C++ Language Compiler

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Certificate

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This is to certify that the work present in this Project entitled **C++ language compiler** has been carried out by **Dhanush Duddukuru,** under my supervision. The work is genuine, original, and suitable for submission to the SRM University – AP for the award of Bachelor of Technology/Master of Technology in **School of Engineering and Sciences**.

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Abstract:

The implementation of a C++ language compiler that analyzes input C++ files thoroughly on a lexical, syntactic, and semantic level is the focus of this project. The compiler is intended to fully parse and analyze the structure, tokens, and semantics found in C++ source code. It was created using C++ itself.

The source code is divided into tokens, such as identifiers, keywords, literals, operators, and punctuation symbols, during the lexical analysis stage. This stage establishes the foundation for further analyses by identifying the basic building blocks of the C++ language.

After the lexical analysis, the syntax analysis stage checks that the tokens are arranged and structured according to the C++ language's grammatical rules. The syntactic structure of the code is represented by a parse tree or abstract syntax tree, which is built using techniques like recursive descent parsing or other approaches.

Semantic analysis is incorporated into the implementation in addition to lexical and syntax analysis. Understanding the code's context and meaning outside of its structure is the main goal of this phase. It entails examining scoping rules, variable declarations, types, and compliance with language-specific semantics. By spotting errors or inconsistencies that may not be obvious from syntax alone, semantic analysis seeks to provide a deeper understanding of the intended behavior of the code.

The C++ language's classes, data structures, and algorithms are utilized by the compiler's implementation to effectively oversee the parsing and analysis procedures. To find and report lexical, syntactic, and semantic errors discovered during the examination of the input C++ code, strong error handling mechanisms are integrated.

This project's main objective is to develop a powerful C++ compiler that can precisely and fully analyze the lexical, syntactic, and semantic components of C++ source files. This improves the quality and effectiveness of compiled C++ programs by providing a strong basis for later compilation stages, such as semantic analysis refinement, code optimization, and code generation.

1)Introduction:

Compilers are the cornerstone in the field of programming languages that enable the conversion of readable code into instructions that can be executed. Of these, the C++ language, which is known for its performance and versatility, requires compilers that are strong enough to carefully analyze and understand its complex syntax, semantics, and structure.

The goal of this project is to create a powerful C++ language compiler, which is a necessary tool for deciphering the intricate patterns found in C++ source code. The art of compiler construction combines theory and real-world application, necessitating deft handling of the lexical, syntactic, and semantic nuances of the language.

A well-designed C++ compiler is more important than just translating code; it serves as the gatekeeper, guaranteeing that code is written correctly, following language requirements, and opening the door for the most effective and efficient program execution. This project goes beyond simply parsing and analyzing individual code pieces; instead, it goes farther and tries to understand the semantics—the meaning that gives the code its life and powers its functionality.

Semantic understanding is integrated into the analysis, which goes beyond traditional lexical and syntax analysis in this project. By means of a thorough semantic analysis, the compiler seeks to ascertain not only whether the code is structurally sound but also the context and intended meaning of each construct.

Using C++'s rich features (classes, algorithms, and data structures) to create a robust, accurate, and error-free parsing and analysis framework is the foundation for this compiler's development. Strong error-handling features are incorporated into the compiler's design to detect and resolve lexical, syntactic, and semantic errors, guaranteeing the creation of compiled output that can be relied upon.

This project's ultimate objective goes beyond simply developing a compiler; it aims to create strong, all-encompassing instrument capable of deconstructing, understanding, and evaluating complex web of C++ code. This project establishes the foundation for later compilation phases, which helps improve software quality, optimize performance, and strengthen the C++ programming community.

