

Compiler Construction Project

Part-3 (Implementation)

GitHub Repository:

<https://github.com/ibrahim-012/Compiler-Construction-Project.git>

Code Structure

```
● ● ●

1 ## Complete File Structure
2 `-- tinygame-compiler/
3     |-- main.py                  # Main CLI
4     |-- lexer.py                 # Part 1
5     |-- parser.py                # Part 2
6     |-- semantic_analyzer.py    # Part 3
7     |-- code_generator.py       # Part 4
8     |-- optimizer.py             # Part 5
9     |-- interpreter.py           # Part 6
10    |-- examples/
11        |-- test1.tg
12        |-- test2.tg
13        |-- test3.tg
14 `-- ```

15
```

UI



```
TinyGame Compiler v1.0.0
A Mini Language Compiler for CS4031
```

Usage:

<code>python main.py <filename></code>	- Compile and run a file
<code>python main.py <filename> --tokens</code>	- Show tokens only
<code>python main.py <filename> --ast</code>	- Show AST only
<code>python main.py <filename> --tac</code>	- Show TAC only
<code>python main.py <filename> --optimized</code>	- Show optimized TAC
<code>python main.py <filename> --trace</code>	- Execute with trace
<code>python main.py <filename> --all</code>	- Show all phases
<code>python main.py --interactive</code>	- Interactive mode
<code>python main.py --help</code>	- Show this help

Examples:

```
python main.py examples/test1.tg
python main.py examples/test2.tg --trace
python main.py examples/test3.tg --all
```

i No file specified. Use --help for usage information.

Would you like to create example files? (y/n):

Stage 1 - Lexical Analysis

Token DataClass

```
● ● ●
1 @dataclass
2 class Token:
3     """Represents a single token"""
4     type: TokenType
5     value: any
6     line: int
7     column: int
8
9     def __repr__(self):
10        return f"Token({self.type.name}, {repr(self.value)}, {self.line}:{self.column})"
```

Functions

```
● ● ●
1 def advance(self):
2     """Move to next character"""
3     if self.current_char == '\n':
4         self.line += 1
5         self.column = 1
6     else:
7         self.column += 1
8
9     self.pos += 1
10    if self.pos >= len(self.source):
11        self.current_char = None
12    else:
13        self.current_char = self.source[self.pos]
14
15 def peek(self, offset: int = 1) -> Optional[str]:
16     """Look ahead at next character(s) without consuming"""
17     peek_pos = self.pos + offset
18     if peek_pos >= len(self.source):
19         return None
20     return self.source[peek_pos]
```

```
● ● ●

1 def tokenize(self) -> List[Token]:
2     """Tokenize entire source code"""
3     tokens = []
4
5     while True:
6         token = self.get_next_token()
7         tokens.append(token)
8
9     if token.type == TokenType.EOF:
10        break
11
12     self.tokens = tokens
13
14 return tokens
```

Input

```
● ● ●

1 # Test code
2     test_code = """
3     player hero {
4         x = 0;
5         y = 0;
6         health = 100;
7     }
8
9     enemy monster {
10         x = 5;
11         y = 5;
12     }
13
14     move hero right 5;
15     move hero up 5;
16
17     if hero.x == monster.x {
18         set hero.health = hero.health - 10;
19         print "Hit by monster!";
20     }
21 """
```

Output

```
Token(SEMICOLON, ';', 17:43)
Token(PRINT, 'print', 18:9)
Token(STRING, 'Hit by monster!', 18:15)
Token(SEMICOLON, ';', 18:32)
Token(RBRACE, '}', 19:5)
Token(EOF, None, 20:5)
```

```
=====
Total tokens: 63
=====
```

Stage 2 - Syntax Analysis

ASTNode DataClass

```
1 @dataclass
2 class ASTNode:
3     """Base class for all AST nodes"""
4     line: int
5     column: int
```

Functions

```
1 def advance(self):
2     """Move to next token"""
3     self.pos += 1
4     if self.pos < len(self.tokens):
5         self.current_token = self.tokens[self.pos]
6     else:
7         self.current_token = None
8
9 def peek(self, offset: int = 1) -> Optional[Token]:
10    """Look ahead at next token(s)"""
11    peek_pos = self.pos + offset
12    if peek_pos < len(self.tokens):
13        return self.tokens[peek_pos]
14    return None
15
16 def expect(self, token_type: TokenType) -> Token:
17    """Consume token of expected type or raise error"""
18    if not self.current_token or self.current_token.type != token_type:
19        self.error(f"Expected {token_type.name}, got {self.current_token.type.name} if self.current_token else 'EOF'")
20    token = self.current_token
21    self.advance()
22    return token
23
24 def match(self, *token_types: TokenType) -> bool:
25    """Check if current token matches any of given types"""
26    if not self.current_token:
27        return False
28    return self.current_token.type in token_types
```

