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AUTOMATED BUILDING CODE AND COMPLIANCE

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ABSTRACT
The verification of building codes and compliance is a crucial aspect of construction and urban development, ensuring safety, structural integrity, and regulatory adherence. However, traditional manual reviews are time-consuming, labor-intensive, and prone to human error, often leading to delays and increased costs. **Automated Building Code and Compliance** systems offer a transformative solution by leveraging **artificial intelligence (AI)**, **machine learning (ML)**, and rule-based algorithms to streamline the verification process. These systems analyze architectural and engineering designs, cross-referencing them against local, national, and international building regulations to identify potential violations at early design stages.

INTRODUCTION

In Architecture, Engineering and Construction (AEC) industry, building designs are checked against the required building codes and regulations. Building codes and regulations are determined and written by government professionals and professional bodies. They could be in various forms such as written texts, tables, equations, etc. Also, they are legally binding so that any building shall comply with the related building codes and regulations. The building codes and regulations are complex documents that include large amount of information. Different types of building codes and regulations exist such as for health and safety, acoustics, fire safety, housing and zoning, etc. In order to get approval for a building project, a building design shall satisfy all of the related building codes and regulations' rules.

OBJECTIVES

- The overall objective of this thesis is to develop a formal representation of the building codes based on the steps below:
- Discussing the previous research efforts on the topics of representing building codes and automated code-checking systems to define the limitations and challenges encountered in those efforts.
- Defining a formal methodology to digitalize building codes in order to ease the overall process of automated code-checking.
- Defining a framework to bridge Building Information Modeling (BIM) and automated code-checking with proposed methodology in order to consistently represent building codes.

LITERATURE REVIEW

Building codes ensure safety, sustainability, and efficiency in construction. Traditional compliance methods are manual, time-consuming, and prone to errors. Recent advances in automation and artificial intelligence (AI) offer promising solutions for streamlining code compliance processes. This literature review explores automated building code compliance, focusing on key technologies,

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challenges, and future directions.

BIM-Based Code Checking

BIM-Based Code Checking refers to the use of **Building Information Modeling (BIM)** technology to automate the process of verifying compliance with building codes and regulations. BIM allows for the creation of detailed 3D models that incorporate essential design, structural, and regulatory data, making it easier to analyze whether a building meets compliance requirements.

Machine Learning and AI

Machine Learning and AI AI-driven approaches use natural language processing (NLP) and deep learning to interpret and assess compliance with complex building regulations.

Rule-based systems

Rule-based systems are one of the earliest and most widely used approaches for automating building code compliance. These systems rely on predefined rule sets that encode regulatory requirements into machine-readable formats. Key aspects include:

- **Expert System Approach**: Rule-based systems function as expert systems that apply logical rules to verify compliance. These rules are manually programmed based on building codes and standards.
- **IF-THEN Logic**: Most rule-based systems use conditional logic, where IF a specific building parameter meets a condition, THEN the system evaluates its compliance.

METHODOLOGY

This thesis presents a building code representation methodology for analyzing building codes in order to ease the automated code-checking process. The proposed methodology is used to classify the building code rules in a formal manner and to check their interpretability conditions to categorize whether the rules can be expressed in a computer readable format or not. The proposed building code representation methodology firstly analyses the building code and decomposes it. Then, it organizes the building code rules into different classes such as Class 1, Class 2, Class 3, and Reference rules and into different interpretability conditions such as Interpretable, Semi-Interpretable, and Non-Interpretable rules. Lastly, the developed building code representation is utilized to determine necessary variables in order to process code- checking in automated systems and platforms in a more efficient and precise way. For instance, determination of LOD, decision of which automated code-checking system or platform will be used for automated code-checking, or prediction of external software solutions required for completely checking a building code, are carried out.

