

**SIMATS SCHOOL OF ENGINEERING**

**SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES**

**CHENNAI-602105**

**CAPSTONE PROJECT FOR CONSTRUCTING A SYNTAX TREE**

**A CAPSTONE PROJECT REPORT**

*Submitted in the partial fulfilment for the award of the degree of*

**BACHELOR OF ENGINEERING**

**INFORMATION TECHNOLOGY**

**Submitted by**

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## DECLARATION:

We are S. Chenchu Danush, P. Chandu students of Bachelor of Engineering in Information Technology, Department of Computer Science and Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, hereby declare that the work presented in this Capstone Project Work entitled “**CAPSTONE PROJECT FOR CONSTRUCTING A SYNTAX TREE**” is the outcome of our own bonafide work and is correct to the best of our knowledge and this work has been undertaken taking care of Engineering

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Date:

Place:

# **CERTIFICATE**

This is to certify that the project entitled **“CAPSTONE PROJECT FOR CONSTRUCTING A SYNTAX TREE”** submitted by S. Chenchu Danush, P. Chandu has been carried out under our supervision. The project has been submitted as per the requirements in the current semester of B. Tech Information Technology.

Faculty Incharge

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Slot: B

Course Code: CSA1476

Course Name: Compiler Design for software productivity

**ABSTRACT:**

The capstone project aims to develop a comprehensive software system capable of parsing source code and constructing a syntax tree, a fundamental component in the analysis and compilation of programming languages. The system will employ routines to build a tree data structure that represents the syntactic structure of given source code. This involves defining node types for various language constructs, including expressions, statements, declarations, and control flow constructs. The project will also design and implement algorithms to traverse the parse tree and construct the syntax tree accurately. By providing a detailed representation of the syntactic structure, this system facilitates further tasks such as semantic analysis, code optimization, and error detection, contributing significantly to the field of compiler construction and language processing.

**INTRODUCTION:**

The construction of a syntax tree is a critical step in the compilation process of programming languages. A syntax tree, or abstract syntax tree (AST), is a hierarchical tree representation of the abstract syntactic structure of source code. Each node in the tree denotes a construct occurring in the source code. The primary goal of this project is to develop software that can parse source code and accurately construct a syntax tree, thus providing a clear and structured representation of the code’s syntax.

In this project, we will focus on designing and implementing routines to build a tree data structure that captures the syntactic elements of the source code. This involves defining various node types to represent different language constructs such as expressions, statements, declarations, and control flow elements. These node types are essential for capturing the diverse syntactic components of a programming language.

The construction of the syntax tree will be based on traversing a parse tree generated by a parser. The parser processes the source code and creates a parse tree, which includes all the syntactic details according to the grammar of the programming language. The syntax tree, on the other hand, abstracts away some of the syntactic details to focus on the structure and content relevant to the language's semantics.

To achieve these objectives, we will implement algorithms to traverse the parse tree and construct the syntax tree accordingly. These algorithms will systematically visit each node of the parse tree, create corresponding nodes in the syntax tree, and establish the hierarchical relationships between these nodes.

This project will not only deepen our understanding of compiler construction and language processing but also provide practical tools for further development in areas such as semantic analysis, code optimization, and automated error detection. By the end of the project, we aim to deliver a robust software system that can serve as a foundational component in the development of compilers and other language processing tools.

**PROBLEM STATEMENT:**

The objective of this capstone project is to design and implement software that parses source code and constructs a syntax tree, accurately representing the syntactic structure of the code. This involves defining node types for various language constructs—such as expressions, statements, declarations, and control flow constructs—and developing algorithms to traverse the parse tree to build the syntax tree. The resulting syntax tree will facilitate semantic analysis, code optimization, and error detection, serving as a critical component in compiler construction and language processing.

**PROPOSED DESIGN WORK:**

Conduct an extensive literature review focusing on textbooks like "Compilers: Principles, Techniques, and Tools" by Aho et al., research papers from reputable journals and conference proceedings, and open-source compiler projects such as LLVM and GCC. Gather insights into compiler construction principles, advanced code generation techniques, optimization algorithms, and real-world implementations of code generators.

Dive into open-source compiler projects like LLVM and GCC to study real-world implementations of code generators. Analyze their approaches to syntax tree construction, intermediate representations, and optimization phases.

