Bahir Dar University Bahir Dar Institute of Technology Faculty of Computing DEPARTMENT OF INFORMATION TECHNOLOGY

Principles of Compiler Design on Syntax Analysis

Individual Assignment

Assignment 01

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Question 1 Explain the concept of predictive parsing.

Definition

Predictive parsing is an efficient form of **Top-Down parsing** used in syntax analysis. Its primary defining characteristic is that it does not require **backtracking**. Instead of guessing which grammar rule to apply and potentially failing a predictive parser determines the correct production rule to apply solely by looking at the current **lookahead symbol** (the next token in the input stream).

How It Works

The parser attempts to construct a Parse Tree from the root (Start Symbol) down to the leaves. It operates on a specific class of grammars known as **LL(k)** grammars (usually LL(1)).

- **Lookahead:** The parser peeks at the next incoming token.
- **Decision:** Based on the current Non Terminal it is trying to expand and that lookahead token it consults a set of rules (often stored in a parsing table) to uniquely identify which production to use.

Key Characteristics

- **Deterministic:** Because the parser knows exactly which path to take at every step the time complexity is linear typically O(n)$O(n)$ where n is the length of the input string. This makes it much faster than general parsing methods.
- **LL(1) Parsing:** Most predictive parsers are classified as LL(1):
  - **L**: Scans input from **L**eft to right.
  - **L**: Produces a **L**eftmost derivation.
  - **(1)**: Uses **1** symbol of lookahead to make parsing decisions.

Implementation Approaches

There are two main ways to implement a predictive parser:

1. **Recursive Descent Parser:**
   - This is a code based approach where every Non Terminal in the grammar corresponds to a function (e.g., void Statement() void Expression()).
   - The functions call each other recursively to match the input against the grammar.
2. **Non-Recursive (Table-Driven) Parser:**
   - This approach uses an explicit **Stack** data structure and a **Parsing Table**.
   - The parsing table is a 2D array constructed using **FIRST and FOLLOW sets**. The parser looks up Table[Top_of_Stack Input_Symbol] to decide whether to push new symbols to the stack or pop matching symbols.

Prerequisites for the Grammar

For predictive parsing to function correctly the underlying grammar must be unambiguous and satisfy two specific conditions:

- **No Left Recursion:** The grammar cannot have rules like $A \to A\alpha$. If present, this causes an infinite loop in the parser. Left recursion must be eliminated during the grammar analysis phase.
- **Left Factored:** The grammar cannot have rules that start with the same symbol (e.g., $A \to \alpha\beta1 \mid \alpha\beta2$). This causes ambiguity for the lookahead. The grammar must be "left factored" so the parser can make a distinct choice.

Question 2: Write a function to count identifiers in a source code string.