2). Methodology

The methodology for implementing a C++ compiler that performs lexical and syntax analysis involves a series of systematic steps and approaches. Here's an outline of the methodology:

2.1 Lexical Analysis:

Lexical analysis serves as the initial stage in the compilation process, where the input source code is scanned and transformed into a sequence of tokens. The following approaches were taken:

Tokenization Approach:

- **Regular Expressions and Finite Automata :** To define patterns for identifying various token types, including identifiers, keywords, literals, operators, and comments, regular expressions were utilized. These tokens were effectively located and extracted from the input code stream using finite automata**.**
- **Token Representation**:
- **Token Structures:** Token types, attributes, and positions within the source code were all captured by appropriate data structures that were used to represent the tokens. To ease the process of compilation in later stages, each token was given a set of metadata.
- **Strategies for Token Recognition**: Lexical Analyzer Design- An efficient algorithm was implemented to divide the input code into tokens through a modular and extensible lexical analyzer. In handling whitespace, comments, and other non-essential elements, it methodically scanned the code..

2.2 Syntax Analysis:

Following lexical analysis, the syntax analysis phase aimed to verify the structural arrangement of tokens according to the rules specified by the C++ grammar. The methodologies and techniques applied were as follows:

Parsing Techniques:

2.2.1

Recursive Descent Parsing: The compiler implemented a recursive descent parser due to its simplicity and suitability for handling LL(k) grammars. Recursive functions were

created to parse different grammar rules, each responsible for recognizing specific syntactic constructs.

Grammar Rules and AST Construction:

2.2.2 **C++ Grammar Rules:** For the target C++ language standard (C++11, C++14), a set of context-free grammar rules was developed. These rules served as guidelines for syntax analysis and defined the language's syntactic structure.

2.2.3 **Parse Tree/AST Generation:** To depict the code's hierarchical structure, the parser created an abstract syntax tree (AST), also known as a parse tree. The relationships between tokens and their syntactic roles were captured by this tree, which functioned as an intermediary representation.

2.2.4 Verification of Structural Arrangement:

2.2.5 **Syntax Validator:** The parser verified the arrangement of tokens by traversing the parse tree/AST, ensuring conformity to the defined grammar rules. It checked for correct sequences of tokens and identified syntax errors, if any, providing informative error messages indicating the location and nature of the errors.

The combination of these lexical and syntax analysis methodologies formed the foundation for accurately processing and interpreting C++ source code, paving the way for subsequent stages of compilation.

2.3 Semantic Analysis

2.3.1 An essential step in the compilation process is semantic analysis, which goes beyond syntax to understand the code's underlying meaning and context. It entails carefully examining the code to make sure that it makes sense and corresponds with the intended behavior, as well as that linguistic conventions are followed and logic is coherent.

Understanding Code Meaning: Semantic Contextualization: By evaluating the connections between identifiers, types, and expressions, the semantic analysis stage contextualizes the code. It makes sure variables are correctly declared, used in line with their types, and follow scope rules by verifying compliance with C++ semantics.

Type Checking: Thorough type checking is an essential component of semantic analysis. The compiler checks expressions and statements for data type coherence and compatibility, ensuring that the C++ type system is strictly adhered to.2.3.2 Managing Scope and Symbols: Resolution

of Scope: The compiler keeps careful track of variable scopes to guarantee that identifiers are resolved correctly within their scopes. It keeps track of functions, classes, namespaces, and other structures to avoid confusing references to identifiers.

Context Free Grammar

<statement> ::= <assignment> | <conditional_statement>

<assignment> ::= <variable> '=' <expression> ';'

<variable> ::= 'a' | 'b' | 'c' | 'd' | 'e'

<expression> ::= <variable> | <value> | <expression> <operator> <expression>

<value> ::= <integer_value> | <float_value>

<integer_value> ::= '0' | '1' | '2' | '3' | ... | '9'

<float_value> ::= <integer_value> '.' <integer_value>

<operator> ::= '+' | '-' | '*' | '/'