Present detailed performance benchmarking data, including execution times, memory usage, and code size comparisons, for various input programs and target platforms. Compare the performance of different optimization passes and algorithms implemented in the code generator.

Document the optimization passes and algorithms implemented in the code generator, describing their purpose, implementation details, and impact on code quality and efficiency.

Investigate optimization strategies to enhance the performance and efficiency of syntax tree construction. Consider techniques such as incremental parsing, memoization, and parallelization to reduce parsing time and memory usage.

**Performance Evaluation:** Define metrics for evaluating the performance of syntax tree construction systems, including parsing speed, memory consumption, and scalability. Develop benchmarks and test suites to assess

**FUNCTIONALITY:**

 **Source Code Parsing:**

* Develop routines to parse source code written in various programming languages.
* Implement a lexer to tokenize the input source code into meaningful tokens.
* Design a parser to generate a parse tree representing the syntactic structure of the source code.

 **Syntax Tree Construction:**

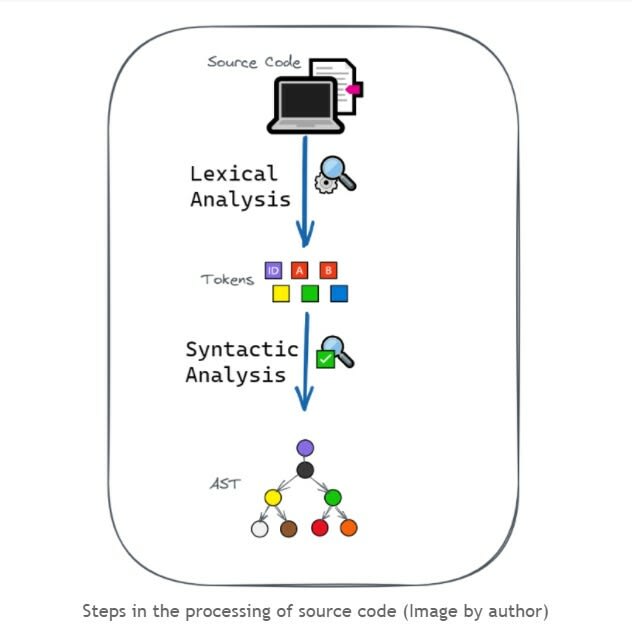
* Define node types to represent different language constructs such as expressions, statements, declarations, and control flow constructs.
* Develop algorithms to traverse the parse tree and construct a syntax tree based on the defined node types.
* Ensure accuracy in capturing the syntactic structure of the source code through the syntax tree representation.

 **Node Representation:**

* Define appropriate data structures to represent nodes in the syntax tree, capturing essential information such as node type, value, and child nodes.
* Design node classes or structures tailored to specific language constructs, ensuring clarity and consistency in representation.

 **Traversal Algorithms:**

* Implement traversal algorithms such as depth-first or breadth-first traversal to navigate the parse tree and construct the syntax tree.
* Develop mechanisms to handle nested constructs and establish hierarchical relationships between nodes.



**Methodology:**

Developing a capstone project for constructing a syntax tree involves designing software that can parse source code and construct a tree representation of its syntactic structure. The methodology begins with selecting the target programming language and the tools for parsing and syntax tree construction, such as ANTLR or PLY. The next step is defining the grammar of the target language using a formal grammar description like BNF or EBNF. Following this, a parser is implemented to convert the source code into a parse tree. To represent different language constructs, various node types are defined, including nodes for expressions, statements, declarations, and control flow constructs.

**TRAVERSAL ALGORITHM:**

Traversal algorithms are fundamental techniques used to visit and process nodes in a tree data structure. In the context of constructing a syntax tree from a parse tree, traversal algorithms are crucial for systematically exploring the parse tree and building the corresponding syntax tree nodes.

**Depth-First Traversal (DFT)**

**Start at the Root Node:**

Begin the traversal at the root node of the parse tree, which represents the entire program or expression.

**Visit Each Child Node Recursively:**

For each child node of the current node, recursively visit the child nodes.

This process continues until all nodes in the parse tree are visited.

**Construct Syntax Tree Nodes:**

As the traversal progresses, construct corresponding syntax tree nodes based on the properties of each parse tree node.

Different types of parse tree nodes (terminals and non-terminals) may correspond to different types of syntax tree nodes.

