# PRESERVING CULTURAL HERITAGE SITES THROUGH RANDOM FOREST AND XGBOOST ALGORITHM FOR MICROCLIMATE MONITORING AND PREDICTION

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# PRESERVING CULTURAL HERITAGE SITES THROUGH RANDOM FOREST AND XGBOOST ALGORITHM FOR MICROCLIMATE MONITORING AND PREDICTION

IMAN AIDI ELHAM BIN HAIRUL NIZAM

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Bachelor of Computer Science (Software Engineering)

School of Computing
Faculty of Engineering
Universiti Teknologi Malaysia

JULY 2023

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I declare that this thesis entitled *" Preserving Cultural Heritage Sites through Random Forest and XGBoost Algorithm for Microclimate Monitoring and Prediction"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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# DEDICATION

This thesis is dedicated to my parents who taught me to work hard and dream big in life. Thank you to my supervisor Associate Prof Dr Mohd Shahizan Othman for guiding me throughout this thesis. Thank you too to my supportive friends who are also struggling to finish their own thesis and has helped me with this thesis either physically or morally.

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In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Professor Dr. Mohd Shahizan Othman, for encouragement, guidance, critics and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Teknologi Malaysia (UTM) for funding my Bachelor study. Librarians at UTM, Cardiff University of Wales and the National University of Singapore also deserve special thanks for their assistance in supplying the relevant literatures.

My fellow undergraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family member.

# ABSTRACT

The preservation of heritage architecture is significant in maintaining the cultural heritage of a region. This study focuses on the development of a machine learning-based microclimate monitoring system to assist local authorities in Johor Bahru, Malaysia, with planning preventive maintenance actions for a designated heritage site. The research project comprises obtaining microclimate data, including temperature, humidity, and wind speed, from the Malaysian Meteorological Department (MET Malaysia). In order to optimize the monitoring and prediction process, the performance of two machine learning algorithms, Random Forest and XGBoost, will be compared to determine the most suitable method for microclimate analysis. The project also involves designing and developing an interactive, user-friendly dashboard that displays real-time microclimate data using data visualization tools. The effectiveness of the developed algorithm and dashboard will be tested to evaluate their potential in aiding local authorities with the implementation of more effective maintenance plans for the heritage site. This research aims to contribute to the preservation of cultural heritage sites by utilizing advanced machine learning techniques for microclimate monitoring and prediction, ultimately supporting sustainable and efficient conservation efforts.

# ABSTRAK

Pemeliharaan senibina warisan memegang peranan penting dalam mengekalkan warisan budaya suatu kawasan. Kajian ini memberi tumpuan kepada pembangunan sistem pemantauan mikroiklim berasaskan pembelajaran mesin untuk membantu pihak berkuasa tempatan di Johor Bahru, Malaysia, merancang tindakan penyelenggaraan pencegahan untuk tapak warisan yang ditetapkan. Projek penyelidikan ini merangkumi mendapatkan data mikroiklim, termasuk suhu, kelembapan, dan kelajuan angin, daripada Jabatan Meteorologi Malaysia (MET Malaysia). Untuk mengoptimumkan proses pemantauan dan ramalan, prestasi dua algoritma pembelajaran mesin, Random Forest dan XGBoost, akan dibandingkan untuk menentukan kaedah yang paling sesuai untuk analisis mikroiklim. Projek ini juga melibatkan reka bentuk dan pembangunan papan pemuka interaktif dan mesra pengguna yang memaparkan data mikroiklim masa nyata menggunakan alat visualisasi data. Keberkesanan algoritma dan papan pemuka yang dibangunkan akan diuji untuk menilai potensi mereka dalam membantu pihak berkuasa tempatan melaksanakan rancangan penyelenggaraan yang lebih berkesan untuk tapak warisan. Penyelidikan ini bertujuan untuk menyumbang kepada pemeliharaan tapak warisan budaya dengan menggunakan teknik pembelajaran mesin yang maju untuk pemantauan dan ramalan mikroiklim, yang pada akhirnya menyokong usaha-usaha konservasi yang mampan dan cekap.

