumption, safety risks, and subjectivity in damage assessment, which can compromise the comprehensiveness and accuracy of diagnoses (Pasqualotti, 2022; Rangel, 2019). The emergence of Unmanned Aerial Vehicle (UAV) technology offers an innovative solution. UAVs enable the collection of high-resolution images and video, facilitating the detection of problems difficult to observe from ground level, while reducing human risk (Lima et al., 2020; Ruiz et al., 2021). Despite their potential, there remains a gap in standardizing UAV inspection protocols for historical heritage, particularly for Brazilian colonial buildings.

This study aims to improve damage inspection and mapping methods in historical buildings by assessing the current condition of the Church of Our Lady of Mount Carmel's facades in Olinda, PE, and demonstrating the effectiveness of UAVs for rigorous and detailed damage mapping. The proposed methodology, combining aerial inspection with comprehensive damage mapping and robust inferential statistical analysis, seeks to provide a reference for future conservation efforts and optimize resource allocation for heritage restoration.

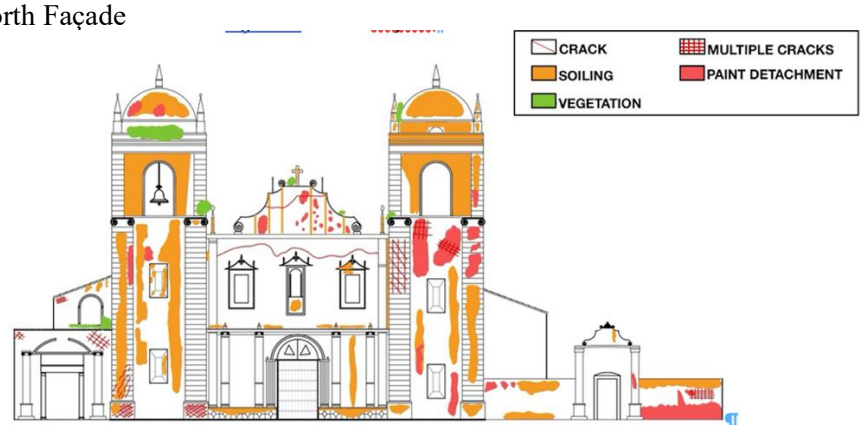
## MATERIALS AND METHODS

The research on the Church of Our Lady of Mount Carmel in Olinda, PE, employed a systematic, multi-stage methodology for detailed inspection and mapping of pathological manifestations. It began with a comprehensive literature review on historical heritage, pathologies, and UAV inspection technologies. Subsequently, a DJI Mini 3 UAV conducted high-resolution image capture of the facades under optimal weather conditions. Technical drawings were then created in AutoCAD, where pathological manifestations were manually mapped using GoodNotes, differentiating damage types and measuring affected areas to form a comprehensive damage map. Finally, an inferential statistical analysis provided a robust quantitative diagnosis through six sequential steps: total and percentage incidence calculation, façade-specific analysis, bar chart generation via RStudio, and Pearson correlation matrix calculation with heatmap visualization to identify dependency relationships among pathologies ($\alpha = 0.05$). This quantitative approach enhanced the scientific understanding of degradation processes and informed effective intervention strategies.

## RESULTS AND DISCUSSION

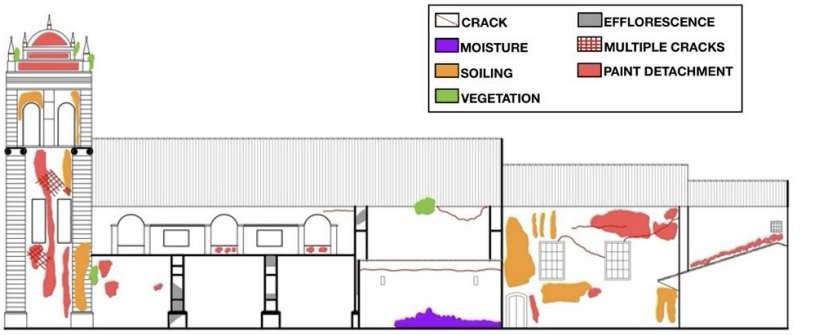
Inspection of the façades revealed varied distribution and severity of pathological manifestations across the four orientations of the building. The North Façade recorded the highest absolute number of pathologies (133 occurrences), predominantly soiling (71 occurrences) and paint detachment (34 occurrences), likely due to its exposure to wind, moisture, and pollution. Figure 01 illustrates the North Façade.

Figure 01 - North Façade



In contrast, the West Façade presented a lower total number of pathologies with 51 occurrences. Paint detachment (20 occurrences) and soiling (10 occurrences) were predominant, as shown in Figure 04. This lower incidence may relate to reduced exposure to climatic factors or protection from adjacent urban elements.

Figure 02 - West Façade

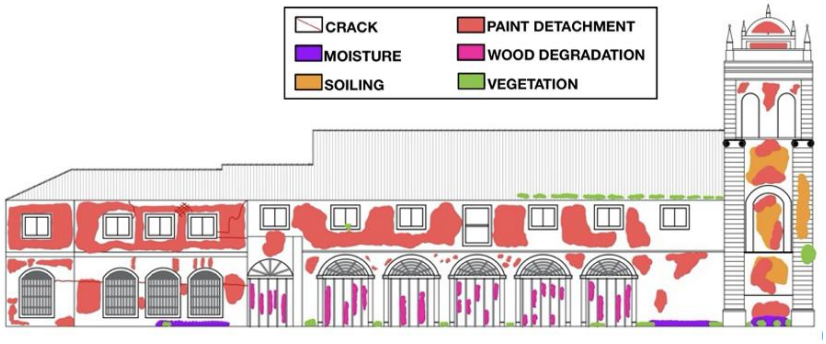



The South Façade recorded 56 occurrences, also a lower volume compared to the North Façade. As depicted in Figure 05, cracks (19 occurrences) and paint detachment (18 occurrences) were the most notable.