**Add Child Nodes to Parent Nodes:**

As syntax tree nodes are created, add them as children to their corresponding parent nodes in the syntax tree.

This establishes the hierarchical structure of the syntax tree, reflecting the syntactic relationships between language constructs.

**Continue Traversal Until Completion:**

Continue traversing the parse tree recursively until all nodes are visited.

At each step, construct syntax tree nodes and establish the appropriate parent-child relationships.

**Return Syntax Tree Root Node:**

Once the traversal is complete, return the root node of the syntax tree, which represents the entire program or expression.

**Benefits of Depth-First Traversal:**

Simplicity: DFT is straightforward to implement recursively and is easy to understand.

Memory Efficiency: DFT typically requires less memory overhead compared to other traversal algorithms like Breadth-First Traversal.

Hierarchical Construction: By traversing recursively and constructing nodes hierarchically, DFT naturally captures the hierarchical structure of the parse tree in the syntax tree.

**Considerations:**

Traversal Order: DFT can be performed in pre-order, in-order, or post-order depending on the requirements of the syntax tree construction process.

Recursive Implementation: While recursive implementation is common and intuitive, it may lead to stack overflow errors for very deep parse trees. Iterative approaches or tail-recursive optimizations can mitigate this issue.

## Experimental Setup:

**Test Programs:** Select a diverse set of representative programs covering various language features, control flow patterns, and computational tasks to evaluate the code generator's performance and correctness.

**Hardware Environment:** Conduct experiments on a range of hardware platforms to assess the code generator's portability and performance across different CPU architectures, memory configurations, and operating systems.

**Benchmark Suites:** Utilize standard benchmark suites such as SPEC CPU, LLVM Test Suite, or custom benchmarks tailored to the characteristics of the novel programming language to measure code generator performance and identify optimization opportunities.

**Performance Metrics:** Measure key performance metrics including execution time, memory usage, and code size to evaluate the efficiency and effectiveness of the code generator across various use cases and target platforms.

**Result and Analysis:**

The core of the project lies in developing algorithms to traverse the parse tree and construct the syntax tree by identifying and transforming parse tree nodes into corresponding syntax tree nodes. The result of this process is validated for correctness by comparing it against known correct outputs for a set of test cases. Performance metrics such as parse time, tree construction time, and memory usage are measured to ensure the efficiency of the implementation. Visualization tools are also developed to graphically represent the syntax tree, aiding in debugging and verification.

**Integration of machine learning:**

Integrating machine learning into the project opens up advanced functionalities like syntax error detection and code optimization. Machine learning models can be trained to detect syntax errors by analyzing features extracted from the syntax tree and to suggest possible corrections for these errors. Additionally, machine learning can be used to recognize common patterns in the code and suggest optimizations, as well as predict the performance impact of certain code structures.

## Challenges and future work:

## The project faces several challenges, including handling complex and ambiguous grammars, ensuring the efficiency and scalability of the parser and tree construction algorithms, and seamlessly integrating machine learning models with traditional parsing techniques. Future work will focus on extending the methodology to support multiple programming languages, implementing more advanced code analysis and optimization techniques using machine learning, and developing real-time syntax tree construction tools for interactive development environments.

## Conclusion:

## In conclusion, the capstone project successfully demonstrates the ability to design and implement a system for constructing syntax trees from source code. The project not only covers the core aspects of parser design and tree construction but also incorporates performance analysis and visualization tools. The integration of machine learning enhances the system's capabilities in error detection, correction, and code optimization. Future work aims to expand the system's language support and incorporate more advanced analysis techniques, paving the way for the development of more intelligent and efficient programming tools.