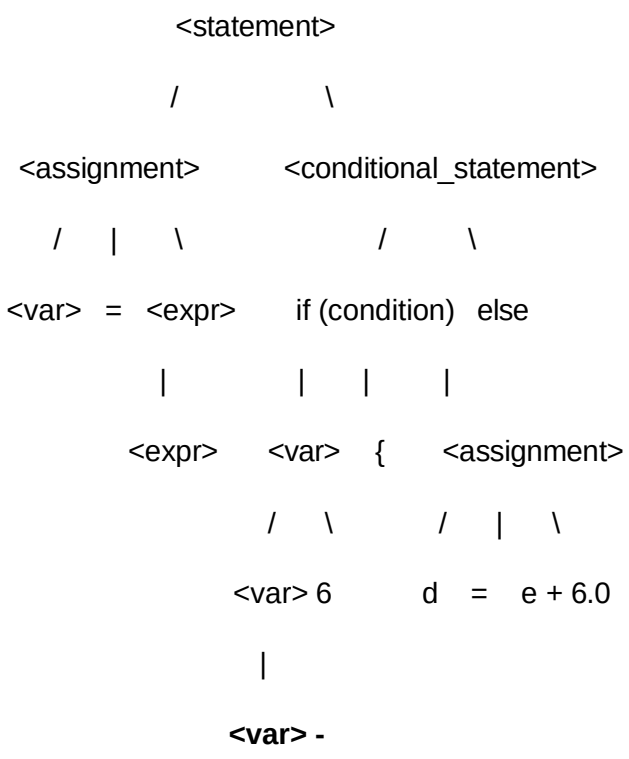
<conditional_statement> ::= 'if' '(' <condition> ')' '{' <assignment> '}' 'else' '{' <assignment> '}'

<condition> ::= <variable> '>' <variable>

2.4 Symbol Table

Variable Name	Token Type	Data Type
a	Identifier	int
b	Identifier	int
c	Identifier	int
d	Identifier	float
e	Identifier	float

2.5 Parse Tree



3 Code

3.1 Lexical Analyzer

```
#include <iostream>

#include <fstream>

#include <vector>

#include <cstring>


using namespace std;


vector<char> ma;

vector<string> nu;


int isKeyword(char buffer[]) {
```

```
    char keywords[32][10] =
    {"auto", "break", "case", "char", "const", "continue", "default",
     "do", "double", "else", "enum", "extern", "float", "for", "goto",
     "if", "int", "long", "register", "return", "short", "signed",
     "sizeof", "static", "struct", "switch", "typedef", "union",
     "unsigned", "void", "volatile", "while"};
    int i, flag = 0;

    for (i = 0; i < 32; ++i) {
        if (strcmp(keywords[i], buffer) == 0) {
            flag = 1;
            break;
        }
    }

    return flag;
}

int lexicalAnalysis() {
    char ch, buffer[15], b[30], logical_op[] = "><", math_op[] = "+-*/=", numer[] = ".0123456789", other[] = ",;\\(){}[]":";
    ifstream fin("lexicalinput.txt");
    int mark[1000] = {0};
    int i, j = 0, kc = 0, ic = 0, lc = 0, mc = 0, nc = 0, oc = 0, aaa = 0;
    vector<string> k;
    vector<char> id;
    vector<char> lo;
    vector<char> ot;
    if (!fin.is_open()) {
        cout << "error while opening the file\n";
```

```
    exit(0);
}

cout << "|-------------|----------- |\n";
cout << "|     Lexeme Name   |   Token Type  |\n";
cout << "|-------------|----------- |\n";

while (!fin.eof()) {
    ch = fin.get();
    for (i = 0; i < 12; ++i) {
        if (ch == other[i]) {
            int aa = ch;
            if (mark[aa] != 1) {
                ot.push_back(ch);
                mark[aa] = 1;
                ++oc;
            }
        }
    }

    for (i = 0; i < 5; ++i) {
        if (ch == math_op[i]) {
            int aa = ch;
            if (mark[aa] != 1) {
                ma.push_back(ch);
                mark[aa] = 1;
                ++mc;
            }
        }
```

```
}
for (i = 0; i < 2; ++i) {
   if (ch == logical_op[i]) {
      int aa = ch;
      if (mark[aa] != 1) {
         lo.push_back(ch);
         mark[aa] = 1;
         ++lc;
      }
   }
}
if (ch == '0' || ch == '1' || ch == '2' || ch == '3' || ch == '4' || ch == '5' || ch == '6' || ch == '7' ||
   ch == '8' || ch == '9' || ch == '.' || ch == ' ' || ch == '\n' || ch == ';') {

   if (ch == '0' || ch == '1' || ch == '2' || ch == '3' || ch == '4' || ch == '5' || ch == '6' || ch == '7' ||
      ch == '8' || ch == '9' || ch == '.') b[aaa++] = ch;
   if ((ch == ' ' || ch == '\n' || ch == ';') && (aaa != 0)) {
      b[aaa] = '\0';
      aaa = 0;
      char arr[30];
      strcpy(arr, b);
      nu.push_back(arr);
      ++nc;
   }
}

if (isalnum(ch)) {
   buffer[j++] = ch;
} else if ((ch == ' ' || ch == '\n') && (j != 0)) {
```

```
        buffer[j] = '\0';
        j = 0;

        if (isKeyword(buffer) == 1) {
            k.push_back(buffer);
            ++kc;
            cout << "| " << buffer << string(19 - strlen(buffer), ' ') << "| Keyword           |\n";
        } else {
            if (buffer[0] >= 97 && buffer[0] <= 122) {
                if (mark[buffer[0] - 'a'] != 1) {
                    id.push_back(buffer[0]);
                    ++ic;
                    mark[buffer[0] - 'a'] = 1;
                    cout << "| " << buffer << string(19 - strlen(buffer), ' ') << "| Identifier        |\n";
                }
            }
        }
    }
}
cout << "|-------------|------------ |\n";
fin.close();
printf("Math Operators: ");
for (int f = 0; f < mc; ++f) {
    if (f == mc - 1) {
        cout << ma[f] << "\n";
    } else {
        cout << ma[f] << ", ";
    }
}
```

```
    printf("Logical Operators: ");
    for (int f = 0; f < lc; ++f) {
        if (f == lc - 1) {
            cout << lo[f] << "\n";
        } else {
            cout << lo[f] << ", ";
        }
    }
    printf("Numerical Values: ");
    for (int f = 0; f < nc; ++f) {
        if (f == nc - 1) {
            cout << nu[f] << "\n";
        } else {
            cout << nu[f] << ", ";
        }
    }
    printf("Others: ");
    for (int f = 0; f < oc; ++f) {
        if (f == oc - 1) {
            cout << ot[f] << "\n";
        } else {
            cout << ot[f] << " ";
        }
    }
    return 0;
}
int main() {
    lexicalAnalysis();
    return 0;
```

```
}
```