Here's a C++ function to count identifiers in a source code string according to typical C/C++ identifier rules:

```
#include <iostream>
#include <string>
#include <cctype>
#include <unordered_set>

/**
 * Counts identifiers in C++ source code.
 * An identifier must:
 * 1. Start with a letter or underscore
 * 2. Contain only letters, digits, or underscores
 * 3. Not be a C++ keyword
 *
 * @param source The source code string
 * @return Number of identifiers found
 */
int countIdentifiers(const std::string& source) {
    // Set of C++ keywords (partial list, can be expanded)
    static const std::unordered_set<std::string> keywords = {
        "alignas", "alignof", "and", "and_eq", "asm", "auto", "bitand", "bitor",
        "bool", "break", "case", "catch", "char", "char8_t", "char16_t", "char32_t",
        "class", "compl", "concept", "const", "const_cast", "consteval", "constexpr",
        "constinit", "continue", "co_await", "co_return", "co_yield", "decltype",
        "default", "delete", "do", "double", "dynamic_cast", "else", "enum",
        "explicit", "export", "extern", "false", "float", "for", "friend", "goto",
        "if", "inline", "int", "long", "mutable", "namespace", "new", "noexcept",
        "not", "not_eq", "nullptr", "operator", "or", "or_eq", "private", "protected"
,
        "public", "register", "reinterpret_cast", "requires", "return", "short",
        "signed", "sizeof", "static", "static_assert", "static_cast", "struct",
        "switch", "template", "this", "thread_local", "throw", "true", "try",
        "typedef", "typeid", "typename", "union", "unsigned", "using", "virtual",
        "void", "volatile", "wchar_t", "while", "xor", "xor_eq"
```

```
};

int count = 0;
size_t i = 0;
size_t n = source.length();

// Skip whitespace, comments, and string literals
auto skipWhitespace = [&]() {
    while (i < n && std::isspace(source[i])) {
        i++;
    }
};

auto skipSingleLineComment = [&]() {
    i += 2; // Skip "//"
    while (i < n && source[i] != '\n') {
        i++;
    }
};

auto skipMultiLineComment = [&]() {
    i += 2; // Skip "/*"
    while (i + 1 < n && !(source[i] == '*' && source[i + 1] == '/')) {
        i++;
    }
    if (i + 1 < n) {
        i += 2; // Skip "*/"
    }
};

auto skipStringLiteral = [&]() {
    char quote = source[i];
    i++; // Skip opening quote

    while (i < n) {
        if (source[i] == '\\') {
            i += 2; // Skip escape sequence
            continue;
        }
```

```cpp
        if (source[i] == quote) {
            i++; // Skip closing quote
            break;
        }
        i++;
    }
};

auto isIdentifierChar = [](char c, bool firstChar) {
    if (firstChar) {
        return std::isalpha(static_cast<unsigned char>(c)) || c == '_';
    } else {
        return std::isalnum(static_cast<unsigned char>(c)) || c == '_';
    }
};

while (i < n) {
    skipWhitespace();
    if (i >= n) break;

    // Handle comments
    if (i + 1 < n && source[i] == '/' && source[i + 1] == '/') {
        skipSingleLineComment();
        continue;
    }

    if (i + 1 < n && source[i] == '/' && source[i + 1] == '*') {
        skipMultiLineComment();
        continue;
    }

    // Handle string and character literals
    if (source[i] == '"' || source[i] == '\'') {
        skipStringLiteral();
        continue;
    }

    // Check for identifier start
    if (isIdentifierChar(source[i], true)) {
            size_t start = i;
            std::string identifier;

            // Extract the full identifier
            while (i < n && isIdentifierChar(source[i], false)) {
                identifier += source[i];
                i++;
            }

            // Check if it's not a keyword
            if (keywords.find(identifier) == keywords.end()) {
                count++;
            }

            continue;
        }

        i++; // Skip other characters
    }

    return count;
}

// Example usage and test
int main() {
    // Test cases
    std::string testCode1 = R"(
        int main() {
            int x = 10;
            int y = x + 5;
            std::cout << "Result: " << y << std::endl;
            return 0;
        }
    )";

    std::string testCode2 = R"(
        // This is a comment
        class MyClass {
        private:
            int memberVar;
        public:
            void myFunction(int param) {
                int localVar = param * 2;
                if (localVar > 10) {
                    return;
                }
            }
        };
    )";

    std::string testCode3 = R"(
        /* Multi-line comment
           with identifiers that shouldn't be counted */
        float calculate_area(float radius) {
            const float PI = 3.14159;
            float area = PI * radius * radius;
            return area;
        }
    )";

    std::cout << "Test 1 - Basic code:" << std::endl;
    std::cout << "Identifiers found: " << countIdentifiers(testCode1) << std::endl;
    std::cout << std::endl;

    std::cout << "Test 2 - Class with members:" << std::endl;
    std::cout << "Identifiers found: " << countIdentifiers(testCode2) << std::endl;
    std::cout << std::endl;

    std::cout << "Test 3 - Function with constants:" << std::endl;
    std::cout << "Identifiers found: " << countIdentifiers(testCode3) << std::endl;

    return 0;
}
```

Key Features:

1. **Identifier Rules**: Follows C++ standard starts with letter/underscore contains letters/digits/underscores.
2. **Keyword Filtering**: Excludes C++ keywords from the count.
3. **Comment Handling**: Skips both single-line (`//`) and multi-line (`/* */`) comments.
4. **String Literal Handling**: Ignores content inside string and character literals.
5. **Escape Sequence Awareness**: Properly handles escape sequences in strings.