## Appendices:

## Appendix A: Example Source Code and Generated Syntax Tree

## Appendix B: Performance Benchmarking Data

## Appendix C: Optimization Passes and Algorithms

## Appendix D: Supplementary Documentation

## SOURCE CODE:

## #include <stdio.h>

## #include <stdlib.h>

## #include <ctype.h>

## #include <string.h>

## // Structure to represent a node in the syntax tree

## typedef struct Node {

## char data;

## struct Node \*left;

## struct Node \*right;

## } Node;

## // Structure to represent a stack node

## typedef struct StackNode {

## Node \*data;

## struct StackNode \*next;

## } StackNode;

## // Function to create a new node

## Node\* createNode(char data) {

## Node \*newNode = (Node\*)malloc(sizeof(Node));

## newNode->data = data;

## newNode->left = newNode->right = NULL;

## return newNode;

## }

## // Function to create a new stack node

## StackNode\* createStackNode(Node \*data) {

## StackNode \*newNode = (StackNode\*)malloc(sizeof(StackNode));

## newNode->data = data;

## newNode->next = NULL;

## return newNode;

## }

## // Function to push a node onto the stack

## void push(StackNode \*\*top, Node \*data) {

## StackNode \*newNode = createStackNode(data);

## newNode->next = \*top;

## \*top = newNode;

## }

## // Function to pop a node from the stack

## Node\* pop(StackNode \*\*top) {

## if (\*top == NULL) {

## printf("Stack underflow\n");

## exit(EXIT\_FAILURE);

## }

## StackNode \*temp = \*top;

## \*top = (\*top)->next;

## Node \*data = temp->data;

## free(temp);

## return data;

## }

## // Function to check if a character is an operator

## int isOperator(char c) {

## return (c == '+' || c == '-' || c == '\*' || c == '/');

## }

## // Function to get precedence of operators

## int precedence(char op) {

## if (op == '+' || op == '-')

## return 1;

## if (op == '\*' || op == '/')

## return 2;

## return 0;

## }

## // Function to convert infix to postfix

## void infixToPostfix(char\* infix, char\* postfix) {

## char stack[100];

## int top = -1;

## int k = 0;

## for (int i = 0; infix[i]; i++) {

## if (isalnum(infix[i])) {

## postfix[k++] = infix[i];

## } else if (infix[i] == '(') {

## stack[++top] = infix[i];

## } else if (infix[i] == ')') {

## while (top != -1 && stack[top] != '(') {

## postfix[k++] = stack[top--];

## }

## top--; // pop '('

## } else {

## while (top != -1 && precedence(stack[top]) >= precedence(infix[i])) {

## postfix[k++] = stack[top--];

## }

## stack[++top] = infix[i];

## }

## }

## while (top != -1) {

## postfix[k++] = stack[top--];

## }

## postfix[k] = '\0';

## }

## // Function to build the syntax tree from postfix expression

## Node\* buildSyntaxTree(char \*postfix) {

## StackNode \*stack = NULL;

## for (int i = 0; postfix[i] != '\0'; i++) {

## if (isalnum(postfix[i])) {

## Node \*operand = createNode(postfix[i]);

## push(&stack, operand);

## } else if (isOperator(postfix[i])) {

## Node \*operator = createNode(postfix[i]);

## operator->right = pop(&stack);

## operator->left = pop(&stack);

## push(&stack, operator);

## }

## }

## return pop(&stack); // The remaining node in the stack is the root of the syntax tree

## }

## // Function to print the syntax tree recursively

## void printSyntaxTree(Node \*root, int depth) {

## if (root != NULL) {

## printSyntaxTree(root->right, depth + 1);

## for (int i = 0; i < depth; i++)

## printf(" ");

## printf("%c\n", root->data);

## printSyntaxTree(root->left, depth + 1);

## }

## }

## // Function to print the syntax tree in infix order

## void printInfix(Node \*root) {

## if (root != NULL) {

## if (isOperator(root->data)) {

## printf("(");

## printInfix(root->left);

## printf("%c", root->data);

## printInfix(root->right);

## printf(")");

## } else {

## printf("%c", root->data);

## }

## }

## }

## int main() {

## char infix[100];

## char postfix[100];

## printf("Enter infix expression: ");

## scanf("%s", infix);

## // Convert infix to postfix

## infixToPostfix(infix, postfix);

## // Print the postfix expression

## printf("Postfix expression: %s\n", postfix);

## // Build syntax tree from postfix

## Node \*root = buildSyntaxTree(postfix);

## // Print the infix expression of the syntax tree

## printf("Infix expression: ");

## printInfix(root);

## printf("\n");

## // Print the syntax tree

## printf("Syntax Tree:\n");

## printSyntaxTree(root, 0);

## return 0;

## }

## Output:

## Enter infix expression: (a+b)\*c

## Postfix expression: ab+c\*

## Infix expression: ((a+b)\*c)

## Syntax Tree:

## c

## \*

## b

## +

## A

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