Input



```
1  # Test code
2  test_code = """
3  player hero {
4      x = 0;
5      y = 0;
6      health = 100;
7  }
8
9  enemy monster {
10     x = 5;
11     y = 5;
12 }
13
14 move hero right 5;
15 move hero up 5;
16
17 if hero.x == monster.x {
18     set hero.health = hero.health - 10;
19     print "Hit by monster!";
20 }
21 """
```

Output

```
=====
TINYGAME PARSER TEST
=====

[1] Tokenizing...
Generated 63 tokens

[2] Parsing...
AST built successfully!

[3] Abstract Syntax Tree:
-----
Program
 Entities:
   Player: hero
     x = 0
     y = 0
     health = 100
   Enemy: monster
     x = 5
     y = 5
Statements:
  Move hero right 5
  Move hero up 5
  If (hero.x == monster.x)
    Set hero.health = (hero.health - 10)
    Print "Hit by monster!"
```

Stage 3 - Semantic Analysis

Symbol DataClass

```
● ● ●

1  @dataclass
2  class Symbol:
3      """Represents a symbol in the symbol table"""
4      name: str
5      symbol_type: str # 'entity', 'property'
6      data_type: str # 'int', 'player', 'enemy'
7      value: Optional[int] = None
8      line: int = 0
9      scope: str = "global"
10
11
12 @dataclass
13 class EntitySymbol:
14     """Represents an entity (player or enemy)"""
15     name: str
16     entity_type: str # 'player' or 'enemy'
17     properties: Dict[str, Symbol] = field(default_factory=dict)
18     line: int = 0
19
```

Functions

```
● ● ●

1 def add_entity(self, name: str, entity_type: str, line: int) -> bool:
2     """Add entity to symbol table"""
3     if name in self.entities:
4         return False
5
6     self.entities[name] = EntitySymbol(name, entity_type, {}, line)
7     return True
8
9 def entity_exists(self, name: str) -> bool:
10    """Check if entity exists"""
11    return name in self.entities
12
13 def add_property(self, entity_name: str, prop_name: str,
14                  value: Optional[int], line: int) -> bool:
15    """Add property to an entity"""
16    if entity_name not in self.entities:
17        return False
18
19    entity = self.entities[entity_name]
20
21    if prop_name in entity.properties:
22        return False
23
24    symbol = Symbol(
25        name=prop_name,
26        symbol_type='property',
27        data_type='int',
28        value=value,
29        line=line,
30        scope=entity_name
31    )
32
33    entity.properties[prop_name] = symbol
34    return True
35
36 def property_exists(self, entity_name: str, prop_name: str) -> bool:
37    """Check if property exists for an entity"""
38    if entity_name not in self.entities:
39        return False
40    return prop_name in self.entities[entity_name].properties
```

Input



```
1 # Test code with errors
2 test_code_2 = """
3 player hero {
4     x = 0;
5     y = 0;
6 }
7
8 // This should cause errors
9 move ghost right 5;
10 set hero.z = 10;
11 """
```

Output

=====

TEST 2: Code with Semantic Errors

=====

=====

SYMBOL TABLE

=====

GLOBAL SCOPE - ENTITIES:

Name	Type	Line	Properties
hero	player	2	2 properties

ENTITY SCOPE: hero

Property	Type	value	Line
x	int	0	3
y	int	0	4

=====

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SEMANTIC ANALYSIS RESULTS

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ERRORS FOUND:

- ✗ Semantic Error at 8:5: Entity 'ghost' is not declared
✗ Semantic Error at 9:5: Entity 'hero' has no property 'z'

Stage 4 - Intermediate Code Generation

TAC Instruction DataClass

```
● ● ●

1 @dataclass
2 class TACInstruction:
3     """Represents a single three-address code instruction"""
4     op: str          # Operation: =, +, -, *, /, ==, !=, >, <, goto, if, label, print, etc.
5     arg1: Optional[str] # First argument
6     arg2: Optional[str] # Second argument
7     result: Optional[str] # Result
8
9     def __str__(self) -> str:
10         """String representation of instruction"""
11         if self.op == 'label':
12             return f"{self.result}:"
13         elif self.op == 'goto':
14             return f"    goto {self.result}"
15         elif self.op == 'if':
16             return f"    if {self.arg1} goto {self.result}"
17         elif self.op == 'iffalse':
18             return f"    iffFalse {self.arg1} goto {self.result}"
19         elif self.op == 'print':
20             return f"    print {self.arg1}"
21         elif self.op == 'move':
22             # move entity direction amount
23             return f"    move {self.arg1} {self.arg2} {self.result}"
24         elif self.op == '=':
25             if self.arg1 is None:
26                 return f"    {self.result} = (uninitialized)"
27             return f"    {self.result} = {self.arg1}"
28         elif self.op in ['+', '- ', '*', '/']:
29             return f"    {self.result} = {self.arg1} {self.op} {self.arg2}"
30         elif self.op in ['==', '!=', '>', '<']:
31             return f"    {self.result} = {self.arg1} {self.op} {self.arg2}"
32         else:
33             return f"    {self.op} {self.arg1} {self.arg2} {self.result}"
```

