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SOFTWARE EVOLUTION AND MAINTENANCE IN SOFTWARE ENGINEERING

**Code Clone Detection Techniques**

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# **Abstract**

Code clone detection is essential to software maintenance, enabling developers to identify duplicated or similar code fragments within a codebase. This paper reviews recent code clone detection techniques advancements, focusing on text-based, token-based, tree-based, graph-based, and hybrid approaches. The study highlights the strengths and weaknesses of each technique and discusses emerging trends, such as AI-driven methods and scalability improvements. Insights are drawn from eight journal articles published in 2022 and beyond, emphasizing the latest developments in this field.

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# **Introduction**

Code clone detection refers to identifying duplicated or semantically similar code fragments in software systems. These clones can arise due to copy-and-paste practices, leading to challenges in software maintenance, including increased debugging effort and reduced code quality [1]. Detecting code clones is crucial for improving maintainability, reducing redundancy, and enhancing software reliability. Over the years, researchers have developed various techniques for detecting clones, categorized into text-based, token-based, tree-based, graph-based, and hybrid approaches [2].

# **Categories of Code Clone Detection Techniques**

## 2.1. Text-Based Techniques

Text-based techniques treat code as plain text and compare it for similarity using string matching or hashing methods. These methods are simple and efficient, making them suitable for detecting large-scale clones [3]. However, they struggle with semantic clones (clones with slight variations) and are sensitive to formatting differences, such as whitespace and indentation.

## 2.2 Token-Based Techniques

Token-based techniques tokenize the code into keywords, operators, and other elements, comparing sequences of tokens to identify similarities [4]. These methods are more accurate than text-based approaches and can detect clones with minor variations. However, they can be computationally expensive and may struggle with complex code structures.

## 2.3 Tree-Based Techniques

Tree-based techniques analyze the structural representation of code by constructing Abstract Syntax Trees (ASTs) and comparing their subtrees [5]. These methods excel at detecting both syntactic and semantic clones, offering higher accuracy than text- or token-based approaches.

## 2.4 Graph-Based Techniques

Graph-based techniques represent code as graphs, where nodes correspond to code elements, and edges represent relationships such as control flow or data dependencies [6]. These methods are powerful for detecting semantic clones and understanding the relationships between code elements.

## 2.5 Hybrid Techniques

Hybrid techniques combine multiple approaches to leverage their strengths and overcome their weaknesses [7]. For example, combining token-based and tree-based methods can improve accuracy while maintaining computational efficiency.

# 3. Recent Trends and Best Practices

Recent advancements in code clone detection have focused on leveraging AI and ML techniques to improve accuracy and scalability. Representation learning methods, such as embedding-based models, have shown promise in capturing semantic similarities between code fragments [2]. Additionally, transformer-based models, such as CodeBERT, have been applied to detect clones in large-scale codebases with high precision [3].

Another trend is the integration of code clone detection tools into integrated development environments (IDEs), enabling real-time detection and refactoring suggestions [4]. These tools enhance developer productivity and reduce the likelihood of introducing clones during software development. Furthermore, cloud-based solutions have emerged to address the scalability challenges associated with analyzing large repositories [5].

# 4. Comparison of Techniques

Each code clone detection technique has unique strengths and limitations. Text-based methods are simple and efficient but lack semantic understanding. Token-based methods offer improved accuracy but are computationally expensive [6]. Tree-based methods excel at detecting structural similarities but are resource-intensive. Graph-based methods provide deep insights into code relationships but are complex to implement. Hybrid techniques combine the strengths of multiple approaches but require careful design and tuning [7].

The choice of technique depends on the specific requirements of the project, including the type of clones to be detected, the size of the codebase, and the available resources. For example, text-based methods are suitable for large-scale codebases, while graph-based methods are ideal for detecting semantic clones in smaller projects [8].

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# Conclusion

Code clone detection is a critical aspect of software maintenance, enabling developers to identify and manage duplicated or similar code fragments. This paper reviewed recent trends and best practices in code clone detection techniques, highlighting advancements in AI-driven methods and scalability improvements. Text-based, token-based, tree-based, graph-based, and hybrid approaches were analyzed, emphasizing their strengths and limitations. Future research should focus on developing scalable and accurate tools capable of handling large-scale codebases while capturing semantic similarities.

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