**CHAPTER ONE**

**INTRODUCTION**

* 1. **BACKGROUND STUDY**

Soil is not simply a static material; it is a dynamic entity that responds to the forces applied upon it. When loaded, soil particles shift and interact, influencing the overall behavior of the soil mass. Deformation occurs as particles move, impacting structures and infrastructure built upon the soil. Settlement, the gradual downward movement of soil, can pose significant challenges for construction projects. At its core, soil is a heterogeneous blend of minerals, organic matter, gases, liquids, and countless organisms that together support life on Earth. The formation of soil is a slow and continuous process that involves the weathering of rock and the decomposition of organic matter, intricately influenced by various environmental factors. This natural process, spanning thousands to millions of years, results in a material with properties that are remarkably diverse and location specific.

For centuries, geotechnical engineers have relied on a blend of scientific principles and field experience to decipher the secrets of soil. From meticulous laboratory tests to visual assessments made with trained eyes, the process of understanding soil characteristics has been one of meticulous investigation and careful interpretation. However, the vast diversity of soil types and the need for ever-increasing efficiency in construction projects have pushed the boundaries of traditional methods.

The diversity in soil composition is striking, with each type exhibiting unique characteristics. Granular soils, such as sand and gravel, consist of larger, coarser particles, providing excellent drainage and stability. Emphasized in the study of clays treated with rice husk ash, which highlights the impact of particle size on soil properties (Li B., F. Li, & Liu, 2024). Cohesive soils, including clay and silt, are characterized by finer particles that tend to stick together, affecting their water retention and plasticity. Organic soils, abundant in decomposed plant matter, add another dimension of complexity with their distinct properties. Understanding the specific composition of a soil type is essential in unraveling its various attributes and potential uses.

Geotechnical engineers rely on sophisticated models and laboratory tests to unravel the mysteries of soil behavior. With thousands of soil types and countless variations within each, the task of soil classification becomes paramount. Soil classification plays a pivotal role in various engineering and environmental applications, influencing decisions ranging from construction site selection to infrastructure design. Traditionally, soil classification relied on tedious and often subjective visual assessments and laboratory tests. While valuable, these methods can be time-consuming, expensive, and prone to human error. This is where the blooming field of artificial intelligence (AI) offers a transformative opportunity. Geotechnical engineers can unlock a new era of rapid, accurate, and non-destructive soil classification by analyzing soil images, capturing the intricate interplay of texture, color, and particle size distribution, and instantaneously receiving a reliable assessment of its type(and properties). This revolutionizes traditional methods, making soil classification efficient, objective, and accessible.

In the last few years, the integration of machine learning techniques has provided efficient and accurate alternatives to enhance the soil classification process. This research paper focuses on the utilization of Convolutional Neural Networks (CNNs) and Adaboost algorithms for soil classification, specifically based on the Unified Soil Classification System (USCS).

Computer vision is a multidisciplinary field that enables computers to interpret and understand visual information from the world. It seeks to replicate the human visual system’s ability to interpret and make decisions based on visual data. The ultimate goal of computer vision is to develop algorithms and systems that can analyze and make sense of images and videos in a manner similar to human vision. Convolutional Neural Networks (CNNs) have demonstrated exceptional capabilities in computer vision tasks, particularly image recognition. In the context of soil classification, CNNs can be leveraged to extract intricate spatial features from soil images, allowing for robust identification and categorization. The hierarchical architecture of CNNs enables the automatic learning of relevant features, making them well-suited for handling the complex and diverse visual characteristics present in soil samples.

Complementing the power of CNNs, the AdaBoost algorithm emerges as an ensemble learning technique that excels in combining the strengths of multiple weak classifiers. By iteratively emphasizing misclassified instances and assigning appropriate weights to classifiers, AdaBoost enhances the overall accuracy of the classification process. In the realm of soil classification, the integration of AdaBoost with CNNs promises a synergistic approach, leveraging the strengths of both methodologies to achieve a more robust and accurate classification of soil types.

The specific focus of this study lies in the application of CNN and AdaBoost algorithms to classify soils based on the Unified Soil Classification System (USCS). The USCS provides a standardized framework for soil categorization, considering both grain-size distribution and plasticity characteristics. By incorporating machine learning techniques into the USCS framework, we aim to streamline and automate the soil classification process, offering a more efficient and accurate means of categorizing soils for engineering and environmental applications.

**1.2 PROBLEM STATEMENT**

The success of civil engineering projects in Nsukka, Nigeria, is severely delayed due to the absence of an efficient and reliable soil classification methods. Traditional techniques come with a cascade of detrimental consequences. Inaccurate assessments are pervasive, as visual and laboratory testing often miss crucial soil properties, leading to misclassification and flawed design decisions (Jiménez, Sánchez, & Török, 2020) . These methods are inherently time-consuming and resource-intensive, demanding extensive lab tests and expert interpretation, which delay project timelines and inflate costs (Abdullah, Ismail, Omar, Abdullah, & Sulaiman, 2018). To worsen things, the subjectivity and inconsistencies inherent in manual interpretation introduce human bias and discrepancies in classification, ultimately compromising the reliability of design calculations. This research proposes a hybrid model of CNNs and AdaBoost to revolutionize soil classification, boosting safety, reducing costs, and promoting sustainable practices.

**1.3 AIM AND OBJECTIVES**

The aim of this work is to develop and implement an image-based classification model consisting of Convolutional Neural Networks (CNNs) and AdaBoost to accurately classify soils in Nsukka, Nigeria, based on the Unified Soil Classification System (USCS), significantly improving the efficiency and reliability of soil analysis compared to traditional methods.

The objectives of this work includes:

1. Building a high-quality dataset of diverse Nsukka soils, meticulously annotated for USCS classes.
2. Designing and optimizing the model to excel in accuracy and outperform traditional methods.
3. Creating a user-friendly interface for on-site, real-world soil classification with the model.

**1.4 SCOPE OF STUDY**

This study will primarily focus on analyzing soil images captured under controlled laboratory conditions. The scope will encompass a range of soil types, including granular soils, cohesive soils, and organic soils. We will prioritize features readily identifiable in images, such as texture, color, and particle size distribution. While acknowledging the importance of other soil characteristics like chemical composition and mechanical properties, the initial focus will be on image-derived features to exploit the strengths of computer vision.

**1.3 SIGNIFICANCE OF STUDY**

This study pioneers a groundbreaking image-based revolution in Nsukka's soil classification by weaving together the potent capabilities of CNN and AdaBoost. This unique fusion unlocks a trifecta of benefits: enhanced accuracy in USCS classifications, streamlined workflows through reduced resource requirements, and a direct path towards sustainable infrastructure development. By eliminating the subjective uncertainties of traditional methods and embracing the power of AI image analysis, this work paves the way for a future where civil engineering in Nsukka thrives on precision, efficiency, and environmental responsibility.

**1.4 Limitations of study**

Recognizing the limitations of this study is the first step towards overcoming them and paving the way for even more robust and widely-applicable AI-based soil classification systems. These limitations are:

1. **Dataset Size and Bias:** Limited availability of diverse Nsukka soil images could lead to training a model with bias towards certain soil types, affecting generalizability.
2. **Overfitting and Generalizability:** Training on limited data may lead to overfitting to the specific training set, compromising the model's ability to perform well on unseen soil samples.
3. **Real-world Environment Variations**: Lighting, shadows, and other unpredictable factors in the field could affect image quality and impact model accuracy compared to controlled laboratory settings.

# References

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