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| | | |
|---|---|---|
| ANN | - | Artificial Neural Network |
| GA | - | Genetic Algorithm |
| PSO | - | Particle Swarm Optimization |
| MTS | - | Mahalanobis Taguchi System |
| MD | - | Mahalanobis Distance |
| TM | - | Taguchi Method |
| UTM | - | Universiti Teknologi Malaysia |
| XML | - | Extensible Markup Language |
| ANN | - | Artificial Neural Network |
| GA | - | Genetic Algorithm |
| PSO | - | Particle Swarm Optimization |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| δ | - | Minimal error |
| $D, d$ | - | Diameter |
| $F$ | - | Force |
| $v$ | - | Velocity |
| $p$ | - | Pressure |
| $I$ | - | Moment of Inersia |
| $r$ | - | Radius |
| Re | - | Reynold Number |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

Cultural heritage sites are the basis for our global and historical values. It connects us to the traditions left by our ancestors and contribute significantly to the cultural identity of human society (Lombardo et al., 2020). However, cultural heritage sites and monuments in various regions are increasingly under threat from natural disasters, such as earthquakes (Okamura et al., 2013), flooding (Ortiz et al., 2016), and rock falls (Mineo and Pappalardo, 2020). Over the past few decades, these sites have encountered dangerous circumstances not only due to human activities but also as a result of land use and climate changes, especially in developing nations (Pioppi et al., 2020). Hence, safeguarding worldwide cultural heritage sites is of utmost importance for preserving cultural identity and human heritage, as well as promoting cultural and tourism-driven economic development (Tarragüel et al., 2012). In recent years, the administration of cultural heritage sites and monuments has gained worldwide focus through the implementation of detection, monitoring, and comprehensive assessment methods. Initiatives are also underway to enhance and preserve these heritage resources by adopting suitable adaptation measures and sustainable management approaches (Guzman et al., 2020).

## 1.2 Problem Background

Natural sites have consistently drawn visitors who seek to spend quality time and pursue unique experiences by engaging with local cultures and communities (Ramkissoon et al., 2013). As a result, the economies of these tourist destinations largely rely on attracting visitors, encouraging repeat visits, garnering recommendations, and generating positive word-of-mouth about the locations (Rezapouraghdam et al., 2021). In addition, the well-being and quality of life for local residents are also enhanced by the natural environments in which tourism activities occur (Ramkissoon et al., 2018). Lately, Johor Bahru has been experiencing frequent climate fluctuations that negatively impact the aesthetic appeal of the area's heritage sites, significantly affecting the tourism industry and local economy. In general, microclimate changes in these regions cause substantial damage to cultural heritage sites and various monuments. Consequently, striking a balance between consumption and conservation strategies presents increasing challenges for the effective management of cultural heritage sites (Buonincontri et al., 2017). Therefore, focusing on the preservation of cultural heritage and promoting sustainable tourism has become a primary objective in recent times to support both cultural heritage tourism and the overall well-being of communities (Megeirhi et al., 2020).

## 1.3 Research Aim

The goal of this study is to identify vulnerable zones of cultural heritage (CH) sites and monuments in Johor Bahru, Malaysia, by employing microclimate monitoring and prediction through the Random Forest and XGBoost algorithms. By assessing temperature, humidity, and wind speed, the study aims to maintain environmental sustainability at these heritage sites. In this research, we have prepared a microclimate monitoring dashboard and evaluated the significance of factors contributing to microclimate changes. The Random Forest and XGBoost algorithms were employed to analyze the impact of these factors on the preservation of CH sites.

## 1.4 Research Objectives

The following are the objectives proposed:

(a) To investigate and identify the most suitable machine learning algorithms for analyzing microclimate data, and to recognize patterns, trends, and potential issues related to the heritage site's preservation.

(b) To evaluate the effectiveness of the developed machine learning models and dashboard in assisting local authorities to plan preventive maintenance actions that preserve the site's aesthetics and cultural values.

(c) To develop and design a user-friendly dashboard that displays real-time microclimate data and provides recommendations for maintenance actions to assist local authorities with heritage site preservation.

## 1.5 Research Scopes

The scope of this research project covers several aspects related to the preservation of heritage architecture in Johor Bahru, Malaysia, using machine learning-based microclimate monitoring. The primary focus is on the development of a dashboard to collect, display, and analyze microclimate parameters for assisting the local authority in planning preventive maintenance actions. The specific areas included in the scope of this research are:

(d) The research involves obtaining microclimate data from the Malaysian Meteorological Department (MET Malaysia) for a designated heritage site in Johor Bahru. This data contains parameters like temperature, humidity, and wind speed.