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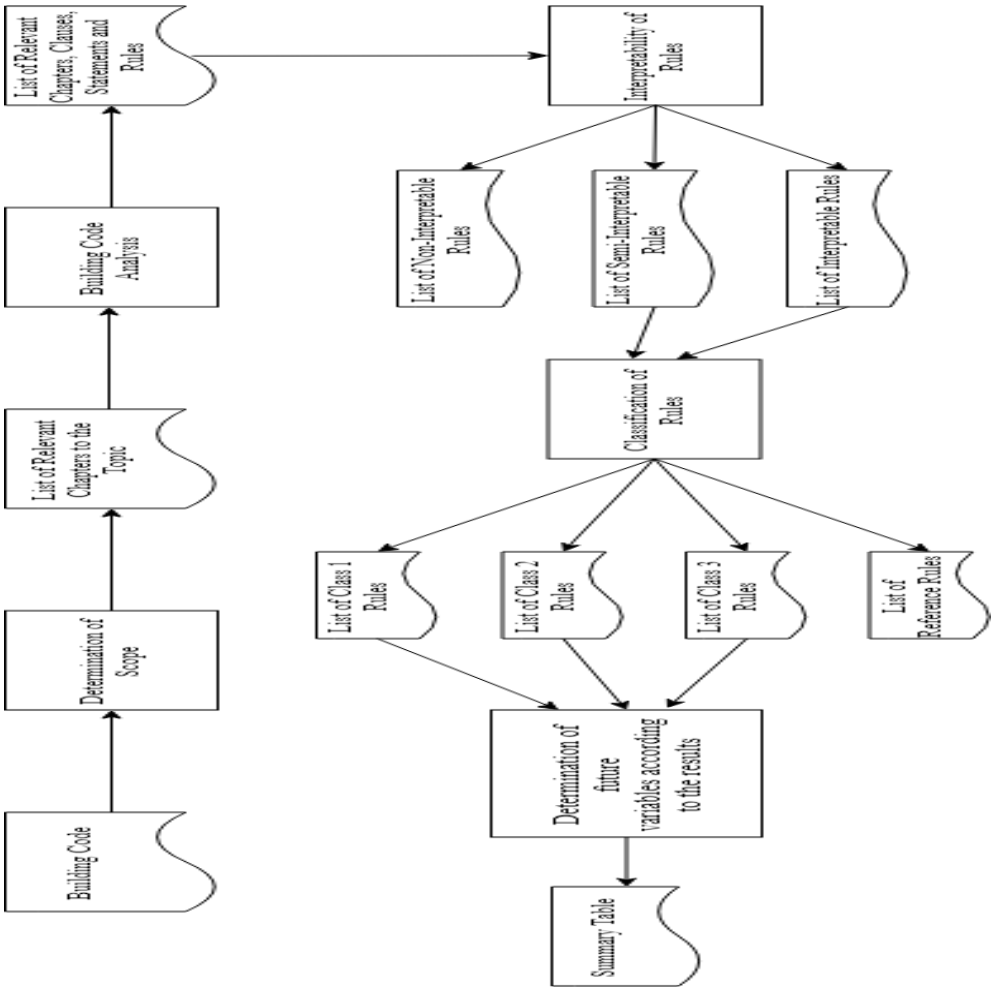

(Figure . Building Code Representation Framework)

RESULTS AND DISCUSSION

In this thesis, a formal representation of building codes is proposed and demonstrated with a methodology which is explained in detail in Section 3.5. This representation provides a basis to decompose a building code, a classification to group the building code rules, and the interpretability conditions of the building code rules to eliminate not-interpretable rules. Utilization of the proposed representation is intended to ease the automated code-checking by investigating the building code structure, determining rule properties, and representing the building code completely.

Automated code-checking has been a research field for academicians for a long time. However, most of the studies in this field focus on analysis of several rules rather than representing a building code completely. It can be said that these studies have limited application in practice. Also, the application of these studies require expert knowledge such as different programming languages and hence they are not widely adopted. Therefore, utilization of these studies are limited to specific people with specific knowledge. Moreover, the majority of the studies utilize black box methods which do not share open-access information about the implementation of codes in code- checking tools. The proposed building code representation in this thesis aims to improve the above limitations.

The main contribution of this thesis is the building code representation methodology as explained in Chapter 3 in detail. The proposed building code representation takes Solihin's (2016) rule classification study as a baseline and further modifies it in order to completely cover building codes.

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CONCLUSION

Automating building code compliance has revolutionized the construction industry by improving accuracy, efficiency, and cost-effectiveness. By integrating rule-based systems, AI, and BIM technologies, automated compliance tools minimize human errors, speed up approval processes, and enhance risk assessment. These advancements lead to better decision-making, ensuring that projects meet regulatory requirements while optimizing design and construction workflows.
However, challenges such as complex regulatory language, interoperability issues, and the need for regulatory acceptance remain significant barriers to full automation. Ensuring transparency, accountability, and continuous updates in AI-driven compliance tools is essential for widespread adoption. Future advancements in AI, NLP, and IoT integration will further refine compliance automation, making it more adaptable and reliable. Standardization of digital code formats and regulatory validation will also play a key role in promoting automated compliance solutions.
Overall, while automated building code compliance is still evolving, its potential to streamline regulatory processes and improve construction outcomes is undeniable. Continued research, technological advancements, and regulatory support will be crucial in realizing its full benefits and ensuring a more efficient and compliant construction industry.

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