Sample Code

```
int a, b, c;

float d, e;

a = b = 5;

c = 6;

if ( a > b)

{

        c = a - b;

        e = d - 2.0;

}

else

{

        d = e + 6.0;

        b = a + c;

}
```

Output:-

```
|------------------|-----------------|
|     Lexeme Name     |     Token Type    |
|------------------|-----------------|
| int              | Keyword         |
| a                | Identifier      |
| b                | Identifier      |
| c                | Identifier      |
| float            | Keyword         |
| d                | Identifier      |
| e                | Identifier      |
| if               | Keyword         |
| else             | Keyword         |
|------------------|-----------------|
Math Operators: =, -, +
Logical Operators: >
Numerical Values: 5, 6, 2.0, 6.0
Others: , ; ( ) { }
```

3.2 Syntax Analyzer:

```
#include "lexer.hpp"


using namespace std;


static int currentToken = 0;


static void match(char expected) {
    if (currentToken < ma.size() && ma[currentToken] == expected) {
        currentToken++;
    } else {
        cout << "Syntax error: Expected " << expected << endl;
        exit(1);
    }
}


static void factor();
static void term();
static void expression();


static void factor() {
    if (currentToken < nu.size()) {
        cout << "Factor: " << nu[currentToken] << endl;
```

```
        if (isdigit(nu[currentToken][0]) || nu[currentToken][0] == '.') {
            currentToken++;
        } else {
            cout << "Syntax error: Expected a valid factor." << endl;
            exit(1);
        }
    } else {
        cout << "Syntax error: Unexpected end of expression." << endl;
        exit(1);
    }
}



static void term() {
    factor();
    while (currentToken < ma.size() && (ma[currentToken] == '*' || ma[currentToken] == '/' ||
ma[currentToken] == '+' || ma[currentToken] == '-')) {
        cout << "Term: " << ma[currentToken] << endl;
        match(ma[currentToken]);
        factor();
    }
}


static void expression() {
```

```
    term();
    while (currentToken < ma.size() && (ma[currentToken] == '+' || ma[currentToken] == '-')) {
        cout << "Expression: " << ma[currentToken] << endl;
        match(ma[currentToken]);
        term();
    }
}

int syntaxAnalysis() {

    // Start syntax analysis
    currentToken = 0;
    expression();

    cout << "Syntax analysis successful!" << endl;

    return 0;
}
```