Limitations and Considerations:

1. **Preprocessor Directives**: This implementation doesn't handle preprocessor directives. Identifiers in `#define`, `#include` etc. would be counted.
2. **Full Keyword List**: The keyword list can be expanded for completeness.
3. **Standard Library Types**: The current implementation counts standard library types (like `std::cout`) as identifiers. You might want to filter them depending on your needs.
4. **Context Awareness**: Doesn't understand scopes or namespaces just counts all valid identifiers

Question 3 Draw the parse tree for "1100"

Grammar Given:

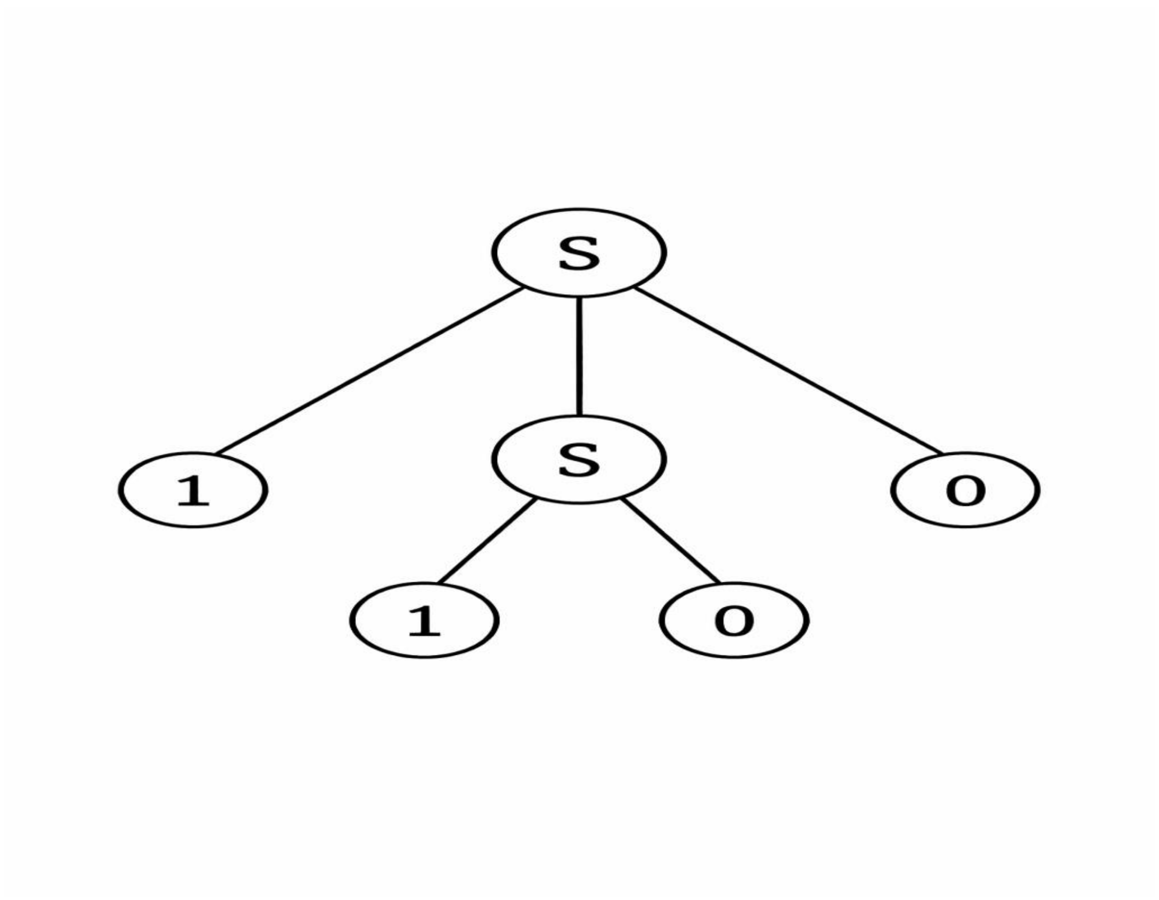
1. S→1S0
2. S→10

String to derive: 1100

Step-by-Step Derivation:
To get 1100, we start with S:

1. Apply S→1S0(Now we have 1, a middle *S*, and 0)
2. Inside that middle S*S*, apply S→10*S*→10
3. Result: 1(10)0=1100

The Parse Tree:



Explanation of the tree:

- The **Root** is the starting symbol S*S*.
- The first branch uses the recursive rule S→1S0.
- The inner S*S* node then uses the "base case" rule S→10 to complete the string.
- Reading the "leaves" (the bottom-most characters) from left to right gives you: **1, 1, 0**.