Functions

```
● ● ●

1 def new_temp(self) -> str:
2     """Generate new temporary variable"""
3     temp = f"t{self.temp_counter}"
4     self.temp_counter += 1
5     return temp
6
7 def new_label(self) -> str:
8     """Generate new label"""
9     label = f"L{self.label_counter}"
10    self.label_counter += 1
11    return label
12
13 def emit(self, op: str, arg1: Optional[str] = None,
14          arg2: Optional[str] = None, result: Optional[str] = None):
15     """Emit a three-address code instruction"""
16     instruction = TACInstruction(op, arg1, arg2, result)
17     self.instructions.append(instruction)
```

Input



```
1  # Test code
2  test_code = """
3  player hero {
4      x = 0;
5      y = 0;
6      health = 100;
7  }
8
9  enemy monster {
10     x = 5;
11     y = 5;
12 }
13
14 move hero right 5;
15 move hero up 5;
16
17 if hero.x == monster.x {
18     set hero.health = hero.health - 10;
19     print "Hit by monster!";
20 }
21 """
```

Output

```
=====
THREE-ADDRESS CODE (INTERMEDIATE REPRESENTATION)
=====
```

```
0  init_hero:
1      hero.x = 0
2      hero.y = 0
3      hero.health = 100
4  init_monster:
5      monster.x = 5
6      monster.y = 5
7      move hero right 5
8      t0 = hero.x + 5
9      hero.x = t0
10     move hero up 5
11     t1 = hero.y + 5
12     hero.y = t1
13     t2 = hero.x == monster.x
14     if t2 goto L0
15     goto L1
16 L0:
17     t3 = hero.health - 10
18     hero.health = t3
19     print "Hit by monster!"
20 L1:
```

```
=====
Total instructions: 21
=====
```

SYMBOL TABLE

GLOBAL SCOPE - ENTITIES:

Name	Type	Line	Properties
hero	player	2	3 properties
monster	enemy	8	2 properties

ENTITY SCOPE: hero

Property	Type	Value	Line
x	int	0	3
y	int	0	4
health	int	100	5

ENTITY SCOPE: monster

Property	Type	Value	Line
x	int	5	9
y	int	5	10

Stage 5 - Code Optimization

Functions

```
● ● ●

1  def optimize(self) -> List[TACInstruction]:
2      """Perform all optimization passes"""
3      print("\n" + "=" * 70)
4      print("OPTIMIZATION PASSES")
5      print("=" * 70)
6
7      # Start with original instructions
8      current_instructions = deepcopy(self.instructions)
9      original_count = len(current_instructions)
10
11     print(f"\nOriginal instruction count: {original_count}")
12
13     # Pass 1: Constant Folding
14     print("\n[Pass 1] Constant Folding...")
15     current_instructions = self.constant_folding(current_instructions)
16     print(f" ✓ Completed. {len(self.optimization_log)} optimizations applied")
17
18     # Pass 2: Dead Code Elimination
19     print("\n[Pass 2] Dead Code Elimination...")
20     current_instructions = self.dead_code_elimination(current_instructions)
21     print(f" ✓ Completed")
22
23     # Pass 3: Copy Propagation
24     print("\n[Pass 3] Copy Propagation...")
25     current_instructions = self.copy_propagation(current_instructions)
26     print(f" ✓ Completed")
27
28     # Pass 4: Algebraic Simplification
29     print("\n[Pass 4] Algebraic Simplification...")
30     current_instructions = self.algebraic_simplification(current_instructions)
31     print(f" ✓ Completed")
32
33     final_count = len(current_instructions)
34     reduction = original_count - final_count
35
36     print("\n" + "=" * 70)
37     print(f"Optimization complete!")
38     print(f"Instructions reduced: {original_count} → {final_count} (-{reduction})")
39     print("=" * 70)
40
41     self.optimized_instructions = current_instructions
42     return current_instructions
```