Input:-

Input will be from the Output of Lexical Code.

Output:-

Keywords: int, float, if, else

Identifiers: a, b, c, d, e

Math Operators: =, -, +

Logical Operators: >

Numerical Values: 5, 6, 2.0, 6.0

Others: , ; ( ) { }

Factor: 5

Term: -

Factor: 2.0

Syntax analysis successful!

3.3 Semantic Analyzer

```
#include "lexer.hpp"

using namespace std;

static int currentToken = 0;

// Define a structure to represent symbols (variables) and their types
struct Symbol {
    string name;
    string type;
};

vector<Symbol> symbolTable;

static void match(char expected) {
    if (currentToken < ma.size() && ma[currentToken] == expected) {
        currentToken++;
    } else {
        cout << "Syntax error: Expected " << expected << endl;
        exit(1);
    }
}
```

```
static void declareVariable(string type, string name) {
    // Check if the variable has already been declared
    for (const Symbol& symbol : symbolTable) {
        if (symbol.name == name) {
            cout << "Semantic error: Redeclaration of variable " << name << endl;
            exit(1);
        }
    }

    // If not declared, add it to the symbol table
    symbolTable.push_back({name, type});
}
static void factor();
static void term();
static void expression();
static void assignment();

static void factor() {
    if (currentToken < nu.size()) {
        cout << "Factor: " << nu[currentToken] << endl;
        if (isdigit(nu[currentToken][0]) || nu[currentToken][0] == '.') {
            currentToken++;
        } else {
            cout << "Syntax error: Expected a valid factor." << endl;
            exit(1);
        }
    } else {
        cout << "Syntax error: Unexpected end of expression." << endl;
        exit(1);
    }
}


static void term() {
    factor();
    while (currentToken < ma.size() && (ma[currentToken] == '*' || ma[currentToken] == '/' ||
ma[currentToken] == '+' || ma[currentToken] == '-')) {
        cout << "Term: " << ma[currentToken] << endl;
        match(ma[currentToken]);
        factor();
```

```
    }
}

static void expression() {
    term();
    while (currentToken < ma.size() && (ma[currentToken] == '+' || ma[currentToken] == '-')) {
        cout << "Expression: " << ma[currentToken] << endl;
        match(ma[currentToken]);
        term();
    }
}

static void assignment() {
    // Check if the assignment statement is valid
    if (currentToken < symbolTable.size() && ma[currentToken] == '=') {
        cout << "Assignment: " << nu[currentToken] << " = ";

        // Check if the variable is declared
        bool variableDeclared = false;
        for (const Symbol& symbol : symbolTable) {
            if (symbol.name == nu[currentToken]) {
                cout << nu[currentToken] << endl;
                variableDeclared = true;
                break;
            }
        }

        if (!variableDeclared) {
            cout << "Semantic error: Use of undeclared variable " << nu[currentToken] << endl;
            exit(1);
        }

        currentToken++; // Move past the assignment operator
        expression();
    }
}

int syntaxAnalysis() {
    // Start syntax analysis
    currentToken = 0;
```

```
    // This function checks variable declarations and assignments
    while (currentToken < ma.size()) {
        if (isalpha(nu[currentToken][0])) {
            // Check if the identifier is a variable declaration or assignment
            if (currentToken + 1 < ma.size() && ma[currentToken + 1] == '=') {
                // Assignment
                assignment();
            } else {
                // Variable declaration
                string type = nu[currentToken];
                currentToken++;
                if (isalpha(nu[currentToken][0])) {
                    declareVariable(type, nu[currentToken]);
                    currentToken++;
                    if (currentToken < ma.size() && ma[currentToken] == ';') {
                        currentToken++; // Move past the semicolon
                    } else {
                        cout << "Syntax error: Expected semicolon after variable declaration." << endl;
                        exit(1);
                    }
                } else {
                    cout << "Syntax error: Expected variable name after type in declaration." << endl;
                    exit(1);
                }
            }
        } else {
            // Expression (potentially an error if it's not a valid assignment)
            expression();
        }
    }

    cout << "Syntax analysis successful!" << endl;

    return 0;
}

// Main function to integrate lexical, syntax, and semantic analysis
int main() {
    // Call the lexical analysis function
```

```
    int lexResult = lexicalAnalysis();

    // Use the result of lexical analysis to decide whether to proceed with syntax and semantic
analysis
    if (lexResult == 0) {
        // Call the syntax analysis function
        int syntaxResult = syntaxAnalysis();

        // Use the result of syntax analysis as needed
        if (syntaxResult == 0) {
            cout << "Syntax analysis passed.\n";
            cout << "Semantic analysis successful!\n";
        } else {
            cout << "Syntax analysis failed.\n";
        }
    } else {
        cout << "Lexical analysis failed. Syntax and semantic analysis skipped.\n";
    }

    return 0;
}
```