(e) The research intends to compare the performance of two machine learning algorithms between Random Forest and XGBoost to determine the most suitable method for microclimate monitoring and prediction.

(f) The project includes designing and developing an interactive user-friendly dashboard by using data visualization tools that display real-time microclimate data.

(g) The research will involve testing the effectiveness of the developed algorithm and dashboard in assisting local authorities with planning more effective maintenance plans for the heritage site.

## 1.6 Research Contribution

A thorough literature review on microclimate impacts on CH sites reveals that many researchers have used various statistical and machine learning methods, including logistic regression (LR), artificial neural network (ANN), Bayesian network (BN), and support vector machine (SVM), to create microclimate monitoring and prediction dashboards. However, the combination of Random Forest and XGBoost algorithms, along with the analysis of temperature, humidity, and wind speed, has not yet been employed in the context of CH site preservation. As a result, this study offers a novel contribution to the geoscientific field, particularly for modeling microclimate threats and risk assessments of cultural heritage sites.

In the context of the current changing climate and landscape, this study is highly relevant and makes a significant contribution to sustainable management of cultural heritage resources. Changing climatic conditions have a considerable impact on temperature, humidity, and wind patterns, which can affect the stability of heritage sites and potentially lead to damage. This research provides valuable insights and technical references for selecting input causative factors, machine learning algorithms, and proper interpretation and evaluation of the results.

Moreover, this study has essential implications for the conservation of natural resources and heritage sites in Johor Bahru, Malaysia. The outcomes of this research will be beneficial for land use planners, landscape professionals, archaeologists, and public administrators as they work to manage CH sites and ensure environmental sustainability through optimal strategies. By monitoring and predicting microclimate changes using the Random Forest and XGBoost algorithms, stakeholders can better preserve and protect cultural heritage sites for future generations.

## 1.7 Report Organization

This report comprises five chapters. Chapter 1 introduces the topic of preserving cultural heritage sites through microclimate monitoring and prediction using Random Forest and XGBoost algorithms, the research background, and the purpose of conducting this study in Johor Bahru, Malaysia. Chapter 2 discusses the literature review related to microclimate monitoring, the assessment of temperature, humidity, and wind speed, as well as the comparison of machine learning techniques for processing and analyzing data from heritage sites. Chapter 3 delves into the methodology of the research, describing how the study is conducted using the Random Forest and XGBoost algorithms to measure and analyze the data on temperature, humidity, and wind speed for preserving cultural heritage sites. Chapter 4 presents the research design and implementation, detailing how the experiment was executed to extract valuable insights from the microclimate data. Chapter 5 showcases the results obtained from this research, including the Power BI dashboard displaying the analyzed data. Finally, Chapter 6 offers a summary and conclusion for the study, highlighting the key findings and implications for the preservation of cultural heritage sites through microclimate monitoring and prediction using Random Forest and XGBoost algorithms.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction to Case Study

Climate change has emerged as a significant global challenge in recent years, impacting various sectors, including the preservation of cultural heritage sites. The increasing frequency and intensity of extreme weather events, along with gradual shifts in temperature, humidity, and wind patterns, have highlighted the need for adaptive solutions to safeguard these invaluable assets.

One promising approach to address these challenges involves the application of advanced algorithms, such as Random Forest and XGBoost, for microclimate monitoring and prediction at cultural heritage sites. These techniques can help preserve and protect these valuable assets by analyzing temperature, humidity, and wind speed data, which are crucial factors in the conservation of these sites.

This case study focuses on the implementation of the Random Forest and XGBoost algorithms for microclimate monitoring and prediction at cultural heritage sites in Johor Bahru, Malaysia. By leveraging these advanced techniques and utilizing Power BI dashboards for data visualization and analysis, this research aims to enhance the understanding of site-specific microclimates and inform effective conservation strategies.

Through continuous assessment and refinement of these methods, researchers, conservators, and heritage site managers can work together to develop improved strategies for preserving cultural heritage sites under changing environmental conditions. This collaborative approach ensures that these invaluable assets are protected and maintained for future generations to appreciate and learn from, despite the challenges posed by climate change.