Figure 03 - South Façade

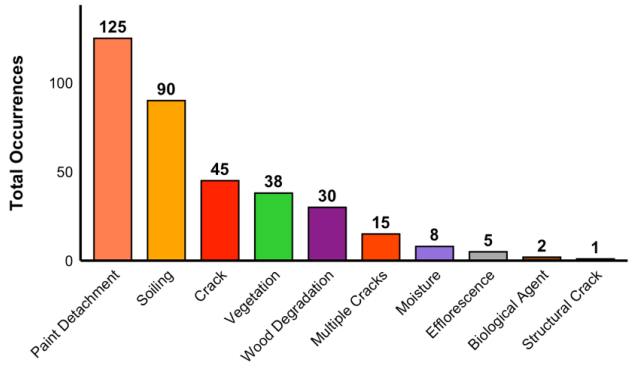

The East Façade showed a high number of anomalies with 121 occurrences, making it the second most affected. As seen in Figure 06, paint detachment (53 occurrences), vegetation (25 occurrences), and wood degradation (28 occurrences) were prominent, possibly indicating strong sun exposure, wetting/drying cycles, or rainwater drainage failures.

Figure 04 - East Façade



This differentiated distribution of pathologies by façade highlights the importance of detailed inspection for each side, as environmental conditions and usage significantly affect material deterioration.

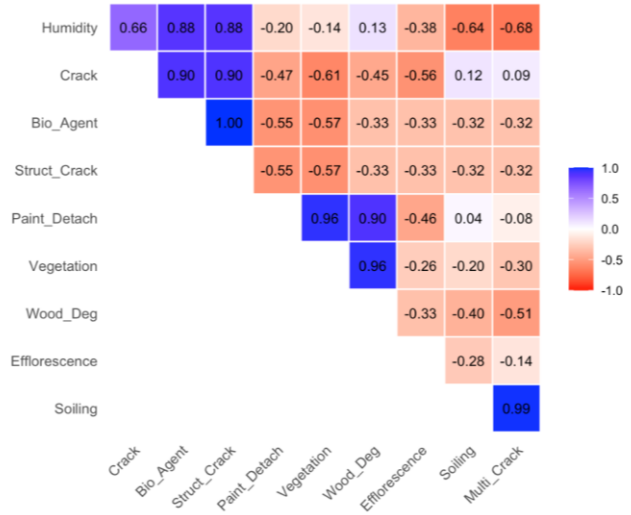
Figure 05 – Total Incidence of Pathological Manifestations on the Façades




The presence of wood degradation, moisture, efflorescence, and biological agents indicates critical issues related to water management. Structural cracks, though less frequent, demand priority attention due to their potential to compromise building stability.

The Pearson correlation matrix, visualized as a heatmap in Figure 06, provided crucial insights into interrelationships.

Figure 06 – Correlation Matrix of Pathological Manifestations




Correlation analysis (values from -1 to +1, with blue tones indicating positive and red negative correlations) revealed key patterns. Moisture showed very strong positive correlations with Cracks (0.88), Biological Agent (0.88), and Structural Cracks (0.88), confirming its role as a triggering factor for fissures and biological growth (Espinosa et al., 2008; Blocken et al., 2013). Interestingly, it exhibited a negative correlation with Soiling (-0.68), suggesting distinct degradation mechanisms. Paint Detachment correlated strongly with Vegetation (0.96) and Wood Degradation (0.90), indicating a progressive cycle where vegetation contributes to wood degradation, affecting paint adhesion (Guerra et al., 2019; Barrellas et al., 2023). Soiling showed a strong correlation with Multiple Cracks (0.99), suggesting that fissured surfaces tend to accumulate more dirt (Flores-Colen et al., 2008; Souza et al., 2016). A perfect correlation (1.00) between Biological Agent and Structural Cracks suggests that cracks create microenvironments for biological growth. These patterns guide integrated

interventions and reinforce the need for detailed inspections for early detection and intervention (Guerra et al., 2019; Mathur et al., 2024).

## CONCLUSIONS

The methodology employed revealed the complexity and diversity of degradation processes on the Church of Our Lady of Mount Carmel façades. Distinct deterioration patterns were observed across façades, with North and East orientations exhibiting the highest number of anomalies. Paint detachment (34.63%), soiling (25.76%), and cracks (12.19%) were the most prevalent pathologies, while wood degradation, moisture, and biological agents highlighted critical water management issues.

Pearson correlation analysis provided cruciais insights into the interrelationships among pathological manifestations. Moisture was confirmed as a priority control factor for cracks, biological agents, and structural cracks. Strong correlations were also found between paint detachment, vegetation, and wood degradation, and between soiling and multiple cracks, suggesting progressive deterioration cycles.

This methodology proved effective and non-invasive for inspecting protected heritage buildings, optimizing data collection and overcoming conventional method limitations. Scientifically, this study validates a robust, quantitative approach that enhances diagnosis and supports the development of more effective maintenance plans, significantly contributing to the durability and safety of architectural heritage.

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