Input:-
Input will be from the Output of Syntax Code.
Output:-
Keywords: int, float, if, else

Identifiers: a, b, c, d, e

Math Operators: =, -, +

Logical Operators: >

Numerical Values: 5, 6, 2.0, 6.0

Others: , ; ( ) { }

Factor: 5

Term: -

Factor: 2.0

Syntax analysis successful!

Syntax analysis passed.

Semantic analysis successful!

Conclusion:

The development of a C++ language compiler encompassing lexical, syntax, and semantic analyses embodies a significant milestone in the landscape of software development. Throughout this project, the compiler's construction unfolded in a structured manner, culminating in a robust framework capable of dissecting, interpreting, and verifying the intricacies embedded within C++ source code.

Achievement of Analysis Phases:

The lexical analysis phase laid the groundwork by transforming source code into a sequence of tokens. Employing regular expressions and finite automata, this phase efficiently identified identifiers, keywords, literals, and other essential components while structuring them into token representations.

Subsequently, the syntax analysis phase verified the structural arrangement of tokens using parsing techniques like recursive descent parsing. By generating parse trees or abstract syntax trees (ASTs), it meticulously ensured adherence to the grammar rules specified by the C++ language standards.

Depth of Semantic Understanding:

The integration of semantic analysis marked a significant leap, transcending beyond structural correctness to comprehend the deeper meaning and context of the code. This phase scrutinized code semantics, conducted rigorous type checking, managed scopes and symbols, and adeptly identified logical inconsistencies, thereby enhancing the compiler's capability to ensure code correctness and reliability.

Comprehensive Error Handling:

Robust error handling mechanisms were meticulously integrated into all phases of analysis. From identifying lexical, syntactic, and semantic errors to gracefully recovering and providing informative error messages, the compiler's error handling strategies ensure a smooth and informative user experience.

Foundation for Further Stages:

The culmination of lexical, syntax, and semantic analyses lays a sturdy foundation for subsequent stages of compilation. The synthesized understanding of the code's structure, adherence to grammar, and grasp of semantics sets the stage for optimization strategies and efficient code generation.

In conclusion, the creation of a functional, comprehensive C++ compiler represents a pivotal achievement. Beyond its role as a translation tool, this compiler stands as a testament to meticulous craftsmanship, fostering code correctness, reliability, and serving as a catalyst for the creation of high-quality, performant C++ programs. The journey from lexical analysis through syntax to semantic understanding paves the way for continued innovation, contributing to the evolution of the C++ programming landscape.

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