## 2.2 Machine Learning Techniques

Machine learning-based microclimate monitoring and prediction methods are developed based on the concept of supervised learning, where a classifier is trained by assigning labels to specific data points or regions in the dataset. These classifiers learn the hidden patterns and signatures of various labeled factors, and then make predictions accordingly. For microclimate monitoring and prediction using multispectral data, it is essential to consider classifiers that can handle large-scale data and achieve high accuracy quickly. Two classifiers, including Extreme Gradient Boosting (XGBoost) and Random Forest used in this study for microclimate monitoring and prediction at cultural heritage sites, are discussed below.

### 2.2.1 Random Forest

The Random Forest algorithm, developed by Breiman (2001), is an ensemble learning model capable of performing tasks such as classification, regression, clustering, interaction detection, and variable selection (Rahmati et al., 2017; Belgiu and Drăguţ, 2016). This learning method is founded on the aggregation of decision trees, which divide the input data based on parameters in a tree-like structure (Ma and Cheng, 2016; Breiman, 2001) (Fig. 4). Each tree is constructed using a bootstrapped sample of the data, with each node in the tree being split according to the optimal subset and randomly chosen predictors at each stage (Araki et al., 2018; Rahmati et al., 2017). The final classification is determined, and output is produced based on the majority vote of the decision trees (Micheletti et al., 2014; Rahmati et al., 2017). Random Forest is known for its resistance to overfitting and outliers, as well as its high-performance capabilities (Balogun et al., 2021; Tella et al., 2021a).

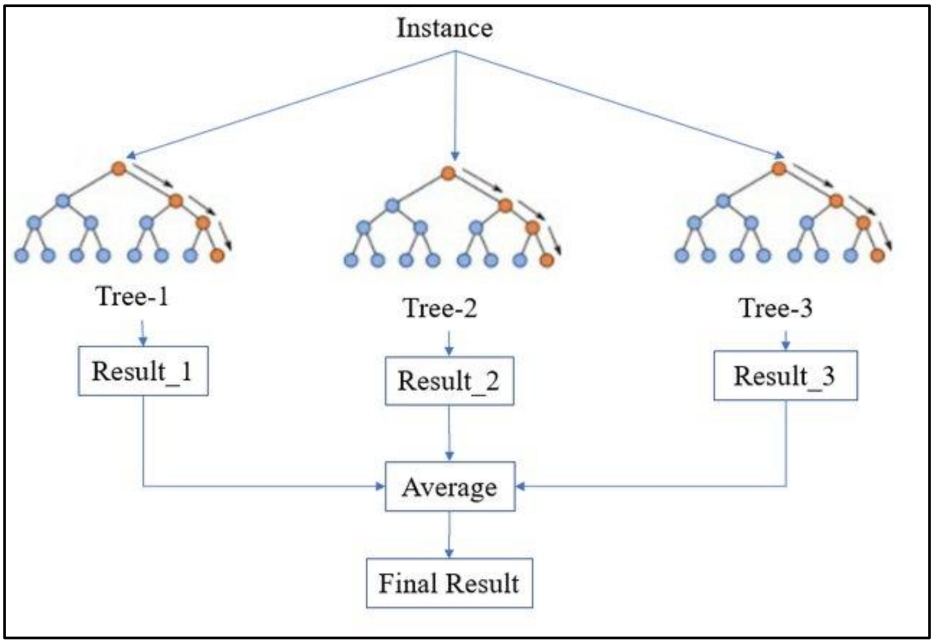


**Figure 1: Random Forest Model Architecture**

### 2.2.2 XGBoost

XGBoost is a parallel tree boosting method that effectively addresses large-scale problems while maintaining high accuracy. As a classifier derived from gradient boosting, XGBoost iteratively combines weak tree classifiers to form a robust classifier. By calculating residual errors for each tree, the error margin for the subsequent tree is reduced, resulting in a lower overall error rate. Each tree contributes to the construction of a strong boosted classifier by creating an ensemble of weak classifiers (Friedman, 2001). Although XGBoost has seen limited use in remote sensing image applications, it has demonstrated higher accuracy when handling large-scale, multi-class data (Bhagwat & Shankar, 2019; Zamani Joharestani et al., 2019; Rumora et al., 2020). Due to its scalability and performance with extensive satellite data, XGBoost is employed in this study for microclimate monitoring and prediction.