Input



```
1 # Test code with opportunities for optimization
2 test_code = """
3     player hero {
4         x = 5 + 3;
5         y = 10 * 1;
6         health = 100 - 0;
7         score = 0 * 999;
8     }
9
10    enemy monster {
11        x = 2 + 2;
12        y = 8 / 1;
13    }
14
15    move hero right 3;
16    set hero.score = hero.score + 0;
17
18    if hero.x == monster.x {
19        set hero.health = hero.health - 5;
20        print "Hit!";
21    }
22 """
```

Output

OPTIMIZED CODE:

```
0 init_hero:  
1     t0 = 8  
2     hero.x = t0  
3     t1 = 10  
4     hero.y = t1  
5     t2 = 100  
6     hero.health = t2  
7     t3 = 0  
8     hero.score = t3  
9 init_monster:  
10    t4 = 4  
11    monster.x = t4  
12    t5 = 8  
13    monster.y = t5  
14    move hero right 3  
15    t6 = hero.x + 3  
16    hero.x = t6  
17    t7 = hero.score  
18    hero.score = t7  
19    t8 = hero.x == monster.x  
20    if t8 goto L0  
21    goto L1  
22 L0:  
23    t9 = hero.health - 5  
24    hero.health = t9  
25    print "Hit!"  
26 L1:
```

OPTIMIZATION SUMMARY

```
Original instructions: 27
Optimized instructions: 27
Reduction:          0 instructions
Optimizations applied: 7
```

Functions

```
● ● ●

1  def generate(self) -> List[TACInstruction]:
2      """Generate intermediate code for entire program"""
3      # Generate code for entity initializations
4      for entity in self.ast.entities:
5          self.generate_entity(entity)
6
7      # Generate code for statements
8      for stmt in self.ast.statements:
9          self.generate_statement(stmt)
10
11     return self.instructions
12
13 def generate_entity(self, entity: Entity):
14     """Generate code for entity initialization"""
15     self.emit('label', result=f"init_{entity.name}")
16
17     for assignment in entity.properties:
18         # Generate code for initial value
19         value_temp = self.generate_expression(assignment.expression)
20
21         # Assign to property
22         property_name = f"{entity.name}.{assignment.var_name}"
23         self.emit('=', value_temp, None, property_name)
24
25 def generate_statement(self, stmt: Statement):
26     """Generate code for a statement"""
27     if isinstance(stmt, MoveStatement):
28         self.generate_move_statement(stmt)
29     elif isinstance(stmt, SetStatement):
30         self.generate_set_statement(stmt)
31     elif isinstance(stmt, IfStatement):
32         self.generate_if_statement(stmt)
33     elif isinstance(stmt, PrintStatement):
34         self.generate_print_statement(stmt)
```

Input



```
1  # Test code
2  test_code = """
3  player hero {
4      x = 0;
5      y = 0;
6      health = 100;
7  }
8
9  enemy monster {
10     x = 5;
11     y = 5;
12 }
13
14 move hero right 5;
15 move hero up 5;
16
17 if hero.x == monster.x {
18     set hero.health = hero.health - 10;
19     print "Hit by monster!";
20 }
21 """
```

Output

```
=====
```

```
TINYGAME INTERMEDIATE CODE GENERATOR TEST
```

```
=====
```

```
[1] Lexical Analysis...
```

```
✓ Generated 63 tokens
```

```
[2] Syntax Analysis...
```

```
✓ AST built successfully
```

```
[3] Semantic Analysis...
```

```
✓ No semantic errors
```

```
[4] Intermediate Code Generation...
```

```
✓ Generated 21 TAC instructions
```

THREE-ADDRESS CODE (INTERMEDIATE REPRESENTATION)

```
0 init_hero:  
1     hero.x = 0  
2     hero.y = 0  
3     hero.health = 100  
4 init_monster:  
5     monster.x = 5  
6     monster.y = 5  
7     move hero right 5  
8     t0 = hero.x + 5  
9     hero.x = t0  
10    move hero up 5  
11    t1 = hero.y + 5  
12    hero.y = t1  
13    t2 = hero.x == monster.x  
14    if t2 goto L0  
15    goto L1  
16 L0:  
17    t3 = hero.health - 10  
18    hero.health = t3  
19    print "Hit by monster!"  
20 L1:
```

Total instructions: 21

SYMBOL TABLE

GLOBAL SCOPE - ENTITIES:

Name	Type	Line	Properties
hero	player	2	3 properties
monster	enemy	8	2 properties

ENTITY SCOPE: hero

Property	Type	Value	Line
x	int	0	3
y	int	0	4
health	int	100	5

ENTITY SCOPE: monster

Property	Type	Value	Line
x	int	5	9
y	int	5	10