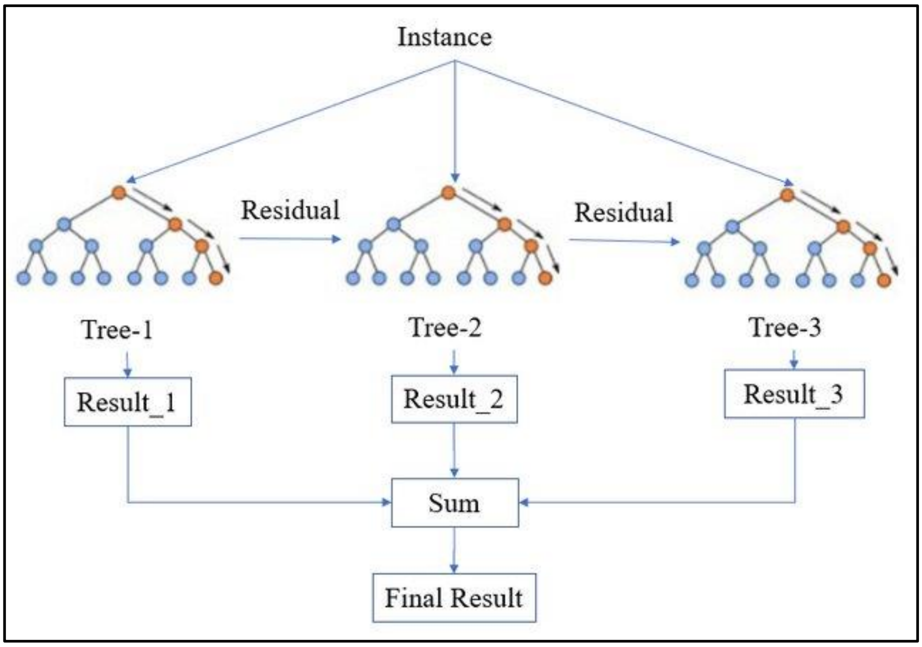


**Figure 2: XGBoost Model Architecture**

## 2.3

### 2.3.1 Comparison Between Random Forest and XGBoost Algorithm

## 2.4 Research Gap

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# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Introduction

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### 3.1.1 Proposed Method

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#### 3.1.1.1 Research Activities

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## 3.2 Tools and Platforms

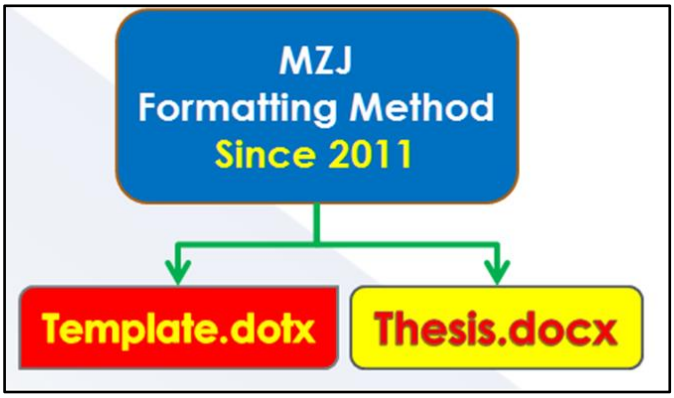


Figure 3.1 Example of Formatting Method

## 3.3 Chapter Summary

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CHAPTER 4

# PROPOSED WORK

## 4.1 The Big Picture

## 4.2 Analytical Proofs

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## 4.3 Result and Discussion

## 4.4 Chapter Summary

[1]Mary Duncan Carterand Rose Mary Magrill, “Building Library Collections" Fourth edition. (Metuchen, N. J.: Scarecrow Press, 1974), pp.61 - 66.

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# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Research Outcomes

## 5.2 Contributions to Knowledge

## 5.3 Future Works

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# Appendix A Mathematical Proofs

# Appendix B Psuedo Code

## Appendix C Time-series Results Long Long Long Long Long Long Long Long Long Long

## LIST OF PUBLICATIONS